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CONIFEROUS FOREST BIOME

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STREAM SYSTEMS

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INTRODUCTION

The long-term objectives and approaches planned in this study were outlined in previous Biome proposals. In this year, we focused more effort on the contribution of allochthonous material in the small streams draining the Douglas-fir system at the H. J. Andrews Experimental Forest. A recent model for Eastern woodland streams circulated by Boling, Petersen, and Cummins (in press) indicates a great predominance of particulate organic matter over net primary production as the source of energy. Some beginnings of a quantification of this work have been made on the Alsea Watershed Study in Oregon, but much work remains to be done.

A wide range of conditions is available from which to sample, including virgin watersheds, watersheds where streamsides have been recently logged, and watersheds where streamside vegetation has grown after past logging. A comparison of the relative importance of allochthonous input under these three conditions are providing a beginning to our budget studies. In this first year of intensive study, emphasis was placed on inter-ties with the terrestrial system by beginning work in the small watersheds where intensive terrestrial work is underway.

The initial studies of stream productivity involved the determination of the aquatic plant community structure. This included the major groups present and their biomass under varying environmental conditions, particularly open and closed canopy and different stream velocities. The rate of primary production by aquatic plants will be obtained by using a ^{32}P material balance method. The total productivity of the stream community is then related to the input of allochthonous material from the coniferous forest. Data on water chemistry from the nutrient cycling group will be essential here. Further experiments will be conducted in order to determine the trophic fate of primary producers and allochthonous material in the stream system so that their relative importance to insect and fish production may be understood.

A survey of the insect fauna of the Lookout Creek drainage currently underway is concerned with establishing the dominant taxa in the streams. Two types of samples have been taken: benthos and emergence. To obtain estimates of density and standing crop of benthos, we are using removable pots that can be buried in the substrate. Emergence trap sampling for adults on a continuous basis will allow for identification of the fauna and an estimate of the amount of energy leaving the stream as adult insects.

Definitive studies of the role of insects in energy transfer between trophic levels is being done by field and laboratory studies of the life history, food habits, and food requirements of selected species. Detritivores (mayflies, caddisflies, and/or stoneflies) that contribute to the breakdown of allochthonous material will be studied in Lookout Creek, Laboratory studies of their feeding habits have been undertaken to determine whether they utilize the detritus or the fungi and bacteria growing on it. These experiments will complement projects undertaken on terrestrial and aquatic decomposers. Population estimates of an algal feeder (glossosomatid caddisflies) are being obtained at Lookout Creek. A detailed production study of a congeneric species has been completed by N. H. Anderson while on sabbatical leave in connection with an IBP project at the Freshwater Biological Association Laboratory, Wareham, England.

The general approach for the first phase of the fish population studies has been to study the relationship between the density of cutthroat trout populations and the availability of their food resources By studying fish population density in several sections throughout the Lookout Creek drainage, we hope to include sufficient variability in food conditions to determine whether such a relationship exists. The study sections have been selected from streams of several sizes and will include different conditions of streamside vegetation. At the time of the population estimates, limited samples are being taken for food habits analysis, so that estimates of insect abundance can be correlated with food utilization by the trout population.

Basic Design Common to the Several Subprojects

From the array of streams available for study on the H. J. Andrews Experimental Forest we have selected three areas for initial study. In order to provide close ties with the intensive terrestrial studies we have been working in the stream draining watershed 10. Since this stream does not have a fish population, it has been necessary to include some larger ones as well. For this purpose we have selected locations on Mack Creek and main Lookout Creek. The Mack Creek study area has been divided into two sections, an upper section that has not been logged and an adjacent section downstream that was included within a clearcut logging unit. This is providing a significant contrast and beginning to provide some insight into the effects of cutting on this aquatic system.

Certain common data are being obtained at all sites and will be used by all investigators. Stream mapping will be undertaken to characterize bottom type and define the wetted area at various stages of flow. Stream flow is being taken from existing gauges on Watershed 10 and Lookout Creek, with a temporary gauge or flow measuring station being set up on Mack Creek. Stream temperature has been taken from existing thermographs. Data on water chemistry is being obtained from present studies of the nutrient cycling group, supplemented by a sampling in other watersheds (Mack Creek, Lookout Creek) sufficient to characterize the nutrient status of these streams. Additional work will be done if significant differences appear among any of the stations.

Allochthonous Energy Input

The forest canopy over small woodland streams has two major influences, the effect of shading the stream community from light energy, and the addition of an energy resource in the form of allochthonous material. Small streams receive great quantities of detritus in the form of terrestrially produced material entering the stream mechanically (leaf, twig, and needle fall; blow in). The importance of this allochthonous material in providing the energy source for a basically heterotrophic system has been described (Nelson and Scott 1962; Hynes 1963; Minshall 1967). The caloric content of such material has been shown to be significant (Kaushik & Hynes 1968, 1971). In spite of the apparent importance of allochthonous material, few studies have been made to ascertain the fate of detrital material once it enters the stream system. Ingestion food webs have been reported (Cummins, Coffman, and Roff 1966), and Hynes (1963), Hynes and Kaushik (1969), and Triska (1970) have studied the processes of decomposition and utilization of the deciduous leaves. Kowal (1969) reported on decomposition of pine litter. Fisher (1970) and Bolling *et al.* (in press), have most recently reported on the role of allochthonous material in the energy budget of small eastern deciduous forest streams.

The present study is an attempt to determine the importance of allochthonous material in the small stream systems of a coniferous forest. The detrital material residual at any one time in the stream bed is of importance to those organisms utilizing it as an energy resource. This material may be sampled successfully with a frozen core device (Ryan 1970) or modified Hess sampler. The remainder of the inventory of allochthonous material would be in the form of imported material and exported material. Litter fall nets, drift nets (for particulate organic matter) and water samples (for dissolved organic matter), and lateral movement traps are currently being used to complete the detritus balance. The export of detritus from a particular stream site is being measured by a large 80μ mesh net. In the few eastern systems where detrital input has been studied, export has not been a significant fate of the material. In our systems, however, where winter freshets occur soon after major leaf fall, export is an important fate, and its sampling has proven rather difficult. Special techniques involving the use of various mesh nets have been developed. These inventories have yielded valuable data for amounts of material. The importance of such material to the biota, however, lies in how it is utilized within the living system.

Such utilization can be by invertebrate detritivores and decomposers or a combination of them, i.e., a detritus-feeding insect consuming the decomposers resident in the detritus. The composition (species present and relative abundance) of these members of the community is, however, only one aspect of their importance. Of significance also is the rate at which they utilize the material (disappearance rate). Results of insect feeding studies are included in this report while studies of decomposition rates were undertaken effective November 1972.

Primary Production

The influence of the forest canopy in providing an allochthonous energy resource has been described. In addition to this influence, however, the forest canopy shades stream systems, denying the aquatic plants a portion of their energy resource, i.e., light (Fisher 1970). Even so, the contribution of autocthonous production within stream systems can be of significance (McIntire and Phinney 1965) especially when the forest canopy is removed by clearcutting or selective removal of the forest trees (Hansmann 1969; Hansmann and Phinney 1973).

It is intersting to know what kinds of autotrophic organisms are present in forest streams, especially to the extent that individual species can be used as indicator organisms (Patrick 1961). Community types are being determined by collection and examination of the algal communities.

Of more importance to the Coniferous Forest Biome Study, however, will be the contribution of the stream autotrophs to the detrital reservoir in the stream and as forage material for the aquatic herbivores. Primary production will be related to stream nutrients, light, current, and temperature. This is being done on the community level, since McIntire (1968) has shown that benthic algal communities function as units or "quasi-organisms" much like lichens. The production of algal material is being measured as a function of biomass, i.e., the development of algal communities with time. The fate of the developed communities will be measured as they disappear with time to contribute to the stream detritus and provide forage material.

These material balance (^{32}P) experiments will be conducted in stream sites under forest canopy and stream sites that have had the canopy removed. It is expected that the results of these investigations will show the contribution made to stream production of an energy resource by autotrophic communities, how this autocthonous material is utilized in the stream, and the effect of canopy removal on stream autocthonous production.

The Invertebrate Community

Hynes (1970, Chap. 22) states that production of the benthos is of considerable importance to an understanding of lotic ecosystems, but at the present time the likely production rates are not known even within 2 or 3 orders of magnitude. As it is obviously impractical to measure production of each species individually, Hynes and Coleman (1968) (with corrections suggested by Hamilton 1969b) proposed a "community" method. Standing crop data from a series of samples are converted to production estimates using size-class measurements as an index of growth and mortality.

An alternative approach is the use of the annual turnover ratio (TR) calculated for the entire benthis fauna (Waters 1969). He suggests that a TR (production/mean biomass) of 3.5 is a good approximate figure for the benthic insects and thus standing crop could be expressed as production.

Biomass data for benthic insects are being collected and sorted in such a way that one of the above methods can be used in analysis. In addition, the emergence trap samples provide the "yield" of adult insects. Samples are being sorted into food-type categories, measured, and dry-weighed.

Sampling sites are the four listed earlier. Specific methods and procedures are listed below:

Mack creek.
Benthos is being sampled by the use of pots (Coleman and Hynes 1970). With this method we are collecting the allochthonous material as well as the benthic insects. Sampling is done monthly when the creek is accessible.

Four emergence traps of the Hamilton (1969a) type are being used above and below the road, which divides the clearcut from the undisturbed area. They are in operation continuously during the major emergence period and emptied twice a week.

Lookout Creek.
This site has 3 pots that were placed in the substrate early in April. It is long, fairly uniform riffle. Two small feeder streams enter and bring some allochthonous material. The site is relatively open, with considerable bankside deciduous trees. The stream broadens by a factor of 3 in the winter so some locations can be sampled at high water that are dry at other times. Benthos samples are taken from the 6 removable pots. Three of these were removed each month. Benthos sampling has been completed and the samples are being processed. These tent-shaped emergence traps are being used to estimate the emergence of adult aquatic insects.

Watershed 10.
Some work on the primary production, allochthonous material, and insect fauna is being done in this small watershed because it is the major area used for terrestrial research. As fish are absent from this stream, predation on aquatic insects is primarily in the adult stages by amphibians and terrestrial organisms.

The small size of the streams and the bedrock substrate lead to unique sampling problems. In essence, much of the fauna is at the stream edge. Flushing by the winter rains has a pronounced effect on energy transfer and utilization in this site. The benthos is sampled with "stove pipe" core samples. All the water is being funneled through a net at the gauging site. Thus, the proportion of stream flow to samples can be established. Emergence traps are the most productive sampling procedure for insects as in the main season a tent trap can cover the width of the stream.

In addition to the routine sampling for total biomass, more intensive sampling is being conducted for studies of energy transfer between trophic levels. Detritivores that contribute to breakdown of leaf material will be sampled intensively, particularly during the fall and early winter. Many species are facultative feeders and their greatest impact on the allochthonous material is probably at the time of its greatest availability. Sampling for detritivores will be selective or stratified in that collections need to be taken from sites where the material accumulates. Concurrent laboratory studies of feeding behavior and growth of selected species are being conducted to determine quantities of allochthonous material consumed.

Glossosomatid caddisflies have been selected as the "grazer" taxa. They feed on the aufwuchs film and occur on the surface of rocks as opposed to down in the substrate. A separate sampling program is required but this is justified in that it seems feasible to obtain an accurate population density and age distribution of these insects. These data are important if food requirements are to be extrapolated to the population level. This work is included in this report.

A detailed production study of a related species of glossosomatids was conducted by N. H. Anderson while on sabbatical leave in connection with an IBP project at the Freshwater Biological Association Laboratory, Wareham, England. In this project, quantitative data on survivorship, larval development and growth rate, and a measurement of population biomass were obtained. Laboratory studies of food requirements and preferences will be conducted to define the trophic position of the species. Growth and development rates from laboratory studies will be a useful check on the reliability of field estimates of growth rate. The data obtained from this definitive study will be used as input into the proposed aquatic model for the Andrews site.

Fish Populations

Relatively little information is available on the influence of watershed practices on fish populations or on the role of resident trout in the total watershed ecosystem. The Alsea Watershed Study, conducted in the Coast Range of Oregon, has provided a starting point (Hall and Lantz 1969). Of particular concern in our Andrews study is the relative contribution of allochthonous and autochthonous production to the ultimate production of fish flesh. We also wish to find how this contribution may be altered by logging or other land management practices. Some preliminary work by Chapman (1966) in the Alsea streams suggested that terrestrial primary production contributed more than 50 percent of the total energy that went into the growth of juvenile coho salmon. Work in the East suggests an even larger role of detritus leading to secondary production (Boling *et al.*, in press; Fisher 1970). Earlier work on trout populations in the Andrews will provide some background (Wustenberg 1954; Wyatt 1959).

Methods.
Study sections in the three study areas where cutthroat trout are found (Watersheds 10 and 2 do not support fish) have been laid out. Sections of 200 m are located in Mack Creek, above and below the road and in Lookout Creek. Intensive field work was not begun on the fish population until September of 1972, due to funding and manpower limitations.

The following data are being collected in the fish population study: population size, feeding behavior, food habits, growth rate, movement rate, and production.

This information is being gathered primarily by sampling the trout populations periodically by means of an electric shocker. Individually numbered tags have been applied to the fish to permit future identification. The streams have been closed to angling, so no disruption of the populations should result.

1. Population size is determined by capture-recapture data using the Jolly method of computation (Ricker 1968).
2. Feeding behavior is determined from direct observations alongside the small streams. Observations with facemask and snorkel may be used in Lookout Creek.
3. Food habits are being determined by taking stomach samples from a small number of trout throughout the season. A non-destructive method of sampling stomach contents has been developed.

4. Growth rate will be determined from two sources: 1) growth of recaptured tagged fish, and 2) analysis of scales taken from sampled fish.

5. Movement rates are being determined from sampling both within and outside the 200 m sampling zone.

Modeling

Modeling efforts to date have been at a relatively coarse level of resolution, in conjunction with other submodels being constructed for Watershed 10. Dave McIntire's model (in press) has been programmed in FLEX. We are currently modifying the model structure on the basis of discussions with project biologists and with some guidance from other stream models (Boling, *et al.*, in press). The general philosophy for our modeling efforts is indicated below, with a diagram of the proposed model structure for the next version of the stream model.

Narrative Description of the stream subsystem.
The basic nature of small streams in coniferous forest systems is to act as processors and exporters of organic matter. The main features of the aquatic subsystem include a periphyton (algae and associated microflora) component, an input of organic matter from litter fall with associated decomposer organisms, and a consumer subsystem. The microorganisms are tightly coupled in both periphyton and litter.

Another major feature of the system is to convert inputs of energy into consumer biomass. The conversion of solar energy into periphyton, plus the seasonal input of leaf litter provides the energy that drives the consumer biomass. Although the streams on the average are heterotrophic (terrestrial litter is the primary energy source), photosynthesis can be important during the part of the year when light is most available. In most systems this period of peak periphyton production occurs in the spring and fall.

Evidence from experimental data and from the model suggests that such systems are strongly light-limited in a heavily-shaded stream such as Watershed 10; the majority of the energy input comes from leaf input. However, when light is at high levels, such as would occur following clearcutting, the periphyton can assimilate large amounts of energy, even though present at low biomass. Model behavior thus far has demonstrated the possible existence of an inverted biomass pyramid often hypothesized for aquatic systems, where comparatively little of the energy is stored in biomass of primary producers. For example, turnover ratios of periphyton (annual production/mean biomass) may range from 10 to 70.

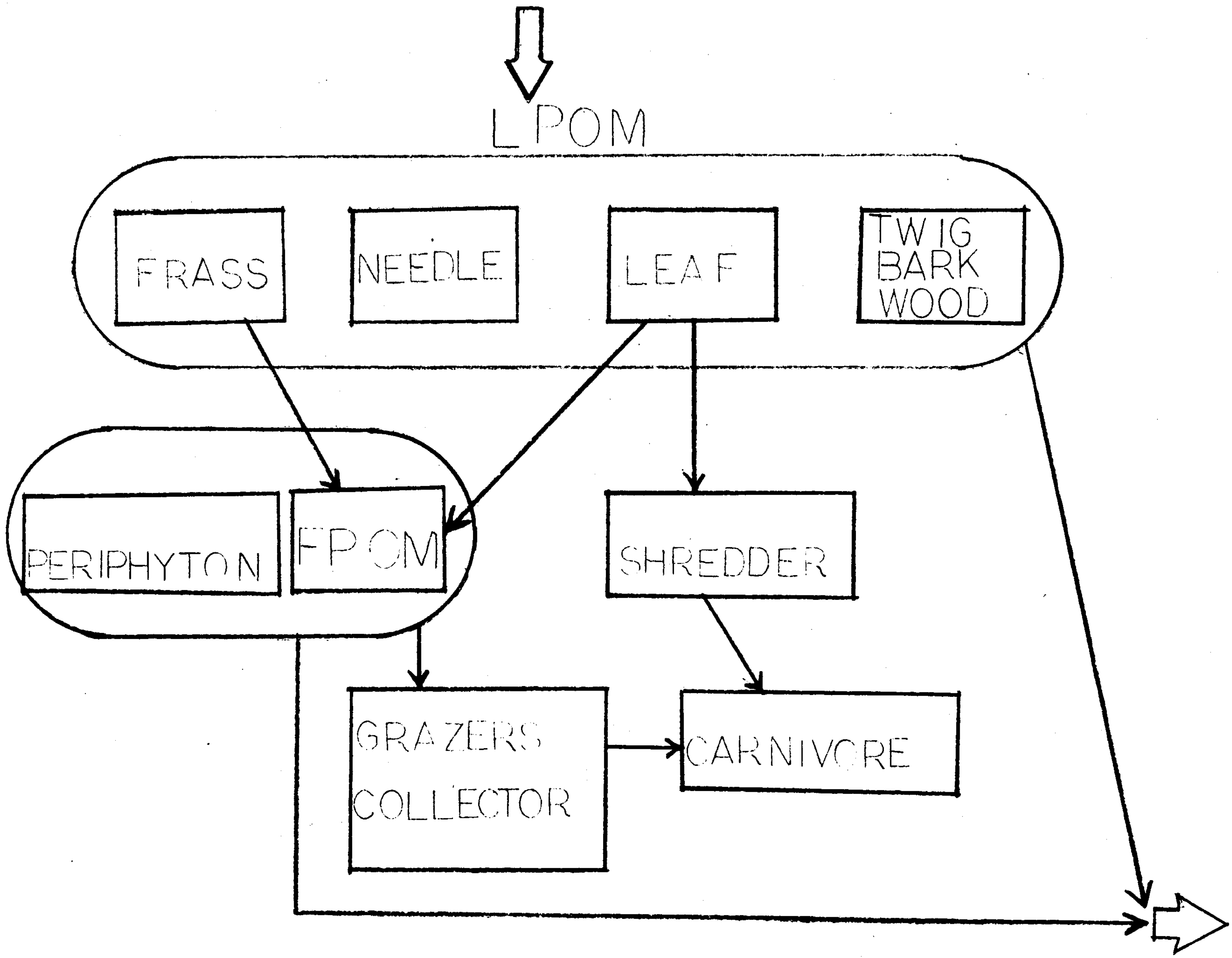
A pervasive feature of these stream systems is export of organic matter, most of it originating from the terrestrial vegetation. Some has been processed by the stream biota, and some is exported in nearly the same state in which it reached the stream. The export is seasonal, related to both the major input or organic matter in the fall and the winter freshets. It is estimated that as much as 90% of the export occurs during the two or three largest storms of the year.

The consumer biota of the stream system processes the inputs of organic matter in several states of breakdown. Shredding insect larvae process the intact leaf meaterial. making it available to collector type insects. The bulk of the energy transfers occur at the fine particulate organic material (FPOM) level. A third group of aquatic invertebrates scrape the periphyton and its associated fine particulate organic matter from rocks. The quality and quantity of various particle sizes of organic material is extremely important in determining the productive capacity of a stream.

Relation of Project to Others in the Andrews Watershed Study

The overall objective of this research is to elucidate the role of a stream in the functioning of the watershed ecosystem. In particular, we wish to explore and identify the ways in which the terrestrial and aquatic subsystems are interrelated. One of the primary ways in which this interaction is expressed is in the dissolved and suspended nutrient load in the streamflow. Our work is designed to determine how these nutrients are either captured and recycled by the biota or transported out of the watershed. This endeavor will tie in with that of several other investigators in the Andrews study.

Fredriksen's work on nutrient cycling will provide data on inputs to the streams and possibly the return of nutrients through uptake by roots in the wetted zone of the stream. Lavender's work on litter fall will provide one measure of detrital input, although further measurements will be needed. It is evident that the decomposer populations will be vital in studies of nutrients and also in utilization of detrital material by stream organisms. Denison, Fogel, and Kromacks' work on soil fungi in the areas adjacent to the streams will be particularly useful in this regard, as it appears that soil fungi are very much involved in detrital breakdown. An additional area where cooperation will be involved is in studies of nutrient flow out of the stream back onto the land. This may take the form of emergence of aquatic insects and their flight to the watershed (to be sampled by Nagel and Daterman) or return to the watershed of energy or nutrients by the action of vertebrate predators feeding in the stream, then returning to the terrestrial system. Vertebrates that may be active in recycling materials from the stream to the terrestrial system will be studied by the vertebrate inventory group (Aussbaum).



LPOM
FRASS
NEEDLE
LEAF
TWIG
BARK
WOOD
PERIPHYTON
FPOM
SHREDDER
GRAZERS
COLLECTOR
CARNIVORE

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NATURAL DEBRIS WITHIN THE STREAM ENVIRONMENT

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Natural accumulations of organic debris in streams are frequent. They are the result of the natural cycle of tree regeneration-growth-decadence. After blowdowns, wildfire, insect infestations, and other natural calamities, these depositions in stream channels may reach significant proportions. Much of the floatable material of these depositions will be flushed out annually. However, it is not every year that the runoff produced by annual winter storms is high enough to flush out the whole drainage, and large debris may be moved only by floods of large size (Froehlich 1971). Very often then, debris accumulates locally until such time as the stream discharge is high enough to move the material downstream. This may be the case only very few times during a 100-year period.

This organic debris provides food and habitat to consumer organisms and reduces stream erosion. The debris that is not used to support respiration in the system, but is eventually exported, nevertheless has an appreciable residence time and lends a certain stability to the system. Normally unrespired inputs represent a potential source of energy which might be exploited if the system is altered, disturbed, or managed with this objective.

The determination of the extent of natural debris in streams is a small part of a much broader study by the senior author. The broad objectives of that study are to determine the effect of different logging methods on the amount and the character of organic debris created by logging operations, especially in stream channels or other sensitive areas, and to develop improved systems for handling of logging residue to ameliorate its effect on the environment.

The goal of this study was to gain more information about the quality and quantity of organic debris within the stream environment of three size types of streams in the H. J. Andrews Experiment Forest in the western Cascades.

STUDY AREA DESCRIPTION

Watershed 10

This is a 10.1 hectare study watershed. It rises from 430 m at the gaging station to 670 m at the highest point on the back ridge. The overall slope of the stream channel is 45 percent, but side slopes and the headwall range up to 90 percent due to deep incision of the basin into the main ridge. The south fork drains a little more than 2.1 hectares and has a 52 percent slope. The north fork drains approximately 3 hectares and has a 51 percent slope. The main branch drains the entire 10.1 hectare watershed and has a slope of 45 percent. The discharge of water from the watershed varies from .008 cfs in late summer to 5 cfs during winter freshets.

Mack Creek

Mack Creek is one of the two major tributaries to Lookout Creek. The area being studied is between 700 m and 900 m in elevation and drains approximately 650 hectares. The watershed slope in this area is 44 percent. In the upper elevations (800-900 m) the stream moves through an undisturbed old-growth Douglas-fir forest. An area immediately below the upper study areas has been clearcut. The length of the stream channel through the clearcut is 1050 ft. The discharge of water at the study area is estimated at between 2-4 cfs in late summer to 50-300 cfs during the winter freshet period.

Lookout Creek

Lookout Creek drains the H. J. Andrews Experiment Forest, which covers an area approximately 6000 hectares. The study point is midway down the watershed and has a slope of 28 percent. The discharge of water ranges between 5-8 cfs in late summer to 800-1600 cfs during the winter freshets.

METHODS

Sample Plots

For Watershed 10, we assumed a width of 10 ft to be the immediate impact zone of the stream. A length of 200 feet seemed to be sufficient to include normal variation for local extraordinary differences. On Mack Creek the sample plots were 30 ft x 40 ft and on Lookout Creek 31 ft x 400 ft, with the center line following the middle axis of the stream channel. These plots were divided into subareas (8 in Watershed 10, 16 in Mack Creek and Lookout Creek). All plots and subplots were marked and numbered with 2 x 2 in. aluminum tags nailed to residual trees or stumps along the creek.

Measurements and Classification of Debris

The classification of fine, branch-type and coarse debris was made for mainly two reasons. Fine debris less than a centimeter in diameter shows a higher BOD per unit weight in comparison to larger fractions. Branch-type material

(1-10 cm), and coarse debris (< 10 cm) were placed in different categories due to differences in the way they can be handled in clean-up operations and again for eventual differences in BOD per unit weight. These major classes, for the reason of providing more meaningful results, again were classified as follows:

1.	Fine debris	a) < 1 cm b) 1 - 3 cm
2.	Branch-type debris	a) 3 - 10 cm
3.	Coarse debris	pieces of more than 10 cm diameter and 30 cm length and of a volume of a) < 1 ft^3 b) 1-4.99 ft^3 c) 5-9.99 ft^3 d) 10 and > 10 ft^3

Measurement of branch-type and fine debris

All size classes in question were measured and computed after the Line Intersect Method described by Van Wagner (1968) as modified by Brown (1971). This method has been proved to work satisfactorily for estimating the volume and weight of slash or other fuel on the ground. For our purpose, we derermined the mean average diameters of fine and branch-type debris after several hundred measurements. Mean average diameters were:

0.423 cm for fine debris	< 1 cm
1.792 cm for fine debris	1- 3 cm
5.049 cm for branch-type debris	3-10 cm

These diameters were entered into a modification of Van Wagner's formula (Rothacher 1959)

$$V = \frac{\pi^2 \Sigma d^2}{8L} \qquad (1)$$

where Σd^2 = count of intersections of all particles in diameter class x mean average diameter, V = volume of wood per unit area, d = mean average diameter of size-class and L = length of sample line.

For obtaining an objective sample line of constant length a metal frame providing a sample line length of 30 cm was used. The total number of sample measurements was 36 per plot for Watershed 10 and 68 per plot for Mack Creek and Lookout Creek. These measurements were randomly distributed over cross sections perpendicular to the stream axis established at the ends of each subarea (9 for Watershed 10 plot and 17 for Mack Creek and Lookout Creek). For calculation and computation, a Monroe 1665 programmable calculator was used.

Measurement of coarse debris

The coarse debris was measured piece by piece with the help of calipers and a steel tape in terms of diameter of the big end, diameter at the small end and length. Pieces that were assumed to break up completely due to lack of solid wood fiber if they were moved downstream were not taken under consideration. The programmable calculator Monroe 1665 was used for the computation of data. This was a relatively easy way to obtain volume per piece (smalian formula), volume per subarea, volume per plot and average colume per unit length of stream.

Conversion of measurement units

We assumed the specific weight of this organic debris to be 0.58 at an average moisture content of 10% (McKimmy and Ching 1968).

As mentioned before, the coarse debris was segregated into three classes, referring to the fact that pieces of different volume and wèight make the use of different equipment necessary while cleaning up.

RESULTS

The volume (M3/100 m) and weight (T/100 m) of debris found in the sample plots of all three streams is contained in Table 1. The definition of the immediate impact zone of a stream is difficult and very arbitrary. Generally it would be the area affected by a 100-200 year storm, or where the flood plain marks were distinct. In Watershed 10 the sample plot width was 5 times the width of the stream channel. The sample plot width in Mack Creek was about 1.5 times the stream width, while on Lookout Creek the plot width and channel width were about equal (Figure 1). Lookout Creek may be too large for the size of sample plot used. Certainly the inclusion of its gravel bar floodplain in the tables makes comparison with the other streams more comparable.

The Watershed 10 data show the variation between sample plots on the same watershed. More sample plots will have to be taken from Lookout Creek in order to have some confidence in the debris total.

Comparison between the streams is difficult but can be done at least two ways. One can calculate the amount of debris on the basis of a standard plot size, e.g., 30 ft by 400 ft. This was done on Table 2 and the results were as one might expect. On Watershed 10, the smallest stream the debris in each category was higher than the two larger streams. As the discharge rate is not very great, the amount of flushing of branch and bale size debris is minimal. The same rational is used to explain why Mack Creek (upper, old-growth) has greater amounts of debris than Lookout Creek. The problem with this comparison is that a 30 ft plot width on Watershed 10 is 60 times its channel width and extends far beyond any possible influence of the stream. Lookout Creek has just the opposite problem, as 30 ft sample plot width is less than the average channel width.

A second type of comparison would be the amount of debris actually in the stream channel (Table 3). In this comparison the amount of debris has a sequence of Mack Creek> Lookout Creek> Watershed. In fact, the amount of debris in Watershed 10 is an order of magnitude less than Mack Creek and

4.5 times less than Lookout Creek, not at all what one would intuitively expect, based on the discharge rates of the streams.

When the total amount of debris in the channels (Table 3) for the three streams is recalculated on the basis of To/100 m/1 cfs, the rank order of the streams if WS10 > Mack Creek>Lookout Creek (average cfs used: WS10 .1, Mack Cr. 10, Lookout Cr. 100). This is the same rank order as that calculated on the basis of a standard sample plot.

Lammel (1973) sampled several cascade streams (slightly smaller than Mack Creek) under old-growth Douglas-fir. He found ranges of 29.15 to 126.24 M3/100 m and 17.05 to 73.85 To/100 m for the fine material. Coarse debris in WS10 and Mack Creek fall within this range. Lookout Creek is much lower than the lowest values from Lammel. The fine material for all three streams is far below Lammel's lowest value.

The results of this study provide us with a reasonable estimate of debris standing crop. Further refinement would require considerably more effort. We feel that the data allow some comparison among the three watersheds, and provide a reasonable baseline measurement for further study.

Table 1. Actual volume (M^3/100 m) and weight (To/100 m) of debris found in immediate impact zones of three Cascade streams in the H. J. Andrews Experimental Forest.

	Fine debris						Total fine debris		Coarse debris	
	0-1 cm		1-3 cm		3-10 cm					
	Vol.	Wt.	Vol.	Wt.	Vol.	Wt.	Vol.	Wt.	Vol.	Wt.
Watershed #10										
South Fork	.391	.311	.260	.206	.563	.448	1.215	.965	18.041	10.554
North Fork	.198	.157	.201	.160	1.592	1.267	1.995	1.585	13.977	11.101
Main Branch	.182	.144	.154	.123	.845	.671	1.181	.937	8.826	5.164
Average	.257	.204	.205	.163	1.000	.795	1.464	1.162	15.281	8.940
Mack Creek										
Upper, old growth	.079	.063	.083	.066	1.410	1.119	1.572	1.248	59.412	34.756
Lower, clear cut	.036	.028	.095	.075	.564	.448	.694	.551	2.321	1.358
Lookout Creek										
Rock Quarry	.027	.022	.059	.047	.752	.597	.838	.666	14.309	8.406
Channel & flood plain	.380	.302	.675	.536	1.974	1.507	3.028	2.404	25.130	14.701

Table 2. Volume (M^3/100m) and weight (To/100m) of debris found in immediate impact zones of three Cascade streams in the H. J. Andrews Experimental Forest. Values are calculated on the basis of a 30 ft by 400 ft sample plot for comparative purposes.

	Fine debris						Total fine debris		Coarse debris	
	0-1 cm		1-3 cm		3-10 cm					
	Vol.	Wt.	Vol.	Wt.	Vol.	Wt.	Vol.	Wt.	Vol.	Wt.
Watershed #10										
South Fork	.740	.588	.492	.390	1.064	.846	2.296	1.824	108.243	63.324
North Fork	.374	.296	.380	.302	3.01	2.396	3.772	2.996	113.862	66.608
Main Branch	.344	.273	.292	.232	1.598	1.268	2.232	1.772	52.956	30.981
Average	.486	.386	.388	.308	1.891	1.503	2.767	2.197	91.687	53.638
Mack Creek										
Upper, old growth	.079	.063	.083	.066	1.410	1.119	1.572	1.248	59.412	34.756
Lower, clear cut	.036	.028	.095	.075	.564	.448	.694	.551	2.321	1.358
Lookout Creek										
Rock Quarry	.026	.021	.057	.045	.727	.577	.808	.644	13.890	8.126

Table 3. Volume ($m^3/_{100m}$) and weight ($To/_{100m}$) of organic debris in stream channel.

	Fine debris						Total fine debris		Coarse debris	
	0-1 cm		1-3 cm		3-10 cm					
	Vol.	Wt.	Vol.	Wt.	Vol.	Wt.	Vol.	Wt.	Vol.	Wt.
Watershed #10										
width										
.25m	.021	.017	.017	.014	.083	.066	.122	.096	1.268	.742
.50m	.043	.034	.034	.027	.167	.133	.244	.194	2.552	1.493
Mack Creek										
6 meter width										
upper	.053	.042	.055	.044	.940	.746	1.049	.832	39.628	23.182
lower	.024	.019	.063	.050	.376	.299	.463	.368	1.548	.906
Lookout Creek										
Rock Quarry	.027	.022	.059	.047	.752	.597	.838	.666	14.309	8.406

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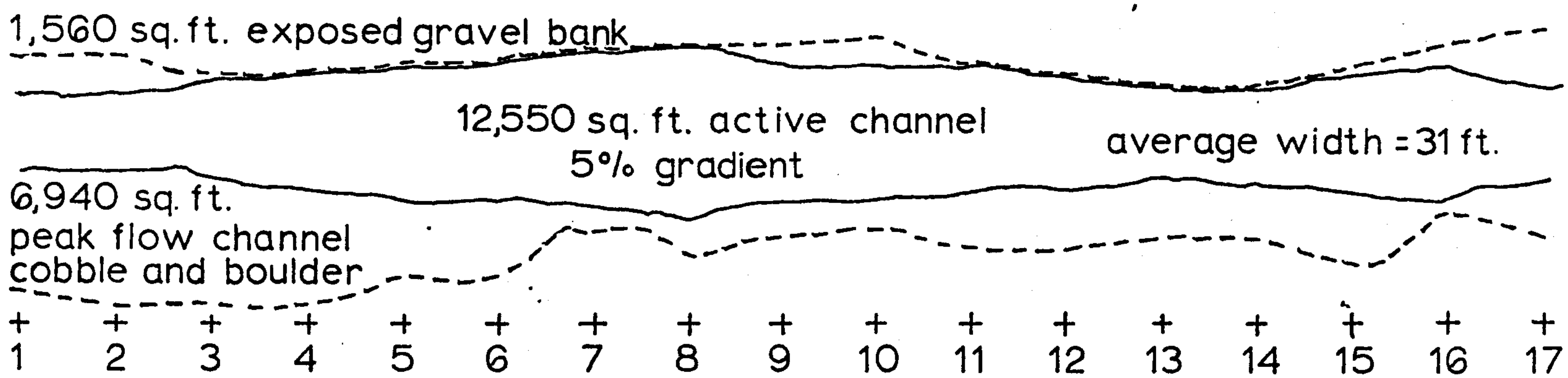
Scale: 1" = 50'



Sketch of sample plot on Lookout Creek – December 5, 1972

TRANSLOCATION OF NUTRIENTS FROM FISH CARCASSES

IN STREAMS

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INTRODUCTION

Autotrophic production is generally considered the principal source of energy in most ecosystems. Particulate organic matter, however, often provides more energy than primary production in running water systems (Nelson and Scott 1962, Hynes 1963). Animal carcasses contribute to the standing crop of detritus in streams, but this contribution is usually insignificant in comparison to allochthonous organic matter. The addition of nutrients in the form of animal carcasses can be significant in such phenological events as the spawning migrations of anadromous fish.

Several investigations have suggested that biogenic enrichment by carcasses plays a significant role in the population dynamics of the sockeye salmon in the lake systems of the Pacific Northwest (Nelson and Edmondson 1955, Donaldson 1967, Krokhin 1967, Hartman and Burgner 1972). The species of Pacific salmon which spawn in streams, the silver and chinook salmon, could provide substantial nutrient loads to streams periodically. The complex intersections between spawning salmon, stream oommunities, and environmental factors prevent the development of a clear correlation between nutrient addition from salmon carcasses and productivity of the system. However, community response to salmon carcasses gives an indication of the potential of the system to utilize nutrients from carcasses. Radiological techniques provide a convenient method for following the uptake of nutrients from carcasses by stream biota. The physical and chemical states of the nutrients can be approximated by injecting trout with selected radionuclides and allowing the fish to incorporate these nuclides into their tissues. The utilization of fish carcasses in streams can be simulated by killing the labeled fish and placing it in a stream.

MATERIALS AND METHODS

A laboratory stream 1.66 m long with a volume of 38 liters was used to simulate stream conditions. A representative stream community was established which consisted of:

1) Primary Producers - Filamentous green algae
   Liverwort (*Chiloscyphus* sp.)

2) Decomposers - Fungi (Introduced with fish carcass. Probably *Saprolegnia*)

3) Primary Consumers
   Herbivores - Mayflies (*Epeorus*, *Paraleptophlebia*)
   Detritus & Periphyton Feeders - Caddis Flies (*Dicosmecus*)
   Snails (*Oxytrema silicula*)

4) Secondary Consumers - Yearling crayfish (*Pacifasticus trowbridgi*)
   Rainbow trout (*Salmo gairdneri*)

Radioactive iodine was injected interperitoneally and intravenously into five rainbow trout. The fish were held in an aquarium for three days to allow them to incorporate the ^{131}I into their tissues. One radioactively labeled trout was killed and placed at the head of the laboratory stream. Stream organisms were removed at various intervals, weighed, monitored for radioactivity, and returned to the stream. Water samples were taken hourly and a 500 ml aliquot was taken from daily composites for radioassay. A method for precipitating iodine from water samples was developed with assistance from Dr. Norm Cutshall, Department of Oceanography, Oregon State University. 100 mg of I^- in the form of NaI as carrier was added to each 500 ml sample. The pH of the sample was adjusted to 10 with NaOH. Organic bound iodine was oxidized by adding 50 ml of 30% H_2O_2 in parts and slowly warming to 90°C. The sample was cooled and adjusted to a pH of 1 and $NaHSO_3$ added to 0.5F. The iodine was then precipitated by adding 200 mg Ag as $AgNO_3$. A 5x5 NaI solid scintillation well detector was used for all radiation detection.

Two of the radioactively labeled fish were killed and homogenized to estimate radioactivity per gram of fish. The remaining fish will be dissected to determine the amount of ^{131}I per gram of skin, muscle, bone, gill filament, liver, spleen, gonad, and thyroid.

RESULTS

The accumulation curves of the stream organisms are presented in Figure 1. Several generalizations about the trophic structure in streams and community response to autochthonous organic material can be made from these data. Caution should be exercised in the interpretation of the data because of the artificial nature of the laboratory stream and "representative biota," the volatile nature of iodine, and the fluctuation in community composition.

The majority of the ^{131}I leached from the carcass within the first 15 days. The second activity peak in the activity curve for water is not reliable because radioactive decay decreased the activity below the limits of quantitative detection. Leaching was possibly a function of the volatile chemical nature of iodine and that a majority of the iodine was not organically bound. The periphyton community responded quickly to the leaching from the carcass; the peak activity in the algae occurred simultaneously with the peak activity in water. Fungal uptake lagged several days behind algal uptake but this was probably due to the time required for the fungal population to develop.

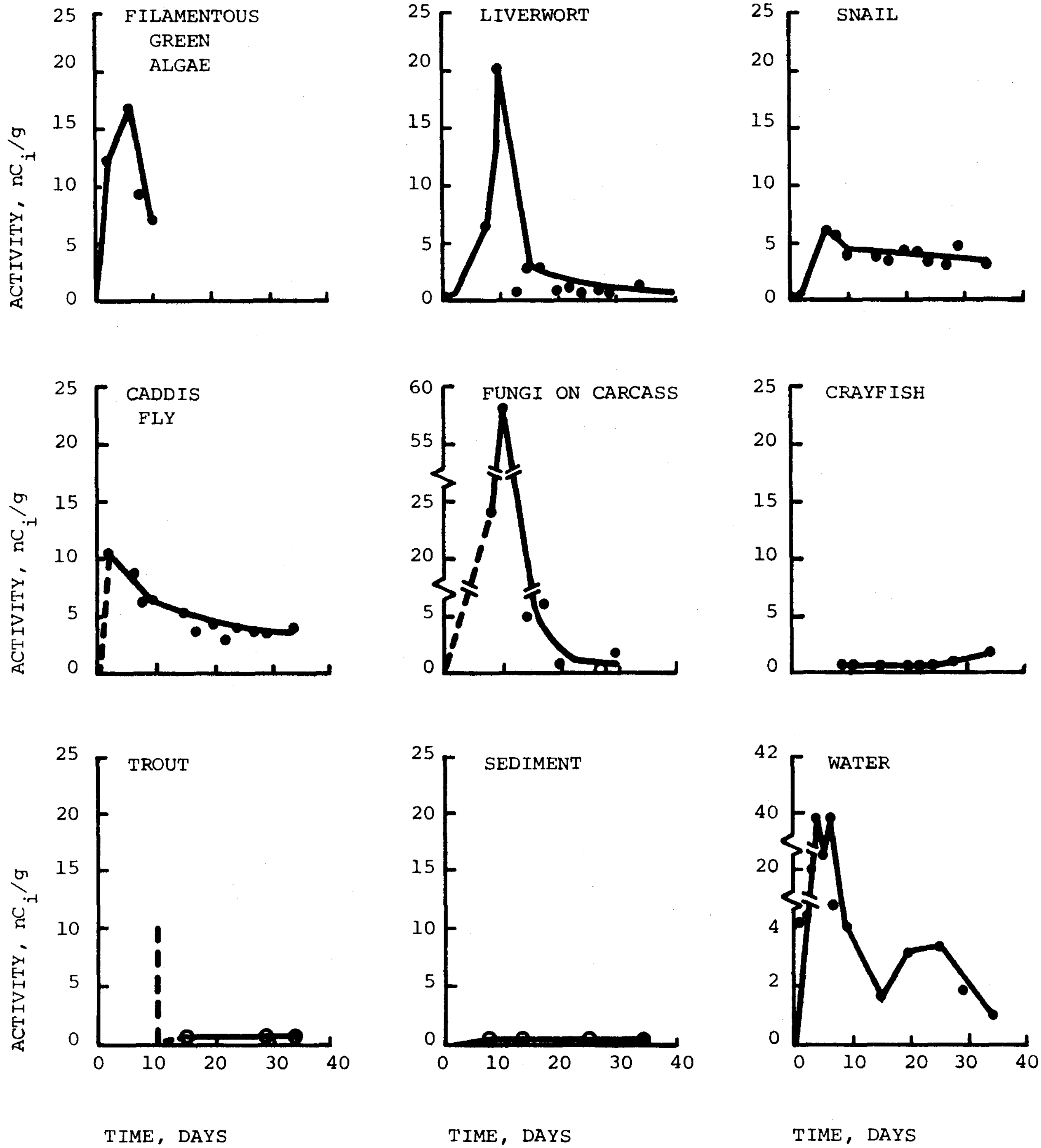
The herbivorous mayflies were not established in sufficient numbers to monitor. However, a trend suggested a curve lagging behind the periphyton curve. Detrital feeders exhibited rapid uptake and reached equilibrium quickly. Both the caddis fly and the snail were observed feeding on the carcass within the first day. Both were instrumental in opening the body cavity and subsequently speeding the rate of decomposition.

Secondly consumers exhibited the typical, gradual accumulation curves of carnivores. The data suggested crayfish lost a large proportion of their accumulated iodine in their exoskeleton upon molting. The trout showed little uptake of iodine, but they were not observed feeding during the experiment.

DISCUSSION

Detrital feeders and primary producers were the initial groups to process large particulate organic matter and leached dissolved matter in streams. The transfer of nutrients from these trophic levels followed normal consumption and decomposition routes. The general response of the system to large particulate organic matter was rapid. This mechanism would prevent substantial loss of nutrients from the system.

This study demonstrated that stream systems utilize large particulate organic matter quickly and showed the general responses of several functional groups. The rates and processes within stream communities will give better understanding of the roles and importance of stream ecosystems than supporting studies of present concepts of trophic structure in streams. Future research should be directed toward the study of rates and processes within various compartments of stream ecosystems.


FILAMENTOUS GREEN ALGAE
LIVERWORT
SNAIL
CADDIS FLY
FUNGI ON CARCASS
CRAYFISH
TROUT
SEDIMENT
WATER
ACTIVITY, nC_i/g
TIME, DAYS
0
5
10
15
20
25
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60
2
4
40
42
30

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A STUDY OF THE ALGAL COMMUNITY BY CHLOROPHYLL EXTRACTION IN THREE CASCADE STREAMS

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A study of Cascade streams from the H. J. Andrews Experimental Forest is currently being undertaken to elucidate three aspects of the primary production component: (1) community structure, (2) effect of clearcut vs. natural over-story, and (3) algal biomass comparisons on three streams of distinctly different flow rates.

METHODS

Primary production estimates of the diatom communities were undertaken using baskets of clean stream substrate incubated from 12 July 1972. Pigment estimates from basket incubated substrate were compared with resident rocks collected periodically. Incubation baskets, fabricated from one-half inch mesh hardware cloth were 10 cm. long x 10 cm. wide x 2.5 cm deep. Substrate consisted of small flat stones placed in baskets to fill as much internal volume as possible. Glass microscope slides were incubated simultaneously in each basket. Baskets were incubated in both pool and riffle sections of each stream. Basket collections were taken monthly to December, after which estimates were made solely from resident substrate. Samples from each site were placed in jars and immediately filled with 90% acetone. Samples were extracted in the dark in ice for 20 hours. Following extraction the volume of acetone from each sample were taken at 665 mμ and 750 mμ on a Beckman 20 spectrophotometer. Samples were then acidified with 1-2 drops IN HCl and readings repeated. Spectrophotometric absorbance was concerted to μg Chl a by the following equation:

$$\mu g \text{ Chl a per sample} = 11.9[2.43(D_b - D_a)]\cdot(v/l)$$

where:

D_b = optical density before acidification
D_a = optical density after acidification
v = volume of solvent used in extraction
l = path length of spectrophotometer cell in cm.

A complete description of the above procedure is provided in IBP Handbook 12, Primary Production in Aquatic Environments (Vollenweider).

For a determination of community structure, slides incubated simultaneously on each basket were examined with a Nikon field microscope at 100x and 400x magnifications.

RESULTS AND DISCUSSION

Direct microscopic examination indicated the pennate diatom *Achnanthes lanceolata* was the dominant algal flora throughout the year in each stream (Figure 1). The green alga, *Prasiola sp.* was observed only in Mack Creek through the spring-summer months of March through August. *Zygnema sp.*, a flamentous green alga, was also present during the warmest months of maximum solar radiation. This also corresponds to the period of lowest stream flow. From August through December *Melosira sp.* was the dominant algal flora in Lookout Creek.

Substrate baskets incubated in clearcut and natural canopy areas of Mack Creek indicated comparatively little difference in chlorophyll a (Figure 2) (Table 1). The open clearcut (Lower Mack Creek), however, was colonized faster than the shaded area (Upper Mack Creek), which exhibited a lag time of approximately two weeks. By 6 October both baskets and resident substrates were colonized almost equally. Similar extent of colonization was observed on collections taken 27 October and 10 November. Final collections taken 1 December indicated the peak of algal biomass in basket samples. Resident substrate was not sampled on that date. A nine-day storm in late December, followed by another on 14 January, washed out the remaining baskets. As a result, from 26 January to present, determinations have been based on samples of resident substrate only. The overall similarity in primary production of shaded and clearcut portions of Mack Creek was unexpected and cannot be readily explained.

Biomass estimates based on chlorophyll determinations indicated that organic biomass was related to stream size. Watershed 10, the smallest stream, had the lowest primary production of all streams investigated. An approximate biomass of 0.33g/m^2 (Figure 3) (Table 3) was calculated for basket collections, and 0.24g/m^2 on resident substrate. Biomass was estimated by multiplying chlorophyll a values by 120 as outlined by Vollenweider for low chlorophyll populations. In such streams of low primary productivity, allochthonous inputs are no doubt essential to the energetic functioning of the stream community. In Mack Creek estimates of biomass were approximately 10 times those found in Watershed 10. At the upper shaded portion of Mack Creek, mean monthly estimates of biomass were 2.38 g/m^2 on basket incubated substrate and 2.75 g/m^2 on resident substrate (Table 3). In the clearcut section of lower Mack Creek, mean monthly biomass averaged 3.09 g/m^2 on incubated rock, and 3.48 g/m^2 on resident substrate, respectively.

Some effects of the absence of canopy can be observed; as noted previously, however, the difference was not as great as initially anticipated. For this reason estimates of both stream sections were averaged together to obtain biomass estimates for the entire stream (Figure 3). Once colonized, incubated gravel from Mack Creek revealed consistent biomass levels in the absence of scouring. Chlorophyll estimates from resident substrate indicate scouring effects in January samples, as well as recolonization in subsequent months. Lookout Creek, the largest of the three streams investigated, indicated the greatest fluctuation in biomass estimates through time (Figure 3). Due to its width, Lookout Creek is exposed to solar radiation through most of the day. It is also the stream most prone to scouring during major storms. During periods of fair weather the gravel substrate is readily colonized, thus the high estimates of algal biomass were not surprising. A very mild, dry autumn permitted colonization far in excess of what might be expected in a more normal year. During the long storms of December and January, the algal populations crashed as rocks became scoured. The mild winter which followed resulted in substantial recolonization of algal populations. Algal biomass on basket-incubated substrate averaged 5.81 g/m^2, on resident rocks the average was 4.28 g/m^2 on a mean monthly basis (Table 3). A major reason for the lower average of resident substrate was the absence of sampling at Lookout Creek 1 December, when primary production peaked.

CONCLUSIONS

Results from Watershed 10, with its extremely low but consistent biomass estimates, indicate little additional information will be required during the 1973 sampling year. Additional emphasis will be placed by doubling sampling effort to biweekly on the larger Lookout Creek and Mack Creek. Differences between clearcut and natural canopy areas will be examined for an additional year on upper and lower Mack Creek. Large numbers of baskets containing clean, natural substrate will be incubated April 1973, and be sampled biweekly to continue estimates of algal biomass. In addition, baskets will be placed in Lookout and Mack Creek biweekly, and incubated for 2 to 4 weeks to obtain colonization rates at various seasons of the year. Colonization rates, in addition to P32 field studies by other investigators, will be used to estimate turnover times of periphyton populations.

Table 1. Chlorophyll determinations by 90% acetone extraction on gravel substrate incubated 12 July 1972 in three Cascade streams (µg Chla/cm^2).

Stream	20 July	27 July	2 Aug	25 Aug	7 Sept	6 Oct	27 Oct	10 Nov	1 Dec
UMC	.10	.58	2.29	2.51	2.01	2.08	2.54	3.09	3.46
	.09	.39	1.58	2.77	3.00	2.14	2.80	2.65	2.18
$\bar{X}$	.10	.48	1.40	2.64	2.50	2.11	2.67	2.60	2.82
LMC	.30	1.56	3.00	2.65	2.78	3.28	3.23	3.80	4.05
	.82	1.46	2.30	1.81	2.91	3.19	2.68	2.75	5.19
								3.15	2.65
$\bar{X}$	.56	1.51	2.65	2.23	2.84	3.24	2.96	3.23	3.96
MC $\bar{X}$	.33	1.00	2.29	2.44	2.68	2.68	2.81	2.92	3.39
LO	.74	1.64	2.42	3.40	3.37	6.18	3.79	6.53	9.35
	.79	1.29	2.08	3.42	5.93	7.26			13.11
									16.54
$\bar{X}$	.77	1.46	2.25	3.41	4.65	6.72			13.00
WS 10	.16	.20	.15	.36	.15	.32		.56	.27

Table 2. Chlorophyll determination (μg Chla/cm^2) by 90% acetone extraction on resident gravel from three Cascade streams

Stream	27 July	31 Aug	6 Oct	27 Oct	10 Nov	26 Jan		16 Feb	10 Mar
UMC		3.09	2.59	2.34		1.52	1.00	3.35	2.49
		5.00				.87	.64	3.31	2.08
		3.23				1.09	.60		.80
$\bar{X}$		3.77				.95		3.33	1.79
LMC		4.16	3.28	3.47	3.56	.65	1.19	4.09	1.94
		4.06		2.44	1.67	.95	.40	2.43	2.83
		3.40				1.04	.80		1.30
$\bar{X}$		3.87		2.96	2.62	.84		3.26	3.02
MC $\bar{X}$		3.82	2.94	2.65		.90		3.30	1.91
LO	3.19	3.43		4.05	3.44	.78	.52	2.92	4.63
	4.19	3.56		2.73		.77	.57	1.43	3.23
		3.30				1.46	.37	2.15	3.31
						.36	1.80	3.56	4.63
							.61	2.97	
								3.21	
$\bar{X}$	3.69	3.43		3.39		.80		2.71	3.93
WS 10	.32			.59				.16	.19
								.08	.08
$\bar{X}$								.12	.11

Table 3. Mean monthly estimate of algal biomass for three Cascade streams (g/m^2).

Stream	Incubated Substrate	Resident Substrate
UMC	2.38	2.75
LMC	3.09	3.48
MC	2.74	3.12
WS 10	0.33	0.24
LC	5.81	4.28

UMC = Upper Mack Creek (shaded)
LMC = Lower Mack Creek (clearcut)
MC = Mack Creek (combined)
WS 10 = Watershed 10
LC = Lookout Creek

Figure 1. Seasonal variation of community type in three Cascade streams.

Community Type	Characteristic Plant	Location	J	F	M	A	M	J	J	A	S	O	N	D
Pennate Diatom	<u>Achnanthes</u>	Upper Mack Creek Lower Mack Creek Lookout Creek Watershed 10	—	—	—	—	—	—	—	—	—	—	—	—
Thallus Chlorophyta	<u>Prasiola</u>	Upper Mack Creek Lower Mack Creek			—	—	—	—	—					
Pilamentous Chlorophyta	<u>Zygnema</u>	Lower Mack Creek Lookout Creek							—	—	—	—	—	
Centric Diatom	<u>Melosira</u>	Lookout Creek								—	—	—	—	—

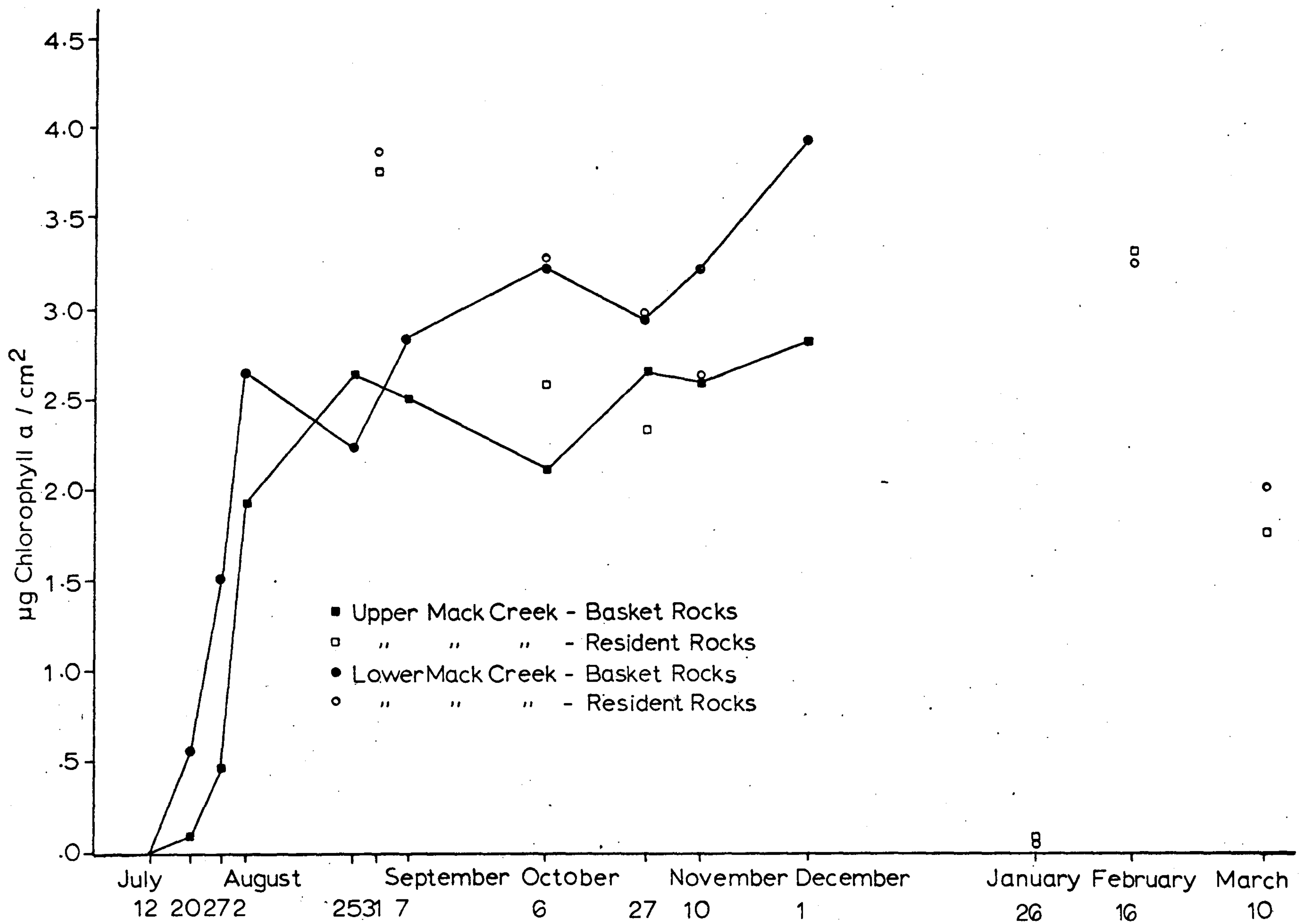

Figure 2: Spectrophotometric estimates of chlorophyll a in upper (shaded) and lower (clearcut) sections of Mack Creek.

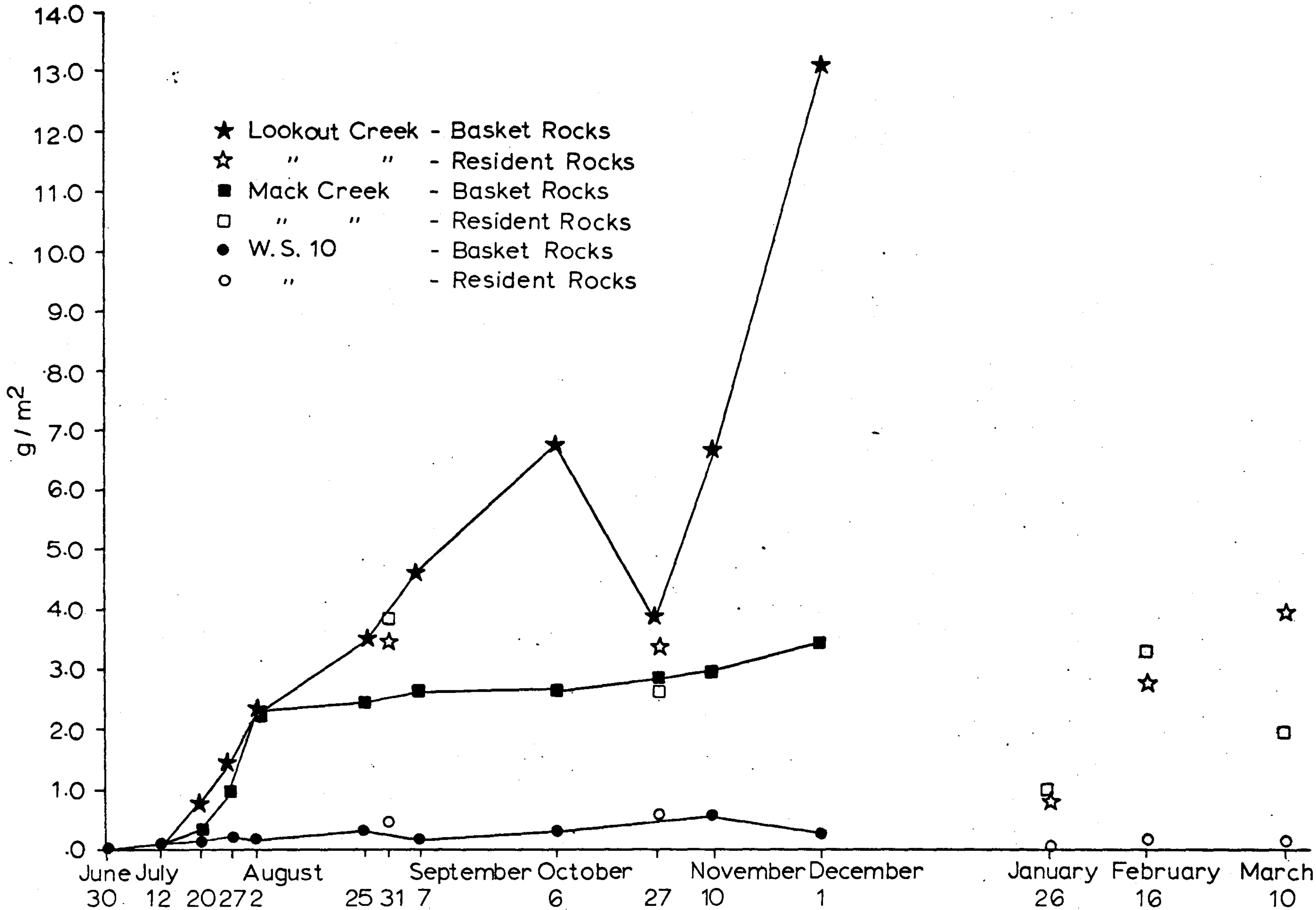

Figure 3: Biomass estimates on three Cascade streams based on chlorophyll extraction techniques.

CADDISFLY STUDIES ON LOOKOUT CREEK

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Glossosomatid caddis flies were selected as the most appropriate taxa of grazing insects for detailed studies in the Andrews watershed. It has been necessary to undertake life history studies of these caddisflies before the production-ecology can be studied.

The numbers of glossomatids in the standard benthos collections (pot samples) were too low to provide data on density or age distribution so a separate sampling program was initiated at one site on Lookout Creek. As these grazers occur on the surface, it is not necessary to collect into the substrate. Thus the collecting method of these "rock surface samples" is to remove the projecting stones from a unit area and wash the organisms into a bucket. Initially three o.5 m^2 collections were taken in a transect, but in 1972 this was modified to five 0.2 m^2 samples.

The sampling method is also effective for collecting net-spinning caddis flies so biomass data are also being obtained on another functional group--the "collectors" of the family Hydropsychidae.

Five collections were made from June to November 1971, and a monthly schedule was initiated in June 1972. A small scale sampling program for glossosomatids is also being done at Berry Creek near Corvallis because winter flooding is not as severe as in the Andrews watershed so collecting can be done all winter. The caddis flies were sorted to instar by head capsule measurements. Mean dry weight of each instar was obtained by weighing a series of each instar (60°C for 48 hrs).

RESULTS

The two species of glossosomatids, *Glossosoma* sp. and *Agapetus bifidus* have very different life cycles. *Agapetus* larvae complete development in about two months (June to August) and most of the year is apparently spent as a diapausing egg. First-instar *Glossosoma* larvae were collected in August (when *Agapetus* were final instars or pupae) and had only developed to the third instar by November. There is apparently some further growth during the winter, with pupation occurring in May and June.

The instar composition of *Glossosoma* and *Agapetus* are compared in Table 1. It is apparent that a monthly collecting schedule is adequate for obtaining field growth rate data on *Agapetus*. However, because of its rapid development, this species will be ideal for laboratory studies of growth and feeding.

Total collections of caddisflies, by month are given in Table 2. *Glossosoma* is the dominant taxa, numerically. There are very similar population trends in both years with numbers increasing in August and September when the new generation begins. In 1971 there was a marked decrease in all groups from September to November. This was associated with early winter rains; the decrease may be due to mortality from the flushing action and/or to a dispersal of the population over the larger surface area when stream width increases. By contrast in 1972 when streamflow had not increased significantly by the November, the population decrease of *Glossosoma* or Hydropsychidae was not as great as in 1971.

Preliminary biomass estimates are given below for *Glossosoma* and Hydropsychidae. Though the former are numerically dominant, the latter are much larger individuals resulting in a greater population biomass. The dry weight (mg/m^2) per month was:

	Jun	Jul	Aug	Sep	Oct	Nov
Glossosoma	66.2	0.2	77.8	249.7	378.8	321.9
Hydropsychidae	4.67	2.4	22.1	613.3	985.4	668.0

Table 1. Instar Distribution of *Glossosoma* and *Agapetus*, Lookout Creek (no./m^2)

	1971						1972					
	Jun	Jul	Aug	Sep	Oct	Nov	Jun	Jul	Aug	Sep	Oct	Nov
Glossosoma												
Instar												
1		3	5336	973		4		26	5414	630		39
2			388	8543		73		4	563	9690	1415	311
3			36	325		537			32	320	3704	3188
4			3	3		33			35	0	284	311
5			23	5		6			14	32	41	39
prepupa	6		1	0		0	1		2	8	0	
pupa	74	4	0	18		0	20			32	8	
pupa	75	5	1	9		0	32			24	4	
Total	155	12	5788	9876		653	53	30	6060	10736	5456	3888
Agapetus												
Instar												
1		1					8					
2		11					8	8				
3		47					3	39				
4		207						124	1			
5		131	47					162	20			
prepupa		3	18			1		9	36			
pupa		1	49						60	4		
pupa		0	47						55	8		
Total	0	402	161	0		1	19	342	172	12	0	0

Table 2. Trichoptera from Lookout Creek, rock surface samples, 1971 and 1972 (number per square meter)

		June		July		August		September		October		November	
		L	P	L	P	L	P	L	P	L	P	L	P
Glossosoma	1971	6	149	3	9	5787	1	9849	27	-	-	653	0
	1972	0	53	30	0	6058	2	10672	64	5444	12	3888	0
Agapetus	1971	0	0	401	1	65	96	0	0	-	-	0	0
	1972	19	0	333	9	21	151	0	12	0	0	0	0
Neophylax	1971	65	6	0	171	4	123	0	133	-	-	1	0
	1972	5	1	1	8	0	10	0	0	12	0	4	0
Hydropsychidae	1971	73	8	not counted		470	0	3053	0	-	-	875	0
	1972	13	7	124	2	725	0	1504	0	1460	0	1052	0
Other Trichop.	1971	not counted		not counted		16	212	0	-	-		111	0
	1972	12	5	600	2	206	448	4	208	0		192	0

ESTIMATES OF FOOD CONSUMPTION BY PERIPHYTON-GRAZING CADDISFLIES

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These data are based on my research at the FBA Laboratory, Wareham, Dorset, using the caddisfly *Agapetus fuscipes* in both field and laboratory studies. Some background information on the field site at Puddletown, Dorset, and rearing methods is given in my ms. from the E.S.A. Montreal meetings, "Growth and Feeding by *Agapetus fuscipes*."

In the present report I am using field data collected from core samples (as opposed to artificial substrates used in the above ms.) and two laboratory methods of estimating food consumption to obtain an "order of magnitude" estimate of the impact of the *Agapetus* population on the periphyton food source. It should be emphasized that these estimates are very preliminary because I was attempting to develop methodology for consumption studies and had no time to repeat the experiments while in England. In addition the experimental design of the field sampling was ruined by an unfortunate, but catastrophic, pollution problem. The routine weed cutting in the stream and clearing of the adjacent water cress beds was carried out when stream flow was exceptionally low. The effluent from the decaying plant material drained into the stream and reduced dissolved oxygen levels to near zero, resulting in a fish-kill and reducing caddisfly populations from 50,000/m^2 to 0 at one site. In addition other parts of the stream almost dried up after the weeds were cut. Thus population estimates had to be pooled from several sites and collection times to obtain a mean density for the year and no confidence intervals are available.

METHODS

Benthos Sampling

Ten to 20 core samples (ranging from 20-66 cm) were taken on 9 sampling dates. The larvae were removed by flotation and examination of the substrate with a low-power dissecting microscope. The larvae were separated into instars by measuring head-capsule widths. Biomass of each instar was obtained by multiplying the numbers per instar by mean instar dry weight (fresh material dried at 60°C for 48 hours).

Faeces Production

Faecal material was obtained from series of 4th, 5th, 6th, early-final and late-final instar larvae. Feces were collected at 1-2 day intervals from each series for at least one week. The faecal material was pipetted from the drippery rearing units and oven dried. As the pellets are a distinctive shape and quite dense it was possible with careful pipetting to separate them from most of the algal material.

Faecal production was expressed as mg/g/day for each instar (rates for instar 4 were also used for instars 1-3). Diatom consumption was calculated, based on a factor of 30% organic matter and using assimilation efficiencies of 20% and 40% organic matter for *Agapetus*. Example:

$$\text{Conc: } (@\ 20\%\ \text{efficiency OM}) = \frac{100}{94} \times \text{Feces.}$$

Chlorophyll Analysis for Consumption Estimates

The chlorophyll *a* levels in trays grazed by final-instar larvae for 6 days were compared with non-grazed trays. Chlorophyll was converted to dry weight biomass using a 50 X factor. To estimate consumption by the field population, it was assumed that final instar larvae accounted for 50% of the consumption so mean annual density of final-instar larvae was doubled.

RESULTS

The results for population estimates, and food consumption estimated by faecal production and by chlorophyll analysis are given in Table 1.

The two methods of estimating consumption are independent, but gave very similar results when expressed as consumption per m^2 for the field population; the chlorophyll method (136 gm/m^2) fell between the 2 estimates based on the faeces method (20% efficiency 134 gm/m^2, 40% efficiency 143 gm/m^2).

The small difference obtained by doubling the assumed efficiency of utilization or organic matter from 20% to 40% suggests that figures from the literature can be used without resorting to further experimentation.

The similarity of results between the 2 methods of estimating consumption suggests that the estimates are in the right order of magnitude. However in these pilot experiments, so many assumptions are involved in the calculations that similarity of results may well be fortuitous. The methods are promising and worth pursuing in greater detail.

Table 1. Food consumption by periphyton-grazing caddisflies.

	Instar					
	1-3	4	5	6	6	Total Density
A. Population estimates of *Agapetus* (M^2)						
Jul	16,500	3,300	1,500	3,900	4,800	30,000
Aug	8,580	2,080	910	780	650	13,000
Sep	12,980	6,380	1,980	220	440	22,000
Dec	540	2,580	1,920	780	180	6,000
Feb	50	325	675	975	475	2,500
Mar	0	39	182	442	637	1,300
Apr	0	0	42	175	483	700
May	0	0	8	60	332	400
Jun	306	72	42	42	138	600
TOTAL	38,956	14,776	7,259	7,374	8,135	76,500
MEAN	4,328	1,642	807	819	904	8,500
MEAN BIOMASS (grams)	.043	.049	.056	.123	.893	1.164
B. Faeces produced (mg/g/day)						
		631	395	446	235	
C. Diatom consumption (mg/g/day) based on B, using 30% organic matter for diatoms						
At 20% assimilation of organic matter		671	420	474	250	
At 40% efficiency		717	449	507	267	
D. Field population consumption (mg/day) based on A, B, and C						
20% efficiency	29	33	24	58	223	= 367mg/m²/day 134 g/m²/yr
40% efficiency	31	35	25	62	238	391mg/m²/day 143 g/m²/yr

E. Consumption extimated by comparison of Chlorophyll *a* values at different intensities of *Agapetus* grazing.

Chlorophyll consumption = 4.1 μg/day
Biomass = (Chl x 50) = .205 mg/day
Larval density = (904 x 2) = 1808/m²

Total consumption = 136 g/m²/yr

GROWTH AND FEEDING BY *Agapetus fuscipes* (TRICHOPTERA: GLOSSOSOMATIDAE)

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INTRODUCTION

This study is part of the IBP research program on the role of aquatic insects in stream ecosystems. The purpose was to select an appropriate insect to study as a grazer - that is, one whose feeding habits put it in the functional role of utilizing the autochthonous primary production by diatoms and other algae, and make this available to the higher trophic levels of carnivores. The ideal model species would be (a) abundant, (b) easy to sample in all life history stages, and (c) amenable to laboratory rearing.

While on sabbatical leave with the Freshwater Biological Association River Laboratory in southern England in 1971-72, I conducted field and laboratory studies of the very common caddis fly, *Agapetus fuscipes*, to determine whether this species or related species of glossomatid caddis flies would be suitable for production studies.

FIELD STUDIES

The field work was conducted in a small chalk stream near Puddletown, Doreset. The substrate was sand, small gravel and flint ranging to first-size. This type of stream is characterized by dense growths of macrophytes (watercress and water buttercup) which are usually cut two or three times a year.

Agapetus larvae were largely restricted to open areas of water between the clumps of macrophytes. The larvae and pupae occurred in dense populations of up to 6000 - 8000 per 0.1 m^2.

A rapid method of population census was devised using artificial substrates. The populations on brick placed in the stream were sampled at one to two week intervals throughout the year. This method provided for rapid collecting and required a minimum of separation of the organisms from the substrate. Even the first instar larvae (case length of 12. - 1.5 mm) could be collected, whereas in core samples from the benthos the search under a microscope for these tiny, sand-grained cases amongst the sand grains was both time consuming and had a very high margin of error.

Artificial substrates were particularly useful for obtaining life cycle data especially the change in population structure with time. The method was also used with advantage in comparing relative population densities at different sites. However, two drawbacks that were not overcome during this study were: (a) there is a tendency for larger larvae and particularly for pupae to occur on larger sized substrate than do the early instars; thus, brick populations tend to overestimate the proportion of late instars and pupae in the samples: and (b) it is probable that the bricks were preferred substrate and that larvae were attracted from some distance - hence use of numbers occurring on bricks for estimates of absolute population density would be misleading.

LABORATORY REARING

Agapetus fuscipes was successfully reared through the complete life cycle for the first time. The techniques developed for rearing provided preliminary information on growth rates and feeding rates, and indicate methodology for detailed studies of these parameters.

The rearing unit was a "drippery," a series of inclined pans with river water exchange provided by dripping faucets. Water temperature was quite similar to that in the field because of the flow-through arrangement. The periphyton community in the trays was similar in species composition to the field community but was dominated by the slow-water forms, e.g., *Melosira* and *Diatoma*.

Red sand was used as a substrate. When the larvae had made cases of this material they were switched to ordinary sand. The marked cases were easily observed, and the building of new cases could be used as an indication of growth and moulting.

GRAZING RATES

Larvae of *Agapetus* feed by grazing the periphyton film on the substrate. The larvae may move forward rasping a trail or cover a circular path using the anal legs as a pivot. As they frequently reverse themselves in the case, feeding can take place at either end and characteristic grazed overlapping circles were seen both in laboratory cultures and field situations. In the few guts examined, diatoms and detritus were dominant and there were also some colonial green algae. The species content of diatoms in the guts was similar to that of the periphyton community except that the small diatom *Achnanthes* was dominant in the guts whereas the filamentous diatom, *Melosira* and the large-celled *Diatoma* were dominant in the periphyton community.

Grazing rates of final-instar larvae were investigated in a preliminary experiment. Five trays were set up in the drippery with a range of caddis larvae densities and three control trays allowed to colonize with algae for two days before the *Agapetus* were placed in them. After six days of feeding, the amount of chlorophyll *a* was determined by spectrophotometric analysis (Figure 1). The results indicate a pronounced decrease in chlorophyll in the attached flora of grazed trays compared with the controls. The obvious decrease in chlorophyll with increasing density of larvae indicates a density-related function which appears to be curvilinear. The amount of chlorophyll in suspension was quite stable at all densities, suggesting that the larvae had a minimal effect on the planktonic fraction.

LABORATORY GROWTH RATES

Twenty groups of first-instar larvae from field-collected eggs were placed in the drippery between August and October. It was planned to remove a series of larvae every 1 to 2 weeks for head capsule measurements for detailed records of growth rates. This procedure was followed for two to three months but more than half the larvae had been removed while the cultures were still in the mid-instar so the remainder of the larvae were allowed to complete their development. Instead of using head capsule measurements, which could only be obtained by killing the larvae, case length was measured as an index of growth. There is a good correlation between case size and in-star but the precise instar of an individual cannot be determined by case length.

Figure 2 shows the increase in mean case length for two series of larvae that emerged about 2 months apart. The results during the experiment were unexpected in that larvae emerging in August when water temperature was higher, grew at a slower rate than the series that emerged in October. However, the results helped to explain the field data in that a method of sybcgronizing the emergence period is suggested. More than 80 percent of both series of larvae entered the pre-pupal stage between late March and mid-April.

LIFE HISTORY

Field collections from the artificial substrates, and the laboratory rearing data were used to interpret the life cycle of *A. fuscipes*. Records from northern England and Germany indicate a one-year life cycle, with the adult flight period from May to October. However, in southern England, an overlap of generations has been reported and a flight period from March to December. In the spring-fed chalk streams of Dorset, where winter water temperatures were near 9°C, and rarely below 6°, the adults have been collected in emergence traps in all months. Thus it seems probable that there is a partial second generation in soughern England.

The percentage of larvae in each instar each month, based on the artificial substrate samples, is shown in Figure 3. Starting with September, there is a well defined rogression of the peak through the instars. Pupation starts in February and increases through March, April and May. These data coincide well with the laboratory results in Figure 2.

The high proportion of 7th instar larvae and pupae in the July and August samples is troublesome. I interpret it as follows: The females have fully developed ovaries at emergence and the incubation period of the eggs is about one month. Thus eggs laid in early April would hatch in early May and with a minimum of three months required to complete the 7 larval instars, the larvae could pupate in August. However, if spring emerging larvae were to complete development during the summer, the rate of pupation should increase in late August and September as a result in the increased number of eggs laid in mid summer. In fact, the numbers pupating decreased after late July and the first week of August. Thus it seems probable that the peak of pupae in July-August results from slowly developing larvae of the previous year and only minimally from a rapid first generation. If synchronous emergence, as was suggested from the laboratory experiment, is a real effect, then the growth rate of larvae from eggs hatched in mid summer would be even slower than that of larvae emerging in August.

Agapetus or other species of glossosomatids are good candidate species for production-ecology studies. The life cycle is relatively straight forward and for a given geographical area can be determined using artificial substrates as collecting sites. The differences between an annual generation and a partial second generation are of obvious importance and require additional data. Laboratory rearing using a drippery is quite practical for detailed studies. Sychronization of emergence from larvae hatching at different times was demonstrated.

An alternative method to radio-tracer studies for measuring food consumption is suggested using a comparison of chlorophyll *a* levels between grazed and nongrazed trays and then converting this to biomass.

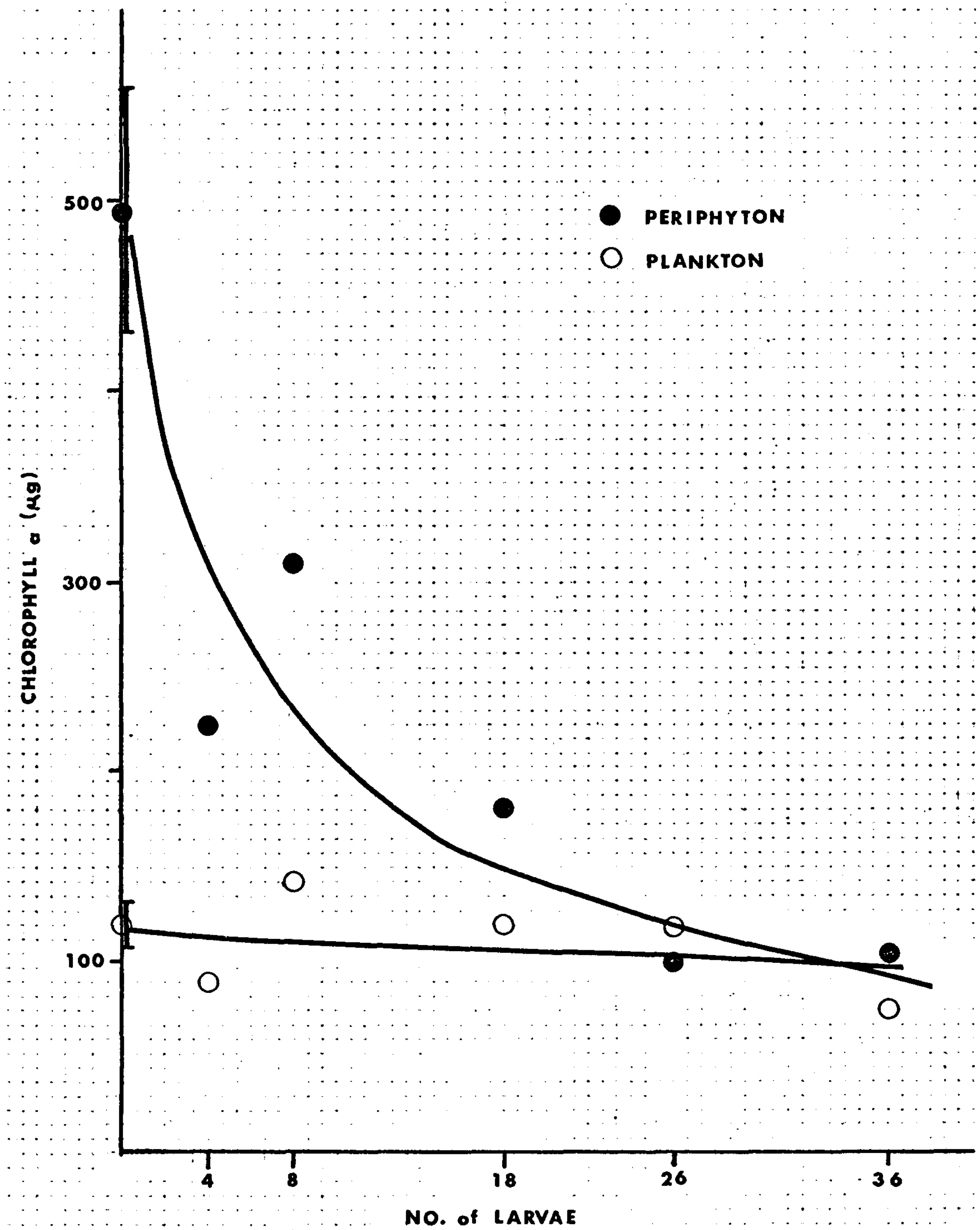

Fig. 1.

CHLOROPHYLL a LEVELS AFTER 6 DAYS FEEDING BY VARIOUS DENSITIES OF AGAPETUS

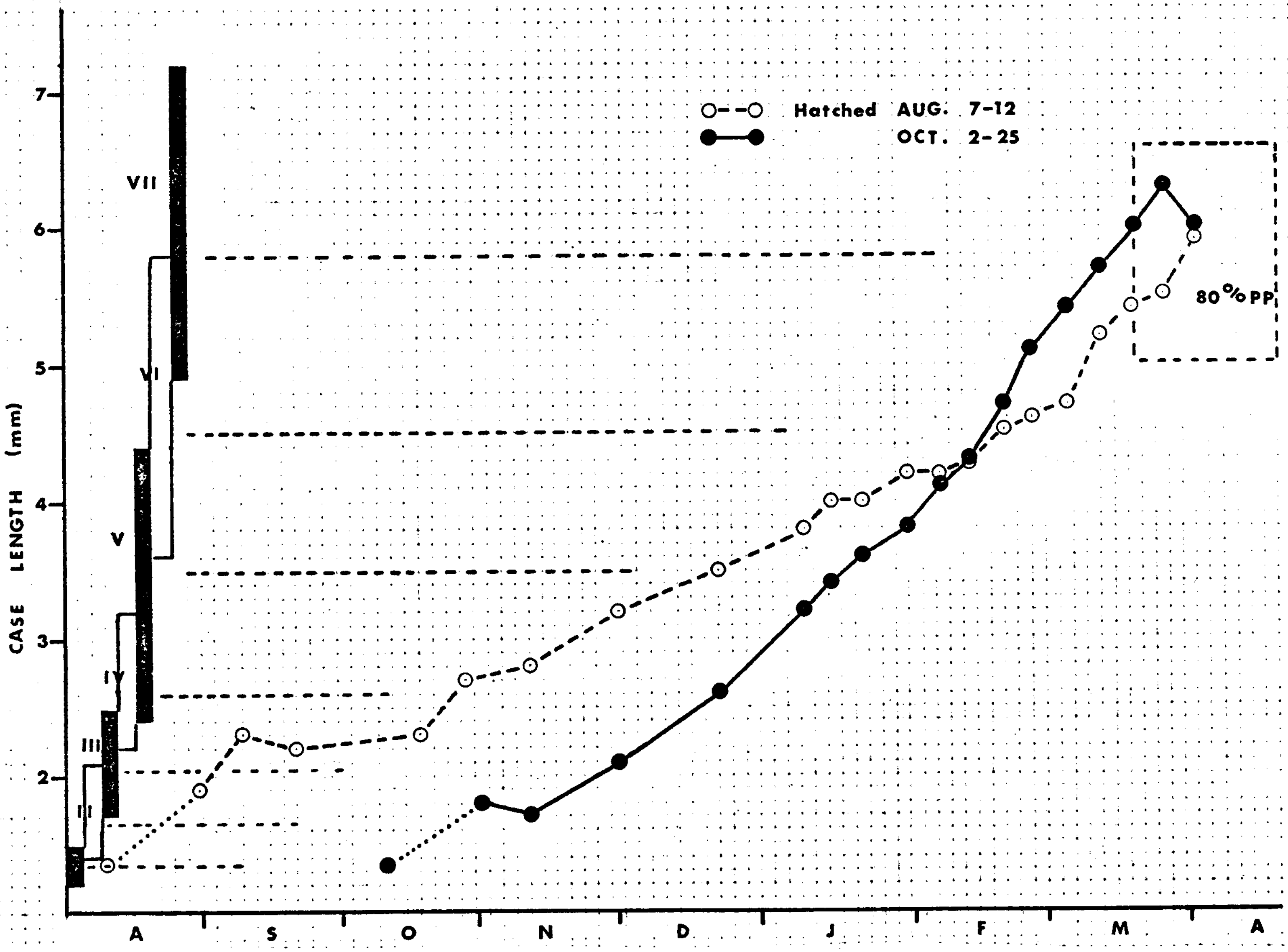

Fig. 2. GROWTH RATE OF A. FUSCIPES LARVAE REARED IN DRIPPERY TRAYS

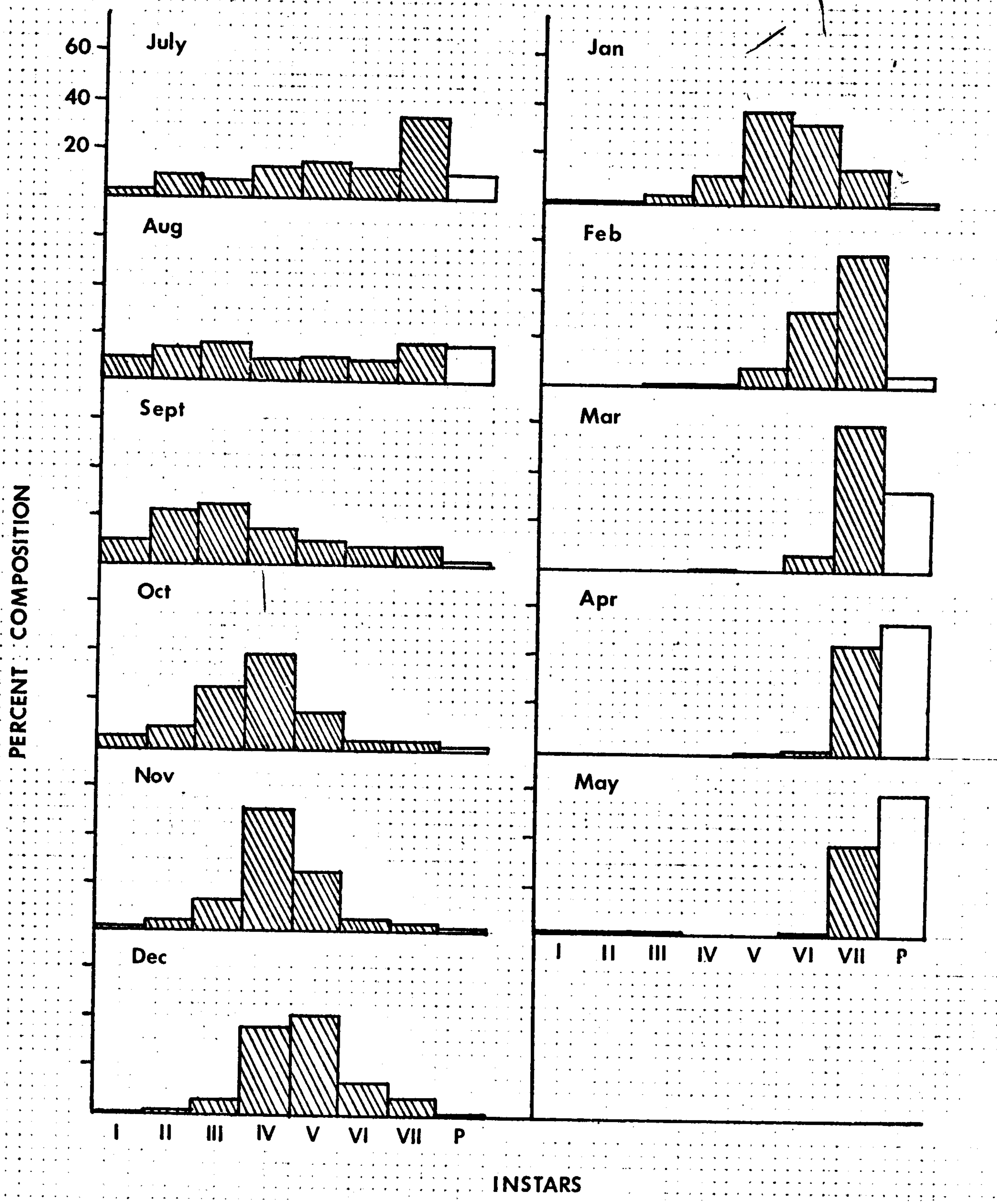

Fig.3. INSTAR DISTRIBUTION OF A. FUSCIPES IN MONTHLY ARTIFICIAL SUBSTRATE SAMPLES PUDDLETOWN, DORSET, 1971-72.

CONSUMPTION OF ^{32}P-LABELED PERIPHYTON BY CADDIS FLY LARVAE

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The consumption of periphyton by several representative genera of caddis fly larvae was determined by labeling a periphyton community with radioactive phosphorus and allowing the insects to feed on it for a certain amount of time. The genera used were *Glossosoma*, *Ecclisomyia*, and *Heteroplectron*. The larvae of *Glossosoma* are algivores which construct stone cases shaped like a tortoise shell with a stone bridge across the ventral opening. *Ecclisomyia* is a algivore-detritivore (Anderson, personal communication) which makes a case of sand grains and conifer needles as a larva. The larvae of *Heteroplectron californicum* are detritivores which hollow out small sticks or wood chips to form cases.

Insects were collected from streams in the H. J. Andrews Experimental Forest and acclimated in a laboratory stream for at least 5 days. A periphyton community was established on a slate plate with periphyton from the streams in which the insects were collected. The plate was placed in a chamber developed by C. D. McIntire to simulate stream conditions. A spike of ^{32}P was released into the chamber for a two-hour period and then flushed. The stream was allowed to run for 2 days prior to the feeding experiments so that any surface-bound ^{32}P would have time to be absorbed or flushed from the chamber.

The insects were placed on the periphyton community in their normal feeding positions so they would not spend time righting themselves. At the end of two hours a sample of 98 *Glossosoma* were removed and prepared for monitoring; the remaining insects were removed at the end of 4 hours. Insects of each genus were removed from their cases, placed in tared weighing pans, dried for 24 hours at 50°C, placed in a dessicator to cool to room temperature, weighed, and monitored for radioactivity. Results are given in Table 1. Nine samples of periphyton were scraped from the plate, placed in tared weighing pans, dried for 24 hours at 50°C, cooled to room temperature in a dessicator, weighed, and monitored for radioactivity. Results of the periphyton samples are shown in Table 2. Consumption of periphyton in mg periphyton/g of insect/day was calculated by the following formula.

$$\text{Consumption} = \left(\frac{\text{mg periphyton}}{\text{counts per minute}}\right)\left(\frac{\frac{\text{counts per minute}}{\text{mg insect}}}{\text{feeding time (hour)}}\right)\left(\frac{24 \text{ hours}}{\text{day}}\right)\left(\frac{1000 \text{ mg}}{\text{g}}\right)$$

Consumption results are given in Table 1.

DISCUSSION

Consumption appears to be uniform between the 3rd, 4th, and 5th instars of *Glossosoma* at approximately 150-200 mg of periphyton/g of insect/day. *Ecclisomyia* has been observed by Anderson in the main current of these streams presumably feeding. The estimates of consumption for this genus indicate that it is an active feeder when in contact with a periphyton community; it consumes almost twice its weight per day (1888 mg periphyton/g of insect/day). The detritivore, *Heteroplectron*, consumes approximately 226 mg periphyton/g of insect/day which is interestingly more than the algivore, *Glossosoma*. These data are difficult to interpret since the insects were not given a choice of food and assimilation efficiencies were not determined. This experiment demonstrates that many aquatic insects will consume whatever is available in the absence of their preferred food. Future experiments should examine assimilation efficiencies with different foods, uptake and loss curves, abd gut loading and unloading times as well as consumption to accurately describe the feeding and food utilization of aquatic insects and their impact on their food sources.

Table 1. Consumption of periphyton by *Glossosoma*, *Ecclisomyia*, and *Heteroplectron*.

Genus	Weight	Feeding Time	Net CPM	CPM/mg	mg peri. g insect/day
Glossosoma					
3rd & 4th instar	8.7 mg	2 hours	160	18	196
3rd & 4th instar	11.5 mg	4 hours	361	31	168
5th instar	18.5 mg	4 hours	536	29	155
Ecclisomyia	24.6 mg	4 hours	8700	354	1888
Heteroplectron californicum	82.8 mg	4 hours	3499	42	226

Table 2. Radioactivity per unit weight of periphyton.

Periphyton Sample	Weight	Net Counts Per Minute	Counts per Minute Per mg
A	24.6 mg	27,719	1129
B	14.0 mg	19,715	1408
C	25.8 mg	29,119	1129
D	17.0 mg	20,949	1232
E	25.7 mg	29,675	1155
F	22.9 mg	22,856	998
G	21.7 mg	25,795	1189
H	3.9 mg	4,150	1064
I	19.5 mg	15,939	817
			10,121
			$\bar{x}$ = 1124 ± 125[a]

[a]95% confidence interval

FOOD CONSUMPTION AND UTILIZATION BY FIVE SPECIES OF STREAM DETRITIVORES

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INTRODUCTION

Recent studies (Nelson and Scott 1962, Hynes 1963) indicate that particulate organic matter from allochthonous sources often provides more energy than primary production in flowing water systems. For this reason a study has been directed toward insect detritivores, since with the exception of a few annelids and snails, they are the only aquatic detritivores in the H. J. Andrews Experimental Forest. Emphasis has been placed on those insects which actively consume the incoming leaf material (shredders and skeletonizers) since this is the first step in energy transfer. Following fragmentation other detritivores (e.g. collectors and filter feeders) are free to feed on faeces and leaf fragments left behind by shredders. For example, in Doe Run, Kentucky, Minckley (1963) found that *Gammarus minus*, a very abundant amphipod, fed almost exclusively on the faeces of *Asellus bivittatus*, an equally abundant isopod.

OBJECTIVES

A. Laboratory studies
   1. Determining the rate of leaf breakdown with and without insects.
   2. Estimating the consumption, assimilation efficiency and gross growth efficiency for several species of insect detritivores.

B. Field studies
   1. Determining the consumption rates for detrital feeding insects under field conditions.

METHODS

Laboratory Experiments

Leaves of the bigleaf maple, *Acer macrophyllus*, were collected after leaf-fall, 1971, from a single tree in Corvallis. After collection the leaves were preleached, dried and stored. Alder leaves, *Alnus rubra*, collected after leaf-fall from several trees in the H. J. Andrews Forest, were also preleached, dried and stored.

Experiments were conducted in laboratory streams at the Oak Creek Fisheries Laboratory, measuring growth and consumption for *Pteronarcys princeps* (Plecoptera; Pteronarcidae) under various conditions. In the first experiment five nymphs were placed in each of four experimental chambers and four other chambers were used as controls to determine the rate of leaf breakdown without insects. Bigleaf maple leaves were incubated in water from a laboratory leaf culture for about 48 hours prior to placement in experimental containers. Experimental leaf material was changed every 48 hours and the insects were weighed approximately every 96 hours for a period of 12 days.

Consumption was calculated using the following formula, assuming a constant feeding rate and a constant rate of leaf leaching and decomposition. This calculation allows for the fact that the leaf material consumed is no longer subject to the normal leaching and decomposition:

$$X_e = \frac{2(PX_i - X_r)}{(1 + P)}$$

X_i = initial leaf weight

X_r = final leaf weight

X_e = weight of leaf material consumed

P = mean percent leaf weight remaining in the controls (without insects)

In the second experiment, the leaf material was changed every 48 hours, the insects were weighed approximately every 96 hours and corrections were made for leaching and decomposition as in the first experiment. Four laboratory streams were used and the leaf material was incubated as before with the addition of the following treatments prior to placement in the respective streams:

Stream	Treatment
Untreated	No additional treatment
Antifungal	Actidione and Nystatin or Sodium Propionate added to incubation water
Antibacterial	Streptomycin and Penicillin "G" added to incubation water
Antibiotic	Both of the above treatments or autoclaving

The second experiment was conducted for 54 days.

Calorie to calorie growth efficiencies were calculated for both experiments from wet weight of growth, dry weight of consumption relations using the following conversion factors:

5.39 gm wet weight of insect per gm of dry weight (See Table 1)
4773 calories per gm dry weight of *Acer*.sp. leaves (Cummins 1971)
5300 calories per gm dry weight of *Pteronarcys scotti* (McDiffett 1970)

$$\frac{\text{wet wt. of insect}}{\text{dry wt. of consumption}} \times \frac{1}{5.39} \times \frac{1}{4773} \times \frac{5300}{1} \times 100 = \%\ \text{cal. growth/cal. consumption}$$

Laboratory experiments on feeding, faecal production and assimilation were conducted using several species of caddis larvae. The experiments were run in a drippery with a slight flow of water through the pans at 11°C. Approximately half of each leaf used in the studies was placed in a separate pan as a control for leaching and decomposition.

Field Experiments

Feeding experiments were undertaken in two streams, using *Halesochila taylori* (Trichoptera; Limnephilidae) in Lookout Creek and *Ecclisomyia* sp. (Trichoptera; Limnephilidae) in Mack Creek. The insects were collected from the experimental location immediately prior to each experiment. Gallon plastic jars were converted to experimental chambers by cutting out the tops and bottoms and replacing them with 333 μ Nitex. Chambers, placed on their sides, were anchored in place with stones.

In Lookout Creek, approximately 0.5gm dry weight of bigleaf maple leaves were placed in each of 10 jars and 10 third instar larvae were added to each of five of the chambers. The chambers remained in place for three weeks at the end of which the insects and leaves were removed. The insects were counted and taken into the laboratory for rearing to adults, while the leaves were redried and weighed.

In Mack Creek, five chambers were placed at each of two sites and approximately 0.1gm dry weight of bigleaf maple leaves were added to each chamber. Ten or fifteen insects were placed in three of the chambers at each site and left undisturbed for eight days. After this period, the leaves and insects were removed and the leaves were redried and weighed. The insects were counted and head capsule measurements were taken on a subsample which was then oven-dried and weighed. The remainder of the insects were preserved in 70% ethanol for reference and identification.

RESULTS AND DISCUSSION

Laboratory Experiments on P. princeps

In the first experiment, mean consumption was 3.88mg dry weight of leaf material/insect/day or 0.01mg dry weight of leaf/mg dry weight of insect/day. Mean growth was 0.37mg wet weight/insect/day or 0.006mg dry weight/mg dry weight of insect/day. Average experimental temperature was 15.3°C. The data is shown in Table 2. A linear regression of wet weight of growth versus dry weight of consumption resulted in the relation shown below and in Figure 1:

$G = -0.57 + 0.24C$

G = mg growth (wet weight)/insect/day

C = mg consumption (dry weight)/insect/day

The slope of the line is the ratio of wet weight of growth to dry weight of consumption (0.24) and is equivalent to a calorie to calorie growth efficiency of 4.94%.

The mean consumption values for the second experiment (see Table 3) are:

	Untreated	Antibacterial	Antifungal*	Antibiotic
mg dry wt. of leaf/insect/day	9.49	10.32	0.92	2.98
mg dry wt. of leaf/mg dry wt. of insect/day	0.16	0.16	0.016	0.04

Low consumption in the antifungal treatment indicates fungi are apparently important factors in the selection of food items, whether by taste or smell.

The mean growth rates (see Table 3) for the four treatments are:

	Untreated	Antibacterial	Antifungal*	Antibiotic
mg wet wt./ insect/day	0.43	-0.05	-0.55	0.03
mg dry wt./ mg dry wt./day	0.01	-0.001	-0.01	0.001

Growth rates are approximately those expected from the consumption data with the exception of the antibacterial treatment. In this treatment, consumption was the highest of any treatment, but growth was far lower than the untreated. This indicates that the bacteria, while not important in food selection, are presumably important in the utilization of leaf material.

Mortality for each treatment for the 54 day experiment is as follows:

	Untreated	Antibacterial	Antifungal*	Antibiotic
% Mortality	15	10	85	30

High mortality in the antifungal treatment was attributed to the high rate of weight loss and the low consumption rates by these insects.

Growth efficiency for each treatment was calculated by linear regression analysis of growth versus consumption (Figures 2 through 6). The gross growth efficiencies shown below were calculated as previously described.

	Untreated	Antibacterial	Antifungal*	Antibiotic
cal growth/ cal consumption	4.94%	1.03%	34.81%	4.74%

*The Nystatin treatments were not included in this data since it appeared that some inhibitory effect was involved as shown in Figure 4.

The very high efficiency obtained for the fungicide treatment may have resulted from the insects feeding on their own faeces in preference to the apparently unpalatable leaf material. Another possible explanation is that the growth consumption relationship is actually a curvilinear function rather than a linear one (Warren 1971) and has a higher slope at very low consumption levels. The relatively high efficiency for the antibiotic treatment may have resulted from either of the above factors or it may be a result of the autoclaving treatment.

A multiple regression of growth versus consumption and temperature was performed for the same data. The calculated calorie to calorie growth efficiencies and the respective correlation coefficients are:

	Untreated	Antibacterial	Antifungal	Antibiotic
cal growth/ cal consumption	5.56%	1.65%	35.85%	4.90%
R	0.79	0.66	0.55	0.44

These efficiencies are quite similar to those resulting from the simple linear regression.

The average weight loss in leaves without insects was 0.8% per day (not including the autoclaved leaves which lost an average of 2.8% per day).

Field and Laboratory Studies on Caddis Larvae

In a drippery, 40 fourth instar larvae of *Lepidostoma* sp. (Trichoptera; Lepidostomatidae) fed on bigleaf maple leaves exhibited the following consumption rates, faecal production and assimilation efficiencies (based on a ratio of faecal production to consumption):

Days	Consumption	Faeces	Assimilation Efficiency (%)
0-1	6.96mg	6.51mg	6.9%
1-7	27.77mg	24.92mg	10.3%
7-11	26.49mg	-	(faeces not measured)
mean/insect/day	0.17mg	0.11mg	7.35%
mean/mg dry wt. of insect/day	0.55mg	0.36mg	-

For 30 fifth instar and 10 fourth instar larvae of *Lepidostoma*, fed on both alder and bigleaf maple leaves, the results were:

Days	Consumption	Faeces	% of Total Consumption *A. rubra*	*A. macrophyllum*
0-7	109.02mg	97.15mg	68*	32*
7- 0	56.44mg	45.48mg	74	26
10-13	73.28mg	73.59mg	no maple used	
13-16	60.21mg	46.79mg	54**	46**
mean/insect/day	0.44mg	0.39mg		
mean/mg dry wt. of insect/day	0.61mg	0.54mg		

The average assimilation efficiency for the second experiment with *Lepidostoma* was 12%.

In experiments on *Heteroplectron californicum* (Trichoptera; Calamoceratidae) larvae, the following results were obtained:

Days	Consumption	Faeces	% of Total Consumption		# of
Days	Consumption	Faeces	*A. rubra*	*A. macrophyllum*	Insects
0-6	31.10mg		88	12	8
6-9	60.36mg		79	21	9
9-12	65.70mg	60.82mg	93	7	9
mean/insect/day	1.38mg	1.69mg			
mean/mg dry wt. of insect/day (estimated)	0.07mg	0.08mg			

The assimilation efficiency for days 9 through 12 was 7.43%.

Using *Halesochila taylori* in the laboratory, the average consumption of bigleaf maple leaves was 0.63mg/insect/day or 0.04mg/mg dry wt. of insect/day. In the field, *H. taylori* consumed an average of 0.19mg/insect/day or 0.01mg/dry wt. of insect/day of bigleaf maple leaves (Table 4). Evidently conditions were in some way unsuitable as mortality was 54% over the 21 day interval. Since the experimental chambers were closed with 333μ Nitex and the insects and cases disappeared, cannibalism was suspected.

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*All of the alder leaf except some vascular tissue had been consumed.
**The maple leaves were incubated for two days prior to the experiment.

Consumption of bigleaf maple leaves was also measured for 80 *Ecclisomyia* larvae in the field. Over a period of eight days, a mean consumption of 0.05mg/insect/day or 0.10mg/mg dry wt. of insect/day was indicated (Table 5). The mortality was two percent.

For the laboratory and field experiments the mean consumption rate was 0.23mg/mg dry wt. of insect/day. For the laboratory experiments where assimilation was measured, the mean consumption rate was 0.36mg/mg dry wt. of insect/day and the mean faecal production was 0.33mg/mg dry wt. of insect/day. The mean assimilation efficiency was 8.93%.

Feeding Techniques

Xerox pictures indicating typical feeding behavior for some of the insects studied appear in Figures 7 through 9. Variation in feeding technique is other than that caused by size difference alone since the specimens of *H. Taylori* and *H. californicum* average approximately 16 and 20mg each respectively and the specimens of *Lepidostoma* and *Ecclisomyia* average approximately 0.72 and 0.50mg each respectively. It appears that *H. californicum* and *Ecclisomyia* are skeletonizers while *H. taylori, Lepidostoma,* and *P. princeps* tend to be shredders. All of the leaves illustrated are *A. rubra* and the distinction is not as clear when other leaf species are used.

CONCLUSION

Using rates from the above experiments, a model of the aquatic detrital system can be proposed as in Figure 10, with the indicated estimates of the energy transfers.

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Table 1. Wet vs. dry weight for *Pteronarcys princeps* nymphs.

Specimen	Wet weight (mg)	Dry weight (mg)	Dry/wet weight (percent)
1	326.80	49.87	15.26
2	321.10	45.46	14.18
3	317.58	54.60	17.19
4	337.76	53.60	15.87
5	200.62	41.97	20.92
6	335.64	47.71	14.21
7	314.93	40.52	12.87
8	202.00	32.40	16.04
9	566.35	99.11	17.50
10	204.32	33.01	16.16
11	578.00	90.00	15.57
12	261.73	44.42	16.97
13	241.83	34.00	14.06
14	204.86	28.00	13.67
15	200.26	20.87	10.42
16	311.66	56.46	18.12
MEANS	307.84	48.25	15.56 $s_{\bar{x}} = 0.60$

Linear regression of wet weight vs. dry weight.

$b = 5.39$ gm wet wt/gm dry wt $\quad s_b = 0.438$

$R = 0.92$

$F = 150$

Table 2. Growth, consumption, and temperature for *Pteronarcys princeps* at Oak Creek. Experiment 1: 28 Feb - 11 Mar 1972.

Replication	Wet weight Growth (mg/insect/day)	Dry weight Consumption (mg/insect/day)	Average Temperature (°C)
28 Feb - 3 Mar 1972			
1.[a]	0.66	0.16	15.2
2.	0.67	3.69	15.2
3.	1.41	5.84	15.2
4.	0.47	1.19	15.2
3 Mar - 7 Mar 1972			
1.[a]	-5.40	0.13	15.7
2.	0.02	3.18	15.7
3.	1.24	3.33	15.7
4.	-0.90	1.31	15.7
7 Mar = 11 Mar 1972			
1.[a]	2.40	0.60	13.0
2.	1.25	7.52	13.0
3.	-0.21	4.94	13.0
4.[b]	15.26[b]	1.88	13.0
MEANS (excluding footnoted entries)	0.35	3.87	14.6

[a]Contained only final instar nymphs which did not feed appreciably.

[b]Contained one final instar nymph which died in the process of emerging as an adult. The resulting weight increase for all five insects was approximately 23 percent.

Table 3. Growth[1] consumption[1] and temperature for *P. princeps*, 20 May - 13 Jul 1972.

Days	Untreated Growth	Untreated Consumption	Antibacterial Growth	Antibacterial Consumption	Antifungal Growth	Antifungal Consumption	Antibiotic Growth	Antibiotic Consumption	Average Temperature (°F)
0-6	0.45	9.44	0.64	12.43	-1.32	2.41[a]	-1.41	2.54[a]	52
6-10	2.37	14.98	0.57	16.82	-1.88	2.05[a]	0.89	2.09[a]	59
10-14	0.89	13.69	-0.44	11.70	-0.92	1.54[a]	-1.75	1.01[a]	61
14-20	-0.38	11.83	-0.33	12.12	-0.05	0.53[b]	0.07	1.08[a]	61
20-24	1.22	9.32	0.09	7.97	-0.84	0.34[b]	-0.66	0.84[a]	53
24-30	-0.20	5.55	0.44	8.68	0.18	0.75[b]	-0.69	1.15[c]	57
30-34	1.32	8.95	-0.38	8.26	0.97	0.51[b]	2.59	2.43[c]	53
34-40	-0.42	6.45	-0.15	7.47	-1.23	0.38[b]	-0.96	2.96[c]	57
40-47	0.50	8.52	-1.28	9.81	0.20	0.68[b]	1.82	7.54[c]	63
47-54	-1.46	6.12	0.37	7.95	-0.59	0.02[b]	0.40	8.16[c]	59
MEANS	0.43	9.49	-0.05	10.32	-0.55	0.92	0.03	2.98	57.5

[1]mg/insect/day, means of four replications. Replications where mortality occurred were not included.

[a]leaves treated with Nystatin and Acti-dione.

[b]leaves treated with sodium propionate and Acti-dione.

[c]leaves autoclaved.

Table 4. Results of feeding experiments on *Halesochila taylori* in Lookout Creek (21 days).

Jar no.	No. of insects initial	No. of insects final	% mortality	leaf weight loss mg.	leaf weight loss (percent)	calculated per insect	consumption[1] (mg) per insect/day
1	10	5	50	50.86	10.30	4.10	0.20
2	0	0		22.81	4.75		
3	10	7	30	76.79	15.48	6.72	0.32
4	0	0		7.57	1.52		
5	10	5	50	34.23	6.90	1.82	0.09
6	0	0		-0.15	-0.03		
7	10	2	80	32.66	6.61	2.03	0.10
8	0	0		40.06	8.04		
9	10	4	60	51.82	10.75	4.61	0.22
10	0	0		32.76	6.73		
MEANS (no insects)					4.20%		
MEANS (with insects)			54%		10.01%	3.86mg $s_{\bar{x}} = 0.90$	0.19mg

Approximate weight per insect = 16 mg

[1]assuming that all mortality occurred midway through the experiment.

Table 5. Results of feeding experiment on *Ecclisomyia* sp. in Mack Creek.

Jar no.	No. of insects	Leaf weight loss mg.	Leaf weight loss percent	Calculated consumption (mg) per insect	Calculated consumption (mg) per insect/day
1	0	4.90	4.52		
2	10	9.62	7.87	0.53	0.07
3	0	3.50	3.11		
4	15	3.65	3.13	-0.04	-0.005
5	0	2.44	2.24		
6	15	8.10	7.43	0.28	0.03
7	0	5.10	4.52		
8	15	11.92	10.28	0.48	0.06
9	10	9.29	8.64	0.55	0.07
10	15	11.32	10.06	0.49	0.06
MEAN (no insects)			3.60		
MEANS (with insects)			7.90	0.38 $s_{\bar{x}} = 0.09$	0.05

Mean weight per insect = 0.50mg $s_{\bar{x}} = 0.06$
(14 specimens)

Mortality = 2%

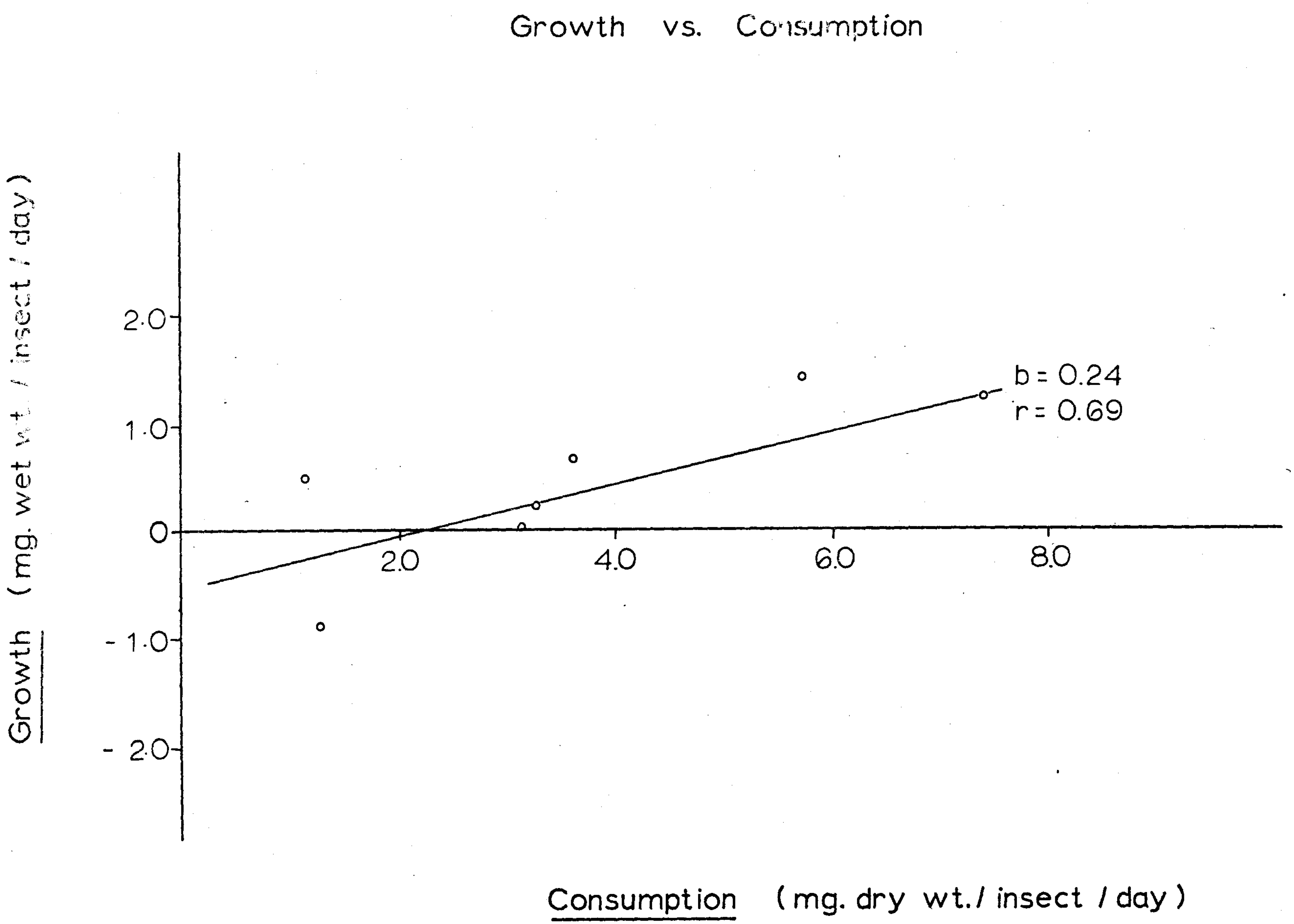


Figure 1: Growth of <u>Pteronarcys princeps</u> nymphs versus consumption of bigleaf maple leaves in an experimental stream for 12 days.

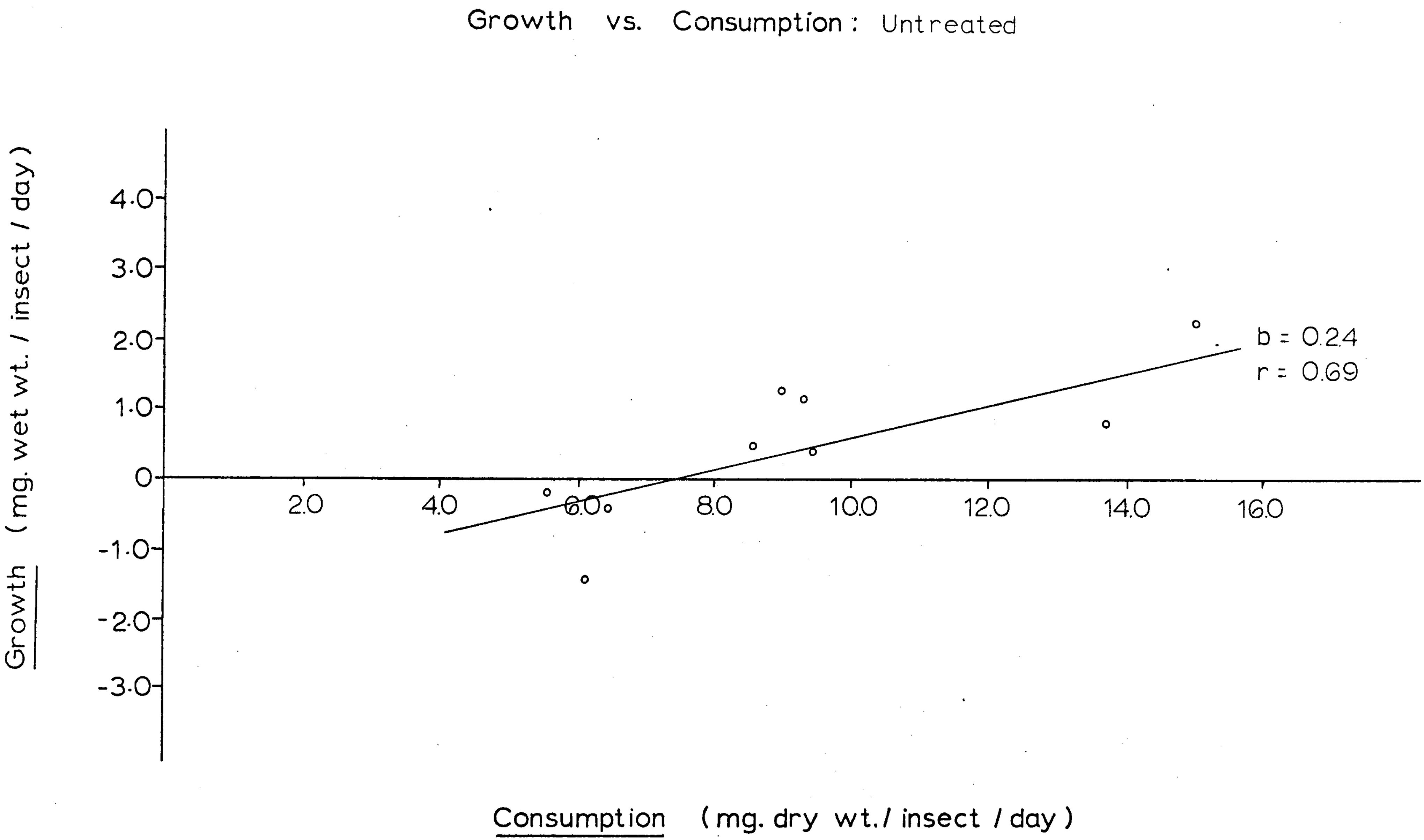


Figure 2: Growth of Pteronarcys princeps nymphs versus consumption of untreated bigleaf maple leaves in an experimental stream for 54 days.

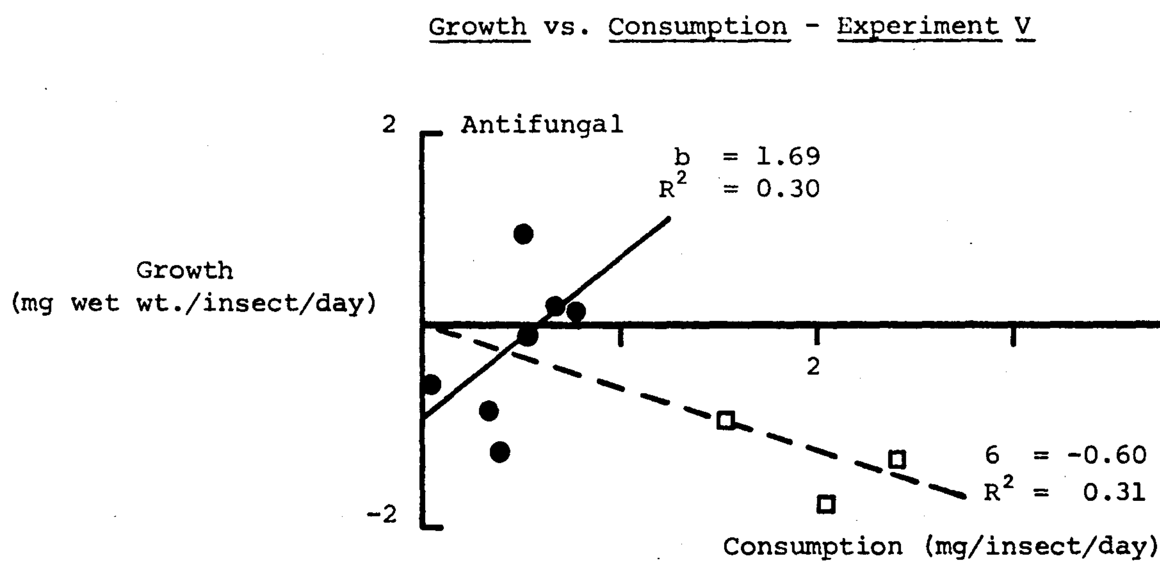


Figure 4: Growth of <u>Pteronarcys princeps</u> nymphs versus consumption of antifungal treated bigleaf maple leaves in an experimental stream for 54 days.

Growth vs. Consumption : Antibacterial Treatment

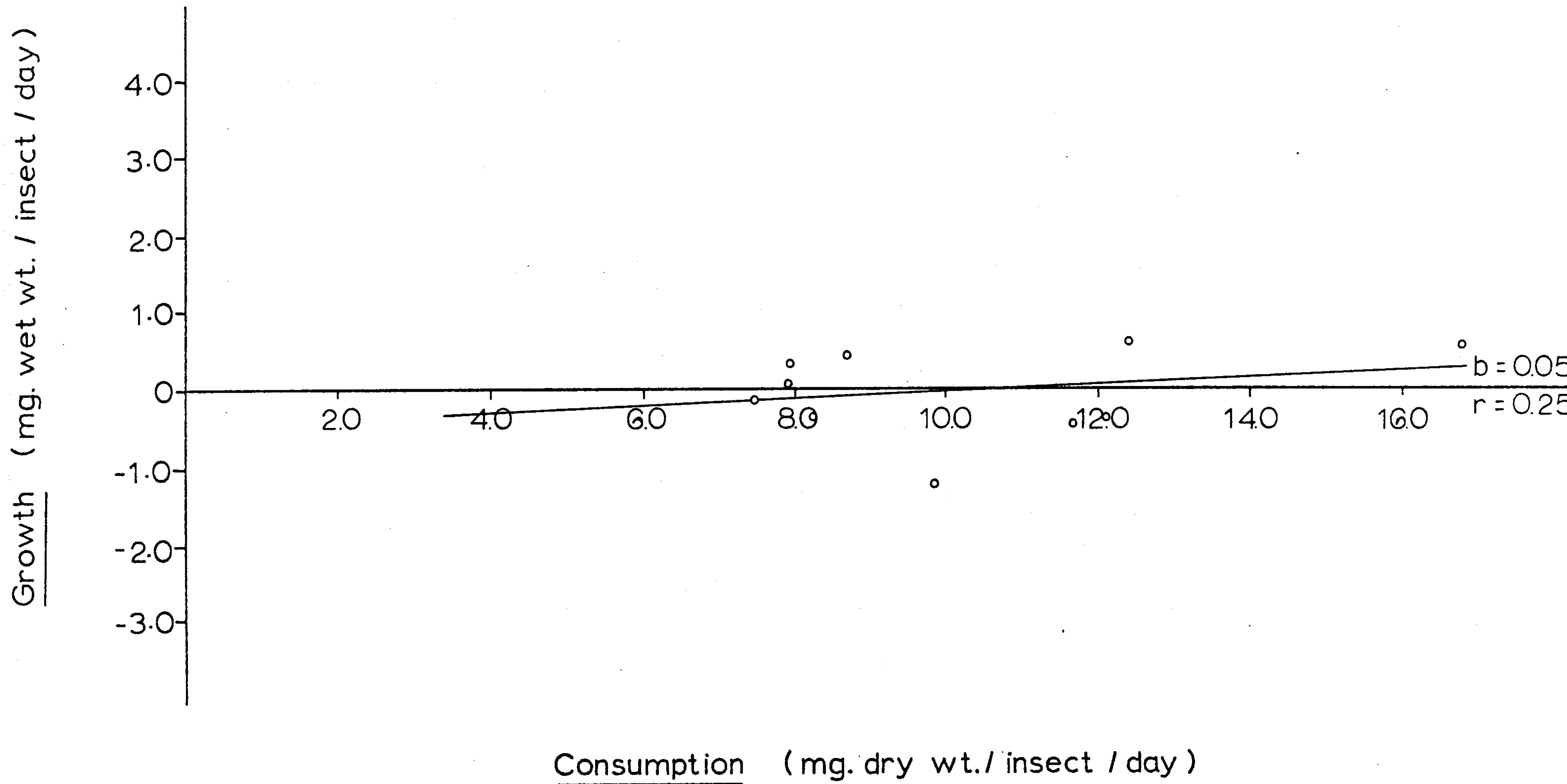


Figure 3: Growth of *Pteronarcys princeps* nymphs versus consumption of antibacterially treated bigleaf maple leaves in an experimental stream for 54 days.

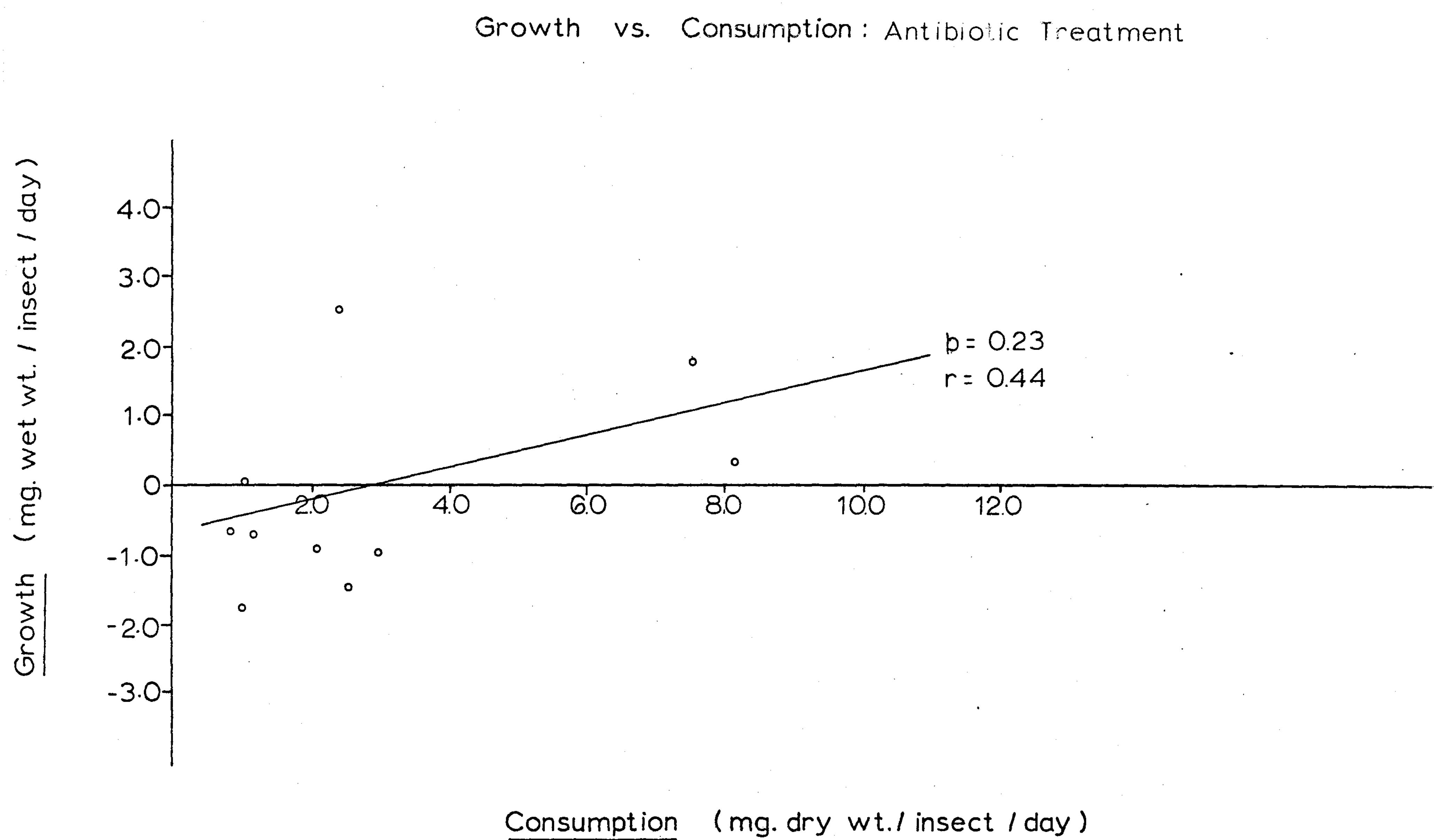


Figure 5: Growth of Pteronarcys princeps nymphs versus consumption of antibiotic treated bigleaf maple leaves in an experimental stream for 54 days.

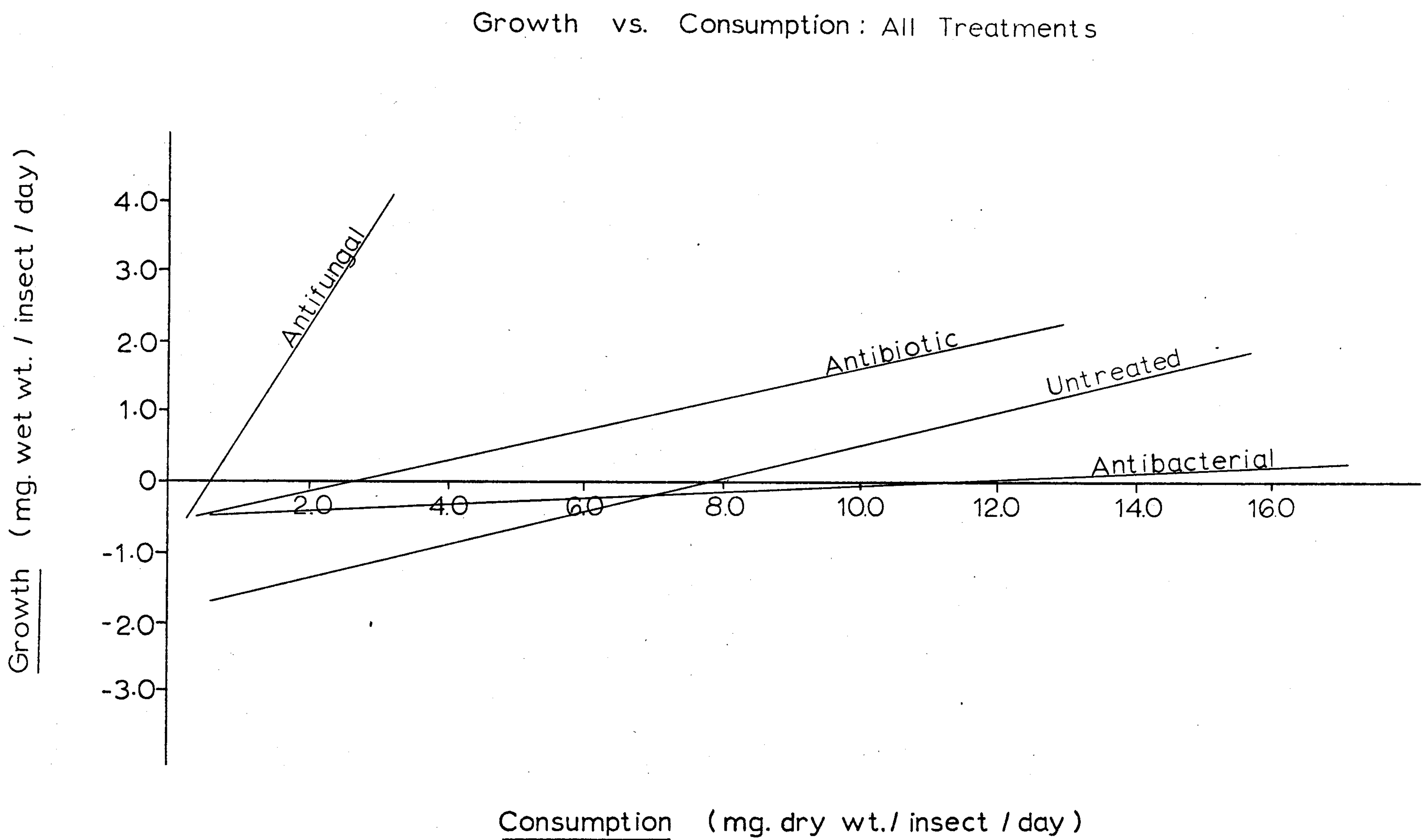
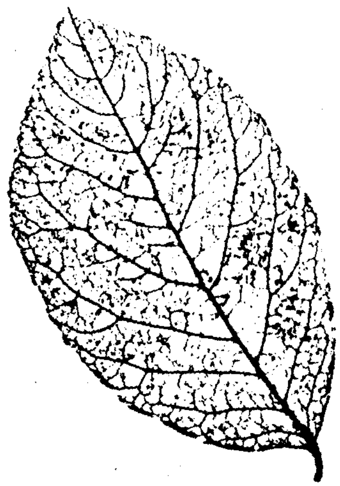


Figure 6: Growth of Pteronarcys princeps nymphs versus consumption of bigleaf maple leaves treated with fungicide, bactericide, antibiotic, or untreated, in an experimental stream.



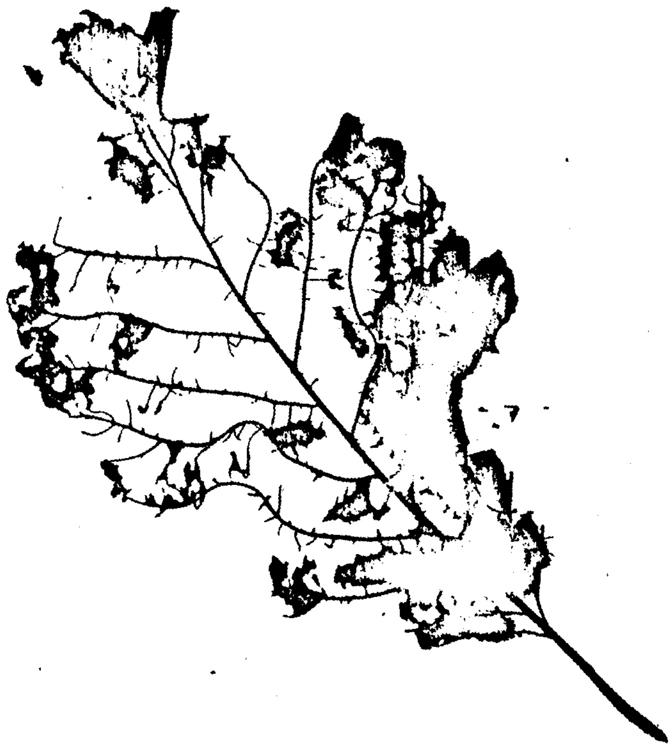
CALAMOCERATIDAE

Heteroplectron californicum

LIMNEPHILIDAE

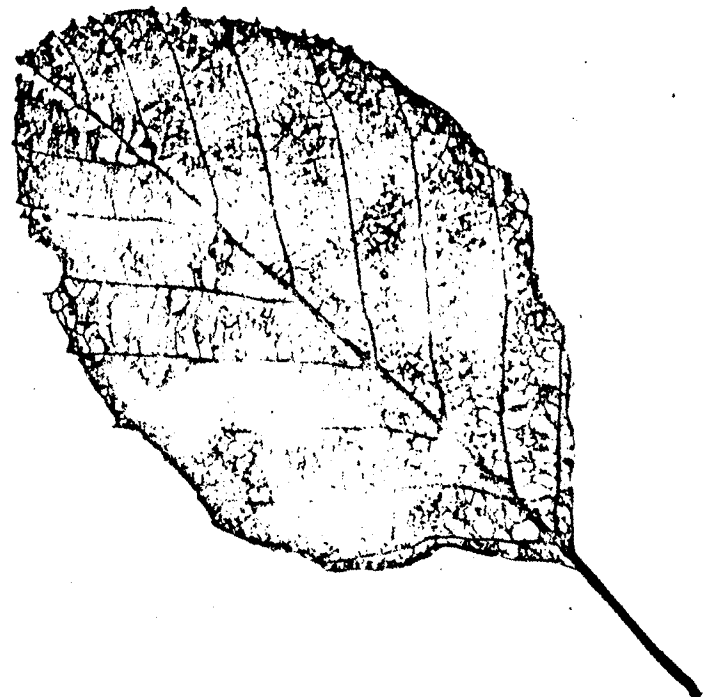
Halesochila taylori

Figure 7: Typical feeding results of two species of caddis larvae feeding on leaves of *Alnus rubra* for five to seven days.



LEPIDOSTOMATIDAE

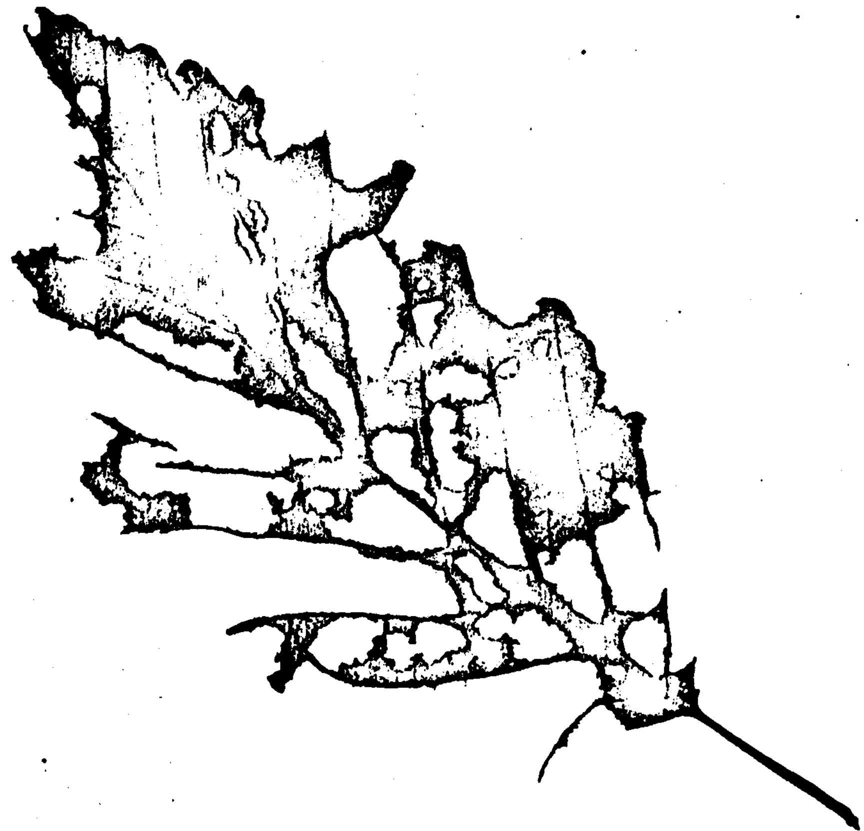
Lepidostoma sp.



LIMNEPHILIDAE

Ecclisomyia sp.

Figure 8: Typical results of two species of caddis larvae feeding on leaves of *Alnus rubra* for five to seven days.



PTERONARCIDAE

Pteronarcys princeps

Figure 9: Typical feeding results of Pteronarcys princeps nymphs feeding on leaves of Alnus rubra for five to seven days.

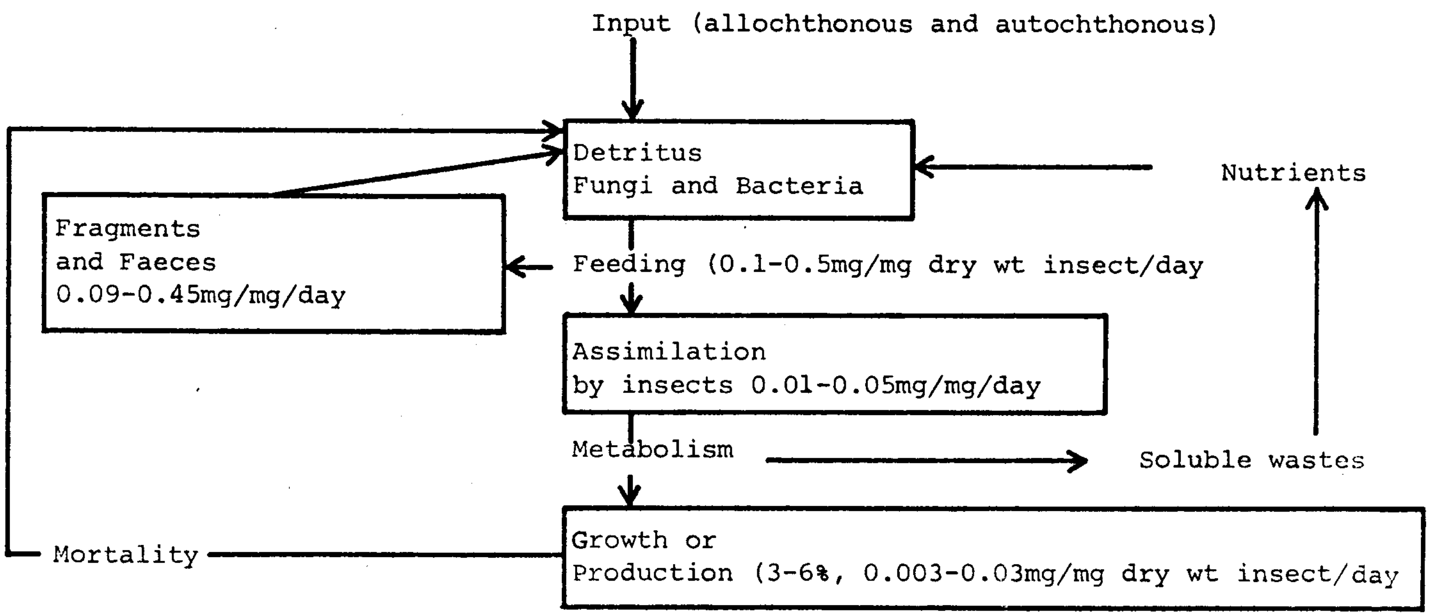


Figure 10: A model of the aquatic detrital system with the indicated estimates of the energy transfers.

A PRELIMINARY STUDY OF FISH POPULATIONS IN THE LOOKOUT CREEK DRAINAGE

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Preliminary work with the fish populations in the H. J. Andrews Experimental Forest began during the month of September 1972. Lookout Creek and the tributaries, Mack and McRae Creeks, have been sampled. The following species were captured: 1) Cutthroat trout *(Salmo Clarki)*, 2) Rainbow trout *(Salmo gairdneri)*, 3) Longnose dace *(Rhinichthys cataractae)*, 4) Blackside dace *(Rhinichthys osculus)*, and 5) Piute sculpin *(Cottus beldingi)*. The cutthroat trout appeared at all sample locations and was the only species of fish found in Mack Creek.

The primary objective of the field work was to become familiar with the fish inhabiting the Lookout system. Population estimates of the trout species were conducted in McRae, Lookout, and Mack Creeks. Trout were tagged in Lookout and Mack Creeks. The results of the preliminary work were to act as a guide for establishing the type of research to be conducted and to suggest suitable problems for solution.

METHODS

Estimates of the numbers of trout in six short sections of stream were made. A back-pact, electrofishing unit was employed for sampling and two-catch estimates were conducted in a manner similar to that described by Seber and LeCren (1967) and Seber and Whale (1970). One three-catch estimate (Seber and Whale 1970) was made at Mack Creek, population estimate site 2 (Figure 1).

One estimate was conducted in McRae Creek, two in Lookout Creek, and four in Mack Creek. Since relatively low numbers of fish were captured at the two upper stations in Mack Creek, the data were combined and classified as population estimate site 3. All captured fish were anesthesized with tricane methane sulfonate (MS 222), measured to the nearest 1 mm fork length, and released near the location of capture. Stop nets were used to prevent e cape of fish from the study area while the stimate was being conducted. The surface area of each site was estimated.

Individually numbered vinyl pennant tags, similar to those described by Pyle (1965), were attached to 233 trout. Nine areas were chosen as tagging sites (Figure 1). The location of capture, the length, and a scale sample were obtained for each tagged trout. Scale samples were also collected from 121 untagged trout.

A face mask and snorkel were used to count the trout in a large pool in Lookout Creek. The result was compared with an estimate previously obtained in the pool (population estimate site 1) by the two-catch method. Snorkel diving observations were made in two pools in Mack Creek in an attempt to evaluate the technique for reading tag numbers of free-swimming trout.

Trout located while snorkeling were captured with a hand-held "slurp" gun, used by scuba divers to collect small fish for aquarium display. The gun sucks the fish and surrounding water into a tubular capture chamber as a piston is withdrawn through the chamber.

RESULTS AND DISCUSSION

The results of the population estimates are shown in Table 1. Short sections of stream were used in making the population estimates. The mean section length was 45 m with a range of 7 to 92 m. This practice resulted in small numbers of fish being captured and relatively unreliable point estimates. Further population estimates will be made over longer sections of stream. The 95 percent confidence intervals for the two-catch estimates are included where the equations given by Seber and Whale (1970) yield reasonable intervals. Seber and Whale include in their paper a table predicting the reliability of interval estimates computed from different combinations of capture data. The confidence interval for the three-catch estimate was made in the manner described by Zippin (1958).

In Lookout Creek both rainbow and cutthroat trout less than 75 mm were classified as "trout" because of the difficulty of identification of small indifiduals of these two species. All trout captured in Mack Creek were classified as cutthroat trout as no identifiable rainbow trout were taken.

No fish were weighed during the preliminary work. The biomass estimates were obtained by using a weight prediction equation given by Lowry (1966) for cutthroat trout in a small western Oregon stream.

A length frequency distribution was obtained from data from 455 cutthroat trout captured in Mack Creek (Figure 2). Three fairly distinct age groups appear. From the length frequency distribution it is impossible to age fis longer than about 140 mm. Scale analysis will later be used for confirmation of the age groups.

In Lookout Creek, population estimate site 1, 40 trout longer than 75 mm were estimated by the two-catch method. Fourteen days later, two snorkel divers made fish counts in the same area. Twenty trout longer than about 9 90 mm were counted by one observer. The other diver counted 25 trout longer than about 80 mm. These estimates should be increased to 32 and 37, respectively, since 12 trout longer than 75 mm had been removed during the shocker sampling. The snorkeling method of population enumeration may prove valuable in pools too large for use of electrofishing gear.

The cutthroat trout in Mack Creek tend to concentrate in large pools. Mack Creek, population estimate site 2, is a pool at the base of a culvert spill with a surface area of approximately 12.5 m and a depth of approximately 1 m. During the third week of September, the pool contained an estimated 115 cutthroat trout with a biomass of 216.2 g/m^2(Table 1). The culvert presumably blocks the upstream passage of fish at all but the highest flows. Mack Creek, population estimate site 3, contains one large pool with dimensions similar to the culvert pool. The remainder of the section is composed of riffles and small pools. A separate population estimate in this pool estimated 33 trout with a biomass of 31.73 g/m^2. The biomass for the entire section was estimated to be 4.94 g/m^2. While tagging cutthroat trout in other sections of Mack Creek, high densities of trout have also been found in large pools.

In recent times, the numbers of rainbow trout have apparently increased in Lookout Creek. Wyatt (1959) marked over 500 trout in Lookout, in the section extending from two miles to four miles above the confluence with Blue River. Less than 2 percent (10 fish) were rainbow trout.

Only cutthroat trout are found in the small tributaries and with one exception, cutthroat appear to be more abundant than rainbow trout in upper Lookout Creek than in the lower stream. The percentage of cutthroat trout steadily increases from 45 percent at stream mile 3.25 to 87 percent at stream mile 5.75.

Several areas for further study have been suggested by our preliminary work. Information on the seasonal periodicity of growth would be useful in assessing the period when maximal use is made of the invertebrate food resource. Growth of tagged members of the population will be the primary source of information, based on periodic shocker sampling. Additional information on population size will be gathered during this electrofishing.

Another areas to receive increased emphasis will be the utilization of food resources by the trout population, particularly in Mack Creek. This will be accomplished by nondestructive sampling of the food in trout stomachs, as well as by direct observation of feeding behavior.

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Table 1. Estimates of the number of trout and the number and weight of trout per square meter in short sections of McRae, Lookout and Mack Creeks. Ninety-five percent confidence intervals around the population estimates where data allowed computation.

Stream	Population estimate site no.	Species	Estimated number	Length of study section (m)	Area of study section (m^2)	Numbers of fish ($no./m^2$)	Biomass of fish (g/m^2)
McRae Creek	1	Cutthroat	275	60	214	1.28	5.02
Lookout Creek	1	Cutthroat	32	39	253	.13	3.61
Lookout Creek	1	Rainbow	8	39	253	.03	.73
Lookout Creek	1	Trout [a]	* [b]	39	253	-	.39
Lookout Creek	2	Cutthroat	77 (46 to 234)	38	289	.27	5.55
Lookout Creek	2	Rainbow	24	38	289	.08	2.68
Lookout Creek	2	Trout	33	38	289	.11	.26
Mack Creek	1	Cutthroat	48 (27 to 206)	35	105	.46	6.49
Mack Creek	2	Cutthroat	116 (60 to 172)	7	12.5	9.3	218.0
Mack Creek	3	Cutthroat	117 (82 to 200	92	296	.40	4.94

[a] A fish less than 75 mm was assigned to the trout category due to difficulty of identification.

[b] A weight of 100 g has arbitrarily been assigned to trout since the data did not allow a population estimate to be computed.

Table 2. Trout species composition in Lookout Creek in relation to distance from the mouth.

Station	Miles upstream from the mouth	No. of rainbow captured	No. of cutthroat captured	% cut-throat
Pop. est. site 1	2	6	14	70
Tagging site 1	3.25	29	24	45
Pop. est. site 2	5.25	17	58	77
Tagging site 2	5.75	3	20	87

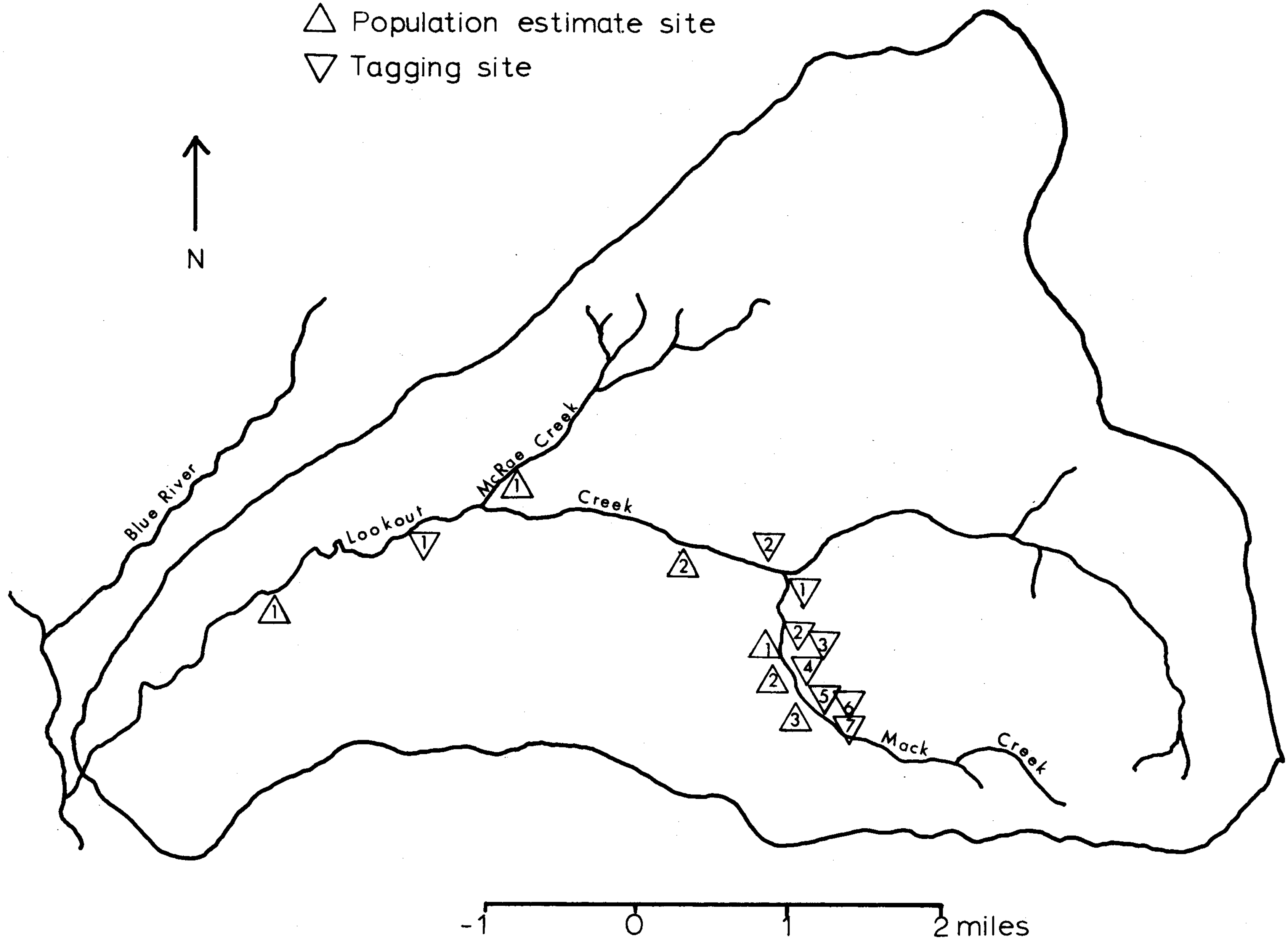

Figure 1: Map of H. J. Andrews Experimental Forest showing the Lookout Creek system and locations of population estimate and tagging sites.

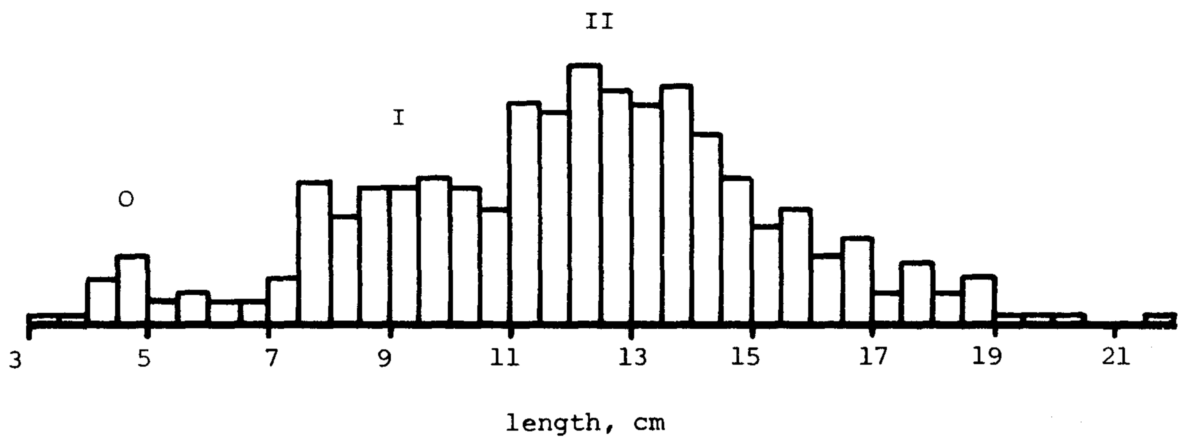

Figure 2: The length frequency distribution of 455 cutthroat trout captured in Mack Creek from September 22 until November 25, 1972. The apparent age-groups are indicated.

TROPHIC RELATION MODELS BASED ON DENSITY DEPENDENT PROCESSES

Charles E. Warren, Gerald E. Davis, W. Michael Booty,
James W. Haefner, Duane L. Higley and John P. Mullooly

Oregon State University

ABSTRACT

The IBP research project entitled "Trophic Relation Models Based on Density Dependent Processes" is an effort to generalize and increase the richness of the graphical models proposed by Brocksen, Davis, and Warren (1970) and Warren (1971) as a much needed alternative to the classical trophic dynamic approach first proposed by Lindeman (1942). These graphical models represent the production of a product of interest as functions of its biomass, age structure, and the productivity of the system for that product--its capacity to produce that product. The concept of productivity involves energy and material resources and competition at all trophic steps leading to the product of interest, and can so be graphically represented. Four lines of theoretical investigation are being followed in this effort: (1) analysis of behavior of parameters in phase space; (2) analysis of the behavior of two computer models of plant and animal communities; (3) development of a complex logical verbal model elaborating the concept of productivity and relating it not only to the original graphical models but also to other conceptual systems underlying ecological thought; and (4) mathematical and graphical attempts to determine ways of representing the concept of productivity (in the sense here used).

SUMMARY PROGRESS REPORT

As a much needed alternative to the classical trophic dynamic approach proposed by Lindeman (1942), Brocksen, Davis, and Warren (1970) and Warren (1971) developed graphical models of the production of a product of interest as functions of its biomass, its age structure, and the productivity of the ecosystem for the product--the capacity of the system to produce that product, whatever the prevailing rate of production. For a carnivore, its age structure, its biomass, the availability of its food, as well as energy and materials resources of organisms further back in its food chain, and competition at all trophic steps are involved in the system of graphs leading to final representation of its biomass and the productivity of the system for that age class.

The conceptual system, which we now most generally and usefully employ graphically, appears to be very generally applicable to the analysis of trophic relations, whatever the trophic kind of the product of interest may be. This system, which was first developed on the basis of studies of laboratory stream communities, has now been helpful in the trophic analysis of lake communities, natural stream communities, and appears to apply to terrestrial communities, even when the product of interest may be a forest tree.

The theoretical research we are now conducting has the ultimate objective of increasing the generality and richness of the present conceptual system, then making it much more useful. Four lines of theoretical investigation are being followed in this effort: (1) analysis of behavior of parameters in phase space; (2) analysis of the behavior of two computer models of plant and animal communities, these models employing parameters of the original conceptual system, one being based on difference equations, the other on differential equations; (3) development of a complex logical verbal model elaborating the concept of productivity and relating it not only to the original graphical models but also to other conceptual systems underlying ecological thought; and (4) mathematical and graphical attempts to determine ways of representing the concept of productivity (in the sense here used) numerically, this being desirable, and perhaps necessary, in the development of more powerful arguments.

The density dependent models described by Brocksen, Davis, and Warren depict predator growth rate and prey density as decreasing functions of predator density for certain food limited systems. The variables in these relationships are mean densities and mean growth rates; e.g., the mean benthos density in a single laboratory stream over a three month experimental period. In the present analysis, the question was asked, "What are the effects on these empirically derived relationships of varying experiment length and frequency of sampling?" The study was conducted by analyzing the output of a computer simulation model (which depicts a fish - benthos - algae system), and by analyzing real data from one of the longer term laboratory stream experiments.

This work has shown that, for the data studied, length of experiment expecially has considerable impact on the relationships between means. This and other results suggest that strict variable definition is required in the use of these relationships to interpret new data.

The work described above has pointed out the distinction between mappings of instantaneous variables in phase space and mappings of time dependent means generated by separate systems. Some observations on phase space relationships for the laboratory streams are described below.

The data of one laboratory stream experiment have been studied to see if they suggest any consistent phase space characteristics. The experiment provided data on benthos densities, fish densities, and fish growth rates in six laboratory streams, which ran for about four months. An interesting observation is that, for four of the streams, the fish growth-benthos density relationship conforms reasonably well to the much used asymptotic form (e.g. the disc equation of Holling (1966); the exponential equation of Ivlev (1961)). 0-growth intercept (maintenance density) is similar among the streams at about 1 g/m^2 wet weight.

The results of this work are encouraging and have provided some hypotheses that can be tested on independent data from the streams. One very challenging problem which may be investigated using the laboratory stream data is the relation of benthos composition to the fish growth-benthos density relationship. Future work will involve such investigation.

Two computer models have been developed to aid in the analysis of the relations of the density dependent models to predator-prey dynamics and equilibria in a three-step community. The first model is a non-linear difference equations model, whose basic features include the weight dependence of metabolism and maximum consumption and asymptotic consumption as a function of prey density. By varying initial densities, experiment length, sampling frequency, and other factors, we have come to better understand the density dependent relations arising from the laboratory stream studies. Further computer work using this model will probably aim at identifying stream experiments which will help refine the concepts presently used in interpreting the data.

The second model is a multi-population extension of Gallopin's (1971) model of a resource-population system. The differentiating feature of this model is that predator density influences the asymptotic consumption *vs.* prey density relationship. The model, mathematically a system of simultaneous non-linear differential equations, exhibits some interesting equilibrium conditions. These conditions have been studied through numerical analysis and through analytic solutions of piecewise linear approximations. The goal is to characterize the stability behavior and steady state dynamics of the model in its present and more complex forms, and to relate these characteristics to the density dependent models derived from the laboratory streams.

The original graphical models appear to be very general and useful--but their use is much too intuitive. The mathematical models are insufficiently realistic and much too constraining. It is our hope to be able to develop logical verbal models that will incorporate the conceptual system underlying the graphical models in a broader conceptual system involving the other most relevant conceptual systems of ecology. Such an overall conceptual system would be subsumed by the organismic generalizations and cybernetics thought. We are now examining systems of thought potentially useful in this effort.

It will be of great help in the above effort if we can find ways of numerically or otherwise simply representing, for different systems, their levels of productivity. A promising approach to this problem, which we are now investigating, is to determine the maximum scope of productivity for an algae-herbivore-carnivore organismic system, where the carnivore would be the product of interest. Graphical representation of simultaneous differential equations representing biomass changes of the three trophic kinds would be used to define this maximum scope within which these biomasses could wander. Actual productivity would be represented by the scope remaining after dimensions of productivity such as temperature, competition, or toxic substances, for example, had reduced the maximum scope.

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STREAM PROJECTS SUPPLYING DATA FOR WATERSHED 10 MODEL

Time Resolution: Yearly, seasonally, monthly

Units: Weight, calories, carbon

Input

Particulate Organics		Dissolved Organics & Inorganics	
Litterfall (meter square, Albee, Pike Sedell)	Lateral Movement (Triska)	Throughfall (Carroll, Lavender)	Soil Solution (Fredricksen, Moore)

Detritus Standing Crop

Standing Crop of Detritus Estimation (Sedell, Cummins)	Log and Branch (1mm dia.) Wood Volume and Biomass (Froelich, Sedell)	Potsamples (Anderson)	Respiration (Triska)

Processing by Stream Organisms

Isotope Experiments (Gregory, Sedell, Group)	Primary Production (Lyford)	Microbe Processing (Triska)	Insect Feeding Experiments (Anderson, Grafius)	Fish Production (Aho, Hall)

Output

Particulate Organics (Wier net 80μ, Sedell	Dissolved Organics & Inorganics (Fredricksen and Noonan)

UNIFORM METHOD FOR REPORTING IBP STREAM DATA

DETRITUS:

1. Leaf Packs (Jim Sedell) Bi--Weekly Samples
   - A. Percent weight loss
   - B. Nitrogen
   - C. Cellulose/lignin
   - D. Carbon/nitrogen

   Percent in grams per gram

   - E. Milligrams O_2 per hour per gram dry weight (Frank Triska)
   - F. Associated Fauna (Insects--Nancy McLean)
     - 1) grams per gram leaf pack
     - 2) 22 taxa - length/weight and number

2. Standing Crop (Frank Triska) Monthly Samples
   - A. Total grams per meter
   - B. Grams per meter squared for each particle size
   - C. Respiration - milligrams O_2 per hour per gram dry weight.

3. Litterfall (Jim Sedell) Monthly Samples
   - A. 8 categories - grams per meter squared
   - B. Grams per Upper Stream, Grams per Lower Stream
   - c. Total grams per stream

4. Output (Jim Sedell) Regular Intervals + All Storms
   - A. Grams per cubic meter for each particle size (Barb Buckley)

5. Lateral Litter Traps (Frank Triska) 30-34 traps Monthly
   - A. Grams per meter square

ALGAL BIOMASS

1. (Jack Lyford) Bi-Weekly Samples
   - A. Chlorophyll A - grams/meter square
   - B. Weights for Filamentous and Prasiola gC/m^2

ALGAE

1. Periphyton (Stan Gregory) Lab Samples
   - A. Net production - periphyton dry weight - $mg/m^2/day$
   - B. Insect grazing rates - $mg/m^2/day$
   - C. Standing crop - mg/m^2
   - D. Stream area available for periphyton growth - m^2

INSECTS

1. Benthic Samples (Ed Graffius) Monthly Pot Samples
   - A. Taxa - 35 categories
   - B. Dry weight per trophic category
   - C. Detritus
     - 1) dry weight and ash weight gm/m^2
     - 2) substrate size - percent composition by weight
2. Emergence Traps (Norm Anderson and Ed Graffius) Weekly Samples
   - A. Taxa - orders
   - B. Dry weight - $gm/m^2/day$
3. Feeding (Ed Graffius and Stan Gregory)
   - A. Consumption - grams/gram dry weight
   - B. Assimilation and growth rates - percent weight gain
4. Glossosomatidae (Norm Anderson)
   - A. Percent/m^2/instar; gm/m^2; gm/instar/m^2

FISH

1. Cutthroat (Jim Hall and Dick Aho) Mack Creek
   - A. Percent/year class/meter squared
   - B. Biomass - per year class - gm/m^2
   - C. Production - grams per meter square per year

APPENDIX 3
Sabbatical Leave 1971-72 Report

N. H. Anderson
Department of Entomology

From June 15, 1971 to June 1, 1972 I was on sabbatical leave with the River Laboratory, Freshwater Biological Association, East Stoke, Wareham, Dorset. Financial support from the schools of Agriculture and Science is acknowledged. I am also grateful to the Western Coniferous Biome IBP project for providing two months' salary and some travel expenses.

The following report summarizes the activities of the F.B.A. and outlines my research activities. In addition I have commented on visits to other research institutions. The report includes the following sections:

- The Freshwater Biological Association
  - The River Laboratory
    - Aims of Research at the River Laboratory
    - Aspects of Research
  - Research Project - Production Ecology of *Agapetus fuscipes*
  - Oxford University
    - Hope Department of Entomology
    - Animal Ecology Research Institute
  - University of Reading - Zoology Department
  - Nature Conservancy - Loch Leven IBP project
  - Water Research Association
  - Oceanology Exhibition
  - Marine Biological Association Laboratory
  - Limnologische Fluss-station, Schlitz, Germany

The Freshwater Biological Association

This is the organization with which I was associated for my sabbatical leave. The FBA was founded in 1929 to pursue fundamental research into all aspects of freshwater biology. It is an independent organization with a membership of private individuals (academic biologists, naturalists, anglers, etc.) water undertakings, fishing clubs, river authorities and the like, but it receives most of its income as a grant from the Natural Environmental Research Council. In 1971, the Rothschild report for government research and development advocated a far greater emphasis on applied research or a customer-contractor relationship. Under this program the FBA could be vulnerable for cuts in budget but because of the need for knowledge about fresh waters as a part of the general concern for the environment it seems probable that their general approach will continue.

The main laboratory, at Ambleside, Westmorland on Lake Windermere has a staff of about 30 scientists and 40 subprofessionals. It is considered the leading center for limnology in the British Isles with work in chemistry, physiology, and ecology. Current research includes work on bacteria, protozoa, fungi, algae, macroinvertebrates and fish. In addition there is an active program in quaternary research and in mathematical and statistical modeling.

Though it had been my intention to spend some weeks at the Windermere Laboratory on my research project my plans changed when the field and laboratory schedule at the River Laboratory did not allow for a break of this length. Thus my visit to Windermere was only 3 days, primarily for discussions with the director, Mr. H. A. Gilson, Drs. T. T. Macan and J. M. Elliott and to use the library. Dr. Elliott's work with downstream drift and biological studies of stream invertebrates was important as a comparison with my results in Oregon. He has also been doing extensive work on the potential or colonization of Morcambe Bay by freshwater invertebrates if this estuary is changed into a reservoir for freshwater. Dr. Macan is author of several books on stream biology, an authority on the taxonomy of freshwater invertebrates and editor of the journal "Freshwater Biology". He provided me with help on identification of my material, and we discussed the possibility of publishing my data in Freshwater Biology. I obtained copies of the FBA annual reports for the past several years which summarize the research of all of the staff.

The River Laboratory

The laboratory situated at East Stoke, Wareham, Dorset, was where I was stationed for my sabbatical leave. This laboratory was built in 1963 with the objective of complementing the work of the Windermere Laboratory on deep unproductive lakes by concentrating on the biologically productive rivers of the South of England. This laboratory, under the direction of E. D. LeCren, has a staff of about 15 scientists and 15 subprofessionals with facilities for most forms of biological research including microbiology, botany, algology, invertebrate zoology, fish ecology, and chemical analysis. Further details of the research program are given in the following sections. In addition to the laboratory facilities there is a fluvarium which was formally opened while I was there in 1971. This building provides unique facilities for the study and culture of all kinds or river plant and animals under simulated natural conditions in flowing water. The field facilities include the mill stream providing water for the fluvarium and several experimental channels and ponds. The laboratory also has ownership or long leases on represnetative sections of chalk streams and acid waters. They also have a laboratory situated at Waterston on a disused water cress bed which is being converted into a series of experimental rivers and channels for research and river ecology. This is the site where I conducted my field research.

Aims of Research (excerpt from FBA brochure)

The work of the River Laboratory can be described as 'orientated fundamental research'. The main theme of the research is 'production ecology'. We try to find out the kinds of animals and plants that live in rivers and why they live where they do and are found in some rivers but not in others. But we are particularly concerned with the commoner animals and plants, how many there are, how fast they multiply, grow and die, and what controls their abundance, activities and relationships with one another. The multiplication and growth, or what is best called 'the production' of the plants, herbivores, and successive carnivores in the 'food chain' of rivers is especially interesting and important to use and forms a link between the scientists studying each particular kind of organism.

We are concerned therefore, with the basic principles of river biology and not with immediate practical problems or applications. We believe, however, that what we are trying to discover will eventually prove to be of great help to those whose job it is to manage rivers for the benefit of Man. We believe that it is impossible to use rivers efficiently as sources of water, or for fishing and other forms of recreation, or to have effective control over floods and pollution without knowing a good bit about the weeds, insects, fish and microbes that live in rivers. We thus keep in close contact with river authorities and other organizations concerned with the practical management of rivers.

Aspects of Research (Excerpt from FBA brochure).

1) Physics and chemistry. No study of animals and plants is complete without knowledge of their environment and its physical and chemical features. We plan to continuously measure and record several of the more important factors and are developing instruments to do this. Meanwhile the temperature of the water in several streams, the light and heat from the sun and the amount of oxygen dissolved in the water are being recorded on charts. Regular chemical analyses of river waters are carried out, especially for the substances such as nitrogen, phosphorus and potassium that are plant nutrients. Samples of the plants and animals themselves are also analyzed for their energy content and chemical composition.

2) Botany. Reeds and water weeds are being studied and measurements made of their growth, the crops they produce and the way light and other factors influence their growth. The weeds, stones and mud on the bottom of rivers are covered with green or brown slimes and flannel weed that are mostly simple and minute plants called algae. Studies of their rate of growth and abundance are in progress.

3) Organic detritus. Much of the weed growth in rivers is not eaten directly by herbivorous animals but together with leaves, etc. wash in from the surrounding land forms a 'leaf mould' or detritus rich in organic matter. We are endeavouring to measure and study this organic detritus because we believe it is important in the natural economy of rivers and that it, or the microbes that live in it form an important source of food for the smaller animals.

4) Invertebrate animals. The identity and life histories of many of the smaller animals - the snails, shrimps, insects and worms - are not yet well known and are being elucidated. Particular emphasis is being put on finding out the numbers of the commoner animals and their vital statistics with the eventual aim of being able to investigate the annual crops that are produced and form the food of most of the fish.

5) Fish. Studies on the fish are concentrated on the vital statistics - the numbers or populations, and the rates of birth, death and growth - of the principal species in a number of different local waters. Preliminary estimates of the total annual production for a few representative waters have already been made. The food eaten by these fish is also investigated and experiments carried out in channels on the effects of the survival and growth of young fish of varying population density.

6) Special projects. As well as long-term studies around the general theme of productivity, other short-term projects are carried out - sometimes on topics of more immediate practical application. Thus a fifteen-month study of the chemical 'budget' of a water-cress bed is just being completed; the effects of a new reservoir in the Pennines on the local fish population is being recorded, and methods of automatically counting migrating salmon are being tested.

Research Project - Production Ecology of *Agapetus fuscipes*

My research project, in part financed by Oregon IBP funds, was designed to tie in with the ongoing research at the River Lab on production of the freshwater invertebrate fauna. The choice of the species for study was based upon its abundance and relative ease of sampling and also because the studies of growth rate, food consumption, and other population statistics could be applied to data collected on the Andrews Forest for the glossomatid caddisflies collected at that site. My work in England complemented studies undertaken by Dr. Pinder on the chironomid fauna, Dr. Ladle on the detritus feeding invertebrates (Simulium and oligochaetes) and emergence trap collections by Mr. Gledhill. In addition, I received assistance from the analyist, Mr. Casey, and particularly from the algologist, Dr. Marker; the latter identified diatoms from my field sites and in gut analysis and also performed chlorophyll analysis in my feeding studies.

My field project involved a sampling program of benthos collections by means of cores at 4 sites in a 200 m stretch of the Waterston stream. Further analysis of population structure and size was obtained from artificial substrates (bricks) in the same section of the stream; these were sampled on a 1 or 2 week basis. The latter was more successful than the coring method because of the economy in collecting and sorting but had the drawback of being difficult to express on a unit area basis. A technique was devised for laboratory rearing of _Agapetus_ in "drippery' trays. This was successful, resulting in the rearing of these caddisflies through the complete life cycle (including oviposition by adults) for the first time. The rearing studies provided data on the detailed life cycle, growth rate, and food requirements. The field work is not completely analyzed as yet because I continued field sampling up to the 1st of June (within a week of leaving) and some samples were sent to me since then to complete a full year of field work.

The intensive field work provided a detailed knowledge of the life cycle of _Agapetus_ but the quantitative data on population size , that I had hoped to obtain, was lost because of a pollution problem. The cress beds adjacent to the stream required cleaning and weed removal was part of the management program for the stream. When these operations were carried out the effluent from decaying water-cress drained into the stream and killed the caddisflies at one site (population declined from 60,000/m^2 to 0). This was apparently due to the increase in BOD, decrease in dissolved oxygen content and increase in stream temperature. A massive fish kill also occurred in this section of the stream. The weed removal had the effect of decreasing water levels so that in the exceptionally dry summer and autumn of 1971 the stream virtually dried up at other collecting sites. The series of catastrophes caused an obvious revision in the field sampling program but did not prevent me from continuing with life history studies. It resulted in a shift toward more detailed work with laboratory rearing and feeding studies.

In general, because I was free to devote my full time to a research program, I was able to complete most of my objectives and consider the study to have been highly successful.

Oxford University

Hope Department of Entomology

I visited with Professor George Varley in the Hope Department of Entomology, University Museum. I did not get to see much experimental work as the Department was moving to new quarters and considerable renovation of facilities was in progress. However, the new experimental facilities leave something to be desired, e.g. the constant temperature rooms had no provision for lighting. To add to this, the power cuts due to the national coal strike were in effect when I was there.

Professor Varley has more or less completed field studies on the winter moth (in part because George Gradwell has moved to the Forestry Department). The majority of the work on the oak tree ecosystem is still to be analyzed - there are 700 species of invertebrates in the system that they have collected in this 15-20 year project. Prof. Varley believes that the "quest theory" of population regulation or interaction as developed from the winter moth studies, is an important contribution to population theory. He mentioned that Dr. Hassell has now done field studies with aphids at Imperial College that also fit the model quite well.

Prof. Varley has about 5 graduate students (all that are in the department) and most of these are doing thesis work on some type of population studies with model ecosystems. Hugh Evans is trying to get Anthocoris nemorum or A. confusus populations established in one cubic meter ecosystems, using beans and pea aphids.

Animal Ecology Research Institute

I visited Dr. Philipson at the Animal Ecology Research Institute in his palatial suite in the new Zoology building. Again the lighting was at half mast so I did not see too much of the research facilities. Dr. Philipson introduced me to Dr. B. R. Allenson, the South African limnologist, who was on sabbatical leave at the AERI. He is doing a project on the transfer of energy from primary production to the secondary trophic levels. He was using Limnephilus as one of the test animals. By using a gravimetric method, and simple culture chambers (small dishes with a screened false bottom) he is able to measure the ingestion and egestion by the insects. He planned to use a snail which is a bacteria feeder to study another energy pathway in the same manner.

Dr. Philipson with his large team of associates (past and present) is continuing with his study of ecosystem energetics. This is a comprehensive study of the entire community in beach-wood litter. In many ways it is analogous to an IBP Biome study, but will probably be more precise as it is all closely integrated under his strong and continuous leadership. Though the "paid" staff is only 4 or 5, the ancillary projects from post-doctorals and graduate students and all of Elton's historial background work on the Witham Wood community means that there is a vast amount of information. The basic invertebrate sampling is done by five different exaction techniques, for example, formalin is poured on the ground to cause the worms to come to the surface for collection.

The main procedural technique used in Philipson's "best estimate" of respiratory metabolism as obtained by laboratory data. With this and with estimates of mean annual biomass and field temperature, he can obtain respiration of the community. Then using the McNiell-Lawton or Weigert line, the relationship between respiration and production is obtained. He gave me copies of his "best estimate" paper and two other handouts on the study.

Philipson does not plan to start modeling his data until another year's field results are available.

Dr. Philipson is editor of the IBP Handbook No. 18, 1971, Methods of Study on Quantitative Soil Ecology: Population, Production, and Energy Flow.

I consider the Animal Ecology Research Institute at Oxford to be one of the leading institutions working in production ecology and ecological energetics. It would be an ideal center for sabbatical work because of the intellectual stimulation, the library facilities and particularly the integrated research program in ecological energetics.

University of Reading, Zoology Department

At the invitation of Dr. A. Berrie, I gave a seminar to the Zoology Department on my work with aquatic insects in Oregon and visited with the Department for 2 days. There is a considerable amount of aquatic entomological work in this department but most of it is not connected with the IBP program. The IBP project on the river Thames was initiated under Dr. K. H. Mann but when he left for a position in Canada it was taken over by Dr. Berrie. The work has decreased considerably since 1969 as most of the European IBP projects are completed. However, Dr. Berrie is now doing another study of fish productivity in the river Thames because the species composition has changed - probably due to an epidemic in the bleak.

The only entomological work connected with the IBP is a study of Chironomidae in Nuphar beds. This is conducted by a Ph.D. student, Peter Mackie. His sampling is done from a boat collecting individual leaves into a plastic bag. The area can then be expanded to per meter and to the total Nuphar beds (which equal 6% of the total area). One or a few species of Crichopotus make up the dominant species, with several generations in the summer. These feed by grazing or filtering onto mucus threads and none are of the mining type. He plans to get production estimates but I don't know his technique.

The University of Reading is hosting the International meetings on Productivity of Freshwaters in September, 1972 that are meant to provide a summary of fresh water research.

I visited with Dr. Crichton and Mrs. Fisher concerning their study of caddisflies collected in the Rothamsted light trap survey of the British Isles. The work on this project is largely summarized in a paper of which I obtained the reprint. Dr. Crichton has yet to obtain Agapetus fuscipes from light traps which probably indicates that it is a day flier because it is one of the most abundant British caddisflies. Peter Barnard, a new student with Dr. Crichton, is planning a study of the reproductive cycle of limnephilid males, particularly those species that diapause over the summer.

Peter Hiley is doing an intensive study of Agapetus fuscipes, the same species that I studied in Britain. His data from the River Lambourne is based on weekly dip net collections. The insects are floated off by several washings. Then he grinds the substrate to break up cases and floats off the remainder. He appears to have a single generation of this species, based on length-frequency distributions.

I visited the River Lambourne and its tributary the Winterbourne with Peter Hiley and Dr. John Wright. They are conducting an intensive study of the invertebrate fauna while Dr. Berrie is studying the fish, with respect to the effects of ground water extraction from the surrounding chalk aquifer. In previous years the pumping has resulted in lowered stream flow, so in order to prevent loss of the stream fauna it may be necessary to augment stream flow by pumping or by using the stream as an aquaduct. The study is based on sampling of 5 types of substrate, much of it different types of macrophytes and also the very fine chalk substrate. Stream mapping on each sampling date is an important part of the project. I was surprised that the substrate did not contain flint pebbles like the stream I studied in Dorset. Dr. Wright is meant to be working on the Chironomidae but the labor required in sorting the benthos samples from the survey has prevented any detailed work as yet.

The Nature Conservancy Loch Leven IBP Project

I visited the field site of this project in 1969 and during my present trip was at Edinburgh twice to discuss progress on the research since that time. The aim of the study is to measure production and production processes in the food chains leading to brown trout, perch, pike, and tufted duck. Loch Leven is a nutrient-rich shallow lake with an area of 13.3 km^2. The IBP project commenced in 1966 as a joint project between the Nature Conservancy, the Freshwater Fisheries Laboratory and Wildfowl Trust. Since then University workers from 5 institutions have joined in the project. Field work was completed on the project in 1972 but it is anticipated that studies will continue for several years as Loch Leven has become a major site for limnology in the United Kingdom. I obtained copies of the project reports for 1971 and 1972 which give the status of the work but the first synthesis of the project was not expected to be available until the Reading IBP meetings in September, 1972.

From an entomological point of view I was particularly interested in the production studies by P. S. Maitland on the Chironomidae in the sand area and the differences between that and production of chironomids in the mud areas by W. N. Charles.

A major strength of the program is the apparent integration of the research studies. The objectives as stated by N. C. Morgan in the 1970-71 report illustrate the approach: "In 1971 an attempt will be made to measure the annual nutrient input and loss, production of phytoplankton, major chironomid species, brown trout and perch for the whole Loch. We should then have comparable figures for production at important points in the food chain for the same year. It should then be possible to fill the gaps, particularly in relation to food intake and utilization, in later years and apply them to the 1971 situation. It is however, most important that production of the major components should be made in the same year, if comparisons are to be meaningful, since our work has shown that there can be a variation of several hundred percent in the production of the same species from year to year."

Water Research Association Laboratory, Medmenham, Marlow, Bucks.

I attended an open day program at this laboratory on April 27, 1972. The laboratory has a large building and staff (100?). The Association's work is largely on aspects of water supply technology for the entire British Isles. Exhibits and tours illustrated the following areas: 1) quality and quantity of surface waters; 2) quantity and quality of underground waters; 3) treatability and product quality; 4) distribution and use; 5) measurement of water quality; and 6) member services (library, publications etc.). As may be apparent from the titles, very little basic aquatic biological work is done here and concern with this area is mostly in relation to pollution sources, bacteria, nuisance blooms of plankton etc.

I was quite interested to see the exhibits relating to requirements for domestic and industrial needs for the next 50 years. Britain does not necessarily suffer from a shortage of water but from unequal distribution throughout the year. Thus schemes for reservoirs, dams, and diversion from one river basin to another are all under consideration. As with so many other economic predictions, water requirements are estimated to increase exponentially; on their projections for 50 years these requirements can be met by an elaborate series of diversion and storage schemes, but if one extrapolates for a further 50 years it seems that the whole of the British Isles would be under 300 feet of reservoir!

Oceanology Exhibition, Brighton

This large international exhibition is an annual venture designed to display research and technology for exploiting marine areas. While the vast majority of it dealt with hardware, e.g. research submarines, life support systems, and oil drilling rigs, there were also a large number of displays concerned with the research on the effects of domestic and industrial pollution of estuaries. Judging from the displays it was also apparent that thermal pollution from nuclear power plants is an area of interest in many countries. One of the most interesting displays was a scale model of the reclamation projects in the Netherlands; dikes, canals, and the vast Europort harbor system were modeled.

Marine Biological Association Laboratory, Plymouth

I toured this laboratory with a group from the FBA which is a sister organization. The MBA has a staff of 25 scientists, 125 total staff and 4 ships. Visiting researchers frequently increase the scientific staff by 25-50%. Their quarters overlook the harbor from whence Sir Francis Drake sailed to defeat the Spanish Armada and the Pilgrim Fathers sailed to the New World. Research is concerned with the West English Channel area. While the director told us that the main thrust of their research was to learn more about the proper keeping of marine animals, he was also quick to admit that it was impossible to culture most of the invertebrates at present and they had to depend on collections of material and from the ships' cruises. The aquarium which is open to the public had a very good display and functions as an educational arm of the laboratory as well as providing some funds and particularly publicity for the organization.

The research at the institution was not sectionalized in theory, but by budget into the following categories: 1) chemistry- the study of water masses, thermocline, trace element work, and nutrient conditions; 2) primary productivity; 3) secondary productivity - particularly of copepods; 4) benthic productivity - coastal, intertidal and channel surveys; 5) physiology - the strongest section particularly since Sir Alec Hodgkin's Nobel-Prize winning research on the giant axon of the squid; 6) tracer lab - monitoring materials and tools for physiological work; 7) the library - with 1600 journals and concerned with publishing the Journal of the Marine Biological Association.

This laboratory has pioneered work in studies of marine oil pollution particularly since the Torrey Canyon disaster of the 1960's was located within the area where they had already conducted considerable biological research. The English Channel is one of the busiest shipping lanes in the world and oil pollution is a chronic problem; I can vouch for this personally as one of the greatest disappointments on my visit to Britain was the ubiquity of this tarry filth on practically every beach.

Limnologische Fluss-station, Schlitz, Germany

Prof. Dr. J. Illies, the director of this laboratory recently published a large work on production ecology estimated by measuring emergence of aquatic insects so I was anxious to discuss the project and see his facilities. An unexpected bonus was to find that one of his students had been studying the ecology of Agapetus fuscipes for 3 years, so we were able to compare our field results.

The institute had good laboratory facilities, classrooms, and an excellent library. A new artificial stream system had just been delivered. This was a facility with a series of 4 stainless steel oval channels with variable speed paddle-wheels for flow control, temperature control and light. There was also facilities for large artificial streams using water directly from the River Schlitz. There were 4 troughs with a variable incline to give speeds of up to 3 m/sec. These are meant to complement the behavior troughs used by Dr. Meijering. His troughs had a pump system for recirculating the water and were about 30-40 cm. wide and 4-5 m long. Gammarus behavior - particularly up-stream migration and drift in relation to temperature, light etc. were studied. Recapture of the specimens after an experiment was done by electrofishing.

I visited the field sites with Luis Benedetto who is doing the research on Agapetus. These two small streams - the Rohrwiesenbach and Breitenbach have had greenhouses built over them for collecting all of the emerging insects. These greenhouses, 12.25 by, 2.8 by 2.3 meters obviously increased the air temperature but according to their data do not significantly affect the water temperature in this relatively short stretch of stream. However, they are large enough to include all of the biotopes from which aquatic insects are expected to emerge. Emergence in these buildings is impressive - for example, more than 52,000 were collected in one year with about 150 species being represented. Collecting is done daily by aspirating with a vacuum and takes two persons approximately 3 hours.

I discussed the methodology of the greenhouse system with F. Ringe, a doctoral student who has spent about 5 years on chironomid taxonomy, largely the adults collected in the greenhouses. He pointed out that the 50,000 per year mentioned in Illies' paper was exceeded by a factor of 5 in the other stream. One of the major pitfalls of the emergence trap study was the difference in numbers collected on different schedules. For example, if numbers collected per two day was x, the numbers per 1 day would be 2x and the numbers for a two-hour schedule would be more than 4x. Chironomidae were the major component of emergence in number of species and biomass.

Another study associated with the emergence studies was the work of F. Ulrich on water mites. These are ecotoparasites, mostly on chironomids but also on black flies, caddisflies, etc. He collects many of the larval mites from adult midges in the greenhouse, but also finds the most abundant species as larvae in the benthos which suggests that some may be free-living as larvae. Other species he is rearing on chironomid larvae for 1-2 weeks before they emerge as free-living nymphs.

Dr. R. Rupprecht was also visiting the laboratory when I was there. He is studying the behavior of stoneflies and has found that drumming is a species specific behavioral pattern assodated with mating. The sound produced is a very low frequency (5-120 cycles/second). Genera so far investigated include Perla, Capnia, Isogenus, and Nemoura. To investigate the structures used in this behavior he is doing electron microscopy work and asked for material from the Pacific Northwest of about 20 species that represent other taxa.

The laboratory at Schlitz has a small staff - only about 5 full time plus several students. The research program in the past has basically dealt with the taxonomy of aquatic insects and mostly only with the adults. At present there is a theme of production ecology with the emergence trap work as the first resultof this change of direction. In addition to this there are energetic studies with Agapetes and the behavioral physiology under Dr. Meigering. While the ecological work may not be breaking much new ground as yet the detailed knowledge of the insect fauna will provide a sound background for the future work.

APPENDIX 4

CONIFEROUS FOREST BIOME

INTERNATIONAL BIOLOGICAL PROGRAM

STREAM WORKSHOP

February 17-18, 1972
Oregon State University
Corvallis, Oregon

A stream workshop was held in Corvallis, Oregon on 17 and 18 February 1972, under the Sponsorship of the International Biological Program Coniferous Forest Biome. The purpose of the workshop was to acquaint stream biologists in North America with Biome approaches to modeling and to encourage the exchange of ideas and information between individuals and groups studying different stream systems.

The stream workshop opened with Charles Warren discussing his concepts of stream biology. The remainder of the workshop continued to explore these concepts, as well as introduce alternative conceptual approaches to the study of streams. Two additional approaches to the study of biological systems which had emerged in the Biome, in addition to Warren's density-dependent relationship, were C. D. McIntire's periphyton dynamics model and Scott Overton's universe coupling structure for biological modeling (for details see Warren 1971; Overton 1972; and McIntire 1973).

Ken Mann discussed several types of models including descriptive, dynamic, and predictive models the ultimate goal. The descriptive model of a stream system was given the highest priority. Descriptive models require data on biomass of compartments and mean annual flows of energy between them. An example of such a model was the energy budget for the Thames River, England. Dynamic models, such as the one built for Marian Lake, British Columbia, were viewed by Mann with skepticism. He doubted whether large complex models could ever be predictive. His modeling approach started with the description of the comparative anatomy of the ecosystem. From this evolved estimates of mean annual energy flow.

Wayne Minshall from the Desert Biome discussed the need to study the interface between terrestrial and aquatic systems. He reported on data from his Deep Creek research area in Idaho.

Dan Nelson from Oak Ridge discribed an isotope method used to estimate periphyton biomass in production rates and grazing rates on the periphyton. Our group is currently checking the assumptions of this method and plans to use it on the streams in the Andrews Forest.

Ken Cummins used the workshop as an opportunity to emphasize the common ground between soil science and stream biology--both being concerned with heterotrophic communities. His group is focusing on microbial interactions with detrital particle sizes and invertebrates. His is one of the few stream groups in North American attempting to actually model an entire stream.

Robin Vannote, at the Stroud Water Resources Center of the Philadelphia Academy of Natural Sciences, has been working primarily at the species level. Discussion of his work indicated that he has what is probably the best data of invertebrate life history and production rate that are available. His natural stream and experimental facilities are unparalleled.

The stream workshop served as an important forum for idea exchange and pointed out the need and desirability for more cooperation and coordination between stream groups. For us in the Coniferous Forest Biome, the workshop helped to put our work into perspective and give us an understanding as to what kinds of contributions we might most profitably make. It became apparent that our stream program has one of the best opportunities for ties with soil scientists and hydrologists and can profit by emphasizing land-water interactions. The discussions on modeling approaches served the same purpose; it put our work and modeling effort into perspective with that going on in other parts of the country.

The workshop laid the groundwork for subsequent very real coordination, data exchange, and cooperation between the major deciduous forest stream groups and our Coniferous Forest Biome stream program.

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STREAM WORKSHOP PARTICIPANTS

Invited Participants

Outside Coniferous Forest Biome

Richard Anderson	Missouri Cooperative Fishery Unit
Robert Boydell	Limnology Department Philadelphia Academy of Science
William Clark	Institute of Animal Resource Ecology University of British Columbia
Kenneth Cummins	Kellogg Biological Station Michigan State University
Arden Gaufin	Department of Biology University of Utah
T. T. Macan	Freshwater Biological Assoc., Windermere, Eng.
Kenneth H. Mann	Marine Ecology Lab., Bedford Institute
G. Wayne Minshall	Department of Biology Idaho State University
Daniel Nelson	Oak Ridge National Laboratory
Robin L. Vannote	Stroud Water Research Laboratory Philadelphia Academy of Science
Robert Boling	System Science Department, MSU
Frederick Howard	Kellogg Biological Station, MSU
Keller Suberkropp	Kellogg Biological Station, MSU
Robert Petersen	Kellogg Biological Station, MSU

IBP - Oregon State University

Michael Booty	James Hall	W. Scott Overton	James Sedell
Gerald Davis	Duane Higley	John Donaldson	John Lyford
Edward Grafius	Stanley Gregory	David McIntire	John Mullooly
			Charles Warren

IBP - University of Washington

Robert Burgner	James Malick	Quentin J. Stober	Douglas Chapman
Larry Male	Paul Olson	Frieda Taub	Demetrious Spyridakis

IBP Coniferous Forest Biome
Stream Workshop
February 17 and 18, 1972
Peavy Arboretum
Corvallis, Oregon

AGENDA

THURSDAY, FEBRUARY 17

8:00-8:30 a.m.	Introduction
8:30-12 noon	Description of density-depdendent model C. E. Warren
12-1:00 p.m.	Catered lunch at the Arboretum
1:00-3:30	Continue morning discussion
4:00-5:00	Periphyton dynamics in flowing water environments: A simulation model C. D. McIntyre
6:00-8:00	Dinner (on your own)
8:00	Social gathering

FRIDAY, FEBRUARY 18

8:00-12 noon	Continue discussing concepts and approaches to stream studies
12-1:00 p.m.	Catered lunch at Arboretum lodge
1:00-5:00	Second verse--same as the first more of the same