THE INFLUENCE OF LEAF LITTER CONDITIONING
TIME ON INGESTION AND GROWTH RATES OF THE
STREAM DETRITIVORE LEPIDOSTOMA COSTALIS (TRICHOPTERA)¹

MASTER

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INTRODUCTION

The general pattern by which organic matter is made available to, and is processed by, the communities of temperate zone woodland stream ecosystems is now fairly clear (Cummins, 1972; Fisher and Likens, 1972) although many critical details (particularly rates) remain to be delineated.

As shown in Fig. 1, the energy inputs to woodland stream ecosystems can be partitioned into two general components: particulate and dissolved organic matter of terrestrial origin, and photosynthetic carbon fixation - the former being quantitatively much greater.

The pool of large particulate organic matter (approx. > 1 mm) is maintained primarily by the terrestrial input of vascular plant tissue e.g. leaves, bud scales, flowers, fruits, bark, twigs, branches and large material such as logs which are subject to very slow processing and, therefore, having long residence times. An important feature of streams is their function as concentrators of this material, since they act as "sticky traps" (terminology from H. B. N. Hynes, Univ. Waterloo, personal communication). If vascular hydrophytes are present (e.g. watercress) they tend to enter the processing cycle primarily as if they were of terrestrial origin rather than through the grazing activities of stream herbivores. The pool of fine particulate matter (approx. < 1 mm) is derived from in-stream processing of large particles (e.g. fragments broken loose through animal activities or physical abrasion by sediments in transport, and animal feces), algal cells sloughed from surfaces, the microorganisms always associated with fine organic particles, and the physical-chemical flocculation of dissolved organics. Other fine particles of terrestrial origin, such as feces of insects feeding in the forest canopy, are also part of this pool and may be quantitatively significant at certain seasons. The dissolved organic pool results from leaching

of terrestrial particulate organics, either before they enter (runoff) or after the particulates are in the stream, and from algal excretions. Leaf litter leaching is rapid (essentially complete 24-48 hours after the litter is wetted) and quantitatively significant (5-40% of the dry weight of the litter).

Leached vascular plant tissue represents an organic substrate composed of resistant carbon compounds (at least half cellulose) and little nitrogen. Although propagules of terrestrial fungi and bacteria are present on the litter before it enters the water, rapid colonization and growth by aquatic forms (e.g. aquatic hyphomycete and gram negative bacterial rods) dominates in the stream. The metabolism of these microorganisms is characterized by cellulose degradation and nitrogen uptake from the water rendering the litter and associated microflora a suitable food source for animal metabolism. Labile organics in the leachate are undoubtedly rapidly taken up by microorganisms associated with the sediments and organic particles, as well as those in transport.

Soon after, and probably in response to, microbial infestation of the large particulate organic matter, such as leaf litter, large particle detritivores ("shredders") move into accumulations of such material and begin feeding. The general effect of shredder feeding is to reduce the average particle size, thereby providing additional substrate surface for microbial colonization and metabolism (especially bacterial) and food for fine particle detritivores ("collectors").

Primary production, usually minimal in woodland streams, is dominated by diatoms which are shade adapted and may function as facultative heterotrophs. Correspondingly, the grazer species feeding on the periphyton are characteristically few and often dependent on the intake of significant amounts of fine

particle detritus that accumulates in the interstices of the periphyton cover.

Populations of collectors and grazers are reduced by stream predators (both invertebrate and vertebrate) throughout the growing portion of their generations while the shredders are subject to significant predator mortality primarily in the early part of the growth period.

Non-predatory death of all animals, animal exuviae and feces quickly enter the fine particle pool. The conversion of reduced carbon compounds to CO_2 is efficient, being at least 80% of particulate and 50% of dissolved materials and, strikingly, a significant portion is accomplished at temperatures below 10°C , which is in sharp contrast to terrestrial, and also probably standing water, systems of the temperate zone.

Against this background of generalized woodland stream ecosystem structure and function, considerable interest has focused on the role of the shredders (large particle detritivores) in converting large particulate detritus to smaller particles, CO_2 and their own biomass (Vannote, 1970; McDiffett, 1970; Wallace et al., 1970; Mackay, 1972; Cummins et al., 1972). However, other than field densities, the two most important parameters (Waldbauer, 1968), relative growth rate ($\text{GR} = \text{wt growth/animal wt/day}$) and consumption index ($\text{CI} = \text{wt food/animal wt/day}$), have not been adequately determined for any shredder species. Particularly critical to stream modeling efforts is the lack of data relating GR and CI to temperature, food quantity and quality, animal age and density, and interactions between species. This paper deals with the relationship between food quality (leaf species and conditioning time) and growth and consumption indices for terminal and penultimate larval instars of the winter-spring shredder L. costalis (Banks).

METHODS

The procedures followed in measuring feeding and growth of Lepidostoma in laboratory culture chambers are shown in Fig. 2. The methods of calculation of relative growth rate, consumption index and the efficiency of conversion of food to growth (Waldbauer, 1968) are given in Table 1.

Augusta Creek, a small, hardwater, brown trout stream in Kalamazoo and Barry Counties, Michigan, served as the source of L. costalis larvae and the site for natural stream conditioning pignut of hickory (Carya glabra) and white oak (Quercus alba) leaves. All weights were determined after oven drying for at least 48 hrs. at 51°C (stored over P_2O_5). Larvae were weighed on an automated Cahn electrobalance ($\pm 2 \mu g$) and leaves on a Metler balance ($\pm .05$ mg). All leaves were collected from two trees just prior to abscission and stored dry until used. Leaves were conditioned in the field as 10 gram (dry weight) leaf packs fastened together loosely with Butoneers (Dennison Co.), lashed to bricks with monofilament line and oriented into the current.

RESULTS AND DISCUSSION

In all instances (Table 2) consumption index and growth was greater when animals were fed hickory leaves than when fed oak. In those instances when growth was negative, due to the fact that the animals were nearing or at the end of the growth period (i.e. each chamber contained some larvae that fastened their cases down, preparatory to pupation, during the experiment) the consumption index was still higher in the hickory chambers. Therefore, at any equivalent conditioning time consumption of hickory leaves is higher than oak and, if the larvae are growing, the resulting increase in weight is greater on hickory.

Using the maximum measured conversion index for L. costalis of 0.997 mg hickory leaf/mg animal/day (Table 2) and a mean dry weight per larva of 2 mg

(instar V), each larva would convert 1.994 mg of leaf per day. At an average field density of 10 larvae in a 10 gram (dry wt) leaf pack for a period of 30 days, 0.598 grams of leaf would be converted or approximately 6% of the 10 gram pack. This compares to an estimated impact of about 8% by other shredders such as Tipula and Pycnopsyche (calculated from Cummins et al., 1972 = TD-C00-2002-13 using: $CI = 0.187$, $\bar{x}$ wt per larva = 28 mg, $\bar{x}$ density 5 larvae/10 gram leaf pack).

NOTE FOR AEC REVIEW

Additional data will be gathered on high (hickory) and low (oak) quality food incubated varying periods in Augusta Creek using L. costalis larvae in instars I through V prior to the first of May. This species must be classified as a winter-spring species rather than a spring-summer species as was originally thought. Therefore, data on this species will be of particular interest since its growth period overlaps the time of spring run off and the concomitant input of terrestrial detritus.

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Fig. 1. Simplified model of woodland stream ecosystem structure (after Cummins, 1972).

Fig. 2. Methods for measuring parameters used in determining relative growth rate (GR), consumption index (CI) and efficiency of conversion of food to growth (ECI); see Table 1 for calculations.

Table 1. Calculation of relative growth rate (GR), consumption index (CI) and efficiency of conversion of food to growth (ECI) using parameters shown in Fig. 2.

$$\bar{x} \text{ Control leaf wt loss/leaf disc} = \bar{x}\text{CIFW} - \bar{x}\text{CFFW}$$

$$\bar{x} \text{ Experimental leaf wt loss/leaf disc} = \bar{x}\text{IFW} - \bar{x}\text{FFW}$$

$$\text{Total control leaf wt loss/chamber} = \text{CIFW} - \text{CFFW} = \text{C}$$

$$\text{Total experimental leaf wt loss/chamber} = \text{IFW} - \text{FFW} = \text{TFWL}$$

$$\text{Total corrected leaf wt loss/chamber} = \text{TFWL} - \text{C}$$

$$\bar{x} \text{ Initial animal wt/individual} = \bar{x}\text{IAW}$$

$$\bar{x} \text{ Final animal wt/individual} = \bar{x}\text{FAW}$$

$$\text{Total initial animal wt/chamber} = (\bar{x}\text{IAW})(20) = \text{TIAW}$$

$$\text{Total final animal wt/chamber} = \text{TFAW}$$

$$\text{Duration of experiment in days} = t$$

$$\text{Total median animal wt over period} = \frac{\text{TIAW} + \text{TFAW}}{2} = \text{MTAW}$$

$$\text{Total median leaf wt over period} = \frac{\text{IFW} + \text{FFW}}{2} = \text{MFW}$$

$$\text{Density factor} = \text{DF} = \frac{\text{MTAW}}{\text{MFW}} \times 100\% = \text{animal biomass as a \% of food biomass}$$

$$\text{Relative growth rate} = \text{GR} = \frac{\bar{x} \text{ FAW} - \bar{x} \text{ IAW}}{(\text{MTAW})(t)} = \text{mg growth/mg animal/day}$$

$$\text{Consumption index} = \text{CI} = \frac{\text{TFWL}-\text{C}}{(\text{MTAW})(t)} = \text{mg food ingested/mg animal/day}$$

$$\text{Efficiency of conversion of food to growth} = \text{ECI} = \frac{\text{GR}}{\text{CI}}$$

Table 2. Growth and feeding of Lepidostoma costalis (Banks). Unless indicated otherwise, all data are means of 3 replicate chamber $\pm$ SD at 12 C. Leaf weight loss due to animal feeding has been corrected for control leaf weight loss (i.e. without animals). See Fig. 2 and Table 1 for methods of measurement and calculation

Lepidostoma density per chamber	Instar	Density factor (DF)	Survivorship (%)	Duration (days) of feeding and growth experi- ment and dates	Leaf wt loss (%)	Leaf Conditioning			Consumption index (CI)	Relative growth rate (GR)	Efficiency of conversion (ECI)
						Leaf type	Site	Conditioning time (days)			
15	V	8.06	93.3	12 5-17 May	45.1	Hickory	---	none ³	0.657 $\pm$.232	0.009 $\pm$.008	0.011 $\pm$.009
15 ¹	V	2.57	80.0	12 5-17 May	7.5	Oak	---	none ³	0.254 --	0.0004 --	0.002 --
15	V	9.76	80.0 ⁴	12 11-23 May	21.4	Hickory	Stream	7	0.219 $\pm$.096	-0.014 $\pm$.011	---
15	V	5.10	100.0 ⁴	12 11-23 May	5.9	Oak	Stream	7	0.105 $\pm$.117	-0.016 $\pm$.015	---
15 ²	IV, V	0.45	78.1	27 6 Apr-3 May	10.3	Hickory	Lab	10 ³	0.997 $\pm$.333	0.032 $\pm$.008	0.036 $\pm$.019
15	V	8.07	95.5 ⁴	12 19-31 May	29.4	Hickory	Stream	14	0.244 $\pm$.024	-0.015 $\pm$.005	---
15	V	3.59	95.5 ⁴	12 19-31 May	none	Oak	Stream	14	-0.662 $\pm$.095	-0.015 $\pm$.003	---
15	V	11.70	100.0 ⁴	12 25 May-6 June	12.1	Hickory	Stream	21	0.048 $\pm$.075	-0.014 $\pm$.005	---
15	V	4.11	93.3 ⁴	12 25 May-6 June	none	Oak	Stream	21	-0.289 $\pm$.078	0.007 $\pm$.016	---
15	V	9.11	82.2 ⁴	12 1-13 June	25.5	Hickory	Stream	28	0.433 $\pm$.249	-0.010 $\pm$.011	---
15	V	3.34	97.8 ⁴	12 1-13 June	1.8	Hickory	Stream	28	0.211 $\pm$.235	-0.013 $\pm$.026	---
15	V	5.40	91.1	12 5-17 May	33.4	Hickory	Stream	35	0.642 $\pm$.225	0.006 $\pm$.003	0.010 $\pm$.025

¹mean of 2 chambers.

²mean of 7 chambers.

³Innoculated with organic foam containing hyphomycete spores and bacteria collected from Augusta Creek.

⁴Some larvae stopped feeding and fastened cases down preliminary to pupation.