THERMAL REGULATION OF FUNCTIONAL
GROUPS IN RUNNING WATER
ECOSYSTEMS

Progress Report
for Period October 1, 1975 - June 30, 1976

K. W. Cummins and M. J. Klug

Kellogg Biological Station
Michigan State University
East Lansing, Michigan 48824

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1.0. ABSTRACT

Thermal Regulation of Function Groups in Running Water Ecosystems

The research plan encompasses three general objectives.

- 1) Characterization of functional groups of running water organisms, particularly macroconsumers (shredders, collectors, scrapers, predators).
- 2) Establishment of the relationship of functional groups to:
 - a) qualitative and quantitative characteristics of organic inputs to stream ecosystems:
 - b) thermal regimes (upper and lower thermal limits and degree-day life cycles).
- 3) Dimensioning the control of feeding and growth by temperature and food quality and quantity, and determination of the extent of compensatory action of each.

INTRODUCTION

The research completed during the 1975-76 contract period centered on three general objectives:

- 1) characterization of key functional groups of running water organisms, particularly macroconsumers (shredders, collectors, scrapers and predators; Cummins, 1974) - including the extensive use of such procedures as correlation techniques to establish size - biomass relationships;
- 2) establishment of the relationships between functional groups and -
 - a) qualitative and quantitative characteristics of organic inputs to stream ecosystems,
 - b) thermal regimes (upper and lower thermal limits and degree-day life cycles); and
- 3) dimensioning the control of feeding and growth by temperature and food quality and quantity and determination of the compensatory action of each (e.g. compensation for increased temperature by reduced food quality to produce normal growth rates).

3.0. CHARACTERIZATION OF FUNCTIONAL GROUPS

The functional groups described by Cummins (1973, 1974) for stream ecosystems have been further investigated (see Cummins, 1975a, 1975b and 1976 which accompany this Progress Report; Table 1). The macroinvertebrate fauna of the headwaters of Augusta Creek (Kalamazoo and Barry Counties, Michigan) is listed by functional group in Table 2. A distinction has been made between obligate and facultative shredders - coarse particulate organic matter (CPOM) feeders. The former include those species that do not exhibit normal growth when fed FPOM (fine particulate organic matter) in laboratory culture. The primary examples - Pycnopsyche; Lepidostoma (Trichoptera) and Tipula (Diptera) - have been shown not to feed on leaf litter when such substrates are kept sterile. When sterile leaf litter was softened with pectinase, Tipula larvae fed, but lost weight.

Filtering (suspension feeders) and gathering (deposit feeders) collectors are also distinguished in Table 2. The separation is useful since the former group is much more responsive to changes in particle distribution of the FPOM in transport. For example, this is reflected in the transition from first order (Strahler, 1957) headwater streams to larger receiving streams in the same drainage. Among the hydropsychid caddisflies, Diplectrona which constructs a very coarse mesh filtering net occurs only in first order streams where more coarse particles predominate. Several species of Hydropsychidae occur in the larger second and third order tributaries - Hydropsyche betterri, bronta and slossonae and Cheumatopsyche sp. These species construct nets covering a range of mesh sizes, but none as large as Diplectrona. In the fifth order receiving stream, the Kalamazoo River, the diversity of hydropsychids is even greater corresponding with the largest load of transported particles, but dominated by fine particles. Hydropsychids such as H. phaelerata construct a fine mesh net and Macronemum zebratum constructs a large coarse net.

A great deal of effort has been expended in gathering data which will permit the rapid conversion of size-specific numerical data to biomass equivalents for each functional group. Data files of over 3,000 weight determinations have been developed and additional size-weight information has yet to be logged. Some examples of the initial analyses are shown in Appendix III.

4.0. RELATIONSHIPS BETWEEN FUNCTIONAL GROUPS AND ORGANIC INPUTS AND THERMAL REGIMES

Analysis of the detritus standing crop of a headwater tributary of Augusta Creek and the associated macroinvertebrate biomass is almost complete and will constitute the basis of a paper now being prepared (see Appendix I, outline of paper). As shown in Table 2,3, the total macroinvertebrate biomass ranges from 0.8 to 13.5 gm/m² with an annual monthly mean of 4.0 g/m². Maximum biomass is in the late winter and midsummer prior to spring and fall emergence periods and corresponding to low periods for detritus standing crop, particularly CPOM. The ratio of shredders (CPOM feeders) to collectors (FPOM feeders) is maximum in the late spring when the shredders (e.g. Pycnopsyche and Tipula) have reached their maximum biomass per individual.

The relationships between particulate organic matter and microbial respiration in detritus processing are discussed in Boling et al., 1975a which accompanies this Progress Report. The data collected from the Augusta Creek system have been used to develop a general simulation model of detritus processing in woodland streams (also see Boling, 1975b).

The dependence on temperature of microbial and macrobial activity in detrital processing are discussed in Suberkropp et al., 1975 which accompanies this Progress Report. The degree-day summation technique has proven to be a useful method of describing leaf litter processing.

A difference in the species of Aquatic Hyphomycetes occurring on leaf litter during seasonal changes in the temperature of Augusta Creek has been documented during the last two years (KBS unpublished data). Further, the temperature-growth response of isolates of the dominant Hyphomycetes from Augusta Creek exhibit different temperature characteristics (Suberkropp, in prep.). These fungi can be placed in three groups on the basis of this response: (1) species with optima near 20°C, maxima between 25 and 30°C and an ability to grow at 1°C; (2) species with optima of 25-30°C, maxima between 30 and 40°C and an inability to grow below 5°C; and (3) one species, Clavariopsis aquatica, which exhibited a high optimum (30°C) and maximum (30-35°C) temperatures for growth but could grow at 1°C.

Species exhibiting a particular temperature optima were not always found to dominate the fungal flora associated with leaf litter at their optimal temperature. In some cases species were found to be major constituents of the mycoflora over the entire annual cycle. These data suggest competitive strategies which may not be totally temperature related.

Data from our laboratory indicates that all species of aquatic hyphomycetes have the enzymatic capabilities required to break down the structural components (hemicellulose, cellulose and lignin) of leaf litter and to macerate the tissue. Obviously no selective advantage would accrue to species having the ability to selectively digest a structural component. It is possible, however, that changes in the thermal regime which the organism is inhabiting will alter the concentration of enzyme to be synthesized.

Normally the synthesis of intracellular enzymes corresponds to the rate of metabolism (i.e. growth) of the organism. It is possible however that the rate of extracellular enzyme synthesis does not necessarily follow these same principles. This would result in a competitive advantage for an organism capable of quantitatively maintaining substrate levels even if it was not growing under optimal conditions.

The major objective of the present on-going experiments is to determine the response, of the elaboration of pectinase, cellulase and a lactase by hyphomycetes, to various thermal regimes. The hyphomycetes being tested are members of three thermal groups described above.

Experiments have been completed on the assessment of the effect of temperature on the respiratory activity of the microbial community on leaf material colonized under different temperature regimes (data not analyzed).

Leaf packs of both oak and hickory were exposed to different temperature regimes by placing them in the stream during the following periods: (1) Fall (Oct. 15-Nov. 5, x temp. 11°C); (2) Winter (Dec. 31-Jan. 28, x temp. 2°C); (3) Summer (July 23-Aug. 6, x temp. 18°C). Packs were recovered after approximately 20% of the original dry weight had been lost. Leaf discs cut from these leaves were measured for their respiration response to temperatures of $5^{\circ}\text{--}40^{\circ}\text{C}$ (at 5° intervals). Field incubations were continued until significant differences in respiration response were determined. The results of these experiments will complement the microbial data already available and should identify the "thermal flexibility" possessed by the diverse microbial community associated with leaf litter on a seasonal basis.

5.0. CONTROL OF GROWTH BY TEMPERATURE AND FOOD QUANTITY AND QUALITY

Preliminary results of studies on the collector-gatherer Paratendipes albimanus (Diptera: Chironomidae, Chironominae, Chironomini) are summarized in Appendix II. The growth of FPOM feeding collector is generally controlled by thermal regime but is strongly influenced by food quality, as measured by several techniques (ATP content, C/N ratio, microbial respiration).

6.0 COMPUTER FACILITY

A critical aspect of the research program has been the collection and processing of data through the use of a minicomputer system - a Hewlett-Packard 2100 computer with a disc operating system, teletypewriter and high speed tape reader input and an intermediate speed printer/plotter output. The existing equipment has been purchased over a period of five years with funds derived from several sources (ERDA and NSF grants) at a total cost of over \$60,000. About one half of this amount has been provided through ERDA support. During the period in which the mini-computer facility has been assembled, heavy emphasis has been placed on the conversion of output from laboratory instruments to punch tape compatible with the HP2100 system and to the development of data storage and operational programs which are presently held on magnetic discs. The major components of the computer facility are listed below.

Existing Computer System

Hardware:

Hewlett-Packard	2100A Minicomputer (16K core)
"	2870 Disc system, controller and power supply
"	7900 Disc system and controller
"	Interface and 8 bit duplex register
"	Teleprinter and interface
"	High speed photo tape reader
Versatec	High speed printer/plotter and interface

Software:

HP	Various system drivers
Versatec	Drivers for printer/plotters
Kellogg Biol. Station	Various drivers and programs

Being Acquired

Hewlett-Packard	Additional core (16K)
"	Real Time Executive System Software and File Manager
"	Time base generator and floating point hardware

Because of difficulty with the Hewlett-Packard 2870 disc drive and controller it was necessary to obtain a 7900 disc system and controller. Although the 2780 was marketed by Hewlett-Packard they did not manufacture it. The manufacturer no longer produces the equipment. Although the 2780 is covered by a maintenance agreement, repair delays can be up to 125 days because of the extreme scarcity of parts. As of the writing of this progress report, the disc drive and controller have been removed for repair. Even though the new disc system is on hand, at present all data files and programs can only be accessed with the 2780. Due to this severe problem, the 2100A has not yet been fully expanded since serious questions were raised concerning the reliability of Hewlett-Packard equipment and a considerable time was spent investigating alternatives. As it turns out, because of the immense investment of time in the present system there is no viable alternative, and expansion is proceeding. Needless to say, the problems related to the 2780 disc system have prevented the level of data analysis originally planned.

Table 4. General classification system for aquatic insect trophic relations. (Applicable only to immature and adult stages that occur in the water.)

Functional Group. (General category based on feeding mechanism)	Subdivision of Functional Group		General Particle Size Range of Food (microns)	Orders Having Dominant Representatives											
	Dominant Food	Feeding Mechanism		Collembola	Plecoptera	Odonata	Ephemeroptera	Hemiptera	Megaloptera	Neuroptera	Trichoptera	Lepidoptera	Coleoptera	Hymenoptera	Diptera
Shredders	Living vascular hydrophyte plant tissue	Herbivores-chewers and miners	>10 ³												
	Decomposing vascular plant tissue- coarse particulate organic matter (CPOM)	Detritivores-chewers and wood borers			+						+	+	+		+
Collectors	Decomposing fine particulate organic matter (FPOM)	Detritivores- filterers or suspension feeders	<10 ³				+				+	+			+
		Detritivores- gatherers or deposit (sediment) feeders (includes surface film feeders)		+			+	+			+		+		
Scrapers	Periphyton- attached algae and associated material	Herbivores-grazing scrapers of mineral and organic surfaces	<10 ³				+	+			+	+	+		

Table 1 Continued

[illegible]

Table 2. Augusta Creek (B Avenue Site) animal taxa categorized by functional group (Cummins, 1973, 1974).

SHREDDERS - obligate

Plecoptera

Filipalpia

Capniidae

Capnia sp.

Leuctridae

Leuctra sp.

Trichoptera

Limnephilidae

Pycnopsyche lepida, guttifer and scabripennis

Limnephilus rhombicus

Hydatophylax argus

Platycentropus radiata

Lepidostomatidae

Lepidostoma costalis

Diptera

Tipulidae

Tipula abdominalis, caloptera

Eriocera spp

Ptycopteridae

Bittacomorpha sp.

SHREDDERS - facultative

Diptera

Chironomidae

Orthocladiinae

Brillia flavifrons

Amphipods

Gammaridae

Gammarus pseudolimnaeus

Isopoda

Asellidae

Asellus sp.

COLLECTORS - Gatherers (Deposit Feeders)

Collembola spp

Ephemeroptera

Ephemeridae

Hexagenia limbata

Orthocladiinae - many species

Heptageniidae

Stenonema (tripunctatum fuscum)

Stenacron (interpunctatum canadense)

Leptophlebeidae

Leptophlebia cupida

Paraleptophlebeidae debilis

Boetidae

Baetis spp?

Trichoptera

Molannidae

Molanna tryphena

Coleoptera

Elmidae (larvae and adults)

Stenelmis sp.

Optioservus sp.

Dubiraphia sp.

Diptera

Tipulidae

Antocha sp.

Empididae

Hemerodromia (probably 3 spp.)

Psychodidae

Pericoma spp?

Tabanidae

Chrysops spp?

Ceratopogonidae

Palpomyia ? spp?

Chironomidae

Chironominae-Chironomini

Microtendipes spp?

Polypedilum sp.

Paratendipes albimanus

Stictochironomus annulicrus

Other Chironomini spp?

Oligochaeta

Naiadidae

Chaetogaster

Enchytraeidae

Limnodrilus

COLLECTORS - Filterers (Suspension Feeders)

Ephemeroptera

Siphonuridae

Isonychia sp.

Trichoptera

Hydropsychidae

Hydropsyche slossonae, bronta, betteni, sp.?

Philopotamidae

Dolophilodes distinctus

Psychomyiidae

Psychomyia flava

Diptera

Simuliidae

Simulium spp?

Prosimulium spp?

Chironomidae

Chironominae - Tanytarsini spp?

Mollusca

Pelecypoda

Sphaeriidae

Pisidium sp.

SCRAPERS (GRAZERS)

Trichoptera

Limnephilidae

Neophylax oligius, fuscus

Goeridae

Goera calcarata

Glossosomatidae

Glossosoma nigrior

Mollusca

Gastropoda

Pleuroceridae

Goniobasis sp.

Ancylidae

Ferrissia rivularis

Bulimidae

Pomatiopsis sp.

PREDATORS

Plecoptera

Setipalpia

Perlidae

Perlesta placida

Paragnetina sp.

Perlodidae

Isoperla confusa

Odonata

Anisoptera

Corduligasteridae

Corduligaster fasciatus

Aeschnidae

Boyeria sp.

Gomphidae

Gomphus sp.

Zygoptera

Calopterygidae (= Agrionidae)

Calopteryx maculatum

Trichoptera

Rhyacophilidae

Rhyacophila sp.

Polycentropidae

Cernotina spicata

Phryganeidae

Oligostomis sp.

Megaloptera

Corydalidae

Nigronia serricornis

Sialidae

Sialis sp.

Coleoptera

Dytiscidae spp?

Diptera

Tipulidae

Dicranota sp.

Rhagionidae

Atherix variegata

Chironomidae

Tanypodinae spp

NON-FEEDING STAGES

Trichoptera - All prepupae and pupae

Diptera - All pupae

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Appendix I.

MICROBIAL-ANIMAL PROCESSING OF DETRITUS IN A FIRST ORDER WOODLAND STREAM

Kenneth W. Cummins
Kellogg Biological Station
Michigan State University

and

Robert C. Petersen
Stroud Water Research Center
Academy of Natural Sciences of Philadelphia

I. Introduction

- A. Relation of present paper to:
 - 1. General importance of stream detritus
 - 2. Petersen and Cummins, 1974 (leaf litter processing)
 - 3. Boling et al., 1975a. 1975b (detritus model)
- B. Literature review (key references only)
 - 1. Detritus in running water systems
 - 2. Detritus respiration
 - 3. Animal (detritivores) assimilation

II. Description of Study Area

- A. Figure (Fig. 1) of Augusta Creek B Avenue site showing sampling areas (Petersen, 1974) with two insets:
 - 1. Michigan - showing location of Augusta Creek watershed
 - 2. Augusta Creek watershed showing B Avenue site
- B. Text describing stream at B Avenue site - a first order stream (modify from Howard, 1974 and Petersen, 1974).
- C. Physical-Chemical
 - 1. Text
 - a. NO_3 in 1-3 mg/ range, PO_4 in 10-30 $\mu\text{g}/\text{l}$ range
 - b. DOC (dissolved organic carbon) in 3-8 mg/l range (Manny and Wetzel, 1973)
 - c. pH 7.5-8.5, total alkalinity 120-150 mg/l CaCO_3
 - d. $\bar{x}$ discharge 1-3 cfs
 - 2. Figures
 - a. Fig. 2. max, min, $\bar{x}$ temp. $^{\circ}\text{C}$, Oct. 1972-Nov. 1973 (with sampling dates indicated)
 - b. Fig. 3. Discharge (B Ave.) and rainfall (KBS), same period (sampling dates indicated)

III. Methods

- A. Detritus particle sizes
 - 1. Sizes as previously discussed in Cummins, 1974; Boling et al., 1975a, 1975b.

2. Table 1. Particle sizes, caloric values and descriptions separated into coarse (CPOM) and fine (FPOM) subcategories.
 3. Arguments for subcategories
 - a. Fungal-CPOM vs. bacterial - FPOM
 - b. Shredders-CPOM vs. collectors - FPOM
 - c. Collectors feed on various FPOM size categories
 - d. RPOM: discuss long processing times, longer than the detritus year (leaf fall to leaf fall)
 4. Drying, weighing, ashing and calorimetry
 - a. Entire size fractions combusted, ashed to a constant wt. (48 hour burns required, especially for RPOM)
 - b. Calorimetry (cite Cummins and Wuycheck, 1971)
- B. Field sampling and washing
1. Fig. 4: summary flow diagram of procedures (modified from former ERDA Progress Reports)
 2. Short test description of sampling and washing procedures
 3. Sampler calibration
 - a. Describe method. A single riffle on a single date; 3 samples removed consecutively from each of 3 sample locations.
 - b. Fig. 5. Results and analysis (from Southwood, 1966)
 - c. Standing crop detritus, corrections made by particle size (give conversion factors, $\bar{x}$, cv for each particle size)
 4. Variation between replicate detritus samples. The CV (standard error) ranged from 8.5 to 88.1% ($\bar{x}$ = 36.8, CV of SE = 15%). Variation greater in coarse particle sizes reflecting their more clumped distribution. (Table 2 standing crop of detritus, AFDW, Respiration)
- C. Microbial activity
1. Sample method. Fig. 4 with supplemental qualitative collections of 16, 4 and 1 mm size fractions in the spring and summer.
 2. Preparation of macroinvertebrate-free detritus Fig. 4 (picked under dissecting microscope)
 3. Gilson (1961) respirometry. Two (14 and 20 station) machines, 7 ml vessels. Runs at ambient stream temperatures. Each vessel averaged over 3 hours - 12 readings at 15 min. intervals. Each particle size replicated with 3 to 5 vessels. The CV's for the standard errors ranged from 3 to 35%.
 4. Microbial detrital (respiratory) processing calculated from $\mu\text{l}/\text{mg}/\text{hr.}$ values to $\text{gm detritus respired}/\text{gm detritus}/\text{m}^2/\text{sampling interval}$ (28-35 days) using the mean caloric value given in Table 1.
- D. Animals
1. Field sampling, Fig. 4.
 2. Sorting
 - a. Microscope sorting of $>1\text{mm}$ particle sizes (including gravel)
 - b. Subsampling (removal of 40 ml from 500 or 1000 ml dilution of sample) of $250\mu\text{m}$ and $75\mu\text{m}$ particle sizes and microscope sorting. Biomass of animals calculated for 250 and $75\mu\text{m}$ sizes used to correct the detritus standing crop values (and to correct Oct., Nov., 1972 animal biomass).

3. Identification of animal functional groups
 - a. Description of groups (Cummins, 1973, 1974)
 - b. Table 3. Macroinvertebrates of B Ave. categorized by functional group.
4. Numbers and biomass cumulated for each sample and averaged for the three samples. Biomass based on over 2500 separate weights representing all taxonomic categories shown in Table 3. Dried at 50°C and stored in desiccators until weighing on a Cahn electrobalance (precision 0.1µg).

IV. Results and Discussion

A. Annual monthly estimate of detritus standing crop

1. Data
 - a. Absolute amounts/m² by particle size and date (Table 2; Fig. 6, parts A and B: A, particle sizes and total; B, subcategories, CPOM and FPOM)
 - b. Relative amounts (%), Fig. 7.
2. Discussion
 - a. Detritus year (leaf fall to leaf fall) standing crop fairly constant; annual mean has 95% confidence interval $\pm$ 20% of mean.
 - b. CPOM: leaves peak in fall, smaller non-leaf CPOM (bud scales, catkins, etc.) peak in spring with minor peak in fall. FPOM: 3 peaks; major peak in spring with run off (Fig. 3). Fig. 6 part B compares CPOM and FPOM. Discuss ratio of CPOM to FPOM over year.
 - c. System dominated by VPOM (0.45 m) throughout the detritus year (40%, Fig. 7).
 - d. Compare B Ave. data to literature values (e.g. Hynes, et al., 1975; Sedell et al., 1975, Darnell, 1967, Naiman, 1976)

B. Respiration

1. Data. Table 2. Annual monthly estimates of respiration by particle size (units µl/mgAFDW/hr.) x, CV of SE) and gms detritus respired (gm/gm/m²/time interval).
2. Discussion
 - a. Mean annual respiration is fairly constant over the detritus year, but not as constant as detritus standing crop; 95% confidence interval $\pm$ 40% of mean.
 - b. Rates are controlled by temperature and the nature of the detritus. Maximum rates in the finest particle sizes, due to surface to volume ratio phenomena (i.e. maximization of the surface area for microbial colonization) and leaves which are planar structures both surface and matrix (by fungi) colonized. Discuss biochemical "conditioning" of detritus and microbial respiration.
 - c. Results of conversion of microbial O₂ consumption to detrital consumption (Table 2). Estimates of microbial and animal processing (conversion) of detritus are shown in Fig. 8. Discussion of differences in slopes and the importance to the total detritus pool.
 - d. Table 5. Comparison of B Ave. respiration values with literature values (e.g. Hargrave, 1972).

C. Animals

1. Data. Fig. 9. Biomass of functional groups, monthly mean estimates. Table 6. Numerical and biomass data and ratios by functional groups. Ratio of animal biomass to detrital biomass Fig. 9.
2. Discussion. Universe relationship between animal and detrital biomass. Maximum biomass in the late winter and mid summer prior to spring and early fall emergence periods and corresponding to low periods for detritus standing crop, particularly CPOM. The ratio of shredders (e.g. Pycnopsycha and Tipula have reached their maximum biomass per individual.

D. Microbial-Animal conversion of detritus standing crop.

1. Data

- a. Fig. 8. Summary figure of detritus standing crop and microbial-animal conversion of detritus.
- b. Fig. 9. Summary figure of net import-export of detritus over detritus year.
- c. Fig. 11. Overall summary processing figure; continuation from Petersen and Cummins (1974).

2. Discussion

- a. Assumptions of animal calculations
 - 1) Animal growth and respiration ratio (Cummins, 1975a) and temperature dependent growth (Cummins et al., 1973)
 - 2) Averaging effect. Not all is consuming detritus, or consuming detritus equally and not all biomass is growing or growing equally. Growth rates of 0.5% body wt/day (BWPD) for 0.5°C, 1.0% BWPD for 5-10°C, 1.5% BWPD for 10-15°C and 2% BWPD for 15-20°C used (Cummins et al., 1973; Cummins 1975a).
- b. Discussion of import and export years. Fig. 10. Return period plot for Augusta Creek, indicating 1972-1973 water year, which corresponds approximately to the detritus year, was an average flood year. (Also discuss June, 1976 calibration sampling on return period graph.) For 1972-1973 detritus year: 6 months import, 6 months export.
- c. Summary statement of partitioning of the processing of detritus. Discussion of variations from year to year and with stream order, along the continuum from first order headwaters to larger streams (Vannote, 1976).

V. Literature Cited

Title: Life History and Pattern of Growth in
Paratendipes albimanus (Meigen) (Diptera:Chironomidae)

Author: G. Milton Ward and Kenneth W. Cummins

ABSTRACT

The natural history and growth pattern of a stream dwelling midge has been studied in Augusta Creek, Kalamazoo County, Michigan. Paratendipes albimanus has been found to be abundant in both depositional and erosional habitats of a first order stream. The species is univoltine in this habitat with an adult flight time from late June to mid July. Collections of egg masses enabled observations of early development of 1st instar larvae. The species has an unusually long 1st instar stadium, for some individuals the period July to September and for others July to April, overwintering than as 1st instar larvae. Growth is curtailed during the winter, presumably by low temperatures and active growth resumes in spring and coincides with a migration of individuals away from erosional habitats into depositional areas. Growth in the species was determined by following changes in mean dry weight of samples from the population. Changes in individual biomass revealed a rather complex pattern in which several periods of active growth were separated by cessations in growth. Prediction of growth patterns have been attempted based on a temperature summation technique.

Introduction

The Chironomidae have been of taxonomic and ecological interest for most of the 20th century, but only recently has interest in their ecological importance reappeared. Still the family is often omitted from studies of entire communities because of the inherent taxonomic difficulties. Even though recent advances in taxonomic knowledge will allow more detailed ecological information to be gained from community studies, advancement on a broad front must await still much more taxonomic work. Because a significantly larger taxonomic knowledge may still be some years away, other types of studies must be employed in the meantime. The concentrated study of individual species, the autecological approach, is one method of obtaining large amounts of detailed ecological data. More generalized conclusions are drawn by comparing the results from other similar studies. Oliver (1971) has encouraged this type of study to expand the knowledge of chironomid life cycles, and Hynes (1970) has cited the extreme dearth of knowledge of chironomid life cycles of stream dwelling species.

Autecological studies of pond and lake species of Chironomidae have been employed several times in the past (Sadler, 1935; Walshe, 1951; Biever, 1967; Armitage, 1971; Danks, 1971; Topping, 1971; and Jonasson, 1972), but rarely have stream species been the subject of these types of studies. Indeed, stream chironomid research in general has lagged behind that of lentic habitats, and only a few taxonomic-ecological publications focusing primarily on lotic environments have appeared in the last few years (Saether, 1968; Coffman, Cummins and Wuycheck, 1971; Lehman, 1971; Lindegaard-Petersen, 1972; Coffman, 1973).

The present study is an autecological description of a stream inhabiting midge, Paratendipes albimanus (Meigen). This investigation was undertaken to add to the knowledge of stream chironomid life cycles and ecology of stream species. This species was chosen for study because of its widespread occurrence throughout the Augusta Creek watershed and for its great abundance at the main study site and its potential for rapid growth. Particular emphasis was placed on the growth pattern and rate of growth of the larval stage, as well as other ecological aspects of the larval ecology. Further studies on the effects of temperature and food quality on the rate and pattern of growth and their effects on the life cycle are now being completed.

Literature Review for
Paratendipes albimanus (Meigen)

Taxonomy

Meigen first described the species as Chironomus annularis in 1804, but in 1818 renamed the species albimanus (Townes, 1945). In 1911 Kieffer erected the genus Paratendipes and assigned albimanus as the type species. Seven species of the genus have now been described from North America, but only the larvae of albimanus is definitely known. Consequently species identification from larvae only should be viewed with suspect and species identifications should be made only from adult males.

Geographical and Habitat Distribution

P. albimanus appears to be holarctic in distribution having been found in northern and central Europe and in North America from Ontario south to North Carolina and Arkansas, and through the midwest to Idaho and California.

Table 1 summarizes the major ecological documentation for P. albimanus. These data support the conclusion that the species is eurytopic, and can inhabit a range of conditions within each habitat type. Thienemann (1954) states that the species has been collected from both upland and lowland streams, oligotrophic and eutrophic lakes as well as from ponds and pools. In North America P. albimanus has been reported from streams, lakes and reservoirs.

The microhabitat of the species seems to be in sandy and/or muddy bottoms of lakes and in slack flow areas of streams where fine particulate detritus collects. However, in the present study and that of Roback, (1957) P. albimanus has also been collected from sand and gravel riffles of streams with moderate flow.

Phenology

Based on phenological data of previous studies, one finds conflicting conclusions regarding the voltinism of this species. Townes (1945) has collected this species from May to September and concluded several generations per year, but only as bivoltine in Lake Chautauqua, New York (Townes, 1938). Other authors have concluded the species as either bivoltine or univoltine in standing water (see Table 1) and usually univoltine in streams. Some of our own experiments testing the effects of temperature on the growth rate of P. albimanus indicate the life cycle may be plastic enough to accommodate at least two generations as temperature and food availability allow. Consequently the life cycle may vary in habitats of different temperature regimes.

Table 1. Major ^{Ec}Geological Documentation for Paratendipes albimanus (Meigen).

Reference	Habitat	Life Stages	Microhabitat	Flight Periods	Comments
Townes (1938)	Chautauqua Lake, New York	L,A	Fine sand with more or less muck, esp. in weed beds; 0.5m to 6.5m	June and August	Usually 50 to 300/m ² but up to 5500/m ²
Nietzke (1938)	Die Kossau, Germany	L,A	Mud in moderate and slack flows	Not Given	
Hall (1951)	River Itchen and Ober Water, England	L,P,A	Fine gravel and silt, with a covering of mud and debris	Not Given	
Curry (1954)	Hunt Creek, Michigan	L,P,A	Backwater areas in sand and muck	Not Given	Abundant when found; easily reared
Dittmar (1955)	Aabach, Germany	L,P?,A	Mud in mid-stream	June	
Roback (1957)	Several streams in Pennsylvania	L,P,A	Rocky and gravel areas, as well as in mud	Not Given	
Riess (1968)	Lake Constance, Germany	L,P,Pe,A	Sandy sublittoral and profundal zones; up to 30m	May-June and	Eury Bathic; numerous in sandy sublittoral zone
Riess (1968)	Several European alpine lakes	A	Not Given	Not Given	
Iovino and Minor (1971)	Beaver Reservoir, Arkansas	L,A	Not Given	May-June	
Lehman (1971)	Fulda River, Germany	L,P,Pe,A	Mud near bank regions	June	Rare
Learner and Potter (1974)	Small Ponds, England	A	Not Given	June	42/m ² Emerging
Present study	Augusta Creek, Michigan	L,P,Pe,A	Sand and gravel riffles; depositional areas of fine particulate detritus	June-July	20,000 to 30,000/ m ² during winter
Present study	Hamilton Lake Michigan	L,P,A	Fine particulate detritus at mouth of inlet stream; up to 9m	June	Found only in detrital accula- tions near mouth of inlet stream; not found in marl sediment in re- mainder of lake

Study Site

Augusta Creek is a small hardwater, brown trout stream in southwestern Michigan. This watershed is part of the larger Kalamazoo River basin which empties in Lake Michigan. First order streams arise from lakes and marshes and flow through heavily wooded hardwood forests, pastures, and farm lands as well as marshes and lakes. Augusta Creek, as a third order stream, has a drainage area of about 70 km^2 and discharge of about 50 cfs.

Although P. albimanus can be found at several sites in the watershed (Fig. 1 and Table 3), the B Avenue E site (Fig. 1, B) was the site of major emphasis. This 1st order tributary is heavily wooded and drains a tamarack swamp. The stream is about 1-3 meters wide with a mean discharge of about 3 cfs. Downstream about 100 meters from the sampling site is a small hardwater lake, Hamilton Lake. The temperature regime of this site shows a low mean daily temperature in January of 1°C , and the highest mean daily temperature in July about $15-16^{\circ}\text{C}$. Total degree-day accumulation for the site is about 3200-3300 per year.

METHODS

Sample Collection Methods

Methods for processing of sediment samples and for collection of other biological samples are outlined in figures 2 and 3.

Biomass Measurements

Specimens collected during this study were sorted live from the sediment and placed on aluminum foil pans and then dried at 50°C for at least one week. Biomass estimates were made on a Cahn Electrobalance fitted with a digital readout to 1 µg. When mean weights of individual larvae were likely to be ≤ 15 µg, numerous individuals were weighed together and mean weights calculated. This was the case during most of the life cycle.

Experimental Facilities

When the sample sizes of field collected adults and pupal exuvia proved to be too small to determine patterns of emergence during the flight period, an artificial stream facility was employed to obtain these data. Each of these two recirculating streams are temperature and photoperiod controlled and have a volume of about 4000ℓ. Each channel is 11 m long, 1 m wide and from .25 to .5 m deep. These facilities are described in detail by Cummins (1972).

Species Identification

Reared specimens with associated larval and pupal exuvia, as well as field collected adults were generously identified by Dr. D. R. Oliver, Biosystematics Research Institute, Agriculture Canada. Specimens from this study were compared to European material identified as P. albimanus. Voucher specimens have been deposited in the Canadian National Collection.

Figure 2

SAMPLE PROCESSING PROCEDURE FOR GREENHOUSE
AND AUGUSTA CREEK SAMPLES

Figure 3

Life History of Paratendipes albimanus (Meigen)

Oviposition and Hatching of Eggs

Although mating and oviposition were never directly observed in the field, egg-laying was followed throughout the emergence period by collections of egg masses. The metal screens described above were placed in both erosional and depositional areas at the B Avenue E site. During June and July of 1974 over 450 egg masses were collected with both depositional and erosional areas accumulating about equal numbers. First eggs are usually found between the 20th and 24th of June and can be found as late as the 15th of July.

Egg masses of P. albimanus are spherical with a diameter of 3.76 mm (S.D. = 0.498) containing a variable number of eggs in the range of 250-400 per mass. A gelatinous string (Fig. 4a) holds the eggs side by side in the mass, as this string winds throughout the mass. The eggs themselves are kidney shaped approximately 200 μ m long and 75 μ m wide (Fig. 4b).

Hatching experiments were performed to determine the length of time required for hatching:

5 C	did not hatch after 25 days
10 C	8-10 days
15 C	3-6 days
20 C	2-3 days
25 C	2-3 days

As hatching took place, the larvulae left behind a chitinlike egg membrane (Fig. 4c). Larvae were very active inside the mass and appeared to be consuming the gelatinous make-up of the mass. At the time the larvae

reach the surface of the mass, the gut tracts are quite clear but soon afterward, detritus, which had collected on the outside of the egg mass while in the stream, begins to appear in the gut tract.

Newly hatched larvae were about 0.5 mm long and weighed about 0.45 μ g. After leaving the egg mass the larvae begin to build cases from available detritus. After 7-10 days the larvae begin to take on the characteristic hemoglobin color, faint pink at first and 3-4 weeks later the familiar deep red color of the older larvae.

Morphometrical Analysis of Larvae

Previous studies on the morphometrical analysis of larvae of the Chironomidae have employed a variety of measurements to determine the instar category of individual specimens. In this study six measurements of various body parts were made to determine which were best suited for obtaining the correct instar (Table 2). These data show that the most easily estimated of these six parameters, body length, head length and head width proved to be least reliable. One can see in Table 2 that the maximum values for body length and the minimum value for that parameter in the next instar overlap between all instars except for the molt to IV instar, head length and head width have the same pattern.

Two other parameters, mandible length, and width of the basal antennal segment overlap on only one occasion, that the molt from instar II to instar III. But in no case do the size ranges of the four median labial teeth overlap between any two instars. This character then appears to provide the most accurate estimate of instar. The disadvantage here, of course, is that this parameter can only be measured from a prepared slide. Although these latter three characters are clearly the most accurate, they all suffer from the same drawback, the need of a prepared

TABLE 2
MORPHOMETRICAL ANALYSIS OF LARVAE OF *Paratendipes albimanus* (Meigen) (Diptera: Chironomidae)

14

INSTAR 1							
CHARACTER	MEAN	MAX	MIN	SD	SE	CV	N
TOTAL LENGTH (MM)	.829	1.310	.390	.363	.026	43.795	14
HEAD LENGTH (MM)	.081	.117	.059	.018	.001	21.925	14
HEAD WIDTH (MM)	.053	.079	.043	.011	.001	21.689	14
MEDIAN TEETH WIDTH (UM)	5.417	5.760	5.280	.225	.016	4.154	14
MANDIBLE LENGTH (UM)	28.526	29.760	26.400	1.009	.072	3.537	14
BASAL ANT SEG WIDTH (MM)	5.177	5.760	4.800	.336	.024	6.484	14
INSTAR 2							
CHARACTER	MEAN	MAX	MIN	SD	SE	CV	N
TOTAL LENGTH (MM)	1.540	2.130	.690	.376	.022	24.440	17
HEAD LENGTH (MM)	.113	.170	.099	.017	.001	14.739	17
HEAD WIDTH (MM)	.065	.088	.041	.011	.001	17.353	17
MEDIAN TEETH WIDTH (UM)	8.479	9.600	7.680	.502	.030	5.919	17
MANDIBLE LENGTH (UM)	37.915	40.950	33.600	2.150	.126	5.670	17
BASAL ANT SEG WIDTH (MM)	7.985	11.700	6.240	1.200	.071	15.031	17
INSTAR 3							
CHARACTER	MEAN	MAX	MIN	SD	SE	CV	N
TOTAL LENGTH (MM)	2.595	3.500	1.530	.556	.026	21.407	21
HEAD LENGTH (MM)	.180	.216	.105	.028	.001	15.722	21
HEAD WIDTH (MM)	.112	.135	.047	.018	.001	16.440	21
MEDIAN TEETH WIDTH (UM)	14.680	15.790	14.040	.638	.030	4.345	21
MANDIBLE LENGTH (UM)	60.794	70.200	33.600	7.812	.372	12.850	21
BASAL ANT SEG WIDTH (MM)	11.316	12.870	7.200	1.145	.055	10.120	21
INSTAR 4							
CHARACTER	MEAN	MAX	MIN	SD	SE	CV	N
TOTAL LENGTH (MM)	4.942	8.000	3.000	1.129	.051	22.843	22
HEAD LENGTH (MM)	.292	.322	.248	.021	.001	7.110	22
HEAD WIDTH (MM)	.194	.216	.173	.012	.001	6.083	22
MEDIAN TEETH WIDTH (UM)	26.715	28.000	25.700	.798	.036	2.986	22
MANDIBLE LENGTH (UM)	109.49	120.50	99.400	4.451	.202	4.065	22
BASAL ANT SEG WIDTH (MM)	17.665	18.720	16.300	.563	.026	3.186	22

Figure 4. Eggs of Paratendipes albimanus (Meigen)
(Diptera: Chironomidae)

(Not yet completed)

30 JUN 76

FIGURE 5

☆ HEAD LENGTH
 ■ HEAD WIDTH
 x MANDIBLE LENGTH

28. JUN. 76

FIGURE 6

GROWTH CURVE OF MEDIAN TEETH WIDTH
AND WIDTH OF BASAL ANTENNAL SEGMENT

△ WIDTH OF BASAL ANTENNAL SEGMENT
● WIDTH OF FOUR MEDIAN TEETH

30. JUN. 76

FIGURE 7

HEAD WIDTH-VS-HEAD LENGTH RELATIONSHIP IN
Paratendipes albimanus (Meigen) (DIPTERA: CHIRONOMIDAE)

slide. Of the first three characters examined, head width and head length are of about equal accuracy and both are far superior to body length as a measure of instar. The growth of five characters are shown in Figures 5 and 6.

If head width and head length from the same specimen are plotted against each other as in Figure 7, more separation between instar groupings can be seen. Instars III and IV clearly stand out, while some blurring occurs between instars I and II. In Figure 7 the 14 points in the lower left-hand corner represent instar I.

Anatomical Changes During 1st Molt

The collection of egg masses and subsequent examination of 1st instar larvae revealed an interesting and little known fact about early instar chironomid larvae. Certain characters of the head capsule in instar I larvae of P. albimanus have a very different anatomical shape than do the same features in subsequent instars. Figure 8 shows the shape of the mentum and antennae in instar I and then the same character after the first molt.

Mentum

The shape of the four median teeth are altered dramatically during the first molt. In instars II-IV these four teeth are of equal height and width and are clear in contrast to the darkly colored lateral teeth. Here in instar I the two ^{middle} ruddle teeth are raised above the outer two median teeth and are rounded rather than triangular as in the later instars (Fig. 8a). All teeth on the mentum of instar I larvae are clear. The paleness of only the four median teeth is usually a key characteristic for the identification of the larvae.

Antennae

Perhaps an equally important key character in this genus is the existence of a six segmented antennae. Instar I larvae have only a five segmented antennae, and those segments have an odd shape (Fig. 8b). These two facts combine to badly mislead anyone attempting to identify the genus in this instar, one would not readily consider *Paratendipes* as being the correct genus.

Mandible

A character of perhaps lesser consequence to identification than the two above is the mandibular brush. In instars II-IV the brush is conspicuous on the inner edge of the mandible. However, it is altogether absent from instar I. (Fig. 8c)

A detailed study of between early and late instars has recently been completed by Dr. D. R. Oliver (personal communication). These differences seem to be widespread through the family.

Larval Distribution in the Watershed

The larvae of *P. albimanus* have been found at several sites in the watershed (Fig. 1; a,b,c,d,e,f). Abundance varies with site but the two sites with the greatest densities are in the upper parts of the watershed. These habitats (a, b in Fig. 1) vary rather significantly from those sites downstream. Site A is just below a wetlands impoundment and has large accumulations of fine particulate organic matter and almost no erosional zones. Current is slight consequently there are large and deep pools. Site B, as described above, is mostly erosional zones with sand and gravel riffles, and shallow pool areas limited to areas along the bank.

Figure 8. Morphological changes
between instar I and instar II
in *Paratendipes albimanus* (Meigen)
(Diptera: Chironomidae)

(Not yet completed)

Table 3. Distribution of Paratendipes albimanus
(Meigen) (Diptera: Chironomidae) in the
Augusta Creek Watershed

Site	Habitat	Type of Sediment	Range of X Temp	Estimated Relative Density	Stream Order
A Lenaar Rd.	slack current down-stream from an impoundment	Deep accumulations of fine particulate detritus		***	1
B B Ave E	Erosional zone	Gravel and sand Riffle	0-15	**	1
	Depositional zone	Fine particulate detritus along stream banks and in areas in slow flow	0-15	****	1
C Smith Site	Erosional zone	Sand	0-15	*	1
D Upper 43rd St.	Erosional zone	Gravel and sand	0-22	*	2
E. C Ave E	Depositional zone	Fine particulate detritus along stream banks	0-20	*	3
F. Kellogg Forest	Depositional zone	Fine particulate detritus along stream banks	0-20	*	3

Although P. albimanus has been collected at several downstream sites, densities never approach those of the upstream sites. Depositional areas along the banks have been the microhabitat source for these downstream collections.

Larval Distribution and Density at Site B

At this site perhaps only 1/3 of the stream bottom is in deposition areas but it was in these areas that the highest densities of larvae were found (Fig. 9). Densities in riffles were fairly stable at around $10,000/m^2$ during the winter, but then decreased in the early spring to less than 500. However, densities in depositional areas rose dramatically at about the same time, from an almost steady $30,000/m^2$ to over $100,000/m^2$. During the four week period from mid-April to mid-May, two of four weekly samples had densities greater than $100,000/m^2$ and two more greater than $75,000/m^2$. A rapid decline in densities followed the peak and coincided with the initiating of the rapid growth phase of this species.

The sudden absence of larvae from the riffles and the coincidental appearance of much larger densities in the pools leads one to theorize on the possible reasons for this event. Possible reasons might be either differential mortality in riffles and clumping of populations in pools, differential emergence of those individuals inhabiting riffles or perhaps an emigration of individuals away from the riffles into the pools.

The first possibility seems unlikely since variance terms for densities in the pools are not large, and no samples were without large numbers of larvae. The differential emergence seems even more unlikely, since temperatures at this time were still much too low to sustain growth, and those individuals remaining in the riffles were of the same weight and size as those larvae in the pools. Although it was

FIGURE 9

DENSITY OF *PARATENDIPES ALBIMANUS* (MEIGEN)
IN RIFFLES AND POOLS AT B AVE E SITE

▲ RIFFLES
● POOLS

never directly observed, emigration of larvae from the riffles is a possibility, however, passive drift is also possible. After overwintering at temperatures near 1°C, the warming of the water may spur activity in the larvae leading to a greater probability that the larvae may get swept away by the current. Spring is the time of the year when high discharges occur, but the maximum discharges at this site usually occur in May, the month after the maximum movement. However, current could still be the force which redistributes the larvae into depositional zones.

Larval Maturation and Emergence

With the onset of spring and the warming of the water larvae of P. albimanus end the overwintering period and enter into a period where growth rates increase as water temperatures increase. Growth continues on a temperature dependent basis until pupation occurs and emergence completes the life cycle in late-June to early-July.

Following a short pupation period, adults begin to emerge within a day or two of the 21st of June and continue for about three weeks. Adults have been difficult to obtain. Adult males do not seem to be attracted to u-v light or else their habits carry them out of site of the light. Females have been trapped in moderately large numbers, when no males were caught at all.

The emergence period then had to be followed by a combination of sample types. Emergence was known to be near by the approach of mature larvae to their known final mean weight. The appearance of pupae in the sediment indicated that the beginning of the emergence was imminent. Finally the appearance of egg masses, pupal exuvia and adults signaled that the emergence had begun. The end of the emergence period was recognized by the disappearance of the larvae in the sediment, egg masses and pupal exuvia.

Sample sizes of pupal exuvia and adults from field collections were often too small for accurate determination of the day-to-day pattern of emergence of this species, consequently these data were obtained through use of the experimental stream facilities described above. The emergence data (Fig. 10) revealed a rather symmetrical pattern typical of temperate species. Emergence in this experiment lasted 24 days, close to the length of field emergence.

Diurnal emergence pattern was observed in this same experimental facility. There was a pronounced peak in emergence just after sunset, with almost 50% of total daily emergence occurring in the three hours just after sunset. ♂♂ and ♀♀ had the same diurnal pattern.

Larval Growth Pattern

Changes in the biomass of individuals in the population at the B Avenue E site have been followed for the period December 1972-June 1975. Samples have been collected from both riffles and pools during this time and Figure 11 and Table 3 illustrate the results from the pool samples during 1973-1974. The striking features of this growth pattern are the apparent inactive periods during the greater part of the year, then the very rapid growth during the latter parts of the life cycle. From the curve in Figure 11, it appears that no growth occurs during the first nine months of the life cycle, however, from the curve in Figure 12 one can see that increases in biomass do occur. Figure 12 shows that at least three and possibly four period of growth in each generation, each separated by a period where there is no growth.

Growth of Instar I

Larvae experience the first period of growth soon after hatching in the June-July period. Initial weights of one day old larvae are 0.45 µg which they have doubled by late July or early August. For the remainder

Figure 10

Emergence of Paratendipes albimanus (Meigen)
from Experimental Streams
1974

27

of the summer and the early fall these first instar larvae maintain a weight of about 1 μg . Standard deviations around these data points are quite small, in fact they are often smaller than the line itself (Fig. 11).

Later in the fall, during October, another short period of growth occurs (Fig. 12), with the larvae again doubling their weight. During this period most of the population molts to second instar, but a significant fraction remains as instar I. The population then overwinters as a mixture of I and II instars.

The individual weights of the overwintering larvae are maintained at about 2.5 μg until the following April.

Growth in Spring

With less than 1% of the final larval weight gained during the first nine months of the life cycle, the remaining three months are active indeed. During April stream temperatures are still between 5-10°C (Fig. 13) and growth rates are still relatively slow. Laboratory experiments have shown that the minimum temperature for growth in this species is around 5°C. The population experiences little growth for the part of April when the temperatures are near five degrees, but larvae will grow during the latter part of the month. For the entire month only 4% of the final weight is added.

May is a time of rapid warming of the water and a time of both growth activity and inactivity for this species. During May there is a molt to Instar III and a small fraction of the population also molts to IV late in the month. Larvae gain weight during the first and last weeks of the month but the population maintains a constant weight for the middle two weeks of the month. Figures 11 and 12 show this cessation. The same pattern was observed in 1973 during the same two weeks of the year. In both years there was a drop in mean daily temperature of the

stream during this time, yet still near 10°C . The minimum temperatures for these weeks were close to 5°C . Lower temperature would normally lower the rates but not cease growth entirely. No satisfactory explanations for this phenomenon have been arrived at so far.

Following this period the animal begins the final phase of growth at a steady rate until reaching maturation. During the month of May 8% of the growth occurs, while in June alone 86% occurs.

Temperature and the Rate of Growth in Larvae

Temperature has often been considered an important rate limiting variable for the growth rate of poikilothermic animals. So it may be for Paratendipes albimanus for parts of its life cycle. Thus temperature has often been considered of prime importance in determining the number of generations per year in non-diapausing species. This may not be necessarily so for this species. We have been able to show that during the spring, the growth rate of P. albimanus will vary linearly with temperature increases between $5-15^{\circ}\text{C}$ and 5°C seems to be just above the critical minimum for growth. Because of this linearity, heat summation techniques can be employed to follow the growth of this species between years and between habitats. Figure 15 illustrates the growth of P. albimanus for 1973 and 1974. Degree-day summations required for the population to reach emergence have been calculated. Three assumptions were made to obtain these summations. One that summation could not begin until vernal equinox, two that summation could not begin until mean daily water temperatures reached 5°C , and thirdly that summations end with the beginning of emergence. In both 1973 and 1974 these degree-day requirements have been near 950 ± 25 . Year to year differences in growth are small, thus the degree-day summation technique seems to be useful in predicting patterns of growth in field populations.

FIGURE 11

CHANGES IN MEAN DRY WEIGHT FOR AN
INDIVIDUAL IN THE POPULATION AT B AVE E SITE
AUGUSTA CREEK, KALAMAZOO COUNTY, MICHIGAN 1973-1974

FIGURE 12

CHANGES IN MEAN DRY WEIGHT FOR AN INDIVIDUAL
IN THE POPULATION AT B AVE E SITE, AUGUSTA CREEK,
KALAMAZOO COUNTY, MICHIGAN, 1973-1974

FIGURE 13

AUGUSTA CREEK

B AVE E 1974

MAX, MEAN, MIN DAILY WATER TEMP

Months	Mean Dry Weight (μ g)	Instar	% of Total Growth
July	0.5 - 1.0	1	<1
August	1.0	1	0
September	1.0	1	0
October	1.0 - 2.5	1 and 2	<1
Nov. - March	2.5	1 and 2	0
April	2.5 - 10	2 and 3	4
May	10 - 25	3 and 4	8
June	25 - 180	4	87

Table 4. Approximate mean dry weights and instar distribution during the life cycle of Paratendipes albimanus (Meigen) (Diptera: Chironomidae)

The degree-day summation technique does not always predict the correct growth pattern of this species. Field observations of early first instar larvae show that no growth occurs in this species between August and October, a time when temperatures seem favorable to support growth. Laboratory experiments have verified these observations. At this time we have no satisfactory explanations for this phenomenon.

Winter is another time when many species do not grow, presumably because of low temperatures. However, laboratory experiments have suggested that temperature may be overridden by other, so far undetermined variables. Favorable temperatures are not enough to force the overwintering larvae to initiate growth. Thus a period of non-growth, similar to a diapause must be present.

Thus one can not suggest that for P. albimanus warm year round temperatures will allow for multiple generations. A pilot experiment on the effects of different foods provided an interesting possibility, however. Perhaps another variable, higher food quality (i.e. greater microbial density on the food) might act to override this summer cessation in growth and allow a summer generation to emerge before cold winter temperatures arrive. Further experiments are being performed to investigate these observations.

FIGURE 14

TEMPERATURE DEPENDENT GROWTH PATTERN IN
Paratendipes albimanus (Meigen) (DIPTERA: CHIRONOMIDAE)

FIGURE 15

GROWTH PATTERN OF PARATENDIPES ALBIMANUS
BASED ON DEGREE-DAY SUMMATION

△ 1973
● 1974

Appendix III

Macroinvertebrate Size-Biomass Relationships

1. Representative data listing for a macroinvertebrate Taxon.
2. Representative plots of size (head width, body length, etc.) and weight. Relative scaled data and transformed (log/log) with major axis of correlation ellipse.

INCLUDES THE FOLLOWING TAXA:

3L *Leptophlebia* sp

IDN	SITE	MON	REP	TAXON	#	M1	M2	WEIGHT	IDN	M1	WEIGHT	IDN	M2	WEIGHT	IDN	M1	M2
1	BAVE	NOV	1	3L	1	.800	3.20		19	.300	.006	41	1.00	.004	19	.300	1.42
2	BAVE	NOV	1	3L	1	1.20	5.00		21	.300	.002	21	1.40	.002	21	.300	1.40
3	BAVE	NOV	1	3L	1	.880	3.80		50	.300	.002	19	1.42	.006	50	.300	1.50
4	SMTH	DEC	5	3L	1	1.20	6.10		17	.320	.009	50	1.50	.002	17	.320	1.60
5	BAVE	DEC	1	3L	1	1.52	7.14	.948	18	.320	.007	84	1.50	.006	18	.320	1.56
6	BAVE	DEC	2	3L	1	.680	3.24	.132	41	.340	.004	18	1.56	.007	20	.320	1.48
7	BAVE	DEC	2	3L	1	.720	3.48	.090	25	.400	.025	17	1.60	.009	41	.340	1.00
8	BAVE	DEC	3	3L	1	1.04	4.07	.304	39	.400	.016	89	1.80	.001	25	.400	2.22
9	BAVE	DEC	3	3L	1	.660	3.15	.053	84	.400	.006	39	2.00	.016	39	.400	2.00
10	BAVE	DEC	3	3L	1	.440	2.04	.014	89	.400	.001	10	2.04	.014	84	.400	1.50
11	L043	DEC	2	3L	1	.800	4.00	.142	80	.420	.013	80	2.20	.013	89	.400	1.80
12	NAGL	DEC	1	3L	1	1.00	3.65	.209	88	.420	.019	25	2.22	.025	80	.420	2.20
13	KFOR	DEC	1	3L	1	1.49	5.64	.840	10	.440	.014	82	2.24	.017	88	.420	2.40
14	KFOR	DEC	1	3L	1	1.08	5.31	.507	82	.460	.017	85	2.30	.022	10	.440	2.04
15	KFOR	DEC	1	3L	1	1.16	5.31	.556	85	.480	.022	87	2.36	.009	82	.460	2.24
16	KFOR	DEC	1	3L	1	1.16	4.90	.443	79	.500	.048	78	2.40	.057	85	.480	2.30
17	KFOR	DEC	1	3L	1	.320	1.60	.009	83	.500	.023	88	2.40	.019	79	.500	2.80
18	KFOR	DEC	1	3L	1	.320	1.56	.007	86	.520	.016	93	2.40	.022	83	.500	2.48
19	KFOR	DEC	1	3L	1	.300	1.42	.006	87	.520	.009	83	2.48	.023	29	.520	2.57
20	KFOR	DEC	1	3L	1	.320	1.48		93	.540	.022	34	2.57	.025	86	.520	2.80
21	KFOR	DEC	1	3L	1	.300	1.40	.002	34	.560	.025	71	2.80	.072	87	.520	2.36
22	KFOR	DEC	2	3L	1	1.20	6.47	.662	81	.560	.036	79	2.80	.048	93	.540	2.40
23	KFOR	DEC	2	3L	1	.900	4.72	.155	71	.600	.072	81	2.80	.036	34	.560	2.57
24	KFOR	DEC	2	3L	1	.700	3.08	.068	78	.620	.057	86	2.80	.016	81	.560	2.80
25	KFOR	DEC	2	3L	1	.400	2.22	.025	9	.660	.053	33	2.99	.119	71	.600	2.80
26	KFOR	DEC	3	3L	1	1.52	6.81	.722	56	.660	.027	40	3.00	.076	78	.620	2.40
27	KFOR	DEC	3	3L	1	1.60	5.98	.713	68	.660	.044	49	3.00	.072	9	.660	3.15
28	KFOR	DEC	3	3L	1	1.12	4.15	.294	6	.680	.132	24	3.08	.068	56	.660	3.24
29	KFOR	DEC	4	3L	1	.520	2.57		24	.700	.068	9	3.15	.053	68	.660	3.15
30	KFOR	DEC	4	3L	1	1.20	5.48	.589	49	.700	.072	68	3.15	.044	6	.680	3.24
31	KFOR	DEC	4	3L	1	1.08	5.15	.488	7	.720	.090	6	3.24	.132	24	.700	3.08
32	KFOR	DEC	4	3L	1	.840	4.32	.172	67	.750	.094	56	3.24	.027	49	.700	3.00
33	KFOR	DEC	4	3L	1	.800	2.99	.119	11	.800	.142	67	3.24	.094	7	.720	3.48
34	KFOR	DEC	4	3L	1	.560	2.57	.025	33	.800	.119	90	3.32	.133	67	.750	3.24
35	KFOR	DEC	5	3L	1	1.78	7.50	1.677	90	.810	.133	7	3.48	.090	1	.800	3.20
36	KFOR	DEC	5	3L	1	.960	4.00	.205	91	.810	.181	91	3.64	.181	11	.800	4.00
37	KFOR	DEC	5	3L	1	1.34	6.50	.672	94	.820	.194	12	3.65	.209	33	.800	2.99
38	KFOR	DEC	5	3L	1	1.36	6.00	.544	62	.830	.181	94	3.67	.194	90	.810	3.32
39	KFOR	DEC	5	3L	1	.400	2.00	.016	65	.830	.133	62	3.74	.181	91	.810	3.64
40	KFOR	DEC	5	3L	1	.860	3.00	.076	66	.830	.062	65	3.74	.133	94	.820	3.67
41	KFOR	DEC	5	3L	1	.340	1.00	.004	32	.840	.172	11	4.00	.142	62	.830	3.74
42	KFOR	DEC	6	3L	1	1.06	4.00	.285	95	.840	.147	36	4.00	.205	65	.830	3.74
43	KFOR	DEC	6	3L	1	1.80	6.00	1.252	40	.860	.076	42	4.00	.285	66	.830	4.15
44	KFOR	DEC	6	3L	1	1.60	7.00	1.277	96	.880	.137	47	4.00	.222	32	.840	4.32

45	K	DEC	6	3L	1	1.28	6.00	.302	23	.900	.155	8	4.07	.304	95	.1	4.17
46	KFOR	DEC	6	3L	1	1.06	5.00	.282	36	.960	.205	52	4.08	.268	40	.1	3.00
47	KFOR	DEC	6	3L	1	1.00	4.00	.222	74	.960	.278	28	4.15	.294	3	.880	3.80
48	KFOR	DEC	6	3L	1	1.14	5.00	.182	12	1.00	.209	66	4.15	.062	96	.880	4.80
49	KFOR	DEC	6	3L	1	.700	3.00	.072	47	1.00	.222	95	4.17	.147	23	.900	4.72
50	KFOR	DEC	6	3L	1	.300	1.50	.002	52	1.00	.268	32	4.32	.172	36	.960	4.00
51	SMTH	JAN	4	3L	1	1.42	7.39	1.181	61	1.00	.263	61	4.32	.263	74	.960	5.56
52	SMTH	JAN	5	3L	1	1.00	4.08	.268	8	1.04	.304	23	4.72	.155	12	1.00	3.65
53	SMTH	JAN	6	3L	1	1.44	6.64	1.046	42	1.06	.285	96	4.80	.137	47	1.00	4.00
54	KFOR	JAN	2	3L	1	1.33	6.23	.763	46	1.06	.282	16	4.90	.443	52	1.00	4.08
55	KFOR	JAN	2	3L	1	1.24	5.64	.685	14	1.08	.507	46	5.00	.282	61	1.00	4.32
56	KFOR	JAN	2	3L	1	.660	3.24	.027	31	1.08	.488	48	5.00	.182	8	1.04	4.07
57	KFOR	JAN	3	3L	1	1.16	5.64	.189	28	1.12	.294	31	5.15	.488	42	1.06	4.00
58	KFOR	JAN	3	3L	1	1.49	6.64	1.114	48	1.14	.182	14	5.31	.507	46	1.06	5.00
59	KFOR	JAN	3	3L	1	1.49	6.64	.882	15	1.16	.556	15	5.31	.556	14	1.08	5.31
60	KFOR	JAN	3	3L	1	1.41	6.14	1.062	16	1.16	.443	30	5.48	.589	31	1.08	5.15
61	KFOR	JAN	3	3L	1	1.00	4.32	.263	57	1.16	.189	70	5.48	.565	28	1.12	4.15
62	KFOR	JAN	3	3L	1	.830	3.74	.181	70	1.16	.565	74	5.56	.278	48	1.14	5.00
63	KFOR	JAN	4	3L	1	1.33	7.47	.535	22	1.20	.662	13	5.64	.840	15	1.16	5.31
64	KFOR	JAN	4	3L	1	1.24	6.64	.288	30	1.20	.589	55	5.64	.685	16	1.16	4.90
65	KFOR	JAN	4	3L	1	.830	3.74	.133	55	1.24	.685	57	5.64	.189	57	1.16	5.64
66	KFOR	JAN	4	3L	1	.830	4.15	.062	64	1.24	.288	27	5.98	.713	70	1.16	5.48
67	KFOR	JAN	4	3L	1	.750	3.24	.094	45	1.28	.302	38	6.00	.544	2	1.20	5.00
68	KFOR	JAN	4	3L	1	.660	3.15	.044	73	1.32	.892	43	6.00	1.252	4	1.20	6.10
69	KFOR	JAN	5	3L	1	1.66	6.81	1.258	54	1.33	.763	45	6.00	.302	22	1.20	6.47
70	KFOR	JAN	5	3L	1	1.16	5.48	.565	63	1.33	.535	60	6.14	1.062	30	1.20	5.48
71	KFOR	JAN	5	3L	1	.600	2.80	.072	37	1.34	.672	54	6.23	.763	55	1.24	5.64
72	KFOR	JAN	6	3L	1	1.76	9.30	2.005	38	1.36	.544	73	6.31	.892	64	1.24	6.64
73	KFOR	JAN	6	3L	1	1.32	6.31	.892	60	1.41	1.062	22	6.47	.662	45	1.28	6.00
74	KFOR	JAN	6	3L	1	.960	5.56	.278	51	1.42	1.181	37	6.50	.672	73	1.32	6.31
76	BAVE	MAR	2	3L	1	1.78	9.17	2.007	53	1.44	1.046	53	6.64	1.046	54	1.33	6.23
77	BAVE	MAR	2	3L	1	1.44	6.67	.842	77	1.44	.842	58	6.64	1.114	63	1.33	7.47
78	UP43	MAR	1	3L	1	.620	2.40	.057	13	1.49	.840	59	6.64	.882	37	1.34	6.50
79	UP43	MAR	1	3L	1	.500	2.80	.048	58	1.49	1.114	64	6.64	.288	38	1.36	6.00
80	UP43	MAR	1	3L	1	.420	2.20	.013	59	1.49	.882	77	6.67	.842	60	1.41	6.14
81	UP43	MAR	1	3L	1	.560	2.80	.036	5	1.52	.948	26	6.81	.722	51	1.42	7.39
82	UP43	MAR	1	3L	1	.460	2.24	.017	26	1.52	.722	69	6.81	1.258	53	1.44	6.64
83	UP43	MAR	1	3L	1	.500	2.48	.023	92	1.52	1.236	44	7.00	1.277	77	1.44	6.67
84	UP43	MAR	1	3L	1	.400	1.50	.006	27	1.60	.713	5	7.14	.948	13	1.49	5.64
85	UP43	MAR	1	3L	1	.480	2.30	.022	44	1.60	1.277	51	7.39	1.181	58	1.49	6.64
86	UP43	MAR	1	3L	1	.520	2.80	.016	69	1.66	1.258	63	7.47	.535	59	1.49	6.64
87	UP43	MAR	1	3L	1	.520	2.36	.009	72	1.76	2.005	35	7.50	1.677	5	1.52	7.14
88	UP43	MAR	1	3L	1	.420	2.40	.019	35	1.78	1.677	92	8.00	1.236	26	1.52	6.81
89	UP43	MAR	1	3L	1	.400	1.80	.001	76	1.78	2.007	76	9.17	2.007	92	1.52	8.00
90	KFOR	MAR	1	3L	1	.810	3.32	.133	43	1.80	1.252	72	9.30	2.005	27	1.60	5.98
91	KFOR	MAR	1	3L	1	.810	3.64	.181							44	1.60	7.00
92	KFOR	MAR	2	3L	1	1.52	8.00	1.236							69	1.66	6.81
93	KFOR	MAR	4	3L	1	.540	2.40	.022							72	1.76	9.30
94	KFOR	MAR	5	3L	1	.820	3.67	.194							35	1.78	7.50
95	KFOR	MAR	5	3L	1	.840	4.17	.147							76	1.78	9.17
96	KFOR	APR	6	3L	1	.880	4.80	.137							43	1.80	6.00

MEASUREMENT/WEIGHT
RELATIONSHIPS FOR:*LEPTOPHLEBIA*

MAX HW = 1.800 mm
MAX BL = 9.300 mm
MAX WT = 2.007 mg

(USED IN SCALING)

MEASUREMENT/WEIGHT
RELATIONSHIPS FOR:*LEPTOPHLEBIA*

LOG/LOG TRANSFORM

MAJOR AXIS: $Y = bX^{\alpha}$

STANDARD SCALING

MEASUREMENT/WEIGHT
RELATIONSHIPS FOR:*EphemereLLA*

MAX HW = 2.000 mm
MAX BL = 12.500 mm
MAX WT = 5.618 mg

(USED IN SCALING)

MEASUREMENT/WEIGHT
RELATIONSHIPS FOR:*EPHEMERELLA*

LOG/LOG TRANSFORM

MAJOR AXIS: $Y = bX^{\alpha}$

STANDARD SCALING

LEAF PACK EXPERIMENT 74-75

RUN 103 (29.JUN.76)

MEASUREMENT/WEIGHT
RELATIONSHIPS FOR:*STENONEMA & STENACRON*

MAX HW = 4.000 mm
 MAX BL = 14.300 mm
 MAX WT = 21.410 mg

(USED IN SCALING)

MEASUREMENT/WEIGHT
RELATIONSHIPS FOR:*STENONEMA & STENACRON*

LOG/LOG TRANSFORM

MAJOR AXIS: $Y = bX^{\alpha}$

STANDARD SCALING

LEAF PACK EXPERIMENT 74-75

RUN 104 (29.JUN.76)

MEASUREMENT/WEIGHT
RELATIONSHIPS FOR:*NEMOURA*

MAX HW = 1.240 mm
MAX BL = 8.000 mm
MAX WT = 1.018 mg

(USED IN SCALING)

MEASUREMENT/WEIGHT
RELATIONSHIPS FOR:

NEMOURA

LOG/LOG TRANSFORM

MAJOR AXIS: $Y = bX^{\alpha}$

STANDARD SCALING

MEASUREMENT/WEIGHT
RELATIONSHIPS FOR:*TAENIOPTERYX*

MAX HW = 1.660 mm
MAX BL = 16.000 mm
MAX WT = 8.208 mg

(USED IN SCALING)

MEASUREMENT/WEIGHT
RELATIONSHIPS FOR:*TAENIOPTERYX*

LOG/LOG TRANSFORM

MAJOR AXIS: $Y = bX^{\alpha}$

STANDARD SCALING

MEASUREMENT/WEIGHT
RELATIONSHIPS FOR:*PERLIDAE & PERLODIDAE*

MAX HW = 5.480 mm
MAX BL = 22.000 mm
MAX WT = 71.690 mg

(USED IN SCALING)

MEASUREMENT/WEIGHT
RELATIONSHIPS FOR:

PERLIDAE & PERLODIDAE

LOG/LOG TRANSFORM

MAJOR AXIS: $Y = bX^{\alpha}$

STANDARD SCALING

MEASUREMENT/WEIGHT
RELATIONSHIPS FOR:*PERLODIDAE*

MAX HW = 2.560 mm
MAX BL = 12.800 mm
MAX WT = 6.980 mg

(USED IN SCALING)

MEASUREMENT/WEIGHT
RELATIONSHIPS FOR:*PERLODIDAE*

LOG/LOG TRANSFORM

MAJOR AXIS: $Y = bX^{\alpha}$

STANDARD SCALING

MEASUREMENT/WEIGHT
RELATIONSHIPS FOR:*NIGRONIA SERRICORNUS*

MAX HW = 4.120 mm
MAX BL = 27.500 mm
MAX WT = 47.650 mg

(USED IN SCALING)

MEASUREMENT/WEIGHT
RELATIONSHIPS FOR:

NIGRONIA SERRICORNUS

LOG/LOG TRANSFORM

MAJOR AXIS: $Y = bX^{\alpha}$

STANDARD SCALING

MEASUREMENT/WEIGHT
RELATIONSHIPS FOR:*BRACHYCENTRUS*

MAX HW = 1.240 mm
MAX BL = 13.100 mm
MAX WT = 11.581 mg

(USED IN SCALING)

BODY LENGTH

n = 44
r = 0.555

HEAD WIDTH

DRY WEIGHT

n = 44
r = 0.402

HEAD WIDTH

DRY WEIGHT

n = 44
r = 0.674

BODY LENGTH

MEASUREMENT/WEIGHT
RELATIONSHIPS FOR:*BRACHYCENTRUS*

LOG/LOG TRANSFORM

MAJOR AXIS: $Y = bX^{\alpha}$

STANDARD SCALING

MEASUREMENT/WEIGHT
RELATIONSHIPS FOR:*LEPIDOSTOMA*

MAX HW = 0.880 mm
MAX BL = 7.830 mm
MAX WT = 1.618 mg

(USED IN SCALING)

MEASUREMENT/WEIGHT
RELATIONSHIPS FOR:*LEPIDOSTOMA*

LOG/LOG TRANSFORM

MAJOR AXIS: $Y = bX^\alpha$

STANDARD SCALING

LEAF PACK EXPERIMENT 74-75

RUN 111 (29 JUN 76)

MEASUREMENT/WEIGHT
RELATIONSHIPS FOR:*PYCNOPSYCHE*

MAX HW = 2.360 mm
MAX BL = 35.000 mm
MAX WT = 67.940 mg

(USED IN SCALING)

LEAF PACK EXPERIMENT 74-75

RUN 111 (29.JUN.76)

MEASUREMENT/WEIGHT
RELATIONSHIPS FOR:*PYCNOPSYCHE*

LOG/LOG TRANSFORM

MAJOR AXIS: $Y = bX^\alpha$

STANDARD SCALING

MEASUREMENT/WEIGHT
RELATIONSHIPS FOR:*HYDROPSYCHIDAE*

MAX HW = 1.520 mm
MAX BL = 17.300 mm
MAX WT = 10.846 mg

(USED IN SCALING)

MEASUREMENT/WEIGHT
RELATIONSHIPS FOR:*HYDROPSYCHIDAE*

LOG/LOG TRANSFORM

MAJOR AXIS: $Y = bX^{\alpha}$

STANDARD SCALING

MEASUREMENT/WEIGHT
RELATIONSHIPS FOR:*HYDROPSYCHE*

MAX HW = 1.440 mm
MAX BL = 15.700 mm
MAX WT = 8.119 mg

(USED IN SCALING)

MEASUREMENT/WEIGHT
RELATIONSHIPS FOR:*HYDROPSYCHE*

LOG/LOG TRANSFORM

MAJOR AXIS: $Y=bX^{\alpha}$

STANDARD SCALING

MEASUREMENT/WEIGHT
RELATIONSHIPS FOR:*CHEUMATOPSYCHE*

MAX HW = 1.340 mm
MAX BL = 13.000 mm
MAX WT = 4.926 mg

(USED IN SCALING)

MEASUREMENT/WEIGHT
RELATIONSHIPS FOR:*CHEUMATOPSYCHE*

LOG/LOG TRANSFORM

MAJOR AXIS: $Y = bX^{\alpha}$

STANDARD SCALING

MEASUREMENT/WEIGHT
RELATIONSHIPS FOR:*DIPLECTRONA*

MAX HW = 1.520 mm
MAX BL = 17.300 mm
MAX WT = 10.846 mg

(USED IN SCALING)

MEASUREMENT/WEIGHT
RELATIONSHIPS FOR:*DIPLECTRONA*

LOG/LOG TRANSFORM

MAJOR AXIS: $Y = bX^a$

STANDARD SCALING

MEASUREMENT/WEIGHT
RELATIONSHIPS FOR:*ELMIDAE LARVA*

MAX HW = 0.640 mm
MAX BL = 6.420 mm
MAX WT = 0.937 mg

(USED IN SCALING)

MEASUREMENT/WEIGHT
RELATIONSHIPS FOR:*ELMIDAE LARVA*

LOG/LOG TRANSFORM

MAJOR AXIS: $Y = bX^{\alpha}$

STANDARD SCALING

MEASUREMENT/WEIGHT
RELATIONSHIPS FOR:*TIPULA*

MAX SW = 0.420 mm
MAX BL = 65.000 mm
MAX WT = 188.000 mg

(USED IN SCALING)

MEASUREMENT/WEIGHT
RELATIONSHIPS FOR:*TIPULA*

LOG/LOG TRANSFORM

MAJOR AXIS: $Y = bX^a$

STANDARD SCALING

MEASUREMENT/WEIGHT
RELATIONSHIPS FOR:*SIMULIIDAE*

MAX HW = 0.820 mm
MAX BL = 10.000 mm
MAX WT = 2.054 mg

(USED IN SCALING)

MEASUREMENT/WEIGHT
RELATIONSHIPS FOR:*SIMULIIDAE*

LOG/LOG TRANSFORM

MAJOR AXIS: $Y = bX^{\alpha}$

STANDARD SCALING

MEASUREMENT/WEIGHT
RELATIONSHIPS FOR:

GAMMARUS

MAX HW = 0.000 mm
MAX BL = 16.000 mm
MAX WT = 18.780 mg

(USED IN SCALING)

MEASUREMENT/WEIGHT
RELATIONSHIPS FOR:*GAMMARUS*

LOG/LOG TRANSFORM

MAJOR AXIS: $Y = bX^{\alpha}$

STANDARD SCALING

BODY LENGTH

 $n = 0$

HEAD WIDTH

DRY WEIGHT

 $n = 0$

HEAD WIDTH

DRY WEIGHT

 $n = 243$
 $r = 0.969$
 $\alpha = 2.920$
 $b = 5.059$
($b \times 1000$)

BODY LENGTH

Appendix IV

Temperature Data for Augusta Creek

First order stream sites:

Smith Site, 1975
B Ave., 1972-1975

Second order stream site:

Upper 43rd St., 1975

Third order stream sites:

Nagel Site, 1975
Kellogg Forest, 1975

AUGUSTA CREEK
SMITH SITE 1975
MAX, MEDIAN, MIN DAILY WATER TEMP

AUGUSTA CREEK

B AVE E 1972

MAX, MEAN, MIN DAILY WATER TEMP

AUGUSTA CREEK

B AVE E 1973

MAX, MEAN, MIN DAILY WATER TEMP

29. JUN. 76

AUGUSTA CREEK

B AVE E 1974

MAX, MEAN, MIN DAILY WATER TEMP

29. JUN. 76

AUGUSTA CREEK

B AVE E. 1975

MAX, MEDIAN, MIN DAILY WATER TEMP

AUGUSTA CREEK
UPPER 43 RD 1975
MAX, MEDIAN, MIN DAILY WATER TEMP

AUGUSTA CREEK

NAGEL SITE 1975.

MAX, MEDIAN, MIN DAILY WATER TEMP

29 JUN 76

AUGUSTA CREEK
KELLOGG FOREST 1975
MAX, MEDIAN, MIN DAILY WATER TEMP