Taxonomic Composition and Phenology of the Chironomidae in Stream Ecosystems in Relation to Canopy Removal

by

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Abstract

TAXONOMIC COMPOSITION AND PHENOLOGY OF THE CHIRONOMIDAE IN STREAM ECOSYSTEMS IN RELATION TO CANOPY REMOVAL

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Potential changes in the species composition and emergence patterns of the Chironomidae, as a result of forest canopy removal, were tested by the collection of chironomid pupal exuviae in Bear Creek and in three previously logged watersheds in the Clearwater River system, Washington. Pre- and post-logging solar exposure levels, water temperature, discharge, detrital input, and algal production were analyzed with respect to their affects on Chironomidae in Bear Creek.

Analysis of the chironomid community in Bear Creek indicated that species composition and emergence patterns did not change appreciably after canopy removal. It is suggested that significant changes did not occur in the chironomid community because the thermal regime after canopy removal was not substantially different from pre-treatment conditions. Changes in species composition between years were minor and occurred primarily among lesser abundant species. The four most abundant species in Bear Creek during this study were: *Thienemanniella* sp. 1, *Corynonerua* sp. 2, *Stempellinella* cf. *brevis*, and *Synothocladius* cf. *semivirens*. Composition of major taxa was similar in the four streams. Among major taxa, Orthocladiinae were predominant. Emergence patterns of the major chironomid species in Bear Creek were not substantially

altered; species which had highly synchronized or long and extended emergence patterns prior to canopy removal maintained the same pattern after canopy removal. Cumulative emergence curves for a complex of the 35 most abundant species in Bear Creek were nearly identical, the EM_{50}'s before and after differed by 11 days and the EM_{25}-EM_{75} intervals differed by only 13 days. Emergence curves for individual species within this complex varied to a greater extent.

Similarities in species composition, emergence patterns, and composition of major taxa between Bear Creek and the Clearwater River streams suggests that neither canopy removal alone (Bear Creek) nor canopy removal in combination with road building and yarding (Clearwater streams) resulted in significant alterations in the chironomid community.

In the discussion differences in chironomid species composition and emergence patterns in streams more profoundly affected by thermal regime increases are considered. A short review of the significance of chironomids to juvenile stream fishes is included.

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INTRODUCTION

This study was undertaken to evaluate how forest canopy removal, in isolation from other phases of logging (e.g., road building and yarding) affects the aquatic insect fauna in headwater streams in the Pacific Northwest. This research was part of a larger project which was designed to document the effects of forest canopy removal on the overall productivity of Bear Creek, a third-order stream on the Olympic Peninsula, Washington (June 1981, Martin et al. 1981).

The Bear Creek investigation was an intensive study on two adjacent sections of stream divided into an upstream control zone (200 m) and a downstream experimental zone (1,000 m). Both sections were studied from April 1977 to December 1978 under natural conditions. In February 1979, the experimental section was logged, according to procedures described in a later section, and both sections (experimental and control) were studied for another year.

Environmental changes which occur following conventional logging operations are not only complicated, but also interrelated. Conventional logging can be viewed as a multiphased operation; trees are felled, roads are built, and timber is yarded and removed. Each phase produces well-documented consequences on the stream environment. Tree felling opens the forest canopy and causes increased solar exposure (Brown 1970), increased water temperature (Brown 1966, 1969; Brown and Krygier 1967, 1970; Hall and Lantz 1969), increased nutrient concentrations (Pierce et al. 1970; Likens et al. 1970; Bormann et al. 1968), and organic debris accumulations (Froehlich 1971; Narver 1970). Road construction and use result in significant additions of sediment to streams (see Gibbons and Salo 1973, and Reid 1981, for review). Timber yarding and removal can disturb the soil surface which may accelerate erosion and siltation from landings (Anderson 1971). Less well-documented, however is the impact each phase imposes on the stream insect fauna.

In order to obtain sufficiently detailed information regarding the effects of canopy removal on the aquatic insect fauna in headwater streams, this investigation was limited to one insect group, the Chironomidae.

The Chironomidae are of particular interest in studies investigating the effects of logging because they form an exceptionally important, abundant, and ubiquitous part of all freshwater insect fauna (Thienemann 1954). In addition, their large number of species provides excellent potential for analysis of stream quality changes. Past investigations which have combined all phases of logging into one study have documented varying effects of logging on aquatic insects, but more importantly, they have illustrated the importance of the Chironomidae to the entire insect community (Tebo 1955; Burns 1972; Newbold et al. 1980; Newbold 1977; Allen 1960; Graynoth 1979).

Chironomids have also been shown to be critically important dietary items of juvenile salmon (Mundie 1969; Gribanov 1948; Graybill et al. 1979; Sparrow 1968; Synkova 1951; Levanidov and Levanidova 1957; Sano 1966; Goodland et al. 1974; Rogers 1968; Woodey 1972; Hoffman 1979) and trout (Tippets and Moyle 1978; Doudoroff 1935, Klassen 1967; Miller 1974; Davis and Warren 1965; White 1936; Nilsson 1957; McCormack 1962, Frost and Smyly 1952). In a general sense the magnitude of recruitment of any salmonid population depends upon the availability of its food. If after logging (canopy removal), a stream's capacity to produce food (e.g., chironomids) is diminished or if the availability of food is mismatched with the food demands of the fry, the balance of effort and reward is likely to become disrupted, and if the fry weakens, it will become susceptible to predation or disease (Mundie 1969).

Although a large number of investigations regarding insect response to logging have been reported in the literature (see Gibbons and Salo 1973), very few have evaluated the importance of light intensity and temperature in regulating chironomid species composition and emergence dynamics following logging. Photoperiod and temperature have been shown to be of primary importance in regulating chironomid life-cycles and species distribution (see Danks 1978; Paris and Jenner 1959; Englemann and Shappirio 1965; Koskinen 1968; Palmen 1955, 1958; Morgan and Waddell 1961). Generally in chironomids, photoperiod controls the transformation from larvae to pupa and influences periodic emergence (Danks 1978; Danks and Oliver 1972; Palmen 1955), whereas the speed of larval development (Sadler 1935; Hilsenhoff 1966; Konstantinov 1958) and initiation of ecdysis are usually independent of photoperiod but under the direct influence of temperature (Danks 1971a, 1978). Other factors which may influence chironomid life-cycles and species distribution under certain conditions include: food quantity and quality (Hilsenhoff 1967; Ward and Cummins 1979), substrate particle size and current velocity (Cummins and Lauff 1969), and habitat (Danks 1971b).

The hypothesis tested in this investigation is that the magnitude of change in chironomid species composition and emergence patterns (either accelerated or delayed) in streams following canopy removal is directly related to the extent of thermal regime increase following the disturbance. If increases in thermal regime following canopy removal are minor (e.g., mean annual temperature increase $<3^{o}C$) chironomid species composition and corresponding emergence patterns will not be significantly different from the original state because the temperature increase is not a significant departure from historical temperature patterns. In contrast, if the thermal regime increases substantially (e.g., mean annual temperature increase $>6^{o}C$) major alterations in chironomid species composition will occur because excessive warming of the seasonal cycle will cause the life-cycles of many of the original species to be disrupted and they will lose their competitive position in the community, perhaps through reduced population densities, and be replaced by other species better adapted (physiologically, behaviorally, and genetically) to accommodate the new thermal patterns in the stream. Emergence patterns will differ from the original state, reflecting the change in species composition, and may, depending upon the extent of heating in the stream result in accelerated emergence patterns (i.e., earlier in the year) to coincide with the timing of favorable temperature regimes.

The hypothesis was tested by: 1) quantifying chironomid larval abundance and biomass in Bear Creek before and during the first year following canopy removal, and 2) quantifying chironomid species composition and emergence patterns in Bear Creek before and after canopy removal. Supportive testing of the hypothesis was made by qualitatively examining the species composition and emergence patterns of chironomids in three streams in the Clearwater River basin that differed from Bear Creek in logging intensity (conventionally logged) and time since being logged (2 to 20 yrs ago) to determine how the chironomid species composition in these streams compared with Bear Creek.

It is highly improbable that all chironomid species are living under "optimal" or near optimal conditions in forested streams. They can, depending on environmental conditions, be expected to respond to a disturbance at various rates. It is unlikely that following canopy removal that each species would be equally susceptible. A more realistic outlook would be that the effects of canopy removal on chironomids, is that some species will be affected while others will not. Many species of Chironomidae are ubiquitous in streams of the Pacific Northwest regardless of prevailing condition (i.e., logged or unlogged). This suggests that many chironomid species possess a general adaptability and hardiness (Brundin 1966) that allows for their existence in a wide range of environmental conditions.

Therefore, a second hypothesis was developed which states that there is a group (a core species complex) of chironomid species (perhaps

10 or 20 species) which are abundant in Pacific Northwest streams regardless of the level of perturbation.

The species of chironomids which make up the core species complex may be those having broad food and habitat requirements enabling maximum resource utilization in relatively stable environments as well as in temporarily fluctuating ones. Alternatively, the core species complex may be a gathering of species which exert greater overall efficiency in the controlled use of available resources (Vannote and Sweeney 1980).

I expect that additions or extinctions in chironomid species composition following canopy removal (and perhaps logging in general) will be associated with species outside of the core complex, i.e., species which may be particularly susceptible to resource levels or temperature regimes outside their optimum for larval growth, development or emergence.

The hypothesis was tested by examination of the species composition and relative abundance levels of the chironomids in Bear Creek before and during the first year following canopy removal. The Bear Creek data were also compared with the chironomid species composition observed in the three Clearwater River streams.

If a core species complex can be identified and verified, it would be a valuable tool in assessing the effects of canopy removal and logging in general because major alterations in the abundance or presence of species in the complex may signal the occurrence of severe disturbance in the stream system. In addition, further research on the core species complex may indicate that this complex is the primary pool from which juvenile fish feed. If this is confirmed, reductions in the abundance or availability of the core complex, as a result of any perturbation, could affect the capacity of a stream to produce juvenile fish.

DESCRIPTION OF STUDY AREA

Bear Creek

Bear Creek is a third-order stream located in the Olympic National Forest on the northwestern slope of the Olympic Peninsula, Washington (Fig. 1). The upper drainage basin of Bear Creek was chosen for study because of its history of little commercial and recreational usage. The physical characteristics of the study section are outlined in Table 1.

Bear Creek drains a northwesterly-facing watershed (Fig. 2) with a maximum elevation of 310 m. At the base of the watershed, Bear Creek empties into the Bogachiel River at 70-m elevation. Only the upper 1200 m of the stream was used in this study since the lower portion of Bear Creek is influenced by clearcut logging and road building operations.

The climate of the Bear Creek vicinity is oceanic with heavy winter precipitation (average annual precipitation = 300 cm) and relatively dry summers. In fall, precipitation begins to increase and reaches a peak in December, then progressively decreases through the spring. Precipitation occurs primarily as rain.

Underlying bedrock within the Bear Creek watershed consists of cretaceous sedimentary rock known as the Soleduck Formation (Snyder et al. 1972). These are the oldest known rocks in the Olympic Mountains, being profoundly folded and composed of coarse-textured, thickly bedded

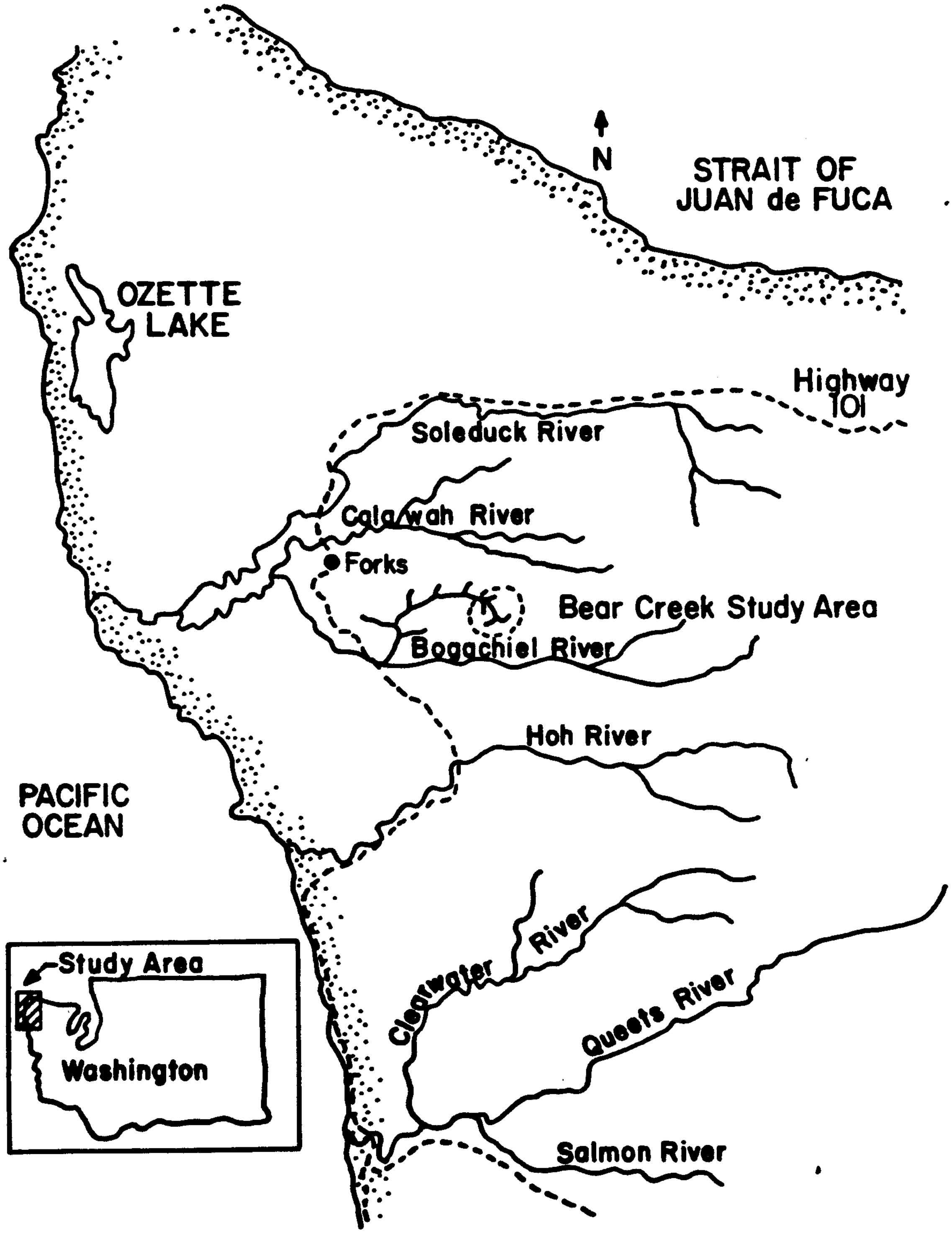

Fig. 1. Location of Bear Creek and Clearwater River study areas.

Table 1. Physical characteristics of the Bear Creek study area.

Characteristic	
Length of study section	1,200 m
Elevation at lower end of study section	184 m
Elevation at headwaters of study section	310 m
Gradient	2.1 %
Watershed area of study section	230 ha
Stream aspect	NW
Approximate minimum discharge	0.05 cfs
Approximate maximum discharge	250 cfs
Water surface area at low flow[1]	3,135 m^2
Percentage pool habitat at low flow	65 %
Percentage riffle habitat at low flow	31 %
Percentage run habitat at low flow	4 %
Water surface area at bankful flow[1]	6,007 m^2
Percentage pool habitat at bankful flow	60 %
Percentage riffle habitat at bankful flow	36 %
Percentage run habitat at bankful flow	4 %

[1] Based on 1,100 m of stream.

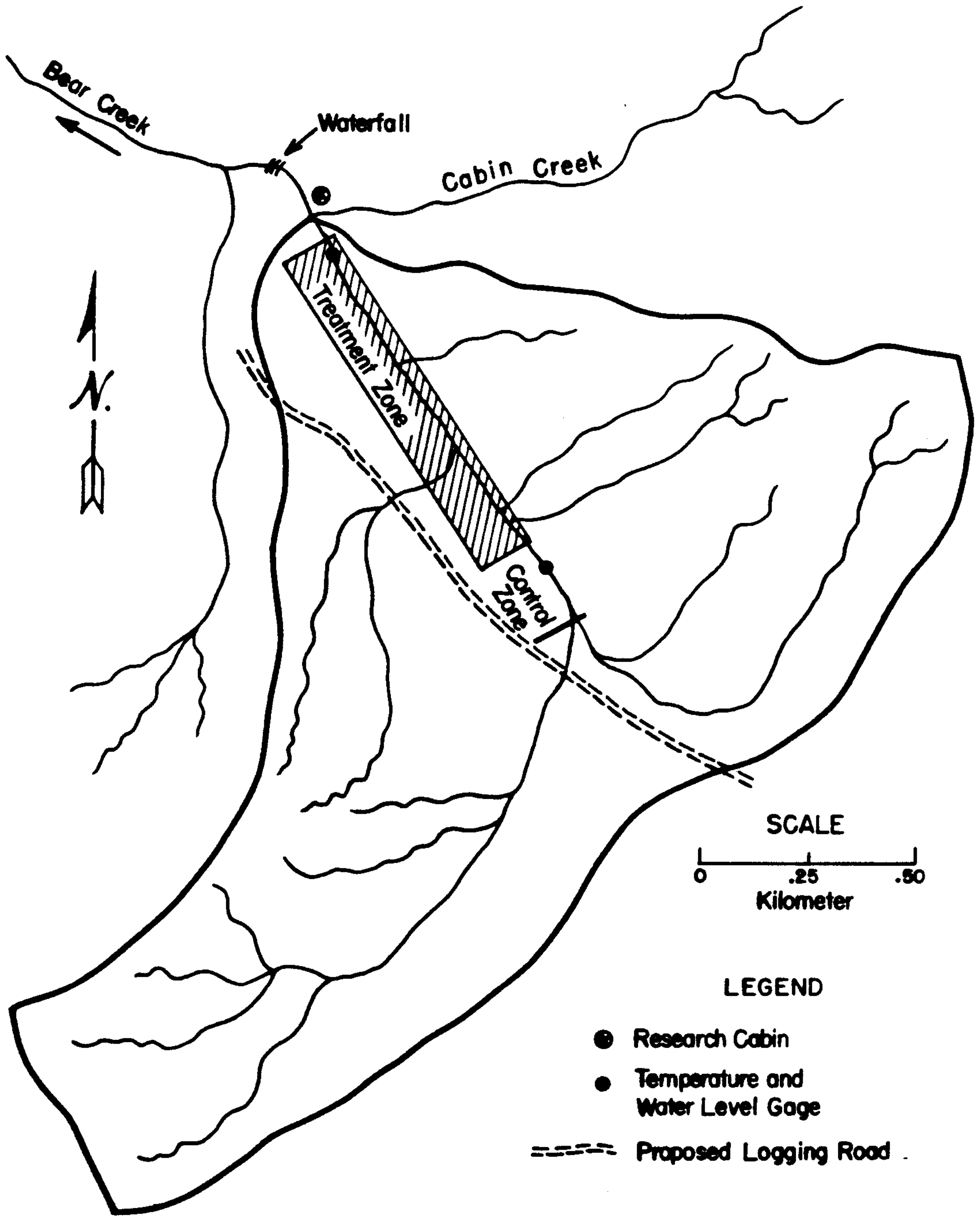

Fig. 2. Upper Bear Creek watershed showing location of treatment zone and control zone.

graywacke interbedded with fine-textured, thinly bedded mudstone, siltstone and argillite (Snyder et al. 1972).

Bear Creek drains an undisturbed, 230 ha, coniferous forest watershed. The dominant tree species, western hemlock (*Tsuga heterophylla*), Sitka spruce (*Picea sitchensis*), and white fir (*Abies amabilis*), form a discontinuous canopy over the streambed. Red alder (*Alnus rubra*) occurs in small clumps along the length of the streambank. Other woody species which occur along the stream include: vine maple (*Acer circinatum*), salmonberry (*Rubus spectabilis*), Devil's club (*Oplopanax horridus*), salal (*Gaultheria shallon*), tall blue huckleberry (*Vaccinium ovalifolium*), and red huckleberry (*V. parvifolium*).

The 1200-m study section contains a native fish community composed of prickly sculpin (*Cottus asper*), and cutthroat trout (*Salmo clarkii*). The study section is intermittently accessible to anadromous salmonids (June 1981).

Clearwater River Basin

The Clearwater River is located approximately 60 km south of Bear Creek and is the major tributary of the Queets River (Fig. 3). It originates on the western slope of the Olympic Mountains and flows southwesterly 60 km to its confluence with the Queets River. The Clearwater watershed incorporates approximately 350 km^2.

Annual precipitation ranges between 350-640 cm, with the major portion occurring as rain. The general geology of the Clearwater River

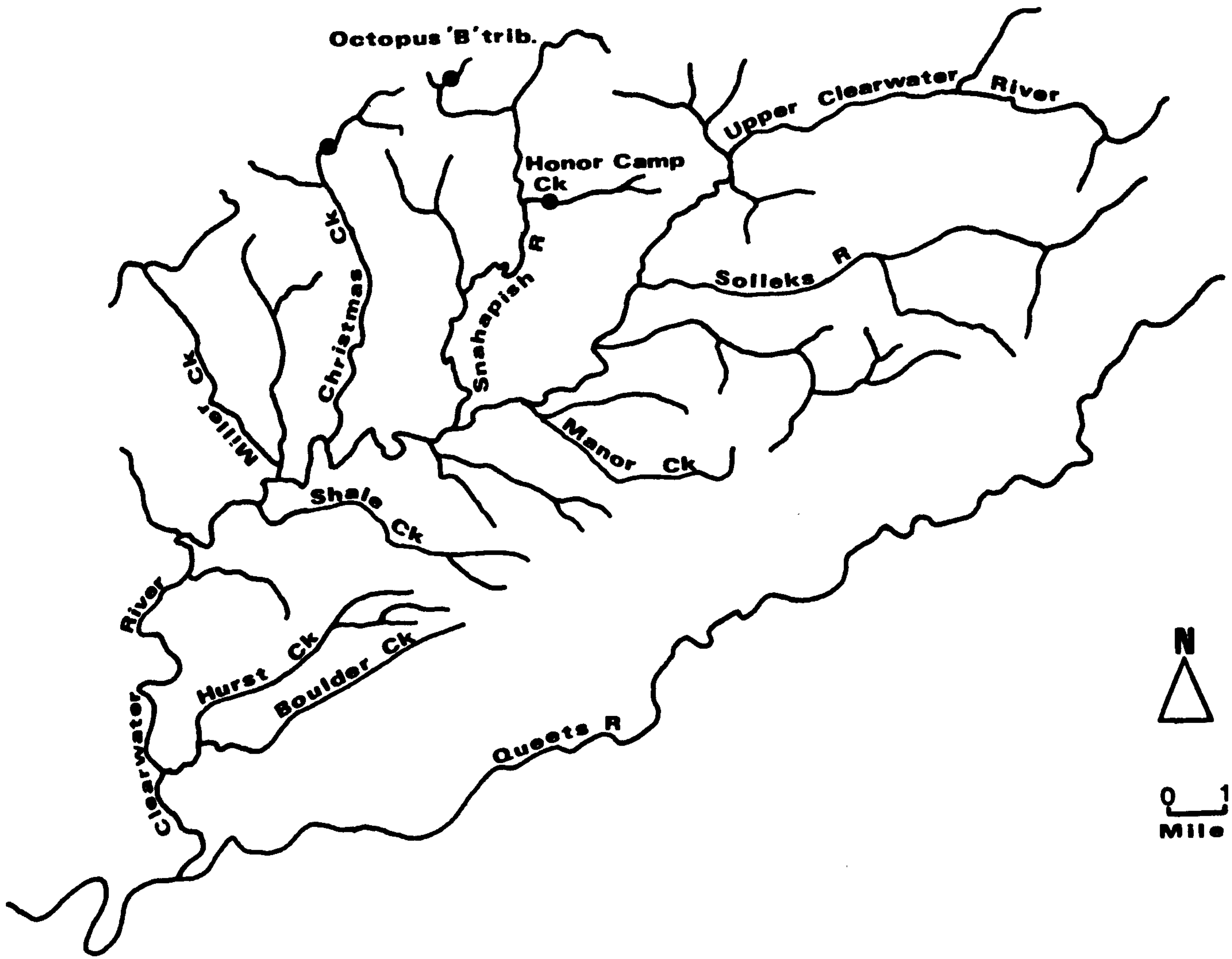

Fig. 3. Location of study sites in the Clearwater River Basin.

watershed is bedrock, comprised of siltstones and sandstones that have been intensely folded and broken (Snyder et al. 1972).

The temperate rain forests of the Clearwater watershed are predominately western hemlock, Sitka spruce, western red cedar (*Thuja plicata*), Douglas fir (*Pseudotsuga menziesii*), and white fir.

Study Streams

Three third-order tributary streams with different stages of logging history were chosen for comparison with Bear Creek (Fig. 3). Criteria for selecting these streams were based on type, intensity, and stage of recovery from logging in the watershed. Octopus "B" is a tributary of Octopus Creek. Octopus Creek feeds into the Snahapish River, which is the largest tributary of the Clearwater River. Octopus "B" was completely clearcut in 1977 and represents the most recently logged watershed of the three (Table 2). Christmas Creek, a tributary of the Clearwater River, was logged in 1973 and represents a mid-range (5-6 yr) post-logging recovery stream. Honor Camp Creek, a tributary of the Snahapish River, was logged in 1960 and represents a relatively long-range (18-19 yr) post-logging recovery stream. A thickly entangled willow canopy completely encloses Honor Camp Creek, whereas Octopus "B" tributary and Christmas Creek are completely open.

All three streams are inhabited by natural populations of cutthroat trout and two species of cottids: the torrent sculpin (*Cottus rotheus*), and the prickly sculpin (Osborn 1981). Octopus "B" also contains a third cottid, the coastrange sculpin (*C. aleuticus*).

Table 2. Some physical and logging treatment characteristics of the study streams in the Clearwater River drainage basin.

Stream	Watershed area (ha)	Study site gradient (%)	Year logged	Approximate discharge in July (liter/sec)	Logging treatment
Octopus "B" tributary	107	9.6	1977	11.0	Clearcut to stream bank--stream cleanout following yarding--ridge roads
Christmas Creek	324	4.1	1973	34.0	Clearcut to stream bank--stream cleanout following yarding--extensive road network
Honor Camp Creek	135	6.3	1960	17.0	Clearcut to stream bank--trees yarded across stream--no stream cleanout following yarding--minimal road network

LOGGING TREATMENT PLAN ON BEAR CREEK

The purpose of this study was to investigate the effects of canopy removal, in isolation from the other phases of logging (e.g., road building and yarding) on the taxonomic composition and phenology of the Chironomidae. This was accomplished by removing all streamside timber (excluding alders and non-merchantable timber) within the experimental section; 60 m wide on the southwest side of the stream, 10 m wide on the northeast side of the stream for 1000 m (6.9 ha) (see Fig. 2).

All timber in the clearcut zone was felled, bucked, and limbed in accordance with procedures prescribed by the Washington Forest Practices Board (1976). All felled timber remained on the ground for the duration of the study since the study design required no road building into the watershed and other methods of timber removal such as helicopter logging, were discounted as uneconomical. Directional felling methods were used to prevent trees from falling into the stream. Some trees were felled over the stream, perpendicular to the stream channel, in a bridge-like fashion. These trees generally did not affect stream flows or channel morphology; however, one tree felled across the stream (850 m) broke and blocked flow resulting in substrate deposition upstream. Other trees (near 100 m) accidentally felled into the stream channel caused localized changes in channel morphology. Slash and debris that fell into the stream during logging were removed and placed in areas where they would not re-enter the stream.

The experimental design was compromised somewhat by a large windstorm on February 13, 1980. This storm occurred when the timber felling operation was approximately 80% completed. As a result of the heavy wind (100 mph), numerous trees that had been left standing along the stream bank blew down. Several trees fell into the stream channel causing changes in channel morphology and other trees fell across the stream disrupting stream banks.

Following the February 13 windstorm, several large storm events caused branch-size debris to accumulate within the stream channel causing further changes in channel morphology; many of the logs and trees that were in the channel as a result of the tree felling and windstorm created dams which forced the stream to spread out, depositing gravel along the stream margins and in pools.

The cumulative effects of the windstorm and freshets resulted in changes in stream morphology in some sections of the study stream. The magnitude of this change, with respect to pre-storm conditions, is unknown and therefore the effects of canopy removal cannot be totally isolated from the effects of the windstorm and freshets.

METHODS AND MATERIALS

The methods and materials used for determining water temperature, solar exposure, discharge, and detrital input is presented in Martin et al. (1981). These parameters were not primary components of this thesis but were collected as a team effort for the Bear Creek investigation. However, a brief description of each method is given below.

Water Temperature

Water temperatures in Bear Creek were monitored by continuously recording thermographs located in the treatment zone (100 m) and control zone (1125 m, Fig. 2). Water temperature measurements started in February 1977 and terminated in October 1979. Maximum-minimum thermographs were installed in each of the Clearwater River streams at the end of August 1978 and remained in operation until September 1979.

Solar Exposure

The degree of canopy shading above Bear Creek was determined prior to canopy removal (January 1979) and after canopy removal (March 1979) with a 35-mm camera fitted with a "fisheye" lens (fisheye canopy densiometer). The camera was secured to a tripod (approximately 1 m above the stream channel) and photographs of the canopy were taken at 25-m intervals in the treatment zone.[1] No photographs were taken in the control zone.

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[1] Photographs were taken by Dr. A. Larsen, College of Forest Resources, University of Washington.

A thorough discussion of the methods and materials for using the fisheye canopy densiometer is given by Wooldridge and Stern (1979). A brief discussion of the principal features of this method is outlined below.

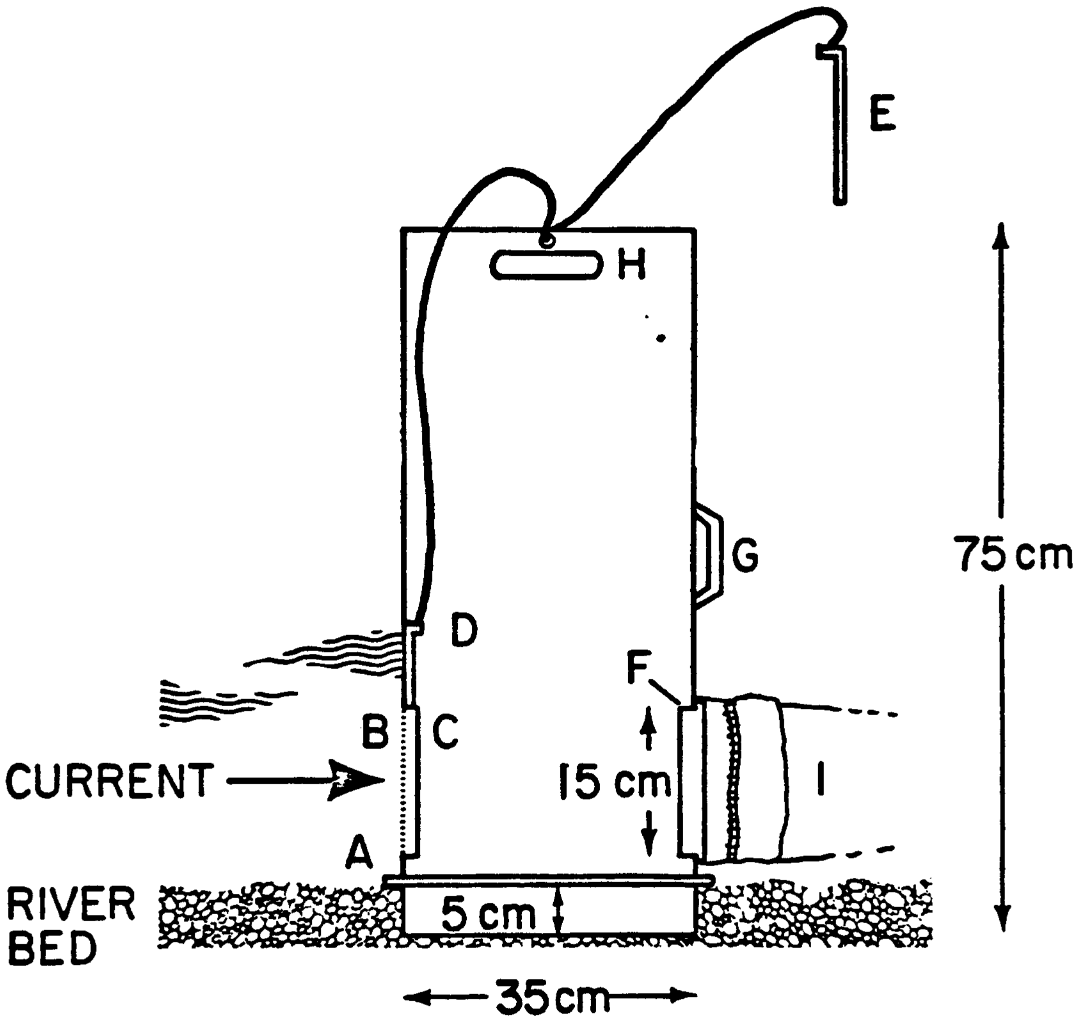
The fisheye canopy densiometer produces circular images of vegetative shade above the stream channel. A polar graph superimposed on the images provided measurements of periods of direct solar radiation, and effective times of sunrise and sunset. Measurements were determined for 21 July because water temperatures in Bear Creek were generally highest during this part of the year. The polar graph was calibrated for the Bear Creek vicinity and represents a plot of solar altitude and azimuth as a function of date, latitude, and hour-angle.

Discharge

A water level recorder was installed in Bear Creek at the lower end of the treatment zone (100 m) in April 1977 and a discharge-stage rating curve was established. A staff gauge was installed in the control zone (1125 m) and treatment zone (100 m) and levels were checked regularly. This information was later correlated with the water level recorder.

Substrate Particle Size

Substrate samples were taken with a Neill cylinder (Fig. 4), which samples approximately 5,000 cm^3 of substrate, at the three benthos locations (Fig. 5) on 13 September 1978 and on 4 May 1979. Four samples were taken within each riffle, perpendicular to the stream. Sampling



A Flange
B Screen over front opening
C Track for sliding door
D Sliding door with attached cord (in track)
E Rear sliding door (hung outside cylinder for flushing)
F Rear opening with flange
G Carrying handle
H Handle for rotating cylinder
I Trailing net
(adapted from Neill, 1938)

Fig. 4. Neill cylinder.

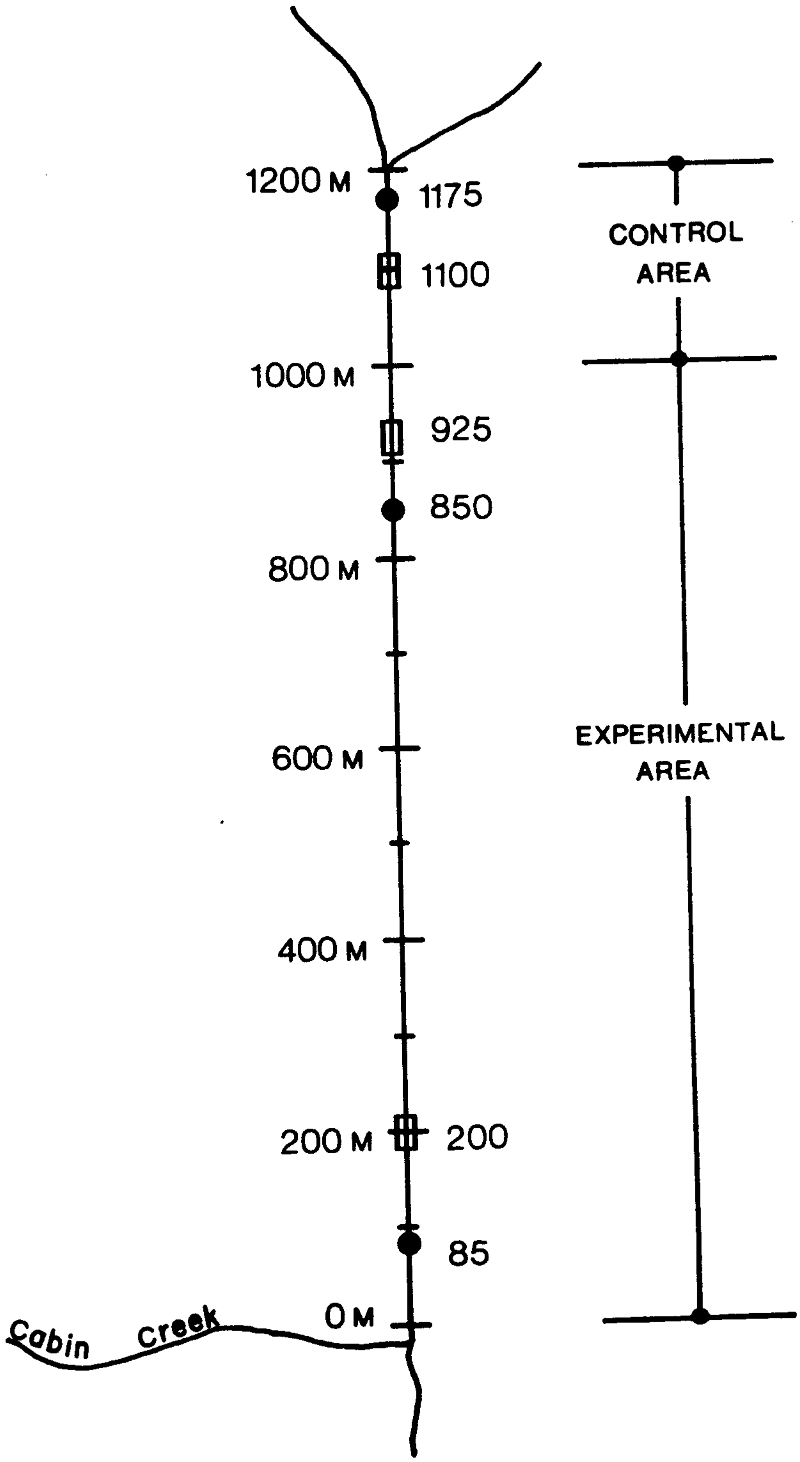


Fig. 5. Diagrammatic representation of upper Bear Creek indicating locations of stations for sampling benthos (●) and chironomid emergence (▥).

sites 1 and 4 were at the stream margins and sites 2 and 3 were in the middle of the stream.

All rocks, gravel, and sand within the cylinder were removed to a depth of 5 cm (i.e., to the lower edge of the cylinder). During analysis the gravel was washed through a series of eight Tyler sieves with the following square-mesh openings: 53.8 mm, 26.9 mm, 13.5 mm, 6.73 mm, 3.36 mm. 1.68 mm, 0.84 mm, and 0.42 mm. The volume of material retained by each sieve was measured in a water volume displacement flask and recorded. The percentage of the total volume of the sample retained and passed by each sieve was determined. Classification of particle size follows Cummins (1962). The phi system (the negative natural log of the particle size in millimeters) was utilized to simplify the presentation. Substrate samples were not taken in the Clearwater River streams.

Detrital Input

Detrital input in Bear Creek was sampled at approximately monthly intervals with 25 1.0-m^2 litter traps randomly placed in the stream, 1.0 m above the substrate. Twenty litter traps were located in the treatment zone and five in the control zone. Litter fall was collected from 4 February 1978 to 12 December 1978, and from 11 April 1979 to 14 November 1979.

Litter samples were dried at 60°C for 24 hr, weighed and sorted into 1) needles, 2) leaves, 3) alder catkins, 4) twigs, 5) cones, and 6) moss.

Algae[2]

Primary production and periphyton biomass was measured in the spring and summer of 1978 and 1979 at station 100 (treatment zone) and at station 1100 (control zone). Primary production was measured by the enclosed-chamber technique (Hansmann et al. 1971) and periphyton biomass, expressed as Chlorophyll a, was sampled by scraping naturally colonized stones and rocks.

Chironomidae Species Composition and Emergence

The taxonomic composition and emergence patterns of the Chironomidae were investigated by collecting pupal exuviae. All chironomid species emerge at the water surface and the exuviae remain trapped in the surface film. Thus, the composition of the surface drift is an accurate quantitative representation of the actual emerging species. Because of their relatively easy collection, slide preparation and identification, examination of pupal exuviae is a valuable method for the assessment of environmental factors affecting local chironomid populations. The value of using chironomid pupal exuviae for comparative faunistic studies was first recognized by Thienemann (1910) and has recently been used in numerous emergence studies in lotic ecosystems (Coffman 1973; Wartinbee and Coffman 1976; Wilson and McGill 1977; Wilson and Bright 1973; Wilson 1977; Wartinbee 1979).

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[2] William J. Foris, personal communication.

Emergence Channels--Bear Creek

Quantitative assessment of chironomid emergence was determined using channels (Wartinbee and Coffman 1976). Two adjacent channels (Fig. 6) enclosing 1.0 m^2 each, were installed in three riffles (Fig. 5); the first in the lower end of the treatment section (200 m), the second at the upper area of the treatment section (925 m), and the third channel was in the control section (1100 m).

Each riffle in the treatment zone (200 m and 925 m) represented a different combination of expected effects. Station 925, located 75 m downstream from the control zone, represented an area unaffected by substantial increases in water temperature but perhaps highly influenced by increased duration and intensity of light. Station 200, located 800 m downstream from the control zone was highly influenced by increased temperature and by increased duration and intensity of light. Station 1100, was the control.

Channels were installed in late February or early March and allowed to colonize for at least one month prior to sampling. The channels could not be maintained in the stream year round due to large storm events. In February 1979 the channel at station 200 (Fig. 5) was moved approximately 3 m from the site used in 1978 as the riffle dried up.

Each channel was enclosed laterally by wooden side boards and sealed at the upstream and downstream ends with large nets (Fig. 6). A long center board (B) separated each channel so that concurrent samples could be taken. The bottom edges of all boards were set approximately

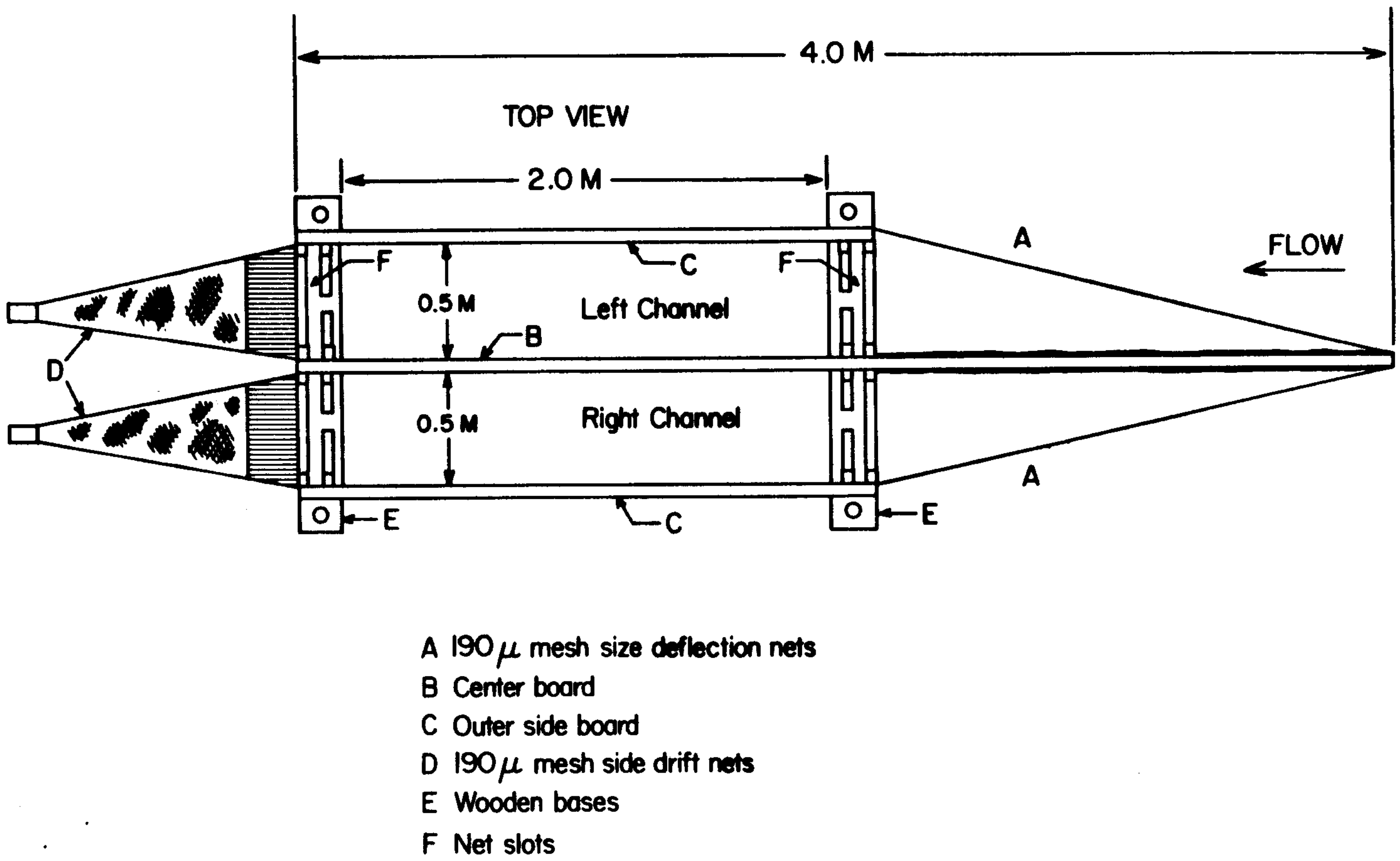

Fig. 6. Chironomid emergence channels.

5 cm into the substrate. The underneath edges of the outer side boards (C) were fitted with strips of foam rubber to prevent leakage. The channel walls were held in place by attachment to wooden bases (E) that had been buried into the substrate and secured with reinforcing bars. Gravel and large rocks were built up around the outer side boards to reduce the flow of water along the lateral walls. The outer side boards and the center board extended approximately 30 cm above the substrate. Leakage was tested for (inside and out) using blue dye.

Triangular front nets (A), approximately 2 m long, 30 cm high, 50 cm wide were used at the opening of the channel. The outer and bottom panels of each net were constructed of 190-μ mesh; however, the inner panel (adjacent to the center board) was constructed of canvas. The outer, bottom, and inner panels were attached to a canvas collar containing a 50 cm x 30 cm rectangular metal bar which fitted into slots (F), designed to hold the nets upright and ensure a tight fit. The front edge of each net wrapped around the leading edge of the center board to prevent leakage.

At the downstream end of each channel, 1.5 m-long drift nets (D) collected drifting material. These nets were also attached to a canvas collar containing a 50 cm x 30 cm rectangular metal bar and were fitted into slots.

In operation the deflection nets were securely fitted into the slots at the upstream opening of the channels and extraneous exuviae which may have entered the channels prior to installation were allowed to drift out for 3-5 min before the drift nets were positioned. All material drifting within the enclosed channels was allowed to accumulate for 24 hr. There is the possibility that some "edge" effect along the inside walls of the channels may have influenced emergence rate; however, Wartinbee and Coffman (1976) considered this to be insignificant. At the end of the collection interval, the drift nets were removed and all collected material was emptied into jars and preserved in 70% ethanol. After the drift nets had been removed and cleaned, the front nets were removed so that normal stream flows could enter the channels.

Pupal exuviae were sorted from the residual debris with the aid of a binocular microscope. All exuviae were then mounted on microscope slides in Euparol. Each exuviae was situated on the slide so that the abdomen and thorax were positioned dorsal side upward to expose the morphological characteristics for identification (Coffman 1973).

All slide mounted pupal exuviae were examined with a compound microscope and identified using the keys of Soponis (1977) and Coffman (unpublished, personal communication). Initial identifications of exuviae were confirmed by W. P. Coffman (Univ. of Pittsburgh) and each "type" specimen was placed in a reference collection to verify that the identification process was consistent.

Emergence in Clearwater River Streams

Qualitative assessment of the chironomid emergence in Octopus "B" tributary, Christmas Creek and Honor Camp Creek (Fig. 3) was also based on the collection of pupal exuviae. No emergence channels were installed in these streams; instead, drift nets, the same dimensions and mesh size as those used in Bear Creek, were mounted into wooden frames which had been secured to the substrate in each stream. The nets extended from the stream bottom to above the surface. The sampling location was in midstream at the downstream end of a riffle.

The drift nets were positioned in the streams near midday and allowed to accumulate drifting material for 24 hr. At the end of the collection interval, the nets were removed and all collected material was emptied into jars and preserved in 70% ethanol. Samples were processed similar to those from Bear Creek.

Sampling Schedules

Emergence investigations in Bear Creek began on 4 April 1978 and ended on 2 November 1978. Sampling at station 200 was delayed until 25 April 1978 due to high flows in early April. Station 925 was not sampled during August 1978 because of leakage problems.

In 1979, sampling began on 4 April and ended on 15 October. Sampling at station 200 was terminated at the end of August because of channel dislodgement.

No regular sampling schedule was established in Bear Creek in 1978 or 1979 because of the irregular nature of high water conditions. An effort was made, however, to take collections at least 2 to 3 times per month.

Because of the irregular sampling schedule and differences in starting and ending timing of sampling, comparisons of chironomid emergence during the early (April) and latter (August-October) parts of the year may not be directly comparable. However, samples taken during the major emergence season (May-August) are comparable among stations and between years since they incorporate the majority of the chironomid species and numbers of individuals. Furthermore, overall emergence during April in both years was minor. Total chironomid emergence averaged 4.1% of the total emergence in April 1978 and 2.1% in 1979. Failure to collect emergence data during August-October 1978 (station 925) and during September-October 1979 (station 200) caused substantial omissions in emergence numbers. Approximately 25% of the total emergence was missed at station 925 (based on emergence data collected at stations 200 and 1100) in 1978 and about 10% was lost at station 200 in 1979.

The sampling schedule for the Clearwater River streams was also irregular, primarily because of distance from Bear Creek and discharge level limitations on the drift nets.

Emergence investigations were initiated in Octopus "B" tributary on 12 July 1978 and ended on 22 September 1979; Christmas Creek was sampled from 23 August 1978 to 22 September 1979; and Honor Camp Creek sampling began on 15 August 1978 and ended on 22 September 1979. Samples were taken in each stream at approximately monthly intervals.

Chironomidae Larvae

Sampling Device

Benthos samples were taken only in Bear Creek and collections were made with a Neill cylinder (Neill 1938). The cylinder (Fig. 4) samples an area of 1,000 cm^2. The 0.233 mm mesh size trailing net (I) is secured with a zipper to a nylon collar that is fastened to the cylinder rear opening flange (F).

The Neill cylinder is operated by rotating the cylinder into the substrate until the projecting flange (A) contacts the substrate surface. The front and rear doors (D and E, respectively) are opened and the larger enclosed stones are scrubbed in the mouth of the net and visually inspected for attached organisms. Then the doors are closed and the remaining gravels and sands disrupted to a depth of 10 cm (i.e., 5 cm below the lower edge of the cylinder) with a metal probe. The doors are again opened, causing all organisms to be flushed into the trailing net. This procedure was repeated three times. The contents of the trailing net were preserved in 70% ethanol.

Sampling Stations and Schedule

Three riffles in Bear Creek, two in the treatment zone (85 and 850) and one in the control zone (1175), were selected for study (Fig. 5). The benthos riffles, located near the emergence channels, were selected for reasons similar to those previously outlined for the emergence channels (i.e., each represents an area in the stream expected to be influenced by a different combination of effects due to canopy removal).

An effort was made to select riffles that were relatively similar as to width, depth, current velocity, and bottom type.

Within each riffle, four replicate samples were taken along a transect perpendicular to the stream. Sampling points 1 and 4 were at the stream margins and points 2 and 3 were in the middle.

Benthos was sampled monthly from January 1978 to December 1979. Only the samples from March-October were processed for each year due to the time-consuming nature of sorting.

Laboratory Processing and Statistical Analysis

Larvae in each sample were sorted into two taxonomic groups (i.e., chironomids and non-chironomids), measured for total length and enumerated with the aid of a binocular microscope fitted with an ocular micrometer. Size categories for chironomid larvae were: 0-3 mm, 3-6 mm, and 6 mm and above. The last two categories were later combined into one (i.e., 3 mm and above), since very few larvae occurred in the larger category. The non-chironomid size categories were: 0-3 mm, 3-6 mm, 6-9 mm, 9-12 mm, and 12 mm and above. The last three categories were combined into one category (i.e., 6 mm and above) to simplify analysis.

Biomass estimations (wet weight) were made for both groups. All individuals within each size category were filtered to remove surface water, transferred to a tared weighing pan and weighed to the nearest .1 mg on a Mettler electronic balance.

The spatial distribution of the larval benthic population was tested for dispersion characteristics and independence of variance (Elliott 1971). These tests indicated that the dispersion of the benthic populations was contagious (i.e., the variance was greater than the mean). Therefore, these data along with weight estimations were transformed to logarithms in order to stabilize the variance and avoid problems of non-normality.

Statistical analysis of population densities and biomass data was accomplished using two-way and three-way analysis of variance (ANOVA). Two-way ANOVA programs were used to test within year differences due to the effects of station (85, 850, 1175) and sampling date. Three-way ANOVA programs were used to test between year differences due to the effects of station (85, 850, 1175), sampling date and year (1978, 1979).

RESULTS

Water Temperature

Bear Creek

Mean monthly water temperature profiles for the lower treatment station (100) and control station (1125) showed that despite the high degree of similarity in the curves, station 100 was usually warmer than station 1125 (Fig. 7).

In 1977 and 1978 water temperature at both stations exhibited the largest rate of increase in May, but in 1979 (post-treatment) maximum increase in water temperature occurred in March. Water temperature peaked in August in all years. Maximum water temperature at stations 100 and 1125 were nearly the same prior to canopy removal (1977, 1978), however after canopy removal (1979) water temperature maxima were 3.6^{o}C warmer (Table 3) in the treatment zone (17.3^{o}) than in the control zone (13.7^{o}C). Warmer water temperatures were also sustained longer in the treatment zone (station 100) after canopy removal. For example, a mean temperature of 14.0^{o}C or warmer was maintained for 29 days at station 100 after canopy removal (1979) whereas the control station (1125) never reached a mean temperature of 14.0^{o}C in 1979. Water temperatures exhibited the greatest rate of decline from September to October during all three years.

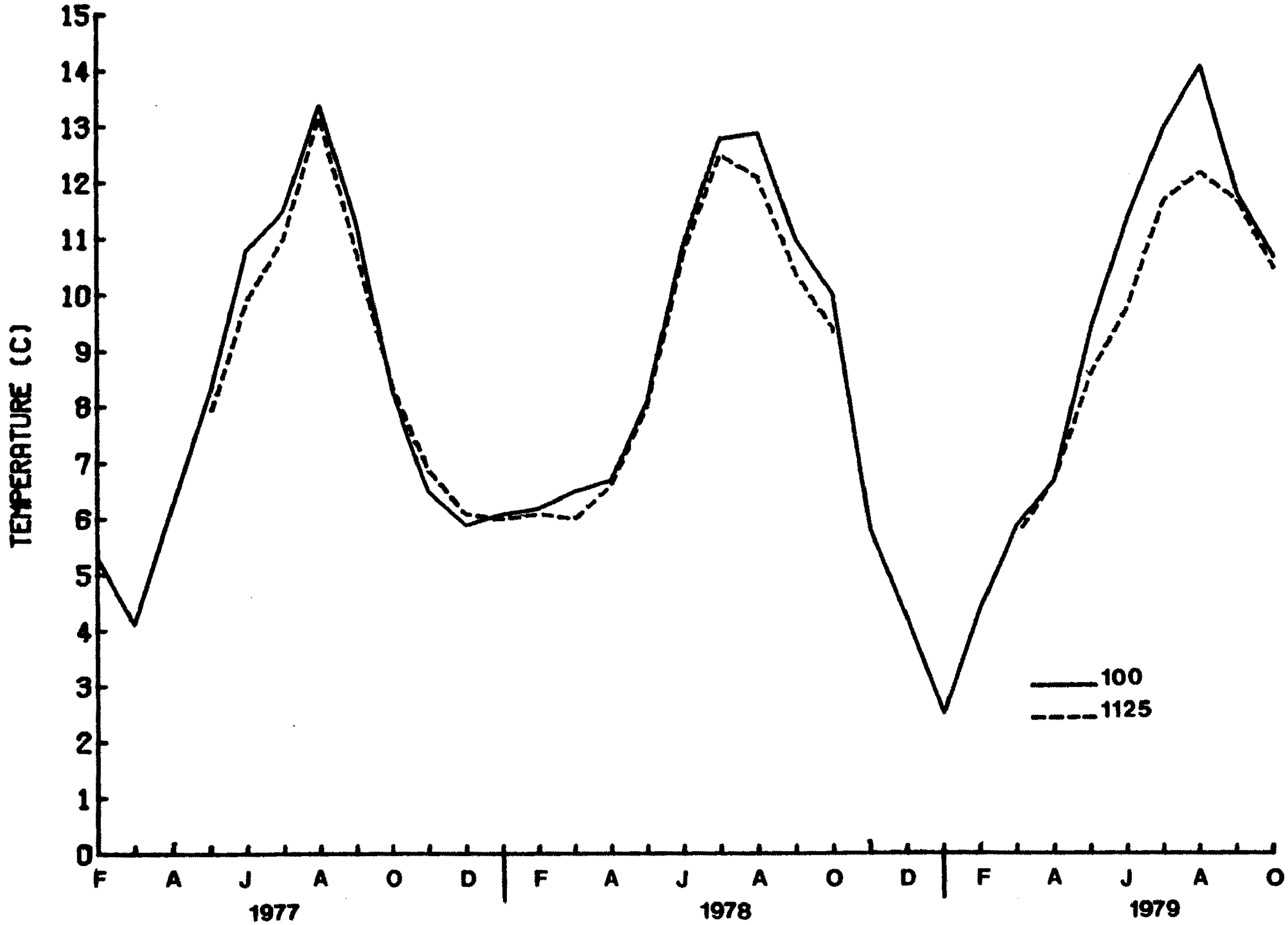

Fig. 7. Mean monthly water temperature at stations 100 and 1125 (control) from February 1977 to October 1979, Bear Creek. Points were not connected during periods when the thermograph functioned improperly.

Table 3. Maximum water temperatures at stations 100 and 1125 during 1977, 1978, and 1979 in Bear Creek.

Year	Maximum temperature (°C)	Date of maximum temperature	Number of days with a mean temp. of ≥ 14.0°C
Station 100			
1977	14.8	17,18 August	9
1978	15.6	10 August	8
1979	17.3	18 July	29
Station 1125			
1977	14.9	17 August	5
1978	14.6	22,23 July	3
1979	13.7	19 July	0

After canopy removal, weekly mean temperatures in the treatment zone (100), from May to August, were significantly higher (ANOVA, $p < 0.05$) than in the control zone (1125).

Total yearly accumulated degree-days were greater at the control zone and treatment zone in 1978 than in 1979 (post-treatment) and the treatment zone (100) was consistently higher than the control zone (Fig. 8). In the spring and summer (March-August) of 1979 there was a distinct difference in accumulated degree-days between sites (Fig. 8b). During this interval station 100 accumulated approximately 190 more temperature units than station 1125 (1865.3 and 1675.4 degree-days at stations 100 and 1125, respectively). Total yearly degree-days however, did not increase dramatically after canopy removal because the higher summer temperatures were buffered by cooler winter temperatures (<u>see</u> Fig. 7). By the first of June total degree-days represented 32% of the total yearly degree-days in 1978 and about 28% after canopy removal (1979). However, by the end of August total degree-days represented about 66% of the total yearly degree-days in 1978 and 1979.

Clearwater Streams

Mean monthly water temperature profiles for Octopus "B" tributary, Christmas Creek and Honor Camp Creek from September 1978 to September 1979 (Fig. 9) indicate that the streams most exposed to direct solar radiation, Christmas Creek, Octopus "B" Tributary, and Bear Creek (station 100), exhibited the highest temperatures, especially from May through September. In contrast, Honor Camp Creek, the only stream with

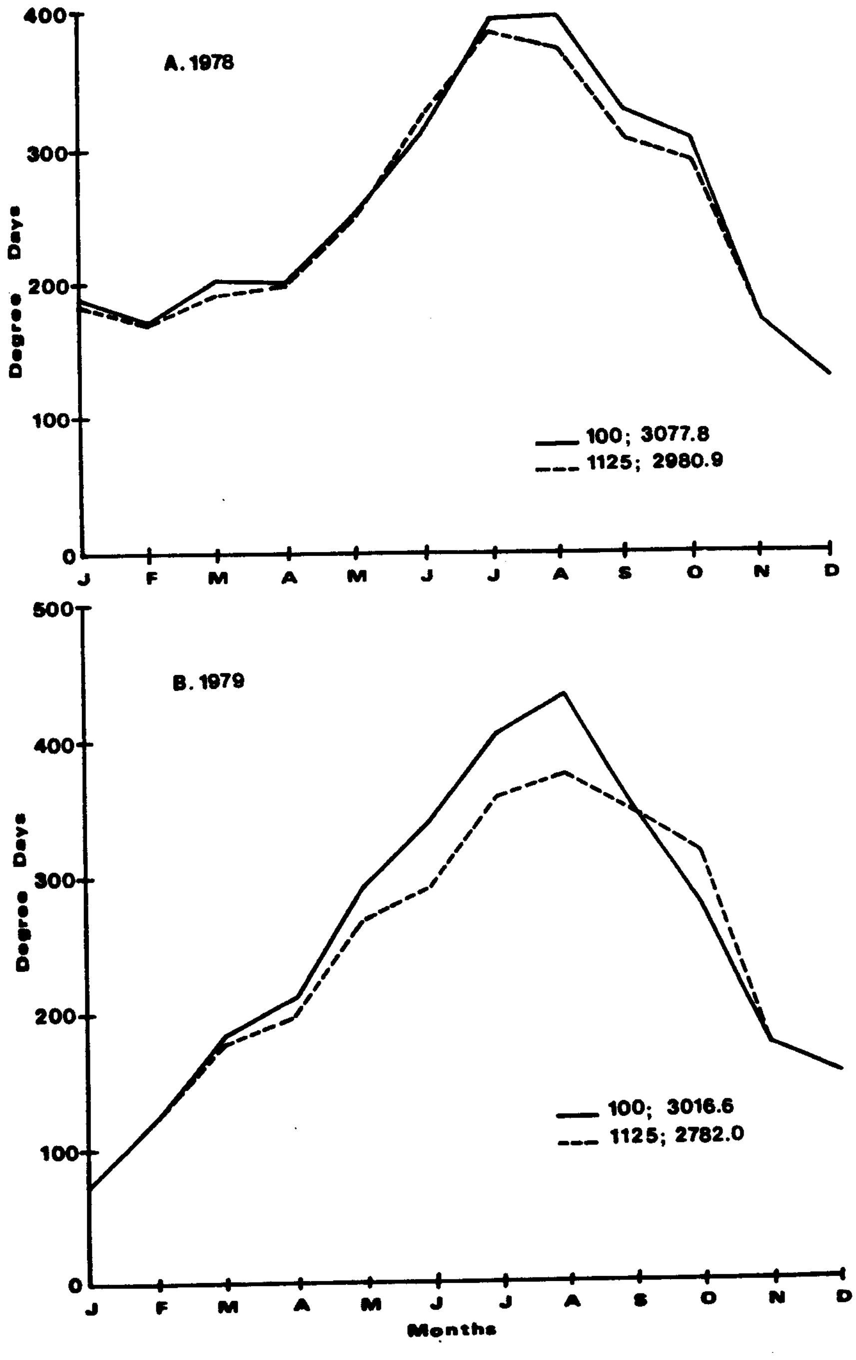

Fig. 8. Heat budget curves for stations 100 and 1125 in Bear Creek during 1978 and 1979. Total accumulated degree days are shown immediately next to each station.

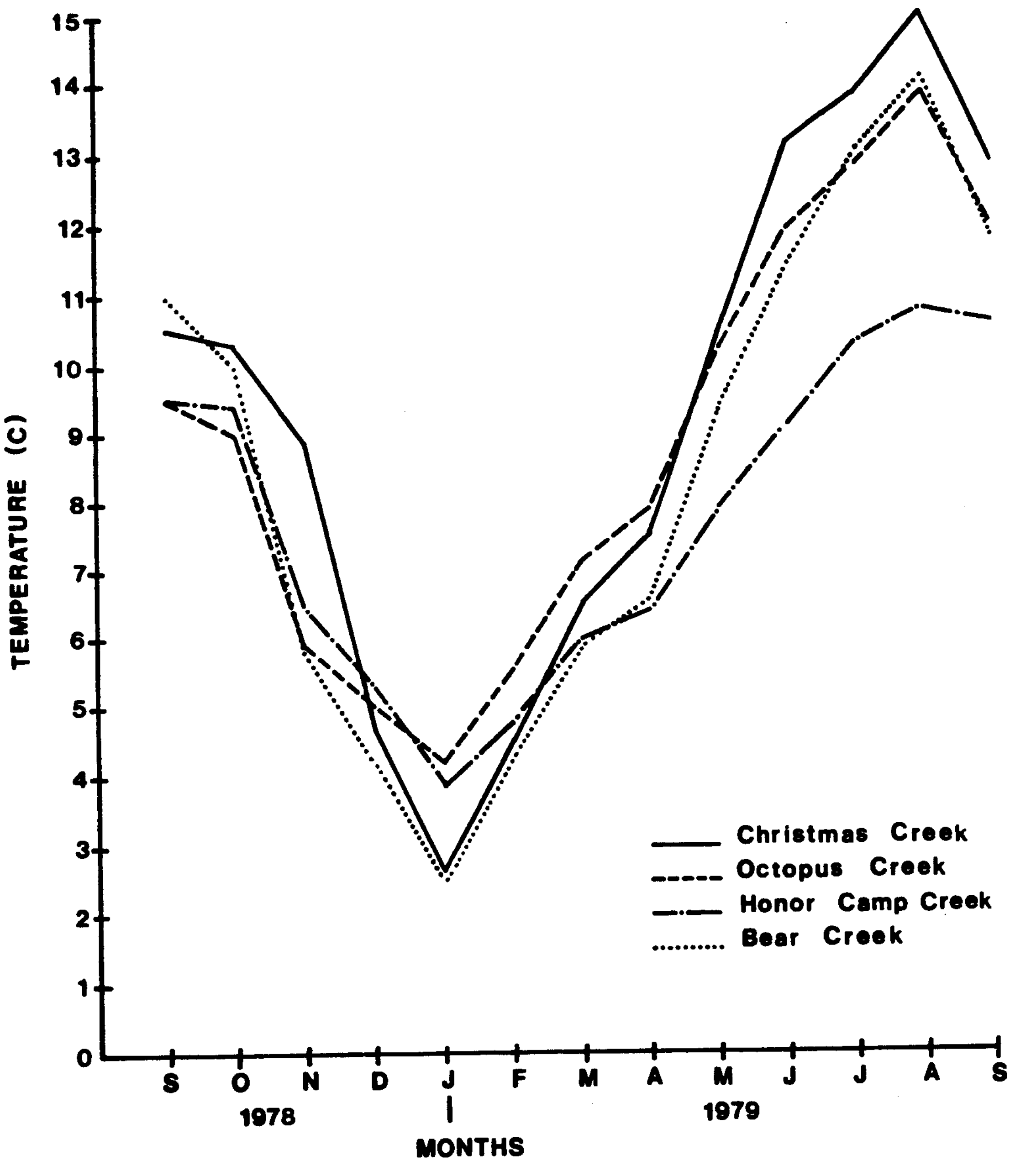

Fig. 9. Mean monthly water temperatures in Christmas Creek, Octopus "B" tributary, Honor Camp Creek, and Bear Creek (station 100) from September 1978 to September 1979.

a canopy, was very much cooler during this interval. Bear Creek (station 100) and Christmas Creek exhibited the greatest annual fluctuation in water temperature (11.6 and 12.5°C, respectively) while Honor Camp Creek had the least fluctuation (6.9°C).

Total accumulated degree-days in each stream reflected the pattern shown for mean monthly temperature (Fig. 10). Christmas Creek had the highest accumulation of degree-days (3322.9), based on data from October 1978 through September 1979, and Honor Camp Creek the fewest (2787.3); Octopus "B" tributary (3226.8) and Bear Creek (3021.3) were intermediate (Appendix Table 25).

Solar Exposure

Prior to canopy removal direct solar exposure was limited at most sites to specific times of day. Sites 50, 400, 575 and 675 were restricted to solar exposure only before noon, whereas other sites (e.g., 125, 475 and 1100) were exposed to direct sunlight only in the afternoon (Fig. 11). Generally, most sites were exposed to direct sunlight between 11:00 and 2:00 prior to canopy removal, and between 10:00 and 4:00 after canopy removal. The overall effect of the treatment was to expose the stream to direct sunlight earlier in the morning and to maintain the exposure longer in the afternoon.

The number of hours of solar exposure in the entire treatment zone was substantially greater after canopy removal. Exposure time, based on a sun track altitude for 21 July, averaged 3.4 hr prior to canopy removal and 7.4 hr after canopy removal (Martin et al. 1981). Only one site

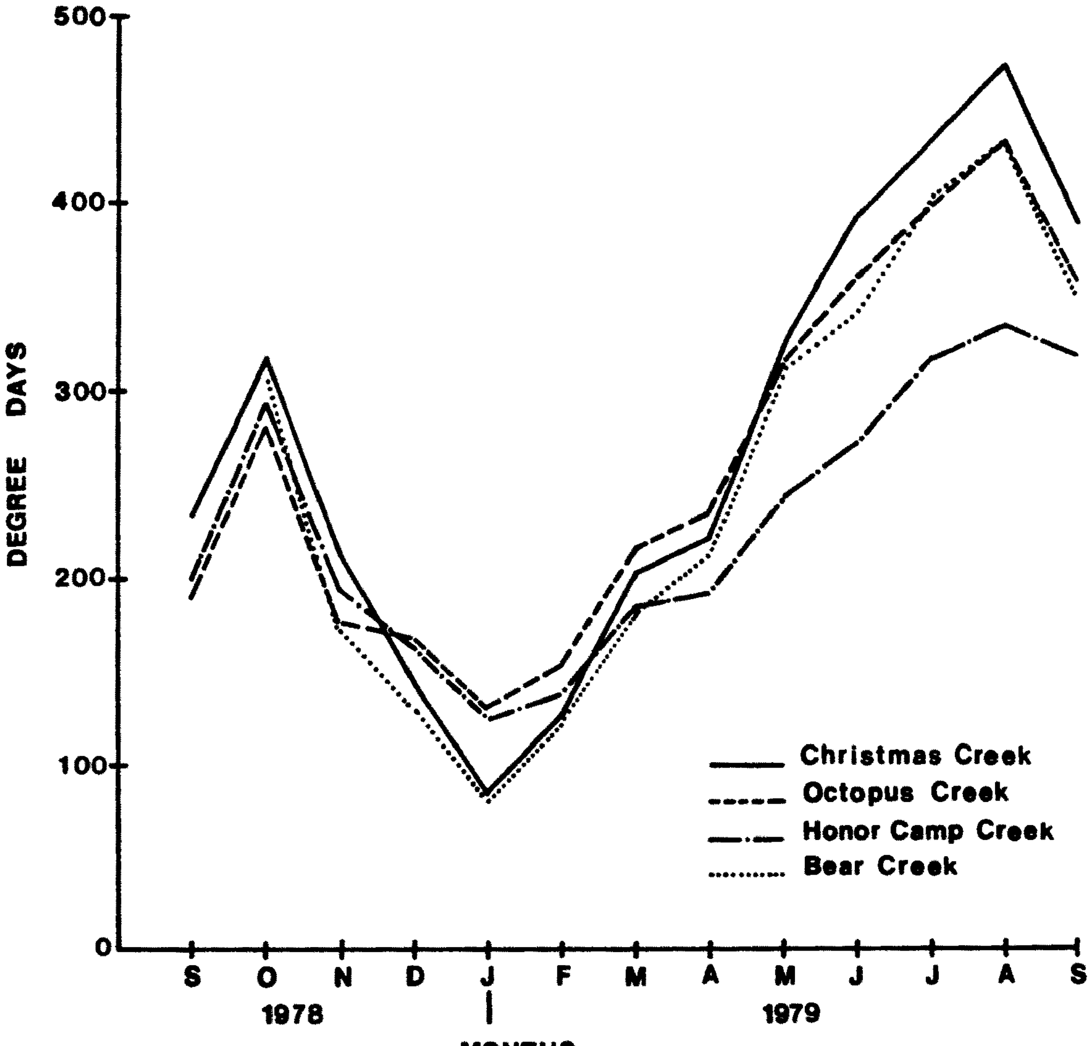

Fig. 10. Heat budget curves for Christmas Creek, Octopus "B" tributary, Honor Camp Creek, and Bear Creek (station 100). Degree days during September 1978 were calculated from the 10th day of the month.

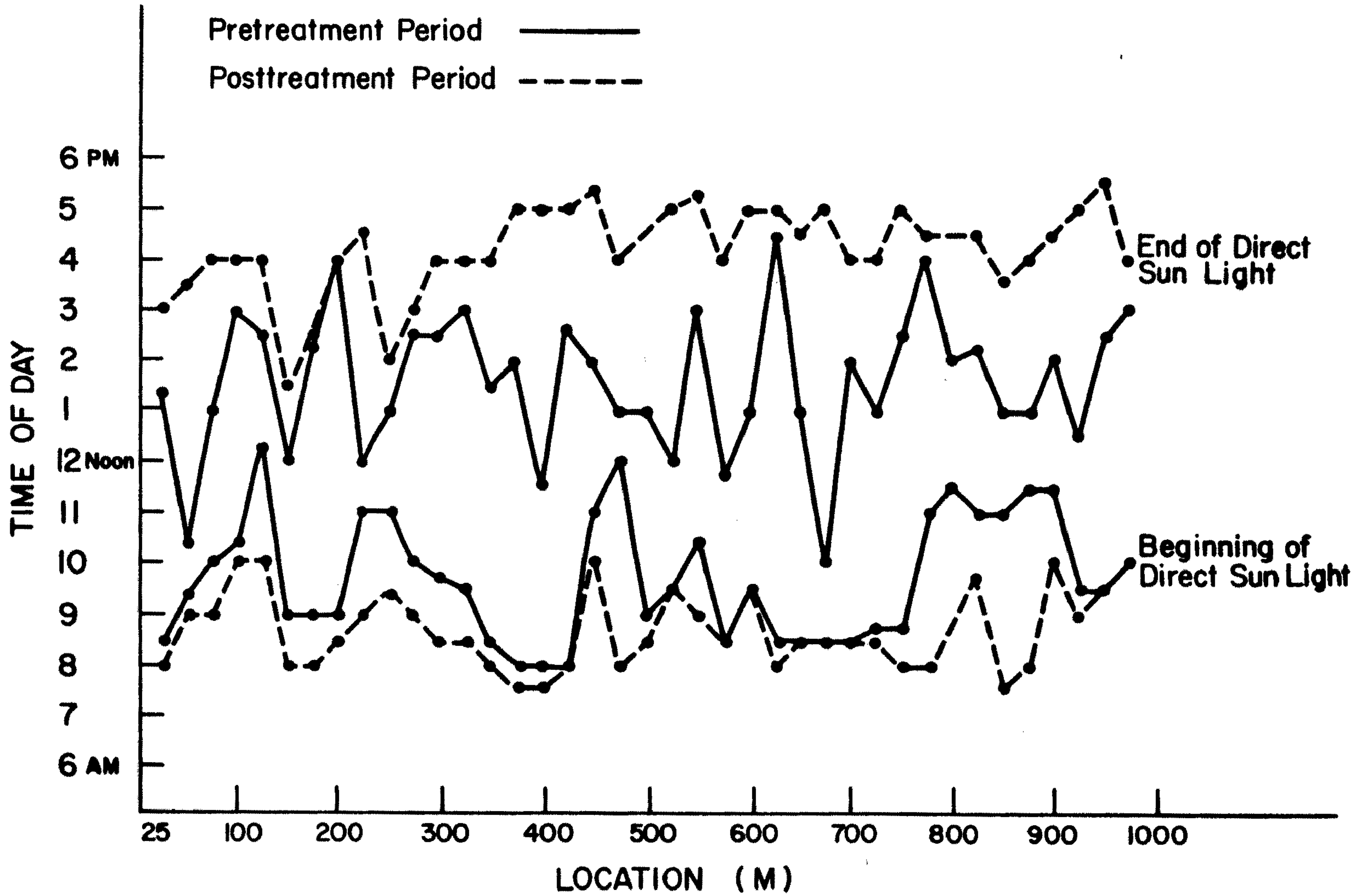

Fig. 11. Timing (beginning and end) of direct solar exposure in the treatment zone in Bear Creek, before (—) and after (---) canopy removal, based on fisheye canopy densiometer photographs taken at 25-m intervals (unpublished data, Martin et al. 1981).

(625) was exposed to direct sunlight for 6 hr before canopy removal, but after canopy removal all but two sites (150 and 250) were exposed for 6 hr or more (Fig. 12). The greatest increase in exposure time of any site occurred at 475. Before canopy removal 475 was exposed to direct sunlight for only 1 hr (12:00-1:00); after treatment it was exposed for 8 hr (8:00-4:00), a 700% increase in exposure time.

The benthos (85, 850) and emergence (200, 925) stations in the treatment zone were very similar in terms of hours of exposure to direct sunlight after canopy removal (Table 4). They did differ, however, in relative percentage increase in exposure. The upper treatment stations (850, benthos and 925, emergence) showed a greater increase in exposure than the lower treatment stations (85, benthos and 200, emergence). The degree of canopy shading was probably greater at the upper stations prior to canopy removal.

Discharge

The discharge profile in Bear Creek is a direct function of the frequency and intensity of freshets in the watershed, which generally occur from October to March (Fig. 13). During most of the year discharge was less than 15 cubic feet per second (cfs). Highest mean monthly discharge during the years monitored occurred in the winter of 1977-1978. During this period discharge was less than 5 cfs from April to September, but as the frequency of storm events increased in fall, discharge increased rapidly to over 80 cfs in November and remained high through December. The peak discharge in February 1979 reflects the

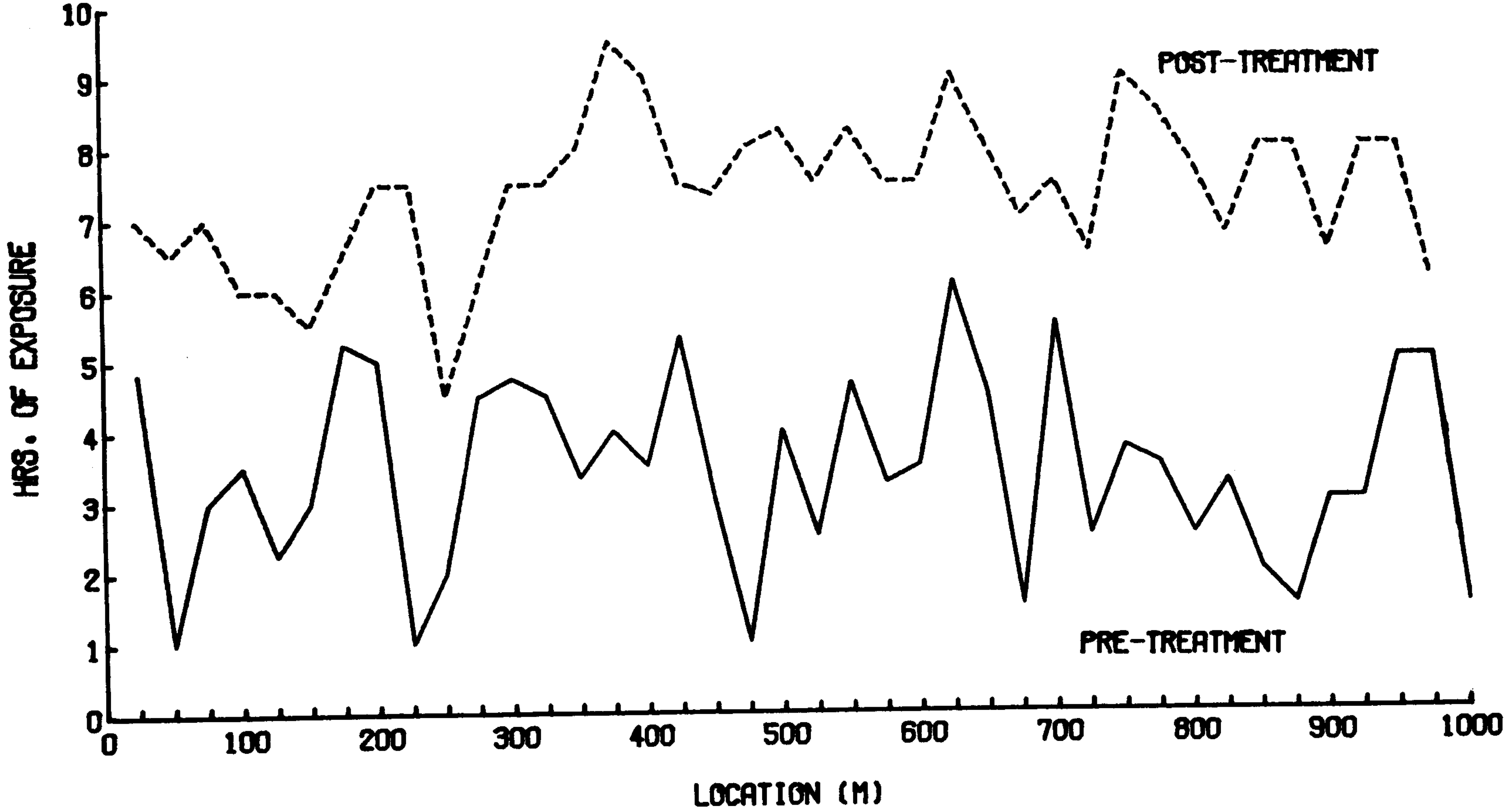

Fig. 12. Total number of hours of solar exposure in the treatment zone during pre-treatment and post-treatment conditions in Bear Creek, based on fisheye canopy densiometer photographs taken at 25-m intervals (unpublished data, Martin et al. 1981).

Table 4. Comparison of hours exposed to direct sunlight and relative percent increase in exposure at the benthos and emergence stations in the treatment zone in Bear Creek prior to and following canopy removal. Start and end times of direct exposure are based on sun altitude data estimated for 21 July (unpublished data, Martin et al. 1981).

Sampling station	Pre-treatment Direct exposure Start	Pre-treatment Direct exposure End	Pre-treatment Exposure hrs.	Post-treatment Direct exposure Start	Post-treatment Direct exposure End	Post-treatment Exposure hrs.	Relative % increase in exposure
Benthos							
85[1]	10:00	1:00	3.0	9:00	4:00	7.0	133.33
850	11:00	1:00	2.0	7:30	3:30	8.0	300.00
Emergence							
200	9:00	4:00	5.0[2]	8:30	4:00	7.5	50.00
925	9:30	12:30	3.0	9:00	5:00	8.0	166.67

1 No measurement was made at site 85, data at site 75 are used instead.

2 An overhanging branch effectively blocked out direct sunlight at this station between 12:30 and 2:30 (2 hrs.); therefore, the number of hrs. of exposure represents the difference between potential direct sunlight (9:00 - 4:00 = 7.0 hrs.) and the 2 hrs. during which direct sunlight was blocked (7.0 hrs. - 2.0 hrs. = 5.0 hrs. exposure).

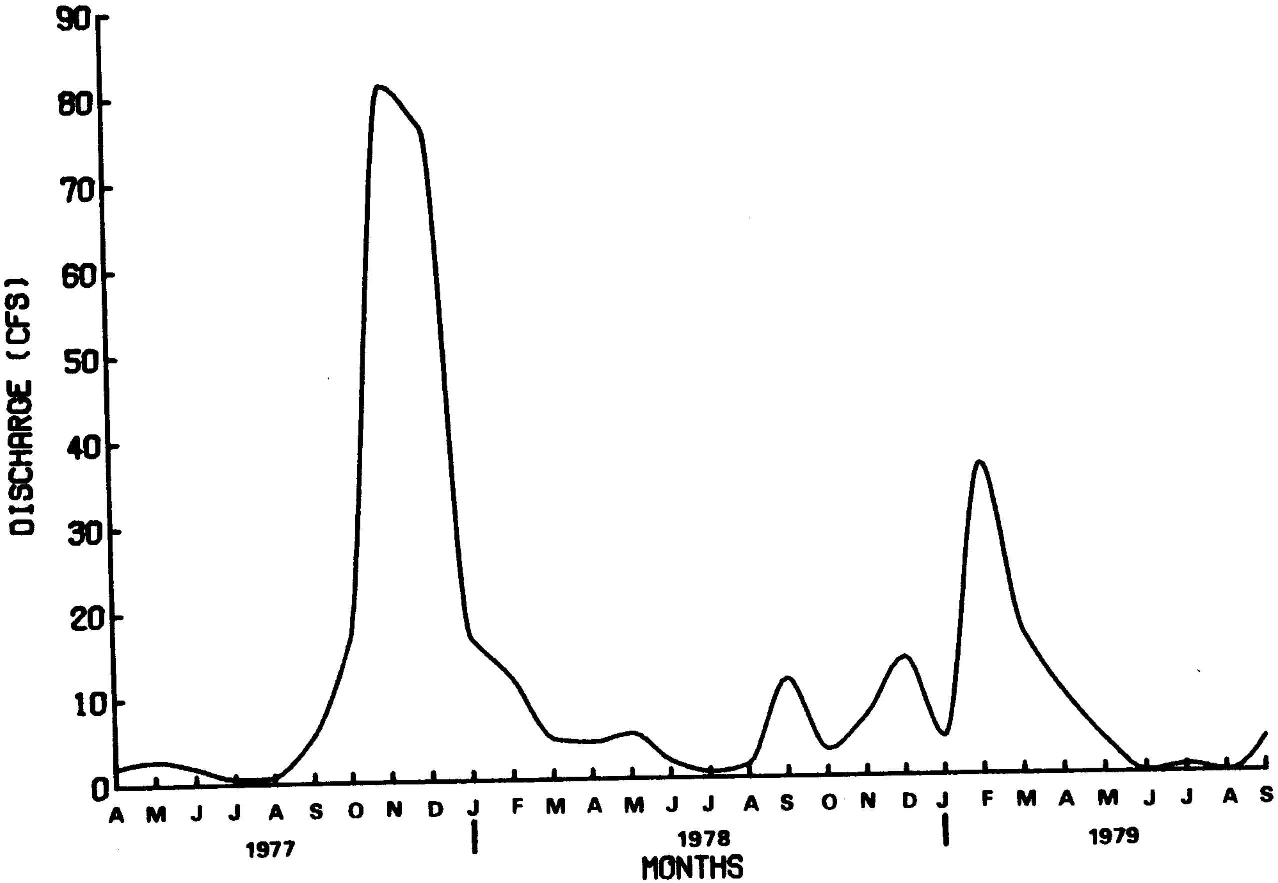

Fig. 13. Mean monthly discharge in Bear Creek from April 1977 to September 1979.

storm events that occurred in the Bear Creek watershed during the tree-felling operations.

The use of mean monthly discharge data conceals shorter-term fluctuations in discharge and masks the significance of individual storm events. For instance, a storm event during a 6-day period in 1977 (October 28-November 3) resulted in discharge levels consistently above 100 cfs, and a later storm during mid-December (December 10-15) resulted in discharge levels near 200 cfs.

Substrate Particle Size

Analysis of substrate particle size was made at the three benthos stations (85, 850 and 1175) in Bear Creek on 13 September 1978 and 4 May 1979.

Substrate particle curves, determined by volumetric analysis, in 1978 and 1979 are shown in Fig. 14. All of the curves are of the same general shape with peaks at either phi -5 (26.9 mm) or phi -6 (53.8 mm), in the cobble-small rock range.

Station 850 showed the greatest change of the three stations between the two years. Larger percentages of pea-size gravel (phi -4) and small rock (phi -6) occurred at station 850 in 1979 while cobble-size particles (phi -5) decreased substantially. Station 85 showed a similar increase in small rock particles but decreased in percentage of pea-size gravel. Station 1175 (the control station) exhibited the least change

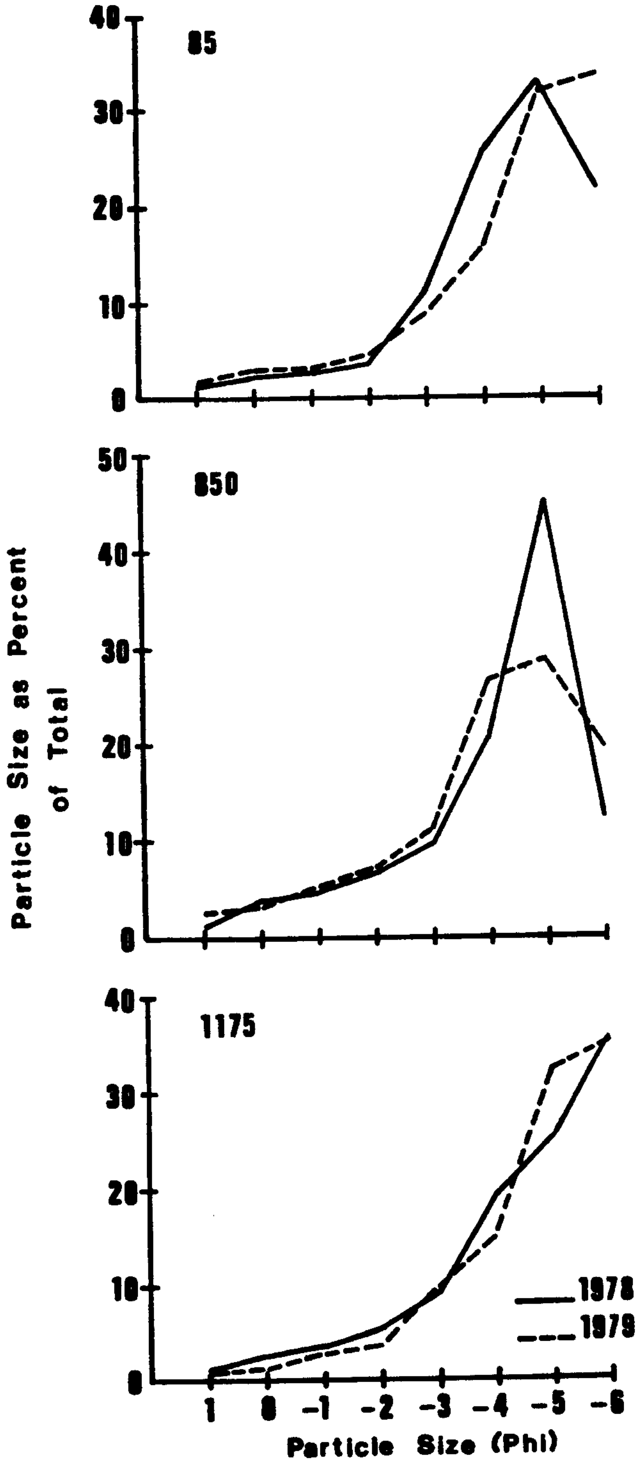

Fig. 14. Substrate particle size, as percent of total, at the benthos stations (85, 850, and 1175) in September 1978 and May 1979.

of any station between 1978 and 1979 and was the only station which increased in percentage of cobble-size particles.

Detrital Input

Particulate organic matter was collected in Bear Creek from February through December. No samples were taken in January. Lowest input occurred in early spring and highest input from July to October (Table 5). Dry weight estimates in the experimental section ranged from 0.19-1.44 g/m^2/day in 1978 (pre-treatment) and from 0.19-0.99 g/m^2/day after canopy removal (1979). A similar seasonal pattern was found in the control zone. Dry weight estimates ranged from 0.24-1.59 g/m^2/day in 1978 and from 0.37-1.70 g/m^{2}day in 1979.

Particulate organic matter input to the 1000-m experimental section in 1978 (9 March to 12 December) was estimated from the total input data. A streambed area of 6,886 m^2 was utilized in the calculations. Total input was calculated to be 1,351.11 kg (192.21 g/m^2) of which 49% was leaves, 38.8% needles, and each of the remainder accounted for less than 5.0% of the total (Table 6). In 1979, after canopy removal, the total input was 785.41 kg (114.06 g/m^2) of which 66% was leaves, 24% needles and the remainder accounted for no more than 6% of the total input. In the control zone total input was similar for both years (261.32 kg in 1978 and 217.74 g in 1979). Needles accounted for 32.0% and 37.1% of the total input in 1978 and 1979, respectively, and leaves accounted for 45% of the total in 1978 and 55% in 1979.

Table 5. Estimated dry weight of particulate organic matter entering the experimental section (streambed area = 6,886 m^2) and control section (streambed area = 1,144 m^2) of Bear Creek from 2 February 1978 to 12 December 1978 (284 days) and from 11 April 1979 to 14 November 1979 (218 days) (unpublished data, Martin et al. 1981).

			Experimental section (1000 m)			Control section (200 m)			Total stream (1200 m)		
	Date	No. days	Kg	g/m^2	$g/m^2/d$	Kg	g/m^2	$g/m^2/d$	Kg	g/m^2	$g/m^2/d$
1978	2/04- 3/09	36	49.37	7.17	.19	9.72	8.50	.24	59.09	7.36	.20
	3/09- 4/12	34	110.25	16.01	.47	32.95	28.80	.85	143.20	17.83	.52
	4/12- 5/16	34	68.72	9.98	.29	12.24	10.70	.31	80.96	10.08	.29
	5/16- 6/14	29	84.87	12.33	.43	13.57	11.86	.41	98.44	12.25	.42
	6/14- 7/17	33	111.14	16.14	.49	27.23	23.80	.72	138.37	17.23	.52
	7/17- 8/14	28	164.50	23.89	.85	37.39	32.68	1.17	201.89	25.14	.89
	8/14- 9/13	30	283.20	41.13	1.37	38.19	33.38	1.11	321.39	40.02	1.33
	9/13-10/23	40	396.43	57.57	1.44	72.99	63.80	1.59	469.42	58.46	1.46
	10/23-12/12	20	133.50	19.39	.97	25.85	22.60	1.13	159.35	19.84	.99
1979	4/11- 5/08	28	41.24	5.99	.21	17.44	14.10	.50	58.68	7.31	.26
	5/08- 6/16	39	52.61	7.64	.19	17.96	14.52	.37	70.57	8.79	.23
	6/16- 7/11	25	75.19	10.92	.44	19.72	15.94	.64	94.91	11.82	.47
	7/11- 8/07	27	160.17	23.26	.86	27.61	22.32	.83	187.78	23.38	.87
	8/07- 9/05	29	94.13	13.67	.47	24.27	19.62	.68	118.40	14.74	.51
	9/05-10/03	28	192.60	27.97	.99	40.00	32.34	1.16	232.60	28.97	1.03
	10/03-11/14	42	169.40	24.60	.59	88.40	71.46	1.70	257.80	32.10	.76

Table 6. Total estimated dry weight of major vegetative categories of particulate organic matter entering the experimental section (streambed area = 6,886 m^2) and control section (streambed area = 1,144 m^2) in Bear Creek from 9 March 1978 to 12 December 1978 (250 days) and from 11 April 1979 to 14 November 1979 (218 days)[1] (unpublished data, Martin et al. 1981).

Vegetative categories	1978			1979		
	Kg	g/m^2	$g/m^2/d$	Kg	g/m^2	$g/m^2/d$
Experimental section						
Needles	524.30	76.14	0.30	192.33	27.93	0.13
Leaves	662.59	96.22	0.38	517.00	75.08	0.34
Alder catkins	49.30	7.16	0.03	3.03	0.44	0.002
Twigs	62.87	9.13	0.04	44.89	6.52	0.03
Cones	42.69	6.20	0.02	13.64	1.98	0.01
Moss	9.36	1.36	0.01	14.52	2.11	0.01
Total	1351.11	196.21	0.78	785.41	114.06	0.52
Control section						
Needles	83.63	73.10	0.29	80.75	70.59	0.32
Leaves	120.09	104.97	0.42	119.57	104.52	0.48
Alder catkins	33.19	29.01	0.12	3.56	3.11	0.01
Twigs	14.84	12.97	0.05	8.59	7.51	0.03
Cones	5.39	4.71	0.02	3.48	3.04	0.01
Moss	4.18	3.65	0.01	1.79	1.56	0.01
Total	261.32	228.41	0.91	217.74	190.33	0.86
Total input	1612.43	424.62	1.69	1003.15	304.39	1.38

[1]Sample period 2/4-3/9/78 was excluded from the calculations because the litterfall was not separated into vegetative categories.

Algae[3]

The dominant algal species in Bear Creek varied seasonally (Table 7). During the winter and spring, diatoms comprised the greatest proportion of the attached algae; in summer and fall the community consisted primarily of the blue-green algae, *Calothrix parietina*, and the filamentous diatom, *Diatoma*.

Prior to canopy removal, the periphyton community in Bear Creek was predominantly *C. parietina*, which formed large purple mats that covered many rocks and large sections of the substrate. The extent of the *Calothrix* mats in Bear Creek and its presence in other streams in the Clearwater River watershed suggested that perhaps these mats are significant as habitat or a food source for the chironomid fauna. Cursory examination of the mats revealed a large contingent population of chironomid larvae, so in the summer of 1978 the *Calothrix* mats in Bear Creek were sampled quantitatively at two stations (200 and 925) with small circular plastic cups (sampling area = 7.0 cm^2) to determine: 1) the extent to which chironomid larvae used the mats and 2) which species of chironomid utilize the mats.

The mean number of chironomid larvae collected on four sampling dates (Table 8) ranged from a low of 6.4 in June to a high of 31.4 in July. If the mean numbers of larvae in the table are extrapolated to numbers/m^2, the importance of the *Calothrix* mats as habitat for

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[3]Algal data provided by William J. Foris (unpublished).

Table 7. Dominant species of algae in each season in Bear Creek.[1]

Winter	Spring	Summer	Autumn
Achnanthes minutissima	*Gomphonema olivaceum*	*Calothrix parietina*	*Calothrix parietina*
Achnanthes lanceolata	*Navicula salinarium*	*Diatoma hiemale*	*Diatoma hiemale*
Cocconeis placentula		*Melosira varians*	*Gomphonema* sp.
			Navicula sp.
			Melosira varians

[1]William J. Foris, personal communication.

Table 8. Total and mean number of chironomid larvae collected in *Calothrix parietina* mats in Bear Creek in 1978.

	Sampling date							
	27 June		11 July		25 July		1 August	
	200	925	200	925	200	925	200	925
Total number	65	58	152	68	278	238	223	134
Number of samples	10	9	10	9	9	9	9	9
Mean	6.5	6.4	15.2	7.6	31.4	26.4	24.8	14.9
% Size group (mm)								
0-3	44.6	82.8	77.0	81.0	81.0	81.0	76.0	76.0
3 and above	55.4	17.2	23.0	19.0	19.0	19.0	24.0	24.0

chironomids can be readily seen. The abundance, for example, on 25 July would be $44,855/m^2$ at station 200 and $37,712/m^2$ at 925. Small larvae (0-3 mm) were very abundant in the mats, comprising between 44 and 83% of the total chironomid community.

Based on the identification of approximately 300 larvae, 20 species of Chironomidae, distributed within four subfamilies, were found in the *Calothrix* mats (Table 9). Orthcladiinae showed the greatest utilization of the mats, accounting for 80% of the total species.

In 1979 (after canopy removal) *C. parietina* did not occur extensively in either the treatment or control zone. Mat formation was severely reduced and limited to a few isolated areas. Therefore, comparison of chironomid utilization of the mats between 1978 and 1979 was not possible.

Mean algae biomass (chlorophyll *a*; mg/m^2) in 1978 and 1979 was higher in the control zone than in the treatment zone (Fig. 15). In 1979 (treatment year) mean algae biomass was lower in the control zone and treatment zone than in 1978. During the 4-month period April-July the control station (1100) had a mean biomass of 39.7 mg/m^2 in 1978 and 33.5 mg/m^2 in 1979 while the treatment station (100) had a mean biomass of 28.5 and 21.2 mg/m^2 in 1978 and 1979, respectively.

The precipitous decline in algae biomass in March 1979 immediately followed the timber-felling operations and may be related to the large rainstorm which occurred in late February (see Fig. 13). Approximately

Table 9. List of the chironomid species collected in *Calothrix parietina* mats in Bear Creek, based on larval identification.[1]

ORTHOCLADIINAE

Brillia sp.
Corynoneura sp.
Eukiefferiella sp.
Orthocladius (*Orthocladius*) cf. *dorenus*
Orthocladius (*O.*) cf. *carlatus*
Orthocladius (*O.*) cf. *manitobiensis*
Orthocladius (*O.*) cf. *obumbratus*
Orthocladius (*O.*) sp.
Orthocladius (*Euorthocladius*) sp.
Orthocladius (*Eudactylocladius*) sp.
Parakiefferiella sp.
Parametriocnemus sp.
Psectrocladius (*Monopsectrocladius*) sp.
Psectrocladius (*Psectrocladius*) sp.
Thienemanniella sp.

CHIRONOMINAE

Tanytarsini

Tanytarsus sp.
Stempellinella sp.

TANYPODINAE

Conchapelopia sp.

DIAMESINAE

Sympotthastia/Potthastia type

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[1]Larvae were identified by Dr. O. Saether, University of Bergen, Bergen, Norway.

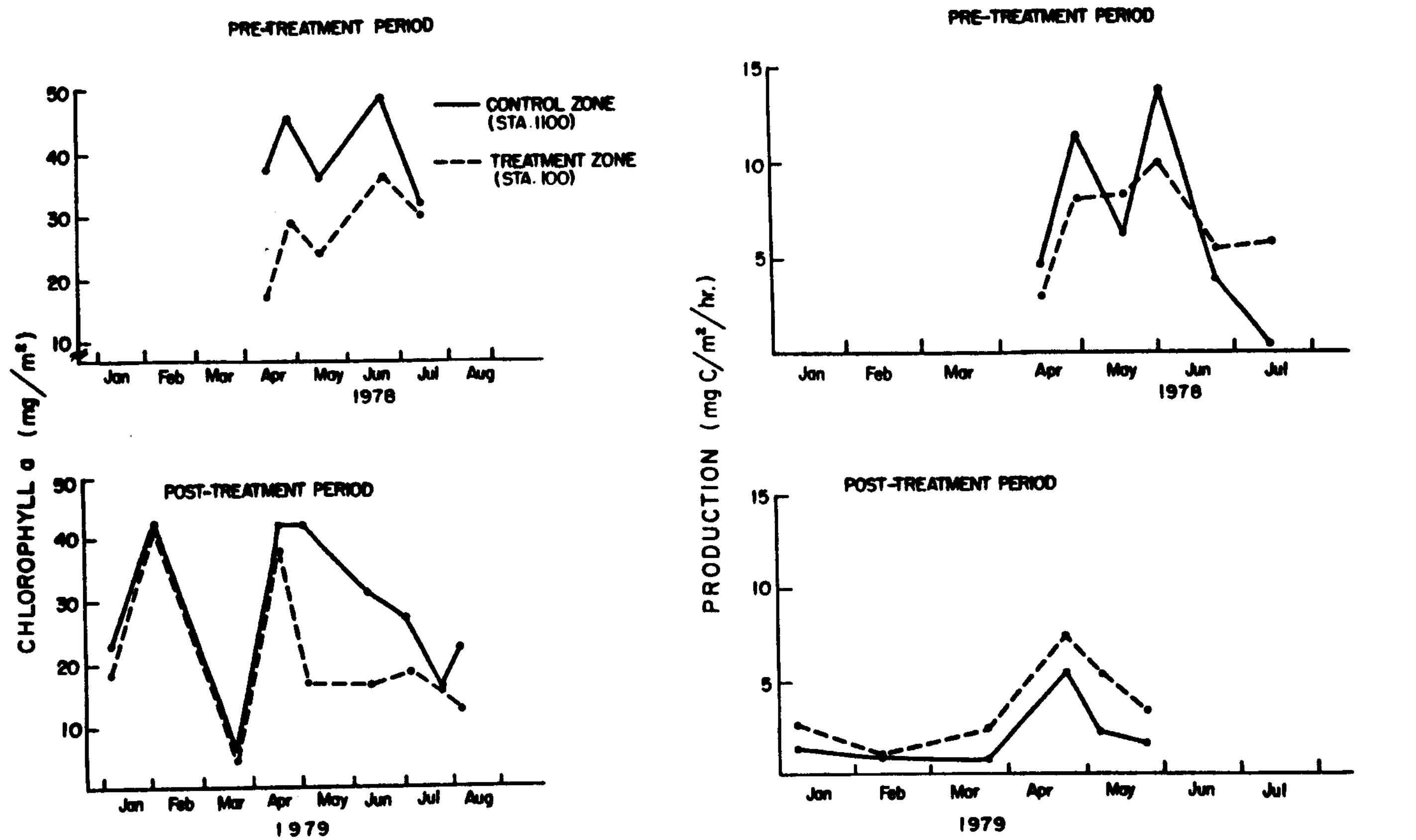

Fig. 15. Algal chlorophyll *a* biomass and net primary production in Bear Creek at station 100 (treatment zone) and station 1100 (control zone), before (1978) and following (1979) canopy removal (W. J. Foris, personal communication; unpublished data, Martin et al. 1981).

one month later, however, both stations reached biomass levels similar to those observed prior to the storm event.

Although primary production (mgC/m^2/hr) fluctuated substantially in 1978 (pre-treatment), the treatment station ($\bar{x}$ = 6.80) and control station ($\bar{x}$ = 6.78) were similar (Fig. 15). After canopy removal (1979), however, the treatment station had consistently greater production than the control except in February when production at both stations was measured as being equal.

Overall, primary production was lower after canopy removal (1979) than before (1978). Comparison of algal production during the interval 25 April to 31 May in 1978 with a similar interval (21 April to 23 May) in 1979 revealed that even though production at the treatment station ($\bar{x}$ = 5.33) was higher than at the control station ($\bar{x}$ = 3.00) in 1979, production was substantially lower than the values observed in 1978 (control $\bar{x}$ = 10.5 and treatment $\bar{x}$ = 8.77).

Chironomidae Species Composition

Bear Creek

The composition of the chironomid fauna in Bear Creek is extremely diverse and dominated by Orthocladiinae. The 99 chironomid taxa identified from pupal exuviae is listed in Appendix Table 7. An additional five species have been found only as larvae. Three genera of Orthocladiinae, *Eukiefferiella* (12 spp.), *Orthocladius* (12 spp.), and

Cricotopus (7 spp.), accounted for over 46% of Orthocladiinae species and 31% of the total chironomid species.

Orthocladiinae accounted for over 67% of the total species and 57% of the total genera (Table 10). Orthocladiinae and Chironominae combined accounted for approximately 88% of the total species and 75% of the total genera.

Similarities in the number of species and genera among stations and between years is particularly striking (Table 11). The greatest difference between any two stations in 1978 was two species and one genus. The difference among stations was slightly greater in 1979 than in 1978. The greatest difference in numbers of total species occurred at station 1100 (Table 11). Chi-square analysis ($p \leq 0.05$), based on a 1:1 ratio for numbers of species within each subfamily was used to test for differences between years. No significant differences in numbers of species, within subfamilies, among stations or between years were found.

There were, however, differences in the actual composition of species making up the chironomid community at each station in 1978 and 1979 (Tables 12-14). For example, the overall difference in total numbers of species at station 200 between 1978 (74 species) and 1979 (76 species) was only two species (Table 11). However, the actual change in species composition between 1978 and 1979 at station 200 was 24 species (Table 12); 11 species which occurred in 1978 were absent in 1979 and replaced by 13 additional species not found in 1978. Furthermore, the total difference in species composition in Bear Creek (i.e., combining all

Table 10. The subfamily and tribal breakdown of Bear Creek chironomids for 1978 and 1979.

Subfamily	Species No.	Species %	Genera No.	Genera %
Orthocladiinae	67	67.7	28	57.1
Chironominae	20	20.2	9	18.4
Tanytarsini	(11)	(11.1)	(6)	(12.2)
Chironomini	(9)	(9.1)	(3)	(6.2)
Tanypodinae	6	6.1	6	12.2
Diamesinae	4	5.1	4	8.2
Prodiamesinae	1	1.0	1	2.0
Podonominae	1	1.0	1	2.0
Total	99		49	

Table 11. Numbers of species (a) and genera (b) plus corresponding percentage values for Bear Creek Chironomidae during 1978 and 1979.

a. Species

	Station 200				Station 925				Station 1100			
	1978		1979		1978		1979		1978		1979	
Subfamily	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Orthocladiinae	53	71.6	50	65.8	53	69.7	45	64.3	49	65.3	46	68.7
Chironominae	15	20.3	16	21.1	16	21.1	15	21.4	17	22.7	13	19.4
(Tanytarsini)	(9)	(12.2)	(10)	(13.2)	(9)	(11.8)	(9)	(12.8)	(10)	(13.4)	(8)	(11.9)
(Chironomini)	(6)	(8.1)	(6)	(7.9)	(7)	(9.3)	(6)	(8.6)	(7)	(9.3)	(5)	(7.5)
Tanypodinae	4	5.4	6	7.9	4	5.3	6	8.6	5	6.7	5	7.5
Diamesinae	2	2.7	3	3.9	3	3.9	4	5.7	2	2.7	2	3.0
Prodiamesinae	0	--	0	--	0	--	0	--	1	1.3	0	--
Podonominae	0	--	1	1.3	0	--	0	--	1	1.3	1	1.5
Total	74		76		76		70		75		67	

b. Genera

	Station 200				Station 925				Station 1100			
	1978		1979		1978		1979		1978		1979	
Subfamily	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Orthocladiinae	23	62.2	20	52.6	23	60.5	18	51.4	20	54.1	21	58.3
Chironominae	8	21.6	8	21.1	8	21.1	7	20.0	8	21.6	7	19.4
(Tanytarsini)	(5)	(13.5)	(6)	(15.8)	(5)	(13.2)	(5)	(14.3)	(5)	(13.5)	(5)	(13.9)
(Chironomini)	(3)	(8.1)	(2)	(5.3)	(3)	(7.9)	(2)	(5.7)	(3)	(8.1)	(2)	(5.5)
Tanypodinae	4	10.8	6	15.8	4	10.5	6	17.1	5	13.5	5	13.9
Diamesinae	2	5.4	3	7.9	3	7.9	4	11.4	2	5.4	2	5.5
Prodiamesinae	0	--	0	--	0	--	0	--	1	2.7	0	--
Podonominae	0	--	1	2.6	0	--	0	--	1	2.7	1	2.8
Total	37		38		38		35		37		36	

Table 12. Chironomid species composition differences and corresponding total number of individuals collected at station 200 (Bear Creek) during 1978 and 1979.

Species that occurred only in 1978	Total No.[1]	Species that occurred only in 1979	Total No.
Orthocladiinae		Orthocladiinae	
Cricotopus (*C.*) sp. 1	1	*Brillia* sp. 1	1
Orthocladius (*O.*) sp. 2	1	*Cricotopus* (*C.*) sp. nr. *tibialis* gr.	4
Orthocladius (*O.*) sp. 3	1	*Orthocladius* (*O.*) sp. 1	12
Orthocladius (Eudactylocladius) sp.	1	*Orthocladius* (*O.*) sp. 4	2
Parorthocladius sp. 1	1	*Rheocricotopus* sp. 1	1
Pseudosmittia sp.	1	*Thienemanniella* cf. *acurticornis*	2
Psilometriocnemus sp. 1	5		
Psilometriocnemus sp. 2	2	Chironominae	
Unk. Orthocladiinae	1	*Polypedilum* sp. 1	3
Chironominae		*Polypedilum* sp. 5	2
Paratendipes sp. 1	3	*Paratanytarsus* sp.	2
Paratendipes sp. 2	6	Tanypodinae	
Total	23	*Krenopelopia* sp.	2
Grand total	2,190	*Rheopelopia* sp.	30
% of Grand total	1.1	Diamesinae	
		Pagastia sp.	1
		Podonominae	
		Boreochlus sp.	1
		Total	63
		Grand total	5,302
		% of Grand total	1.2

[1]Numbers represent the combined total for all sampling dates.

Table 13. Chironomid species composition differences and corresponding total numbers of individuals collected at station 925 (Bear Creek) during 1978 and 1979.

Species that occurred only in 1978	Total No.[1]	Species that occurred only in 1979	Total No.
Orthocladiinae		Orthocladiinae	
Bryophaenocladius cf. *subvernalis*	1	*Brillia* sp. 1	3
Cricotopus (C.) sp. 1	1	*Limnophyes* sp.	1
Heterotrissocladius sp.	2	Chironominae	
Orthocladius (O.) sp. 2	1	*Paracladopelma* sp. 1	1
Orthocladius (Euorthocladius) sp. 1	8	Tanypodinae	
Paraphaenocladius cf. *impensus*	1	*Krenopelopia* sp.	1
Parorthocladius sp. 1	1	*Nilotanypus* sp.	2
Psilometriocnemus sp. 1	1	Diamesinae	
Rheocricotopus sp. 2	3	*Diamesa* sp. 1	1
Unk. Orthocladiinae	1	Total	9
Chironominae		Grand total	3,859
Paratendipes sp. 1	2	% of Grand total	0.2
Polypedilum sp. 5	2		
Total	24		
Grand total	2,277		
% of Grand total	1.1		

[1]Numbers represent the combined total for all sampling dates.

Table 14. Chironomid species composition differences and corresponding total number of individuals collected at station 1100 (Bear Creek) during 1978 and 1979.

Species that occurred only in 1978	Total No.[1]	Species that occurred only in 1979	Total No.
Orthocladiinae		Orthocladiinae	
Brillia sp. 2	1	*Bryophaenocladius* cf. *subvernalis*	1
Cricotopus (C.) cf. *cylindraceus*	1	*Cricotopus (C.)* sp. 2	1
Cricotopus (C.) tremulus gr. sp. nr. *tremulus*	4	*Orthocladius (Eudactylocladius)* sp.	3
Eukiefferiella sp. 2	1	*Parorthocladius* sp. 2	1
Orthocladius (O.) sp. 1	1	*Rheocricotopus* sp. 2	1
Orthocladius (O.) sp. 2	1		
Orthocladius (Euorthocladius) sp. 1	9	Chironominae	
Paraphaenocladius cf. *impensus*	3	*Polypedilum* sp. 5	1
		Total	8
Chironominae		Grand total	2,645
		% of Grand total	0.3
Paracladopelma sp. 1	1		
Paracladopelma sp. 2	1		
Polypedilum sp. 1	2		
Micropsectra sp. 4	1		
Tanytarsus sp. 1	6		
Prodiamesinae			
Monodiamesa sp.	1		
Total	33		
Grand total	4,466		
% of Grand total	0.7		

[1]Numbers represent the combined total for all sampling dates.

stations) between 1978 and 1979 (Table 15) was 12 species at the treatment stations (200 and 925) and three species at the control station (1100). The noteworthy feature regarding the differences in species composition among the stations and between years is that none of the changes in composition occurred among abundant species, in fact, most of the species that changed were rare (i.e., less than 10 total individuals collected). Therefore, although there were alterations in chironomid species composition following canopy removal, the changes, in regard to the total number of individuals collected, were insignificant.

Clearwater River Streams

The composition of the chironomid fauna in Octopus "B" Tributary, Christmas Creek, and Honor Camp Creek is very similar to Bear Creek (see Appendix Table 7). Orthocladiinae were predominant in all three streams (see Appendix Tables 20-22). *Eukiefferiella* spp., *Orthocladius* spp., and *Cricotopus* spp. accounted for 56%, 53%, and 57% of the Orthocladiinae species in Octopus "B" Tributary, Christmas Creek, and Honor Camp Creek, respectively. Together, these genera composed between 35% and 39% of the total chironomid species in the streams.

Subfamily and tribal breakdown of the chironomid species and genera in the Clearwater streams showed a remarkable similarity among the three streams (Table 16). Although the total number of species (67-89) and genera (32-41) differed, the percentage composition of major taxa indicates only minor differences among the streams.

Table 15. Overall differences in chironomid species composition and corresponding total number of individuals collected between 1978 and 1979 in Bear Creek.

	Total Number
A. Species which occurred in 1978 but not in 1979	
Treatment Stations (200 and 925)	
Cricotopus (C.) sp. 1	2
Orthocladius (O.) sp. 2	2
Parorthocladius sp. 1	2
Pseudosmittia sp.	1
Unk. Orthocladiinae	2
Paratendipes sp. 2	6
Subtotal	15
Control Station (1100)	
Eukiefferiella sp. 2	1
Orthocladius (O.) sp. 2	1
Subtotal	2
Total	17
Grand total for 1978	8,933
% of Grand total	0.2
B. Species which occurred in 1979 but not in 1978	
Treatment Stations (200 and 925)	
Brillia sp.1	4
Orthocladius (O.) sp. 4	2
Thienemanniella cf. *acuticornis*	2
Paratanytarsus sp.	2
Krenopelopia sp.	3
Diamesa sp.	1
Subtotal	14
Control Station (1100)	
Parorthocladius sp. 2	1
Subtotal	1
Total	15
Grand total for 1979	11,806
% of Grand total	0.1

Table 16. Comparison of number of species (a) and genera (b) and corresponding percentage values for the three Clearwater River streams.

a. Species

Subfamily	Octopus "B" Trib. Number	%	Christmas Ck. Number	%	Honor Camp Ck. Number	%
Orthocladiinae	60	67.4	51	65.4	46	68.7
Chironominae	18	20.2	20	25.6	13	19.4
(Tanytarsini)	(10)	(11.2)	(11)	(14.1)	(9)	(13.4)
(Chironomini)	(8)	(9.0)	(9)	(11.5)	(4)	(6.0)
Tanypodinae	6	6.7	5	6.4	5	7.5
Diamesinae	4	4.5	2	2.6	3	4.5
Podonominae	1	1.1	0	--	0	--
Total	89		78		67	

b. Genera

Subfamily	Octopus "B" Trib. Number	%	Christmas Ck. Number	%	Honor Camp Ck. Number	%
Orthocladiinae	21	51.2	17	48.6	17	53.1
Chironominae	9	21.9	11	31.4	7	21.9
(Tanytarsini)	(6)	(14.6)	(6)	(17.1)	(5)	(15.6)
(Chironomini)	(3)	(7.3)	(5)	(14.3)	(2)	(6.3)
Tanypodinae	6	14.6	5	14.3	5	15.6
Diamesinae	4	9.8	2	5.7	3	9.4
Podonominae	1	2.4	0	--	0	--
Total	41		35		32	

A combined total of 118 species was found in Bear Creek and the Clearwater River streams. Comparison of the species composition among the streams showed a difference of 36 species--17 species were exclusive to Bear Creek and 19 species were exclusive to the Clearwater streams (Table 17). However, most of the species exclusive to Bear Creek were rare (i.e., less than 10 total individuals) and contributed very little to the total number of individuals collected. Among the 118 combined total species, 90 were found in Bear Creek in 1978 and 88 in 1979 (Table 18). During both years the treatment stations (200 and 925) and control station (1100) in Bear Creek were very similar to Christmas Creek and Honor Camp Creek, in terms of number of total species, but all were substantially lower than Octopus "B" tributary. However, when all stations are combined the total number of species in Bear Creek and Octopus "B" tributary is almost identical.

Comparison of the percentage composition of species and genera within major taxa in Bear Creek and the Clearwater River streams indicates that all streams were similar (Table 19). Christmas Creek, however, was the most dissimilar stream. The percentage composition of Orthocladiinae species in Christmas Creek was intermediate among the streams (65.4) but percentage composition of genera was the lowest (48.6). The lower composition in Orthocladiinae genera was due to a higher composition in Chironominae (31.4). Christmas Creek was also the only stream which deviated significantly from a 3:1 ratio of Orthocladiinae to non-Orthocladiinae (heterogeneity chi-square analysis, $P < 0.05$). The higher composition of Chironominae, and specifically

Table 17. Overall differences in chironomid species composition between Bear Creek and the three study streams in the Clearwater River basin.

Species exclusive to Bear Creek	Total No.	Species exclusive to the Clearwater River stations[1]
Orthocladiinae		Orthocladiinae
Bryophaenocladius cf. *subvernalis*	2	*Brillia* cf. *retifinis*
Cricotopus (Cricotopus) sp. 2	1	*Cardiocladius* sp.
Eukiefferiella sp. 2	1	*Cricotopus (Cricotopus)* cf. *bicinctus*
Orthocladius (Orthocladius) sp. 4	2	*Cricotopus (C.)* sp.3
Paraphaenocladius cf. *impensus*	6	*Cricotopus (Isocladius)* sp.
Parorthocladius sp. 1	2	*Eukiefferiella* sp. 3
Parorthocladius sp. 2	1	*Eukiefferiella* sp. 4
Pseudosmittia sp.	1	*Orthocladius (Orthocladius)* cf. *mallochi*
Psilometriocnemus sp. 1	13	*Orthocladius (Euorthocladius)* cf. *rivulorum*
Unk. Orthocladiinae genus No. 5	23	*Psectrocladius (Psectrocladius)* sp. 1
Unk. Orthocladiinae	2	*Psectrocladius (P.)* sp. 2
		Tokunagia sp.
Chironominae		Chironominae
Paracladopelma sp. 1	4	*Microtendipes* sp.
Paratendipes sp. 2	6	*Phaenopsectra* sp.
Micropsectra sp. 4	1	*Polypedilum* cf. *fallax* gr. sp.
		Constempellina sp. 2
		Tanytarsus (subletti) coffmani
Tanypodinae		Tanypodinae
Krenopelopia sp.	3	*Arctopelopia* sp.
Diamesinae		Diamesinae
Diamesa sp. 1	1	*Diamesa* sp. 2
Prodiamesinae		
Monodiamesa sp.	1	
Total	70	

[1]Quantitative samples were not taken in the Clearwater River streams.

Table 18. Comparison of the total number of chironomid species and corresponding percentage composition for each stream, based on a combined total of 118 species found in the four streams.

Stream	No. species	Percentage
Bear Creek, 1978		
200	74	62.7
925	76	64.4
1100	75	63.6
Total	90	76.3
Bear Creek, 1979		
200	76	64.4
925	70	59.3
1100	67	56.8
Total	88	74.6
Clearwater River streams		
Octopus Creek	89	75.4
Christmas Creek	78	66.1
Honor Camp Creek	67	56.8

Table 19. Comparison of percentage composition of major taxa for Bear Creek and the Clearwater River streams.

	Bear Creek						Clearwater streams[1]			
	Pre-Treatment 1978			Post-Treatment 1979						
Subfamily	200	925	1100	200	925	1100[2]	OC	CC	HC	Mean[3]
Orthocladiinae										
Species	71.6	69.7	65.3	65.8	64.3	68.7	67.4	65.4	68.7	66.3
Genera	62.2	60.5	54.1	52.6	51.4	58.3	51.2	48.6	53.1	51.4
Chironominae										
Species	20.3	21.1	22.7	21.1	21.4	19.4	20.2	25.6	19.4	21.5
Genera	21.6	21.1	21.6	21.1	20.0	19.4	21.9	31.4	21.9	23.3
(Tanytarsini)										
Species	(12.2)	(11.8)	(13.4)	(13.2)	(12.8)	(11.9)	(11.2)	(14.1)	(13.4)	(12.9)
Genera	(13.5)	(13.2)	(13.5)	(15.8)	(14.3)	(13.9)	(14.6)	(17.1)	(15.6)	(15.5)
(Chironomini)										
Species	(8.1)	(9.3)	(9.3)	(7.9)	(8.6)	(7.5)	(9.0)	(11.5)	(6.0)	(8.6)
Genera	(8.1)	(7.9)	(8.1)	(5.3)	(5.7)	(5.5)	(7.3)	(14.3)	(6.3)	(7.8)
Tanypodinae										
Species	5.4	5.3	6.7	7.9	8.6	7.5	6.7	6.4	7.5	7.4
Genera	10.8	10.5	13.5	15.8	17.1	13.9	14.6	14.3	15.6	15.5
Diamesinae										
Species	2.7	3.9	2.7	3.9	5.7	3.0	4.5	2.6	4.5	4.2
Genera	5.4	7.9	5.4	7.9	11.4	5.5	9.8	5.7	9.4	8.8

[1] OC = Octopus "B" Trib., CC = Christmas Creek, HC = Honor Camp Creek.

[2] Station 1100 was the control station in 1978 and 1979.

[3] Represents mean value for the three Clearwater streams plus stations 200 and 925 in Bear Creek in 1979 (post-treatment).

Chironomini, in Christmas Creek may be a reflection of the temperature regime (<u>see</u> Fig. 9). Christmas Creek reached the highest water temperatures of any stream and sustained the warmer temperatures longest.

The overall similarity in percentage composition of major taxa between Bear Creek and the three Clearwater River basin streams suggests that neither canopy removal alone (Bear Creek) nor canopy removal in combination with road building and yarding (Clearwater streams) caused significant alterations in the structural framework of the chironomid community. Furthermore, the percentage composition of major taxa showed no consistent trend (either increase or decrease) with differences in time of recovery since logging (1 to 20 yr) in the three Clearwater streams.

Chironomidae Emergence Dynamics

Emergence of Species

The pattern of total numbers of species emerged at each station during 1978 and 1979 (Figs. 16 to 18) showed a similar overall pattern, with numbers of species emerged increasing rapidly in late April and early May, corresponding to rapid increases in water temperature at this time of year (<u>see</u> Fig. 7). The increase in emergence continued through May and an early peak generally occurred in mid-June, followed by a slight decline and then a second and usually higher peak in mid- to late July. This second peak was associated with the highest temperatures of the year. Fluctuations in the number of emerged Orthocladiinae species followed those of the total community closely, emphasizing the overall

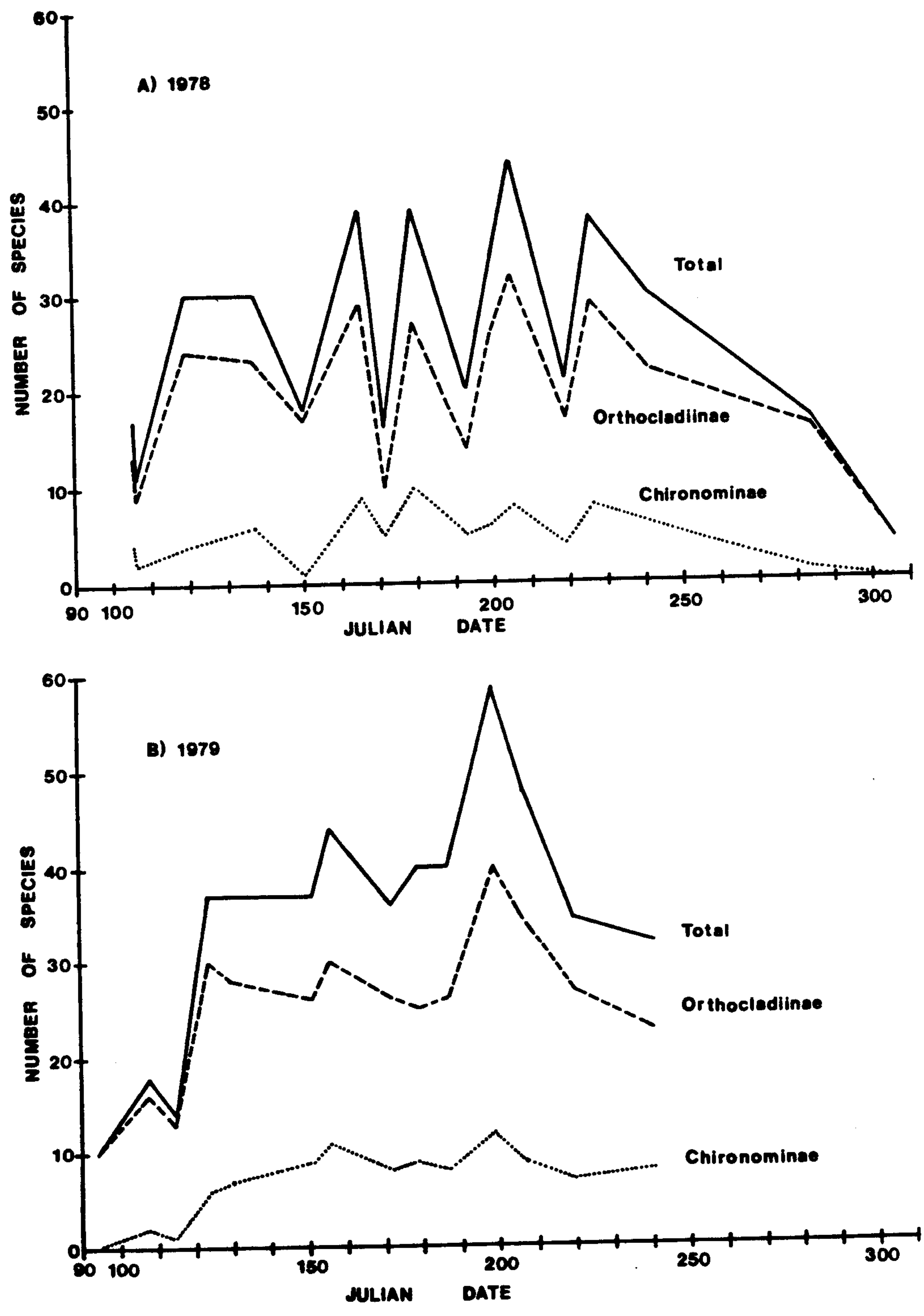

Fig. 16. Pattern of the total number of emerging chironomid species at station 200 in Bear Creek during 1978 (pre-treatment) and 1979 (post-treatment).

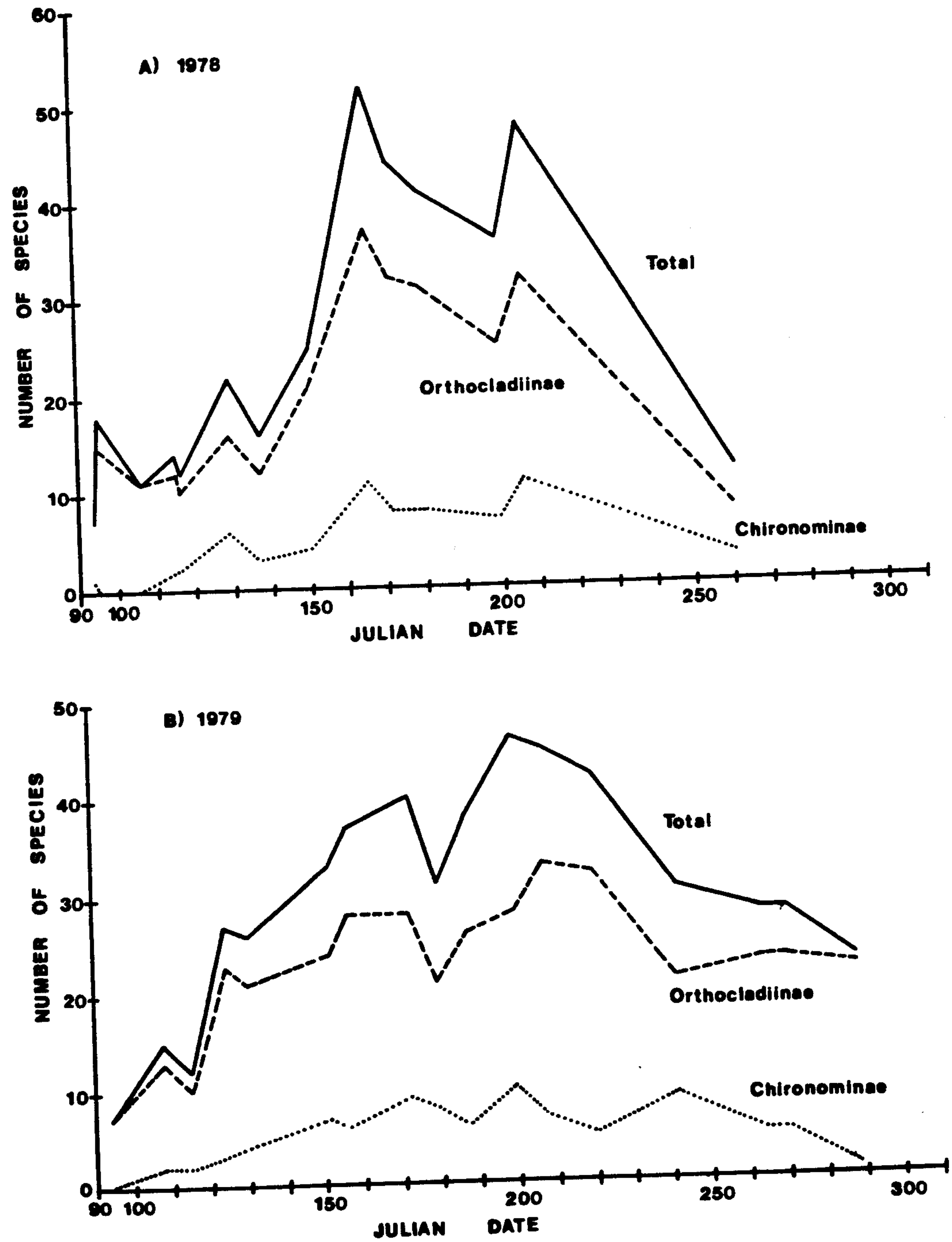

Fig. 17. Pattern of the total number of emerging chironomid species at station 925 in Bear Creek during 1978 (pre-treatment) and 1979 (post-treatment).

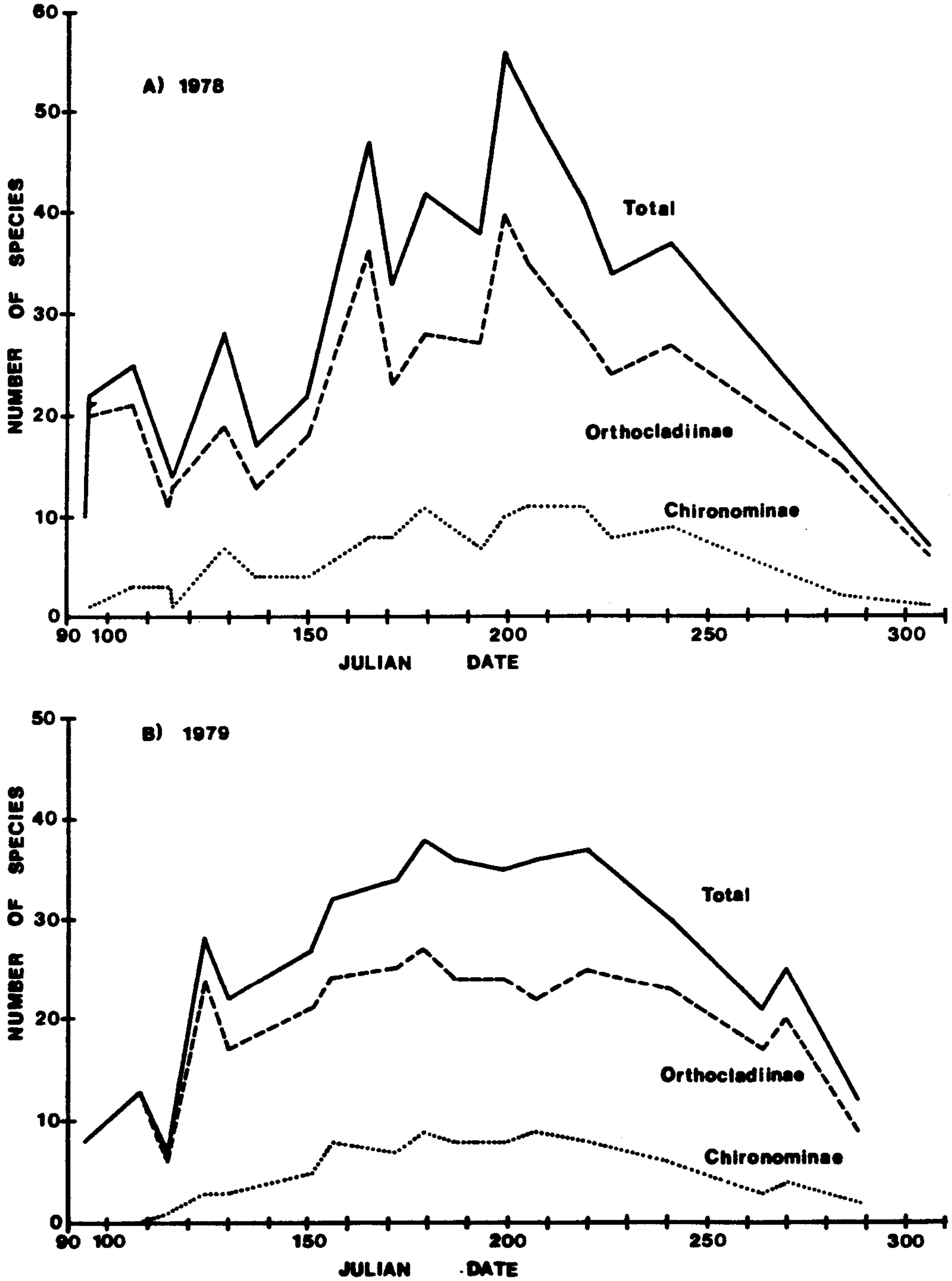

Fig. 18. Pattern of the total number of emerging chironomid species at station 1100 in Bear Creek during 1978 (pre-treatment) and 1979 (post-treatment).

importance of this group to the total chironomid community. The Chironominae occurred regularly but showed a less well-defined pattern of emergence by month.

Data on numbers of species in each major taxon and the percentage composition of the emerging chironomids are outlined in Appendix Tables 8 to 13, by sampling date, station and year. Orthocladiinae generally accounted for between 60 and 80% of the total number of emerging species and the Chironominae for approximately 10 to 25% of the total (Figs. 19-21). The general decline in the percentage composition of Orthocladiinae began in late April-early May and reached a low of about 60% in late June-early July. The Chironominae began to increase in late April-early May, corresponding to the decrease in Orthocladiinae. The Tanypodiinae were generally insignificant until the early part of June, when temperatures were increasing rapidly and usually above 10^{o}C, and reached a level of about 10% in mid-July.

Because the Orthocladiinae accounted for such a large proportion of the total species emerged on each sampling date, heterogeneity chi-square analysis (Zar 1973) was used to determine if the chironomid community in Bear Creek conformed to a particular frequency distribution with respect to Orthocladiinae and the remaining taxa. Data from each sampling date (by station and year) were tested against the hypothesis of a 3:1 ratio of Orthocladiinae to non-Orthocladiinae in the community from which the samples came. Tests were performed first on individual sampling dates at each station, and except for three dates, none of the

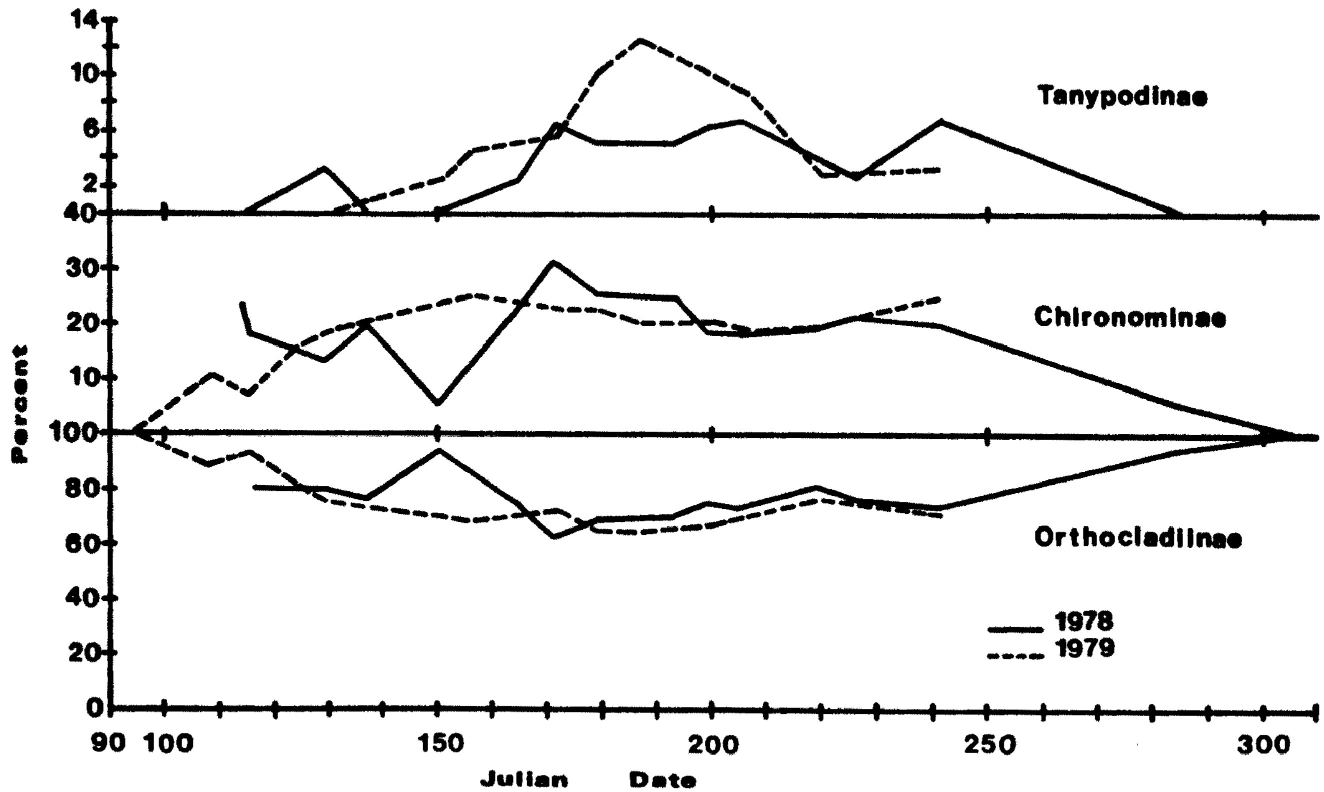

Fig. 19. Percent composition of emerging chironomids in Bear Creek by major subfamily at station 200 during 1978 (pre-treatment) and 1979 (post-treatment).

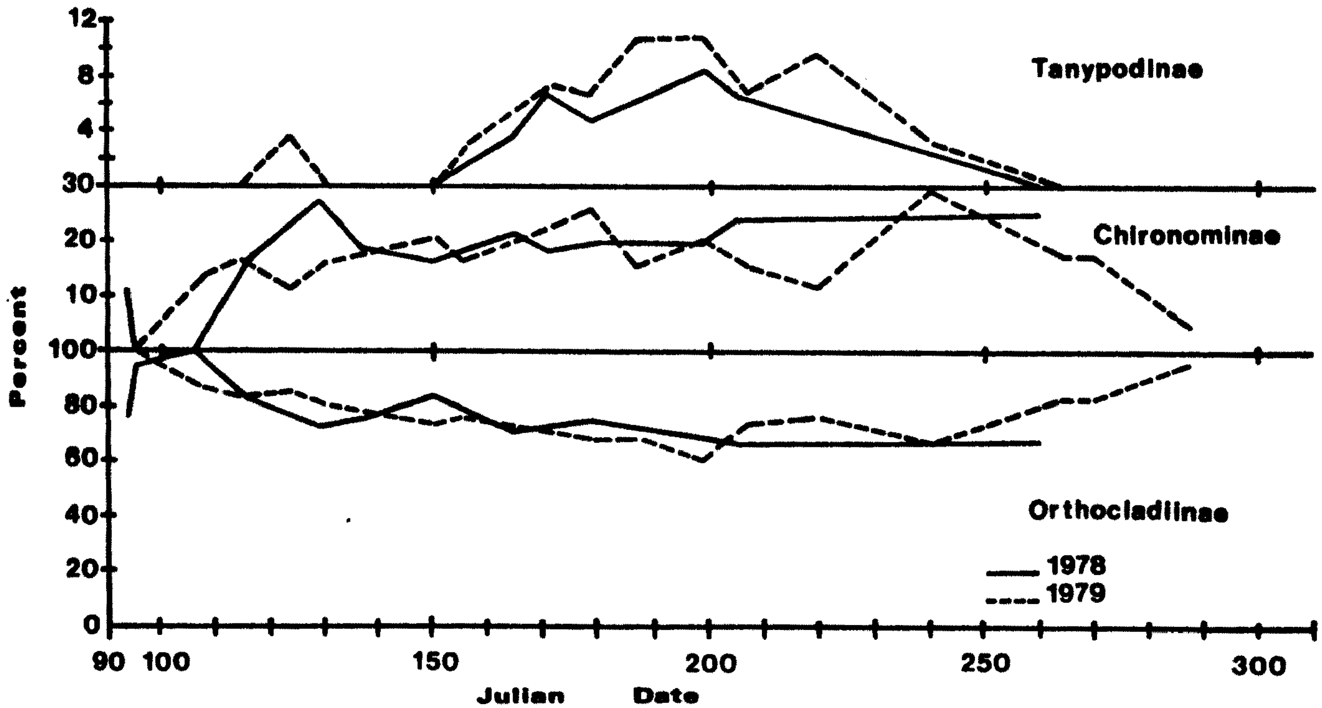

Fig. 20. Percent composition of emerging chironomids in Bear Creek by major subfamily at station 925 during 1978 (pre-treatment) and 1979 (post-treatment).

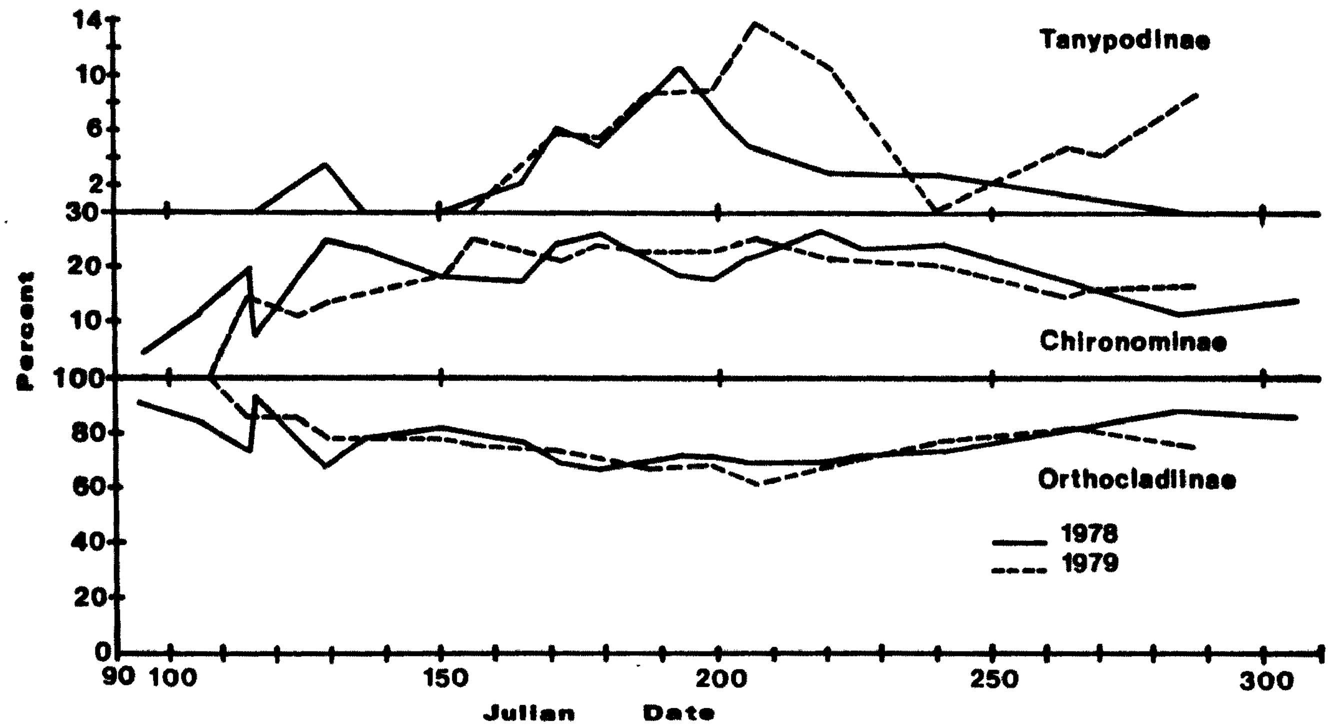

Fig. 21. Percent composition of emerging chironomids in Bear Creek by major subfamily at station 1100 during 1978 (pre-treatment) and 1979 (post-treatment).

individual chi-square tests detected a significant deviation from the hypothesis. All sampling dates, for each station, were then pooled. Chi-square analysis on the pooled data also detected no significant departure from a 3:1 ratio of Orthocladiinae to non-Orthocladiinae. Therefore, the samples were considered homogeneous. This strongly suggests that the structural framework of the chironomid community in Bear Creek was 75% Orthocladiinae and 25% non-Orthocladiinae, and more importantly, that the framework was maintained at all stations following canopy removal in 1979.

Species accumulation curves, as a function of days, are plotted for each station in 1978 and 1979 in Fig. 22. According to Coffman (1973) these plots demonstrate the periods of maximum change in the composition of the chironomid fauna through the addition of newly emerged species. The three curves in 1978 (Fig. 22a) are similar but station 1100 showed a distinctly earlier accumulation of species. Species emerged rapidly during April (Julian dates:91-120) at all three stations and at least 50% of the total species had emerged by the end of May; (Julian date: 151). Station 1100 attained the 50% emergence level earliest (May 1; Julian Date:121) and station 925 latest (May 19; Julian Date: 139)—a difference of 18 days. Station 200 was intermediate (May 14; Julian Date: 134).

If the species accumulation curves for 1979 are examined (Fig. 22b) effects of canopy removal appear to be minimal as the three curves are

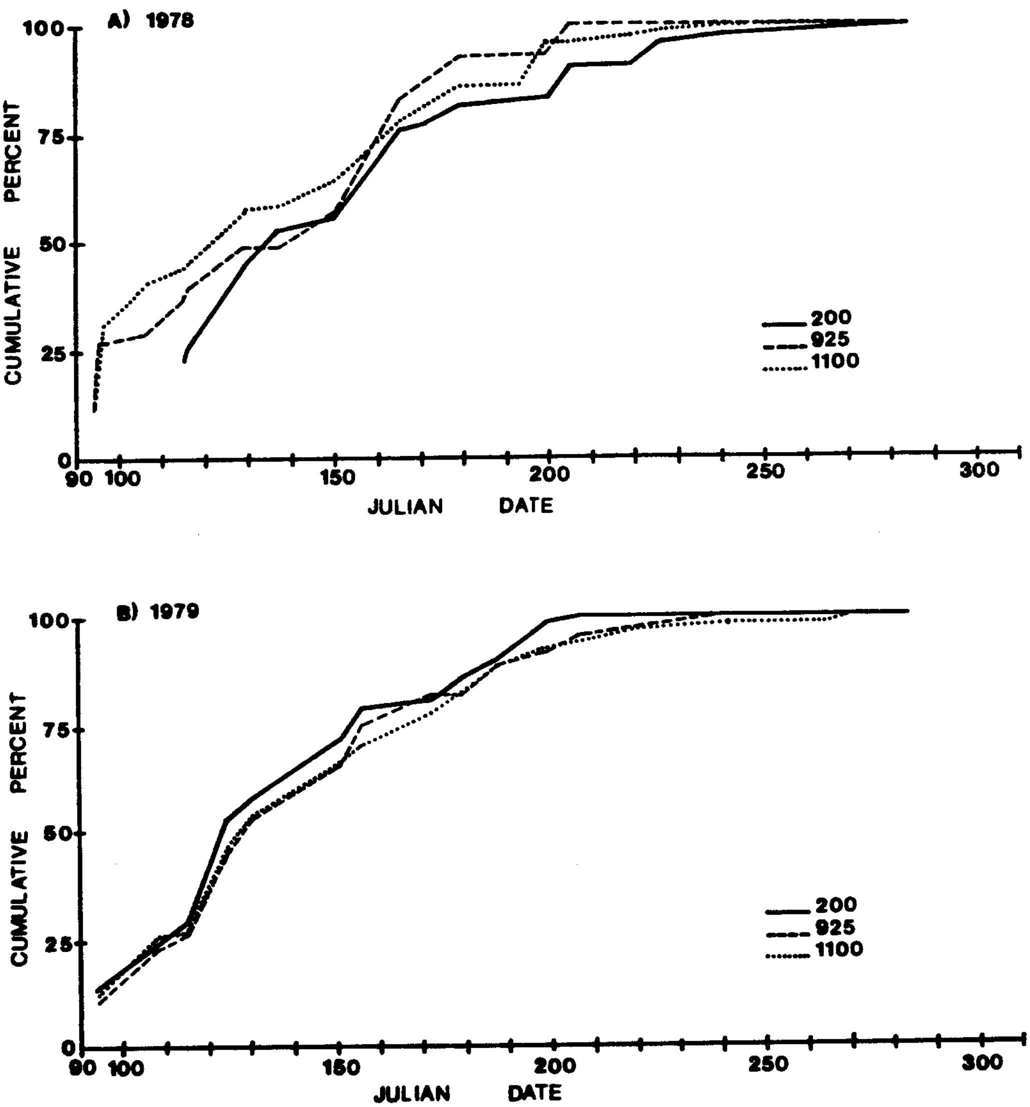

Fig. 22. Chironomid species accumulation curves as a function of days at stations 200, 925, and 1100 during A) 1978 (pre-treatment) and B) 1979 (post-treatment), Bear Creek.

practically identical. All three stations showed rapid emergence of species through April and May (Julian Dates:91-151) and all attained the 50% emergence level earlier in 1979 than in 1978. There was a difference of only 5 days between the stations in attaining the 50% emergence level, with station 200 the earliest (May 3; Julian Date:123; and station 925 the latest (May 8; Julian Date:128). Both treatment stations (200 and 925) reached the 50% emergence level 11 days earlier in 1979, whereas the control station was 5 days later.

Total Numbers Emerged

Numbers in this section represent a mean of the right and left emergence channel. The total number of chironomid pupal exuviae collected in each channel for all sampling dates is presented in Appendix Table 4 for 1978 and 5 for 1979. Kruskal-Wallis non-parametric tests ($p<0.05$) showed that the total number of exuviae collected in each channel for all dates were not significantly different among stations in 1978 or 1979 (Appendix Table 6).

During this study, a total of 20,739 exuviae was collected--i.e., 8,933 during 1978 and 11,806 during 1979 (Appendix Table 27). Orthocladiinae accounted for the greatest number of individuals at every station in both years and they composed 71% (6,354) of the total chironomid fauna in 1978 and 68% (7,986) in 1979. Every subfamily increased in abundance (no/m^2) after canopy removal (1979) at the treatment stations (200 and 925), and except for the Tanypodinae and Podonominae, all decreased in abundance at the control station (Table 20).

Table 20. Subfamily and tribal breakdown of the mean number (no./m^2) of emerging chironomids at each station in Bear Creek in 1978 and 1979.

	Station 200		Station 925		Station 1100	
Subfamily	78	79	78	79	78	79
Orthocladiinae	100.0	253.6	108.9	166.2	169.9	94.7
Chironominae	34.4	111.4	50.3	54.2	59.4	53.8
(Tanytarsini)	(31.2)	(100.4)	(47.4)	(49.4)	(55.3)	(49.7)
(Chironomini)	(3.2)	(11.0)	(2.9)	(4.8)	(4.1)	(4.1)
Tanypodinae	2.2	10.8	2.4	4.2	3.9	6.3
Diamesinae	0.3	2.8	1.1	2.4	1.4	0.2
Prodiamesinae	--	--	--	--	0.1	--
Podonominae	--	0.1	--	--	0.4	0.5
Total	136.9	378.7	162.6	227.0	235.1	155.6
Std. Deviation	140.7	337.6	199.8	151.5	288.5	129.6
No. Samples	16	14	14	17	19	17

The mean number (no/m^2) of emerging chironomids was not significantly different ($p<0.05$) among the three stations in 1978, but after canopy removal (1979) the mean number of emerging chironomids at station 200 ($378.7/m^2$) was significantly greater than at the control station ($155.6/m^2$; see Fig. 23). Within major taxa at station 200, the mean number of Orthocladiinae and Diamesinae were significantly ($p<0.05$) greater than at station 1100, whereas, all other taxa were not significantly different. Station 925 (upper treatment station) was not significantly different from either station 200 or 1100.

Between year comparison indicated that the mean number of emerging chironomids at station 200 (lower treatment station) was significantly greater ($p<0.05$) after canopy removal ($378.7/m^2$) than before ($136.9/m^2$; see Table 20). Within major taxa, Orthocladiinae, Tanytarsini, and Diamesinae were significantly greater at station 200 after canopy removal. The upper treatment station (925) and control station (1100) were not significantly different between 1978 and 1979.

The four most common chironomid species in Bear Creek (Table 21) in order of abundance were: *Thienemanniella* sp. 1 (2,135), *Corynoneura* sp. 2 (1,854), *Stempellinella* cf. *brevis* (1,788), and *Synorthocladius* cf., *semivirens* (1,354). Together these four species accounted for 36% of the total chironomid emergence in 1978 and 33% in 1979. *Thienemanniella* sp. 1, *Corynoneura* sp. 2, and *S.* cf. *semivirens* increased substantially in abundance at the treatment stations (200 and 925) after canopy removal, but all three species decreased at the control station (1100).

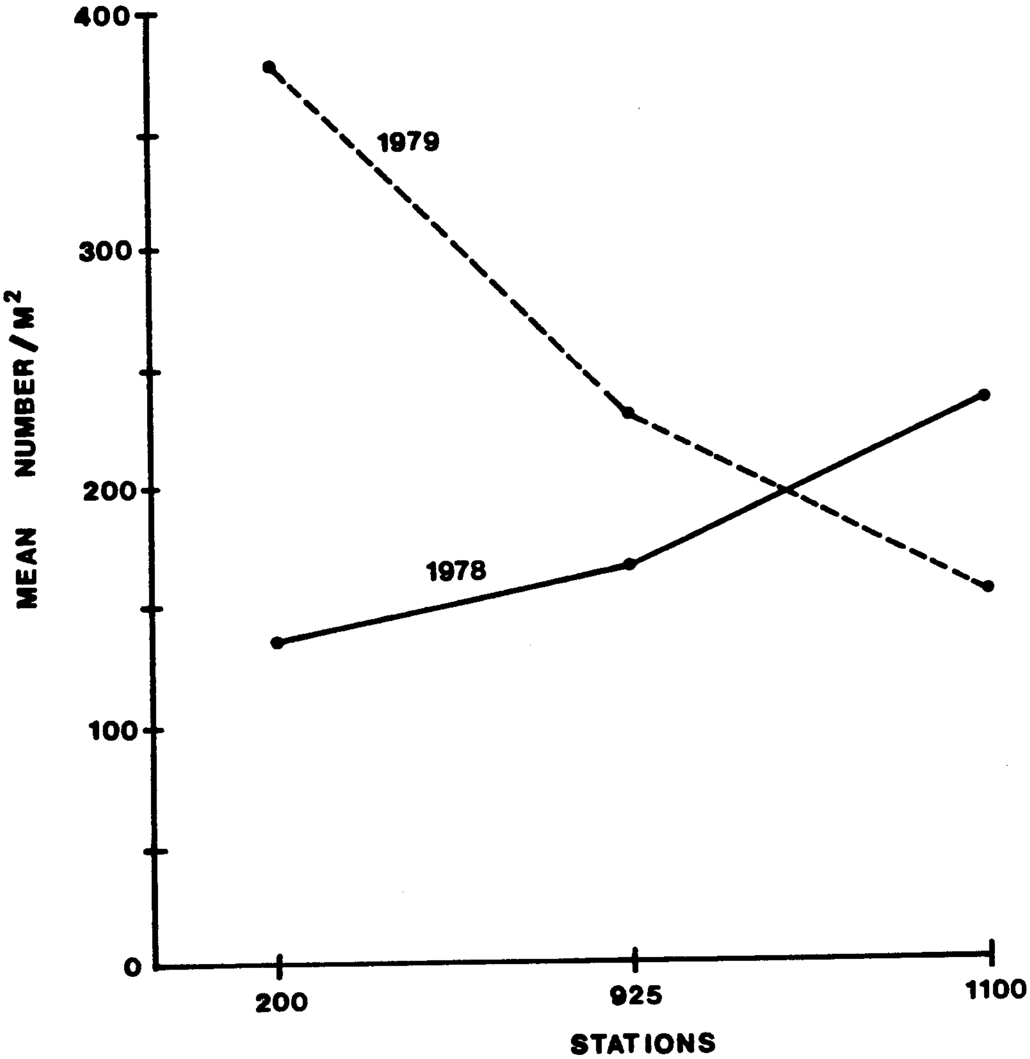

Fig. 23. Comparison of the overall mean number (no./m^2) of emerging chironomids at stations 200, 925, and 1100 in 1978 (pre-treatment) and 1979 (post-treatment), Bear Creek.

Table 21. Total number of individuals for the 99 species of Chironomidae at each station in 1978 and 1979. Numbers represent the combined total for all sampling dates.

	Station 200		Station 925		Station 1100		Total		Grand
	78	79	78	79	78	79	78	79	total
Orthocladiinae									
Brillia cf. *flavifrons*	18	9	9	5	27	8	54	22	76
Brillia sp. 1		1		3			0	4	4
Brillia sp. 2					1		1	0	1
Bryophaenocladius cf. *subvernalis*			1			1	1	1	2
Chaetocladius sp.	1	2	1	4	4	6	6	12	18
Corynoneura sp. 1	19	152	10	133	53	98	82	383	465
C. sp. 2	159	704	109	220	476	186	744	1,110	1,854
C. sp. 3	285	144	82	111	185	124	552	379	931
Cricotopus (Cricotopus) cf. *cylindraceus*	5	20	1	4	1		7	24	31
C. (C.) sp. nr. *magus* gr.	40	99	86	104	67	16	193	219	412
C. (C.) sp. nr. *tibialis* gr.		4	1	12			1	16	17
C. (C.) tremulus gr. sp. nr. *tremulus*	5	22	14	12	4		23	34	57
C. (C.) tremulus gr. sp. nr. *tristis*	13	57	22	26	37	5	72	88	160
C. (C.) sp. 1	1		1				2	0	2
C. (C.) sp. 2						1	0	1	1
Eukiefferiella cf. *bavarica*	6	10	8	17	9	32	23	59	82
E. cf. *brehmi*	5	24	4	25	10	4	19	53	72
E. cf. *brevicalcar*	64	79	37	105	211	142	312	326	638
E. cf. *calvescens*	27	121	2	16	48	10	77	147	224
E. cf. *claripennis*	4	11	6	10	11	6	21	27	48
E. cf. *coerulescens*	73	292	51	225	105	66	229	583	812
E. cf. *devonica*	2	15	1	17	6	3	9	35	44
E. cf. *lobifera*	13	18	11	28	30	39	54	85	139

Table 21. Total number of individuals for the 99 species of Chironomidae at each station in 1978 and 1979. Numbers represent the combined total for all sampling dates - continued.

	Station 200		Station 925		Station 1100		Total		Grand total
	78	79	78	79	78	79	78	79	
Eukiefferiella cf. *minor-potthastia*	5	18	1	24	1	4	7	46	53
*E.*cf. *pseudomontana*	28	22	11	59	32	14	71	95	166
E. sp. 1	2	27	5	16	10	8	17	51	68
E. sp. 2					1		1	0	1
Heleniella sp.	53	101	97	31	41	36	191	168	359
Heterotrissocladius marcidus gr.sp.	1	2	2		5	3	8	5	13
Krenosmittia cf. *boreoalpina*	112	137	47	114	63	92	222	343	565
K. cf. *camptophleps*	79	157	55	32	63	54	197	243	440
Limnophyes sp.	2	1		1	2	2	4	4	8
Nannocladius (*Nannocladius*) cf. *balticus*	3	4	6	11	9	14	18	29	47
N. (*N.*) cf. *rectinervis*	15	35	14	5	95	18	124	58	182
Orthocladius (*Orthocladius*) cf. *appersoni*	23	41	186	67	141	14	350	122	472
O. (*O.*) cf. *curtiseta*	6	51	24	45	14	6	44	102	146
O. (*O.*) cf. *dentifer*	11	10	9	14	11	8	31	32	63
O. (*O.*) cf. *frigidus*	12	84	44	76	53	6	109	166	275
O. (*O.*) cf. *nigritus*	1	3					1	3	4
O. (*O.*) sp. 1		12	2	4	1		3	16	19
O. (*O.*) sp. 2	1		1		1		3	0	3
O. (*O.*) sp. 3	1						1	0	1
O. (*O.*) sp. 4		2					0	2	2
O. (*Eudactylocladius*) sp.	1					3	1	3	4
O. (*Euorthocladius*) cf. *thienemanni*	8	10	7	32	7	2	22	44	66
O. (*E.*) sp. 1	3	7	8		9		20	7	27
O. (*E.*) sp. 2			1	2			1	2	3
Paracricotopus sp.			1	1			1	1	2
Parakiefferiella sp. 1	70	152	69	86	80	29	219	267	486

Table 21. Total number of individuals for the 99 species of Chironomidae at each station in 1978 and 1979. Numbers represent the combined total for all sampling dates - continued.

	Station 200		Station 925		Station 1100		Total		Grand total
	78	79	78	79	78	79	78	79	
Parakiefferiella sp. 2	33	20	57	46	102	78	192	144	336
Parametriocnemus cf. *lundbecki*	18	70	8	21	33	35	59	126	185
P. sp. 1	51	40	27	33	47	43	125	116	241
Paraphaenocladius cf. *impensus*	1	1	1		3		5	1	6
Paratrichocladius sp.	22	11	65	66	91	21	178	98	276
Parorthocladius sp. 1	1		1				2	0	2
P. sp. 2						1	0	1	1
Pseudosmittia sp.	1						1	0	1
Psilometriocnemus sp. 1	5		1		3	4	9	4	13
P. sp. 2	2				4	1	6	1	7
Rheocricotopus cf. *effusus*	16	57	19	33	38	23	73	113	186
R. sp. 1		1					0	1	1
R. sp. 2			3			1	3	1	4
Synorthocladius cf. *semivirens*	151	244	127	164	563	105	841	513	1,354
Thienemanniella cf. *acuticornis*		2					0	2	2
T. sp. 1	113	443	161	764	418	236	692	1,443	2,135
Unk. Orthocladiinae (Genus No. 5)	8	2	7	1	3	2	18	5	23
Unk. Orthocladiinae	1		1				2	0	2
Total	1,600	3,551	1,525	2,825	3,229	1,610	6,354	7,986	14,340
Chironominae									
Chironomini									
Paracladopelma sp.1	1	1		1	1		2	2	4
P. sp. 2			1	1	1		2	1	3
Paratendipes sp. 1	3		2		7	5	12	5	17
P. sp. 2	6						6	0	6
Polypedilum sp. 1		3	5	4	2		7	7	14

Table 21. Total number of individuals for the 99 species of Chironomidae at each station in 1978 and 1979. Numbers represent the combined total for all sampling dates - continued.

	Station 200		Station 925		Station 1100		Total		Grand total
	78	79	78	79	78	79	78	79	
Polypedilum sp. 2	2	13	2	2	11	9	15	24	39
P. sp. 3	36	133	28	71	52	47	116	251	367
P. sp. 4	3	2	1	4	5	8	9	14	23
P. sp. 5		2	2			1	2	3	5
Total	51	154	41	83	79	70	171	307	478
Tanytarsini									
Constempellina sp. 1	71	390	39	208	50	231	160	829	989
Micropsectra sp. 1	31	70	55	87	37	49	123	206	329
M. sp. 2	3	31	12	7	10	5	25	43	68
M. sp. 3	43	94	72	66	70	44	185	204	389
M. sp. 4					1		1	0	1
Paratanytarsus sp.		2					0	2	2
Rheotanytarsus cf. *distinctissimus*	32	137	39	37	204	84	275	258	533
R. cf. *exiguus*	6	77	15	32	46	83	67	192	259
Stempellinella cf. *brevis*	243	467	262	213	404	199	909	879	1,788
Tanytarsus sp. 1	8	11	13	47	6		27	58	85
T. sp. 2	63	127	156	142	222	150	441	419	860
Total	500	1,406	663	839	1,050	845	2,213	3,090	5,303
Tanypodinae									
Conchapelopia sp.	8	5	6	5	10	18	24	28	52
Krenopelopia sp.		2		1			0	3	3
Nilotanypus sp.	1	17		2	3	1	4	20	24
Pentaneura sp.	2	13	5	8	18	20	25	41	66
Rheopelopia sp.		30	2	13	6	3	8	46	54

Table 21. Total number of individuals for the 99 species of Chironomidae at each station in 1978 and 1979. Numbers represent the combined total for all sampling dates - continued.

	Station 200		Station 925		Station 1100		Total		Grand total
	78	79	78	79	78	79	78	79	
Zavrelimyia (Paramerina) sp.	24	84	20	43	37	65	81	192	273
Total	35	151	33	72	74	107	142	330	472
Diamesinae									
Diamesa sp. 1				1			0	1	1
Pagastia sp.		1	1	3			1	4	5
Potthastia sp.	1	26	4	28	1	1	6	55	61
Sympotthastia sp.	3	12	10	8	25	3	38	23	61
Total	4	39	15	40	26	4	45	83	128
Podonominae									
Boreochlus cf. *longiseta*		1			7	9	7	10	17
Total		1			7	9	7	10	17
Prodiamesinae									
Monodiamesa sp.					1		1	0	1
Total					1		1	0	1
Grand Total	2,190	5,302	2,277	3,859	4,466	2,645	8,933	11,806	20,739
Number of Species	74	76	76	70	75	67			

S. cf. *brevis* also increased in abundance at station 200 (lower treatment station) but decreased at station 925 (upper treatment) and at the control station after canopy removal.

After canopy removal, a greater number of species increased in abundance at the treatment stations (200 and 925) than at the control station (Table 22). A total of 63 species (72.4%) and 51 species (62.2%) increased in abundance at stations 200 and 925, respectively. In contrast, only 24 species (29.6%) increased in abundance at the control station and surprisingly, nearly 68% of the species decreased in abundance in 1979. These results suggest a trend toward greater abundance of more species as the influence of canopy removal presumably increases. However, it is not known why such a large percentage of species decreased in abundance at the control station (1100) in 1979.

Examination of the total number of chironomid species collected at each station in 1978 and 1979 (Table 21) revealed that many of the species collected were rare (i.e., 10 or fewer total individuals) and relatively few species were abundant (i.e., 51 or more total individuals). For example, 54.1% of the total species collected at station 200 in 1978 were rare whereas, only 13 species (17.6%) were relatively abundant (Table 23). Therefore, instead of examining the entire chironomid species complex, the emergence dynamics of the chironomids was limited to a complex of the most ubiquitous and abundant species.

Table 22. Number of chironomid species which increased (I), decreased (D), and did not change (S) in total number of individuals after canopy removal at stations 200, 925, and 1100, Bear Creek.[1]

Subfamily	Station 200			Station 925			Station 1100		
	I	D	S	I	D	S	I	D	S
Orthocladiinae	40	18	1	36	18	1	14	39	1
Chironominae	14	3	1	7	8	2	6	12	0
(Tanytarsini)	(10)	(0)	(0)	(4)	(5)	(0)	(3)	(7)	(0)
(Chironomini)	(4)	(3)	(1)	(3)	(3)	(2)	(3)	(5)	(0)
Tanypodinae	5	1	0	5	1	0	3	2	0
Diamesinae	3	0	0	3	1	0	0	1	1
Prodiamesinae	--	--	--	--	--	--	1	0	0
Podonominae	1	0	0	--	--	--	0	1	0
Total	63	22	2	51	28	3	24	55	2
Percentage	72.4	25.3	2.3	62.2	34.1	3.7	29.6	67.9	2.5

[1]Table illustrates the changes in abundance of all species occurring at each station during 1978 and 1979. Therefore, the total number of species differs from the values in other tables (i.e., 74 species were found at station 200 in 1978, but 76 were found in 1979. The total for station 200 in this table, 87, reflects the combined species composition for both years.)

Table 23. Categorization of the abundance (total number of individuals collected for all sampling dates) of chironomid species at stations 200, 925, and 1100 in Bear Creek during 1978 and 1979.

			Abundance category					
			1-10 Individuals		1-50 Individuals		51 or more Individuals	
Station	Year	Total No. species	No. species	%[1]	No. species	%	No. species	%
200	1978	74	40	54.1	61	82.4	13	17.6
	1979	76	26	34.2	49	64.5	27	35.5
925	1978	76	42	55.3	58	76.3	18	23.7
	1979	70	25	35.7	51	72.9	19	27.1
1100	1978	75	34	45.3	53	70.7	22	29.3
	1979	67	33	49.3	51	76.1	16	23.9

[1]Percent of total number of species.

Core Species Complex

The core species complex is based on the observed species composition in Bear Creek (1978 and 1979) and in the Clearwater River streams. Because these streams reflect widely different conditions in terms of logging intensity and time of recovery since logging, examination of the common features of the chironomid species composition among these streams potentially provides information as to the most tolerant, ubiquitous, and perhaps most important species of Chironomidae in the streams of the Pacific Northwest.

Four criteria were used to select the core species complex: 1) chironomid species which occurred in all sites in Bear Creek in 1978 and 1979 and also occurred in all three Clearwater River streams; 2) chironomid species which occurred in at least one station in Bear Creek during both years and also occurred in all three Clearwater River streams; 4) chironomid species which occurred in relatively high numbers (i.e., more than 75 total individuals for 1978 and 1979 combined) in Bear Creek, and in addition satisfied the conditions outlined in the first three criteria.

Based on the above criteria, 35 species were selected for inclusion in the core species complex.

A total of 18,892 core individuals was collected, i.e., 8,146 during 1978 and 10,746 in 1979. In both years the entire core complex comprised 91% of the total individuals collected in Bear Creek.

Of the 35 core species selected, 25 (71.4%) were Orthocladiinae, 9 (25.7%) were Chironominae, and one (2.9%) was a Tanypodinae.

The entire core species complex increased substantially at the treatment stations (200 and 925) after canopy removal (Table 24) but decreased at the control station (1100). All but four species, *Brillia* cf. *flavifrons*, *Corynoneura* sp. 3, *Eukiefferiella* cf. *pseudomontana*, and *Paratrichocladius* sp., increased in abundance after canopy removal at station 200. At station 925, 23 species increased in abundance and at station 1100, only 10 species increased in abundance in 1979. Two species, *B.* cf. *flavifrons* and *Paratrichocladius* sp., decreased at all three stations in 1979.

Timing of emergence patterns for the core complex at the three stations varied widely during the two emergence seasons (Figs. 24 to 26). Station 200 showed the greatest change after canopy removal. In 1978, station 200 exhibited four relatively low peaks during summer (June-August) and the greatest number of individuals emerged in July (Fig. 24). In contrast, in 1979 there were two distinct peaks; the first in early May and a second in July. The major peaks in both years occurred in July. The early peak in May 1979 was caused primarily by five species: *Corynoneura* sp. 1, *Corynoneura* sp. 2, *Eukiefferiella* cf. *coerulescens*, *Thienemanniella* sp. 1, and *Constempellina* sp. 1. In 1978, these five species accounted for 56 individuals, but after canopy removal they accounted for 578 individuals. *Constempellina* sp. 1 accounted for the majority of the peak, increasing from 42 individuals

Table 24. Comparison of the mean number of individuals per sampling date for each species in the core complex at stations 200, 925, and 1100 in Bear Creek during 1978 and 1979.

Species	Station 200		Station 925		Station 1100		Mean total	Mean total	Grand mean total
	1978	1979	1978	1979	1978	1978	1978	1979	
Brillia cf. *flavifrons*	1.1	0.6	0.6	0.3	1.4	0.5	1.1	0.5	0.8
Corynoneura sp. 1	1.2	10.9	0.7	7.8	2.8	5.8	1.7	8.0	4.8
Corynoneura sp. 2	9.9	50.3	7.8	12.9	25.1	10.9	15.2	23.1	19.1
Corynoneura sp. 3	17.8	10.3	5.9	6.5	9.7	7.3	11.3	7.9	9.6
Cricotopus (*Cricotopus*) sp. nr. *magus* gr.	2.5	7.1	6.1	6.1	3.5	0.8	3.9	4.6	4.2
C. (*C.*) *tremulus* gr. sp. nr. *tristis*	0.8	4.1	1.6	1.5	1.9	0.3	1.5	1.8	1.6
Eukiefferiella cf. *bavarica*	0.4	0.7	0.6	1.0	0.5	1.9	0.5	1.2	0.8
E. cf. *brevicalcar*	4.0	5.6	2.6	6.2	11.1	8.4	6.4	6.8	6.6
E. cf. *calvescens*	1.7	8.6	0.1	0.9	2.5	0.6	1.6	3.1	2.3
E. cf. *coerulescens*	4.6	20.9	3.6	13.2	5.5	3.9	4.7	12.1	8.4
E. cf. *lobifera*	0.8	1.3	0.8	1.6	1.6	2.3	1.1	1.8	1.4
E. cf. *pseudomontana*	1.8	1.6	0.8	3.5	1.7	0.8	1.5	2.0	1.7
Heleniella sp.	3.3	7.2	6.9	1.8	2.2	2.1	3.9	3.5	3.7
Krenosmittia cf. *boreoalpina*	7.0	9.8	3.4	6.7	3.3	5.4	4.5	7.1	5.8
Krenosmittia cf. *camptophleps*	4.9	11.2	3.9	1.9	3.3	3.2	4.0	5.1	4.5
Nanocladius cf. *rectinervis*	0.9	2.5	1.0	0.3	5.0	1.1	2.5	1.2	1.9
Orthocladius (*Orthocladius*) cf. *appersoni*	1.4	2.9	13.3	3.9	7.4	0.8	7.1	2.5	4.9
Orthocladius (*O.*) cf. *curtiseta*	0.4	3.6	1.7	2.6	0.7	0.4	0.9	2.1	1.5
Orthocladius (*O.*) cf. *frigidus*	0.8	6.0	3.1	4.5	2.8	0.4	2.2	3.5	2.8
Parakiefferiella sp. 1	4.4	10.9	4.9	5.1	4.2	1.7	4.5	5.6	5.0
Parametriocnemus cf. *lundbecki*	1.1	5.0	0.6	1.2	1.7	2.1	1.2	2.6	1.9
Paratrichocladius sp.	1.4	0.8	4.6	3.9	4.8	1.2	3.6	2.0	2.8
Rheocricotopus cf. *effusus*	1.0	4.1	1.4	1.9	2.0	1.4	1.5	2.4	1.9
Synorthocladius cf. *semivirens*	9.4	17.4	9.1	9.6	29.6	6.2	17.1	10.7	13.9
Thienemanniella sp. 1	7.1	31.6	11.5	44.9	22.0	13.9	14.1	30.1	22.0
Polypedilum sp. 3	2.3	9.5	2.0	4.2	2.7	2.8	2.4	5.2	3.8
Constempellina sp. 1	4.4	27.9	2.8	12.2	2.6	13.6	3.3	17.3	10.2
Micropsectra sp. 1	1.9	5.0	3.9	5.1	1.9	2.9	2.5	4.3	3.4
Micropsectra sp. 3	2.7	6.7	5.1	3.9	3.7	2.6	3.8	4.3	4.0
Rheotanytarsus cf. *distinctissimus*	2.0	9.8	2.8	2.2	10.7	4.9	5.6	5.4	5.5
Rheotanytarsus cf. *exiguus*	0.4	5.5	1.1	1.9	2.4	4.9	1.4	4.0	2.7
Stempellinella cf. *brevis*	15.2	33.4	18.7	12.5	21.3	11.7	18.6	18.3	18.4
Tanytarsus sp. 1	0.5	0.8	0.9	2.8	0.3	0.0	0.6	1.2	0.9
Tanytarsus sp. 2	3.9	9.1	11.1	8.4	11.7	8.8	9.0	8.7	8.9
Zavrelimyia (*Paramarina*) sp.	1.5	6.0	1.4	2.5	1.9	3.8	1.7	4.0	2.8
Grand mean	124.5	348.6	146.6	205.8	215.8	139.2	166.2	223.9	194.8
Number of samples	16	14	14	17	19	17	49	48	97

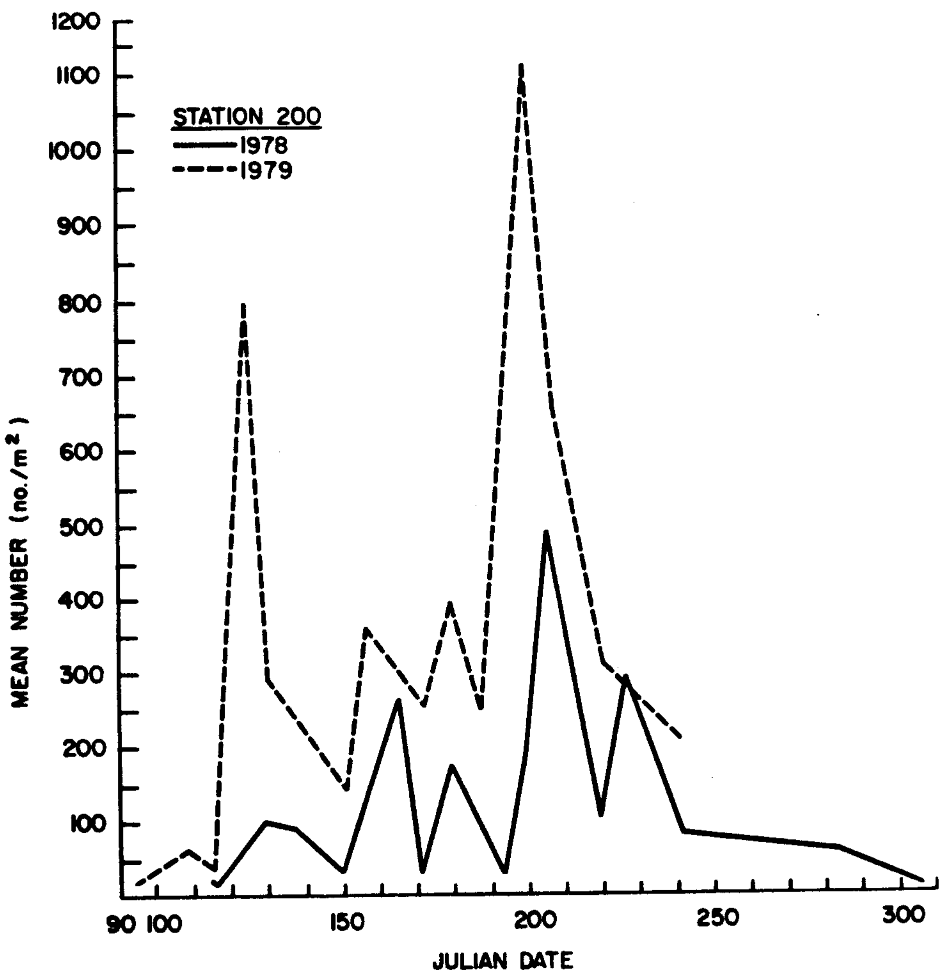

Fig. 24. Emergence patterns for the total core species complex at station 200, Bear Creek, during 1978 (pre-treatment) and 1979 (post-treatment).

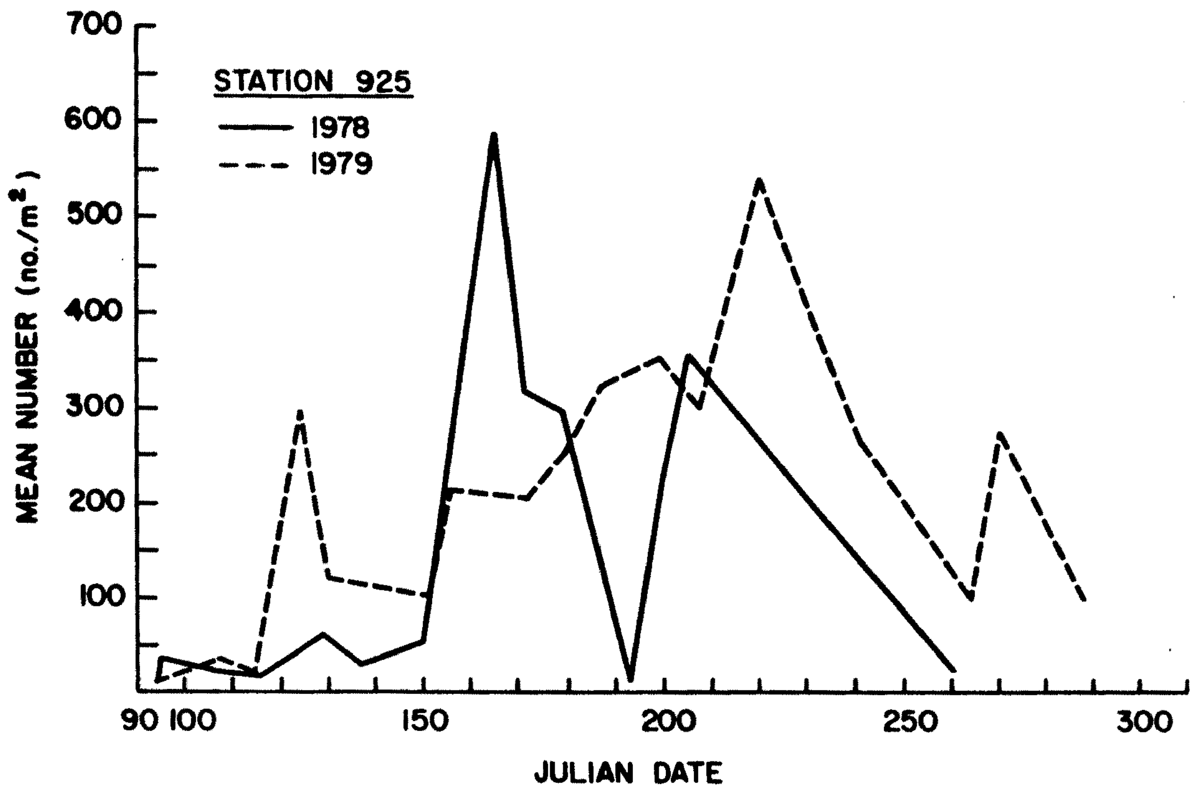

Fig. 25. Emergence patterns for the total core species complex at station 925, Bear Creek, during 1978 (pre-treatment) and 1979 (post-treatment).

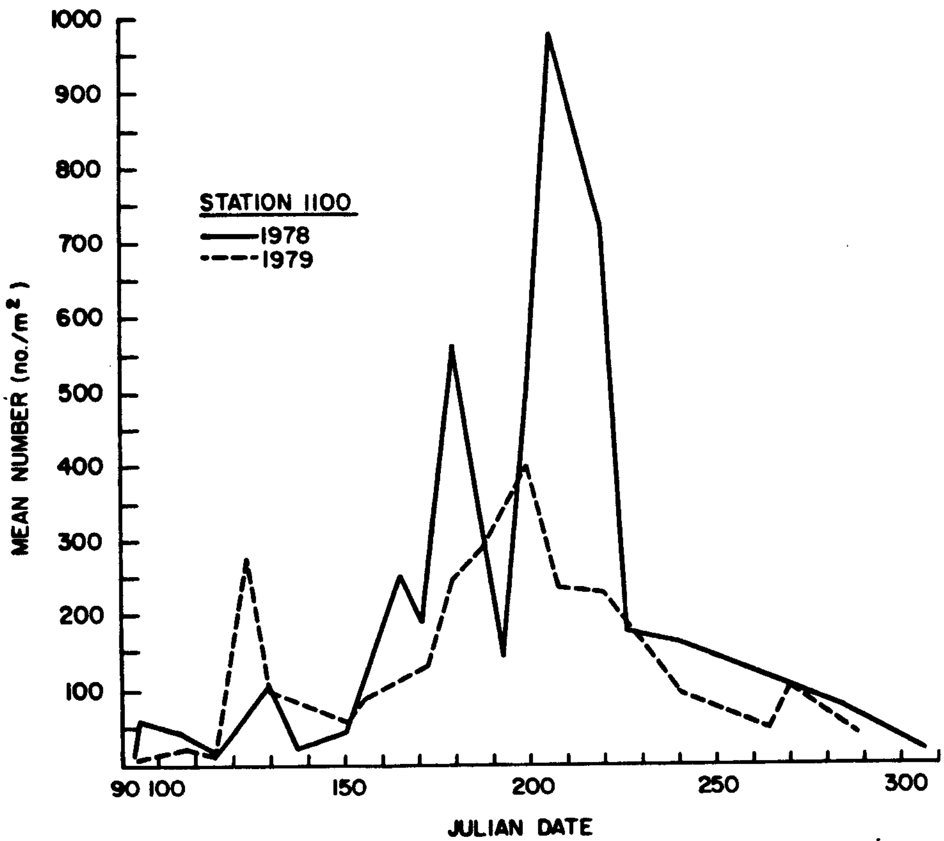

Fig. 26. Emergence patterns for the total core species complex at station 1100, Bear Creek, during 1978 (pre-treatment) and 1979 (post-treatment).

in May 1978 to 302 individuals in May 1979. The second and larger peak in July 1979 was due also to *Corynoneura* sp. 2 (18 in 1978, and 354 in 1979) and *E.* cf. *coerulescens* (4 in 1978, and 87 in 1979) but other species and species groups also contributed to the second peak. *Stempellinella* cf. *brevis*, for example, increased from 5 individuals in July 1978 to 158 in July 1979. *Cricotopus* and *Orthocladius* gr. species along with the Tanypodinae also substantially increased in July 1979. These taxa together accounted for only 41 individuals in 1978, but after canopy removal they accounted for 809 individuals.

Station 925 did not differ substantially in terms of total numbers of core individuals between 1978 and 1979 (Fig. 25), but did differ in timing of the major emergence peaks. As was shown at station 200, two peaks also occurred at station 925 after canopy removal--the first in early May and the second in August. The early May peak was caused by the same species responsible for the early May peak at station 200 in 1979, except *Corynoneura* sp. 1 was replaced by *Krenosmittia* cf. *boreoalpina*. *Constempellina* sp. 1 again accounted the major portion of the peak, increasing from 23 individuals in 1978 to 142 in 1979. The second and larger peak in August was generally due to the same taxa observed at station 200; however, *Thienemanniella* sp. 1 was substantially greater at station 925 than at station 200. The Tanypodinae along with other species groups (e.g., *Cricotopus* and *Orthocladius*) were of only minor importance at station 925 after canopy removal.

Station 1100 had two distinct peaks in 1978, one in June and a second in July (Fig. 26). The major peak in July was due to *Corynoneura* sp. 2, *Thienemanniella* sp. 1, *Stempellinella* cf. *brevis*, and *Tanytarsus* sp. 2. After canopy removal, station 1100 also had two emergence peaks, one in early May and a second in July and both peaks were due to the same species that caused the peaks at stations 200 and 925.

Cumulative percentage emergence curves for the entire core species complex, as a function of days, at the three stations (Fig. 27) shows that emergence was earlier at the lower treatment station (200) and control station (1100) after canopy removal, but much later at station 925, the upper treatment station. The dissimilarity among the stations and between years may in part be an artifact of the irregular beginning and ending of sampling dates. For instance, in 1978 sampling at stations 925 and 1100 began on 4 April, whereas sampling at station 200 was delayed until 25 April. The delay in the beginning of sampling at station 200, however, was insignificant because the three additional sampling periods at stations 925 and 1100 represented less than 4% of the total chironomid emergence at both sites. Moreover, by the end of April 1978 chironomid emergence represented less than 5% of the total emergence at all stations. Station 925 may have been the most significantly affected site, particularly during the later part of 1978, because it was sampled only once (9 September) after July. Chironomid emergence from August to November at stations 200 and 1100 represented about 27% of the total emergence at both stations. Therefore, it is possible that at least 25% of the chironomid emergence at station 925

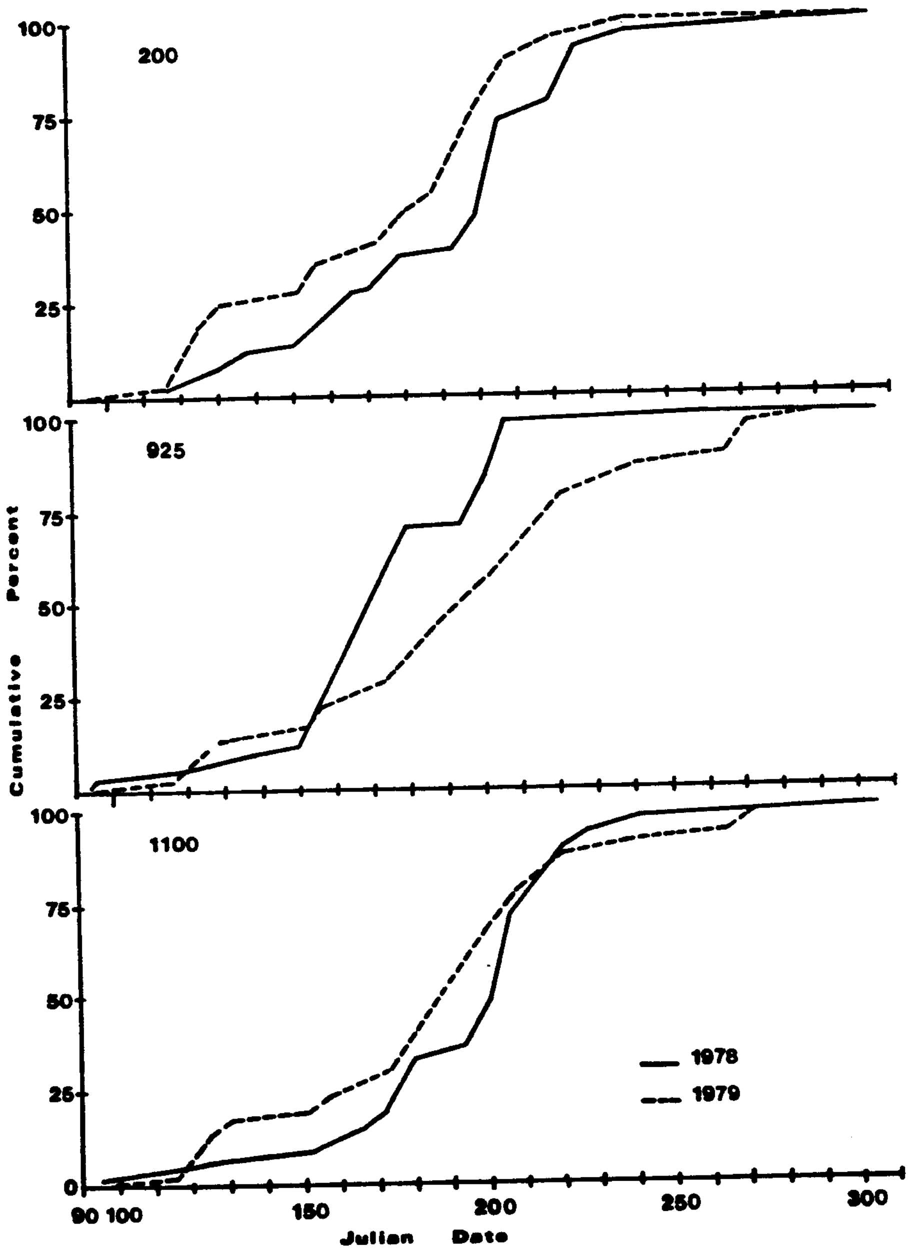

Fig. 27. Cumulative emergence curves for the 35 chironomid species of the core complex in Bear Creek, as a function of days, at stations 200, 925, and 1100 during 1978 (pre-treatment) and 1979 (post-treatment).

may have been missed. A similar situation also occurred in 1979, at station 200. No samples were taken at this site after August, however three additional samples were taken at stations 925 and 1100 in 1979 (two in September and one in October). The emergence during this interval represented 13% of the total emergence at station 925 and about 8% at station 1100. Thus, approximately 10% of the emerging chironomids in the latter part of 1979 were missed at station 200.

The day (Julian date) on which 50% emergence (EM_{50}) occurred at the 3 stations ranged from 168 (17 June) to 199 (18 July) in 1978, and from 183 (2 July) to 192 (11 July) after canopy removal (Table 25). If the first and last 25% of the emergence curves are separated, the most active period of emergence (EM_{25}-EM_{75}) at the three stations is clearly different between the two years. The number of days required to complete this interval was consistently less at all stations in 1978. The emergence patterns were more extended at all stations after canopy removal. This may in part be explained on the basis of voltinism. Substantial increases in the number of spring univoltine species (e.g, *Constempellina* sp. 1) in combination with similar increases in numbers in the second generation of bivoltine (multivoltine) summer species (e.g., *Thienemanniella* sp. 1) and univoltine summer species (e.g., *Orthocladius* spp.) may account for the apparent extended emergence patterns after canopy removal.

Comparison of the cumulative emergence curves, for all stations combined, between 1978 and 1979 (Fig. 28) indicates that even though the

Table 25. Estimated Julian date for 25% (EM_{25}), 50% (EM_{50}), and 75% (EM_{75}) emergence of the core species complex in Bear Creek during 1978 and 1979.

Station	Year	EM_{25}	EM_{50}	EM_{75}	EM_{25}-EM_{75} interval (days)
200	1978	162 (11 June)	199 (18 July)	211 (30 July)	49
	1979	132 (12 May)	183 (2 July)	198 (17 July)	66
925	1978	156 (5 June)	168 (17 June)	187 (6 July)	31
	1979	159 (8 June)	192 (11 July)	216 (4 August)	57
1100	1978	174 (23 June)	199 (18 July)	207 (26 July)	33
	1979	157 (6 June)	185 (4 July)	204 (23 July)	47

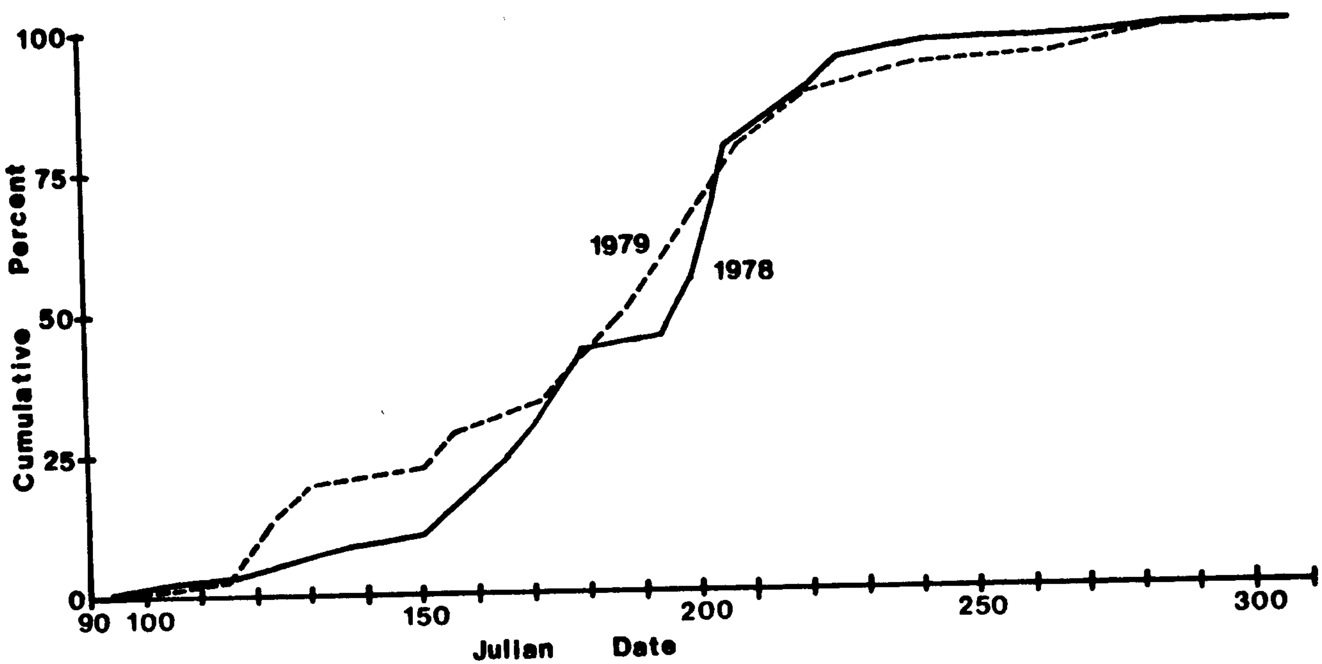

Fig. 28. Cumulative emergence curves for the core species complex in Bear Creek, as a function of days, for all stations combined during 1978 (pre-treatment) and 1979 (post-treatment).

total number of core individuals differed between the two years (8,146 in 1978 and 10,746 in 1979), effects of canopy removal on time of emergence are minimal since the two curves are similar in shape. During both years the 50% emergence level (EM_{50}) was reached in July and differed in timing by only 11 days. The number of days required to complete the EM_{25}-EM_{75} interval differed by only 13 days between the two years (38 days in 1978 and 51 days in 1979) and the interval occurred during June and July, corresponding to the time of most rapid temperature unit accumulation in both years.

Ten species in the core complex were selected for closer examination of emergence patterns (Figs. 29 and 30). The ten species illustrated different emergence patterns. *E.* cf. *coerulescens*, *S.* cf. *semivirens*, *K.* cf. *boreoalpina*, *Corynoneura* sp. 2, and *Thienemanniella* sp. 1 were selected because they exhibited relatively long and extended emergence patterns. *S.* cf. *brevis*, *Tanytarsus* sp. 2, *Polypedilum* sp. 3, *Heleniella* sp., and *Constempellina* sp. 1 were chosen because they illustrated highly synchronized emergence patterns. The highly synchronized patterns probably represent univoltine species whereas the long and extended patterns may reflect the addition of newly emerged generations of biovoltine or even multivoltine species later in the year. The general shape of the emergence pattern did not change, for any species, after canopy removal. That is, those species with highly synchronized or long and extended emergence patterns in 1978 maintained the same pattern in 1979.

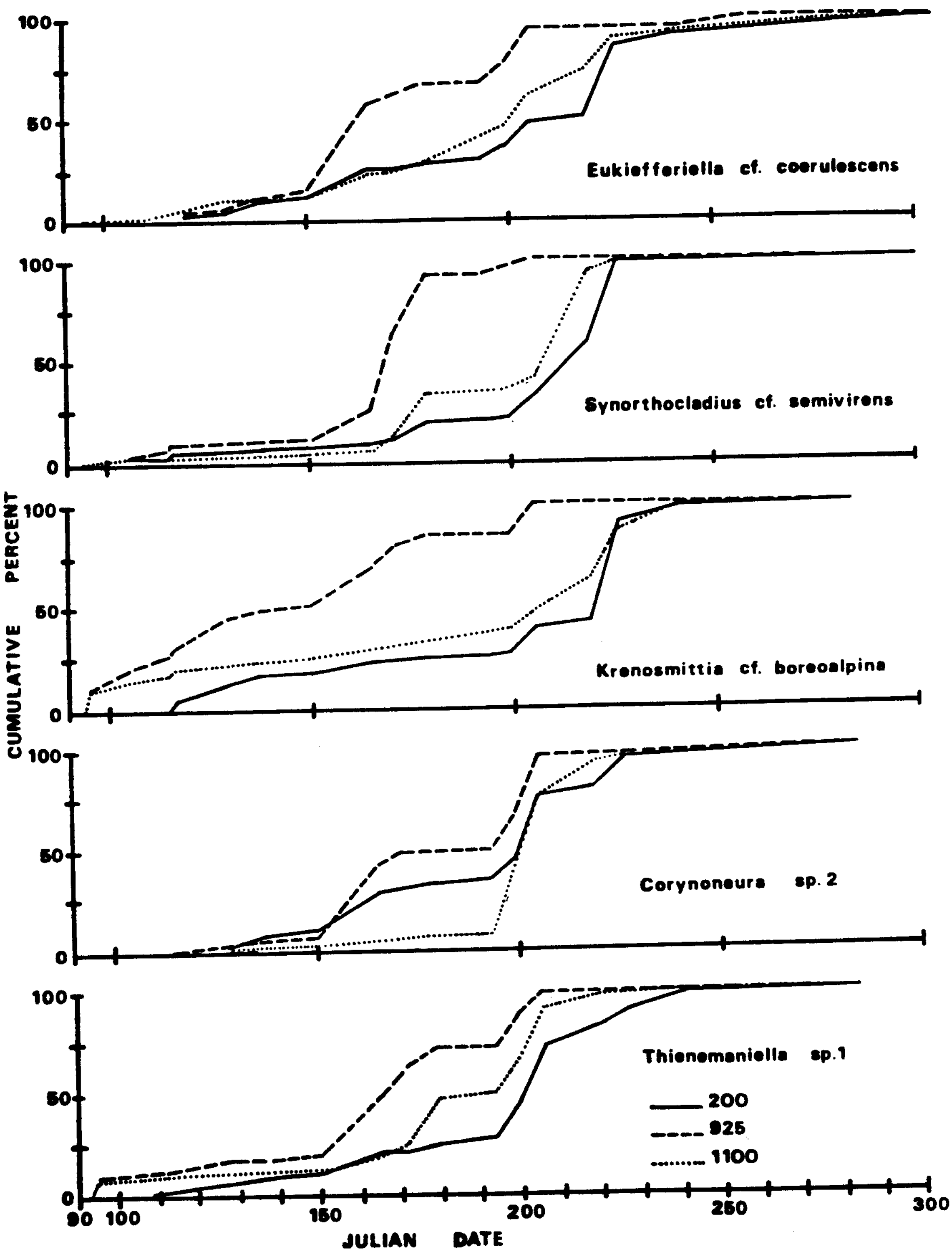

Fig. 29. Cumulative emergence curves, as a function of days, for ten core species in Bear Creek at stations 200, 925, and 1100 during 1978 (pre-treatment).

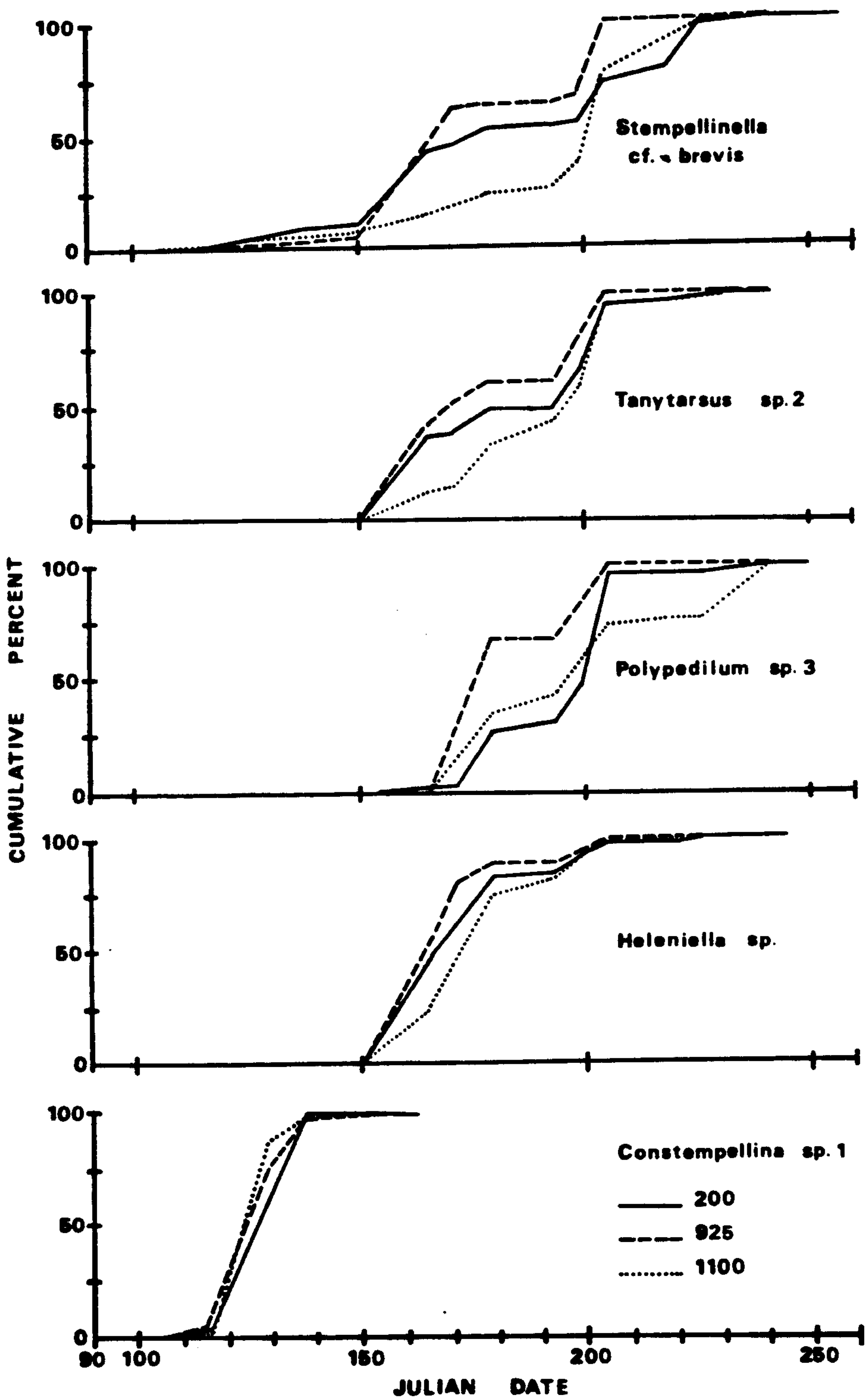

Fig. 29. Cumulative emergence curves, as a function of days, for ten core species in Bear Creek at stations 200, 925, and 1100 during 1978 (pre-treatment) - continued.

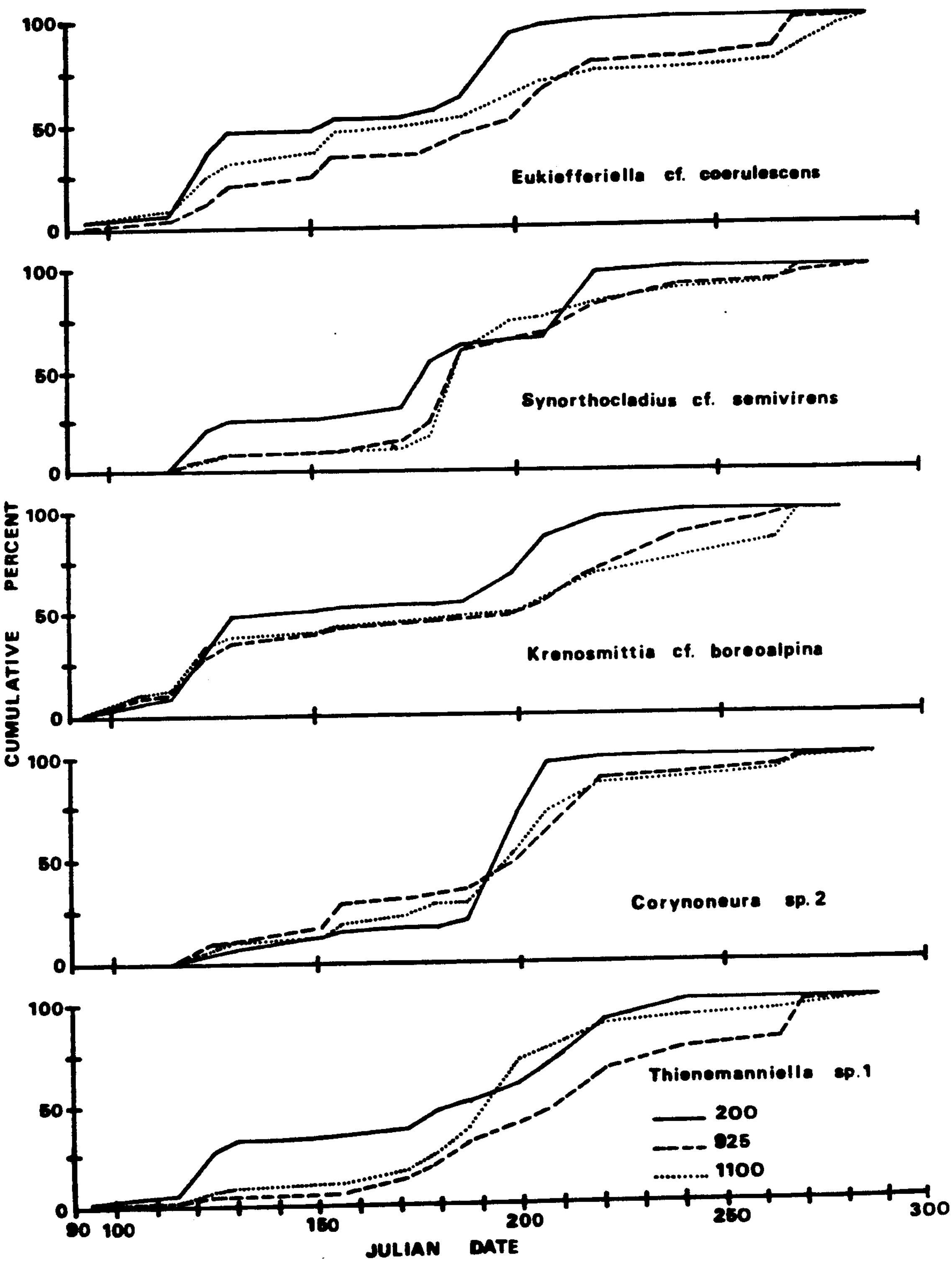

Fig. 30. Cumulative emergence curves, as a function of days, for ten core species in Bear Creek at stations 200, 925, and 1100 during 1979 (post-treatment).

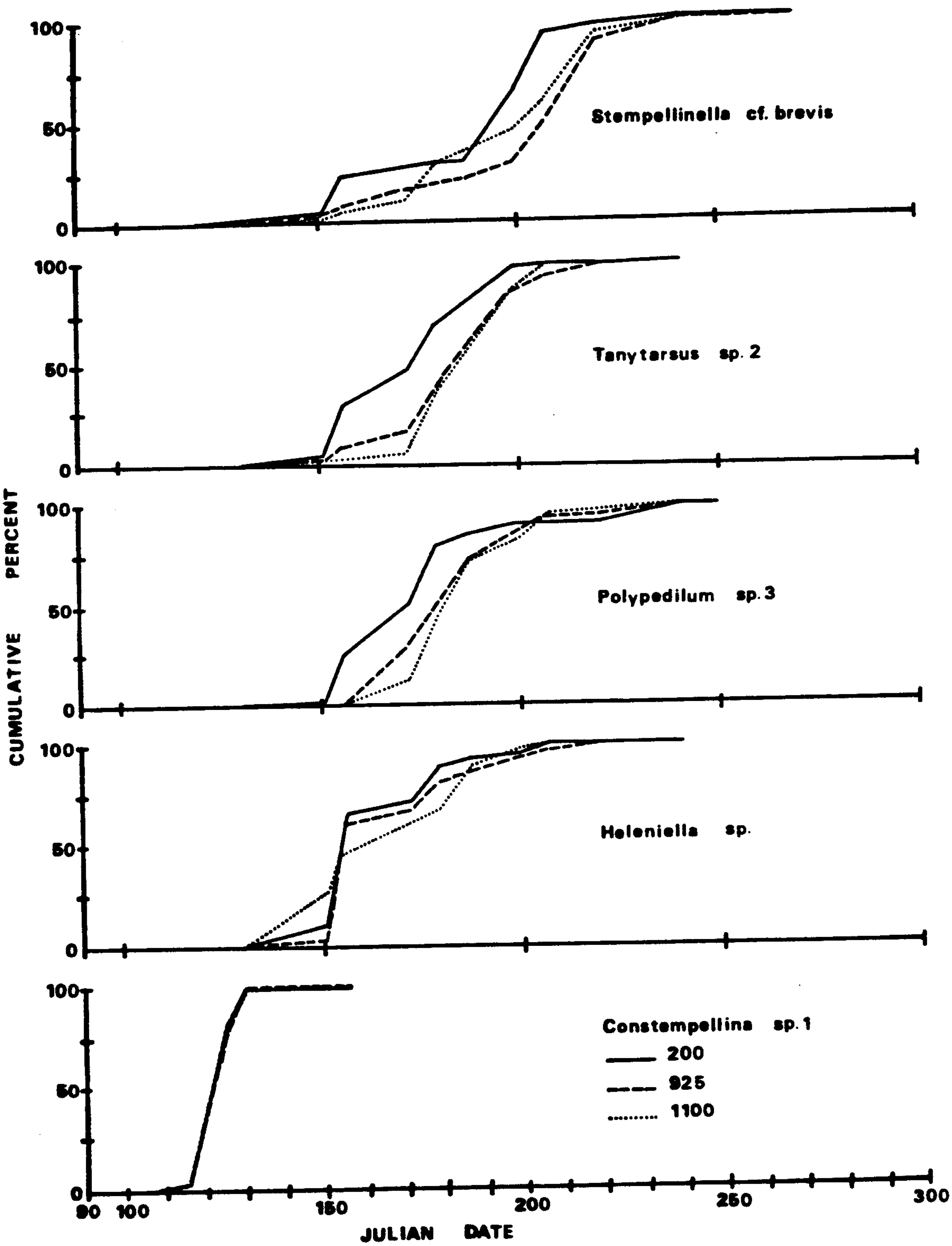

Fig. 30. Cumulative emergence curves, as a function of days, for ten core species in Bear Creek at stations 200, 925, and 1100 during 1979 (post-treatment) - continued.

There were differences, however, in timing of emergence among the three stations and between years. In 1978, all ten species emerged earlier at station 925. Stations 200 and 1100 showed no particular trend among the species, but emergence was consistently later than at 925 (Fig. 29). In contrast, all ten species emerged earliest at station 200 in 1979, whereas emergence was generally later at stations 925 and 1100 (Fig. 30).

At all stations, only two species, *Tanytarsus* sp. 2 and *Constempellina* sp. 1, required fewer days to complete the EM_{25}-EM_{75} interval after canopy removal (Table 26), although, *S.* cf. *brevis* did require fewer days to complete the interval at the two treatment stations (200 and 925) in 1979. Overall, five of the ten species required fewer days to complete the EM_{25}-EM_{75} interval at station 200, three at 925, and five at 1100.

Comparison of the 50% emergence dates for the ten species between 1978 and 1979 indicated that *Heleniella* sp. and *Constempellina* sp. 1 were the only species which had earlier EM_{50}'s at all three stations in 1979 (Table 27). The differences between the two years, however, were extremely small and could be attributable to natural variation. All species at stations 200 (lower treatment) and 1100 (control), except *S.* cf. *brevis*, reached the EM_{50} earlier after canopy removal. Earlier emergence of some species was minor (e.g., *Thienemanniella* sp. 1, station 1100) while in others the earlier emergence was substantial (e.g., *Eukiefferiella* cf. *coreulescens* and *Krenosmittia* cf. *boreoalpina* ,

Table 26. Estimated number of days required to complete the 25%-75% (EM_{25}-EM_{75}) emergence interval for ten species in the core complex in Bear Creek during 1978 and 1979.

Species	Station 200			Station 925			Station 1100		
	78	79	Difference in 1979	78	79	Difference in 1979	78	79	Difference in 1979
Eukiefferiella cf. *coerulescens*	62	71	+9	45	66	+21	58	105	+47
Synorthocladius cf. *semivirens*	16	81	+65	19	35	+16	39	26	-13
Krenosmittia cf. *boreoalpina*	45	81	+36	56	103	+47	75	117	+42
Corynoneura sp. 2	43	12	-31	43	58	+15	8	35	+27
Thienemanniella sp. 1	26	88	+62	41	55	+14	29	26	-3
Stempellinella cf. *brevis*	55	35	-20	42	22	-20	21	34	+13
Tanytarsus sp. 2	41	28	-13	38	19	-19	26	17	-9
Polypedilum sp. 3	25	21	-4	25	31	+6	38	25	-13
Heleniella sp.	18	21	+3	13	24	+11	15	33	+18
Constempellina sp. 1	12	6	-6	9	7	-2	8	6	-2

Table 27. Comparison of estimated Julian date for 50% (EM_{50}) emergence in 1978 and 1979 for ten species in the core complex, Bear Creek.

Species	Station	EM_{50} 1978	EM_{50} 1979	Difference in 1979 (days)
Eukiefferiella cf. *coerulescens*	200	217	154	-63
	925	173	197	+24
	1100	201	179	-22
Synorthocladius cf. *semivirens*	200	215	178	-37
	925	169	185	+16
	1100	208	186	-22
Krenosmittia cf. *boreoalpina*	200	220	140	-80
	925	142	199	+57
	1100	207	199	-8
Corynoneura sp. 2	200	200	194	-6
	925	193	197	+4
	1100	201	200	-1
Thienemanniella sp. 1	200	200	185	-15
	925	165	210	+45
	1100	193	191	-2
Stempellinella cf. *brevis*	200	176	194	+18
	925	167	208	+41
	1100	201	201	0
Tanytarsus sp. 2	200	193	173	-20
	925	170	184	+14
	1100	196	185	-11
Polypedilum sp. 3	200	196	172	-24
	925	176	179	+3
	1100	199	181	-18
Heleniella sp.	200	166	155	-11
	925	164	155	-9
	1100	172	160	-12
Constempellina sp. 1	200	126	121	-5
	925	125	121	-4
	1100	123	121	-2

station 200). Station 925 was strikingly different from stations 200 and 1100 after canopy removal. All species at station 925, except *Heleniella* sp. and *Constempellina* sp. 1, reached the EM_{50} later in 1979. The later emergence at station 925 after canopy removal was substantial (in terms of number of days) in three species (i.e., *K.* cf. *boreoalpina*, *Thienemanniella* sp. 1, and *S.* cf. *brevis*) but insignificant in other species (e.g., *Corynoneura* sp. 2 and *Polypedilum* sp. 3).

Chironomidae Larvae

Standing crop estimates of chironomid larvae in Bear Creek are based on samples collected at approximately monthly intervals from March through October in 1978 and 1979.

The numerical contribution of chironomid larvae to the total benthic community was relatively low in both years (Fig. 31). Highest values, in terms of percentage composition, occurred at station 1100 in 1978 (60%) and the lowest values at station 85 in 1979 (10%). This may in large part be due to mesh size used to collect the larvae. The diameter of the head capsule determines whether a chironomid larvae will be retained or lost (Jonasson 1955). Since newly hatched larvae have a maximum head capsule width of approximately 60 μ, the net used in this study (mesh size 233 μ) may have, at certain times of the year, allowed up to 80% of the larvae to pass through the net (Mundie 1971). Furthermore, many of the smaller larvae were undoubtedly overlooked during sorting. Errors of this nature are particularly significant in Bear

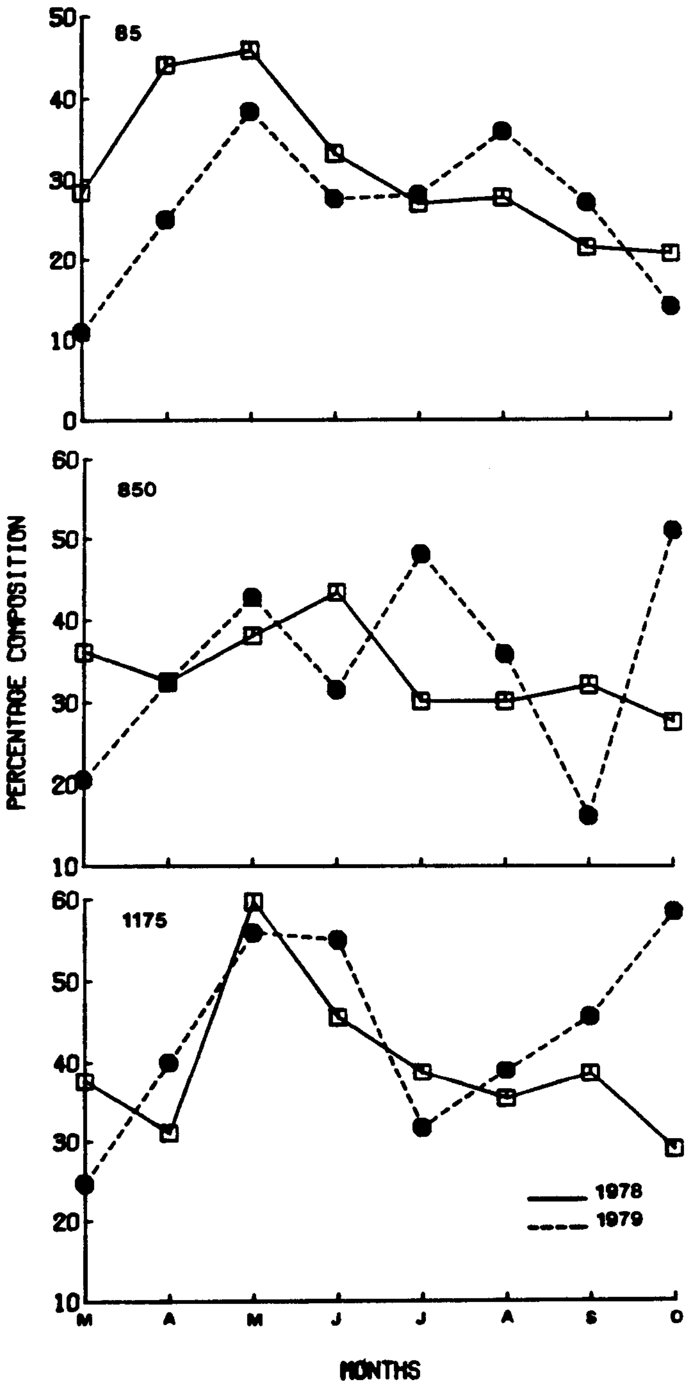

Fig. 31. Percentage composition of chironomid larvae to the total benthic community at stations 85, 850, and 1175 in Bear Creek during 1978 (pre-treatment) and 1979 (post-treatment).

Creek because smaller larvae (i.e., less than 3 mm) predominate the community (Fig. 32).

The mean standing crop (i.e., mean of the four replicate samples) of chironomid larvae in Bear Creek is summarized in Tables 28 and 29. In 1978 and 1979, station 1175 had the highest standing crop in numbers (Fig. 33), but the lowest standing biomass in 1978 (Fig. 34). During both years station 850 had the largest standing biomass.

Two-factor analysis of variance (station x month) was used to test for differences in standing crop data. In 1978 there were no significant differences ($p<0.05$) among the three stations in terms of total mean standing crop (numbers/m^2); however, when separated into size categories, smaller larvae (0-3 mm) were significantly more abundant at the control station (1175), while larger larvae were significantly more abundant at the lower treatment station (85). No significant differences were found among the stations for either total mean biomass or for mean biomass within each size category in 1978. In contrast to 1978, all three stations were significantly different in terms of numbers in 1979; station 1175 (control) had the highest mean number of larvae and station 85 (lower treatment) the lowest. The same pattern was also found for the smaller larvae (0-3 mm), but the mean number of larger larvae (3 mm and above) was not significantly different among the three stations. Mean biomass of smaller larvae was significantly higher at the upper treatment station (850) and control station (1175) in 1979.

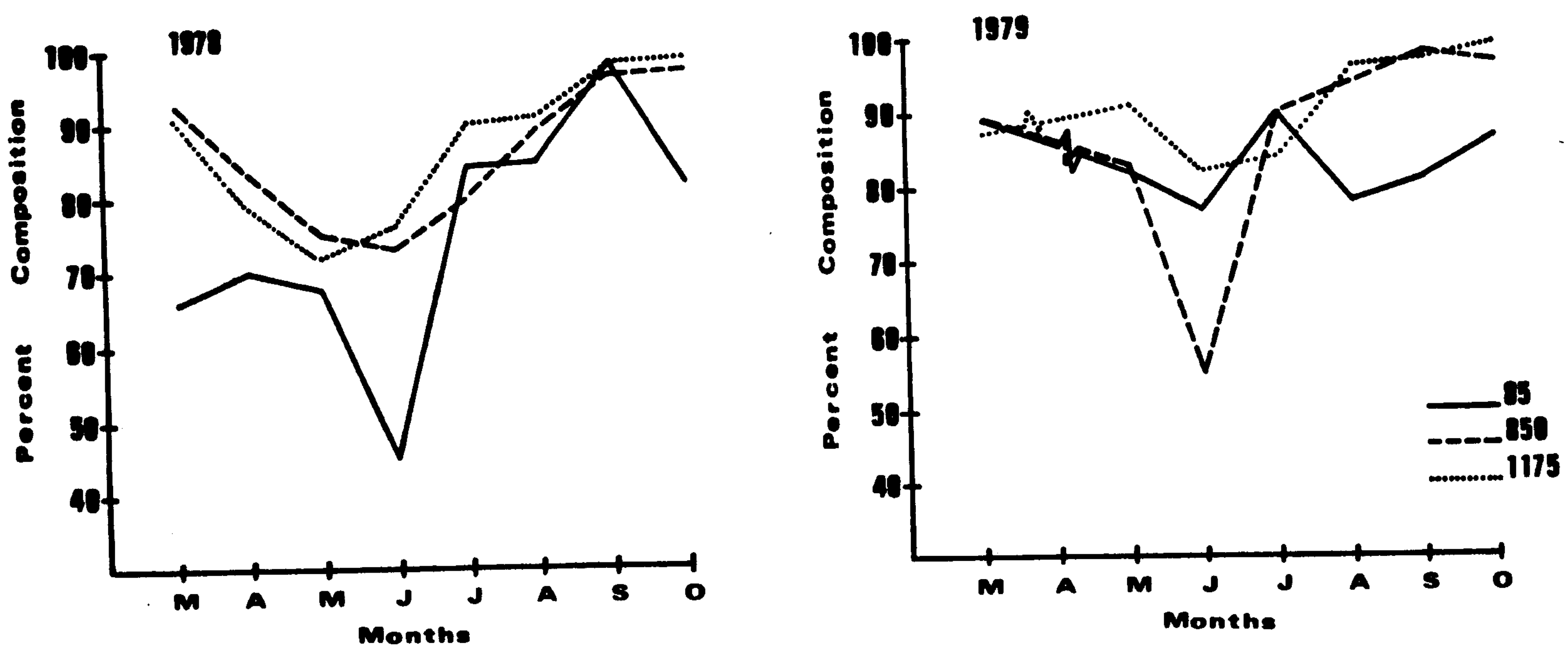

Fig. 32. Percentage composition of chironomid larvae less than 3 mm total length in Bear Creek during 1978 (pre-treatment) and 1979 (post-treatment).

Table 28. Chironomid larvae mean standing crop in Bear Creek in 1978: (a) Numbers/m^2; (b) mg/m^2 wet weight.

Station	Size group (mm)	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Mean[1]
(a) Numbers/m^2										
85	0-3	680	1,413	1,718	957	4,100	5,037	1,465	2,142	2,189
	3 and above	345	602	807	1,185	797	915	35	460	643
	Total	1,025	2,015	2,525	2,142	4,897	5,952	1,500	2,602	2,832
850	0-3	857	1,383	1,158	1,320	3,216	4,625	2,525	2,025	2,130
	3 and above	65	272	392	613	790	545	95	60	331
	Total	922	1,655	1,550	1,933	4,006	5,170	2,620	2,085	2,461
1175	0-3	1,123	675	2,020	2,625	7,225	6,250	4,910	3,576	3,630
	3 and above	110	177	780	825	820	590	110	50	456
	Total	1,233	852	2,800	3,450	8,045	6,840	5,020	3,626	4,087
(b) mg/m^2 wet weight										
85	0-3	19.0	20.4	41.0	35.8	54.5	298.8	29.8	35.3	66.8
	3 and above	35.8	67.6	63.8	154.5	251.0	270.3	9.3	275.8	141.0
	Total	54.8	88.0	104.8	190.3	305.5	569.1	39.1	311.1	207.8
850	0-3	22.3	121.0	13.5	45.7	55.0	123.5	29.5	21.8	54.3
	3 and above	10.1	813.0	47.8	116.3	360.0	136.5	22.0	58.0	192.6
	Total	32.4	934.0	61.3	162.0	415.0	260.0	51.5	79.8	246.9
1175	0-3	26.0	7.3	53.0	98.5	167.0	61.5	24.3	27.0	60.2
	3 and above	21.8	11.0	164.5	246.8	215.9	75.5	11.8	9.3	99.8
	Total	47.8	18.3	217.5	345.3	382.9	137.0	36.1	36.3	160.0

[1] Overall mean for all sampling dates.

Table 29. Chironomid larvae mean standing crop in Bear Creek in 1979: (a) Numbers/m^2; (b) mg/m^2 wet weight.

Station	Size group (mm)	Mar	Apr[1]	May	Jun	Jul	Aug	Sep	Oct	Mean[2]
(a) Numbers/m^2										
85	0-3	247		1,495	3,140	2,880	3,540	2,330	1,495	2,161
	3 and above	30		322	920	327	1,000	560	217	482
	Total	277		1,817	4,060	3,207	4,540	2,890	1,712	2,643
850	0-3	1,158		3,467	2,350	15,340	8,186	2,980	21,480	7,839
	3 and above	147		715	1,910	1,670	560	60	560	812
	Total	1,305		4,182	4,260	17,010	8,746	3,040	22,040	8,651
1175	0-3	1,330		2,725	8,900	7,760	9,180	14,280	26,920	10,483
	3 and above	203		267	2,000	1,522	380	420	280	744
	Total	1,533		2,992	10,900	9,282	9,560	14,700	27,200	11,227
(b) mg/m^2 wet weight										
85	0-3	8.3		31.9	71.3	99.7	57.0	108.5	25.3	53.4
	3 and above	10.3		70.4	278.4	551.0	190.5	211.5	37.3	192.8
	Total	18.6		102.3	349.7	650.7	247.5	320.0	62.6	250.2
850	0-3	6.0		110.6	113.0	268.0	125.3	118.0	190.0	133.3
	3 and above	4.7		162.5	806.0	711.0	44.0	3.0	45.0	261.5
	Total	10.7		273.1	919.0	979.0	169.3	121.0	235.0	394.8
1175	0-3	6.7		21.0	255.0	105.5	117.0	180.0	114.0	118.1
	3 and above	17.0		178.5	527.0	371.4	13.5	30.0	56.0	176.1
	Total	23.7		199.5	782.0	476.9	130.5	210.0	170.0	294.3

[1]No samples were taken in April.
[2]Overall mean for all sample dates.

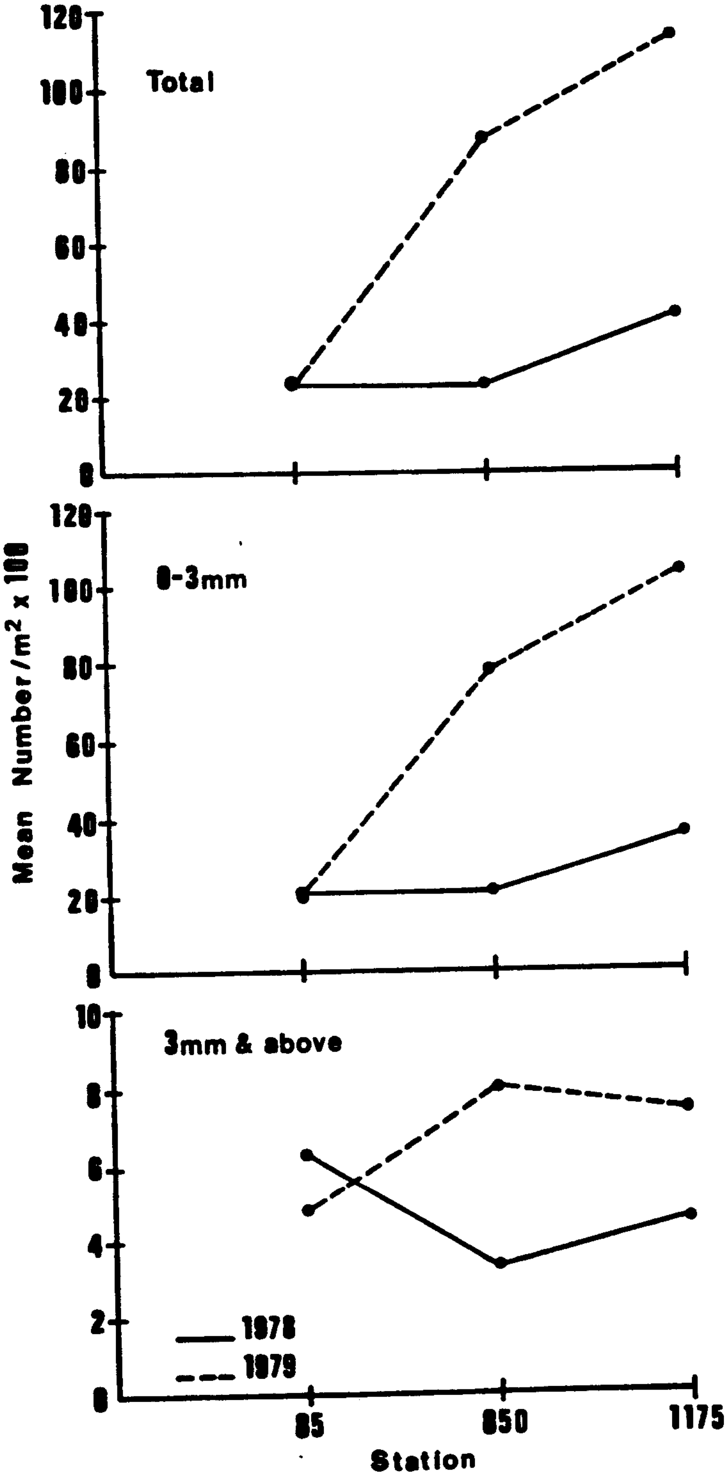

Fig. 33. Comparison of mean chironomid larvae standing crop (no./m^2) at stations 85, 850, and 1175 in Bear Creek during 1978 (pre-treatment) and 1979 (post-treatment).

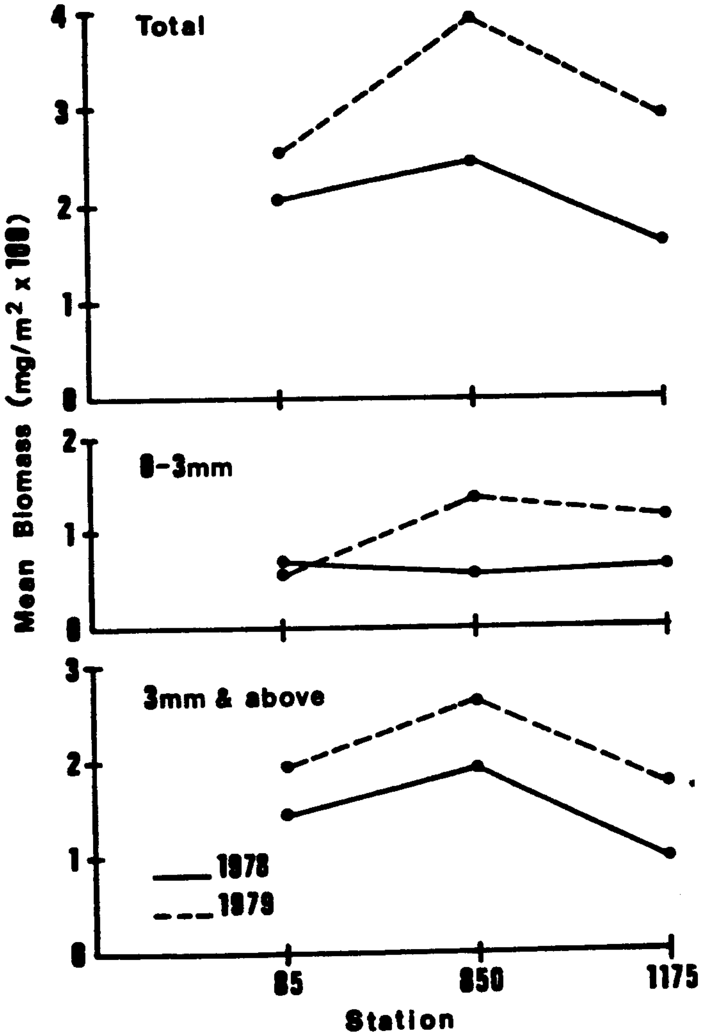

Fig. 34. Comparison of mean chironomid larvae biomass (mg wet weight/m^2) at stations 85, 850, and 1175 in Bear Creek during 1978 (pre-treatment) and 1979 (post-treatment).

Comparison of mean number and mean biomass at the three stations between years was tested using three-way factorial analysis of variance (station x month x year). No significant difference in mean number between the two years was found at station 85, but stations 850 and 1175 were significantly higher in 1979. The same pattern was also found for the smaller larvae but larger larvae were not significantly different among stations or between years. Total mean biomass and mean biomass of larger larvae were not significantly different at the three stations between 1978 and 1979. Smaller larvae mean biomass was, however, significantly higher at stations 850 and 1175 in 1979.

In summary, station 85, the lower treatment station, showed the least change in chironomid larvae mean number and mean biomass after canopy removal, whereas station 1175, the control station, showed the most significant change. Examination of total mean chironomid standing crop (numbers/m^2) data in 1979 (Fig. 33) suggests a trend towards a reduction in the mean number of larvae/m^2 as the influence of canopy removal increases (i.e., highest numbers at the control station and lowest at the lower treatment station), however, the mean number of chironomid larvae was not significantly different at station 85 between 1978 and 1979. Therefore, it is possible that factors other than those associated with canopy removal were controlling chironomid abundance at station 85 in 1979.

Monthly trends in mean chironomid standing crop are illustrated in Figs. 35 and 36. All curves are of the same general shape in 1978, with

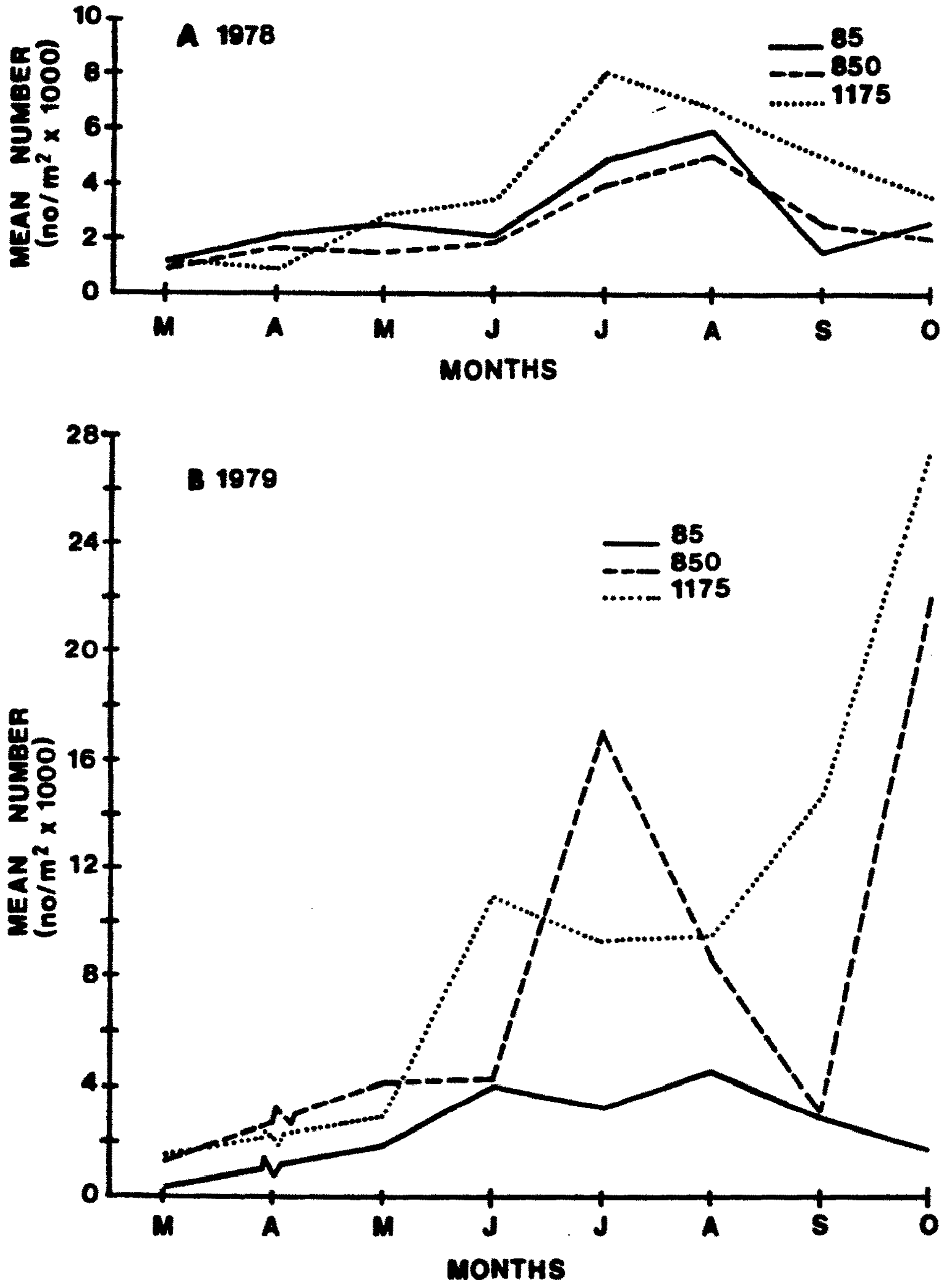

Fig. 35. Chironomid larvae mean standing crop (no./m^2) in Bear Creek during 1978 (pre-treatment) and 1979 (post-treatment).

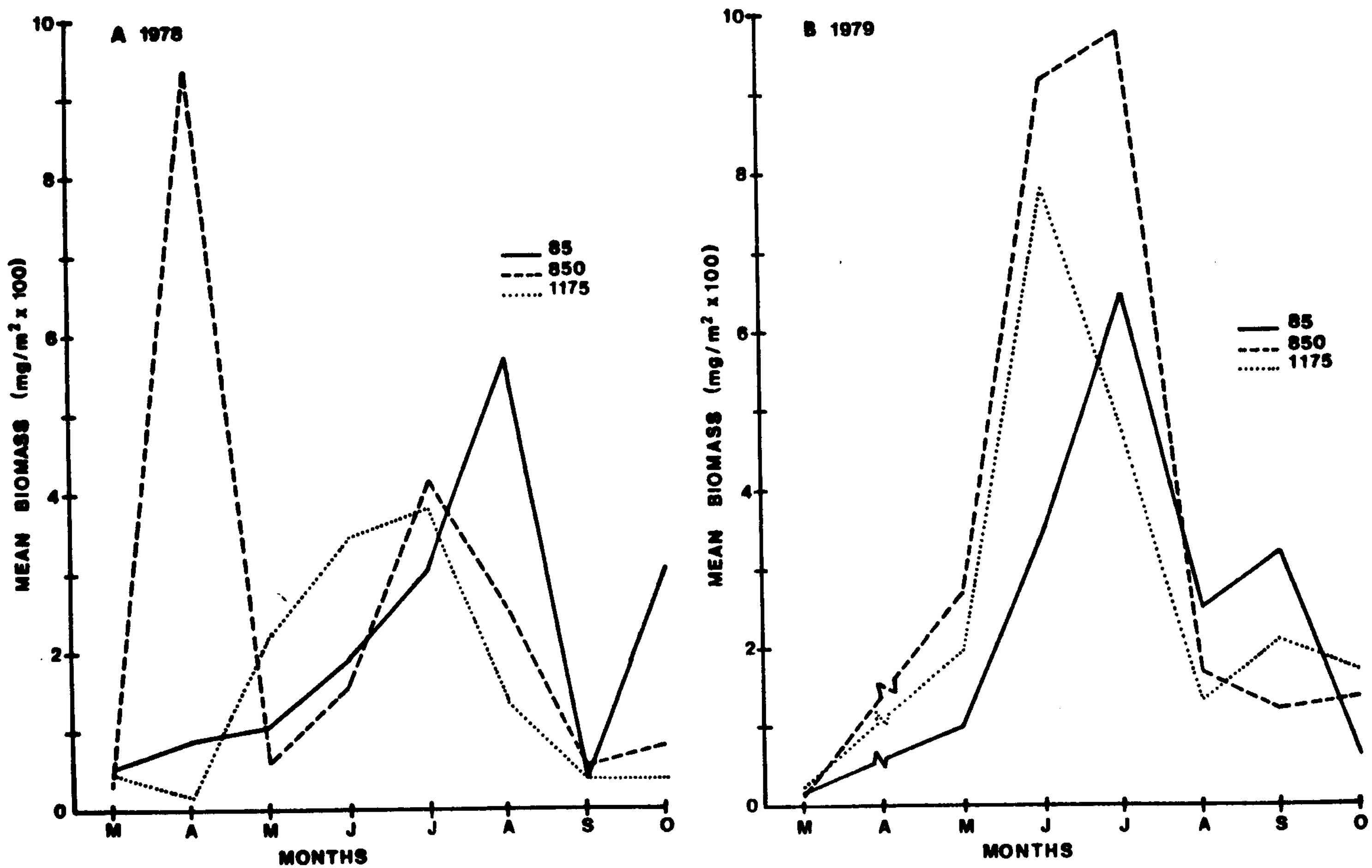

Fig. 36. Chironomid larvae mean biomass (mg wet weight/m^2) in Bear Creek during 1978 (pre-treatment) and 1979 (post-treatment).

slow increases in numbers through spring with peaks in either July or August (Fig. 35). In contrast, the three stations were widely different in 1979. Stations 850 and 1175 were the most dissimilar with major peaks in mean number occurring during October. This peak was associated with large increases in smaller newly recruited larvae.

In terms of mean biomass (Fig. 36), the three stations varied more in 1978 than in 1979. All stations peaked in mean biomass in mid- to late summer, but 850 was the only station which exhibited a high peak during the spring of 1978. This peak was not apparent in 1979.

The monthly trend in mean chironomid larvae number (no/m^2) reflects those of the total benthic community very closely (compare Figs. 35 and 37); however, trends of mean chironomid larvae biomass (mg/m^2) are not similar (compare Figs. 36 and 38).

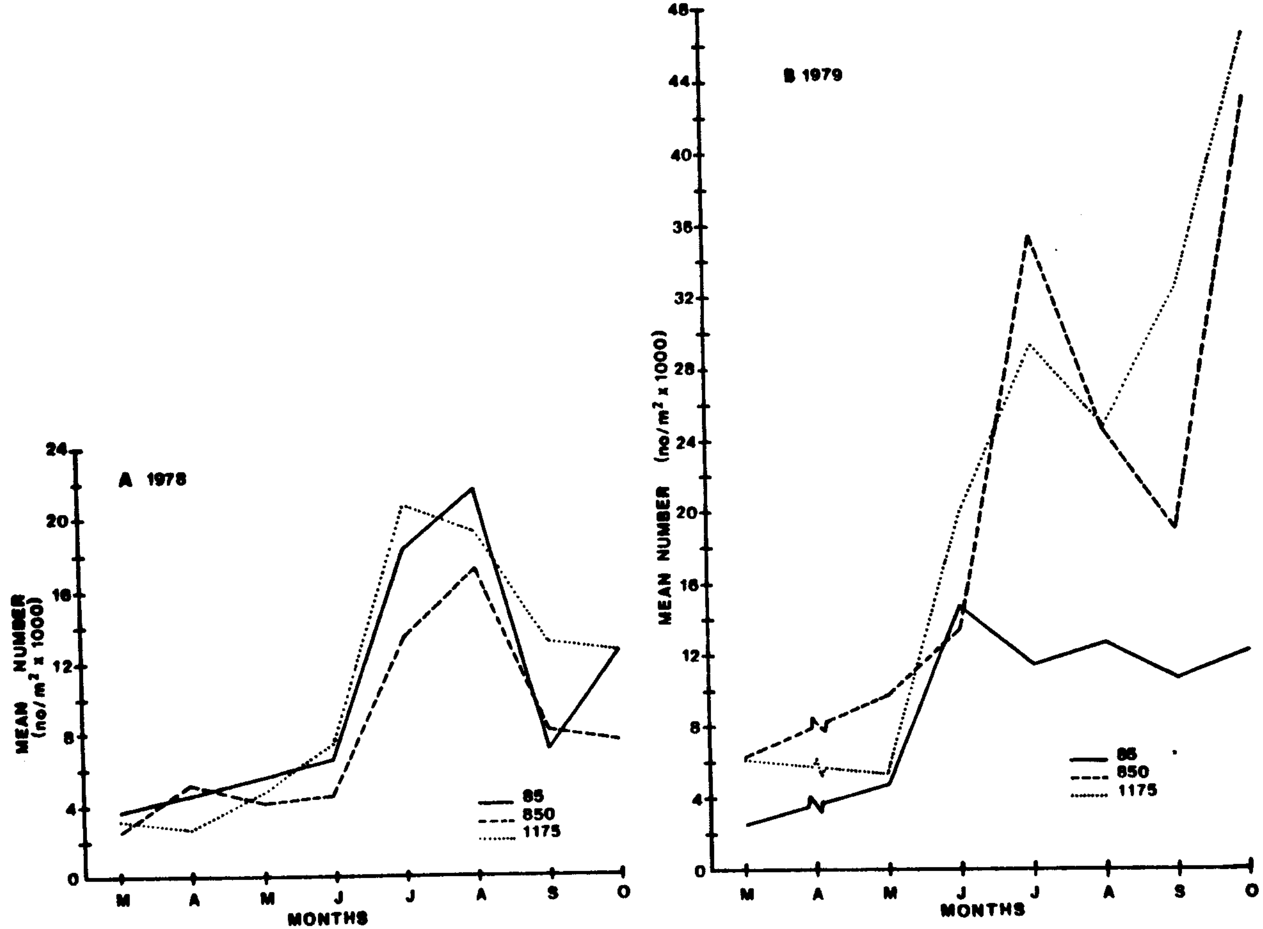

Fig. 37. Total benthic community mean standing crop (no./m^2) in Bear Creek during 1978 (pre-treatment) and 1979 (post-treatment).

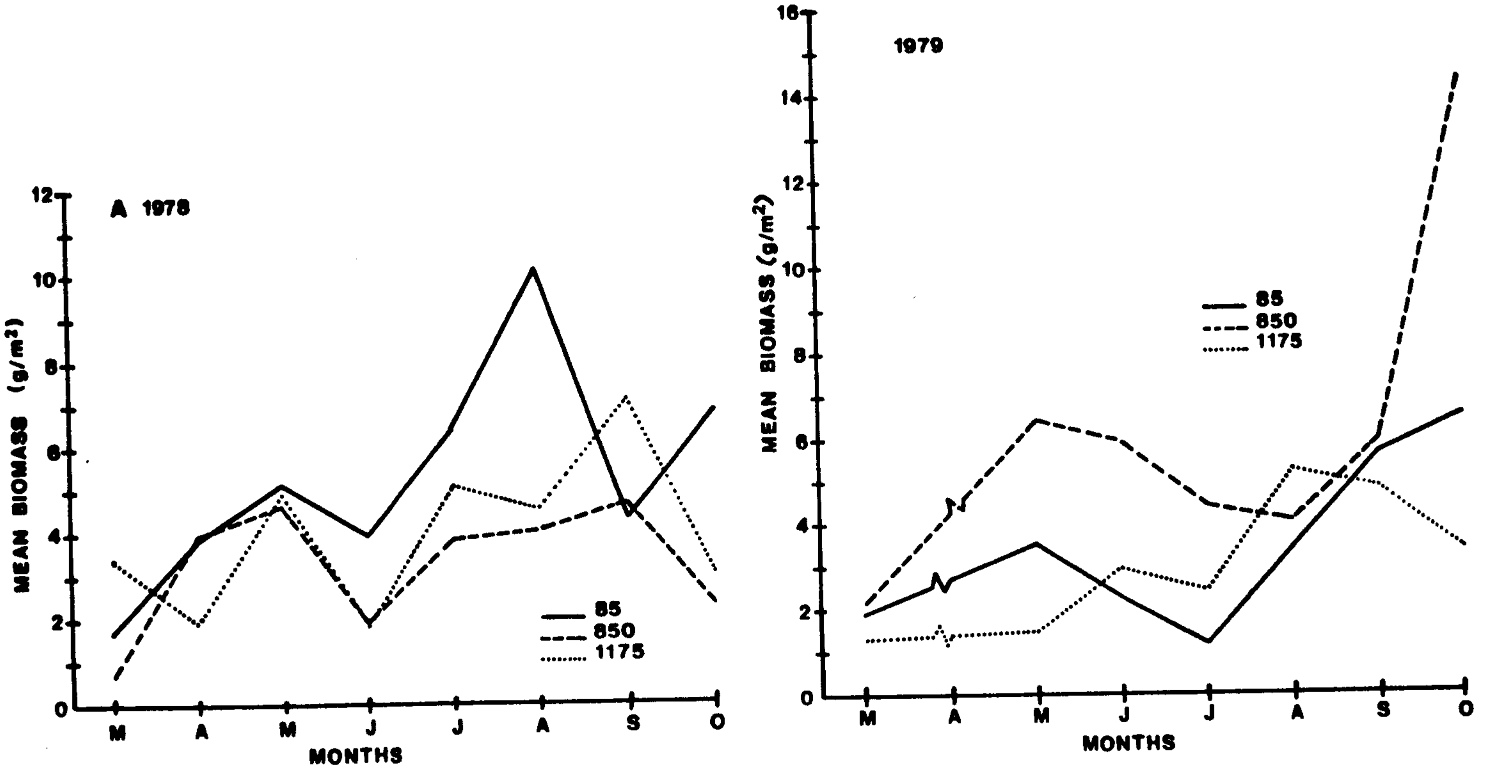

Fig. 38. Total benthic community mean biomass (g wet weight/m^2) in Bear Creek during 1978 (pre-treatment) and 1979 (post-treatment).

DISCUSSION

Effects of Canopy Removal on Physical Characteristics and Energy Input

Past investigations which have combined all phases of logging (i.e., tree-felling, road building, and yarding) into one study have effectively documented the major changes that occur in streams following logging (e.g., Hall and Lantz 1969; Moring 1975; Meechan et al. 1969; Graynoth 1979; Gibbons and Salo 1973). Foremost among the changes in logged watersheds is increased solar exposure, increased water temperature, sediment and organic debris input, damaged stream banks, and altered stream morphology.

Removal of the forest canopy at Bear Creek resulted in increased: solar exposure (Fig. 12), water temperature (Fig. 7), and algal production (Fig. 15), but reductions in detrital input during certain times of year (Tables 5 and 6). The physical structure of Bear Creek however, remained relatively unchanged after canopy removal. Sediment and organic debris inputs were not substantially increased and alterations in stream banks and stream morphology, except for a few areas, were minimal.

The thermal regime increase in Bear Creek after canopy removal was similar to changes in some logged watersheds (e.g., Swift and Messer 1971; Narver 1972) but far different from others (e.g., Brown and Krygier 1970). An important aspect of the water temperature regime in Bear Creek was the existence of contributory groundwater seepage which exerted a stabilizing effect on the stream temperature despite increased solar exposure. Smith and Lavis (1975) have similarly shown that under low-flow conditions, groundwater seepage reduced water temperatures in northern England streams by 4-5^{o}C over a distance of only 300 m.

Increased algal production following logging has been reported in many watersheds (Hansmann and Phinney 1973; Likens et al. 1970; Burton and Likens 1973; Lyford and Gregory 1975). Although algal production was slightly higher in the treatment zone after canopy removal in Bear Creek, it was lower than levels that occurred prior to canopy removal (see Fig. 15), which implies that factors other than light may be limiting algal production in Bear Creek.

Removal of the forest canopy caused a reduction in detrital input during several months of the year. However, it is possible that more detrital matter entered Bear Creek after canopy removal than before. Several tributary streams empty into the treatment zone in Bear Creek. The felled trees, lying in a bridge-like fashion over these tributaries, probably produced a constant rain of needles to these streams which could potentially have been continuously transported into the main channel. If additional amounts of needles had been transported into the main channel via tributary streams, the increased detrital input combined with algal production may have produced greater quantities of energy in Bear Creek after canopy removal.

Effects of Canopy Removal on Chironomid Taxonomic Composition, Emergence Patterns, and Larval Abundance

The overall species composition of the chironomid community in Bear Creek did not change appreciably following canopy removal. The structural framework of chironomid species was dominated by Orthocladiinae prior to canopy removal and this framework was maintained at all stations following canopy removal in 1979.

Each station did however exhibit some degree of change in species composition between 1978 and 1979 (Tables 12, 13, and 14). The differences however, occurred primarily among rare species (i.e., less than 10 total individuals for all sampling dates), and therefore did not significantly affect the total number of individuals collected at each station.

The percentage of the total composition of major taxa at all stations before and after canopy removal in Bear Creek showed only minor differences (Table 11). Comparison of the species composition and percentage composition of major taxa between Bear Creek and the three Clearwater streams indicated remarkable similarity considering the distance and extent of perturbation separating them. The extremes in the series among the Clearwater streams, in terms of recovery since logging, Octopus "B" tributary (logged 3 yr ago) and Honor Camp Creek (logged approximately 20 yr ago), showed the greatest difference in numbers of species—Honor Camp Creek had the fewest species—but the percentage composition of the major taxa was virtually the same (Table 16).

The overall similarities in species composition and percentage composition of major taxa between Bear Creek and the Clearwater streams suggests that neither canopy removal alone (Bear Creek) nor canopy removal in combination with roadbuilding and yarding (Clearwater streams) caused significant alterations in the structural framework of the chironomid communities. Furthermore, there was no consistent trend (either increase or decrease) in composition of major taxa (Table 19) in spite of the difference in time of recovery since logging (ranging from 1 yr to 20 yr).

A core species complex, as suggested in the second hypothesis (see introduction), was established based on the common features of the species composition in Bear Creek and the Clearwater River streams. A total of 35 species (out of 118 species from the four streams) was included in the complex. Orthocladiinae species represented 71% of the total complex, which indicates the overall importance of this group to the total chironomid community. The 35 species in the core complex comprised 91% of the total number of individual collected in Bear Creek during both 1978 and 1979. Thus, the value of concentrating on the core complex is clearly apparent because, the probability of accurately describing the total numbers of emerging chironomids in Bear Creek, based on data obtained for the 35 species (out of 99 total species in Bear Creek) is relatively high.

The core species hypothesis, however, requires further evaluation and testing in a wider spectrum of streams with different logging histories, gradients, and hydrologic patterns before it can accurately be used to assess the effects of a disturbance in a wide variety of streams.

Canopy removal in Bear Creek resulted in no discernable changes in emergence timing of chironomid species. Species accumulation curves, for the entire chironomid community (Fig. 22), clearly show that emergence of species was similarly synchronized among the stations in Bear Creek before (1978) and after (1979) canopy removal. Presumably, the environmental stimulus initiating emergence of species was the same at all stations during 1978 and 1979. In other words, environmental conditions at each station (notably temperature) were not sufficiently different to cause changes in emergence timing of chironomid species. Some species however, did show differences in emergence timing among the stations in 1979 (see Fig. 30), but it is difficult to assign the differences solely to canopy removal.

The mean number (no/m^2) of emerged chironomid individuals substantially increased at the two treatment stations (200 and 925) after canopy removal, but decreased at the control station (1100). Specifically, canopy removal appears to have caused increases in some species (e.g., *Thienemanniella* sp. 1, *Corynoneura* sp. 2, and *Constempellina* sp. 1) but only minor or inconsistent affects on other species (e.g., *Corynoneura* sp. 3, *Orthocladius* (*O.*) cf. *appersoni*, and *O.* (*O.*) cf. *dentifer*).

Emergence curves for the entire core species complex (Fig. 28) and for ten species within the complex (Fig. 29 and 30) showed only minor differences in emergence timing between 1978 and 1979. In fact, the relative constancy in emergence patterns at each station from year to year (e.g., *Constempellina* sp. 1, *Tanytarsus* sp. 2, *Heleniella* sp.) implies that the onset and duration of emergence was related to stream temperature (degree-days) and that the synchrony at each station resulted from a similar local temperature regime acting on individuals at the same developmental stage. In other words, the slightly higher temperatures at the treatment stations after canopy removal were not substantial enough to cause significantly more rapid larval development which could have accelerated emergence.

Thus, regardless of the numbers of individuals emerging at any given station, the entire chironomid community responded to environmental conditions in much the same manner at all three stations in Bear Creek. The similarities among stations and between years indicate that emergence at all stations was synchronized within the area in which the stations were situated, and that the synchrony in emergence at individual stations was not due to factors (temperature) characteristic of each particular station but rather to more general features of the environment which characterize the entire area.

Data on larval density at the three benthos stations after canopy removal illustrated a completely opposite situation from emergence abundance. Emergence data showed abundance to be greatest at the lower treatment station (200) and lowest at the control station (1100). In contrast, larval density was greatest at the control station (1175) and lowest at the lower treatment station (85).

Interpretation of the differences in larval abundance between years requires consideration of habitat conditions at each site. Station 85 (lower treatment) was significantly altered by high discharge levels as a result of the storm event in February 1979. The morphology of the station changed from a broad, stable riffle with shallow depth to a narrow constricted channel with greater depth and velocity in addition to larger and highly unstable substrate particles. Station 850 (upper treatment) did not change in morphology but had a substantial increase in particles in the phi-5 range. Station 1100 (control) neither changed in morphology nor in substrate particle size.

The significant increase in chironomid larval abundance at stations 850 and 1175 strongly suggests that environmental conditions in Bear Creek were more favorable for chironomid population development in 1979 than in 1978. The fact that larval abundance at station 85 did not similarly increase in 1979 but instead remained at levels similar to those in 1978 may be more a reflection of the unstable substrate at this station rather than a direct effect of canopy removal.

Finally, the first hypothesis, presented in the introduction, which stated that the magnitude of change in chironomid species composition and emergence patterns is directly related to increases in thermal regime following logging, could not be rejected based on the observations in Bear Creek. Specifically, removal of the forest canopy at Bear Creek did not substantially increase the thermal regime, and consequently, no major alterations in chironomid species composition or emergence patterns occurred. The hypothesis was tested however only at the lower end of the thermal regime spectrum at Bear Creek. Further studies are needed in streams subjected to greater thermal regime changes to either verify or reject the hypothesis at the upper end of the spectrum.

Effects of Thermal Regime Alterations as a Result of Canopy Removal on the Chironomidae

One of the most important environmental parameters affected by canopy removal is the increase in annual water temperature. Temperature is known to affect growth, reproduction, emergence, and distribution of aquatic insects (Vannote and Sweeney 1980; Wieser 1973; Danks and Oliver 1972; Konstantinov 1958). The range and character of changes that might be expected in chironomid populations after canopy removal are in large part conditioned by the initial situation in the stream. Clearly, a significant departure from historical water temperature patterns could have severe consequences on any population (Vannote and Sweeney 1980). In streams with a dense canopy, for example, moderate increases in heating could cause changes in chironomid populations more profound than would similar heating increases in more open streams.

Problems with canopy removal (logging) arise because abundance of a population can be altered by any environmental factor (i.e., temperature) which has a constant effect on either birth rate or mortality rate (Enright 1976). According to Sweeney and Vannote (1978) each species has an optimum temperature regime that permits an insect to attain maximum adult size and fecundity, and further, that any modification (either warmer or cooler) of that temperature regime will affect larval development and growth, and will result in diminished adult body size and fecundity. Thus, warming of the seasonal cycle, through the effects of canopy removal, may result in reduced population densities of some species causing their competitive position in the community to be low, and the probability of displacement, due to further environmental change to be increased (Vannote and Sweeney 1980). There are many published accounts of increased development of invertebrates with higher temperature (Anderson 1974; Brittian 1973; McNaught and Fenlon 1972; Nebeker 1971). Konstantinov (1958) has demonstrated, for a number of chironomids, that a rise in temperature can increase developmental rate and result in drastically reduced body size at pupation.

Species respond to increased heating in streams through highly diverse ecological, behavioral, physiological, and genetic adaptations which compose their overall adaptive strategies (Levins 1968; Valentine 1976; Biesiadka et al. 1978). According to Tauber and Tauber (1978) the most basic and most unifying component of a species' overall adaptive strategy is its phenological strategy. Phenological strategy is defined as the alteration in timing of an organism's seasonal cycles to coincide with resource availability and to avoid unfavorable abiotic or biotic conditions (see Lieth 1974).

Chironomid populations probably respond to disturbances by means of a hierarchical system of adjustment mechanisms, the actual pattern of response being dictated by the extent of the environmental change. Relatively minor increases in water temperature would require only minor adjustments by the populations, whereas more severe temperature increases would require more profound alterations, such as changes in physiology.

The changes in water temperature that accompany logging, however, are extremely variable. For example, changes in annual maximum water temperature after logging range from about 2°C (Meehan 1968) in Southeast Alaskan streams to over 15°C (Brown and Krygier 1970) in a first-order stream in Oregon. The response of chironomid populations would probably not be the same under these two conditions, even if differences in species composition were considered. Even though these may be exaggerated examples of thermal pattern changes, they effectively illustrate the wide spectrum of thermal patterns that can be expected in streams following logging.

Therefore, to adequately evaluate the effect of canopy removal on the adaptive properties and population densities of chironomids, some distinction must be made between streams subjected to low, moderate, and high thermal regime increases. A similar distinction in thermal regime changes has been utilized by Biesiadka et al. (1978), for cooling waters of thermal power plants.

The response of chironomids in streams subjected to low (ΔT from 0.5 to 3.0°C) increased temperature regimes would probably be minor. The species composition in these streams would not differ substantially from the original state. The overall structural and functional aspects of the communities would remain intact. A minor component of the species complex in the stream may be displaced but these species may have been those previously living under marginally acceptable conditions. Response mechanisms of chironomid populations are probably those associated with slight phenological modifications in response to the prevailing environmental conditions. Bear Creek and perhaps Octopus "B" trib. provide examples of streams subjected to low increases in thermal regime.

In moderately affected streams (ΔT from 4 to 6°C) the response of the chironomid community would extend longer in time. Species composition may begin to change because thermal regimes may be outside the tolerance range of many species. As suggested by Vannote and Sweeney (1980) warming of the seasonal cycle may cause some species to be displaced because of alterations in adult body size and fecundity. There may be fundamental changes in the structural and functional components of the community. The character of the new conditions may in large part be determined by the invasion of replacement species, from tributaries outside the influence of the affected area, more highly adapted to accommodate the new conditions. Christmas Creek provides supporting evidence for expected changes in moderately affected streams. Christmas Creek had the highest mean temperature (15.0°C) of any of the streams, and maintained the higher temperatures the longest (62 days with a mean temperature of 14.0^{o}C or greater). Furthermore, this was the only stream which showed a significant departure from a 3:1 ratio of Orthocladiinae to non-Orthocladiinae. The species complex in these streams is probably in a transitional phase and the amount of resemblance (in terms of species composition) with other moderately heated streams is probably dependent upon the availability of replacement species, extent of heating in the stream and time of recovery since the perturbation. Response mechanisms of the chironomid populations would include migration to habitats beyond the influence of the temperature increase. Physiological changes may occur among some species of the community, while other species may exhibit greater phenological modifications, such as accelerated emergence (earlier in the year) to coincide with the timing of favorable water temperature patterns. However, earlier emergence could be a tenuous strategy because the amplitude and phase of the temperature cycle may be widely different in water and air depending on the season and latitude of the stream. Species which would normally emerge in April or May, when corresponding air temperatures are relatively mild, may emerge in February or March and experience unusually harsh air temperatures (Nebeker 1971). If a species did emerge into lethally cold air temperatures, the adults could die, prevent mating and thus eliminate the species. Furthermore, increases in stream temperatures could disrupt the emergence timing of males and females, the males could emerge and die before the females even began to emerge. There is evidence in the literature suggesting that males typically emerge before females (Brink 1949; Nebeker 1971). Therefore, as pointed out by Kureck

(1979), for the emerging aquatic insect, the air temperature is at least as important as the water temperature.

In streams with excessive warming (ΔT above $6^{o}C$) adaptional response of the chironomid communities might be a very long-term process. This would include, perhaps, a complete reshaping of the composition of the fauna (i.e., being very much different from the original state). Species composition changes would probably be extensive due to the displacement of the major portion of the original complex and increased invasion pressure of species from higher order streams which are capable of successfully acclimating to the prevaling environmental conditions. Thus, the structural and functional aspects of the stream favors species groups highly adapted to warmer thermal regimes. In chironomids, this may mean an overall decrease in Orthocladiinae species and a corresponding increase in Chironominae species; the observations in Christmas Creek suggest such a trend.

Profound physiological and phenological modification probably characterize species from the original fauna which remain in the affected area of the stream. Their population densities, however, would undoubtedly be suppressed because of competition and limited habitats available. The probability of their displacement, should further environmental changes occur (such as increased sediment input), is probably very high (cf. Vannote and Sweeney 1980). Invasion pressure from species outside the affected area is of critical importance to the eventual achievement of a relatively constant community structure.

Speculations on the Effects of Canopy Removal on the Chironomidae

It has long been known that the numbers in any biological population do not remain constant but rather fluctuate (Andrewarth and Birch 1954), either increasing or decreasing in size progressively through time. In fact, violent fluctuations in abundance are characteristic of many insect populations (Solomon 1964). The range of fluctuations in abundance is however, influenced by many different factors including, variability in climate, the reproductive capacity of the population, food shortage, predation or disease. If the chironomid community in Bear Creek had been examined over a sufficiently representative period of time (e.g., 10 yr) the individual populations would have been found to fluctuate; increasing in abundance during highly favorable conditions and declining rapidly under unfavorable conditions. The change from year to year however, would probably have fluctuated in an irregular but restricted manner around a rather long-term mean, between relatively constant upper and lower limits (Kendeigh 1961).

Among the processes which influence insect populations, the major categories can be distinguished as: density-dependent (i.e., the influence becomes increasing adverse as density rises, and decreasingly so when population densities fall), and density-independent (i.e., the influence is entirely independent of the population and its density; see Solomon 1964). There is presently no general agreement in the literature as to relative contributions of each process in controlling (or regulating) insect populations. Schwerdtfeger (1971, p. 31) writes:

"Only density-dependent factors in the broadest sense--are able to cause a balance. Influences which are independent of abundance, e.g., components of the weather, can considerably increase or decrease the density but not in a determined manner; occasionally, they may become effective as regulators and thus assist or even replace the density-dependent or density-governed factors, but in principle the maintenance of a balance will be caused by the latter." In contrast, Andrewartha and Birch (1954) have long supported the idea that density-independent factors control population density among insects. Others, however, argue that density-dependent factors could also be invoked to explain population densities in the data of Andrewartha and Birch (see Solomon 1964). Some authors have even suggested that density-independent factors may often depend, at least in part, on population density (Andrewartha and Birch 1954; Debach 1958). According to Debach (1958, p. 476): "if intensity of unfavorable weather reduces the number of shelters and hence the number of insects surviving, weather acts in the manner of a density-dependent factor in that the higher the insect population becomes during favorable periods, the greater percentagewise, will be the reduction during unfavorable periods. To sum up, weather may regulate insect populations by being of sufficient severity to restrict the size, quality and/or numbers of inhabitable spots in a given area."

Bear Creek and perhaps most of the streams on the Olympic Peninsula, represent environments sensitive to density-independent factors, due to the frequency and intensity of storm events. So, population densities that chironomids can attain are primarily influenced by climatic conditions.

In view of this, the actual response of the chironomid populations that can be expected following canopy removal or logging may be conditioned on the population densities existing in the stream before the perturbation. For example, if population densities were low in the year prior to canopy removal, it may have been due to a relatively unfavorable year for populations to attain maximum densities. Under these conditions, canopy removal could potentially enhance environmental conditions and significantly increase population densities. However, it is possible that even if a significant increase in abundance did occur after canopy removal, the increase may not exceed the upper limits for maximum densities determined for the populations under natural (undisturbed) conditions. That is, if I had accumulated data on annual variations on the densities of chironomids in Bear Creek for ten years, naturally occurring upper and lower limits could have been determined. It is the upper limit which I would not expect to be exceeded even if densities increased significantly after canopy removal.

In contrast, if population densities from the year prior to canopy removal had been near the maximum that the environment was capable of supporting, or a favorable year, canopy removal would either further enhance the environment, perhaps resulting in even greater population densities, or reduce the favorability of the environment causing a corresponding reduction in density. If population densities were near the maximum that could be supported, canopy removal may have a greater probability of reducing the favorability of the environment for most species and thus, reduce population densities. According to Nicholson (1933, p. 135): "for the production of balance, it is essential that a controlling factor should act more severely against an average individual when the density of animals is high, and less severely when the density is low. In other words, the action of the controlling factor must be governed by the density of the population controlled." But again, even if a significant decrease in population density was detected after canopy removal, I would expect that the decrease would not be below the lower limit determined for the population under natural conditions.

A complicating factor to this hypothesis is that populations may fluctuate (either between generations or between years) mainly through the actions of density-independent processes, but the rate of change in density, either upward or downward may be regulated by density-dependent processes. Since the actions of density-dependent processes decrease as population density declines and intensify when densities increase, the process tends to reduce fluctuations in density, whether upwards or downwards, that exceed the average or normal levels of abundance (Solomon 1964). Nicholson (1933) regarded density-dependent processes as acting in a compensatory way against any departure from an equilibrium level. However, in any fluctuating population the rate of decrease may be greater than the rate of increase or vice versa. Solomon (1971) has pointed out that the rates of increase and decrease in population densities should not be expected to be equal.

Although changes in chironomid population densities were expected following canopy removal in Bear Creek, canopy removal alone did not prove to be a perturbation of significant magnitude (perhaps because of the relatively low temperature change) which would force the densities beyond the hypothetical limits suggested for maximum and minimum densities. Population densities could perhaps, be forced outside the hypothetical limits in streams more profoundly affected by changes in thermal regime, or by more severe changes in environmental conditions due to road building or yarding.

To sum up, the natural control of the chironomid populations in Bear Creek is probably due to a combination of density-independent and density-dependent processes. One way of visualizing this is to consider a given population, endowed with the capacity to produce large numbers of young, in which density-independent processes kill most of the young before they reach maturity, but the survivors of the density-independent mortality are highly sensitive to regulation by density-dependent processes. In other words, it is possible that in streams on the Olympic Peninsula, the frequency and intensity of storm events and corresponding discharge (density-independent) provide the primary mortality or "coarse adjustment" of chironomid population densities, whereas water temperature and solar exposure (also density-independent) provide the fine adjustment; and microhabitat availability, food quality and quantity, and competition (density-dependent) produce the "ultra-fine adjustment."

Significance of Chironomidae to Stream Fishes

One of the most significant features of Chironomidae in stream systems, is their importance as a food source for juvenile fish. Due to their small size, and to some extent habitat limitations, fry can only eat a certain size range of prey organisms. The Chironomidae not only provide an abundant food supply for smaller fish but also an optimum prey size range.

Extensive literature is available confirming the overall importance of chironomids as a food source for juvenile salmonids. Chironomid larvae have been shown to dominate the diet of coho (Mundie 1969; Gribanov 1948) and chinook salmon fry (Graybill et al. 1979). In addition, examination of the dietary components of chum and pink fry (Sparrow 1968; Synkova 1951; Levanidov and Levanidova 1957; Sano 1966) revealed that chironomid larvae were the predominant food item. Research on the feeding habits of sockeye salmon juveniles in river (Goodland et al. 1974) and lake (Rogers 1968; Hoffman 1979; Woodey 1972) systems have also indicated that, during certain times of the year (April-June) sockeye fry depend heavily upon chironomid larvae and pupae.

Many trout species have also been shown to rely heavily upon chironomid larvae and pupae. Miller (1974) showed that the diet of brook trout fry, soon after emergence was 97% chironomid larvae and pupae. Several authors (Tippets and Moyle 1978; Graybill et al. 1979; Doudoroff 1935; and Klassen 1967) have indicated that age-0 rainbow trout and juvenile steelhead trout extensively utilize chironomid larvae and pupae. Preliminary analysis of the stomach contents of cutthroat trout fry in Bear Creek (Martin, personal communication) showed that these fish subsisted almost entirely on chironomids. Chironomids have also been shown to be important dietary components of Atlantic and brown trout juveniles (White 1936; Nilsson 1957; McCormack 1962; Frost and Smyly 1952).

The Chironomidae not only provide a direct food source for juvenile trout and salmon but they also contribute indirectly, acting as important prey items for larger invertebrates which in turn provide the major food source for larger fish. Chironomid larvae have been shown to be extensively utilized prey items for several species of stoneflies (Davis and Warren 1965; Siegfried and Knight 1976; MacKereth 1957; Winterbourn 1974), and caddisflies (Thut 1969a, 1969b).

Chironomid larvae and pupae are clearly significant dietary components of juvenile salmonids, but their importance in the diet diminishes as the fish grow. The larger (and presumably older) fish are capable of extending their habitat and are also able to take advantage of a larger size range of prey organisms (Tippets and Moyle 1978; Miller 1974).

Griffiths (1975) developed two general feeding behavior models which can be related to differences in feeding strategy between salmonid fry (age 0) and older fish (e.g., age 1, age 2) in streams. The first model, which he terms a numbers maximizer model, assumes that predators eat prey as they are encountered so that the most abundant prey organism in the environment should be the most numerous in the diet. The second model, termed an energy maximizer model, assumes that predators feed to maximize their energy intake. Thus, prey organisms which represent the greatest energy source in the environment should be taken most frequently.

Based on the above feeding models, salmon fry can probably be described as numbers maximizers, that is, they capture prey, within the size range they can eat, as the prey are encountered in their habitat. On the other hand, older salmonids have probably adopted an energy maximizer strategy. This strategy, however, as pointed out by Griffiths (1975), requires more information regarding the numbers of organisms in the environment as well as their size distribution and availability.

Griffiths (1975) has shown, over a wide range of predators, that most larval and juvenile predators are numbers maximizers while most older and larger predators are energy maximizers. These findings support the contention that considering salmonid fry as numbers maximizers and older individuals as energy maximizers is appropriate.

If this reasoning is correct, older salmonids (e.g., age 1, age 2) should be expected to have greater control over their choice of food than younger (age 0) individuals. Under conditions of low prey density, for example, older salmonids and fry probably feed as numbers maximizers, that is, they take prey items proportional to their abundance in the stream, but at high prey densities only the fry would remain numbers maximizers, the older fish could, depending on the abundance of prey items, adopt either strategy.

The larval or fry period is an especially critical period because it is during this phase in the life history of fish that population numbers are regulated through density-dependent mortality generated by a combination of food and habitat availability.

Younger fish, as suggested above, having less choice of food aquisition, are probably more vulnerable than older fish to changes in food supply, whether naturally produced or as a result of anthropogenic pressure. Canopy removal in Bear Creek neither diminished the stream's capacity to produce food (see Tables 28 and 29) nor changed the availability of specific size ranges of prey organisms (see Figs. 33 and 34) during periods of demand by fry. So, the balance between effort and reward for the fry was presumably not disrupted and competition between different age groups was probably minimal. Therefore, alterations in population abundance or growth rate of cutthroat trout in Bear Creek is probably due to factors associated more with changes in habitat than with food.

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APPENDIX: TABLES

Appendix Table 1. Total number of species of Chironomidae collected in each channel for all stations and dates in Bear Creek, 1978.

	Stations					
	200		925		1100	
Date	R	L	R	L	R	L
4/04			2	8	8	10
4/05			5	18	17	17
4/16			8	8	21	14
4/25	9	14	7	12	8	11
4/26	7	10	4	10	10	8
5/09	21	21		22[1]		28[1]
5/17	16	31		16[2]	10	11
5/30	15	10	15	23	12	17
6/14	24	36	38	50	43	34
6/20	8	15	35	39	28	29
6/28	35	31	32	37	37	37
7/12	18	14			33	27
7/18	30	27	36	29	52	34
7/24	44	30	41	37	43	47
8/07	14	18			34	38
8/14	31	30			29	29
8/29	22	24			31	31
9/17				12[1]		
10/11	13	14			13	14
11/02	4	4			6	3

[1] Right and left channel were combined.

[2] Right channel sample lost.

Appendix Table 2. Total number of species of Chironomidae collected in each channel for all stations and dates in Bear Creek, 1979.

	Stations					
	200		925		1100	
Date	R	L	R	L	R	L
4/04	9	8	6	7	4	7
4/18	10	16	10	11	9	9
4/25	13	12	8	9	7	4
5/04	30	35	22	22	26	21
5/10	29	29	21	24	16	18
5/31	29	35	30	29	25	20
6/05	33	40	32	27	26	22
6/21	24	34	33	33	27	27
6/28	36	34		31[1]	27	36
7/06	31	35	35	31	29	28
7/18	56	44	33	40	31	28
7/26	35	46	37	36	30	26
8/08	15	33	39	31	23	35
8/29	24	30	29	26	26	22
9/21			27	16	20	11
9/27			24	22	23	14
10/15			21	11	11	8

[1] Right and left channel were combined.

Appendix Table 3. Total, pooled and heterogeneity chi-square analysis for species composition in Bear Creek and Clearwater River streams. Hypothesis tested: the Chironomidae community sampled has a 3:1 ratio of Orthocladiinae to non-Orthocladiinae.

Stream	Total chi-square	d.f.	Pooled chi-square	d.f.	Heterogeneity chi-square	d.f.
Bear Ck.						
200 1978	11.920	16	0.433	1	11.487	15
1979	17.995	14	1.151	1	16.844	13
925 1978	12.074	14	0.092	1	11.982	13
1979	20.823	17	0.016	1	20.839	16
1175 1978	16.614	19	0.135	1	16.479	18
1979	17.581	17	0.037	1	17.618	16
Octopus "B" Trib.	39.585	22	21.456	1	18.129	21
Christmas Ck.	37.035	12	3.308	1	33.727*	11
Honor Camp Ck.	22.934	12	3.484	1	19.450	11

$P^{15}_{0.05} = 24.996$; $P^{13}_{0.05} = 22.362$; $P^{16}_{0.05} = 26.296$;

$P^{18}_{0.05} = 28.869$; $P^{21}_{0.05} = 32.671$; $P^{11}_{0.05} = 19.675$

Appendix Table 4. Total number of chironomid pupal exuviae collected in each channel (R = right and L = left) for all stations and dates in Bear Creek, 1978.

	Stations								
	200			925			1100		
Date	R	L	Total	R	L	Total	R	L	Total
4/04				2	9	11	39	29	68
4/05				11	79	90	79	66	145
4/16				17	20	37	60	35	95
4/25	11	32	43	10	25	35	9	19	28
4/26	10	22	32	5	24	29	10	16	26
5/09	116	107	223		111	111[1]		214	214[1]
5/17	35	165	200		35	35[2]	21	16	37
5/30	35	25	60	50	55	105	36	42	78
6/14	113	450	563	301	994	1295	296	244	540
6/20	32	35	67	263	410	673	175	204	379
6/28	197	187	384	287	319	606	750	436	1186
7/12	37	19	56				180	147	327
7/18	224	158	382	285	186	471	718	310	1028
7/24	708	310	1018	433	333	766	1209	850	2059
8/07	73	125	198				774	689	1463
8/14	437	191	628				210	173	383
8/29	71	94	165				210	148	358
9/17					28	28[1]			
10/11	40	65	105				72	79	151
11/02	12	9	21				33	8	41

[1] Right and left channel were combined.

[2] Right channel sample lost.

Appendix Table 5. Total number of chironomid pupal exuviae collected in each channel (R = right and L = left) for all stations and dates in Bear Creek, 1979.

	Stations								
	200			925			1100		
Date	R	L	Total	R	L	Total	R	L	Total
4/04	24	19	43	9	12	21	5	9	14
4/18	40	84	124	27	43	70	22	17	39
4/25	23	56	79	21	13	34	13	6	19
5/04	605	1098	1703	270	367	637	426	212	638
5/10	238	371	609	121	144	265	93	99	192
5/31	121	184	305	139	153	292	65	53	118
6/05	292	460	752	225	228	453	105	81	186
6/21	190	312	502	212	203	415	149	117	266
6/28	355	442	797		257	257[1]	189	357	546
7/06	217	308	525	439	223	662	271	345	616
7/18	1461	935	2396	340	425	765	514	317	831
7/26	551	849	1400	422	216	638	313	204	517
8/08	135	536	671	861	297	1158	250	232	482
8/29	178	256	434	413	154	567	117	72	189
9/21				130	62	192	62	29	91
9/27				272	277	549	142	68	210
10/15				146	64	210	32	42	74

[1] Right and left channel were combined.

Appendix Table 6. Results of Kruskal-Wallis test for numbers of exuviae collected in the right and left channel of the emergence traps, Bear Creek, for 1978 and 1979 ($p < 0.05$).

Station	Mean rank Right channel	N[1]	Left channel	N[1]	Chi-square	Sig.
200						
1978	16.09	16	16.91	16	0.060	.806
1979	12.64	14	16.36	14	1.427	.232
925						
1978	12.04	13	14.96	13	0.950	.330
1979	18.00	16	16.06	17	0.332	.564
1100						
1978	20.13	19	17.81	18	0.427	.514
1979	18.38	17	16.62	17	0.267	.605

[1] N = number of sampling dates.

Appendix Table 7. Comparison of chironomid species composition in Bear Creek and the three Clearwater River streams for 1978 and 1979 as determined by the collection of pupal exuviae (B.C. = Bear Creek, O.C. = Octopus "B" tributary, C.C. = Christmas Creek, and H.C. = Honor Camp Creek).

	B.C.	O.C.	C.C.	H.C.	Total
Orthocladiinae					
Brillia cf. *flavifrons*	x	x	x	x	4
Brillia cf. *retifinis*				x	1
Brillia sp. 1	x	x			2
Brillia sp. 2	x		x		2
Bryophaenocladius cf. *subvernalis*	x				1
Cardiocladius sp.		x			1
Chaetocladius sp.	x	x		x	3
Corynoneura sp. 1	x	x	x	x	4
Corynoneura sp. 2	x	x	x	x	4
Corynoneura sp. 3	x	x	x	x	4
Cricotopus (*Cricotopus*) cf. *bicinctus*		x	x		2
Cricotopus (*C.*) cf. *cylindraceus*	x	x	x	x	4
Cricotopus (*C.*) sp. nr. *magus* gr.	x	x	x	x	4
Cricotopus (*C.*) sp. nr. *tibialis* gr.	x	x	x	x	4
Cricotopus (*C.*) *tremulus* gr. sp. nr. *tremulus*	x	x	x	x	4
Cricotopus (*C.*) *tremulus* gr. sp. nr. *tristis*	x	x	x	x	4
Cricotopus (*C.*) sp. 1	x				1
Cricotopus (*C.*) sp. 2	x				1

Appendix Table 7, cont'd

	B.C.	O.C.	C.C.	H.C.	Total
Cricotopus (*C.*) sp. 3		x			1
Cricotopus (*Isocladius*) sp.		x			1
Eukiefferiella cf. *bavarica*	x	x		x	3
cf. *brehmi*	x	x	x	x	4
cf. *brevicalcar*	x	x	x	x	4
cf. *calvescens*	x	x	x	x	4
cf. *claripennis*	x	x	x	x	4
cf. *coerulescens*	x	x	x	x	4
cf. *devonica*	x	x	x	x	4
cf. *lobifera*	x	x	x	x	4
cf. *minor-potthastia*	x	x	x	x	4
cf. *pseudomontana*	x	x	x	x	4
sp. 1	x	x		x	3
sp. 2	x				1
sp. 3				x	1
sp. 4				x	1
Heleniella sp.	x	x	x		3
Heterotrissocladius cf. *marcidus* gr.	x		x	x	3
Krenosmittia cf. *boreoalpina*	x	x	x	x	4
Krenosmittia cf. *camptophleps*	x	x	x	x	4
Limnophyes sp.	x	x			2

Appendix Table 7, cont'd

	B.C.	O.C.	C.C.	H.C.	Total
Nannocladius (*Nannocladius*) cf. *balticus*	x		x	x	3
Nannocladius (*N.*) cf. *rectinervis*	x	x	x	x	4
Orthocladius (*Orthocladius*) cf. *appersoni*	x	x	x	x	4
(*O.*) cf. *curtiseta*	x	x	x	x	4
(*O.*) cf. *dentifer*	x	x	x	x	4
(*O.*) cf. *frigidus*	x	x	x	x	4
(*O.*) cf. *mallochi*		x	x		2
(*O.*) cf. *nigritus*	x	x	x		3
(*O.*) cf. *obumbratus*		x			1
(*O.*) sp. 1	x	x	x	x	4
(*O.*) sp. 2	x	x	x		3
(*O.*) sp. 3	x	x			2
(*O.*) sp. 4	x				1
(*Eudactylocladius*) sp.	x	x	x	x	4
(*Euorthocladius*) cf. *rivulorum*		x			1
(*E.*) cf. *thienemanni*	x	x	x	x	4
(*E.*) sp. 1	x	x	x	x	4
(*E.*) sp. 2	x	x	x		3
Paracricotopus sp.	x	x	x	x	4
Parakiefferiella sp. 1	x	x	x	x	4
Parakiefferiella sp. 2	x	x			2

Appendix Table 7, cont'd

	B.C.	O.C.	C.C.	H.C.	Total
Parametriocnemus cf. *lundbecki*	x	x	x	x	4
Parametriocnemus sp. 1	x	x	x		3
Paraphaenocladius cf. *impensus*	x				1
Paratrichocladius sp.	x	x	x	x	4
Parorthocladius sp. 1	x				1
Parorthocladius sp. 2	x				1
Psectrocladius (*Psectrocladius*) sp. 1		x			1
Psectrocladius (*P.*) sp. 2			x		1
Pseudosmittia sp.	x				1
Psilometriocnemus sp. 1	x	x	x	x	4
Psilometriocnemus sp. 2	x				1
Rheocricotopus cf. *effusus*	x	x	x	x	4
Rheocricotopus sp. 1	x	x	x	x	4
Rheocricotopus sp. 2	x		x		2
Synorthocladius cf. *semivirens*	x	x	x		3
Thienemanniella cf. *acuticornis*	x	x	x	x	4
Thienemanniella sp. 1	x	x	x	x	4
Tokunagia sp.		x			1
Unk. Orthocladiinae (genus No. 5)	x				1
Unk. Orthocladiinae	x				1

Appendix Table 7, cont'd

	B.C.	O.C.	C.C.	H.C.	Total
Chironominae					
Chironomini					
Microtendipes sp.			x		1
Paracladopelma sp. 1	x				1
Paracladopelma sp. 2	x	x	x		3
Paratendipes sp. 1	x	x	x	x	4
Paratendipes sp. 2	x				1
Phaenopsectra sp.			x		1
Polypedilum fallax gr. sp.		x			1
Polypedilum sp. 1	x	x	x	x	4
sp. 2	x	x	x	x	4
sp. 3	x	x	x	x	4
sp. 4	x	x	x		3
sp. 5	x	x	x		3
Tanytarsini					
Constempellina sp. 1	x	x		x	3
Constempellina sp. 2			x		1
Micropsectra sp. 1	x	x	x	x	4
sp. 2	x	x	x	x	4
sp. 3	x	x	x	x	4
sp. 4	x				1

Appendix Table 7, cont'd

	B.C.	O.C.	C.C.	H.C.	Total
Paratanytarsus sp.	x	x	x		3
Rheotanytarsus cf. *distinctissimus*	x	x	x	x	4
Rheotanytarsus cf. *exiguus*	x		x	x	3
Stempellinella cf. *brevis*	x	x	x	x	4
Tanytarsus (*Subletti*) *coffmani*		x	x		2
Tanytarsus sp. 1	x	x	x	x	4
Tanytarsus sp. 2	x	x	x	x	4
Tanypodinae					
Arctopelopia sp.		x	x		2
Conchapelopia sp.	x	x		x	3
Krenopelopia sp.	x				1
Nilotanypus sp.	x	x	x	x	4
Pentaneura sp.	x	x	x	x	4
Rheopelopia sp.	x	x	x	x	4
Zavrelimyia (*Paramarina*) sp.	x	x	x	x	4
Diamesinae					
Diamesa sp.	x	x			2
Pagastia sp.	x	x		x	3
Potthastia sp.	x	x	x	x	4
Sympotthastia sp.	x	x	x	x	4

Appendix Table 7, cont'd

	B.C.	O.C.	C.C.	H.C.	Total
Prodiamesinae					
Monodiamesa sp.	x				1
Podonominae					
Boreochlus sp.	x	x			2
TOTAL	99	89	78	67	

Appendix Table 8. The composition of the emerging chironomid community (species) at station 200, 1978, Bear Creek.

Date	Orthocladiinae No. spp	Orthocladiinae %	Chironomini No. spp	Chironomini %	Tanytarsini No. spp	Tanytarsini %	Tanypodinae No. spp	Tanypodinae %	Diamesinae No. spp	Diamesinae %	Podonominae No. spp	Podonominae %	Total No. species
4/25	13	76.5	—		4	23.5	—		—		—		17
4/26	9	81.8	—		2	18.2	—		—		—		11
5/09	23	79.3	—		4	13.8	1	3.4	1	3.4	—		29
5/17	23	74.2	1	3.2	5	16.1	—		2	6.5	—		31
5/30	17	94.4	—		1	5.6	—		—		—		18
6/14	29	74.4	3	7.7	6	15.4	1	2.6	—		—		39
6/20	10	62.5	1	6.3	4	25.0	1	6.3	—		—		16
6/28	27	69.2	3	7.7	7	17.9	2	5.1	—		—		39
7/12	14	70.0	1	5.0	4	20.0	1	5.0	—		—		20
7/18	25	75.8	2	6.1	4	12.1	2	6.1	—		—		33
7/24	32	72.7	2	4.5	6	13.6	3	6.8	1	2.3	—		44
8/08	17	80.9	—		4	19.1	—		—		—		21
8/14	29	76.3	2	5.3	6	15.8	1	2.6	—		—		38
8/29	22	73.3	1	3.3	5	16.7	2	6.7	—		—		30
10/11	16	94.1	—		1	5.9	—		—		—		17
11/02	4	100.0	—		—		—		—		—		4

Appendix Table 9. The composition of the emerging chironomid community (species) at station 200, 1979, Bear Creek.

Date	Orthocladiinae No. spp	Orthocladiinae %	Chironomini No. spp	Chironomini %	Tanytarsini No. spp	Tanytarsini %	Tanypodinae No. spp	Tanypodinae %	Diamesinae No. spp	Diamesinae %	Podonominae No. spp	Podonominae %	Total No. species
4/04	10	100.0	—		—		—		—		—		10
4/18	16	88.9	—		2	11.1	—		—		—		18
4/25	13	92.9	—		1	7.1	—		—		—		14
5/04	30	81.1	2	5.4	4	10.8	—		1	2.7	—		37
5/10	28	75.7	1	2.7	6	16.2	—		1	2.7	1	2.7	37
5/31	26	70.3	2	5.4	7	18.9	1	2.7	1	2.7	—		37
6/05	30	68.2	3	6.8	8	18.2	2	4.5	1	2.3	—		44
6/21	26	72.2	1	2.8	7	19.4	2	5.6	—		—		36
6/28	25	62.5	2	5.0	7	17.5	4	10.0	2	5.0	—		40
7/06	26	65.0	2	5.0	6	15.0	5	12.5	1	2.5	—		40
7/18	40	67.8	4	6.8	8	13.6	6	10.2	1	1.7	—		59
7/26	34	70.8	1	2.1	8	16.7	4	8.3	1	2.1	—		48
8/08	27	77.1	1	2.9	6	17.1	1	2.9	—		—		35
8/29	23	71.9	1	3.1	7	21.9	1	3.1	—		—		32

Appendix Table 10. The composition of the emerging chironomid community (species) at station 925, 1978, Bear Creek.

Date	Orthocladiinae No. spp	Orthocladiinae %	Chironomini No. spp	Chironomini %	Tanytarsini No. spp	Tanytarsini %	Tanypodinae No. spp	Tanypodinae %	Diamesinae No. spp	Diamesinae %	Podonominae No. spp	Podonominae %	Total No. species
4/04	7	77.8	—		1	11.1	—		1	11.1	—		9
4/05	17	94.4	—		—		—		1	5.5	—		18
4/16	11	100.0	—		—		—		—		—		11
4/25	12	85.7	—		2	14.3	—		—		—		14
4/26	10	83.3	—		2	16.7	—		—		—		12
5/09	16	72.7	—		6	27.3	—		—		—		22
5/17	12	75.0	—		3	18.8	—		1	6.2	—		16
5/30	21	84.0	—		4	16.0	—		—		—		25
6/14	37	71.2	3	5.8	8	15.4	2	3.8	2	3.8	—		52
6/20	32	72.7	1	2.3	7	15.9	3	6.8	1	2.3	—		44
6/28	31	75.6	2	4.9	6	14.6	2	4.9	—		—		41
7/18	25	69.4	1	2.8	6	16.7	3	8.3	1	2.8	—		36
7/24	32	66.6	3	6.3	8	16.7	3	6.3	2	4.2	—		48
9/17	8	66.7	—		3	25.0	—		1	8.3	—		12

Appendix Table 11. The composition of the emerging chironomid community (species) at station 925, 1979, Bear Creek.

Date	Orthocladiinae No. spp.	%	Chironomini No. spp.	%	Tanytarsini No. spp.	%	Tanypodinae No. spp.	%	Diamesinae No. spp.	%	Podonominae No. spp.	%	Total No. species
4/4	7	100	--		--		--		--		--		7
4/18	13	86.7	--		2	13.3	--		--		--		15
4/25	10	83.3	--		2	16.7	--		--		--		12
5/4	23	85.2	1	3.7	2	7.4	1	3.7	--		--		27
5/10	21	80.8	1	3.8	3	11.5	--		1	3.8	--		26
5/31	24	72.7	1	3.0	6	18.2	--		2	6.1	--		33
6/5	28	75.7	--		6	16.2	1	2.7	2	5.4	--		37
6/21	28	70.0	2	5.0	7	17.5	3	7.5	--		--		40
6/28	21	67.7	1	3.2	7	22.6	2	6.5	--		--		31
7/6	26	68.4	1	2.6	5	13.2	4	10.5	2	5.3	--		38
7/18	28	60.9	3	6.5	7	15.2	5	10.9	3	6.5	--		46
7/26	33	73.3	2	4.4	5	11.1	3	6.7	2	4.4	--		45
8/8	32	76.2	1	2.4	4	9.5	4	9.5	1	2.4	--		42
8/29	21	67.7	2	6.5	7	22.6	1	3.2	--		--		31
9/21	23	82.1	--		5	17.9	--		--		--		28
9/27	23	82.1	--		5	17.9	--		--		--		28
10/15	22	95.7	--		1	4.3	--		--		--		23

Appendix Table 12. The composition of the emerging chironomid community (species) at station 1100, 1978, Bear Creek.

Date	Orthocladiinae No. spp	Orthocladiinae %	Chironomini No. spp	Chironomini %	Tanytarsini No. spp	Tanytarsini %	Tanypodinae No. spp	Tanypodinae %	Diamesinae No. spp	Diamesinae %	Podonominae No. spp	Podonominae %	Prodiamesinae No. spp	Prodiamesinae %	Total No. species
4/04	10	90.9	—		—		—		1	9.1	—		—		11
4/05	20	90.9	—		1	4.5	—		1	4.5	—		—		22
4/16	21	84.0	—		3	12.0	—		1	4.0	—		—		25
4/25	11	73.3	—		3	20.0	—		1	6.7	—		—		15
4/26	13	92.9	—		1	7.1	—		—		—		—		14
5/09	19	67.9	1	3.6	6	21.4	1	3.6	1	3.6	—		—		28
5/17	13	76.5	—		4	23.5	—		—		—		—		17
5/30	18	81.8	—		4	18.2	—		—		—		—		22
6/14	36	76.6	2	4.3	6	12.8	1	2.1	1	2.1	—		1	2.1	47
6/20	23	69.7	2	6.1	6	18.2	2	6.1	—		—		—		33
6/28	28	66.7	3	7.1	8	19.0	2	4.8	1	2.4	—		—		42
7/12	27	71.1	2	5.3	5	13.2	4	10.5	—		—		—		38
7/18	40	71.4	3	5.4	7	12.5	4	7.1	1	1.8	1	1.8	—		56
7/24	35	68.6	3	5.9	8	15.7	4	7.8	1	2.0	—		—		51
8/07	28	68.3	3	7.3	8	19.5	2	4.9	—		—		—		41
8/14	24	70.6	3	8.8	5	14.7	1	2.9	1		1	2.9	—		34
8/29	27	73.0	3	8.1	6	16.2	1	2.7	—		—		—		37
10/11	15	88.2	—		2	11.8	—		—		—		—		17
11/02	6	85.7	—		1	14.3	—		—		—		—		7

Appendix Table 13. The composition of the emerging chironomid community (species) at station 1100, 1979, Bear Creek.

Date	Orthocladiinae No. spp	Orthocladiinae %	Chironomini No. spp	Chironomini %	Tanytarsini No. spp	Tanytarsini %	Tanypodinae No. spp	Tanypodinae %	Diamesinae No. spp	Diamesinae %	Podonominae No. spp	Podonominae %	Total No. species
4/04	8	100.0	—		—		—		—		—		8
4/18	13	100.0	—		—		—		—		—		13
4/25	6	85.7	—		1	14.3	—		—		—		7
5/04	24	85.7	1	3.6	2	7.1	—		—		1	3.6	28
5/10	17	77.3	1	4.5	2	9.1	—		1	4.5	1	4.5	22
5/31	21	77.8	1	3.7	4	14.8	—		1	3.7	—		27
6/05	24	75.0	1	3.1	7	21.9	—		—		—		32
6/21	25	73.5	2	5.9	5	14.7	2	5.9	—		—		34
6/28	27	71.1	2	5.3	7	18.4	2	5.3	—		—		38
7/06	24	66.7	2	5.6	6	16.7	3	8.3	1	2.8	—		36
7/18	24	68.6	2	5.7	6	17.1	3	8.6	—		—		35
7/26	22	61.1	2	5.6	7	19.4	5	13.9	—		—		36
8/08	25	67.6	4	10.8	4	10.8	4	10.8	—		—		37
8/29	23	76.7	1	3.3	5	6.7	—		—		1	3.3	30
9/21	17	81.0	—		3	14.3	1	4.8	—		—		21
9/27	20	80.0	—		4	16.0	1	4.0	—		—		25
10/15	9	75.0	—		2	16.7	1	8.3	—		—		12

Appendix Table 14. The composition of the emerging chironomid community (number of individuals) at station 200, 1978, Bear Creek.

Date	Orthocladiinae		Chironomini		Tanytarsini		Tanypodinae		Diamesinae		Podonominae		Total number
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	
4/25	23	82.1	—		5	17.9	—		—		—		28
4/26	16	88.9	—		2	11.1	—		—		—		18
5/09	65	53.7	—		54	44.6	1	0.8	1	0.8	—		121
5/17	59	54.6	1	0.9	46	42.6	—		2	1.9	—		108
5/30	30	85.7	—		5	14.3	—		—		—		35
6/14	177	60.8	4	1.4	105	37.5	1	0.3	—		—		291
6/20	27	67.5	1	2.5	11	27.5	1	2.5	—		—		40
6/28	122	60.1	11	5.4	62	30.5	8	3.9	—		—		203
7/12	22	66.7	1	3.0	9	27.3	1	3.0	—		—		33
7/18	162	81.0	7	3.5	22	11.0	9	4.5	—		—		200
7/24	408	78.3	21	4.0	80	15.4	11	2.1	1	0.2	—		521
8/08	87	82.9	—		18	17.1	—		—		—		105
8/14	258	79.6	4	1.2	61	18.8	1	0.3	—		—		324
8/29	73	80.2	1	1.1	15	16.5	2	2.2	—		—		91
10/11	59	98.3	—		1	1.7	—		—		—		60
11/02	12	100.0	—		—		—		—		—		12
Total	1600		51		500		35		4		0		2190

Appendix Table 15. The composition of the emerging chironomid community (number of individuals) at station 200, 1979, Bear Creek.

Date	Orthocladiinae No.	%	Chironomini No.	%	Tanytarsini No.	%	Tanypodinae No.	%	Diamesinae No.	%	Podonominae No.	%	Total number
4/04	24	100.0	—		—		—		—		—		24
4/18	64	97.0	—		2	3.0	—		—		—		66
4/25	35	81.4	—		8	18.0	—		—		—		43
5/04	542	62.8	5	0.6	312	36.2	—		4	0.5	—		863
5/10	207	65.9	1	0.3	97	30.9	—		8	2.5	1	0.3	314
5/31	107	66.9	2	1.3	45	28.1	—	0.6	5	3.1	—		160
6/05	194	50.0	35	9.0	155	40.0	2	0.5	2	0.5	—		388
6/21	112	42.9	33	12.6	111	42.5	5	1.9	—		—		261
6/28	248	60.5	40	9.8	104	25.4	16	3.9	2	0.5	—		410
7/06	182	66.2	10	3.6	50	18.2	29	10.5	4	1.5	—		275
7/18	902	74.4	10	0.8	219	18.1	69	5.7	13	1.1	—		1213
7/26	518	72.5	5	0.7	164	23.0	26	3.6	1	0.1	—		714
8/08	286	82.9	1	0.3	56	16.2	2	0.6	—		—		345
8/29	130	57.5	12	5.3	83	36.7	1	0.4	—		—		226
Total	3551		154		1406		151		39		1		5302

Appendix Table 16. The composition of the emerging chironomid community (number of individuals) at station 925, 1978, Bear Creek.

Date	Orthocladiinae		Chironomini		Tanytarsini		Tanypodinae		Diamesinae		Podonominae		Total
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	number
4/04	7	77.8	—		1	11.1	—		1	11.1	—		9
4/05	47	92.2	—		—		—		4	7.8	—		51
4/16	23	100.0	—		—		—		—		—		23
4/25	18	85.7	—		3	14.3	—		—		—		21
4/26	18	90.0	—		2	10.0	—		—		—		20
5/09	33	51.6	—		31	48.4	—		—		—		64
5/17	21	60.0	—		13	37.1	—		1	2.9	—		35
5/30	54	87.1	—		8	12.9	—		—		—		62
6/14	423	63.8	8	1.2	222	33.5	6	0.9	4	0.6	—		663
6/20	238	68.8	7	2.0	95	27.5	5	1.4	1	0.3	—		436
6/28	212	67.7	13	4.2	85	27.2	3	0.9	—		—		313
7/18	170	69.7	4	1.6	59	24.2	10	4.1	1	0.4	—		244
7/24	243	61.1	9	2.3	135	33.9	9	2.3	2	0.5	—		398
9/17	18	64.3	—		9	32.1	—		1	3.6	—		28
Total	1525		41		663		33		15		0		2277

Appendix Table 17. The composition of the emerging chironomid community (number of individuals) at station 925, 1979, Bear Creek.

Date	Orthocladiinae		Chironomini		Tanytarsini		Tanypodinae		Diamesinae		Podonominae		Total number
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	
4/04	13	100.0	—		—		—		—		—		13
4/18	38	95.0	—		2	5.0	—		—		—		40
4/25	19	90.5	—		2	9.5	—		—		—		21
5/04	171	52.5	1	0.3	153	46.9	1	0.3	—		—		326
5/10	76	54.3	1	0.7	61	43.6	—		2	1.4	—		140
5/31	128	82.6	2	1.3	12	7.7	—		13	8.4	—		155
6/05	195	82.6	—		32	13.6	1	0.4	8	3.4	—		236
6/21	132	60.6	23	10.6	60	27.5	3	1.4	—		—		218
6/28	162	63.0	16	6.2	76	29.6	3	1.2	—		—		257
7/06	245	71.6	14	4.1	72	21.1	9	2.6	2	0.6	—		342
7/18	244	61.8	13	3.3	100	25.3	35	8.9	3	0.8	—		395
7/26	244	73.3	8	2.4	64	19.2	12	3.6	5	1.5	—		333
8/08	479	81.0	1	0.2	98	16.6	6	1.0	7	1.2	—		591
8/29	196	67.6	4	1.4	88	30.3	2	0.7	—		—		290
9/21	98	93.3	—		7	6.7	—		—		—		105
9/27	274	96.5	—		10	3.5	—		—		—		284
10/15	111	98.2	—		2	1.8	—		—		—		113
Total	2825		83		839		72		40		0		3859

Appendix Table 18. The composition of the emerging chironomid community (number of individuals) at station 1100, 1978, Bear Creek.

Date	Orthocladiinae		Chironomini		Tanytarsini		Tanypodinae		Diamesinae		Podonominae		Prodiamesinae		Total number
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	
4/04	30	83.3	–		–		–		6	16.7	–		–		36
4/05	66	84.6	–		1	1.3	–		11	14.1	–		–		78
4/16	48	87.3	–		4	7.3	–		3	5.5	–		–		55
4/25	16	80.0	–		3	15.0	–		1	5.0	–		–		20
4/26	17	94.4	–		1	5.6	–		–		–		–		18
5/09	47	40.9	1	0.9	65	56.5	1	0.9	1	0.9	–		–		115
5/17	15	57.7	–		11	42.3	–		–		–		–		26
5/30	38	84.4	–		7	15.6	–		–		–		–		45
6/14	202	71.4	2	0.7	75	26.5	2	0.7	1	0.2	–		1	0.3	283
6/20	148	74.4	9	4.5	40	20.1	2	1.0	–		–		–		199
6/28	466	77.2	15	2.5	112	18.5	9	1.5	2	0.3	–		–		604
7/12	106	60.6	5	2.9	56	32.0	8	4.6	–		–		–		175
7/18	399	75.0	11	2.1	93	17.5	27	5.1	1	0.2	1	0.2	–		532
7/24	705	67.6	11	1.1	304	29.1	21	2.0	–		2	0.2	–		1043
8/07	604	81.3	6	0.8	131	17.6	2	0.3	–		–		–		743
8/14	151	75.1	4	2.0	41	20.4	1	0.5	–		4	2.0	–		201
8/29	87	46.0	15	7.9	86	45.5	1	0.5	–		–		–		189
10/11	62	76.5	–		19	23.5	–		–		–		–		81
11/02	22	95.7	–		1	4.3	–		–		–		–		23
Total	3229		79		1050		74		26		7		1		4466

Appendix Table 19. The composition of the emerging chironomid community (number of individuals) at station 1100, 1979, Bear Creek.

Date	Orthocladiinae		Chironomini		Tanytarsini		Tanypodinae		Diamesinae		Podonominae		Total
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	number
4/04	10	100.0	—		—		—		—		—		10
4/18	25	100.0	—		—		—		—		—		25
4/25	9	75.0	—		3	25.0	—		—		—		12
5/04	139	42.5	2	0.6	179	54.7	—		—		7	2.1	327
5/10	48	47.1	1	1.0	50	49.0	—		2	2.0	1	1.0	102
5/31	56	83.6	2	3.0	8	11.9	—		1	1.5	—		67
6/05	79	76.0	3	2.9	22	21.1	—		—		—		104
6/21	87	61.7	8	5.7	44	31.2	2	1.4	—		—		141
6/28	129	45.3	19	6.7	117	41.1	20	7.0	—		—		285
7/06	170	53.5	14	4.4	109	34.3	24	7.6	1	0.3	—		318
7/18	307	72.1	8	1.9	98	23.0	13	3.1	—		—		426
7/26	164	60.7	7	2.6	64	23.7	35	13.0	—		—		270
8/08	150	60.0	5	2.0	85	34.0	10	4.0	—		—		250
8/29	62	60.2	1	1.0	39	37.9	—		—		1	1.0	103
9/21	45	86.5	—		6	11.5	1	1.9	—		—		52
9/27	95	84.8	—		16	14.3	1	0.9	—		—		112
10/15	35	85.4	—		5	12.2	1	2.4	—		—		41
Total	1610		70		845		107		4		9		2645

Appendix Table 20. The composition of the emerging chironomid community (species) in Octopus "B" tributary during 1978 and 1979.

Date	Orthocladiinae		Chironomini		Tanytarsini		Tanypodinae		Diamesinae		Podonominae		Total No. species
	No. spp	%	No. spp	%	No. spp	%	No. spp	%	No. spp	%	No. spp	%	
7/12/78	33	82.5	—		2	5.0	3	7.5	2		—		40
7/13/78	37	82.2	1	2.2	4	8.9	3	6.7	—		—		45
8/01/78	21	84.0	2	8.0	2	8.0	—		—		—		25
8/15/78	31	77.5	3	7.5	4	10.0	2	5.0	—		—		40
8/23/78	28	75.7	2	5.4	5	13.5	2	5.4	—		—		37
8/31/78	22	81.5	1	3.7	3	11.1	—		1	3.7	—		27
9/14/78	33	76.7	4	9.3	3	6.9	1	2.3	1	2.3	1	2.3	43
10/12/78	22	84.6	—		2	7.7	—		1	3.8	1	3.8	26
10/17/78	20	90.9	—		2	9.1	—		—		—		22
11/03/78	18	100.0	—		—		—		—		—		18
11/16/78	12	100.0	—		—		—		—		—		12
12/05/78	6	100.0	—		—		—		—		—		6
12/21/78	8	100.0	—		—		—		—		—		8
2/02/79	14	100.0	—		—		—		—		—		14
3/09/79	5	100.0	—		—		—		—		—		5
4/19/79	25	89.3	—		1	3.6	—		2	7.1	—		28
5/11/79	25	89.3	—		2	7.1	—		1	3.6	—		28
5/24/79	18	78.3	—		3	13.0	—		2	8.7	—		23
6/21/79	24	80.0	1	3.3	4	13.3	—		1	3.3	—		30
7/18/79	26	81.3	—		3	9.4	3	9.4	—		—		32
8/17/79	24	66.7	2	5.6	7	19.4	2	5.6	1	2.8	—		36
9/22/79	20	71.4	2	7.1	4	14.3	1	3.6	1	3.6	—		28

Appendix Table 21. **The composition of the emerging chironomid community (species) in Christmas Creek during 1978 and 1979.**

Date	Orthocladiinae No. spp.	%	Chironomini No. spp.	%	Tanytarsini No. spp.	%	Tanypodinae No. spp.	%	Diamesinae No. spp.	%	Total No. species
8-23-78	20	51.3	7	17.9	10	25.6	2	5.1	--		39
10-17-78	16	88.9	--		2	11.1	--		--		18
12-21-78	12	92.3	--		1	7.7	--		--		13
2-22-79	5	100.0	--		--		--		--		5
3-9-79	11	100.0	--		--		--		--		11
4-19-79	16	88.9	--		2	11.1	--		--		18
5-11-79	29	80.6	--		5	13.9	--		2	5.6	36
5-24-79	16	76.2	1	4.8	3	14.3	1	4.8	--		21
6-21-79	21	56.8	4	10.8	8	21.6	4	10.8	--		37
7-18-79	27	67.5	2	5.0	6	15.0	4	10.0	1	2.5	40
8-17-79	29	60.4	5	10.4	10	20.8	4	8.3	--		48
9-22-79	21	70.0	2	6.7	6	20.0	1	3.3	--		30

Appendix Table 22. The composition of the emerging chironomid community (species) in Honor Camp Creek during 1978 and 1979.

Date	Orthocladiinae No. spp	Orthocladiinae %	Chironomini No. spp	Chironomini %	Tanytarsini No. spp	Tanytarsini %	Tanypodinae No. spp	Tanypodinae %	Diamesinae No. spp	Diamesinae %	Total No. species
8/15/78	30	73.2	2	4.9	6	14.6	3	7.3	—		41
8/23/78	28	71.8	2	5.1	7	17.9	1	2.6	1	2.6	39
10/17/78	17	94.4	—		1	5.6	—		—		18
2/22/79	11	100.0	—		—		—		—		11
3/09/79	12	100.0	—		—		—		—		12
4/19/79	15	93.8	—		1	6.2	—		—		16
5/11/79	18	90.0	—		2	10.0	—		—		20
5/24/79	21	95.5	—		1	4.5	—		—		22
6/21/79	24	75.0	2	6.3	4	12.5	2	6.3	—		32
7/18/79	26	68.4	2	5.3	5	13.2	4	10.5	1	2.6	38
8/17/79	24	72.7	1	3.0	4	12.1	3	9.1	1	3.0	33
9/22/79	13	72.2	1	5.6	3	16.7	1	5.6	—		18

Appendix Table 23. Total benthic macroinvertebrate mean standing crop in Bear Creek in 1978, a) numbers/m^2; b) g/m^2 wet weight.

a) Numbers/m^2

Station	Size group (mm)	Months M	A	M	J	J	A	S	O	Mean
85	0-3	2625	2770	3512	4210	15590	18830	6042	10932	8064
	3-6	887	1635	1762	1972	2237	2302	727	1350	1609
	6 and above	95	162	228	265	323	340	216	260	236
	Total	3607	4567	5502	6447	18150	21472	6985	12542	9909
850	0-3	2363	3830	2745	3260	11510	15775	7260	6742	6686
	3-6	160	1152	1187	1110	1476	1125	740	702	957
	6 and above	33	105	135	83	290	215	146	73	135
	Total	2556	5087	4067	4453	13276	17115	8146	7517	7778
1175	0-3	2851	2075	2922	6080	18772	17935	12333	12076	9381
	3-6	327	622	1574	1335	1762	1217	520	380	967
	6 and above	99	40	194	150	238	243	199	77	155
	Total	3277	2737	4690	7565	20772	19395	13053	12533	10503

b) g/m^2 wet weight

Station	Size group (mm)	Months M	A	M	J	J	A	S	O	Mean
85	0-3	0.24	0.23	0.27	0.22	0.99	1.90	0.61	0.85	0.66
	3-6	0.56	1.32	1.70	1.03	1.59	2.01	0.98	1.17	1.29
	6 and above	0.91	2.32	3.18	2.65	3.82	6.26	2.71	4.89	3.34
	Total	1.71	3.87	5.15	3.90	6.40	10.17	4.30	6.91	5.29
850	0-3	0.28	0.29	0.15	0.20	0.65	1.05	0.53	0.74	0.49
	3-6	0.19	1.35	1.14	0.66	1.05	0.65	0.70	0.80	0.82
	6 and above	0.24	2.27	3.40	0.73	2.17	2.33	3.46	0.76	1.92
	Total	0.71	3.91	4.69	1.59	3.87	4.03	4.69	2.30	3.23
1175	0-3	0.21	0.18	0.37	0.25	0.76	0.77	0.76	0.85	0.52
	3-6	0.14	0.43	2.38	0.79	1.57	0.92	0.51	0.44	0.89
	6 and above	3.07	1.35	2.18	0.84	2.84	2.87	5.86	1.78	2.60
	Total	3.42	1.96	4.93	1.88	5.17	4.56	7.13	3.07	4.01

Appendix Table 24. Total benthic macroinvertebrate mean standing crop in Bear Creek in 1979, a) numbers/m^2; b) g/m^2 wet weight.

a) Numbers/m^2

Station	Size group (mm)	M	A	M	J	J	A	S	O	Mean
85	0-3	2150		3292	12800	10500	9420	7715	9007	7841
	3-6	302		1272	1750	823	2930	2620	2615	1759
	6 and above	60		163	170	100	310	325	558	241
	Total	2512		4727	14720	11423	12660	10660	12180	9841
850	0-3	5377		7043	9640	31700	21760	17540	41050	19159
	3-6	892		2406	3350	4070	2373	1140	1670	2129
	6 and above	56		331	470	510	253	120	290	290
	Total	6325		9780	13460	35280	24386	18800	43010	21578
1175	0-3	5513		4180	16440	25985	23170	30020	45000	21473
	3-6	643		1020	3020	2875	1380	1940	1240	1731
	6 and above	57		157	350	397	240	280	300	254
	Total	6213		5357	19810	29257	24790	32240	46540	23458

b) g/m^2 wet weight

Station	Size group (mm)	M	A	M	J	J	A	S	O	Mean
85	0-3	0.18		0.27	0.47	0.45	0.28	0.32	0.17	0.31
	3-6	0.42		1.54	1.14	0.75	0.97	1.54	0.79	1.02
	6 and above	1.30		1.74	0.68	0.71	2.23	3.76	5.59	2.29
	Total	1.90		3.55	2.29	1.91	3.48	5.62	6.55	3.62
850	0-3	0.45		0.59	0.38	0.96	1.18	1.08	1.17	0.83
	3-6	0.73		2.68	3.41	1.98	1.81	1.32	1.09	1.86
	6 and above	0.92		3.17	2.17	1.49	1.08	3.56	12.00	3.48
	Total	2.10		6.44	5.96	4.43	4.07	5.96	14.26	6.17
1175	0-3	0.33		0.09	0.51	0.59	0.75	0.70	0.65	0.52
	3-6	0.44		0.65	1.36	1.31	0.94	1.46	0.74	0.98
	6 and above	0.57		0.71	1.04	0.53	3.52	2.66	2.01	1.58
	Total	1.34		1.45	2.91	2.43	5.21	4.82	3.40	3.08

Appendix Table 25. Summary table of degree-days per month for Bear Creek (Sta 100), Octopus "B" tributary, and Christmas Creek, and Honor Camp Creek from October 1978 to September 1979.

		Stream			
Year	Month	Bear Creek (Sta 100)	Octopus "B" tributary	Christmas Creek	Honor Camp Creek
1978	October	308.6	281.6	319.5	295.7
	November	173.0	176.1	211.2	194.9
	December	129.2	164.9	144.9	162.9
1979	January	70.5	130.8	83.1	123.4
	February	122.0	152.5	125.2	139.4
	March	182.4	216.6	200.7	185.8
	April	211.8	236.2	223.2	192.5
	May	291.1	314.8	321.2	245.9
	June	341.6	360.8	391.6	272.5
	July	402.2	397.1	437.5	318.5
	August	436.2	435.9	474.8	336.3
	September	352.7	359.7	390.0	319.5
	TOTAL	3021.3	3226.8	3322.9	2787.3

Appendix Table 26. Total hours of solar exposure per site in the treatment zone of Bear Creek in January 1979 (pre-treatment) and March 1979 (post-treatment), based on fisheye canopy densiometer photographs taken at 25-m intervals (unpublished data, Martin et al. 1981).

Site	Hrs exposure (pre-treatment)	Hrs exposure (post-treatment)	Increase in hrs exposure	Relative % increase
25	4.80	7.00	2.2	45.8
50	1.00	6.50	5.5	550.0
75	3.00	7.00	4.0	133.3
100	3.50*	6.00	2.5	71.4
125	2.25	6.00	3.75	166.7
150	3.00	5.50	2.5	83.3
175	5.25	6.50	1.25	23.8
200	5.00*	7.50	2.5	50.0
225	1.00	7.50	6.5	650.0
250	2.00	4.50	2.5	125.0
275	4.50	6.00	1.5	33.3
300	4.75	7.50	2.75	57.9
325	4.50*	7.50	3.0	66.7
350	3.30*	8.00	4.7	139.5
375	4.00*	9.50	5.5	137.5
400	3.50	9.00	5.5	157.1
425	5.30*	7.50*	2.2	41.5
450	3.00	7.30	4.3	144.3
475	1.00	8.00	7.0	700.0
500	4.00	8.25*	4.25	106.3
525	2.50	7.50	5.0	200.0
550	4.60	8.25	3.65	77.0
575	3.25	7.50	4.25	130.8
600	3.50	7.50	4.0	114.3
625	6.00*	9.00	3.0	48.0
650	4.50	8.00	3.5	77.8
675	1.50	7.00*	5.5	366.7
700	5.50	7.50	2.0	36.4
725	2.50*	6.50*	4.0	160.0
750	3.75*	9.00	5.25	140.0
775	3.50*	8.50	5.0	142.9
800	2.50	7.75*	5.25	210.0

Appendix Table 26. Total hours of solar exposure per site in the treatment zone of Bear Creek in January 1979 (pre-treatment) and March 1979 (post-treatment), based on fisheye canopy densiometer photographs taken at 25-m intervals (unpublished data, Martin et al. 1981) - continued.

Site	Hrs exposure (pre-treatment)	Hrs exposure (post-treatment)	Increase in hrs exposure	Relative % increase
825	3.25	6.75	3.5	107.7
850	2.00	8.00	6.0	300.0
875	1.50	8.00	6.5	433.3
900	3.00	6.50	3.5	116.7
925	3.00	8.00	5.0	166.7
950	5.00	8.00	3.0	60.0
975	5.00	6.00	1.0	20.0
1000	1.50	--	--	--

*Approximate values because these sites could not be measured directly or were shaded during the day by overhanging branches or by logs.

Appendix Table 27. Subfamily and tribal breakdown of the total number of emerging chironomids at each station in 1978 and 1979.[1]

	Station 200		Station 925		Station 1100		Total	
Subfamily	78	79	78	79	78	79	78	79
Orthocladiinae	1,600	3,551	1,525	2,825	3,229	1,610	6,354	7,986
Chironominae	551	1,560	704	922	1,129	915	2,384	3,397
(Tanytarsini)	(500)	(1,406)	(663)	(839)	(1,050)	(845)	(2,213)	(3,090)
(Chironomini)	(51)	(154)	(41)	(83)	(79)	(70)	(171)	(307)
Tanypodinae	35	151	33	72	74	107	142	330
Diamesinae	4	39	15	40	26	4	45	83
Prodiamesinae	0	0	0	0	1	0	1	0
Podonominae	0	1	0	0	7	9	7	10
Total	2,190	5,302	2,277	3,859	4,466	2,645	8,933	11,806

[1]Numbers represent combined total for all sampling dates.

VITAE

Steven Theodore White, son of Telford T. and Roberta B. White, was born in Detroit, Michigan on July 23, 1948. He graduated from Berkley High School in 1966, and enrolled at Eastern Michigan University. He received his Bachelor of Science degree in Zoology in 1970. He was admitted into the University of Washington's graduate school in 1973, and received his Master of Science degree in Fisheries Science in 1975. In the Fall of 1977 he was awarded a Pre-doctoral Research Assistantship with the Fisheries Research Institute, University of Washington.

He married Grace M. DiLiberti in St. Clair Shores, Michigan, on July 18, 1969. They have a daughter Libby, and a son Thomas, and currently reside in Seattle, Washington.