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PRODUCTIVITY OF CHIRONOMID LARVAE IN A LITTORAL AREA OF THE HUDSON RIVER ESTUARY

by

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A dissertation submitted to the graduate faculty in Biology in partial fullfillment of the requirements for degree of Doctor of Philosophy, The City University of New York.

1978

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This manuscript has been read and accepted for the Executive Committee in Biology in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

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ABSTRACT

Chironomid production in a littoral cove of Bowline Pond, an embayment of the Hudson River Estuary, was estimated to be 15-19 g m^{-2} yr^{-1} (dry weight) during 1975. Estimates were based on eight species that comprised more than 98% of the total number of chironomid larvae. Depending on the species, the Hynes & Coleman, Allen Curve, or Turnover Ratio methods were used in calculating productivity. Data used in these calculations were obtained from a field survey of chironomid standing crops and age structure as well as on laboratory observations of development rates. The most productive species were Dicrotendipes modestus, which lived in the sediments as well as on the aquatic plant Myriophyllum spicatum; Cricotopus sylvestris, which lived primarily on aquatic plants; and Chironomus attenuatus, which lived solely in the sediments. Abundance of chironomids in the sediments of the cove averaged 13,600 larvae per m^2 and ranged up to 20,475 per m^2; abundance of chironomids living on plants in the cove averaged 18,300 larvae per m^2 and ranged up to 51,200 per m^2. Total abundance of invertebrates retained on a 0.12 mm mesh seive averaged 124,600 organisms per m^2 (sediment and plant populations combined) and ranged up to 201,200 per m^2.

Production of chironomids in the littoral cove is estimated to be over twenty times greater than that in sublittoral areas of the same reach of the Hudson. Factors considered most significant in contributing to the productivity of littoral chironomids include: (1) the

presence of aquatic plants which provide additional habitat for support, and (2) the more rapid development rates of chironomid species associated with aquatic plants. Species living on the plants exhibited 3-5 generations per year while those living solely in the sediments exhibited 1-2 generations. Larval development of Cricotopus sylvestris and Dicrotendipes modestus (species which lived on the plants) was completed in 9 and 14 days respectively at 22°C in the laboratory.

Based on a study of C. sylvestris, approximately 30% of produced chironomid biomass left the littoral system as adult emergence. Of the 70% that remained within the system, 88% was consumed by naiads of the damselfly Enallagma spp. and 12% was lost to other sources of mortality. The importance of Enallagma as a predator was shown in cage experiments conducted in the field as well as in feeding rate experiments conducted in the laboratory. The cage experiments were conducted to evaluate the effects of fish predation by excluding them from within the cages and measuring the changes in chironomid standing crops. However, at the end of the experiments, chironomid standing crops were lower inside the cages than outside; this unexpected result is attributed to the higher standing crops of Enallagma spp. observed within the cages. In the laboratory, naiads of Enallagma spp. consumed daily an average of 22% of their body weight in chironomid biomass.

Chironomids were eaten by other invertebrate predators as well as by fish. Invertebrate predators of chironomids (including damselfly naiads and amphipods) also are eaten by fish. The relatively high productivity of littoral chironomids (as compared to the sublittoral), and the observations that chironomids are eaten by fish and invertebrates (preyed upon by fish) suggests that, although the littoral areas comprise only a small part of the Hudson River, they may be important to the support of Hudson River fish species.

ACKNOWLEDGMENTS

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1. INTRODUCTION

The shallow water region of ponds, lakes, and rivers where light penetrates to the bottom is referred to as the littoral zone (Odum, 1971). This region is typically occupied by submerged rooted aquatic plants which are important in maintaining diversity and productivity of invertebrate and fish fauna (Sculthorpe, 1967; Odum, 1971; Fairbrothers and Moul, 1973).

One of the major macrofaunal invertebrate (macrofauna) groups which inhabit littoral areas and live on rooted aquatic plants are chironomid insect larvae (Miller, 1941; Berg, 1950; Darby, 1962; Gerking, 1962; Petr, 1968; Gaevskaya, 1969; Ringger, 1973; Tiedy et al., 1975). Chironomid larvae are important in the trophic dynamics of many aquatic systems. Most larvae build tubes in sediments or on aquatic plants and feed on particulate organic matter drawn into the tubes by currents created by the larvae's undulating movements (Walshe, 1951; Darby, 1962). Some chironomid larvae are predacious (Roback, 1969) and still others feed on rooted aquatic plants (Gaevskaya, 1969). Chironomid larvae are an important food source for many fish (McLarney et al., 1974). They have been reported to be eaten by such Hudson River species as striped bass, Morone saxitilis (Gomez, 1970), Atlantic sturgeon, Acipencer oxyrhynchus (Townes, 1936), white perch, Morone americanus (Cooper, 1941; Leach, 1962), bluegill sunfish,

Lepomis macrochirus (Gerking, 1962; Keast and Webb, 1966) spottail shiner, Notropis hudsonius (Dymond, 1926), and alewife Alosa pseudoharengus (Grabe, 1977). The larvae also are eaten by many invertebrates including hydrozoans, turbellarians (Legner et al., 1975), leeches (Hilsenhoff, 1963), water mites (Paterson, 1970), beetles (Bay, 1974), and damselfly naiads (Hamilton, 1965). In addition, chironomids may be parasitized by mermithid nematodes (Hominick and Welch, 1971).

Estimates of production provide a basis for evaluating the importance of species in the trophic dynamics of a system. Standing crop data alone may not provide adequate information on the amount of produced food available to consumers during a year (Hayne and Ball, 1956). Although there have been numerous investigations of chironomid larval standing crops, comparatively few studies have been made of their production. Most information on chironomid production have been obtained for infaunal populations; these include the studies of Miller (1941), Borutsky (1939), Nees and Dugdale (1969), Hall et al. (1970), Kajak and Ryback (1970), Kimerle and Anderson (1971), Charles et al. (1974), Paterson and Walker (1974), and Jonasson (1975). To my knowledge there have been no production studies of chironomids associated with aquatic plants. Yet, the populations living on plants and in the littoral area as a whole may be more productive than sublittoral infaunal populations.

The high productivity of littoral chironomids can be illustrated by considering an equation for production (from Edmondson and Winberg, 1971):

$$P = G \cdot B$$

Increases in standing crops (B) or growth rates (G) would result in increased production (P), and both of these may be higher for littoral chironomids as compared to the sublittoral fauna. Higher standing crops of chironomids could possibly be supported in littoral areas because of the additional habitat provided by aquatic plants; sublittoral chironomids on the other hand, are limited to sediments. The importance of aquatic plants in supporting higher standing crops of macrofaunal invertebrates has been shown by Richardson (1921), Needham (1929), Surber (1930), Pate (1932, 1934), Gerking (1962), and Krull (1970).

Growth and developmental rates of littoral chironomids may be higher than those of sublittoral chironomids. This appeared to be the case for the chironomids Cricotopus bicinctus (Humphries, 1938; Lindemann, 1942; Mundie, 1957), Parachironomus vitiosus (Mundie, 1957), and Tanypus sp. (Borutsky, 1939) which exhibited greater numbers of generations per year in the littoral as compared to sublittoral areas. Miller (1941) and Lindemann (1942) attributed the more rapid growth and development of littoral chironomids to the generally higher temperatures which occur in these shallow environments during most of the year.

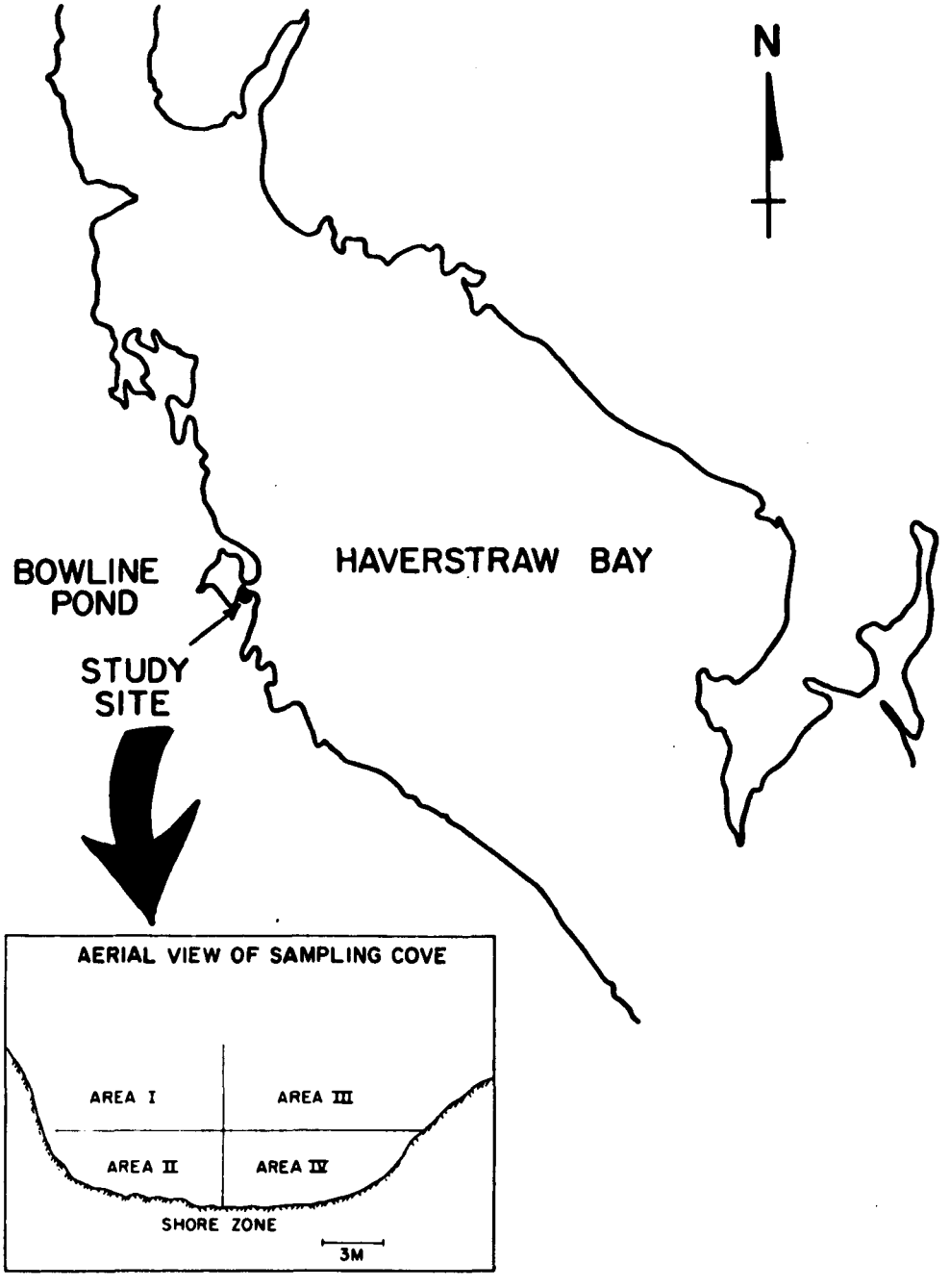
The major objective of this study was to estimate the productivity of chironomids in a littoral area of the Hudson River Estuary and to evaluate the role these chironomids may have in the trophic dynamics of the system. The Hudson Estuary supports commercially and recreationally important fish species such as striped bass, shad, alewife, and white perch and a productive littoral chironomid fauna may be important as food for these fish or for other organisms that are eaten by the fish. A search of the literature and discussions with Drs. S. Roback

and W. Mason indicated that there was little published ecological information on the chironomid fauna of estuaries and virtually none for those associated with aquatic plants in estuarine littoral areas. This is surprising since biological surveys of such estuaries on the James River (Boesch et al., 1976), Hudson River (Townes, 1936; Menzie et al., 1976) and Pocasset River (Sanders et al., 1967) revealed that chironomids were the most abundant insects. My study appears to be the first to examine the productivity of chironomids in a littoral area of a United States east coast estuary.

A cove within Bowline Pond, a small embayment of the Hudson River located on the west shore 37 miles north of the New York Battery (Figure 1), was selected for study. This site was selected because it was small enough to be sampled adequatly in its entirety and also because it contained only one species of rooted aquatic plant, (Myriophyllum spicatum). This species is abundant throughout the Hudson and in many east coast lakes, rivers, and estuaries (Krecker, 1939; Patten, 1955; Hotchkiss, 1967; Anderson, 1972; Fairbrothers and Moul, 1973; and Menzie, 1974a).

The basin which was to become Bowline Pond was excavated for clay used in the Hudson River brick industry; broken pieces of discarded brick dating back to the 19th century can still be found scattered along its shores. The pond was formed when Hudson River water entered the claypit. The pond has an area of 0.27 square kilometers and a volume of 1.8×10^6 m^3. In 1969, Orange and Rockland Utilities began constructing a fossil fuel power plant at Bowline Point, adjacent to the pond. The cooling water intake of the plant was placed in Bowline Pond and the inlet of the pond to the river was widened and dredged to facilitate river flow into the pond.

Figure 1. Location of study area on Haverstraw Bay, Hudson River. The sampling cove is shown in insert.



Bowline Pond experiences the estuarine influence of the Hudson. Hudson River circulation is characteristic of partially mixed estuarine systems (Abood, 1974), with more saline water intruding upriver near the bottom and mixing with freshwater which flows downstream near the surface. Tidal flow flushes the littoral areas in the Bowline Pond region twice a day and saline water intrudes into these areas periodically. Salinity data obtained by Lawler, Matusky, and Skelly Engineers (1974, 1975) indicate this reach of the Hudson may be classified as oligohaline (1-5°/oo), with periodic intrusions of higher saline water during low freshwater flow conditions. Benthic fauna of the sublittoral areas (Menzie, 1974b) is similar to that described for estuarine transitional zones by Emery and Stevenson (1957) and Carriker (1967).

2. MATERIALS AND METHODS

Productivity of chironomids was measured using one of three methods. The method used for a particular species depended upon the ecological characteristics of the species and my ability to obtain the data required for application of a particular method. The Allen Curve Method (Mann, 1971) was used to estimate production when cohorts were discernible. Use of this method requires field survey data on changes in population size and mean body weight of larvae during the course of their development.

The Hynes and Coleman (1968) method as modified by Hamilton (1969) was used when cohorts were indiscernible and data were obtained on the growth pattern of the species. Assumptions of the methods and probable consequences of violation for each assumption are presented by Hamilton (1969). The equation used in the method is:

$$P = c \sum_{j=1}^{c} (n_j - n_{j+1}) \times \frac{B_j + B_{j+1}}{2}$$

where P is the annual production in mg m^{-2} yr^{-1}

B_j is the mean biomass of larvae of instar j

c is the number of instars in the life cycle

n_j is the number of individuals that developed into instar j during the year

When the development times of the various instars are of different duration and/or when the species is not univoltine, n_j is estimated by

$$n_j = nb \frac{Pe}{Pa}$$

where n_j is the number of individuals that developed into instar j during the year

n is the mean number of individuals in the instar

b is the number of generations per year

Pe is the estimated proportion of the life cycle spent in each instar (1/c)

Pa is the actual proportion of the life cycle spent in a particular instar

Use of the Hynes and Coleman method requires field information on abundance of larvae in each instar and mean biomass of each instar. Information on the actual proportion of the life cycle spent in each instar was obtained in this study from laboratory observations of growth and development rates. Numbers of generations per year were estimated by considering field survey data together with laboratory estimates of generation times.

The third method, which employed the concept of turnover ratio for estimating production, was used when cohorts were indiscernible and no information was available on larval growth and development patterns. Turnover ratio (T) is the ratio of production to mean biomass over some time interval (Ricker, 1971). I assumed a T of 3.5 per generation for those chironomid species for which there was no information on development and mortality rates. This value is based, in part, on Waters' (1969) analyses of T for a number of differentially shaped hypothetical

Allen curves. Based on these analyses and a review of the literature, Waters (1969) observed that the turnover ratio, T, was relatively constant over a wide range of conditions. Further, he suggested that aquatic insects are likely to exhibit turnover ratio values per generation of between 3 and 4. These theoretical values agree well with field observations on chironomid larvae. Using the published data, I calculated T for species, and found that 3.5 was the median value of T per generation (Nees and Dugdale, 1959), (Miller, 1941), (Peterson and Hilsenhoff, 1972). Annual biomass turnover ratios of a species were calculated by multiplying the number of generations by 3.5; production was estimated by multiplying the annual turnover ratios by the mean biomass of the species. Application of this method required field survey data on larval standing crops and estimates of numbers of generations per year.

Utilization of chironomid biomass as food by invertebrate predators was evaluated by examining gut contents of invertebrates collected in field surveys and by estimating the feeding rate of damselfly nymphs on chironomid larvae in the laboratory. Fish exclusion cage experiments were conducted to examine the effects of fish predation.

Methods used to conduct field surveys and laboratory observation of live chironomids and damselflys are presented below.

2.1 FIELD SURVEYS

Field surveys were conducted from January 1975 through January 1976. Samples were collected to measure the physical and chemical conditions in the sampling cove; to obtain data on the composition and standing crops of chironomids, other macrofauna, and aquatic plants in the cove; to delineate emergence patterns of adult chironomids; and to

evaluate the magnitude of fish predation through cage exclusion experiments. Sampling in the cove was conducted using a stratified random design. The cove was partitioned into four areas approximately 6.5 by 4 m (Figure 1). Areas I and IV had an average depth of 1.25 m at mean low water; areas II and III had a mean depth of 0.5 m at mean low water. Axes bounding each area were divided into 0.5 m intervals. These were numbered, thereby providing a coordinate system for each area. Prior to each sampling date, pairs of random numbers representing coordinates of sampling points along axes were drawn from a bag containing numbered pieces of cardboard.

2.1.1 Collection and Analyses of Physical and Chemical Data

Four sediment samples, one from each area in the sampling cove (Figure 1), were collected monthly for sediment analyses with a 6.35 cm diameter plexiglass corer inserted to a depth of 7 cm below the sediment surface. Organic content of the sediments was measured by drying the sediment for 24 hours at 103°C, weighing the sample, ashing the sample at 500°C for 24 hours, and then reweighing the sample. Particle size distribution of sediments was measured according to the methods of Krumbein and Pettijohn (1938).

Water temperature was measured weekly with a thermometer, and salinity was measured by conductivity using a Yellow Springs Instrument Company conductivity meter.

2.1.2 Collection and Analyses of Aquatic Animal and Plant Samples

Estimates of standing crops of infaunal invertebrates were made monthly by collecting two sediment samples from each sampling area for a total of eight samples on each date. A 6.35 cm diameter

plexiglass corer was used to collect the infaunal samples. The corer was inserted into the sediment to a depth of approximately 7 cm, and the samples preserved in 10% formalin. A corer was used rather than a grab sampler (e.g., Ekman) because Paterson and Fernando (1971) observed that estimates of standing crops were 50% higher when samples were taken with a simple corer rather than with an Ekman grab. They noted that the corer decreased the volume of sediment collected and reduced the tediousness of examining large samples.

Estimates of standing crops of invertebrates associated with Myriophyllum were made using a "two stage" approach. Densities of invertebrates per unit of Myriophyllum leaf dry weight biomass were first estimated; these densities were multiplied by the standing crop of Myriophyllum leaf dry weight biomass per square meter to provide estimates of the standing crops of invertebrates per square meter. Densities of invertebrates on Myriophyllum were measured biweekly by collecting two plant stems from each sampling area for a total of eight plant stems per date. Collections were made with a plexiglass tube (6.35 cm diameter) which was placed over individual stems. The top of the tube was covered with nylon netting (0.12 mm mesh) to prevent loss of chironomids. (Preliminary investigations showed this mesh size efficiently retained second, third, and fourth instars and 70% of the first chironomid larval instars of Cricotopus sylvestris, the dominant chironomid on the plants.) The plant stem was clipped at the base of the tube and the water in the tube was drained through the end covered with nylon netting. The sample was then rinsed from the tube into a collection jar and preserved with 10% formalin. Biomass estimates of Myriophyllum m^{-2} of bottom area were made monthly by collecting eight

plant samples. An aluminum guadrat (0.1 m^2) was placed on the bottom and all plants rooted within it were removed by hand. These collections were made at the same coordinates at which plant stems were collected for faunal analyses on that date.

The two stage approach to estimating standing crops of invertebrates associated with aquatic plants avoids several problems that have been encountered with other samplers described by Marsh (1970) and Ringger (1973). Some conventional samplers, including those of Macan (1949), Gerking (1957), and Gillespie and Brown (1966), are designed to sample a specific area for plants and their associated fauna. Since the area sampled must be sufficiently large to avoid significant edge effects (Kajak, 1971), a large amount of material is obtained for analyses of the fauna. Separation of the fauna from a large mat of collected plant matter is laborious and likely to be inefficient; in addition, because a number of plants are collected in the same sample, information is lost on the distribution and association of animals on a per plant basis. The two stage approach minimizes these problems.

Samples collected for faunal analyses were washed on a 0.12 mm mesh sieve, rinsed into glass jars and preserved with 10% formalin - Rose Bengal solution. All animals retained on the sieve were enumerated; in the present study these animals are referred to as macrofauna. Chironomid larvae were identified and instars of individual species were differentiated by measuring head-capsule size as recommended by McCauley (1971). Larvae were sorted by species and instar. Individual larval body volumes were estimated from length and width measurements by considering the larvae as geometric cylinders (Hynes

and Coleman, 1968). Larvae were weighed after drying at 103°C for 24 hours and a mean dry weight to volume ratio was calculated for each instar. The tubes of chironomids were not included in the biomass estimates since they are composed of nonliving material.

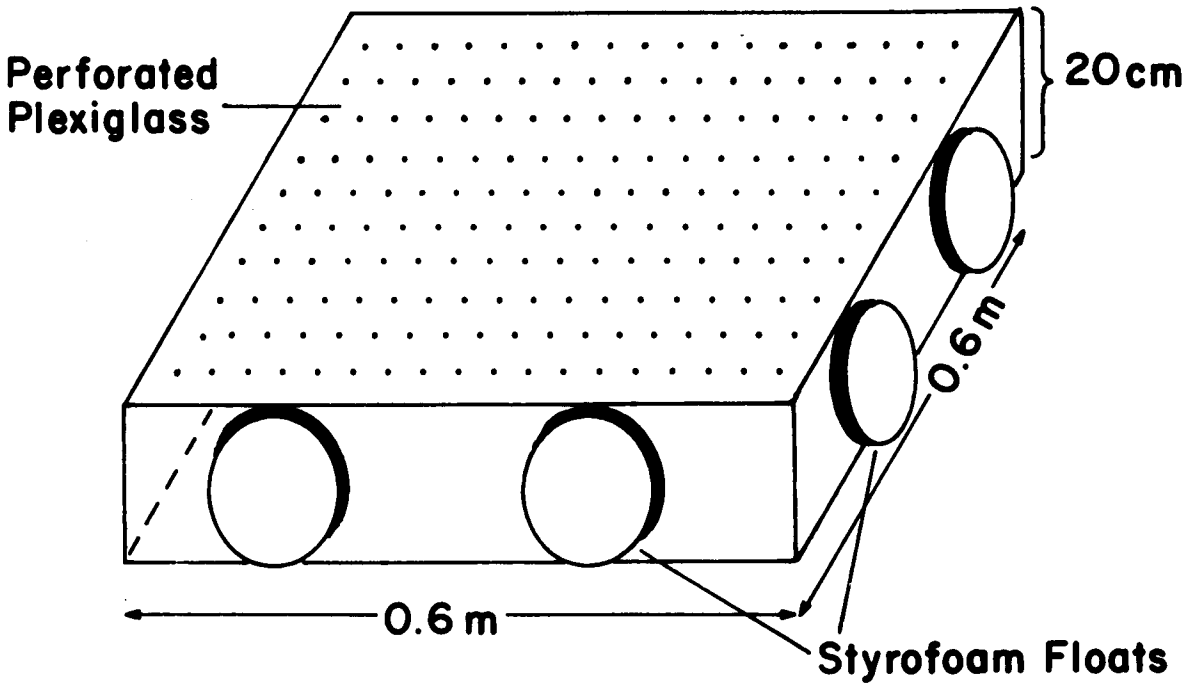
Gut analyses of coelenterates and arthropods were conducted to see if they preyed on chironomids; this involved counting and identifying gut contents. Although turbellarians also may be chironomid predators (Legner et al., 1975), their food habits cannot be determined from gut analyses (Reynoldson, 1966). The gut contents of chironomid species also were dissected and examined under a compound microscope.

Dry weight of plant material was obtained by washing the plants free of animals and debris, removing leaves, and weighing the leaves and stems after drying for 24 hours at 103°C.

2.1.3 Collection of Adult Chironomids

Periods of peak adult chironomid emergence were determined from weekly collections using a floating emergence trap and a sweep net. Initially, a floating emergence trap designed according to specifications given by Mundie (1971) was used. Unfortunately, this and other conspicuous floating traps attracted vandals and were destroyed. Therefore, a more durable and less conspicuous wooden box trap was constructed (Figure 2). The trap, which covered an area of 0.36 m^2, was floated by styrofoam, and was covered with perforated plexiglass to prevent escape of adults. The inner lining of the trap was covered with fly paper which caught the emerged adults, preventing them from falling back into the water. However, the sticky paper made it difficult to identify many of the species and quantitative data were obtained only for Cricotopus sylvestris, which has distinctive body

Figure 2. Box trap used for collecting adult chironomids as they emerged from the water. The styrofoam floats enabled the trap to float on the water's surface. The inner walls of the trap were lined with fly paper to catch the emerged adults thereby preventing them from falling back into the water.



coloration. The trap was anchored to a cinder block with sufficient line to allow it to drift among the four sampling areas. Since aquatic vegetation on which chironomids lived reached the surface, conventional cone traps (Hamilton, 1965) could not be used in this study. Sweep net collections were made over a specified transect on the south shore of Bowline Pond. Adults collected in these samples were identified and counted.

2.1.4 Fish Exclusion Cage Experiments

Cage experiments were conducted to estimate the impact of fish predation on chironomid standing crops. Stainless steel mesh (0.64 cm mesh diameter) enclosures (0.5 m diameter, 1.0 m high) were used to exclude fish from plant areas. Four enclosures were placed in the cove for a 2-week period in July and another in August 1975. After each period, two plant stems were collected from each enclosure. The density of chironomids on the stems within the cages were compared to the density on stems outside the cages. A net was swept through the enclosures after the stems had been sampled to ensure that no fish had been accidently entrapped. No fish were observed in either experiment.

2.2 LABORATORY OBSERVATIONS OF LIVE CHIRONOMIDS AND DAMSELFLYS

Chironomid egg masses and larvae were collected alive from the cove on each sampling date to observe their development rates and behavior in the laboratory. Collection of live naiads of the damselfly Enallagma sp. were made during August to observe their feeding behavior in the laboratory.

2.2.1 Chironomids

Chironomids were reared in the laboratory for identification purposes, to determine growth and development rates, and to make observations of the behavior of the larvae. Larvae, laboratory hatched from egg masses or collected as individuals in the field, were grown in chambers (12:12 h light dark cycle) at four temperatures, 9°C, 15°C, 22°C, and 29°C. The temperature chosen for a particular growth rate experiment was that closest to ambient field temperatures at time of collection. Larvae, grown in petri dishes containing filtered (0.12 mm) Hudson River water, were fed Tetramin (Tetra) fish food. Growth was measured from volumetric determinations because handling the larvae during weighing would have damaged individual organisms. Their volume was estimated from length and width measurements (volume = length $x\pi(\text{width}/2)^2$) made every 1 to 2 days. Volumes were converted to dry weights using mean dry weight to volume ratios obtained for field collected organisms. The stadium (duration between larval molts) was determined for each instar and average growth rate was estimated by:

$$\text{Growth rate for each instar} = W/T$$

where W = the average increase of volume (weight) of the instar

T = the average stadium of that instar (days)

2.2.2 Feeding Behavior of Damselflys

Naiads of the damselfly Enallagma sp. were placed in petri dishes containing filtered Hudson River water. Chironomid larvae and/or amphipods were provided and the feeding behavior of Enallagma observed.

Amount of food consumed daily by Enallagma was estimated for five naiads. These naiads were starved for 48 hours and then fed a surplus of chironomid larvae. Numbers and sizes (instars) of chironomids eaten were determined over a three-day period by examining fecal pellets of Enallagma for the undigestible head capsules of chironomid larvae. Biomass of chironomids eaten was calculated by multiplying number of larvae in each instar and species (determined from examination of head capsules) by mean dry weight of that instar and species (determined from field collections). Naiads of Enallagma were weighed at the end of the feeding experiment after drying at 103°C for 24 hours.

2.3 STATISTICAL ANALYSES USED TO EXAMINE VARIATIONS IN ABUNDANCE OF CHIRONOMID POPULATIONS

Two-way Analyses of Variance (ANOVA) with replication were used to detect differences in chironomid species' abundances among sampling dates and among sampling areas. Since the ANOVA tests are strictly valid for only normally distributed data, numerical abundance data were normalized by a logarithmic transformation (log (n+1)) prior to being used in the tests (Steel and Torrie, 1960). Differences were considered significant at $\alpha \geq 0.05$.

3. RESULTS

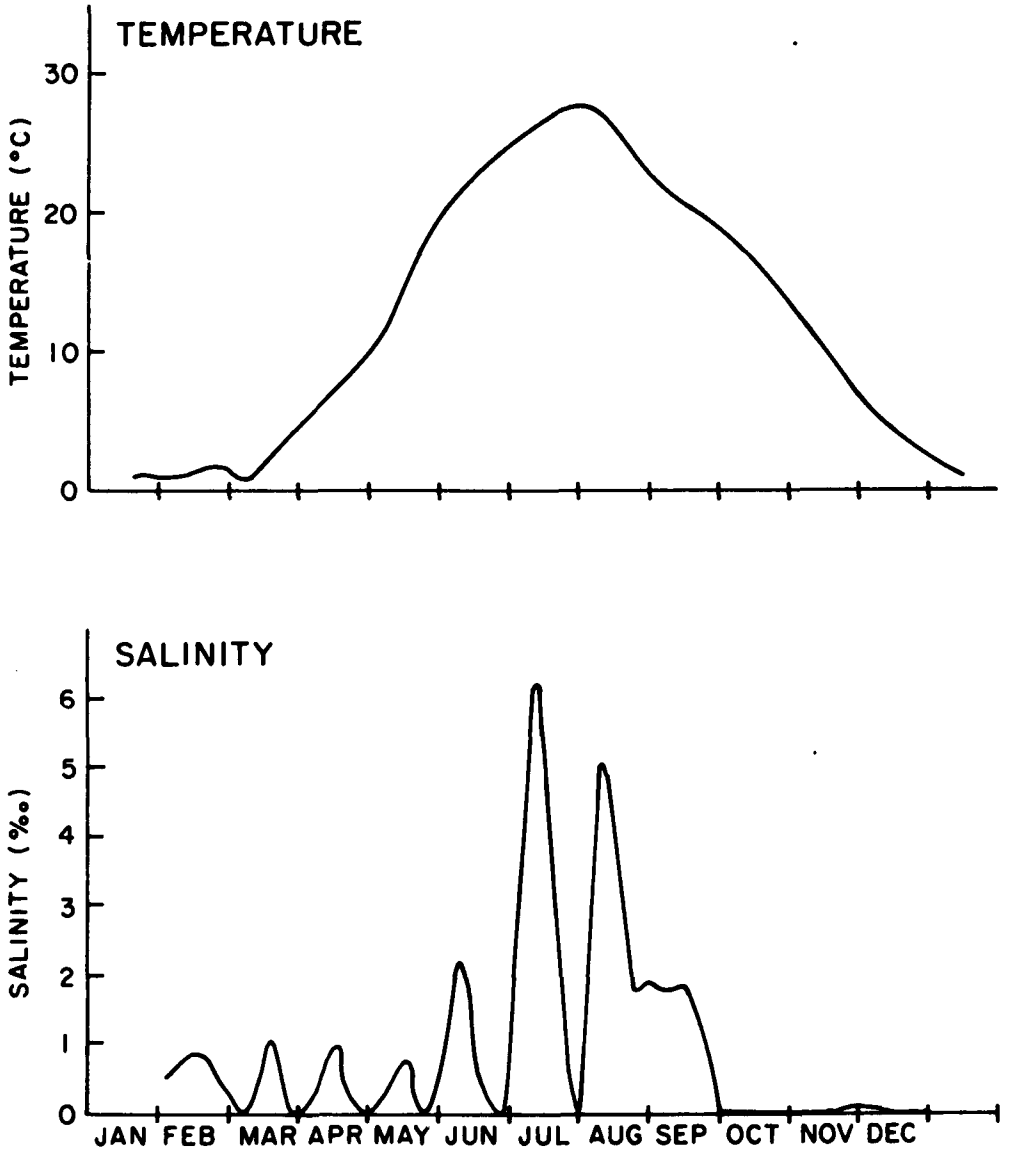
3.1 PHYSICAL AND CHEMICAL MEASUREMENTS

3.1.1 Temperature and Salinity

Surface water temperatures were between 1-4°C in January and February 1975, began increasing in March, and reached a maximum of 27-28°C in July and August (Figure 3). Surface water temperature normally reflected temperature throughout the plant stand and the general pattern of temperature variations in the littoral cove. However, exceptionally high temperatures were measured on two days in August within the compact mat of Myriophyllum and algae which formed at the water's surface at low tide. A temperature of 35°C was recorded in the plant mat on 1 August at 1230 hours; 7 cm below the mat, temperature dropped to 30°C. On 2 August at 1400 hours, the highest temperature observed during the study (42°C) occurred in the plant mat. On that date, temperature ranged between 33-35°C in open spaces within the mat, and 15 cm below the mat the temperature was 30°C. Surface temperature of Bowline Pond beyond the littoral area was 27°C for both dates. Thus, temperatures in the plant mat were elevated as much as 15°C above those beyond the littoral zone.

Salinity oscillated throughout the sampling period (Figure 3). These oscillations were most pronounced during summer, when salinity ranged from near 0 to 6.2 °/oo. The freshwater runoff resulting from

Figure 3. Water temperature and salinity in the littoral cove during 1975.



a heavy rain, was reflected by a sharp drop in salinity between July and August. Despite the oscillations recorded, salinities remained characteristic of oligohaline (1-5 $^{o}/_{oo}$) estuarine conditions.

3.1.2 Sediments

Sediments were composed primarily of broken pieces of brick, larger pieces of which gave the intertidal zone a rocky, gravelly appearance. Variations in median particle size of the sediments showed no common pattern among the four sampling areas (Table 1). Median particle size averaged 0.37 mm in Area I, 0.34 mm in Area II, 0.55 mm in Area III, and 0.33 mm in Area IV. These particle sizes fall in the range of fine to coarse sands. The sediments in Area I were more compact and easier to core than those of the other areas and the median particle size remained comparatively constant. Quartile deviation, is a measure of the degree to which sediments are sorted, averaged 1.68ϕ in Area I, 1.25ϕ in Area II, 1.47ϕ in Area III, and 1.71ϕ in Area IV. Organic content of the sediments ranged between 3 and 19% with no apparent seasonal pattern. Sediments of Areas I and IV, which were in 1.25 m of water at mean low tide, were richer in organic matter than those in the shallower areas II and III, which were 0.5 m deep at mean low tide.

3.2 GROWTH OF THE ROOTED PLANT MYRIOPHYLLUM SPICATUM

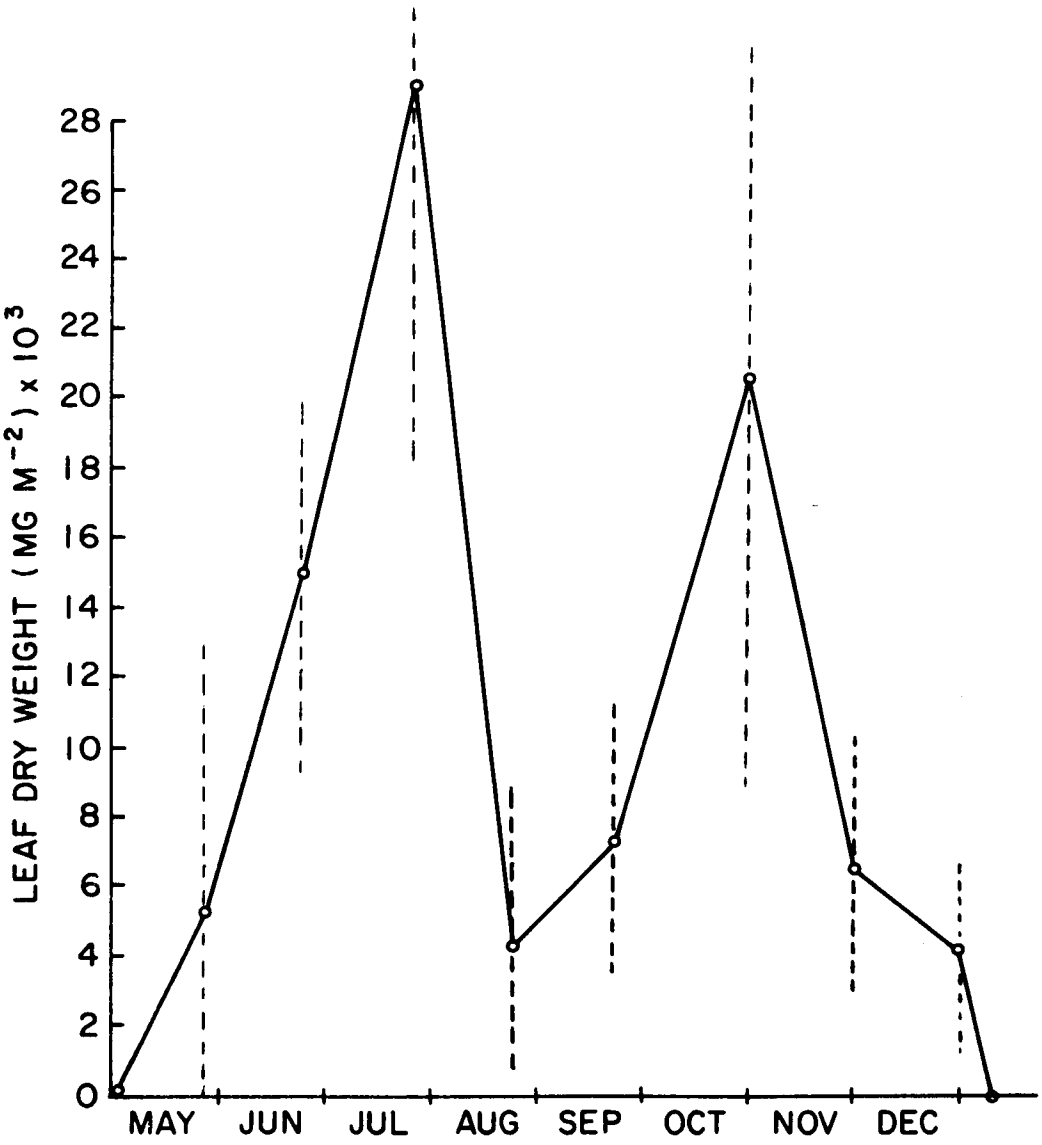
The main growth period of Myriophyllum extended from May through December (Figure 4); only a few stems were observed in the cove between January and April. Peaks in the leaf dry-weight biomass of Myriophyllum were observed in July (31,000 mg m^{-2}) and October (20,600 mg m^{-2}). The decrease in biomass in August seemed to correspond with the period of highest temperatures in the stand of Myriophyllum. Four

Table 1. Median particle size, quartile deviation, and % organic content of sediments sampled in the littoral cove during 1975.

	Median Particle Size (mm)				Quartile Deviation ϕ Units*				% Organic Content			
	Sampling Area				Sampling Area				Sampling Area			
	I	II	III	IV	I	II	III	IV	I	II	III	IV
January	NO DATA				NO DATA				NO DATA			
February	0.35	0.40	0.50	0.20	1.60	1.30	1.50	1.70	14.0	5.8	3.1	8.9
March	0.45	0.17	0.88	0.16	1.72	1.24	1.36	1.70	16.0	8.5	8.9	8.3
April	0.43	0.45	0.48	0.48	1.82	1.50	1.50	1.76	4.0	3.2	3.6	14.8
May	0.40	0.35	0.45	0.85	1.71	0.79	1.29	1.53	7.3	4.3	4.1	5.0
June	0.35	0.58	0.50	0.20	1.38	2.01	1.73	1.60	10.1	9.2	6.3	8.0
July	0.45	0.43	0.49	0.30	1.75	1.50	1.50	1.65	11.1	6.2	6.3	10.0
August	0.43	0.40	0.42	0.42	1.71	1.50	1.63	1.62	10.8	4.3	6.4	15.0
September	0.42	0.35	0.50	0.40	1.65	1.40	1.45	1.70	11.0	4.2	5.3	12.0
October	0.45	0.30	1.30	0.30	1.70	1.28	1.32	2.03	10.4	4.4	3.9	10.9
November	NO DATA				NO DATA				NO DATA			
December	0.40	0.45	0.49	0.35	1.76	1.30	1.40	1.80	15.0	6.2	4.0	9.1
Average	0.37	0.34	0.55	0.33	1.68	1.25	1.47	1.71	10.9	5.6	5.2	10.2

* $\phi = -\log_2$ particle size (mm)

Figure 4. Standing crop of Myriophyllum spicatum leaf dry weight in the littoral cove during 1975. Vertical lines indicate 95% confidence intervals.



days following the high temperature measurements of 2 August, mats of Myriophyllum and associated algae were washed up on the shore of Bowline Pond. Plants were apparently breaking apart, leaving bare areas within the stand. Prior to and on 2 August, the plants appeared healthy, i.e., there was no evidence of wasting or disease effects which would otherwise account for the sudden extensive degeneration. The loss of plant biomass from November to January represented winter die-off.

3.3 MACROFAUNAL INVERTEBRATES OF THE LITTORAL COVE

3.3.1 Inventory and Abundance

Invertebrate taxa observed in the littoral cove are given in Table 2. Twenty-three species of chironomids were identified during the study. The mean abundance of macrobenthos living in the sediments is given in Table 3 and for those living on the rooted plant Myriophyllum in Table 4. Copepods, oligochates and chironomids, which respectively averaged 34,000, 29,264, and 13,607 organisms m^{-2}, were the most abundant macrofauna in the sediments. Abundance of infaunal copepods was highest from April to June, abundance of oligochates was highest in September and December, and abundance of chironomids was highest in June and October. Total macrofaunal abundance in the sediments averaged 98,693 organisms m^{-2} and ranged from 72,767 organisms m^{-2} in January to 164,619 organisms m^{-2} in June.

Chironomids, copepods and cladocerans, which respectively averaged 18,278, 3,171, and 2,725 organisms m^{-2}, were the most abundant macrofauna living on Myriophyllum. Abundance of chironomids living on Myriophyllum was highest in July (51,198 organisms m^{-2}) while abundance

Table 2. Inventory of Macrofauna Collected in the Littoral Cove

TAXA
Hydrozoa
Hydra sp.
Cordylophora lacustris
Nematoda
Turbellaria
Tardigrada
Gastropoda
Pelecypoda
Congeria leucophaeta
Polychaeta
Hypaniola grayi
Scolecolepides viridis
Oligochaeta
Naidae
Paranais frici
Stylaria fossularis
Tubificidae
Aulodrilus pigueti
Limnodrilus hoffmeisteri
L. profundicola
Peloscolex benedeni
Tubifex tubifex
Copepoda
Cladocera
Ostracoda
Cumacea
Almyracuma proximoculi
Amphipoda
Corophium lacustre
Gammarus daiberi
Leptochierus plumulosus
Monoculoides edwardsi
Isopoda
Chiridotea almyra
Cyathara polita
Decapoda
Rhithropanopeus harrisii
Acari
Zygoptera
Enallagma sp.
Tricoptera
Ceratopogonidae
Chironomidae
Ablabesmyia sp.
Brillia sp.
Chironomus attenuatus
Cladotanytarsus viridiventris
Coelotanypus scapularis
Cricotopus bicinctus
C. sylvestris
Cryptochironomus fulvus
Cryptotendipes emorsa
Dicrotendipes modestus
D. Nervosus
Glyptotendipes lobiferus
Harnishia curtilamellata
Microspectra nigripilus
Parachironomus frequens
P. monochromus
Polypedilum digitifer
P. illinoense
Procladius bellus
P. sublettei
Rheotanytarsus sp.
Tanypus sp.
Tanytarsus sp.

Table 3. The abundance of macrofauna (No. organisms per m^2 of bottom area) in sediments in the littoral cove. Major taxa are ranked in order of abundance. *

			ABUNDANCE (NUMBER ORGANISMS PER M^2)										
Rank	Taxa	Average	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Dec
1	Copepoda	34,010	11,143	36,303	25,909	60,750	43,706	94,311	8,505	23,822	15,120	41,355	13,191
2	Oligochoeta	29,624	14,805	34,099	38,273	13,410	16,813	27,909	32,805	39,020	43,515	21,510	43,706
3	Chironomidae	13,607	14,451	15,829	14,726	3,741	3,662	28,476	16,065	10,749	13,590	20,475	7,914
4	Nematoda	10,970	19,254	26,460	13,348	12,555	9,253	11,907	2,610	1,063	7,155	12,465	4,607
5	Gastropoda	7,151	9,568	11,143	2,835	4,050	1,693	693	15,480	11,340	13,455	5,175	3,229
6	Amphipoda	1,034	906	591	473	630	236	441	1,665	2,402	3,690	270	79
7	Acari	596	512	1,417	748	2,070	709	504	135	118		270	79
8	Ostracoda	324							855	788	630	1,170	118
9	Pelecypoda	308	315	197	39				900	1,851		90	
10	Cladocera	287							2,385	512	135	90	39
11	Turbellaria	221	788	591	512	45						495	
12	Polychaeta	197	473	473	354	90		126	225	118	90	135	79
13	Ceratopogonidae	112	158	39	315				135	315		270	
14	Zygoptera	78	197	79	118			63	45	39	45	270	79
15	Isopoda	68	39	79	39	90	39		135	118	90	45	79
16	Cumacea	60			79		79	189	180	39		90	
17	Tardigrada	25	158	79	39							495	
18	Decopoda	8							45		45		
19	Tricoptera	7		39						39			
20	Hydrozoa	4											39
	Totals	98,693	72,767	127,418	97,807	97,431	76,190	164,619	82,170	92,333	97,560	104,175	73,159

*Each value represents the mean obtained from eight samples on each sampling date.

Table 4. The abundance of macrofauna (No. organisms per m^2 of bottom area) on Myriophyllum in the littoral cove. Major taxa are ranked in order of abundance*

		ABUNDANCE (No. organisms per m^2)														
Rank	Taxa	Average	26 May	7 Jun	24 Jun	9 Jul	25 Jul	8 Aug	23 Aug	9 Sep	22 Sep	11 Oct	1 Nov	15 Nov	30 Nov	1 Jan
1	Chironomidae	18,278	3,960	26,239	34,661	21,638	51,198	46,816	3,793	6,786	4,777	6,608	13,916	28,496	6,573	426
2	Copepoda	3,171	12,777			3,533	2,618	16,218	698	585	808	4,077	2,285	178	598	18
3	Cladocera	2,725	18,955			2,870	2,618	9,865	349	468	662	1,687	623	34	17	
4	Oligochaeta	409	3,168	203	1,206				22	29	42	161	291	397	199	18
5	Pelecypoda	346					3,200	336	392	351	515	15		34		
6	Tricoptera	293			19	110	87	836	88	44	74	281	831	1,644	83	
7	Ostracoda	230					58	1,338	262	293	441	562	62	192	8	
8	Amphipoda	202	53		75	110	203	84	218	585	809	322	104	178	66	24
9	Gastropoda	201			603	281	873	669	262	29	37	56				
10	Zygoptera	63		25		110	145	84	44	82	147	112	124	14		
11	Acari	14				28		167	5							
12	Nematoda	5	66													
13	Turbellaria	1									14					
14	Hydrazoa	0.5									7					
	Totals	25,938	38,979	26,467	36,564	28,680	61,000	76,413	6,133	9,252	8,333	13,881	18,236	31,167	7,544	486

*Each value represents the mean obtained from eight samples on each sampling date.

of copepods and cladocerans, respectively, were highest in August and May. Total macrofaunal abundance on Myriophyllum averaged 25,938 organisms m^{-2} and ranged up to 76,413 organisms m^{-2} in July. The number of major taxa living on Myriophyllum was lowest in spring and winter and highest during summer. Taxa which were not observed on Myriophyllum until after June included pelecypods, ostracods, Acari, turbellarians, and hydrozoans.

3.4 CHIRONOMID FAUNA OF THE LITTORAL COVE

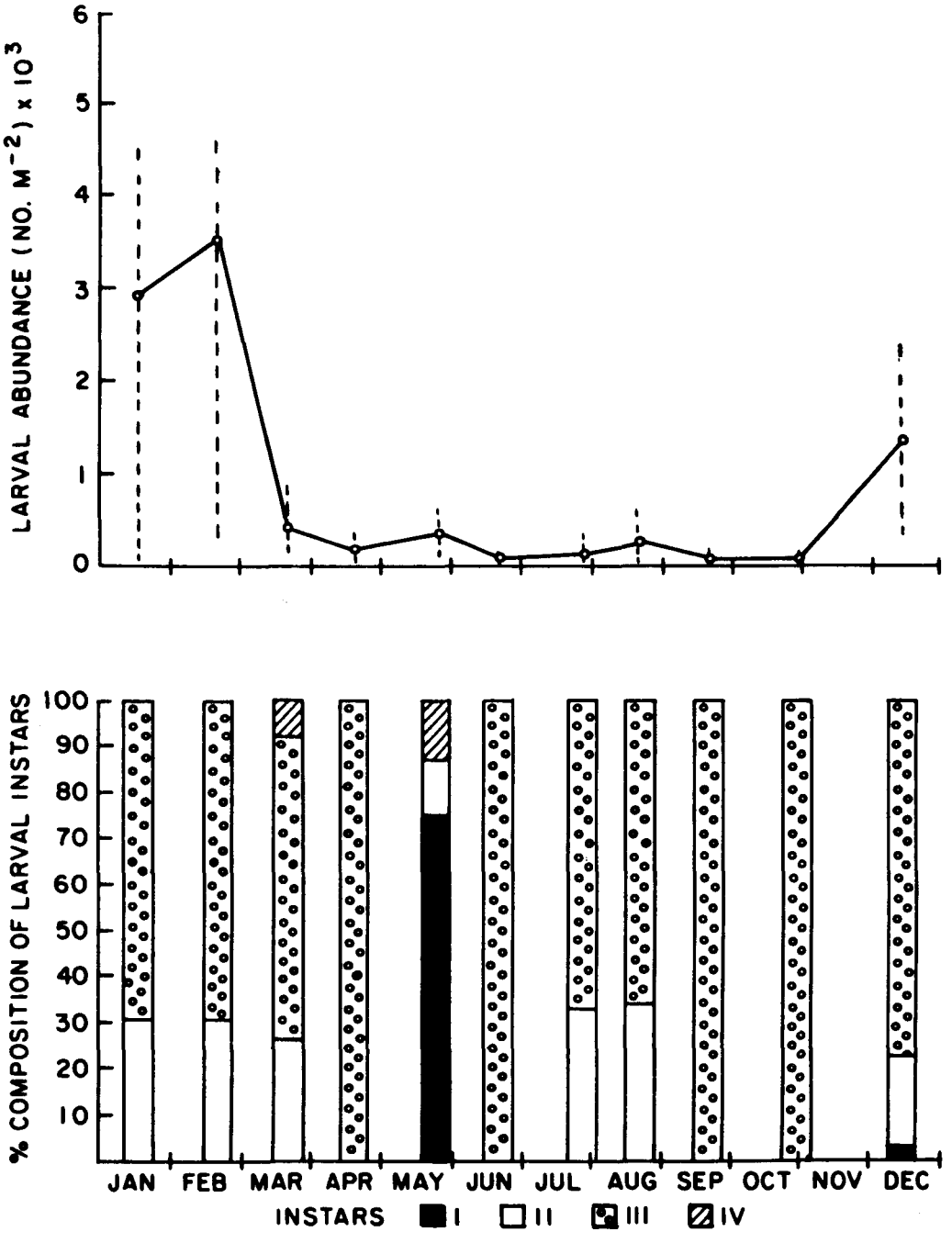
Eight chironomid species accounted for 98% of chironomid larvae in the cove. Observations were made on the seasonal trends in larval standing crops and adult emergence, and on development rates and behavior of larvae as measured in the laboratory. These observations are used to estimate the production of chironomids in the cove. Tabulated data on larvae collected on Myriophyllum and in the sediments are presented respectively in Appendices A and B. Results of Analyses of Variance (ANOVA) used to detect spatial and temporal differences in larval abundance ($\alpha \geq 0.05$) are presented in Appendix C. Differences were considered significant at the $\alpha \geq 0.05$ level.

3.4.1 Cricotopus sylvestris

Observations on Standing Crops of C. sylvestris

C. sylvestris larvae were present in the sediments and on the rooted plant Myriophyllum. For both sediment and plant populations, significant differences were detected among sampling dates in the abundance of larvae but not among the four sampling areas (Appendix C). Larval abundance in the sediments was higher in winter than summer with a maximum, 3,600 larvae m^{-2}, occurring in February (Figure 5). Sediment populations of C. sylvestris were dominated by

Figure 5. Abundance and instar composition of Cricotopus sylvestris larvae living in sediments of the littoral cove during 1975. Vertical lines indicate 95% confidence intervals.



second and third instars (Figure 5). During summer most C. sylvestris larvae lived on Myriophyllum where they comprised 80% of all chironomids. Abundance of C. sylvestris on Myriophyllum (Figure 6) peaked in June (25,242 larvae m^{-2}), August (45,294 larvae m^{-2}), and October (22,331 larvae m^{-2}). An extended period of comparatively low abundance (3,500 larvae m^{-2}) occurred from August to October. Following an increase to 24,000 larvae m^{-2} in November, abundance of C. sylvestris on Myriophyllum decreased to less than 300 larvae m^{-2} in January.

Fluctuations in abundance of C. sylvestris on Myriophyllum reflected fluctuations in the larval density per 100 mg leaf biomass (Figure 7). Peaks in larval density corresponded closely with those in leaf biomass but lagged the latter as was indicated by the significant correlation ($r = 0.63$; $N = 52$) between larval density and leaf biomass from the previous sampling date two weeks earlier.

There were two distinct patterns in the age structure of C. sylvestris larvae on Myriophyllum. From May through early October third and fourth instars composed greater than 50% of all C. sylvestris larvae, while from late October through December second and third instars composed greater than 80% of all instars (Figure 6).

Larvae biomass ranged between 2 mg m^{-2} in April and 968 mg m^{-2} in July (Figure 8). Average annual biomass was 277 mg m^{-2} which represented 17.7% of total chironomid biomass.

Observations on Adult C. sylvestris

Adult C. sylvestris were collected in emergence traps from May through October (Figure 9). The largest emergence rate (252 adults m^{-2} day^{-1}) was in July. Emergence traps set out in April and early May

Figure 6. Abundance and instar composition of Cricotopus sylvestris larvae living on Myriophyllum in the littoral cove during 1975. Vertical lines indicate 95% confidence intervals.

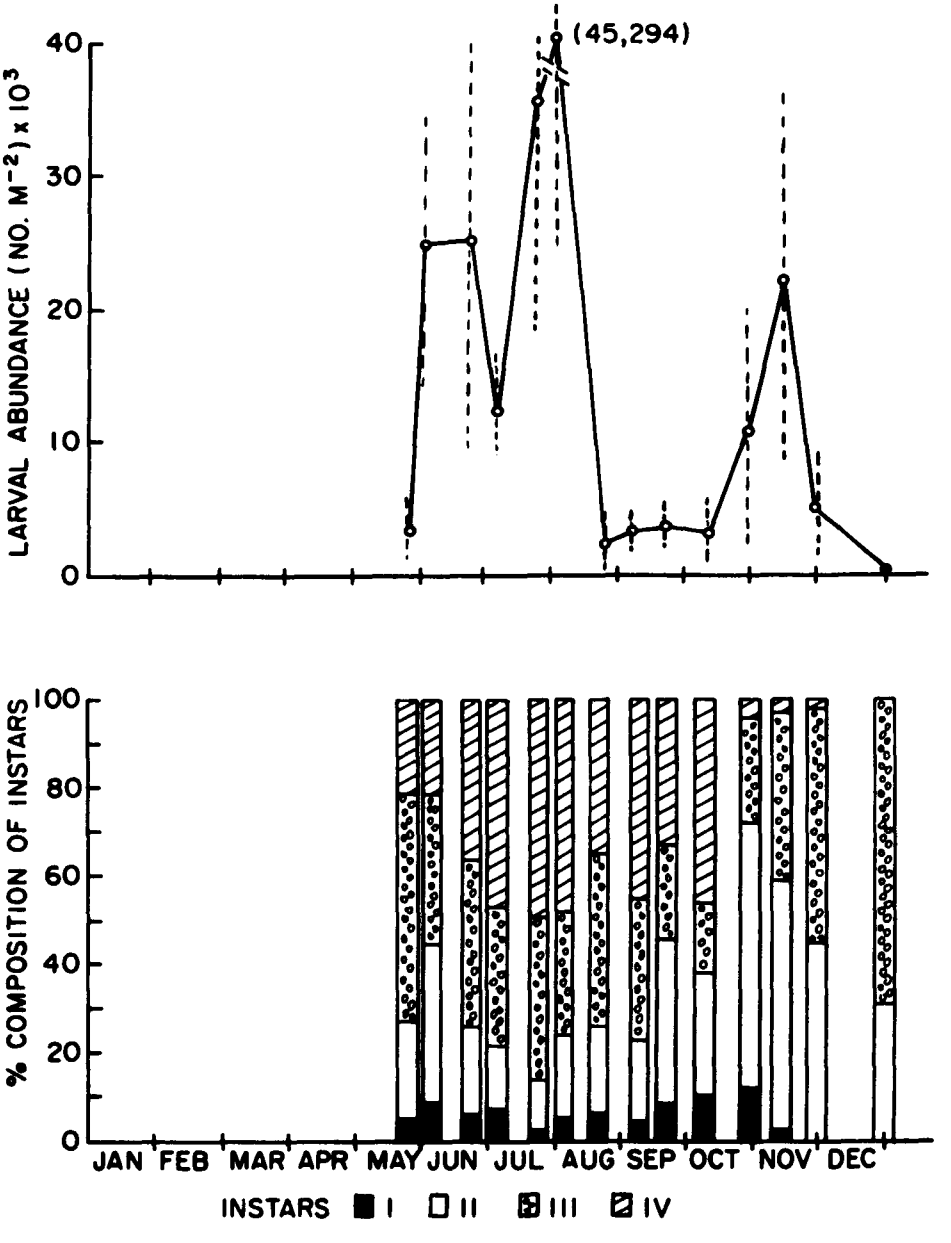


Figure 7. Densities of Cricotopus sylvestris larvae on Myriophyllum in the littoral cove during 1975. Vertical lines indicate 95% confidence intervals.

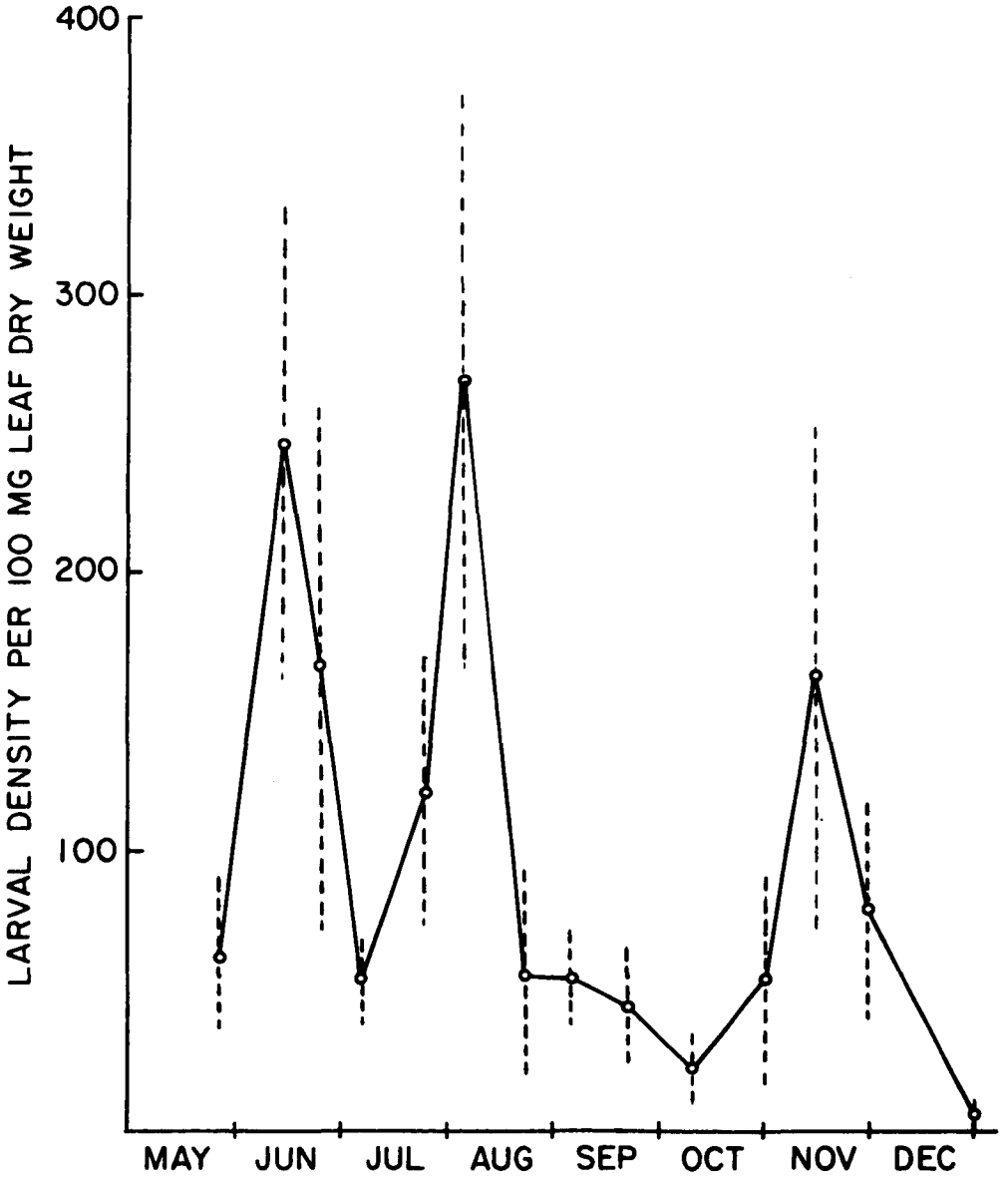


Figure 8. Dry weight biomass of Cricotopus sylvestris in the littoral cove during 1975. Data are for the combined populations living in the sediments and on Myriophyllum.

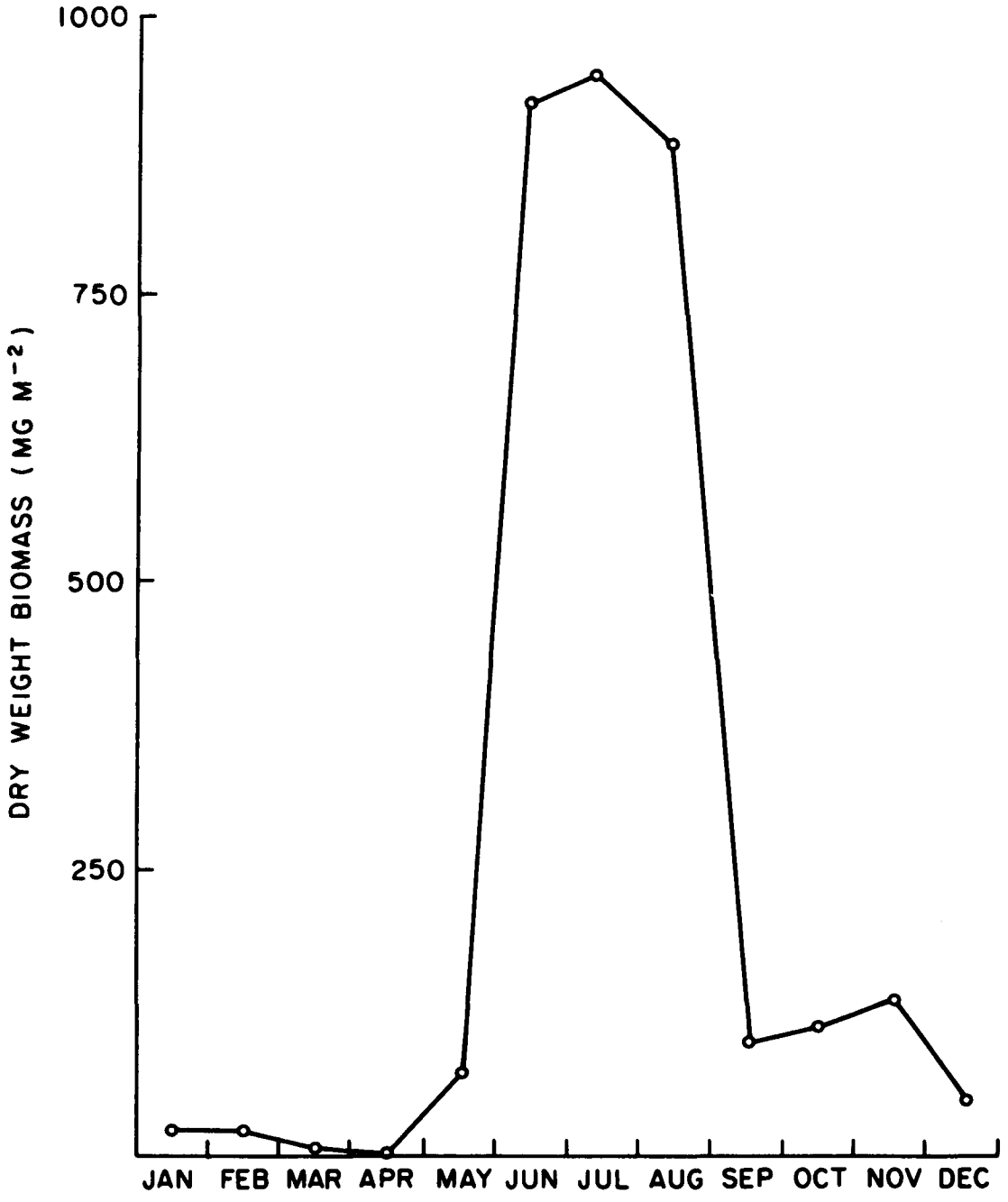
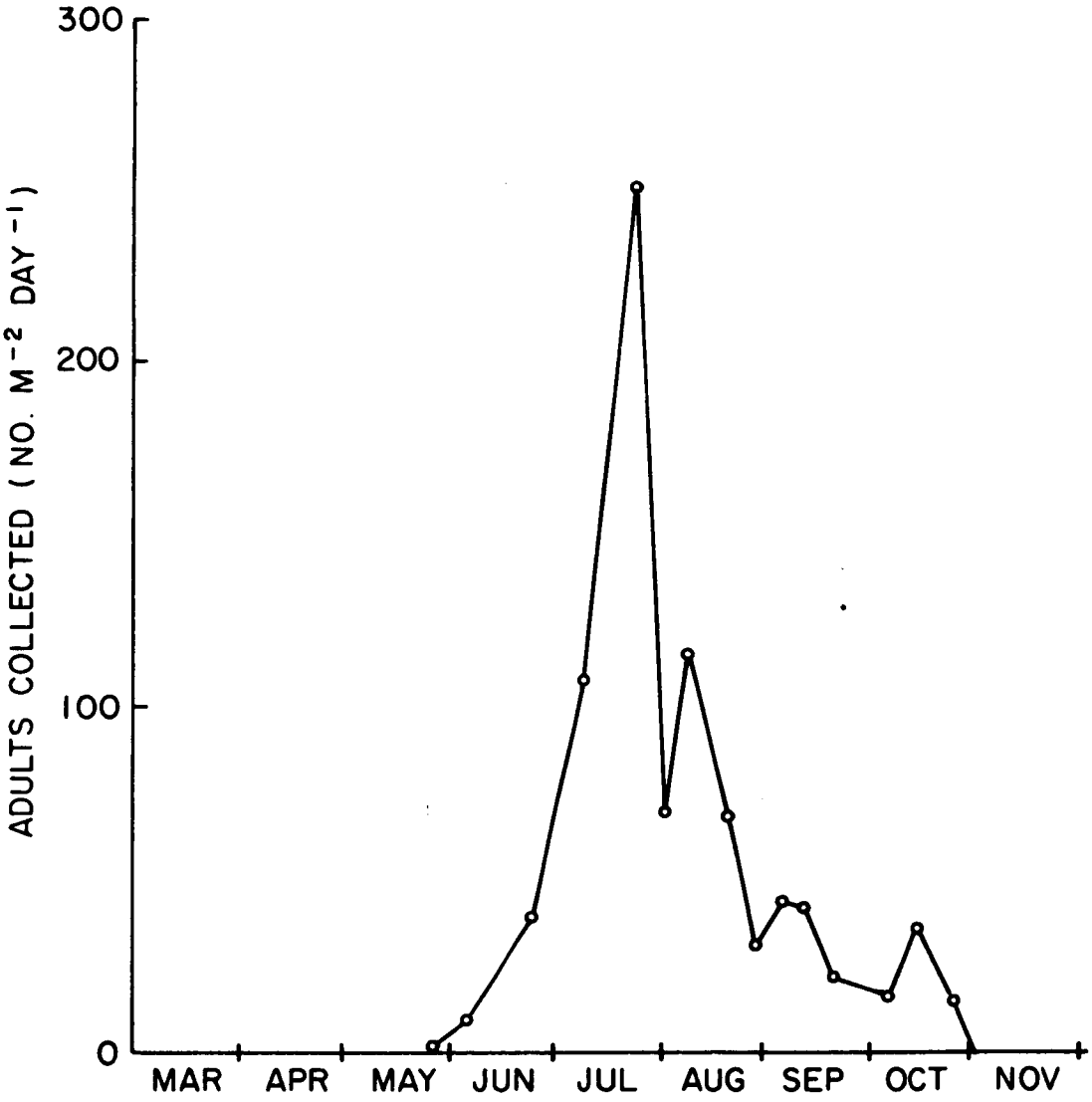


Figure 9. Number of adult Cricotopus sylvestris collected with a box trap in the littoral cove during 1975.



were destroyed by vandals and therefore no record of emergence is available for that period. Throughout the summer, adults were occasionally collected in sweep nets along the Bowline Pond shore transect. However, they were observed swarming along roadways several hundred yards from the water. These swarms, spherical in shape, were usually 1-2 m from the ground. Female C. sylvestris also were observed on aquatic vegetation at the water's surface, where they laid long stringlike gelatinous egg masses, containing 200-300 eggs.

Laboratory Observations on C. sylvestris Larvae

Larvae built silk tubes into which water containing particulate organic matter was drawn by body undulations. Gut analyses of larvae collected in the cove revealed diatom frustules and a large amount of unidentifiable matter. First and second instars of C. sylvestris larvae frequently left their tubes to crawl around within the culture dishes while older third and fourth instars usually remained within their tubes.

When larvae were crowded into a culture dish (e.g., up to 20 placed in a single dish), individuals appeared to defend the area around their tubes by nipping at other approaching larvae. In displaying this behavior, larvae rarely came all the way out of their tubes, but usually extended a distance equal to about half their body length.

Development of C. sylvestris larvae took 28 days at 15°C, and 10 days at 22 and 29°C (Table 5). At 9°C, development through the third instar required at least 37 days or more. Pupation took place within 3 days at temperatures of 22 and 29°C and eggs collected in the field hatched within 4 days. No quantitative data were obtained on duration

Table 5. Developmental rates and growth rates of Cricotopus sylvestris larvae reared in the laboratory.

Temperature (C°)	Instars	Stadium (Days) + 95% Confidence Limits	Average Growth Rate (mg individual^{-1} day^{-1})
9	I	None Observed	--
	II	None Observed	--
	III	>37 days	--
	IV	No Growth	--
	Total		--
15	I	4.25 ± 2.00	0.00018
	II	7.00 ± 3.80	0.00032
	III	6.20 ± 1.65	0.00359
	IV	10.30 ± 1.18	0.01730
	Total	27.80	--
22	I	0.70 ± 0.30	0.00106
	II	2.00 ± 0.47	0.00112
	III	2.34 ± 0.30	0.00950
	IV	4.90 ± 0.34	0.02680
	Total	9.94	--
29	I	1.17 ± 0.56	0.00063
	II	1.04 ± 0.23	0.00216
	III	2.75 ± 0.56	0.00810
	IV	5.18 ± 0.37	0.01780
	Total	10.14	--

of mating or egg laying. However, assuming that mating and egg laying occur within 2 days following emergence, one generation of C. sylvestris would be completed in about 19 days at temperatures between 22-29°C.

Production of C. sylvestris Larvae

Individual cohorts were indiscernible but data were obtained in the laboratory on growth patterns of the larvae. Therefore, the Hynes and Coleman method is used to estimate production of this species.

Based on field survey data, there were at least three generations during the year as evidenced by the three major peaks in larval abundance. However, laboratory-based estimates of generation times indicate there may have been as many as five generations. There were 84 days during 1975 having temperatures at or greater than 22°C, and, at an estimated generation time of 19 days, approximately four generations could have been completed during this period. Since development of C. sylvestris larvae continues down to a temperature of at least 15°C, an additional generation of C. sylvestris could have occurred after temperatures had dropped below 22°C.

Production of C. sylvestris larvae is estimated to be 4,056-6,759 mg m^{-2} for 3-5 generations, respectively (Table 6).

3.4.2 Dicrotendipes modestus

Observations on Larvae of D. modestus Collected in the Sampling Cove

Larvae of D. modestus were present in the sediments and on Myriophyllum. Significant differences in abundance of the sediment population of D. modestus occurred among sampling dates; no differences were detected among the four sampling areas within the cove (Appendix C).

Table 6. Productivity estimates for Cricotopus sylvestris using Hynes and Coleman's (1968) method.

Instar	Annual Mean Standing Crop (n) No. m^{-2}	Proportion of Time in Each Instar (Pa)[1]	Adjustment Factor (Pe/Pa)	Number of Generations b	Adjusted Standing Crop No. m^{-2}	Number Lost at Stage No. m^{-2}	Average Weight at Loss mg	Number of Instars (C)	Annual Production mg/m^{-2}
I	769	0.11	2.27	3-5	5,237-8,728	*	0.0011	4	*
II	4,000	0.18	1.39	3-5	16,680-27,800	687-1,145	0.0058	4	16-27
III	5,126	0.24	1.04	3-5	15,993-26,655	8,486-14,143	0.0355	4	1,205-2,008
IV	4,634	0.46	0.54	3-5	7,507-12,512	7,507-12,512	0.0944	4	2,835-4,725
Total									4,056-6,759

1. Proportion of time spent in each instar was estimated from data presented in Table 5.

D. modestus comprised 35.6% of all chironomids living in the sediments. The abundance of infaunal D. modestus larvae, primarily in the third and fourth instars, ranged between 5,800 and 8,600 larvae m^{-2} during January, February, and March (Figure 10). An increased abundance of first instars in June is attributed to recruitment resulting from the spring adult emergence of overwintering individuals. During July, August, and September, abundance of larvae in sediments, primarily third and fourth instars, ranged between 1500-3000 m^{-2}.

There were significant differences among sampling dates in abundances of D. modestus larvae living on Myriophyllum; differences were also observed among the four sampling areas (Appendix C). Area III, which was one of the two shallower sampling areas, contained significantly higher abundance of D. modestus larvae than the other three areas. D. modestus larvae, which were observed on Myriophyllum from June through November, showed a peak (6,225 larvae m^{-2}) in June and July (Figure 11). D. modestus abundance on Myriophyllum was generally less than 1000 larvae m^{-2} from August through November. The drop in abundance on Myriophyllum after July reflects the decreased density of larvae 100 mg^{-1} of leaf biomass (Figure 12) as well as the decreased standing crop of Myriophyllum (mg leaf dry weight m^{-2}).

First and second instars comprised more than half of the D. modestus larvae living on Myriophyllum on 24 June, 23 August, and 22 September (Figure 11). There was an increase of third and fourth instars from 24 June to 28 July, suggestive of cohort development. A similar shift from younger to older instars occurred between 23 August and 9 September. During October and November, third instars composed

Figure 10. Abundance and instar composition of Dicrotendipes modestus larvae living in sediments of the littoral cove during 1975. Vertical lines indicate 95% confidence intervals.

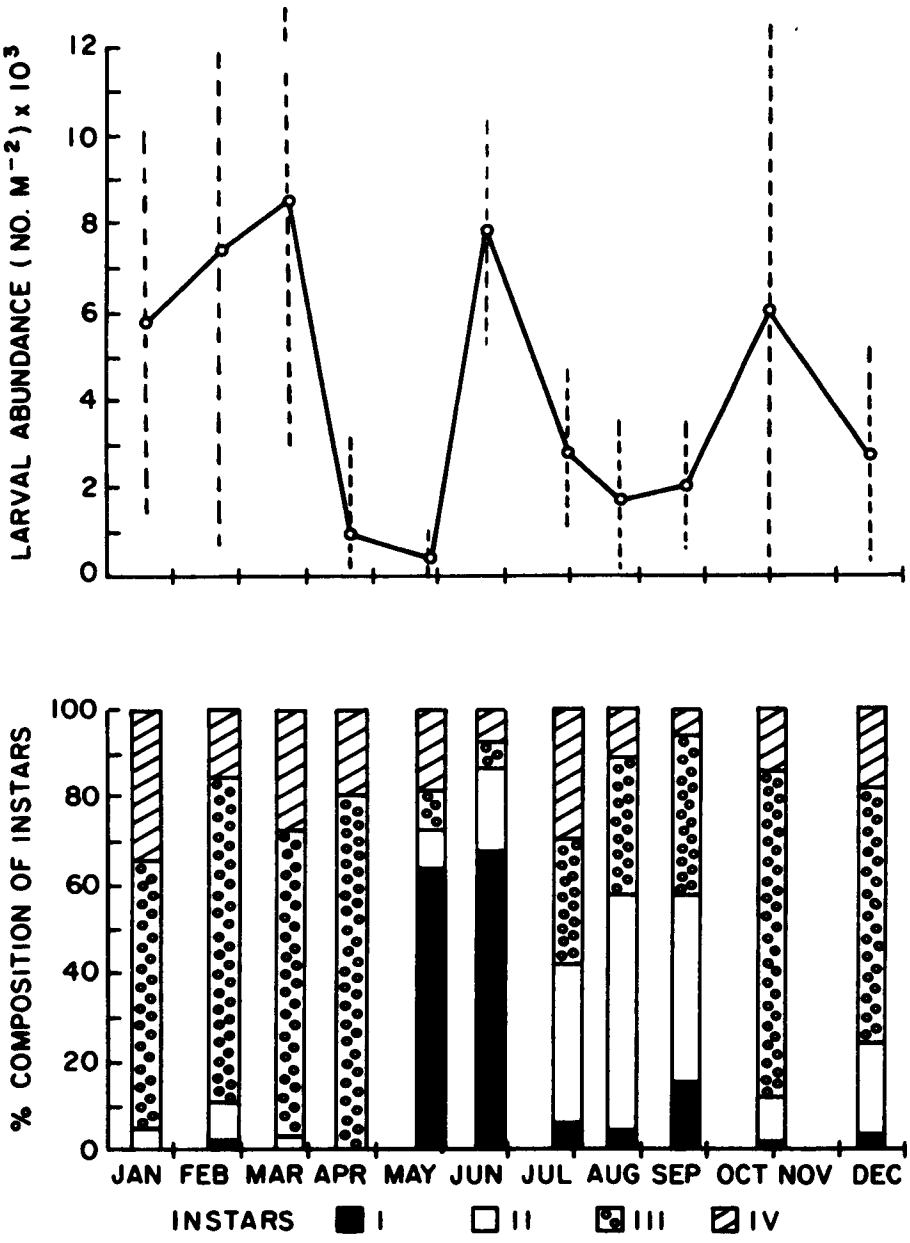


Figure 11. Abundance and instar composition of Dicrotendipes modestus living on Myriophyllum in the littoral cove during 1975. Vertical lines indicate 95% confidence intervals.

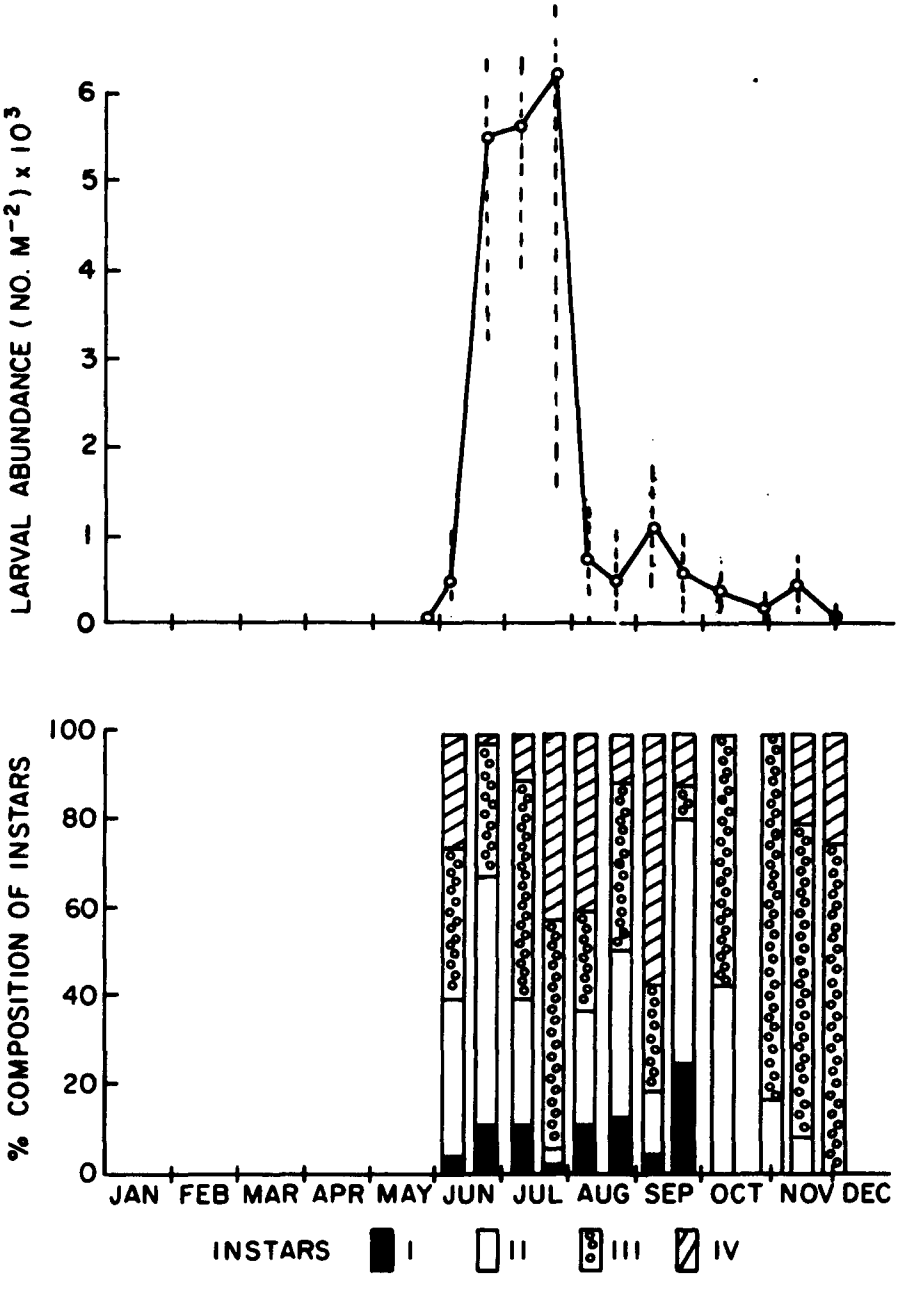
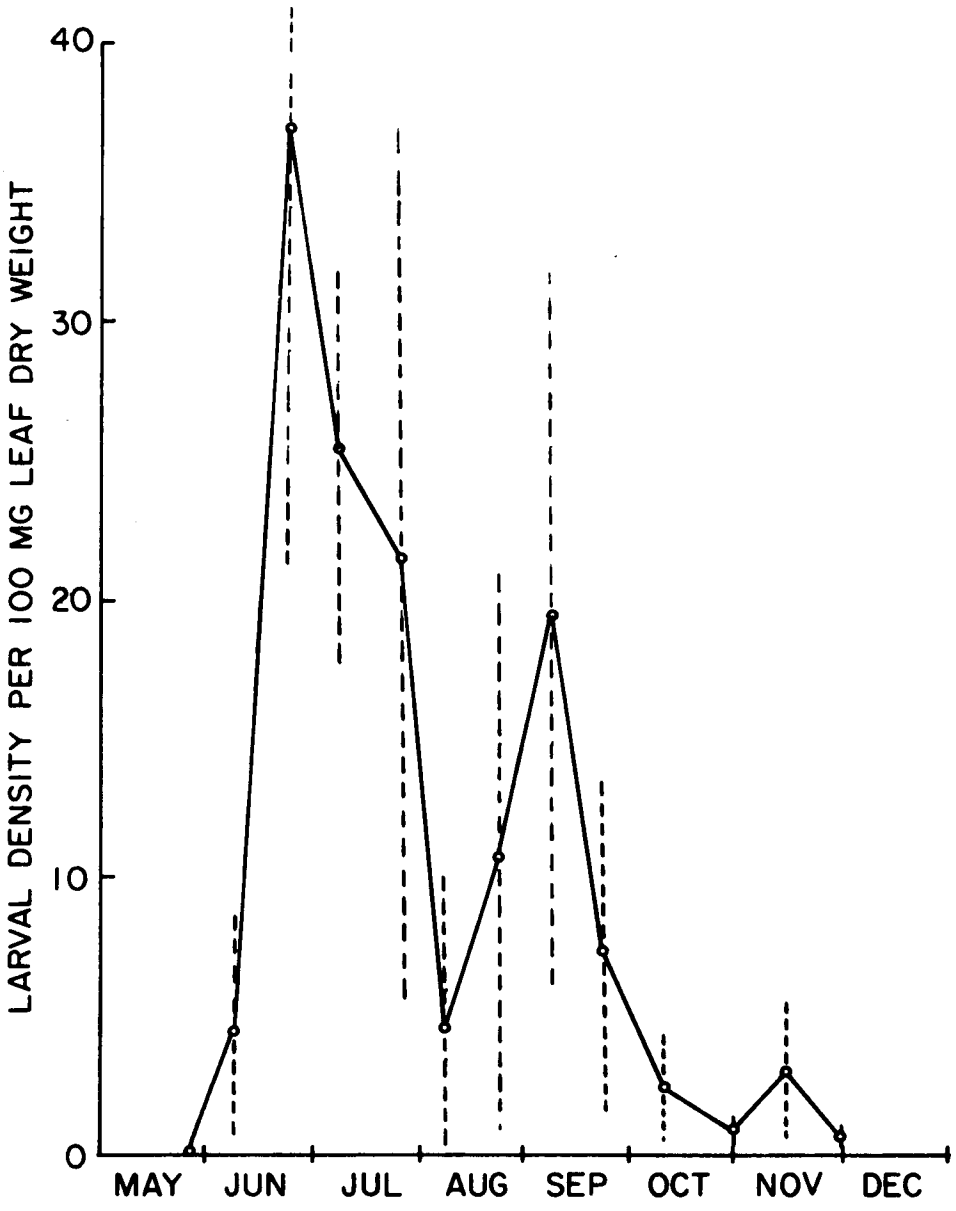


Figure 12. Density of Dicrotendipes modestus larvae on Myriophyllum in the littoral cove during 1975. Vertical lines indicate 95% confidence intervals.



50-80% of D. modestus larvae. These shifts in the relative abundance of instars suggests there were at least three generations of D. modestus during the year.

Larval biomass ranged between 23 mg m^{-2} in May and 439 mg m^{-2} in January (Figure 13). Average biomass was 213 mg m^{-2} which represents 13.6% of total average chironomid biomass.

Observations on Adult D. modestus

Adults were collected by sweep net from May to October. Peaks in the number of adults collected were observed in June, July, and September (Figure 14). Adult swarming behavior was not observed. Females collected in the field or reared in the laboratory laid spherical gelatinous egg masses which contained between 40 and 180 eggs.

Laboratory Observations on D. modestus Larvae

Larvae of D. modestus built tubes through which water and particulate organic matter was drawn by body undulations. Particles which collected on the tube's walls were grazed upon. Gut analyses of larvae collected in the cove revealed diatom frustules and an abundance of unidentifiable matter. Laboratory reared larvae defended areas around their tubes, a behavior similar to that observed for C. sylvestris.

The development period of D. modestus larvae was 15 days at 22°C and 14.5 days at 29°C. Little growth was observed at 15°C and larvae took more than 55 days to pass through the third and fourth instars (Table 7). No growth was observed at 9°C. First, second, and third instars of D. modestus developed more rapidly than the fourth instar. Pupation and adult emergence of D. modestus occurred within 3 days at temperatures of 22 and 29°C and eggs collected in the field hatched within 4 days. No data were obtained on duration of

Figure 13. Dry weight biomass of Dicrotendipes modestus in the littoral cove during 1975. Data are combined for populations living in sediments and on Myriophyllum.

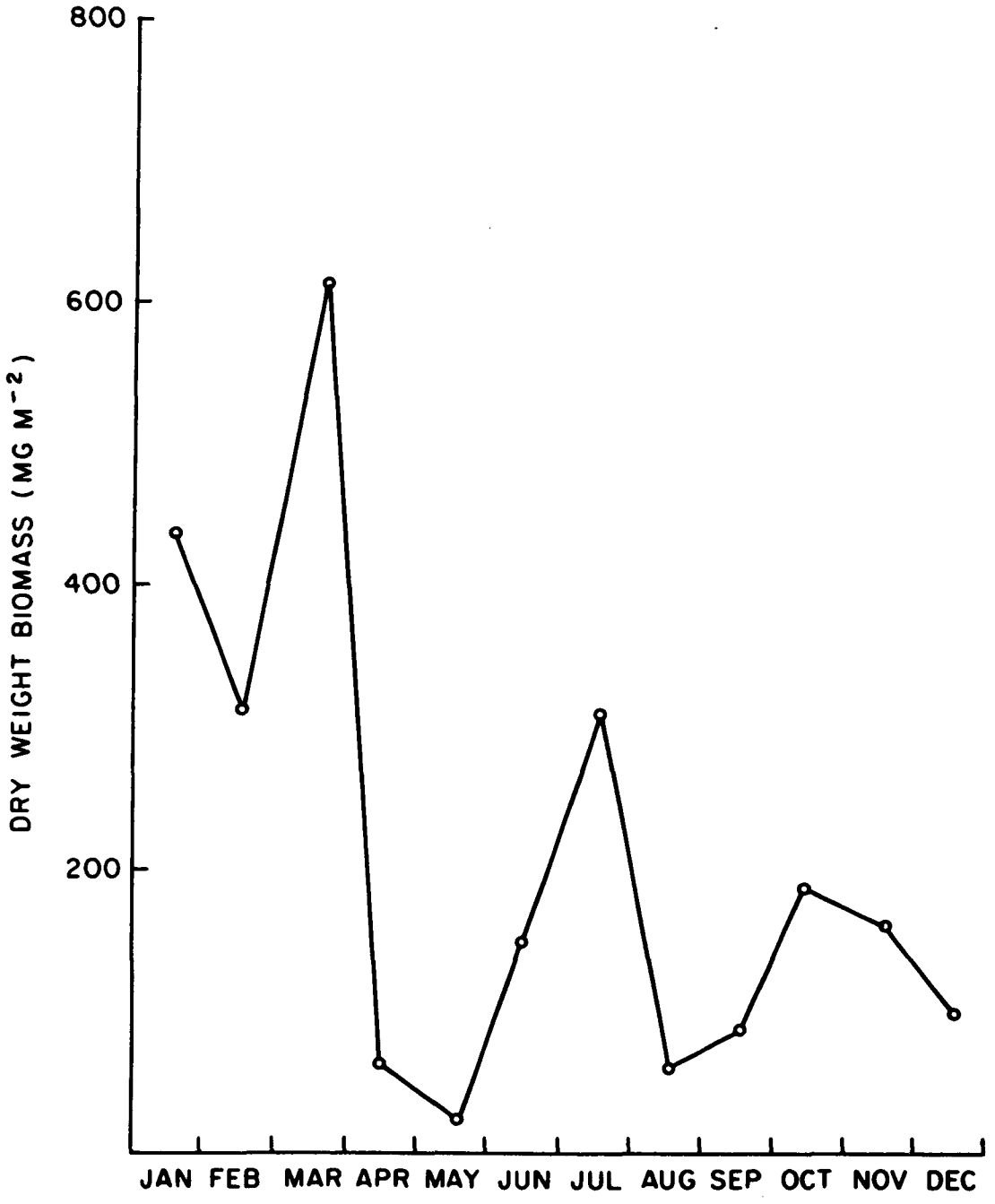


Figure 14. Number of adult Dicrotendipes modestus collected by sweep net along the southern shore of Bowline Pond during 1975.

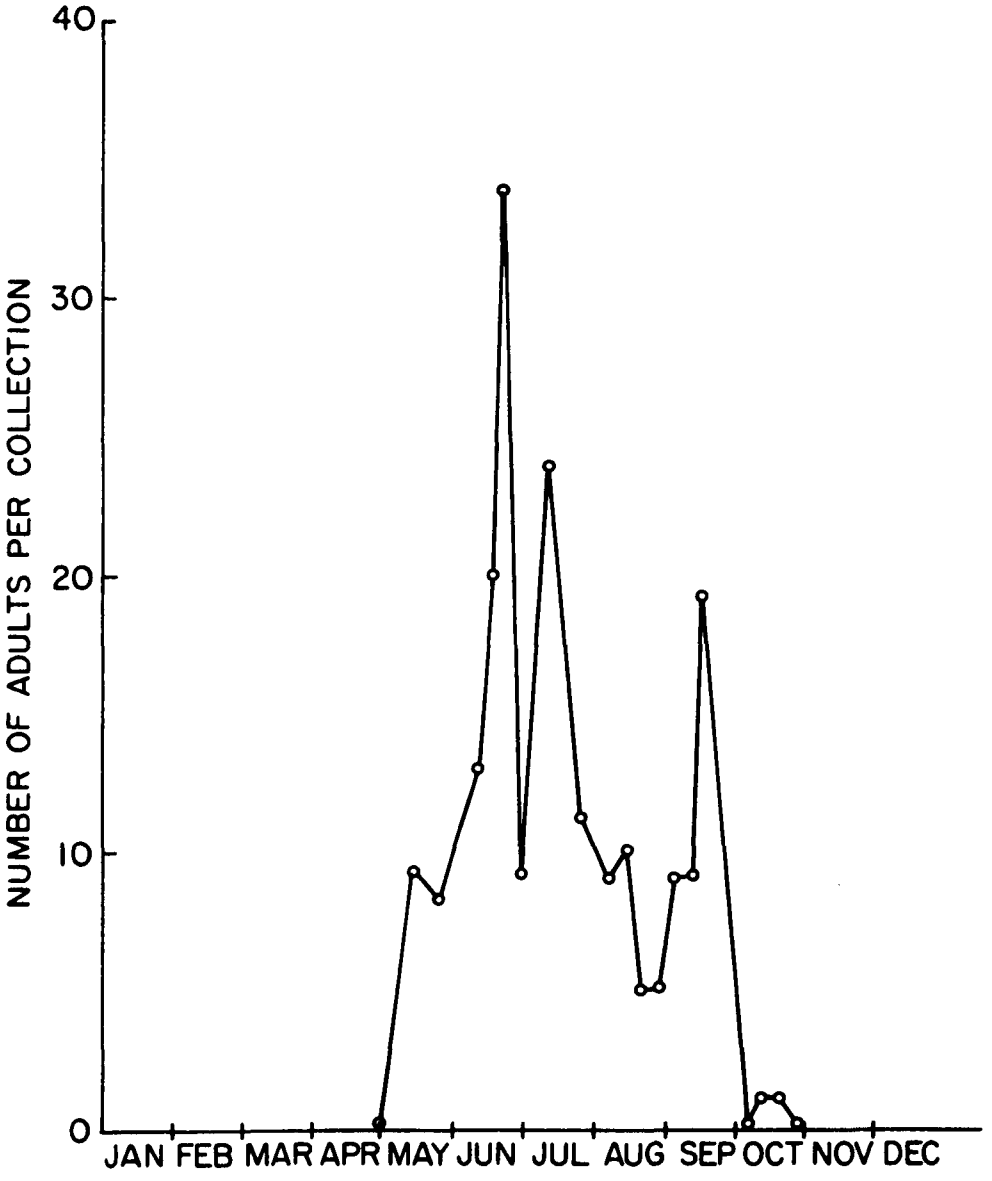


Table 7. Developmental rates and growth rates of Dicrotendipes modestus larvae reared in the laboratory.

Temperature (C°)	Instars	Stadium (Days) + 95% Confidence Limits	Average Growth Rate (mg individual^{-1} day^{-1})
9	I	No Development	--
	II	occurred at this	--
	III	temperature	--
	IV		--
	Total		--
15	I	Did not develop	--
	II	Did not develop	--
	III	> 54 days	--
	IV		--
	Total		--
22	I	1.99 ± 0.54	0.00080
	II	2.79 ± 0.84	0.00510
	III	2.50 ± 0.64	0.01110
	IV	7.70 ± 1.14	0.02300
	Total	14.98	--
29	I	2.70 ± 0.34	0.00060
	II	2.62 ± 0.46	0.00540
	III	2.24 ± 0.34	0.01240
	IV	6.97 ± 0.93	0.02540
	Total	14.53	--

mating and egg laying, but assuming that mating and egg laying occur within 2 days after emergence, a generation of D. modestus would be completed in 24 days at temperatures between 22 and 29°C.

Production of D. modestus Larvae

Individual cohorts were indiscernible but data were obtained in the laboratory on growth patterns of the larvae. Therefore, the Hynes and Coleman method is used to estimate production of this species.

There were at least three generations in the field during the year. However, laboratory based estimates of generation time indicate there could have been four generations. At an estimated generation time of 24 days, three and one-half generations could have been completed during the 84-day period when temperatures were at or exceeded 22°C. The "one-half" generation could have resulted in a fourth overwintering generation.

Production of D. modestus larvae is estimated to be 5,663-7,550 mg m^{-2} $year^{-1}$ for 3-4 generations, respectively (Table 8).

3.4.3 Polypedilum illinoense

Observations on Larvae of P. illinoense Collected in the Sampling Cove

Only three P. illinoense larvae were observed in the sediments. All other larvae of P. illinoense were collected on Myriophyllum and represented 5% of the chironomids on this plant. Significant differences among sampling dates were observed in the abundance of P. illinoense larvae and significant differences were also observed among the four sampling areas (Appendix C). Area IV, which was one of the two deeper sampling areas, contained significantly less larvae of P. illinoense than did the other three areas. During the May-November

Table 8. Productivity estimates for Dicrotendipes modestus using Hynes and Coleman's (1968) method.

Instar	Annual Mean Standing Crop (n) No. m^{-2}	Proportion of Time in Each Instar (Pa)[1]	Adjustment Factor (Pe/Pa)	Number of Generations b	Adjusted Standing Crop No. m^{-2}	Number Lost at Stage No. m^{-2}	Average Weight at Loss mg	Number of Instars (C)	Annual Production mg m^{-2} yr^{-1}
I	761	0.16	1.56	3-4	3,561-4,749	*	0.0035	4	*
II	1,105	0.19	1.32	3-4	4,376-5,834	*	0.0154	4	*
III	2,988	0.16	1.56	3-4	13,984-18,645	12,169-16,225	0.0886	4	4,313-5,750
IV	1,210	0.50	0.50	3-4	1,815-2,420	1,815-2,420	0.1860	4	1,350-1,800
Total									5,553-7,550

1. Proportion of time spent in each instar was estimated from data presented in Table 7.

period, abundance of P. illinoense on Myriophyllum ranged between 200-1840 larvae m^{-2} (Figure 15). With the exception of a peak in September, larval abundance m^{-2} of bottom area reflected fluctuations in biomass of Myriophyllum. In September, when leaf biomass was low, the density of larvae per 100 mg of leaf biomass increased; this resulted in a peak in the abundance of larvae per m^2 (Figure 16). This increase of P. illinoense coincided with a period when the density of C. sylvestris, the normally dominant chironomid species on Myriophyllum, was low.

The first and second instars composed more than 50% of P. illinoense larvae on 26 May, 24 June, 23 August, 11 October, and 15 November (Figure 15). These five sampling dates were separated by periods when older instars predominated which indicates at least five major recruitment periods.

Larval biomass ranged between 5.8 mg m^{-2} in November and 162.9 mg m^{-2} in July (Figure 17). Average biomass was 25.3 mg m^{-2} which represents 1.6% of average total chironomid biomass.

Observations on Adult P. illinoense

Adults were collected in sweep nets from June through October (Figure 18). Four peaks in the number collected were observed at approximately monthly intervals.

Laboratory Observations on P. illinoense Larvae

P. illinoense larvae reared in the laboratory constructed silk tubes. Observations on development and growth rates were not made because only two live larvae were collected and these were in the third and fourth instars.

Figure 15. Abundance and instar composition of Polypedilum illinoense on Myriophyllum in the littoral cove during 1975. Vertical lines indicate 95% confidence intervals.

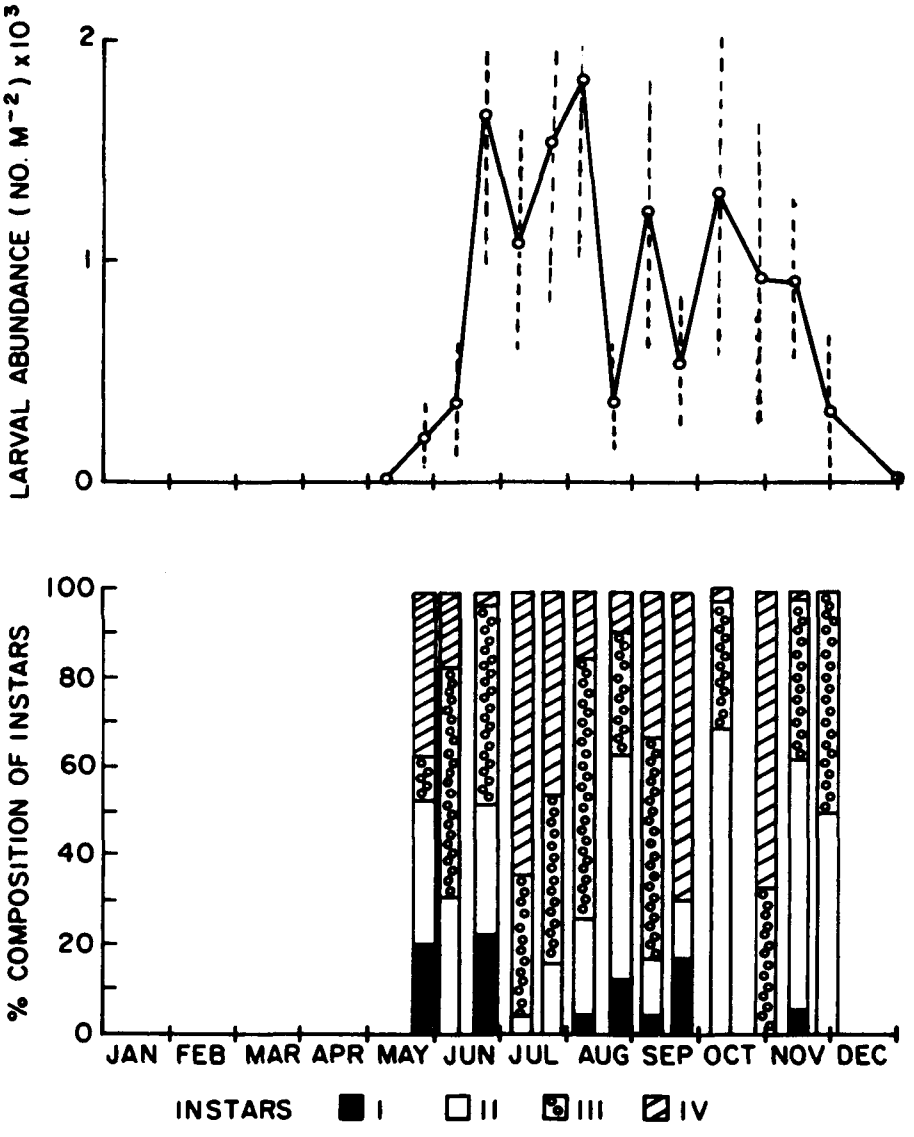


Figure 16. Densities of Polypedilum illinoense on Myriophyllum in the littoral cove during 1975. Vertical lines indicate 95% confidence intervals.

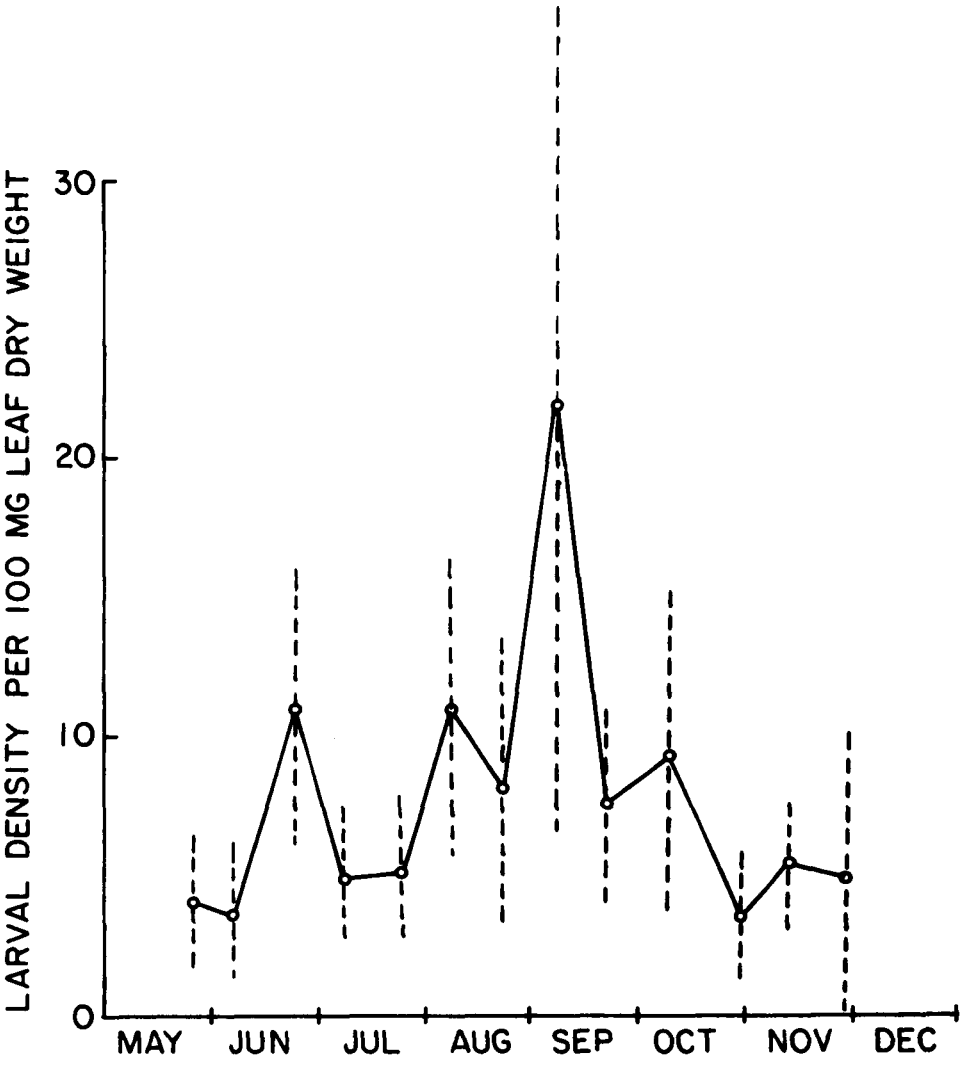


Figure 17. Dry weight biomass of Polypedilum illinoense larvae in the littoral cove during 1975.

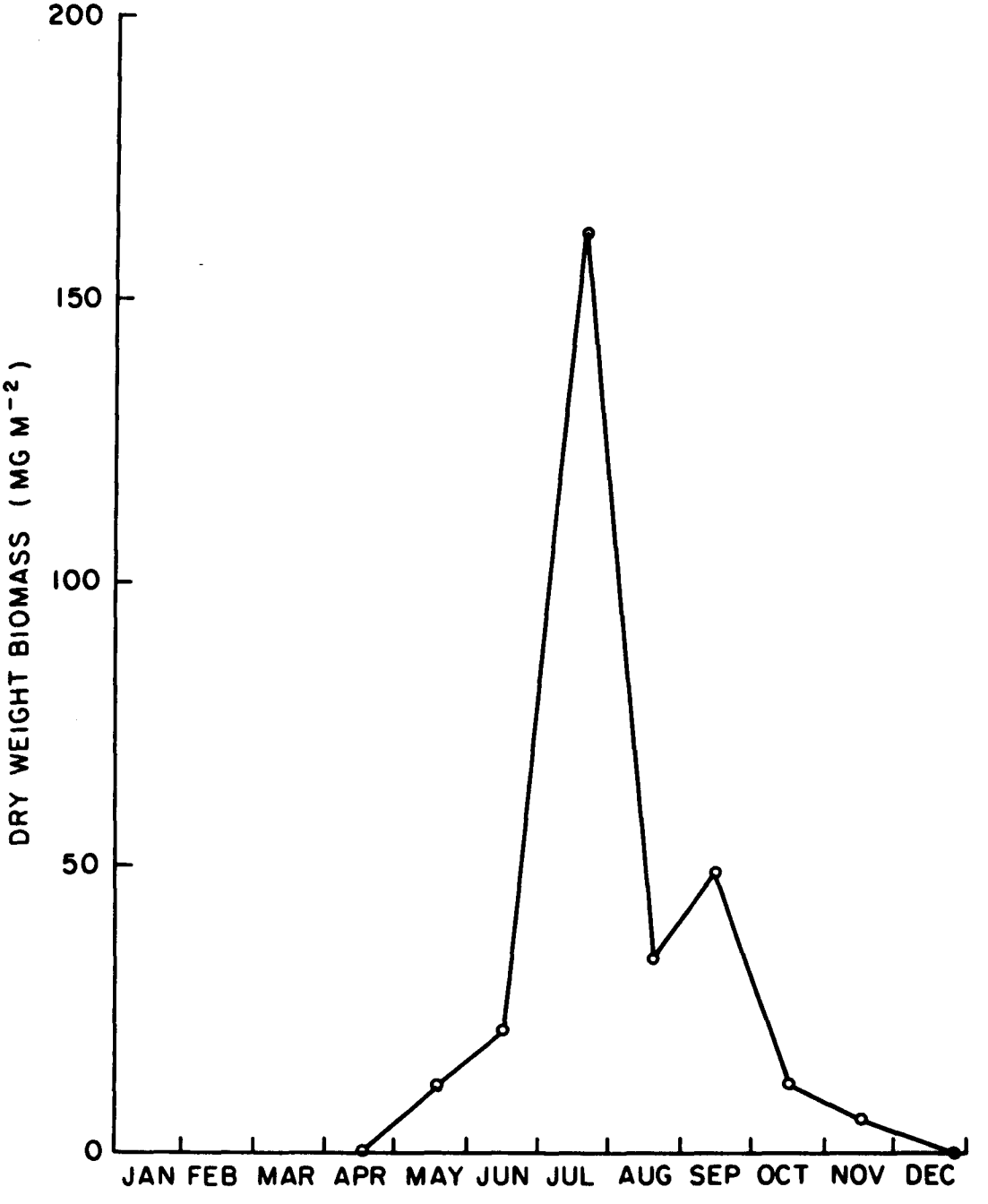
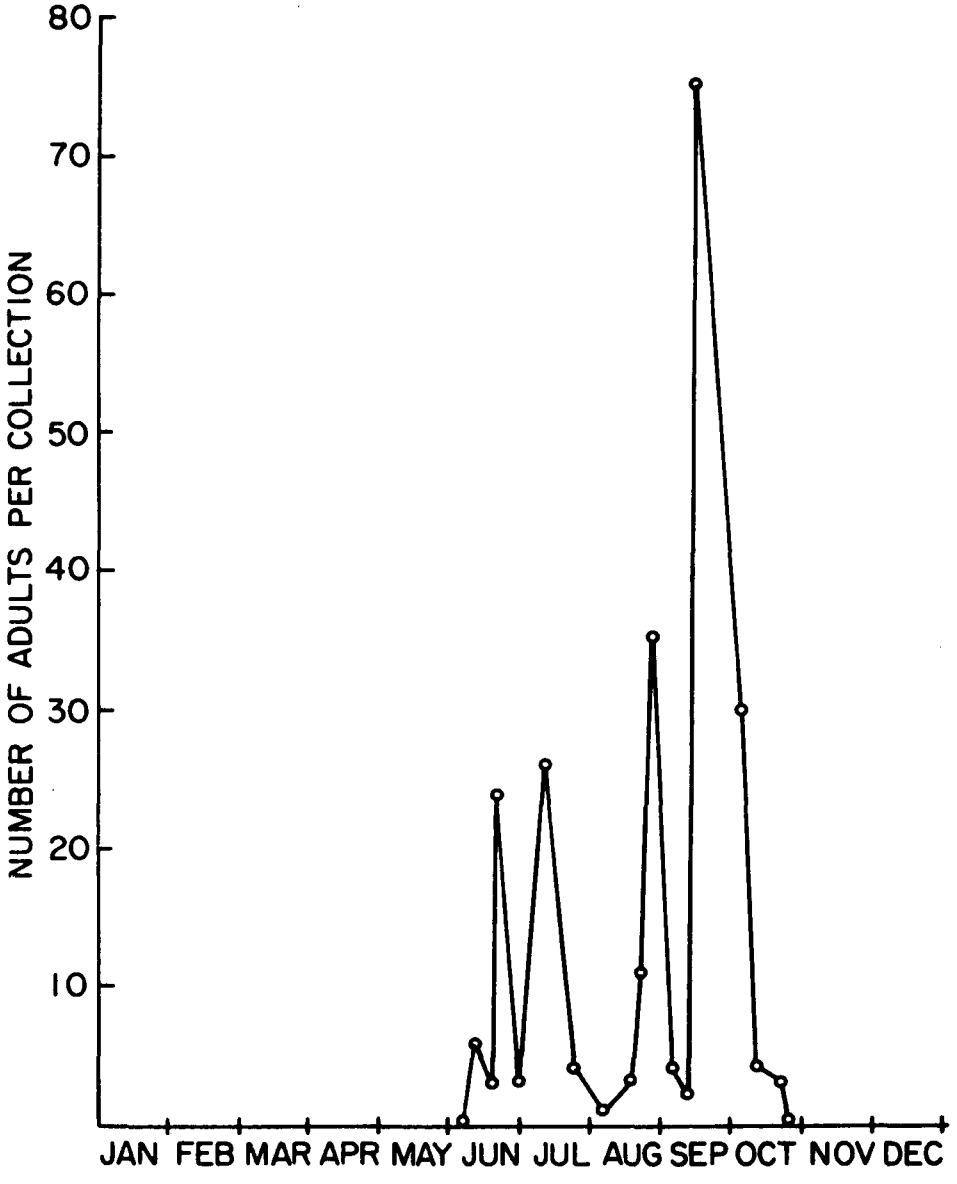


Figure 18. Number of adult Polypedilum illinoense collected by sweep net along the southern shore of Bowline Pond during 1975.



Production of P. illinoense Larvae

Cohorts were indiscernible and no information was obtained on larval growth patterns. Therefore, production was estimated using the turnover ratio approach. Based on field survey data, there were five generations of P. illinoense during the year. An annual turnover ratio of 17.5 is estimated by multiplying number of generations by 3.5, an average turnover ratio per generation (see Methods and Materials). An annual production estimate of 443 mg m^{-2} yr^{-1} is obtained by multiplying the annual turnover ratio by 25.3 mg m^{-2}, the average annual biomass of this species.

3.4.4 Rheotanytarsus sp.

Observations on Larvae of Rheotanytarsus Collected in the Sampling Cove

Rheotanytarsus larvae collected on Myriophyllum represented 2.6% of all chironomid larvae on this plant. Significant differences among sampling dates were observed in the abundance of Rheotanytarsus larvae; no differences were observed among the four sampling areas (Appendix C). Maximum abundance of Rheotanytarsus on Myriophyllum (1480 larvae m^{-2}) was observed in November (Figure 19). At other times, larval abundance was generally less than 1000 larvae m^{-2}. Fluctuations in abundance per m^2 reflected fluctuations in density of larvae 100 mg^{-1} of leaf biomass (dry weight) (Figure 20) and the biomass of Myriophyllum m^{-2}. Densities of 10 larvae 100 mg^{-1} leaf biomass and 11 larvae 100 mg^{-1} of leaf biomass were observed on 9 September and 15 November, respectively. For all other sampling dates, the density of Rheotanytarsus was less than 5 larvae 100 mg^{-1} of leaf biomass.

Figure 19. Abundance and instar composition of Rheotanytarsus sp. larvae living on Myriophyllum in the littoral cove during 1975. Vertical lines indicate 95% confidence intervals.

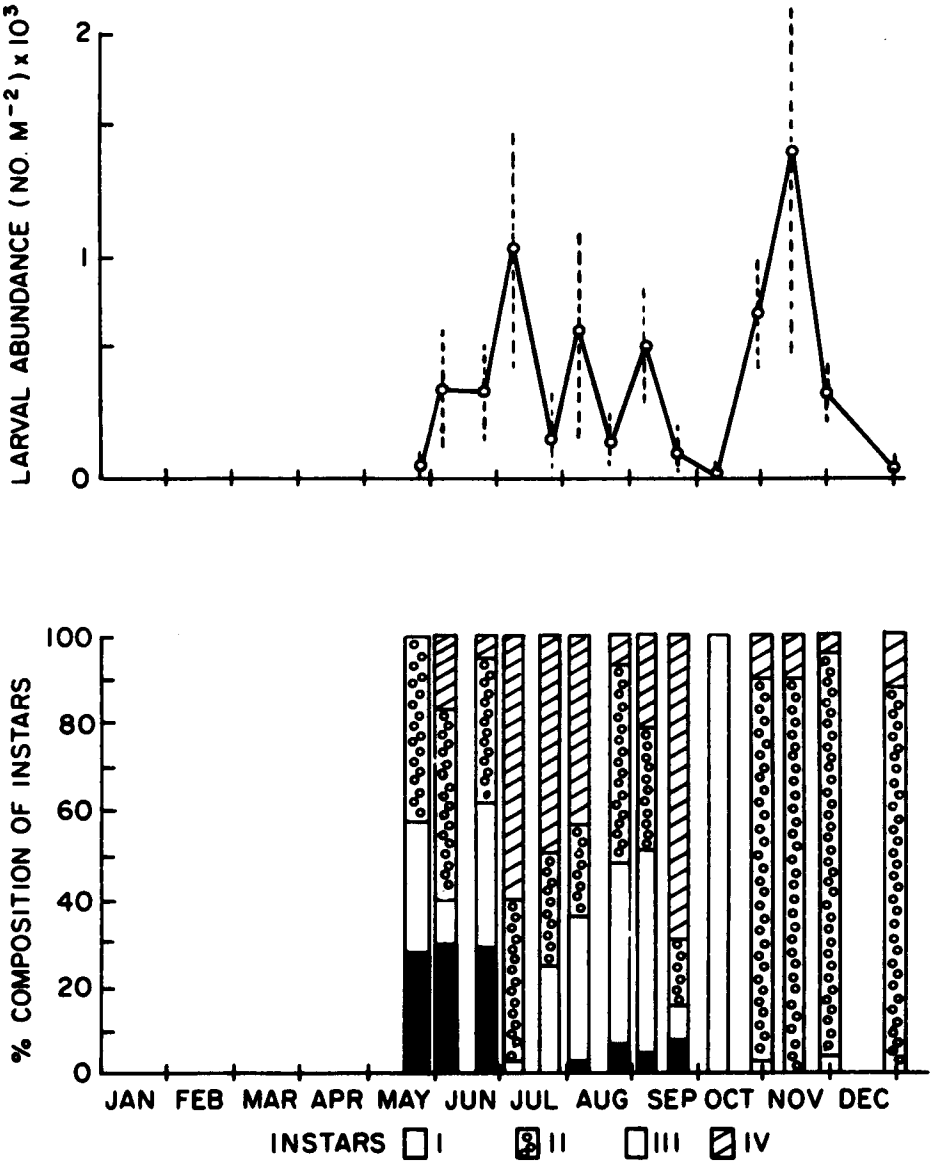
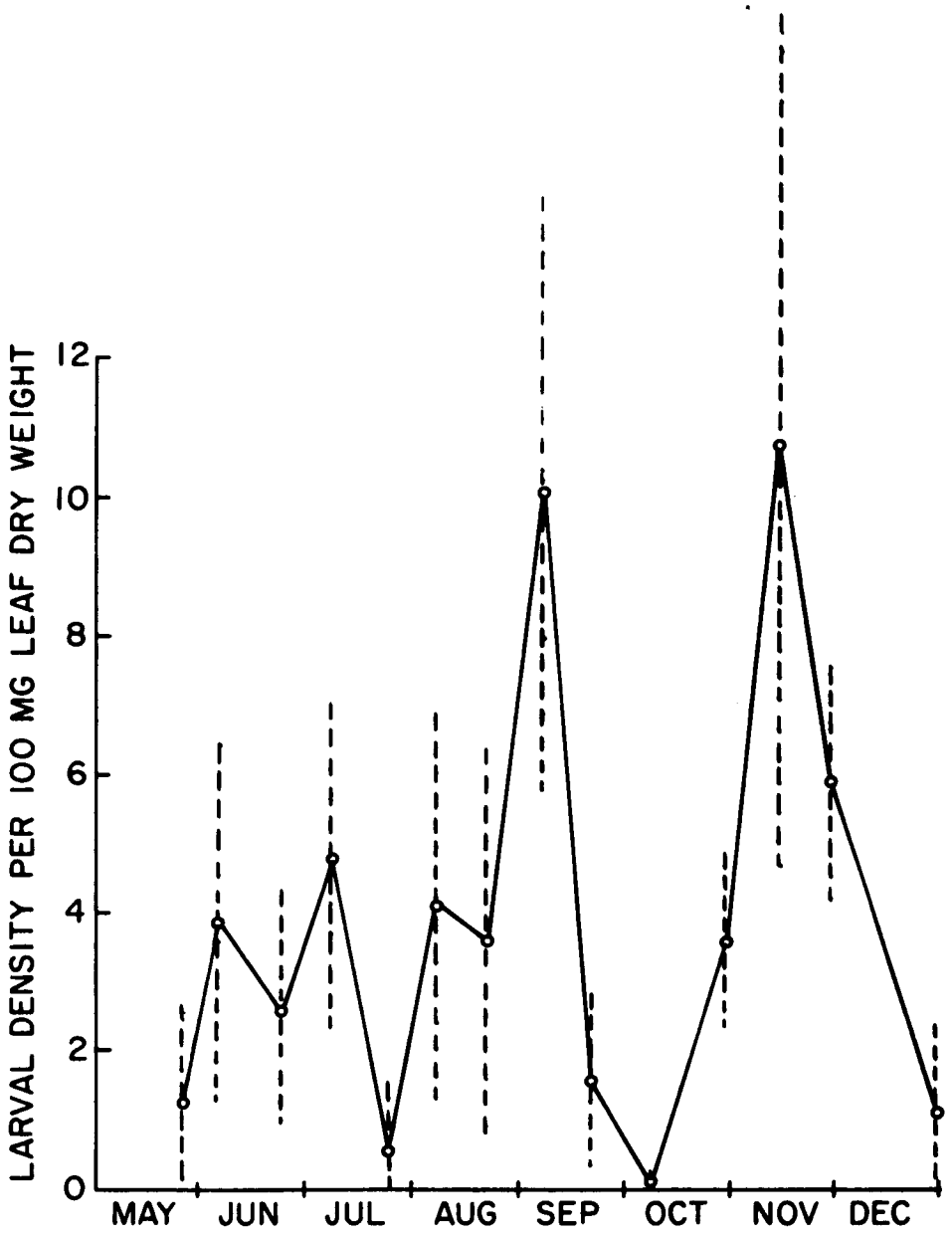


Figure 20. Densities of Rheotanytarsus sp. larvae on Myriophyllum in the littoral cove during 1975. Vertical lines indicate 95% confidence intervals.



There were three major shifts in the relative abundance of younger (first and second instars) and older (third and fourth instars) larvae. The first occurred from May to early July, the second from August to September, and the third from October through November. These shifts correspond with major fluctuations in larval density (Figure 19) and suggest there were at least three generations of Rheotanytarsus during the year. From late October to January, most larvae were in the third instar which represents the overwintering conditions initiated in late October when water temperatures were 12-15°C.

Larval biomass ranged between 0.2 mg m^{-2} in May and 24.1 mg m^{-2} in July (Figure 21). Average biomass was 5.0 mg m^{-2} which represents 0.3% of the average total chironomid biomass.

Observations on Adult Rheotanytarsus

Since there are no comprehensive keys for adults of the Tanytarsini chironomid tribe, species of Tanytarsini which includes genus Rheotanytarsus were not identified. therefore, information on adults is not presented.

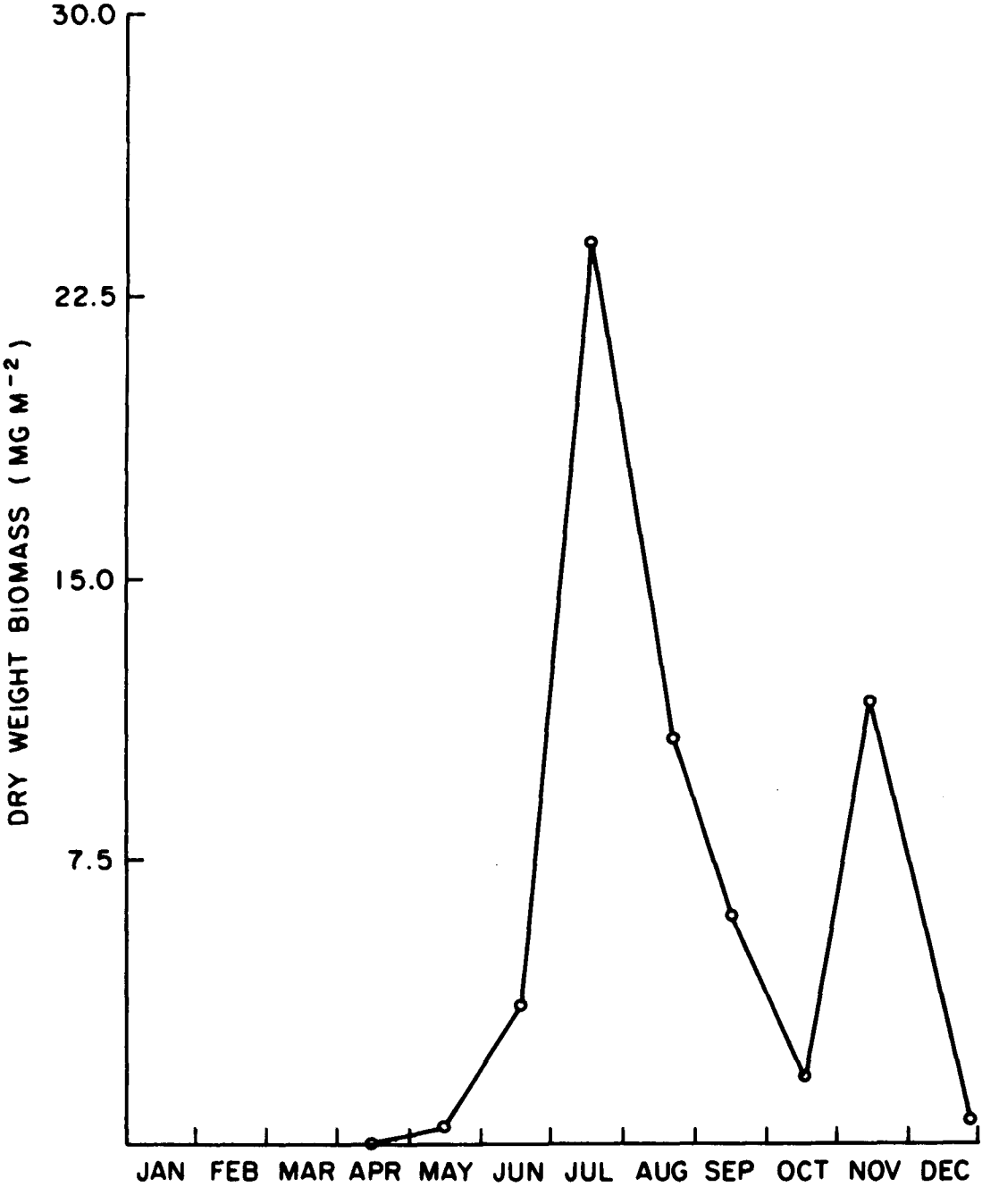
Laboratory Observations of Rheotanytarsus Larvae

As a result of low densities of Rheotanytarsus in the field, no live Rheotanytarsus larvae were among those examined in the laboratory. Therefore, no observations were made of behavior or developmental rates.

Production of Rheotanytarsus Larvae

Cohorts of Rheotanytarsus were indiscernible and no information was obtained on larval growth patterns. Therefore, production was estimated using the turnover ratio approach. There were three

Figure 21. Dry weight biomass of Rheotanytarsus sp. in the littoral cove during 1975.



generations during the year in the field. Annual turnover ratio is estimated to be 10.5 (3 generations x 3.5, the turnover ratio per generation). An annual production estimate of 52.5 mg m^{-2} yr^{-1} is obtained by multiplying the annual turnover ratio by 5 mg m^{-2}, the average annual biomass.

3.4.5 Chironomus attenuatus

Observations on Larvae of C. attenuatus Collected in the Sampling Cove

All C. attenuatus larvae were collected from the sediments where they represented 12.3% of all chironomid larvae. Significant differences existed among sampling dates in the abundance of C. attenuatus larvae; no differences were observed among the four sampling areas within the cove (Appendix C). The abundance of C. attenuatus was less than 300 larvae m^{-2} during the January-May period (Figure 22). Peaks in larval abundance were observed on 22 June (3,500 larvae m^{-2}) and 22 September (4,700 larvae m^{-2}). C. attenuatus differed from other chironomids in that it overwintered solely as fourth instar larvae (Figure 22). Therefore, the population, composed of second instars in May, would appear to be offspring of the overwintering population. The third and fourth instars represented greater than 80% of the larvae during July, August, and September. The gradual shift from younger to older instars from May through December suggests that this species had one generation during the year.

Larval biomass ranged between 3.0 mg m^{-2} in May and 1879.7 mg m^{-2} in December (Figure 23). Average biomass was 786.4 mg m^{-2} which represents 50.1% of the average total chironomid biomass.

Figure 22. Abundance and instar composition of Chironomus attenuatus in the sediments of the littoral cove during 1975. Vertical lines indicate 95% confidence intervals.

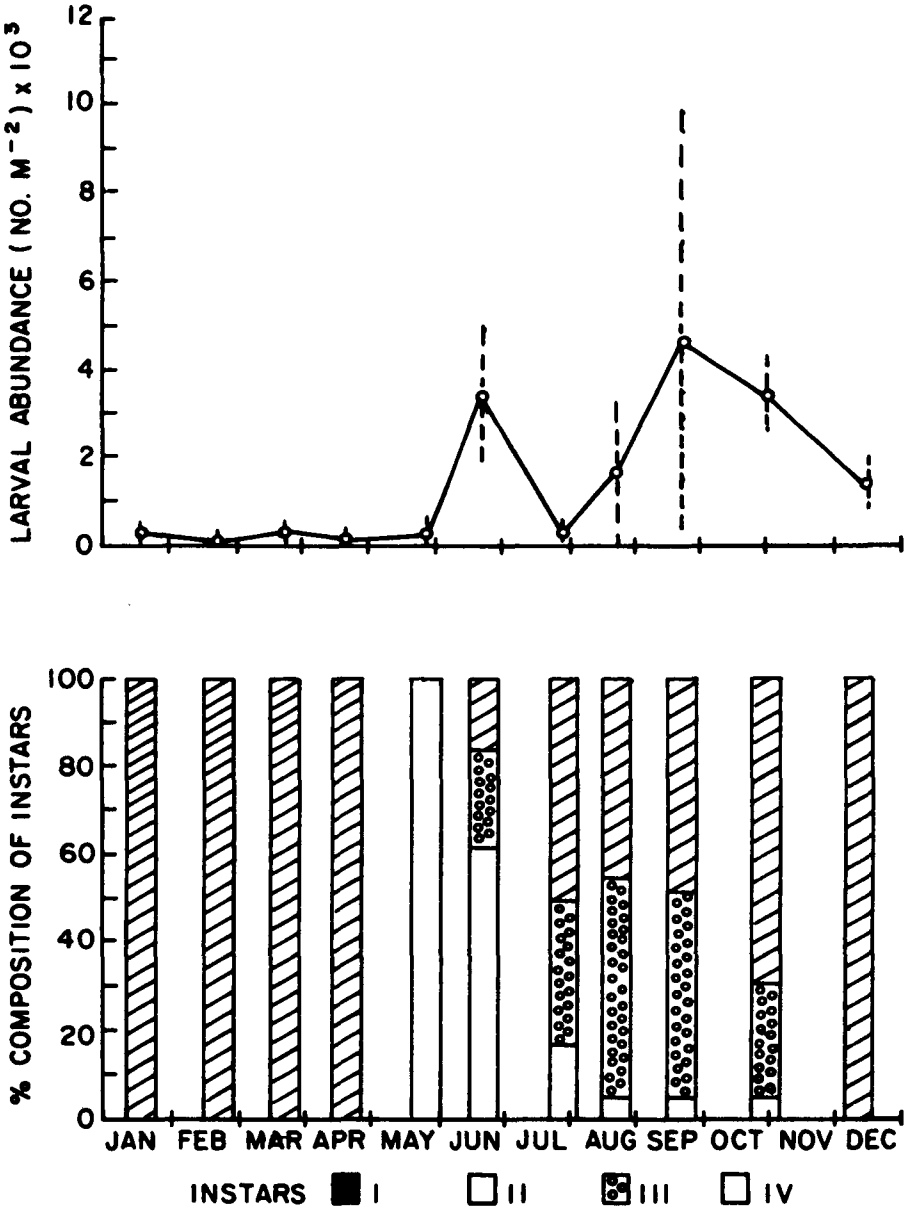
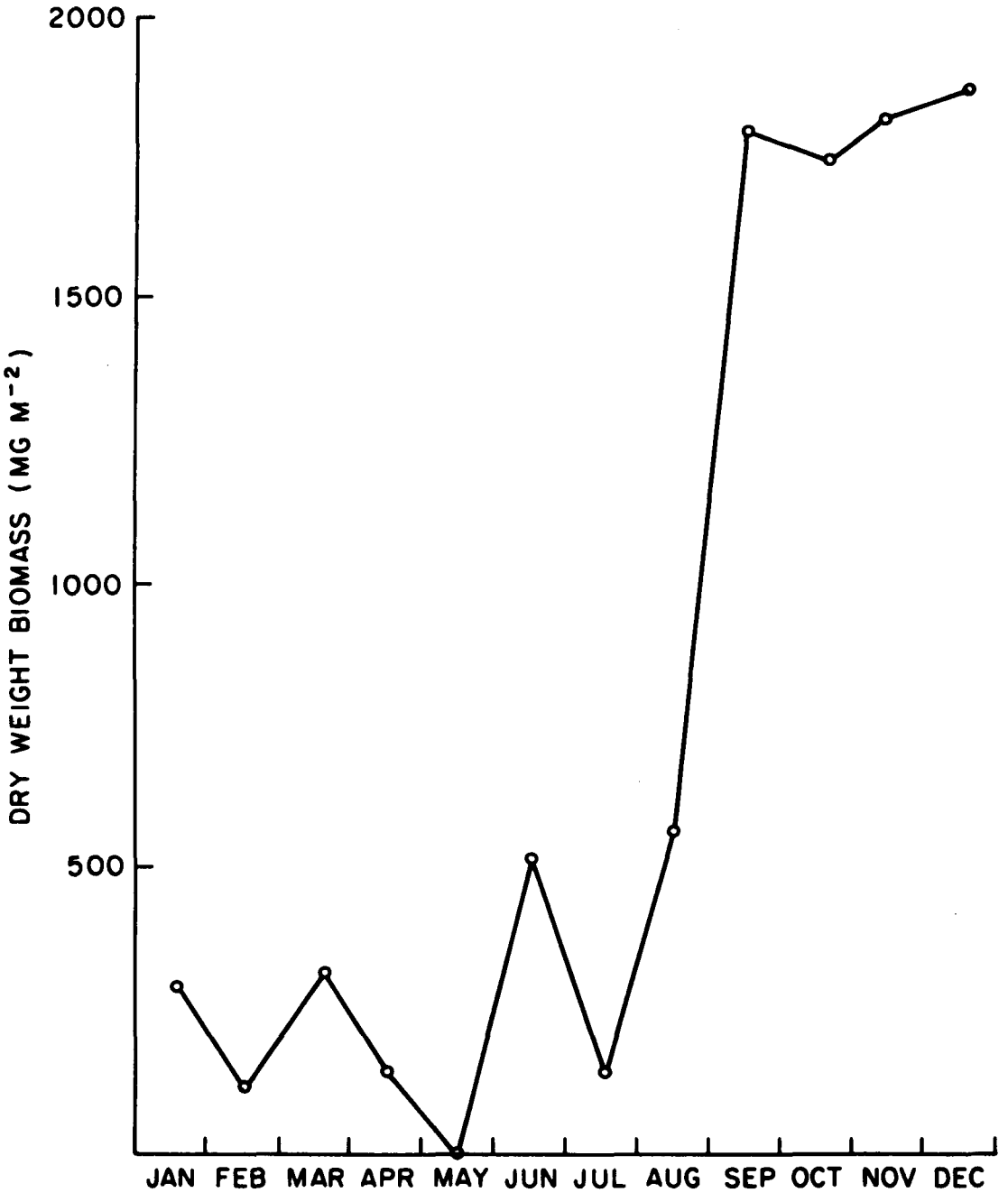


Figure 23. Dry weight biomass of Chironomus attenuatus larvae in the littoral cove during 1975.



Gut analyses of C. attenuatus larvae collected from the cove revealed mostly dark mud-like matter within which diatom frustules were observed.

Observations of Adult C. attenuatus

Adults were collected in sweep nets from May through October (Figure 24). Largest numbers of adults were collected during July and September. The occurrence of adults from late spring to early fall suggests that larval recruitment could have occurred throughout this period and that there was a potential for a greater number of generations than the single one indicated by the data on larval instar composition (Figure 23).

Laboratory Observations on C. attenuatus Larvae

In culture dishes, larvae of C. attenuatus built tubes out of mud particles. By undulating their bodies, the larvae drew water and organic matter into the tube. They grazed on the particles which collected on the tube's walls.

Larval development through the third and fourth instars was 9.75 days at 22°C and 8.75 days at 29°C (Table 9). Developmental periods of first and second instars were not determined. At 15°C larval development slowed down in the fourth instar; only 30% of the larvae pupated. The rest curled up within their tubes, were relatively inactive, and were difficult to dislodge from the tubes for measurement; the dislodged larvae immediately sought the shelter of their tubes and became quiet. Larvae did not develop at 9°C. No eggs of C. attenuatus were collected, and, therefore, data on egg developmental rates were not obtained. Pupation occurred in 3 days at 22°C.

Figure 24. Number of adult Chironomus attenuatus collected by sweep net along the southern shore of Bowline Pond during 1975.

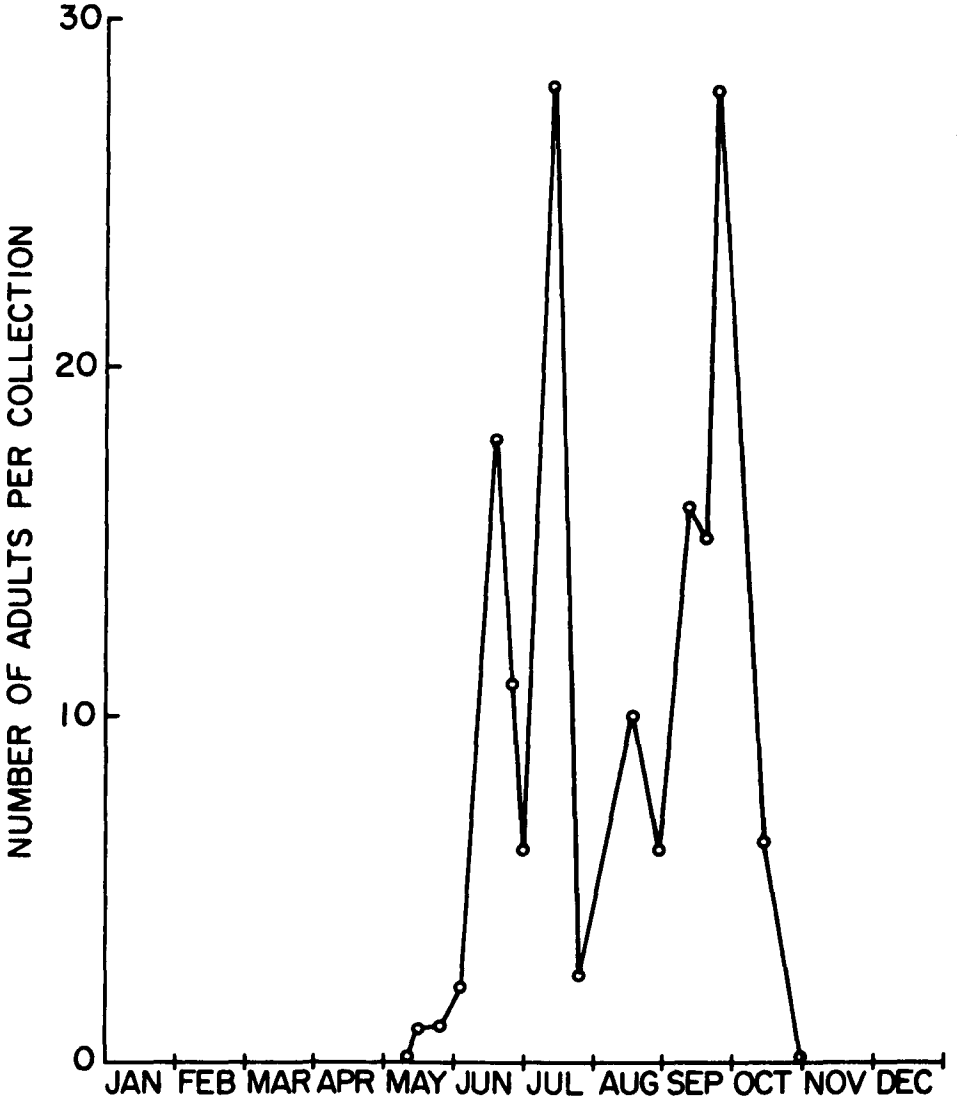


Table 9. Developmental rates and growth rates of Chironomus attenuatus reared in the laboratory.

Temperature (C^{o})	Instars	Developmental Period Days + 95% Confidence Limits	Average Growth Rate (mg individual^{-1} day^{-1})
9	I	No development	
	II	occurred at this	
	III	temperature	
	IV		
	Total		
15	I	Not observed	
	II	8.7 ± 2.2	0.01509
	III	Development not	
	IV	completed	
	Total		
22	I	No Determination	
	II	No Determination	
	III	4.25 ± 1.1	0.03091
	IV	5.5 ± 1.0	0.19957
	Total	15.25	
29	I		
	II		
	III	3.75 ± 0.57	0.03503
	IV	5.0 ± 0.67	0.21953
	Total	15.25	

Production of C. attenuatus Larvae

Production of this species is difficult to estimate. Data on larval abundance and instar composition suggest there was only one generation of C. attenuatus during the year. However, adult collections indicate that larval recruitment should have been continuous from late spring to early fall. In addition, larvae developed through the third and fourth instars in less than 10 days at 22-29°C in the laboratory. These rates of development are similar to those observed for Dicrotendipes modestus, a species whose overall generation time was estimated to be only 24 days. Thus, if the generation time of C. attenuatus was similar to that of D. modestus, as many as four generations of C. attenuatus could be completed during the year.

Assuming that there was only one generation during the year — the conservative (low) value — the annual turnover ratio is estimated to be 3.5 (1 generation x 3.5). An annual production estimate of 2,752 mg m^{-2} is obtained by multiplying the annual turnover ratio by 786.4 mg m^{-2}, the average annual biomass of this species.

3.4.6 Tanytarsus sp.

Observations on Larvae of Tanytarsus Collected in the Sampling Cove

Larvae of Tanytarsus were never observed on Myriophyllum; those collected from sediments represented 22.6% of all infaunal chironomid larvae. Significant differences occurred among sampling dates in the abundance of Tanytarsus sp. larvae; no differences were observed among the four sampling areas (Appendix C). Tanytarsus had two generations during 1975. A summer generation, which proceeded from June through

August, was indicated by a shift from younger to older instars (Figure 25). Although first and second instars were observed earlier, the major recuritment of Tanytarsus occurred between May and June when larval density increased from 750 larvae m^{-2} to over 10,000 larvae m^{-2} (Figure 25). Abundance declined through August and September with a proportional increase of older instars. A second generation was initiated in October when the densities of larvae, composed primarily of first and second instars, increased to 4250 m^{-2} (Figure 25). This generation overwintered as second and third instars.

Larval biomass ranged from 0.2 mg m^{-2} in March to 304.9 mg m^{-2} in July (Figure 26). Average biomass was 46.1 mg m^{-2} which represents 2.9% of the average total chironomid biomass.

Gut analyses of Tanytarsus larvae collected in the sampling cove revealed algal cells and unidentifiable particulate matter.

Observations on Adult Tanytarsus

Problems were encountered in the identification of adult members of the Tanytarsini; therefore, information on adults is not presented.

Observations on Tanytarsus Larvae in the Laboratory

Tanytarsus larvae constructed silk tubes and drew in water and organic matter by undulating their bodies. Tanytarsus larvae did not develop in the laboratory, and no data were obtained on growth or developmental rates.

Production of Tanytarsus Larvae

This species exhibited a well-defined summer generation and production was estimated using the Allen Curve method. Mean body weight was plotted versus population size for successive sampling dates

Figure 25. Abundance and instar composition of Tanytarsus sp. larvae in sediments of the littoral cove during 1975. Vertical lines indicate 95% confidence intervals.

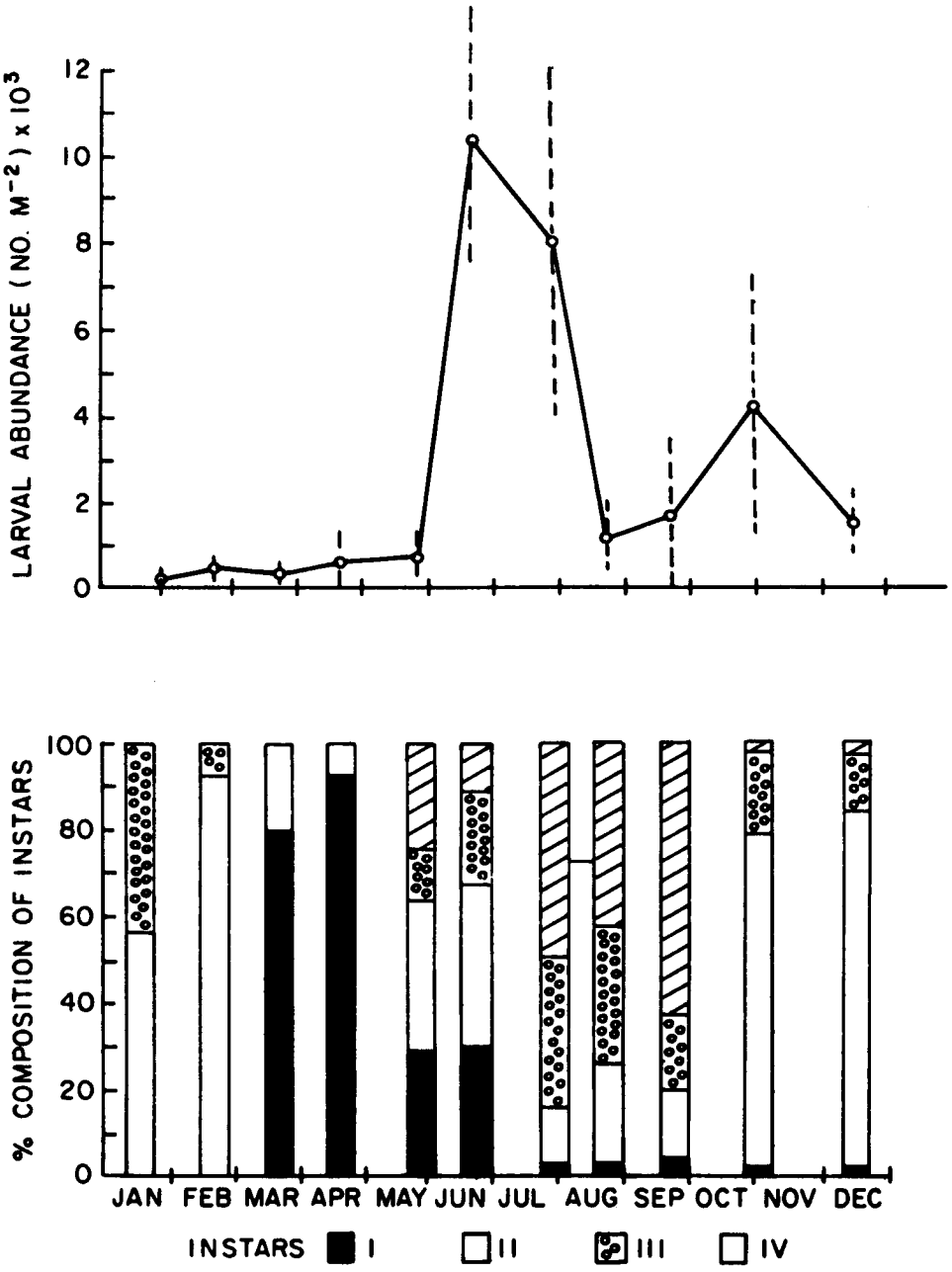
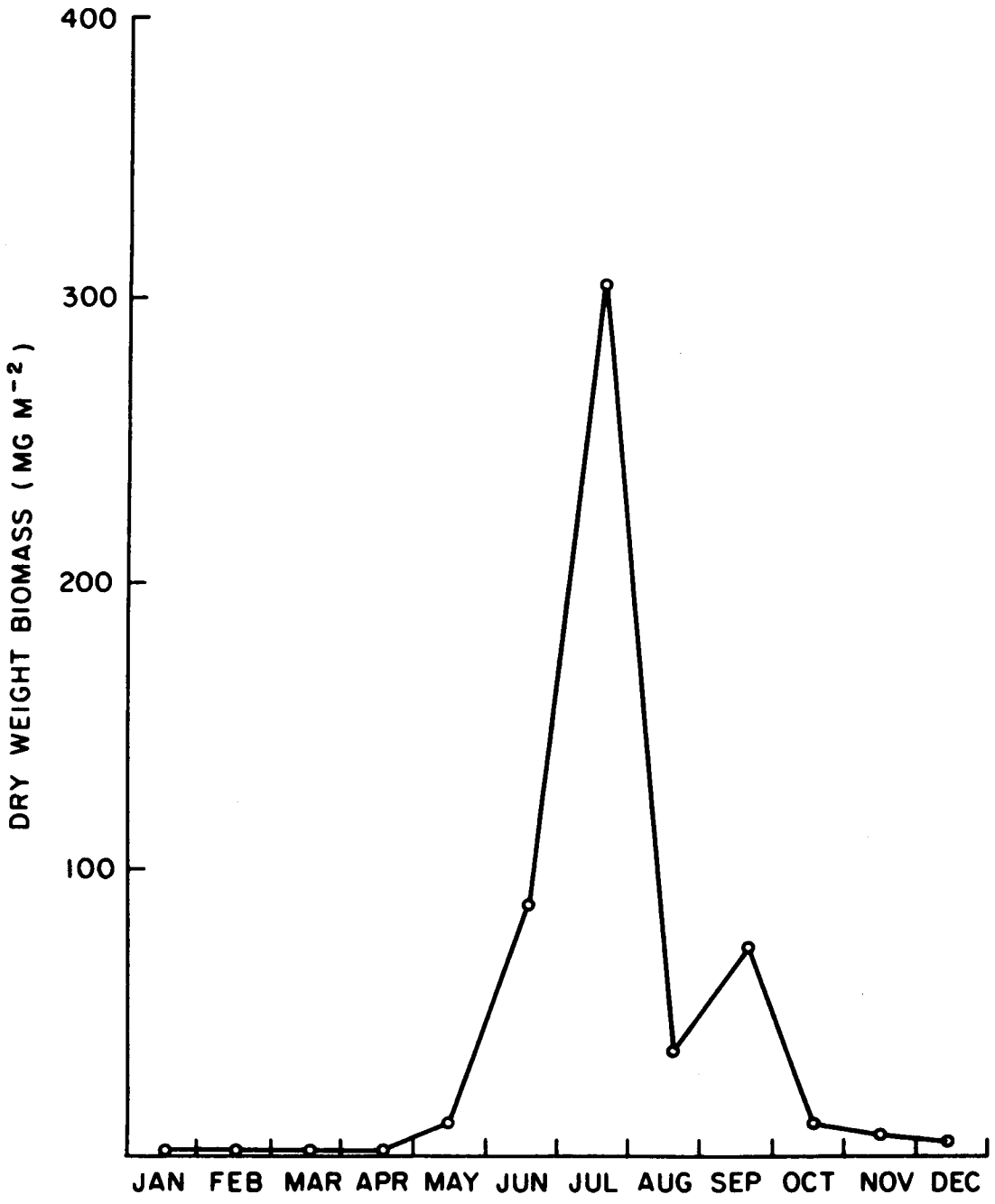


Figure 26. Dry weight biomass of Tanytarsus sp. larvae in the littoral cove during 1975.



and an estimate of 468 mg m^{-2} was obtained by planimetering the area under the curve (Figure 27). Production of the winter generation was estimated using the turnover ratio method. A winter production estimate of 22.5 mg m^{-2} is obtained by multiplying the turnover ratio per generation (3.5) by 6.4 mg m^{-2}, the average winter biomass of this species. Annual production of Tanytarsus was 491 mg m^{-2} yr^{-1}.

3.4.7 Procladius sublettei

Observations on Larvae of P. sublettei Collected in the Sampling Cove

P. sublettei larvae were not present on the rooted plant Myriophyllum. All larval P. sublettei were collected from the sediments where they represented 15% of the chironomid larvae. Significant differences existed among sampling dates in the abundance of P. sublettei larvae; no differences were observed among the four sampling areas (Appendix C). Abundance of P. sublettei larvae remained relatively constant during January, February, and March, ranging up to 1400 larvae m^{-2} (Figure 28). Abundance decreased during April and May, as a result of adult emergence, and then increased steadily through August, reaching a maximum abundance of 4400 larvae m^{-2}. With the exception of July, first and second instars comprised greater than 50% of the population during the summer (Figure 28), indicating continual larval recruitment. Two major shifts in the relative abundance of younger (first and second instar) and older (third and fourth instar) larvae occurred from June through July and August through October, suggesting that there were at least two generations. Larvae overwintered as second, third and fourth instars.

Figure 27. Allen production curve for the summer generation of Tanytarsus sp. in the littoral cove during 1975.

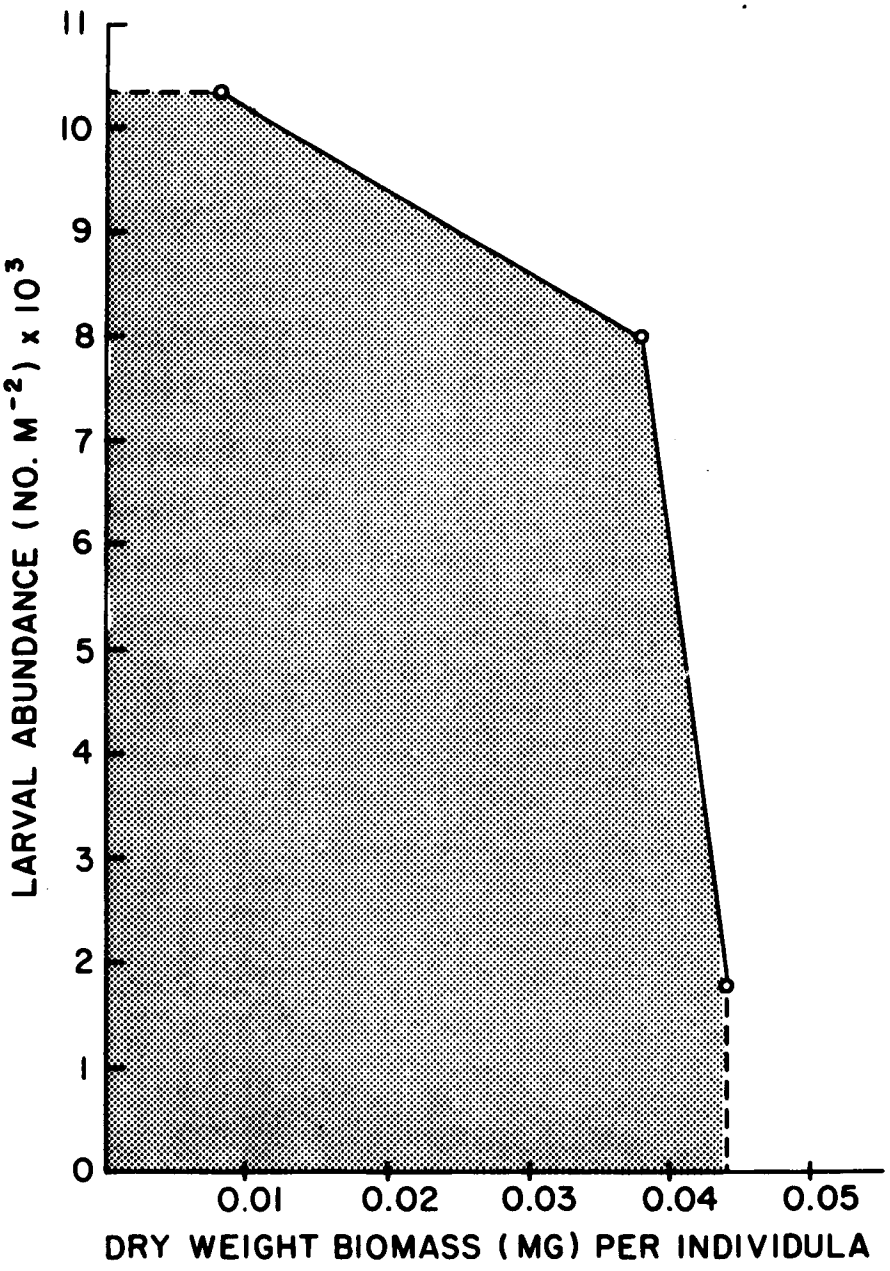
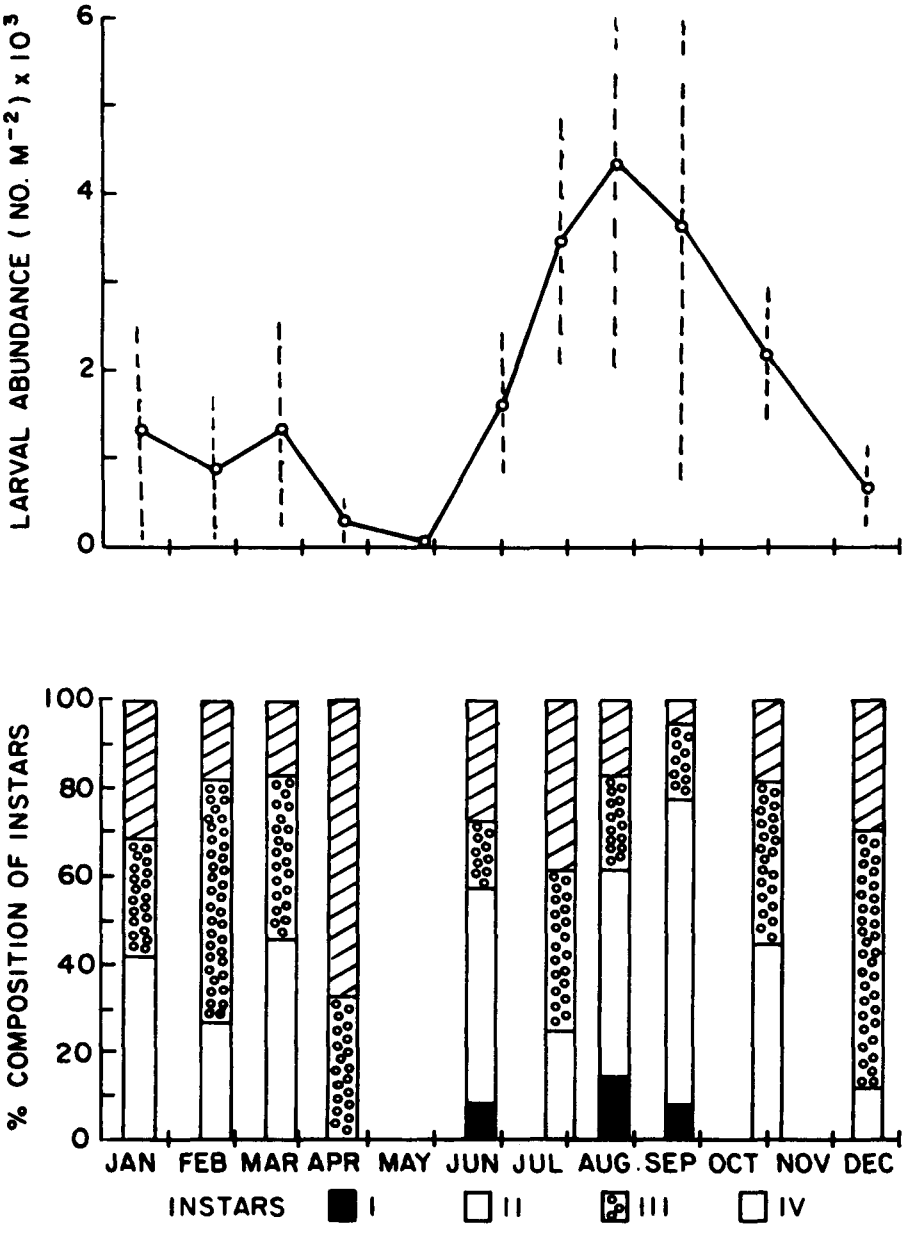


Figure 28. Abundance and instar composition of Procladius sublettei larvae in sediments of the littoral cove during 1975. Vertical lines indicate 95% confidence intervals.



Larval biomass ranged between an undetectable amount in May and 432.6 mg m^{-2} in July (Figure 29). Average biomass was 151.1 mg m^{-2} which represents 9.6% of the average total chironomid biomass.

Gut analyses of P. sublettei larvae revealed the remains of other larvae including setae of oligochates and head capsules of smaller chironomids.

Observations on Adult P. sublettei

Adults were collected in sweep nets from May through October (Figure 30). The number of adults collected fluctuated throughout the year with the largest number being collected in August.

Laboratory Observations on P. sublettei Larvae

Larvae of P. sublettei did not build tubes but crawled about on the bottom of the culture dishes. The other chironomid species, which built tubes, fed by filtering organic particulate matter through the tube. However, gut analyses of P. sublettei larvae collected in the cove indicate that the species is predacious. Most chironomids move by a sinusoidal-like wriggling while P. sublettei larvae move backwards by flicking their abdomens underneath their bodies similar to escape behavior of lobsters and crayfishes. This mode of movement would help P. sublettei larvae escape from predators as well as help the larvae pull prey (e.g., oligochates and chironomids) from their burrows.

Larvae of P. sublettei did not develop in the laboratory and no data were obtained on growth rates.

Production of Procladius sublettei Larvae

Cohorts were indiscernible and no data were obtained on the growth patterns of the larvae. Therefore, the turnover ratio method is

Figure 29. Dry weight biomass of Procladius sublettei larvae in the littoral cove during 1975.

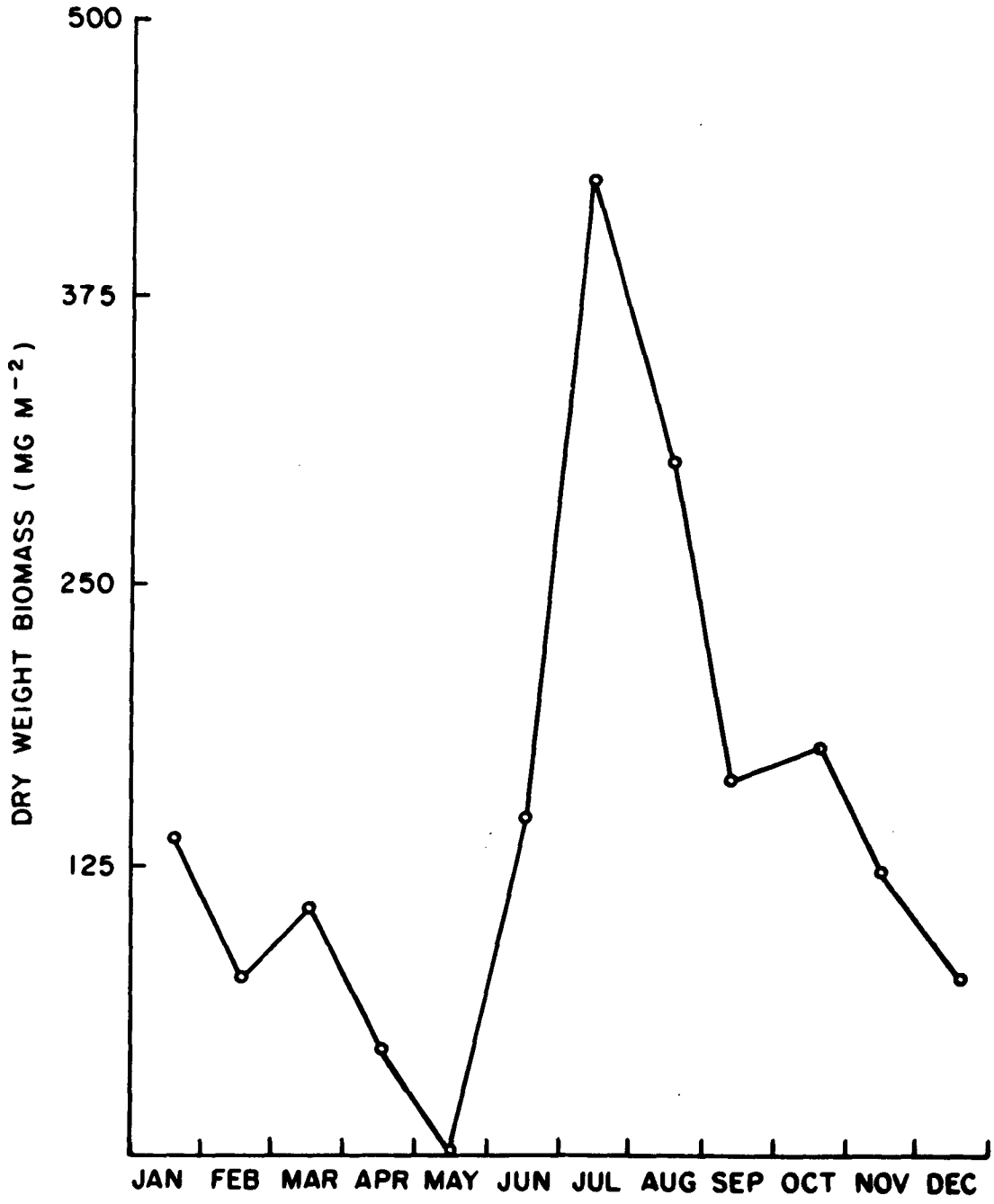
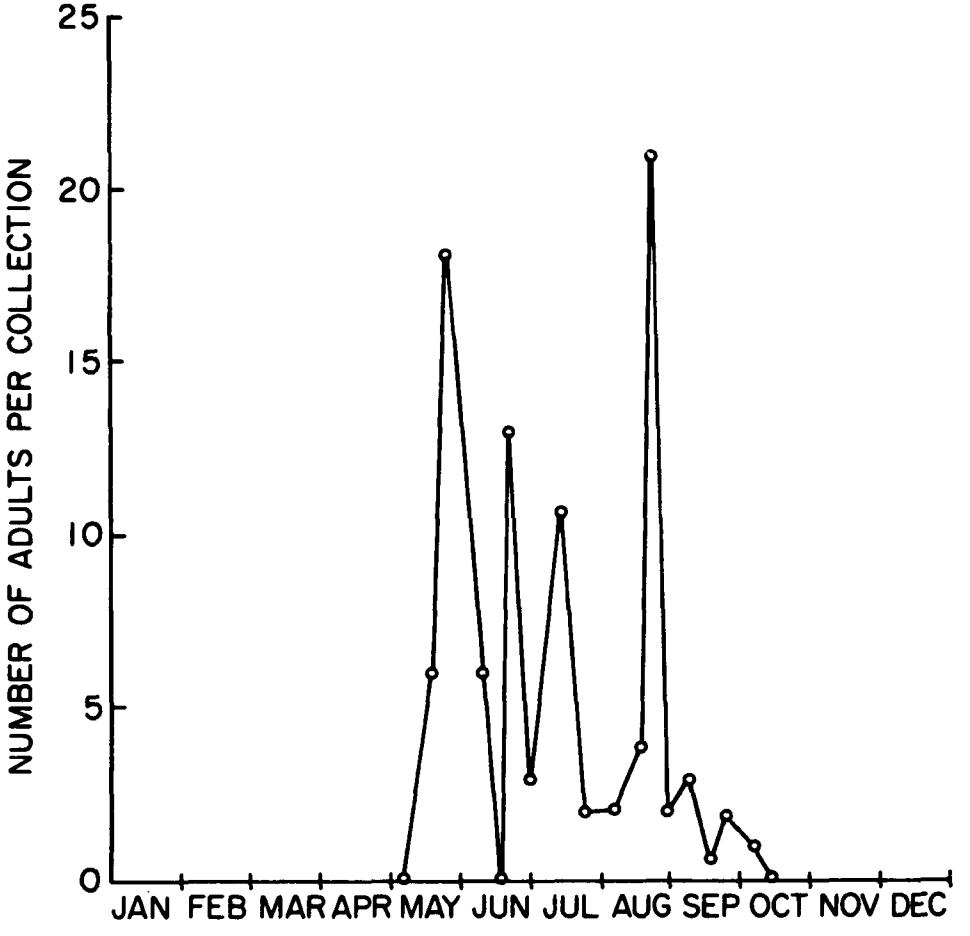


Figure 30. Number of adult Procladius sublettei collected by sweep net along the southern shore of Bowline Pond during 1975.



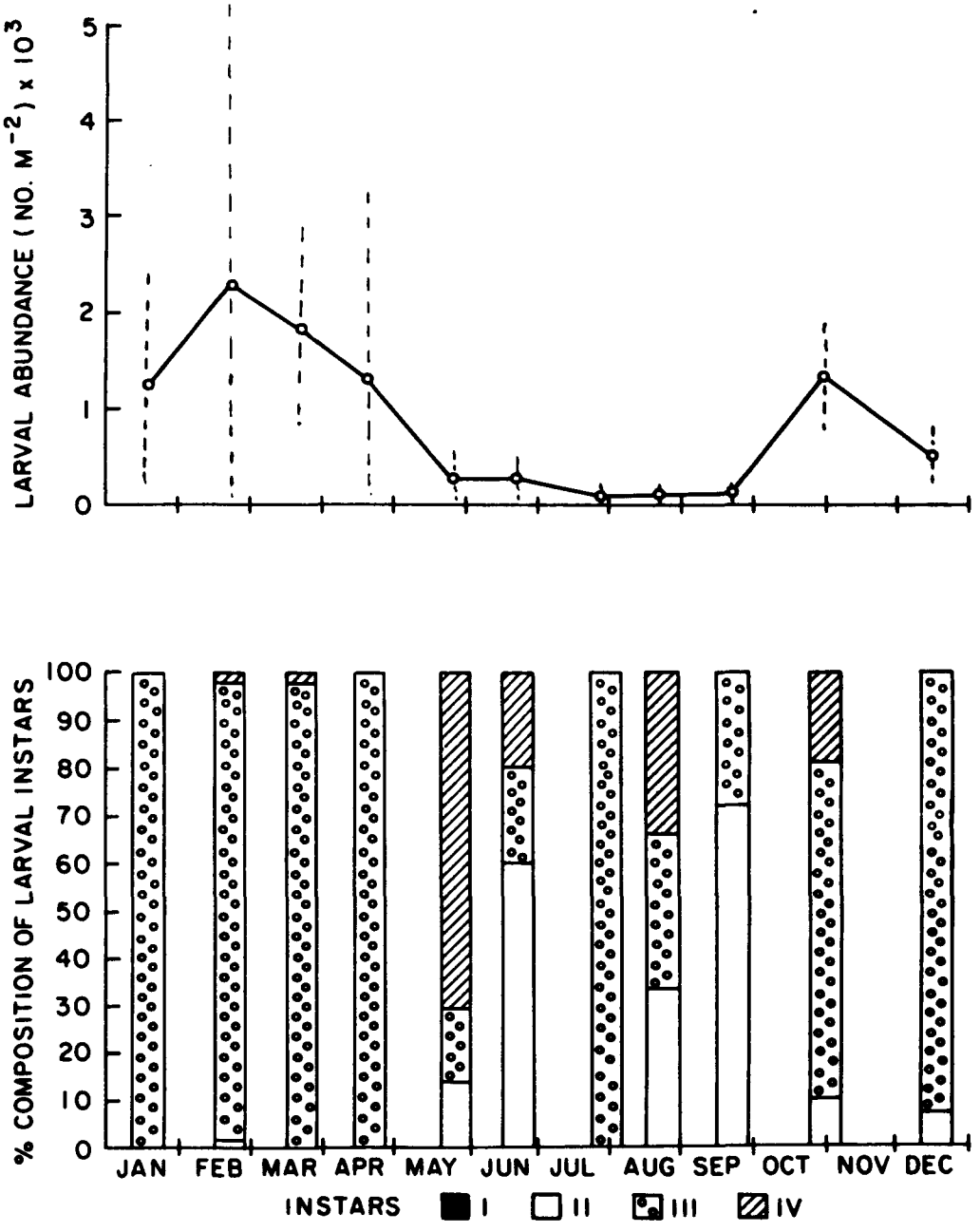
used to estimate production. Recruitment of larvae appeared to be continuous throughout the summer and there may have been more than two generations. However, based on the two major shifts in the relative abundance of young and old larvae, two generations per year is the best estimate. The annual turnover ratio is estimated to be 7 (two generations x 3.5). An annual production estimate of 1,058 mg m^{-2} yr^{-1} is obtained by multiplying the annual turnover ratio by 151.1 mg m^{-2}, the average annual biomass of this species.

3.4.8 Polypedilum digitifer

Observations on Larvae of P. digitifer Collected in the Littoral Cove

P. digitifer larvae were not observed on Myriophyllum but composed 7.3% of chironomid larvae in the sediments. Significant differences were detected among sampling dates in the abundance of P. digitifer larvae; differences were also observed among the four sampling areas (Appendix C). Area I, one of the two deeper sampling areas, contained a significantly higher number of P. digitifer larvae than did Area IV, the other deeper sampling area. Larval abundance was higher in the winter than summer with maximum abundance in February (2300 m^{-2}) and minimum in July (92 m^{-2}) (Figure 31). P. digitifer overwintered as third instars which developed into fourth instars in May. The winter generation emerged in June and July and recruitment was reflected by a comparatively high percentage of second instars in June (Figure 31). The second instars also composed a large percentage of the population in September, indicating a second major recruitment period and the initiation of the winter generation.

Figure 31. Abundance and instar composition of Polypedilum digitifer larvae living in sediments of the littoral cove during 1975. Vertical lines indicate 95% confidence intervals.



Larval biomass ranged from 3.7 mg m^{-2} in July to 103.9 mg m^{-2} in October (Figure 32). Average biomass was 46.5 mg m^{-2} which represents 3% of the average total chironomid biomass.

Observations of Adult P. digitifer

Adults were collected in sweep nets from June through September (Figure 33). A peak of adults in June was followed in July by the collection of the largest number of adult P. digitifer.

Laboratory Observations of P. digitifer Larvae

P. digitifer occurred in low abundance and larvae of this species were not among those that were brought into the laboratory for observation.

Production of P. digitifer Larvae

Although only two generations of this species were observed, cohorts could not be defined in a manner sufficient for the use of the Allen Curve Method, and, since no information was obtained on larval growth patterns, production is estimated using the turnover ratio method. Annual turnover ratio is estimated to be 7 (two generations x 3.5). An annual production estimate of 325.5 mg m^{-2} yr^{-1} is obtained by multiplying the annual turnover ratio by 46.5 mg m^{-2}, the average biomass of this species.

3.5 PREDATORS OF CHIRONOMIDS

3.5.1 Invertebrate Predators

Chironomid remains were observed among gut contents of the hydrozoans, Hydra sp. and Cordylophora lacustris, adults of the amphipod Gammarus daiberi; and naiads of the damselfly Enallagma sp. Gut analyses of other invertebrates did not reveal chironomid remains.

Figure 32. Dry weight biomass of Polypedilum digitifer larvae in the littoral cove during 1975.

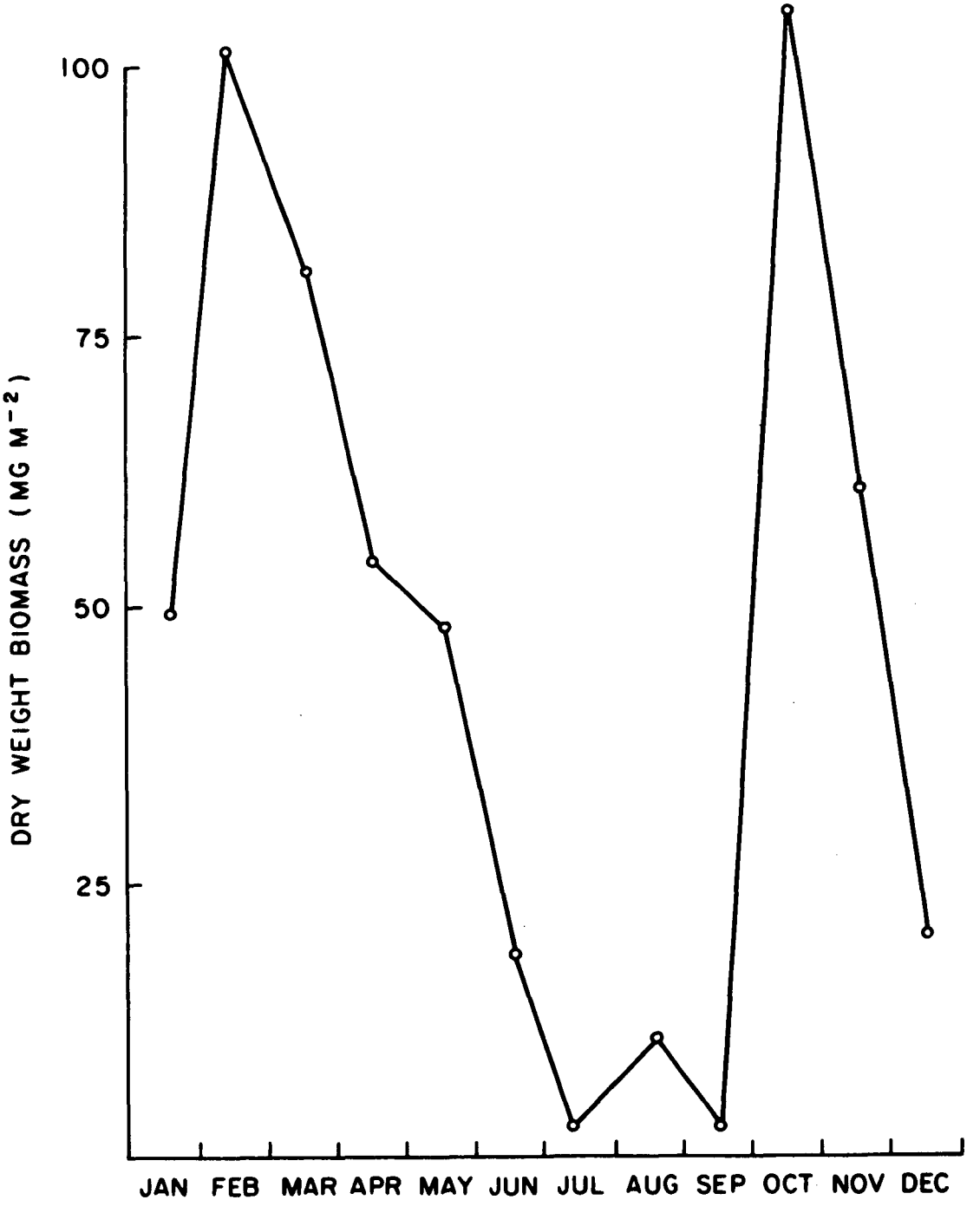
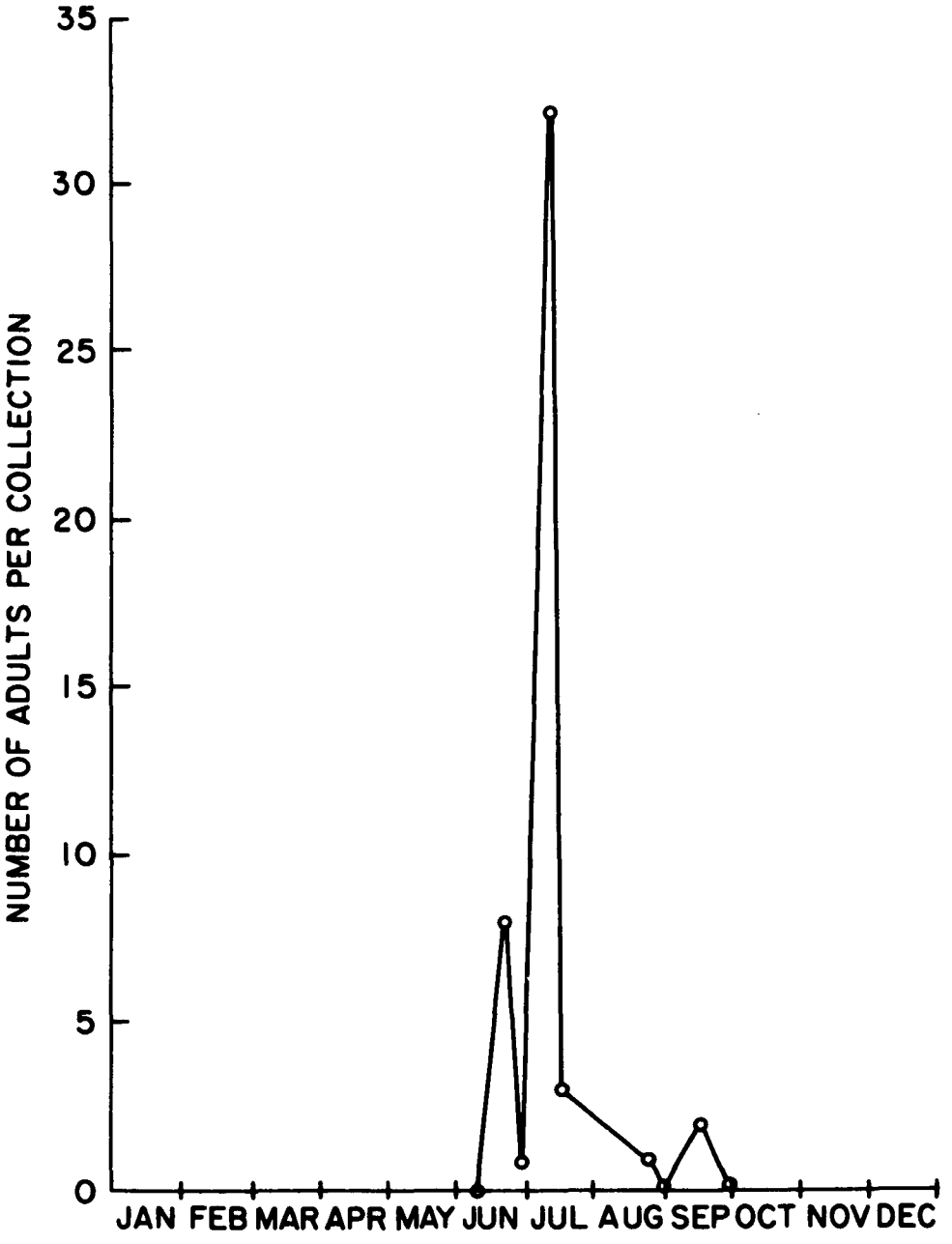


Figure 33. Number of adult Polypedilum digitifer collected by sweep net along the southern shore of Bowline Pond during 1975.



Turbellarians and water mites, which also prey on chironomids (Paterson, 1970; Legner et al., 1975) do not ingest whole organisms, and consequently, the degree to which they preyed on chironomid in the littoral cove could not be revealed by gut analyses.

Quantitative field data were obtained on gut contents of all naiads of Enallagma sp. (Table 10), for which chironomid larvae were the primary source of food. Almost all chironomid larvae eaten by Enallagma were Cricotopus sylvestris. Cladocerans were eaten less frequently than chironomids. Predation by Enallagma on chironomids was size selective. Naiads, 1-3 mm in body length, ate primarily younger first and second C. sylvestris instars (92% of their identifiable diet), while larger Enallagma (≥8 mm body length) ate older third and fourth instars (88% of their identifiable diet).

Enallagma naiads actively pursued prey presented to them in the laboratory. They approached moving chironomid larvae and ignored those lying quietly. At close range, naiads oriented their antennae toward prey prior to striking. Strikes were rapid and prey were swallowed whole, either head or tail first. Naiads also caught and ate amphipods which were larger than their mouth aperture. These were crushed while being swallowed. However, only in situations where numerous amphipods were placed in the observation dish, and after many missed strikes, did naiads of Enallagma eventually catch amphipods. Amounts of food consumed daily by Enallagma were determined for five naiads varying in length from 5-9 mm (Table 11). Amount of food consumed daily averaged 22% of the naiads' body weight and ranged between 9-31%.

Table 10. Gut analyses of naiads of the damselfly Enallagma collected in the sampling cove.

Enallagma Size Interval (mm)	Number of Naiads Examined	Numerical Composition of Identifiable Prey				
		Cricotopus sylvestris instars				Cladocera
		I	II	III	IV	
1-3	37	25	67	0	0	8
3-5	19	0	15	45	18	9
6-8	13	0	9	54	28	9
>8	6	0	12	19	69	0

Table 11. Amount of chironomid biomass consumed by five naiads of the damselfly Enallagma in a 3-day feeding experiment.

Enallagma Naiad	Body Length of Naiad (mm)	Dry Weight Biomass of Naiad (mg)	Dry Weight Biomass of Chironomid Consumed by Naiad Over 3-day Period*	Amount of Food Consumed Daily as a Percentage of Naiad Biomass
1	4.5	0.39	0.28	24%
2	5.0	0.51	0.47	31%
3	6.2	0.98	0.76	26%
4	9.2	2.98	0.80	9%
5	10.0	4.15	2.49	20%
				22%

*Biomass of chironomids eaten was estimated by counting number of head capsules of chironomid larvae in fecal pellets of Enallagma and multiplying this number of mean biomass of appropriate instars as determined from field sampling program.

The amount of invertebrate biomass consumed by naiads is estimated to be 4,734 mg m^{-2} for the May-November period, a value obtained by multiplying the standing crop of the naiads by 0.22, the daily food ration for Enallagma (Table 12).

3.5.2 Results of Fish Exclusion Cage Experiments

The cage experiments were designed to estimate the impact of fish predation on chironomid standing crops. It was anticipated that, at the end of the experiments, chironomid standing crops inside the cages would be greater than those outside. However, at the conclusion of each of the two experiments, standing crops of chironomids within cages were significantly less than those outside cages (Table 13), the opposite of what was expected. Since densities of Enallagma were 2-3 times higher within cages (Table 13), the anomalous results are attributed to more intense predation by Enallagma on chironomids within the cages. The higher densities of Enallagma within cages may have resulted from protection from fish predation that the cages afforded.

3.5.3 Estimate of Fish Predation

Because the cage experiments provided no insight into the amount of chironomid biomass consumed by fish, data on standing crops of fish in littoral areas of Bowline Pond were used to estimate the amount consumed. Data on fish collected by seine in the Pond were provided by Lawler, Matusky and Skelly Engineers. These data were converted to fish biomass per m^2 by dividing the biomass collected in the seine by 730 m^2, the area swept by a 30.5 m seine (Figure 34). It was assumed that fish consumed a quantity of food equivalent to 2.17% of their body weight per day, a value obtained from data on bluegill,

Table 12. Estimated amount of invertebrate biomass consumed by the damselfly Enallagma in the littoral cove.

Date	Enallagma Standing Crop ($mg\ m^{-2}$)	Invertebrate[1] Biomass Consumed Daily ($mg\ m^{-2}\ day^{-1}$)	Invertebrate Biomass[2] Consumed During Sampling Interval ($mg\ m^{-2}$)
26 May	0	0	
			8.9
7 June	6.4	1.4	
			12.7
24 June	0	0	
			6.0
9 July	3.6	0.8	
			295.2
25 July	164.1	36.1	
			1,675.8
8 August	924.1	203.3	
			1,545.8
23 August	12.7	2.8	
			133.5
9 September	58.6	12.9	
			254.2
22 September	119.1	26.2	
			300.2
11 October	24.6	5.4	
			309.8
1 November	109.6	24.1	
			179.9
15 November	7.3	1.6	
			12.0
30 November	0	0	
		Total =	4,734.0 $mg\ m^{-2}\ yr^{-1}$

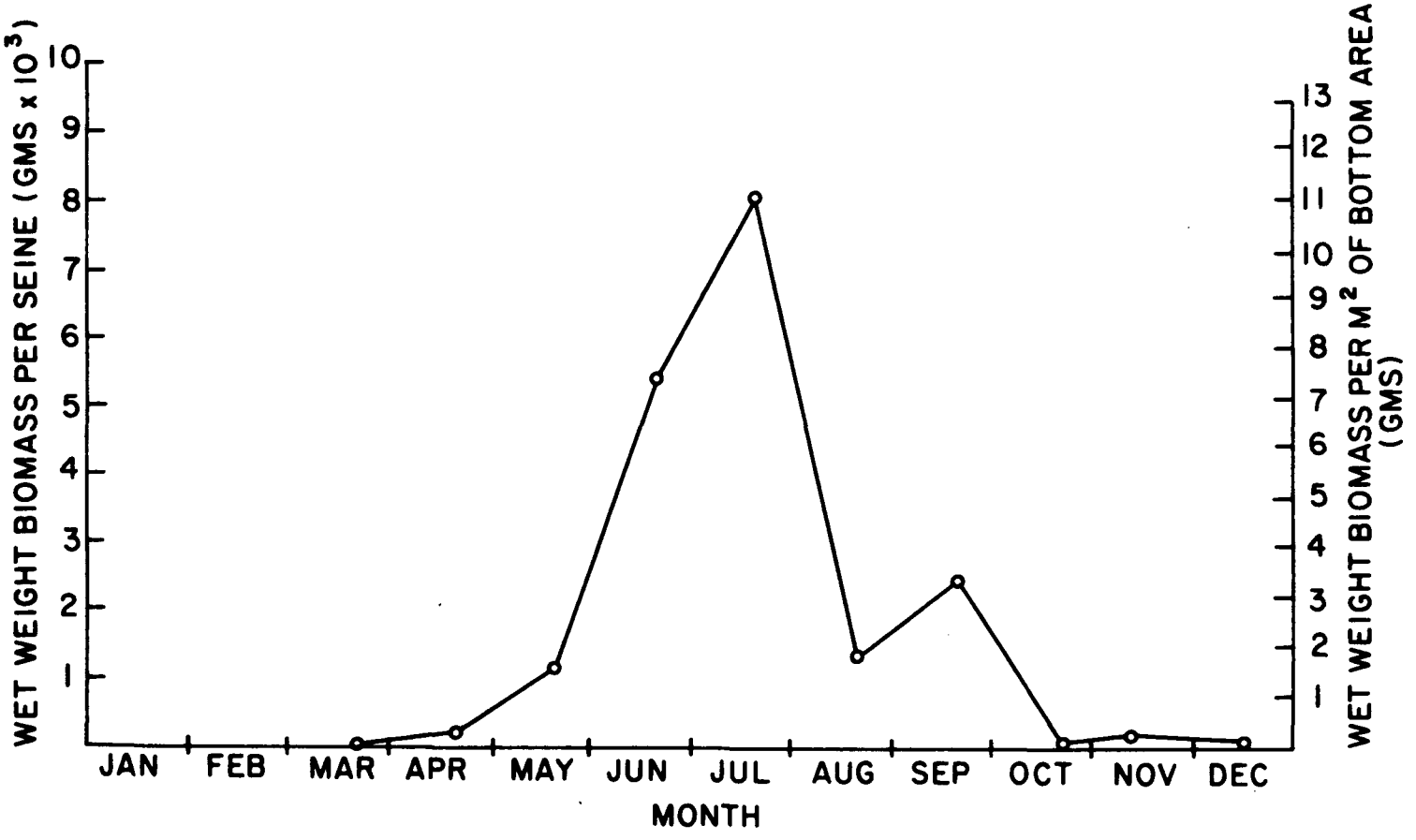
[1]Estimated by multiplying standing crop of Enallagma by daily average food ration of 0.22 obtained in feeding experiments.

[2]Estimated by multiplying the average amount consumed for each sampling interval by number of days in the sampling interval.

Table 13. Densities of chironomid larvae and naiads of Enallagma on Myriophyllum within and outside cages placed in the littoral cove for two week periods.

	EXPERIMENTAL PERIOD	
	25 July-8 August	9 September-22 September
	Density (No. 100 mg^{-1} leaf dry weight) ±95% Confidence Interval	Density (No. 100 mg^{-1} leaf dry weight) ±95% Confidence Interval
Chironomid Density		
at beginning of experimental period	165 ± 70	115 ± 46
within cages at end of experimental period	35 ± 5	10 ± 10
outside cages at end of experimental period	270 ± 147	68 ± 30
Enallagma Density		
at beginning of experimental period	0.38 ± 0.15	1.44
within cages at end of experimental period	1.04 ± 0.15	3.36 ± 0.91
outside cages at end of experimental period	0.53 ± 0.24	1.05 ± 0.43

Figure 34. Standing crops of fish collected by seine in Bowline Pond during 1975.



Lepomis macrochirus (El Shamy, personal communication). J. Kitchell, University of Wisconsin (personal communication) notes that this value is generally representative of young-of-the-year bluegills but may overestimate the feeding rate of mixed fish communities. Amount of invertebrate biomass consumed by fish is estimated to be 1,650.8 mg m^{-2} for the May-September period (Table 14).

Table 14. Estimates of invertebrate biomass (dry weight) consumed by fish in littoral areas of Bowline Pond.

Month	Invertebrate Biomass[1] Consumed Daily (mg m^{-2})	Invertebrate Biomass[2] Consumed During the Month (mg m^{-2})
May	3.6	111.6
June	16.1	483.0
July	23.8	737.8
August	3.4	105.4
September	7.1	213.0
	Total	1,650.8

[1]Estimated by multiplying standing crop of fish as wet weight (obtained from LMS Engineers) by a daily food ration for fish of 0.0217 of their wet weight body weight (a value obtained for bluegills by El Shamy, in preparation). Invertebrate wet weight biomass consumed was converted to dry weight biomass by multiplying by 0.10.

[2]Estimated by multiplying daily estimate for the month by number of days in the month.

4. DISCUSSION

4.1 FACTORS AFFECTING CHIRONOMID PRODUCTION

A summary of data obtained for the eight chironomid species examined in the littoral cove is presented in Table 15. The species are ranked in order of decreasing productivity so that relationships between production and other species' characteristics (e.g., standing crop and turnover rate) can be compared. However, comparison of species' productivities and detection of relationships between production and other species' characteristics are confounded somewhat by the use of three different methods for estimating production. The methods differ in the type and amount of data required to utilize them. These differences, as well as differences in the assumptions made in applying the different methods, introduce some degree of error in the comparison of productivity values.

The methods of estimating production used in this study are Hynes and Coleman's (1968) generalized cohort method, the Allen Curve method (Mann, 1971), and the turnover ratio method (Ricker, 1971). Estimates obtained using the Hynes and Coleman and Allen Curve methods are based completely on data obtained in the present study. Application of these methods is relatively straightforward and the resulting productivity estimates are comparable. However, because the two methods differ in the mechanics of application, some differences are expected between

Table 15. Summary of data obtained on chironomid species collected in the littoral cove during 1975. Species are ranked in order of decreasing productivity.

	Major Habitat	Mean Abundance (No. m^{-2})	Mean Biomass (mg m^{-2})	Mean Biomass Per Individual (mg $individual^{-1}$)	Reproductive[1] Period	Number of Generations Per Year	Annual Turnover Rate	Annual Production (mg m^{-2} yr^{-1})	Method Used To Estimate Production
Dicrotendipes modestus	Aquatic Plants and Sediments	6,392	213	0.033	May-October	3-4	26.6-35.4	5,663-7,550	Hynes and Coleman
Dicrotendipes modestus	Aquatic Plants and Sediments	6,392	213	0.033	May-October	3-4	10.5-14.0	2,237-2,982	Turnover Ratio
Cricotopus sylvestris	Aquatic Plants	15,480	277	0.018	May-October	3-5	14.6-24.4	4,056-6,759	Hynes and Coleman
Cricotopus sylvestris	Aquatic Plants	15,480	277	0.018	May-October	3-5	10.5-17.5	2,908-4,847	Turnover Ratio
Chironomus attenuatus	Sediments	1,674	786	0.470	May-October	1	3.5	2,752	Turnover Ratio
Procladius sublettei	Sediments	2,041	151	0.074	May-October	2	7.0	1,058	Turnover Ratio
Tanytarsus sp.	Sediments	3,075	46	0.015	March-November	2	10.7	491	Allen Curve
Tanytarsus sp.	Sediments	3,075	46	0.015	March-November	2	7.0	322	Turnover Ratio
Polypedilum illinoense	Aquatic Plants	914	25	0.027	June-October	5	17.5	443	Turnover Ratio
Polypedilum digitifer	Sediments	993	47	0.047	June-September	2	7.0	326	Turnover Ratio
Rheotanytarsus sp.	Aquatic Plants	475	5	0.011	May-October	3	10.5	53	Turnover Ratio

[1]For most species reproductive period is based on collections of adult chironomids. In the cases of *Tanytarsus* and *Rheotanytarsus*, for which adults were not identified, reproductive period is based on shifts in age structure of larval instars.

them. Hamilton (1969) observed that the Hynes and Coleman method modified to account for the actual number of generations per year and nonlinear growth of a species, as is done in the present study, actually represents an algebraic form of the graphical Allen Curve method. He notes that the basic difference between the two methods is that the Allen Curve is based on actual cohorts while the Hynes and Coleman method is based on average cohorts.

Unlike the Hynes and Coleman and Allen Curve methods, application of the turnover ratio method involves a major assumption about species' growth. A turnover ratio of 3.5 per generation was selected to represent the turnover ratio of species whose actual growth patterns and turnover rates could not be determined from the field and laboratory data. The value of 3.5 represents the median value of ratios obtained from the literature on chironomid productivity. Values obtained from the literature ranged from 2.5 to 8.5 per generation but most occurred between 2.5 and 5. Considering the relatively narrow range of most of the values (2.5-5), it is likely that the assumed value of 3.5 per generation will be within 50% of the true turnover ratio. As Hamilton (1969) has pointed out, this amount of error in converting standing crop data to production may be inconsequential relative to the much larger sampling errors.

The turnover ratio method can be used to estimate production of all eight species and therefore can be compared to estimates made with the Hynes and Coleman and Allen Curve methods. Production estimates for Dicrotendipes modestus and Cricotopus sylvestris using the Hynes and Coleman method were respectively 2.5 and 1.4 times greater than those obtained using the turnover ratio method. The production estimate for Tanytarsus was 1.5 times higher using the Allen Curve method

as compared to the turnover ratio method. Higher productivity estimates obtained using the more reliable Hynes and Coleman and the Allen Curve methods as compared to the turnover ratio method suggest that a turnover ratio of 3.5 per generation, assumed in the application of the turnover ratio method, may be low. Ratios obtained in the present study of 8.8 per generation for Dicrotendipes modestus (Hynes and Coleman method), 4.9 per generation for Cricotopus sylvestris (Hynes and Coleman method), and 5.4 per generation for Tanytarsus (Allen Curve method) are within or only slightly higher than the range of values reported in the literature but are greater than the 3.5 per generation median value.

If higher turnover ratios are characteristic of littoral chironomids, then productivity of species in the littoral cove is underestimated using the turnover ratio method and an assumed turnover ratio of 3.5 per generation. Utilizing a higher turnover ratio (e.g., 5) would increase the estimated production of species but, with one exception, would not alter the ranking of species productivities; the order of Tanytarsus and Polypedilum illinoense might be switched by utilizing a higher turnover ratio per generation for estimating production of P. illinoense. In addition, productivity estimates obtained by utilizing a higher assumed turnover ratio of 5 would be within 45% of the estimates obtained by using the literature-based ratio of 3.5. Therefore, the estimates presented in Table 15 are considered suitable for comparing species' productivities and detecting relationships between production and other species' characteristics.

The species' characteristics which have a direct relationship with production are standing crop and turnover rate as illustrated by the equation from Edmondson and Winberg, (1971):

$$P = G \cdot B$$

where

P is production

G is growth or turnover rate

B is standing crop

The data in Table 15 show that standing crop and turnover rate differ among species in their relative importance to production.

High standing crops as well as high turnover rates contributed to the high productivity of Dicrotendipes modestus and Cricotopus sylvestris. These species ranked respectively third and second in biomass standing crop and first and second in turnover rate. The third most productive species, Chironomus attenuatus, ranked first in biomass standing crop, but eighth in turnover rate. Further, the least productive species, Rheotanytarsus, had a higher turnover rate than four of the more productive species, but had the lowest biomass standing crop. Because production of a species can be described in terms of its biomass standing crop and turnover rate, factors affecting production can be analyzed according to how they affect these two species' characteristics.

4.1.1 Factors Affecting Production By Affecting Standing Crops

Factors which could affect standing crops of littoral chironomids in Bowline Pone include the physical characteristics of the environment,

and such biological factors as body size of individual chironomid species, competition among chironomid species, and predation by invertebrates and fish.

Aquatic plants (considered to be a physical factor in terms of providing habitat), sediments, tidal currents, and salinity are the physical factors which could affect chironomid standing crops in the littoral cove. Aquatic plants, represented in the cove by Myriophyllum spicatum, are considered the most significant of these factors.

Aquatic Plants

Aquatic plants supported a different assemblage of chironomid species than did the littoral sediments. Cricotopus sylvestris, Dicrotendipes modestus, Polypedilum illinoense, and Rheotanytarsus lived on aquatic plants during a part of the year while Chironomus attenuatus, Tanytarsus sp., Procladius sublettei, and Polypedilum digitifer lived only in the sediments. With the exception of D. modestus, which extensively used both plant and sediment habitats, chironomids living on aquatic plants occurred in low abundance in the sediments, if at all, during the productive summer months. Production of chironomids associated with aquatic plants represented about one-half of the total chironomid production in the littoral cove; this indicates that the plants are important in sustaining the production of chironomids.

Aquatic plants are spatially and temporally varying habitats and as a result chironomid species associated with the plants may exhibit large spatial and temporal variations in standing crop and production. For example, habitat provided by the aquatic plant Myriophyllum

spicatum in the littoral cove fluctuated throughout the year; standing crops of the plants increased from May through July, decreased through August, increased again during September and October, decreased through November and December, and had completely died off above the substrate by mid-January. These fluctuations in available habitat naturally affected standing crops of chironomids which utilized the plant habitat. In particular, changes in standing crops of Cricotopus sylvestris, the dominant chironomid on the plants, closely paralleled those of the aquatic plants. When standing crops of plants decreased during August, standing crops of C. sylvestris decreased from about 45,000 larvae m^{-2} to less than 5,000 larvae m^{-2} and, when standing crops of plants increased in September and October, C. sylvestris standing crop increased to about 20,000 larvae m^{-2}. The temporally and spatially variable standing crops of aquatic plants and associated chironomids in the littoral cove probably contribute to more variable patterns of chironomid productivity than that which occurs in non-vegetated sublittoral areas. For example, complete loss of the plants would probably result in a substantial decrease in chironomid productivity of littoral areas.

The importance of aquatic plants in supporting standing crops and chironomids and other invertebrates in the littoral cove is consistent with what is generally considered to be a major ecological role of the plants. Klugh (1926) reviewed the early literature and suggested that the presence of aquatic plants along the margins of water bodies be used as an index of fish productivity since these areas were rich in important "fish food" invertebrates. Percival and Whitehead (1929) observed that English river beds supported 60,000-400,000 organisms m^{-2}

while sublittoral or bare areas supported only 3,000-4,000 organisms m^{-2}. Needham (1928, 1929) observed an average of 99 g m^{-2} wet weight of "fish food" in littoral vegetated regions of New York streams; he compared this with 2.8 g m^{-2} in pool bottoms and 13.0 g m^{-2} in stream bottoms without plants and concluded that "fish food production" was increased substantially by the presence of aquatic plants. Pate (1932, 1934) found that standing crops of invertebrates in plant beds of streams were 17.5 times higher than in bare pools and 6.7 times higher than the average stream bottom. Areas of plant growth in Wyland Lake, Indiana, contained an average of 12,620 organisms m^{-2} while sublittoral areas contained only 2,900 organisms m^{-2} (Gerking, 1962). Ringger (1973) also noted that littoral areas of a Wisconsin marsh containing aquatic vegetation supported a greater abundance of fish food invertebrates than did other areas of the marsh.

Sediments

Characteristics of the sediment habitat could affect standing crops of littoral chironomids. Other studies have attributed variations in chironomid standing crops to variations in sediments (Wene, 1940; Slack, 1969; McLachlan, 1976). Standing crops of infaunal chironomid species did not differ significantly among the four sampling areas in the littoral cove. This may be attributed, in part, to the small size of the cove (8 x 13 m) and the fact that there were no sharp or systematic differences in sediment grain size among the four sampling areas. However, organic content of the sediments did exhibit a systematic pattern with concentrations being about twice as high at deeper sampling areas (~10% organic matter) as at shallow areas (~5% organic matter); chironomid standing crops did not appear to be

affected by these differences in organic content of the sediments. Although the relatively small variations in sediments within the cove may not be important in affecting chironomid standing crops, larger variations in sediments among littoral areas could be a major factor affecting the large scale distribution of chironomid species' standing crops.

Visual examination of sediments from other littoral areas of Bowline Pond and the Hudson River revealed various sediment types. The sediments of the littoral cove were composed of fine to coarse sands, a sediment type which occurs in some other littoral areas as well. However, other littoral areas and most of the sublittoral regions of Bowline Pond and the Haverstraw Bay reach of the Hudson are characterized by sediments composed primarily of silt (Orange and Rockland, 1977). Although variations in sediment characteristics among littoral areas probably affect chironomid standing crops, the relationships between standing crops and sediment types are unknown for these littoral areas.

Tidal Current

Tidal currents with velocities of up to 30 cm sec^{-1} flush the littoral cove twice a day, and, during the flood and ebb stage of each cycle, chironomid larvae not in their tubes may be washed out of the plant stand, thus reducing standing crops. Younger first and second instars may be particularly vulnerable to such washing. Laboratory observation of Cricotopus sylvestris and Dicrotendipes modestus showed that younger instars were more mobile than older instars and spent more time out of their tubes. If younger instars exhibit this behavior in the field they would be more susceptible to effects of currents than would older instars.

Tidal currents may be a key factor contributing to the dominance (80% by abundance) of the chironomid Cricotopus sylvestris on the aquatic plant Myriophyllum spicatum in the littoral cove. Larvae of this species are covered with numerous prominent hairs which could adhere to leaves, stems, and filamentous algae, thereby preventing the larvae from being washed off the plants and out of the plant stand by tidal currents. Other chironomid species observed on the aquatic plant Myriophyllum did not have prominent body hairs, and, therefore, were probably more vulnerable to being washed out of the plant stand. In less dynamic (low current) systems, such as Lake Wingra, Wisconsin, where Cricotopus sp. comprised only 10% of the chironomid fauna on Myriophyllum (Peterson and Hilsenhoff, 1972), the body hairs on C. sylvestris would not provide the same advantage as it does in Bowline Pond.

Rate of removal of chironomids from the plant stand by tidal currents is probably affected by the density of aquatic plants. Increased plant densities would decrease current velocities through the stand and thereby reduce the probability that chironomids would be washed off the stems. Increased plant densities also would increase the probability that larvae washed off a stem would encounter and cling to another. The possible effects of increased plant density on decreasing the rate of removal of chironomids is suggested by the significant correlation between density of C. sylvestris on the aquatic plant Myriophyllum spicatum and the standing crop of these plants. Similar correlations were not observed for other species of chironomids living on the plants; this suggests that other factors such as competition may have been important in affecting densities of these other species.

An alternate explanation for the apparent relationship between M. spicatum standing crop and the density of C. sylvestris is that, as a result of high temperature and loss of plants in August, a large portion of the C. sylvestris population on the plants was lost. Therefore, subsequent recruitment was low and, as a result, C. sylvestris density on the plants was low during a period when M. spicatum standing crop was low.

Tidal current is a physical characteristic that distinguishes estuarine littoral areas from littoral areas of inland ponds, lakes, streams, and rivers. Organisms living in estuarine littoral areas are exposed to diurnal variations in velocity and direction of currents while organisms in ponds and lakes are exposed to relatively static and random currents, and organisms in inland streams and rivers are exposed to unidirectional currents having a relatively constant velocity. The effects of these different current regimes on biological adaptations and standing crops of littoral chironomids has not yet been explored.

Body Size of Individual Chironomid Species

The importance of body size to the biomass standing crops of littoral chironomids can be seen from Table 15. For example, although the largest larval chironomid species, Chironomus attenuatus, ranked only fifth in mean abundance, it ranked first in mean biomass because of its large size. The mean biomass per individual of C. attenuatus was 0.47 mg, which is about six times greater than that of Procladius sublettei, the species having the second largest mean individual biomass. Further, the mean biomass standing crop of Cricotopus sylvestris (277 mg m^{-2}) was only about one-third that of C. attenuatus, although the former species was about nine times more abundant.

Table 15 also shows that chironomid species associated with aquatic plants were generally smaller than chironomids which lived only in the sediments. A decreasing ranking of these species according to mean biomass per individual and their major habitat is as follows: Chironomus attenuatus (sediments), Procladius sublettei (sediments), Polypedilum digitifer (sediments), Dicrotendipes modestus (sediments and aquatic plants), Polypedilum illinoense (aquatic plants), Cricotopus sylvestris (aquatic plants), Tanytarsus (sediments), and Rheotanytarsus (aquatic plants). The smaller body size of chironomid species associated with aquatic plants may have adaptative value for living on the delicate and often narrow leaves and stems. Smaller body size of the species associated with aquatic vegetaton led Peterson and Hilsenhoff (1972) to conclude that, although these species were abundant, they made only a minor contribution to biomass standing crops of chironomids in Lake Wingra, Wisconsin. This conclusion may not be generally applicable because in other water bodies the large abundance of chironomids associated with aquatic plants or a relatively large standing crop of the plants may offset the smaller size and result in large biomass standing crops of the chironomids.

Competition

Standing crops of chironomid species as well as other invertebrates in the littoral cove could be affected through competition for limiting resources. Available habitat is a resource that is probably critical to chironomids and other invertebrates in the littoral cove. Temporal variations in standing crops of species suggest that competition for habitat space affected standing crops of some species.

Among the chironomid species which lived on the aquatic plant, Myriophyllum spicatum, one species, Cricotopus sylvestris, was clearly dominant, comprising 80% of larval abundance on the plants. It was suggested earlier that density of C. sylvestris was affected by such physical factors as plant density and tidal currents. In addition, densities of other species on aquatic plants appear to respond to fluctuations in C. sylvestris density. When C. sylvestris density decreased in August following a decrease in standing crop of aquatic plants, densities of Polypedilum illinoense, Rheotanytarsus, and Dicrotendipes modestus all increased. This is the opposite of what would be expected if these species were being removed in large numbers from the plant stands by current activity. The patterns of abundance of the above species suggest that C. sylvestris normally outcompetes other chironomids for space on aquatic plants. As suggested earlier, the prominent body hairs on C. sylvestris larvae would prevent the species from being washed off the plants and out of the stand. The competitive advantage over other species gained thereby would obviously disappear as plant densities decreased, enabling other chironomid species to increase their population sizes.

Temporal patterns in standing crops of chironomids also suggest competition for habitat space in the sediments. This may explain the asynchronous patterns in standing crop exhibited by Tanytarsus sp. and Chironomus attenuatus. Collection of adult C. attenuatus and laboratory observations of larval growth rates suggests that C. attenuatus would develop large standing crops during the summer. However, the biomass and abundance of C. attenuatus increased in late summer only

after the biomass and abundance of Tanytarsus sp. had decreased; this suggests that the latter species may have somehow interfered with recruitment of C. attenuatus larvae.

Competition for habitat among chironomids may involve direct mechanical interference (e.g., tube building, feeding) of a settled population on recruitment of other species' larvae (McLachlan, 1969; Jonasson, 1970; Biever, 1971). In addition, observations made in the laboratory on C. sylvestris and D. modestus indicate that larvae who have settled and constructed tubes may "defend" the areas around their tubes by nipping at other larvae which come within striking distance, a length equivalent to about one-half the larvae's body length from either end of the tube. A less direct effect of one species on another was suggested by Ikeshoji (1973), who observed that chemicals given off by a settled population appeared to interfere with additional larval recruitment.

Predation

Predation by invertebrates and fish could periodically control standing crops of chironomids. Gut analyses of organisms collected in Bowline Pond revealed that a number of invertebrates including the hydrozoans Hydra sp. and Cordylophora lacustris, the amphipod Gammarus daiberi, the damselfly Enallagma, and the chironomid Procladius sublettei preyed on chironomids. Other invertebrates in the cove which have elsewhere been reported to feed on chironomids include turbellarians (Legner et al., 1975), water mites (Paterson, 1970) and the chironomid, Cryptochironomus fulvus (Darby, 1962). In addition, information presented in Gomez (1970), Scott and Crossman (1973), Grabe (1977), and

my own observations indicate that most fish species found in the Hudson River will prey on chironomids.

The significance of predation on chironomid larvae by one invertebrate species, naiads of the damselfly Enallagma, was suggested by the results of the fish exclusion cage experiments. Although these experiments were designed to evaluate the effects of fish predation, at the end of each experiment density of chironomids in the protective cages was significantly less than their density outside the cages. This unexpected result may be attributed to the significantly higher density of damselfly naiads observed within the cages. Gut analyses of naiads collected throughout the study revealed that chironomids comprised approximately 90% of the naiads' diet on a numerical basis.

4.1.2 Factors Which Affect Production By Affecting Turnover Rate

Species Development Rates

Differences in turnover rates among chironomid species were related primarily to differences in the numbers of generations completed during the year, with species having a greater number of generations usually having a higher turnover rate (Table 15). Species associated with aquatic plants in the littoral cove completed more generations per year than did species which lived only in sediments. Three or more generations per year were observed for species living on plants while two or less generations were observed for species which lived in sediments. Three or more generations per year have been reported infrequently in the literature while one and two generations per year are frequently observed. Studies by Humphries (1938), Borutsky (1939), Miller (1941), Lindeman (1942), Judd (1953), Mundie

(1957), Darby (1962), Hamilton (1965), Hilsenhoff (1966), Thut (1969), Nees and Dugdale (1969), Charles et al. (1974), Shiozowa and Barns (1975), and Ward and Cummins (1975) comprise 41 chironomid species that have one or two generations per year. Three or more generations per year have been reported for eight species including Chironomus attenuatus (Rodgers, 1974), Cladotanytarsus artidorsum (Mundie, 1957), Cricotopus sylvestris, Dicrotendipes nervosus, Polypedilum nubeculosum, and Tanytarsus lugens (Mundie, 1957), Tanypus (Borutsky, 1939) and Tanytarsus barbitarsis (Paterson and Walker, 1974).

The high numbers of generations of chironomids associated with aquatic plants in the present study reflect the relatively short generation times of these species. Data on the development rates were obtained for two of these species, Dicrotendipes modestus and Cricotopus sylvestris. At 22-29°C, a generation time of 24 days was calculated for D. modestus and 19 days for C. sylvestris. I have not seen any published data on development rates and generation times of D. modestus with which the development rates obtained in the present study can be compared. However, there are data for C. sylvestris. Konstantinov (1958) observed that larvae of this species developed in 14 days at 22°C and 21 days at 18°C. These rates are similar to those observed in the present study of approximately 10 days at 22-29°C and 28 days at 15°C. Based on adult emergence patterns, Mundie (1957) interpreted that there were three generations per year of C. sylvestris in an English reservoir which also was the lower limit of the probable number of generations of C. sylvestris in the littoral cove. Relatively rapid development rates have been reported for other species as

well. Dejoux (1971) observed that larval Chironomus pulcher developed in 13 days at 30°C and 17 days at 24°C; Biever (1971) observed that at 26.7°C larval Chironomus sp. developed in 11-15 days, larval Glyptotendipes holoprasinus developed in 9-14 days, and larval Tanypus grodhausis developed in 15-22 days; for Tanytarsus dissimilis, development from egg to adult occurred in 12 days at 28°C, 13 days at 25°C, and 16 days at 21°C (Nebeker, 1973).

The more rapid development rate of chironomid species living on aquatic plants may be related to the smaller body size of the species on the plants. In general, invertebrates exhibit more rapid developmental rates with decreasing body size of the species (Slobodkin, 1962).

The more rapid development rates of chironomid species associated with aquatic plants in Bowline Pond probably provides an adaptive advantage to living on the spatially and temporally variable habitat provided by the plants. As was observed for Myriophyllum spicatum in the littoral cove, aquatic plants may exhibit fluctuations in standing crop and thus in available habitat throughout the year. Species with rapid development rates would be able to take advantage of the habitat provided by the plants during periods of plant growth; population of species with slow development rates (e.g., univoltine species) could be greatly reduced as a result of decreases in plant standing crops and would not be able to rapidly recolonize the plants during subsequent periods of plant growth.

The foregoing discussion of turnover rates focuses on factors that are intrinsic to the species. Extrinsic factors that could affect

turnover rates include temperature, salinity, and predation. No direct effects of salinity and predation on chironomid growth rates were observed in the present study.

Temperature

Temperature probably was a major extrinsic factor affecting the growth rates of chironomids in Bowline Pond. As indicated, larvae grew at different rates at different temperatures in the laboratory. For example, development rates of Cricotopus sylvestris was approximately three times more rapid at 22°C than at 15°C, and little growth occurred at 9°C.

During the productive summer months, temperatures in the littoral areas of the Hudson River are warmer than in the deeper sublittoral area. For example, a temperature of 42°C was observed in the littoral cove in early August and this represented a 15°C elevation above the temperature of the water beyond the littoral cove. However, this was an extreme case and generally temperatures are only a few degrees warmer in the littoral areas. As a result of warmer water temperatures in littoral areas, growth rates of chironomids are probably higher in littoral as compared to sublittoral areas of the Hudson River. No comparative data on growth rates of sublittoral chironomids in the Hudson River, which would be needed to verify this, have been obtained. However, other studies in lakes have indicated that higher growth rates of littoral chironomids are, in part, attributable to the higher water temperatures of these areas (Lindeman, 1942; Miller, 1941). It would be difficult to isolate the effects of increased temperature on growth rates of littoral chironomids from the intrinsically rapid development

of chironomid species associated with aquatic plants. Both factors work simultaneously in having a positive effect on production of littoral chironomids.

Water temperature also affects emergence of adult chironomids and thus the duration of reproduction and subsequent larval recruitment. Since temperatures are generally warmer in the littoral areas, reproductive periods of species there may be greater than those of sublittoral chironomids. The reproductive periods of the eight chironomid species are given in Table 15. For most species, this period lasted approximately six months; shorter periods were observed for Polypedilum digitifer (four months) and Polypedilum illinoense (five months), and a longer period (nine months) was observed for Tanytarsus sp.

There was no apparent relation between length of reproductive period and the number of generations per year. Tanytarsus, the species having the longest estimated reproductive period exhibited only two generations, while P. illinoense, the species with one of the shortest estimated reproductive periods, exhibited five generations. However, for any one species, the number of generations would probably be affected by variations in the reproductive period. Thus, the same species may exhibit more generations per year and thus higher turnover rates in warmer climates.

4.1.3 Summary of Factors Affecting Production of Chironomids in the Littoral Cove

Factors which may affect chironomid production by affecting standing crops or turnover rates are summarized in Table 16. Factors shown in the present study, that would enhance the productivity of

Table 16. Factors which may affect chironomid production in the littoral cove by affecting standing crops or turnover rates.

Factors Affecting Standing Crops	Factors Affecting Turnover Rates
Physical/Chemical Factors	
• Aquatic Plants (presence of plants result in increased chironomid standing crops)	• Temperature (increases in temperature generally result in increased growth rates)
• Sediments (relationship between standing crops and sediment type undetermined)	
• Tidal Currents (removal of chironomids by tidal currents decreases standing crops)	
Biological Factors	
• Body Size of Individual Species (smaller bodied individuals associated with aquatic plants may limit standing crops that can be achieved by these species)	• Species Specific Development Rates (species associated with aquatic plants exhibit higher rates than species living in sediments)
• Competition (tends to limit standing crops)	
• Predation (could decrease standing crops)	

littoral chironomids include the presence of aquatic plants, and the rapid development rates of species associated with these plants. Factors which would limit the productivity of chironomids include the effects of tidal currents and interspecific competition. The smaller body sizes of chironomids associated with aquatic plants also may limit the standing crops that these species may achieve and thus limit productivity. Increased temperatures in littoral coves may have a positive effect on turnover rates and, thus, production. Predation may limit production of chironomids by controlling and reducing standing crops. Sediment size per se also may have a direct effect on chironomid species distribution but any such relationships have not yet been observed.

4.2 COMPARISON OF CHIRONOMID PRODUCTIVITY IN THE LITTORAL COVE WITH CHIRONOMID PRODUCTIVITY ESTIMATES FROM OTHER AREAS

Productivity values obtained for chironomid species in the littoral cove are in the middle to low range of values reported in the literature (Table 17). The highest reported values are 161 g m^{-2} yr^{-1} for Glyptotendipes barbipes in a sewage lagoon, 66.4 g m^{-2} yr^{-1} for Tanytarsus barbitarsis in an Australian saline lake, and 25.7 g m^{-2} yr^{-1} for Chironomus anthracinus in an English freshwater lake. The highest value for a chironomid species in the littoral cove was 5.66-7.55 g m^{-2} yr^{-1} for Dicrotendipes modestus.

The differences in chironomid productivities primarily reflect differences in standing crops; differences in turnover rates among the species were relatively less important. This is revealed by significant correlation ($r = 0.98$; $\alpha \geq 0.05$) between chironomid production

Table 17. Comparison of productivity values for chironomid species in the littoral cove with values reported in the literature. Species are ranked in order of decreasing productivity. Species observed in the littoral cove are indicated with an arrow (→).

	Production ($g\ m^{-2}\ yr^{-1}$)	Mean Biomass ($g\ m^{-2}$)	Turnover Rate	Environment	Reference
Glyptotendipes barbipes	161.0	18.9	8.49	Sewage Lagoon	Kimerle and Anderson (1971)
Tanytarsus barbitarsis	66.4	7.9	8.33	Saline Lake	Paterson and Walker (1974)
Chironomus anthracinus	25.7	6.6	3.9	Freshwater Lake	Charles et al. (1974)
Chironomus tentans	16.0			Freshwater Pond	Hall et al. (1970)
Chironomus anthracinus	12.6			Freshwater Lake	Jonasson (1975)
Chironomus spp.	11.0	0.63	17.5	Freshwater Lake	Peterson and Hilsenhoff (1972)
→ *Dicrotendipes modestus*	5.66-7.55	0.21	26-35	Estuarine Littoral Area	Present Study
→ *Cricotopus sylvestris*	4.06-6.76	0.28	15-24	Estuarine Littoral Area	Present Study
→ *Chironomus attenuatus*	2.75	0.79	3.5	Estuarine Littoral Area	Present Study
Glyptotendipes paripes	1.66	0.66	2.5	Freshwater Lake	Charles et al. (1974)
Tanytarsus jucundus	1.1	0.32	3.4	Littoral Area of Lake	Nees and Dugdale (1969)
→ *Procladius sublettei*	1.06	0.15	7.0	Estuarine Littoral Area	Present Study
Polypedilum nebeculosus	0.64	0.14	4.5	Freshwater Lake	Charles et al. (1974)
Limnochironomus pulsus	0.59	0.15	4.0	Freshwater Lake	Charles et al. (1974)
→ *Tanytarsus* sp.	0.52	0.05	10.7	Estuarine Littoral Area	Present Study
→ *Polypedilum illinoense*	0.44	0.03	17.5	Estuarine Littoral Area	Present Study
→ *Polypedilum digitifer*	0.33	0.05	7.0	Estuarine Littoral Area	Present Study
→ *Rheotanytarsus* sp.	0.05	0.005	10.5	Estuarine Littoral Area	Present Study

and standing crop and lack of correlation ($r = 0.01$) between production and turnover rate. The mean biomasses of G. barbipes, T. barbitarsis, and C. anthracinus were 31-89 times higher than the mean biomass of D. modestus, the most productive species in the littoral cove, and 8-24 times higher than the mean biomass of Chironomus attenuat·s, the chironomid species which attained the highest standing crop .. the cove. On the other hand, turnover rate of D. modestus was 3-9 times higher than those of the three most productive chironomids listed in Table 17.

Differences in the standing crops of the chironomid species shown in Table 17 may be the result of important differences in the environments of these species'. For example, the high standing crops of G. barbipes and T. barbitarsis may be the result of reduced competition, and predation as well as high concentrations of organic matter in the sediments. G. barbipes was studied in a waste stabilization lagoon and T. barbitarsis in a shallow saline lake where these species were the only chironomids present. Perhaps the lack of interspecies competition allowed these species to exploit available resources and develop high standing crops. In addition, populations of these species may have been relatively free of predation. No predators of G. barbipes were mentioned in Kimerle and Anderson's (1971) discussion of the role of this chironomid in the energetics of the lagoon, and Paterson and Walker (1974) observed only one predator, a dytiscid beetle, on T. barbitarsis. These two species' environments differed radically from that of the chironomids in Bowline Pond wherein were observed twenty-six chironomid species and numerous predators. The high organic

content of sediments in the sewage lagoon and in Lake Werowrap would also have a positive effect on chironomid production in these environments.

Total chironomid production in the littoral cove is estimated to be between 15-19 g m^{-2} yr^{-1} which is above the median of values reported in the literature (Table 18). The lowest value reported, 0.3 g m^{-2} yr^{-1}, is for a deep water area of Lake Ontario, and the highest value, 161 g m^{-2} yr^{-1}, is for the fauna of a sewage lagoon. Approximately one-half of the reported values, including that for the littoral cove, fell within a relatively narrow range of 13-19 g m^{-2} yr^{-1} and this range is considered to represent moderate levels of chironomid productivity.

No productivity estimates have been obtained for sublittoral chironomid populations of the Hudson River. However, biomass data are available for sublittoral regions of Bowline Pond and Haverstraw Bay in the Hudson. During 1975, mean dry weight biomass of sublittoral chironomids was estimated from data presented in Orange and Rockland (1977) to be 0.10 g m^{-2}. Assuming that sublittoral chironomids completed at most two generations per year (the maximum number observed for infaunal chironomids in the littoral cove) and that turnover rate per generation was 3.5, production of sublittoral chironomids in Bowline Pond and Haverstraw Bay is estimated to be 0.70 g m^{-2} yr^{-1} (2 generations x 3.5 per generation x mean biomass of 0.10 g). This estimate suggests that littoral chironomid fauna may be 21-27 times more productive than sublittoral chironomid fauna in this reach of the Hudson.

Table 18. Comparison of total chironomid production in the littoral cove with values reported in the literature. The aquatic systems studied are ranked in order of decreasing chironomid productivity.

Aquatic System	Production (g m^{-2} yr^{-1})	Reference
Sewage Lagoon, Oregon	161.0(1)	Kimerle and Anderson (1971)
Lake Werowrap, Australia	66	Paterson and Walker (1974)
Loch Leven, England	34	Charles et al. (1974)
Bay of Quinte at Glenora, Lake Ontario	18(1)	Johnson and Brinkhurst (1971)
Littoral Cove of Hudson River Estuary, New York	15-19	Present study
Lake Taltowisko, Poland	14	Kajak and Ryback (1970)
Lake Mikolejskie, Poland	13	Kajak and Ryback (1970)
Bay of Quinte at Big Bay, Lake Ontario	13(1)	Johnson and Brinkhurst (1971)
Lake Esrom, Sweden	13	Jonasson (1975)
Lake Wingra, Wisconsin	≥13	Peterson and Hilsenoff (1972)
Lake Snierdwy, Poland	7.2	Kajak and Ryback (1970)
Lake Lisunie, Poland	1.3	Kajak and Ryback (1970)
Lake Plosek, Poland	1.3	Kajak and Ryback (1970)
River Thames, England	1.03	Mann (1964)
Bay of Quinte at Conway, Lake Ontario	1.0(1)	Johnson and Brinkhurst (1971)
Deep Water Areas of Lake Ontario	0.3(1)	Johnson and Brinkhurst (1971)

(1)Production values in g m^{-2} yr^{-1} were estimated from values given in Kcal m^{-2} yr^{-1}.

4.3 UTILIZATION OF CHIRONOMID BIOMASS

Chironomids have a terrestrial adult stage as well as an aquatic larval stage. As a result of emergence of adults from the aquatic system, a certain portion of biomass produced during larval growth is removed from the aquatic system and, does not enter into the aquatic food web. Some of the adults which emerge do fall into the water and may be eaten. These include females which fly out over the water to lay eggs. In adddition, because adult chironomids feed little and, therefore, do not generate additional biomass, the egg masses laid in the water represent a return of a certain portion of the biomass produced by the previous larval generation. The portion of produced biomass that does not leave the aquatic system as adult emergence may be utilized as food by invertebrate and fish predators, parasites, or may die "naturally" and be decomposed.

Information on the amount of produced chironomid biomass that is utilized within the aquatic environment is provided by data on the littoral chironomid Cricotopus sylvestris. This was the only littoral species for which reliable estimates of adult emergence were obtained using the box trap designed for this study. Based on adult emergence data for C. sylvestris and mean biomass of 0.06 mg per individual adult, the biomass of emerged adults is estimated to be 2 gm^{-2} yr^{-1} (dry weight). This estimate represents approximately 30% of produced larval C. sylvestris biomass and, therefore, 70% of the produced biomass of this species (excluding adults and egg masses returned to the system) is utilized within the aquatic system.

The portion of C. sylvestris biomass that is utilized within the cove (70%) is within the range observed for other chironomid species. The range is broad and Kajak (1964) indicated that in some cases, mortality is high and over 90% of the produced chironomids remain in the system while in others, mortality may be negligible and most of the larvae emerge as adults. Reported estimates of the portions of produced biomass that remain within a system include 60% for Glyptotendipes barbipes in a sewage lagoon (Kimerle and Anderson, 1971), 65% for Chironomus tentans in experimental ponds in New York (Hall et al., 1971), 80% for Calospectra dives in a temperate cold spring (Teal, 1957), 82% for Tanytarsus jucundus in a littoral area of a lake (Nees and Dugdale, 1969), and 90% for Anatopynier dyciri in a temperate cold spring (Teal, 1957). The differences in the amount of produced chironomid biomass that remains within the aquatic system reflect differences among the systems in mortality rates due to differences in the intensity of predation, disease, or physiological problems.

A large portion of produced C. sylvestris biomass utilized within the aquatic system was probably eaten by naiads of the damselfly Enallagma. Gut analyses of naiads collected in the littoral cove revealed that C. sylvestris comprised approximately 90% (by abundance) of the naiads' diet. An estimate of the amount of C. sylvestris biomass eaten by naiads is obtained from the feeding rate experiments which indicated that naiads consumed 4.7 g m^{-2} yr^{-1} of invertebrate biomass within the cove. If 90% of this was C. sylvestris biomass, then 4.2 g m^{-2} yr^{-1} of this species biomass was consumed by naiads. This estimate represents 88% of the amount of produced C. sylvestris biomass utilized within the aquatic system. Because the amount of

invertebrate biomass consumed by damselfly naiads was estimated using a constant feeding rate obtained in the laboratory, it may not provide an accurate estimate of the amount consumed in the field. However, additional observations in the field program suggest that damselfly naiads did prey heavily upon the C. sylvestris population. Results of cage experiments indicated that the significant reduction in chironomid density (mostly C. sylvestris) within the cages was probably due to an increase in density of predaceous damselfly naiads.

The remaining 12% of C. sylvestris biomass that remains within the system is either consumed by other predators or dies and decomposes. Estimates on the partitioning of this portion of produced biomass cannot be accurately made. Fish were calculated to have consumed 1.6 g m^{-2} yr^{-1} of invertebrate biomass within the cove but the portion comprised by C. sylvestris was not estimated. However, this estimate indicates that predation by fish species was less important, i.e., smaller in amount, than predation by invertebrates of which the damselfly Enallagma was only one.

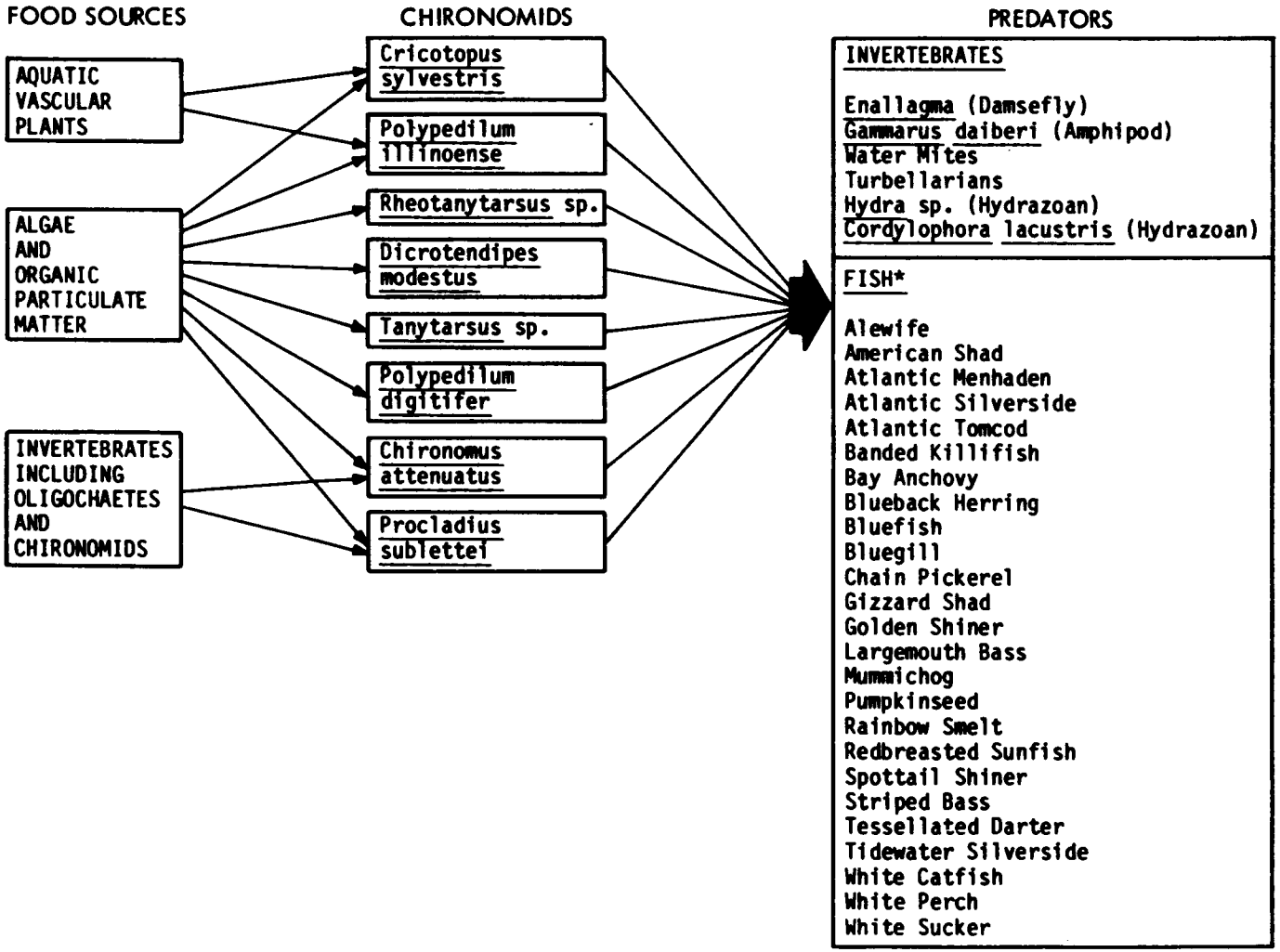
The large portion of chironomid, i.e., C. sylvestris, biomass calculated to be consumed by invertebrates in Bowline Pond agrees with a detailed study of chironomid standing crops and predation on them by rainbow trout in Lake Marion, Canada (Hamilton, 1965). Based on analyses of rainbow trout gut contents and digestion rates, he determined that the fish ate only 0.06% of the chironomid standing crop per day, a negligible amount. However, he noted that the lake bottom supported populations of caddisfly larvae and dragonfly naiads and that in the laboratory, these consumed large numbers of chironomid larvae.

In addition, he observed that predaceous Tanypodinae chironomid larvae represented 7.9% of the fauna, and, therefore, also could have been important predators of other chironomid larvae.

Invertebrates which prey on chironomids may be utilized as food by fish and thus serve as an intermediate link between chironomid and fish production. The results of the cage experiments conducted in the present study suggest that damselfly naiads are preyed upon by fish because the numbers of naiads inside the cages were higher than those outside. The cages probably protected the naiads from fish predation. Hamilton's (1965) study also shows that chironomid predators in Lake Marion such as caddisfly larvae and dragonfly naiads were consumed in large quantities by fish. Therefore, utilization of littoral chironomids by fish may be either through direct consumption as well as through invertebrates that feed on chironomids.

A simplified illustration of the trophic relationships of chironomids, their food and their predators is presented in Figure 35. Food habits of chironomids and other invertebrates are based, in part, on gut analyses conducted during this study. Additional information on feeding behavior of Cricotopus sylvestris and Polypedilum illinoense, i.e., that they feed on aquatic plants, was obtained from Berg (1950) and Darby (1962). Information on feeding behavior of Chironomus attenuatus, i.e., that it preys on other invertebrates, was obtained from Loden (1974). Fish species presented are those observed in seine collections made by Lawler, Matusky, and Skelly Engineers in

Figure 35. Trophic interrelationships involving chironomids in the littoral cove.



*Fish collected by Lawler, Matusky, and Skelly in littoral areas of Bowline Pond during 1975.

littoral areas of Bowline Pond during 1975. Information provided in Gomez (1970), Scott and Crossman (1973), Grabe (1977), and my own observations indicate that all these fish species feed on chironomid larvae at some time during their life; for example, even in the case of pisciverous fish such as largemouth bass, striped bass, and pickerel, chironomids are eaten by juveniles.

Grabe's (1977) observations on feeding habits of Cluepeids (herrings) are particularly interesting. He examined stomachs of alewife, shad, and blueback herring collected over 24-hour periods in a littoral area of the Hudson River three miles downriver from Bowline Pond, and observed that these fish moved into the littoral area at different times of the day to feed. Chironomids were among the organisms eaten and in the case of the alewife, which fed primarily at night, comprised most of the diet. Cricotopus was the most abundant chironomid in the guts of alewife followed by Dicrotendipes and Polypedilum; these organisms probably were being eaten off the Myriophyllum plants which occurred throughout the area of Grabe's (1977) study. These observations suggest that chironomids in littoral areas could be an important food source for commercially important anadromous herrings in the Hudson River.

5. CONCLUSIONS

Chironomid production in the littoral cove of Bowline Pond is estimated to be over twenty times greater than that in sublittoral areas of the same reach of the Hudson River. Factors considered most significant in contributing to the productivity of littoral chironomids include: 1) the presence of aquatic plants which provide additional habitat for support, and 2) the more rapid development rates of chironomid species associated with aquatic plants.

Compared to other water bodies, chironomid production in the littoral cove (15-19 g m^{-2} yr^{-1}) was slightly above the median of values reported in the literature (13 g m^{-2} yr^{-1}). Differences in chironomid production among water bodies primarily reflect differences in standing crops. Lower standing crops of chironomids in the littoral cove of Bowline Pond as compared to some other water bodies may be due to several factors including the presence of tidal currents, competition, predation, and the relatively small body size of species associated with aquatic plants.

Chironomid biomass in the littoral cove is utilized as food by other invertebrates and fish, with the invertebrates probably consuming most of the biomass. Invertebrate predators of chironomids, e.g., amphipods and damselfly naiads, also are eaten by fish and, therefore, represent a link between chironomid production and fish production.

The high productivity of chironomids estimated for the littoral area and the observations that the chironomids are eaten by fish and by invertebrates (preyed upon by fish) suggests that, although the littoral areas comprise only a small part of the Hudson River, they may be important to the support of Hudson River fish species. In particular, since many fish species breed in shallow littoral areas and since juvenile fish seem to congregate in these areas (Boyde, 1971; Fairbrothers and Moul, 1973; Scott and Crossman, 1973), littoral areas may be an essential feature of the fishes' nursery grounds.

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APPENDIX A

DENSITIES OF CHIRONOMIDS LIVING ON MYRIOPHYLLUM SPICATUM DURING THE 1975 FIELD SURVEY

NOTE

Two samples of plant stems were collected from each of the four sampling areas (I, II, III, and IV) on each of fourteen dates for analyses of the associated fauna. Densities are presented as numbers per 100 mg (dry weight) of Myriophyllum leaf weight.

Table A.1. Density of chironomid larvae living on Myriophyllum spicatum (No. per 100 mg of leaf biomass) on 26 May 1975.

		SAMPLES							
SPECIES	INSTAR	I-1	I-2	II-1	II-2	III-1	III-2	IV-1	IV-2
Cricotopus sylvestris	I	9	2	0	2	2	2	4	6
	II	31	29	1	2	8	18	15	6
	III	46	68	20	19	29	32	36	18
	IV	15	22	17	15	10	13	20	2
	Total	101	121	38	38	49	65	75	32
Dicrotendipes modestus	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	III	0	0	0	0	0	0	0	0
	IV	0	0	0	0	0	0	0	0
	Total	0	0	0	0	0	0	0	0
Polypedilum illinoensae	I	5	0	0	0	0	0	1	0
	II	4	0	0	1	2	1	3	0
	III	1	2	0	0	0	1	0	0
	IV	1	1	1	2	2	2	1	3
	Total	11	3	1	3	2	4	5	3
Parachironomus monochromus	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	III	0	0	0	0	0	0	0	0
	IV	0	0	0	0	0	0	0	0
	Total	0	0	0	0	0	0	0	0
Rheotanytarsus sp.	I	2	0	0	0	0	0	0	0
	II	2	0	0	0	0	0	0	0
	III	0	1	0	1	0	1	0	0
	IV	0	0	0	0	0	0	0	0
	Total	4	1	0	1	0	1	0	0
Brillia sp.	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	III	0	0	0	0	0	0	0	0
	IV	0	0	0	0	0	0	0	0
	Total	0	0	0	0	0	0	0	0
UNIDENTIFIED LARVAE		25	15	1	0	0	6	2	1
TOTAL LARVAE		141	140	40	42	51	76	81	36

Table A.2. Density of chironomid larvae living on Myriophyllum spicatum (No. per 100 mg of leaf biomass) on 7 June 1975.

		SAMPLES							
SPECIES	INSTAR	I-1	I-2	II-1	II-2	III-1	III-2	IV-1	IV-2
Cricotopus sylvestris	I	49	49	27	16	8	17	5	5
	II	134	114	152	73	58	127	30	19
	III	114	105	114	96	64	109	35	33
	IV	52	42	14	66	85	101	32	36
	Total	349	310	307	251	215	354	102	93
Dicrotendipes modestus	I	0	0	0	0	0	0	0	1
	II	0	0	0	0	2	2	3	1
	III	0	0	0	0	7	4	2	5
	IV	2	0	1	0	4	0	0	3
	Total	2	0	1	0	13	6	5	10
Polypedilum illinoensae	I	0	0	0	0	0	0	0	0
	II	1	4	0	0	0	2	2	0
	III	1	3	1	0	5	4	1	0
	IV	0	2	0	0	0	1	1	1
	Total	2	9	1	0	5	7	4	1
Parachironomus monochromus	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	III	0	0	0	0	0	0	0	0
	IV	0	0	0	0	0	0	0	0
	Total	0	0	0	0	0	0	0	0
Rheotanytarsus sp.	I	1	0	8	0	0	1	0	0
	II	0	0	0	0	1	0	1	1
	III	3	2	0	0	3	3	1	1
	IV	0	1	3	0	0	1	0	0
	Total	4	3	11	0	4	5	2	2
Brillia sp.	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	III	0	0	0	0	0	0	0	0
	IV	0	0	0	0	0	0	0	0
	Total	0	0	0	0	0	0	0	0
UNIDENTIFIED LARVAE		0	20	110	0	43	2	3	5
TOTAL LARVAE		357	342	430	251	279	374	116	111

Table A.3. Density of chironomid larvae living on Myriophyllum spicatum (No. per 100 mg of leaf biomass) on 24 June 1975.

		SAMPLES							
SPECIES	INSTAR	I-1	I-2	II-1	II-2	III-1	III-2	IV-1	IV-2
Cricotopus sylvestris	I	20	8	2	15	20	3	4	4
	II	39	16	48	68	47	20	12	13
	III	73	58	44	152	73	34	53	27
	IV	54	58	48	196	40	42	36	13
	Total	186	140	142	431	180	99	105	57
Dicrotendipes modestus	I	3	5	1	0	20	5	7	9
	II	15	18	13	50	23	17	12	15
	III	3	9	9	25	10	3	6	10
	IV	0	1	0	1	2	0	1	0
	Total	21	33	23	76	55	25	26	34
Polypedilum illinoensae	I	3	2	4	7	10	2	0	2
	II	3	12	1	0	0	3	1	6
	III	4	7	9	7	0	2	0	1
	IV	0	1	1	1	0	0	0	0
	Total	10	22	15	15	10	7	1	9
Parachironomus monochromus	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	III	0	0	0	0	0	0	0	0
	IV	0	0	0	0	0	0	0	0
	Total	0	0	0	0	0	0	0	0
Rheotanytarsus sp.	I	0	1	1	1	0	3	0	0
	II	1	1	0	3	1	0	1	0
	III	5	1	0	0	1	0	0	0
	IV	0	0	0	0	0	1	0	0
	Total	6	3	1	4	2	4	1	0
Brillia sp.	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	III	0	0	0	0	0	0	0	0
	IV	0	0	0	0	0	0	0	0
	Total	0	0	0	0	0	0	0	0
UNIDENTIFIED LARVAE		21	44	5	14	10	3	1	3
TOTAL LARVAE		244	242	186	540	255	138	134	103

Table A.4 Density of chironomid larvae living on Myriophyllum spicatum (No. per 100 mg of leaf biomass) on 9 July 1975.

		SAMPLES							
SPECIES	INSTAR	I-1	I-2	II-1	II-2	III-1	III-2	IV-1	IV-2
Cricotopus sylvestris	I	7	5	1	4	3	1	3	3
	II	12	12	6	11	8	6	7	11
	III	28	10	14	15	24	7	30	12
	IV	48	13	20	27	25	38	19	16
	Total	95	40	41	57	60	52	59	42
Dicrotendipes modestus	I	2	2	0	1	2	2	6	6
	II	14	7	1	3	12	3	6	13
	III	12	12	5	8	22	12	17	13
	IV	2	5	4	2	1	3	5	1
	Total	30	26	10	14	37	20	34	33
Polypedilum illinoensae	I	0	0	0	0	0	0	0	0
	II	0	1	0	0	0	0	0	0
	III	2	1	4	2	0	3	0	1
	IV	2	7	4	4	0	1	2	5
	Total	4	9	8	6	0	4	2	6
Parachironomus monochromus	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	III	0	0	0	0	0	0	0	0
	IV	0	0	0	0	0	0	0	0
	Total	0	0	0	0	0	0	0	0
Rheotanytarsus sp.	I	0	0	0	0	0	0	0	0
	II	0	0	1	0	0	0	0	0
	III	6	1	0	2	1	1	1	2
	IV	2	1	6	2	1	8	3	0
	Total	8	2	7	4	2	9	4	2
Brillia sp.	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	III	0	0	0	0	0	0	0	0
	IV	0	0	0	0	0	0	0	0
	Total	0	0	0	0	0	0	0	0
UNIDENTIFIED LARVAE		0	3	0	2	2	3	3	1
TOTAL LARVAE		137	80	66	83	101	88	102	84

Table A.5 Density of chironomid larvae living on Myriophyllum spicatum (No. per 100 mg of leaf biomass) on 25 July 1975.

		SAMPLES							
SPECIES	INSTAR	I-1	I-2	II-1	II-2	III-1	III-2	IV-1	IV-2
Cricotopus sylvestris	I	7	2	0	0	0	0	0	0
	II	40	9	28	13	9	1	7	24
	III	68	33	99	48	26	23	37	44
	IV	56	33	116	54	53	62	25	71
	Total	171	77	243	115	88	86	69	139
Dicrotendipes modestus	I	0	0	0	0	2	0	1	0
	II	0	1	0	0	2	2	1	1
	III	19	3	5	2	25	14	7	7
	IV	34	2	5	2	19	9	4	4
	Total	53	6	10	4	48	25	13	12
Polypedilum illinoensae	I	0	0	0	0	0	0	0	0
	II	1	0	3	1	1	2	0	1
	III	2	1	5	2	4	5	2	0
	IV	26	2	0	0	2	1	1	0
	Total	49	3	8	3	7	8	3	1
Parachironomus monochromus	I	1	1	0	0	0	2	1	2
	II	3	1	0	0	1	7	3	9
	III	4	1	0	0	2	5	4	9
	IV	3	2	2	1	1	2	4	4
	Total	11	5	2	1	4	16	12	24
Rheotanytarsus sp.	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	1
	III	0	0	0	0	0	1	0	1
	IV	0	0	0	0	0	1	0	1
	Total	0	0	0	0	0	2	0	3
Brillia sp.	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	III	0	0	0	0	0	0	0	0
	IV	0	0	0	0	0	0	0	0
	Total	0	0	0	0	0	0	0	0
UNIDENTIFIED LARVAE		3	4	0	0	0	0	0	10
TOTAL LARVAE		247	95	263	123	147	137	97	189

Table A.6. Density of chironomid larvae living on Myriophyllum spicatum (No. per 100 mg of leaf biomass) on 8 August 1975.

		SAMPLES							
SPECIES	INSTAR	I-1	I-2	II-1	II-2	III-1	III-2	IV-1	IV-2
Cricotopus sylvestris	I	25	23	0	9	16	21	7	14
	II	44	119	13	19	86	34	38	53
	III	76	168	38	43	78	102	57	93
	IV	63	203	144	49	187	154	83	108
	Total	208	513	195	120	367	311	185	268
Dicrotendipes modestus	I	0	0	0	1	3	0	0	0
	II	0	1	0	0	8	0	0	0
	III	1	1	0	0	6	0	0	0
	IV	1	5	0	1	5	2	0	0
	Total	2	7	0	2	22	2	0	0
Polypedilum illinoensae	I	0	0	1	1	2	0	0	0
	II	2	0	0	0	9	2	3	3
	III	3	18	5	4	6	8	4	4
	IV	2	5	0	1	3	0	2	1
	Total	7	23	6	6	20	10	9	8
Parachironomus monochromus	I	1	0	0	0	0	0	0	0
	II	0	0	0	0	5	1	0	0
	III	3	2	0	1	5	1	0	0
	IV	2	3	0	4	9	3	4	4
	Total	6	5	0	5	19	5	4	4
Rheotanytarsus sp.	I	0	0	0	0	0	0	0	1
	II	0	1	0	1	3	2	1	3
	III	1	1	0	1	3	1	0	0
	IV	2	1	1	1	6	2	1	0
	Total	3	3	1	3	12	5	2	4
Brillia sp.	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	III	0	0	0	0	0	0	0	0
	IV	0	0	0	0	0	0	0	0
	Total	0	0	0	0	0	0	0	0
UNIDENTIFIED LARVAE		0	2	0	0	0	0	0	0
TOTAL LARVAE		226	553	202	136	440	333	200	284

Table A. 7. Density of chironomid larvae living on Myriophyllum spicatum (No. per 100 mg of leaf biomass) on 23 August 1975.

		SAMPLES							
SPECIES	INSTAR	I-1	I-2	II-1	II-2	III-1	III-2	IV-1	IV-2
Cricotopus sylvestris	I	7	3	4	5	6	3	1	0
	II	28	7	8	9	19	10	4	3
	III	71	10	11	11	23	18	17	12
	IV	61	16	16	9	19	15	12	10
	Total	167	37	39	34	67	46	34	25
Dicrotendipes modestus	I	0	1	1	0	9	0	0	0
	II	3	2	0	0	19	7	1	1
	III	7	2	6	0	5	10	1	2
	IV	3	1	0	1	2	3	0	0
	Total	13	6	7	1	35	20	2	3
Polypedilum illinoensae	I	0	0	1	3	2	2	1	0
	II	2	3	1	7	16	0	2	2
	III	4	2	1	3	3	1	2	2
	IV	2	0	0	2	0	1	1	1
	Total	8	5	3	15	21	4	6	5
Parachironomus monochromus	I	0	0	0	0	0	1	0	0
	II	1	2	1	1	5	2	1	1
	III	10	2	9	2	22	2	1	2
	IV	7	2	1	4	11	2	0	1
	Total	18	6	11	7	38	7	2	4
Rheotanytarsus sp.	I	0	0	0	0	2	0	0	0
	II	0	1	4	2	2	2	0	1
	III	1	0	6	2	2	0	1	1
	IV	1	0	1	0	0	0	0	0
	Total	2	1	11	4	6	2	1	2
Brillia sp.	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	III	0	0	0	0	0	0	0	0
	IV	0	0	0	0	0	0	0	0
	Total	0	0	0	0	0	0	0	0
UNIDENTIFIED LARVAE		0	0	10	3	8	0	0	7
TOTAL LARVAE		208	55	81	64	175	79	45	46

Table A.8. Density of chironomid larvae living on Myriophyllum spicatum (No. per 100 mg of leaf biomass) on 9 September 1975.

		SAMPLES							
SPECIES	INSTAR	I-1	I-2	II-1	II-2	III-1	III-2	IV-1	IV-2
Cricotopus sylvestris	I	2	3	0	3	2	4	1	4
	II	11	5	13	12	4	6	5	27
	III	13	8	23	42	4	23	15	14
	IV	29	29	24	40	15	22	23	13
	Total	55	45	60	97	25	55	44	58
Dicrotendipes modestus	I	1	0	0	0	1	3	1	0
	II	1	3	1	8	1	7	2	0
	III	3	12	6	3	1	8	3	0
	IV	8	8	17	7	2	34	7	2
	Total	13	23	24	18	5	52	13	2
Polypedilum illinoensae	I	0	0	3	2	1	1	0	0
	II	3	0	6	5	3	4	1	1
	III	13	1	24	32	6	5	2	3
	IV	23	0	7	7	9	5	1	5
	Total	39	1	40	46	19	15	4	9
Parachironomus monochromus	I	0	0	0	0	0	0	0	0
	II	1	0	0	0	2	1	0	0
	III	1	1	3	0	0	0	1	0
	IV	3	5	7	0	0	1	7	0
	Total	5	6	10	0	2	2	8	0
Rheotanytarsus sp.	I	0	1	0	2	1	0	0	0
	II	2	1	7	2	5	4	12	4
	III	3	0	6	5	3	3	3	0
	IV	2	0	1	8	1	3	1	1
	Total	7	2	14	17	10	10	16	5
Brillia sp.	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	III	0	0	1	0	0	0	0	0
	IV	0	0	0	0	0	0	0	0
	Total	0	0	1	0	0	0	0	0
UNIDENTIFIED LARVAE		4	11	11	2	0	17	2	0
TOTAL LARVAE		123	88	160	180	61	151	87	74

Table A.9. Density of chironomid larvae living on Myriophyllum spicatum (No. per 100 mg of leaf biomass) on 22 September 1975

		SAMPLES							
SPECIES	INSTAR	I-1	I-2	II-1	II-2	III-1	III-2	IV-1	IV-2
Cricotopus sylvestris	I	2	1	2	10	2	1	9	2
	II	5	18	10	25	31	4	35	11
	III	5	9	8	16	12	4	15	7
	IV	6	10	12	27	21	4	26	15
	Total	18	38	32	78	66	13	85	35
Dicrotendipes modestus	I	0	0	0	2	0	4	6	3
	II	0	1	2	2	0	9	15	4
	III	0	0	2	0	0	1	0	1
	IV	0	0	0	2	1	1	0	3
	Total	0	1	4	6	1	15	21	11
Polypedilum illinoensae	I	0	0	1	9	0	0	0	0
	II	1	1	4	1	0	0	0	1
	III	1	4	6	0	1	2	0	2
	IV	3	5	4	0	5	3	0	5
	Total	5	10	15	10	6	5	0	8
Parachironomus monochromus	I	0	0	0	0	0	0	0	0
	II	0	1	0	0	2	0	0	0
	III	0	0	2	1	0	0	0	0
	IV	1	1	0	3	0	1	0	1
	Total	1	2	2	4	2	1	0	1
Rheotanytarsus sp.	I	0	0	0	1	0	0	0	0
	II	0	0	0	1	0	0	0	0
	III	1	0	0	0	0	0	0	1
	IV	1	0	1	2	0	0	3	2
	Total	2	0	1	4	0	0	3	3
Brillia sp.	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	III	0	0	0	0	0	0	0	0
	IV	0	0	0	4	0	0	3	0
	Total	0	0	0	4	0	0	3	0
UNIDENTIFIED LARVAE		0	3	6	5	0	0	0	0
TOTAL LARVAE		26	54	60	111	75	34	112	58

Table A.10. Density of chironomid larvae living on Myriophyllum spicatum (No. per 100 mg of leaf biomass) on 11 October 1975.

		SAMPLES							
SPECIES	INSTAR	I-1	I-2	II-1	II-2	III-1	III-2	IV-1	IV-2
Cricotopus sylvestris	I	4	3	7	2	2	0	0	1
	II	18	3	13	6	1	9	0	4
	III	8	2	10	3	0	4	3	2
	IV	22	9	8	5	5	12	9	5
	Total	52	17	38	16	8	25	12	12
Dicrotendipes modestus	I	0	0	0	0	0	0	0	0
	II	2	0	5	2	0	0	0	1
	III	4	2	0	0	1	1	1	1
	IV	0	0	0	0	0	0	0	0
	Total	6	2	5	2	1	1	1	2
Polypedilum illinoensae	I	0	0	0	0	0	0	0	0
	II	2	7	21	6	2	6	4	2
	III	6	2	5	4	2	3	1	2
	IV	2	0	0	0	0	1	0	0
	Total	10	9	26	10	4	10	5	4
Parachironomus monochromus	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	III	2	0	0	0	1	0	0	0
	IV	0	0	0	0	0	1	0	1
	Total	2	0	0	0	1	1	0	1
Rheotanytarsus sp.	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	1	0	0	0
	III	0	0	0	0	0	0	0	0
	IV	0	0	0	0	0	0	0	0
	Total	0	0	0	0	1	0	0	0
Brillia sp.	I	2	0	0	0	0	0	0	0
	II	6	3	0	2	1	2	0	2
	III	13	1	13	0	0	1	1	1
	IV	26	2	3	0	0	2	0	3
	Total	47	6	16	2	1	5	1	6
UNIDENTIFIED LARVAE		3	0	0	1	0	2	3	0
TOTAL LARVAE		118	34	85	31	16	44	22	25

Table A.11. Density of chironomid larvae living on Myriophyllum spicatum (No. per 100 mg of leaf biomass) on 1 November 1975.

		SAMPLES							
SPECIES	INSTAR	I-1	I-2	II-1	II-2	III-1	III-2	IV-1	IV-2
Cricotopus sylvestris	I	3	10	2	4	2	14	10	6
	II	5	24	14	44	12	112	28	20
	III	1	6	6	35	5	24	15	12
	IV	1	2	3	5	1	1	3	2
	Total	10	42	25	88	20	151	56	40
Dicrotendipes modestus	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	1	0
	III	1	0	0	1	1	1	1	0
	IV	0	0	0	0	0	0	0	0
	Total	1	0	0	1	1	1	2	0
Polypedilum illinoensae	I	0	0	0	0	0	0	0	0
	II	0	0	1	2	2	3	0	1
	III	1	2	1	5	0	5	1	5
	IV	0	0	0	0	0	0	0	0
	Total	1	2	2	7	2	8	1	6
Parachironomus monochromus	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	III	0	0	0	0	0	0	0	0
	IV	0	0	0	0	0	0	0	0
	Total	0	0	0	0	0	0	0	0
Rheotanytarsus sp.	I	0	0	1	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	III	3	2	4	5	3	5	0	3
	IV	0	0	0	0	0	0	1	2
	Total	3	2	5	5	3	5	1	5
Brillia sp.	I	0	0	1	0	0	0	0	0
	II	0	1	0	0	1	0	0	0
	III	0	3	8	2	9	2	0	5
	IV	0	0	0	0	0	0	0	0
	Total	0	4	9	2	10	2	0	5
UNIDENTIFIED LARVAE		0	0	0	7	0	7	2	7
TOTAL LARVAE		15	48	41	110	36	175	62	63

Table A.12. Density of chironomid larvae living on Myriophyllum spicatum (No. per 100 mg of leaf biomass) on 15 November 1975.

		SAMPLES							
SPECIES	INSTAR	I-1	I-2	II-1	II-2	III-1	III-2	IV-1	IV-2
Cricotopus sylvestris	I	4	7	5	2	2	5	0	2
	II	78	109	244	53	40	67	89	65
	III	42	60	145	32	25	105	57	24
	IV	7	0	20	1	0	8	0	2
	Total	131	176	414	88	67	185	146	93
Dicrotendipes modestus	I	0	0	0	0	0	0	0	0
	II	0	0	0	2	0	0	0	0
	III	1	0	4	0	2	5	6	0
	IV	0	0	5	0	0	0	0	0
	Total	1	0	9	2	2	5	6	0
Polypedilum illinoensae	I	0	0	0	0	0	0	2	0
	II	0	2	11	1	3	5	2	0
	III	3	2	0	3	2	0	4	2
	IV	0	0	0	0	0	0	0	0
	Total	3	4	11	4	5	5	8	2
Parachironomus monochromus	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	III	0	7	0	0	0	0	4	0
	IV	0	0	0	0	0	0	0	0
	Total	0	7	0	0	0	0	4	0
Rheotanytarsus sp.	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	2	0	0	0
	III	10	21	11	3	12	12	4	2
	IV	0	2	5	0	2	0	0	0
	Total	10	23	16	3	16	12	4	2
Brillia sp.	I	0	0	0	0	0	0	0	0
	II	5	0	0	0	0	12	0	2
	III	31	0	0	8	10	25	13	13
	IV	0	0	0	0	0	0	0	0
	Total	36	0	0	8	10	37	13	15
UNIDENTIFIED LARVAE		1	4	4	0	2	4	0	3
TOTAL LARVAE		182	214	453	105	102	248	181	115

Table A.13. Density of chironomid larvae living on Myriophyllum spicatum (No. per 100 mg of leaf biomass) on 30 November 1975.

		SAMPLES							
SPECIES	INSTAR	I-1	I-2	II-1	II-2	III-1	III-2	IV-1	IV-2
Cricotopus sylvestris	I	0	0	0	0	0	1	1	0
	II	37	33	46	65	21	23	27	16
	III	31	41	46	119	35	30	20	16
	IV	0	1	7	0	1	0	1	0
	Total	68	75	99	184	57	54	49	32
Dicrotendipes modestus	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	III	0	1	0	0	1	0	1	0
	IV	0	0	0	2	0	0	0	0
	Total	0	1	0	2	1	0	1	0
Polypedilum illinoensae	I	0	0	0	0	0	0	0	0
	II	3	0	0	9	3	1	2	1
	III	2	2	0	13	1	0	2	1
	IV	0	0	0	0	0	0	0	0
	Total	5	2	0	22	4	1	4	2
Parachironomus monochromus	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	III	1	0	0	2	1	0	1	3
	IV	1	1	0	0	0	0	1	0
	Total	2	1	0	2	1	0	2	3
Rheotanytarsus sp.	I	0	0	0	0	0	0	0	0
	II	0	0	0	2	0	0	0	0
	III	5	2	7	7	6	6	6	4
	IV	0	0	0	0	1	0	0	1
	Total	5	2	7	9	7	6	6	5
Brillia sp.	I	0	0	0	0	0	0	0	0
	II	0	1	0	0	1	0	0	0
	III	14	9	15	0	2	7	6	3
	IV	0	0	0	0	0	0	0	0
	Total	14	10	15	0	3	7	6	3
UNIDENTIFIED LARVAE		0	10	0	3	4	0	0	0
TOTAL LARVAE		94	100	121	222	77	68	68	45

Table A.14. Density of chironomid larvae living on Myriophyllum spicatum (No. per 100 mg of leaf biomass) on 1 January 1976.

		SAMPLES							
SPECIES	INSTAR	I-1	I-2	II-1	II-2	III-1	III-2	IV-1	IV-2
Cricotopus sylvestris	I	0	0	0	0	0	0	0	0
	II	7	5	1	0	1	2	3	4
	III	0	12	2	1	5	0	5	4
	IV	0	0	0	0	0	0	0	0
	Total	7	17	3	1	6	2	8	8
Dicrotendipes modestus	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	III	0	0	0	0	0	0	0	0
	IV	0	0	0	0	0	0	0	0
	Total	0	0	0	0	0	0	0	0
Polypedilum illinoensae	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	III	0	0	0	0	0	0	0	0
	IV	0	0	0	0	0	0	0	0
	Total	0	0	0	0	0	0	0	0
Parachironomus monochromus	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	III	0	0	0	0	0	0	0	0
	IV	0	0	0	0	0	0	0	0
	Total	0	0	0	0	0	0	0	0
Rheotanytarsus sp.	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	III	0	3	1	0	2	2	0	1
	IV	0	1	0	0	0	0	0	0
	Total	0	4	1	0	2	2	0	1
Brillia sp.	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	III	0	0	0	0	0	0	0	0
	IV	0	0	0	0	0	0	0	0
	Total	0	0	0	0	0	0	0	0
UNIDENTIFIED LARVAE		0	0	0	0	0	0	0	0
TOTAL LARVAE		7	21	4	1	8	4	8	9

APPENDIX B

DENSITIES OF CHIRONOMIDS LIVING IN SEDIMENTS OF THE LITTORAL COVE DURING THE 1975 FIELD SURVEY

NOTE

Two sediment samples were collected from each of four sampling areas (I, II, III, and IV) on each of eleven dates for analyses of fauna. Densities are presented as numbers per 31.63 cm^2, the area sampled by the plexiglass cover used in this study.

Table B.1. Density of chironomid larvae (No. per 31.63 cm^2) living in the sediments on 18 January 1975.

SPECIES	INSTAR	SAMPLES I-1	I-2	II-1	II-2	III-1	III-2	IV-1	IV-2
Chironomus attenuatus	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	III	0	0	0	0	0	0	0	0
	IV	1	1	0	0	1	1	0	2
	Total	1	1	0	0	1	1	0	2
Dicrotendipes modestus	I	0	0	0	0	0	0	0	0
	II	0	4	0	1	0	0	3	0
	III	31	19	10	3	3	5	2	18
	IV	18	12	2	2	1	5	0	9
	Total	49	35	12	6	4	10	5	27
Procladius subletei	I	0	0	0	0	0	0	0	0
	II	3	2	3	0	0	0	0	6
	III	3	0	2	0	0	0	1	4
	IV	1	0	6	0	1	0	0	1
	Total	7	2	11	0	1	0	1	11
Tanytarsus sp.	I	0	0	0	0	0	0	0	0
	II	1	2	0	0	0	0	0	0
	III	0	0	0	0	0	0	3	0
	IV	0	0	0	0	0	0	0	0
	Total	1	2	0	0	0	0	3	0
Polypedilum digitifer	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	III	9	10	1	0	7	3	0	2
	IV	0	0	0	0	0	0	0	0
	Total	9	10	1	0	7	3	0	2
Cryptochironomus fulvus	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	III	0	0	0	0	0	0	0	0
	IV	0	0	1	0	0	0	0	0
	Total	0	0	1	0	0	0	0	0
Cricotopus sylvestris	I	0	0	0	0	0	0	0	0
	II	0	11	0	1	0	0	9	2
	III	0	22	1	1	0	4	22	2
	IV	0	0	0	0	0	0	0	0
	Total	0	33	1	2	0	4	31	4
Other Larvae		23	8	2	0	5	5	9	16
TOTAL LARVAE		90	91	28	8	18	23	49	62

Table B.2. Density of chironomid larvae (No. per 31.63 cm^2) living in the sediments on 22 February 1975.

SPECIES	INSTAR	SAMPLES I-1	I-2	II-1	II-2	III-1	III-2	IV-1	IV-2
Chironomus attenuatus	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	III	0	0	0	0	0	0	0	0
	IV	2	0	0	0	0	0	1	0
	Total	2	0	0	0	0	0	1	0
Dicrotendipes modestus	I	1	3	0	0	0	0	0	0
	II	2	0	1	0	0	0	8	6
	III	59	45	7	1	5	1	14	7
	IV	14	4	3	2	2	0	2	3
	Total	76	52	11	3	7	1	24	16
Procladius subletei	I	0	0	0	0	0	0	0	0
	II	3	1	0	0	0	1	0	1
	III	1	4	0	0	0	0	1	6
	IV	0	1	0	0	0	0	1	2
	Total	4	6	0	0	0	1	2	9
Tanytarsus sp.	I	0	0	0	0	0	0	0	0
	II	3	3	1	0	3	1	1	1
	III	0	0	0	0	1	0	0	0
	IV	0	0	0	0	0	0	0	0
	Total	3	3	1	0	4	1	1	1
Polypedilum digitifer	I	0	0	0	0	0	0	0	0
	II	0	0	1	0	0	0	0	0
	III	33	2	14	1	2	3	2	0
	IV	0	0	0	0	0	0	0	1
	Total	33	2	15	1	2	3	2	1
Cryptochironomus fulvus	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	III	2	1	0	0	1	0	0	0
	IV	0	0	0	0	0	0	0	0
	Total	2	1	0	0	1	0	0	0
Cricotopus sylvestris	I	0	0	0	0	0	0	0	0
	II	0	15	6	0	0	3	4	7
	III	8	26	4	0	4	2	8	2
	IV	0	0	0	0	0	0	0	0
	Total	8	41	10	0	4	5	12	11
Other Larvae		0	1	5	0	1	1	4	8
TOTAL LARVAE		128	106	42	4	19	12	46	46

Table B. 3. Density of chironomid larvae (No. per 31.63 cm^2) living in the sediments on 23 March 1975.

SPECIES	INSTAR	SAMPLES I-1	I-2	II-1	II-2	III-1	III-2	IV-1	IV-2
Chironomus attenuatus	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	III	0	0	0	0	0	0	0	0
	IV	1	0	1	2	0	2	0	1
	Total	1	0	1	2	0	2	0	1
Dicrotendipes modestus	I	0	0	0	0	0	0	0	0
	II	1	3	1	2	0	0	0	0
	III	10	58	20	34	17	3	8	3
	IV	8	13	5	9	14	6	2	1
	Total	19	74	26	45	31	9	10	4
Procladius subletei	I	0	0	0	0	0	0	0	0
	II	0	5	0	0	0	3	4	4
	III	1	4	0	0	0	1	2	5
	IV	0	0	0	0	0	2	1	3
	Total	1	9	0	0	0	6	7	12
Tanytarsus sp.	I	1	1	2	1	1	0	2	0
	II	1	1	0	0	0	0	0	0
	III	0	0	0	0	0	0	0	0
	IV	0	0	0	0	0	0	0	0
	Total	2	2	2	1	1	0	2	0
Polypedilum digitifer	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	III	4	8	10	11	7	3	3	0
	IV	0	1	0	0	0	0	0	0
	Total	4	9	10	11	7	3	3	0
Cryptochironomus fulvus	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	III	0	0	2	2	0	0	0	0
	IV	0	0	0	1	0	0	0	0
	Total	0	0	2	3	0	0	0	0
Cricotopus sylvestris	I	0	0	0	0	0	0	0	0
	II	0	2	0	0	0	0	0	1
	III	1	3	1	0	0	2	1	0
	IV	0	0	0	0	0	0	1	0
	Total	1	5	1	0	0	2	2	1
Other Larvae		5	11	4	1	3	6	7	3
TOTAL LARVAE		33	110	46	63	42	28	31	21

Table B.4. Density of chironomid larvae (No. per 31.63 cm^2) living in the sediments on 19 April 1975.

SPECIES	INSTAR	SAMPLES I-1	I-2	II-1	II-2	III-1	III-2	IV-1	IV-2
Chironomus attenuatus	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	III	0	0	0	0	0	0	0	0
	IV	0	1	0	0	0	0	2	0
	Total	0	1	0	0	0	0	2	0
Dicrotendipes modestus	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	III	3	21	0	0	0	0	1	2
	IV	0	6	0	0	0	0	0	0
	Total	3	27	0	0	0	0	1	2
Procladius subletei	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	III	0	1	0	0	0	0	0	1
	IV	0	1	1	0	0	0	0	2
	Total	0	2	1	0	0	0	0	3
Tanytarsus sp.	I	2	9	1	0	2	0	0	2
	II	0	1	0	0	0	0	0	0
	III	0	0	0	0	0	0	0	0
	IV	0	0	0	0	0	0	0	0
	Total	2	10	1	0	2	0	0	0
Polypedilum digitifer	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	III	2	22	2	1	2	0	1	4
	IV	0	0	0	0	0	0	0	0
	Total	2	22	2	1	2	0	1	4
Cryptochironomus fulvus	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	III	0	0	0	0	0	0	0	0
	IV	0	1	0	1	0	0	0	0
	Total	0	1	0	1	0	0	0	0
Cricotopus sylvestris	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	III	0	2	0	0	1	1	0	1
	IV	0	0	0	0	0	0	0	0
	Total	0	2	0	0	1	1	0	1
Other Larvae		1	6	0	0	1	0	0	0
TOTAL LARVAE		8	71	4	2	6	1	4	12

Table B.5. Density of chironomid larvae (No. per 31.63 cm^2) living in the sediments on 26 May 1975.

SPECIES	INSTAR	SAMPLES I-1	I-2	II-1	II-2	III-1	III-2	IV-1	IV-2
Chironomus attenuatus	I	0	0	0	0	0	0	0	0
	II	0	0	1	3	0	3	1	0
	III	0	0	0	0	0	0	0	0
	IV	0	0	0	0	0	0	0	0
	Total	0	0	1	3	0	3	1	0
Dicrotendipes modestus	I	0	0	0	3	0	4	1	0
	II	0	0	0	0	0	1	0	0
	III	0	1	0	0	0	0	0	0
	IV	0	2	0	0	0	0	0	0
	Total	0	3	0	3	0	5	1	0
Procladius subletei	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	III	0	0	0	0	0	0	0	0
	IV	0	0	0	0	0	0	0	1
	Total	0	0	0	0	0	0	0	1
Tanytarsus sp.	I	0	0	1	0	0	0	2	4
	II	1	0	0	1	1	1	0	2
	III	0	0	0	0	1	0	0	1
	IV	0	0	0	0	1	3	0	0
	Total	1	0	1	1	3	4	2	7
Polypedilum digitifer	I	0	0	1	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	III	0	1	0	0	0	0	0	0
	IV	3	1	1	0	0	0	0	0
	Total	3	2	2	0	0	0	0	0
Cryptochironomus fulvus	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	III	0	0	0	0	0	0	0	0
	IV	0	0	0	0	0	0	0	0
	Total	0	0	0	0	0	0	0	0
Cricotopus sylvestris	I	1	0	2	2	0	1	1	0
	II	0	0	0	1	0	0	0	0
	III	0	0	0	0	0	0	0	0
	IV	0	0	0	0	0	1	0	0
	Total	1	0	2	3	0	2	1	0
Other Larvae		3	0	20	1	5	3	0	5
TOTAL LARVAE		8	5	26	11	8	17	5	13

Table B.6. Density of chironomid larvae (No. per 31.63 cm^2) living in the sediments on 22 June 1975.

SPECIES	INSTAR	SAMPLES I-1	I-2	II-1	II-2	III-1	III-2	IV-1	IV-2
Chironomus attenuatus	I	0	0	0	0	0	0	0	0
	II	6	11	3	4	11	2	5	7
	III	2	2	1	1	6	1	2	4
	IV	0	3	1	1	4	1	3	2
	Total	8	16	5	6	21	4	15	13
Dicrotendipes modestus	I	1	17	13	17	19	32	18	20
	II	6	3	3	4	4	7	2	4
	III	1	0	1	1	1	4	1	2
	IV	0	0	4	7	2	1	1	1
	Total	8	20	21	29	25	44	22	27
Procladius subletei	I	0	0	0	0	1	1	0	1
	II	5	1	1	0	6	1	4	3
	III	1	1	1	0	2	0	0	1
	IV	0	5	1	0	1	1	1	2
	Total	6	7	3	0	10	3	5	7
Tanytarsus sp.	I	20	14	2	3	3	9	20	7
	II	9	15	7	6	17	15	17	13
	III	9	9	6	7	4	5	6	8
	IV	5	2	1	0	11	2	6	5
	Total	43	40	16	16	35	31	49	33
Polypedilum digitifer	I	0	0	0	0	0	0	0	0
	II	0	1	1	0	1	1	0	1
	III	0	0	1	0	1	0	0	0
	IV	0	1	0	0	0	0	0	0
	Total	0	2	2	0	2	1	0	1
Cryptochironomus fulvus	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	III	0	0	0	0	1	0	0	0
	IV	0	0	0	0	0	0	0	0
	Total	0	0	0	0	1	0	0	0
Cricotopus sylvestris	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	III	0	0	0	0	0	1	0	0
	IV	0	0	0	0	0	0	0	0
	Total	0	0	0	0	0	1	0	0
Other Larvae		42	6	0	9	8	8	0	0
TOTAL LARVAE		107	91	47	60	102	92	96	81

Table B.7. Density of chironomid larvae (No. per 31.63 cm^2) living in the sediments on 28 July 1975.

SPECIES	INSTAR	SAMPLES I-1	I-2	II-1	II-2	III-1	III-2	IV-1	IV-2
Chironomus attenuatus	I	0		0	0	0	0	0	0
	II	1		0	0	0	0	0	0
	III	0		0	0	2	0	0	0
	IV	0		0	1	0	0	2	0
	Total	1		0	1	2	0	2	0
Dicrotendipes modestus	I	0		0	0	0	1	1	2
	II	3		4	9	0	2	4	1
	III	0		2	4	1	7	3	1
	IV	1		1	4	0	11	0	2
	Total	4		7	17	1	21	8	6
Procladius subletei	I	0		0	0	0	0	0	0
	II	8		3	1	1	0	2	4
	III	9		1	1	3	7	5	3
	IV	3		4	2	5	6	3	6
	Total	20		8	4	9	13	10	13
Tanytarsus sp.	I	0		2	1	0	1	1	0
	II	5		0	3	2	3	9	2
	III	7		3	10	12	10	8	12
	IV	4		1	13	37	26	4	2
	Total	16		6	27	51	40	22	16
Polypedilum digitifer	I	0		0	0	0	0	0	0
	II	0		0	0	0	0	0	0
	III	0		1	0	1	0	0	0
	IV	0		0	0	0	0	0	0
	Total	0		1	0	1	0	0	0
Cryptochironomus fulvus	I	0		0	0	0	0	0	0
	II	1		0	0	0	0	0	0
	III	0		0	0	1	0	0	1
	IV	0		0	0	0	0	0	0
	Total	1		0	0	1	0	0	1
Cricotopus sylvestris	I	0		0	0	0	0	0	0
	II	0		1	0	0	0	0	0
	III	0		1	0	0	0	1	0
	IV	0		0	0	0	0	0	0
	Total	0		2	0	0	0	1	0
Other Larvae		5		1	4	0	4	6	4
TOTAL LARVAE		47		25	53	65	78	49	40

Table B.8. Density of chironomid larvae (No. per 31.63 cm^2) living in the sediments on 23 August 1975.

SPECIES	INSTAR	SAMPLES I-1	I-2	II-1	II-2	III-1	III-2	IV-1	IV-2
Chironomus attenuatus	I	0	0	0	0	0	0	0	0
	II	0	0	1	0	0	1	0	0
	III	1	3	2	0	2	4	8	2
	IV	1	3	0	0	0	2	12	0
	Total	2	6	3	0	2	7	20	2
Dicrotendipes modestus	I	0	0	0	0	0	1	0	0
	II	3	0	0	1	2	0	8	8
	III	0	3	0	0	0	0	10	5
	IV	0	1	0	0	0	0	1	2
	Total	3	4	0	1	2	1	19	15
Procladius subletei	I	0	2	4	0	3	6	0	0
	II	9	5	13	1	6	7	12	0
	III	1	2	3	2	1	8	6	0
	IV	7	2	3	2	0	1	5	0
	Total	17	11	23	5	10	22	23	0
Tanytarsus sp.	I	0	0	0	0	0	1	0	0
	II	0	0	1	2	0	4	0	0
	III	3	1	1	1	0	3	0	1
	IV	3	2	0	1	0	2	5	0
	Total	6	3	2	4	0	10	5	1
Polypedilum digitifer	I	0	0	0	0	0	0	0	0
	II	1	0	0	0	0	0	0	0
	III	0	0	0	0	0	1	0	0
	IV	1	0	0	0	0	0	0	0
	Total	2	0	0	0	0	1	0	0
Cryptochironomus fulvus	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	III	0	0	0	0	1	0	0	0
	IV	0	0	0	0	1	1	0	0
	Total	0	0	0	0	2	1	0	0
Cricotopus sylvestris	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	2	0
	III	0	0	0	0	2	0	2	0
	IV	0	0	0	0	0	0	0	0
	Total	0	0	0	0	2	0	4	0
Other Larvae		1	2	2	1	0	2	18	6
TOTAL LARVAE		31	26	30	11	18	44	89	24

Table B.9. Density of chironomid larvae (No. per 31.63 cm^2) living in the sediments on 22 September 1975.

SPECIES	INSTAR	SAMPLES I-1	I-2	II-1	II-2	III-1	III-2	IV-1	IV-2
Chironomus attenuatus	I	0	0	0	0	0	0	0	0
	II	0	1	0	0	19	0	2	0
	III	6	2	0	1	28	0	1	3
	IV	2	6	5	10	20	2	10	2
	Total	8	9	5	11	67	2	13	5
Dicrotendipes modestus	I	0	0	0	0	0	0	3	5
	II	1	0	0	4	2	5	10	1
	III	0	0	2	3	3	6	4	1
	IV	0	0	0	1	0	2	0	0
	Total	1	0	2	8	5	13	17	7
Procladius subletei	I	0	0	0	0	7	0	0	0
	II	4	2	2	13	22	0	16	5
	III	1	0	0	1	5	7	1	1
	IV	0	0	1	2	1	0	0	1
	Total	5	2	3	16	35	7	17	7
Tanytarsus sp.	I	0	0	1	1	0	0	0	0
	II	0	1	1	2	1	0	1	1
	III	0	0	0	2	5	0	1	0
	IV	1	1	2	11	10	1	0	2
	Total	1	2	4	16	16	1	2	3
Polypedilum digitifer	I	0	0	0	0	0	0	0	0
	II	0	0	1	0	0	1	1	0
	III	0	0	0	0	0	0	0	1
	IV	0	0	0	0	0	0	0	0
	Total	0	0	1	0	0	1	1	1
Cryptochironomus fulvus	I	0	0	0	0	0	0	0	0
	II	1	0	0	0	0	0	1	0
	III	0	0	1	0	0	0	0	0
	IV	0	0	1	0	0	0	0	0
	Total	1	0	2	0	0	0	1	0
Cricotopus sylvestris	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	III	0	0	0	0	1	0	0	0
	IV	0	0	0	0	0	0	0	0
	Total	0	0	0	0	1	0	0	0
Other Larvae		1	1	0	0	3	0	4	2
TOTAL LARVAE		17	14	17	51	128	24	55	25

Table B.10. Density of chironomid larvae (No. per 31.63 cm^2) living in the sediments on 31 October 1975.

SPECIES	INSTAR	SAMPLES I-1	I-2	II-1	II-2	III-1	III-2	IV-1	IV-2
Chironomus attenuatus	I	0	0	0	0	0	0	0	0
	II	0	1	1	0	1	2	0	0
	III	2	7	1	2	3	1	2	5
	IV	7	8	4	11	8	8	10	6
	Total	9	16	6	13	12	11	12	11
Dicrotendipes modestus	I	0	0	0	1	0	0	0	1
	II	0	5	3	5	2	0	1	1
	III	3	67	2	3	14	11	7	7
	IV	1	10	1	0	3	3	1	2
	Total	4	82	6	9	19	14	9	11
Procladius subletei	I	0	0	0	0	0	0	0	0
	II	1	5	2	8	3	2	2	2
	III	2	7	1	1	3	1	3	3
	IV	2	0	1	1	1	1	4	0
	Total	5	12	4	10	7	4	9	5
Tanytarsus sp.	I	1	0	1	0	0	0	0	0
	II	3	28	17	13	10	3	5	4
	III	1	8	5	1	3	3	0	0
	IV	0	1	0	1	0	0	0	0
	Total	5	37	23	15	13	6	5	4
Polypedilum digitifer	I	0	0	0	0	0	0	0	0
	II	0	2	1	0	0	0	0	0
	III	6	3	3	4	3	3	0	3
	IV	0	4	0	0	1	0	1	1
	Total	6	9	4	4	4	3	1	4
Cryptochironomus fulvus	I	0	0	0	0	0	2	0	0
	II	0	0	0	1	1	1	2	2
	III	0	1	0	0	0	1	0	0
	IV	3	0	1	0	1	1	2	1
	Total	3	1	1	1	2	5	4	3
Cricotopus sylvestris	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	III	0	0	0	0	0	1	0	0
	IV	0	0	0	0	0	0	0	0
	Total	0	0	0	0	0	1	0	0
Other Larvae		11	11	2	4	0	16	2	2
TOTAL LARVAE		43	168	46	56	57	60	42	40

Table B.11. Density of chironomid larvae (No. per 31.63 cm^2) living in the sediments on 15 December 1975.

SPECIES	INSTAR	SAMPLES I-1	I-2	II-1	II-2	III-1	III-2	IV-1	IV-2
Chironomus attenuatus	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	III	0	0	0	0	0	0	0	0
	IV	4	5	7	4	0	5	6	7
	Total	4	5	7	4	0	5	6	7
Dicrotendipes modestus	I	0	1	0	0	1	0	0	0
	II	1	3	2	7	0	1	0	1
	III	2	0	4	18	10	0	3	4
	IV	0	0	3	4	5	1	0	0
	Total	3	4	9	29	16	2	3	5
Procladius subletei	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	1	0	1
	III	0	0	1	3	2	2	1	1
	IV	0	0	0	3	1	1	0	0
	Total	0	0	1	6	3	4	1	2
Tanytarsus sp.	I	1	0	0	0	0	0	0	0
	II	0	1	2	10	4	4	5	6
	III	0	0	0	2	1	1	0	1
	IV	0	0	0	0	0	1	0	0
	Total	1	1	2	12	5	6	5	7
Polypedilum digitifer	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	1	0	0
	III	1	1	4	1	3	1	1	1
	IV	0	0	0	0	0	0	0	0
	Total	1	1	4	1	3	2	1	1
Cryptochironomus fulvus	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	1	0	0	0
	III	0	0	0	0	0	0	0	0
	IV	0	0	1	1	0	0	0	0
	Total	0	0	1	1	1	0	0	0
Cricotopus sylvestris	I	0	0	0	1	0	0	0	0
	II	1	1	2	3	0	0	0	0
	III	3	6	2	9	3	2	0	1
	IV	0	0	0	0	0	0	0	0
	Total	4	7	4	13	3	2	0	1
Other Larvae		0	0	0	0	4	5	2	2
TOTAL LARVAE		13	18	28	66	35	26	18	25

APPENDIX C

STATISTICAL ANALYSES OF DATA ON CHIRONOMID ABUNDANCE

Table C.1. Statistical analyses of Cricotopus sylvestris abundance in the littoral cove.

A. Abundance in the sediments

Two-way ANOVA on log-transformed data

Source	SS	DF	MS	F
Dates	7.79	10	0.78	15.60*
Sampling areas	0.19	3	0.06	1.20
Interaction	3.28	30	0.11	2.20
Error	2.24	44	0.05	
Total	13.50	87		

*Significant at $\alpha \geq 0.05$.

B. Abundance on Myriophyllum

Two-way ANOVA on log-transformed data

Source	SS	DF	MS	F
Dates	39.31	13	3.02	52.07*
Sampling areas	0.33	3	0.11	1.90
Interaction	3.57	39	0.09	1.55
Error	3.23	56	0.058	
Total	46.44	111		

*Significant at $\alpha \geq 0.05$.

Table C.2. Statistical analyses of Dicrotendipes modestus abundance in the littoral cove.

A. Abundance in the sediments

Two-way ANOVA on log-transformed data

Source	SS	DF	MS	F
Dates	12.30	10	1.23	10.10*
Sampling areas	0.52	3	0.17	1.40
Interaction	8.88	30	0.30	2.46
Error	5.36	44	0.12	
Total	27.06	87		

*Significant at $\alpha \geq 0.05$.

B. Abundance on Myriophyllum

Two-way ANOVA on log-transformed data

Source	SS	DF	MS	F
Dates	37.82	13	2.91	29.52*
Sampling areas	0.84	3	0.28	2.84*
Interaction	5.90	39	0.15	1.52
Error	5.52	56	0.10	
Total	50.08	111		

*Significant at $\alpha \geq 0.05$.

Table C. 3. Statistical analysis of Polypedilum illinoensae abundance in the littoral cove.

A. Abundance on Myriophyllum

Two-way ANOVA on log-transformed data

Source	SS	DF	MS	F
Dates	14.44	13	1.11	8.54*
Sampling areas	1.85	3	0.62	4.77*
Interaction	2.94	39	0.08	0.62
Error	7.16	56	0.13	
Total	26.39	111		

*Significant at $\alpha \geq 0.05$.

Table C. 4. Statistical analysis of Rheotanytarsus abundance in the littoral cove.

A. Abundance on Myriophyllum

Two-way ANOVA on log-transformed data

Source	SS	DF	MS	F
Dates	12.26	13	0.94	11.75*
Sampling areas	0.35	3	0.12	1.50
Interaction	3.22	39	0.08	1.0
Error	4.47	56	0.08	
Total	20.30	111		

*Significant at $\alpha \geq 0.05$.

Table C.5. Statistical analysis of Chironomus attenuatus abundance in the littoral cove.

A. Abundance in sediments

Two-way ANOVA on log-transformed data

Source	SS	DF	MS	F
Dates	5.69	10	0.57	1.78
Sampling areas	0.17	3	0.06	0.19
Interaction	9.45	30	0.32	4.00*
Error	3.43	44	0.08	
Total	18.74	87		

*Significant at $\alpha \geq 0.05$.

Table C.6. Statistical analysis of Tanytarsus abundance in the littoral cove.

A. Abundance in sediments

Two-way ANOVA on log-transformed data

Source	SS	DF	MS	F
Dates	15.23	10	1.52	22.07*
Sampling areas	0.09	3	0.03	0.43
Interaction	3.18	30	0.11	1.57
Error	3.03	44	0.07	
Total	21.53	87		

*Significant at $\alpha \geq 0.05$.

Table C.7. Statistical analysis of Procladius subletei abundance in the littoral cove.

A. Abundance in sediments

Two-way ANOVA on log-transformed data

Source	SS	DF	MS	F
Dates	10.37	10	1.04	8.85*
Sampling areas	0.58	3	0.19	1.62
Interaction	3.72	30	0.12	1.00
Error	5.17	44	0.12	
Total	19.84	87		

*Significant at $\alpha \geq 0.05$.

Table C.8. Statistical analysis of Polypedilum digitifer abundance in the littoral cove.

A. Abundance in sediments

Two-way ANOVA on log-transformed data

Source	SS	DF	MS	F
Dates	6.51	10	0.65	9.29*
Sampling areas	0.99	3	0.33	4.71*
Interaction	1.11	30	0.04	0.57
Error	2.92	44	0.07	
Total	11.53	87		

*Significant at $\alpha \geq 0.05$.