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SECONDARY PRODUCTION OF THE
CHIRONOMIDAE (INSECTA: DIPTERA) IN
A SECTION OF THE OTTAWA RIVER NEAR OTTAWA-
GATINEAU, CANADA

by Thomas A. Clair

Thesis presented to the School of Graduate Studies
in partial fulfillment of the requirements for the
degree of Master of Science in Biology

University of Ottawa,
OTTAWA, CANADA, 1975

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Abstract

A study of the Chironomidae (Insecta:Diptera) larvae was carried out in a 4.8 kilometer section of the Ottawa River near Ottawa-Gatineau during 1973 and 1974 to determine their distribution, abundance and productivity. Nineteen stations were sampled at monthly intervals along three transects in 1973. In 1974, two stations which represented major habitat types as determined through the previous year's sampling, were studied at six day intervals.

The 1973 sampling showed low biomasses of larvae in the large channels and the Quebec shore which was influenced by a pulp mill. The areas with the highest biomasses were the island shores and parts of the Ontario shore.

Intensive sampling in 1974 showed that two species of the genus Polypedilum dominated, one at each site. Production of Chironomids at the Ontario shore site was 539.9 mg./m^2 and at the Kettle Island site, it was 178.2 mg./m^2 . Production to biomass ratios (P/B), were 9.7 at the former site and 8.9 at the latter. The number of generations of these species at each site was 4 and 3 respectively.

Abrégé

L'étude des larves de la famille Chironomidae (Insectes: Diptères) fut poursuivie en 1973-1974 dans une section de la rivière Outaouais près d'Ottawa-Hull. Le but était de constater leur distribution, abondance et productivité. En 1973, dix-neuf sites reportés sur une distance de 4.8 km. furent échantillonnés mensuellement. L'échantillonnage de 1974 se fit aux deux endroits représentant les types d'habitats les plus importants. Ceux-ci ayant été déterminés par l'échantillonnage de l'année précédente.

Les résultats de 1973 démontrent de faibles populations de larves dans les endroits larges du lit de la rivière ainsi qu'à la rive québécoise en aval d'une usine de papier. Les endroits avec les hautes populations étaient situés sur les rives des îles Kettle et Upper Duck et à certains endroits de la rive ontarienne.

L'échantillonnage intensif de 1974 laissa voir deux espèces du genre Polypedilum comme étant dominantes. La production biologique au poste situé à la rive ontarienne fut 539,9 mg/m² et 178,2 mg/m² au poste de l'île Kettle. Les proportions Production/Biomasse furent 9,7 au poste antérieur et 8,9 au dernier des deux. Les nombres de générations de larves s'élevaient à quatre et trois respectivement.

Acknowledgements

I am indebted to many people for their help and collaboration in the preparation of this work, notably Stewart Hamill and Allan Armstrong, for their patience in sorting the field collections, Mrs. Mary Roussel for helping in the identification of difficult larvae, and Drs. D. R. Oliver, M. Dickman, R. Reed and A. S. W. DeFreitas for their suggestions and criticisms of the field study and manuscript.

I also thank my supervisor, Dr. S. U. Qadri, for his financial support, supervision and help in the preparation of my work.

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Introduction

The objective of this study was to calculate the secondary biological production of the Chironomidae (Diptera: Insecta) in a 4.8 kilometer section of the Ottawa River near Ottawa-Gatineau, Canada. This was done in two parts: 1) the area was described in as great a detail as possible in terms of biomass of the larvae as well as in terms of types of habitats; 2) specific areas were sampled intensively in order to give some estimation of production, productivity and life cycles of the larvae. The results of the productivity work were then applied to the descriptive data to give an estimate of overall chironomid production of the study area.

The larvae are a major component of the benthic invertebrates of the Ottawa River, at some sites being the only invertebrates found (Mackie, 1971; Hamil, 1975). They are a major source of food for brown bullheads (Ictalurus nebulosus) (J. Gunn, pers. comm.) and yellow perch (Perca flavescens) (Stobo, 1971) and are thus involved in a major part of the energy transfer in the ecosystem.

The larvae of the Chironomidae species (midges) are all holometabolous, with the egg, larval and pupal stages being aquatic, the adult stage being terrestrial (Oliver, 1971). The only feeding, thus productive stage, is the larval stage. Therefore, all biomass and production effort was focused on the four larval instars.

Midges have great differences amongst themselves in duration of life cycles, in special adaptations, as well as tolerances to various external factors. This can be shown by the large numbers of habitats in which midges are found and also by the great complexity of their taxonomy. Factors which may affect life cycles and life styles of the larvae include: 1) the effect of drift and current on populations (Waters, 1962, Müller, 1974); 2) substrate preference (Iyengar et al, 1963; McLachlan, 1969); 3) the effects of macrophytic vegetation on the larval populations (Egglshaw, 1964; Barber and Kevern, 1973); and 4) larval response to pollution from a paper mill (Hynes, 1960; Curry, 1965). The above factors were thus examined to determine their importance in the Ottawa River.

There has been little work done on large rivers in the past, but recent studies (Waters, 1966; Berrie, 1972; Hynes, 1972; Mann et al, 1972; Thibeault, 1972) have begun to show the complexities of lotic systems and have begun developing methods to deal with the difficult conditions found in river habitats. In particular, Coffman (1973) writes, "Lotic system benthos studies are frequently hindered by inadequate sampling programs, natural history information, and taxonomic literature. With respect to all three factors, the family Chironomidae is often the chief source of difficulties. The high densities of immature stages, generally small sizes, and highly irregular distribution patterns of members of the family have, too

frequently, resulted in its superficial inclusion or total exclusion in ecological studies."

Secondary production is defined as the formation of consumer organisms in a community (Edmondson and Winberg, 1971) or the net accumulation of biomass in consumers, above respiration and excretion (Allen, 1971).

The computation of secondary production has been the subject of an increasing amount of work in recent years. Allen (1951), Neese and Dugdale (1959), Hynes and Coleman (1968), Hamilton (1969) and Mann (1972), have laid the groundwork for the quantitative study of populations of invertebrates in freshwater systems. Kimerle and Anderson (1971), Jonasson (1972), Maitland et al (1972) and Paterson and Walker (1974) have variously modified the above methods to reflect the needs of different types of insect life cycles and habitats. Such modifications are also done in the present study to bring more precision and manageability to the production estimates.

Area

The Ottawa River is part of the St. Lawrence River drainage system, starting at Lac Temiscaming near the Ontario-Quebec border and ending near Montreal. It has a total length of approximately 1113 km. and has a watershed area of about 145,000 square km. (O.W.R.C. Report, 1971).

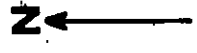
The University of Ottawa-National Research Council of Canada study area has a total length of 4.8 km. and has an approximate width of 1500 meters, and is situated between the city of Ottawa, Ontario and the town of Gatineau, Quebec. Included in this area are Kettle Island and the upper part of Upper Duck Island (Fig. 1).

The depth profile of the study area (Fig. 2) shows a deep mid-channel section and steep inclines from the river side. The substrates (Fig. 3) are predominantly sandy but have clay banks which are found on the Ontario shore. Figure 4 shows the rates of water flow in the main south channel. Hydrological studies (Welch, 1952; Reid, 1961) lead to the belief that similar patterns of flow can be expected in the other channels. Water temperature in 1973-1974 ranged between 0 and 23 degrees Celsius and are shown in Fig. 5. The pH ranged between 6.5 and 7.0.

Further descriptions of the study area can be found in Ottawa River Program Interim Reports no. 1 (1973) and no. 2 (1974).

Figure 1

The Ottawa River study area. The 'x's show the sites sampled in 1973 and the 'o's, the 1974 sites.



QUEBEC

Can. International
Paper Co.

Kettle Island

flow →

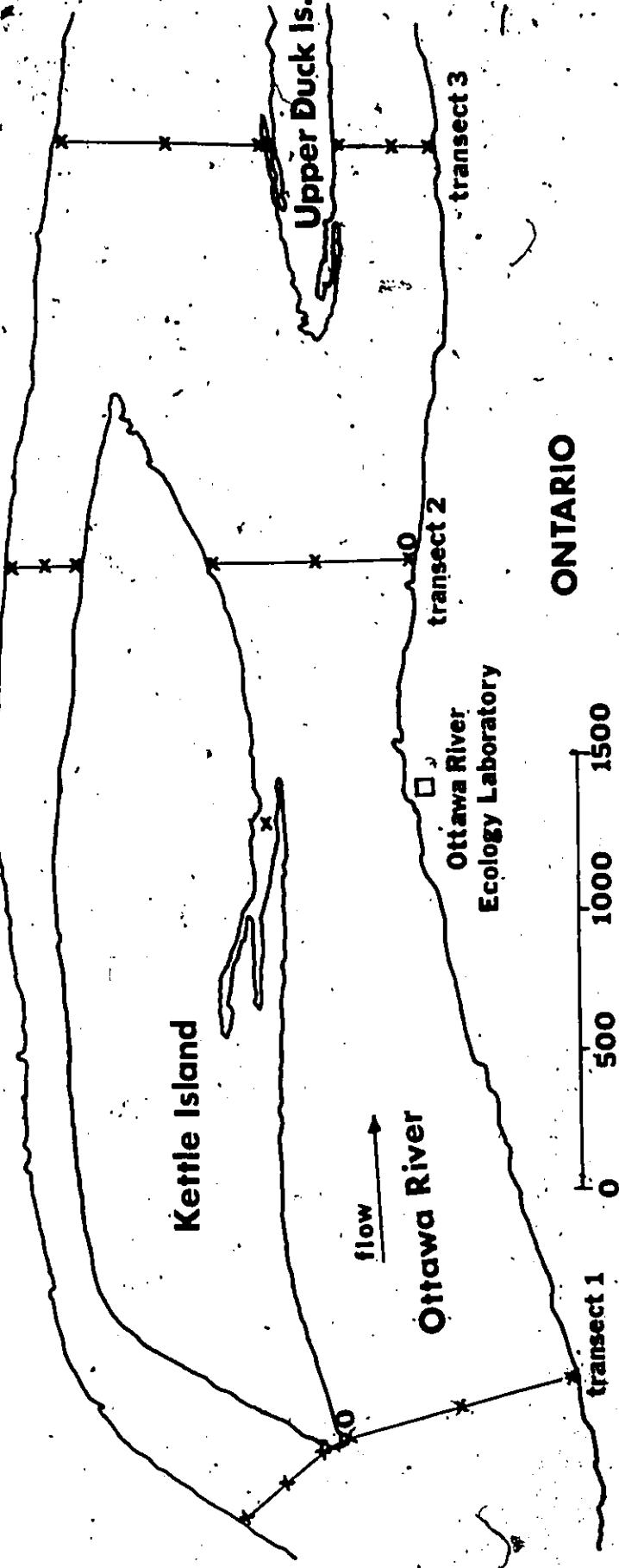
Ottawa River

Ottawa River
Ecology Laboratory

ONTARIO



Meters



Upper Duck Is.

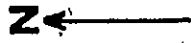
transect 3

transect 2

transect 1

Figure 2

Depth profile of the Ottawa River study area.



QUEBEC

Can. International Paper Co.

Kettle Island

Upper Duck Is.

Ottawa River Ecology Laboratory

ONTARIO

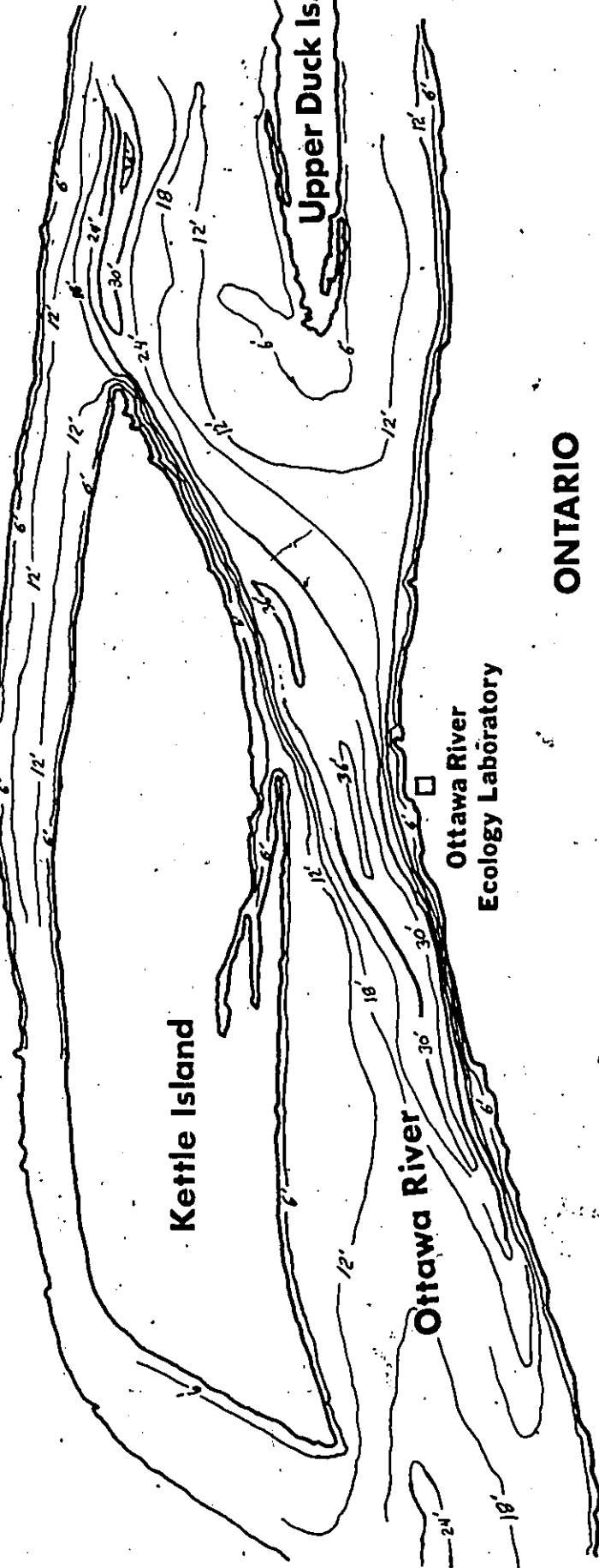


Figure 3

Substrate types of the Ottawa River study area. (Fig. modified from Townsend 1973).



QUEBEC

ONTARIO

Can. International Paper Co.

fine sand and woodchips

wood fibers

Kettle Island

Upper Duck Is.

Ottawa River Ecology Laboratory

medium sand

Ottawa River medium coarse sand

clay

silt & clay

transect 2

transect 3

transect 1

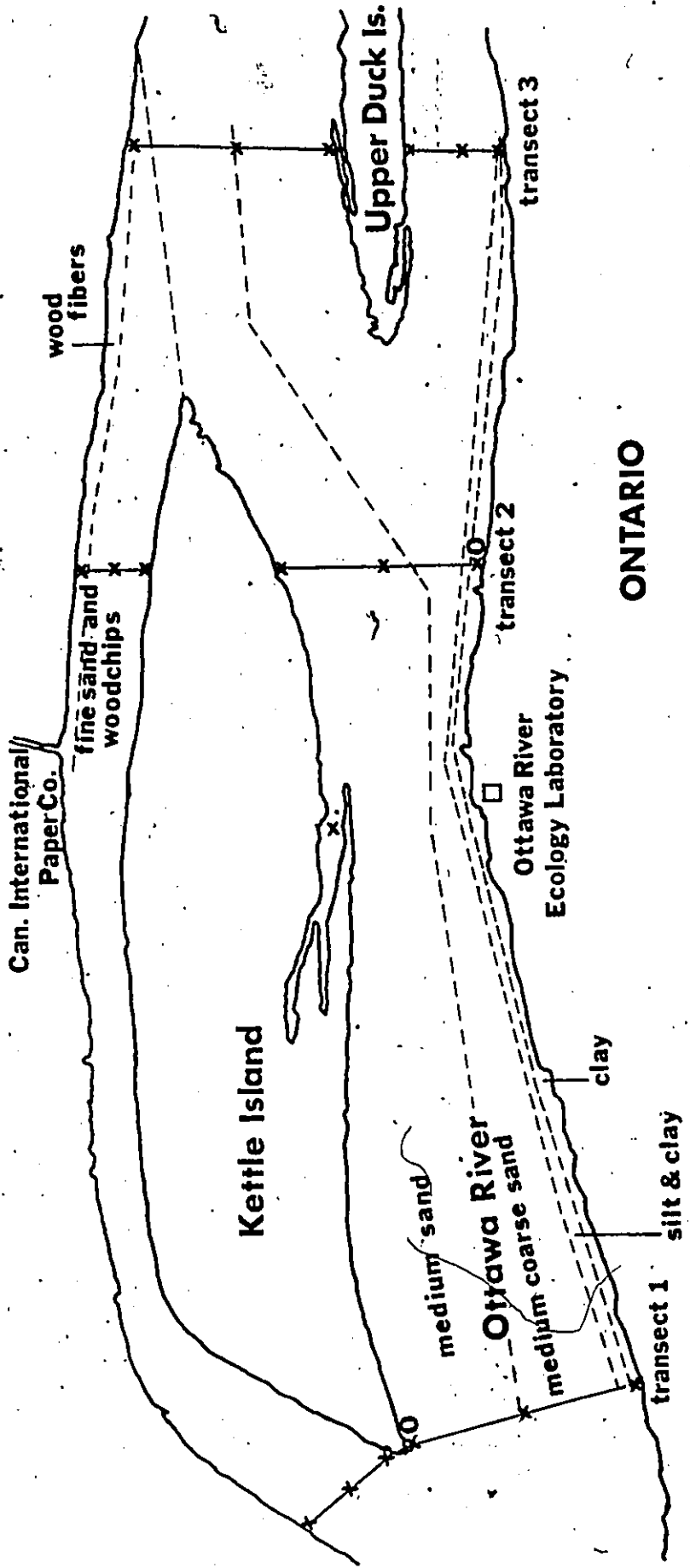


Figure 4

Rates of flow in the main south channel at transect two in July 1972. Similar types of flow patterns can be expected from all the other channels. From Warnock (1974).

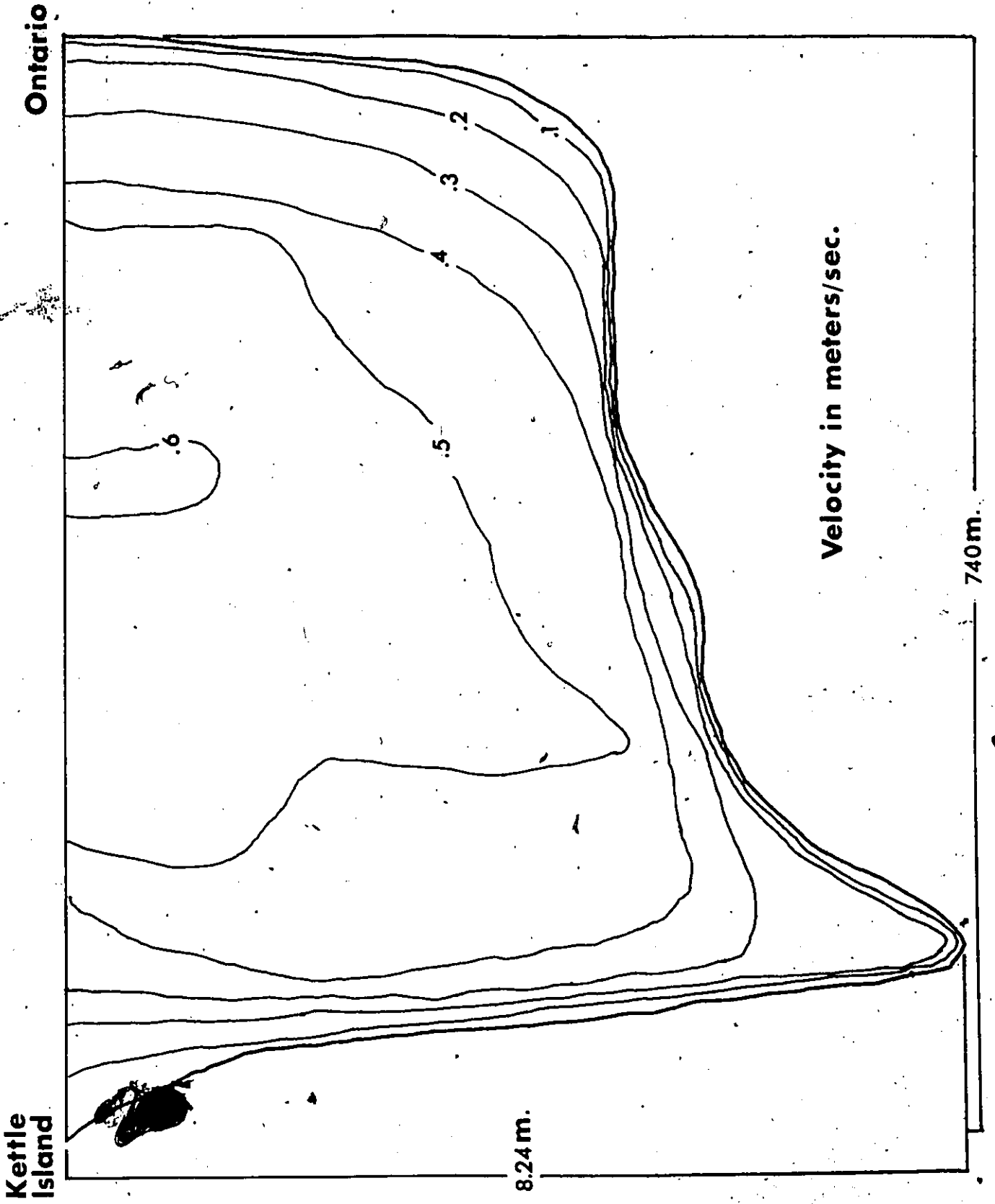
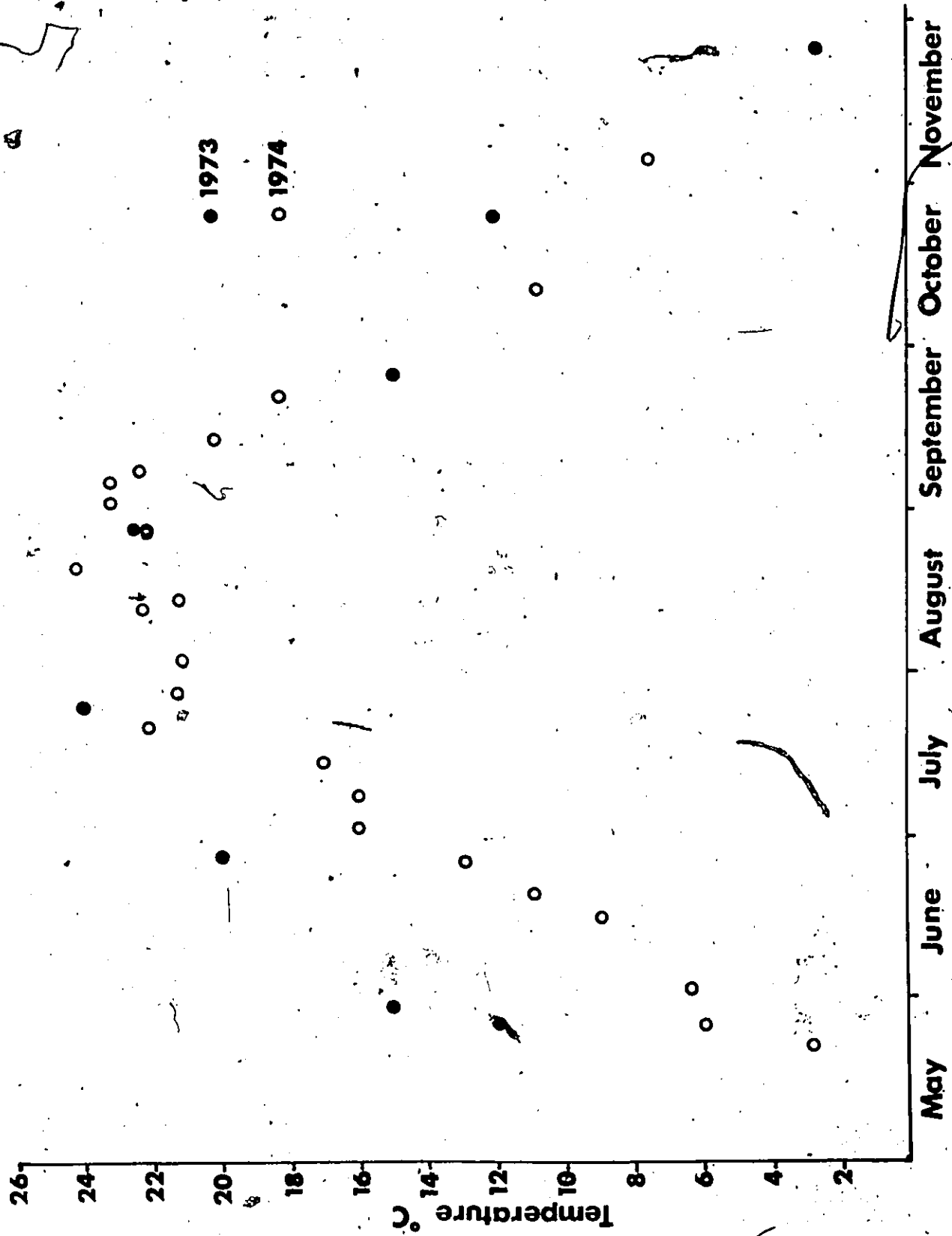


Figure 5

Temperature ranges in the study area during the 1973 and 1974 sampling seasons. Temperatures did not vary between stations on the same sampling days.



Methods

1973

Sampling in 1973 was designed to describe as completely as possible the study area in terms of the distribution of the Chironomidae larvae. To do this, sampling sites were located on three transects which were chosen to cover the major types of habitat in the study area. The transects were numbered starting at the upper tip of Kettle Island, transect one, transect two, and transect three (Fig. 1). On each of these transects, six sampling stations were established: 1) close to the Ontario shore, 2) the mid-south channel, 3) near the south shore of the island, 4) near the north shore of the island, 5) the mid-north channel, and 6) close to the Quebec shore. Another site chosen was Kettle Island Bay.

For this general sampling, the method of Mackie (1971) was used, where three standard $15 \times 15 \times 23 \text{ cm}^3$ Ekman grabs were taken at each of the 19 sampling stations at monthly intervals, lumped and then sieved through a 370 micron mesh. The sieved samples were then sorted by hand without magnification. Further work has shown that the standard error of this technique at transect one, Kettle Island shore, ranged from 33 to 80 percent (%) of the mean.

On the basis of the 1973 data, the study area was divided into zones demarcated on the basis of sampling results

at the 19 stations, substrates, vegetation types, biomasses of larvae, geographical location and in the case of the C.I.P. channel, the presence of a major pollution source. Using one, or a combination of these conditions, the stations were then combined with each other. This done, the stations were extrapolated to encompass the areas between each other to form large zones. The total biomass of their constituent stations were combined and averaged. In this fashion, an estimate for average values of biomass per unit area was produced for large zones. This biomass figure was multiplied by the total area of that particular zone to give total biomasses for the whole study area for 1973.

1974

The 1974 sampling was designed to give accurate quantitative estimates of production, productivity, and life cycles of various species of Chironomidae. Therefore, in 1974, only two stations were studied, these being the south shore of Kettle Island at transect one, and the Ontario shore at transect two. They were chosen because the 1973 sampling showed that these two stations were representative of the major productive zones of the river. Also, they were sampled at six-day intervals in order to discover all the changes in biomass that occurred.

A general rule in establishing precise sampling programs is that the larger the number of samples taken, the better,

regardless of the sample size (Elliot, 1971). Therefore, Ekman grab samples were replaced by 4.8 cm. diameter core samples. The corer was a plexiglass tube which was hand driven into the sediments. The sediments were then extruded and processed.

The number of core samples to be taken was determined using the method of Cassie (1971), where the number of samples to be taken increases in an exponential fashion as the precision needed increases. An arbitrary number of ten core samples were taken at each of the 1974 stations, sieved and sorted separately. The numbers of larvae found were then used in the formula:

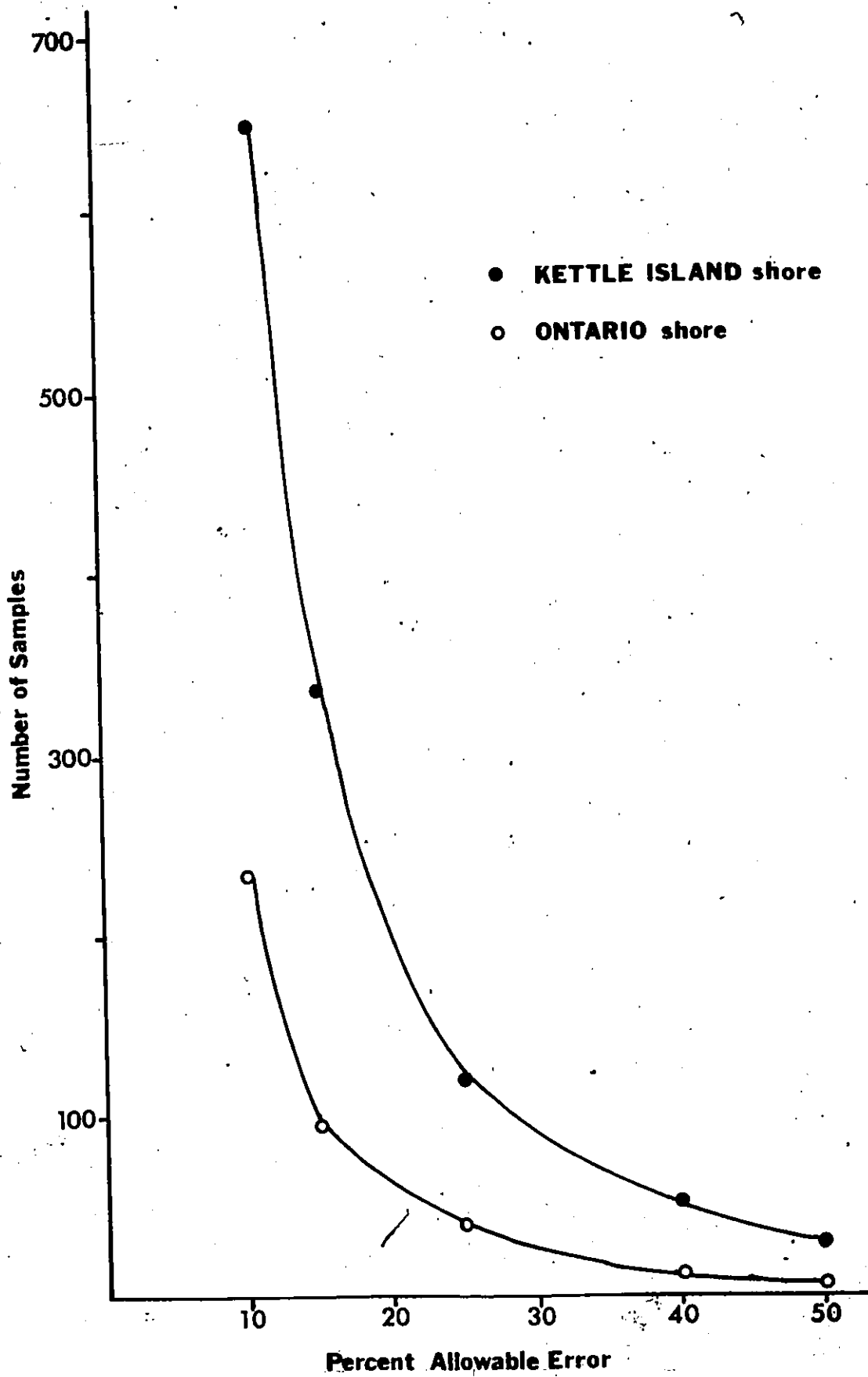
$$N = (t\sigma / L)^2$$

where N is the number of samples, t is the Student's t at the 0.05 probability level, L is the permissible error of the mean, and σ is the standard deviation of the population samples.

Figure 6 shows the ensuing curves when errors of 10, 15, 25, 40 and 50 percent are allowed at both stations. The Kettle Island site seemed to demand a great number of samples for a precision greater than 45% at the 95% confidence level. The Ontario shore station, on transect two, needed fewer samples and 32 core samples were required there for 25% precision. The precision at the Kettle Island site, according to the test

Figure 6

Number of core samples to be taken at the 1974 sampling sites for various levels of precision. The percent allowable error is at the 95% confidence level.



samples was not going to be very high, due to the low numbers of midge larvae found during the test period. During the following sampling dates, however, greater numbers of larvae were found at the site which would decrease the standard deviation of the samples, and thus decrease the number of samples needed for adequate precision.

Sorting was done by hand, without magnification for two reasons. First, preliminary work using flotation methods gave unsatisfactory results, as sorting of the sediments afterwards revealed a large number of larvae still clinging to detritus. In Kettle Island sediments, the larvae of Polypedilum were very visible against the white sand and sorting presented few problems. Sorting through the more difficult Ontario shore sediments was done very carefully to minimize the chances of missing larvae.

For all the sampling dates after the test sampling, except for November, the 32 core samples taken at each station were combined for manageable handling and sorted by hand. In November, the 32 core samples were taken from each station, sieved and sorted separately and the mean, standard error, and confidence limits calculated. Results showed precisions of 27% at the Ontario shore and 25% at the Kettle Island site. The high precision at the Kettle Island site, compared to the early spring sampling, is explained by the higher numbers of

larvae found at that site at the sampling date, thus improving the odds that a more even distribution of larvae will occur.

The 1973 work also revealed the lack of the smaller first and second instar larvae of the Chironomidae in the samples. In an attempt to find them, sieving in 1974 was done through a 200 micron mesh, as suggested by Jonasson (1958). The instar stages were determined using the method of Ford (1959) and McCauley (1974) of measuring headcapsule widths and plotting them against numbers. Since the different instar stages have different average weights, finding the instar stage allowed a rapid estimation of weights of individuals once the larvae had been classified as belonging to a particular instar.

Samples taken in the spring and early summer were sorted, identified to genus, and weighed. The live larvae were then dried at 60 degree Celcius for 24 hours to find dry weights. (Table 1). Identification of the summer and early fall samples was not done until the fall, so that the average weights for the spring and early summer were applied to the remaining preserved samples. Though the percent water content of the larvae varies during the year in some studies (Paterson and Walker, 1974; Jonasson, 1972), an average factor of .202 wet weight to dry weight was calculated for the larvae and no

TABLE 1

Average individual weights of various instar stages for the genus Polypedilum found in the spring and early summer of 1974. The values are in milligrams dry weight. Approximately 200 larvae were used in each measurement.

	Weights (mg.)	
	3rd instar	4th instar
<u>Polypedilum</u>		
Ontario shore	.032±.002 S.E.	.094±.014
Kettle Island shore	.028±.006 S.E.	.114±.014



statistically significant differences from this mean were found using a t-test, in either winter, spring or summer. All weights are reported on a dry weight basis.

Computations of secondary production can be done following various authors (Winberg, 1971; Hamilton, 1969; Neese and Dugdale, 1959). The method used usually varies with the rates of change in the population structure and the type of habitat studied. In a rapidly changing population, a graphic (Allen, 1951; Winberg, 1971) rather than an algebraic method (Hamilton, 1969; Fager, 1969) is used. The method used here is a modified type of Allen curve, the Boysen-Jensen method (Mann, 1969; Edmondson, 1974). In this method, the change in the numbers of individuals in a cohort is plotted against the average weight of one individual of that cohort. The area under the line or curve formed is a measure of production. This can also be expressed as:

$$P_{ij} = 1/2 (N_i + N_j) (W_j - W_i)$$

where N_i , W_i , N_j , and W_j are the estimated mean densities and individual weights at times T_i and T_j respectively

(Charles et al., 1974).

Since there were very rapid changes in the midge populations, the average weights of an individual at a certain time was substituted by the average weight of an individual at a certain instar stage. This method of processing allowed for more accurate production estimates in the summer when samples could not be processed. The greater accuracy occurred

because preserved samples lose a large proportion of their weight when in preservatives (Howmiller, 1972; Dermott and Paterson, 1973). Weighing the preserved samples would then lead to an underestimate of the larval biomass.

Although second instars were found, their numbers were not sufficiently large to be used in production estimates, as sampling was not adequate for that group. Thus there were fewer second instars than third found for the same cohort. The use of these second instars in an Allen curve would then change the curve from a decreasing exponential as for a normal population, to a bell-type form. Since the area under the curve is a measure of production, it can be seen that the exclusion of second instars from the calculations would give a larger and thus more accurate estimate of production of the cohort (Fig. 7 a & b).

Thus, at each generation or cohort, the maximum number of larvae of each instar is used in the Boysen-Jensen method previously described. In cases where more fourth than third instars were found, the standing crop biomass of the fourth instars was used as a measure of total production for the same reason as for the exclusion of the second instars. Production was measured for every cohort of the species studied and these added up to give total production of each species at each station.

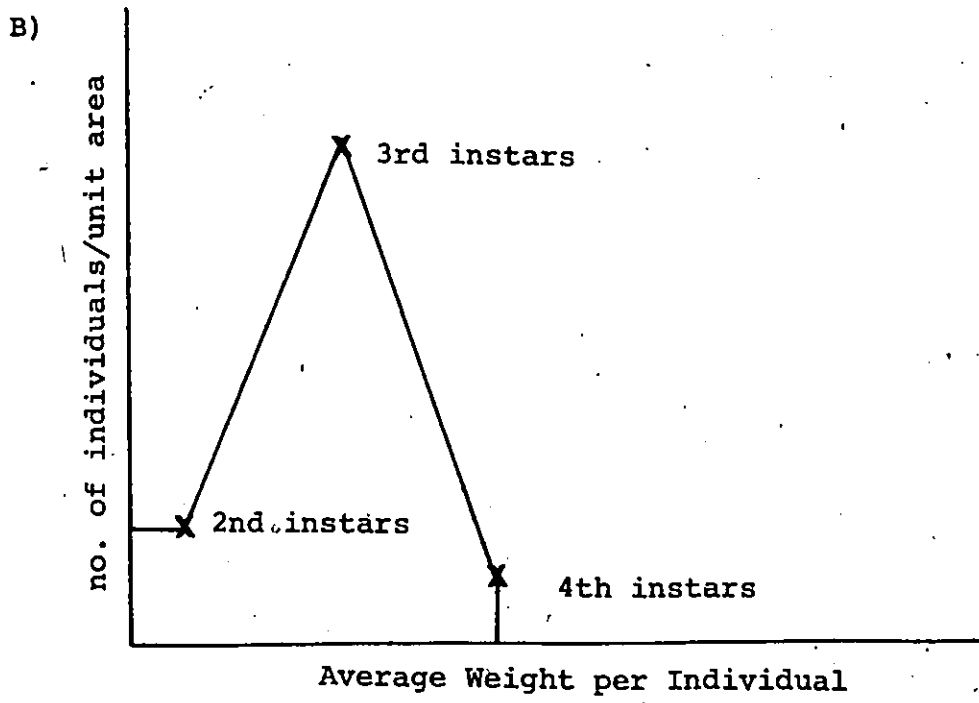
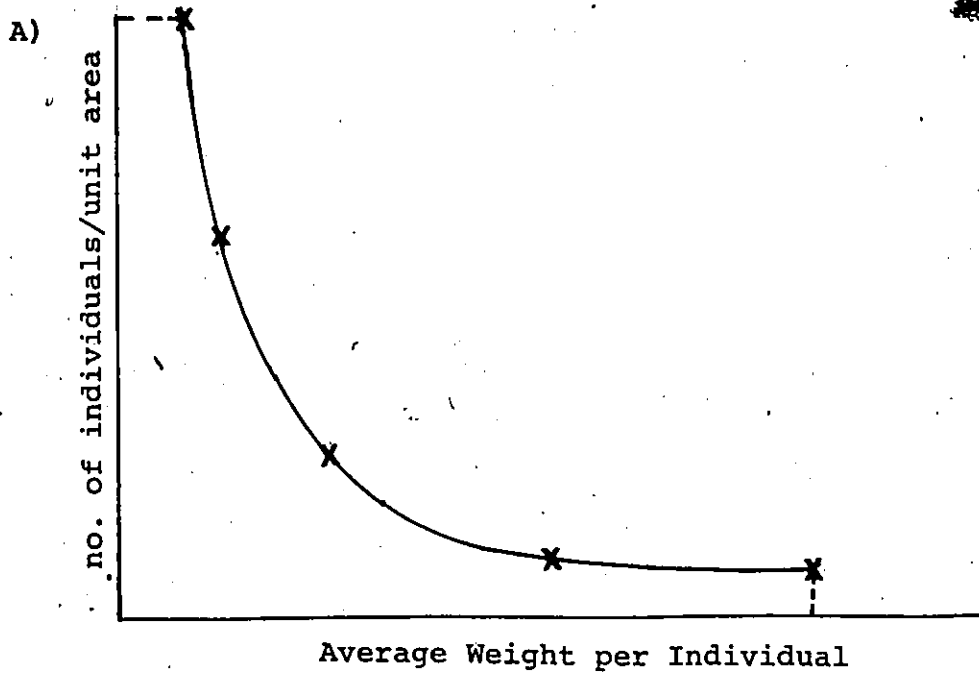
Productivity was measured by the method of Winberg. (1971)

Figure 7a

Generalized relationship between mean larval weight and cohort size of an ideal population.

Figure 7b

Production curve of a sampled population showing the effect of including 2nd instar numbers when these are less than the 3rd instar numbers.



where production (P) is divided by the average biomass (B). The resulting ratio is a measure of the rate of production in a population. A modification of this idea is the Turnover Ratio (T.R.) (Waters, 1969), where P/B is measured strictly for one cohort during its life cycle. This method gives more information in describing particular cohorts, but in the case of overlapping cohorts, or species with very long emergence periods, it cannot be applied due to confusion in interpreting the numbers found.

Once computed, the average of the P/B ratios for the two stations was then multiplied with the total biomass values for the different zones from 1973. These were then summed to give an estimate of total production of the Chironomidae in the 4.8 km. section of the Ottawa River under study.

For both 1973 and 1974, the larvae found were identified using Mason (1968), Bryce and Hobart (1972) and Oliver (unpub. manus.).

Results

1973

Tables 2, 3 and 4 present the results for the 19 stations sampled in 1973. The physical and chemical data for those sites are shown in Table 5.

The almost total lack of larvae in the sandy, mid-channel sites (transects one and two, mid-south channel and transect three, mid-north channel) should be noted. Average standing crop biomasses for these stations ranged from 0.8 to 10.1 mg./m², with the largest numbers of larvae being found in the spring, and with very few in the summer.

The channel between Kettle Island and the Québec shore below the Canadian International Paper mill seemed to be greatly affected by its effluents. The four stations in this area were: transects two and three, Québec shore; transect two, mid-north channel; and transect two, north shore of Kettle Island.

As shown by Table 5, substrate types were varied in this section of the river, but low biomasses were evident throughout. There is a plume coming from the mill which is composed to a large extent of wood fibers which settle along the shore and thus constitute a major part of the substrate. This, along with the increased turbidity and B.O.D. (Table 6), probably have a major effect on the benthic fauna. The Québec shore stations had low average biomasses of 8.1 mg./m² at

TABLE 2

Numbers / m² (Parentheses) and standing crop biomass in mg./m² (dry weight) of Chironomidae for 1973 on transect 1.

	Ontario shore	mid-south channel	south is. shore	north is. shore	mid-north channel	Québec shore
January	--	2.8 (59)	--	375.7 (3,063)	--	179.8 (1,347)
February	--	20.2 (385)	--	367.6 (4,128)	--	92.9 (148)
March	--	0 (0)	--	680.7 (5,298)	--	272.7 (710)
April	12.1 (50)	0 (0)	48.7 (206)	2.0 (488)	6.1 (30)	--
May	66.7 (443)	1.4 (15)	20.0 (59)	99.0 (329)	23.0 (118)	11.9 (103)
June	23.4 (103)	0 (0)	88.9 (310)	26.3 (88)	16.8 (148)	137.4 (562)
July	1.8 (29)	0 (0)	17.6 (138)	0 (0)	16.4 (133)	11.5 (103)
August	545.4 (3,128)	0 (0)	37.4 (622)	66.7 (1,080)	11.9 (118)	99.0 (902)
September	84.8 (1,768)	--	25.7 (340)	444.4 (4,765)	19.2 (384)	1.2 (15)
October	84.8 (439)	--	54.5 (747)	258.6 (3,018)	66.7 (542)	157.6 (788)
November	204.0 (2,051)	--	2.0 (103)	163.6 (1,919)	111.1 (1,201)	--
Average	127.3	4.0	36.4	226.2	34.3	107.1

(--) no sample taken

TABLE 3

Numbers / m² (parentheses) and standing crop biomass in mg./m² (dry weight) of Chironomidae for 1973 on transect 2.

	Ontario shore	mid-south channel	south is. shore	north is. shore	mid-north channel	Québec shore
January	--	4.0	--	--	--	8.0 (29)
February	--	--	--	--	--	0 (0)
March	--	--	--	20.7 (74)	--	0 (0)
April	62.6 (296)	--	161.6 (1,465)	0	117.2 (1,125)	--
May	139.4 (266)	44.6 (74)	5.9 (163)	0	49.5 (236)	34.3 (88)
June	149.5 (1,569)	2.0 (15)	8.9 (133)	46.1 (133)	44.4 (148)	1.8 (44)
July	5.3 (133)	0 (0)	250.5 (1,021)	0	1.0 (29)	0 (0)
August	78.8 (769)	--	595.9 (947)	0	16.2 (222)	0 (0)
September	113.1 (1,893)	--	82.8 (2,738)	0	13.9 (266)	--
October	284.8 (4,101)	--	62.6 (674)	--	--	--
November	80.8 (850)	--	22.2 (307)	--	6.4 (30)	--
Average	115.1	10.1	155.5	10.1	36.4	8.0

(--) no sample taken

TABLE 4

Numbers / m² (parentheses) and standing crop biomass in mg./m² (dry weight) of Chironomidae for 1973 on transect 3 and Kettle Island Bay.

	Ontario shore	mid-south channel	south is. shore	north is. shore	mid-north channel	Québec shore	Kettle Is. Bay
January	--	2.0 (74)	--	--	--	0.0 (0)	--
February	--	14.1 (162)	--	22.4 (310)	--	0.0 (0)	--
March	--	2.9 (207)	--	474.7 (1,805)	--	38.4 (30)	--
April	187.9 (385)	2.0 (118)	1313.0 (2,768)	--	0.0 (0)	--	187.9 (385)
May	363.6 (1,008)	5.8 (59)	78.8 (962)	274.7 (740)	4.4 (15)	169.7 (1,760)	363.6 (1,008)
June	25.3 (44)	0 (0)	48.5 (1,580)	97.0 (710)	0.0 (0)	5.9 (29)	25.3 (44)
July	3.8 (29)	0 (0)	32.5 (118)	34.3 (510)	0.0 (0)	2.4 (74)	0.0 (0)
August	44.4 (236)	2.0 (44)	383.8 (1,717)	155.5 (1,909)	0.0 (0)	0.0 (0)	119.2 (636)
September	5.9 (103)	--	195.9 (2,812)	244.4 (5,564)	--	--	--
October	--	--	286.8 (1,669)	1480.7 (22,608)	--	--	--
November	--	--	38.4 (644)	1028.2 (14,652)	--	--	--
Average	46.5	4.0	296.9	424.2	21.0	30.3	119.2

(--)
No sample taken

Table 5

Depth of water during the summer, sediment type, particle size and percent (%) ash-free dry weight for the stations sampled in 1973.

Location	Depth (in meters)	Sediment type	Particle * size (φ)	% ash-free dry weight
main mid-channels	5.4-9.0	sand	1.33	0
Quebec shore Transects 2 and 3	1.5-2.0	wood fibers and silt	-	27.0
Transect two mid-north channel	3.0-4.0	sandy with wood chips	2.65	7.5
Transect two, north island shore	1.0-1.5	sandy and detritus	2.65	20.0
Kettle and Upper Duck Island shores	1.0-2.5	sand	3.95-2.00	0.29-8.0
Quebec shore above C.I.P.	1.0-2.0	sand	5.10	-
Transect one, mid- north channel	2.5-3.0	sand	2.62	-
Transect one Ontario shore	1.5-2.0	clay	8.86	0.25-1.71
Transect two Ontario shore	1.5-2.0	clay and sand	4.54	15.5
Transect three Ontario shore	1.0-1.5	clay and sand	6.22-5.0	-
Kettle Bay	2.5-3.0	detritus	-	-

(-) not measured. * Rust 1974 Nordstrom and Bronstein 1974

Table 6

Values of some chemical factors for stations in the C.I.P. channel (compared to transect one, mid-south channel (from Stobo, 1971). Averages and ranges of both surface (S) and bottom (B) samples are given.

Station	Dissolved O ₂	Dissolved CO ₂	5-day B.O.D.	Phenols (ppb)	Iron (ppm)	Sulphate (ppm)
Transect 1 mid-south channel	S 8.9	7.3	0.9	4.9	0.40	10.7
	7.5-11.0	5.0-15.0	0.3-2.0	0-15.0	0.22-0.60	5-16
Transect 2 Quebec shore	B 8.7	5.4	1.0	4.0	0.65	11.6
	7.0-11.0	3.0-10.0	0.3-1.8	0-8.0	0.23-3.65	5-17
mid-north channel	S 8.3	7.5	2.7	23.0	0.47	10
	7.0-9.0	5.0-10.0	1.8-3.2	2.0-60.0	0.38-0.59	8-12
Kettle Island shore	B 8.5	6.9	1.7	8.5	0.44	9
	7.0-10.0	5.0-10.0	1.0-2.0	0.0-20.0	0.23-0.63	6-13
Transect 1 mid-south channel	S 9.0	6.0	0.9	5.0	0.55	12
	8.0-10.0	5.0-8.0	0.6-1.3	4.0-6.0	0.54-0.56	10-13
Transect 2 Quebec shore	B 10.0	5.5	1.2	16.5	0.51	12
	10.0-10.0	5.0-6.0	0.9-1.4	3.0-30.0	0.42-0.62	12-13
Kettle Island shore	S 8.5	7.5	1.0	4.5	0.42	11
	7.0-11.0	5.0-10.0	0.5-1.6	0-8.0	0.32-0.50	12-20
Transect 1 mid-south channel	B 8.4	7.5	1.0	6.0	0.32	13
	7.0-11.0	5.0-10.0	0.7-1.6	2.0-12.0	0.27-0.40	11-17

transect two and 30.3 mg./m² at transect three. Transect two, mid-north channel, had a mean biomass of 36.4 mg./m² while the Kettle Island site averaged 10.1 mg./m². The biomass of all these stations decreased to zero as the summer progressed.

The littoral zones of Kettle and Upper Duck Islands at the sampling sites had similar compositions except for transect two, north shore of the island, described above, and transect three, north shore of the island which was a sheltered bay and contained a large population of Tanytarsus sp. found nowhere else.

The sites supported macrophytic vegetation in large quantities (Erickson, 1974). The average biomasses for these stations ranged from 36.4 to 296.9 mg/m². This area is very important to the Ottawa River Project, as the macrophytic vegetation shelters large populations of fish such as, brown bullheads, Ictalurus nebulosus (Rubec, 1975); pumpkinseed, Lepomis gibbosus; yellow perch, Perca flavescens; and many other species of Cyprinidae (Qadri and Coad, 1974), which would affect the local populations of chironomid larvae.

The Quebec shore above the C.I.P. resembled the Kettle Island shore and produced an average biomass of 107.1 mg./m².

The mid-channel station between the Québec and Kettle Island shores on transect one, had a slower current than the other channels (Warnock, 1974). Also, there was submerged

vegetation at this site, as revealed by the grab samples. This station had an average biomass of 34.3 mg/m^2 .

The three Ontario shore stations revealed three different types of substrates varying from clay at transect one, silt at transect two, and a combination of both at transect three (Table 5 and Fig. 3). Transect one had an average biomass of 127.3 mg./m^2 , transect two, with overhanging vegetation had 115.1 mg./m^2 , and transect three, which was under erosional stress from the river bank, had an average biomass of 46.5 mg./m^2 .

The Kettle Island Bay station had an average biomass of 119.2 mg./m^2 .

Subdivision of the study area

The largest area is obviously the mid-channel section which covers 311.4 hectares (Table 7). However, the average biomasses per m^2 found were the lowest of any other zone. This was probably due to the low detritus levels found in the substrate, the fast current in the mid-channels (Fig. 4) and the movement of sand dunes underwater (Rust and Waslenchuk, 1974) which would prevent the colonization of the habitat even for short periods of time.

The Québec shore below the C.I.P. is also an area where a low biomass was found. This area was also probably greatly affected by the effluent chemicals from the mill which are shown in Table 6. The chemicals monitored follow the shore

Table 7

Average and total biomass of the chironomid fauna in the study area.

Location	Area (hectares)	Average biomass (mg/m ²)	Total biomass (kg.)
Deep channel	311.399	23	72
Channel above C.I.P.	39.158	170	67
Kettle and Upper Duck Island shore	30.671	880	270
Québec shore above C.I.P.	9.565	530	51
Total Channel below C.I.P.	54.687	100	55
Upper Ontario shore	6.468	620	40
Mid Ontario shore	4.966	570	28
Lower Ontario shore	2.079	230	5
Kettle Bay	5.00	590	30

line for a longer distance than at the mid-stream areas, thus having a greater effect there. The biomass at these sites were the lowest in the summer and fall when the effects of the pollutants are greater (Cairns et al., 1974), a trend which was also repeatedly noticed during sorting in the laboratory. The effects of drift during the spring runoff might also contribute to the presence of larger spring populations.

The island shore stations were treated as a unit, except for transect two and transect three, the north shores of Kettle and Upper Duck Islands, because the substrate and vegetation types greatly resembled each other. These stations showed large variations in biomass amongst themselves over the sampling period, but treatment with the Kruskal-Wallis non-parametric test for differences in mean level between several samples showed that the biomass at these stations resembled each other enough to assume that they all belonged to the same population. The transect three, north shore of Upper Duck Island site was not included in the calculations as a large population of Tanytarsus sp. was found there but nowhere else.

The other zones studied were, the Québec shore above C.I.P., the north channel on transect one, and the three zones found on the Ontario shore. These are all shown in Fig. 8.

Figure 8

Various zones of the study area as indicated by benthic sampling in 1973.

- 1 - Main channels
- 2 - C.I.P. channel
- 3 - island shores
- 4 - Québec shore above C.I.P.
- 5 - north channel above C.I.P.
- 6 - upper Ontario shore
- 7 - mid Ontario shore
- 8 - lower Ontario shore

x - sampled in 1973

o - sampled in 1974



QUEBEC

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Kettle Island

flow →

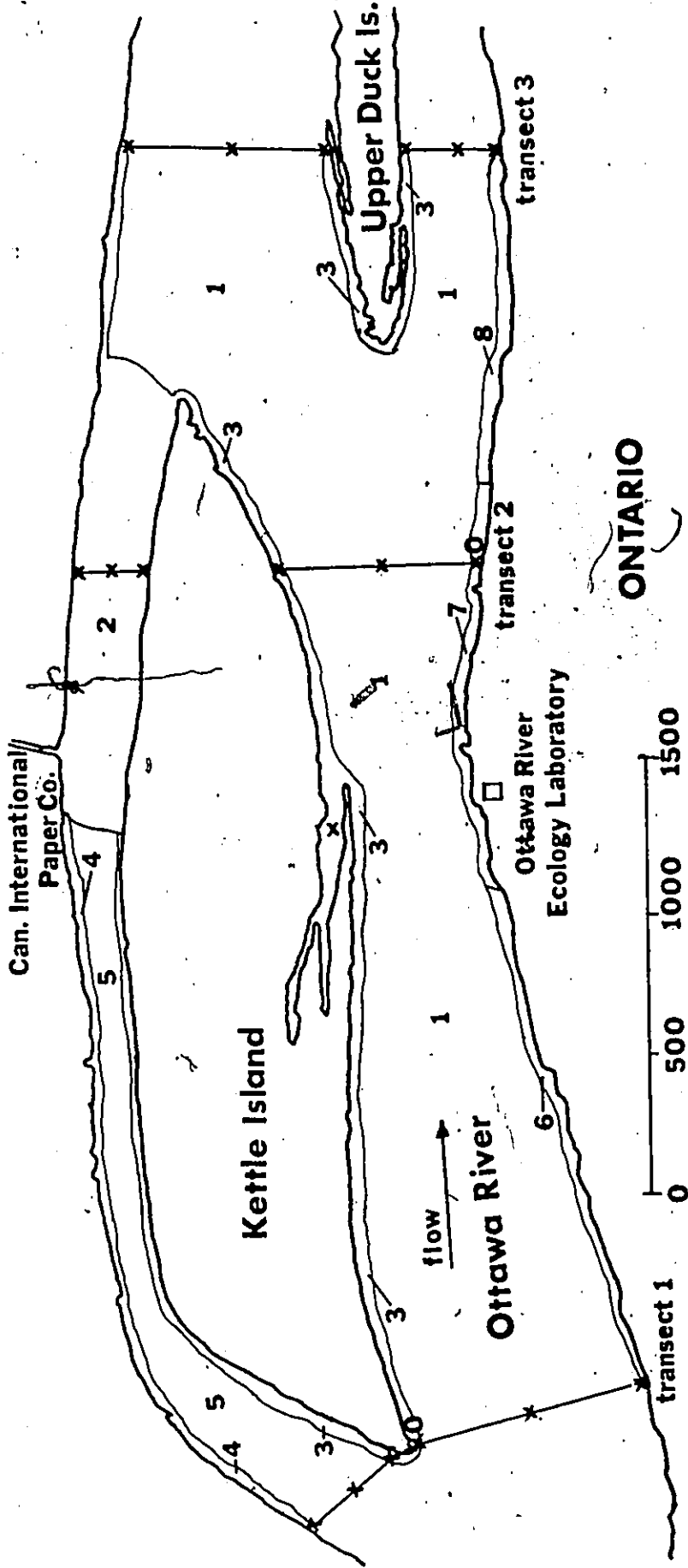
Ottawa River

Ottawa River Ecology Laboratory

ONTARIO



Meters



1974

Sampling results showed that the only genus found in numbers large enough for production studies was the genus Polypedilum. Headcapsule analysis of this genus are shown in Fig. 9 and 10 for the Ontario shore and for the Kettle Island stations respectively. This means that two species of Polypedilum were found, one at each station. They will now be called, sp. A, at the Ontario shore site, and species B at the Kettle Island site. The average weights of the fourth instars suggest this also, even though there are no significant differences between the two (Table 1).

In order to follow the life cycles of the cohorts of Polypedilum, the percent composition of each instar stage of the larvae in relation to the other instar stages is shown for both stations (Fig. 11 and 12). It is also shown by the headcapsule analysis that the first instar larvae were not found in the samples, so that only the second, third and fourth instars are recorded. The lack of the first instars was probably due to a loss in sieving, or to their pelagic nature and thus not sampled by our methods. This analysis will allow us, then, to follow the presence of various instar stages, to find out when they change from one stage to another, and thus give a better idea of life cycle duration.

It can be seen that peaks in second instars are usually followed by peaks of third and then, fourth. Soon after

Figure 9

Headcapsule widths of Polypedilum sp. A at the Ontario shore station for 1974. Widths are in eyepiece micrometer units.

Polypedilum sp. A
Ontario shore

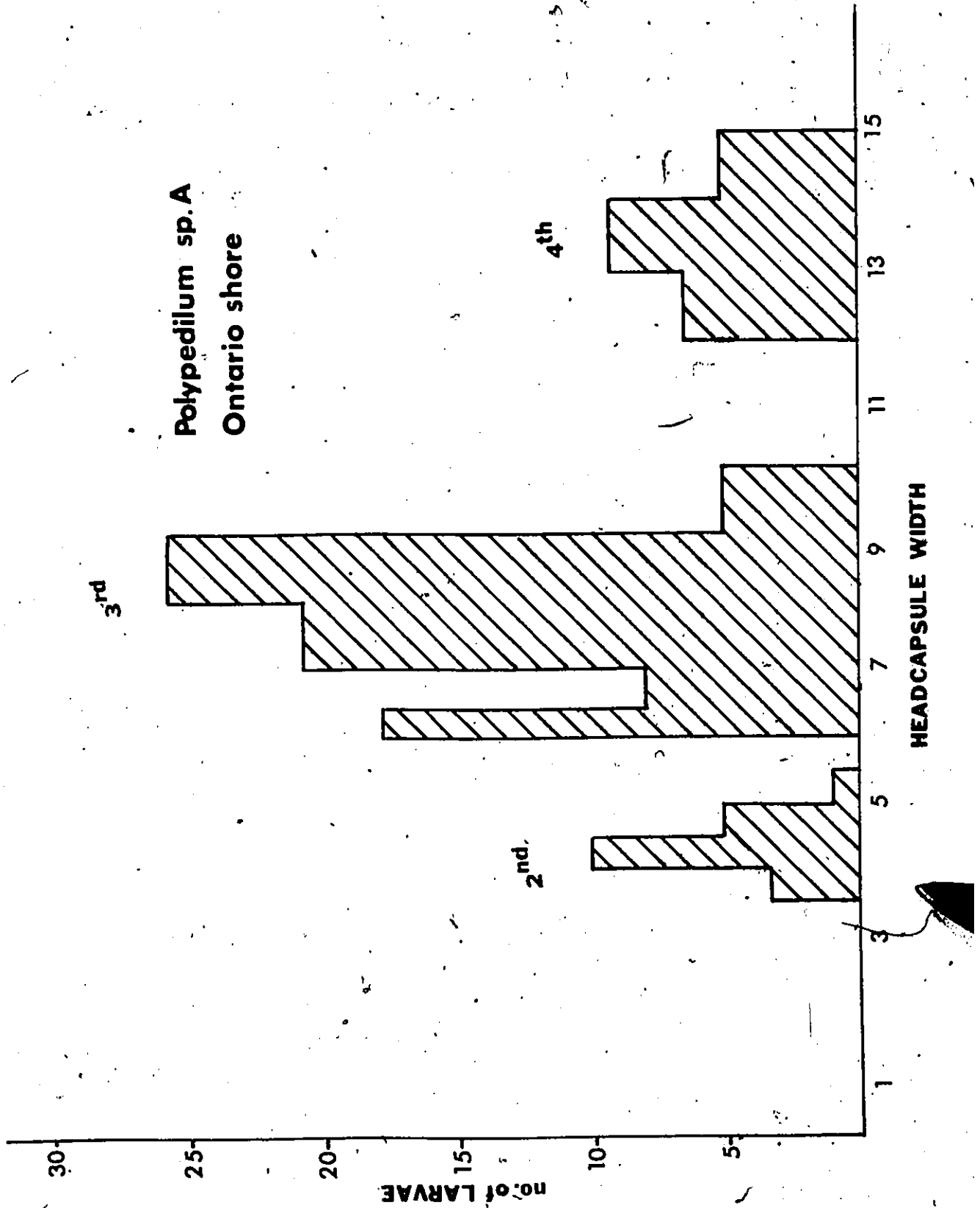


Figure 10

Headcapsule widths for Polypedilum sp. B at the Kettle Island shore station for 1974. Widths are measured in eyepiece micrometer units.

Polypedium sp.B
Kettle Island shore

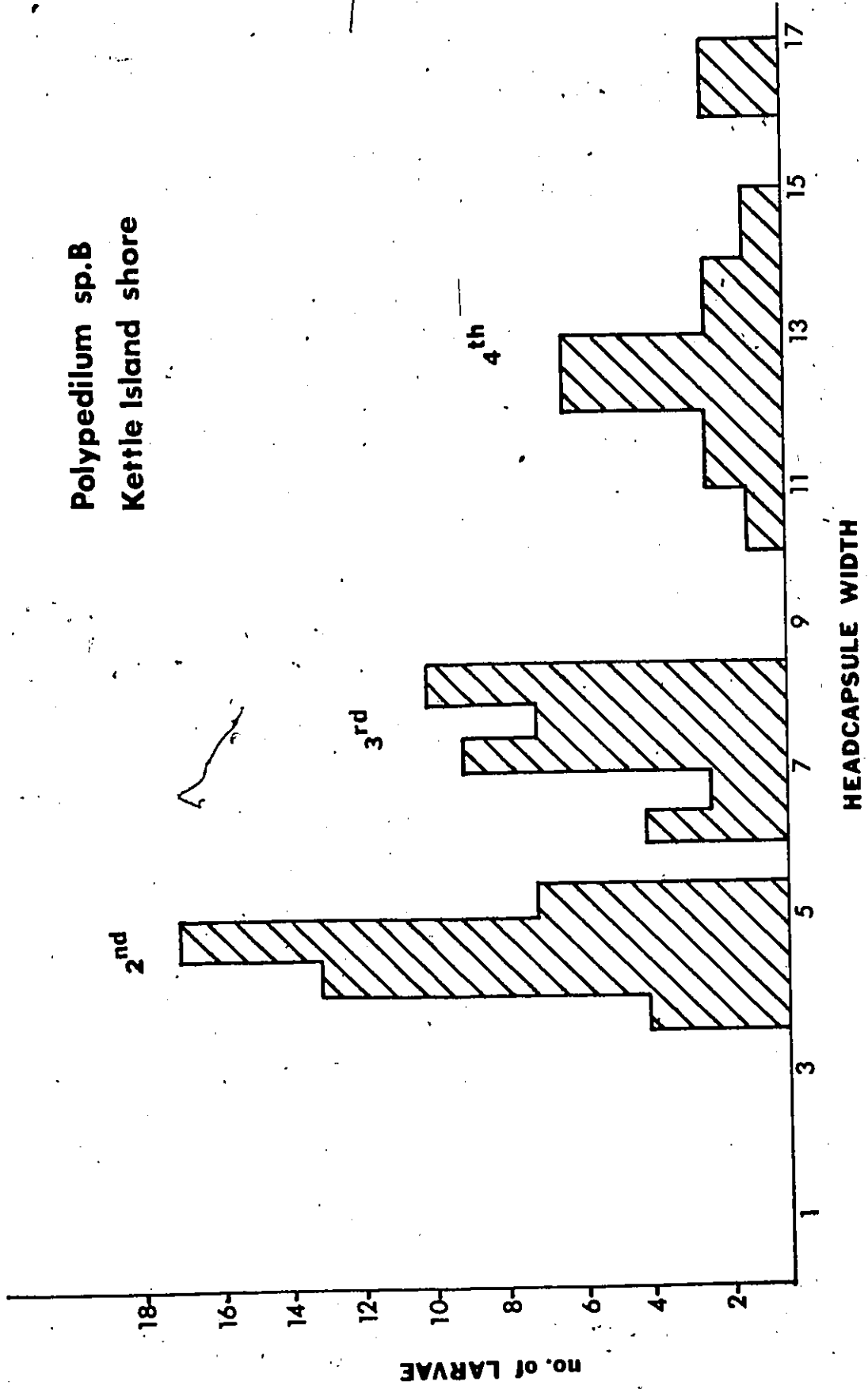


Figure 11

Percent composition of the instar stages of Polypedilum
sp. A at the Ontario shore station for 1974.

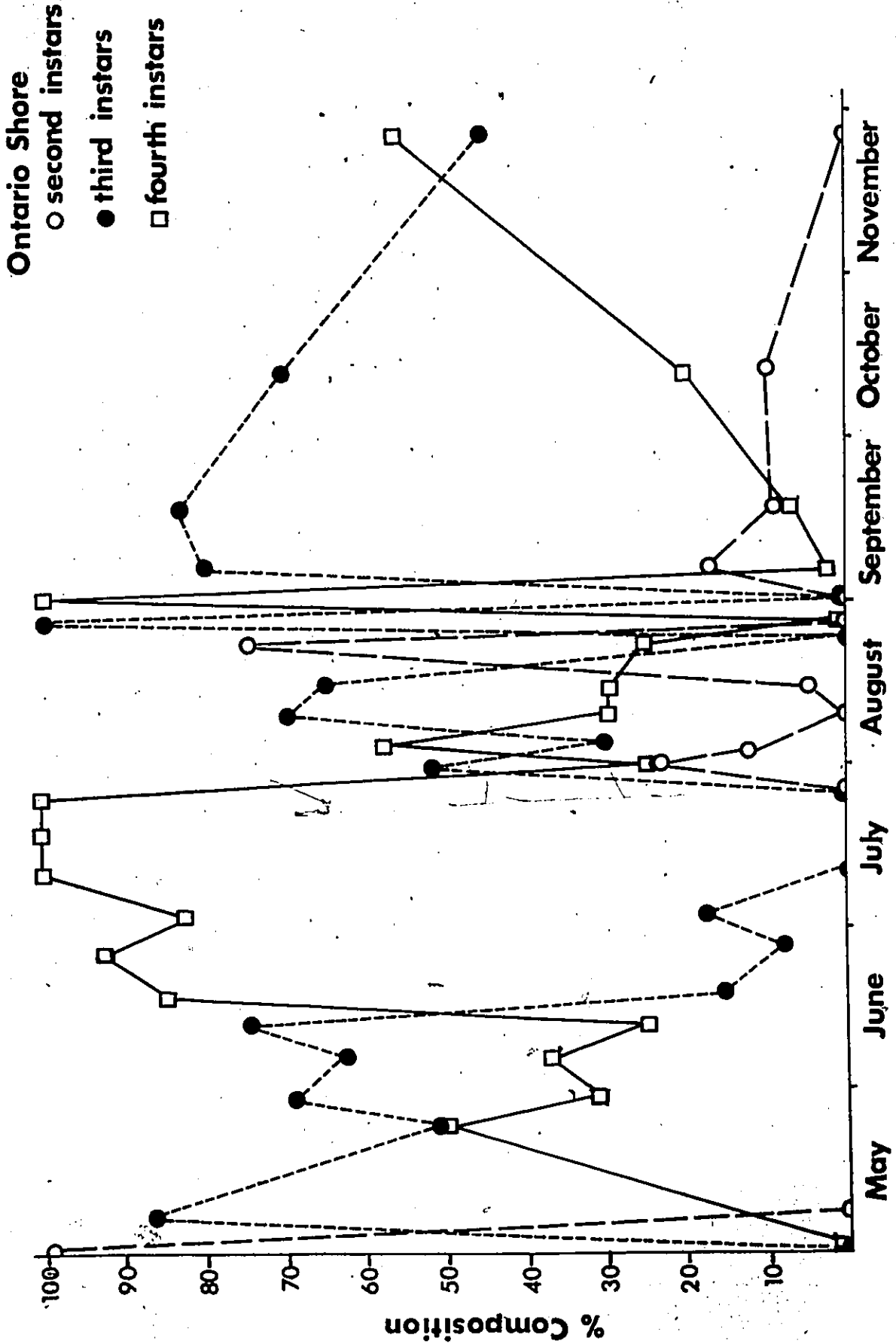
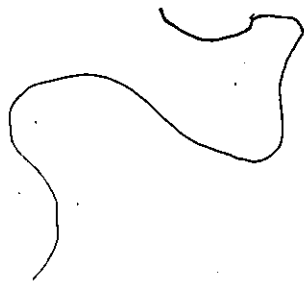
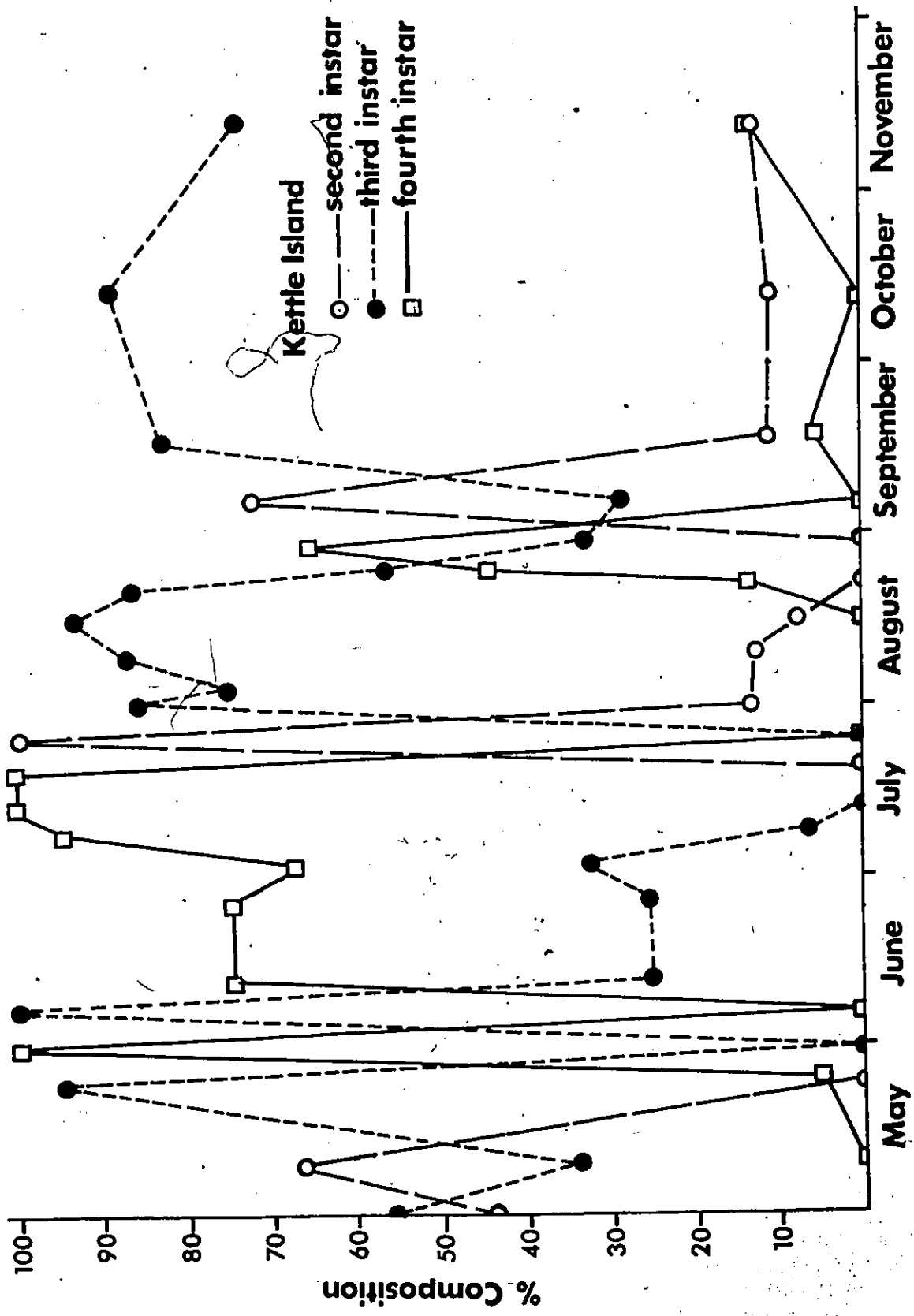


Figure 12

Percent composition of the instar stages of Polypedilum
sp. B at the Kettle Island shore station for 1974.





peaks of fourth instars, there is a large proportion of second instars, which are then, the offspring of the adults which came from the preceding fourth instars and thus, belong to another generation or cohort.

Ontario shore

The data show three major divisions of the growing year for larvae. The first occurs in the spring and early summer (Fig. 11). At this time, the eggs laid by the overwintering generation hatch and the larvae grow. This is shown by the high percentage of second instar larvae in early May and the total absence of any other class. The third and fourth instars which follow, disappear in late July.

The next period occurs during the mid-summer and lasts until early September. This stage starts with a smaller, or partial generation in late July which goes through its life cycle and then is followed by another high proportion of second instars, thus another cohort in mid-August.

A new period begins in mid-September when the overwintering cohort starts to appear. These will emerge in the spring, lay their eggs and their offspring will form the spring and early summer generation.

Kettle Island

The pattern is similar to that found at the Ontario shore site, except that the timing of the periods is different, and that during the summer period, only one generation is produced (Fig. 12). The spring generation lasts until mid-July, and the summer one, until mid-September. There is only one generation during the summer months, lasting about two months. A major difficulty in understanding the workings of this population, occurs in late May and early June, when there are great fluctuations in the numbers and instar proportions of the larvae. These occur when the Ekman grab was used for sampling and probably reflects sampling error.

But despite using the 1973 method of sampling on two dates in May, the results from this sampling were included in the study for two reasons: 1) though the probable sampling error is high, it was felt that there were changes in the population and that some attempt should be made to record these; 2) the results of this sampling fall within reasonable limits of what could be expected, and probably approximate realistic values.

Production

The lengths and limits of the life cycles thus established, using percent larval composition, the actual numbers of larval instars found were plotted against the sampling dates. Figures

13 and 14 show the changes in numbers of the larvae of Polypedilum sp. A and Polypedilum sp. B at the Ontario and Kettle Island shore stations for 1974.

Ontario shore

The results of the production study at this site are shown in Table 8a. The spring generation produced 217.5 mg./m² in a generation time of approximately 98 days. This figure is derived from the maximum number of fourth instars only.

The length of the life cycles of the second and third generations were both approximately three weeks and their production was low at 40.0 mg./m² and 40.1 mg./m².

The production of the fall generation, up until November was calculated at 242.3 mg./m², though this was obviously an underestimate as growth of that cohort was still possible over the remaining winter months.

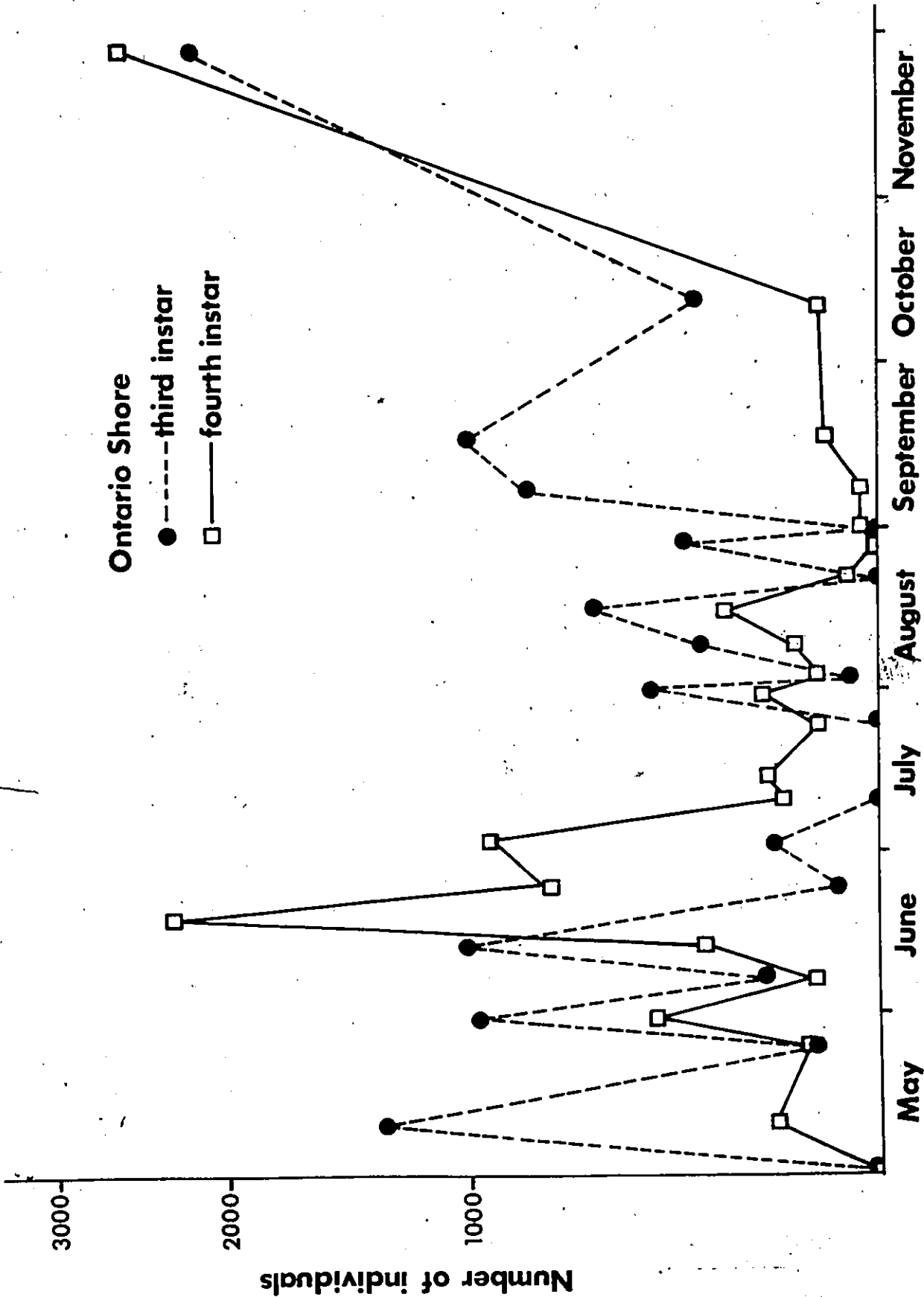
Total production for this site from May to November in 1974 was thus estimated at being 539.9 mg./m².

Kettle Island

The Kettle Island site was slightly different from the previous site in that there were only three generations instead of four (Table 8b). The overall production was also less. The spring generation had a production of 56.1 mg./m², the summer generation produced 55.0 mg./m² and the fall generation, 67.1 mg./m².

Figure 13

Changes in numbers of the third and fourth instar larvae
at the Ontario shore site for the genus Polypedilum (sp. A)
during 1974.






Figure 14

Changes in numbers of the third and fourth instar larvae
at the Kettle Island site for the genus Polypedilum (sp. B)
during 1974.

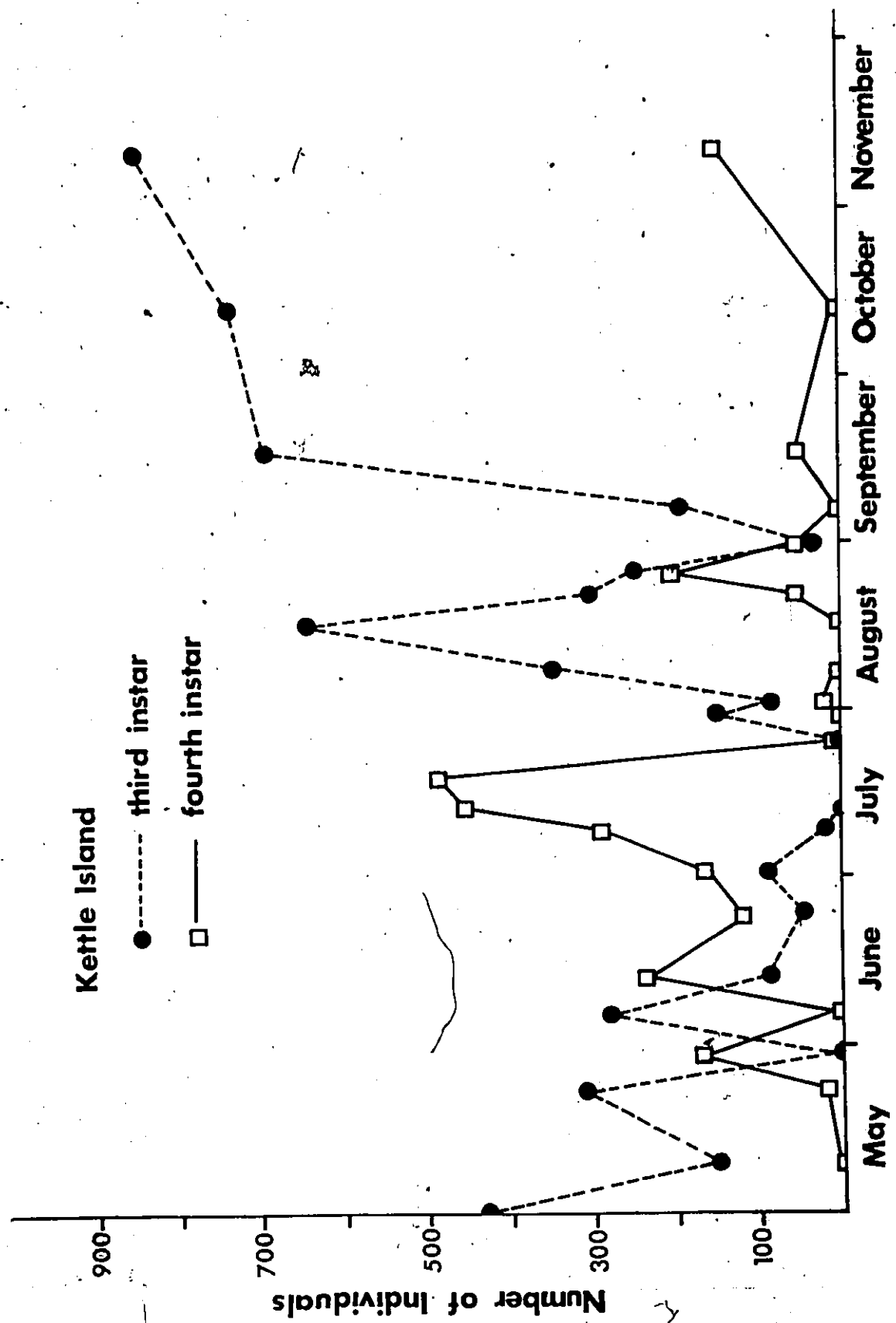


Table 8

Average biomass in mg/m², production and length of life cycles of the genus Polypedilum at the Ontario and Kettle Island shores for 1974.

(a) Ontario shore (sp. A)		Average biomass (mg)	Production (mg)	Turnover Ratio
Generation	Generation Time			
spring	April 23 to July 30	61.3	217.5	3.6
summer	July 30 to August 20	14.7	40.0	2.7
summer	August 14 to September 9	12.8	40.1	3.1
fall	September to spring of next year	101.0	242.3	2.4
P/B (annual) = 9.7		55.4	539.9	
(b) Kettle Island (sp. B)		Average biomass (mg)	Production (mg)	Turnover Ratio
Generation	Generation Time			
spring	May 8 to July 17	26.4	56.1	2.1
summer	July 25 to August 30	12.6	55.0	4.4
fall	August 30 to spring of next year	23.3	67.1	2.9
P/B (annual) = 8.9		20.1	178.2	

Productivity

Ontario shore

Turnover ratios (T.R.) are shown in Table 8a for the generations of Polypedilum sp. A, as is the overall P/B ratio. Turnover ratios ranged from 2.4 to 3.6 with the highest values occurring in the spring during a period of rapid population changes. The values for this cohort would have been much lower had there been a high population of third instars to give a greater average biomass, thus bringing the T. R. value down. The second highest value (3.1) occurred in the second summer generation and is similar to the first summer cohort. The fall value is predictably low as the accumulation of biomass had all winter to develop and thus maintained a slower pace of growth.

The P/B ratio for all the generations at this site, from May to November was 9.7, which means that the total production was slightly less than ten times the average biomass.

Kettle Island

The results of productivity computations are shown in Table 8b. As should be expected, the highest value occurs during the ~~summer~~ generation with a value of 4.4. The spring cohort has a low T. R. value of 2.1, due to the very slow increase in fourth instar numbers, which increased the average biomass without augmenting the production. Productivity of the fall and winter cohort was 2.9 up to November. The P/B ratio was found to be 8.9.

Overall Production

Results of overall production are shown in Table 9. The area with the greatest overall production is the shore of Kettle and Upper Duck Islands. It also has the greatest average production and thus is the most important part of the study area considering Chironomidae production. The other zones vary in importance with the deep mid-channel section being the least important.

Table 9
 Total chironomid production of the study area for 1973 using 1974 P/B ratios

Location	Av. biomass (mg/m ²)	Total biomass (kg)	P/B	Av. Production (mg/m ²)	Total Production (kg)
Deep channel	23	71.6	9.4	198	645.8
Channel above C. I. P.	170	66.6	9.4	1,462	572.8
Québec shore above C.I.P.	530	50.7	9.4	7,568	436.0
Channel below C.I.P.	100	54.7	9.4	4,558	435.6
Island shores	880	269.9	9.4	7,568	2321.1
Kettle Island Bay	590	29.5	9.4	6,136	306.8
Upper Ontario shore	620	40.10	9.4	6,448	417.0
Mid Ontario shore	570	28.30	9.4	5,928	294.3
Lower Ontario shore	230	4.78	9.4	2,392	49.7
				Total	5479.1

Discussion

The Ottawa River study area was shown by the study of Mackie (1971), and this study, to contain a great diversity of habitats as in other rivers (Hynes, 1972; Reid, 1961; and Macan and Worthington, 1972). This means that the composition of the benthic fauna, chironomids in particular, should reflect this variety of habitats. This was shown by the 30 genera and species of Chironomidae found in the 1973 sampling (Appendix A).

The 1973 sampling allowed me then, to describe the major types of habitats found in the study area. This information is important especially in planning future sampling programs where various habitats would be sampled.

The results of this work showed that the two most productive sections of the Ottawa River study area were the island shores with the high amounts of vegetation and the section of the Ontario shore around transect two. These were thus the two areas sampled extensively in 1974.

Of the factors possibly affecting larval populations, temperature is suspected of decreasing resistance to chemicals by the larvae and thus causing low numbers in the C.I.P. channel (Cairns et al., 1974; Curry, 1965; Warren, 1971), however, no deductions of its effect at the other stations could be made.

The effects of current speed on the benthic fauna has been discussed by some authors (Hynes, 1972; Muller, 1974) and the general rule is that the greater the current, the lower the numbers of larvae. This has been shown to be the case in the mid-channel section of the river. Because of the long period of time between sampling dates in 1973, the effects of other potential modifying factors could not be studied.

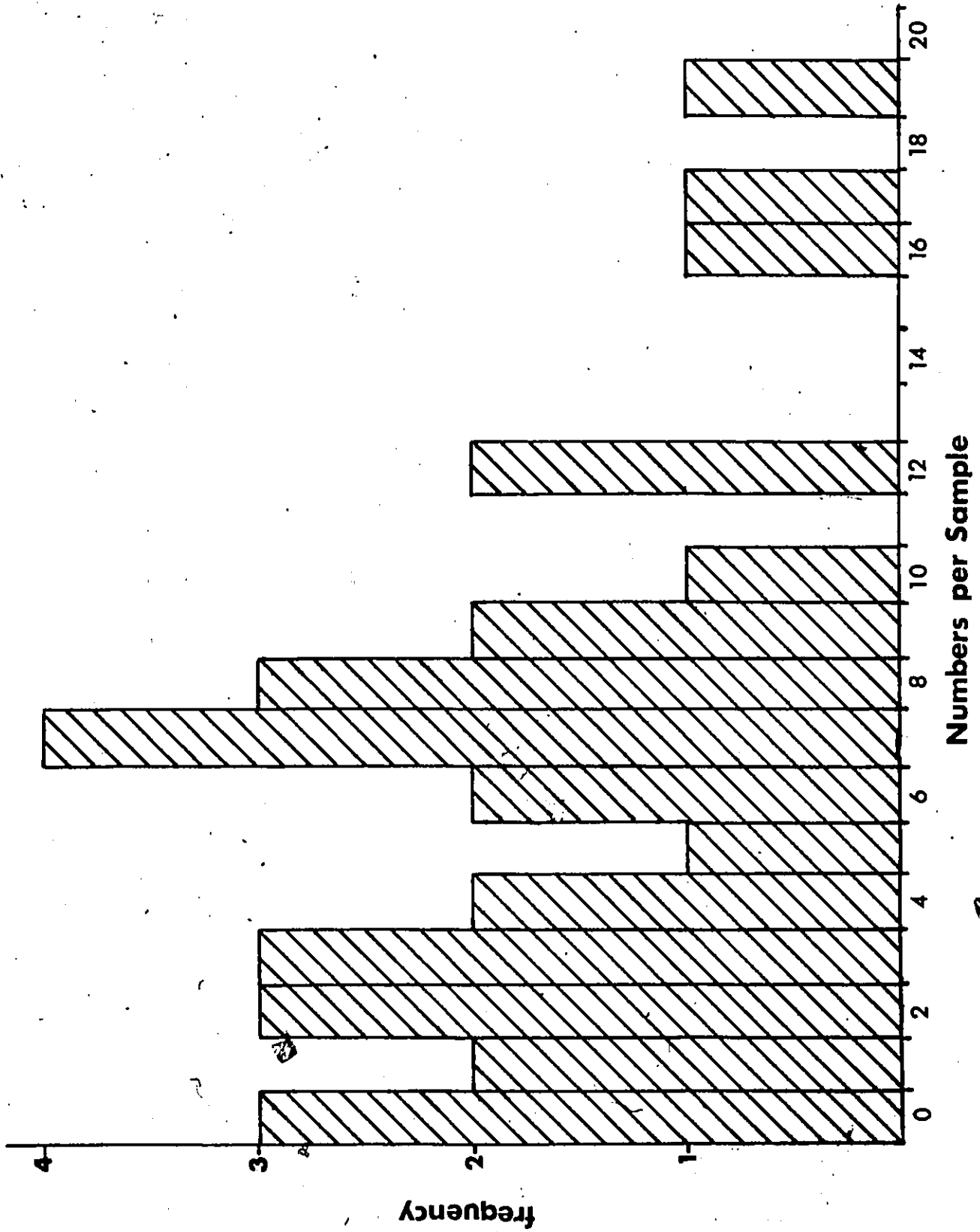
Sampling in 1974

The 32 core samples taken at six day intervals required the maximum effort which could be expended under the circumstances. With this effort, the precision was quite good in November despite the very irregular distribution of larvae present. Figure 15 shows the frequency distribution of the larvae per core sample at the Kettle Island site for this date. This type of larval distribution produces a negative binomial distribution equation which means an extremely irregular distribution of larvae in the sediment. Thus, sampling of benthos on the Ottawa River was dependent on three factors: 1) the nature of the habitat as was shown by the 1973 sampling; 2) the distribution pattern of the larvae (Fig. 15); 3) the method of sampling, as shown by the different kinds of results and precisions between 1973 and 1974.

The taking of the 32 core samples seems to have taken

Figure 15

Frequency of core samples with various numbers of larvae
at the Kettle Island site for November 1974. ✓



care of the major problems of precision in sampling a river habitat, as those found ($\pm 25\%$ and $\pm 27\%$) are well within accepted ranges of lotic water sampling (Elliott, 1971).

Another source of possible error in the production estimates was the loss of third and fourth instars through the mesh. However, samples which weren't sieved during the summer had no significant differences in numbers of these larvae with samples which were. The probable error due to loss of third and fourth instars in sieving was thus practically negligible.

Lost in the sieving, however, were the first and second instars. This is probably not very important, as Kajak, (1967) thought their contribution to be negligible. This was supported by Maitland et al. (1972) where first and second instars contributed 2.7% of the production of one genus, and by Charles et al. (1974) where their contribution was 5.0% for four species. Though no estimate of their contribution was made here, it is assumed, because of the very rapid disappearance of the second instar larvae, that in the short time that they are present, production of even a large number of larvae would not surpass that found in other studies.

Production at the Ontario shore will always be greater than at the Kettle Island site because of the numbers of

larvae involved. The reasons for this difference in numbers are very complex and are probably due to a combination of factors: 1) current speed; 2) sediment type; 3) macrophytic vegetation; 4) temperature; and 5) species composition.

The temperature factor is important, as the rate of production increases at both sites with an increase in temperature, as shown by Fig. 11 and 12 for the summer months. However, there is no difference in temperature between the two sites.

Field observations have shown the current to be much greater at the Kettle Island shore than at the Ontario shore. In the summer, on the other hand, it is slowed down by the macrophytic vegetation growing along the island shore, so that it can support higher numbers of larvae in the summer than it can in the spring or late fall. The macrophytic vegetation at the Kettle Island station should also provide food and protection for many species of larvae. Barber and Kevern (1973) have shown that chironomid larvae in their study showed marked preference for areas with macrophytic vegetation and had higher populations there.

An important factor in regulating population size is the substrate composition. Larvae of Polypedilum are detritivores, as shown by their gut contents. This is not unlike the results of Davies (1972) and Coffman (1967) working with various species of larvae. Detritus can

also be shown to be a limiting factor (Iyengar et al., 1963; McLachlan, 1969). Since the percent ash-free dry weight can be interpreted as being the amount of organic material in the sediments, the higher content at the Ontario shore (15.5%) compared to the Kettle Island site (8.0%) suggests that the Ontario shore populations would be larger than the one found at Kettle Island due to a better food supply.

Another factor which might have some influence on the production of larvae is the possibility of two species of Polypedilum being found, one at each station. There is no direct taxonomic proof of this, as attempts at rearing proved futile in 1974, but indirect evidence suggests that this is a possibility. The major piece of evidence is that the headcapsule widths found for Polypedilum at both sites differ from each other. Figures 9 and 10 show results of measurements from both sites, and it can readily be seen that the ranges of widths of third and fourth instars do not coincide. The large differences in substrate and macrophytic vegetation between the two stations would also suggest the possibility of two species existing. More work, however, needs to be done on this topic.

It is quite probable that the population size is affected by all of the above factors, with the sediment composition particularly in terms of its organic content, being

the most important factor. The population size is also affected, to a lesser extent by the seasonal appearance of macrophytic vegetation at Kettle Island, and by the effect of the current speed at both sites. It should also be noted that the conditions at the Ontario shore fluctuated much less than those at Kettle Island perhaps resulting in a more stable population of larvae.

Life histories of Polypedilum

The types of life cycles encountered in this study seem straightforward. The presence of 3 and 4 generations at the two sites is similar to those found by Potter and Learner (1974), Learner and Potter (1974), Bracken and Murray (1973), and Heuschele (1969). Naturally, this is dependent on the species involved, but multi-voltinism is quite common amongst many chironomid species.

The only report of Polypedilum sp. is from Danks (1971a) who studied P. simulans in ponds near Ottawa. His data show an emergence in late April-early May and another one extending from mid-July to mid-September. These periods resemble the ones in the present study and it is possible that the long summer emergence period is composed of many small cohorts emerging in rapid succession. Also, his percent larval instar compositions in the fall resembles mine, with his 1970 results resembling the Ontario shore results and his 1969, the Kettle Island situation. Even though Danks studied a very different

habitat from this study area, there is a great similarity between the two studies.

It should be emphasized however, that the life cycles of the larvae can vary from year to year (Danks, 1971b; Armitage, 1970) and further sampling would probably give different results depending on a variety of physical factors (Welch, 1973; Danks, 1971 a,b).

A factor of interest was the very rapid disappearance of the second instar larvae. Taking the sampling method into consideration, it is unlikely that sieving would allow the loss of all second instars. No such short period of time (one to two weeks) was recorded in any of the above papers.

The data from the changes in numbers (Fig. 13 and 14) are also consistent with other studies. Niedzwiecki (1970) shows the patterns in number changes from several species from the river Suprasl in Poland, and though the instar stages are not separated, the major patterns of occurrence of larvae of certain species show some agreement with my results. Of particular interest is the summer-fall period when rapid changes in the population are seen. The timing of these isn't the same as in the Ottawa River, but may be due to different temperature regimes between the two rivers.

Overall production

The use of P/B ratios and the 1973 data to give an overall production figure has many drawbacks. Species other than Polypedilum were found in the study area, the major ones being Cryptochironomus, Phaenopsectra, Cricotopus, and Procladius. Their appearance in the core samples in 1974, though not in numbers large enough to justify production estimates, suggests that each of these genera had more than one generation. Taking this lack of information into consideration, the assumption was made that their P/B ratio was similar to that of Polypedilum. It is not precise, but is the only method which can be used to give an estimate. This may not be unreasonable, as data from Berrie (1972) give P/B ratios of 10.0 and 9.0 for the total chironomid community. Mann (1964), by back-calculating from fish feeding studies suggests a P/B ratio of 18.

Despite this reservation and other stated previously, the total figure is of some use in calculating total mercury and pesticide uptake by the larval population of the river. It should also be noted that due to the loss of smaller larvae, the figure is likely to be an underestimate and will undoubtedly vary from year to year.

Production and Productivity

Turnover ratios for the generations found are shown in

Table 8. These are within the ranges reported by Waters (1969), except for the spring generation which had a low value of 2.1 at Kettle Island. Generally, productivity was higher for the summer cohorts than at any other time.

Turnover ratios help explain some of the behaviour of individual generations and the seasonality of rates of production. They also help explain how generations vary from each other. However, unless the larvae are univoltine, or unless life cycles remain the same from year to year, the T. R. values cannot be used to give broad, general estimates for long intervals of time, nor can they predict the productivity of cohorts over shorter periods than the length of the life cycle of the organism involved. Instead, P/B ratios are calculated for certain periods of time (Winberg 1971).

The P/B estimates were 9.7 at the Ontario shore and 8.9 at the Kettle Island site in 1974. The reasons for these differences in values have been discussed above, along with the fact that one more generation was produced at the Ontario shore than at the other station.

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APPENDIX A

Species of Chironomidae found in a 4.8 km. section of the Ottawa River near Ottawa-Gatineau in 1973.

Tanypodinae

Procladius sp. 1
Procladius sp. 2
Procladius sp. 3
Zavrelimyia sp.
Tanypus sp.

Orthocladinae

Brillia sp.
Cricotopus sp. 1
Cricotopus sp. 2
Paratrichocladus sp.

Chironominae

Chironomus sp. 1
Chironomus sp. 2
Cryptochironomus sp. 1
Cryptochironomus sp. 2
Cryptochironomus sp. 3
Cryptocladopelma sp.
Dicrotendipes sp. 1
Dicrotendipes sp. 2
Dicrotendipes sp. 3

Chironominae (cont.)

Einfeldia sp.
Demicryptochironomus sp.
Paracladopelma sp.
Phaenopsectra sp. 1
Phaenopsectra sp. 2
Polypedilum sp. 1
Polypedilum sp. 2
Polypedilum sp. 3
Polypedilum sp. 4
Polypedilum sp. 5
Pseudochironomus sp.
Stictochironomus sp. 1
Stictochironomus sp. 2
Tanytarsus sp. 1
Tanytarsus sp. 2

addenda:

Orthocladinae

Psectrocladius sp. 1
Psectrocladius sp. 2