Results and Discussion

Part I

The Benthos:

This study focuses on the benthos as a potential food resource base for the fish population. To this end, the present working definition of the benthos is that assemblage of macroinvertebrates living in, on, or associated with the sediments and attached macrophytes. This definition makes no attempt to define the trophic levels occupied by each group and is rather broader in scope than the definition of Brinkhurst (1974) "...that assemblage of animals living in, or on the sediments and dependent upon the decomposition cycle for most if not all of its basic food supply."

For most benthic taxocenes a complete taxonomy is not available (Mason, 1977), and for those taxocenes where the taxonomy is relatively complete, the natural history, physiology and ecology are generally incomplete (Merritt and Cummins, 1978).

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The emphasis in this study was placed on classification of organisms into morphologically similar groups with a degree of relatedness at lower taxonomic

to Order. These groups were then identified to family or, where groups were monospecific, to species.

Aquatic Macrophyte *Chara*

and Benthic Invertebrate Distributions

Qualitative observations while conducting the sampling and processing suggested that the diversities and abundances of macroinvertebrates in samples could be predicted on the basis of the amount of *Chara* present in the sample. This appeared to be a more important parameter of distribution than did sample site. Changes in the benthic invertebrate distributions appeared to fluctuate with depth in a pattern reflecting changes in the abundance of *Chara* with depth.

Scoring of the abundance of *Chara* in a sample was initiated during June. Scoring was based on a scale of three where "1" indicated a large amount of *Chara* and "3" indicated an absence of *Chara* in a sample.

A simple method of checking the validity of the aforementioned observations is to count the incidences (presence or absence) of any particular benthic taxocene relative to different abundances of *Chara* and to compare these to the incidences of the same taxocenes at different sites and using different samplers.

In Tables 2,3, and 4, the incidence data is pre-

Aquatic Macrophyte Data

and Benthic Invertebrate Distributions

Qualitative observation while conducting the sampling and processing suggested that the diversity and abundance of macroinvertebrates in samples could be predicted on the basis of the amount of *Chara* present in the sample. This appeared to be a more important parameter of distribution than soil sample size. Changes in the benthic invertebrate distribution appeared to fluctuate with depth in a pattern reflecting changes in the abundance of *Chara* with depth.

Sorting of the abundance of *Chara* in a sample was initiated during June. Sorting was based on a scale of three where "2" indicated a large amount of *Chara* and "1" indicated an absence of *Chara* in a sample.

A simple method of checking the validity of the subsamplingand observations is to count the presence/absence of absence of any particular benthic taxonomic relative to different abundances of *Chara* and to compare them in the incidences of the most taxonomic or different sizes and using different samplers.

In Tables 7,5, and 4, the incidence data is pro-

sented according to site. Considerable variation exists in the abundance of the different taxocenes where taken in the same month at different sites. There is little internal consistency other than a trend towards a lower frequency of incidence of many of the taxocenes such as Decapoda, Anisoptera, Zygoptera and Hydracarina at the RHS site.

Tables 5,6 and 7, contain the same data arranged in terms of the three Chara abundances. Here consistent trends are seen in taxocene occurance. For ease of interpretation the data are presented for the entire sampling period in Table 8.

Chironomids,a Gastropod, Viviparus, and Hexagenia, an Ephemeropteran occur at similar frequencies irrespective of the abundance of Chara. The Oligochaetes are the only taxocene to show an appreciable increase in frequency with decreasing abundance of Chara. Decapods, Anisoptera, Zygoptera, Ephemerella, Trichoptera, Physa, Amphipoda and the Hydracarina are all reduced in numbers by decreasing abundance of Chara.

The RHS sample site shows a low degree of variability in the benthic taxocenes it supports. This is apparently due to its relatively barren nature (see Study Site). It bears only patches of Chara.

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Ceriodaphnia, a Cladoceran, Viviparus, and Haxapenia, an Sphaerosyteran occur at similar frequencies irrespective of the abundance of Chara. The Oligochaetes are the only taxocene to show an appreciable increase in frequency with decreasing abundance of Chara. Decapoda, Anisopteria, Zygopteria, Chaoborella, Trichopteria, Physa, Amphipoda and the Hydracarina are all reduced in numbers by decreasing abundance of Chara.

The RHS sample site shows a low degree of variability in the benthic taxocenes it supports. This is apparently due to its relatively barren nature (see study site). It bears only patches of Chara.

Table 2

The frequency with which each benthic taxocene was encountered in benthic samples from the OUTLET site. The values are the proportion of the total number of samples collected on each date that contained individuals of each taxocene.

Table 3

The frequency with which each benthic taxocene was encountered in benthic samples from the FLAG site. Values are the proportion of all samples collected on each date that contained one or more individuals from respective taxocenes.

Table 2
PROPORTION OF TOTAL POSSIBLE INCIDENCES OF EACH BENTHIC TAXOCENE

	OUTLET				
	May	June	July	Sept	Nov
Chironomidae	87.5	100.0	100.0	94.4	100.0
Decapoda	62.5	22.2	16.7	–	30.0
Anisoptera	62.5	11.1	38.9	44.4	50.0
Zygoptera	25.0	16.7	16.7	55.5	70.0
Hexagenia	50.0	–	22.2	5.5	–
Ephemerella	12.5	55.5	55.5	50.0	70.0
Trichoptera	25.0	16.7	11.1	27.8	–
Viviparus	25.0	67.0	77.8	83.3	60.0
Other Gastropoda	12.5	–	55.5	38.9	90.0
Amphipoda	25.0	–	72.2	61.1	70.0
Oligochaeta	50.0	11.1	16.7	38.9	60.0
Hydracarina	50.0	–	33.3	61.1	50.0
Other	–	33.3	33.3	11.1	70.0

Table 3
PROPORTION OF TOTAL POSSIBLE INCIDENCES OF EACH BENTHIC TAXOCENE

	FLAG			
	May	June	July	Sept
Chironomidae	100.0	100.0	100.0	90.0
Decapoda	50.0	77.8	22.2	20.0
Anisoptera	80.0	94.4	38.9	50.0
Zygoptera	40.0	38.9	–	40.0
Hexagenia	30.0	5.5	–	–
Ephemerella	20.0	94.4	27.8	40.0
Trichoptera	20.0	44.4	22.2	30.0
Viviparus	30.0	100.0	88.9	70.0]
Other Gastropoda	30.0	77.8	38.9	40.0
Amphipoda	20.0	88.9	61.1	50.0
Oligochaeta	30.0	11.1	5.5	20.0
Hydracarina	60.0	33.3	16.7	50.0
Other	10.0	22.2	38.9	20.0

Table 4

The frequency with which each benthic taxocene was encountered in benthic samples from the RHS site. Values are the proportion of all samples collected on each sampling date that contained individuals from each respective taxocene.

Table 5

The frequency with which each benthic taxocene was encountered in benthic samples containing an abundance of Chara (Chara 1). Values are the proportion of all samples collected on each sampling date that contained individuals from each respective taxocene.

Table 4
PROPORTION OF TOTAL POSSIBLE INCIDENCES OF EACH BENTHIC TAXOCENE

	RHS			
	May	June	July	Sept
Chironomidae	100.0	100.0	100.0	88.9
Decapoda	67.0	5.5	-	5.5
Anisoptera	100.0	-	16.7	33.3
Zygoptera	100.0	5.5	11.1	22.2
Hexagenia	33.0	38.9	-	5.5
Ephemerella	67.0	22.2	27.8	33.3
Trichoptera	67.0	11.1	5.5	16.7
Viviparus	67.0	55.5	44.4	83.3
Other Gastropoda	33.0	-	5.5	27.8
Amphipoda	100.0	5.5	61.1	27.8
Oligochaeta	67.0	50.0	22.2	22.2
Hydracarina	67.0	11.1	11.1	27.8
Other	67.0	27.8	38.9	16.7

Table 5
PROPORTION OF TOTAL POSSIBLE INCIDENCES OF EACH BENTHIC TAXOCENE

	CHARA=1			
	June	July	Sept	Nov
Chironomidae	100.0	100.0	100.0	100.0
Decapoda	28.6	44.4	25.0	50.0
Anisoptera	64.3	88.9	68.8	83.3
Zygoptera	50.0	16.7	68.8	100.0
Hexagenia	14.3	11.1	6.3	0.0
Ephemerella	85.7	44.4	75.0	83.3
Trichoptera	28.6	16.7	43.8	100.0
Viviparus	85.7	83.3	87.5	83.3
Other Gastropoda	71.4	77.8	6.3	50.0
Amphipoda	78.6	94.4	100.0	100.0
Oligochaeta	7.1	27.8	12.5	16.7
Hydracarina	21.4	55.6	81.3	66.7

Table 6

The frequency with which each benthic taxocene was encountered in benthic samples containing a small amount of Chara (Chara 2). Values are the proportion of all samples collected on each sampling date that contained individuals from each respective taxocene.

Table 7

The frequency with which each benthic taxocene was encountered in benthic samples containing no Chara (Chara 3). Values are the proportion of all samples collected on each sampling date that contained individuals from each respective taxocene.

Table 6
PROPORTION OF TOTAL POSSIBLE INCIDENCES OF EACH BENTHIC TAXOCENE

	CHARA=2		
	June	July	Sept
Chironomidae	100.0	100.0	100.0
Decapoda	35.7	21.4	0.0
Anisoptera	71.4	28.6	100.0
Zygoptera	42.9	0.0	50.0
Hexagenia	21.4	0.0	0.0
Ephemerella	78.6	42.9	50.0
Trichoptera	21.4	21.4	0.0
Viviparus	100.0	71.4	100.0
Other Gastropoda	64.3	14.3	0.0
Amphipoda	64.3	57.1	75.0
Oligochaeta	35.7	14.3	25.0
Hydracarina	14.3	21.4	0.0

Table 7
PROPORTION OF TOTAL POSSIBLE INCIDENCES OF EACH BENTHIC TAXOCENE

	CHARA=3			
	June	July	Sept	Nov
Chironomidae	96.1	95.5	77.8	100.0
Decapoda	3.8	0.0	0.0	0.0
Anisoptera	7.7	0.0	11.1	0.0
Zygoptera	0.0	0.0	11.1	25.0
Hexagenia	30.8	0.0	0.0	0.0
Ephemerella	11.5	22.7	22.2	25.0
Trichoptera	3.8	4.5	11.1	0.0
Viviparus	50.0	45.5	55.6	100.0
Other Gastropoda	0.0	0.0	0.0	0.0
Amphipoda	3.8	9.1	16.7	0.0
Oligochaeta	69.2	31.8	27.8	75.0
Hydracarina	11.5	0.0	16.7	0.0

Table 8

The frequency with which each benthic taxocene was encountered in benthic samples collected using the Pushnet sampler. Values are the proportion of all samples collected on each sampling date that contained individuals from each respective taxocene.

Table 9

The frequency with which each benthic taxocene was encountered in benthic samples collected as Shallow Ekman samples. Values are the proportion of all samples collected on each sampling date that contained individuals from each respective taxocene.

Table 8
PROPORTION OF TOTAL POSSIBLE INCIDENCES OF EACH BENTHIC TAXOCENE

	PUSHNET			
	May	June	July	Sept
Chironomidae	95.2	100.0	100.0	93.8
Decapoda	66.7	33.3	20.8	6.7
Anisoptera	76.2	41.7	25.0	3.8
Zygoptera	42.8	16.7	8.3	25.0
Hexagenia	33.3	50.0	–	18.8
Ephemerella	23.8	45.8	37.5	50.0
Trichoptera	28.6	16.7	8.3	6.2
Viviparus	33.3	50.0	75.0	8.8
Other Gastropoda	23.8	37.5	25.0	3.8
Amphipoda	33.8	33.3	54.2	50.0
Oligochaeta	42.8	70.8	20.8	25.0
Hydracarina	57.1	25.0	20.8	50.0
Other	22.8	25.0	20.8	12.5

Table 9
PROPORTION OF TOTAL POSSIBLE INCIDENCES OF EACH BENTHIC TAXOCENE

	SHALLOW EKMAN			
	June	July	Sept	Nov
Chironomidae	100.0	100.0	100.0	100.0
Decapoda	6.7	40.0	20.0	60.0
Anisoptera	40.0	40.0	80.0	100.0
Zygoptera	33.3	6.7	73.3	100.0
Hexagenia	–	6.7	–	–
Ephemerella	46.7	40.0	60.0	100.0
Trichoptera	26.7	20.0	66.7	100.0
Viviparus	93.3	80.0	93.3	80.0
Other Gastropoda	36.7	53.3	66.7	60.0
Amphipoda	40.0	86.7	100.0	100.0
Oligochaeta	26.7	33.3	20.0	–
Hydracarina	13.3	40.0	80.0	100.0
Other	13.3	33.3	40.0	100.0

Table 10

The frequency with which each benthic taxocene was encountered in benthic samples collected as Deep Ekman samples. Values are the proportion of all samples collected on each sampling date that contained individuals from each respective taxocene.

Table 11

Considering all the benthic samples collected, each benthic taxocene is presented as the proportion of the total (180) number of samples collected which contained individuals from each benthic taxocene and these are arranged by the Chara abundance of each sample. Also shown are the relative numbers of samples that fell in each Chara abundance category, These, expressed as percentages of the whole, are the maximum possible values for each column.

Table 10
PROPORTION OF TOTAL POSSIBLE INCIDENCES OF EACH BENTHIC TAXOCENE

	DEEP EKMAN			
	June	July	Sept	Nov
Chironomidae	100.0	100.0	80.0	100.0
Decapoda	20.0	–	–	–
Anisoptera	40.0	33.3	20.0	–
Zygoptera	20.0	6.7	20.0	40.0
Hexagenia	6.7	–	–	–
Ephemerella	66.7	33.3	20.0	40.0
Trichoptera	40.0	13.3	–	20.0
Viviparus	86.7	53.3	60.0	100.0
Other Gastropoda	46.7	26.7	–	80.0
Amphipoda	46.7	40.0	20.0	20.0
Oligochaeta	20.0	33.3	33.3	80.0
Hydracarina	–	6.7	13.3	20.0
Other	26.7	20.0	13.3	0.0

Table 11
PROPORTION OF TOTAL POSSIBLE INCIDENCES OF EACH BENTHIC TAXOCENE

	Chara=1	Chara=2	Chara=3	Not Present
Chironomidae	32.9	19.5	39.0	8.6
Decapoda	11.6	4.9	0.6	82.9
Anisoptera	25.0	11.6	2.4	61.0
Zygoptera	18.3	4.9	1.8	75.0
Hexagenia	3.0	1.8	4.9	90.3
Ephemerella	23.2	11.6	7.9	78.3
Trichoptera	15.2	3.0	1.8	80.0
Viviparus	28.0	17.1	22.6	32.3
Other Gastropoda	22.6	6.7	0.0	70.7
Amphipoda	30.5	15.2	3.7	50.6
Oligochaeta	5.5	4.9	20.1	69.5
Hydracarina	18.3	3.0	3.7	75.0
Number of benthic samples	54.0	72.0	54.0	
Proportion of Total	30	40	30	

Table 12

The total number of benthic samples collected (180) is broken down by the sampler used (Pushnet, Shallow Ekman, Deep Ekman) and by the abundance of *Chara* in the sample (Chara 1, Chara 2, Chara 3).

Table 12
PROPORTION OF TOTAL POSSIBLE INCIDENCES OF EACH BENTHIC TAXOCENE

	Pushnet	Shallow Ekman	Deep Ekman	Total
Chara=1	0	52	2	54
Chara=2	8	18	46	72
Chara=3	32	0	22	54
Total	40	70	70	

The distribution of all the major benthic invertebrate groups is clearly affected by the abundance of Chara in the sample, as anticipated. The effect is distinct at the level of species presence or absence and would be more profound if numerical abundances of each group under each condition were considered.

In Tables 9,10 and 11, the same data are again presented. This time arranged by the sampling method used. The trends observed correlate well with the hypothesis that shallow ekman samples tend to represent Chara=1, deep ekman samples tend to represent Chara=2, and pushnet samples tend to represent Chara=3. Confirmation of this is seen in Table 12.

Data on the abundances of Chara are not available for the May samples when records were not kept of its presence or absence in a sample so all the benthic data is presented by sampler as the best way to preserve, in so far as possible, the Chara abundance distinction in samples.

habitat described for RMS (see study site) bearing, as the many patches of Chara.

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In Tables 9,12 and 11, the same data are again presented. This time arranged by the sampling method used. The trends observed correlate well with the hypothesis that shallow chara samples tend to represent *Chara*=1, deep chara samples tend to represent *Chara*=2, and pushnet samples tend to represent *Chara*=3. Confirmation of this is seen in Table 12.

Data on the abundance of *Chara* are not available for the Ray sample when records were not kept of its presence or absence in a sample so all the benthic data is presented by sampler as the best way to preserve, in so far as possible, the *Chara* abundance distinction in samples.

Order Diptera

Chironomid Larvae

This taxocene represents a large number of species which, in many instances, cannot be distinguished in the larval stages (Jonassen, 1969). Their dynamics as benthic organisms are complicated by this large species diversity and by their massive, periodic emergences. Considerable variation in precise habitat requirements and in life cycles (some species are univoltine and some are di or trivoltine) occurs. This, coupled with the short sampling span relative to the intersampling period, means that the dynamics of the chironomid larvae, as a group, are represented more coarsely than species specific studies might indicate. Chironomid larvae were grouped into 2mm size categories so that fluctuations in the size distribution could be seen.

The size distributions for each site are presented by month in Figures 2,3 and 4. The general trend seen is for the numbers of large pupae to decrease as the summer progresses with a simultaneous increase in the number of pupae caught. The majority of larvae sampled always fell on the 4-6 mm category suggesting that they are the smallest size category accurately retained by

Order Diptera

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The size distributions for each site are presented by month in figures 2,3 and 4. The general trend seen is for the numbers of large pupae to decrease as the summer progresses with a simultaneous increase in the number of pupae caught. The majority of larvae sampled always fell on the 4-6 mm category suggesting that they are the smallest size category accurately retained by

Figure 2:
The size distribution of Chironomid larvae from the OUTLET sampling site. Individuals were grouped into 2 mm categories. The data is arranged by sampling date (a,b,c,d,e).

During May (a), shallow and deep ekman samples were not collected.

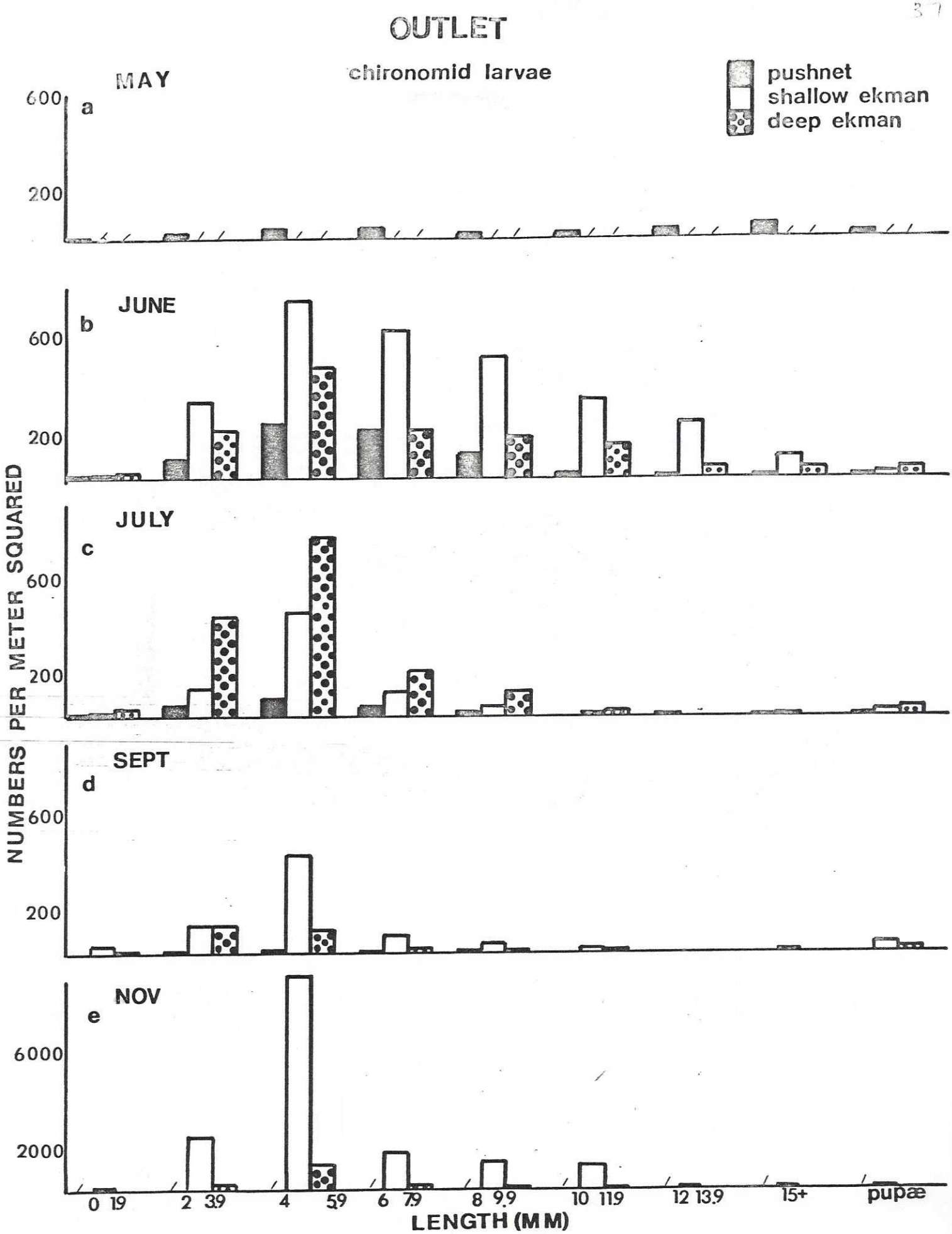

OUTLET
chironomid larvae
pushnet
shallow ekman
deep ekman
MAY
a
JUNE
b
JULY
c
SEPT
d
NOV
e
NUMBERS PER METER SQUARED
600
200
6000
2000
0 1.9
2 3.9
4 5.9
6 7.9
8 9.9
10 11.9
12 13.9
15+
pupae
LENGTH (MM)

Figure 3:
The size distribution of Chironomid larvae from the FLAG sampling site. Individuals were grouped into 2 mm size categories. The data is arranged by sampling date (a,b,c,d).

During May (a), no shallow or deep ekman samples were collected. November samples were not collected at the FLAG site.

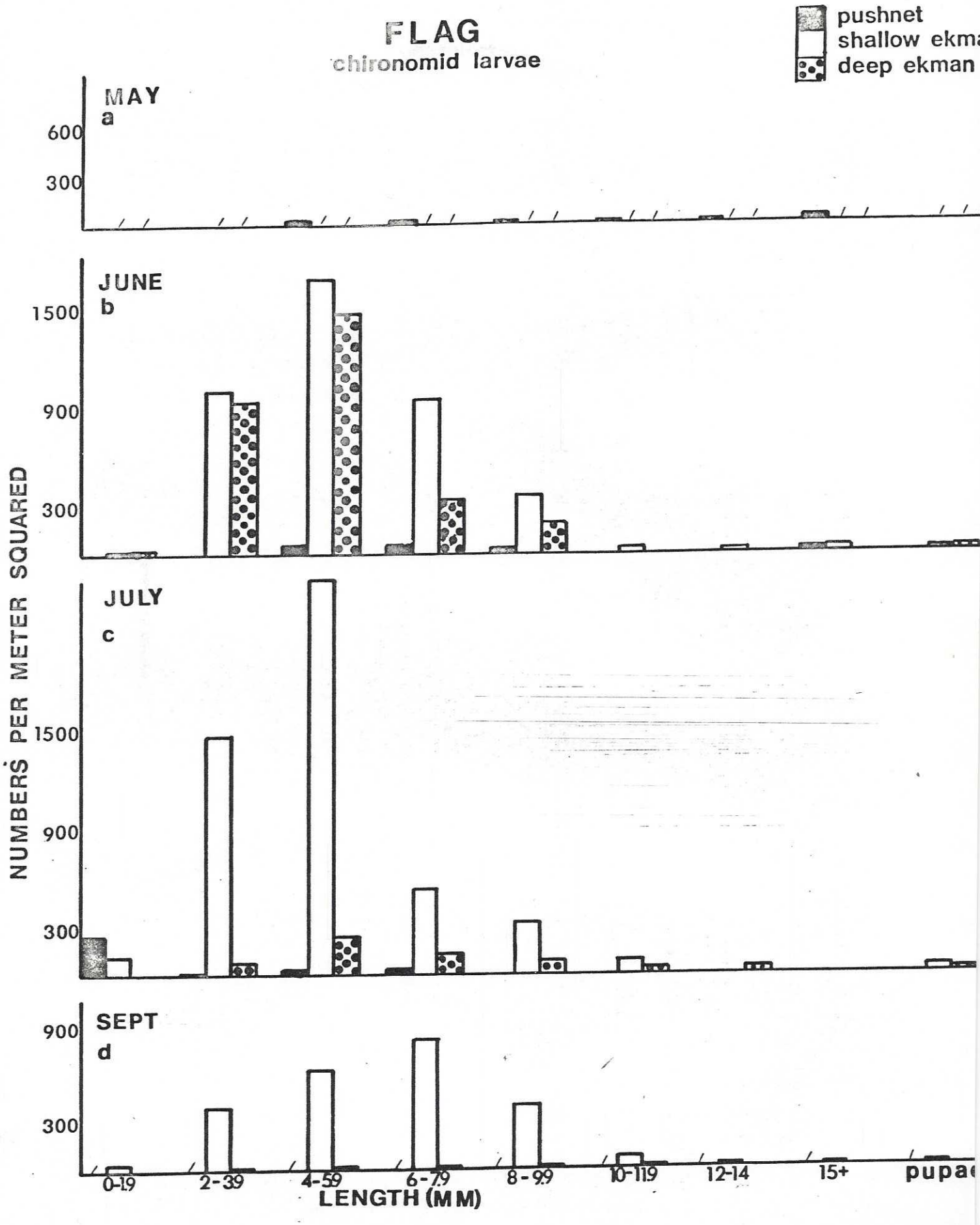

FLAG
chironomid larvae
pushnet
shallow ekma
deep ekman
MAY
a
600
300
JUNE
b
1500
900
300
JULY
c
1500
900
300
SEPT
d
900
300
NUMBERS PER METER SQUARED
0-1.9
2-3.9
4-5.9
6-7.9
8-9.9
10-11.9
12-14
15+
pupa
LENGTH (MM)

Figure 4:
The size distribution of Chironomid larvae from the RHS sampling site. Individuals were grouped into 2 mm size categories. The data is arranged by sampling date (a,b,c,d).

During May (a), no shallow or deep ekman samples were collected. November samples were not collected at the RHS site.

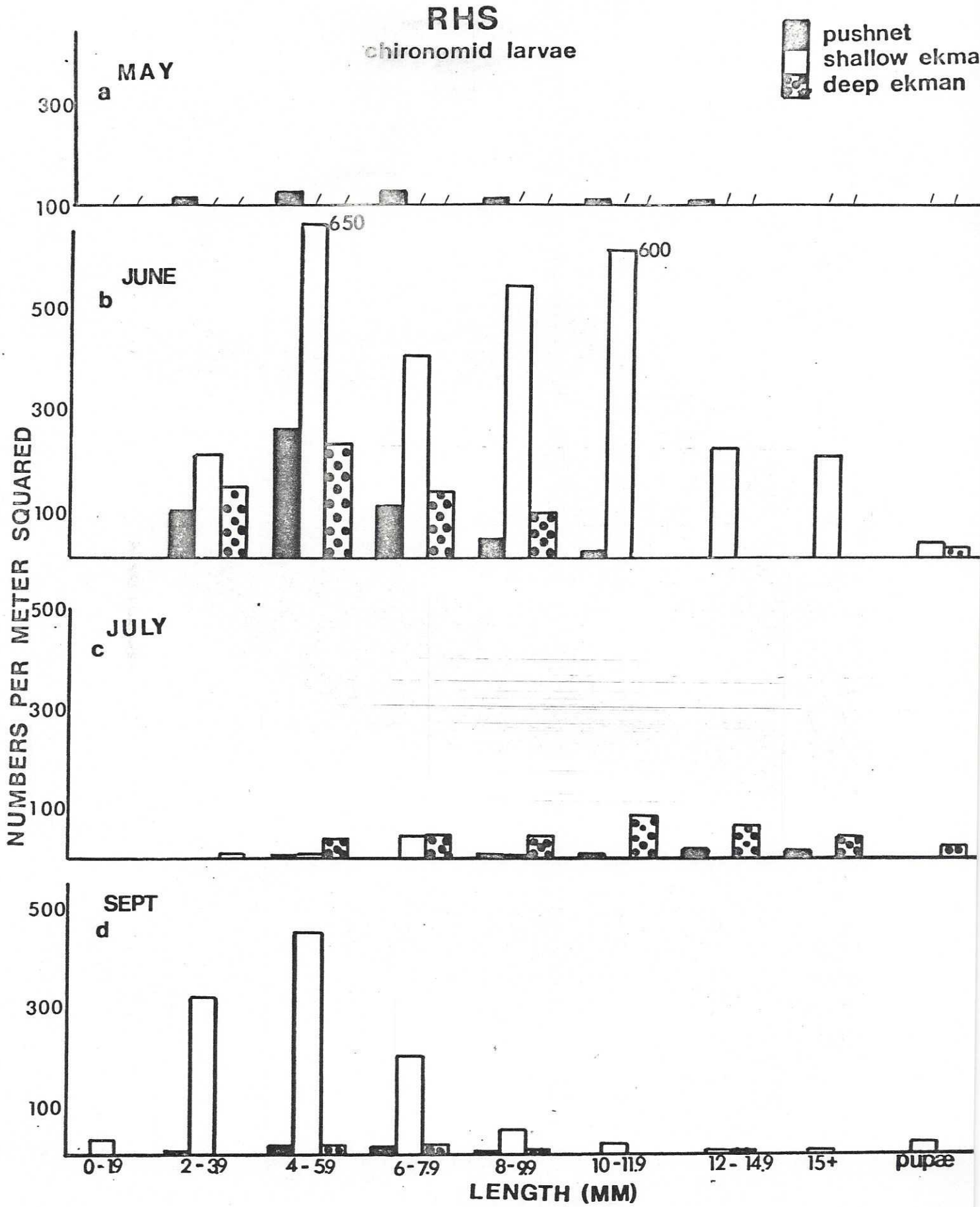

RHS
chironomid larvae
pushnet
shallow ekma
deep ekman
MAY
a
300
100
JUNE
b
650
600
500
300
100
JULY
c
500
300
100
SEPT
d
500
300
100
NUMBERS PER METER SQUARED
0-1.9
2-3.9
4-5.9
6-7.9
8-9.9
10-11.9
12-14.9
15+
pupae
LENGTH (MM)

Figure 5:
The numerical abundance and percent volume contribution of Chironomid larvae to benthic samples. The data is presented seasonally for each site, first by numerical abundance (a,b,c) and then by percent volume (d,e,f).

CHIRONOMIDAE

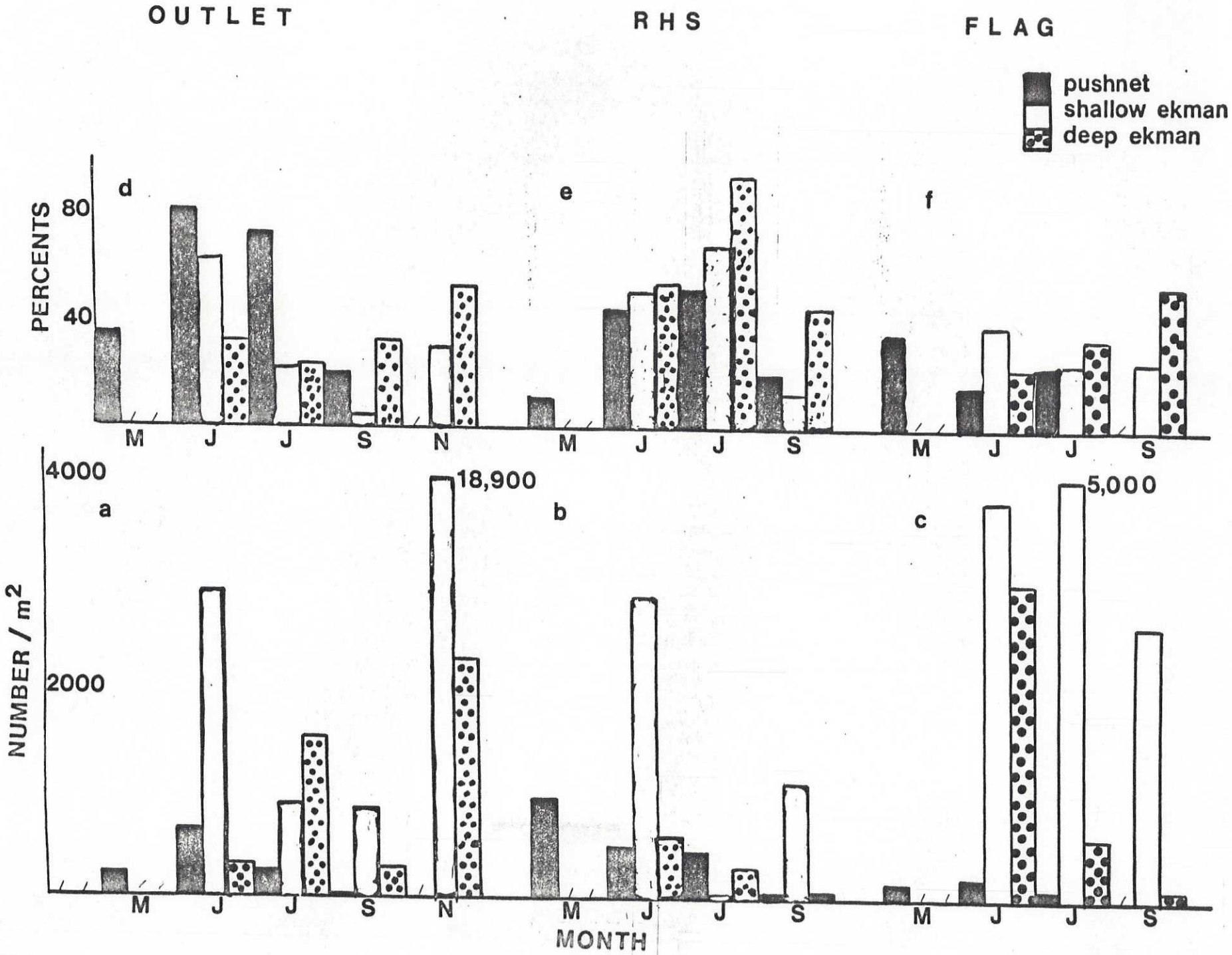
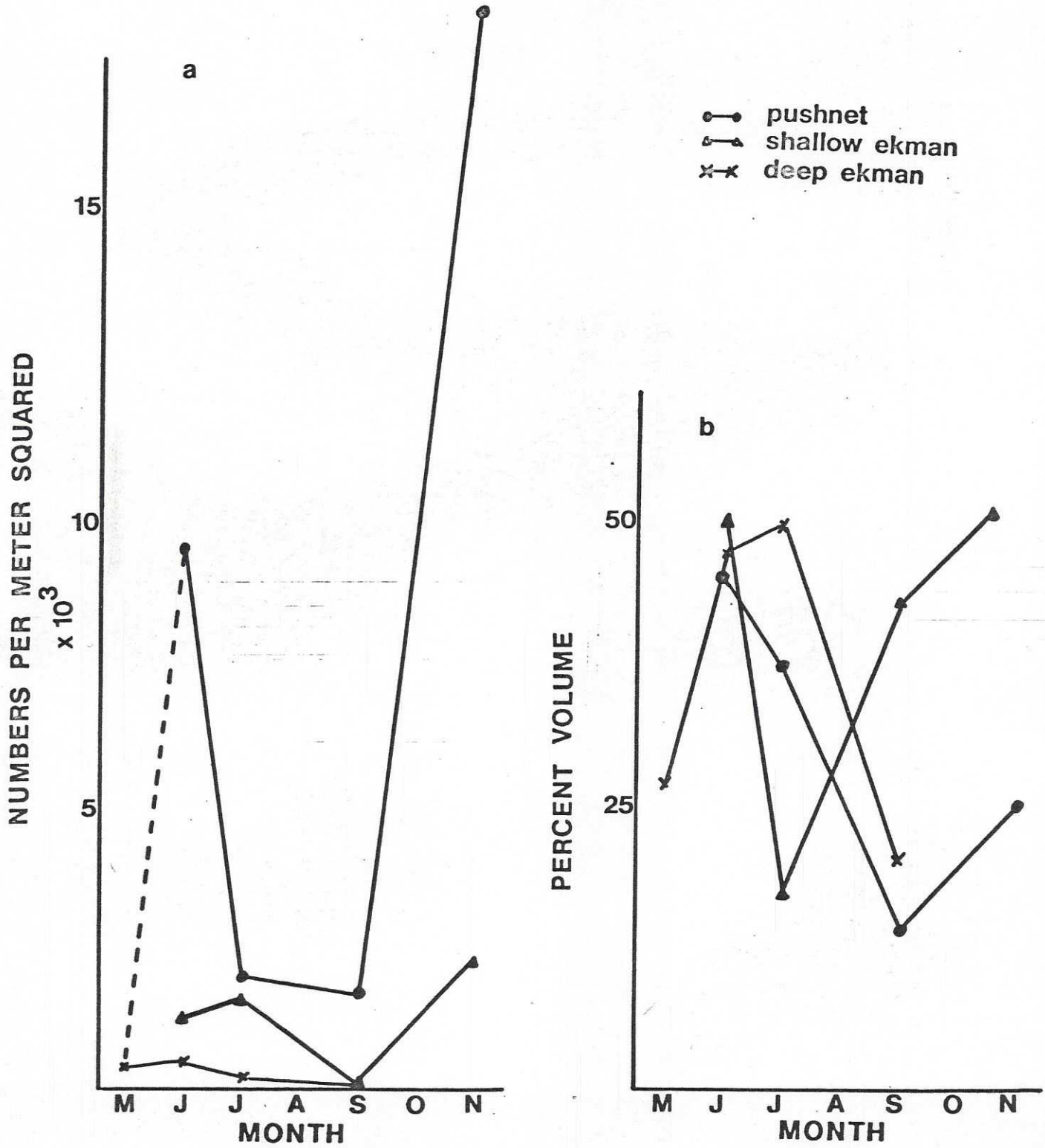


Figure 6:
Seasonal variation in the numbers (a) and the percent volume (b) of Chironomid larvae in benthic samples. Data for all three sites is combined and presented by the sampling method used (ie: pushnet, shallow ekman, deep ekman).

CHIRONOMIDS

COMBINED SEASONAL DATA



the sampling and screening method. The OUTLET and the FLAG sampling sites (Figures 2,4) show similar distributions. The RHS site (Figure 3) contains relatively greater numbers of large chironomids in June than do the other sites, indicating either that emergence may be somewhat later at this site or that the species composition at this site may be different than at the other sites. The overall numbers of chironomids are lowest at the RHS site as shown in Figure 5, although they tend to account for more of the biomass percent volume at this site than they do at the other sites.

Figure 6 gives a comparison of the numbers and percent volume of chironomids averaged over all sites. There is an overall decrease in numerical abundance from July through September and numerical peaks in late June and in November. These correspond in June to a pre-emergence increase in chironomids of a size that will be adequately sampled by the screening procedure and in November to the overwintering population.

Class Crustacea

Order Decapoda:

the sampling and screening method. The BUTLER and the TLAC sampling sites (Figures 2,4) show similar distributions. The RHS site (Figure 3) contains relatively greater numbers of large chironomids in June than do the other sites, indicating either that emergence may be somewhat later at this site or that the species composition at this site may be different than at the other sites. The overall numbers of chironomids are lowest at the RHS site as shown in Figure 5, although they tend to account for more of the biomass percent volume at this site than they do at the other sites.

Figure 6 gives a comparison of the numbers and percent volume of chironomids averaged over all sites. There is an overall decrease in numerical abundance from July through September and numerical peaks in late June and in November. These correspond in time to a pre-emergence increase in chironomids of a size that will be adequately sampled by the screening procedure and in November to the overwintering population.

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Order Decapoda