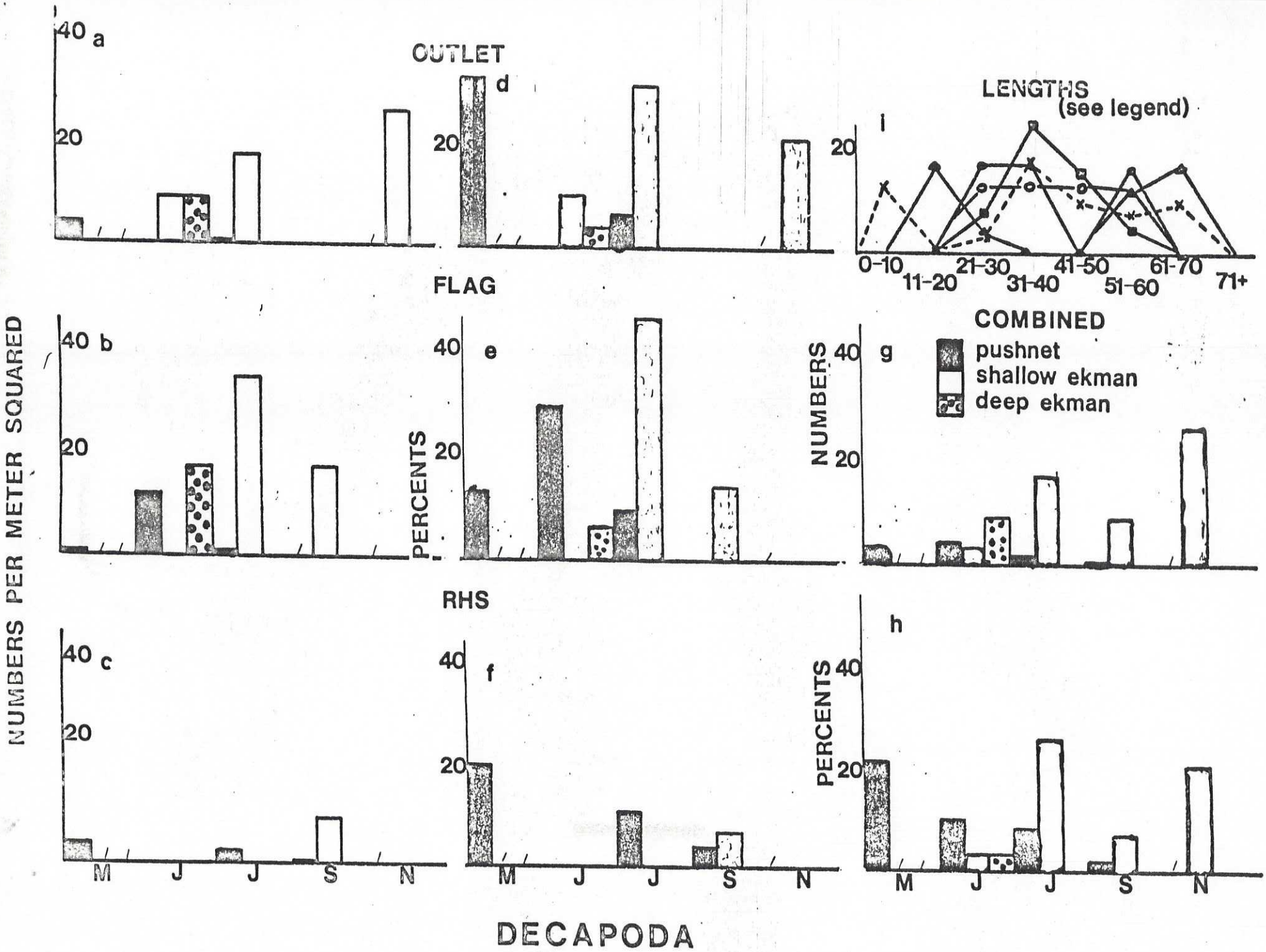
Figure 7:
Seasonal changes in the numbers (a,b,c) and the percent volume (d,e,f) contribution of Decapods, Orconectes rusticus, to benthic samples from each sampling site and for all sites combined (g,h). The different sampling methods are distinguished (pushnet, shallow ekman, deep ekman).
The size distribution of all crayfish caught (i) is presented by sampling date.
No shallow or deep ekman samples were collected during May. No pushnet samples were collected at the FLAG site during September. Only the OUTLET site was sampled during November.

Size distribution

May
June
July
September
November


OUTLET
FLAG
RHS
LENGTHS
(see legend)
COMBINED
pushnet
shallow ekman
deep ekman
NUMBERS PER METER SQUARED
PERCENTS
NUMBERS
PERCENTS
a
b
c
d
e
f
g
h
i
40
20
0-10
11-20
21-30
31-40
41-50
51-60
61-70
71+
M
J
J
S
N
DECAPODA

The Decapoda include the largest individuals caught as benthos and were a monospecific assemblage of Orconectes rusticus, ranging in size from 10-75 mm (see Figure 7). Crayfish tend to be scavengers (Crocker and Barr, 1971). A qualitative sample of 5 crayfish stomachs from the July collections confirmed that the crayfish were consuming chironomid larvae and detritus.

Figure 7 shows the numbers of crayfish caught in benthic samples and the percent volume they contributed to respective samples. In July, the numbers at the FLAG ekman site reached 34 individuals per meter squared contributing 45 percent of the sample volume. The large size range of crayfish indicates that the crayfish may have a three year life cycle in the lake (Crocker and Barr 1971).

Order Odonata

Anisoptera and Zygoptera nymphs were distinguished because of their different body morphologies.

Suborder Anisoptera:

The dragonfly nymphs in Sunfish Lake proper are all of the family Lebullidae although in the OUTLET stream itself rare catches of other families were made. Figure

The Decapoda include the largest individuals caught in benthos and were a monospecific assemblage of Orconectes virilis, ranging in size from 12-25 mm (see Figure 7). Crayfish tend to be scavengers (Crocker and Barr, 1971). A qualitative sample of 5 crayfish stomachs from the July collections confirmed that the crayfish were consuming chironomid larvae and detritus.

Figure 7 shows the numbers of crayfish caught in benthic samples and the percent volume they contributed to respective samples. In July, the numbers at the PIAD camp site reached 24 individuals per meter squared contributing 45 percent of the sample volume. The large size range of crayfish indicates that the crayfish may have a three year life cycle in the lake (Crocker and Barr 1971).

Order Odonata

Anisoptera and Zygoptera nymphs were distinguished because of their different body morphologies.

Suborder Anisopterra

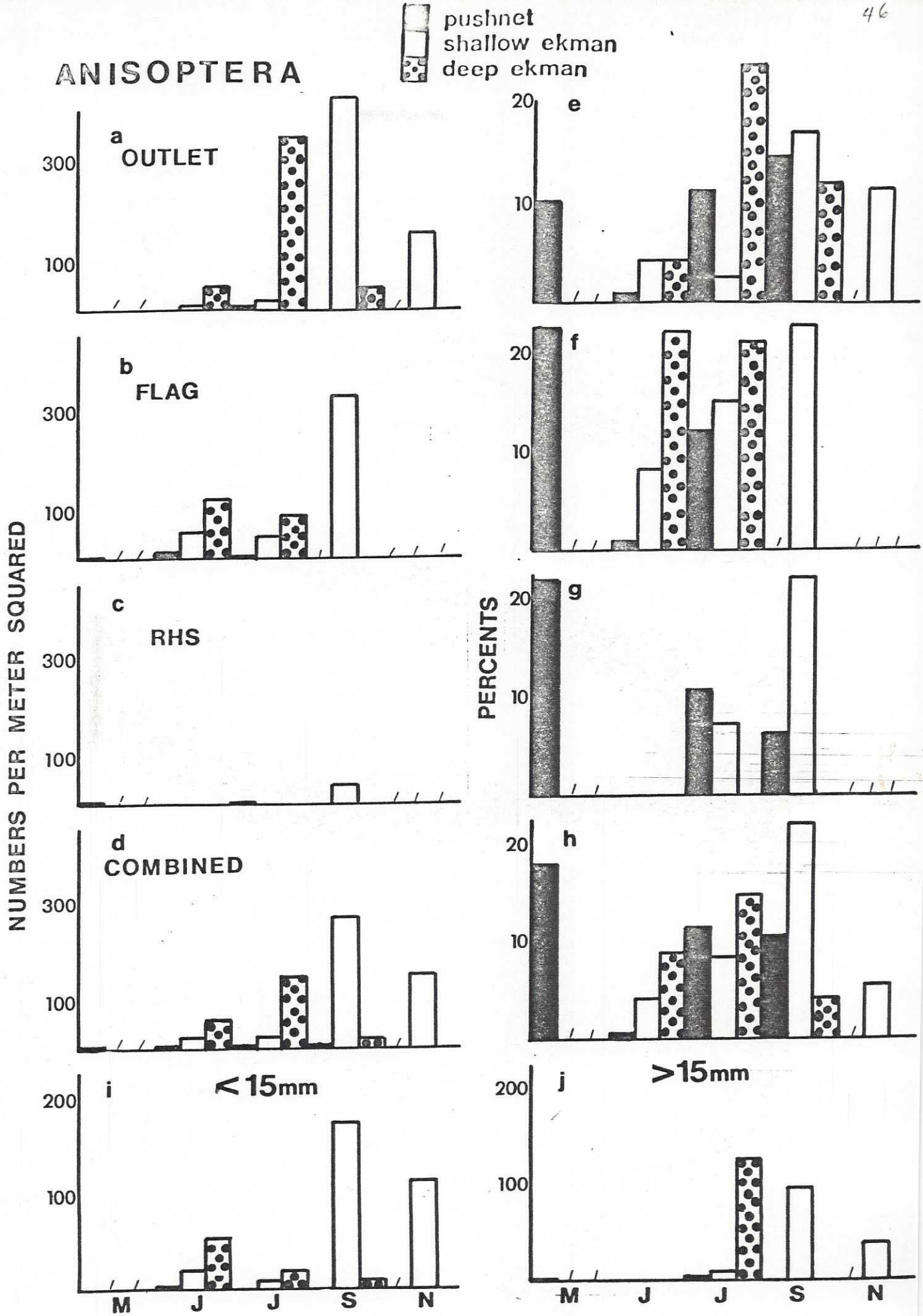
The dragonfly nymphs in Bonilla Lake proper are all of the family Libellulidae although in the OUTLET stream family Aeshnidae catches of other families were made. Figure

8 diagrams the numerical abundances and percent volumes of the Anisoptera nymphs on a seasonal basis . Also shown is a breakdown of the counts into two size categories, those less than 15mm in length and those greater than 15mm in length. 15mm is a natural break in the size distribution that probably corresponds to one of the instar moults. Wing pads were only visible on nymphs greater than 15 mm in length. The largest Lebullidae caught were 23mm in length and the smallest were 6mm. It can be seen from the single size division that, although a few, large Anisoptera nymphs are found in May, the preponderance of the June collections are of small individuals. In July the emphasis shifts to larger individuals and this trend persists into September when there is a reappearance of large numbers of smaller individuals contributing to the high, 260 individuals per meter squared, numerical abundance composing 22 percent of the volume in surface ekman samples. This suggests a seasonal cycle of emergence in May, June and July and a recruitment of early instar nymphs in September. November localization is in the shallow water. The Anisoptera nymphs were found in association with the Chara. This probably relates to the concentration of food in that area and to the protection offered by the cover as the nymphs are generally slow moving (Walker, 1953). Lebullidae are predatorial (Merritt and Cummins 1978).

8 diagrams the numerical abundances and percent volumes of the anisopteran nymphs on a seasonal basis. Also shown is a breakdown of the counts into two size categories, those less than 15mm in length and those greater than 15mm in length. 15mm is a natural break in the size distribution that probably corresponds to one of the instar moults as with pads were only visible on nymphs greater than 15 mm in length. The largest Lebellidae caught were 23mm in length and the smallest were 6mm. It can be seen from the single size division that, although a few, large anisopteran nymphs are found in May, the preponderance of the June collections are of small individuals. In July the emphasis shifts to larger individuals and this trend peraists into September when there is a reappearance of large numbers of smaller individuals contributing to the high, 266 individuals per meter squared, numerical abundance composing 22 percent of the volume in surface stream samples. This suggests a seasonal cycle of emergence in May, June and July and a recruitment of early instar nymphs in September. November localization is in the shallow water. The Anisopteran nymphs were found in association with the Chara. This probably relates to the concentration of food in that area and to the protection afforded by the cover as the nymphs are generally slow moving (Walker, 1953). Lebellidae are predatorial (Merritt and Cummins 1978).

Figure 8:
Seasonal changes in the numbers (a,b,c) and the percent volume (d,e,f) contribution of Anisoptera nymphs (Lebullidae) to benthic samples from each sampling site and for all sites combined (g,h). The different sampling methods are distinguished (pushnet, shallow ekman, deep ekman).
Seasonal changes in the numbers of individual nymphs <15 mm or >15 mm (i,j) are also shown.

No shallow or deep ekman samples were collected during May. No pushnet sampleas were collected at the FLAG site during September. Only the OUTLET site was sampled in November.


pushnet
shallow ekman
deep ekman
ANISOPTERA
a
OUTLET
b
FLAG
c
RHS
d
COMBINED
e
f
g
h
i
<15mm
j
>15mm
NUMBERS PER METER SQUARED
PERCENTS
300
100
20
10
200
M
J
J
S
N


AMISOPTERA
a OUTLET
b FLAE
c RHS
d COMBINED
< 15mm
> 15mm
NUMBERS BELOW BEAM WIDTH SCANNED
PERCENTAGE
M J J S N
pudnoc
shallow ekman
deep ekman

Suborder Zygoptera:

The seasonal changes in abundance and percent volume of the damselfly nymphs are shown in figure 9. A single genus, Protallagma, was represented (Family Coenagrionidae). Low numbers of nymphs present during May sampling account for almost 5 percent of the sampled biomass. This declines to less than 2.5% of the volume in June and July with damselfly nymphs absent at the OUTLET site. This indicates anemergence which is followed in September by a large recruitment raising the abundance to over 120 individuals per meter squared. This 10 fold numerical increase over the July sample reflects a 5 fold increase in the percent volume contribution of the nymphs. Recorded lengths ranged from 6 to 12 mm exclusive of caudal gill filaments with larger individuals recorded in May and in November and a preponderance of smaller individuals in September. The distribution of the Zygoptera nymphs was similar to that of the Anisoptera nymphs although, wherever found, the numbers of Anisoptera and their percent volume contribution exceeds that of the Zygoptera.

Order Ephemeroptera:

Ephemeroptera, or mayfly nymphs are collector-

Suborder Zygopteria:

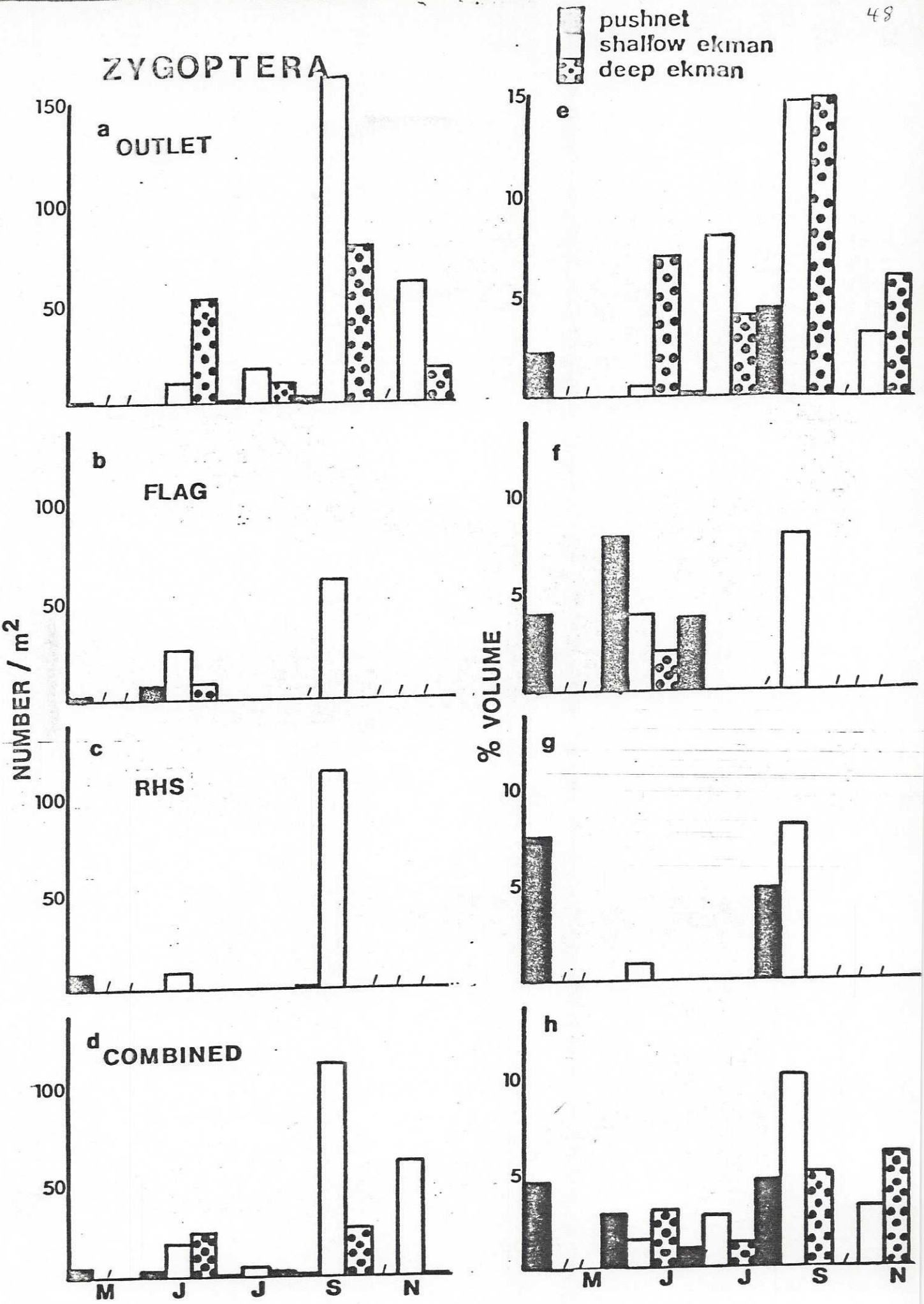
The seasonal changes in abundance and percent volume of the damselfly nymphs are shown in Figure 8. A single genus, Protoallagma, was represented (family Coenagrionidae). Low numbers of nymphs present during dry sampling accounted for almost 5 percent of the sampled biomass. This declines to less than 2.5% of the volume in June and July with damselfly nymphs absent at the OUTLET site. This indicates emergence which is followed in September by a large recruitment raising the abundance to over 120 individuals per meter squared. This is followed numerical increase over the July sample reflects a 5 fold increase in the percent volume contribution of the nymphs. Recorded lengths ranged from 8 to 12 mm exclusive of caudal gill filaments with larger individuals recorded in May and in November and a preponderance of smaller individuals in September. The circulation of the Zygopteran nymphs was similar to that of the Anisopteran nymphs although, wherever found, the numbers of Anisopteran and their percent volume contribution exceeded that of the Zygopterans.

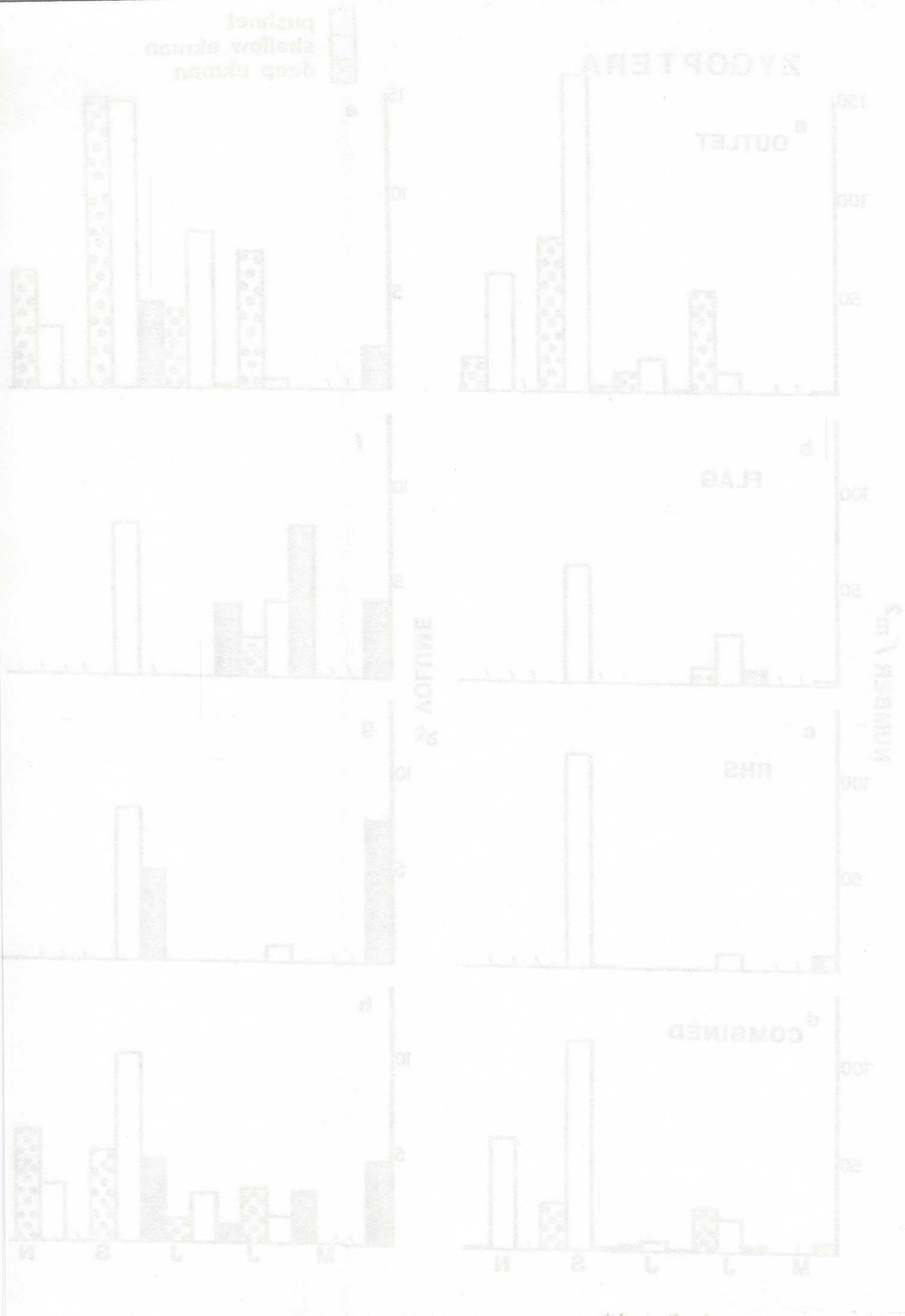
Order Ephemeroptera:

Ephemeroptera, or mayfly nymphs are collector-

Figure 9:
Seasonal changes in the numbers (a,b,c) and the percent volume (d,e,f) contribution of Zygoptera nymphs, Protallagma, to benthic samples from each sampling site and for all sites combined (g,h). The different sampling methods are distinguished (pushnet, shallow ekman, deep ekman).

No shallow or deep ekman samples were collected during May. No pushnet samples were collected at the FLAG site during September. Only the OUTLET site was sampled during November.


pushnet
shallow ekman
deep ekman
ZYGOPTERA
a OUTLET
b FLAG
c RHS
d COMBINED
e
f
g
h
NUMBER / m2
% VOLUME
150
100
50
15
10
5
M
J
J
S
N


ZYGOPTERA
a OUTLET
b FLAG
c RHS
d COMBINED
pristinet
shallow ukmap
deep ukmap
% AUTUMN
NUMBER / m²
M
J
J
S
N

gatherers rather than predators (Merritt and Cummins, 1978) and are seasonal residents of the benthos. The data for the Order are presented in two distinct groups.

Family Ephemeridae:

The first group is Family Ephemeridae, a monospecific assemblage of Hexagenia bilineata (see Figure 10). The nymphs are large, 16 - 24 mm exclusive of caudal filaments. Although numerically rather sparse they account for a considerable proportion of the sample biomass volume in May and June samples, making the most significant contribution at the relatively impoverished RHS site. Similar to the Odonata nymphs, the OUTLET site is characterized by high numerical densities in July when the nymphs are absent for the other sites. Emergence is complete by the September sampling and there is no evidence for an autumn recruitment of nymphs. This is in accord with the diapause postulated for this species in temperate climates (Edmunds et al, 1971). Barber and Kevern (1973), describe a positive correlation between this species distribution and aquatic macrophytes. The distribution observed in Sunfish Lake was not completely Chara dependent, particularily at the RHS site. This is possibly the result of the predator protection afforded by the semi-

gatherers rather than predators (Merritt and Cummins, 1978) and are seasonal residents of the benthos. The data for the Order are presented in two distinct groups.

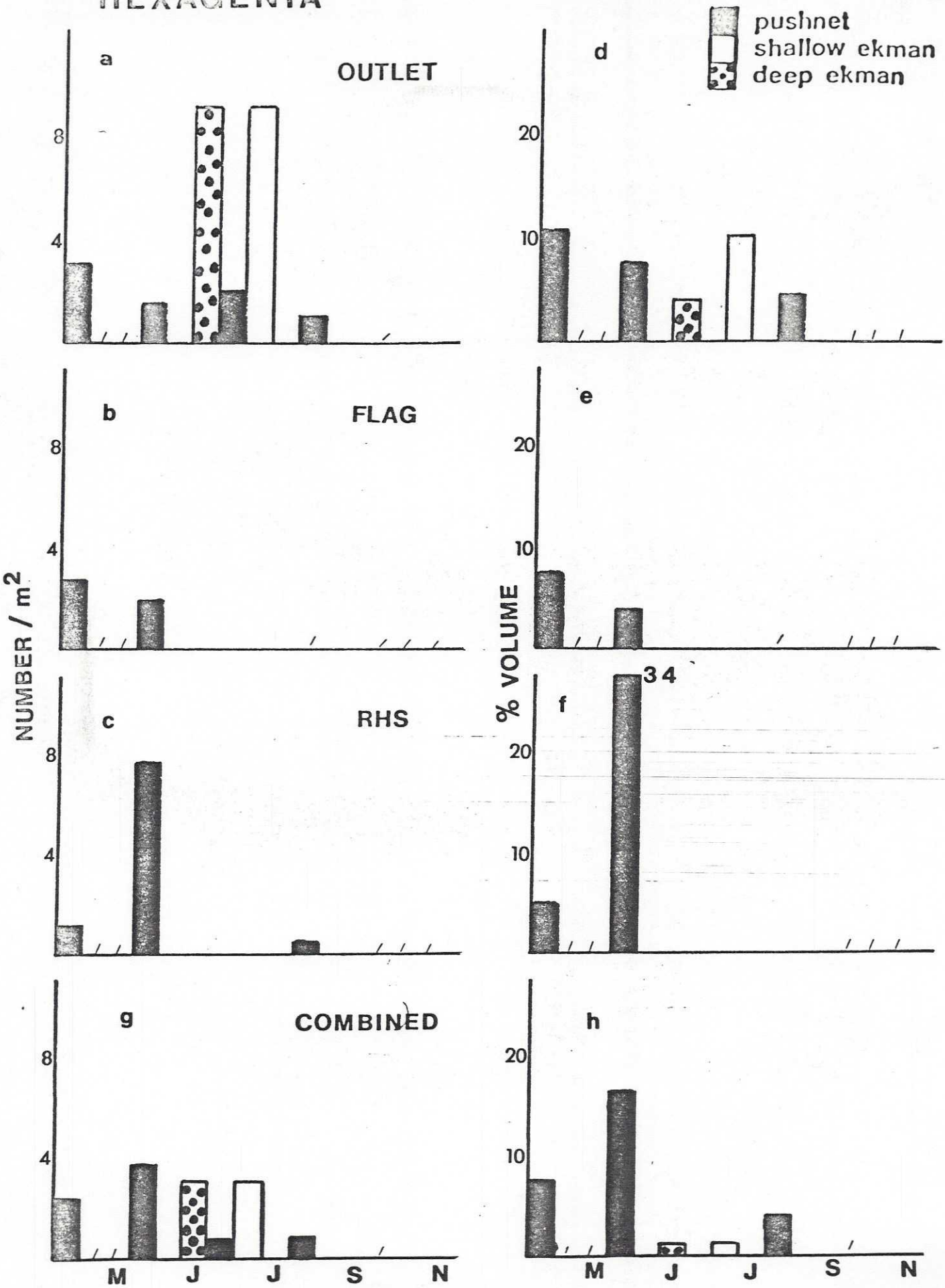
Family Ephemeridae:

The first group is Family Ephemeridae, a monospecific assemblage of Hexagenia bilineata (see Figure 10). The nymphs are large, 16 - 24 mm exclusive of caudal filaments. Although numerically rather sparse they account for a considerable proportion of the sample biomass volume in May and June samples, making the most significant contribution at the relatively improverished RSS site. Similar to the Oconee nymphs, the OUTLET site is characterized by high numerical densities in July when the nymphs are absent for the other sites. Emergence is complete by the September sampling and there is no evidence for an autumn recruitment of nymphs. This is in accord with the diapause postulated for this species in temperate climates (Edmunds et al. 1971). Barber and Kevern (1973), describe a positive correlation between this species distribution and aquatic macrophytes. The distribution observed in Sonfish Lake was not completely Chara dependent, particularly at the RSS site. This is possibly the result of the predator protection afforded by the veni-

Figure 10:
Seasonal changes in the numbers (a,b,c) and the percent volume (d,e,f) contribution of Hexagenia bilineata (Ephemeroptera) nymphs to benthic samples from each of the sites and for all the sites combined (g,h). The different sampling methods are distinguished (pushnet, shallow ekman, deep ekman).

During May, shallow and deep ekman samples were not collected. No pushnet sample was collected at the FLAG site in September. Only the OUTLET site was sampled during November.

HEXAGENIA


pushnet
shallow ekman
deep ekman
a
OUTLET
b
FLAG
c
RHS
g
COMBINED
d
e
f
h
34
NUMBER / m2
% VOLUME
8
4
20
10
M
J
J
S
N

permanent burrows individuals occupy in the substrate (Edmunds et al 1971). Larger bodied individuals tend to be associated with larger grain size sediments (Barber and Kevern, 1973), such as the marl of the RHS site.

Family Ephemerellidae:

The second group of Ephemeropterans are much smaller than the Hexagenia and belong to the genus Ephemerella. They are small, 2 - 6mm, dorsoventrally flattened and tended to be found in association with patchy Chara. Their small size means that the early instars are likely to be underrepresented in the samples. Numerical abundances reach maxima of 400 individuals per meter squared at RHS in June and 450 individuals per meter squared at OUTLET in July accounting for 19 and 26% of the sample volumes respectively. Overall values are considerably lower, approximately 6 percent of the sample volume, but indicate that the nymphs are present throughout the summer and are probably a di- or trivoltine population of overlapping generations. (Edmunds et al 1971). The Ephemerella, too, are nonpredacious collector-gatherers (Merritt and Cummins 1978).

Order Trichoptera:

The Trichoptera, or caddisflies, are a

permanent burrows. Individuals occupy in this substrate (Edmunds et al 1971). Larger bodied individuals tend to be associated with larger grain size sediments (Barber and Kavanagh, 1973), such as the marl of the RMS site.

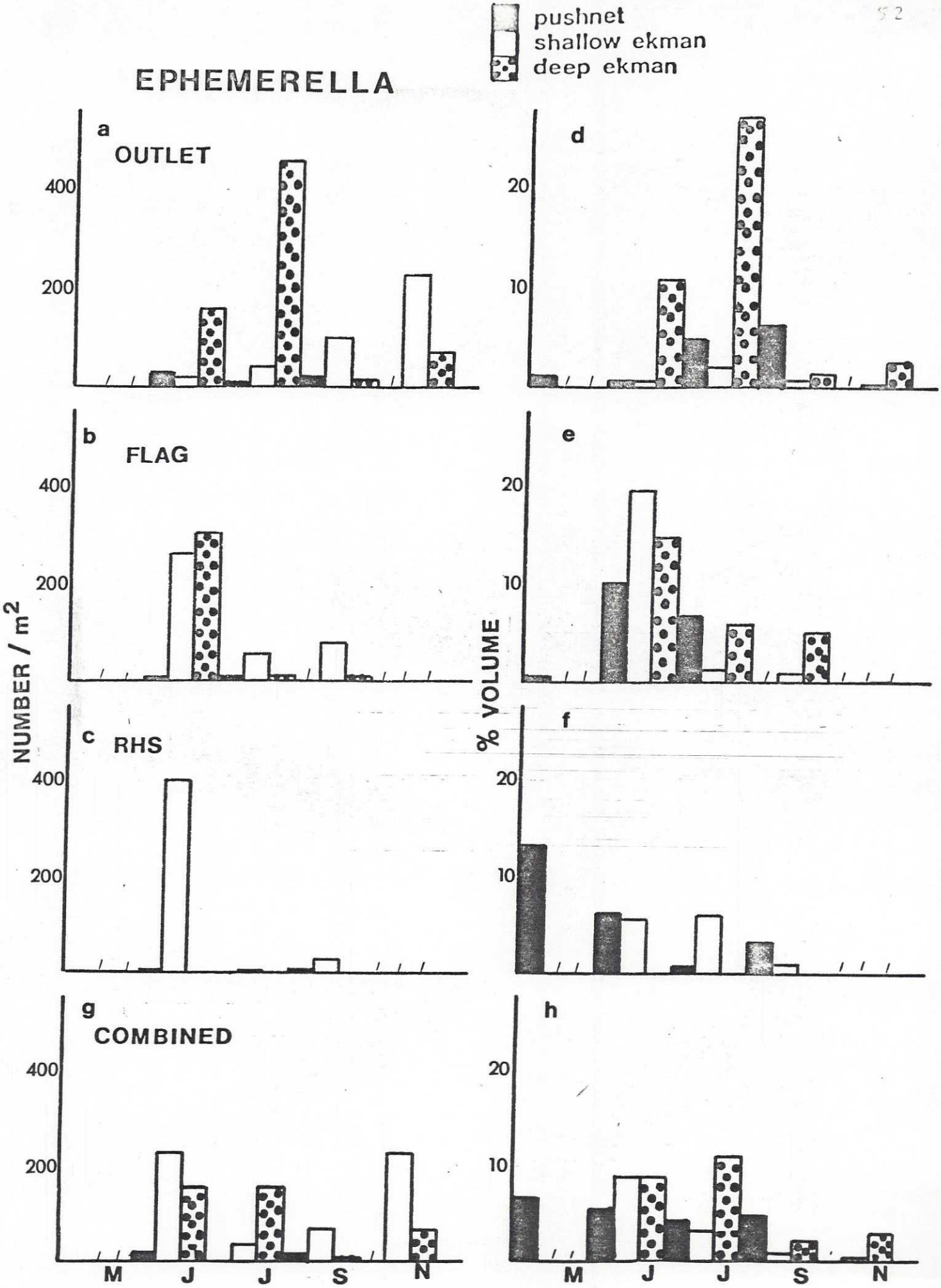
Family Ephemerellidae:

The second group of Ephemeroptera are much smaller than the Hexagenia and belong to the genus Ephemerella. They are small, 2 - 6mm, dorsoventrally flattened and tended to be found in association with patchy Chara. Their small size means that the early instars are likely to be underrepresented in the samples. Numerical abundances reach maxima of 489 individuals per meter squared at RMS in June and 459 individuals per meter squared at OUTLET in July accounting for 19 and 26% of the sample volumes respectively. Overall values are considerably lower, approximately 6 percent of the sample volume, but indicate that the nymphs are present throughout the summer and are probably a di- or trivoltine population of overlapping generations. (Edmunds et al 1971). The Ephemerella, too, are nonpredacious collector-gatherers (Merritt and Cummins 1978).

Order Trichoptera:

The Trichoptera, or caddisflies, are a

Figure 11:
Seasonal changes in the numbers (a,b,c) and the percent volume (d,e,f) contribution of Ephemerella (Ephemeroptera) nymphs to benthic samples from each of the sites and for all the sites combined (g,h). The different sampling methods are distinguished (pushnet, shallow ekman, deep ekman). No shallow or deep ekman samples were collected during May. No pushnet samples were collected from the FLAG site during September. Only the OUTLET site was sampled during November.


pushnet
shallow ekman
deep ekman
EPHEMERELLA
a
OUTLET
b
FLAG
c
RHS
g
COMBINED
d
e
f
h
NUMBER / m2
% VOLUME
400
200
20
10
M
J
J
S
N

holometabolous order of insects with obligate aquatic larvae. The larvae are found in a wide variety of lentic and lotic habitats and are often recognized by the unique tubes or cases they build and often carry with them (Wiggins, 1977). Sunfish Lake trichopteran larvae belong almost exclusively to the family Limniphilidae. The family are non-predatorial collector-gatherers and scrapers (Wiggins, 1977).

A summary of trichopteran larvae in the sample catches is shown in Figure 12. Larvae and were invariably found with their cases bound to fronds of Chara. No pupae were caught during sampling. For convenience their size distribution is given in terms of individuals greater or less than 9mm in total length exclusive of cases.

Low population densities persisted at one or more of the sample sites throughout the summer. In the late summer and early fall the numbers of individuals increased to over 370 individuals per meter squared with a consequent 4-fold increase in the percent volume contribution made by the group. The numerical distribution of larvae is clearly associated with sampling habitat indicating a localization to the dense Chara at depths characteristic of shallow ekman samples. The high November population at large size suggests that the

holometabolous order of insects with obligate aquatic larvae. The larvae are found in a wide variety of lentic and lotic habitats and are often recognized by the unique tubes or cases they build and often carry with them (Wiggins, 1977). Scottish lake trichopteran larvae belong almost exclusively to the family Limnephilidae. The family are non-predaceous collector-gatherers and scrapers (Wiggins, 1977).

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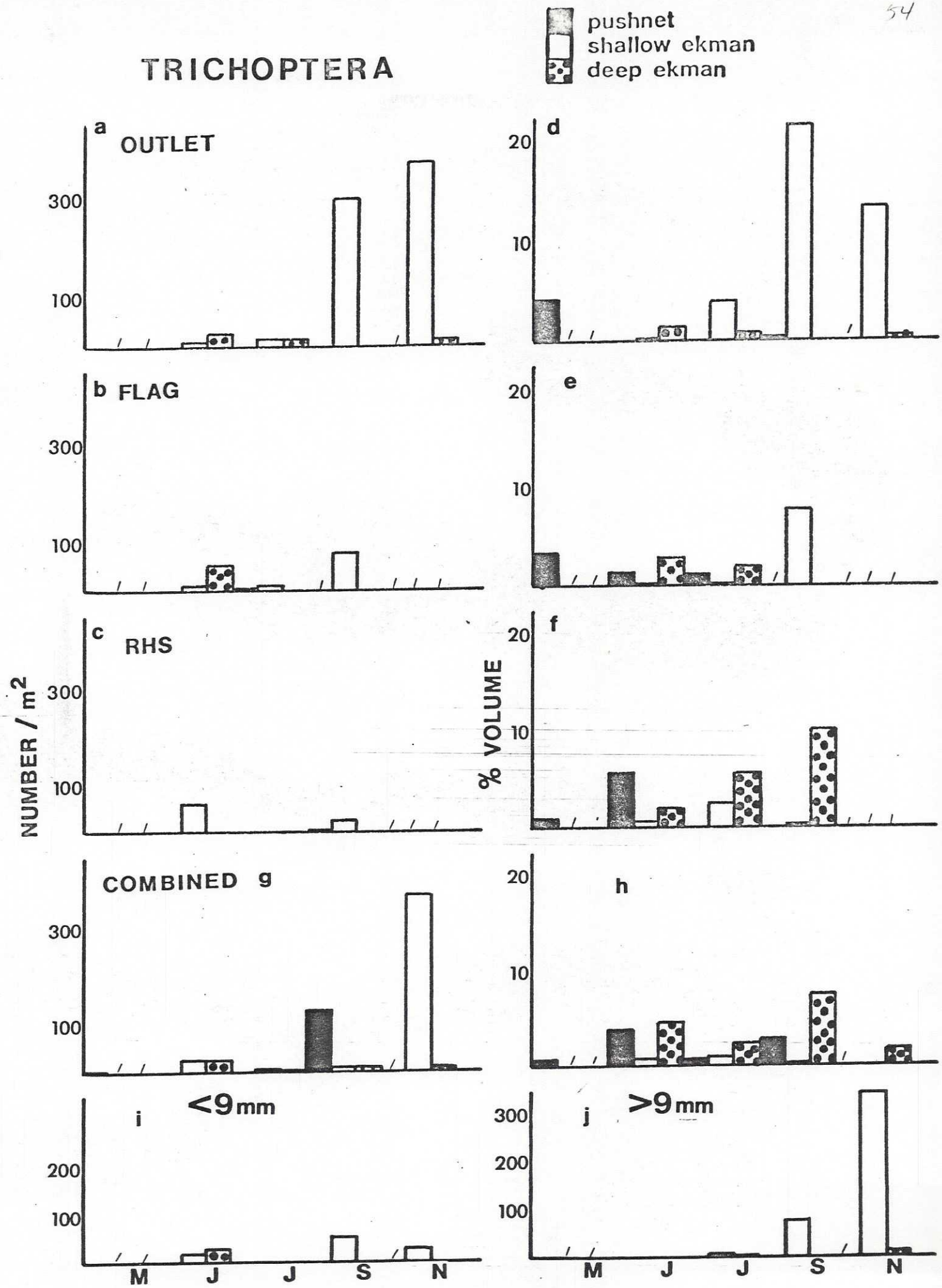
Low population densities prevailed at one or more of the sample sites throughout the summer. In the late summer and early fall the numbers of individuals increased to over 270 individuals per meter squared with a consequent 4-fold increase in the percent volume contribution made by the group. The numerical distribution of larvae is clearly associated with sampling method indicating a localization to the dense Chara at depths characteristic of shallow sloman samples. The high November population at large size suggests that the

Figure 12:
Seasonal changes in the numbers (a,b,c) and the percent volume (d,e,f) contribution of Trichopteran larvae to benthic samples from each of the sites and for all the sites combined (g,h). Seasonal changes in the numbers of individuals <9 mm and >9 mm (i,j) are shown. The different sampling methods are distinguished.
No shallow or deep ekman samples were collected during May. No pushnet samples were collected at the FLAG site during September. Only the OUTLET site was sampled during November.

TRICHOPTERA



larvae overwinter as sub-adults. This is in accord with other data on the family (Wiggins 1977).

Mollusca

The molluscs of Sunfish Lake represent 3 species of gastropods and one species of Lamellibranch which is a rare occurence. One of the gastropods, Viviparus georgicanicus was present in great abundance and is treated as a single unit, (see Figure 13). The remainder of the molluscs collected are considered together (see Figure 14). The gastropods are grazers of microalgae and microfauna, particularly where epiphytic on the Chara, and also consume benthic detritus.

Gastropoda:

Viviparus georgicanus: This species of gastropod was numerically important at all sites in all months except May. Very low numbers tended to be associated with pushnet samples and the highest levels with shallow ekman samples at the OUTLET site. There is a tendency to move to depth in November presumably to overwinter. This overwintering at depth is probably the cause of the small numbers collected in May. Also shown in Figure 13 are the size distributions of the Viviparus based on the range of 1 to 6mm in maximum length. The June distribution is broad relative to the distribution in other months, particulary September, when the OUTLET site shows a considerable recruitment of smaller individuals.

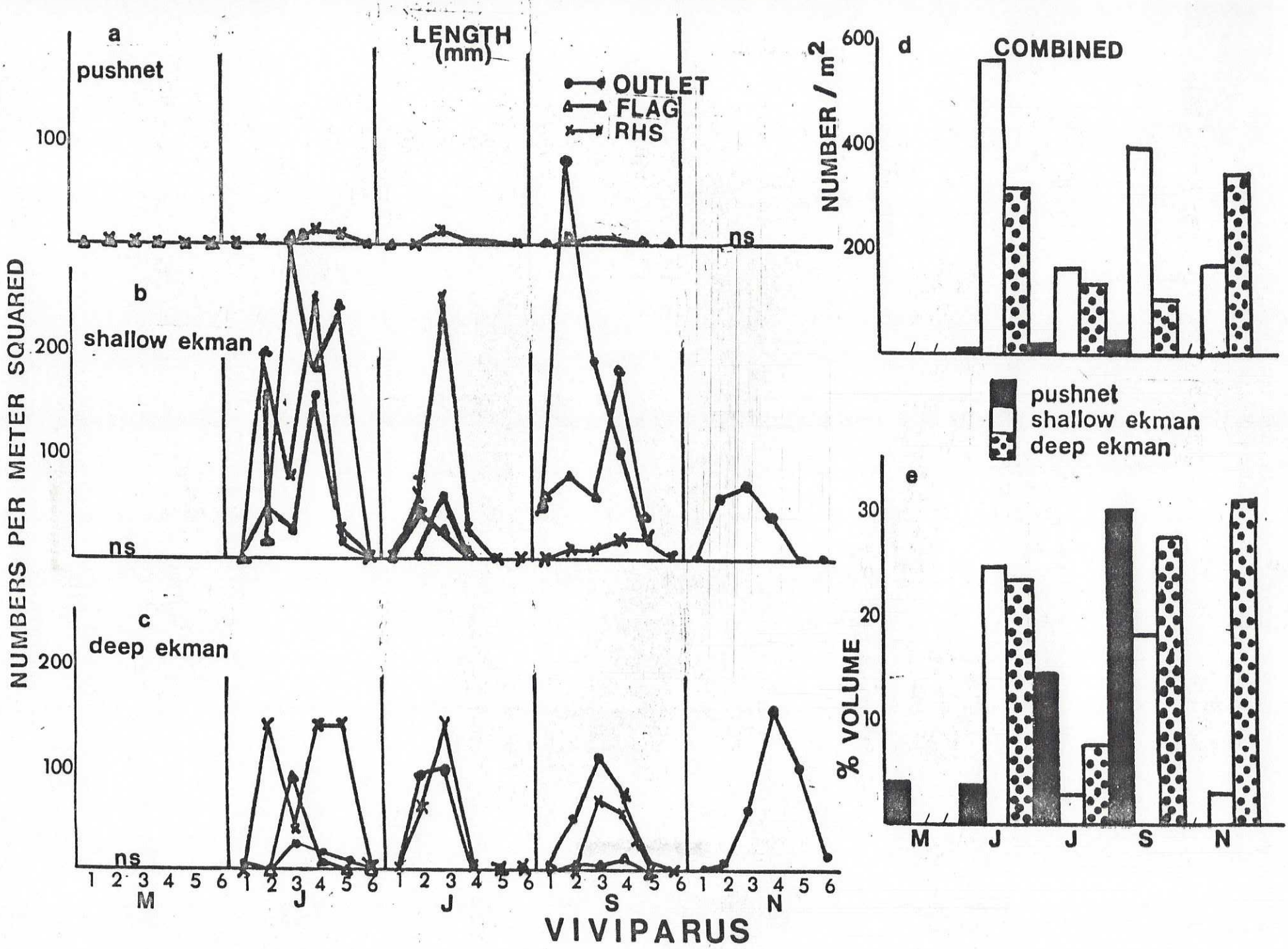
Molluscs

The molluscs of Ronalds Lake represent a species of gastropods and one species of bivalves which is a rare occurrence. One of the gastropods, *Vivipara georgianensis* was present in great abundance and is treated as a single unit, (see Figure 13). The remainder of the molluscs collected are considered together (see Figure 14). The gastropods are grazers of microalgae and microfauna, particularly where epiphytic on the *Chara*, and also consume humbic detritus.

Gastropoda:

Viviparus georgianus. This species of gastropod was numerically important at all sites in all months except May. Very low numbers tended to be associated with positive samples and the highest levels with shallow shoan samples at the OUTLET site. There is a tendency to move to depth in November presumably to overwinter. This overwintering at depth is probably the cause of the small numbers collected in May. Also shown in Figure 13 are the size distributions of the *Viviparus* based on the range of 1 to 6mm in maximum length. The same distribution is broad relative to the distribution in other months, particularly September, when the OUTLET site shows a considerable recruitment of smaller individuals.

Figure 13:
Seasonal changes in the size distribution of Viviparus georgianicus (Gastropoda) are shown by the sampling method used (a,b,c). The different sites are distinguished (OUTLET, FLAG, RHS).
Seasonal changes in the numbers (d) and the percent volume (e) contribution of Viviparus to the benthic samples are shown for all the sites combined. The different sampling methods are distinguished (pushnet, shallow ekman, deep ekman).
No shallow or deep ekman samples were collected during May. No pushnet samples were collected from the FLAG site during September. Only the OUTLET site was sampled during November.


a
pushnet
LENGTH (mm)
OUTLET
FLAG
RHS
100
ns
b
shallow ekman
200
100
ns
c
deep ekman
200
100
ns
NUMBERS PER METER SQUARED
1 2 3 4 5 6 1 2 3 4 5 6 1 2 3 4 5 6 1 2 3 4 5 6 1 2 3 4 5 6
M
J
J
S
N
VIVIPARUS
d
COMBINED
NUMBER / m2
600
400
200
pushnet
shallow ekman
deep ekman
e
% VOLUME
30
20
10
M
J
J
S
N

The absence of larger individuals late in the summer indicates that the species may be annual (see also Turnbull, 1975) overwintering at a mean size of 4mm. Particularily at depth the Viviparus account for a relatively large proportion of the percent volume in samples. Several of the 3.5 meter samples without Chara contained only Viviparus and Chironomids.

Other molluscs:

The other molluscs are dominated by Physa, a large bodied gastropod found exclusively on Chara. A slight contribution to the numbers and percent volume is made by Gyraulus, a dorsoventrally flattened gastropod whose shells are common in the sediments but of which less than 10 live individuals were collected in the course of sampling. The final contribution to the molluscan fauna is Pisidium, a small, (6-8mm) white bivalve collected alive only 3 times. The Physa are numerically important at the FLAG sample site in July although they compose only 6 percent of the volume at that time. The largest volume contributions by the Physa are made in low diversity samples where their individual bulk becomes important relative to that of small bodied Chironomids (pers. obs).

Crustacea:

Order Amphipoda:

The absence of larger individuals late in the summer indicates that the species may be annual (see also Turnbull, 1975) overwintering at a mean size of 4mm. Particularly at depth the Viviparus account for a relatively large proportion of the percent volume in samples. Several of the 5.5 meter samples without Chara contained only Viviparus and Chironomids.

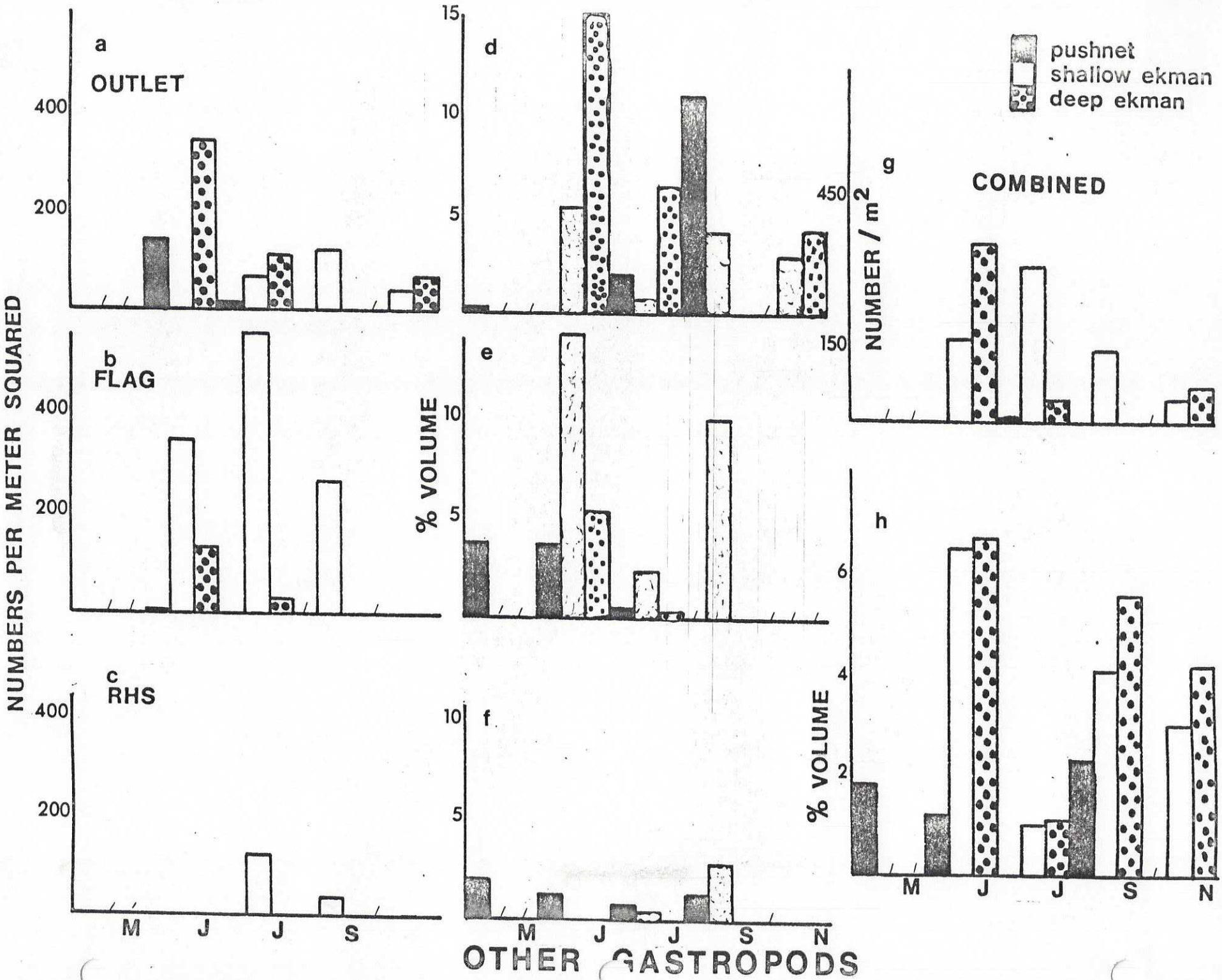
Other mollusks:

The other mollusks are dominated by Physa, a large bodied gastropod found exclusively on Chara. A slight contribution to the number and percent volume is made by Gyraulus, a dorsoventrally flattened gastropod whose shells are common in the sediments but of which less than 10 live individuals were collected in the course of sampling. The final contribution to the molluscan fauna is Platylon, a small, (5-8mm) white bivalve collected alive only 3 times. The Physa are numerically important at the FLAG sample site in July although they comprise only 6 percent of the volume at that time. The largest volume contributions by the Physa are made in low diversity samples where their individual bulk becomes important relative to that of small bodied Chironomids (pers. obs).

Crustaceans:

Order Amphipoda:

Figure 14:
Seasonal changes in the numbers (a,b,c) and the percent volume (d,e,f) contribution of other Gastropods (predominantly Physa)to benthic samples from each of the sampling sites and for all the sites combined (g,h). The different sampling methods are distinguished (pushnet, shallow ekman, deep ekman).
No shallow or deep ekman samples were collected during May. No pushnet samples were collected from the FLAG site during September. Only the OUTLET site was sampled during November.


a
OUTLET
b
FLAG
c
RHS
NUMBERS PER METER SQUARED
400
200
M
J
J
S
d
e
f
% VOLUME
15
10
5
N
g
COMBINED
NUMBER / m2
450
150
h
6
4
2
pushnet
shallow ekman
deep ekman
OTHER GASTROPODS

The amphipod population of Sunfish Lake is monospecific, composed of Hyalella azteca individuals. Figure 15 shows the size distribution of Amphipods in the samples. The intermediate (2 - 3mm) sized individuals predominate throughout the season. In June there are appreciable numbers of the largest individuals (>3mm) which presumably constitute the breeding population (Cooper, 1965). Throughout the remainder of the season, the intermediate (2 - 3mm) individuals predominate. A substantial recruitment of small individuals is seen in July and again in September. By November, reproduction has ceased and the distribution becomes far more compact, consisting of the overwintering population of adults and subadults (Cooper, 1965). High numerical abundances and percent volumes are clearly associated with shallow samples and the protection afforded by the Chara. Amphipods are a reliable indicator of the presence of Chara in a sample (see Table H). The overwintering population constitutes a 3 fold increase over the observed September values indicating growth of a September recruitment of individuals to a size detectable by the sampling methods used. Seasonal variation in the abundance of amphipods is very large, with a November surface ekman mean of 4250 individuals per meter squared and a June surface ekman mean of less than 100 individuals per meter squared.

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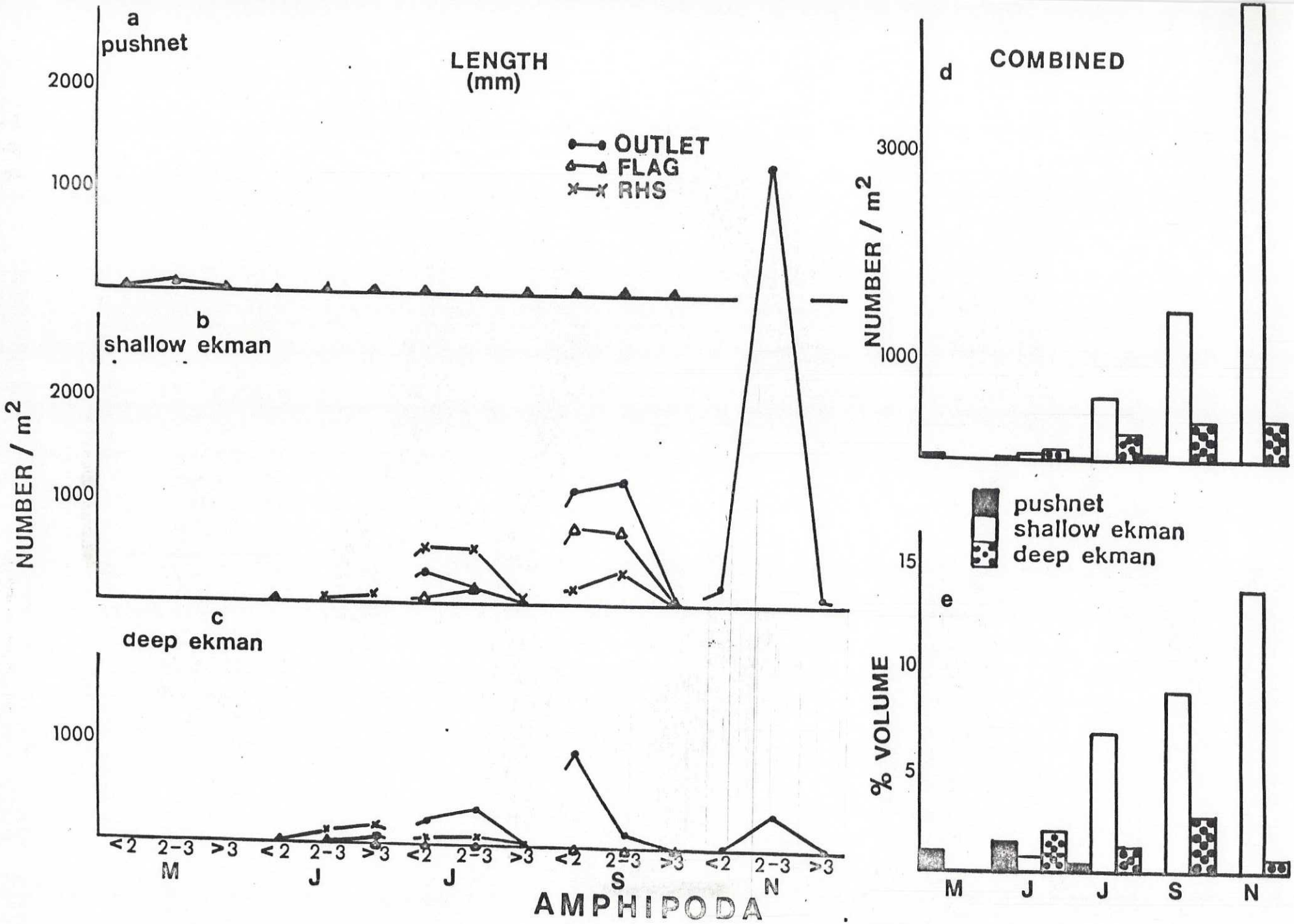
Figure 15:
Seasonal changes in the size distribution of Hyalella azteca (Amphipoda) are presented by the sampling method used (a,b,c). The different sampling sites are distinguished (OUTLET,FLAG, RHS). Seasonal changes in the numbers (d) and the percent volume (e) contribution are presented for all the sites combined.
No shallow or deep ekman samples were collected during May. No pushnet samples were collected from the FLAG site during September. Only the OUTLET site was sampled during November.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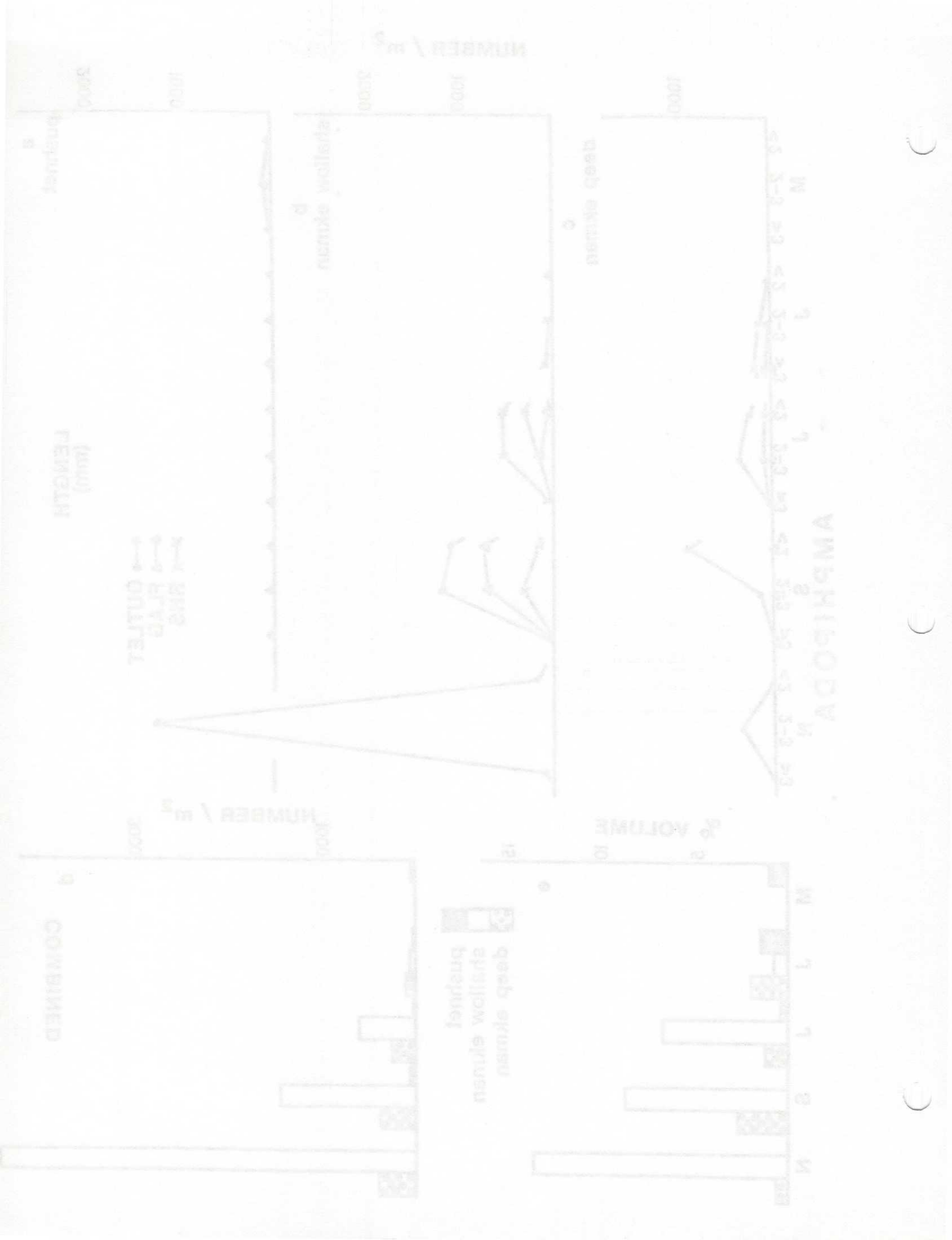

Hydracarina:

The mite population is dominated by a soft-bodied, red mite that lives exclusively in association with Chara. During their peak abundances in July and September the mites were visible from the water surface as bright red mottlings of the Chara fronds. Minimal numbers (a maximum of 40 individuals per meter squared) were found of a group of hard bodied mites. These were distinguished in the collections but all the mites are presented collectively in Figure 16. The mites are small relative to other benthic macroinvertebrates studied (1 - 2.5mm) so they never contribute more than 4% of the sample volume although the numerical abundance reaches 210 individuals per meter squared in surface ekman samples at the FLAG site during September. The mites are virtually absent from May and June samples, thereafter they increase rapidly in abundance. It is probable that the group is univoltine and that smaller individuals or larvae were not retained in June. Little is known of the natural history of the Hydracarina (Parker, 1975).

Phylum Annelida:

Oligochaeta

Hydracarina:

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Phylum Annelida:

Oligochaeta