

Figure 34:

The diet of the Hymenoptera Hymenoptera.

Figure 35:

The diet of the Hymenoptera Hymenoptera.

The size of each slice represents the percent volume contribution of each prey taxon to the total stomach contents. The peripheral numbers are the mean number of prey items this would represent. The sample size is given for each diagram.

- 1. Chalcididae
- 2. Cynipidae
- 3. Ichneumonidae
- 4. Braconidae
- 5. Aphididae
- 6. Psyllidae
- 7. Homoptera
- 8. Thysanoptera
- 9. Hemiptera
- 10. Coleoptera
- 11. Diptera
- 12. Lepidoptera
- 13. Trichoptera
- 14. Hymenoptera
- 15. Arachnida
- 16. Mollusca
- 17. Plant tissue
- 18. Organic debris
- 19. Other

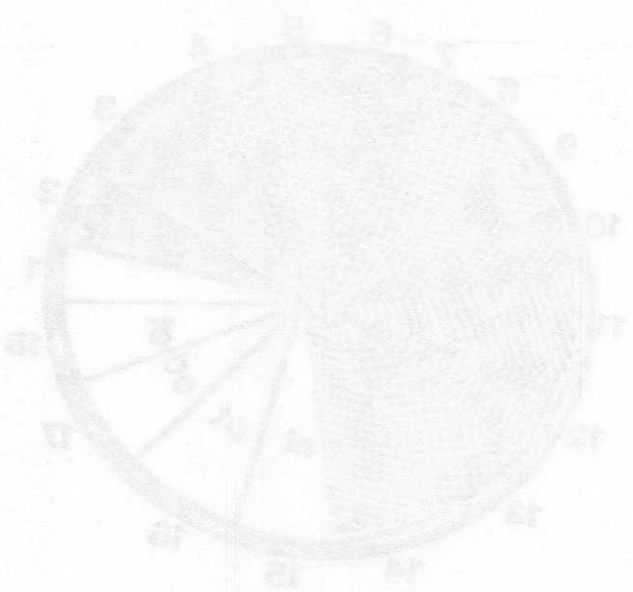


Figure 34:

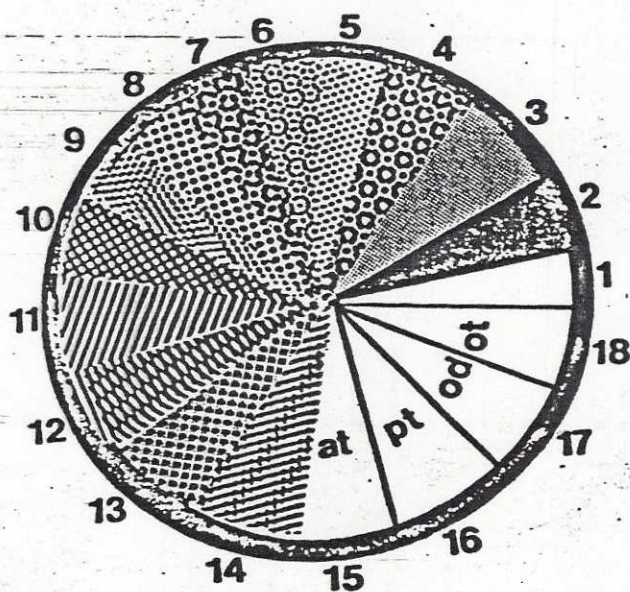
The diet of the Bluntnose Minnow.

Figure 35:

The diet of the Brook Stickleback

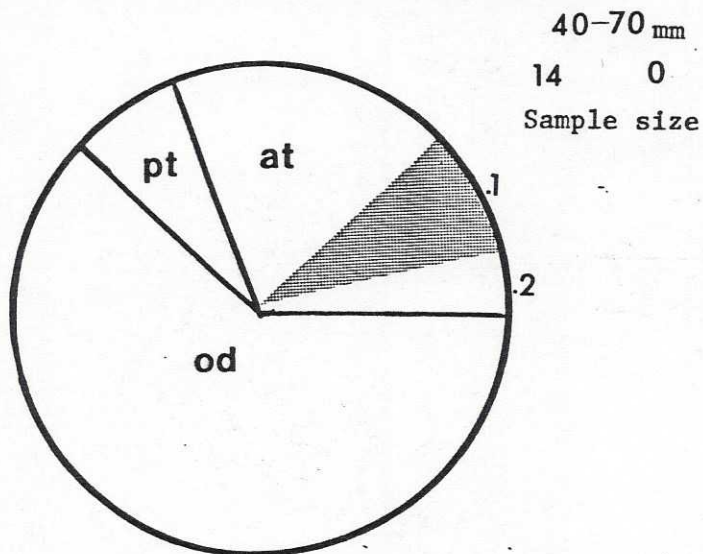
The size of each slice represents the percent volume contribution of each prey taxocene to the total stomach contents. The peripheral numbers are the mean number of prey items this would represent.

The sample size is given for each diagram.

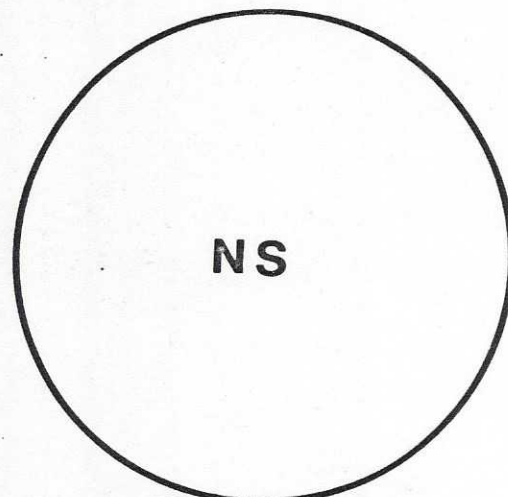


- 1 cladocerans
- 2 copepods/ostracods
- 3 chironomid larvae
- 4 decapods
- 5 anisoptera nymphs
- 6 zygoptera nymphs
- 7 Ephemerella nymphs
- 8 Hexagenia nymphs
- 9 trichopteran larvae
- 10 Viviparus
- 11 amphipods
- 12 hydracarina
- 13 terrestrial insects
- 14 fish
- 15 animal tissue
- 16 plant tissue
- 17 organic debris
- 18 other

BLUNTNOSE MINNOW

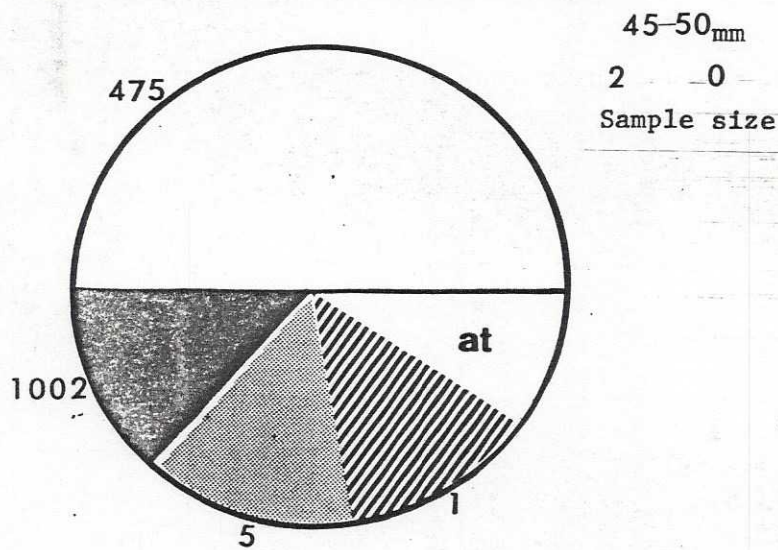


MAY

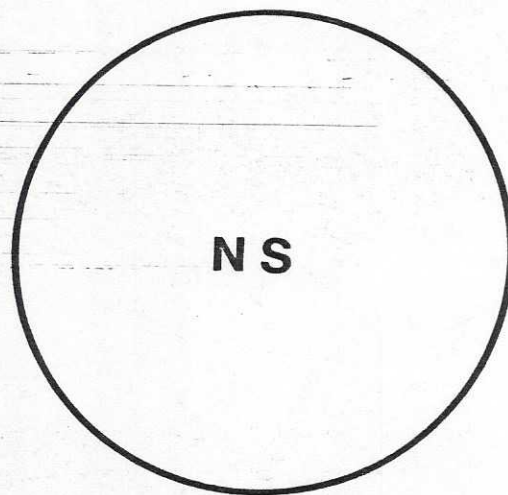


JULY

BROOK STICKLEBACK



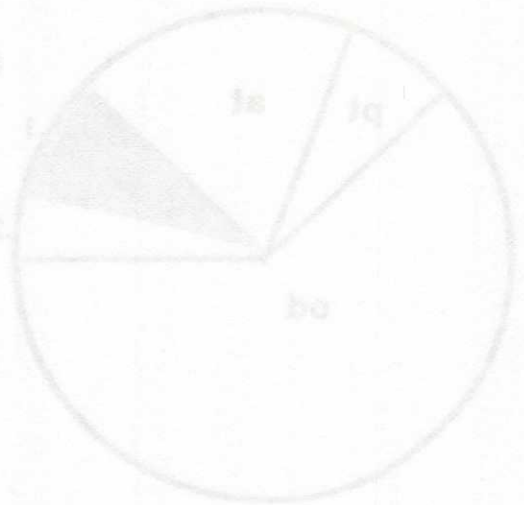
MAY



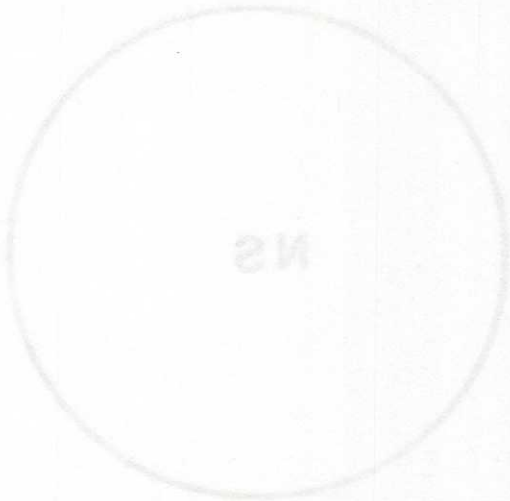
JULY

BLUNTNOSE MINNOW

40-50 mm
0
Sample size



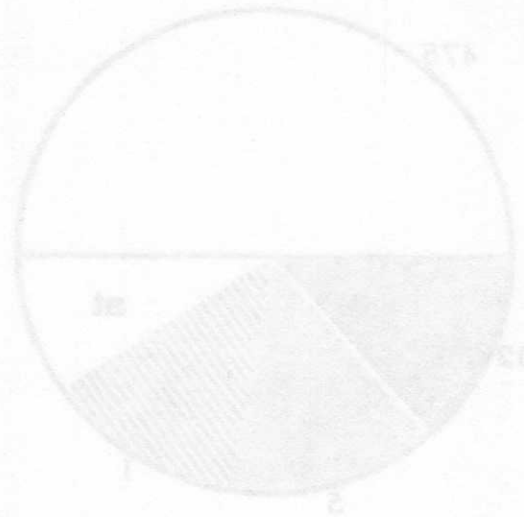
MAY



JULY

BROOK STICKLEBACK

40-50 mm
0
Sample size



MAY



JULY

available food ranging from detritus to fish. The present sample is too small to permit generalization about the species food habits in Sunfish Lake.

Tadpole Madtom

(N=1: M=1, J=0)

The stomach contents of a single Tadpole Madtom (49 mm, 1.32 g) caught during May are presented in figure 37. 75% of the stomach volume consisted of animal tissue. Small numbers of Cladocera and chironomids were present. Scott and Crossman (1974) indicate the food of this species to consist of a range of small bodied benthic invertebrates, Cladocera and ostracods. Again the sample is too small to permit generalization about the species food habits in Sunfish Lake.

available food varying from 10 to 15%. The
present sample is too small to permit generalization
about the species food habits in South Lake.

Tadpole Habitat

(N=1; M=1, 3-8)

The stomach contents of a single tadpole habitat (N=1, M=1) caught during May are presented in figure 1. 75% of the stomach volume consisted of animal tissue. Small numbers of diatoms and chironomids were present. Scott and Crossman (1973) indicate the food of this species to consist of a range of small bodied benthic invertebrates, cladocera and ostracods. Again the sample is too small to permit generalization about the species food habits in South Lake.

Figure 36:

The diet of the Brown Bullhead.

Figure 37:

The diet of the Spotted Salamander.

The size of each slice represents the percent volume contribution of each prey taxocene to the total stomach contents. The peripheral numbers are the mean number of prey items this would represent. The sample size is shown for each station.

- 1 cladocerans
- 2 copepod/oligochaetes
- 3 chironomid larvae
- 4 decapods
- 5 amphipods
- 6 isopods
- 7 ephemeropteran nymphs
- 8 hexagenia nymphs
- 9 trichopteran larvae
- 10 viviparus
- 11 amphipods
- 12 hydracina
- 13 terrestrial insects
- 14 fish
- 15 animal tissue
- 16 plant tissue
- 17 organic debris
- 18 other

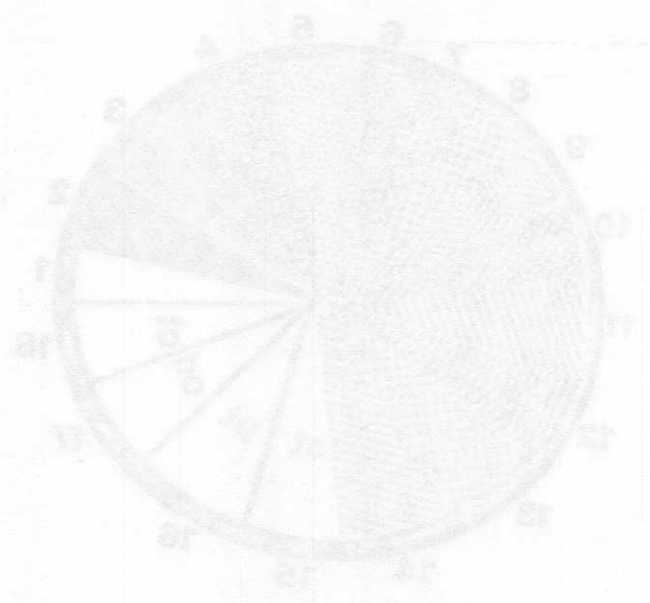


Figure 36:

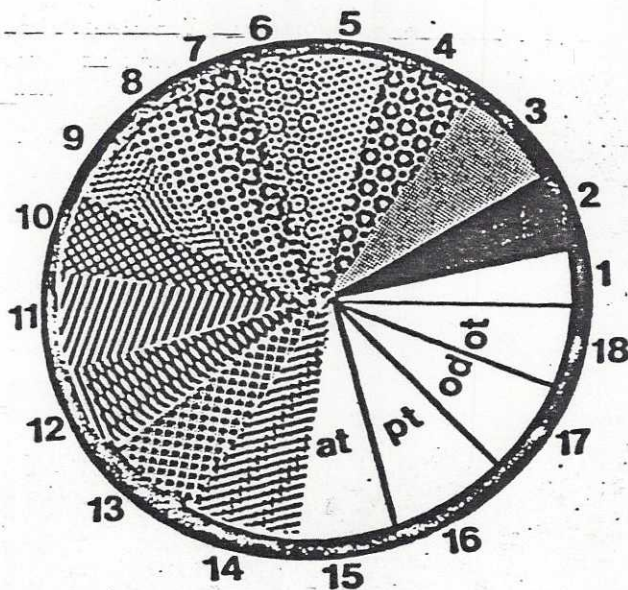
The diet of the Brown Bullhead.

Figure 37:

The diet of the Tadpole Madtom.

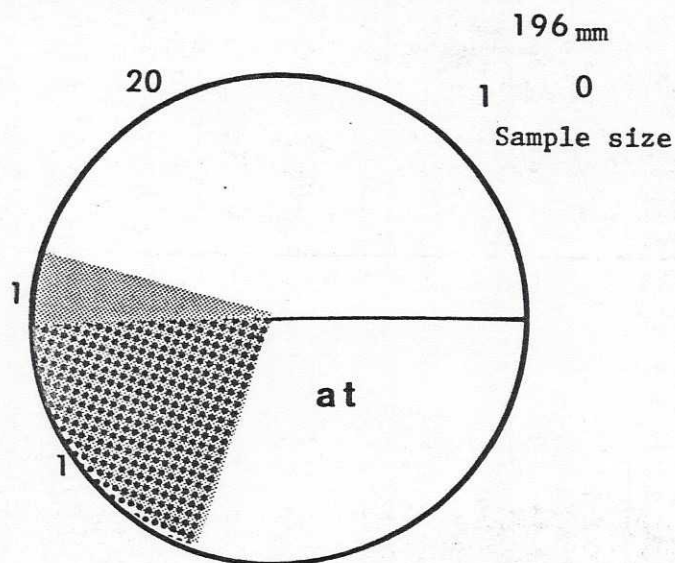
The size of each slice represents the percent volume contribution of each prey taxocene to the total stomach contents. The peripheral numbers are the mean number of prey items this would represent.

The sample size is shown for each diagram.

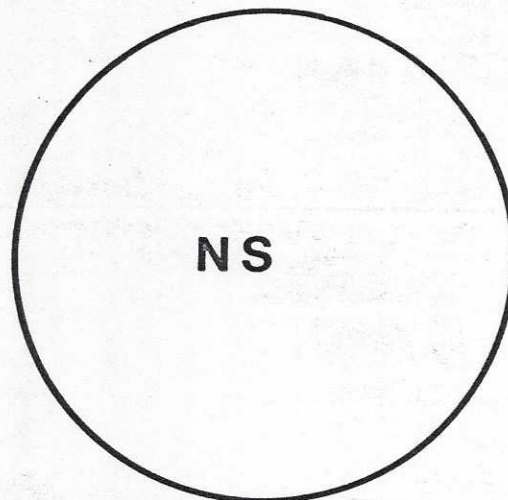


- 1 cladocerans
- 2 copepods/ostracods
- 3 chironomid larvae
- 4 decapods
- 5 anisoptera nymphs
- 6 zygoptera nymphs
- 7 Ephemerella nymphs
- 8 Hexagenia nymphs
- 9 trichopteran larvae
- 10 Viviparus
- 11 amphipods
- 12 hydracarina
- 13 terrestrial insects
- 14 fish
- 15 animal tissue
- 16 plant tissue
- 17 organic debris
- 18 other

BROWN BULLHEAD

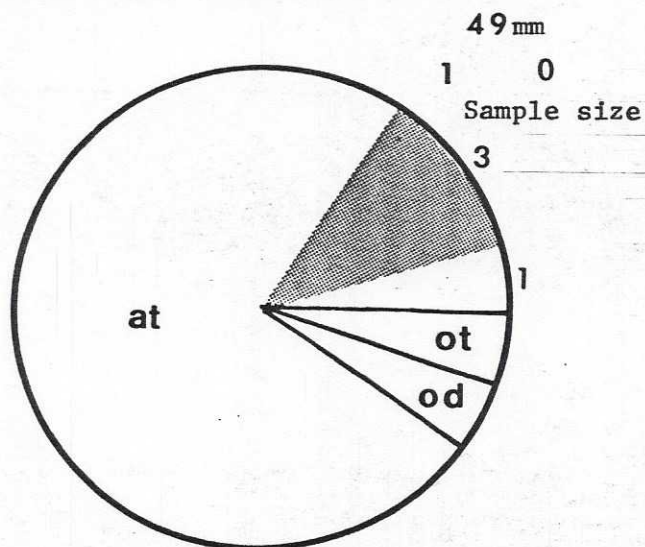


MAY

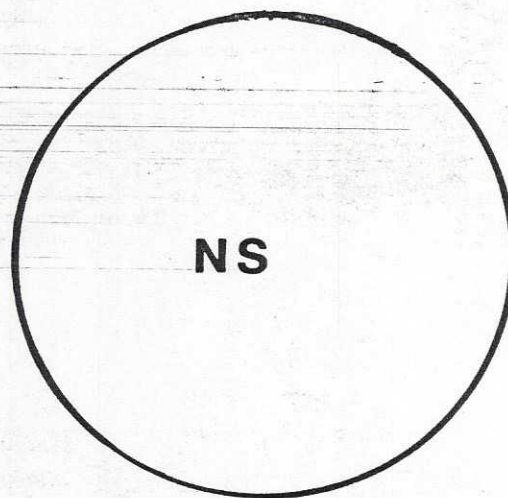


JULY

TADPOLE MADTOM



MAY

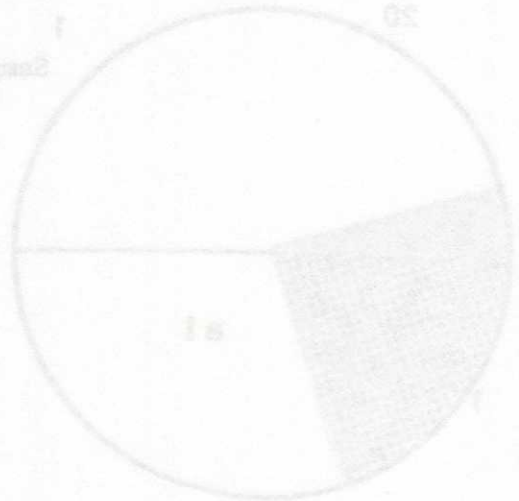


JULY

BROWN BULLHEAD

1967

Sample size



MAY

TADPOLE MADDON

1967

Sample size



MAY



JULY



JULY

The Fish Sample Size

A retrospective look at the fish diets relative to sample size indicates that some of the trends observed may be artifacts of the small sample size.

The largest observed diversities in diet occur in the Yellow Perch, Group I, May (N=19), the Pumpkinseed, Group III, July (N=27) and the Rock Bass, Group I, May, (N=26). I would anticipate that the lower diversities in prey taken by other groups of the same species are, at least in part, due to their smaller sample size.

Contrary examples are the Largemouth Bass, Group I, May (N=4) and July (N=8) with a high prey diversity in a small sample. This suggests that the individual fish are consuming a wide range of prey items during a single feeding period.

The Iowa Darter shows little change in the diversity of the prey consumed with changes in sample size (N=5, 19, 3). This suggests that the Iowa Darter forages among a few prey taxocenes during the same feeding period.

On the basis of these trends it is not justifiable to assume low diversity of prey consumption in those fish groups that have small samples and show higher diversity on the other sampling occasion. Notable in this regard is the Group III, May, Pumpkinseed (N=1) that contained a single coleopteran adult. (taxocene= "Other").

A retrospective look at the fish diets relative to sample size indicates that some of the trends observed may be artifacts of the small sample size.

The largest observed diversity in diet occurs in the Yellow Perch, Group I, May (N=12), the Pumpkinseed, Group III, July (N=27) and the Rock Bass, Group I, May (N=26). I would anticipate that the lower diversities in prey taken by other groups of the same species are, at least in part, due to their smaller sample size. Contrary examples are the largemouth bass, Group I, May (N=4) and July (N=8) with a high prey diversity in a small sample. This suggests that the individual fish are consuming a wide range of prey items during a single feeding period.

The Iowa Darter shows little change in the diversity of the prey consumed with changes in sample size (N=5, 12, 37). This suggests that the Iowa Darter forages among a few prey taxonomic during the same feeding period.

On the basis of these trends it is not justifiable to assume low diversity of prey consumption in those fish groups that have small samples and show higher diversity on the other sampling occasion. Notable in this regard is the Group III, May, Pumpkinseed (N=1) that contained a single coleopterian adult (Taxonomic "Other").

PART III

UTILIZATION OF THE BENTHOS

As a first approximation to the utilization of the benthos by the fish population it is possible to consider the proportionate numerical contribution of each benthic prey category to a summed fish diet and to the composition of benthic samples.

Table 17 indicates that 85.4% of the organisms in stomach samples from May consisted of planktonic groups, cladocera and copepods/ostracods. The only other group to contribute more than 1% of the prey organisms taken during May were the chironomid larvae (4.9%). In July the planktonic organisms represent 88.2% of all prey items and chironomids increase in importance to 9.3%. Amphipods and Ephemerella contribute 0.9% and 0.5% respectively.

For the purposes of comparison with the benthos as a potential resource base the proportionate contributions by prey items exclusive of planktonic species are also presented (Table 17). Chironomids show numerical dominance with 90.6% of the summed diet items in May and 80.5% in July. Amphipods fall second in importance in

PART III

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Table IV indicates that 85.4% of the organisms in stomach samples from May consisted of planktonic groups, cladocera and copepods/nauplii. The only other group to contribute more than 1% of the prey organisms taken during May were the chironomid larvae (1.2%). In July the planktonic organisms represent 85.2% of all prey items and chironomids increase in importance to 9.3%. *Hyphessobrycon* and *Hyphessobrycon* contribute 3.9% and 2.5% respectively.

For the purposes of comparison with the benthos as a potential resource base the proportional contributions by prey items exclusive of planktonic species are also presented (Table IV). Chironomids show numerical dominance with 55.6% of the summed diet items in May and 20.5% in July. *Hyphessobrycon* fall second in importance in

Table 17

The diet of each fish species is recorded as the number of prey items contained in a mean 15% stomach. These values are multiplied by the relative abundance of these groups on each sampling occasion and an estimate of the total numerical composition of prey items is achieved. These values are expressed as a percentage of the total number of prey items consumed that belong to each benthic taxonomic. The percentages are given for all prey items and for the benthic prey organisms only. The values are indicative, generally, of the number of organisms of prey, not necessarily of their relative importance to the diet.

Table 17

The diet of each fish species is recorded as the number of prey items contained in a mean fish stomach. These values are multiplied by the relative abundances of these Groups on each sampling occasion and an estimate of the total numerical consumption of prey items is achieved. These values are expressed as a percentage of the total numbers of prey items consumed that belong to each benthic taxocene. The percentages are given for all prey items and for the benthic prey organisms only. The values are indicative, generally, of the number of pursuits of prey, not necessarily of their caloric importance to the diet.

Table 17
TOTAL BENTHOS CONSUMPTION

(expressed as a percentage of the total number of prey items taken)

		Including Planktonic Species	Excluding Planktonic Species
Cladocera	May	79.0	-
	July	88.2	-
Copepoda	May	16.4	-
	July	tr	-
Chironomidae	May	4.2	90.6
	July	9.3	80.5
Decapoda	May	-	-
	July	0.5	4.5
Anisoptera	May	tr	0.1
	July	tr	0.3
Zygoptera	May	tr	0.7
	July	0.1	0.6
Hexagenia	May	tr	tr
	July	tr	tr
Ephemerella	May	0.2	3.3
	July	0.5	4.1
Trichoptera	May	tr	0.1
	July	-	-
Viviparus	May	-	-
	July	0.2	1.8
Amphipoda	May	0.2	4.8
	July	0.9	8.1
Hydracarina	May	tr	0.3
	July	-	-
Other	May	-	-
	July	-	-

Table 17
TOTAL BENTHIC CONSUMPTION

(expressed as a percentage of the total number of prey items taken)

Including Planktonic Species	May	July	Including Planktonic Species	May	July
Cladocera	78.8	88.1	Cladocera	78.8	88.1
	-	-		-	-
Copepoda	16.4	12	Copepoda	16.4	12
	-	-		-	-
Chironomidae	4.2	9.3	Chironomidae	4.2	9.3
	98.8	98.8		98.8	98.8
Isopoda	-	8.5	Isopoda	-	8.5
	4.5	-		4.5	-
Amphipoda	12	12	Amphipoda	12	12
	8.1	8.3		8.1	8.3
Tropidopoda	12	8.1	Tropidopoda	12	8.1
	8.7	8.6		8.7	8.6
Hexapoda	12	12	Hexapoda	12	12
	12	12		12	12
Squilla	8.5	8.5	Squilla	8.5	8.5
	1.3	4.1		1.3	4.1
Tropidopoda	12	12	Tropidopoda	12	12
	8.1	-		8.1	-
Viviparus	-	8.5	Viviparus	-	8.5
	-	1.8		-	1.8
Nephtys	8.1	8.9	Nephtys	8.1	8.9
	4.8	8.1		4.8	8.1
Squilla	12	12	Squilla	12	12
	8.1	-		8.1	-
Other	-	-	Other	-	-
	-	-		-	-

Table 18

Considering only those grey taxonemes that were concerned as grey, the relative contribution of each to the total number of potential grey individuals in penicillin samples is given for both May and July.

Table 18

Considering only those prey taxocenes that were consumed as prey, the relative contribution of each to the total number of potential prey individuals in benthic samples is given for both May and July.

TABLE 18
ENVIRONMENTAL BENTHIC AVAILABILITY¹
(Numerical abundance expressed as percentage of the total number
of potential prey items in the environment)

		May	July
	Chironomids	65.1	84.7
	Decapoda	3.6	.3
15mm <	Anisoptera	.8	.4
	Zygoptera	2.7	.1
	Hexagenia	1.9	.1
	Ephemerella	.7	2.8
9mm <	Trichoptera	0.0	tr
	Viviparus	.6	4.6
	Amphipoda	18.9	4.4
	Hydracarina	2.6	1.7
	Other	3.8	.8

¹Considering only those taxocenes which have been consumed as prey.

TABLE 15
ENVIRONMENTAL BENTHIC AVAILABILITY
(Percent abundance expressed as percentage of the total number
of potential prey items in the environment)

Prey	May	July
Chironomids	25.1	21.7
Hydracarina	3.8	1.3
Isopoda	0.0	0.0
Amphipoda	2.2	1.1
Hexapoda	1.9	1.1
Rotatoria	1.7	2.8
Trichoptera	0.0	0.0
Worms	0.0	0.0
Neuroptera	22.9	0.0
Hydracarina	1.0	1.1
Other	1.8	0.0

Considering only those taxonomic which have been consumed as prey.

The combined fish diet. Only prey taxonomic levels in stomach samples are considered. The size of each slice represents the percent of the total number of prey items consumed that are derived from each prey taxonomic level. The peripheral numbers are the same. The diameter of the available prey items represents the same prey taxonomic as were used as fish food. The size of each slice represents the percentage of the total number of environmental prey items that are derived from each prey taxonomic. The peripheral numbers are the same values.

- 1 cladocera
- 2 copepoda/oligochaeta
- 3 chironomid larvae
- 4 diptera
- 5 simuliid larvae
- 6 cymatodonta nymphs
- 7 ephemeroptera nymphs
- 8 hexagenia nymphs
- 9 trichoptera larvae
- 10 viviparus
- 11 amphipods
- 12 isopods
- 13 terrestrial insects
- 14 fish
- 15 animal tissue
- 16 plant tissue
- 17 organic debris
- 18 other

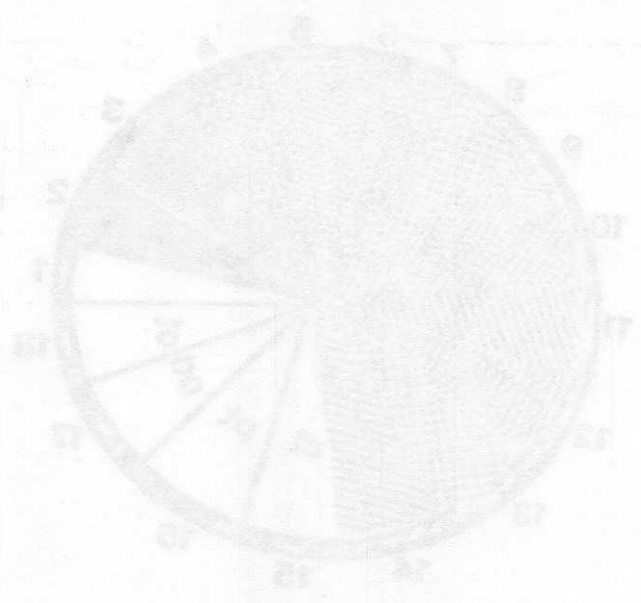
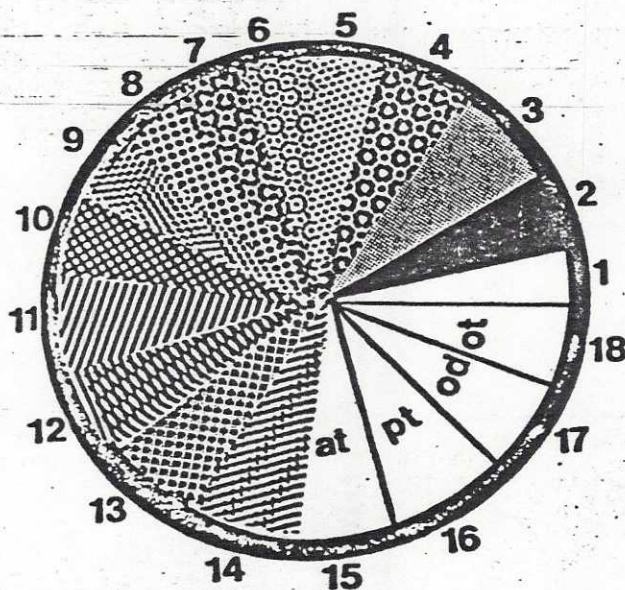


Figure 38:

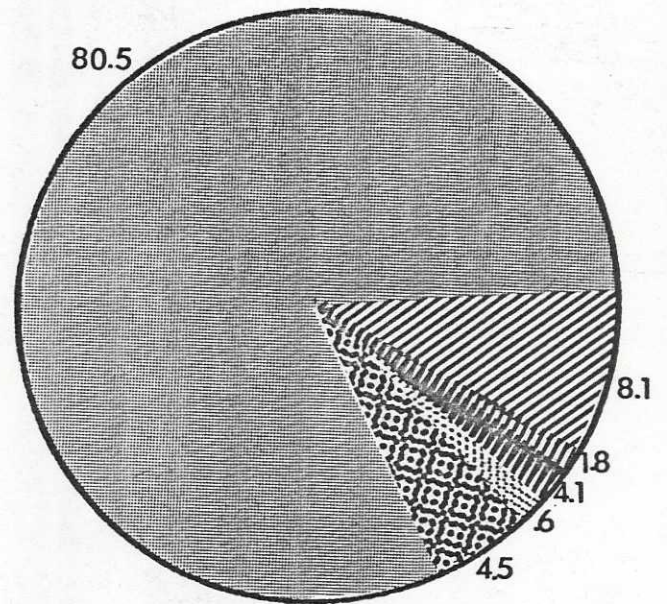
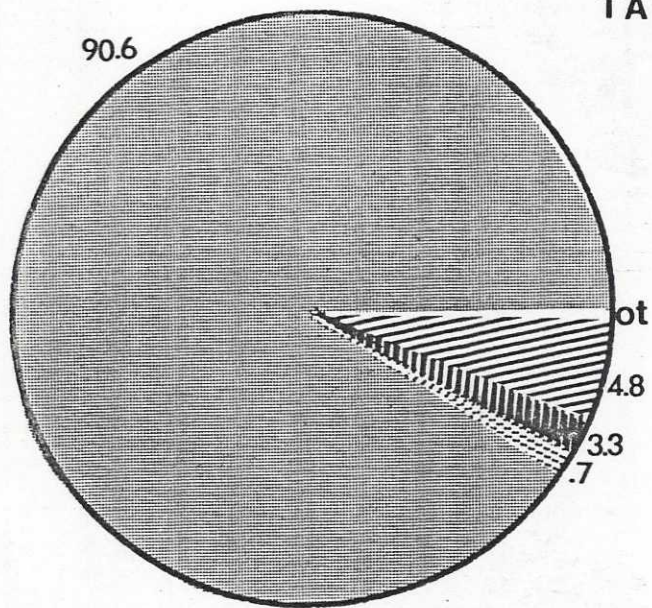
The combined fish diet. Only prey taxocenes found in stomach samples are considered. The size of each slice represents the percent of the total number of prey items consumed that are derived from each prey taxocene. The peripheral numbers are the same. The diagram of the available prey items considers the same prey taxocenes as were used as fish food. The size of each slice represents the percentage of the total number of environmental prey items that are derived from each prey taxocene. The peripheral numbers are the same values.



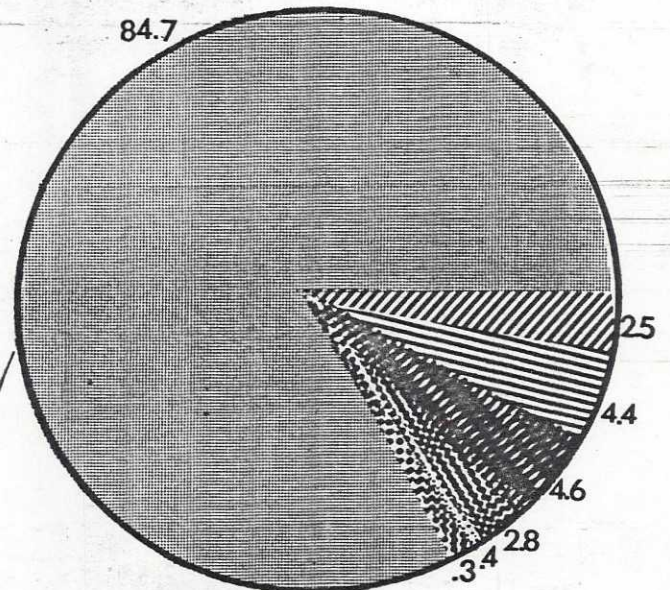
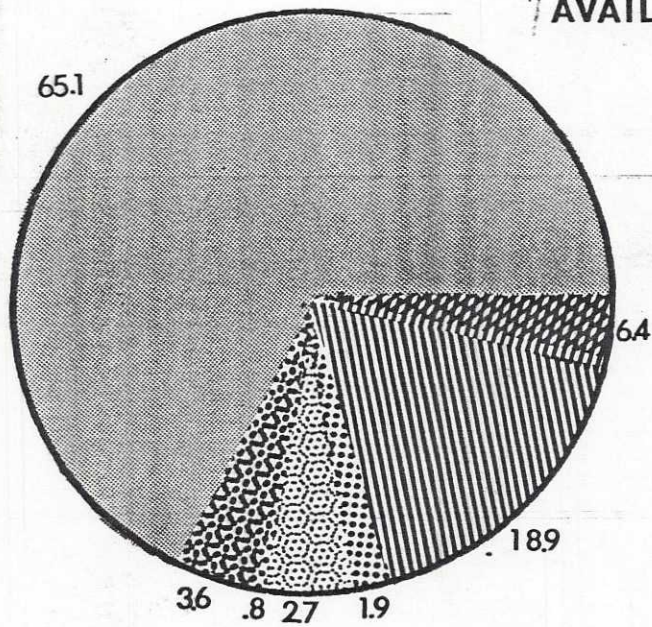
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- 10 Viviparus
- 11 amphipods
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- 13 terrestrial insects
- 14 fish
- 15 animal tissue
- 16 plant tissue
- 17 organic debris
- 18 other

COMBINED FISH DIET

TAKEN



AVAILABLE



MAY

JULY

both months with values of 4.8% and 8.1%. Viviparus and decapods are not taken in May. Hydracarina are not taken in July. Ephemerella, Zygoptera and Anisoptera nymphs gain slightly in importance from May to July.

For the benthic taxocenes consumed by one or more fish species proportionate numerical abundances in samples are shown in Table 18. In May the greatest contribution is by chironomid larvae at 65.1%. amphipods are second at 18.9%, followed by decapods 3.6%, Zygoptera nymphs 2.7% and Hydracarina 2.6%.

In July the emphasis on chironomid larvae is even greater (84.7%) and it is followed by Viviparus (4.6%), amphipods (4.4%), Ephemerella (2.8%) and Hydracarina (1.7%) in importance.

A comparison of fish consumption and benthic production by month is shown in Figure 38. In May, chironomid larvae are consumed in proportions greater than those available on the benthos and amphipods are underrepresented in fish diets relative to their benthic abundance. All other prey categories are consumed in proportions similar to their benthic abundances. This suggests either some selective predation of chironomids and avoidance of amphipods or, and this is perhaps more likely, different habitats for chironomids and amphipods

both months with values of 4.82 and 5.12. Hydracarina and Decapoda are not taken in May. Hydracarina are not taken in July. Ephemeroptera, Hydracarina and Amphipoda nymphs gain slightly in importance from May to July.

For the benthic taxocene consumed by one or more fish species proportions numerical abundances in samples is shown in Table 18. In May the greatest contribution is by Chironomid larvae at 55.12. Amphipoda are second at 18.92, followed by Decapoda 3.62, Ephemeroptera nymphs 2.72 and Hydracarina 2.22.

In July the emphasis on Chironomid larvae is even greater (56.72) and it is followed by Viviparus (4.62), Amphipoda (4.22), Ephemeroptera (3.82) and Hydracarina (1.72) in importance.

A comparison of fish consumption and benthic production by month is shown in Figure 20. In May, Chironomid larvae are consumed in proportions greater than those available on the bottom and amphipods are underrepresented in fish diets relative to their benthic abundance. All other prey categories are consumed in proportions similar to their benthic abundance. This suggests either some selective predation of Chironomids and avoidance of amphipods or, and this is perhaps more likely, different habitats for Chironomids and amphipods.

///

which afford different amounts of protection from predation.

Proportions of chironomids consumed and available in July are similar (80.5%, 84.7%). Amphipods are under-utilized (8.1%, 4.4%). An increase in the number of Ephemerella present in the environment leads to increased predation pressure upon them (4.1%). Zygoptera and Anisoptera nymphs remain at similar environmental levels and their utilization does not change significantly. Decapod consumption increases from May to July while the environmental availability decreases. This is probably a function of the size distribution of prey available. Increased availability of Viviparus in July is reflected in the appearance of the gastropod in fish diets.

Assuming the fish catch to be representative of the lake population, there is some degree of correlation between proportionate consumption and availability in those prey items taken. This suggests a stable relationship between predation and production on the two dates considered even though the prey composition varies greatly from species to species.

Notably absent from the fish diets are all the larger bodied Anisoptera, Physa, and Decapoda which are

100
which affect different amounts of the population from pre-
dation.

Proportions of childrens consumed and available
in July are similar (50.5% and 54.5%). An increase in the number
under-stuffed (5.1% and 4.4%).
of *Ephemerella* present in the environment leads to
increased predation pressure (5.1% and 4.4%).
Hypoglycemia and Antagonism effects remain at similar en-
vironmental levels and their utilization does not change
significantly. Despite consumption increases from May
to July while the environmental availability decreases.
This is probably a function of the time distribution of
grey available. Increased availability of *Vipera* in
July is reflected in the appearance of the population in
fish diets.

Assuming the fish catch to be representative of
the lake population, there is some degree of correlation
between proportionate consumption and availability in
these grey items taken. This suggests a stable re-
lationship between predation and production as the two
data considered even though the prey composition varies
greatly from species to species.

Notably absent from the fish diets are all the
larger bodied Antagonists, *Vipera*, and *Antagonism* which are

too big to be taken by any but the largest predators. Oligochaetes were not recognized in any stomachs, probably a result of the very rapid digestion of Oligochaetes (Brinkhurst 1974). They may account for a portion of the stomach bulk recorded as animal tissue. Trichoptera larvae were unimportant in the lake during May and July and are also unimportant in the fish diet during those months.

too big to be taken by any but the largest predators.
Oligochaetes were not recognized in any stomachs, prob-
ably a result of the very rapid digestion of
Oligochaetes (Brinkman 1974). They may account for a
portion of the stomach bulk recorded as animal remains.
Tricopeia larvae were important in the lake during
May and July and are also important in the fish diet
during those months.

PART IV

THE FISH POPULATION: DIETARY GROUPS

On the basis of the diets observed for the different fish species in Sunfish Lake it is possible to divide the fish species into broad categories. The objective of this thesis is to investigate the utilization of the benthic invertebrates by the fish population. In table 20, the fish species are arranged, according to diet, as predominantly benthic feeders, facultative benthic feeders, predominantly plankton feeders and others, including piscivorous and insectivorous groups.

The Iowa Darter and the Bluntnose Minnow are the only two species which concentrate on feeding on the benthos throughout their life-cycles. The smallest size categories of every other important species consist of facultative benthic and pelagic feeders. These include the White Sucker, the Yellow Perch, the Golden Shiner, the Pumpkinseed, the Rock Bass and the Largemouth Bass. Group II (and III where three groups are distinguished) fish diverge from the mixed food resource to become either predominantly benthic feeders, (the Pumpkinseed and Rock Bass), predominantly planktivorous, (the White Sucker and Yellow Perch), insectivorous, (the Golden Shiner), or piscivorous, (the Largemouth Bass). The

THE FISH POPULATION: DIETARY GROUPS

On the basis of the data observed for the 1955-56 fish species in Hamilton Lake it is possible to divide the fish species into three categories. The objective of this thesis is to investigate the utilization of the benthic invertebrates by the fish population. In Table 2, the fish species are arranged, according to diet, as predominantly benthic feeders, facultative benthic feeders, predominantly plankton feeders and others, including piscivores and miscellaneous groups.

The four diets and the stomach contents are the only two species which concentrate on feeding on the benthos throughout their life-cycle. The majority of categories of every other important species consist of facultative benthic and pelagic feeders. These include the White Sucker, the Yellow Perch, the Golden Shiner, the Pumpkinseed, the Rock Bass and the Largemouth Bass. Group II (and III where three groups are distinguished) fish diverge from the mixed food spectrum to become either predominantly benthic feeders (the Pumpkinseed and Rock Bass), predominantly planktivorous (the White Sucker and Yellow Perch), insectivorous (the Golden Shiner), or piscivorous (the Largemouth Bass). The

Table 19

The fish species of British Lake are divided into dietary groups based upon their degree of dependence upon the benthos as a food resource. The divisions are based upon the observed fish diets in May and July.

Table 19

The fish species of Sunfish Lake are divided into dietary groups based upon their degree of dependance upon the benthos as a food resource. The divisions are based upon the observed fish diets in May and July.

Table 19: FISH DIETARY GROUPS¹

PREDOMINANTLY BENTHIC FEEDERS

Pumpkinseed	Group II	May, July
	Group III	May, July
Rock Bass	Group II	No sample, July
Largemouth Bass	Group II	, July
Iowa Darter	Group I	May, July
	Group II	May, July
Bluntnose Minnow		May, No sample
Tadpole Madtom		May, No sample

FACULTATIVE BENTHIC FEEDERS

With Plankton:

White Sucker	Group I	May, No sample
Yellow Perch	Group I	May, July
Golden Shiner	Group I	May, No sample
Pumpkinseed	Group I	May, July
Rock Bass	Group I	May, No sample
Largemouth Bass	Group I	May,
Brown Bullhead	Group I	May, No sample

With Fish:

Largemouth Bass	Group I	, July
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With Insects:

Golden Shiner	Group II	No sample, July
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PREDOMINANTLY PLANKTON FEEDERS

White Sucker	Group II	May, No sample
	Group III	May, No sample
Yellow Perch	Group II	May, July
	Group III	May, July
Brook Stickleback		May, No sample

PREDOMINANTLY FISH FEEDERS

Largemouth Bass	Group II	May,
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¹ A division of the fish species based on their dependence upon the benthos as a source of food.

Table 13. FISH DIETARY GROUPS

PREDOMINANTLY BENTHIC FEEDERS		
May, July	Group II	Parakeet
May, July	Group III	Black Bass
May, July	Group II	Largemouth Bass
May, July	Group I	Less Insect
May, July	Group II	Bluntnose Minnow
May, no sample		Redfin Perch

TACTATIVE BENTHIC FEEDERS		
May, no sample	Group I	With Flank:
May, July	Group I	White Sucker
May, no sample	Group I	Yellow Perch
May, July	Group I	Golden Shiner
May, no sample	Group I	Parakeet
May, no sample	Group I	Black Bass
May, no sample	Group I	Largemouth Bass
May, no sample	Group I	Brook Silverside
May, no sample	Group I	With Flank:
May, no sample	Group I	Largemouth Bass
May, no sample	Group II	With Insect:
May, no sample	Group II	Golden Shiner

PREDOMINANTLY PLANKTON FEEDERS		
May, no sample	Group II	White Sucker
May, no sample	Group III	Yellow Perch
May, July	Group II	Brook Silverside
May, July	Group III	

PREDOMINANTLY FISH FEEDERS		
May, no sample	Group II	Largemouth Bass

I A division of the fish species based on their dependence upon the benthos as a source of food.

White Sucker and the Yellow Perch, in other lake systems that have been studied, (Keast 1965, Scott and Crossman 1974) have been found to be benthic and fish feeders respectively.

110
White moved and the yellow perch. In other lake systems
that have been studied, (West 1962, Scott and Crossman
1974) have been found to be benthic and fish leaders
respectively.

PART V: BENTHIC UTILIZATION BY THE IOWA DARTER
AND BY THE PUMPKINSEED

In a manner similar to that used to relate the population diet to benthic availability it is possible to consider individual species. The following is a comparison of Iowa Darter and Pumpkinseed (groups II and III only) diets relative to benthic standing crops on each sampling date. The data are presented in Tables 20, 21 and 22 and Figures 39 and 40. Non-benthic prey items such as Cladocera, copepods and insects, where they occur in the diets, are omitted from the proportion analysis although they have been considered in part II of this discussion.

Iowa Darter

Group I: During May, chironomids are consumed in greater numbers (89.5%) than the proportionate representation in the environment (73.6%). The discrepancy observed may be due to underrepresentation of the smallest chironomids in benthic samples as 2 - 4 mm chironomids account for approximately 25% of the individuals taken. A (21.2%) prey resource of amphipods is not exploited. All the prey taken are small bodied. Potential prey not consumed that fall in the appropriate

Table 20

For the four hares (Groups I and II) and the two rabbits (Groups III and IV) the proportionate contribution of each prey taxon to the total prey consumption by each species is given. Values are percentages of the number of prey consumed.

Table 20

For the Iowa Darter (Groups I and II) and the Pumpkinseed (Groups II and III) the proportionate contribution of each prey taxocene to the total prey consumption by each species is given. Values are percentages of the number of prey consumed.

Table 20
PERCENTAGE ABUNDANCE OF PREY CATEGORIES IN FISH DIETS
(Numerical abundance expressed as percentage of total number
of prey items consumed)

		DARTER		PUMPKINSEED	
		Group I	Group II	Group II	Group III
Chironomids	May	89.5	93.8	100.0	-
	July	75.0	86.8	85.9	87.1
Anisoptera	May	-	-	-	-
	July	-	-	-	1.9
Zygoptera	May	-	-	-	-
	July	-	-	-	1.9
Hexagenia	May	-	-	-	-
	July	-	-	-	0.2
Ephemerella	May	-	0.2	-	33.3
	July	-	3.8	2.6	0.7
Viviparus	May	-	-	-	-
	July	-	-	-	6.3
Amphipoda	May	-	5.8	-	50.0
	July	16.7	7.5	11.5	1.9
Other	May	10.5	0.2	-	16.7
	July	8.3	1.9	-	-

Table 11

The proportionate environmental soundness (numbers) of those prey
 taxonomic assessed by the four factors, in percent samples. The sampling
 method (shallow, shallow, deep, deep) is distinguished.

Table 12

The proportionate environmental soundness (numbers) of those prey
 taxonomic assessed by the four factors (Group II or III), in percent samples.
 The different sampling methods (shallow, shallow, deep, deep) are distinguished.

Table 21

The proportionate environmental abundances (numbers) of those prey taxocenes consumed by the Iowa Darter, in benthic samples. The sampling method (Pushnet, Shallow Ekman, Deep Ekman) is distinguished.

Table 22

The proportionate environmental abundances (numbers), of those prey taxocenes consumed by the Pumpkinseed (Group II or III), in benthic samples. The different sampling methods (Pushnet, Shallow Ekman, Deep Ekman) are distinguished.

Table 21
AVAILABLE INVERTEBRATE PREY: DARTER¹
(Numerical abundance expressed as percentage of total)

	MAY ²		JULY		
	Pushnet	Pushnet	Shallow Ekman	Deep Ekman	Total July
Chironomids	73.6	65.6	82.8	85.5	83.4
Ephemerella	.8	.2	.2	-	.2
Amphipoda	21.2	33.5	16.1	13.5	15.5
Other	4.4	.7	.9	1.0	1.0

Table 22
AVAILABLE INVERTEBRATE PREY: PUMPKINSEED¹
(Numerical abundance expressed as percentage of total)

	MAY ²		JULY		
	Pushnet	Pushnet	Shallow Ekman	Deep Ekman	Total July
Chironomids	69.7	55.6	79.0	79.1	78.6
Anisoptera	.8	.3	.3	.9	.5
Zygoptera	2.8	.3	.1	.1	.1
Hexagenia	.9	.6	.1	-	.1
Ephemerella	.8	.2	.2	-	.1
Viviparus	.7	14.0	4.1	6.4	5.0
Amphipoda	20.1	28.4	15.4	12.5	14.6
Other	4.1	.6	.9	1.0	.9

¹ The available invertebrate prey considers just those prey taxocenes consumed by the species in question. The values are the percentage of the total environmental numbers of utilized prey that are derived from each taxocene.

² During May, only pushnet samples were collected.

Table 21
AVAILABLE INVERTEBRATE PREY: LARVAE
(Numerical abundance expressed as percentage of total)

	MAY	JULY	Total July
Chironomidae	73.6	82.8	83.4
Syntherisma	8	2	2
Amphipoda	21.2	16.1	15.8
Other	4.4	9	1.8

Table 22
AVAILABLE INVERTEBRATE PREY: PUPAE
(Numerical abundance expressed as percentage of total)

	MAY	JULY	Total July
Chironomidae	69.7	75.8	78.6
Amphipoda	8	3	2
Syntherisma	2.8	1	1
Hexagramma	3	1	1
Chironomidae	8	2	1
Viviparus	7	4.1	5.8
Amphipoda	28.1	12.4	14.6
Other	4.1	9	9

1 The available invertebrate prey consists just those prey taxonomic consumed by the species in question. The values are the percentage of the total environmental numbers of collected prey that are derived from each taxonomic.

2 During May, only pupae samples were collected.

The relative numerical importance of different prey items to the diet of
 chironomid larvae and their environmental abundance. Considering only those
 prey items consumed by the Iowa Darter, the relative numerical importance
 of each given the size of each slice and the associated value. For the
 environment, the data is presented with complete diatrichid and with samples
 combined. Sample sizes are shown for the fish.

- 1 chironomids
- 2 copepod/oligochaetes
- 3 chironomid larvae
- 4 diatoms
- 5 anisopoda nymphs
- 6 xyphopoda nymphs
- 7 ephemeroptera nymphs
- 8 hexapoda nymphs
- 9 trichoptera larvae
- 10 viviparus
- 11 amphipods
- 12 hyacinths
- 13 terrestrial insects
- 14 fish
- 15 animal tissue
- 16 plant tissue
- 17 organic debris
- 18 other

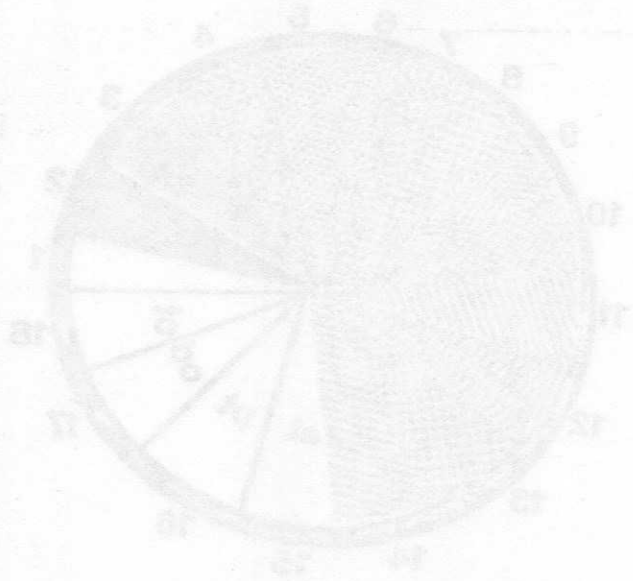
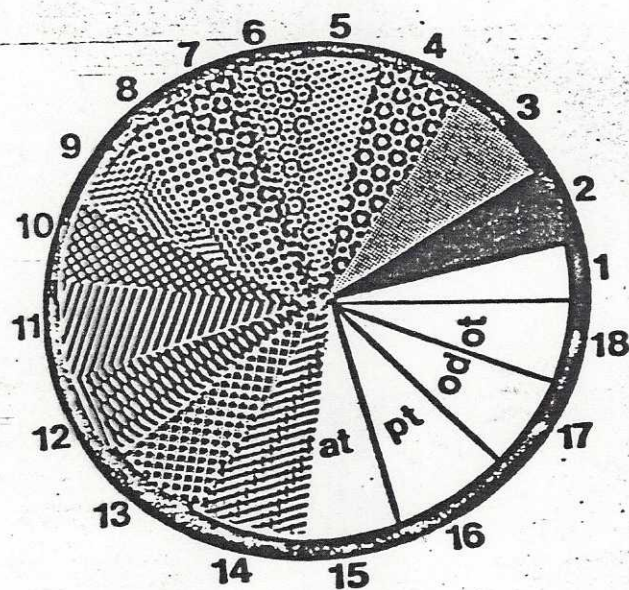


Figure 39:

The relative numerical importance of different prey items to the diet of the Iowa Darter and their environmental abundances. Considering only those prey taxocenes consumed by the Iowa Darter, the relative numerical importance of each gives the size of each slice and its associated value. For the environment, the data is presented with samplers distinguished and with samplers combined. Sample sizes are shown for the fish. During May, only pushnet samples were collected.



- 1 cladocerans
- 2 copepods/ostracods
- 3 chironomid larvae
- 4 decapods
- 5 anisoptera nymphs
- 6 zygoptera nymphs
- 7 Ephemerella nymphs
- 8 Hexagenia nymphs
- 9 trichopteran larvae
- 10 Viviparus
- 11 amphipods
- 12 hydracarina
- 13 terrestrial insects
- 14 fish
- 15 animal tissue
- 16 plant tissue
- 17 organic debris
- 18 other

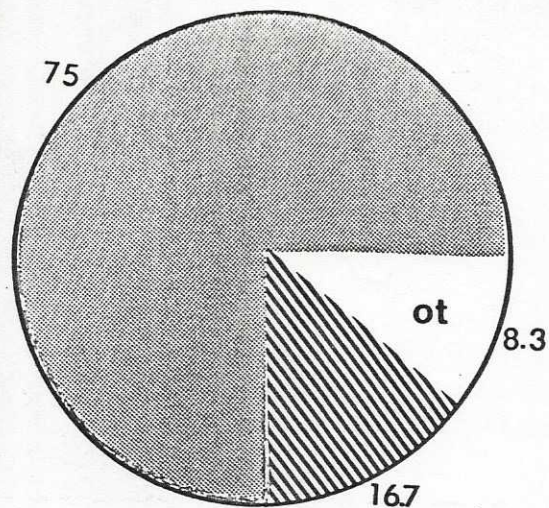
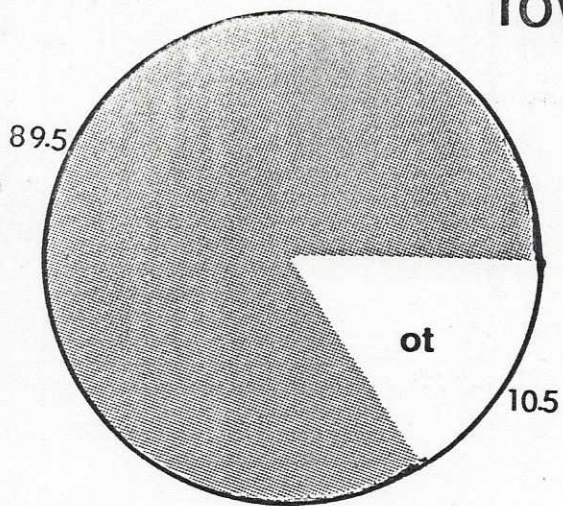
IOWA DARTER

119

TAKEN

GROUP 1

5 28-40 mm 1
Sample size

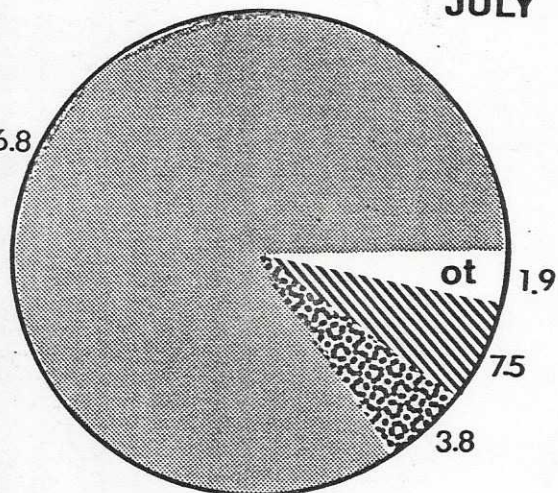
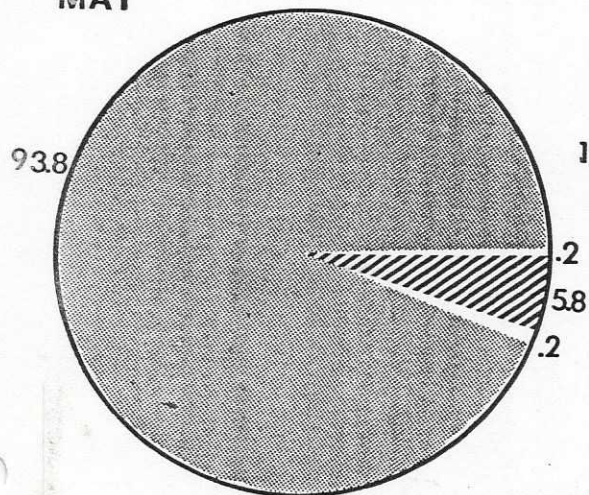


MAY

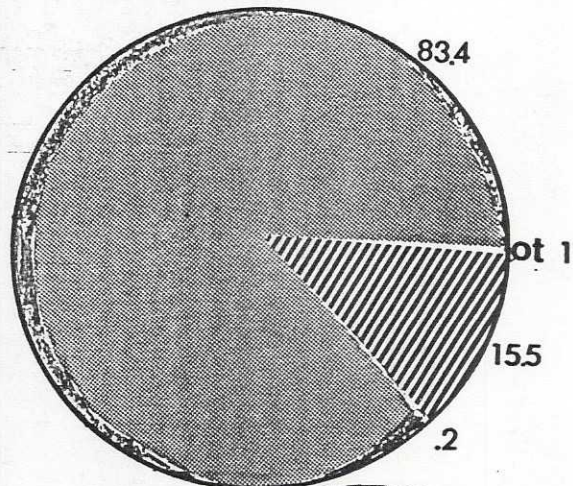
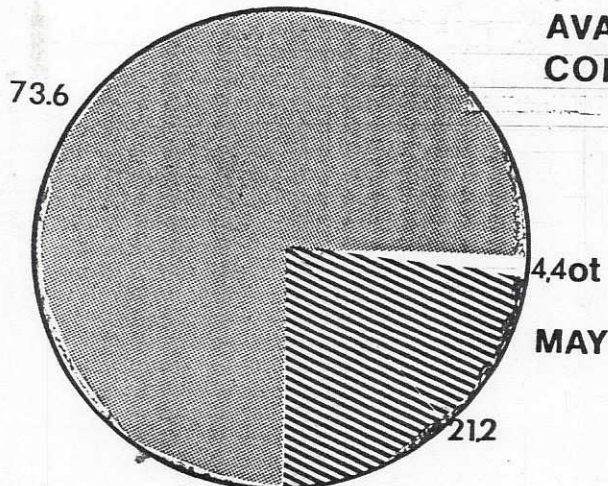
JULY

GROUP 11

19 41-54mm 3 86.8
Sample size



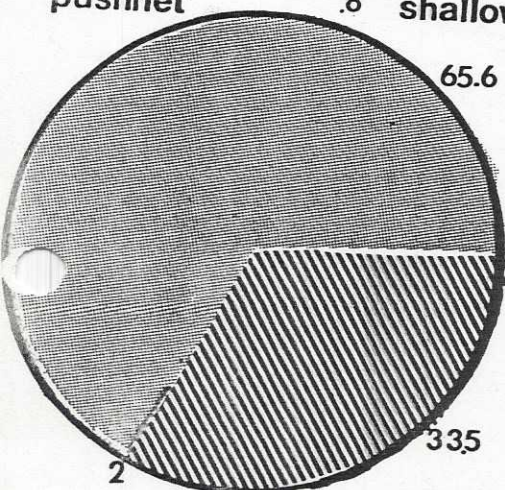
AVAILABLE COMBINED



MAY

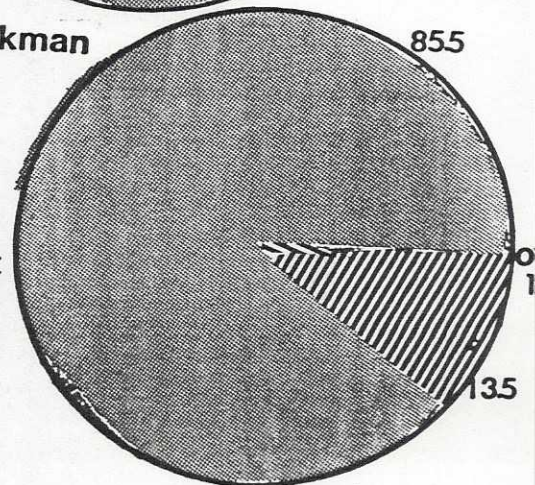
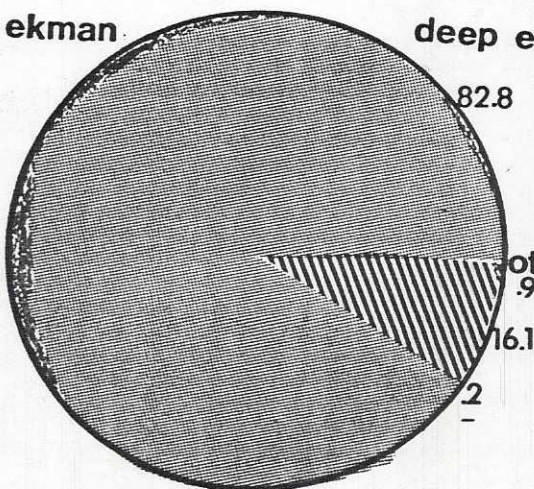
JULY

pushnet .8 shallow ekman



JULY

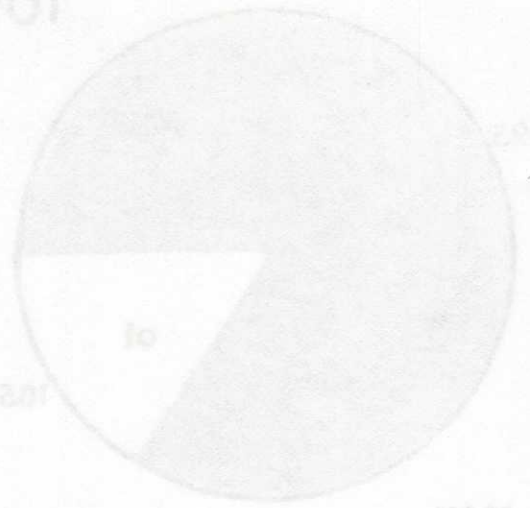
deep ekman



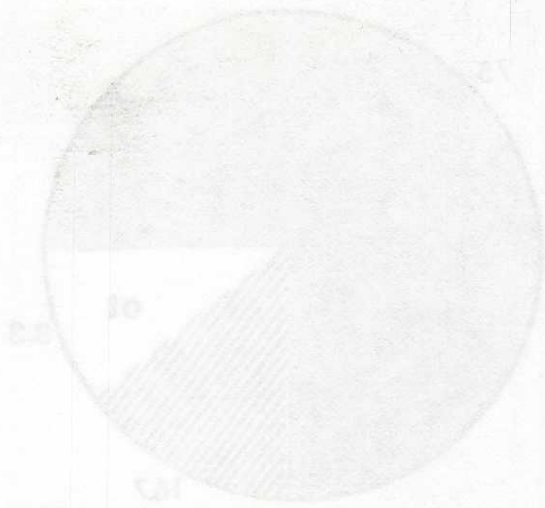
IOWA DARTER

TAKEN

GROUP 1
28-40 mm
Sample size



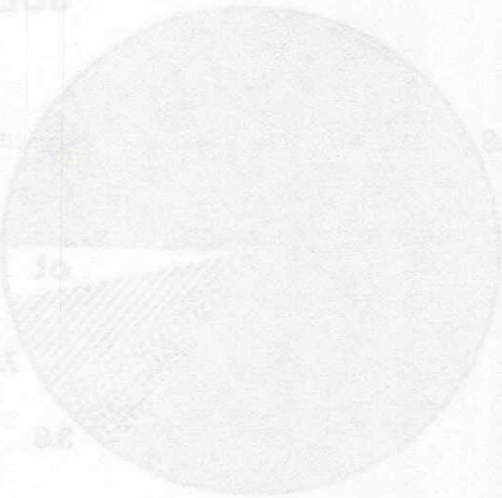
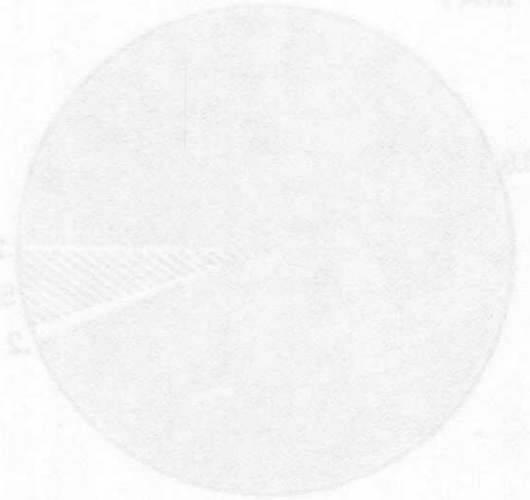
MAY



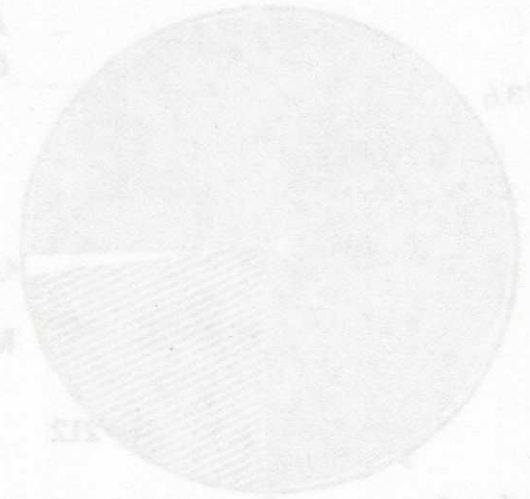
JULY

GROUP 11

41-54 mm
Sample size

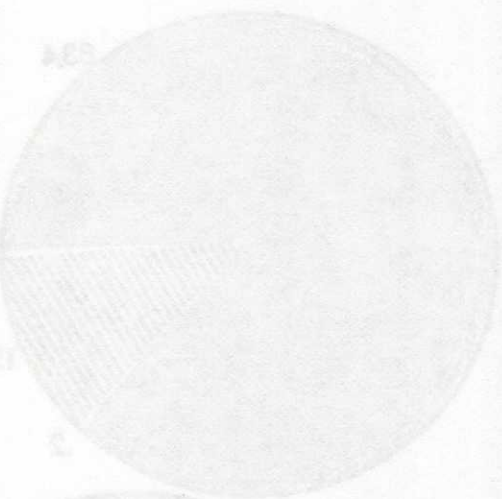


AVAILABLE
COMBINED



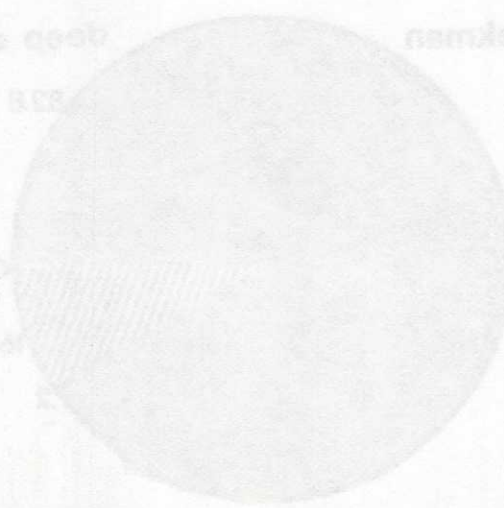
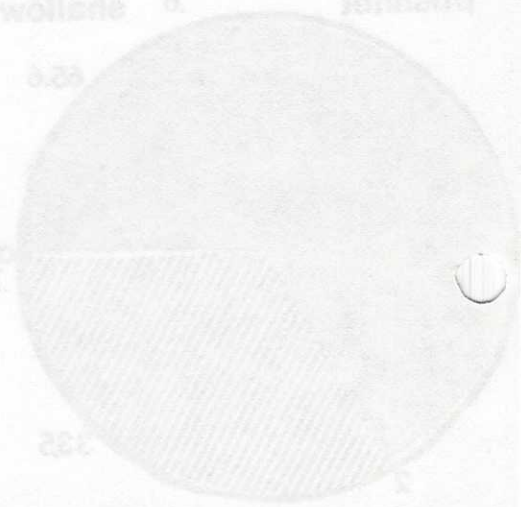
MAY

JULY

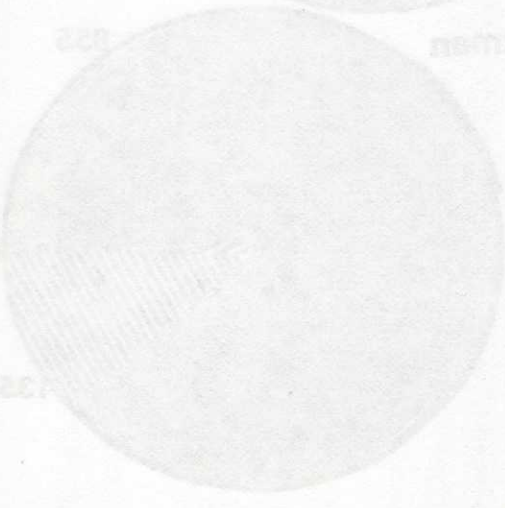


JULY

shallow stream



deep stream



size range are Ephemerella, and Hydracarina, both at low densities in May but high densities in July (see figure 39). In July, chironomids contribute 75% of the volume relative to 84.4% in the environment. Amphipods contribute 16.7% of the volume relative to 15.5% in the environment.

Total environmental numbers of chironomids increase from May to July as do numbers of amphipods (see Appendix 1 and Figure 39). The absence of amphipods from the group I May diet may reflect a size refugium from predation for the amphipods which have successfully overwintered. The amphipod population is predominantly >3 mm (see Figure 15) during May.

Group II: During May, 93.8% of the new items in the diet are composed of chironomids relative to the previously mentioned 73.6% in the environment. The 21.2% amphipods are exploited for only 5.8% of the prey numbers and just one Ephemerella was found in a stomach. During July, chironomids continue to dominate with 86.8% of the prey taken followed by amphipods at 7.5% and Ephemerella at 3.8, accurately reflecting available chironomids (83.4%), underutilizing amphipods (15.5%) and over exploiting Ephemerella nymphs.

Only four benthic taxocenes are consumed by Iowa

also range are *Ephemera*, and *Hydropsyche*, both of low densities in May but high densities in July (see figure 10). On July, chironomid contribute 75% of the volume relative to 84.4% in the environment. Amphipods contribute 16.7% of the volume relative to 15.5% in the environment.

Total environmental numbers of chironomids increase from May to July as do numbers of amphipods (see Appendix I and figure 10). The species of amphipods from the group I May diet may reflect a diet selection from the amphipods which have successfully overwintered. The amphipod population is predominantly 3 mm (see figure 10) during May.

Group II: During May, 93.8% of the new items in the diet are composed of chironomids relative to the previously mentioned 77.5% in the environment. The 21.2% amphipods are exploited for only 5.4% of the prey number and just one *Ephemera* was found in a stomach. During July, chironomids continue to dominate with 86.8% of the prey taken followed by amphipods at 7.5% and *Ephemera* at 3.8%. *Ephemera* is relatively rare in the available chironomids (83.4%), underutilized amphipods (15.5%) and over exploiting *Ephemera* types.

Only four benthic taxa were consumed by lake

Darters over the two sampling dates. Predation appears to be size specific with a size refugium afforded to larger bodied prey, including late instar Hyaella or Ephemerella. The heavy emphasis on chironomid larvae as prey seen during May probably reflects predation on an abundance of <4 mm chironomids that benthic sampling methods underestimate.

It is not possible to directly correlate Iowa Darter foraging with one of the habitats sampled by the different samplers. Numbers of chironomids are higher in association with Chara (see Appendix 1) than where it is absent so chironomid abundance would be greatest in the shallow ekman habitat. Visual location of prey might, however, be better outside the Chara mats. Amphipods are found only in association with Chara so the under-utilization of the amphipod resource may indicate that foraging in the Chara is inefficient. Ephemerella tend to occur on the sediment itself and are over-utilized relative to their availability. This suggests that the Iowa Darter seeks refuge in the Chara (it was often caught in the ekman sampler) but forages predominantly beyond the Chara on relatively open sediment.

Barren over the two sampling dates. Predation appears to be size specific with a size reduction afforded to larger bodied prey, including large larval *Ephyra* or *Eusmerella*. The heavy emphasis on chironomid larvae as prey seen during May probably reflects predation on an abundance of 42 mm chironomids that definite sampling methods underestimate.

It is not possible to directly correlate low Barren foraging with one of the habitats sampled by the different samples. Numbers of chironomids are higher in association with Chars (see Appendix 1) than where it is absent so chironomid abundance would be greatest in the shallow estuarine habitat. Visual location of prey might, however, be better outside the Char beds. Amphipods are found only in association with Chars so the under-utilization of the amphipod resource may indicate that foraging in the Char is inefficient. *Ephyra* tend to occur on the adjacent flats and are over-utilized relative to their availability. This suggests that the low water seeks refuge in the Char (it was often caught in the same sample) but forages predominantly beyond the Char on relatively open sedi-

ment.

Pumpkinseed

Group II: In May, only chironomids are taken from the benthos ignoring, as with the Iowa Darter, the 20.1% amphipod abundance. In July, also as with the Iowa Darters, the emphasis on chironomids lessens (85.9%) and allows some predation on amphipods (11.5%).

These are similar to the environmental abundances. Ephemerella nymphs are consumed to a greater extent than is indicated for benthic availability. Very small Ephemerella will also have been underrepresented in the sampling. Figure 11 indicates that there are considerable between site differences in the abundance of Ephemerella so that feeding may be proportional to availability in a particular habitat.

Group III: During May, group III Pumpkinseeds *were not observed to* consume chironomids, making them the only groups not exploiting what is numerically the most abundant resource. This is *probably* due to the small sample size. Ephemerella and *amphipods* comprise the diet seen. As for the group II *Pumpkinseeds*, availability of Ephemerella appears to be habitat dependent.

In July, the diet taken is much more diverse. Chironomids are the most important at 87.1% , closely

Group III: In May, only chironomids are taken from the
beachbox ignoring, as with the Iowa Garden, the 20.13
sampled abundance. In July, also as with the Iowa
Garden, the asphids on chironomids (mean 152.92) and
allows some prediction on asphids (71.57).

These are similar to the environmental abundances.
Ephemerella nymphs are consumed to a greater extent than
is indicated for benthic availability. Very small Eph-
emerella will also have been underrepresented in the
sampling. Figure 11 indicates that there are consider-
able between site differences in the abundance of Eph-
emerella so that feeding may be proportional to
availability in a particular habitat.

Group III: During May, group III pumpkins are not eaten
consumed chironomids, making them the only groups not
exploiting what is numerically the most abundant re-
source. This is certainly due to the small size of
Ephemerella and asphids comprise the diet seen. As
for the group II pumpkins, availability of Eph-
emerella appears to be habitat dependent.

In July, the diet taken is much more diverse.
Chironomids are the most important at 8.17, closely

Figure 4B:

The diet of the pupfishes, Groups 1 and 2, relative to environmental food. Considering only those prey taxonomic categories by the Group 1 and 2 pupfishes, their relative numerical importance as prey items corresponds to the size of the slices and to the associated number. To determine environmental availability a similar comparison of the relative abundances of the same taxonomic was used. During May, only bucket samples were collected. Only the environmental food is presented by sampling method as well as to a combined format.

- 1 cladocera
- 2 copepod/rotifers
- 3 chironomid larvae
- 4 detritus
- 5 annelid worms
- 6 amphipods
- 7 ephemeroptera nymphs
- 8 hexagenia nymphs
- 9 trichoptera larvae
- 10 viviparus
- 11 amphipods
- 12 hyacinths
- 13 terrestrial insects
- 14 fish
- 15 animal tissue
- 16 plant tissue
- 17 organic debris
- 18 other

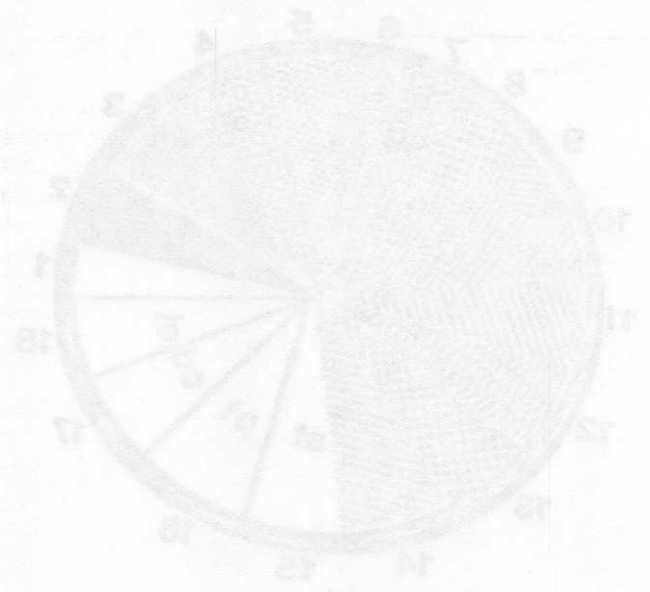
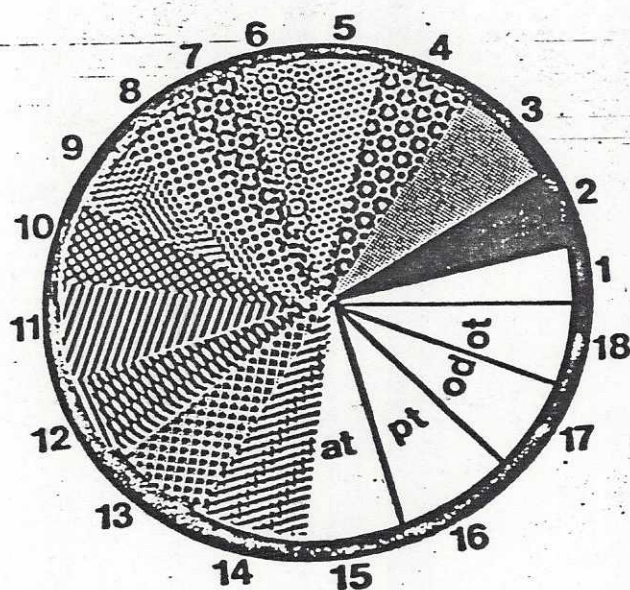


Figure 40:

The diet of the Pumpkinseed, Groups 2 and 3, relative to environmental food. Considering only those prey taxocenes consumed by the Group 2 and 3 Pumpkinseeds, their relative numerical importance as prey items corresponds to the size of the slice and to the associated number. To determine environmental availability a similar comparison of the relative abundances of the same taxocenes was used. During May, only pushnet samples were collected. For July the environmental food is presented by sampling method as well as in a combined format.

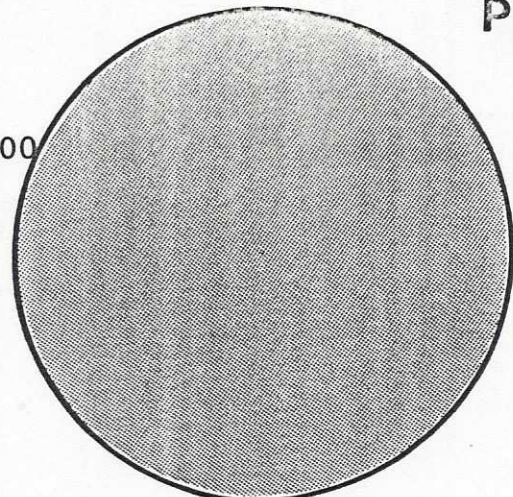


- 1 cladocerans
- 2 copepods/ostracods
- 3 chironomid larvae
- 4 decapods
- 5 anisoptera nymphs
- 6 zygoptera nymphs
- 7 Ephemerella nymphs
- 8 Hexagenia nymphs
- 9 trichopteran larvae
- 10 Viviparus
- 11 amphipods
- 12 hydracarina
- 13 terrestrial insects
- 14 fish
- 15 animal tissue
- 16 plant tissue
- 17 organic debris
- 18 other

PUMPKINSEED

123

100



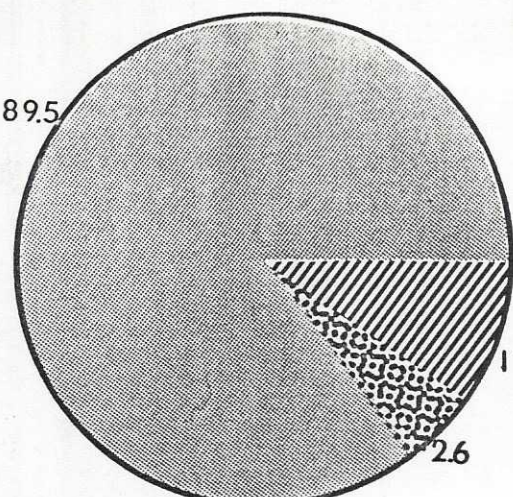
GROUP 11

48-95mm

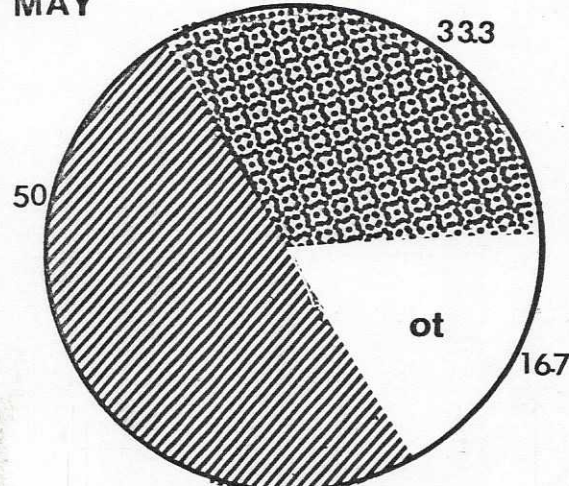
Sample size

TAKEN

89.5



MAY

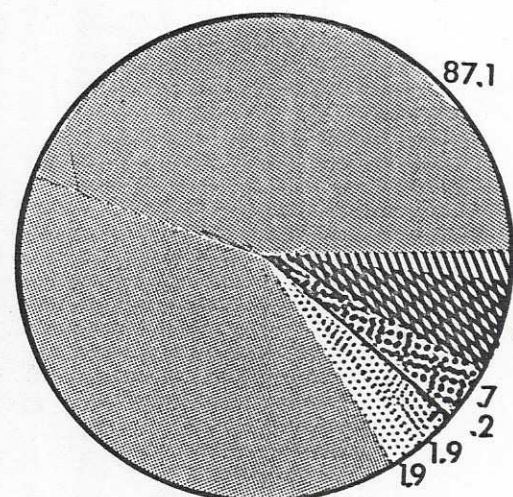


GROUP 111

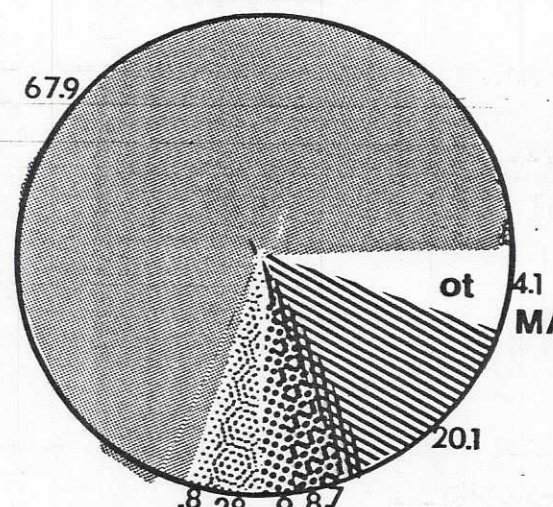
96-145 mm

Sample size

AVAILABLE
COMBINED



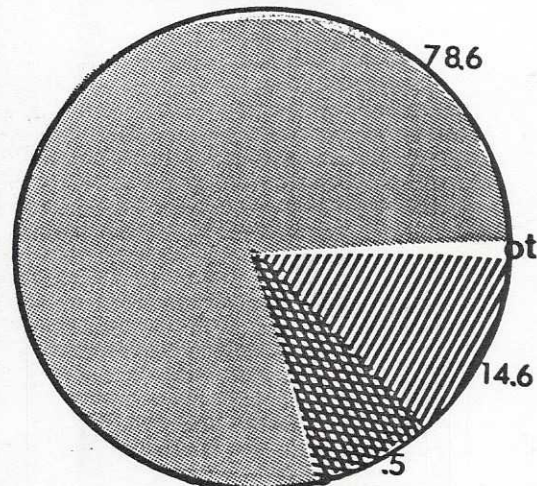
67.9



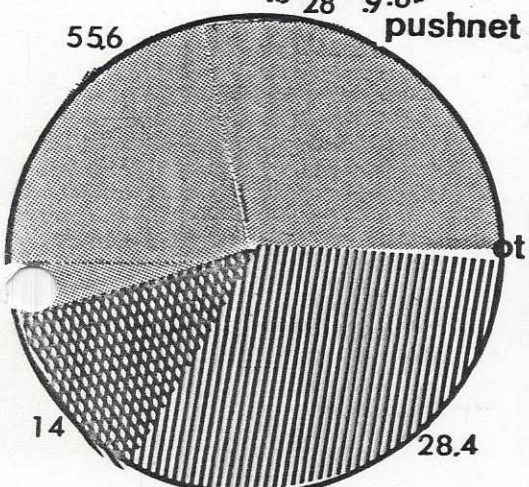
MAY

shallow ekman

78.6

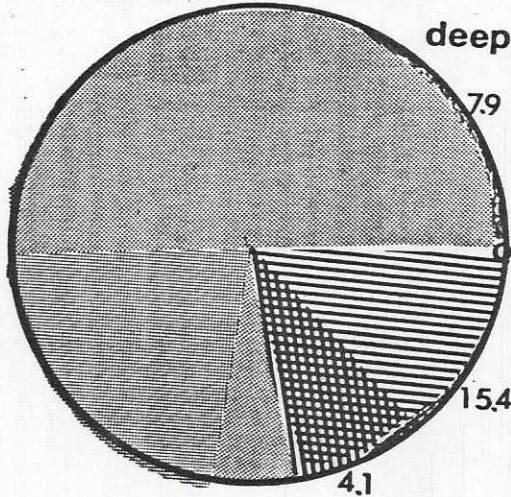


55.6

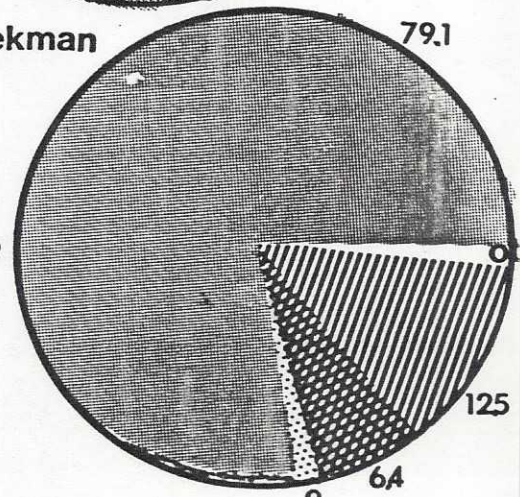


pushnet

deep ekman



79.1



PUMPKINSEED

GROUP II

48-52mm
sample size 20

TAKEN

GROUP III

95-145mm
sample size 20

AVAILABLE
COMBINED

shallow ekman

deep ekman

pumpkin

