Figure 34:

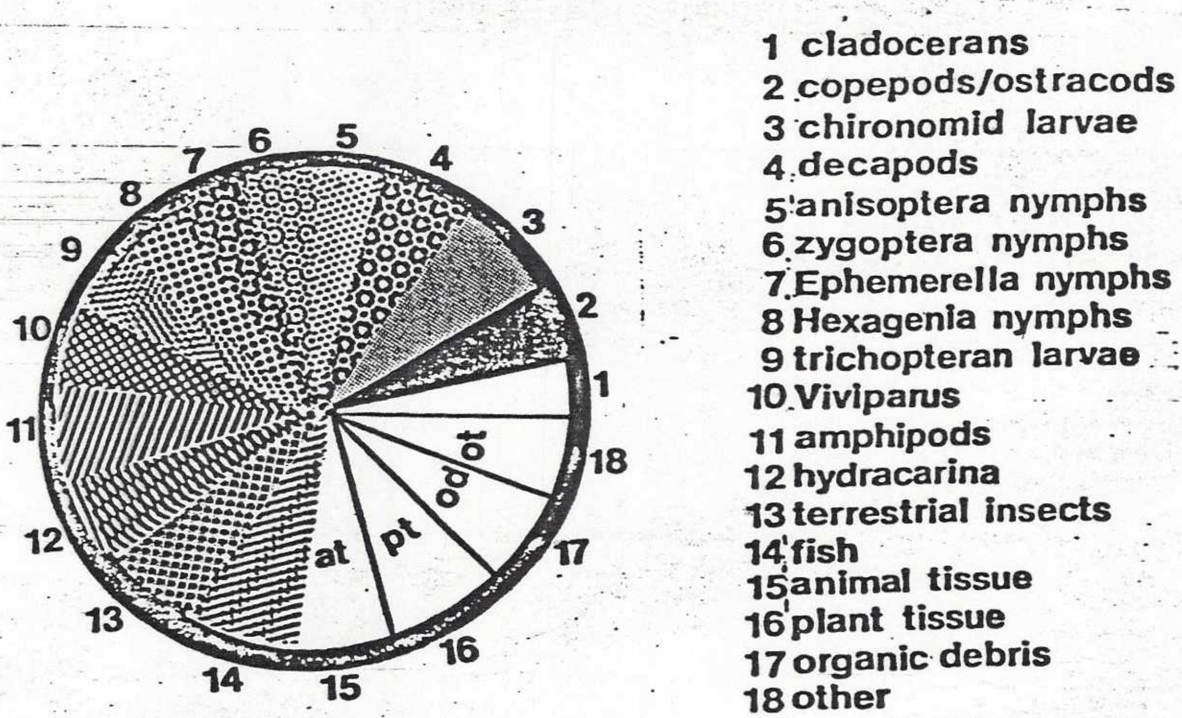
The diet of the Bluntnose Minnow.

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.

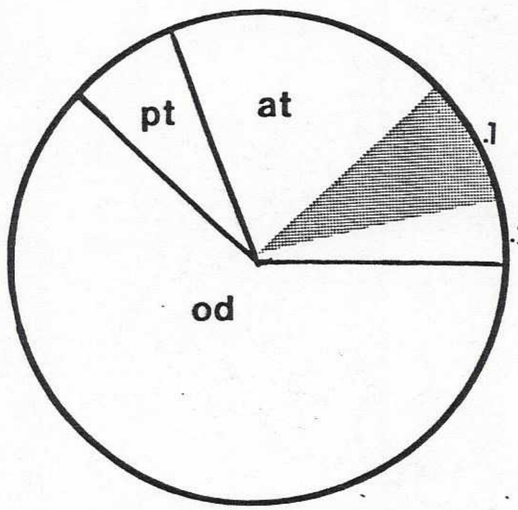


BLUNTNOSE MINNOW

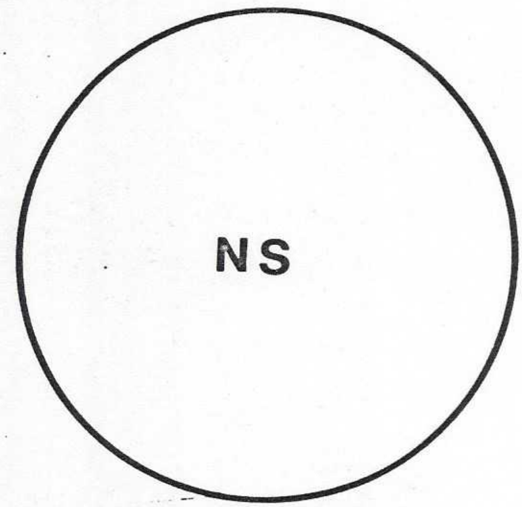
40–70 mm

14 0

Sample size



MAY



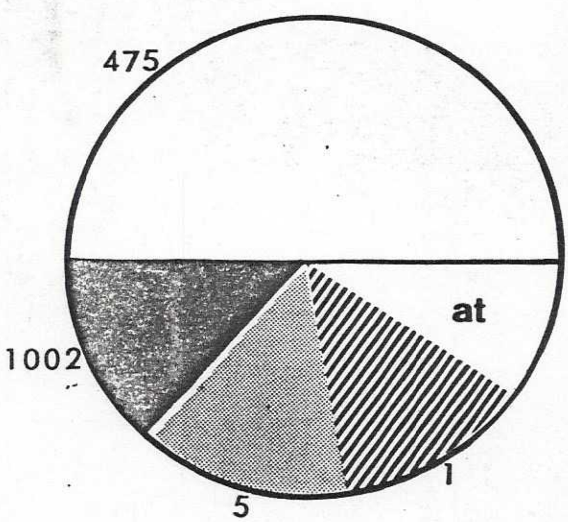
JULY

BROOK STICKLEBACK

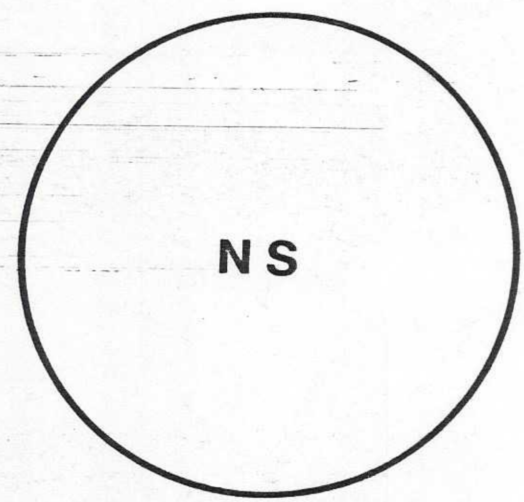
45–50mm

2 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=Ø)

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.

Figure 36:

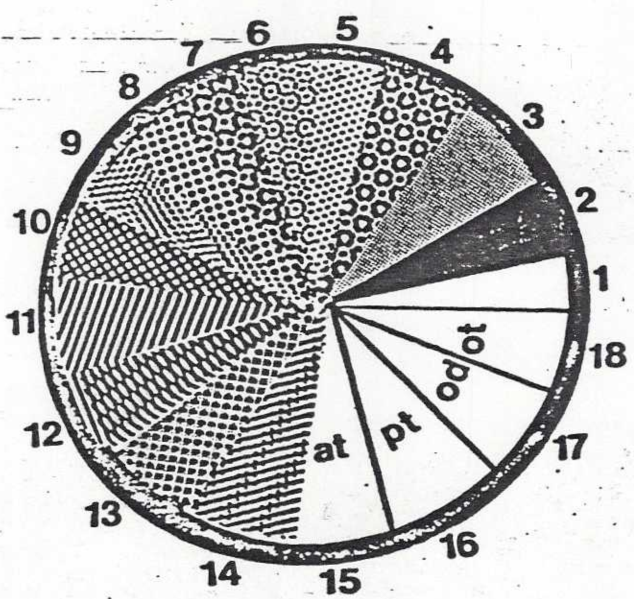
The diet of the Brown Bullhead.

Figure 37:

The diet of the Tadpole Madtom.

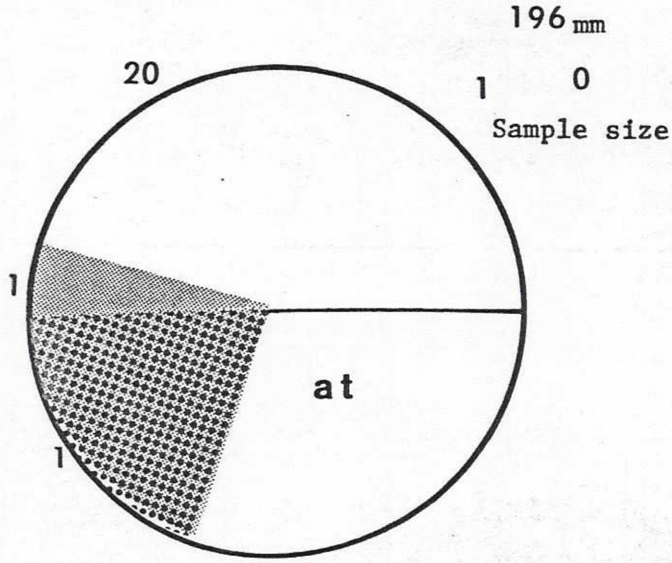
The size of each slice represents the percent volume contribution of each prey taxocene to the total stomach contents. The peripheral numbers are the mean number of prey items this would represent.

The sample size is shown for each diagram.

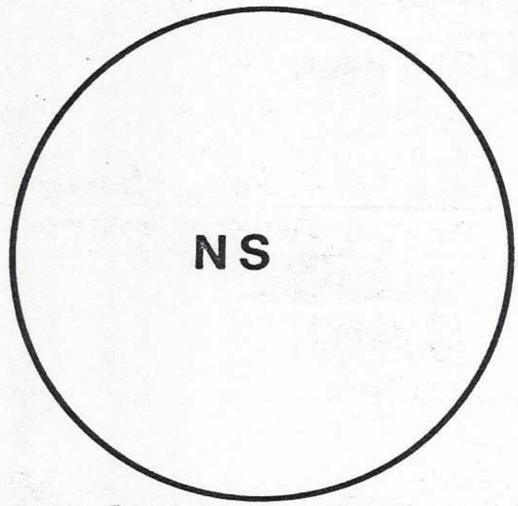


1 cladocerans
2 copepods/ostracods
3 chironomid larvae
4 decapods
5 anisoptera nymphs
6 zygoptera nymphs
7 Ephemerella nymphs
8 Hexagenia nymphs
9 trichopteran larvae
10 Viviparus
11 amphipods
12 hydracarina
13 terrestrial insects
14 fish
15 animal tissue
16 plant tissue
17 organic debris
18 other

BROWN BULLHEAD

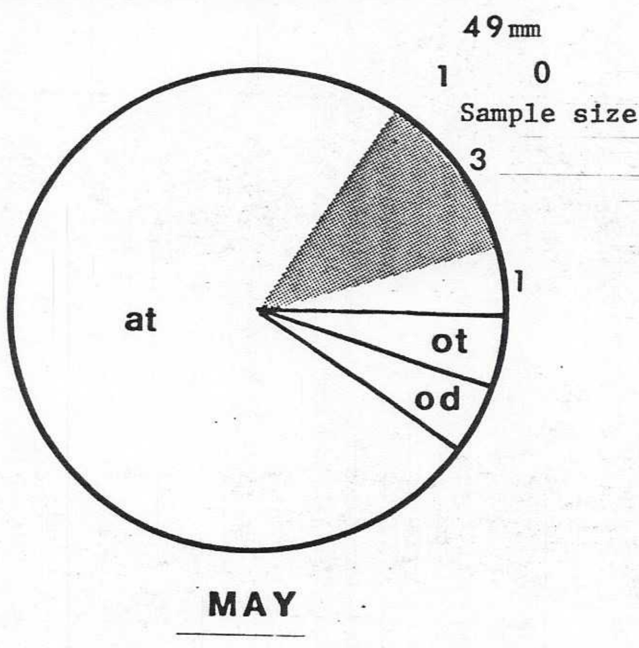


MAY

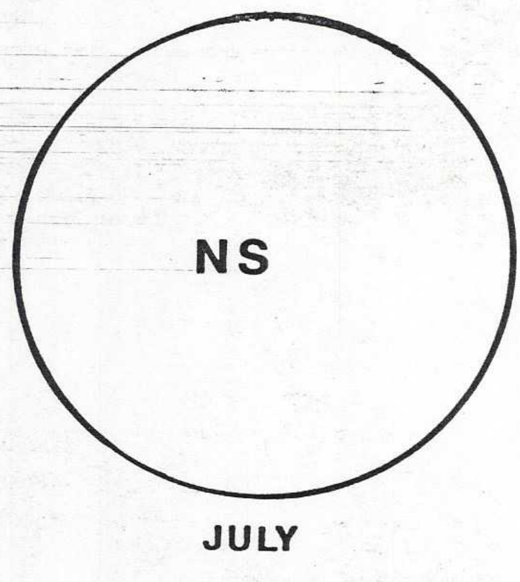


JULY

TADPOLE MADTOM



MAY



JULY

The Fish Sample Size

A retrospective look at the fish diets relativeto 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=5,1 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 occassion. Notable in this regard is the Group III, May, Pumpkinseed (N=1) that contained a single coleopteran adult. (taxocene= "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, ladocera 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 Ø.9% and Ø.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 9Ø.6% of the summed diet items in May and 8Ø.5% in July. Amphipods 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 fish stomach. These values are multiplied by the relative abundances of these Groups on each sampling occassion and an estimate of the total numerical consumption of prey items is acheived. 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.Ø	–
	July	88.2	–
Copepoda	May	16.4	–
	July	tr	–
Chironomidae	May	4.2	9Ø.6
	July	9.3	8Ø.5
Decapoda	May	–	–
	July	Ø.5	4.5
Anisoptera	May	tr	Ø.1
	July	tr	Ø.3
Zygoptera	May	tr	Ø.7
	July	Ø.1	Ø.6
Hexagenia	May	tr	tr
	July	tr	tr
Ephemerella	May	Ø.2	3.3
	July	Ø.5	4.1
Trichoptera	May	tr	Ø.1
	July	–	–
Viviparus	May	–	–
	July	Ø.2	1.8
Amphipoda	May	Ø.2	4.8
	July	Ø.9	8.1
Hydracarina	May	tr	Ø.3
	July	–	–
Other	May	–	–
	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 AVAILABILITY[1]

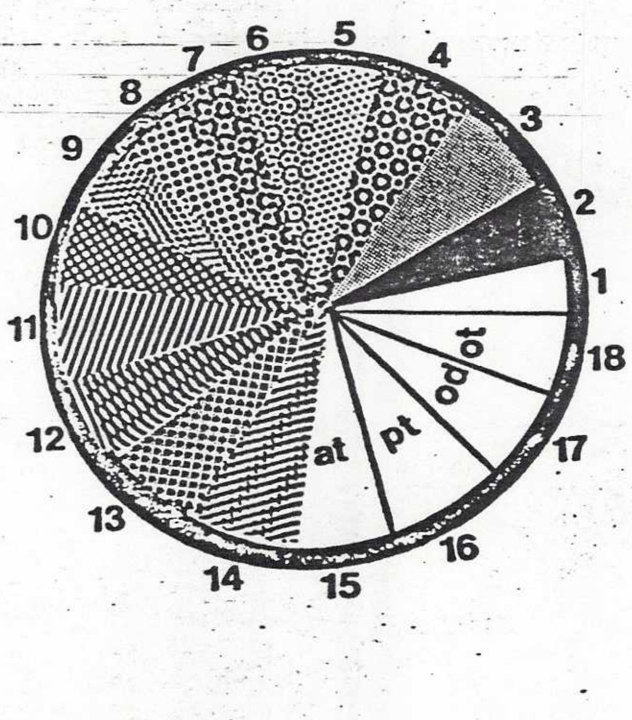
(Numerical abundance expressed as percentage of the total number of potential prey items in the environment)

		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	Ø.Ø	tr
	Viviparus	.6	4.6
	Amphipoda	18.9	4.4
	Hydracarina	2.6	1.7
	Other	3.8	.8

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

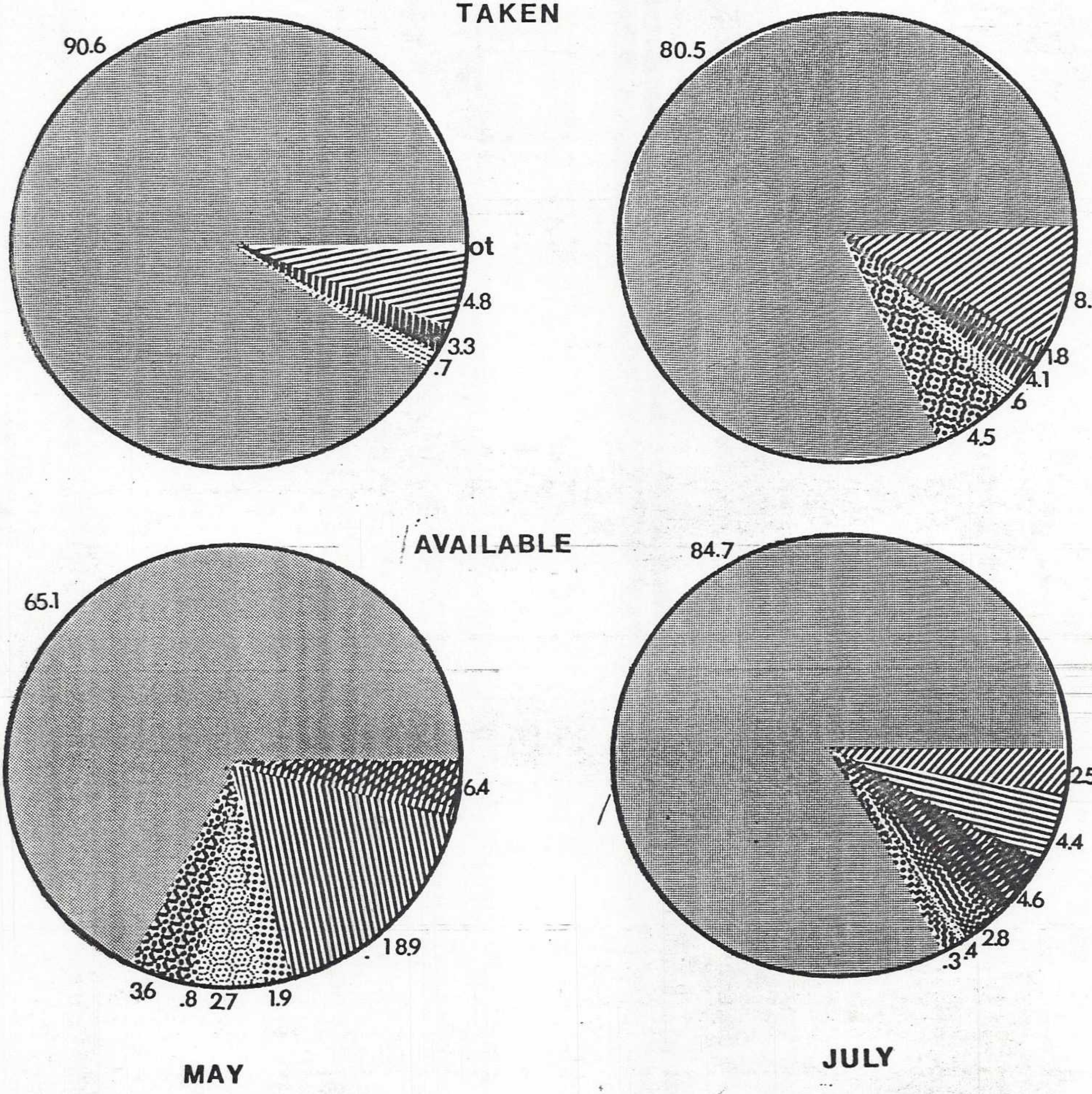
Figure 38:

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 availible 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.



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

COMBINED FISH DIET



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

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

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.

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

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 GROUPS[1]

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
With Insects:		
Golden Shiner	Group II	No sample, July
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,

[1] 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.

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 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 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: DARTER[1]

(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: PUMPKINSEED[1]

(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

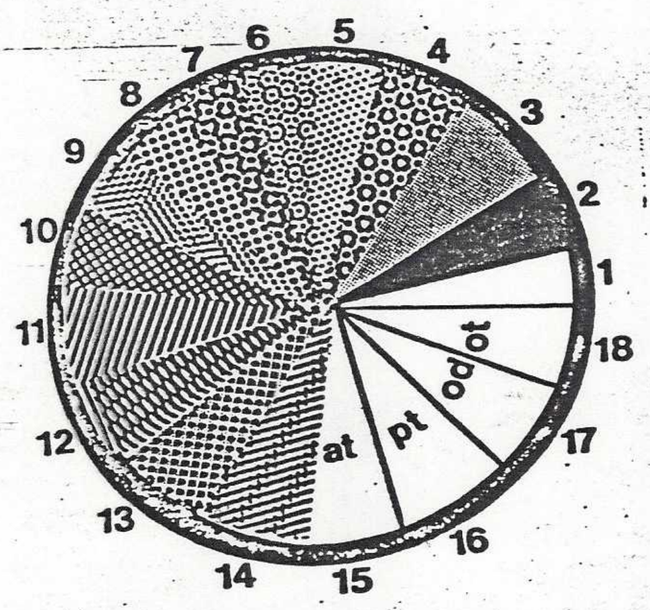
[1] The available invertebrate prey considers just those prey taxocenes consumed by the species in question. The values are the percentage of the total environmental numbers of utilized prey that are derived from each taxocene.

[2] During May, only pushnet samples were collected.

Figure 39:

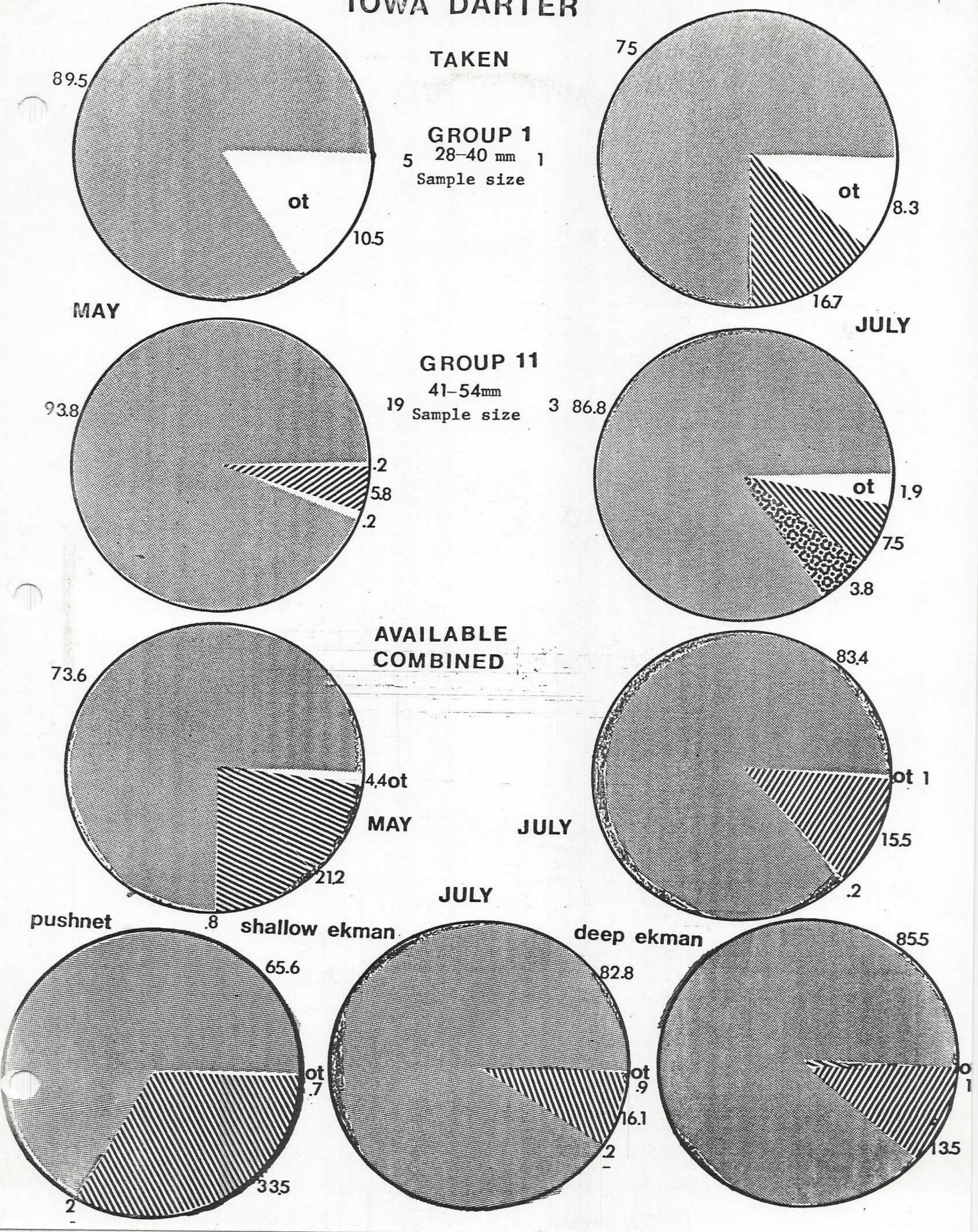
The relative numerical importance of different prey items to the diet of the Iowa Darter and their environmental abundances. Considering only those prey taxocenes consumed by the Iowa Darter, the relative numerical importance of each gives the size of each slice and its associated value. For the environment, 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


TAKEN
GROUP 1
28–40 mm
Sample size
5
1
89.5
ot
10.5
75
ot
8.3
16.7
MAY
JULY
GROUP 11
41–54mm
Sample size
19
3
93.8
.2
5.8
.2
86.8
ot
1.9
7.5
3.8
AVAILABLE
COMBINED
73.6
4.4ot
21.2
.8
MAY
JULY
83.4
ot 1
15.5
.2
JULY
pushnet
65.6
ot
.7
33.5
.2
shallow ekman
82.8
ot
.9
16.1
.2
deep ekman
85.5
o
1
13.5

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

Darters over the two sampling dates. Predation appears to be size specific with a size refugium afforded to larger bodied prey, including late instar Hyalella 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 ther 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.

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%).

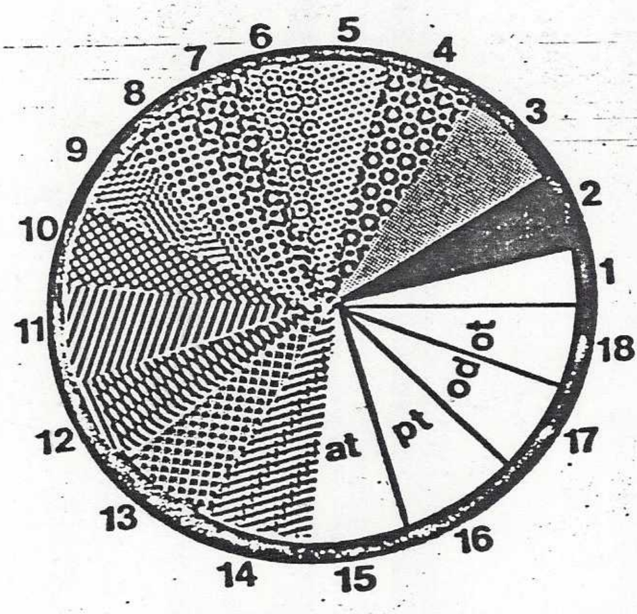
These are similar to the environmental abundances. Ephemerella nymphs are consumed to a greater extent than is indicated for benthic availability. Very small Ephemerella will also have been underrepresented in the sampling. Figure 11 indicates that there are considerable between site differences in the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

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