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Feeding Ecology of Fishes in a South Dakota Power Plant Cooling Reservoir

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FEEDING ECOLOGY OF FISHES IN A SOUTH DAKOTA POWER PLANT COOLING RESERVOIR

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This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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FEEDING ECOLOGY OF FISHES IN A SOUTH DAKOTA POWER PLANT COOLING RESERVOIR

Abstract

Robert J. Krska, Jr.

The food habits of bluegills (Lepomis macrochirus), black bullheads (Ictalurus melas), and muskellunge (Esox masquinongv) in the Big Stone Power Plant cooling reservoir were studied from January through December 1979.

The diet of 794 bluegills >50 mm TL was dominated by vegetation, planktonic crustaceans, dipteran larvae and pupae, and fishes: 214 bluegills < 50 mm TL fed primarily upon chironomid larvae and pupae and cladocerans. There was a significant difference (P<0.05) between diets of bluegills X50 mm and those >50 mm. This was determined by Spearman rank correlation coefficients based upon percent number and percent volume of food items, and mean number of taxa per stomach.

Both bluegill length-groups positively selected Chydorinae, ostracods, Caenis spp. larvae, chironomid pupae, and Physa spp., while they negatively selected cyclopoid copepods, Ceriodaphnia spp., and Tanypodinae larvae. Chironomid larvae were positively selected by bluegills <_50 mm, but were negatively selected by those >50 mm.

Fishes and chironomid larvae were the major food items of 105 black bullheads >120 mm TL; fishes and filamentous algae were the dominant food items of 146 bullheads 5120 mm. Ostracods and dipteran pupae were positively selected, while Tanvpodinae and Chironominae

larvae were negatively selected. Chydorinae, cyclopoid copepods, and Physa spp. were negatively selected by bullheads >120 mm. Chydorinae and Physa spp. were positively selected and cyclopoid copepods were ingested in proportions equal to those in the environment by bullheads X120 mm.

The diet of 107 yearling and young-of-the-year muskellunge was dominated by Johnny darters (Etheostoma nigrum), fathead minnows (Pimephales promelas), and centrarchids (Lepomis spp.). There were positive correlations between jaw width (closed) of muskellunge and prey size (total length and body depth); and body depth of muskellunge and prey size.

INTRODUCTION

The objective of this study was to determine the food habits of bluegills (*Lepomis macrochirus*), black bullheads (*Ictalurus melas*), and muskellunge (*Esox masquinongy*) in a power plant cooling reservoir. In addition, selectivity indices were calculated for bluegills and black bullheads to determine preferred food items.

Demand for electrical power has accelerated construction of electrical generating stations. Power plants utilizing cooling reservoirs to dissipate waste heat are expected to represent 20% of all power plants by the year 2000 (Meredith 1973). Cooling reservoirs possess potential secondary uses such as areas for fish production. If adequate forage is available in the heated water of cooling reservoirs, these fishes might be utilized in some form of fish culture activity. This study was conducted to document the forage used by selected fishes in a South Dakota power plant cooling reservoir.

STUDY AREA

The Big Stone Power Plant and cooling reservoir, owned jointly by Montana-Dakota Utilities Company, Northwestern Public Service Company, and Otter Tail Power Company, is located in Grant County, South Dakota, 3.2 km west of Big Stone City. The Big Stone plant, a coal-fired 440 MW steam electric generating facility, became operational in May, 1975. The cooling reservoir (Fig. 1) was completed in 1972, and filled with water pumped from Big Stone Lake, located on the South Dakota-Minnesota border. The reservoir has a surface area of 145 ha, maximum depth of 10 in, and a mean depth of 2.6 m at a water level of 341.1 m above mean sea level (msl). During the present study, the water level fluctuated from a high of 342.0 m to a low of 340.1 m above msl. As water evaporated from the reservoir, additional water was intermittently pumped in from Big Stone Lake.

Cooling water for the plant is pumped from the reservoir by 2 circulating pumps with a total capacity of 8.64 m^3/s. The intake structure is protected from large debris by vertical trash racks. Two vertical traveling screens, located behind the trash racks, rotate past a jet water spray which dislodges impinged fishes and debris into a sluiceway. Fishes are held in a collection basket at the end of the sluiceway.

The entire shoreline of the reservoir is rip-rapped with crushed granite. Extensive stands of submerged macrophytes, predominantly <u>Potamogeton</u> <u>pectinatus</u> grew in the southwest portion of the reservoir and in front of the cooling water intake structure during late spring and summer. Ice covered the south half of the reservoir, except for a

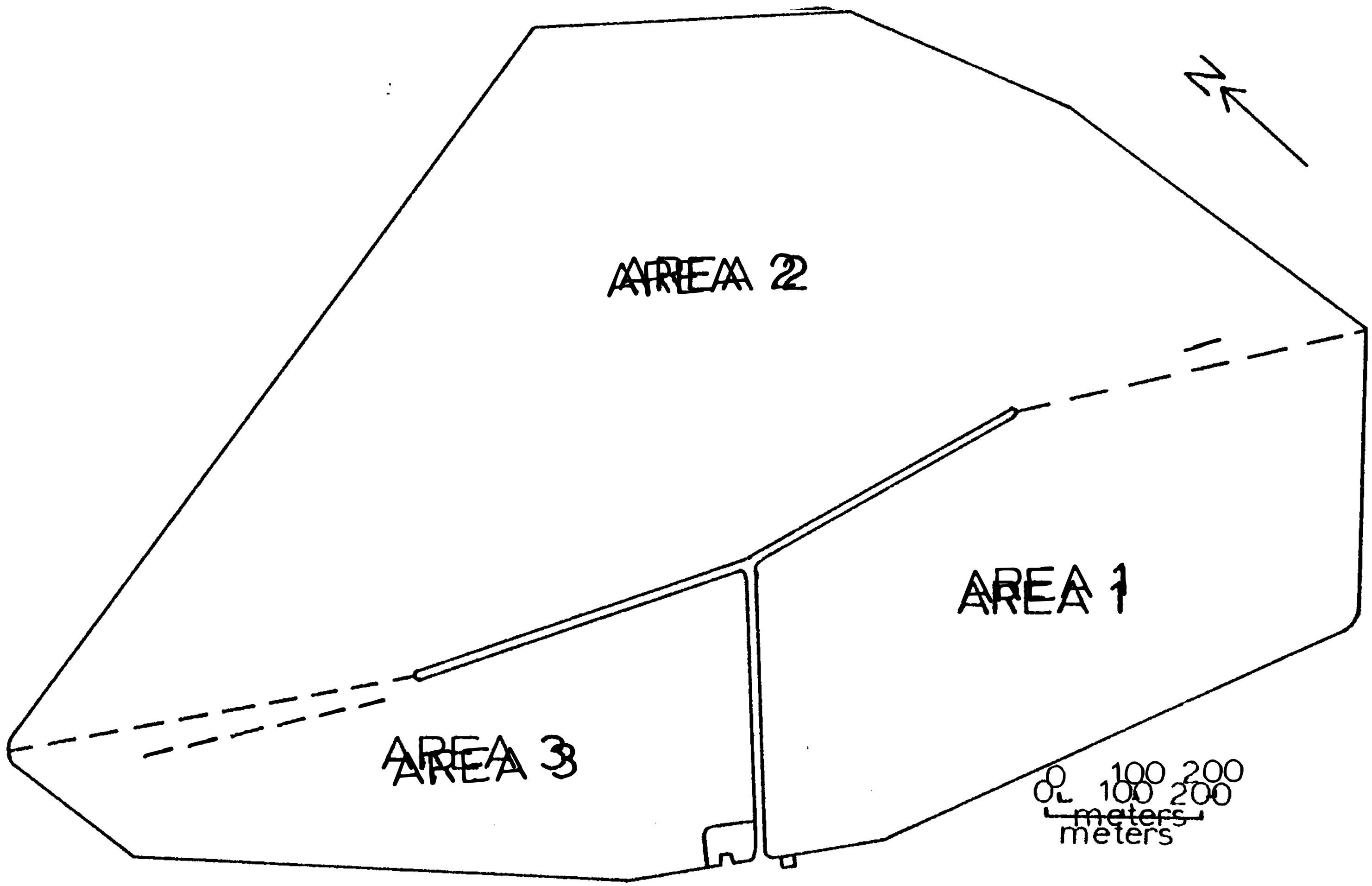

Fig. 1. Areas of the Big Stone Power Plant cooling reservoir, South Dakota, sampled for fishes for food habits analysis, 1979.

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small area adjacent to the intake structure, from late December to February or March. In March, 1979, a plant shut-down permitted ice to form over the entire reservoir.

MATERIALS AND METHODS

Bluegills and black bullheads were collected monthly in January, February, and April, and bimonthly from May through December, 1979, for food habits analysis. Ice cover prevented sampling in March. Samples in January and February were collected with an experimental gill net, and trap nets emptied hourly. The gill net was fished as a seine; it was extended perpendicular to the shore and the outer end was moved in a wide arc back to the shore. From April to December, fishes were collected with an alternating current (A.C.) boom-shocker during daylight in each of the 3 areas of the reservoir. Delineation of the 3 areas was based upon data from Wheeler (1979) who noted a temperature gradient from the heated-water discharge (area 3) to the intake (area 1). On 11 and 12 July, bluegills were collected by electro-shocking and seining from area 1 at 6 h intervals to determine their diel feeding cycle. A temperature profile at the mid-point of each sampling area was obtained at 1 m intervals with a Yellow Springs Instruments Model No. 33 thermister.

In the field, bluegills and black bullheads were anesthetized in a quinaldine solution to prevent regurgitation. Specimens were then killed and fixed in 10% formalin (Bagenal 1978). After approximately 1 week, specimens were rinsed in fresh water for several days and preserved in 70% isopropanol (Bagenal 1978).

Muskellunge specimens were obtained from the intake screen wash collection basket from August, 1978 to January, 1980. All specimens were dead at time of collection and were preserved in 10% formalin.

In the laboratory, fishes were measured to the nearest 1 mm (TL) and weighed to the nearest 0.1 g. Stomachs, from the esophagus to the pylorus, were removed and the contents were examined under a variable power (7-30x) dissecting microscope. Food items were identified utilizing several identification manuals (Edmonson 1966; Hilsenhoff 1975; Wiggins 1977; Pennak 1978). Items were then enumerated and volumes determined by water displacement.

Two bluegill size-groups (:550 mm and >50 mm TL) were analyzed separately for food habits to permit comparison of the diets of the 2 groups. Similarly, black bullheads were separated into 2 size-groups (5120 mm and >120 mm TL).

Zooplankton and benthos samples were collected concurrently with fish samples (Johnson 1980; Sloane 1980). These data enabled the electivity index of Ivlev (1961) to be used to determine preference or avoidance for food items by bluegills and black bullheads. Electivity indices were calculated separately for zooplankton and benthic components of the diet. Only organisms for which environmental abundance data were available were included in the calculations.

Electivity indices were calculated using the formula:

$$E = \frac{r_i - p_i}{r_i + p_i}$$

where E = electivity index

r - percent abundance of a food item in the diet

p - percent abundance of the same item in the environment

Electivity index values range from -1.0 to +1.0. Positive values indicate a preference, or selection, for an item, and negative values indicate avoidance. A value of 0 indicates no selection; the item was fed upon in the same proportion as it occurred in the environment.

The mean number of taxa and mean evenness values per stomach were calculated for bluegills collected from May through December, 1979, and analyzed by a Model I Analysis of Variance. The evenness value is based upon the Shannon function species diversity index H' (Pielou 1977), and is calculated by the equation:

$$H' = \frac{n \log n - \sum f_i \log f_i}{n}$$

where n = sample size (total number of individuals of all taxa)

f_i = number of individuals in taxon "i"

This function measures the uncertainty of predicting the taxon of the next individual collected (or consumed by a fish). The evenness value expresses the observed diversity, H', as a percentage of the maximum possible diversity, the H' value obtained assuming a single individual in each taxon. A population (fish stomach) with a high evenness value, approaching +1, has individuals evenly distributed among all taxa. A stomach with a majority of individuals concentrated in a few taxa has a relatively low evenness value, approaching 0. Student-Newman-Keul's test was utilized to determine which means were significantly different. A probability level of 0.05 was used for all statistical tests.

Spearman rank correlation coefficients were used to compare diets of bluegills (Fritz 1974) based upon area of collection and size. Food items were ranked according to their percent number and percent volume, i.e., the highest percent value received a rank of 1, and the lowest received a rank of n, or the number of ranks. Spearman rank correlation coefficients were then calculated using the formula:

$$r = 1.0 - \frac{6\Sigma d^2}{n^3 - n}$$

where r = Spearman rank correlation coefficient

d = the difference between paired ranks

n = the number of ranks

Significance of coefficients was tested using t-tests (Steel and Torrie 1960), calculated by the formula:

$$t = r\sqrt{\frac{n - 2}{1 - r^2}}$$

where r = Spearman rank correlation coefficient

n = the number of ranks

A significant t-value indicated no significant difference between diets. Comparisons of the diet in an area to that in each of the other 2 comprised a non-orthogonal comparison. Such comparisons were valid (Steel and Torrie 1960), however, in that it was desired to detect only general trends in diet composition between the 3 areas.

The relationships between various muskellunge body measurements and prey body measurements were determined by linear correlation. Significance of correlation coefficients (r) was tested with Student's t-test (Steel and Torrie 1960).

RESULTS AND DISCUSSION

Food Habits of Bluegills

Bluegills >50 mm

A total of 794 bluegills, ranging in length from 51 to 185 mm TL, was examined for food habits for the period January through December, 1979. Of these, 664 (83.6%) contained food. The mean annual diet was comprised of 18.0% vegetation by volume, 14.4% planktonic crustaceans (89.7% by number), 28.7% dipteran larvae and pupae (8.7% by number), 12.0% of the gastropod Physa spp. (0.4% by number), and 16.5% fish (<0.05% by number) (Table 1). The remainder of the diet was comprised of bryozoans, Hyalella azteca, Hydracarina, and aquatic and terrestrial insects. The mean number of food items per stomach was 158.9, with a mean volume of 0.08 ml. These findings are generally consistent with those reported by Ball (1948), DiCostanzo (1957), Gerking (1962), Seaburg and Moyle (1964), Keast and Webb (1966), and Etnier (1971).

Invertebrates appeared to be limited in abundance and/or availability during July and August, as shown by the increased importance of vegetation in the diet. Ball (1948) stated that plant matter serves as a substitute food during the summer months when aquatic invertebrates undergo reductions in abundance. Morgan (1951) stated that the amount of plant matter in the diet may be broadly correlated with the severity of competition for animal food. An increase in proportion of plant food in the diet, up to the dominant item, often corresponds to a midsummer decrease in availability of animal food.

Table 1. Percent number and, in parentheses, percent volume of stomach contents of 794 bluegills (*Lepomis macrochirus*) (51 to 185 mm TL, range) collected January to December, 1979, from the Big Stone Power Plant cooling reservoir, South Dakota.

Food Items	Jan	Feb			Jun	Jul
Algae	(2.3)	(3.0)	(0.1)			(19.6)
Vascular macrophvtes				(0.1)		(38.4)
Cruatacea						
Cladocera	1.5	12.4	29.0	72.9	72.9	0.3
	(0.1)	(3.9)	(2.1)	(19.5)	(28.2)	(T)*
Chydorinae	1.5	12.4	29.0	12.0		
	(0.1)	(3.9)	(2.1)	(0.3)		
Ceriodaphnia spp.						
Daphnia pulex				60.9	72.9	0.3
				(19.2)	(28.2)	(T)
Copepoda	98.5	87.2	58.7	0.3		13.3
	(26.3)	(54.7)	(80.9)	(T)		(0.1)
Oetracoda		0.3	10.7	2.2	0.4	27.7
		(0.2)	(1.6)	(0.1)	(T)	(0.1)
Inaecta						
Ephemeroptera [1]				T	T	1.9
				(0.1)	(8.0)	(0.7)
Bemiptera [2]		T	T	0.1	0.1	
		(0.3)	(2.4)	(1.5)	(0.8)	
Trichoptera [3]			T	T	0.2	11.9
			(0.1)	(0.1)	(1.2)	(2.8)
Coleontera [4]			T	T	0.4	0.3
			(0.4)	(0.2)	(4.7)	(0.2)
Diptsra						
Larvae [5]	T	0. 1	1.3	2.9	22.1	20.5
	(1.2)	(7.2)	(8.1)	(11.6)	(47.2)	(4.1)
Pupas			0.3	15.7	3.5	2.7
			(4.2)	(51.0)	(5.2)	(1.4)
Other insecta [6]						
Molluaca						
Phyea app.			T	0.1	0.1	2.7
			(0.1)	(2.3)	(3.8)	(2.8)
Fish	T	T		5.6**		1.3
	(70.1)	(30.7)		(13.3)**		(26.2)
Miscellaneous [7]			T	0.2	0.3	16.9
			(T)	(0.2)	(0.9)	(3.6)
Mean no. per stomach***	218.5	201.1	607.2	136.8	214.9	6.4
Mean vol. (ml) per stomach***	0.0307	0.0122	0.0439	0.1203	0.1441	0.0547
No. of stomachs examined	59	46	92	78	78	78
No. with food	42	27	87	67	76	59

* Less than 0.05%
** Fish ova
***Among stomachs with food

Table 1 (cant).

Food Items	Aug	Sep	Oct	Nov	Dec	Total
Algae	(15.3)	**(37.8)**	**(26.6)**	(13.3)	(32.9)	(11.7)
Vascular macrophytes	(37.4)	(8.0)	(14.5)	(1.5)	(2.8)	(6.3)
Crustacea						
Cladocera	**0.5**	**43.6**	**63.9**	59.1	30.1	**38.6**
	(T)	(0.2)	(0.8)	(0.6)	(0.4)	(10.3)
Chydorinas	**0.5**	**43.6**	**62.6**	16.2	23.9	**19.6**
	Cr)	(0.2)	(0.8)	(0.2)	(0.3)	(0.8)
Ceriodaphnia spp.			1.3	**42.9**	6.2	2.5
			(T)	(0.4)	(0.1)	(0.1)
Daphnia pulex						**16.5**
						(9.4)
Copepoda	7.7	**2.4**	13.1	25.7	37.3	45.3
	(T)	(T)	(0.3)	(0.7)	(1.0)	(3.6)
Ostracoda	**3.6**	1.7	1.0	0.5	**0.6**	**5.8**
	(T)	(T)	(T)	(T)	(T)	(0.5)
Inaecta						
Ephemeroptera [1]	**13.5**	**0.5**		0.1	0.1	0.1
	(2.0)	(0.4)		(0.3)	(2.7)	(2.1)
Hemiptera [2]		**1.4**	1.1	0.3	0.3	0.1
		(5.7)	(7.7)	(2.1)	(2.2)	(2.6)
Trichoptera [3]	***5.4***	*3.7*	1.9	T	0.1	0.2
	(1.0)	(0.4)	(3.0)	(T)	(0.2)	(0.9)
Coleoptera [4]	1.8	**3.0**	T			0.1
	(1.0)	(9.3)	(0.4)			(2.0)
Diptera						
Larvae [5]	**12.2**	27.1	**14.6**	10.1	25.3	6.2
	(0.6)	(2.4)	(4.1)	(4.8)	(9.6)	(17.0)
Pupae	**48.0**	**14.3**	1.7	2.1	0.6	2.5
	(3.5)	(5.5)	(0.9)	(1.1)	(0.3)	(11.7)
Other insecta [6]		**0.9**	T	T		T
		(0.1)	(0.3)	(T)		(T)
Molluscs						
Physa app.	0.5	0.8	2.6	2.0	**5.5**	0.4
	(0.2)	(4.3)	(20.7)	(38.2)	(36.7)	(12.0)
Fish	**5.4**	**0.6**	0.1	0.1	0.1	0.5
	(38.6)	(25.9)	(20.7)	(37.4)	(11.1)	**(18.6)**
!4iscellaneous [7]	1.4		T	T	T	0.2
	(0.4)		(T)	(T)	(0.1)	(0.7)
Haan no. per stomach***	4.0	13.3	**36.9**	79.3	61.4	158.9
Haan vol. (ml) per stomach***	0.0749	0.0542	0.0549	0.1014	0.0847	0.0759
No. **of stomachs examined**	57	77	78	78	73	794
No. with food	55	65	63	70	53	**664**

'Includes Baetidae, Caenidae, and Ephemeridae
[2] **lncludes Corixidae, Nabidae, and Cycadellidae**
[3] **lncludes Hydroptilidae, Leptoceridae, and Polycentropodidae**
[4] **Includes Dytiscidae, Cyrinidaa, Hydrophilidae, Halipiidae (larvae and adults), Curculionidae, and unidentified**
[5] **lncludes Tanypodinae, Orthocladinae, Chironominae, and Caratopogonidae**
[6] **lncludes Collembola and Zygoptera**
[7] **lncludes Bryozoa, Hyalella azteca, and Hydracarina**

In general, an inverse relationship between mean number of taxa per stomach and mean surface water temperatures was observed for the period May through December (Fig. 2). An increase in mean number of taxa per stomach coincided with increasing water temperatures in May and June. The number of taxa consumed decreased as water temperatures increased in July and August. As water temperatures decreased in late summer, the number of taxa ingested increased until November. The number of taxa again decreased in December, probably as a result of water temperatures too low to sustain high numbers of food taxa. Overall, the mean numbers of taxa per stomach were generally similar between areas (Table 2).

The relationship between mean evenness values and mean surface water temperatures was, in general, the opposite of that between number of taxa and water temperature (Fig. 3). Low evenness values were noted in May and June as a result of concentration of feeding effort upon *Daphnia pulex.* Evenness values increased in July and remained relatively high through October, indicating bluegills distributed feeding effort relatively evenly among all taxa consumed. In November and December, eveness values decreased, following the decrease of water temperatures to low levels. Bluegills generally fed to the same degree upon available food items in each area within each month (Table 3).

Spearman rank correlation coefficients based upon percent number indicated similar diets for bluegills from at least 2 areas for all months but July (Table 4). For the periods February through June and October through November, bluegills in all 3 areas generally fed upon

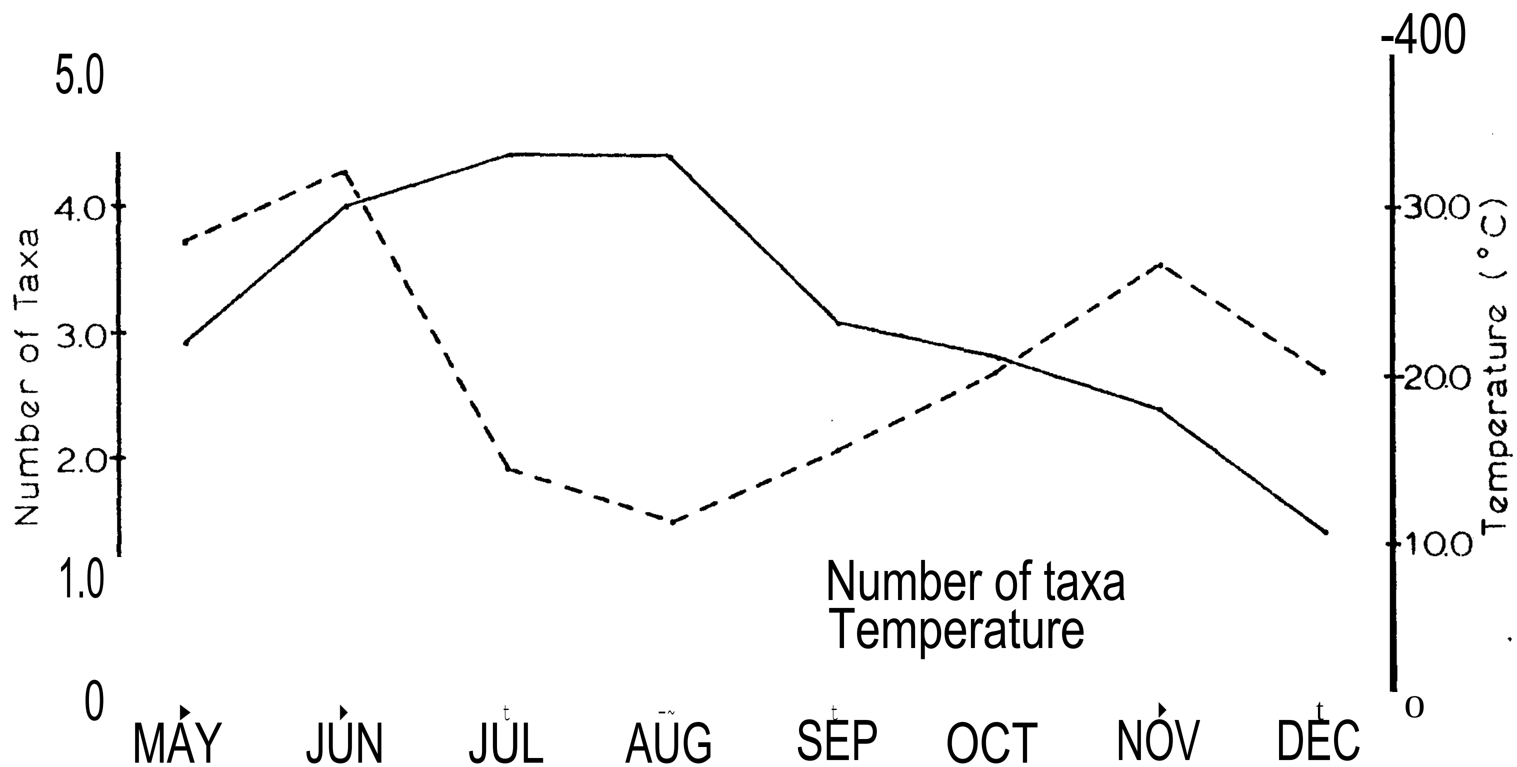


Fig. 2. **Relationship between mean number of taxa per stomach of bluegills** (*Lepomis macrochirus*) >50 mm TL **and mean surface water temperatures, Big Stone Power Plant cooling reservoir, South Dakota,** 1979.

Table 2. Mean number of taxa per stomach of bluegills *(Lepomis macrochirus)* >50 mm TL collected from the 3 areas of the Big Stone Power Plant cooling reservoir, South Dakota, 1979.

Month	Area 1	Area 2	Area 3	Mean
May	3.4 (21)[1]	4.1 (22)	3.5 * (24)	3.7
June	5.7 (25)	3.7 (26)	3.6 (25)	4.3
July	2.7 (23)	1.7 (19)	1.2 (17)	1.9
August	1.5 (24)	2.2 (13)	0.7 (9)	1.5
September	2.7 (24)	2.0 (23)	1.6 (18)	2.1
October	2.8 (21)	2.9 (22)	2.5 (20)	2.7
November	3.6 (21)	3.5 (26)	3.8 (23)	3.6
December	2.1 (19)	3.5 (23)	2.5 (21)	2.7

* Overscored values indicate no significant difference at the 0.05 level of probability

[1] Sample size in parentheses

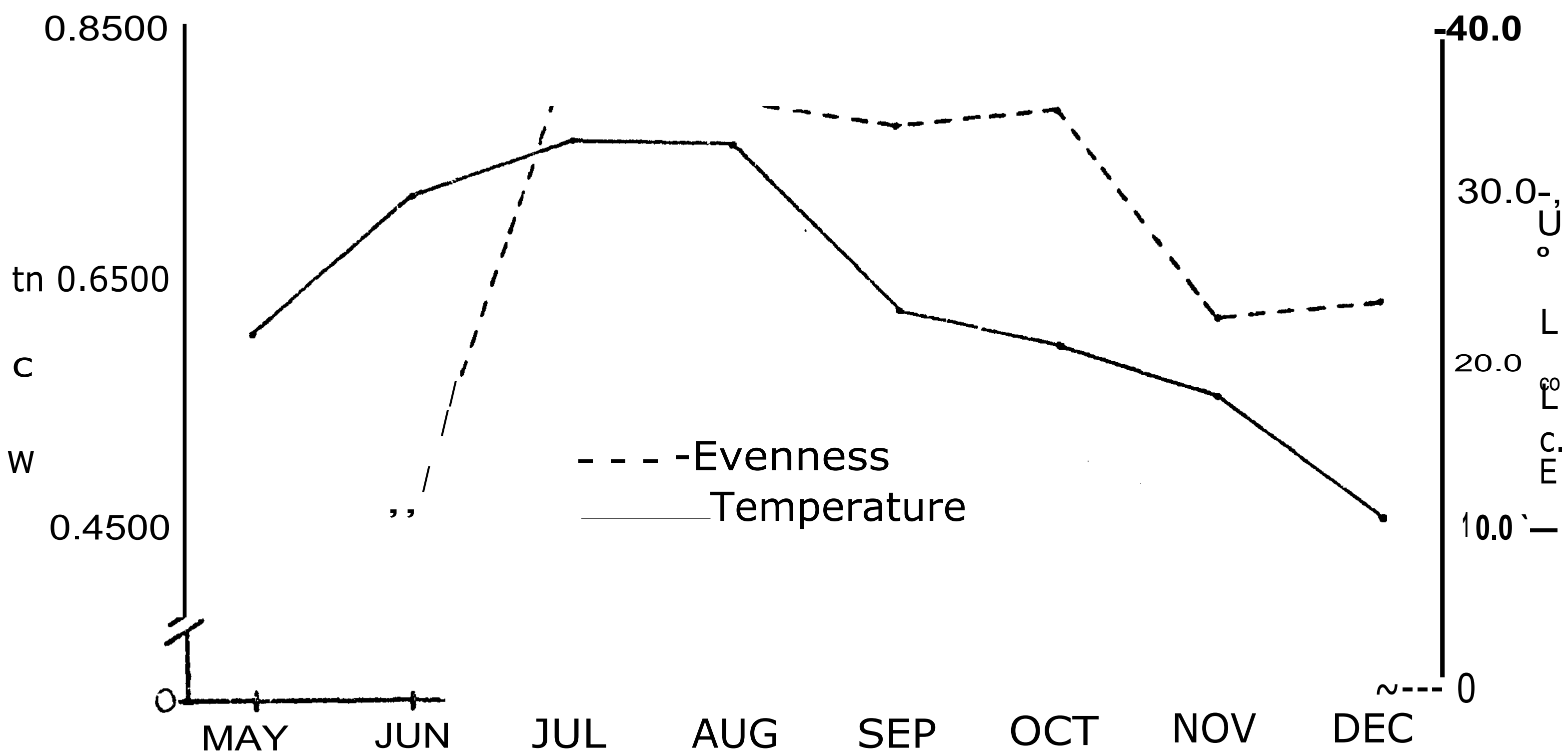


Fig. 3. **Relationship between mean evenness values per stomach of bluegills** <u>(*Lepomis macrochirus*)</u> > 50 mm TL **and mean surface water temperatures, Big Stone Power Plant cooling reservoir, South Dakota, 1979.**

Table 3. Mean evenness value per stomach of bluegills (*Lepomis macrochirus*) >50 mm TL collected from the 3 areas of the Big Stone Power Plant cooling reservoir, South Dakota, 1979.

Month	Area 1	Area 2	Area 3	Mean
May	0.4289 (18)[1]	0.5420 (20)	0.5603 (23) *	0.5155
June	0.5609 (24)	0.4737 (21)	0.3533 (23)	0.4625
July	0.8464 (14)	0.8347 (4)	0.7648 (5)	0.8266
August	0.7482 (8)	0.8100 (9)	1.0000 (1)	0.7931
September	0.7102 (17)	0.8506 (13)	0.7512 (8)	0.7669
October	0.8355 (16)	0.7525 (16)	0.7214 (8)	0.7795
November	0.5136 (18)	0.7113 (22)	0.6112 (18)	0.6189
December	0.7287 (10)	0.5546 (20)	0.6639 (12)	0.6273

* Overscored values indicate no significant difference at the 0.05 level of probability

1 Sample size in parentheses

Table 4. Spearman rank correlation coefficients by percent number and t-values for diet comparisons of bluegills (*Lepomis macrochirus*) >50 mm TL collected from the 3 areas of the Big Stone Power Plant cooling reservoir, South Dakota, 1979.

Month	Area 1 vs. Area 2	Area 2 vs. Area 3	Area 1 vs. Area 3
February			0.7381 2.68* (6)[1]
April	0.7286 4.12* (15)	0.4566 1.92 (14)	0.5714 2.31* (11)
May	0.4938 2.27* (16)	0.6125 2.90* (14)	0.3076 1.25 (15)
June	0.7887 5.44* (15)	0.9363 10.32* (15)	0.8609 6.98* (17)
July	0.2603 1.01 (14)	0.4352 1.67 (12)	0.2170 0.73 (11)
August	0.9595 10.21* (9)	-0.7000 -2.77* (8)	-0.1801 -0.58 (10)
September	0.5677 2.58* (14)	0.0772 0.29 (14)	0.0313 0.12 (15)
October	0.5778 3.00* (18)	0.5005 2.31* (16)	0.6917 3.95* (17)
November	0.8431 6.07* (15)	0.7312 4.29* (16)	0.5669 2.57* (14)
December	0.3221 1.27 (14)	0.6571 3.02* (12)	0.3625 1.46 (14)

* Significant at the 0.05 level of probability

[1] Degrees of freedom in parentheses

food items in the same proportions. This suggests that the abundance and/or availability of the majority of food items may not have been greatly affected by the thermal gradients during these periods. Overall, correlation coefficients based upon percent volume revealed about two-thirds fewer diet similarities than those based upon percent number (Table 5).

Bluegills $\leq$ 50 mm

A total of 214 bluegills, ranging in length from 26 to 50 mm TL, **were examined** for the **period** July through September, 1979. Ninety-**three** percent of the stomachs examined contained food. The mean food for this period was comprised of 9.9% cladocerans by volume (80.2% by number), 33.9% chironomid larvae (3.8% by number), and 40.0% dipteran pupae (1.2% by number) (Table 6). The remainder of the diet was comprised of vegetation, copepods, ostracods, other insects, *Physa* spp., and miscellaneous aquatic invertebrates. The mean number of items per stomach was 74.3 with a mean volume of 0.01 ml.

The mean number of taxa per stomach in July was significantly different between the 3 areas (Table 7). High water temperatures, especially in **area** 3, may have reduced the abundance and/or availability of certain taxa. As temperatures decreased in August and September, the number of taxa per stomach increased in areas 2 **and** 3 until there were no significant differences in September.

Mean **evenness** values showed fewer significant differences between areas (Table 8). In July, bluegills in all 3 areas distributed feeding effort **equally** among the taxa **ingested**. In **August** and September,

Table 5. Spearman rank correlation coefficients by percent volume and t-values for diet comparisons of bluegills (*Lepomis macrochirus*)>50 mm TL collected from the 3 areas of the Big Stone Power Plant cooling reservoir, South Dakota, 1979.

Month	Area 1 vs. Area 2	Area 2 vs. Area 3	Area 1 vs. Area 3
February			-0.3000 -0.83 (7) [1]
April	0.5738 2.80* (16)	0.2748 1.11 (15)	0.5670 2.38* (12)
May	0.2673 1.11 (16)	0.4926 2.12 (14)	0.0675 0.28 (17)
June	0.3575 1.62 (18)	0.4044 1.71 (15)	0.5588 2.78* (17)
July	0.5526 2.65* (16)	0.0404 0.16 (15)	0.0683 0.26 (14)
August	0.6374 2.74* (11)	-0.0455 -0.14 (10)	-0.0033 -0.01 (12)
September	0.7296 4.27* (16)	0.4556 2.04 (16)	0.2728 1.17 (17)
October	0.3210 1.52 (20)	0.0578 0.25 (19)	0.2691 1.24 (20)
November	0.4382 2.01 (17)	0.2436 1.07 (18)	0.3354 1.42 (16)
December	0.0859 0.36 (17)	0.6330 3.17* (15)	0.1244 0.50 (16)

* Significant at the 0.05 level of probability

[1] Degrees of freedom in parentheses

Table 6. Percent number and, in parentheses, percent volume of stomach contents of 214 bluegills (*Lepomis macrochirus*) (26 to 50 mm TL, range) collected July to September, 1979, from the Big Stone Power Plant cooling reservoir, South Dakota.

Food Items	July	August	September	Total
Algae	(1.5)	(1.7)	(3.3)	(2.6)
Vascular macrophytes	(6.1)	(1.7)	(0.1)	(1.4)
Crustacea				
Cladocera	26.1	71.3	89.4	80.2
	(7.4)	(3.6)	(14.2)	(9.9)
Chydorinae	5.4	69.2	89.3	77.7
	(0.4)	(3.4)	(14.2)	(8.9)
Other cladocera[1]	20.7	2.1	0.1	2.5
	(7.0)	(0.2)	(T)*	(1.0)
Copepods	24.6	7.3	4.8	7.3
	(4.3)	(0.7)	(1.5)	(1.5)
Ostracoda	31.7	8.8	2.3	6.3
	(5.7)	(0.8)	(0.7)	(1.4)
Insecta				
Ephemeroptera				
Caenis app.	1.7	0.3		0.2
	(7.9)	(1.9)		(1.6)
Coleoptera[2]	0.1		T	T
	(3.1)		(2.2)	(1.6)
Diptera				
Chironomidae larvae	8.0	6.6	2.7	3.8
	(28.4)	(75.7)	(10.0)	(33.9)
Pupae	0.2	4.6	0.7	1.2
	(6.1)	(9.0)	(66.9)	(40.0)
Other insecta[3]	0.4	0.2	T	T
	(6.2)	(2.1)	(0.4)	(1.7)
Molluscs				
Physa app.	0.8	0.1		0.1
	(6.9)	(1.2)		(1.3)
Miscellaneous[4]	6.4	0.8	0.1	0.9
	(16.4)	(1.6)	(0.7)	(3.1)
Mean no. per stomach**	22.7	39.1	143.3	74.3
Mean vol. (ml) per stomach**	0.0047	0.0153	0.0172	0.0124
No. of stomachs examined	76	60	78	214
No. with food	68	53	78	199

* Less than 0.05%

**Among stomachs containing food

[1] Includes *Simocephalus* spp., *Camptocercus* spp., *Ceriodashnia* app., and *Diaphanasoma* spp.

[2] Includes Curculionidae and unidentified

[3] Includes Collembola, Thripidae, Corixidae, Hydroptilidae, and Leptoceridae

[4] Includes Bryozoa, *Hyalella azteca*, and Hydracarina

Table 7. Mean number of taxes per stomach of bluegills *(Lepomis macrochirus)* < 50 mm TL collected from the 3 areas of the Big Stone Power Plant cooling reservoir, South Dakota, 1979.

Month	Area 1	Area 2	Area 3	Mean
July	5.4 (25)[1]	3.2 (22)	2.1 (21)	2.1
August	4.1 (22)	3.7 (19)	2.3 (12)	3.5
September	5.3 (26)	4.5 (26)	4.2 (26)	4.7

[1] Sample size in parentheses
* Overscored values indicate no significant difference at the 0.05 level of probability

Table 8. Mean evenness values per stomach of bluegills *(Lepomis macrochirus)* 5 50 mm TL collected from the 3 areas of the Big Stone Power Plant cooling reservoir, South Dakota, 1979.

Month	Area 1	Area 2	Area 3	Mean
July	0.8133 (24)[1]	0.7451 (17)	0.8736 (14)	0.8076
August	0.5896 (20)	0.8216 (18)	0.6683 (9)	0.6935
September	0.4254 (26)	0.5934 (24)	0.4953 (26)	0.5024

* Overscored values indicate no significant difference at the 0.05 level of probability
[1] Sample size in parentheses

distribution of feeding effort among those food categories consumed was significantly different between area 1 and area 2.

Spearman rank correlation coefficients based upon percent number indicated similar diets between at least 2 areas in August and September (Table 9). Diets in each area were significantly different in July. Similar diets based upon percent volume were noted only in September (Table 10).

Diets of Bluegills <_ 50 mm Versus Those > 50 mm

In general, diets of bluegills 5 50 mm long differed from those >50 mm. One indication of this was the large number of significant differences in number of taxa per stomach between the 2 size-groups (Table 11). Bluegills 5 50 mm consistently consumed a greater number of taxa, a result of their feeding upon various species of zooplankton. Evenness values indicated a greater degree of similarity (Table 12). Values were not significantly different in July and August. Bluegills 550 mm fed primarily upon Chydorinae in September, whereas bluegills >50 mm continued to feed relatively evenly upon all taxa consumed.

Spearman rank correlation coefficients indicated significantly different diets in each area between the 2 size-groups, based upon percent number and percent volume. Bluegills S 50 mm generally fed upon zooplankton in much greater proportions than those > 50 mm. Bluegills >50 mm, on the other hand, fed to a greater extent upon larger food items, particularly certain insect larvae.

No difference in diets of bluegills with increased size was noted by Ball (1948) or Gerking (1962). Doxtater (1964) noted decreased

Table 9. Spearman rank correlation coefficients by percent number and t-values for diet comparisons of bluegills *(Lepomis macrochirus)* S 50 mm TL collected from the 3 areas of the Big Stone Power Plant cooling reservoir, South Dakota, 1979.

Month	Area 1 vs. Area 2	Area 2 vs. Area 3	Area 1 vs. Area 3
July	0.3364 1.47 (17)[1]	0.4355 1.94 (16)	0.3959 1.83 (18)
August	0.4963 2.21* (15)	0.5857 2.28* (10)	0.4132 1.57 (12)
September	0.7099 3.49* (12)	0.4045 1.33 (9)	0.6621 2.90* (11)

[1] Degrees of freedom in parentheses
* Significant at the 0.05 level of probability

Table 10. Spearman rank correlation coefficients by percent volume and t-values for diet comparisons of bluegills (*Lepomis macrochirus*) $\leq$ 50 mm TL collected from the 3 areas of the Big Stone Power Plant cooling reservoir, South Dakota, 1979.

Month	Area 1 vs. Area 2	Area 2 vs. Area 3	Area 1 vs. Area 3
July	0.1669 0.76 (20) [1]	0.3234 1.49 (19)	-0.2139 -1.00 (21)
August	0.0726 0.31 (18)	-0.0232 -0.08 (13)	0.1873 0.75 (16)
September	0.5392 2.48* (16)	0.0091 0.03 (9)	0.5472 2.53* (15)

[1] Degrees of freedom in parentheses
* Significant at the 0.05 level of probability

Table 11. Mean number of taxa per stomach of bluegills (*Lepomis macro-chirus*) < 50 mm and >50 mm TL collected from the Big Stone Power Plant cooling reservoir, South Dakota, 1979.

Month	Area 1	>	Area 2	>	Area 3	>
July	5.4 (25)[1]	2.7 (23)	3.2 (22)	1.7 (19)	2.1 (21)	1.2 (17)
August	4.1 (22)	1.5 (24)	3.7 (19)	2.2 (13)	2.3 (12)	0.7 (9)
September	5.3 (26)	2.7 (24)	4.5 (26)	2.0 (23)	4.2 (26)	1.6 (18)

[1] Sample size in parentheses
* Overscored values indicate no significant difference at the 0.05 level of probability

Table 12. Mean evenness values per stomach of bluegills (*Lepomis macro-chirus*) 5_50 mm and >50 mm TL collected from the Big Stone Power Plant cooling reservoir, South Dakota, 1979.

Month	Area 1 <	>	Area 2 <	>	Area 3 <	
July	0.8133 (24)[1]	0.8464 (14)	0.7451 (17)	0.8347 (9)	0.8736 (14)	0.7648 (5)
August	0.5896 (20)	0.7482 (8)	0.8216 (18)	0.8100 (9)	0.6683 (9)	1.0000 (1)
September	0.4254 (26)	0.7102 (17)	0.5934 (24)	0.8506 (13)	0.4953 (26)	0.7512 (8)

* Overscored values indicate no significant difference at the 0.05 level of probability
[1] Sample size in parentheses

utilization of cladocerans as bluegills increased in size. He found that use of chironomid larvae increased with size of bluegills, up to 100 mm, with decreased use by fish 100 to 152 mm in length. Hall et al. (1970) found experimentally that bluegills switched from plankton to benthos when the fish were between 38 and 50 mm long. By the time a bluegill was 50 mm, it could ingest the entire range of available benthic invertebrates.

Diel Food Habits

There was a change in the food ingested by bluegills > 50 mm collected on 11 and 12 July at 6 h intervals. Algae and vascular macrophytes decreased from a high of 71.2% of the food volume at 1200 h to a low of 8.7% at 0000 h (Table 13). Ingestion of invertebrates, mostly *Hyalella azteca* and ephemeropteran larvae, increased during the same period. The greater utilization of these organisms may have been due to their increased activity, and thus, vulnerability to predation, at dusk and night (Pennak 1978).

Twenty-one caddisfly pupae, the only ones observed in stomachs throughout the study, and 8 *Hexagenia* spp. adults comprised 58.0% of the stomach volume of bluegills collected at midnight. Emergence of these 2 groups occurs in late afternoon or dusk (Edmunds at al. 1976; Pennak 1978) and may have accounted for their occurrence in stomachs at night.

The mean number and volume of food items per stomach ranged from a low of 4.2 and 0.01 ml at 1800 h to a high of 42.5 and 0.14 ml at 0000 h. Bluegills appeared to feed more intensely at night.

Table 13. Percent number and, in parentheses, percent volume of stomach contents of 56 bluegills (*Lepomis macrochirus*) (53 to 159 mm TL, range) collected at 6 h intervals, 11-12 July, from the intake area (area 1) of the Big Stone Power Plant cooling reservoir, South Dakota, 1979.

Food Items	11 July 1200 h	11 July 1800 h	12 July 0000 h
Alga*	(17.9)	(7.0)	(5.2)
Vascular macrophytes	(53.3)	(11.6)	(3.5)
Bryozoa		(7.0)	(1.2)
Crustacea			
Simocephalus spp.		6.0 (0.2)	1.1 (T)*
Ostracoda	22.0 (0.1)	16.0 (0.3)	28.8 (0.3)
Hyalella azteca	22.7 (6.0)	20.0 (15.5)	32.7 (16.6)
Arachnoidea			
Hydracarina	6.8 (0,5)	4.0 (0.8)	1.3 (0.2)
Insecta			
Ephemeroptera[1]	3.8 (1.8)	6.0 (8.3)	17.6 (47.6)
Corixidae			0.5 (1.4)
Trichoptera[2]			
Larvae	10.6 (3.8)	28.0 (25.0)	2.5 (1.6)
Pupae			3.4 (10.4)
Unidentified Coleoptera			0.3 (0.3)
Diptera			
Larvae[3]	24.3 (7.0)	16.0 (15.0)	3.3 (1.6)
Pupae	5.3 (4.2)	4.0 (9.3)	6.3 (7.8)
Molluscs			
Physa spp.	4.5 (5.4)		2.0 (0.7)
Fish			0.2 (1.6)
Mean no. per stomach**	5.7	4.2	42.5
Mean vol. (ml) per stomach**	0.0365	0.0090	0.1446
No. of stomachs examined	26	15	15
No. with food	23	12	15

* Less than 0.052

**Among stomachs containing food

[1] Includes *Caenis* spp. and *Hexagenia* spp.

[2] Includes Hydroptilidae and Polycentropodidae

[3] Includes Chironomidae and Ceratopogonidae

Keast and Welsh (1968) reported that bluegills >90 mm TL in Lake Opinicon, Ontario, fed most intensely at 1500 h, and after a gradual decline, resumed active feeding at approximately 2030 h, which continued intermittently throughout the night. They suggested that in the case of generalized feeders, such as the bluegill, different feeding times may reduce interspecific contact and competition. Based upon mean number and volume of food items per stomach and number of empty stomachs, peaks in feeding activity of bluegills in this study differed from those observed by Keast and Welsh (1968).

Diets of bluegills ≤ 50 mm also differed at 6 h intervals. Consumption of cladocerans and *Hyalella azteca* decreased from 1800 h on 11 July to 0600 h on 12 July (Table 14). Dipteran larvae, mostly Chironomidae, decreased in the diet during the 3 sample periods, while dipteran pupae increased. Pennak (1978) stated that most chironomids emerge between 1800 and 0600 h, which may account for the increased consumption of pupae after dark; pupae are most vulnerable during emergence. The mean number and volume of items per stomach were consistent from one sample period to the next, although the volume at 0000 h was about 60% of the volumes at 1800 h and 0600 h.

Food Selectivity of Bluegills

Bluegills > 50 mm

Bluegills >50 mm TL positively selected Chydorinae, *Daphnia pulex*, and ostracods, and negatively selected *Ceriodaphnia* spp. and cyclopoid copepods (Table 15). After an initial electivity index of -0.7 in January and February, Chydorinae were positively selected (Fig. 4). The

Table 14. Percent number and, in parentheses, percent volume of stomach contents of 58 bluegills (*Lepomis macrochirus*) (29 to 50 mm TL, range) collected at 6 h intervals, 11-12 July, from the intake area (area 1) of the Big Stone Power Plant cooling reservoir, South Dakota, 1979.

Food Items	11 July 1800 h	12 July 0000 h	12 July 0600 h
Algae		(17.1)	
Crustacea			
Cladocera[1]	58.6	22.5	29.2
	(13.7)	(1.9)	(1.7)
Copepoda	16.7	1.2	6.9
	(2.4)	(0.3)	(1.1)
Ostracoda	5.3	58.2	45.8
	(0.8)	(12.8)	(7.2)
Hyalella azteca	6.8	5.5	0.9
	(14.4)	(13.0)	(1.6)
Arachnoidea			
Hydracarina	2.7	1.2	2.1
	(4.4)	(2.9)	(3.8)
Insecta			
Caenis spp.	3.6	3.5	4.5
	(13.2)	(7.7)	(21.2)
Corixidae	0.1		
	(5.8)		
Hydroptilidae	0.4		
	(3.1)		
Diptera			
Larvae[2]	4.8	5.6	2.8
	(30.6)	(24.5)	(7.4)
Pupae	0.3	2.3	6.4
	(5.8)	(19.8)	(38.7)
Mollusca			
Physa spp.	0.7		1.4
	(5.8)		(17.3)
Mean no. per stomach*	25.0	26.4	28.1
Mean vol. (ml) per stomach*	0.0064	0.0039	0.0067
No. of stomachs examined	28	15	15
No. with food	27	13	15

* Among stomachs containing food

1 Includes Chydorinae, *Simocephalus* spp., and *Ceriodaphnia* spp.

2 Includes Chironomidae and Ceratopogonidae

Table 15. Electivity indices for zooplankton by bluegills (*Lepomis macrochirus*) > 50 mm TL, percent abundance in stomachs, in parentheses, and percent abundance in zooplankton samples, Big Stone Power Plant cooling reservoir, South Dakota, 1979.

Month	Chydorinae	*Ceriodaphnia spp.*	*Daphnia pulex*	Cyclopoida	Ostracoda
January	-0.9			+0.3	
	(1.3)			(98.5)	
	40.2			55.8	
February	-0.6			0	
	(12.5)			(61.3)	
	45.6			59.6	
April	+0.5			-0.4	+0.7
	(45.9)			(30.0)	(23.9)
	15.8			69.0	4.5
May	-0.4		+0.5	-1.0	+0.6
	(17.1)		(77.3)	(0.4)	(5.2)
	45.0		26.8	53.9	1.5
June	-1.0		+0.2	-1.0	+0.1
	(--)		(96.5)	(--)	(3.5)
	0.1		68.7	15.8	2.9
July	-1.0	-1.0	+0.3	-0.5	+0.8
	(--)	(--)	(0.7)	(20.2)	(79.1)
	1.8	1.2	0.4	67.5	6.9
August	-0.4	-1.0		-0.3	+0.5
	(0.7)	(--)		(35.7)	(5.3)
	1.5	17.8		60.0	1.6
September	+0.9	-1.0		-0.5	
	(46.9)	(--)		(12.5)	
	3.2	44.9		37.4	
October	+0.8	-0.8		0	
	(67.8)	(8.0)		(21.0)	
	9.2	64.4		23.2	
November	+0.8	-0.2		-0.1	+0.8
	(28.3)	(37.4)		(33.5)	(0.8)
	3.4	52.6		42.3	0.1

Table 15 (cont).

Month	Chydorinae	Ceriodaphnia spp.	Daphnia pulex	Cyclopoida	Ostracoda
December	+0.8 (31.7) 2.6	+0.2 (18.7) 13.5		-0.4 (31.2) **81.8**	
Mean	+0.2 (22.9) 15.3	-0.5 (10.7) 32.4	+0.3 (58.2) 32.0	-0.2 (31.3) 51.5	+0.7 **(19.6)** 2.9

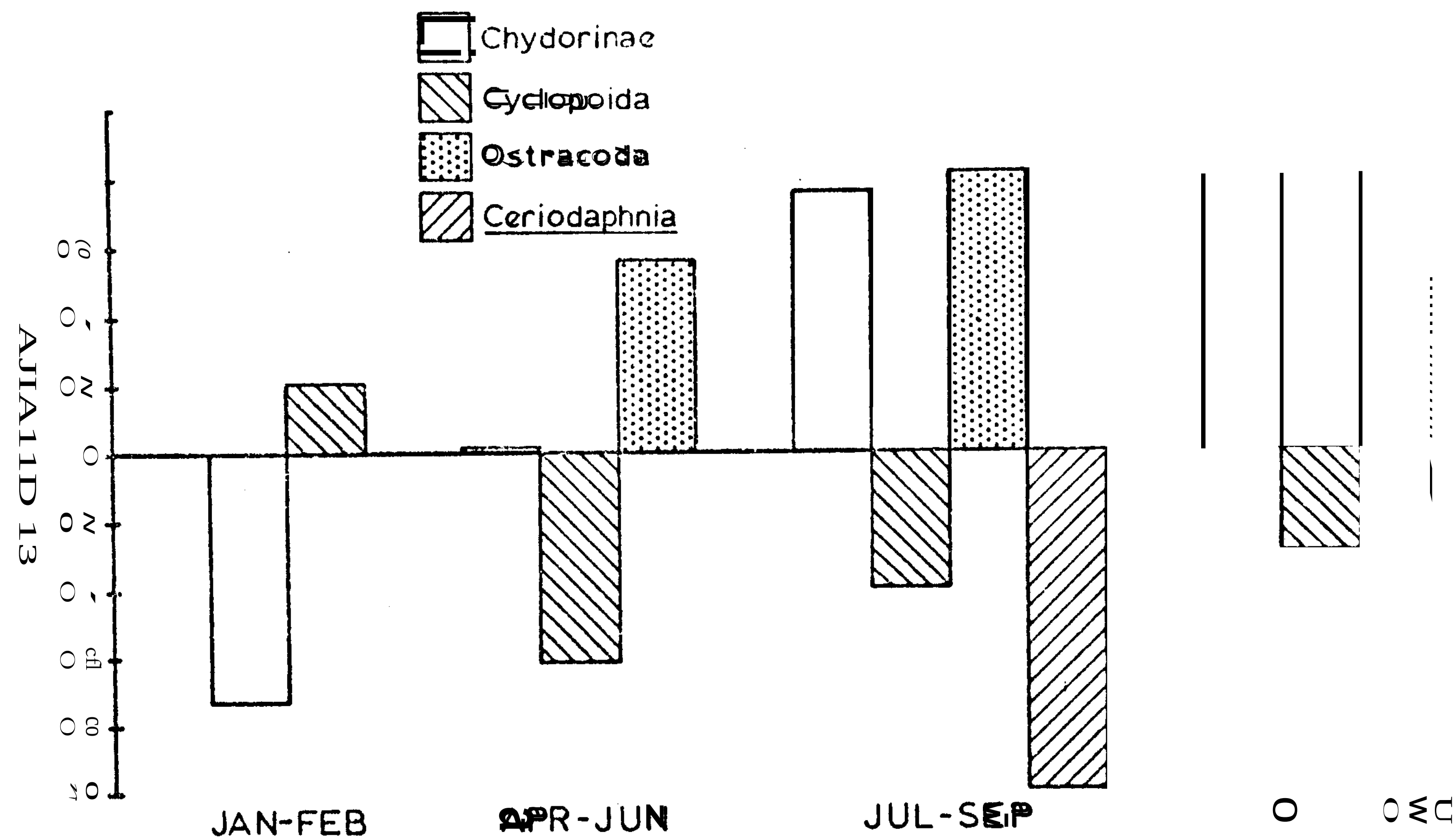


Fig. 4. Mean seasonal electivity indices for zooplankton by bluegills (*Lepomis macrochirus*) > 50 mm TL, Big Stone Power Plant cooling reservoir, South Dakota, 1979.

opposite trend was noted for cyclopoid copepods, which were positively selected in January and February but negatively selected the remainder of the year. Ostracods were consistently positively selected, which may be misleading. Edmonson (1966) stated that ostracods are rarely caught in plankton nets because most live in or near the bottom. In addition, Johnson (1980) noted significantly higher numbers of ostracods in **zooplankton** samples collected at night than during the day. Thus, zooplankton samples may have underestimated the abundance of ostracods, accounting for high positive electivity index values.

Ceriodaphnia snp. first appeared consistently in zooplankton samples in mid-July. It comprised a mean abundance in zooplankton samples of 21.3% for the period July-September, but was not found in bluegill stomachs. Its abundance in zooplankton samples declined from a high of 64.4% in October to a low of 13.5% in December, with a mean of 43.5% for the period, but electivity indices increased from a low of -0.8 to a high of +0.2 for the same period, with a mean of -0.3.

Daphnia pulex first appeared in zooplankton samples on 11 May. It comprised 26.8% in zooplankton samples that month, and increased to 68.7% in June, when 96.5% of the **zooplankton** in bluegill stomachs was D. pulex. Except for ostracods, D. pulex was the only positively selected zooplankter during May and June, when it was at the height of its abundance.

Among benthic organisms regularly occurring in larger bluegill stomachs, Tanypodinae and **Chironoaeinae larvae** had **negative mean** electivity indices, while Caenis spp. larvae, dipteran pupae, and Physa spp. had positive mean indices (Table 16). Bluegills negatively selected

Table 16. Electivity indices for benthos by bluegills (*Lep anis macro-chirus*) >50 mm TL, percent abundance in stomachs, in parentheses, and percent abundance in benthos samples, Big Stone Power Plant cooling reservoir, South Dakota, 1979.

Month	*Caenis* spp.	Tanypodinae larvae	Chironominae larvae	Dipteran pupae	*Physa* spp.
April	-1.0 (--) 0.2	-1.0 (0.5) 22.9	-1.0 (51.6) 67.0	+0.9 (47.9) 2.1	
May	0 (0.2) 0.2	-1.0 (0.6) 34.3	-0.4 (25.6) 59.2	+0.9 (73.6) 4.2	+0.9 (1.4) 0.1
June	+0.5 (0.3) 0.1	-0.9 (1.0) 18.1	-0.1 (56.8) 76.7	+1.0 (34.4) 0.8	+0.8 (4.8) 0.6
July	+0.4 (6.9) 2.8	-1.0 (0.5) 64.0	+0.6 (74.7) 17.4	+1.0 (7.1) 0.1	+1.0 (9.7) 0.2
August	+0.7 (9.5) 1.4	-1.0 (0.2) 54.8	+0.1 (12.6) 10.9		
September	+0.2 (1.1) 0.8	-0.9 (0.6) 15.4	-0.1 (50.8) 64.2	+1.0 (34.5) 0.1	
October		-0.9 (0.2) 5.5	-0.2 (63.3) 90.4		
November	+0.6 (2.4) 0.6	-1.0 (0.2) 23.1	-0.2 (43.0) 68.6	+1.0 (22.8) 0.1	
December		-1.0 (0.2) 42.5	0 (43.3) 47.6		
Mean	+0.5 (2.9) 0.9	-1.0 (0.4) 31.2	-0.1 (46.9) 55.8	+0.9 (36.7) 1.2	+0.9 (5.3) 0.3

Chironominae larvae except in July, August, and December. Tanypodinae larvae never comprised more than 1.0% of the benthic organisms consumed, although they made up 31.2% of the mean annual number of benthic organisms sampled. The consistent negative selection for Tanypodinae larvae may have been related to their accessibility; other organisms with lower environmental abundances had high positive electivity index values. Active avoidance of predation, reduced visibility, or deeper burrowing into the sediments may have contributed to the negative selection for them.

Dipteran pupae, most of which belonged to the family Chironomidae, were positively selected, never having an electivity index below +0.9. The large abundance in the May bluegill diet could have been due to intense feeding upon pupae brought about by a major spring emergence. The high electivity index values for pupae may have been due to their increased vulnerability during this life stage; they actively swim within the water column prior to emergence at the surface (Pennak 1978).

Caenis spp. larvae, although never abundant in the diets, were generally positively selected. In April, they were not found in stomach samples, and in October, they were absent from both environmental and stomach samples. Physa spp. was highly selected throughout the period May-July.

Bluegills < 50 mm

Electivity indices of smaller bluegills for zooplankton and benthos were similar to those for larger bluegills for the period July-September (Fig. 5 and 6). Of the zooplankton, Chydorinae and ostracods were

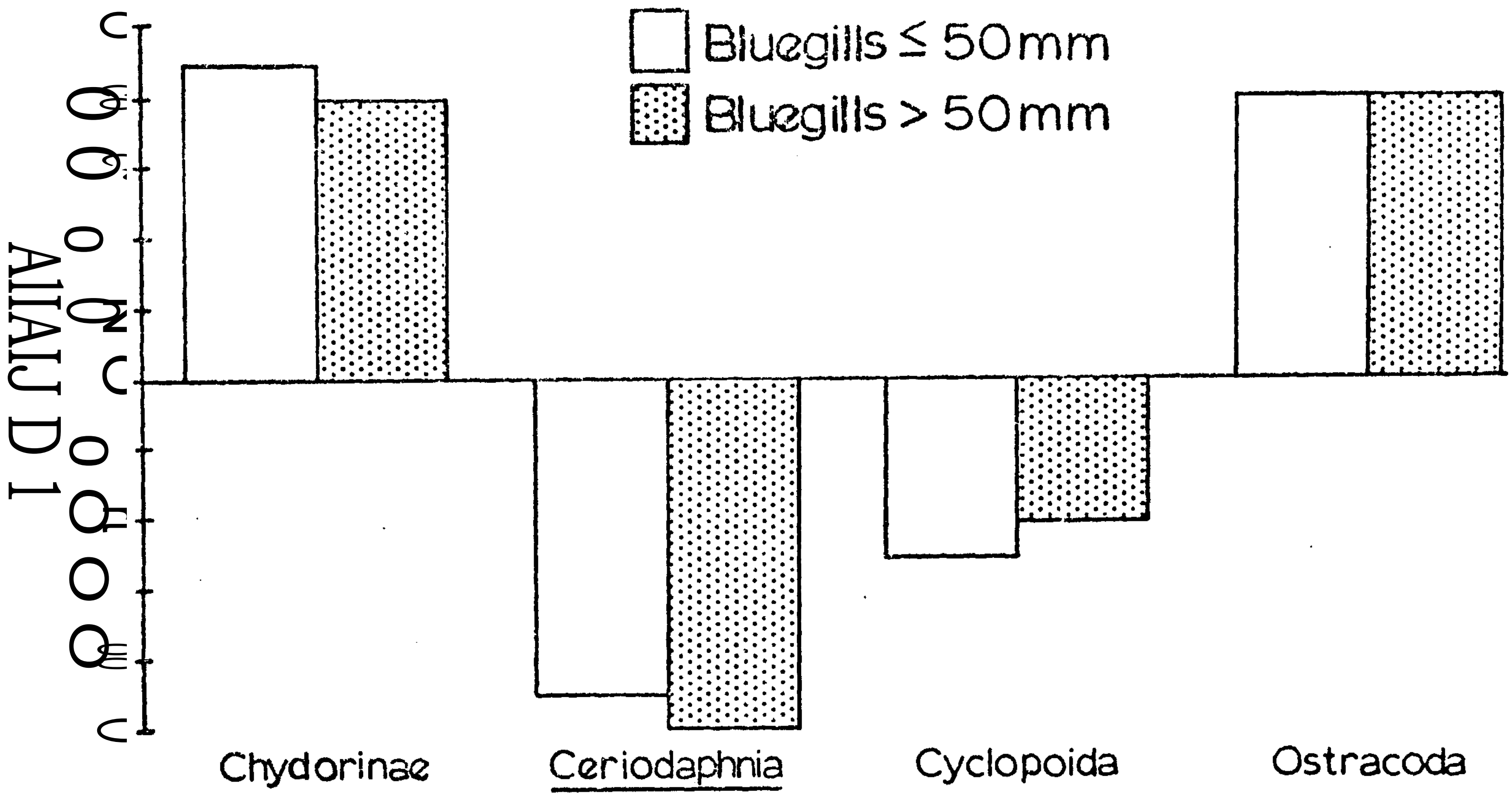
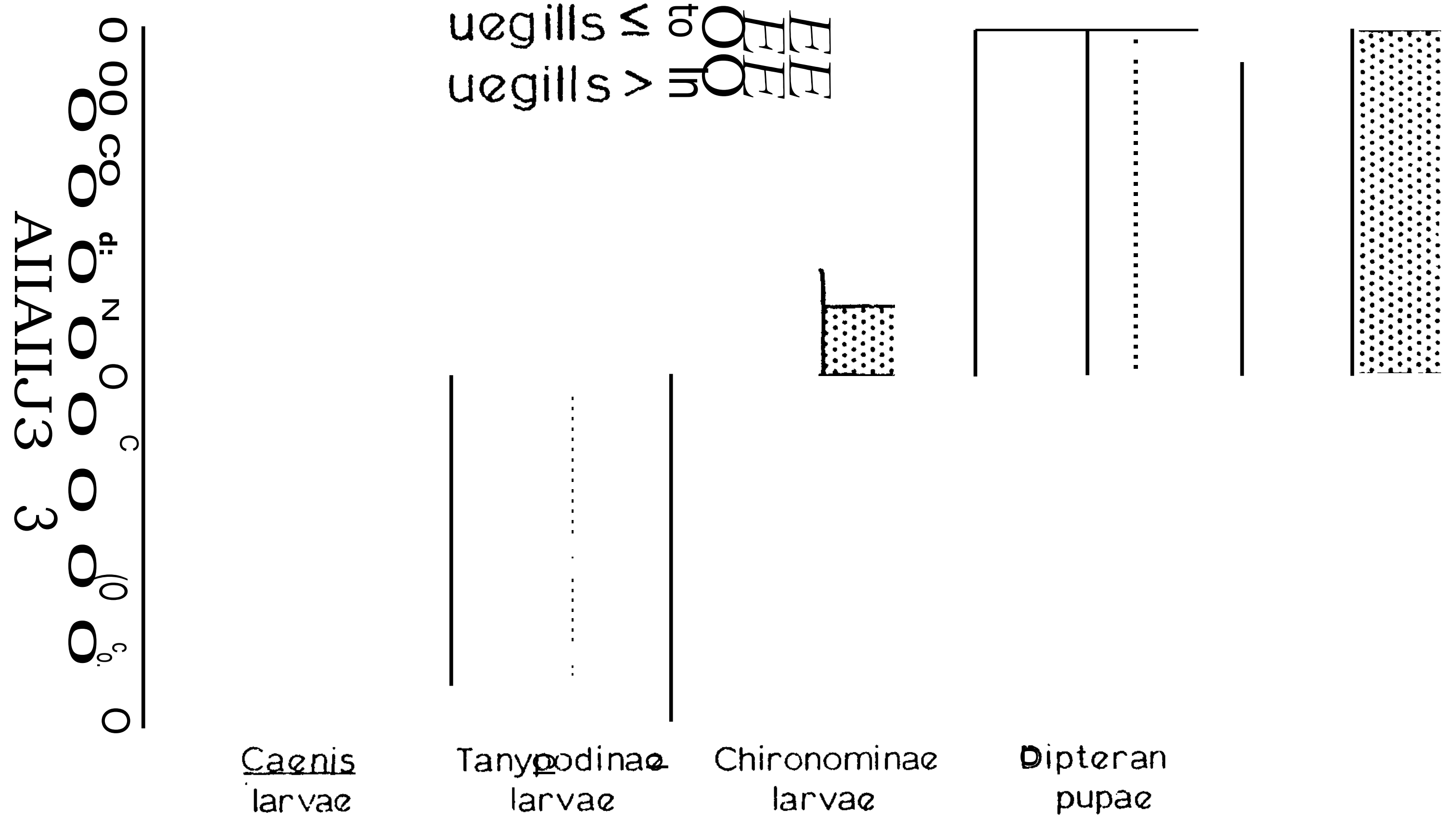


Fig. 5. Mean electivity indices for zooplankton by bluegills (Lepomis macrochirus) ≤ 50 mm and > 50 mm TL, July through September, 1979, Big Stone Power Plant cooling reservoir,



6. Mean electivity indices for benthos by bluegills (*Lepomis macrochirus*) ≤ 50 mm and > 50
July through September, 1979, Big Stone Power Plant cooling reservoir, South Dakota.

positively selected with mean electivity indices of +0.9 and +0.8, respectively (Table 17). Chydorinae never constituted more than 3.2% of the organisms in **zooplankton** samples, but they increased in percent composition in stomachs to a maximum of 91.9% of zooplankton consumed in September. Cyclopoid copepods became increasingly negatively selected during this **period**. This may **be explained** by the greater utilization of the **preferred Chydorinae**. **Ceriodaphnia** spp. was the least preferred item of those for which electivity indices were calculated, with a mean of -0.9. In September, Ceriodaphnia spp. comprised nearly half of the zooplankton in the environment but was still selected against.

Among the benthos, Tanypodinae larvae were the only negatively selected items, with a mean value of -0.9 (Table 18). Even though the larvae **comprised** 64.5% of the benthos **samples** in July and August, *they* were selected against (-0.9). Chironominae larvae had a mean electivity index of +0.3. They were most preferred in August (+0.7) and least in September (0). Dipteran pupae were positively selected in July and September but were absent from stomachs and benthos samples in August. Electivity indices for Caenis spp. larvae decreased from a high of +0.6 in July to -1.0 in September. Edmunds et al. (1976) stated that in the northern part of its range, **emergence** of Caenis spp. occurs chiefly in June and July with sporadic emergences occurring in September. This may have explained the reduced abundance in the benthos in August and September. **No** similar **decreasing trend** in **electivity** for the same period was noted for bluegills > 50 mm. Physa spp., not occurring in benthos samples in August or in either benthos samples or stomachs in September, had a mean electivity index of +0.9.

Table 17. Electivity indices for zooplankton by bluegills (*Lepomis macrochirus*) :550 mm TL, percent abundance in stomachs, in parentheses, and percent abundance in zooplankton samples, Big Stone Power Plant cooling reservoir, South Dakota, 1979.

Month	Chydorinae	*Ceriodaphnia* spp.	Cyclopoida	Ostracoda
July	+0.6 (7.5) 1.7	-0.9 (0.1) 1.5	-0.4 (28.9) 67.6	+0.7 (32.6) 5.7
August	+0.9 (35.3) 2.4	-0.7 (2.8) 15.5	-0.5 (18.5) 57.4	+0.9 (28.7) 1.4
September	+0.9 (91.9) 3.2	-1.0 (0.1) 44.9	-0.8 (5.1) 37.4	
Mean	+0.9 (44.9) 2.4	-0.9 (1.9) 20.6	-0.5 (17.5) 54.1	+0.8 (30.7) 3.6

Table 18. Electivity indices for benthos by bluegills (*Lepomis macrochirus*) 550 mm TL, percent abundance in stomachs, in parentheses, and percent abundance in benthos samples, Big Stone Power Plant cooling reservoir, South Dakota, 1979.

Month	*Caenis* spp.	Tanypodinae larvae	Chironominae larvae	Dipteran pupae	*Physa* spp.
July	+0.6 (20.4) 4.8	-0.9 (3.8) 64.6	+0.4 (64.5) 28.8	+0.8 (2.5) 0.3	+0.9 (8.5) 0.3
August	+0.2 (1.9) 1.4	-0.9 (4.7) 64.5	+0.7 (51.6) 10.8		
September	-1.0 (--) 1.7	-1.0 (--) 15.4	0 (79.5) 75.6	+1.0 (20.6) 0.1	
Mean	+0.5 (7.4) 2.6	-0.9 (2.8) 48.2	+0.3 (65.2) 38.4	+1.0 (11.6) 0.2	+0.9 (8.5) 0.3

Food Habits of Black Bullheads

Bullheads >120 mm

A total of 105 black bullheads, ranging in length from 122 to 268 mm TL, was collected during the period January through December. No fish were collected in November and the stomachs of 7 fish collected in December were empty. Of the 105 stomachs examined, 64 (61.0%) contained food. The annual diet was dominated by fishes, which comprised 92.5% of the food volume (7.8% by number), and chironomid larvae, which comprised 4.8% of the volume (61.7% by number) (Table 19). The remainder of the diet was comprised of aquatic vegetation, planktonic crustaceans, *Physa* spp., and miscellaneous aquatic invertebrates. The mean number of food items per stomach was 25.5, with a mean volume of 1.06 ml. Forney (1955), Baur (1970), and Repsys (1972) found adult and sub-adult black bullheads to feed upon the same general range of items, although black bullheads in this study were more piscivorous.

Bullheads X120 mm

A total of 146 black bullheads, ranging in length from 68 to 120 mm TL, was collected during the period July through December. Of 108 fish (74.0%) containing food, one-half of the volume of the mean annual diet was comprised of filamentous algae (49.8%) with the remainder comprised of 43.6% fishes, 6.0% aquatic invertebrates, 0.4% vascular macrophytes, and 0.2% gravel (Table 20). Numerically, zooplankton was the dominant food, with copepods contributing 44.2%, cladocerans 23.6%, and ostracods-17.2% of the mean annual number. The mean number of food items per stomach was 4.6, and the mean volume was

Table 19. Percent number and, in parentheses, percent volume of stomach contents of 105 black bullheads (*Ictalurus melas*) (122 to 268 mm TL, range) collected January to December, 1979, from the Big Stone Power Plant cooling reservoir, South Dakota.

Food Items	Jan	Feb	Apr	May	Jun	Jul	Aug	Sep	Oct	Total
Algae			**(39.8)**			(13.8)	(1.4)	(3.3)	(1.0)	(0.9)
Vascular macrophytea			**(2.8)**			**(0.5)**		**(2.1)**	**(0.2)**	**(0.2)**
Crustacea										
Cladocera[1]			4.8	100.0	7.1			15.8	45.1	8.2
			(T)*	(0.6)	(1.1)			(T)	(T)	(0.1)
Copepods			22.6					15.8	12.9	1.5
			(0.3)					(T)	(T)	(T)
Ostracoda			14.5		19.4				1.6	**16.6**
			(0.2)		**(0.3)**				(T)	(T)
Insects										
Diptera										
Chironomidae larvae[2]			27.5		71.4		0.9	10.5	35.6	61.7
			(22.8)		(91.3)		(T)	(0.1)	(0.3)	(4.8)
Pupae			**30.6**		2.1	100.0				3.1
			(34.1)		(3.6)	(4.2)				(0.3)
Molluaca										
P_hysa app.		52.6					2.8	5.2		0.9
		(1.3)					(0.3)	(0.3)		(0.5)
Other invertebrata[3]					T			15.6	1.6	0.2
					(0.1)			(0.9)	(0.1)	(0.1)
Fish[4]	100.0	47.4					**96.3**	37.1	3.2	7.8
	(98.6)	(98.7)				(81.5)	**(98.3)**	(93.3)	**(98.2)**	**(92.5)**
Unidentified	**(0.7)**									**(0.1)**
Cravel	(0.7)			**(96.4)**	**(3.6)**				**(0.2)**	**(0.5)**
Mean no. per stomach**	0.8	2.1	15.5	5.0	449.0	0.4	**8.9**	1.7	10.3	25.5
Mean vol. (ml) per stomach**	0.8913	2.6333	0.0450	0.0400	1.1600	0.0470	1.3300	0.0736	2.6500	1.0573
No. of stomachs examined	12	24	5	3	3	15	13	14	9	105***
No. with food	8	9	4	1	3	10	12	11	6	64

*** Less than 0.05%**
**** Among stomachs containing food**
*****Includes 7 empty stomachs collected in December**
Includes Chydorinae, *Ceriodaphnia* app., and Daphnia *pulex*
2 Includes Tanvpodinae and Chironominae
3 Includes ilydracarina, Ephemeroptera, Trichoptera, and Coleoptera
4 Includes Johnny darter, Centrarchidae, and unidentified remains

Table 20. Percent number and, in parentheses, percent volume of stomach contents of 146 black bullheads (Ictalurus .else) (68 to 120 mat TL, range) collected July through December, 1979, from the Big Stone Power Plant cooling reservoir, South Dakota.

Food Items	Jul	Aug	Sep	Oct	Nov	Dec	Total
Algae	(58.2)	(50.0)	(46.7)	(72.2)	(20.6)	(28.0)	(49.8)
Vascular .acrophytes		(0.3)	(0.6)	(8.8)			(0.4)
Bryozoa	(0.4)	(0.1)					(1.6)
Crustacea							
Cladocera[1]	0.5		8.4	20.0	28.9	77.5	23.6
	(0.4)		(T)*	(0.1)	(0.3)	(0.8)	(T)
Copepods	66.0	49.3	11.1	64.0	60.0	12.1	44.2
	(0.3)	(T)	(T)	(0.4)	(1.4)	(0.2)	(0.1)
Ostracoda	17.3	31.2	58.3		2.2	3.2	17.2
	(0.1)	(T)	(0.1)		(0.1)	(0.1)	(T)
Insects							
Diptera							
Chironomidae larvae[2]	6.3	5.1	16.6	12.0		1.6	5.6
	(1.4)	(0.2)	(1.3)	(5.3)		(1.3)	(0.7)
Pupae	1.1	4.2			2.2		1.6
	(1.1)	(0.3)			(2.7)		(0.5)
Mollusca							
Physa app.	0.5		2.8		6.7	4.8	2.2
	(0.4)		(1.2)		(54.5)	(22.4)	(1.6)
Other invertebrats[3]	5.5	6.1		4.0			3.4
	(2.4)	(1.3)		(8.8)			(1.5)
Fish[4]	2.8	4.1	2.8			0.8	2.2
	(35.3)	(47.8)	(49.5)	(4.4)	(13.6)	(47.2)	(43.6)
Gravel			(0.6)		(6.8)		(0.2)
Mean no. per stomach**	5.2	2.1	3.3	3.6	15.0	15.5	4.6
Mean vol. (.1) per stomach**	0.0415	0.0874	0.0736	0.0157	0.0233	0.0275	0.0611
No. of stomachs examined	50	48	14	10	6	18	146
No. with food	33	46	11	7	3	8	108

* Less than 0.05Z

** Among stomachs containing food

1 Includes Chydorinas and Ceriodaphnla spp.

2 Includes Tanypodinae, Orthocladinae, and Chironominae

3 Includes Hyalella azteca, Hydrecarina, Ephemeroptera, Trichoptera, Hemiptera, and Coleoptera

4 Includes Johnny darter, Centrarchidae, and unidentified remains

0.06 ml. The range of items fed **upon generally agreed with the findings of Ewers and Boesel (1935), Forney** (1955), and Repsys (1972).

Food Selectivity of Black Bullheads

Bullheads>120 mm

Electivity indices for **zooplankton** by black bullheads >120 mm **indicated negative selection** for all but Daphnia pulex and ostracods **(Table** 21). In May, a single bullhead consumed only D. **pulex which contributed** to an **inflated mean** percent **abundance** and, in turn, a positive electivity index. In June, D. pulex was negatively selected even though it comprised 67.9% of the zooplankton sampled. Repsys (1972) found adult black bullheads in Lake Poinsett, South Dakota, to **positively** select D. pulex. Ostracods were generally positively selected, possibly a result of increased abundance of ostracods among the benthos during daylight, when most bullheads were collected. The negative mean electivity indices for Chydorinae (-0.3), Ceriodaphnia spp. (-0.5), and cyclopoid copepods (-0.6) reflect the minimal importance of **these zooplankters** in the diet. **Repsys** (1972) also found copepods to be negatively selected.

Electivity indices for benthic organisms fed upon by bullheads >120 mm ranged from -0.9 for Tanypodinae larvae to near +1.0 for dipteran **pupae** and **Physa** spp. **(Table** 22). Except **during** April and June, bullheads **completely avoided Tanypodinae larvae**. Chironominae **larvae**, with a **mean electivity** index of -0.1, occurred in stomachs in about the same proportions as in the environment, although electivity indices ranged from -1.0 to +0.4 on a monthly basis. Bullheads were

Table 21. Electivity indices for zooplankton by black bullheads (*Ictalurus melas*) > 120 mm TL, percent abundance in stomach samples, in parentheses, and percent abundance in zooplankton samples, Big Stone Power Plant cooling reservoir, South Dakota, 1979.

Month	Chydorinae	*Ceriodaphnia* spp.	*Daphnia pulex*	Cyclopoida	Ostracoda
January	-1.0 (--) 40.2			-1.0 (--) 55.8	
February	-1.0 (--) 37.8			-1.0 (--) 60.7	
April	-0.2 (11.5) 19.0			-0.1 (53.9) 70.9	+0.8 (34.6) 4.0
May	-1.0 (--) 43.9		+0.9 (100.0) 3.1	-1.0 (--) 47.2	-1.0 (--) 3.2
June	-1.0 (--) 0.1		-0.4 (26.7) 67.9	-1.0 (--) 19.3	+0.9 (73.3) 2.5
July	-1.0 (--) 2.7	-1.0 (--) 1.8	-1.0 (--) 0.4	-1.0 (--) 77.6	-1.0 (--) 3.9
August	-1.0 (--) 2.3	-1.0 (--) 22.5		-1.0 (--) 63.9	-1.0 (--) 0.8
September	-1.0 (--) 2.1	-0.1 (50.0) 58.6		+0.3 (50.0) 26.8	
October	+0.8 (70.3) 8.2	-0.9 (5.4) 68.8		0 (18.9) 19.5	
Mean	-0.3 (9.1) 17.4	-0.5 (13.9) 37.9	+0.3 (42.2) 23.8	-0.6 (13.6) 49.1	+0.8 (21.6) 2.9

Table 22. Electivity indices for benthos by black bullheads (*Ictalurus melas*) > 120 mm TL, percent abundance in stomachs, in parentheses, and percent abundance in benthos samples, Big Stone Power Plant cooling reservoir, South Dakota, 1979.

Month	Tanypodinae larvae	Chironomi-larvae	Dipteran pupae	Physa spp.
April	-0.3 (13.9) 27.5	-0.3 (33.3) 63.4	+0.9 (52.8) 2.2	
May	-1.0 (--) 64.2	-1.0 (--) 30.9	-1.0 (--) 2.5	
June	-0.9 (0.6) 10.1	+0.1 (96.6) 83.3	+0.5 (2.8) 0.9	-1.0 (--) 0.9
July	-1.0 (--) 65.0	-1.0 (--) 17.5	+1.0 (100.0) 0.4	-1.0 (--) 0.7
August	-1.0 (--) 71.4	+0.4 (25.0) 10.7		
September	-1.0 (--) 4.3	-0.2 (66.7) 90.7		
October	-1.0 (--) 6.4	+0.1 (100.0) 88.4		
Mean	-0.9 (2.1) 35.6	-0.1 (45.9) 55.0	+1.0 (38.9) 0.9	-1.0 (--) 0.8

selective for chironomid pupae except in May when they were not found in the stomachs examined. Repsys (1972) found similar electivity indices of black bullhead adults for Chironominae larvae and chironomid pupae. Physa spp. did not occur in bullhead stomachs in June or July.

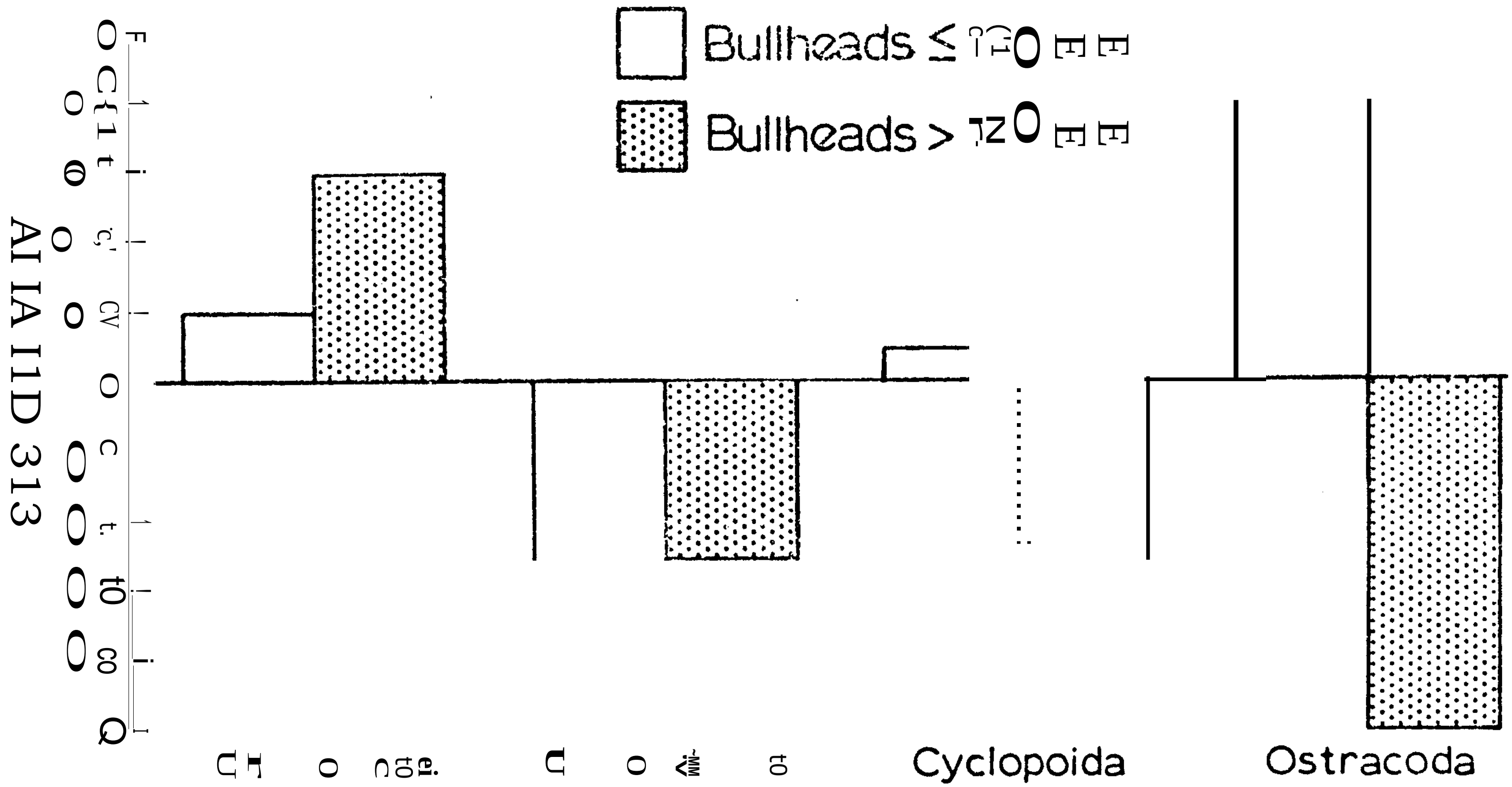
Bullheads 5120 mm

Black bullheads 5120 mm positively selected Chydorinae and ostracods, with mean electivity indices of +0.7 and +0.9, respectively, while they negatively selected Ceriodaphnia spp. (-0.9) and did not select for or against cyclopoid copepods (0) (Table 23). Some Chydorinae, especially Alona spp. which was a commonly occurring taxon, are littoral species (Edmonson 1966). These zooplankters were usually found in stomachs with large quantities of filamentous algae, which may indicate ingestion incidental to foraging. Cyclopoid copepods were consumed in proportions equal to those in the environment in July and August, with no clear trend in selection the remainder of the year. Repsys (1972) found young-of-the-year black bullheads in Lake Poinsett to negatively select Cyclops vernalis in August and September, which is similar to the findings in the present study.

Zooplankton electivity indices of bullheads IS120 mm and those >120 mm were generally similar for the period July through October (Fig. 7). Larger bullheads, however, exhibited negative selection for cyclopoid copepods (-0.5) and ostracods (-1.0), as compared to positive selection for these items by bullheads X120 mmm (+0.1 and +0.8, respectively). Bullheads both -Sand > 120 mm positively selected

Table 23. Electivity indices for zooplankton by black bullheads (*Ictalurus melas*) $\frac{1}{5}$ 120 mm TL, percent abundance in stomachs, in parentheses, and percent abundance in zooplankton samples, Big Stone Power Plant cooling reservoir, South Dakota, 1979.

Month	Chydorinae	*Ceriodaphnia* spp.	Cyclopoida	Ostracoda
July	-0.6 (0.7) 2.7	-1.0 (--) 1.8	0 (78.5) 77.7	+0.7 (20.8) 3.9
August	-1.0 (--) 1.8	-1.0 (--) 18.9	0 (61.0) 66.2	+0.9 (39.0) 1.4
September	+0.6 (7.1) 1.7	-0.9 (3.6) 61.2	-0.3 (14.3) 29.0	
October	+0.3 (19.1) 10.8	-0.9 (4.8) 61.3	+0.5 (66.7) 24.4	
November	+0.8 (31.7) 3.0	-1.0 (--) 60.4	+0.3 (65.9) 36.2	
December	+0.9 (83.5) 2.5	-1.0 (--) 23.4	-0.7 (13.0) 71.7	
Mean	+0.7 (23.7) 3.8	-0.9 (1.4) 37.8	0 (49.9) 50.9	+0.8 (29.9) 2.7



Ictalurus melas) ≤ 120 mm and
ng reservoir, South Dakota.

Chydorinae (+0.2 and +0.6, respectively), and negatively selected *Ceriodaphnia* spp. (-0.9 and -0.5).

Among the benthos, black bullheads X120 mm negatively selected Tanypodinae and Chironominae larvae, and positively selected *Caenis* spp. larvae, dipteran pupae, and *Physa* spp. (Table 24). Chironominae larvae were positively selected in July and August, and negatively selected October through December. Mean electivity indices for dipteran pupae and *Physa* spp. were +0.9 and +0.8, respectively. *Caenis* spp. larvae were negatively selected except in August, when they were **positively** selected.

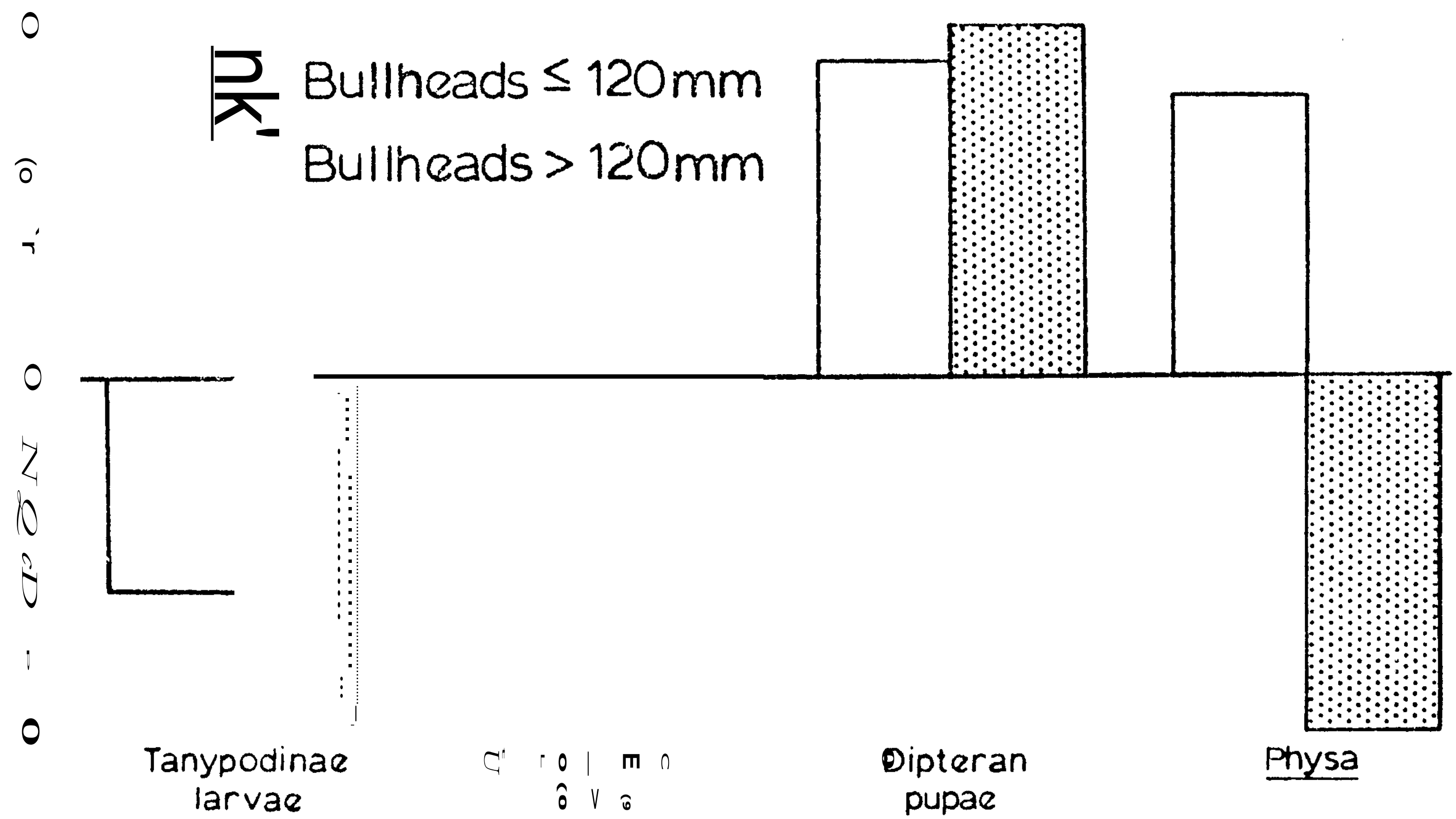
Both size-groups of bullheads exhibited a greater degree of similarity of selectivity for benthic organisms than for zooplankton (Fig. 8). Increased vulnerability of chironomid pupae may have accounted for electivity indices near +1.0. Chironominae larvae were neutrally selected by both size-groups, and Tanypodinae larvae were negatively selected. Bullheads X120 mm positively selected *Phvsa* spp., while larger bullheads completely avoided them.

Food Habits of Muskellunge

A total of 107 muskellunge, ranging from 60 to 386 mm TL, was collected from the screen wash collection basket between August 1978 and January 1980. Of the 47 (43.9%) containing food, 89.1% of the total food number and 99.8% of the volume was comprised of fishes (Table 25). Johnny darters *(Etheostoma nigrum)* contributed 23.87. of the volume, fathead minnows *(Pimephales promelas)* 24.1%, bluegills 35.1%, orangespotted sunfish *(Lepomis humilis)* 7.6%, unidentified

Table 24. Electivity indices for benthos by black bullheads (*Ictalurus melas*) < 120 mm TL, percent abundance in stomachs, in parentheses, and percent abundance in benthos samples, Big Stone Power Plant cooling reservoir, South Dakota, 1979.

Month	*Caenis* spp.	Tanypodinae larvae	Chironominae larvae	Dipteran pupae	*Physa* spp.
July	-0.1 (6.3) 7.5	-0.7 (12.5) 65.0	+0.5 (56.3) 17.5	+1.0 (18.8) 0.4	+0.8 (6.3) 0.7
August	+0.9 (23.1) 1.4	-0.8 (7.7) 59.9	+0.4 (38.5) 15.0		
September	-1.0 (--) 0.4	+0.4 (14.3) 6.8	0 (71.4) 76.7	-1.0 (--) 0.3	
October	-1.0 (--) 0.1	-1.0 (--) 5.1	-0.1 (75.0) 90.6		
November		-1.0 (--) 15.3	-1.0 (--) 81.3		
December		-0.6 (12.5) 43.1	-0.6 (12.5) 49.5		
Mean	+0.5 (7.4) 2.4	-0.6 (7.8) 32.5	-0.1 (42.3) 55.1	+0.9 (9.4) 0.4	+0.8 (6.3) 0.7



lheads (*Ictalurus melas*) ≤ 120 mm and > 120 mm
oling reservoir, South Dakota.

Table 25. **Percent** number and, in **parentheses**, percent **volume** of stomach contents of 107 muskellunge (*Esox masquinongy*) (60 to 386 mm TL, range) **collected** from the **impingement collection** basket, **August** 1978 to January 1980, Big Stone Power Plant cooling reservoir, South Dakota.

Food Items	Percent number (Percent volume)
Ephemeroptera	
Baetidae	10.9 (0.2)
Fish	
Johnny darter	30.9 (23.8)
Fathead minnow	5.5 (24.1)
Orangespotted sunfish	9.1 (7.6)
Bluegill	14.5 (35.1)
Unidentified Lepomis spp.	9.1 (1.5)
Unidentifed remains	20.0 (7.7)
Mean no. per stomach*	1.2
Mean vol. (ml) per stomach*	**0.6181**
No. of stomachs examined	107
No. with food	47

* Among stomachs containing food

Lepomis spp. 1.5%, and unidentified fish remains 7.7%. One muskellunge 73 mm long ingested 6 Baetid mayflies.

Muskellunge fry feed on zooplankton for OD to 30 days, after which they feed on forage fishes (Hourston 1952; Oehmcke et al. 1958; Parsons 1959). Adult muskellunge are general carnivores, with soft-rayed forage fishes preferred (0ehmcke et al. 1958). Hourston (1952) found that yellow perch (Perca flavescens) and other fusiform shaped fishes dominated the diets of muskellunge in Canada, but this may have been a function of **availability** rather than preference. Bus (1960) stated that adult muskellunge are not selective for forage, but prey on whatever fishes are available.

Muskellunge preferred certain-sized prey fishes (Table 26). There were positive correlations between jaw width (closed) of muskellunge and prey size (total length and body depth); and body depth of muskellunge and prey size. There was no correlation between total length of muskellunge and prey size.

Johnson (1969) found that northern pike (Esox lucius) in Murphy Flowage, Wisconsin, **selected food** fishes that were **generally** one-half narrower than the width of the jaw. He found width, not length, of prey to be an important factor in determining its presence in stomachs. Lawrence (1957) reported that largemouth bass (Micropterus salmoides) utilized large numbers of forage fishes with maximum body depth equal to or slightly greater than the mouth width of bass, but when given a choice, bass preferred fishes that were smaller than the maximum jaw width.

Table 26. Linear correlation coefficients for the relationships between 3 muskellunge (*Esox masquinongy*) body measurements and 3 prey fish body measurements, Big Stone Power Plant cooling reservoir, South Dakota, 1978-1980.

Muskellunge Body Measurement vs. Prey Body Measurement	Correlation Coefficient	Degrees of Freedom	Calculated t-value
Jaw width vs. body depth (closed)	0.6655	17	3.68*
Jaw width vs. total length (closed)	0.8315	17	6.17*
Body depth vs. body depth	0.5897	17	3.01*
Body depth vs. total length	0.4246	17	1.93*
Total length vs. body depth	-0.1898	17	0.80
Total length vs. total length	0.2741	17	1.18

* Significant at the 0.05 level of probability

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APPENDIX

Appendix Table 1. Surface and, in parentheses, bottom temperatures (° C), January through December, 1979, Big Stone Power Plant cooling reservoir, South Dakota.

Sampling Date	Area 1	Area 2	Area 3
January 25	2.5 (3.0)		21.0 (21.0)
February 13	3.0 (3.5)		17.0 (6.0)
April 24	17.8 (17.0)	23.3 (18.8)	27.5 (22.3)
May 8	16.0 (16.0)	16.5 (17.3)	23.5 (18.5)
May 23	22.0 (21.5)	21.5 (21.5)	34.0 (21.5)
June 12	26.0 (25.8)	31.0 (26.8)	32.0 (30.9)
June 26	28.0 (27.0)	29.2 (27.5)	35.0 (29.0)
July 11	30.5 (30.5)	31.2 (30.8)	37.0 (34.0)
July 27	32.0 (29.0)	34.0 (27.0)	42.0 (29.0)
August 7	31.7 (31.5)	33.2 (29.6)	39.8 (29.0)
August 23	28.6 (25.9)	31.7 (25.9)	38.5 (27.0)
September 6	26.8 (26.3)	28.8 (27.0)	29.6 (27.4)
September 20	18.9 (18.7)	18.8 (18.2)	18.0 (17.8)
October 4	17.5 (17.5)	18.0 (18.0)	27.8 (19.0)

Appendix Table 1 (cont).

Sampling Date	Area 1	Area 2	Area 3
October 18	19.2 (19.0)	18.9 (17.5)	27.1 (20.0)
November 6	13.8 (13.8)	15.9 (15.9)	25.0 (24.2)
November 27	12.0 (12.0)	11.0 (11.0)	24.5 (24.2)
December 4	9.3 (9.3)	10.3 (10.2)	17.5 (15.2)
December 18	3.0 (3.0)	4.3 (3.2)	20.5 (6.7)