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Food Selectivity of the Black Bullhead (Ictalurus melas, Rafinesque) in Lake Poinsett, South Dakota

Andrew J. Repsys

FOOD SELECTIVITY OF THE BLACK BULLHEAD (*Ictalurus melas*, Rafinesque) IN LAKE POINSETT, SOUTH DAKOTA

By

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IN LAKE POINSETT, SOUTH DAKOTA

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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FOOD SELECTIVITY OF THE BLACK BULLHEAD (Ictalurus melas) IN LAKE POINSETT, SOUTH DAKOTA

Abstract

Andrew J. Repsys

The food habits of young-of-the-year, subadult and adult black bullheads were studied in Lake Poinsett, South Dakota, from March, 1970, to April, 1971. Two hundred twenty young-of-the-year (37-87 mm total length) fed primarily on limnetic cladocerans and copepods. Leptodora and Diaphanosoma comprised 86.5% of the total food volume. Chironomid larvae and pupae made up 5.6% of the total. Other benthic organisms and littoral cladocerans together contributed less than 1%.

Stomach contents of 608 subadult and adult bullheads (143-304 mm total length) indicated significant seasonal variation in diet. Daphnia pulex and chironomid larvae were important food items in winter. Bullheads fed primarily on chironomid pupae, Daphnia pulex, and crayfish, in the spring. Fish and Leptodora were the principal organisms consumed in summer and fall.

Food selectivity of young-of-the-year and adult bullheads for seven major species of zooplankton and adults for five categories of benthos was determined using the index described by Ivlev (1961). Adults and young-of-the-year positively selected limnetic cladocerans. Selection was greatest for Leptodora and Daphnia pulex. Copepods were least selected by bullheads of all age groups. All chironomid larvae were negatively selected by adult bullheads while chironomid

pupae (99% *Chironomus* spp.) were strongly selected (+0.75). Selectivity index for all food organisms appeared to be dependent on their abundance, size, degree of exposure, and ability to avoid ingestion either by outmaneuvering their predators or by retreating into the bottom sediments.

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INTRODUCTION

Food and feeding relationships of fishes commonly dominate their ecological association and an understanding of the food habits relationship is necessary for the proper handling of our fisheries resource (Bailey and Harrison 1945). Starostka (1969) studied the largely planktivorous bigmouth buffalo (*Ictiobus cyprinellus*) in Lake Poinsett with special reference to its selectivity for the major categories of zooplankton. The black bullhead (*Ictalurus melas*) is generally considered a more versatile feeder, reputedly consuming algae and other plant matter as readily as it does a wide variety of animal food. Objectives of this study were to determine the food habits and degree of selectivity of black bullheads for the food resources of Lake Poinsett, South Dakota.

STUDY AREA

Lake Poinsett is a shallow, hard-water eutrophic lake formed some 10,000-15,000 years ago by glacial action. It is the largest natural lake in South Dakota with a maximum length of 8.89 km (5.5 miles), a maximum width of 4.83 km. (3.0 miles), and encompassing 3157 hectares. Drainage is provided from a natural watershed entering the lake from the west connecting Lake Poinsett to Lake Albert and six smaller lakes. A diversion ditch constructed in 1929 diverts water from the Big Sioux River to Lake Poinsett via Dry Lake immediately north of Lake Poinsett. The only outlet is located in the northeast section of the lake and is connected to the Big Sioux River. During severe flooding, waters from the river back up into this outlet channel and enter the lake. Lake Poinsett has a maximum depth of 6.0 meters (19.7 ft.) with an average depth of 2.4 meters (8 ft.). The lake is roughly ovoid with a uniform shoreline. Shore development is 1.6.

Lake Poinsett is exposed to brisk winds which maintain the water in a mixed state from top to bottom and prevent the formation of a lasting thermocline or stratification of any sort. Higher aquatic vegetation is absent except in the outlet. The filamentous green alga Cladophora dominates the shallows and a dense bloom of Aphanizomenon develops throughout the lake in the summer months.

ml) and three 1 ml subsamples counted in a circular counting chamber at 30X. Stomach contents were counted in their entirety. Cladocerans and copepods were identified to species using keys in Fresh Water Biology (Edmondson, 1959). The volume of each organism was determined by water displacement (Lagler, 1952).

Environmental data for benthic organisms was obtained from a study by Smith (1971). He determined mean abundance in numbers of organisms per square meter per sampling date in sand, sand-sapropel, and sapropel substrata for five categories of benthic organisms. These were *Chironomus* spp. larvae, other Chironomin larvae, Tanypodinae (*Procladius*) larvae, Chironomidae pupae and Caenidae nymphs (mayflies). [The above information is found in Tables 4, 5, and 6 on pages 28, 31, and 33 of Smith (1971).] The types of substrate underlying the area where bullheads were captured and types of benthic organisms present in stomach samples (whether characteristic of sand or sapropel) determined the table used to obtain percent-occurrence-in-the-environment figures.

On several occasions when fish were captured above all three substrate types during one sampling period, averages of Tables 4, 5, and 6 were employed. During the course of the study certain chironomid genera occurred in stomach contents that were not present in Ekman dredge samples (Smith, 1971). These were excluded from selectivity calculations, but as they collectively made up only 7.4% of the total number of chironomid larvae ingested by adult bullheads (Figure 4) and a correspondingly small percentage of the total volume consumed, the loss was not considered excessive. The volumes of benthos were also determined by water displacement.

Food selectivity of young-of-the-year, subadult, and adult black bullheads for seven species of zooplankton and five categories of benthos for subadult and adult fish was determined by means of an electivity index (Ivlev, 1961). Indices were calculated with the formula:

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

where E = electivity (selectivity)

r = percent occurrence of a food item in the stomach

p = percent occurrence of the item in the environment

Electivity values range from -1 to +1. The former indicates complete avoidance, while the latter value indicates exclusive selection for a given food item. An index of zero is an indication of no selection for the food item in question.

Selectivity indices have not been determined for many of the food items due to a lack of environmental data.

Table 1. Displacement volumes of major food organisms of young-of-the-year, subadult, and adult black bullheads, March 1970 to April 1971. Lake Poinsett, South Dakota.

Organism	Volume in microliters
Cladocera	
Daphnia pulex (May adults with eggs & subadults)	1.05
Daphnia pulex (July adults & subadults)	0.30
Daphnia galeata mendotae	0.19
Leptodora kindtii (adults)	7.50
Leptodora kindtii (juveniles)	0.94
Diaphanosoma leuchtenbergianum	0.14
Kurzia latissima	0.01
Copepoda	
Diaptomus clavipes	0.50
Diaptomus siciloides	0.10
Cyclops vernalis (copepodites 80% & adults 20%)	.04
Insecta	
Chironomidae	
Chironomus plumosus (last instar larvae)	18.18
Chironomus plumosus pupae	20.00
Procladius sp. larvae	3.00
Other Chironomidae larvae (May)	1.77
Other Chironomidae larvae (August)	1.33
Ephemeroptera	
Caenis sp. nymphs	2.60

RESULTS AND DISCUSSION

Food Habits of Subadult and Adult Black Bullheads

During Ice Cover

The first sample in this study was collected through the ice on 15 March, 1970, and consisted of ten adult fish ranging from 210-275 mm. in total length. Of these only three contained food in the form of 1128 over-wintering adult *Daphnia pulex.* No other food organisms were present.

The next samples during ice cover were taken in the period from 22 January - 26 February, 1971. The 13 adult bullheads captured contained no recognizable food organisms other than four calanoid copepods and only very small amounts of organic debris. It must be noted that during the above period *Daphnia pulex* were absent from the plankton. *D. pulex* did not reappear until November, 1971 and then only in trace numbers. The crustacean plankton in the winter of 1970-71 consisted almost entirely of calanoid and cyclopoid copepods which were negatively selected by adult black bullheads during open water periods (Figure 1).

Sampling on 26 March, 1971, produced 30 adult fish (225-280 mm total length) of which 28 had empty stomachs. The remaining 2 contained 539 late-instar chironomid larvae of the genus *Chironomus*, tentatively identified as *C. plumosus.*

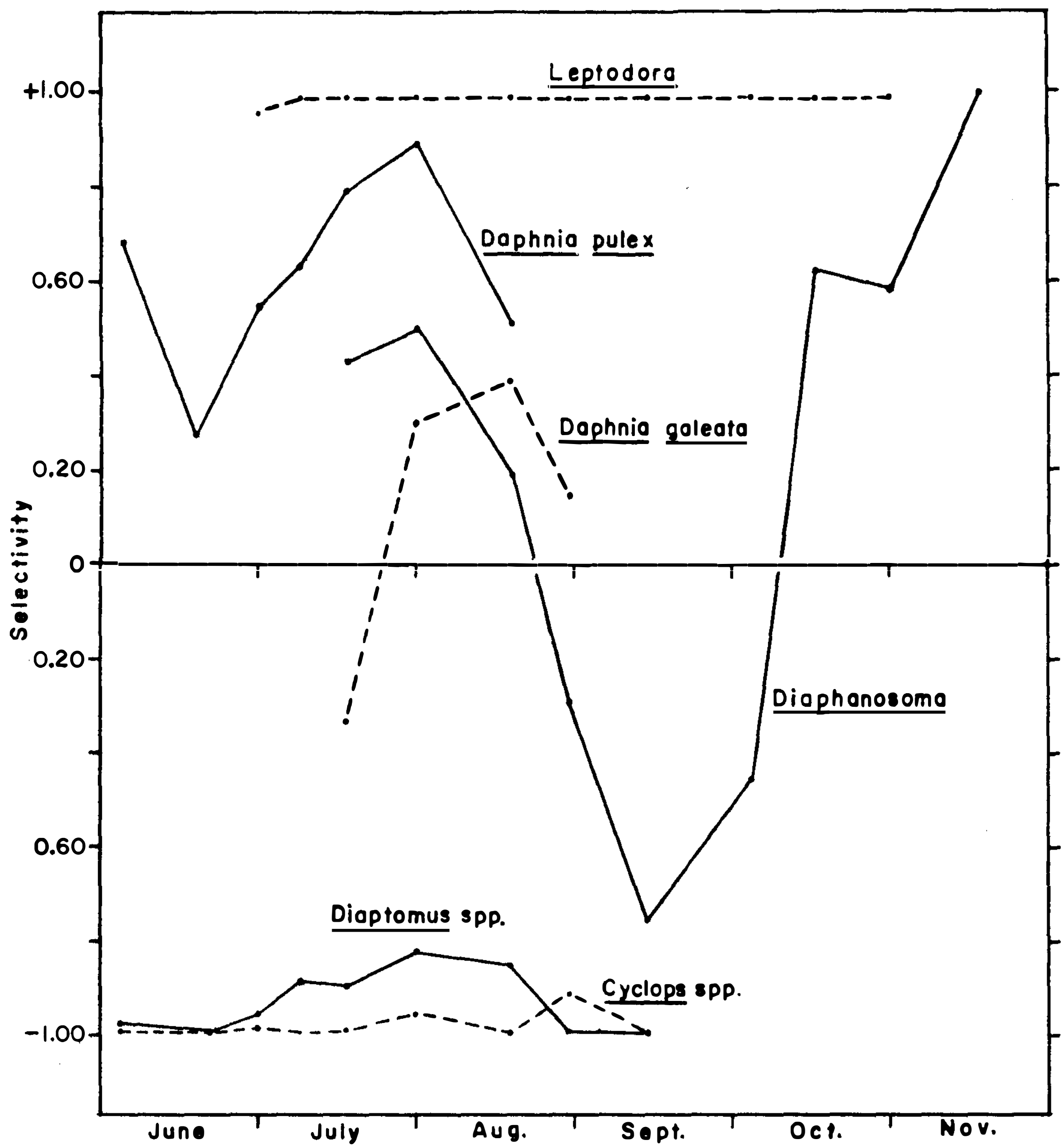

Figure 1. Food selectivity indices for zooplankton by subadult and adult black bullheads, June to November, 1970, Lake Poinsett, South Dakota.

While the sample available during the ice cover periods was considered too small (53 fish) to draw definite conclusions, the above results suggest that feeding activity may be at a minimum during ice cover. Adult bullheads selected D. pulex and avoided copepods. Chironomid larvae were also utilized to some extent in late winter.

During Open Water

Samples collected on 1 May, 1970, in 2 m of water over sand substrate indicated high utilization of adult and subadult Daphnia pulex (94.6% by volume). Chironomid larvae and the filamentous green alga, Cladophora glomerata, formed minor components of the total diet (2.1 and 2.2 percent respectively). Cryptochironomus sp. and Procladius sp. made up 47% and 44% of the number of chironomid larvae consumed and Chironomus spp., which were not abundant in sand substrates (Smith, 1971), constituted 5.2%. Other aquatic organisms taken in small numbers at the time included representatives from Ephemeroptera, Trichoptera, Amphipoda, Acari, Corixidae, Copepoda, and Hirudinae.

Rising water temperatures and an abundance of food supplied by the spring phytoplankton pulse in late April and early May resulted in an increased growth rate of chironomid larvae and facilitated their subsequent metamorphosis. Chironomid pupae probably first appeared in the bottom sediments during the first week of May. They were present in benthos samples on 15 May in appreciable numbers.

The highest numbers of pupae recorded for the entire year occurred in late May and early June in concentrations of over 200 organisms per square meter (Smith 1971). Bullheads captured on the morning of 4 June, had fed primarily on chironomid pupae (79% by volume) of which 99% were Chironomus spp. of the winter generation. About 10% of the pupae were parasitized by mermithid nematodes which made them easier prey. Chironomid pupae (almost all Chironomus spp.) constituted the bulk of the June diet with 63.4 % of the monthly food volume. Consumption of Daphnia pulex decreased considerably in June, making up only 2.2% of the total while a small number of large crayfish contributed a substantial 25% and one black crappie made up 6.6%. Food items of lesser importance in June were chironomid larvae and representatives from Ephemeroptera, Trichoptera, terrestial insects (70% Coleoptera), Leptodora, fish eggs, and Cladophora.

During July no single food item was clearly dominant in the diet as was the case in May and June. Chironomid pupae (99% Chironomus spp.) comprised 38. 1% of the monthly volume. Procladius sp. pupae were absent from the stomach contents although the number of Procladius larvae ingested at this time was more than twice that of Chironomus spp. larvae consumed. Moreover, many of the former larvae were in prepupa stages with some pupal characteristics readily discernible, as were many of the Chironomus spp. larvae. Thus, it must be assumed that fully-formed Procladius pupae must have been present in or above the sediments in appreciable numbers. It is not clear, then, why they were not ingested. Possibly they are very active and are able to avoid ingestion by adult bullheads. During the course of the year only one Procladius pupa was found in a stomach. Another was captured in a plankton tow with a Miller sampler. All chironomid larvae formed 12.8% of the stomach content volume for the month of July. Utilization of Leptodora increased to 21.6% and one crayfish contributed 17% of the total. Ingestion of Cladophora rose to 9.6% - more than a four-fold increase over the previous months. Organisms of minor importance volumetrically in July included Daphnia pulex, Copepoda, Ephemeroptera, Gammarus lacustris, Daphnia galeata, Hirudinea, Diaphanosoma and Acari.

Small fish, yellow perch and crappies (53-70 mm total length), were the principal food of adult bullheads in August, making up 48.5% of the volume ingested. Leptodora were next in importance with 25.4% and one large tiger salamander (Ambystoma tigrinum) contributed a disproportionate 21% to the monthly total. Consumption of Cladophora declined sharply to 1.0% as did ingestion of chironomid larvae and pupae to 3.2% and 1.2% respectively. Diaphanosoma, Daphnia pulex, Daphnia galeata, and copepods were again insignificant components of the diet, collectively representing less than 1% of the total food volume for August.

Crappie and yellow perch (65-145 mm), and Leptodora remained the major food items in September. Fish accounted for 51% by volume and ingestion of Leptodora increased to 48%. Utilization of chironomid larvae and pupae declined further to 0.6%. Diaphanosoma contributed 0.4%. The large proportion of empty stomachs during the autumn period prompted the examination of the lower digestive tracts of all adult fish to support or refute trends evident from stomach samples alone. Lower tract contents for September indicated very heavy utilization of Leptodora. Remains of 1540 subadult and adult Leptodora per fish were counted. This represented nearly 8 times the volume found in the stomachs. At the time of fish sampling the concentration of Leptodora in the plankton was 113 per cubic meter. In addition the lower tracts contained 3941 Leptodora winter eggs per fish. These eggs were completely intact and did not appear to be affected by the digestive process. It may be that they pass through the entire digestive tract in viable condition. Four Chironomus spp. pupae per fish were also noted.

Leptodora was the principal food of bullheads in October, representing nearly 60% of the total fare. One large spottail shiner (Notropis hudsonius) contributed 39.5%. Numbers of Diaphanosoma consumed rose to a yearly maximum, but the volume this represented was negligible. Chironomid larvae were also a minor item. Lower tracts from fish sampled on 4 October, and 16 October, contained, in addition to 62,000 Leptodora winter eggs, adult Leptodora with average concentrations of 1062 and 67 per fish, respectively. The decrease in Leptodora uptake for the above period, indicated by both stomach and lower tract contents, was correlated with a decrease in Leptodora numbers from $122/m^3$ to $39/m^3$ in the plankton during the first half of October. The lower tracts of fish collected in early October also contained 10 ml of Cladophora, a greater volume than was present in stomachs of all previous sampling dates combined. It may be that Cladophora is more important in the local food habits than stomach samples have indicated in this study. Mixed with the Cladophora were some 1177 filaments (fragments) of the colonial bryozoan, Fredericella sultana. There is some evidence that the relatively large uptake of Cladophora and Bryozoa during this time by adult bullheads was perhaps due to the scarcity of more desirable foods (e.g. chironomids, Daphnia pulex, Leptodora, etc.) but this contention remains to be proved.

Of 22 fish taken on 30 October, and 17 November, only 4 contained food. It consisted of 4 Leptodora and 170 Diaphanosoma. A sharp drop in water temperature from 11C to 4C in late October probably contributed to the decline in feeding activity. Lower tracts were for the most part empty. Interestingly, the lower tract of one adult bullhead on 17 November, contained 6810 Diaphanosoma even though no Diaphanosoma was evident in the plankton.

The last open water sample was obtained on 23 April, 1971. Seven adult bullheads captured were found to be highly selective for Daphnia galeata, avoiding the copepods which clearly dominated the plankton in April. Daphnia pulex was absent from Miller tow samples taken at this time.

A summary of the analysis of the stomach contents of 595 subadult and adult bullheads taken during the period discussed above is presented in Table 2.

Food habit studies of subadult and adult black bullheads by Ewers and Boesel (1935), Forney (1955), Kutkuhn (1955), and Welker (1962) indicate a transition from planktonic crustacea to chironomid larvae as the bullheads approach maturity with an eventual reliance on fish by adults. During the course of the year, Lake Poinsett adult bullheads consume 32% planktonic crustaceans, 27% chironomid larvae and pupae, and 27% fish by volume. Heaviest predation on chironomids took place in connection with emergence of the insects. Filamentous algae were found to be of lesser importance (1.7% by volume) than studies by Applegate and Mullan (1967) and Kutkuhn (1955) have indicated.

Food Selectivity of Subadult and Adult Black Bullheads For Zooplankton

Food selectivity by subadult and adult black bullheads for six genera of zooplankton is shown in Figure 1. Leptodora kindtii was clearly the most highly selected zooplankter during the study period. The large size (12 mm) and clumsy rowing motions of this predaceous cladoceran make it a prime food item for many species of fish wherever it occurs. Leptodora first appeared in the plankton in the latter half of June, 1970. At the end of the month when it comprised only 0.1% of the plankton, it was already being highly selected (+0.96). This trend continued throughout the summer months

Table 2. Stomach contents of 595 subadult and adult black bullheads (143-304 mm total length) from Lake Poinsett, South Dakota, March 1970 to April 1971. Expressed as monthly numbers and volumes* in milliliters.

	1970 March	May	June	July	August	Sept.	Oct.	Nov.	1971 March	April	Totals	Percent Total Volume
Daphnia pulex	1128 (1.19)	40841 (42.9)	4199 (3.38)	1117 (0.32)	25 (0.007)						47310 (47.80)	8.62
Copepods		324 (0.023)	38 (0.004)	88 (0.012)	134 (0.009)					4 (T)	584 (0.048)	T[1]
Chironomid larvae		538 (0.955)	239 (1.87)	2119 (8.32)	341 (3.35)	2 (0.04)	6 (0.12)		539 (9.80)		3784 (24.46)	4.41
Chironomid pupae			6390 (95.94	1242 (24.72)	64 (1.24)	43 (0.86)					7739 (122.76)	22.16
Mayfly (*Caenis* sp.) nymphs		84 (0.216)	18 (0.046)	15 (0.039)							(0.117) (0.30)	T
Crayfish (*Orconectes* sp.)			4 (38.0)	1 (11.0)							5 (49.0)	8.84
**Fish			1 (10.0)		6 (51.0)	3 (79.0)	1 (8.0)				11 (148.0)	26.71
Leptodora kindtii			72 (0.54)	1863 (13.98)	3563 (26.65)	9871 (74.0)	1605 (12.03)				16974 (127.2)	22.96
Diaphanosoma leuchtenbergianum				183 (0.026)	799 (0.111)	483 (0.092)	1186 (0.166)	167 (0.024)			2818 (0.42)	T
Daphnia galeata mendotae				7 (0.001)	272 (0.052)					109 (0.020)	279 (0.053)	T
Filamentous algae (*Cladophora* sp.)		(1.0)	(1.0)	(6.2)	(1.0)						(9.2)	1.66
***Miscellaneous		24 (0.401)	308 (2.01)	14 (0.278)	1 (22.0)						347 (24.69)	4.45
Number of bullheads examined	10	61	116	118	113	51	76	13	30	7	595	
Number of bullheads with food	3	43	76	86	72	19	32	3	2	6	342	
Average food volume (ml) per stomach[2]	0.12	0.75	1.32	0.55	1.46	3.02	0.27	0.002	0.33	0.003	0.78	
Average food No. per stomach[2]	112.8	685.4	97.15	56.3	46.1	204.0	36.8	12.8	18.0	15.6	128	

* In parentheses.
** White crappies, black crappies, yellow perch, spottail shiner.
*** *Hyalella azteca*, *Gammarus lacustris*, Acari, Corixidae, Trichoptera, terrestial insects, Hirudinea, tiger salamander (*Ambystoma tigrinum*)
1 Trace (T) = less than 0.1 percent.
2 Includes empty stomachs.

to the end of October when Leptodora numbers had diminished to $8/m^3$. The most intense predation in terms of numbers of organisms per stomach was noted in September (Table 3).

Diaphanosoma leuchtenbergianum was positively selected when it initially appeared in countable numbers in July and during most of August. In September and early October it occurred as 32.2% and 38.1% of the plankton, but was strongly selected against. Percent occurrence declined during the remainder of the autumn but selection increased to high positive values during the last half of October and November (Figure 1). Rejection of Diaphanosoma (29 August-4 October) appeared to be related to the increased utilization of Leptodora during this period. When Leptodora numbers declined in late October adult bullheads again positively selected Diaphanosoma.

Subadult and adult Daphnia pulex formed almost the entire diet of adult bullheads on 15 March and 1 May (Table 3). No environmental plankton samples were obtained for those dates so that selectivity indices could not be determined, but past samples have shown plankton composition to consist of at least 50% copepods during the dates in question. It can, therefore, be reasonably inferred that Daphnia pulex was selected at these times. Daphnia pulex had a mean index of +0.62 for the remainder of the year. It was positively selected even when it occurred as 0.8% of the plankton on 18 August. At the end of the month the population had collapsed to a trace and was undetectable thereafter for the next 14 months. Selective predation by a large fish population, which often results in the disappearance of

Table 3. Mean number per liter of plankters in lake samples and mean number per stomach (parentheses) of subadult and adult black bullheads, March 1970 to April 1971, Lake Poinsett, South Dakota.

	15 March	1 May	4 June	18 June	30 June	8 July	17 July	31 July	18 Aug.
Daphnia pulex	(113)	(669.5)	8.33 (38.6)	25.50 (10.7)	16.25 (48.8)	10.2 (41.4)	3.23 (11.6)	2.19 (1.2)	1.00 (0.40)
Daphnia galeata mendotae			T**	T			0.22 (0.05)	1.56 (0.08)	3.99 (1.2)
Leptodora kindtii					0.063 (2.4)	0.105 (24.2)	0.152 (25.0)	0.203 (1.9)	0.331 (7.6)
Diaphanosoma leuchtenbergianum			T		T		1.32 (1.4)	22.4 (2.0)	30.50 (5.7)
Chydorus sphaericus			0.66 (3.8)	2.42	T	T	0.24	2.3	0.14
Calanoid Copepods (*Diaptomus* spp.)		(1.6)	21.92 (0.23)	10.09	19.00 (0.37)	24.40 (1.4)	30.75 (0.80)	43.5 (0.13)	35.19 (0.37)
Cyclopoid copepods (*Cyclops* spp.)		(3.5)	10.09 (0.06)	6.13	23.25 (0.27)	38.63	63.85 (0.27)	112.0 (0.08)	48.70

* In parentheses

** Trace (T) = less than .05 per liter

Table 3. Continued.

	29 Aug.	14 Sept.	4 Oct.	16 Oct.	30 Oct.	2 Nov.	6 Nov.	17 Nov.	23 April
Daphnia pulex	0.05								
Daphnia galeata mendotae	1.48 (3.9)								0.31 (15.6)
Leptodora kindtii	0.211 (60.6)	0.113 (193.5)	0.122 (40.0)	0.039 (5.2)	0.008 (0.44)	0.004	0.005		
Diaphanosoma leuchtenbergianum	8.75 (8.7)	10.18 (9.5)	12.21 (6.8)	6.30 (30.3)	2.35 (0.33)	2.73	1.67	(12.8)	
Chydorus sphaericus	0.13		0.02	0.05					
Calanoid Copepods (Diaptomus spp.)	6.22 (0.02)	8.00	11.05	16.30	12.80	8.61	11.72	17.28	6.2 (0.14)
Cyclopoid copepods (Cyclops spp.)	21.70 (2.2)	13.10	8.52	8.94	5.54	6.20	4.11	5.83	75.0 (0.43)

the larger species of zooplankton (Brooks, 1969) may have been an important factor in this instance. *Daphnia pulex* adults were observed to decrease in size after June to the extent that they were scarcely larger than the adults of *Daphnia galeata.* Selective fish predation may be implicated in this case also as a possible cause for the seasonal diminution (Brooks, 1965). Rainbow trout (*Salmo gairdneri*) and yellow perch (*Perca flavescens*) will select large *D. pulex*, although smaller subadults and juveniles may be present in substantial numbers (Galbraith, 1967). Other morphological changes included a lengthening of the tail spine in excess of one half of the rest of the animal and a marked straightening of the ventral contour of the head. With regard to length of tail spine and head form, adult *Daphnia pulex* taken in July and August closely resembled mature *Daphnia schødleri.*

Daphnia galeata mendotae was avoided when it first appeared on 17 July, as 0.2% of the plankton, but was selected in August when its population had increased to 3.6%. By September *D. galeata* numbers had also declined to a trace and were not observed again until sampling under ice disclosed trace densities in December through March. *Daphnia pulex* did not reappear in the spring of 1971, but *D. galeata* increased to 0.4% on 23 April, and was strongly selected by adult bullheads (+0.99). Copepods which comprised over 99% of the plankton on the above date were rejected as usual.

Copepods (*Diaptomus* spp. and *Cyclops* spp.) were found to be the least important zooplankton consumed regularly by adult bullheads. Despite their dominant numbers in the plankton, they were consistently avoided during the entire study period (Figure 1). Ingested in relatively small quantities (Table 2), copepods may be considered as very minor elements in the diet of adult bullheads. Moreover, there seems to be no conclusive evidence to indicate that they are of any greater importance in the food habits of adults of other fresh-water game and pan fishes. Limnetic copepods are significant only for planktivorous species such as bigmouth buffalo (*Ictiobus cyprinellus*) (Starostka, 1969) and the alewife (*Alosa pseudoharengus*) (Brooks and Dodson, 1965).

For Benthos

Food selectivity for five categories of benthos by adult bullheads is shown in Figures 2 and 3. The highest selectivity (mean +0.75) was for chironomid pupae of which almost all were *Chironomus* spp. Chironomid pupae were positively selected for each sampling date represented in Figure 2. Heaviest utilization occurred on 4 June, and 17 July, when major emergences were probably in progress (Table 4). At the end of July, ingestion of pupae sharply declined, although there were still substantial numbers present in the sediments. Thereafter, pupae numbers diminished, but were still positively selected until September. Observations of the habits of *Chironomus plumosus* in the laboratory have shown its pupae to be highly vulnerable to predation, especially by bottom-feeding fishes. Several days prior to their

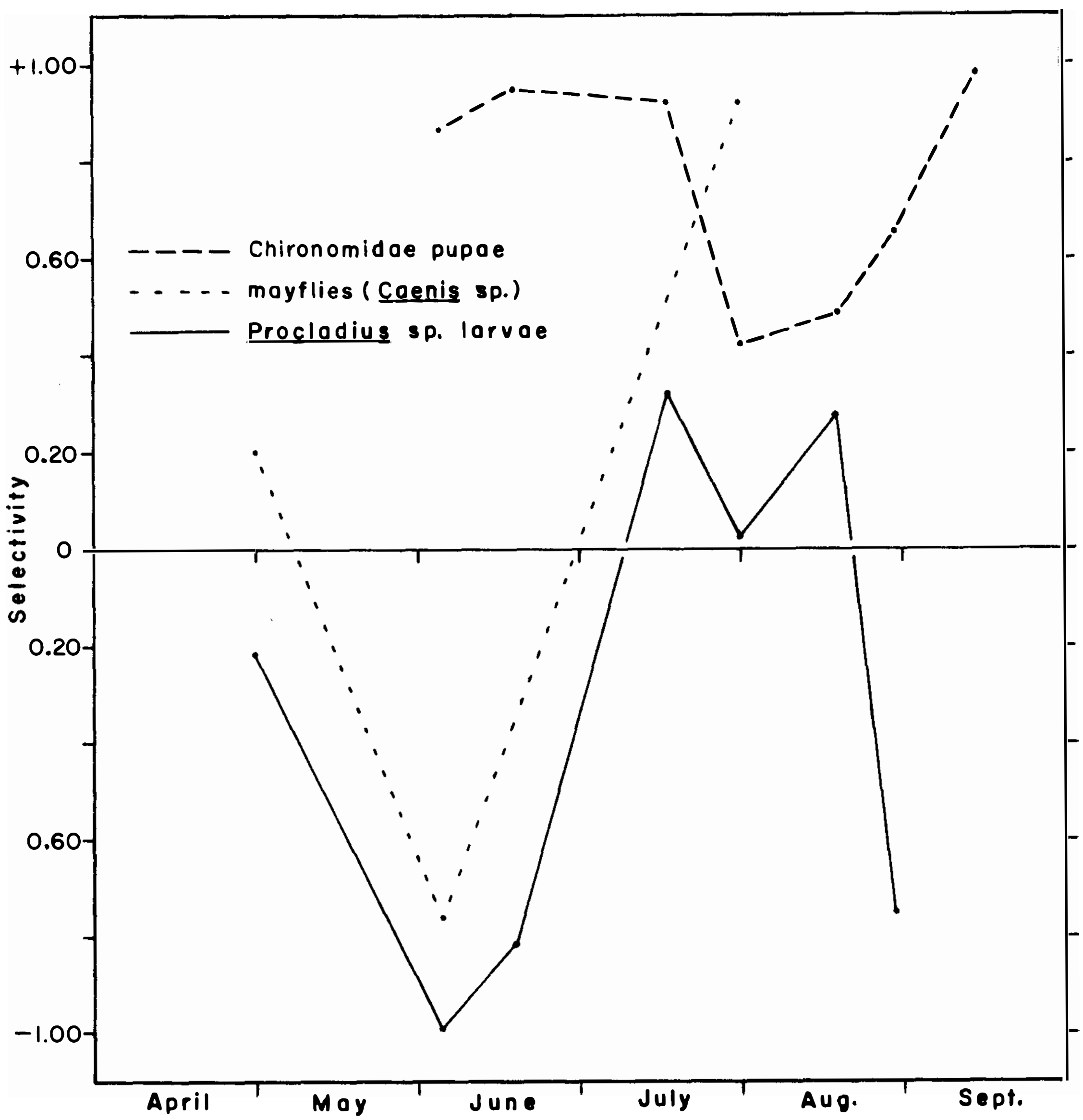

Figure 2. Food selectivity indices for benthos by subadult and adult black bullheads, May to September, 1970, Lake Poinsett, South Dakota.

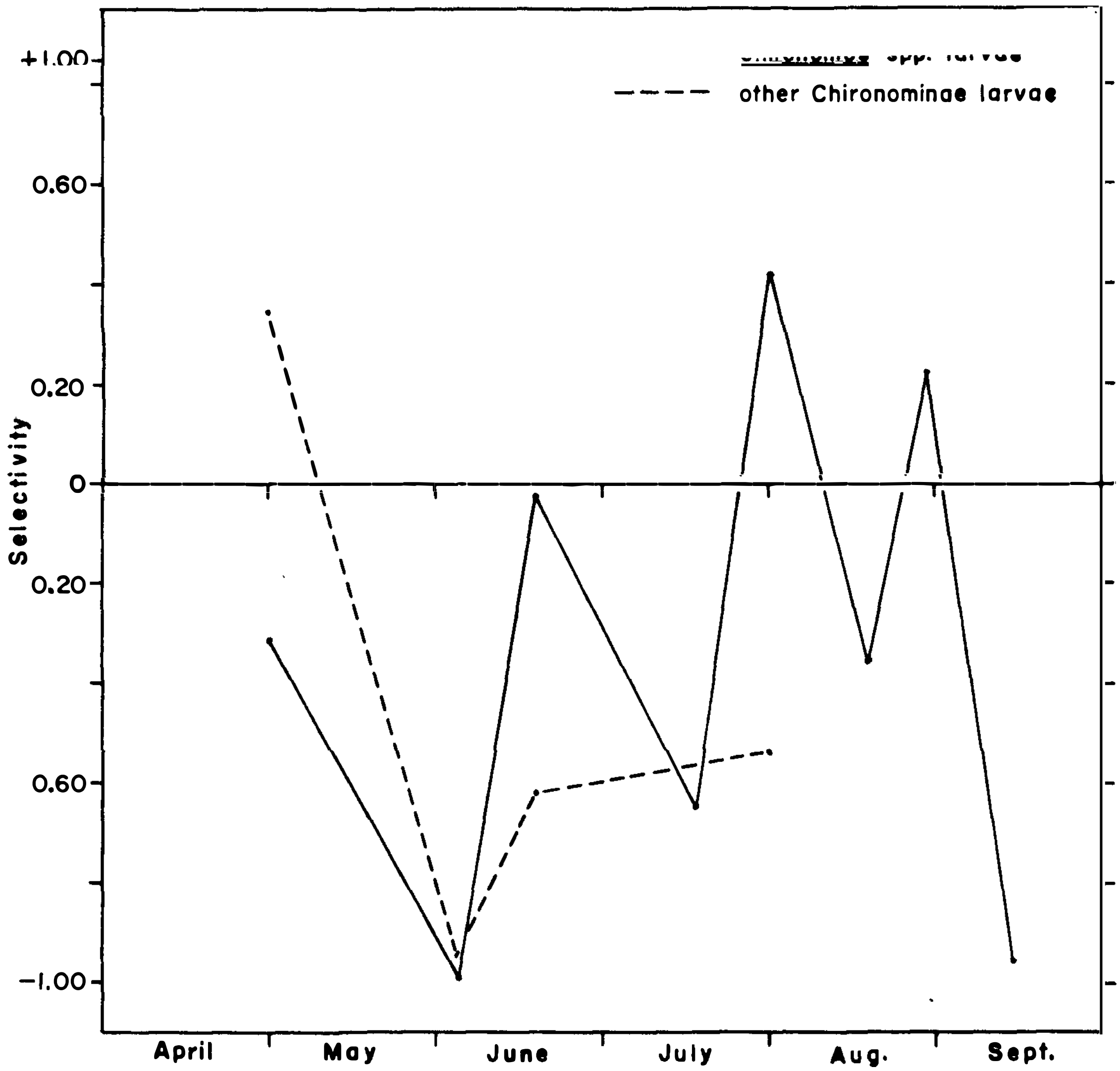

Figure 3. Food selectivity indices for benthos by subadult and adult black bullheads, May to September, 1970, Lake Poinsett, South Dakota.

Table 4. Mean number of benthic organisms per square meter and mean number per stomach (parentheses) of subadult and adult black bullheads, May to September, 1970, Lake Poinsett, South Dakota.

	15 March	1 May	4 June	18 June	30 June	8 July	17 July	31 July	18 Aug.	29 Aug.	14 Sept.
Chironomus spp. larvae		58 (0.46)	295 (0.03)	1472 (4.10)	(0.07)	(1.12)	1765 (7.84)	16 (0.06)	257 (1.69)	304 (0.94)	525 (0.04)
Other Chironominae larvae		136 (4.13)	1023 (1.26)	477 (0.33)	(0.07)	(0.12)		601 (0.30)			
Procladius sp. larvae		407 (3.85)	762 (0.06)	315 (0.10)	(0.10)	(8.62)	512 (20.48)	99 (0.17)	118 (2.85)	197 (0.06)	
Chironomidae pupae			163 (97.51)	20 (2.19)	(0.20)	(3.88)	37 (18.81)	140 (0.55)	25 (1.00)	4 (0.04)	6 (0.84)
Mayfly (*Caenis* sp.) nymphs		62 (1.38)	47 (0.28)					8 (0.32)			

* In parentheses

emergence as adults, Chironomus pupae left their tubes and spent considerable time resting on the surface of the sediments. The author does not know if this extended exposure takes place in nature. In the presence of predators, pupae probably spend much less time on the sediment surface.

All chironomid larvae registered negative mean selectivity indices. Adult bullheads fed primarily on Procladius sp. and Chironomus spp. (Figure 4). Procladius sp. was taken with greater frequency-48% as compared to 35% for Chironomus spp.-and recorded the least negative mean index (-0.30). Why Procladius was preferred over the much larger (Table 1) Chironomus spp. is not clear. Possibly the degree of exposure of the two genera was a significant factor determining the extent of selection. The predacious Procladius sp. is probably more active than the herbivorous Chironomus spp. and may spend a greater proportion of time moving about on the surface or just beneath the bottom sediments in search of prey. Chironomus spp. characteristically construct tubes and are know, particularly the large Chironomus plumosus, to bury deeper into the sediments than most other Chironomidae. During the larval stages Chironomus spp. venture outside their enclosures only at infrequent intervals, thus minimizing exposure to predation.

Other chironomid larvae, mainly Cryptochironomus sp., had a mean index of -.44 (Figure 3). Most of these were recorded in stomachs of bullheads caught over sand substrates on 1 May. The larvae were under 12 mm in length and constituted only a small percentage of

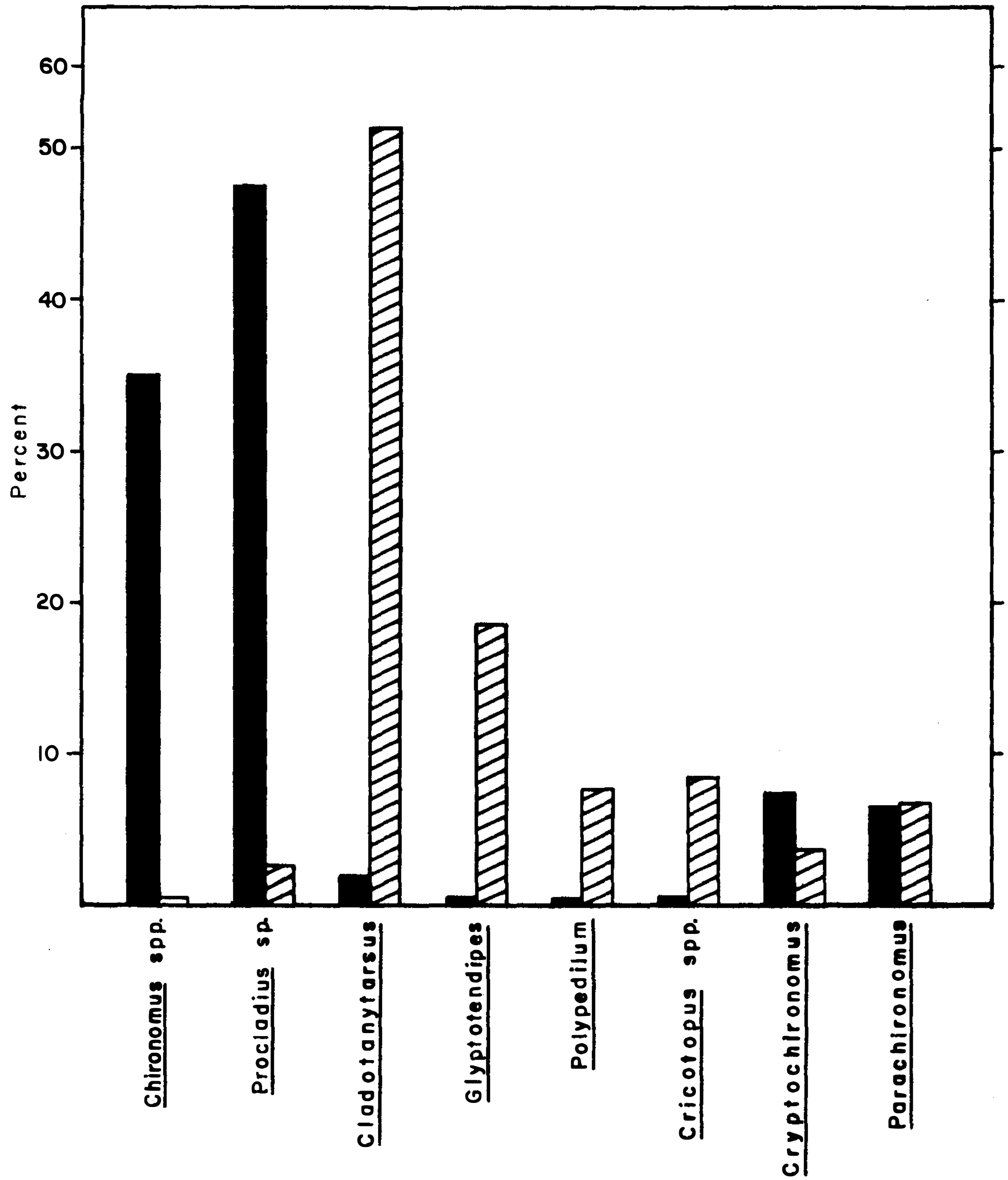

Figure 4. Percent composition by number of Chironomidae larvae in stomach of adult (solid bars) and young-of-the-year (cross-hatched bars) black bullheads.

the total food volume for that date. Parachironomus sp. [=Cryptochironomus abortivus, (Mason, 1968)] was not included in selectivity calculations because of its absence from all Ekman dredge samples. Parachironomus sp. typically builds its case on filaments of Cladophora and occurred in stomachs of adult bullheads when the fish had been feeding on this alga.

Nymphs of the small mayfly, Caenis, that inhabit the surface of sand substrates were positively selected on the average (+0.36). A high degree of exposure and limited mobility probably contributed to their selection.

Food Habits of Young-of-the-Year Black Bullheads

Two-hundred-twenty juvenile bullheads (37-87 mm total length) were captured during the period 4 August to 14 September, at weekly and bi-weekly intervals. Five samples were obtained with 210 fish containing food.

All samples were collected in the area of the outlet within 100 meters of the mouth at approximately midday. The young-of-the-year apparently fed in a relatively restricted area of not more than 200 m in diameter over a sand and rubble bottom with a water depth of less than 2.5 m. No bullhead schools were observed over sapropel substrates.

There was no indication of a change in food with increasing size of the young-of-the-year fish. Therefore, no attempt was made to group them into size categories. There was an increase in the number of chironomids consumed in August, but this was assumed to be only a small percentage of the total food consumed and their uptake dropped sharply in late August and September even though the fish at this time were the largest for the entire sampling period.

The principal foods of the juvenile bullheads were limnetic cladocerans and copepods (Table 5). They comprised 94% of the total volume for the entire period. Leptodora kindtii contributed 51% of this volume. These findings generally agree with those of Applegate and Mullan (1967) for Beaver Reservoir, Arkansas, and Forney (1955) for Clear Lake, Iowa. Littoral cladocerans were insignificant items (0.2%) as a whole, but seemed important to a few fish whose stomachs contained thousands of the minute crustaceans. Other minor food items included Hyalella azteca, Corixidae, Acari, Argulus sp., and Ostracoda. Also present in trace amounts were strands of filamentous algae - Oedogonium, Spirogyra, and Cladophora. A modest number of small Anacystis colonies which were probably ingested accidentally were also observed. Copepod nauplii were not found in any stomachs.

Chironomid larvae and pupae made up 5.6% of the total fare. Almost all of these were small species (11 mm) that typically attach to solid substrates and are probably characteristic of sand and rubble bottoms (Figure 4). Parachironomus sp. constructs its case on Cladophora filaments. Glyptotendipes spp. are found on drowned trees, twigs, rocks, and stems of aquatic plants. Cricotopus spp. commonly inhabit rubble and rock substrates. Cladotanytarsus sp. (5-8 mm), the

Table 5. Stomach contents of 220 young-of-the-year black bullheads, 4 August to 14 September, 1970. Lake Poinsett, South Dakota.

Zooplankton			
Cladocera			
Diaphanosoma leuchtenbergianum	84336	11.80	35.3
Leptodora kindtii	4558	17.12	51.2
Daphnia galeata mendotae	2664	0.51	1.5
Daphnia pulex	1113	0.32	1.0
Kurzia latissima	6146	0.06	0.2
Pleuroxus trigonellus	232	T**	T
Pleuroxus procurvus	12	T	T
Chydorus sphaericus	64	T	T
Scapholeberis kingi	15	T	T
Copepoda			
Cyclops vernalis	26867	1.07	3.2
Diaptomus siciloides	5070	0.51	0.15
Diaptomus clavipes	292	0.15	0.4
Benthos			
Chironomidae larvae	1138	1.51	4.5
Chironomidae pupae	287	0.38	1.1
Corixidae	13	T	T
Acari	13	T	T
Ostracoda	32	T	T

* ml
** Trace (T) = Less than .06 ml

most frequently ingested chironomids, occur on the surface of sand substrates and often attach tubes to various kinds of organic debris. Procladius sp. larvae and Chironomus spp. larvae and pupae, principal items in the diet of adult bullheads, were the least important for the young-of-the-year.

Food Selectivity of Young-of-the-Year Black Bullheads

For Zooplankton

Food selectivity for the seven major species of zooplankton by young-of-the-year bullheads is shown in Figures 5 and 6. Daphnia pulex and Daphnia galeata were both highly selected until their populations collapsed in the first half of September.

Leptodora kindtii was again the most highly-selected zooplankter. Heaviest utilization was recorded for 31 August, when Leptodora comprised 73% of the food volume. In September, population density declined (Table 6) and selectivity decreased to +0.38.

Diaphanosoma leuchtenbergianum (Figure 5) was positively selected on the first sampling date when it constituted 74% of the total food volume. On 10 August Diaphanosoma registered a negative selectivity index (-0.12) Avoidance of Diaphanosoma on this occasion may have been related to the increased selection of Leptodora at this time. Thereafter, Diaphanosoma was again positively selected.

Calanoid and cyclopoid copepods were, with one exception, consistently selected against. Diaptomus siciloides had the most negative

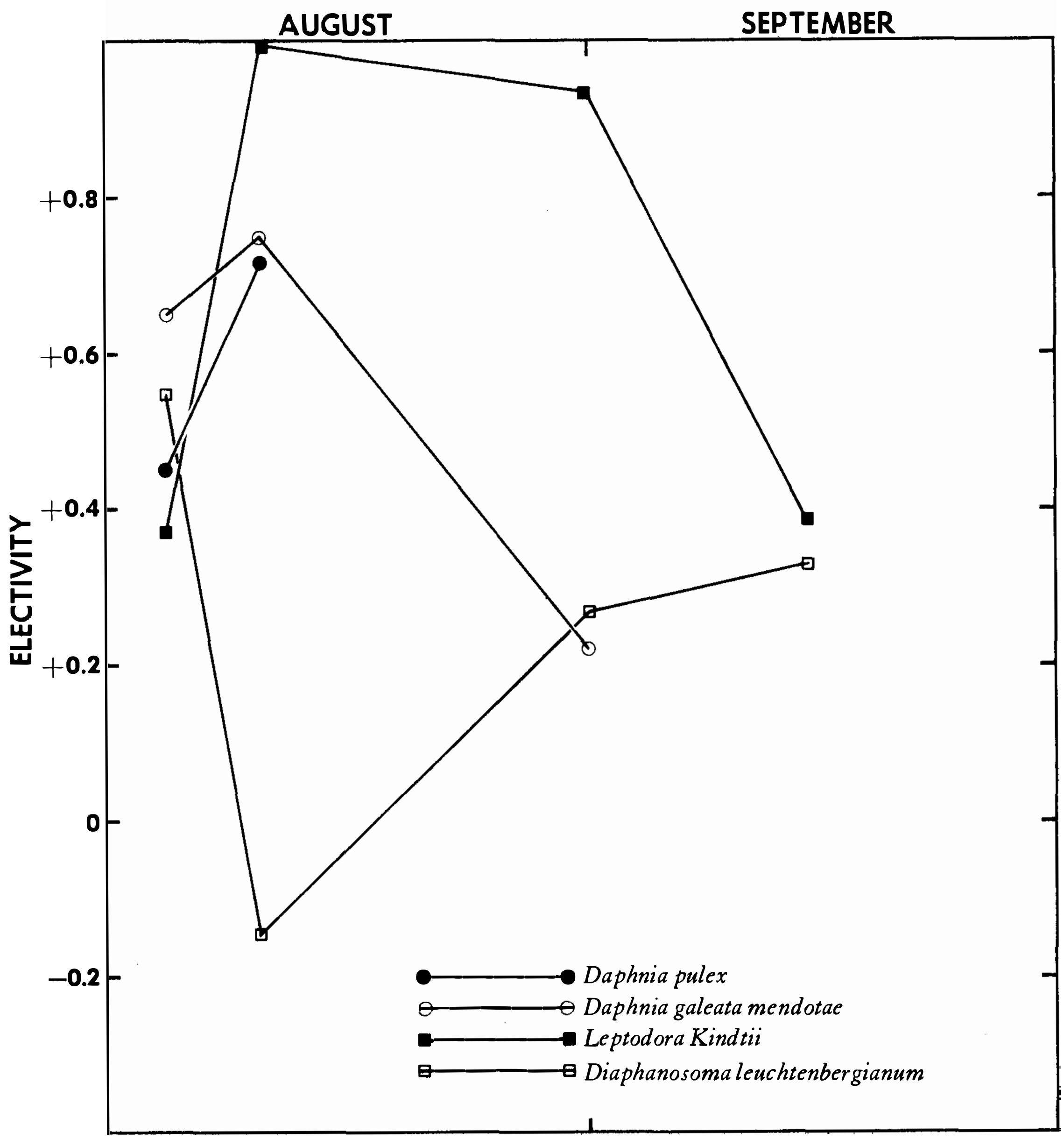

Figure 5. Food selectivity indices for limnetic cladocerans by young-of-the-year black bullheads. August to September, 1970, Lake Poinsett, South Dakota.

Table 6. **Mean number of plankters per liter in lake samples and mean number per stomach (parentheses) of young-of-the-year black bullheads, 4 August to 14 September, 1970, Lake Poinsett, South Dakota.**

	August 4	10	31	September 14
Daphnia pulex	1.30 (20.2)	0.56 (2.0)	0.0 (0.0)	0.0 (0.0)
Daphnia galeata mendotae	0.58 (15.3)	1.80 (7.7)	0.78 (28.3)	0.07 (0.0)
Leptodora kindtii	0.10 (1.3)	0.17 (24.5)	0.11 (56.3)	0.06 (4.1)
Diaphanosoma leuchtenbergianum	21.80 (422.6)	22.00 (9.8)	17.80 (517.9)	14.10 (695.0)
Cyclops vernalis	65.10 (149.0)	49.6 (7.1)	24.2 (203.3)	13.4 (161.1)
Diaptomus siciloides	22.70 (33.4)	16.40 (0.9)	6.70 (25.2)	8.40 (39.8)
Diaptomus clavipes	0.66 (2.3)	0.51 (0.2)	0.08 (0.4)	0.11 (2.8)
Bullhead Length Range in mm	37-58	50-66	61-87	62-87

mean index (-0.68), Diaptomus clavipes the least negative (-0.23) with Cyclops vernalis falling between the two (-0.43).

Selection of an organism by fish for food appears to be dependent both on its size and activity-that is, its ability to evade a predator. In an attempt to roughly measure the latter quality, four to six of each species of zooplankton were placed in a 1.0 l beaker containing lake water. A suction pipette was then employed to capture each zooplankter individually, simulating, perhaps, a small fish selecting single plankters. The average number of attempts (time) required to capture each species was taken as some indication of its success in avoiding a predator. In order of increasing difficulty of capture (where width of spacing indicates degree of difference):

Daphnia pulex
Daphnia galeata mendotae } approximately similar
Leptodora kindtii
Diaphanosoma leuchtenbergianum

Cyclops vernalis

Diaptomus siciloides } approximately similar
Diaptomus clavipes

These results indicate that cladocerans are captured with relative ease and calanoid copepods only with some difficulty. Cyclops vernalis (copepodites < 1 mm long) was the easiest copepod to capture, shedding some light on a possible reason for its selection (Figure 6) over the larger Diaptomus siciloides (1.3 mm). Selection of Diaptomus clavipes over the other copepods appeared to be most influenced by its relatively large size (up to 2.5 mm), since it was the least abundant limnetic copepod and apparently quite adept at avoiding capture.

SUMMARY

Stomach contents of young-of-the-year, subadult and adult black bullheads from Lake Poinsett, South Dakota, were analyzed from March, 1970 to April, 1971, using both numerical and volumetric methods. Two-hundred-twenty young-of-the-year fish (37-87 mm total length) fed primarily on limnetic cladocerans and copepods. Leptodora and Diaphanosoma comprised 86.5% of the total food volume. Chironomid larvae and pupae, the most important benthic organisms consumed, made up 5.6% of the total. Other benthos-Acari, Corixidae, Ostracoda and Amphipoda contributed 0.2%. Littoral cladocerans, mainly Kurzia latissima, also formed 0.2% of the entire diet. The algae genera, Spirogyra, Oedogonium, Anacystis, and Cladophora occurred in trace quantities. Organic detritus present in the stomachs was also negligible.

Food selectivity of young-of-the-year bullheads for seven major species of zooplankton was determined using the index described by Ivlev (1961). All limnetic cladocerans were selected positively for every sampling date with a single exception for Diaphanosoma on 10 August. The average indices for Leptodora kindtii, Daphnia pulex, Daphnia galeata, and Diaphanosoma leuchtenbergianum were, respectively, +0.67, +0.58, +0.54, and +0.25. Calanoid and cyclopoid copepods were negatively selected. Average indices for Cyclops vernalis, Diaptomus clavipes, and Diaptomus siciloides were -0.43, -0.23, and -0.68 These

results suggest that selectivity is dependent both on the size of the food organism and on its ability to avoid ingestion.

Stomach contents of six-hundred-eight subadult and adult bullheads (143-304 mm total length) revealed significant seasonal differences in diet. During periods of ice cover (January-April) *Chironomus* spp. larvae and *Daphnia pulex* comprised 89.0% and 11.0% of the food items by volume. *Daphnia pulex* made up 94.6% of the total in early May. During June adult bullheads fed primarily on *Chironomus* spp. pupae (63.4%) and crayfish, *Orconectes* (25.1%). Fish (yellow perch and crappies) constituted 50.1% of the entire diet in August and September. *Leptodora* accounted for 38.8% and one tiger salamander contributed 8.5% of the total. *Leptodora* was the most important food item during October, comprising 59.3% of the volume for the month. One spottail shiner represented 39.4% for the same period.

Ivlev's selectivity index was again employed both for zooplankton and benthos. All limnetic cladocerans were, on the average, selected positively by adult bullheads. Average indices for *Leptodora* and *Daphnia pulex* were, respectively, +0.99 and +0.62. All copepods were negatively selected. Chironomid larvae were also negatively selected: *Chironomus* spp. -0.33; other Chironominae spp. -0.44; *Procladius* sp. -0.30; Chironomid pupae (99% *Chironomus* spp.) were strongly selected (+0.75) by adult bullheads during most of the sampling period. This result points up the vulnerability of pupae to predation. It may be that they cannot retreat into the sediments as effectively as larvae when confronted by a predator. Their vulnerability is further heightened when they become planktonic for a short time during the last stages of the emergence process.

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