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Food selectivity of Bluegill and Green Sunfish Fry

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FOOD SELECTIVITY OF BLUEGILL

AND GREEN SUNFISH FRY

BY

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Dedicated to

MY WIFE AND CHILDREN

for the sacrifices they made and

their support and encouragement.

MY THESIS ADVISOR

for his enviable advisory commitment.

FOOD SELECTIVITY OF BLUEGILL

AND GREEN SUNFISH FRY

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.

Dr. Timothy Modde — Thesis Advisor — Date

Dr. Charles G. Scalet — Head, Wildlife and Fisheries Sciences Department. — Date

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Abstract

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Four genera of zooplankton and cladoceran egg cases, collected from a municipal sewage lagoon, were made available as food to green sunfish (Lepomis cyanellus) and bluegill (Lepomis macrochirus) fry, to examine their food selectivity. Green sunfish and bluegill fry ranged in size from 8.5-11.0 mm and 8.0-10.5 mm at stocking and were reared for 31 and 30 days, respectively.

The gut contents of 1488 green sunfish and 1440 bluegill fry, representing day and night samples were examined. Diet composition was evaluated using the linear food selection index. Both green sunfish and bluegill fry selected for Cyclops vernalis and consistently selected against cladoceran egg cases and Potamocypris spp. Moina brachiata was consistently selected for by bluegills but was initially consumed by green sunfish in approximately the same proportion as they were available and later preferentially selected for by larger green sunfish fry. The mean length of prey species selected for, increased linearly with mean length of green sunfish fry; the food length relation for bluegill fry as the fish increased in size was curvilinear. There were no significant ($P>0.05$) differences between day and night prey species and prey size selection. The number of prey organisms consumed by bluegill fry increased linearly with mean length of fish, and the

differences between day and night quantities were significant ($P \leq 0.05$). The relationship between the number of prey organisms ingested and mean length of green sunfish fry was exponential. The differences in numbers of prey items ingested by green sunfish during lighted and dark hours were only significant ($P \leq 0.05$) for fry of mean total length 12.7 mm and greater.

INTRODUCTION

Considering the importance of bluegills (*Lepomis macrochirus*) as a cultured game fish species, relatively little information exists relating to their larval food selection. Although fishes are very fecund, their survival during larval stages is extremely low (Kramer and Smith 1962; Nikolsky 1963). It has been suggested that lack of an appropriate quality and size of food during the period young fish are dependent on plankton is a cause of high mortalities in some fish species (Sette 1943). Toetz (1966) reported high mortality of larval bluegills during their change from endogenous to exogenous sources of energy. Knowledge of the food requirements of larval bluegills would contribute to improving their survival in a hatchery system.

Those studies which have described the food utilized by bluegills have primarily addressed diet composition (Werner 1969; Siefert 1972; Sadzikowski and Wallace 1976; Keast 1980; Lemly and Dimmick 1982), whereas few studies have investigated prey size as an index of prey availability to fish. Schoener (1969) stated that fishes feed in a way to optimize net energy yield. Optimal energy yield by some particulate planktivorous fishes is accomplished by selecting larger prey (Werner and Hall 1974). Galbraith (1967) reported that size of *Daphina* was an important factor in rainbow trout (*Salmo gairdneri*) predation on daphnids. Several studies have reported prey size dependent patterns of food selection in muskellunge (*Esox masquinongy*) (Applegate 1981), walleyes (*Stizostedion vitreum vitreum*), yellow perch (*Perca flavescens*) (Raisanen 1982; Raisanen and Applegate 1983) and other fish species (e.g. Wong and Ward 1972).

The food habits of green sunfish (Lepomis cyanellus) have received little attention in either field or laboratory research (Flemer and Woolcott 1966). Sadzikowski and Wallace (1976) stated that bluegills and green sunfish juveniles shared similar diets but that the sizes of prey ingested differed. Eggers (1977) proposed, on the basis of optimal foraging theory, that a predator would change its diet breadth as the relative abundance of available prey, or the relative size of available prey changed. He further predicted that, a change in the ability of a predator to exploit available prey would result in a change in diet breadth. Carlander (1955) reported that bluegill crops were inversely related to green sunfish crops. The green sunfish was included in the present study to gain insight into its potential competition with bluegills during larval stages.

The objective of this study was to investigate food selectivity of intensively cultured bluegill and green sunfish fry utilizing a live diet of planktonic invertebrates.

MATERIALS AND METHODS

Experimental Fish

Green sunfish fry ranging from 8.5-11.5 mm total length (mean = 10.5 mm) were stocked at a rate of 2000 fish in each of four 115 liter rectangular tanks on 2, August 1983. Bluegill fry (range = 8.0-10.5 mm, mean = 9.5 mm) were stocked at the same rate in four additional 115 liter rectangular tanks 12 days later. All tanks were covered with 12.7 mm mesh vexar netting two weeks after stocking to prevent the fry from jumping out of the tanks.

Study tanks were aerated continuously and water, at a temperature of 25.0 $\pm$ 1.0 C, flowed through each tank at a rate of approximately 4.0 liter/minute. Charcoal-filtered municipal water was used throughout the study. A 12 hour (0600 to 1800 hours) light regime was maintained in the rearing facility throughout the study. The photoperiod was regulated by an automatic timer. Light intensity above tanks varied between 350 and 420 lux, as measured with a LAMBDA model LI-185 photometer. Dissolved oxygen, measured twice weekly with a Hach water quality test kit, was never less than 5.0 mg/liter throughout the study. All tanks were cleaned twice daily by siphoning the tank bottom.

Samples of green sunfish and bluegill fry were taken at 1130 and 2330 hours each day for 31 and 30 days, respectively. Six fry were collected from each tank during each sampling period. Fry were removed from the tank with a dip net and allowed to suffocate, were measured for total length under a dissecting microscope to the nearest 0.5 mm, and preserved in 4.0% formalin solution.

Experimental Food

Fish fry were provided zooplankton daily from 0900 to 2300 hours at 2 hour intervals. Zooplankton used for food was collected twice daily from a local (Volga, South Dakota) municipal sewage lagoon with a 153 micrometer mesh dip net. The food organisms were filtered through a 1050 micrometer mesh net to remove detritus and large predaceous invertebrates. Food organisms were mechanically mixed in an approximately 100 liter tub, and a 10.0 ml sample (i.e. food concentrate) was preserved in a 1.0% formalin solution. Food organisms were added to study tanks in sufficient quantities to make zooplankton swarms visible. Samples of the food organisms in each study tank were taken at 1800 hours twice a week and preserved in a 1.0% formalin solution.

Identification of Food Organisms

Preserved food concentrates were placed in a circular plankton counting chamber and analyzed under a Bausch and Lomb StereoZoom (Zoom range 0.7x to 3.0x) microscope equipped with a calibrated micrometer disc. The first 600 individuals were identified to species or genus using Ward and Whipple (1959) or Pennak (1978), and then enumerated. *Cyclops vernalis* (copepod), *Moina brachiata* (cladoceran), *Potamocypris* spp. (ostracod), *Brachionus* spp. (rotifer), and cladoceran egg cases were identified as food organisms offered to the fish. The lengths of 100 individuals each of *Cyclops vernalis* and *Moina brachiata* were measured from daily diurnal and nocturnal food samples. Total lengths of 100 each of Brachionus spp. and cladoceran egg cases were also measured. No measurements were made of Potamocypris spp. Length of Moina brachiata was measured from the anterior edge of the head region to the posterior edge of the carapace. Cyclops vernalis length was measured from the anterior edge of the head to the posterior edge of the caudal ramus (Fig 1). All measurements were made to the nearest 0.05 mm.

The diets of 1488 green sunfish and 1440 bluegill fry were examined. Fish sampled at 1130 and 2330 hours were used for feeding analysis. During the first 10 days (size ≤ 15.0 mm) of rearing the contents of the alimentary tract from the esophagus to the anal sphincter were examined. The region of the gut from the esophagus to the pyloric end of the stomach was examined thereafter. Food organisms were identified to the species or genus level using Ward and Whipple (1959) and Pennak (1978), and then counted. Lengths of unfragmented Cyclops vernalis and Moina brachiata were measured to the nearest 0.05 mm.

Data Analysis

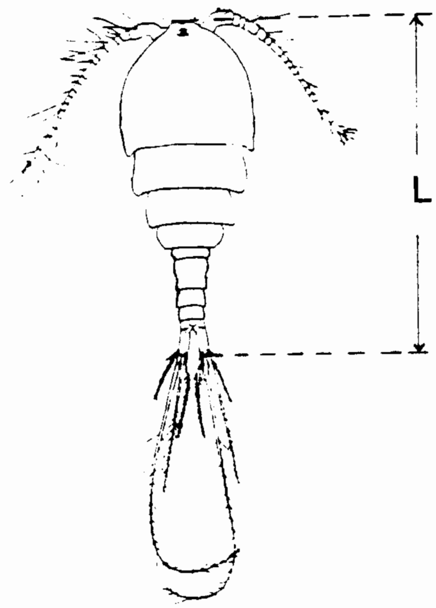
Food selection of bluegills and green sunfish was evaluated using the linear food selection index (L). The formula for L is as follows:

$$L = r - p$$ (Strauss 1979)

where:

r = the relative abundance of prey item in the gut

p = the relative abundance of the same prey in the food source.



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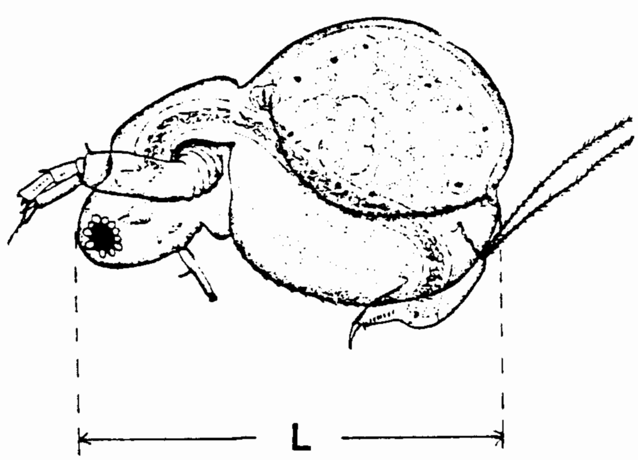

B

Figure 1. Criteria for Length (L) measurements of Cyclops vernalis (A) and Moina brachiata (B) used in a food selection study of bluegills (Lepomis macrochirus) and green sunfish (Lepomis cyanellus), 1983.

Values of L range from +1.0 to -1.0 or +100.0 to -100.0 when expressed as a percentage. Positive L values indicate selection for a food type, zero means random selection, and negative values indicate selection against a food type. Values of L were tested for significant ($P \leq 0.05$) departure from zero and for significant differences between 1130 and 2330 hours by Student's t-test. A three-way least squares analyses of variance, using the General Linear Models (GLM) procedure, was performed to determine factors contributing to the variations in calculated L values. The three treatments tested were period (age or size of fish), time (day and night), and prey type. Two-way analyses of variance (GLM) were performed to test differences in mean fish length, mean number of organisms ingested, mean length of prey ingested between day and night, and among study periods. The mean lengths of prey ingested and those of prey available to fish were also tested for significant difference between time and study period with a two-way analysis of variance. Mean fish length was tested with mean length of prey ingested and mean number of prey consumed for determination of linear correlation. Chi-square analysis was used to test differences in composition of food in the food source and in experimental tanks. For purposes of data analysis the data were divided into six uniform time periods.

RESULTS

Prey Selection by Bluegills

Cyclops vernalis and Moina brachiata comprised the main food items of the diet of bluegills until day 10 when the latter disappeared from the food source. The relative proportions of Cyclops vernalis, Moina brachiata and egg cases in the diet for the first 10 days of feeding were 75.4, 24.0, and 0.6% respectively. Cyclops vernalis remained the main food item of bluegill fry throughout the rearing period. Potamocypris spp. and egg cases were numerically unimportant components of the diet. The latter comprised only 0.8% of the number of food organims ingested by bluegill fry.

A significant ($P \leq 0.05$) difference occurred between the numbers of organisms ingested during day and night (Table 1) among all bluegill length groups. The mean number of organisms ingested by bluegill fry increased linearly with growth of fish (Fig. 2). Fish length alone accounted for 96.5 and 98.5% of the variations in numbers of organisms ingested during lighted and dark hours, respectively.

Bluegill fry selected for Cyclops vernalis and Moina brachiata, and selected against Potamocypris spp. and cladoceran egg cases (Fig. 3). The degree of bluegill selection ranged from weak selection for Cyclops vernalis and weak selection against Potamocypris spp. and egg cases during the first 15 days to moderate selection for Cyclops vernalis and moderate selection against Potamocypris spp. and egg cases thereafter. Bluegill fry selection for or against prey organisms did

Table 1. Mean total lengths of bluegills (*Lepomis macrochirus*), mean number of organisms ingested, and mean length of *Cyclops vernalis* and *Moina brachiata* ingested during lighted and dark hours for 30 days of feeding, 1983; standard error in parentheses.

Mean total length of bluegill (mm)		Mean number of organisms ingested		Mean length of food item (mm)			
				Cyclops vernalis		*Moina brachiata*	
1130 hours	2330 hours	1130 hours	2330 hours	1130 hours	2330 hours	1130 hours	2330 hours
8.7 (0.06)	8.8 (0.11)	9*(0.77)	6*(0.52)	0.71 (0.03)	0.77 (0.04)	0.59 (0.01)	0.53 (0.03)
12.7 (0.14)	12.7 (0.13)	53*(2.13)	28*(1.31)	0.94 (0.003)	0.97 (0.003)	0.72 (0.01)	0.74 (0.01)
17.9 (0.10)	17.9 (0.10)	69*(1.44)	47*(1.34)	1.07 (0.004)	1.09 (0.004)	0.78 (0.01)	0.79 (0.01)
22.7 (0.11)	22.7 (0.12)	104*(1.83)	82*(1.99)	1.03 (0.003)	1.06 (0.003)	0**	0**
27.2 (0.09)	27.2 (0.96)	164*(3.47)	99*(1.28)	1.01 (0.003)	1.00 (0.003)	0**	0**
31.0 (-)	30.5 (-)	202*(-)	116*(0.50)	0.86 (0.03)	0.92 (0.02)	0**	0**

*Significant difference between paired values ($P \leq 0.05$).

***Moina brachiata* unavailable in food source.

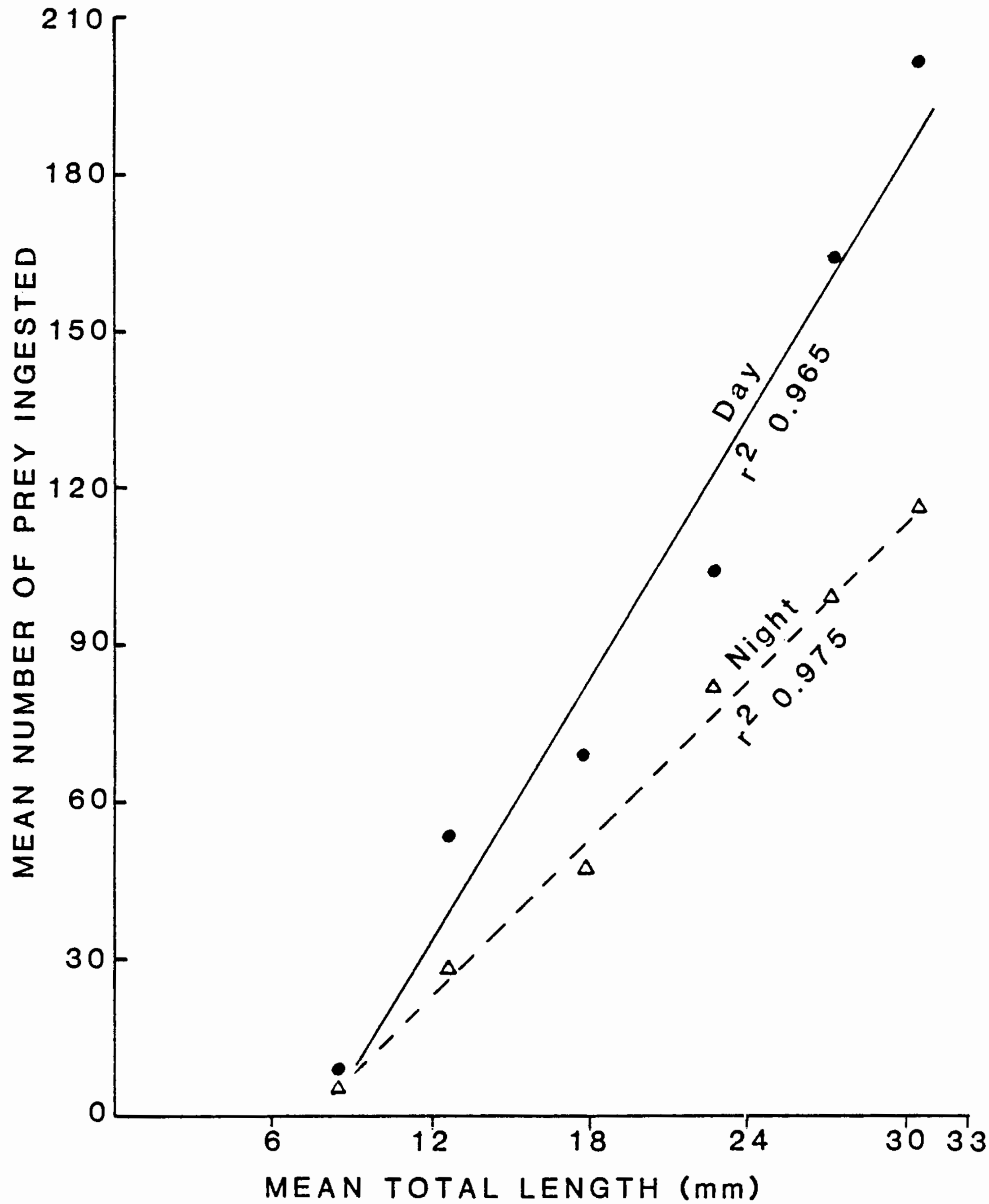

Figure 2. Relationship between mean number of organisms ingested during the day (●) and night (△), and mean total length of bluegills (*Lepomis macrochirus*) for 30 days of feeding, 1983.

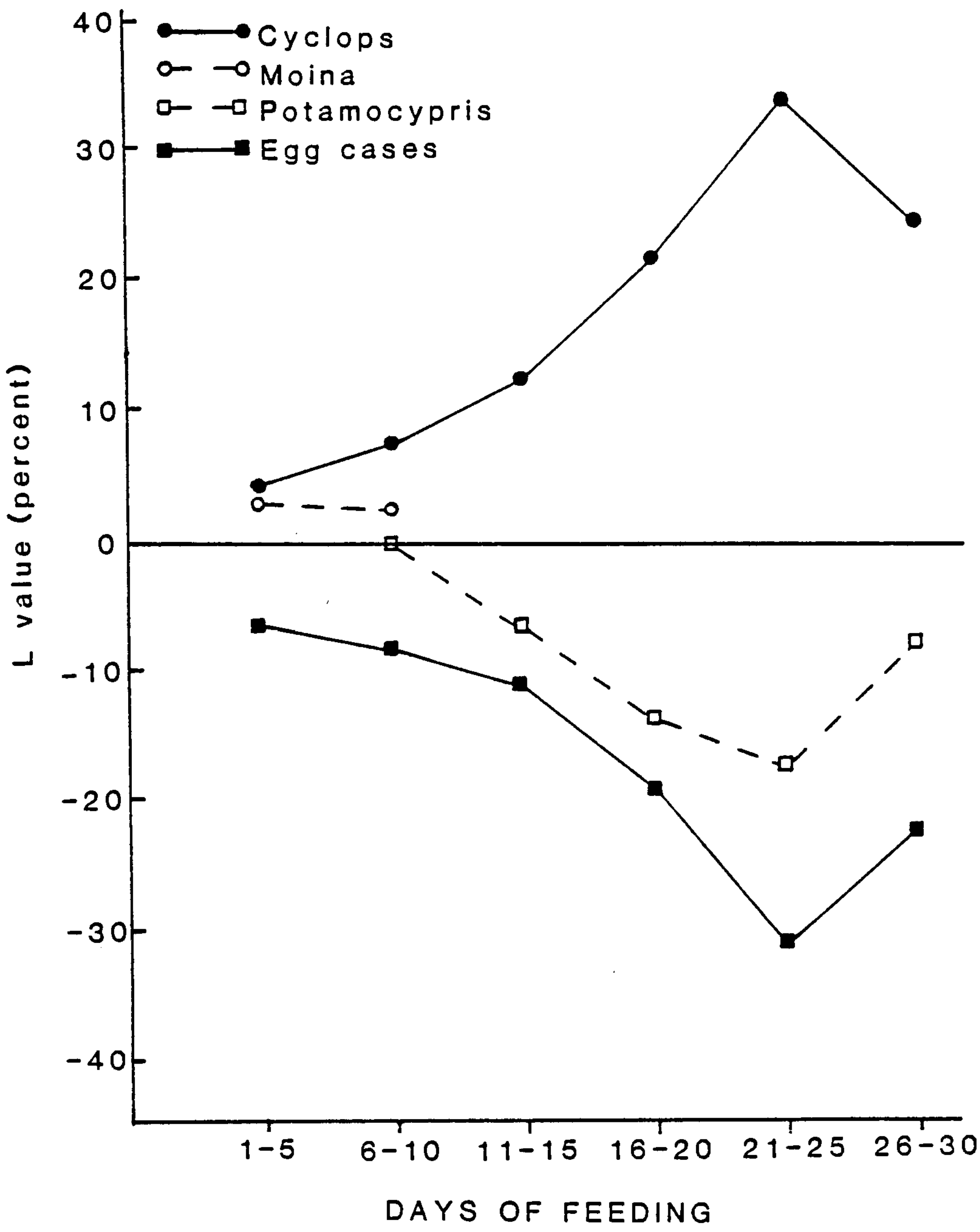

Figure 3. Linear food selection index values (L) of bluegills (*Lepomis macrochirus*) for *Cyclops vernalis*, *Moina brachiata*, egg cases, and *Potamocypris* spp. utilized as food for 30 days, 1983.

differ significantly (P>0.05) between day and night. Type of organism and its interaction with period were the main factors contributing to the variation in calculated linear food selection index values (Table 2).

The mean length of food organisms utilized by bluegill fry increased with increasing fish length, but the relationship, although positive, was not linear (Fig. 4). The apparent decrease in mean length of Cyclops vernalis ingested by bluegills larger than 18.0 mm was due to the relatively smaller sizes of Cyclops vernalis available after day 10. Bluegill fry consistently preyed upon Cyclops vernalis longer than the mean length available from the food source after day 5 (Fig. 5). Bluegill ingested longer Cyclops vernalis than Moina brachiata during the period both species occurred simultaneously as food items.

Prey Selection by Green sunfish

Cyclops vernalis and Moina brachiata formed the bulk of the food ingested by green sunfish fry, and comprised 78.4 and 20.3% of the total food ingested, respectively. Potamocypris spp. and egg cases occurred in the alimentary tract of few fish and were not numerically important as food items.

Young green sunfish (9.5 mm or less) appeared to feed with equal intensity during both day and night (Table 3). As they grew larger they tended to feed more intensely during the day than at night. A Student's t-test indicated no significant (P>0.05) difference between number of organisms ingested during day and night by fish of mean total length 8.8

Table 2. Three-way analysis of variance table showing factors contributing to the variations in calculated linear food selection index values for bluegills (Lepomis macrochirus) intensively reared on zooplankton for 30 days, 1983.

Source	df	MS	Type III SS	R^2	F value	Pr. F
Model	24	382.82		0.99	431.85	0.0001[a]
Error	8	0.89				
Organism	2		7026.72		3963.36	0.0001[a]
Period	5		11.46		2.59	0.1118
Organism * Period	9		2137.61		267.93	0.0001[a]
Time	1		2.31		2.61	0.1450
Organisms * Time	2		1.56		0.88	0.4511
Period * Time	5		7.20		1.62	0.2582

[a]Significant ($P \leq 0.05$).

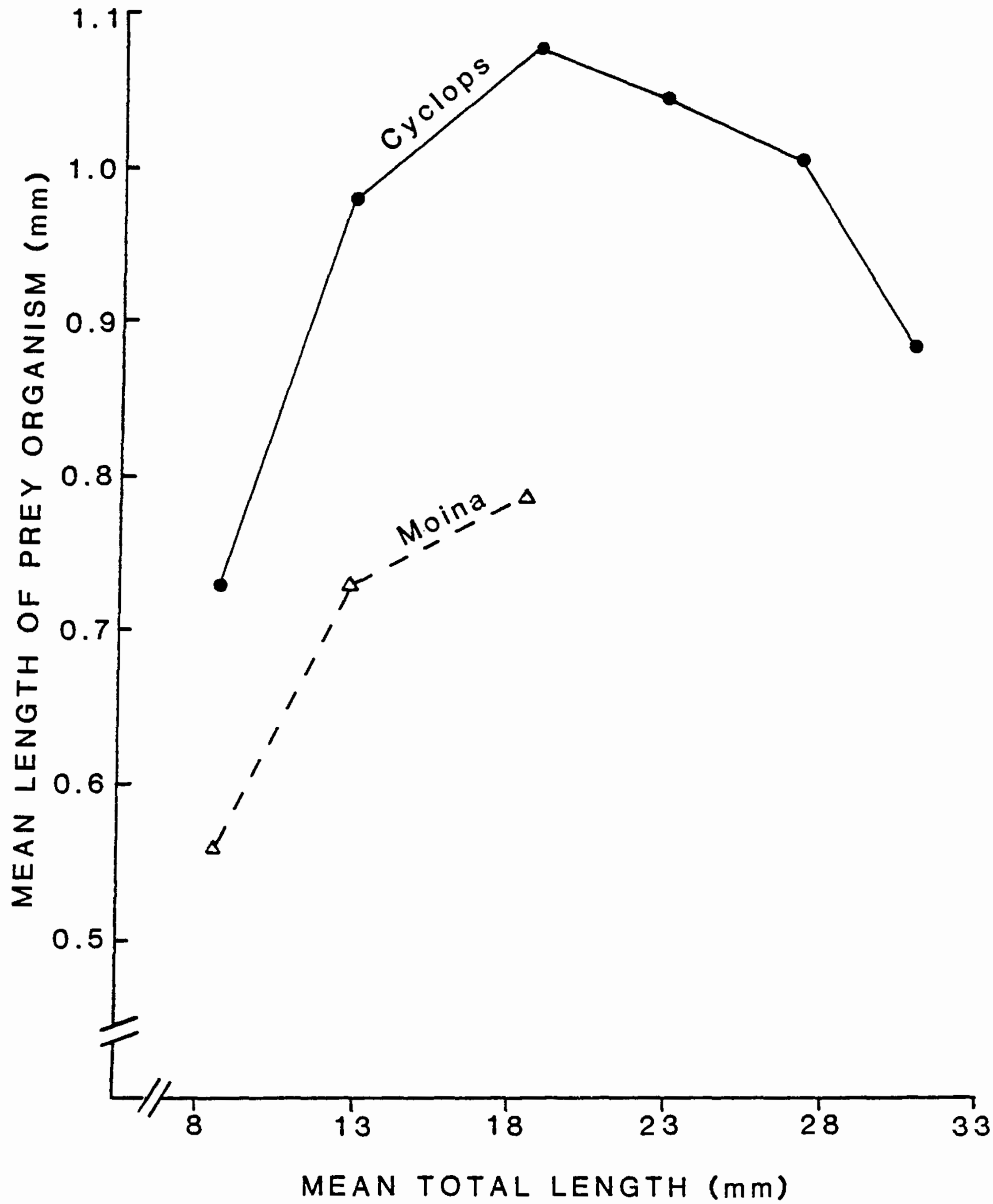

Figure 4. Relationship between mean length of prey item ingested and mean total length of bluegills (Lepomis macrochirus) intensively reared on zooplankton for 30 days, 1983.

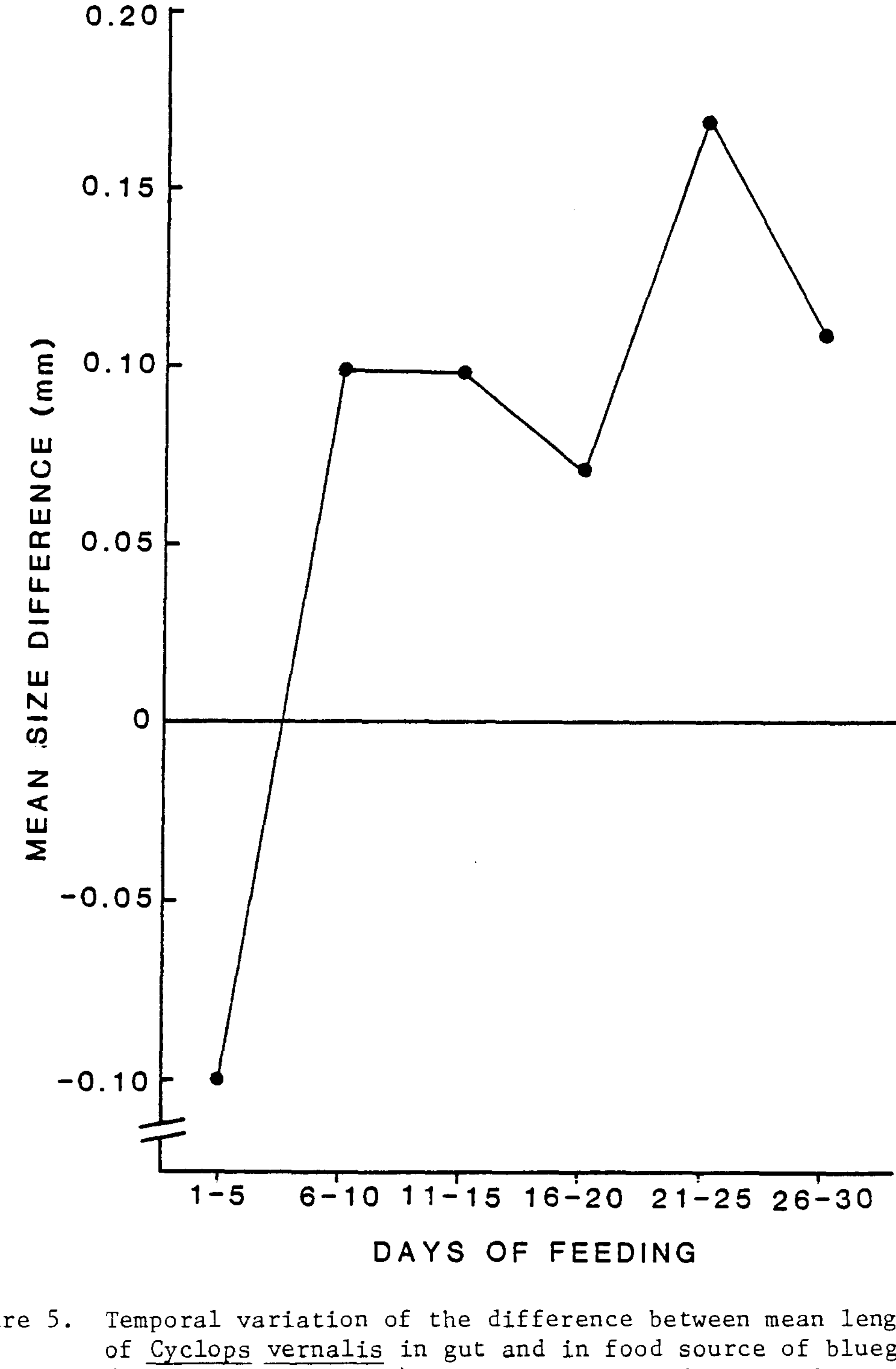

Figure 5. Temporal variation of the difference between mean length of Cyclops vernalis in gut and in food source of bluegills (Lepomis macrochirus) intensively reared on zooplankton for 30 days, 1983.

Table 3. Mean total length of green sunfish (*Lepomis cyanellus*), mean number of organisms ingested, and mean length of *Cyclops vernalis* and *Moina brachiata* ingested during lighted and dark hours for 31 days of feeding, 1983; standard error in parentheses.

Mean total length of fish (mm)		Mean number of organisms ingested		Mean length of food item (mm)			
				Cyclops vernalis		*Moina brachiata*	
1130 hours	2330 hours	1130 hours	2330 hours	1130 hours	2330 hours	1130 hours	2330 hours
8.7 (0.33)	8.8 (0.34)	11 (3.10)	9 (3.38)	0.80 (0.11)	0.77 (0.15)	0.50 (0.09)	0.53 (0.09)
12.5 (1.66)	12.4 (1.66)	18*(6.08)	12*(3.63)	1.01 (0.19)	1.02 (0.19)	0.66 (0.13)	0.67 (0.12)
17.8 (1.33)	17.7 (1.30)	28*(15.29)	17*(10.67)	0.90 (0.23)	0.93 (0.21)	0.83 (0.20)	0.82 (0.16)
22.8 (1.29)	22.7 (1.29)	62*(25.73)	40*(15.55)	0.99 (0.23)	1.00 (0.22)	1.16 (0.15)	1.15 (0.14)
27.7 (1.50)	27.7 (1.50)	133*(37.50)	82*(33.07)	1.15 (0.18)	1.18 (0.17)	1.28 (0.12)	1.27 (0.11)
30.9 (0.44)	30.8 (0.43)	146*(34.40)	87*(22.11)	1.19 (0.16)	1.18 (0.16)	0**	0**

*Significant difference between paired values ($P \leq 0.05$).

*******Moina brachiata* unavailable in food source.

mm (range 8.0-9.0 mm). Student's t-test and two-way analysis of variance indicated that the number of organisms ingested by larger green sunfish during lighted hours was significant ($P \leq 0.05$), and consistently greater than numbers consumed during dark hours. The numbers of food items ingested during day and night were found to increase exponentlally with increased fish length (Fig. 6). Fish total length accounted for 97.4 and 96.6% of the variations in the numbers of organisms ingested during day and night samples, respectively.

Linear food selection index values for prey organisms ingested by green sunfish fry indicated that cladoceran egg cases and Potamocypris spp. were consistently selected against while Cyclops vernalis was selected for (Fig. 7). Moina brachiata initially was selected randomly but after days 11-15 was selected for. Green sunfish selection for Cyclops vernalis and selection against egg cases became magnified when Moina brachiata disappeared from the food source.

A three-way analysis of variance indicated that organism type and organism type*period interaction were factors which contributed significately ($P \leq 0.05$) to the variation in calculated linear food selection index values (Table 4). Green sunfish fry selected prey organisms according to species composition, and selection was not influenced by time of day. Temporal variations in the composition of food fed to fish also appeared to affect L values. Disappearance of Moina brachiata from the food source resulted in green sunfish fry feeding almost exclusively on Cyclops vernalis which subsequently exhibited larger L values after day 25.

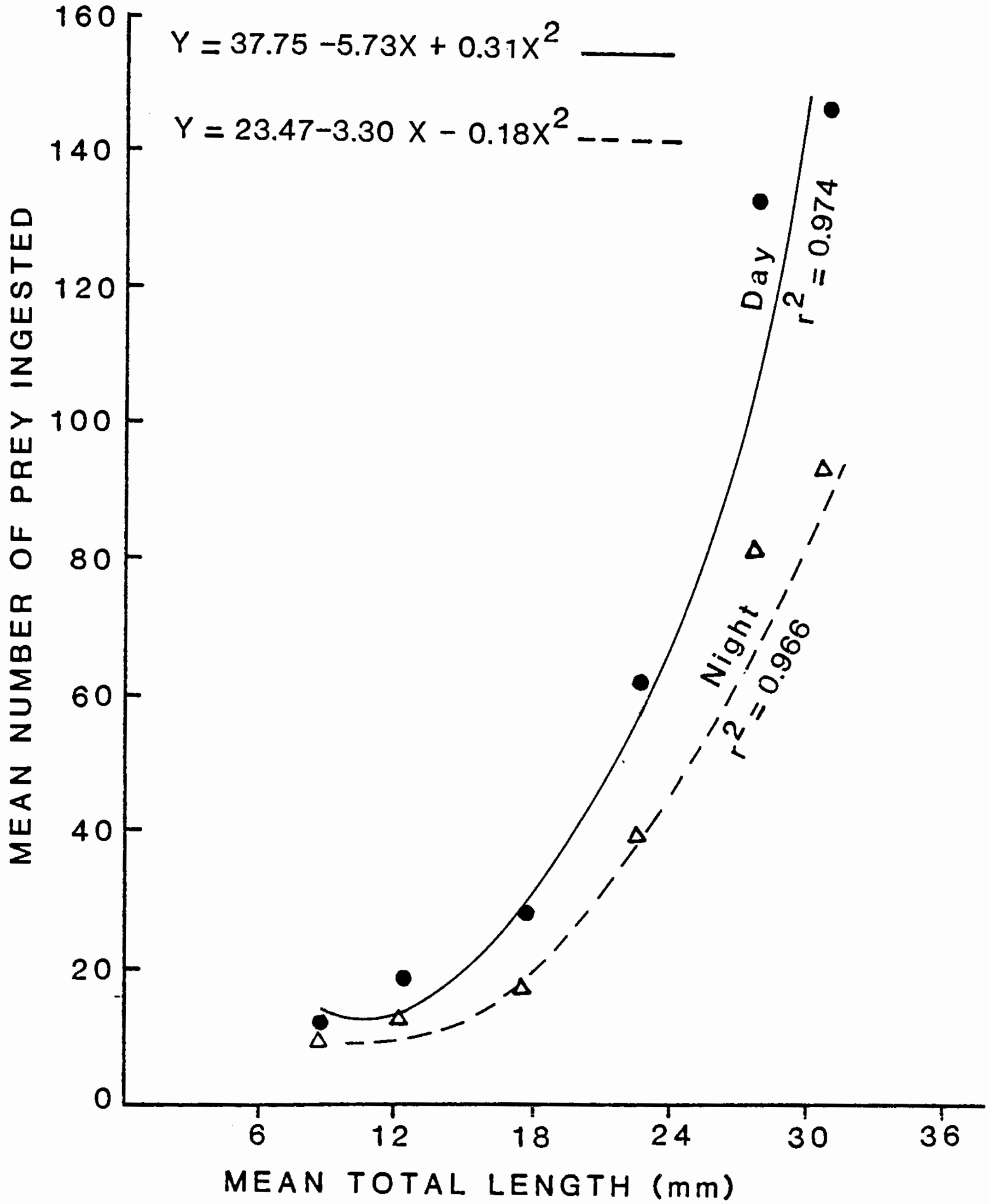

Figure 6. Relationship between mean number of organisms ingested during the day (●) and night (△), and mean total length of green sunfish (Lepomis cyanellus) for 31 days of feeding, 1983.

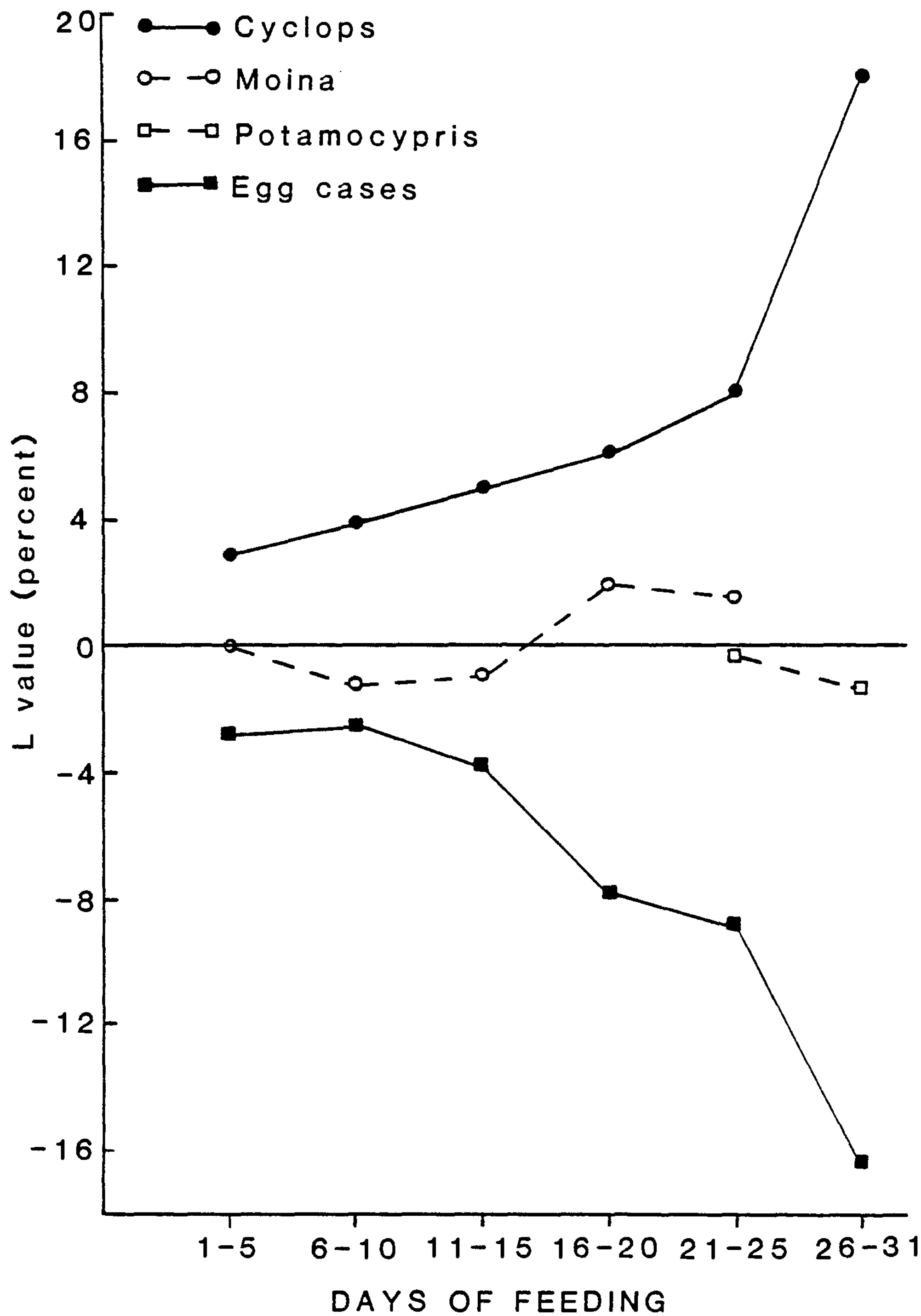

Figure 7. Linear food selection index (L) values of green sunfish (Lepomis cyanellus) for Cyclops vernalis, Moina brachiata, egg cases, and Potamocypris spp. utilized as food for 31 days, 1983.

Table 4. Three-way analysis of variance table showing factors contributing to the variations in calculated linear food selection index values for green sunfish (Lepomis cyanellus) intensively reared on zooplankton for 31 days, 1983.

Source	df	MS	Type III SS	R^2	F value	Pr. F
Model	24	77.93		0.97	11.26	0.0004[a]
Error	9	6.92				
Organism	2		1239.21		89.49	0.0001[a]
Period	5		2.74		0.08	0.9939
Organism * Period	9		622.88		10.00	0.0010[a]
Time	1		0.32		0.05	0.8341
Organisms * Time	2		6.22		0.45	0.6517
Period * Time	5		0.66		0.02	0.9998

[a]Significant ($P \leq 0.05$).

The length of food organisms ingested by green sunfish increased with increasing fish length. There was no significant ($P>0.05$) difference in length of food type ingested between day and night intervals. The relationship between length of green sunfish and prey length was linear ($P\leq0.05$) (Fig. 8). Fish length alone accounted for 98.1% of the variation in length of *Moina brachiata* ingested (Fig. 8). In the case of *Cyclops vernalis*, fish length was responsible for 77.5% of the variation in prey length. The mean lengths of *Cyclops vernalis* and *Moina brachiata* ingested by fish averaging 8.8 mm were 0.84 and 0.52 mm, respectively. Green sunfish of mean length less than 21.0 mm ingested longer *Cyclops vernalis* compared to *Moina brachiata* (Fig. 8). For larger fry the mean lengths of *Moina brachiata* ingested were greater than for *Cyclops vernalis*.

The relationship between prey size available and those selected varied with fish length. The difference between mean length of food item ingested and those available was initially negative (Fig. 9). This difference increased to positive values for larger fry. Negative values indicated that the mean length of a prey item in the food source was greater than the same prey item ingested by fish. As fish grew they utilized increasingly larger prey compared to the mean length of prey organism available to them.

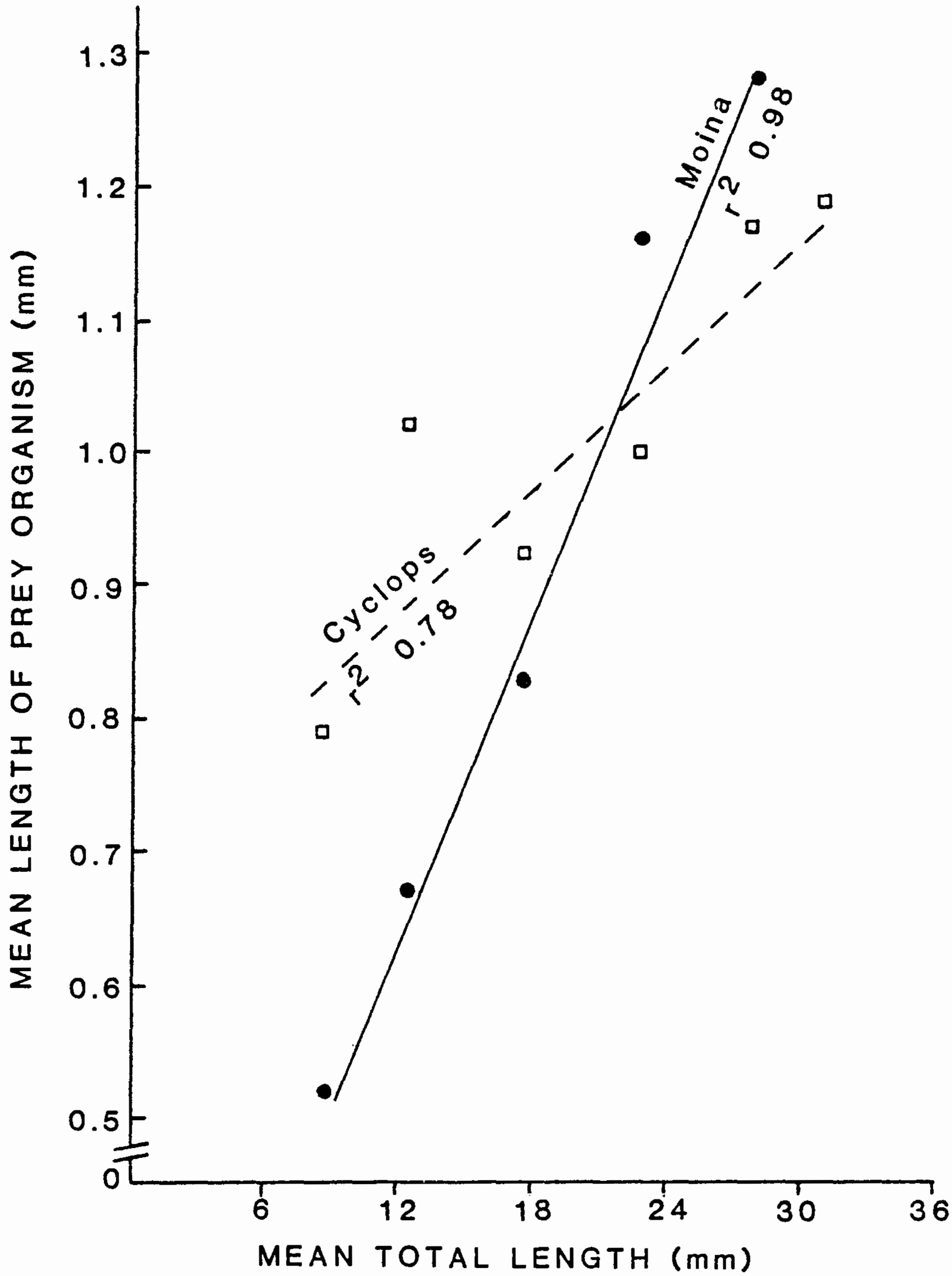

Figure 8. Relationship between mean length of prey items, Moina (●) and Cyclops (□), ingested and mean total length of green sunfish (Lepomis cyanellus) intensively reared on zooplankton for 31 days, 1983.

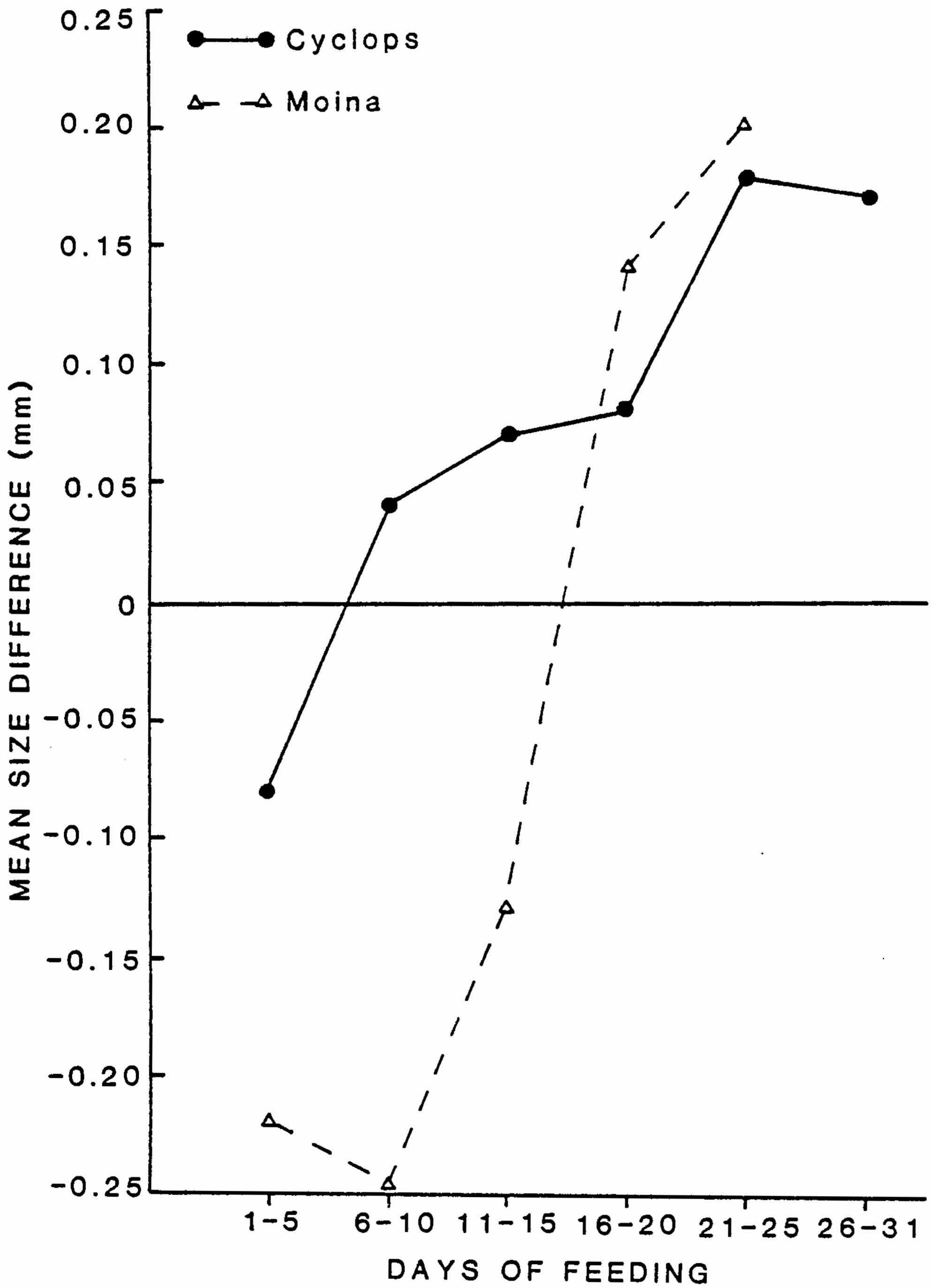

Figure 9. Temporal variation of the difference between mean length of prey in gut and among prey available to green sunfish (Lepomis cyanellus) intensively reared on zooplankton for 31 days, 1983.

Verification of Assumption

An important assumption determining the validity of the linear food selection index as an estimator of food selection by fishes is that the food sample from the food source or environment is an adequate representation of the relative proportions of the food organisms available to fish. The composition of food organisms in the food concentrate and that present in the fish tanks indicated that organisms selected as prey were fewer in experimental tanks than in the food source (Tables 5 and 6). Clacadoran egg cases which were selected against showed slight increases over their corresponding numbers in food source. However, chi-square analyses indicated that the observed differences were not significant ($P>0.05$) (Tables 7 and 8).

Table 5. Species composition of food fed to bluegill (*Lepomis macrochirus*) fry and in experimental tanks during 30 days of feeding, 1983.

	Food in experimental tanks				Food fed to bluegill fry			
JDATE [a]	*Cyclops vernalis*	*Moina brachiata*	Egg cases	*Potamocypris* spp.	*Cyclops vernalis*	*Moina brachiata*	Egg cases	*Potamocypris* spp.
229	288	239	74	0*	301	241	58	0*
232	408	101	92	0*	419	103	78	0*
236	403	103	80	15	410	112	65	13
239	493	0*	90	18	504	0*	79	17
243	436	0*	162	3	494	0*	104	0
246	395	0*	189	15	417	0*	170	13
248	315	0*	252	34	370	0*	200	30
250	359	0*	223	19	423	0*	149	28
254	405	0*	182	14	461	0*	125	14

[a] Julian date is the day of the year.

*Food organisms unavailable in food source.

Table 6. Species composition of food fed to green sunfish (*Lepomis cyanellus*) fry and in experimental tanks during 31 days of feeding, 1983.

	Food in experimental tanks				Food fed to green sunfish fry			
JDATE[a]	*Cyclops vernalis*	*Moina brachiata*	Egg cases	*Potamocypris* spp.	*Cyclops vernalis*	*Moina brachiata*	Egg cases	*Potamocypris* spp.
221	159	318	123	0*	181	316	103	0*
224	10	546	45	0*	16	564	20	0*
229	284	231	61	0*	301	241	58	0*
232	404	96	101	0*	419	103	78	0*
236	395	106	85	13	410	112	65	15
239	480	0*	110	17	504	0*	79	19
243	421	0*	177	0	496	0*	104	2
245	418	0*	163	14	444	0*	144	19

[a] Julian date is the day of the year.

*Food organism unavailable in food source.

Table 7. Two-way chi-square test table; comparison of species composition of food fed to bluegill (*Lepomis macrochirus*) fry and in experimental tanks during 30 days of feeding, 1983.

Organism	Chi-square	df	Prob.
Cyclops sp.	6.117	8	0.6341
Moina sp.	0.005	1	0.9462
Egg cases	8.348	8	0.4002
Potamocypris spp.	5.250	6	0.5122

Table 8. Two-way chi-square test table; comparison of species composition of food fed to green sunfish (*Lepomis cyanellus*) fry and in experimental tanks during 31 days of feeding, 1983.

Organism	Chi-square	df	Prob.
Cyclops sp.	3.816	7	0.7939
Moina sp.	0.344	4	0.9868
Egg cases	12.345	7	0.0898
Potamocypris spp.	1.812	3	0.4641

DISCUSSION

The diets of young sunfishes (Lepomis spp.) consist largely of zooplankton. Latta and Merna (1976) reported that bluegill fry utilized zooplankton almost exclusively as a food source. Siefert (1972) reported that the diet of bluegill fry (total length - 8.0 mm) consisted primarily of cladocerans and cyclopoid copepods. Young bluegills and green sunfish have been reported to exhibit similiar feeding habits (Werner 1969; Sadzikowski and Wallace 1976).

In the present study bluegill and green sunfish fry were found to prey mainly upon Cyclops vernalis and Moina brachiata. The rotifer, Brachionus spp. was not utilized by either species. Siefert (1972) observed that rotifers were important food items of bluegills of total length 7.0 mm or less. Beard (1982) found the rotifer, Polyarthra spp. to be an important food item of bluegills smaller than 8.0 mm. Latta and Merna (1976) rarely found rotifers in the stomachs of bluegill fry. Egg cases were seldom ingested by both green sunfish and bluegill fry in this study; this was consistent with the observations of Werner (1969) in Crane Lake, Indiana. Beard (1982) reported that bluegills 11.0-20.0 mm long diversified their diet to include ostracods. Sadzikowski and Wallace (1976) observed that ostracods were important food items of bluegills and green sunfish 29.0-70.0 mm long. In the present study bluegills and green sunfish were reared to a mean total length of 27.7-30.1 mm (31.0-32.0 mm maximum), yet the ostracod, Potamocypris spp. was never a major component of the diet. Latta and Merna (1976) also reported that ostracods were rare in the stomachs of bluegill fry.

In the present study green sunfish showed temporal variation in the selection of *Moina brachiata*. *Moina brachiata* were initially selected randomly and later selected for by fry of mean total length 18.9 mm and over. This variation in food selection could be attributed to growth of the fry. Siefert (1972) observed that cladocerans become more important food items in larger fry. Such temporal changes in prey selection have been observed in other fish species. Barger and Kilambi (1980) reported temporal variation in prey selection of shad (*Dorosoma* sp.) and attributed such changes to fish growth rather than changes in prey composition.

More food items were ingested during lighted hours than during night in the present study. This difference could be attributed to differential visibility of fry in light and darkness. Werner (1969) reported that bluegills are daylight feeders, depending on sight, to locate and capture their prey. Decreases in light intensity not only alter the relative visibility of prey (Werner and Hall 1974) but also acts as a refuge for prey through attenuation of contrast that makes prey less visible (Lythgoe 1966).

The selective nature of fish predation upon zooplankters is well documented (Ivlev 1961; Brooks and Dodson 1965; Galbraith 1967; Cramer and Marzolf 1970; Zaret 1972; Vinyard 1977). Prey species, size, conspicuousness, and escape ability are factors frequently cited as influencing prey selection. Characteristics of predatory behavior, such as preference as it relates to palatability and caloric value of prey, constitute important components of the predation process. Contrast between prey species, in terms of pigmentation, apparent size, and activity, are important factors of prey detection by visual predators (Ware 1972; Confer and Blades 1975; Elmore et al. 1983). Vinyard and O'Brien (1975) demonstrated that prey motion was important in prey choice of bluegills, although the extent of motion did not seem to affect selectivity. They further observed that at high prey densities, when more than one prey are often seen, bluegills based their selection of prey on apparent size rather than the probability of encounter alone. Apparent size of prey is a measure of the angle that the prey image forms on the retina of the predator. Optimal foraging theory predicts that predator fishes feed efficiently, in terms of net energy yield, by selecting optimal prey (e.g. Schoener 1969, 1971; Werner 1974).

Werner (1974) stated that optimal prey size was related linearly to prey body size. Optimal prey size is limited physically and bioenergetically by mouth gape and ease of prey capture (Werner 1974; Durbin 1974). In the present study, motility, pigmentation and apparent size were important in prey detection by fry but size of prey and energetic value were probably more important in the selection of a prey item. Except for cladoceran egg cases, prey items in the present study were motile (Ward and Whipple 1959; Pennak 1978) enough to attract fry. Brachionus spp. and cladoceran egg cases were probably not selected for because of their small size and lack of motility, respectively. Werner and Hall (1974) proposed that bluegills choose the most energetically rewarding prey to optimize energy intake. The lack of utility of egg cases to fish fry may have contributed to their negative selection.

Ward and Whipple (1959) stated that some cladoceran eggs pass through the gut of fish undigested. Elmore et al. (1983) concluded that body size and escape ability were important factors in young bluegill selection of diaptomid copepods. The capture successes of *Daphnia* and *Cyclops* by pumpkinseeds (*Lepomis gibbosus*) are reported as 100.0 and 80.0% respectively (Confer and Blades 1975). O'Brien et al (1976) also reported 100.0% bluegill capture success for *Daphnia*. The present study results indicated that *Cyclops vernalis* were selected more frequently than *Moina brachiata*. More frequent fry encounters with *Cyclops vernalis* could be a means of compensating for the difference in capture success. The jerky movement of *Cyclops* (Pennak 1978) probably attracted fry more than the hop and sink movement of *Moina*. Differences in prey size could also contribute to the differential selection observed. It would seem that fry encountered more suitably sized *Cyclops vernalis* than *Moina brachiata*. Hutchinson (1971) observed that cladocerans are wider and have greater volumes than copepods of the same length.

Size of prey item was found to be important in intraspecies selection. The size of prey item selected by green sunfish fry was linearly related to total length of the fish. It would seem the mouth or gape size increased isometrically with body length, at least during the study period, and that may explain the linear increase of ingested prey size with fish length. Hall et al. (1970) reported progressive selection of larger prey by young bluegills as the fish increased in size. In the present study the relationship between ingested prey size and bluegill length, although positive, was not linear. Werner and Hall

(1974) stated that structure of prey communities affects the diet breadth of a predator. Durbin (1979) stated that the efficient threshold size of prey may change under different circumstances of plankton availability, abundance, and size distribution. Eggers (1977) proposed that diet breadth of predators should change when the relative size of available prey changes. The apparent decrease in prey size ingested by larger bluegill fry was attributable to relatively smaller prey available to fry. Although, prey size distribution shifted downwards, bluegill fry fed optimally by selecting larger available prey.

CONCLUSIONS

Bluegill and green sunfish fry showed similar food selection in which *Cyclops vernalis* and *Moina brachiata* were the dominant component of the diet of both species. These sunfishes fed more intensively during lighted hours than in darkness, an indication that sight was an important factor in prey capture. The quantities of organisms ingested by bluegills increased isometrically with the size of fish. The relationship between mean number of prey organisms ingested and mean total length of green sunfish was curvilinear. Prey species, size, and motility appeared to be the most important factors determining prey selectivity. Time of day did not seem to influence diet composition, although active feeding was reduced in darkness. Bluegill and green sunfish fry selected size ranges of prey in relation to their lengths. The relationship of mean length of food item ingested to length of fry was linear and curvilinear for green sunfish and bluegills, respectively.

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