THE UNIVERSITY OF MANITOBA

A STUDY OF PREY PREFERENCE AND SELECTION BY CREEK CHUB, *SEMOTILUS ATROMACULATUS*, IN THE MINK RIVER, MANITOBA

by

G.E. (BUCK) NEWSOME

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES

IN PARTIAL FULFILMENT OF THE REQUIREMENTS

FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

DEPARTMENT OF ZOOLOGY

WINNIPEG, MANITOBA

JULY, 1975

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ABSTRACT

In the Mink River adult creek chub are selective feeders consuming mostly brook stickleback in early summer and crayfish in late summer despite the abundance of other species of potential prey. Johnny darters were the most highly preferred species of prey followed by cyprinids (pearl dace and common shiners), brook stickleback, and crayfish. Johnny darters were inaccessable to chub in the presence of a rocky substrate. The presence of vegetation reduced the accessability of brook stickleback. The presence of the cyprinid fright pheromone although detectable by chub had no influence on the preference of chub for cyprinids and did not appear to affect the accessability of cyprinids. An alternate mechanism controlling the accessability of cyprinids is discussed.

ACKNOWLEDGEMENTS

Dr. J.H. Gee provided considerable advice during the course of this project and I am particularly grateful for his criticisms and suggestions in the preparation of this thesis. I wish also to express thanks to Drs. C.C. Lindsey and K.W. Stewart for their help with certain sections of this thesis and to Drs. G.F. Atchinson and R.J. MacKay for their assistance with the statistical analysis of the data. S. Chalanchuk, P. Goossen, K. Machniak, R. Moshenko, F. Plummer and R. Weselowski provided most valuable field assistance. Special thanks to my wife, Austina, for her assistance in the field and lab., and for immeasurable support in preparing the intermediate draughts of this thesis. Financial assistance was provided through a grants-in-aid of research to Dr. J. H. Gee from the Northern Studies Committee and the Aquatic Biology Research Unit of the University of Manitoba.

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INTRODUCTION

During summer, adult chub (Semotilus atromaculatus) form schools in deep pools and channels of streams, and are piscivorous (Barber and Minckley 1971; Moshenko and Gee 1973). Barber and Minckley (1971) suggested that chub of their study area were non-selective in their choice of fish prey since they ate mostly common shiner (Notropis cornutus) which was an abundant species cohabiting the stream with chub. However, observations of Moshenko and Gee (1973) indicated that chub may be selective in their choice of fish prey. Adult chub in the population they studied ate brook stickleback (Culaea inconstans) almost exclusively even though this species occurred in lower densities than a number of other potential prey fishes. They postulated that the avoidance of other species, mostly cyprinids, was due to the cyprinid fright pheromone (Pfeiffer 1962; 1963; Reed 1969). The objectives of this study were: 1) to determine the degree to which creek chub prey selectively on fishes and 2) to describe some of the factors that influence selection of prey.

Ivlev (1961) considered selection of prey to be controlled by two major factors: preference of the predator and accessability of the prey. Preference is an inherent characteristic of the predator, determined by physiological properties such as innate inclination, degree of satiation and conditioning. Estimates of a predator's preference can be obtained by maintaining a similarity in the accessability of potential prey. In this situation selection of prey by a predator would reflect preference (Ivlev 1961). Accessability is a

more difficult parameter to investigate since it involves attributes of the predator and prey both of which can be further subdivided into contributing factors such as distribution, abundance, size, and behaviour (Ivlev 1961).

PLAN OF INVESTIGATION

An estimation of the degree to which creek chub prey selectively on fish was determined by comparing the proportion of each species of an edible size found in the environment occupied by chub with their proportion in the diet of chub. Significant differences in these proportions for any particular species would indicate selection or rejection. The extent to which accessability of prey influences their selection was determined by relating the frequency of different species in the diet of chub to their ranking in terms of preference. The preference of chub for different species of fish was determined in the laboratory by presenting chub with a number of dead, equally accessable, individuals of a number of species that chub commonly encounter in the Mink River. Experiments were designed to determine the effect of current, substrate, vegetation and abundance of alternate food on the accessability and resulting selection of prey by chub. Observations were also conducted in the field and laboratory to investigate the reaction of chub and potential prey to the cyprinid fright pheromone to determine if this affected accessability and selection of prey.

MATERIALS AND METHODS

Selectivity in Feeding by Chub

Eleven samples of creek chub and potential prey fishes were collected from four sites (500-700 m apart) in the middle zone (Gibbons and Gee 1972; Moshenko and Gee 1973) of the Mink River, Manitoba, during June-August, 1972 (Appendices 1 and 2). To sample fish, a deep channel or sheltered pool (Moshenko and Gee 1973), 15-20 m in length, was quickly enclosed by barrier nets (6.2 m x 1 m, 3.5 mm mesh) to block the possible escape of fishes. Then a two-man seine (1.4 m x 2.0 m, 3.5 mm mesh) was used to capture all fishes. On capture, fishes were placed in containers of water and seining continued in all portions of the site until no further captures were made.

Since fish become a major component of the diet of creek chub approximately 80 mm fork length (Moshenko and Gee 1973), chub greater than 90 mm standard length were kept for analysis of stomach contents. They were killed in MS222, a solution of 10% formalin was injected into the anterior portion of the digestive tract to arrest further digestion, and fixed in 20% formalin. Of the remaining fishes captured, every second one was preserved so that estimates of the densities of potential prey fishes occuring in the same environment as the creek chub could be made. The rest were returned to the stream. Measurements of depth, temperature, flow, and area sampled were recorded upon completion of the sampling procedure (Appendix 1). Samples obtained were returned to the laboratory and washed in water for 24 hours and then preserved in 70 percent isopropyl alcohol.

Fish were identified and standard lengths (S L) measured ($\pm$ 1 mm).

Stomach contents of chub greater than 90 mm S L were removed and classified according to their dominant food item (by weight). Creek chub lack a well defined stomach and therefore the region between the esophagus and the second loop of the digestive tract was considered to be the stomach. Non-cypriniform fishes found in stomach contents of chub were identified by the shape of the opercular bone (Appendix 3) while species-specific differences in pharyngeal bones were used to identify cypriniform species (Appendices 3 and 4).

Creek chub were divided into two groups to simplify analysis of diet: Group 1 (90-129 mm S L), and Group 2 (>129 mm S L).

Size of fish that each group of chub caught and ate was determined from the estimated length of fish found in the stomachs of chub. These estimates were established from regression equations relating the logarithm of the standard length to the logarithm of the length of the anterior margin of the opercular bone for each of the 10 species of fish commonly found with the creek chub in the middle zone of the Mink River (Appendix 5). These measurements were used to correct the observed densities of potential prey fishes so that only densities of fishes that were 'edible' by chub were used in determining the degree of prey selectivity.

Electivity indices (Ivlev 1961) were calculated, where sufficient data were available for each of the fish species consumed by creek chub. This index (E) compares the proportion of food items observed in the diet (r_i) with the proportion of the food item observed in

the environment (p_i) in the following manner,

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

The index varies between plus and minus one, so that indices greater than zero indicate that food items occur in the diet in a greater proportion than in the environment. Negative indices indicate an avoidance or inaccessability of the potential food item, and indices near zero indicate that the item is chosen in equal proportion to the occurrence of the item in the environment. Potential prey fishes too large to be eaten by chub were not considered in these calculations.

Feeding Preference of Creek Chub

Preference experiments were carried out in a 1200 l round fiberglass tank (1.81 m diam) filled to a depth of 0.6 m and supplied with a constant flow (500 l/h) of water at 12°C and 13 h period of light. The tank was screened with black curtains but observations could be made without disturbing the fish through five plexiglass windows in the sides of the tank below the water surface.

Eight chub (105-140 mm S L) were used as predators in all the experiments. Whenever possible chub from the Mink River were used but due to a winter-kill (1972-1973) in the study area chub became unavailable. In some tests chub from the Norquay Channel, Manitoba, were used. Immediately after collection, chub were placed in a 45 l aquarium at 12°C for 48 h. Both Norquay Channel and Mink River chub had been feeding on crayfish (Orconectes virilis) almost exclusively prior to capture (from analysis of feces). Chub were then placed in the experimental tank and acclimated for 5-7 days

without food.

Two experiments each consisting of five replicates were performed. The first experiment used Norquay Channel chub and the second Mink River chub as predators. Prey, 10 each of brook stickleback, johnny darter (Etheostoma nigrum), pearl dace (Semotilus margarita), common shiner and crayfish, were killed by freezing. Swimbladders were punctured to ensure that all prey settled to the bottom of the experimental tank. The five prey species were randomly scattered in the tank 5-10 minutes before the beginning of the light period. Food items not consumed were removed and counted 12 h after the beginning of each replicate.

To test the possible effect of the fright pheromone on choice of prey by creek chub a preparation of the pheromone was added to the water during the first preference experiment. The pheromone was prepared by scraping the skin of a large pearl dace and washing in 2 l of water. This solution was added to the experimental tank at a rate of one drop per minute using a Mariotte bottle (Leduc 1966). It was considered that by maintaining a constant presence of the pheromone during this experiment, the effect of the fright reaction on prey choice by creek chub would be reduced or eliminated. This procedure was not followed during the second preference experiment so that any differences in prey selection would either be the result of the presence of the pheromone or of differences in preference between Norquay Channel and Mink River chub. To reduce possible contamination with fright pheromone of the dead cyprinid prey, they were immersed in tap water for 30 min and rinsed with distilled water before being scattered in the experimental tank.

Factors Affecting Selection of Prey

Five selection experiments were performed (Table 1) in the same tank utilizing the same eight predators from the Norquay Channel and Mink River as in the preference experiments. Unlike the preference experiments, chub had access to the 'prey spectrum' for 24 h. All prey were living and were removed, counted, and new prey added each day at the beginning of the light cycle. These experiments were conducted so that comparisons in food selection by creek chub from both live and dead (preference experiments) prey 'spectra' could be made, and to determine the effect of various combinations of current, substrate, vegetation, and high density of crayfish, on the choice of prey by chub.

The first and second experiments were performed immediately following the respective preference experiments in the bare experimental tank to examine selection of live prey by Norquay Channel and Mink River chub. Results of these two experiments were then compared with those of the two preference experiments, which used dead prey, as described above.

The remaining three selection experiments were performed to investigate possible environmental factors which might influence prey selection by creek chub. These experiments were conducted in sequence using Norquay Channel chub following the completion of the first selection experiment described above (Table 1).

The third experiment tested the effect of presence and/or absence of current and substrate on selection of prey. Current (20 cm/sec) was maintained in the circular tank by using two submersible pumps. Substrate consisted of rocks, 3-10 cm diam glued to four removable fiberglass plaques.

TABLE 1. Summary of the conditions used in each test of the five selection experiments conducted using Norquay Channel or Mink River creek chub. Five replicates trials were performed in each test. [STBK=brook stickleback, JD=johnny darter, PD=pearl dace, CS=common shiner, CRFH=crayfish, + present, - absent]

Sel. Exp.	Test No.	Origin of Predators	No. Prey per Replicate	Features investigated		
				current	substrate	vegetation
1	1	Norquay Ch.	10 each of STBK, JD, PD, and CS	-	-	-
2	1	Mink R.	10 each of STBK, JD, PD, CRFH	-	-	-
3	1	Norquay Ch.	10 each of STBK, JD, PD, and CS	+	-	-
3	2	"	"	+	+	-
3	3	"	"	-	+	-
4	1	"	10 each of STBK, JD, CRFH, 5 each of PD and CS	+	+	-
4	2	"	"	+	+	+
4	3	"	"	+	-	+
5	1	"	5 STBK, 3 JD, 5 PD, 1 CS, 26 CRFH	+	+	+

The fourth experiment was designed to investigate the effect of substrate and vegetation on the choice of prey by chub. 'Vegetation' consisted of dark green plastic sheeting cut into strips anchored to a hardware cloth frame and bouyed up by small pieces of styrofoam.

The fifth experiment was conducted to investigate the effect of large numbers of crayfish on the choice of prey by the chub. The relative numbers of prey used closely resembled the occurrence of the same prey in the Mink River during June of 1972. Current, substrate, and vegetation were provided as described above.

A pool was found in the middle zone of the Mink River which afforded excellent conditions for observing behaviour of chub toward potential prey and responses to the cyprinid fright pheromone. A total of approximately 10 hours were spent observing the chub using facemask and snorkel, the longest single observation period being 1.5 hrs.

Field tests to determine the response of chub to the cyprinid fright pheromone and its possible effect on prey selection were performed on June 29, July 9, and July 26, 1972, as follows. Cyprinids (pearl dace, blacknose dace (Rhinichthys atratulus), or common shiners) and non-cyprinids (brook stickleback or johnny darter) were offered separately to a school of creek chub and their behaviour recorded. The offered fish was pithed, squashed slightly, and held tightly between thumb and first finger. The number of attempts to seize it by large creek chub were counted for one minute. The procedure was repeated only four times on any one particular occasion, twice for non-cyprinid and twice for a cyprinid prey in sequence as follows:

1) non-cyprinid prey presented (1 min),

2) recovery period (15 min),

3) cyprinid prey presented (1 min),

4) recovery period (15 min),

5) non-cyprinid prey presented (1 min),

6) recovery period (15 min),

7) cyprinid prey presented (1 min).

Steps 1 and 3 were designated first test results and those at steps 5 and 7 as second test results.

Laboratory experiments were also conducted to observe and quantify the response of creek chub to three sources of the fright pheromone. Five chub (between 100 and 120 mm S L) were placed in a 270 l modified stream tank (Gee and Bartnik 1969) with a running water supply at 12^{o}C. An extract of the pheromone was prepared as outlined by von Frisch (1941), using a sacrificed cyprinid in three experiments (creek chub, pearl dace, and blacknose dace respectively). The test tank (45 cm x 90 cm x 50 cm) was isolated from external visual stimuli and the extract introduced using an hydraulically-operated remote control syringe. The observation side of the aquarium was marked off in four equal horizontal rows such that the depth position, using the eye of each fish, could be recorded at the end of each minute of observation. Location of chub was recorded at one minute intervals for 15 minutes in the first experiment, and 10 minutes in the second and third experiments, prior to introduction of the fright pheromone. After introduction of the pheromone the location of the chub was recorded for 10 minutes in the first experiment and for 5 minutes in the second and third.

RESULTS

Selectivity in Feeding by Chub

Summer diet of creek chub. Fish were the major food of group 1 (90-129 mm S L) chub through most of the summer although there was a general decline in the proportion of stomachs containing them as the season progressed (Table 2). Crayfish were the dominant item in only 16-32% of the stomachs examined although they were the major food item during the last sampling period. 'Other' food items (primarily aquatic insect larvae, but also terrestrial insects, molluscs and leeches) were dominant in 29% or less of the stomachs examined.

Group 2 (> 129 mm S L) chub change their diet very significantly during the summer (Table 2). In early June the dominant food item was fish which were found in 65% of the 31 stomachs examined. Crayfish accounted for 13% and aquatic and terrestrial insects only 6%. By early July, the proportions of fish and crayfish were reversed with little change in the contribution by aquatic and terrestrial insects. Crayfish continued to increase as the dominant food item through July at the expense of fish but by early August a sharp decline was observed.

In the August sample a substantial increase in the proportion of empty stomachs among both groups of creek chub was also observed.

Size of fish consumed by creek chub. Group 1 chub consumed significantly ($p < 0.001$; analysis of variance) smaller prey than did group 2 (Fig. 1). The size range of prey that each group caught and ate were considered to be plus and minus two standard deviations of the mean. Thus creek chub of group 1 and 2 could catch and eat prey

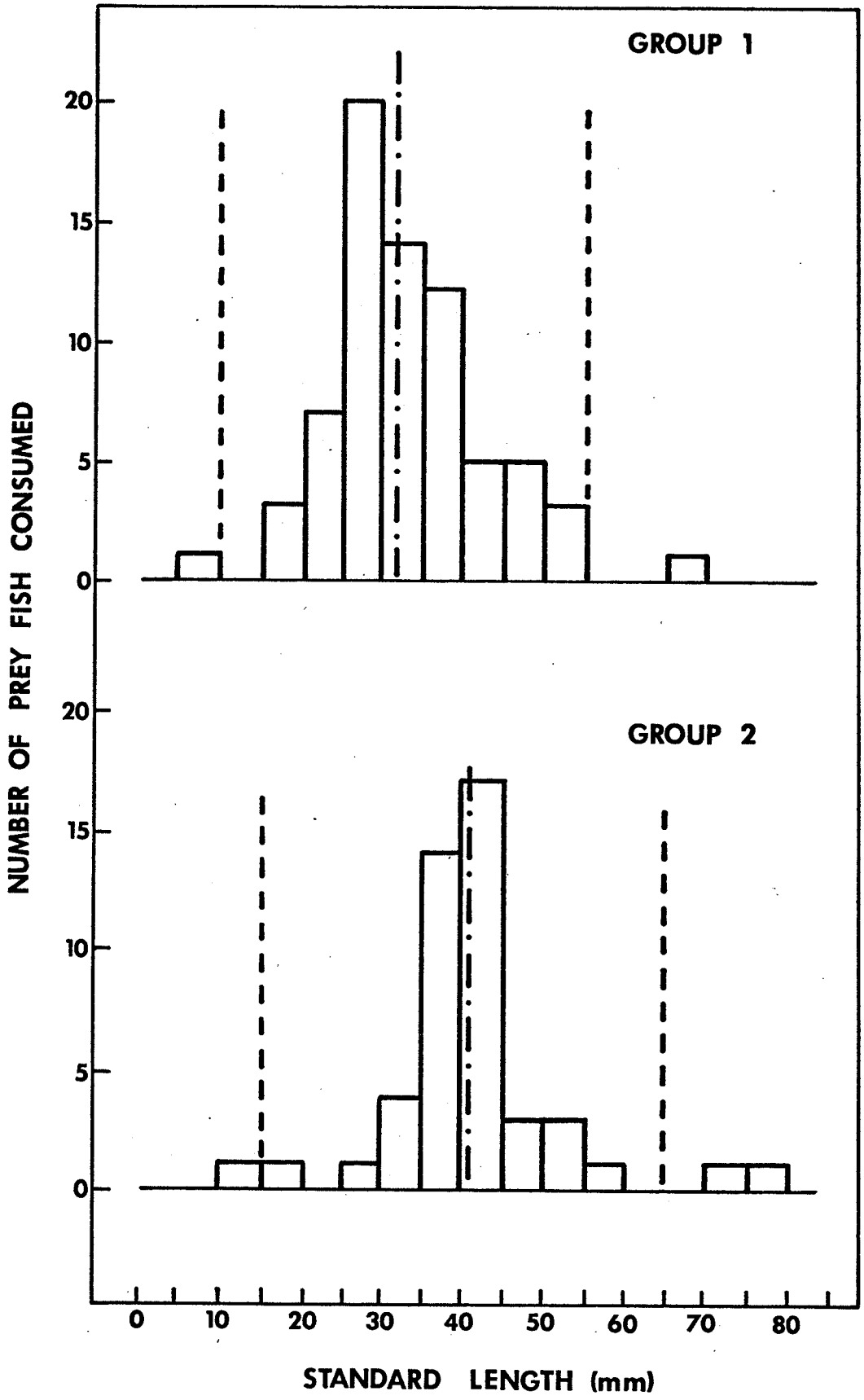
TABLE 2. Major components of the summer diet of creek chub expressed as a percent of the total number of stomachs examined, each of which were classed according to the dominant food item by weight.

Creek chub Group	Date	Percent of stomachs in which the dominant prey were: Fish	Crayfish	'Other'	% of stomachs empty	No. of stomachs examined
1 (90-129 mm S L)	Jun 6-7	56	16	28	0	25
	Jul 7-9	39	32	29	0	38
	Jul 25-26	63	21	8	8	24
	Aug 10	13	29	13	46	24
2 (> 129 mm S L)	Jun 6-7	65	13	6	16	31
	Jul 7-9	26	61	9	4	23
	Jul 25-26	0	82	9	9	11
	Aug 10	12	20	4	64	25

FIGURE 1. Frequency distribution for the estimated standard lengths of prey fish found in the stomachs of size groups 1 and 2 creek chub.

-·- = mean

--- = two standard deviations of the mean, rounded to the nearest class interval.


GROUP 1
GROUP 2
NUMBER OF PREY FISH CONSUMED
0
5
10
15
20
0
10
20
30
40
50
60
70
80
STANDARD LENGTH (mm)

between 10-50 mm and 15-60 mm S L respectively.

Relative frequency of stickleback and other fishes in diet of creek chub and in environment. Although large numbers of non-stickleback prey occur with the creek chub, they contribute very little to the fish diet. This is especially evident among group 2 chub (Fig. 2).

In late summer there is no apparent relation between the proportion of brook stickleback present in the stream and their occurrence in the diet of group 1 chub (Fig. 2). Within almost all size classes of potential prey fish that the chub can handle, non-stickleback fish outnumber the stickleback although the occurrence of non-stickleback fish in the diet is very low.

Electivity indices of prey selection by both groups of creek chub, calculated for brook stickleback and 'other' fishes are given in Table 3, based on the data for early and late summer (Appendix 7 and 8). The indices indicate a strong positive selection for brook stickleback and an avoidance of 'other' fishes by both groups of chub.

Feeding Preference of Creek Chub

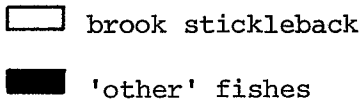
There was no significant difference (goodness-of-fit test, Sokal and Rohlf 1969; see Appendix 9) between Norquay Channel and Mink River creek chub in the proportions of dead prey consumed, shown as follows (refer to Table 1 for the key to symbols used for prey fishes):

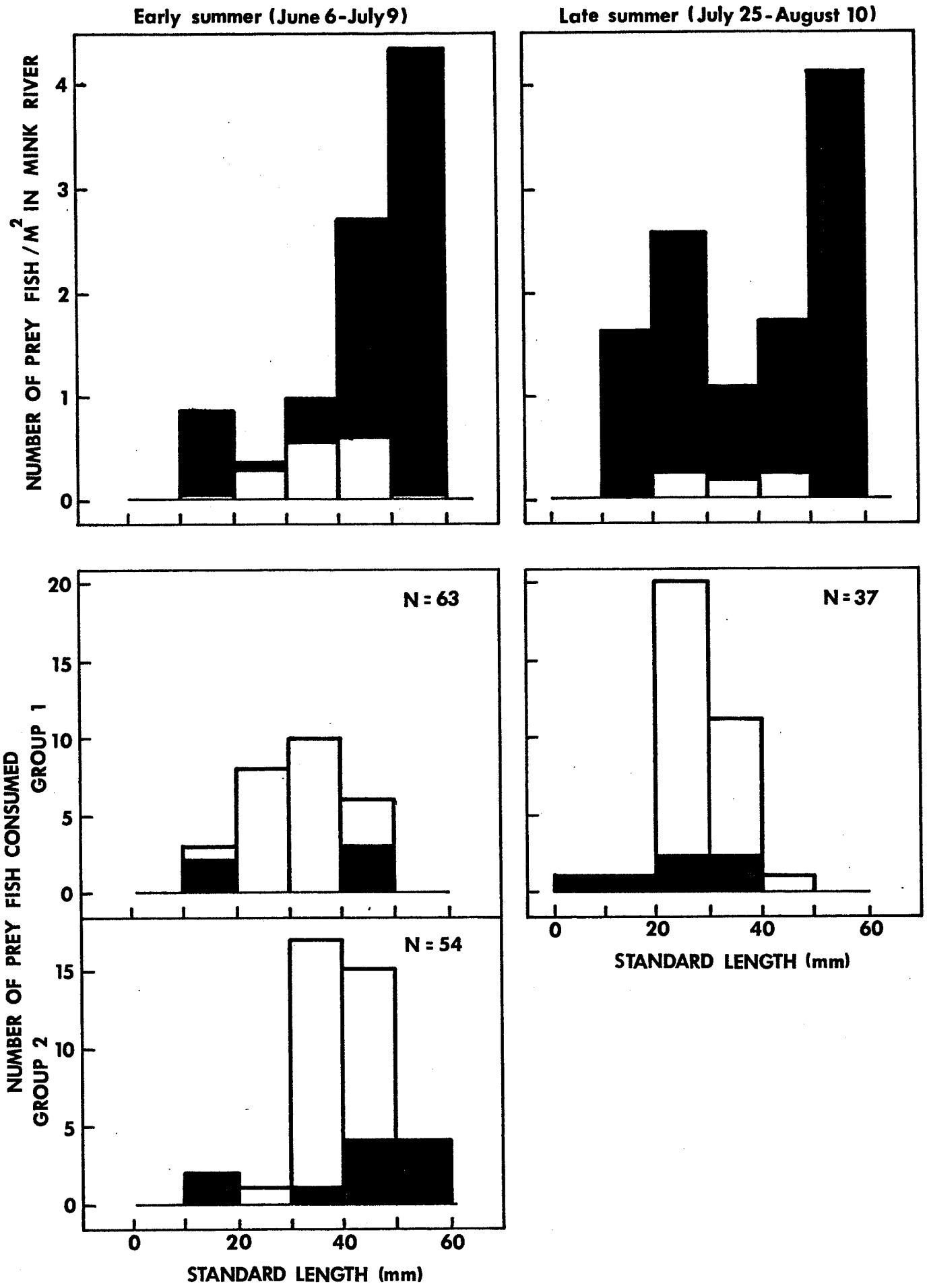
Species	STBK	JD	PD	CS	CRFH	Total
No. of prey consumed:						
Expt. 1, Norquay Ch. chub	13	46	22	25	2	108
Expt. 2, Mink R. chub	10	43	26	13	5	97
	23	89	48	38	7	205

TABLE 3. Electivity indices by both size groups of creek chub, during early and late summer, toward brook stickleback (STBK) and 'other' fishes. The column 'density of fishes present', represents all fishes in the size range 'edible' by creek chub.

Chub Size Group	Time	No. of STBK consumed	Total fishes consumed	Density of STBK present (m^{-2})	Density of fishes present	Electivity	
						STBK	'Other'
1	early summer	22	32	1.42	8.22	0.60	-0.45
2	early summer	29	45	1.41	19.68	0.63	-0.41
1	late summer	30	36	0.67	8.59	0.83	-0.69
2	late summer	1	2	0.67	10.43	0.77	-0.30

FIGURE 2. Frequency distribution of prey fish found in stomach contents of creek chub compared with densities of prey fish in the Mink River. A figure for group 2 chub in late summer is not given since only two fish were eaten.




Early summer (June 6-July 9)
Late summer (July 25-August 10)
NUMBER OF PREY FISH / M2 IN MINK RIVER
0
1
2
3
4
NUMBER OF PREY FISH CONSUMED
GROUP 1
GROUP 2
N = 63
N = 37
N = 54
0
5
10
15
20
0
20
40
60
STANDARD LENGTH (mm)
STANDARD LENGTH (mm)

Pooling the results of the two preference experiments demonstrated that a definite preference was shown by the chub for at least one of the five species of prey ($p < 0.001$). Ivlev's index of electivity was calculated on the total number of prey consumed in both experiments. Johnny darters were highly preferred while brook stickleback and crayfish were strongly rejected, shown as follows:

Species	JD	PD	CS	STBK	CRFH
Electivity index	0.37	0.08	-0.04	-0.28	-0.71

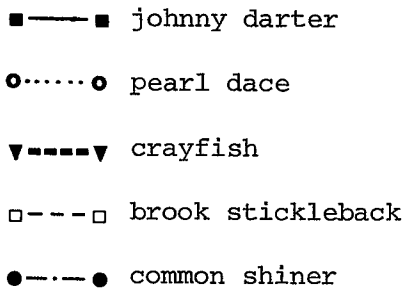
However, inspection of the results (Appendix 9) also showed a slight change in the degree of selection for each prey consumed over the period of five trials (Fig. 3). Electivity for johnny darters changed very little from the first to the fifth trial. Electivity for both pearl dace and common shiners fluctuated more widely about zero, while, the electivity of creek chub toward both stickleback and crayfish decreased with time. The overall effect caused a decline in the total number of prey consumed but preferred items generally rose in their contribution to the chub's diet while non-preferred items declined.

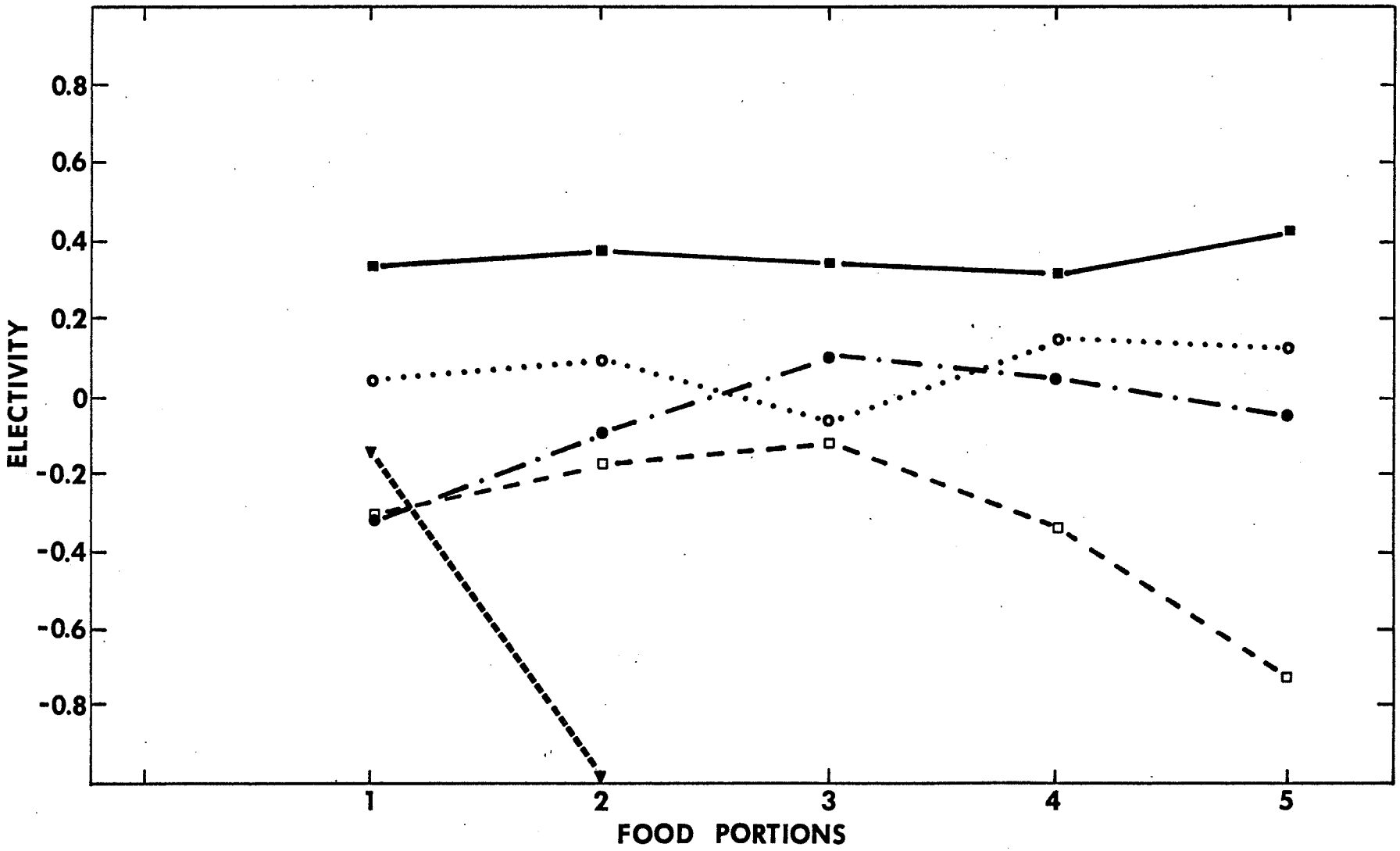
Factors Affecting Prey Selection

Selection of live prey. The pooled results of the two experiments in which Norquay Channel and Mink River creek chub selected food from a 'spectrum' of live prey (Appendix 10) are given as follows:

Species	STBK	JD	PD	CS	CRFH	Total
No. of prey consumed:						
Norquay Ch. chub	0	30	2	3	-	35
Mink R. chub	34	12	18	-	5	69

FIGURE 3. Changes in the electivity of creek chub toward five prey species over five food portions (see text).




0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
ELECTIVITY
1
2
3
4
5
FOOD PORTIONS

Analysis showed a significant ($p < 0.001$, test of independence omitting common shiner and crayfish data) lack of independence in the selection of live prey between Norquay Channel and Mink River chub. Therefore Norquay Channel and Mink River chub select prey differently. Comparison of these results, in a similar manner, with the results of the preference experiments also showed a significant ($p < 0.001$) difference between the selection of live and dead prey by both Norquay Channel and Mink River chub (Appendix 10). However, the reasons for the differences in prey selection were found to be different upon closer examination of the data.

Selection of live prey by Norquay Channel chub showed a disproportionate decrease in the numbers of brook stickleback, pearl dace, and common shiners consumed when compared with their selection from a 'spectrum' of dead prey. However, johnny darters were the dominant selection from both live and dead prey 'spectra' although relatively more live than dead johnny darters were consumed as follows:

Species	JD	Others (STBK + PD + CS)	Total
No. of prey consumed:			
Dead	46	60	106
Live	30	5	35

On the other hand, examination of the selection by Mink River chub from 'spectra' of live and dead prey showed that the dominant item consumed differed. From a 'spectrum' of live prey, the dominant choice was brook stickleback whereas from a 'spectrum' of dead prey Mink River chub chose johnny darters. At the same time, selection of other components from both live and dead prey 'spectra' did not differ significantly as follows:

Species	STBK	JD	Others (PD + CRFH)	Total
No. of prey consumed:				
Dead	10	43	31	84
Live	34	12	23	69

Comparisons of the total numbers of live and dead prey consumed by Norquay Channel and Mink River chub also demonstrated that Norquay Channel chub consumed proportionately fewer ($p < 0.001$, 2x2 test of independence) live than dead prey than did Mink River chub as follows:

Prey condition	Dead	Live	Total
No. of prey consumed:			
Norquay Ch. chub	108	35	143
Mink River chub	97	69	166
Total	205	104	309

Effects of current, substrate, and vegetation on prey selection.

Analysis of experiments (Appendix 11) comparing selection by chub from a 'spectrum' of live prey in the presence and absence of current and a rock substrate demonstrated that current had no significant effect on prey choice as follows:

Species	STBK	JD	PD	CS	Total
No. of prey consumed:					
current absent	15	38	3	5	61
current present	10	34	3	4	51

However, in the presence of a rock substrate, a significant ($p < 0.001$) change in selection of prey was observed as follows: