M. Ted Tyndall. SEASONAL AND DIEL FEEDING PATTERNS AMONG JUVENILE FISH IN BOND CREEK, BEAUFORT COUNTY, NORTH CAROLINA. (Under the direction of Charles W. O'Rear, Ph.D.) Department of Biology, July 1987.

The seasonal and diel feeding pattern of spot *(Leiostomus xanthurus)*, Atlantic croaker *(Micropogonias undulatus)*, southern flounder *(Paralichthys lethostigma)*, and bay anchovy *(Anchoa mitchilli)* were examined during their residence in the midreaches of Bond Creek. Stomach analysis in addition to estimates of the abundance of zooplankton and benthos indicated that spot and Atlantic croaker are opportunistic feeders. The items most often found in the stomachs were usually those items exhibiting a seasonal peak in abundance. Southern flounder however, extensively utilized mysids regardless of the season and exhibited a secondary piscivorous feeding habit. Bay anchovy were found to be zooplanktivores utilizing larger zooplankton with increasing size.

Little diel difference was seen in the type of prey consumed. Benthos however, were consumed more frequently at night by spot in early spring and late summer and in early summer by Atlantic croaker.

Diet breadths were widest in spot and Atlantic croaker and narrowest in southern flounder and bay anchovy. Diet overlap values were high for all six combinations. Mysids were the most selected prey using Ivlev's electivity index while calanoid copepods were the most avoided prey. Food source was not limited in Bond Creek during the study period consequently the four species occupied similar niches within Bond Creek.

SEASONAL AND DIEL FEEDING PATTERNS AMONG JUVENILE FISH IN BOND CREEK, BEAUFORT COUNTY, NORTH CAROLINA

A Thesis

Presented to

The Faculty of the Department of Biology

East Carolina University

In Partial Fulfillment

of the Requirements for the Degree

Master of Science in Biology

by

M. Ted Tyndall

July 1987

SEASONAL AND DIEL FEEDING PATTERNS
AMONG JUVENILE FISH IN BOND CREEK
BEAUFORT COUNTY, NORTH CAROLINA

by

M. Ted Tyndall

APPROVED BY:

DIRECTOR OF THESIS — Charles W. O'Rear, Ph.D.

COMMITTEE MEMBER — Mark M. Brinson, Ph.D.

COMMITTEE MEMBER — Vincent J. Bellis, Jr., Ph.D.

COMMITTEE MEMBER — Ronald G. Hodson, Ph.D.

CHAIRPERSON OF THE DEPARTMENT OF BIOLOGY — Charles E. Bland, Ph.D.

DEAN OF THE GRADUATE SCHOOL — Joseph G. Boyette, Ph.D.

ACKNOWLEDGEMENTS

This study was part of a project conducted by the Institute of Coastal and Marine Resources which was funded by Texasgulf Inc. ICMR and the Biology Department of East Carolina University provided the equipment and facilities for successful completion of this project. This study would not have been possible without the early guidance and direction from the late Dr. Thomas J. Lawson.

I would like to thank Dr. Charles W. O'Rear my committee chairman and members of my thesis committee, Dr. Mark M. Brinson, Dr. Vincent J. Bellis Jr., and Dr. Ronald G. Hodson for their helpful comments and suggestions.

I would also like to acknowledge Loede Harper for helping with the data collection and processing, and Susan Holth for typing the manuscript.

Special thanks to my wonderful parents and B.J. for their constant support and companionship.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

The juvenile fish communities of shallow estuarine tributaries in the southeastern United States are composed of transient species along with a few permanent resident species (Miller et al. 1984). These transient species immigrate into the shallow tributaries as postlarvae and maintain residency until they emigrate as juveniles (Carr and Adams 1973, Chao and Musick 1977, and Weinstein 1979). During this residence time, competition for habitat and food resources is great (Stickney et al. 1975; Currin et al. 1984). For these abundant populations to coexist, a resource partitioning or niche separation must occur.

Christiansen and Fenchel (1977) described niche separation of populations using three main dimensions involving time, habitat, and resource. Feeding-habit studies involving several species of fish have documented various factors involved in resource partitioning including differences in feeding periods (Kjelson et al. 1975; Hobson and Chess 1976), size differences and functional morphologies (Chao and Musick 1977; Keast 1985), habitat preference (Thorman 1983), and food partitioning (Kinch 1979; Galat and Vucinich 1983; MacDonald and Green 1986). However, as Schoener (1974) suggested, a complete understanding of resource partitioning involves examination of the whole community including analysis at the individual level as well as the population level and not just a documentation of the differences in diet among the species. An understanding of the food resources available for each size class of all species that co-occur must be included. Simple documentation of prey items eaten by each species and size class during each season ignores competition among the species and size classes.

Trawl data collected from a small tributary of the Pamlico River in 1980 indicated that three transient species and one resident species comprised over 90% of the total juvenile fish catch (Lawson 1981). These four species were spot *(Leiostomus xanthurus)*, Atlantic croaker *(Micropogonias undulatus)*, southern flounder *(Paralichthys lethostigma)*, and bay anchovy *(Anchoa mitchilli)*. The diets and modes of feeding of these four species have been extensively documented. Spot and Atlantic croaker have been classified as opportunistic feeders utilizing the most abundant and available prey. Prey items found in the stomach have included copepods, polychaetes, and bivalve siphons (Darnell 1958; Kjelson et al. 1975; Stickney et al. 1975). Southern flounder are more selective in their feeding habits frequently choosing mysids and fish (Darnell 1958; Powell and Schwartz 1979). Anchovies have been described as zooplanktivores and utilize prey including copepods and mysids (Detwyler and Houde 1970; Schwartz 1980).

Unfortunately, most of the studies only documented diet differences among the species with seasonal variations. Many studies attempted to explain the resource partitioning but failed to have the ancillary biological data necessary to answer questions involving prey abundances, diel effects, or possible ontogenetic changes in feeding habits.

The purpose of this study was to determine the feeding habits of these four species of juvenile fish in a North Carolina estuary and to assess any niche separation or overlap among them. This assessment involved the testing of one major hypothesis and three sub-hypotheses:

1) Niche separation exists among the species as a result of differences in diets.
   A) Species exhibit seasonal differences in diets.
   B) Species exhibit diel differences in diets.
   C) Species exhibit varying degrees of selectivity in diet.

MATERIALS AND METHODS

This study was conducted in the midreaches of Bond Creek which is located near the mouth of South Creek, a major tributary of the Pamlico River (Figure 1). Eight sampling trips were made between October 1980 and October 1982. Four species of juvenile fish (spot, Atlantic croaker, southern flounder, and bay anchovy) were collected during five consecutive seasons through December 1981. Zooplankton were collected during March and June 1981 while benthos were sampled over five consecutive seasons from September 1981 through October 1982. Since aquatic organisms are often dependent upon water temperature throughout several life stages and not on the calendar dates, the collection dates were categorized into seasons according to water temperature (Table 1).

For stomach analyses, a diel series of trawl samples was taken during each season. Sampling times were scheduled so that each diel series coincided with the two predicted lunar high and low tides during the day and night.

Juvenile fish were collected with a 4.0-m, two-seam trawl made of 6.4-mm bar mesh equipped with a cod end bag of 3.2-mm mesh. The stomachs of all large fish (> 25mm) were injected with a buffered formalin solution within approximately 1 h after collection to stop digestion. Then the entire trawl catch was preserved in a 10% buffered formalin solution.

Zooplankton were also collected during the diel series using two 250-*um* mesh conical nets with a mouth area of 800 cm^2. The nets were

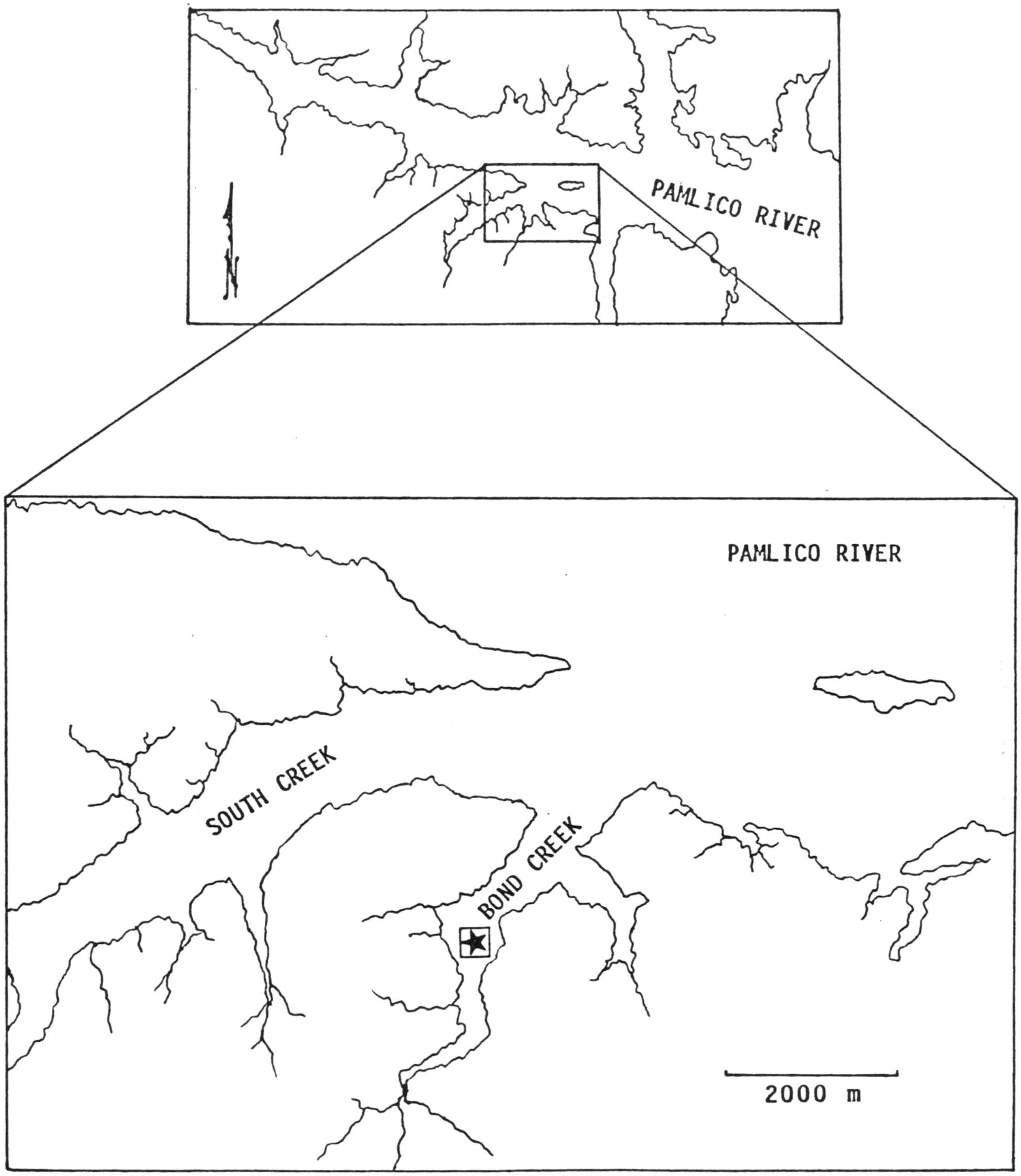

Figure 1. Location of Bond Creek indicating the area sampled.

Table 1. Collection dates, temperature ranges, and seasons during the 1980 - 1982 Bond Creek study. The data set for each date is indicated.

Collection Date	°C	Season	Data Set
October 27-28, 1980	13.0-14.6	Late Fall	Stomach contents
March 5-6, 1981	11.5-14.0	Early Spring	Stomach contents Zooplankton
June 8-9, 1981	26.0-29.2	Early Summer	Stomach contents Zooplankton
September 22-23, 1981	21.0-25.0	Late Summer	Stomach contents Benthos
December 21-22, 1981	3.2 - 5.8	Winter	Stomach contents Benthos
April 20-21, 1982	18.4-19.8	Late Spring	Benthos
August 17-18, 1982	27.0-29.6	Summer	Benthos
October 20-21, 1982	17.6-18.6	Early Fall	Benthos

mounted on rectangular aluminum frames welded together so that they could be towed simultaneously. Replicate samples were collected from just below the water surface and, using an aluminum sled, from just above the creek bottom. Each net was equipped with a General Oceanics flowmeter provided with a slow speed rotor. The two nets were towed for 2.5 min at a speed of approximately 2 km/h, after which their contents were pooled. All samples were preserved in 10% buffered formalin.

Benthos were sampled using a 15.2 x 15.2 x 22.9-cm Ekman grab. Triplicate benthic samples were taken with each benthic sample consisting of the pooled contents of three grabs washed through a 500-*um* mesh sieve and preserved in formalin. The total area sampled was approximately $0.07m^2$.

Surface and bottom temperature, salinity, and dissolved oxygen concentration were measured during each series of sample collections. A Yellow Springs Instrument Model 33 STC meter was used to measure salinity and temperature, while a Model YSI 51A oxygen meter was used to measure dissolved oxygen concentration.

For each set of trawls, three specimens of each species were selected and their standard length measured to the nearest mm. Each was then weighed to the nearest 0.1 g. The stomachs of these individuals were then removed for content analysis. The contents were sorted in a Petri dish, identified to the lowest taxonomic level practicable, food items enumerated and then oven dried at 60°C for 24 h.

The zooplankton samples were subsampled volumetrically. All organisms were then sorted and identified to the lowest taxonomic level practicable. The volume of water filtered by each net was then calculated and the number of organisms/m^3 calculated for each taxa.

Benthic samples were emptied onto a 500-*um* mesh sieve for thorough washing and returned to the jar for staining with Rose Bengal. All organisms were sorted, identified to the lowest taxonomic level practicable and counted. Organisms were then reported in number/m^2.

Stomach contents were reported in four major food groups as in Chao and Musick (1977) and Hodson et al. (1981): macrozooplankton, microzooplankton, benthos, and fish. Unidentifiable material (organics) and plant debris (detritus) were also noted. Frequency of occurrence, percent composition by number, and percent composition by dry weight were determined.

Diet overlap (α) which indicates the extent to which two particular species are utilizing the same prey items was calculated for each pair of fish using Schoener's index (Keast 1985):

$$\alpha = 1 - 0.5\ [\sum_{i=1}^{n}(P_{ij} - P_{ik})]$$

in this equation P_{ij} is the proportion of the i^{th} prey consumed by species j, and P_{ik} is the proportion of the i^{th} prey consumed by species k.

Diet breadth (B) which indicates the relative range of prey eaten was also calculated according to the method described by Keast (1985):

$$B = 1/(P_i)^2$$

where P_i is the proportion of the prey category.

Ivlev's index of electivity (E), as described by Strauss (1979), was used in comparing food found in the stomach to that available for consumption. This index of electivity is stated as:

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

where r_i is the proportion of the prey in the gut, and P_i the proportion of the same prey in the environment.

An analysis of variance was used to determine if any differences observed in feeding patterns according to season, time of feeding, or prey preference were significant ($P \leq 0.05$). Prior to these analyses, an arc sine square root transformation was performed to achieve uniform variance of percentage data.

RESULTS

Hydrography

The coldest water temperature recorded was 3.2°C during the winter of 1981, while the warmest temperature was 29.6°C recorded during the summer of 1982 (Table 2). Salinity fluctuated yearly with high values around 13 and 14 ppt during 1981 and low values around 7 and 8 ppt in 1982. Dissolved oxygen was inversely related to temperature with the low of 1.2 ppm recorded at night during the early summer. The highest values were observed during the day in the winter of 1982 and ranged between 10 and 13 ppm.

Zooplankton

Calanoid copepods (*Acartia tonsa* and *Eurytemora affinis*) dominated the zooplankton samples. Mean densities of approximately $2.3x10^5/m^3$ and $1.6x10^6/m^3$ were found during early spring and early summer (Table 3). Other abundant taxa included mysids, polychaete larvae, and barnacle nauplii during early spring and barnacle nauplii, grass shrimp, and harpacticoid copepods during early summer. The densities of these abundant taxa each averaged between approximately $2.0x10^3/m^3$ and $5.0x10^3/m^3$.

Benthos

The dominant benthic organism throughout the study was chironomid larvae which had a peak abundance in late spring (Table 4). These were followed by capitellid polychaetes in early fall, and the spionid polychaetes in winter and early fall. Diversity was greatest during winter when 13 taxa were collected followed by late

Table 2. Seasonal surface (S) and bottom (B) water temperature, salinity, and dissolved oxygen (D.O.) values from Bond Creek during 1980 - 1982 studies.

		Tide Status							
		Day High		Day Low		Night High		Night Low	
Season	Parameter	S	B	S	B	S	B	S	B
Late Fall '80	Temp.	13.8	14.0	14.1	14.6	13.2	14.0	13.0	14.0
	Sal.	9.8	10.0	11.0	12.0	7.5	8.2	9.5	10.0
	D.O.	10.6	10.4	9.5	10.2	8.5	9.0	9.5	10.0
Early Spring '81	Temp.	12.0	11.5	11.9	12.0	13.9	14.0	13.0	13.0
	Sal.	14.4	13.8	13.1	13.2	13.2	13.7	13.5	13.0
	D.O.	10.8	11.8	9.1	9.2	10.0	10.0	10.8	9.8
Early Summer'81	Temp.	26.5	26.0	29.2	26.0	28.5	28.0	26.8	26.0
	Sal.	12.2	13.6	10.0	13.8	9.0	12.5	8.8	12.4
	D.O.	8.7	4.6	9.4	8.0	10.3	9.0	3.6	1.2
Late Summer '81	Temp.	21.5	21.0	25.1	23.2	25.0	23.4	23.0	22.9
	Sal.	14.0	13.8	14.4	12.6	13.5	11.1	13.6	13.5
	D.O.	4.4	6.9	7.8	7.6	7.4	6.0	7.9	7.7
Winter '81	Temp.	3.2	4.5	3.5	4.0	4.6	5.2	5.4	5.8
	Sal.	13.6	15.5	15.0	15.8	14.2	13.5	14.4	12.6
	D.O.	12.5	9.9	12.2	12.3	12.4	11.9	11.5	10.0
Late Spring '82	Temp.	19.8	19.2	19.2	19.2	19.5	19.2	19.0	18.4
	Sal.	6.8	6.8	7.2	7.2	7.4	7.0	7.2	6.8
	D.O.	9.0	6.1	8.2	6.5	7.0	4.9	7.7	4.7
Summer '82	Temp..	29.6	29.2	27.8	28.0	27.8	27.0	28.0	27.8
	Sal.	8.2	8.3	7.6	7.5	8.0	8.0	8.2	8.2
	D.O.	7.7	7.4	-	-	5.9	5.7	8.0	7.6
Early Fall '82	Temp.	18.1	17.8	18.6	18.1	18.6	18.1	17.6	18.0
	Sal.	8.0	8.2	8.4	8.6	8.2	8.4	7.4	8.1
	D.O.	12.0	12.3	8.5	8.6	5.4	5.5	4.8	5.1

Table 3. Mean densities (#/m^3 $\pm$ 1 S.E.) of zooplankton collected during the day and night from two seasons in Bond Creek.

	Early Spring		Early Summer	
Taxon	Day	Night	Day	Night
Calanoid copepods (Day)	123,378 ± 108,266		1,809,422 ± 2,164,205	
(Night)	330,015 ± 181,183		1,296,129 ± 571,693	
Mysids	57 ± 152	10,239 ± 28,494	50 + 130	1049 ± 2155
Polychaete larvae	3006 ± 3039	7490 ± 11,015	5 ± 8	8 ± 18
Barnacle nauplii	3445 ± 3544	380 ± 1045	2715 ± 5344	4131 ± 6903
Grass shrimp	0 ± 0	1515 ± 4200	3042 ± 5621	1289 ± 1339
Harpacticoid copepods	130 ± 310	550 ± 903	23 ± 66	4233 ± 7867
Barnacle cyprids	341 ± 471	69 ± 194	1149 ± 2498	797 ± 1124
Crab zoea	0 ± 0	0 ± 0	283 ± 396	768 ± 857
Cyclopoid copepods	0 ± 0	298 ± 842	0 ± 0	530 ± 1003
Ostracods	20 ± 55	0 ± 0	0 ± 0	0 ± 0

Table 4. Mean densities(#/m^2 ± 1 S.E.) of benthic invertebrates by season collected from Bond Creek (total area sampled = 0.07m^2).

Phylum Species/Taxon	1981 Late Summer	1981 Winter	1982 Late Spring	1982 Summer	1982 Early Fall
Rhynchocoela					
Nemertean	5±8	14±14	33±34		
Mollusca					
Pelecypoda					
Macoma sp.	5±8	10±17	196±133		9±8
Macoma siphons					10±17
Annelida					
Polychaeta					
Phyllodocidae		14±14			
Nereidae	14±14	24±42	24±17		
Capitellidae	9±8	1100±832	1913±234		3239±1244
Spionidae	450±356	2750±872	1000±145		2588±739
Amparetidae		77±36	72±50		
Oligochaeta					
Naididae		459±502	5±8		
Tubificidae		5±8	5±8		
Arthropoda					
Insecta					
Chironomidae l.	196±133	1311±296	4936±395		569±187
Chironomidae p.	5±8				29±14
Crustacea					
Ostracoda		5±8			
Harpacticoida					5±8
Corophium sp.		24±30	5±8		
Mysidopsis bigelowi	10±17	5±8			62±36

spring when 10 taxa were collected. Summer grabs were void of benthic organism.

During the late summer, the spionids comprised over 64% of the total number of benthic invertebrates collected, followed by chironomid larvae with a percent relative abundance over 28% (Table 5). During the winter spionids comprised over 47% while chironomid larvae and capitellids comprised 23% and 19% of the total number respectively. Late spring grabs were dominated by chironomid larvae with a percent relative abundance over 60%. Capitellids comprised over 23% and spionids over 12% of the total number collected. The early fall grabs were dominated by capitellids at 50% and spionids at 40%.

Stomach Contents

Spot - Stomachs of 37 spot collected during four seasons were examined. Food items were found in 92% (34) of these stomachs (Table 6). Polychaetes, ostracods, and nematodes were found in the stomachs during all seasons while mysids, chironomids, harpacticoids, calanoids, cyclopoids, oligochaetes, isopods and bivalve siphons were present in the stomachs during three of four seasons.

Seasonally, harpacticoids, ostracods, nematodes, and chironomid larvae were found in at least 75% of the stomachs containing food during late fall. However, mysids which occurred in only 62% of the stomachs made up over 40% of the contents when percent dry weight was calculated (Table 7). Chironomid larvae and fish comprised between 19% and 15% of the dry weight. Polychaetes and calanoids were found in 60% and 40% of the stomachs respectively while polychaetes, calanoids, and isopods each comprised between 31% and 25% of the dry

Table 5. Seasonal relative abundance (%) by number of benthic invertebrates collected from Bond Creek.

Phylum Species/Taxon	1981 Late Summer	1981 Winter	1982 Late Spring	1982 Summer	1982 Early Fall
Rhynchocoela					
Nemertean	0.72	0.24	0.40		
Mollusca					
Pelecypoda					
Macoma sp.	0.72	0.17	2.39		0.14
Macoma siphons					0.15
Annelida					
Polychaeta					
Phyllodocidae		0.24			
Nereidae	2.02	0.41	0.30		
Capitellidae	1.30	18.97	23.36		49.75
Spionidae	64.84	47.43	12.21		39.75
Amphaetidae		1.33	0.88		
Oligochaeta					
Naididae		7.92	0.06		
Tubificidae		0.09	0.06		
Arthropoda					
Insecta					
Chironomidae l.	28.24	22.61	60.28		8.74
Chironomidae p.	0.72				0.44
Crustacea					
Ostracoda		0.09			
Harpacticoida					0.08
Corophium sp.		0.41	0.06		
Mysidopsis bigelowi	1.44	0.09			0.95

Table 6. Percentage of occurrence of different food items in the stomachs of spot containing food, collected during diel studies from Bond Creek during four seasons.

Food Item	Season				Seasons Combined
	Late Fall	Early Spring	Early Summer	Late Summer	
Macrozooplankton					
Mysids	62.5		8.3	33.3	26.5
Chironomid larvae	75.0		58.3	33.3	47.1
Dipteran pupae				11.1	2.9
Microzooplankton					
Harpacticoids	100.0		8.3	55.6	41.2
Calanoids		40.0	41.7	11.1	23.5
Cyclopoids	25.0	20.0		44.4	26.5
Copepodites				55.6	8.8
Ostracods	87.5	20.0	8.3	11.1	29.4
Barnacle cyprids			8.3		2.9
Benthos					
Polychaetes	25.0	60.0	75.0	44.4	52.9
Oligochaetes	12.5		25.0	11.1	14.7
Amphipods	37.5			11.1	11.8
Isopods		20.0	8.3	11.1	8.8
Nematodes	75.0	20.0	66.7	88.9	67.6
Bivalve siphons		20.0	75.0	11.1	32.4
Fish					
Gobies	12.5				2.9
Scales			33.3	11.1	14.7
Organics	75.0	40.0	25.0	66.7	50.0
Detritus	25.0		66.7	55.6	44.1
Algae	25.0				5.9
Number fish examined	9	7	12	9	37
Number fish with food	8	5	12	9	34

Table 7. Percent dry weight of the stomach contents of spot from Bond Creek. Mean lengths of spot in mm are indicated.

Food Item	Late Fall	Early Spring	Early Summer	Late Summer	Seasons Combined
	$\bar{x}$=104	$\bar{x}$=24	$\bar{x}$=63	$\bar{x}$=89	
Macrozooplankton					
Mysids	40.34		0.04	77.08	43.51
Chironomid larvae	18.86		8.85	2.32	9.16
Dipteran pupae				1.42	0.58
Microzooplankton					
Harpacticoids	2.80		0.04	0.04	0.91
Calanoids		28.20	0.20	0.03	0.20
Cyclopoids	1.54	2.56		0.37	0.62
Copepodites				0.14	0.06
Ostracods	0.96	2.56	0.04	0.03	0.32
Barnacle cyprids			0.04		0.01
Benthos					
Polychaetes	0.42	30.77	41.73	16.74	19.10
Oligochaetes	0.38		0.12	0.03	0.16
Amphipods	2.69			0.57	1.04
Isopods		25.64	0.40	0.28	0.35
Nematodes	0.23	2.56	1.04	0.48	0.58
Bivalve siphons		2.56	46.90	0.03	13.53
Fish					
Gobies	15.37				4.61
Scales			0.16	0.03	0.06
Organics	16.25	5.13	0.12	0.17	5.01
Detritus	0.08		0.32	0.14	0.17
Algae	0.08				

weight during the early spring. Polychaetes, bivalve siphons, and nematodes were present in over 66% of all the stomachs with bivalve siphons and polychaetes each comprising over 41% of the dry weight of all the stomach contents during early summer. Nematodes were the dominant organisms during late summer and were present in almost 89% of the stomachs. Mysids were found in only 33% of the stomachs but comprised over 77% of the dry weight.

Overall, nematodes, polychaetes, and chironomid larvae were found most frequently in the stomachs of spot, while mysids dominated the percent dry weight at over 43% followed by polychaetes (19%) and bivalve siphons (14%).

No significant difference among the major food groups consumed by spot was observed ($P \leq 0.05$; $F=0.102$). This suggest that spot utilized a wide range of prey and infers an opportunistic feeding behavior.

Atlantic croaker - Stomachs of 51 croaker collected during five seasons were examined and over 88% (45) contained food (Table 8). Mysids, chironomid larvae and polychaetes were present in the stomachs during four of five seasons while harpacticoids, calanoids, and amphipods were found in the stomachs during three of five seasons.

Seasonally, mysids and chironomid larvae were found in all stomachs that contained food during late fall. Mysids comprised almost 49% of the dry weight while chironomid larvae comprised 27% (Table 9). Calanoids were present in over 77% of the stomachs and accounted for 48% of the total dry weight during early spring while mysids,

Table 8. Percentage of occurrence of different food items in the stomachs of Atlantic croaker containing food, collected during diel studies from Bond Creek during five seasons.

Food Items	Season					Seasons Combined
	Late Fall	Early Spring	Early Summer	Late Summer	Winter	
Macrozooplankton						
Mysids	100.0	33.3		88.9	20.0	48.9
Chironomid larvae	100.0	11.1	75.0	100.0		64.4
Dipteran pupae	30.0		8.3			6.7
Palaemonid zoea			8.3			2.2
Crustacean zoea			8.3			2.2
Microzooplankton						
Harpacticoids	20.0	33.3	8.3			13.3
Calanoids		77.7	41.7		40.0	31.1
Cyclopoids			8.3			2.2
Ostracods	20.0			11.1		6.7
Benthos						
Polychaetes	20.0	22.2	75.0	88.9		46.7
Oligochaetes	30.0		75.0			26.7
Amphipods	10.0	22.2		11.1		6.7
Isopods				11.1		4.4
Nematodes			25.0			6.7
Bivalve siphons			75.0	11.1		22.2
Fish						
Anchovies				11.1		2.2
Gobies	10.0			11.1		4.4
Menhaden				22.2		4.4
Scales			16.7	11.1		6.7
Organics	70.0	11.1	58.3	88.9	40.0	55.6
Detritus	10.0		25.0	77.8		24.4
Sand	10.0		8.3			4.4
Algae	40.0			44.4		17.8
Number fish examined	10	9	12	9	11	51
Number fish with food	10	9	12	9	5	45

Table 9. Percent dry weight of the stomach contents of Atlantic croaker from Bond Creek. Mean lengths of Atlantic croaker in mm are indicated.

Food Item	Late Fall	Early Spring	Early Summer	Late Summer	Winter	Seasons Combined
	Season					
	$\overline{x}$=126	$\overline{x}$=36	$\overline{x}$=66	$\overline{x}$=137	$\overline{x}$=28	
Macrozooplankton						
Mysids	48.80	13.32		64.44	20.00	55.64
Chironomid larvae	27.00	4.61	33.52	4.57		13.83
Dipteran pupae	3.37		2.61			1.31
Palaemonid zoea			0.07			<0.01
Crustacean zoea			0.07			<0.01
Microzooplankton						
Harpacticoids	0.02	13.82	0.07			0.10
Calanoids		47.93	0.91		40.00	0.36
Cyclopoids			0.07			<0.01
Ostracods	0.02			0.01		0.01
Benthos						
Polychaetes	0.02	14.29	17.90	5.12		3.96
Oligochaetes			0.59			0.04
Amphipods		0.92		0.30		0.18
Isopods	0.01			0.40		0.24
Nematodes			0.20			0.01
Bivalve siphons			43.20	0.01		1.97
Fish						
Anchovies				7.96		4.73
Gobies	4.04			2.10		2.68
Menhaden				13.88		8.25
Scales			0.20	0.01		0.01
Organics	16.66	4.61	0.46	1.14	40.00	6.62
Detritus	0.01		0.13	0.04		0.03
Algae	0.03			0.02		0.02

harpacticoids, and polychaetes each comprised nearly 14% of the total dry weight. Chironomid larvae, polychaetes, oligochaetes, and bivalve siphons, each occurred in 75% of the stomachs containing food during early summer. The percent dry weight was dominated by bivalve siphons at 43%, chironomid larvae at 34%, and polychaetes at 18%. During late summer, chironomid larvae, mysids, and polychaetes were each present in over 89% of the stomachs that contained food. Mysids dominated by percent dry weight at over 64%. Calanoids and mysid remains were the only food items found during winter with calanoids comprising the higher percent dry weight at 40%.

Overall, chironomid larvae were present in 64% of the stomachs, while mysids were found in 49% and polychaetes 47%. Percent dry weight was dominated by mysids at over 55%.

Analysis of variance showed no significant difference in diet by major food groups found in the stomachs ($P \leq 0.05$; $F=0.0503$). This suggest there was a wide variety of prey consumed by Atlantic croaker.

Southern flounder - Stomachs of 21 southern flounder collected during five seasons were examined. Food was found in 67% (14) of these stomachs (Table 10). Mysids and fish dominated the prey items and were found in the stomachs during three of five seasons.

Mysids were found in over 87% of the stomachs, while a piscivorous tendency was noted in 25% during late fall. Percent dry weight indicated mysids comprised over 65% of the total contents, while fish remains comprised over 30% (Table 11). Mysids were the only food items found during early spring. Mysids were the dominant food items

Table 10. Percentage of occurrence of different food items in the stomachs of southern flounder containing food, collected during diel studies from Bond Creek during five seasons.

Food Item	Season					Seasons Combined
	Late Fall	Early Spring	Early Summer	Late Summer	Winter	
Macrozooplankton						
Mysids	87.5	100.0	66.7			78.6
Benthos						
Tanaids		50.0				7.1
Fish						
Gobies	25.0					7.1
Unidentified	12.5				100.0	21.4
Scales			33.3			7.1
Organics	37.5					21.4
Detritus	12.5					7.1
Number fish examined	9	2	6	2	2	21
Number fish with food	8	2	3	0	1	14

Table 11. Percent dry weight of the stomach contents of southern flounder from Bond Creek. Mean lengths of southern flounder in mm are indicated.

Food Item	Season					Seasons Combined
	Late Fall	Early Spring	Early Summer	Late Summer	Winter	
	$\bar{x}$=120	$\bar{x}$=118	$\bar{x}$=69	$\bar{x}$=100	$\bar{x}$=117	
Macrozooplankton						
Mysids	65.59	99.97	99.45			64.26
Benthos						
Tanaids		0.03				0.01
Fish						
Gobies	8.95					4.34
Unidentified	21.92				100.00	29.66
Scales			0.55			0.01
Organics	2.12					1.03
Detritus	1.42					0.69

found during early summer being present in 67% of the stomachs. They comprised 99% of the total dry weight. Only two flounder were collected during late summer and the stomachs of both fish were empty. During the winter, only two flounder were collected and only one stomach contained food which consisted of unidentified fish parts.

Overall, mysids were present in almost 79% of the stomachs that contained food while fish remains were found in over 21%. Mysids comprised over 64% of the total dry weight with fish remains comprising another 30%. Analysis of variance indicated a significant difference among major food groups consumed ($P \leq 0.05$; $F=0.006$). This infers that southern flounder prefer macrozooplankton (mysids) and fish over the microzooplankton and benthos.

Bay anchovy - Stomachs of 34 bay anchovies collected during four seasons were examined. Food was found in 71% (24) of the stomachs (Table 12). Calanoids, ostracods, and polychaete larvae were found in the stomachs during three of the four seasons.

Phytoplankton was found in over 45% of the stomachs while mysids were found in 36% of the stomachs during late fall. Mysids comprised over 95% of the total dry weight (Table 13). Calanoids and unidentified copepodites were the most frequent food item found during early spring and occurred in over 62% and 87% respectively, of the stomachs that contained food. Mysids occurred in only 12.5% of the stomachs but comprised over 71% of the total dry weight. During late summer, calanoids were found in 67% of the stomachs and comprised 61% of the total dry weight. Eight anchovies were collected during winter, but only two stomachs contained food. Calanoids, cyclopoids, and oli-

Table 12. Percentage of occurrence of different food items in the stomachs of bay anchovy containing food, collected during diel studies from Bond Creek during four seasons.

Food Item	Season: Late Fall	Early Spring	Late Summer	Winter	Seasons Combined
Macrozooplankton					
Mysids	36.4	12.5			20.8
Chironomid larvae			33.3		4.2
Microzooplankton					
Harpacticoids	9.1	50.0			20.8
Calanoids		62.5	66.7	50.0	33.3
Cyclopoids				50.0	4.2
Copepodites		87.5			29.2
Copepod eggs		12.5			4.2
Ostracods	18.2	37.5	33.3		25.0
Barnacle nauplii			33.3		4.2
Benthos					
Polychaetes	9.1	12.5	33.3		12.5
Oligochaetes				50.0	4.2
Isopods		12.5			4.2
Bivalves	9.1				4.2
Phytoplankton	45.5	12.5	33.3		29.2
Organics	45.5	50.0	66.7		45.8
Number fish examined	12	10	4	8	34
Number fish with food	11	8	3	2	24

Table 13. Percent dry weight of the stomach contents of bay anchovy from Bond Creek. Mean lengths of bay anchovy in mm are indicated.

Food Item	Season: Late Fall	Season: Early Spring	Season: Late Summer	Season: Winter	Seasons Combined
	$\bar{x}$=42	$\bar{x}$=41	$\bar{x}$=37	$\bar{x}$=35	
Macrozooplankton					
Mysids	95.31	71.03			88.22
Chirononid larvae			5.56		0.11
Microzooplankton					
Harpacticoids	0.14	2.19			0.55
Calanoids		7.65	61.10	33.34	2.75
Cyclopoids				33.33	0.22
Copepodites		3.83			0.77
Copepod eggs		0.55			0.11
Ostracods	0.29	1.64	5.56		0.66
Barnacle nauplii			5.56		0.11
Benthos					
Polychaetes	1.42	5.46	5.56		2.31
Oligochaetes				33.33	0.11
Isopods		5.46			1.10
Bivalves	1.42				1.10
Phytoplankton	0.71	0.55	5.56		0.77
Organics	0.71	1.64	11.10		1.10

gochaetes were each found in 50% of the stomachs and each comprised approximately 33% of the total dry weight.

Overall, calanoids were found in 33% of the stomachs. Copepodites and phytoplankton were each found in 29% of the stomachs. Mysids occurred in 21% of the stomachs but comprised over 83% of the total dry weight. Although calanoids were present in numerous stomachs they comprised only 3% of the total dry weight. No significant difference was found in the major food groups consumed by bay anchovy ($P \leq 0.05$; F=0.2741). However since the analysis was based on percent dry weight, this is misleading. The microzooplankton consumed most often by bay anchovy do not weigh as much as the larger prey items and consequently a nonsignificance was seen.

Seasonality

Winter - The mean length (28 mm SL) of spot in the winter trawl collections indicated that Atlantic croaker had immigrated into the nursery area. They fed evenly on macrozooplankton and microzooplankton and shared the microzooplankton with the 35-mm bay anchovy. The bay anchovy also fed on young benthic organisms during the day where the spot did not (Fig. 2). Southern flounder fed only at night and had no competition for their preferred diet of fish.

There was no significant difference in day/night preference for selection of the four major food groups.

Early spring - The small fish that migrated into the nursery areas during late winter had taken up residence by early spring with an increase in mean length. Spot (24 mm SL) and Atlantic croaker (36 mm SL) were smaller than southern flounder (118 mm SL) that had prob-

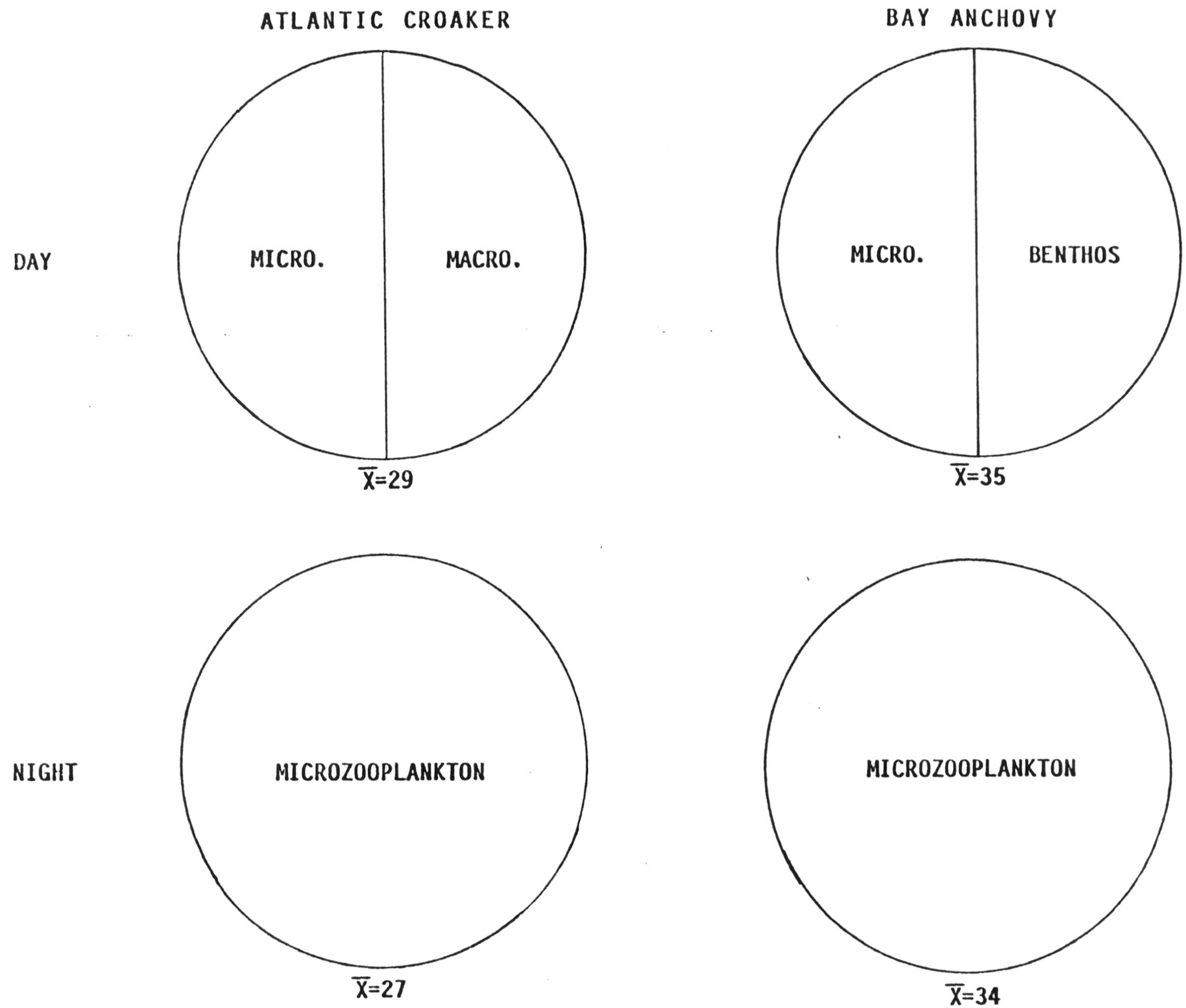

Figure 2. Percent composition by dry weight of major prey consumed by two species of fish collected during the day and night in Bond Creek, Beaufort County, N.C. during winter 1981.

ably overwintered in the creeks and also smaller than the estuarine spawned bay anchovy (41 mm SL). The small spot utilized microzooplankton and benthos exclusively while Atlantic croaker basically consumed microzooplankton with some macrozooplankton and benthos noted (Fig. 3). The southern flounder maintained a preference for macrozooplankton while the bay anchovy consumed food items from all the major food categories except fish.

Figure 3 also displays diel differences in food selection of all four species collected during early spring. However, the results of an analysis of variance suggests there is no significance in the diel differences in the basic food groups utilized.

Early Summer - Growth of spot (63 mm SL) and Atlantic croaker (66 mm SL) and the immigration of young southern flounder (69 mm SL) forced fish of similar size to coexist. Food partitioning was evident by spot predominantly utilizing benthos, while Atlantic croaker utilized benthos at night but switched to macrozooplankton during the day (Fig. 4). Southern flounder again fed extensively on the macrozooplankton.

The selection of food for the two species collected during both day and night in early summer did not indicate any significant diel differences.

Late summer - The mean length range of juvenile fish collected during late summer was wider than at anytime of the year. Spot averaged 89 mm, Atlantic croaker averaged 137 mm while southern flounder had grown to 100 mm. The ubiquitous bay anchovy averaged around 37 mm in length. Prey items consumed were similar for spot

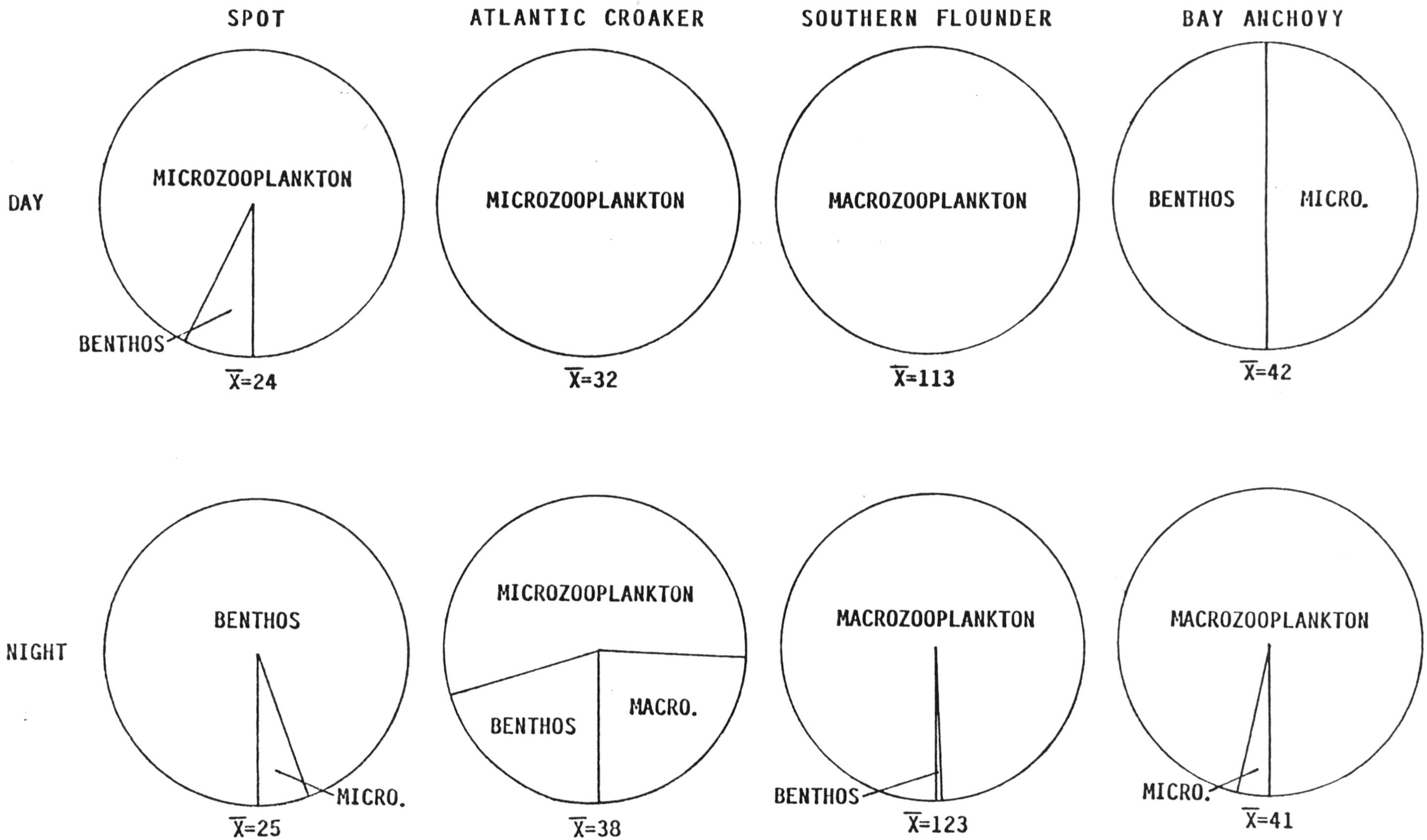

Figure 3. Percent composition by dry weight of major prey consumed by four species of fish collected during the day and night in Bond Creek, Beaufort County, N.C. during early spring 1981.

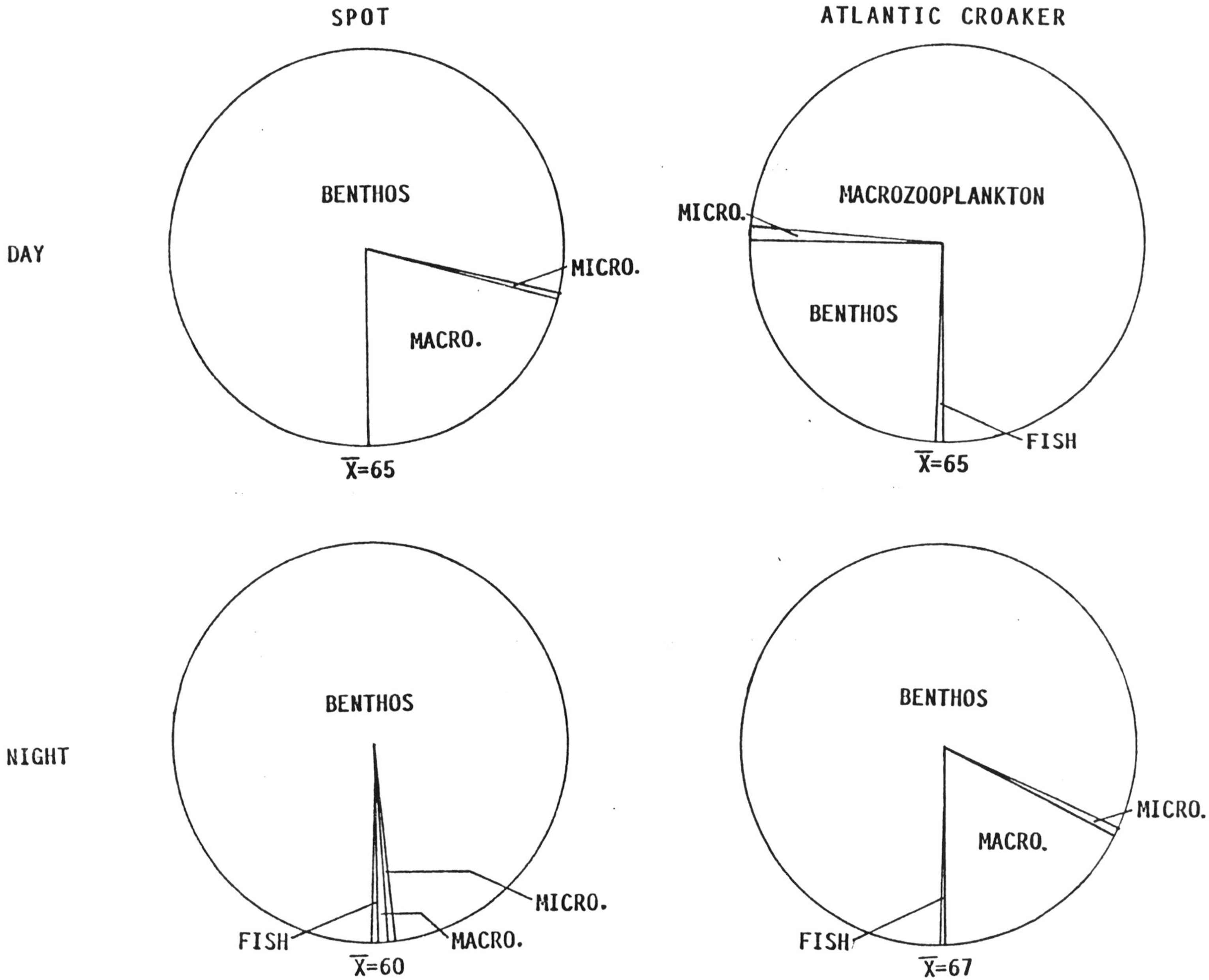

Figure 4. Percent composition by dry weight of major prey consumed by two species of fish collected during the day and night in Bond Creek, Beaufort County, N.C. during early summer 1981.

and Atlantic croaker during the day with both extensively utilizing macrozooplankton (Fig. 5). Partitioning was more evident at night with spot switching to benthos and Atlantic croaker showing a primary piscivorous habit in addition to a secondary macrozooplankton and benthos preference. Bay anchovy fed mainly on microzooplankton while the southern flounder examined did not feed.

Late fall - During the fall and prior to emigration, the average length increased to 104 mm for spot, 126 mm for Atlantic croaker, 120 mm for southern flounder, and 42 mm for bay anchovy. All species predominantly utilized macrozooplankton as their main prey (Fig. 6). Spot and southern flounder diets however were more diverse and included a secondary piscivorous habit.

No day/night differences for any species were found in food preference. The major food chosen during the day was also the preferred diet at night.

Diet Breadth

Diet breadth indicates the relative range of prey eaten. High values indicate a wide range of diet while low values near 1.0 suggest exclusive use of one prey item. Highest diet breadth values were observed for spot and Atlantic croaker and lowest for southern flounder and bay anchovy (Table 14). Diet breadth for spot was highest during late fall and early spring when numerous prey items were chosen in large quantities and lowest during late summer when mysids and polychaetes made up the bulk of the diet. Diet breadth of Atlantic croaker was consistently high throughout the study also indicating a wide use of prey items. Diet breadth for southern flounder

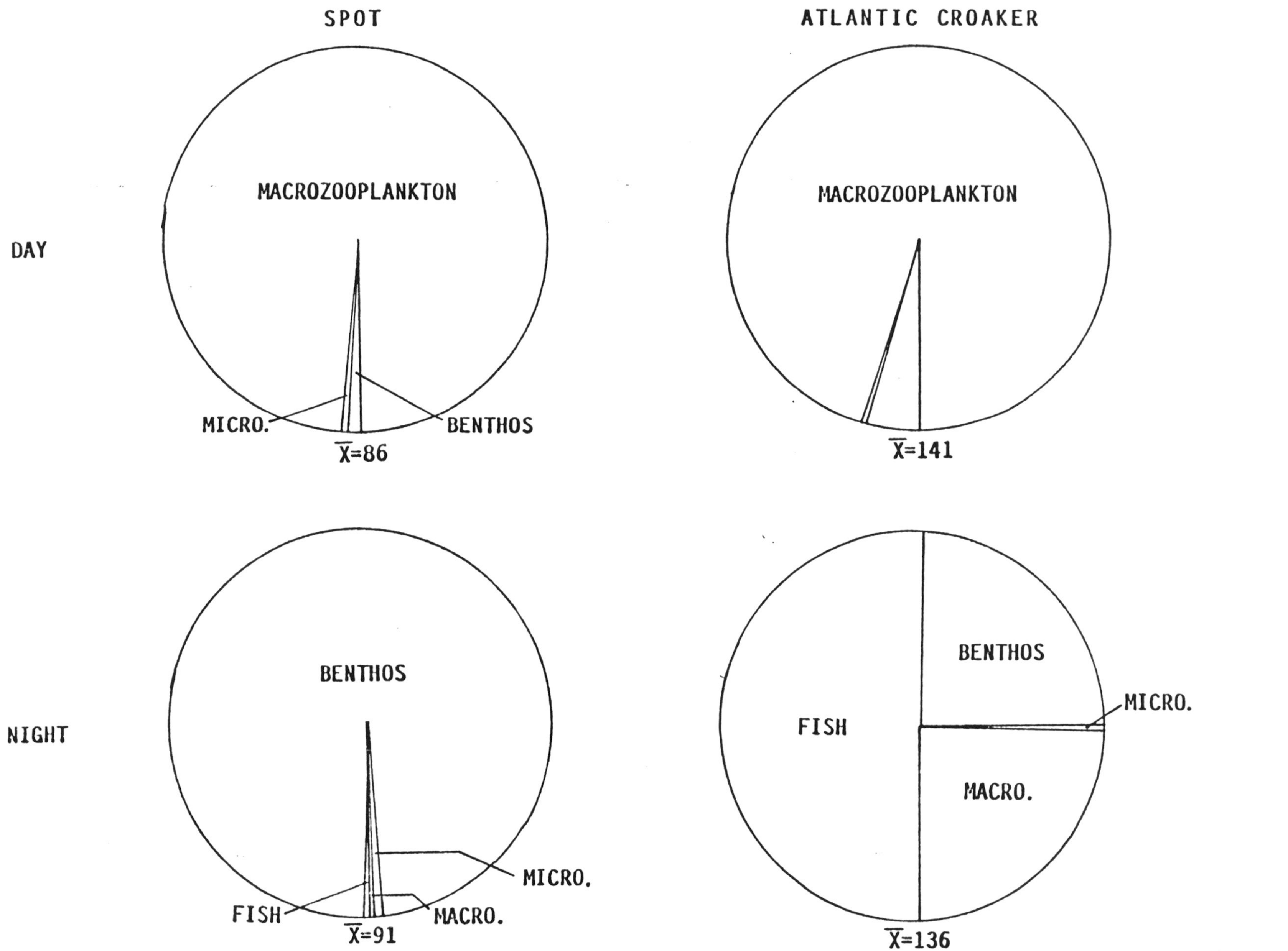

Figure 5. Percent composition by dry weight of major prey consumed by two species of fish collected during the day and night in Bond Creek, Beaufort County, N.C. during late summer 1981.

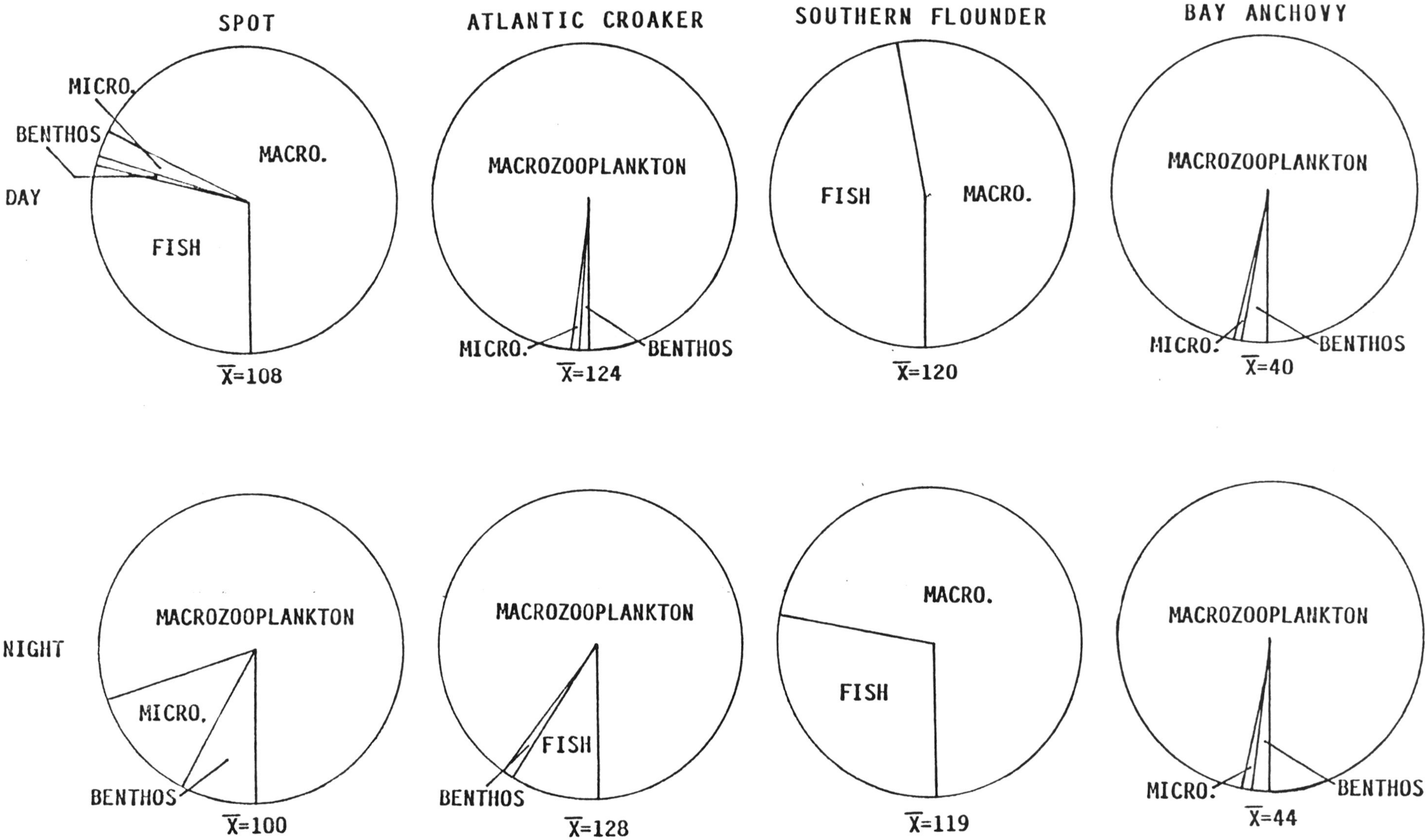

Figure 6. Percent composition by dry weight of major prey consumed by four species of fish collected during the day and night in Bond Creek, Beaufort County, N.C. during late fall 1980.

Table 14. Diet breadths of juvenile fish in Bond Creek based on mean percent dry weight of stomach contents.

Season	Spot	Atlantic croaker	Southern flounder	Bay anchovy
Late Fall	4.00	2.93	2.05	1.10
Early Spring	4.08	3.42	1.00	1.93
Early Summer	2.49	3.01	1.01	-
Late Summer	1.61	2.24	0.00	2.49
Winter	-	2.78	1.00	1.80
15-Month Avg.	3.89	2.90	1.26	1.83

was highest during late fall when a dual feeding habit was noted; however, this was substantially less than for both spot and Atlantic croaker. During early spring, early summer, and winter, the diet breadth of southern flounder was near 1.00 which indicated the utilization of a single food item (either mysids or fish). Diet breadth of bay anchovy was highest in late summer with microzooplankton being dominant and lowest in late fall with extensive use of mysids as a food source. Overall, the diet breadth of bay anchovy was slightly higher than for southern flounder but substantially lower than for both spot and Atlantic croaker.

Diet Overlap

Diet overlap values between individual fish pairs were greater than 0.60 for 5 of the 6 cases indicating utilization of similar prey items (Table 15). The spot-bay anchovy combination was the lone exception at 0.50. This resulted from spot utilizing a range of prey items with few microzooplankton eaten which are the basic diet of bay anchovy. The Atlantic croaker-southern flounder combination had the highest diet overlap value at 0.75 which indicated the intensive use of mysids by both species as a basic food source. The spot-Atlantic croaker combination also indicated a high diet overlap at 0.68 which resulted from both frequently consuming mysids, chironomid larvae and polychaetes.

Ivlev's Index of Electivity

Four dominant food categories were chosen for evaluation of electivity. Proportions of calanoids, polychaetes, mysids, and chironomid larvae found present in the environment were compared with

Table 15. Diet overlap between juvenile fish in Bond Creek based on mean percent dry weight of stomach contents.

Species	Overlap value
Spot - Atlantic croaker	0.68
Spot - southern flounder	0.61
Spot - bay anchovy	0.50
Atlantic croaker - southern flounder	0.74
Atlantic croaker - bay anchovy	0.61
Southern flounder - bay anchovy	0.65

proportions in the gut of the selected fish species. Spot and Atlantic croaker in late summer and southern flounder in both early spring and early summer displayed electivity values that indicated active selection of mysids as their prey (Table 16). Conversely, spot and Atlantic croaker in early summer and southern flounder in both early spring and early summer displayed electivity values that suggested avoidance of calanoid copepods as their prey. The slightly negative electivity of bay anchovy towards calanoid copepods is somewhat misleading. High relative abundance percentages of calanoids in the environment skew the values towards the negative/avoidance side.

Spot during late summer displayed an electivity suggesting avoidance or inaccessability of polychaetes while Atlantic croaker displayed similar negative values towards chironomid larvae.

Table 16. Relative abundance (%) by number of selected prey items found in the gut (PG) and the environment (PE) and Ivlev's index of electivity (E).

	Calanoids			Polychaetes			Mysids			Chironomids		
	PG	PE	E	PG	PE	E	PG	PE	E	PG	PE	E
Spot												
Early spring	36.54	94.31	-.44									
Early summer	0.70	99.36	-.99									
Late summer				6.12	68.16	-.84	22.70	1.44	+.88			
Atlantic croaker												
Early spring	82.50	94.31	-.07	2.50	2.17	+.07	6.25	2.13	+.49			
Early summer	11.43	99.36	-.79									
Late summer							79.91	1.44	+.96	6.80	23.24	-.61
Southern flounder												
Early spring	0.00	94.31	-1.00				78.57	2.13	+.95			
Early summer	0.00	99.36	-1.00				100.00	0.03	+1.00			
Bay anchovy												
Early spring	63.28	94.31	-.20	4.47	2.17	+.35						
Late summer	46.00	99.36	-.37									

DISCUSSION

Hydrographic parameters can affect the species composition of estuarine ecosystems (Gunter 1961). During 1981, salinity in South Creek and its tributaries was abnormally high due to a statewide drought (Davis et al. 1985). Consequently, the species composition and abundance of fish as well as prey items available may have undergone some shifts. However, the organisms reported in this study are basically the same as those from similar creeks (Lawson 1981; West 1985). The hydrographic parameters reported here are in agreement with those from creeks on the north side of South Creek (Davis et al. 1985).

Postlarval spot feed mainly on zooplankton, while larger juveniles are more benthic oriented feeders (Roelofs 1954; Schwartz 1980; Hodson et al. 1983; Currin 1984). Spot collected during early spring in this study utilized both of these major food groups. This dual feeding habit may reflect the morphological changes occurring in the fish at that time and result in an ontogenetic change in their feeding habit (Kjelson and Johnson 1976). Spot collected later in the year became more opportunistic in their feeding behavior. Benthos were preferred in early summer and macrozooplankton in late summer and late fall as was found by Chao and Musick (1977) and Koblinski and Sheridan (1979).

Small Atlantic croaker (36 mm SL) utilize zooplankton extensively prior to a shift in diet to crustaceans and polychaetes (Darnell 1958; Stickney et al. 1975; Overstreet and Heard 1978). Atlantic croaker collected during the winter and early spring from this study also utilized zooplankton extensively, while juveniles collected during the summer preferred bivalve siphons in addition to crustaceans and polychaetes. These results concur with findings from Rose Bay where bivalve siphons dominated the diet of many juvenile croaker (Currin 1984). As the Atlantic croaker grew throughout the year, macrozooplankton became more prevalent in the diet suggesting a selection towards larger prey, similar to findings by Stickney et al. (1975). A piscivorous tendency by larger juvenile Atlantic croaker (>70 mm SL) was noted by Koblinski and Sheridan (1979) in Apalachicola Bay, Florida and was supported in this study.

Juvenile southern flounder and bay anchovy collected throughout the study did not follow the basic immigration - growth - emigration pattern shown by spot and Atlantic croaker. Flounder collected during winter and early spring had possibly overwintered in the creek system. Bay anchovy which spawn all year, were basically uniform in length during the study. Southern flounder fed on macrozooplankton (mysids) and fish almost exclusively. This feeding habit is in agreement with findings by Darnell (1958) and Powell and Schwartz (1979). Smaller bay anchovy are classified as zooplanktivores and as their length increases macrozooplankton become increasingly more important (Carr and Adams 1973; Schwartz 1979). In this study, microzooplankton dominated the stomach contents from all seasons except late fall when mysids and phytoplankton were more prevalent. Kinch (1979) noted a secondary piscivorous tendency among larger anchovies which was not substantiated in this study.

Similar diets for all four species suggest niche overlap was prevalent. However, spot and Atlantic croaker have wide diet breadths during the peak growing season of their preferred prey. This opportunistic feeding behavior allows for shifts in prey selection when primary prey items become difficult to obtain. Zooplankton abundances in this type of system are usually highest during early spring when larval fish begin establishing residence in the nursery areas (Thayer et al. 1974). Likewise (Turner 1981) has shown that rapid growth of larval spot coincides with peak plankton production. Consequently, when spot and Atlantic croaker moved into Bond Creek, zooplankton were present in great numbers and were readily available. As these two species grew, chironomid larvae and bivalves became more abundant and accessible as prey. West (1985) in his studies of the benthos in Short Creek a tributary of South Creek also found high densities of chironomid larvae in late fall. A seasonal shift occurred in the diet of spot and Atlantic croaker toward these abundant prey. When the polychaetes (capitellids and spionids) exhibited their highest peaks of abundance later in the year, they also became a major contributor to the diet of these species.

Diel feeding patterns have been noted in many studies. Hodson et al. (1981) suggested juvenile spot collected from a tidally inundated marsh after their transition to the benthic feeding behavior, fed more actively at night. Likewise, this study showed that spot had a tendency to consume higher concentrations of benthos after sunset during four of the five seasons. Studies from Rose Bay, a system similar to Bond Creek, did not indicate however, any apparent diel feeding pattern (Currin 1984). This shift towards benthos during the night provides a greater variety in diet and less competition among these dominant fish species.

The diet overlap combination of spot-Atlantic croaker suggested a higher degree of diet overlap during their entire residence in the nursery area. However, the opportunistic feeding behavior of each, as evidenced by high diet breadths, allows both species to occupy similar niches. Atlantic croaker and southern flounder also utilized the same basic food group and consequently exhibited a similar high diet overlap. This suggests stiff competition for the preferred diet. Southern flounder, however, displayed a narrow diet breadth and actively selected mysids during early spring and early summer and actively avoided microzooplankton. Atlantic croaker on the other hand consumed large numbers of calanoid copepods (microzooplankton) in the spring and showed an affinity for mysids in the late summer while southern flounder were scarce during this period and fed intermittently.

It has been noted that marine larvae and juveniles show low diet overlaps (Larouche 1982). The high diet overlap values experienced by these estuarine species suggest that competition potentially exists if resources were limiting, which in this creek apparently are not. The fact that food resources from this system were seasonal in abundance as evidenced by the high numbers of zooplankton during spring and summer while benthos were more abundant in the late fall and winter suggests that the food resources found in Bond Creek are not limited.

SUMMARY AND CONCLUSIONS

Spot and Atlantic croaker are both opportunistic feeders. Younger juvenile spot utilized microzooplankton and benthos before they switched to the opportunistic feeding behavior as older juveniles. The young Atlantic croaker utilized microzooplankton (calanoid copepods) extensively before they also became an opportunistic feeder as older juveniles. Spot displayed a diet breadth value of four while Atlantic croaker indicated a diet breadth value near three, both of which indicate a wide range of prey consumed.

Southern flounder utilized macrozooplankton (mysids) extensively but also showed a secondary piscivorous feeding habit. Extensive utilization of the macrozooplankton occurred during those seasons when the other species were consuming other preferred prey. A diet breadth value near one suggests the exclusive use of a single food source. Bay anchovy predmoninantly consumed zooplankton. Smaller bay anchovy(<40 mm SL) preferred microzooplankton (calanoid copepods) while the larger fish basically consumed macrozooplankton (mysids). A diet breadth near two emphasized the use of both categories of zooplankton.

Zooplankton reached their peak abundance during the recruitment period of these predatory fish. Zooplankton consequently became the major food source during this time. The early summer growing season of these fish coincided with high densities of benthos which were extensively consumed. After the benthic die off, the macrozooplankton then became the dominant food item eaten.

Only small diel differences in the type of prey consumed was seen. The benthos were consumed more frequently at night by spot in the early spring and late summer and in the early summer by Atlantic croaker.

Mysids were the most selected prey using Ivlev's electivity index while the calanoid copepods were the most avoided prey except by the bay anchovy.

The four species of fish often occupied similar niches during their residence in the nursery area. However, a seemingly unlimited food supply allowed these abundant fish populations to coexist.

LITERATURE CITED

Carr, W.E.S. and C.A. Adams. 1973. Food habits of juvenile marine fishes occupying seagrass beds in the estuarine zone near Crystal River, Florida. *Trans. Am. Fish. Soc.* 102:511-540.

Chao, L.N. and J.A. Musick. 1977. Life history, feeding habits, and functional morphology of juvenile Sciaenid fishes in the York River Estuary, Virginia. *Fish. Bull.* 75:657-702.

Christiansen, F.B. and T.M. Fenchel. 1977. Theories of populations in biological communities. Springer-Verlag, New York. 144p.

Currin, B.M. 1984. Food habits and food consumption of juvenile spot, *Leiostomus xanthurus* and croaker, *Micropogonias undulatus* in their nursery areas. Masters Thesis. North Carolina State University, Raleigh. 103p.

Currin, B.M., J.P. Reed, and J.M. Miller. 1984. Growth, production, food consumption, and mortality of juvenile spot and croaker: a comparison of tidal and nontidal nursery areas. *Estuaries.* 7:451-459.

Davis, G.J., H.D. Bradshaw, M.M. Brinson, and G.M. Lekson. 1985. Salinity and nutrient dynamics in Jacks, Jacobs, and South Creeks in North Carolina, October 1981 - November 1982. *J. Elisha Mitchell Sci. Soc.* 101:37-51.

Darnell, R.M. 1958. Food habits of fishes and larger invertebrates of Lake Ponchartrain, Louisiana, an estuarine community. Publ. Inst. Mar. Sci., Univ. Texas. 5:353-416.

Detwyler, R. and E.H. Houde. 1970. Food selection by laboratory-reared larvae of the scaled sardine *Harengula pensacolae* (Pisces: Clupeidae) and the bay anchovy *Anchoa mitchilli* (Pisces: Engraulidae). Mar. Biol. 7:214-222.

Galat, D.L. and N. Vucinich. 1983. Food partitioning between young of the year of two sympatric tui chub morphs. *Trans. Am. Fish. Soc.* 112:486-497.

Gunter, G. 1961. Some relationships of estuarine organisms to salinity. *Limnol. Oceanogr.* 6:182-190.

Hobson, E.S. and J.R. Chess. 1976. Trophic interactions among fishes and zooplankters near shore at Santa Catalina Island, California. *Fish. Bull.* 74:567-598.

Hodson, R.G., J.O. Hackman, and C.R. Bennett. 1981. Food habits of young spots in nursery areas of the Cape Fear River Estuary, North Carolina. *Trans. Am. Fish. Soc.* 110:495-501.

Keast, A. 1985. Development of dietary specializations in a summer community of juvenile fishes. *Environmental Biology of Fishes.* 13:211-224.

Kinch, J.C. 1979. Trophic habits of the juvenile fishes within artificial waterways--Marco Island, Florida. Univ. Texas, Mar. Sci. Inst. 22:77-90.

Kjelson, M.A., D.S. Peters, G.W. Thayer, and G.N. Johnson. 1975. The general feeding ecology of postlarval fishes in the Newport River Estuary. *Fish. Bull.* 73:137-144.

Kjelson, M.A. and G.N. Johnson. 1976. Further observations of the feeding ecology of postlarval pinfish, *Lagodon rhomboides*, and spot, *Leiostomus xanthurus*. *Fish. Bull.* 74:423-432.

Kobylinski, G.J. and P.F. Sheridan. 1979. Distribution, abundance, feeding, and long-term fluctuations of spot, *Leiostomus xanthurus*, and croaker, *Micropogonias undulatus*, in Apalachicola Bay, Florida, 1972-1977. Univ. Texas, Mar. Sci. Inst. 22:149-161.

Larouche, J.L. 1982. Trophic patterns among larvae of five species of sculpins (Family: Cottidae) in a Maine estuary. *Fish. Bull.* 80:827-840.

Lawson, T. 1981. Nursery area assessment of Bond, Long, and Short Creeks, Beaufort County, North Carolina. Annual report to Texasgulf Chemicals, Inc. 134pp.

MacDonald, J.S. and R.H. Green. 1986. Food resource utilization by five species of benthic feeding fish in Passamaquoddy Bay, New Brunswick. *Can. J. Fish. Aquat. Sci.* 43:1534-1546.

Miller, J.M., J.P. Reed, and L. Pietrafesa. 1984. Patterns, mechanisms and approaches to the study of migrations of estuarine-dependent fish larvae and juveniles. *In* J.D. McCleave, G.P. Arnold, J.J. Dodson, and W.H. Neill (eds.), Mechanisms of Migration in Fishes. Plenum Press, New York. 554pp.

Overstreet, R.M. and R.W. Heard. 1978. Food of the Atlantic croaker, *Micropogonias undulatus*, from Mississippi Sound and the Gulf of Mexico. *Gulf Res. Re,* 6:145-152.

Powell, A.B. and F.J. Schwartz. 1979. Food of *Paralichthys dentatus* and *P. lethostigma* (Pisces: Bothidae) in North Carolina estuaries. *Estuaries*. 2:276-279.

Roelofs, E.W. 1954. Food studies of young Sciaenid fishes, *Micropogon* and *Leiostomus* from North Carolina. *Copeia* 1954:151-153.

Schoener, T.W. 1974. Resource partitioning in ecological communities. *Science*. 185:27-39.

Schwartz, F.J. 1980. Food analysis of selected fishes captured in Cape Fear Estuary and adjacent Atlantic Ocean, North Carolina. 1973-1978. Tech. Rpt. to Carolina Power and Light, Vol. 8: Inst. of Mar. Sci., Univ. of North Carolina, Morehead City, N.C.

Strauss, R.E. 1979. Reliability estimates for Ivlev's electivity index, the forage ration, and a proposed linear index of food selection. *Trans. Am. Fish. Soc.* 108:344-352.

Stickney, R.R., G.L. Taylor, and D.B. White. 1975. Food habits of five young southeastern United States estuarine Sciaenidae. *Chesapeake Sci.* 16:104-114.

Thayer, G.W., D.E. Hoss, M.A. Kjelson, W.F. Hettler, Jr. and M.W. LaCroix. 1974. Biomass of zooplankton in the Newport River Estuary and the influence of postlarval fishes. *Chesapeake Sci.* 15:9-16.

Thorman, S. 1983. Food and habitat resource partitioning between three estuarine fish species on the Swedish west coast. *Estuarine, Coastal and Shelf Science*. 17:681-692.

Turner, R.E. 1981. Plankton and the distribution of fishes on the southeastern United States continental shelf. *Science.* 214:353-354.

Weinstein, M.P. 1979. Shallow marsh habitats as primary nurseries for fishes and shellfish, Cape Fear River, North Carolina. *Fish Bull.* 77:339-357.

West, T. 1985. Abundance and diversity of benthic macrofauna in sub-tributaries of the Pamlico River Estuary. *J. Elisha Mitchell Sci. Soc.* 101:142-159.