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FOOD HABITS OF THE GAME FISHES OF LAKE ANNA, VIRGINIA

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This is to certify that the thesis prepared by Thomas Kenneth Rohrer entitled Food Habits of the Game Fishes of Lake Anna, Virginia has been approved by his committee as satisfactory completion of the thesis requirement for the Master of Science degree in Biology.

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THESIS

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science at Virginia Commonwealth University

by

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This thesis is dedicated to my wife, Marsha, for her patience and encouragement while the manuscript was in preparation.

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ABSTRACT

Rohrer, Thomas Kenneth, M. S., Virginia Commonwealth University, May, 1975. Food Habits of the Game Fishes of Lake Anna, Virginia. Dr. James R. Reed, Jr., major professor.

Beginning in May, 1973 and continuing through August, 1974 the food habits of several species of game fishes from Lake Anna, Virginia were investigated via gut content analysis. A variety of collecting methods were employed to secure specimens for examination and stomach contents were reported as percent frequency of occurrence. A total of one hundred and two collections were made yielding 287 largemouth bass, Micropterus salmoides (Lacépède); 166 chain pickerel, Esox niger LeSueur; 53 bluegill, Lepomis macrochirus Rafinesque; 32 pumpkinseed, Lepomis gibbosus (Linnaeus); and 63 black crappie, Pomoxis nigromaculatus (LeSueur). It was found that M. salmoides and E. niger were the top carnivorous fishes in the lake with fish remains being the most commonly occurring food item. Fish remains were present in from 23.3% to 87.5% of the M. salmoides collected and were found in 45.6% to 76.0% of the E. niger sampled.

Specific dietary preferences of M. salmoides showed changes as the populations of forage fish species changed. In the first months of the study Cyprinidae were found

to be the dominant food item for this species. As the Centrarchidae population increased, members of that family became the primary forage fish. Gizzard shad, Dorosoma cepedianum (LeSueur) were found to be the most frequently occurring food species for both M. salmoides and E. niger during the last two months of the study after a dramatic increase in the D. cepedianum population in the lake was noted.

The food habits of three species of smaller Centrarchidae (bluegill, Lepomis macrochirus Rafinesque; pumpkinseed, Lepomis gibbosus (Linnaeus); and black crappie, Pomoxis nigromaculatus (LeSueur)) were also investigated during the latter half of the study. The three Centrarchidae species appeared to have species-specific dietary patterns allowing for minimal competition for food resources between the species.

INTRODUCTION

A study of the food habits of the dominant fishes of a particular aquatic ecosystem offers much information about the fish fauna of that system. Food relationships do at least in part determine the size, condition, and overall viability of fish populations (Lagler, 1956). This is especially true in restricted ecosystems such as warm water lakes and reservoirs. A complete picture of the food web of an aquatic ecosystem is not only valuable from the standpoint of sport fisheries management but is also prerequisite to any study of environmental effects on that ecosystem. A disruption of any aspect of a delicately balanced food web may result in an upset of the entire ecosystem (Odum, 1959). This is especially true for the food relationships which support game fish populations.

Numerous studies have considered the food habits of the largemouth bass, Micropterus salmoides, (summary by Emig, 1966) and the chain pickerel, Esox niger as they represent two of the major sport fish species in warmwater lakes. Previous studies have, however, been performed on established lakes which have reached a state of dynamic equilibrium. Further information on the dynamics of the food habits of these species and the

entire food web for newly created reservoirs is nearly absent in the literature. Information on the food habits of the fishes of newly impounded reservoirs would contribute greatly to the successful management of the sport fishery of these systems and assist in maximizing the recreational use of such bodies of water. It was in the hopes of obtaining such information that a detailed study of the food habits of the fishes of Lake Anna, Virginia was begun within the first year of the lake's full impoundment.

THE STUDY AREA

Lake Anna consists of a 9,600 surface acre reservoir and an adjacent 3,400 surface acre lagoon system separated from the main body of water by a series of compacted earth dikes. The lake was created by the impoundment of the North Anna River by the Virginia Electric and Power Company (VEPCO) for use in their North Anna nuclear power station operations. When construction on the power station is completed, the main body of the reservoir will serve as a source of cooling water for the nuclear reactor operations while the lagoon system will receive thermal effluent from the plant. The lake is located in the North-Central region of Virginia (Figure 1) and is within the York River drainage basin (Figures 2 and 3). The lake encompasses parts of Orange, Spotsylvania, and Louisa Counties.

Figure 1. Location of Collecting Stations on Lake Anna, Virginia.
Location of Lake Anna, Virginia.

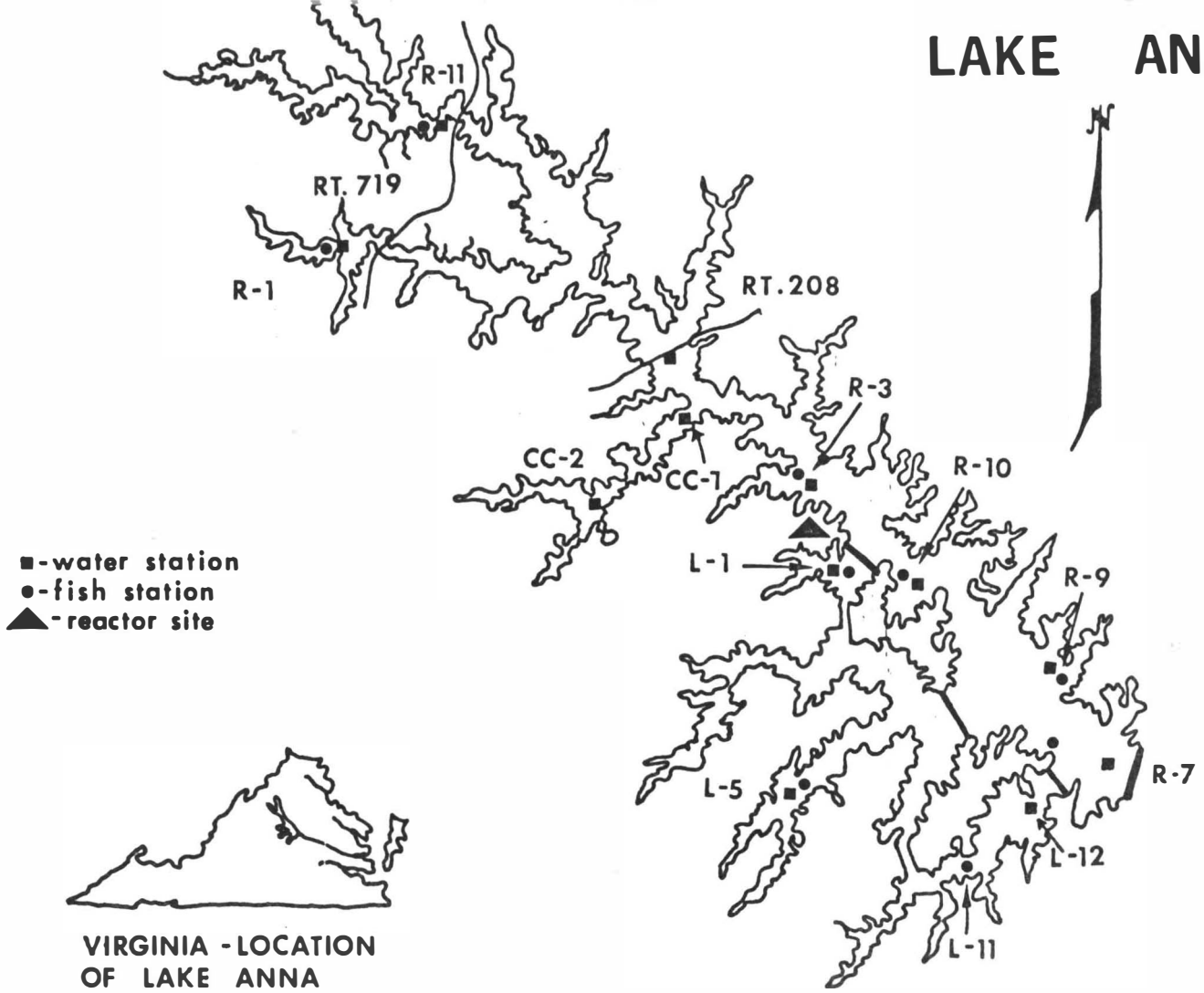
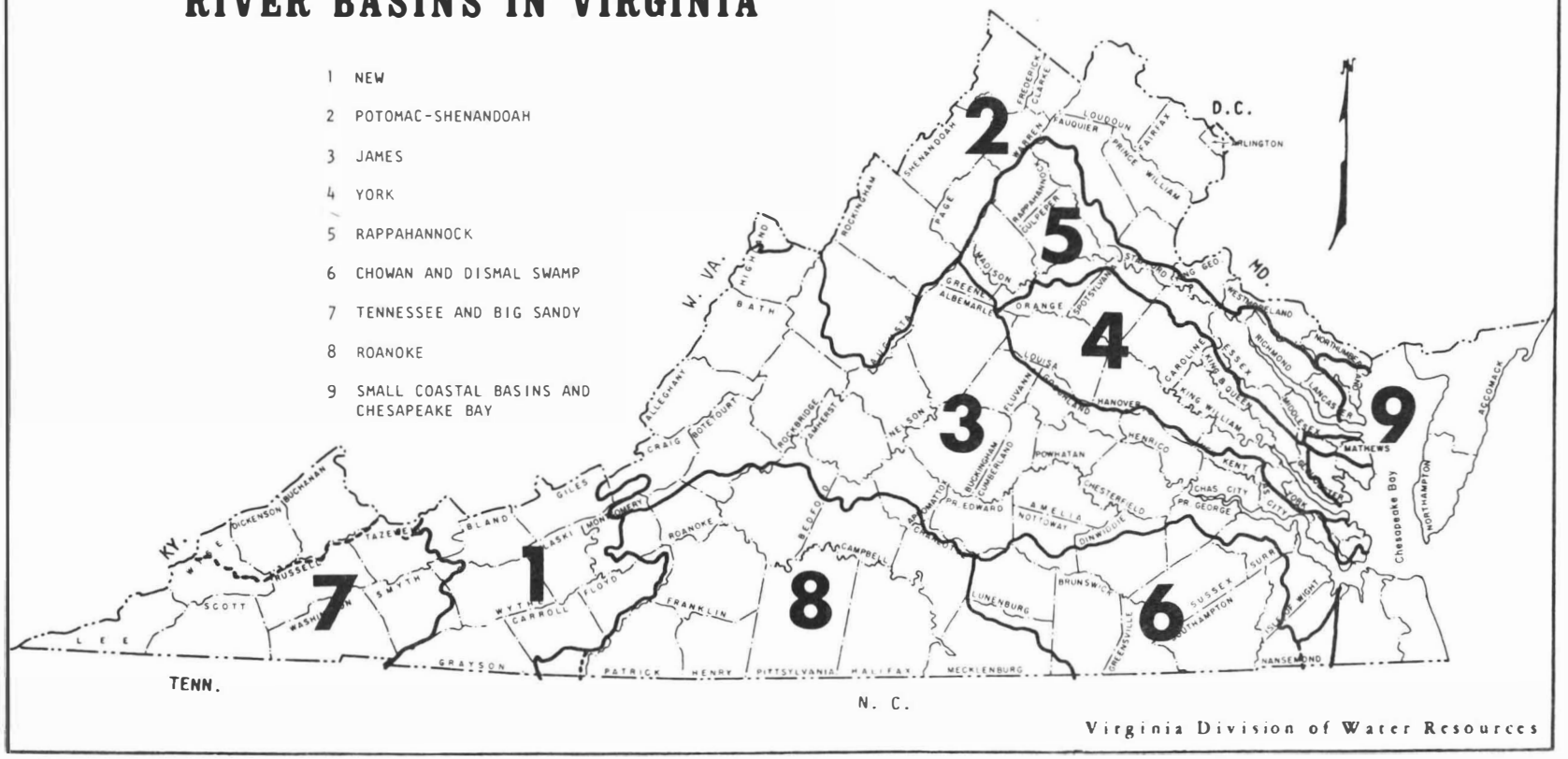

LAKE ANNA
R-11
RT. 719
R-1
RT. 208
R-3
CC-2
CC-1
R-10
L-1
R-9
R-7
L-5
L-12
L-11
■-water station
●-fish station
▲-reactor site
VIRGINIA - LOCATION
OF LAKE ANNA

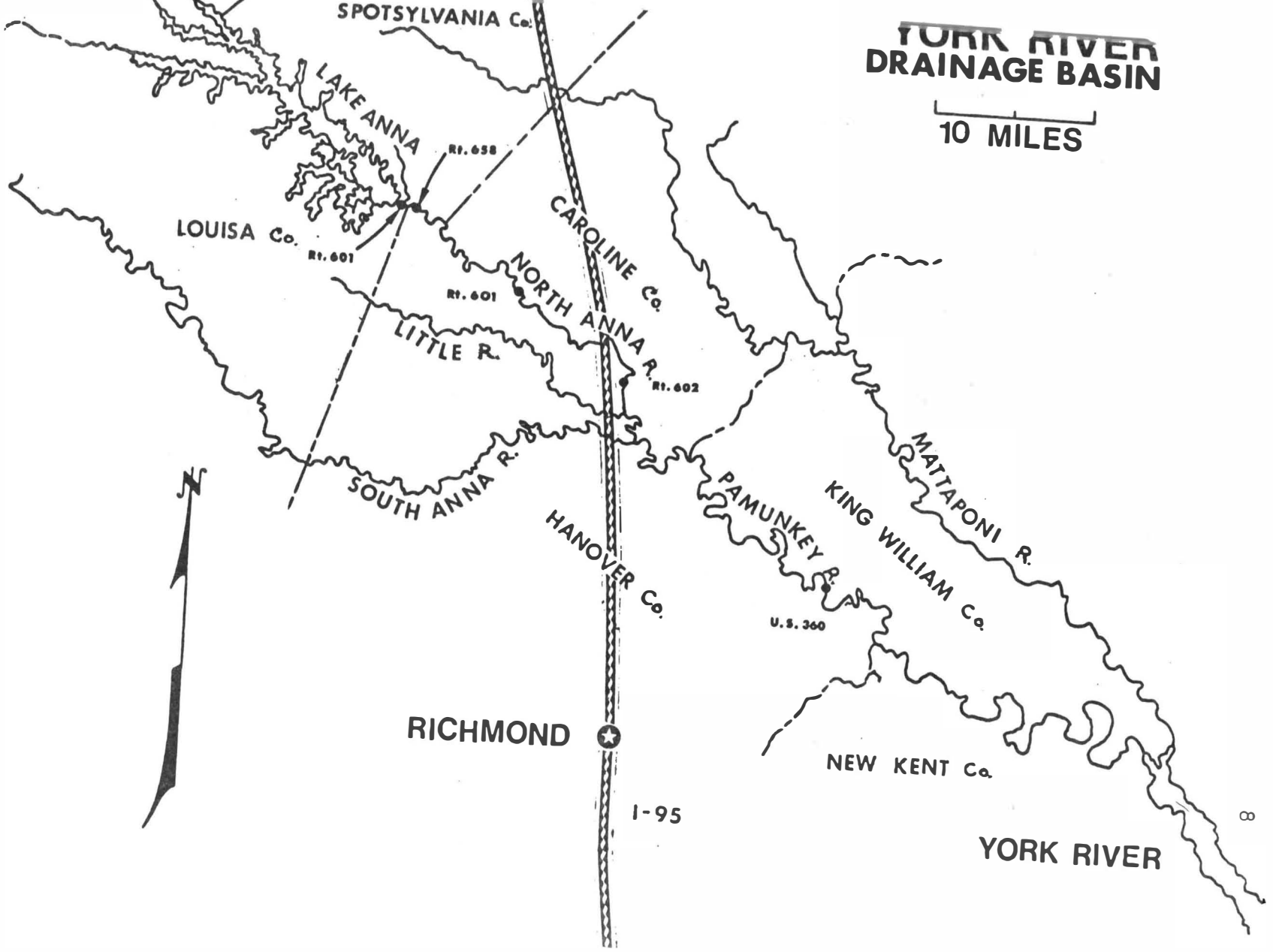
Figure 2. Major River Basins in Virginia.

RIVER BASINS IN VIRGINIA



Virginia Division of Water Resources

Figure 3. York River Drainage Basin Showing the Location of Lake Anna.


YORK RIVER
DRAINAGE BASIN
10 MILES
SPOTSYLVANIA Co.
LAKE ANNA
Rt. 638
LOUISA Co.
Rt. 601
Rt. 601
CAROLINE Co.
NORTH ANNA R.
Rt. 602
LITTLE R.
SOUTH ANNA R.
HANOVER Co.
PAMUNKEY R.
U.S. 360
KING WILLIAM Co.
MATTAPONI R.
RICHMOND
I-95
NEW KENT Co.
YORK RIVER

A full pool elevation of 250 feet was maintained throughout the study. Prior to impoundment the entire area occuppied by the lake was clear-cut and the debris removed. Lake Anna began filling in January of 1972 and a full pool stage was reached by April, 1972. Fish species present include native species that had previously inhabited the impounded rivers and streams and those fish that were stocked by the Virginia Commission of Game and Inland Fisheries (Table 1). Dominant game fish species and, thus, those with which this study was primarily concerned include the largemouth bass, Micropterus salmoides and the chain pickerel, Esox niger. Several species of Centrarchidae are also valuable to the sport fishery of the lake among them being the bluegill, Lepomis macrochirus; pumpkinseed, Lepomis gibbosus; and black crappie, Pomoxis nigromaculatus.

MATERIALS AND METHODS

Collections of fish used in this study were made at the stations shown in Figure 1. During the period May through August, 1973, seven hundred and fifty feet of experimental mesh gill net and six hoop nets were set overnight at each station once per month. The gill net mesh sizes ranged from 1½" to 6" diagonal stretch with the mesh size changing every fifty feet of net length. All panels of the net were six feet in depth. The open end of the hoop nets measured three

Table 1. Summary of Fishes Stocked in Lake Anna, Virginia.

SPECIES	NUMBER	WEIGHT (lbs.)	DATE
Micropterus salmoides	254,720	138.5	May, 1972
	3,100	13.0	July, 1972
Ictalurus punctatus	95,300	2,157.0	September, 1971
	287,000	1,642.0	August, 1972
	12,458	257.0	October , 1972
Lepomis macrochirus	369,000	256.5	March, 1972
	6,000	300.0	April, 1972
	1,099,000	476.0	September, 1972
	2,019,077	1,915.0	October, 1972
Lepomis microlophus	101,000	101.0	April, 1972
	494,401	626.0	October, 1972
	200,250	89.0	November, 1972

feet in diameter. Supplementary collecting methods used during the summer of 1973 included the use of an A. C. electrofishing apparatus and the use of straight and bag seines from ten feet to fifty feet in length.

Beginning in December of 1973 and continuing through August, 1974 gill netting was reduced to three hundred feet of net per station per month. Four foot diameter fyke nets were added to our methods beginning in May, 1974. Seining, electrofishing, and angling were also used as collecting methods beginning in March and continuing through August, 1974. Electrofishing during this period was limited to several mid-summer collections while seining and angling were employed every month during this period.

Fish of an individual species from all collections were pooled each month to comprise the sample for a particular month in the case of largemouth bass (Micropterus salmoides) and chain pickerel (Esox niger). The smaller Centrarchidae-bluegill, Lepomis macrochirus; pumpkinseed sunfish, Lepomis gibbosus; and black crappie, Pomoxis nigromaculatus were grouped by species to comprise one large sample for each species. Collections of these fish were made throughout the spring and early summer of 1974. In all, one hundred and two collections were made throughout the study period of May, 1973 to August, 1974 with thirty-nine of the collections being

made in 1973 and sixty-three in 1974. A summary of the total fish collected is presented in Tables 2 and 3. The total sample size (N) for respective species is as follows:

largemouth bass, Micropterus salmoides=287
chain pickerel, Esox niger = 166
bluegill, Lepomis macrochirus = 53
pumpkinseed, Lepomis gibbosus = 32
black crappie, Pomoxis nigromaculatus= 63

Largemouth bass and chain pickerel used in the study were selected to include only those of a total length of 19.0 cm minimum. The stomachs of these fish were excised in the field and immediately preserved in a solution of 10% formaldehyde. In the case of the smaller Centrarchidae, individuals up to a total length of 12.0 cm were selected and preserved whole in a solution of 10% formaldehyde immediately after being removed from the lake. The stomach contents of all fish were later identified in the laboratory to the lowest possible taxon using Blair, et. al. (1968), Chu (1949) Edmonson (1959), Needham and Needham (1962), Eddy (1957), American Public Health Association, et. al. (1954), Prescott (1969, 1970) and Usinger (1956).

Gut contents of the smaller fish (less than 12.0 cm in total length) were mixed with an equal volume of distilled water and placed on a microscope slide for

TABLE 2. Summary of Fish Collected in Lake Anna, May - August, 1974

	Collecting Stations								
	1L	5L	11L	7R	9L	10R	3R	11R	Rt.719
# of Collections	4	4	4	4	4	4	4	4	4
# of Families	7	6	6	7	7	7	7	6	6
# of Species	12	10	11	13	12	13	14	9	11
Total # of Fish per Station	231	126	149	214	112	141	263	40	188

Table 3. Summary of Fish Collected
In Lake Anna, May - August, 1973.

	Collecting Stations							
	1L	3L	5L	6L	11L	Dam	3R	Rt.719
# of Collections	6	6	5	5	4	4	5	4
# of Families	5	5	6	6	6	6	8	6
# of Species	10	11	11	13	14	15	18	14
Total # of Fish per Station	634	1438	1655	756	383	910	789	806

examination. Slides were then scanned at 40 power magnification and food items identified. The slides were then re-examined at 100 power magnification for smaller organisms.

Temperatures were taken at one meter intervals throughout the water column at each station near the gill net set with a Yellow Springs Instrument Company Model 51 dissolved oxygen/temperature meter.

In all cases gut contents of the species examined are reported as percent frequency of occurrence. Lagler (1956) states that this method gives the most accurate view of the food habits of predatory species which are primarily piscivorous. Nomenclature follows that of Blair, Blair, Brodkorb, Cagle, and Moore (1968) and Bailey, Fitch, Herald, Lachner, Lindsey, Robins, and Scott (1970).

RESULTS AND DISCUSSION

Preliminary Study: May-August, 1973

In the preliminary stages of the study primary interest was given to the food habits of the largemouth bass, Micropterus salmoides, and to the chain pickerel, Esox niger, due to their position as the top carnivores of the food web as well as their popularity as sport fish species. The number and percent frequency of occurrence of food items found in the stomachs of largemouth bass during this period are presented in Table 4. The most frequently occurring food item for each month was the remains of other fishes. This is to be expected as all bass used in this study were beyond the age at which they become predominantly piscivorous (Breder, 1966; Carlander, in press). Fish remains were found to occur at the percent frequencies of 44.0, 56.4, 42.9, and 64.8 respectively for the months May, June, July, and August, 1973. Of the identifiable fish species, members of the Cyprinidae family (primarily the golden shiner, Notemigonus crysoleucas) occur five times as frequently as a food item as do members of the Centrarchidae in the May sample. In both June and July there is an apparent reversal of this feeding pattern with Centrarchidae being present four

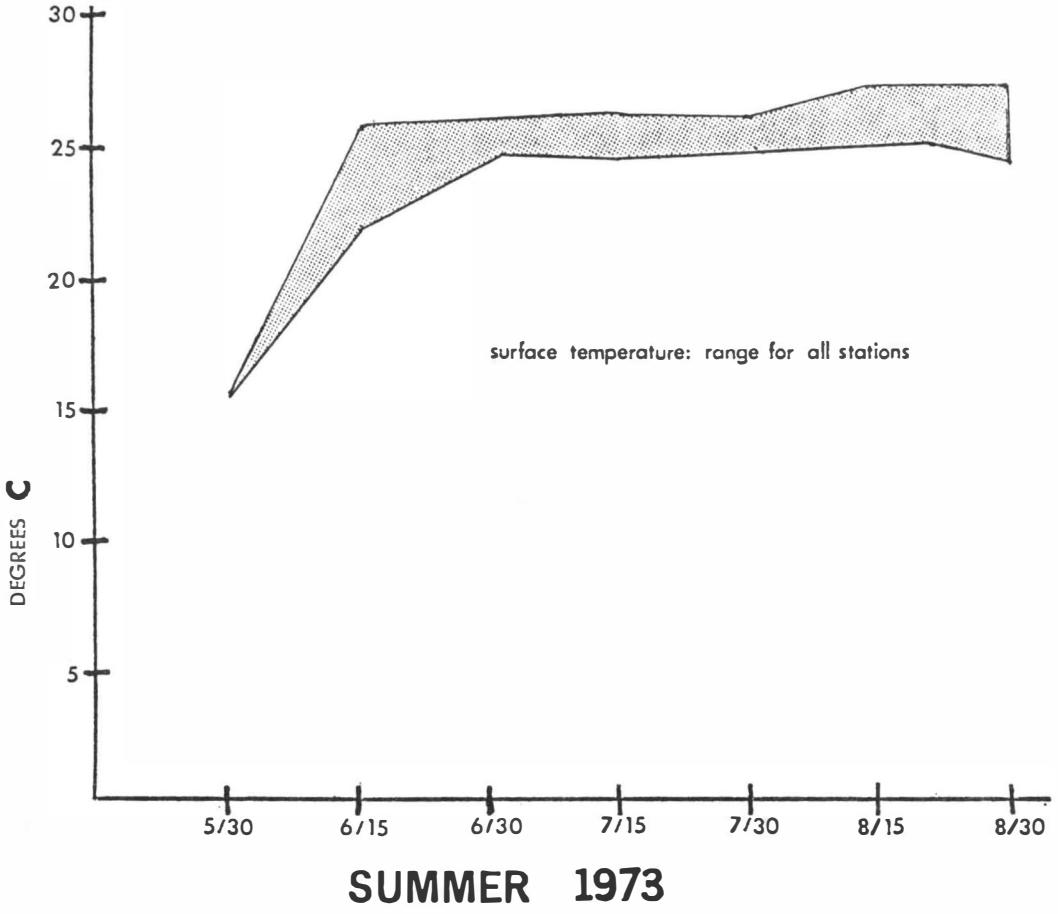
Table 4. Stomach Contents of Largemouth Bass, Micropterus salmoides, Collected From Lake Anna, Virginia (May- August, 1973). N=102.

Food Item	May		June		July		August	
	No.	% Freq.	No.	% Freq.	No.	% Freq.	No.	% Freq.
Pisces (total)	11	44.0	22	56.4	9	42.9	11	64.8
Unidentifiable	3	12.0	12	31.0	5	23.8	7	41.2
Centrarchidae	1	4.0	8	20.2	3	14.3	1	5.9
Cyprinidae	7	28.0	2	5.2	1	4.8	2	11.8
Ictaluridae	-	-	-	-	-	-	1	5.9
Insecta (Total)	1	4.0	4	10.3	2	9.6	-	-
Hymenoptera	-	-	1	2.6	-	-	-	-
Odonata	1	4.0	1	2.6	1	4.8	-	-
Unidentifiable	-	-	2	5.1	1	4.8	-	-
Plant Material (total)	1	4.0	3	7.7	6	28.5	-	-
Woody material	-	-	3	7.7	1	4.8	-	-
Algae, leaves and other herbaceous material	-	-	-	-	5	23.7	-	-
Empty	12	48.0	10	25.6	4	19.0	6	35.2
Total Number Sampled	25		39		21		17	

times as often as Cyprinidae in June and three times as often in July. The Centrarchidae utilized as food items consisted of members of the genus Lepomis as well as a large number of Micropterus salmoides fry and fingerlings. It is evident from this that there is a high incidence of cannibalism among the largemouth bass population of Lake Anna. Carlander (in press) has also noted this phenomenon and states that the most successful members of largemouth bass populations are those individuals which exhibit the greatest degree of cannibalism. This seems to be especially true in environments where the density of forage fish species is small and other individuals of the same species are thus a large percentage of the available food supply.

The apparent reversal of food item preference between May and June, 1973 may be explained by the phenology of reproduction in Micropterus salmoides and other members of the Centrarchidae in relation to ambient water temperatures. Wiebe (1935) observed that largemouth bass do not spawn at temperatures lower than 64 F (18 C). Surface water temperatures for all stations averaged 16C on May 30, 1973 and rose to an average of 24 C by June 15, 1973. Figure 4 illustrates the range of surface water temperatures for all stations on the lake from May 30, 1973 to August 30, 1973. During the two week period from the end of May to June 15, 1973

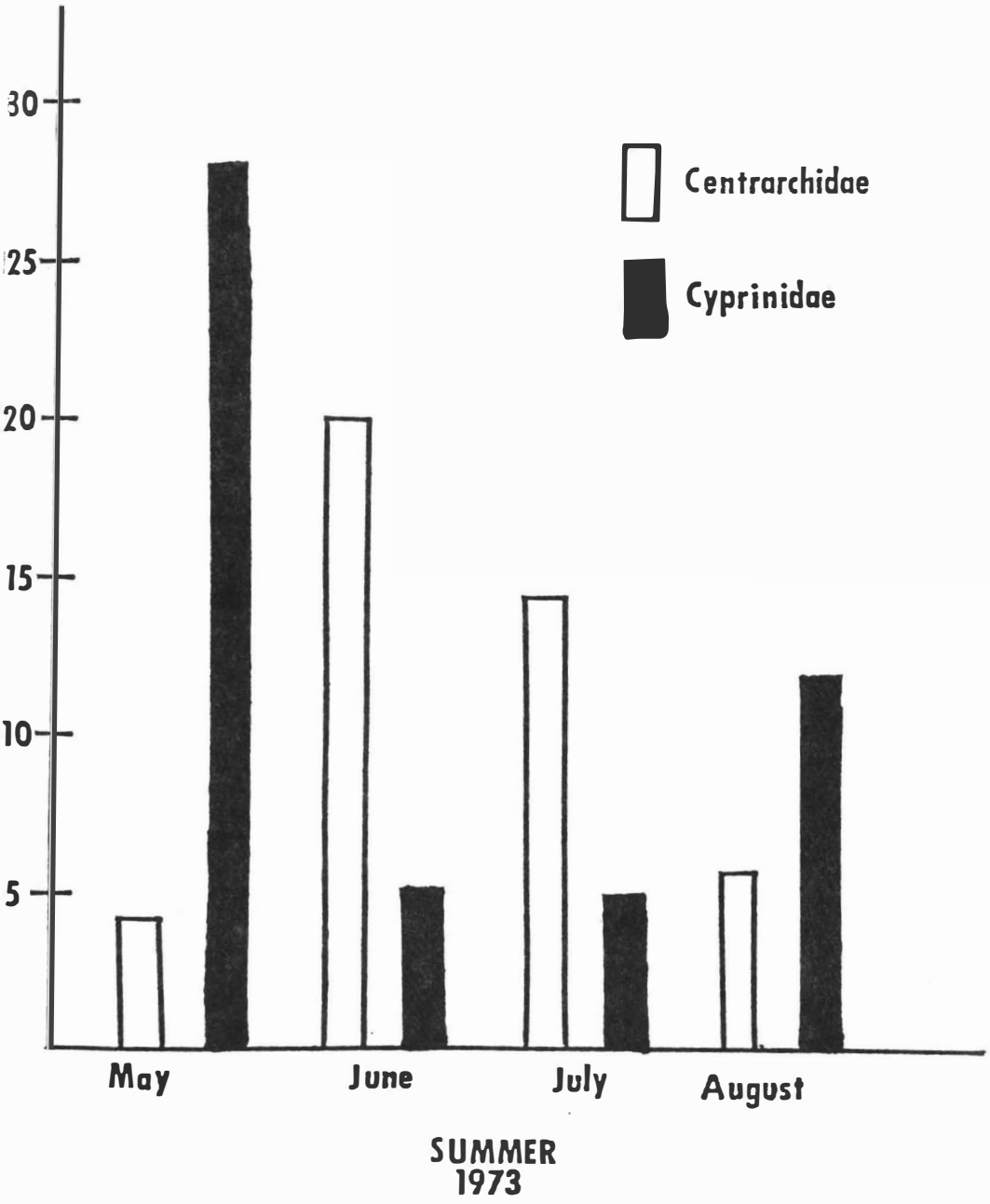
Figure 4. Surface Water Temperature Range for All Collecting Stations (May-August, 1973).


30
25
20
15
10
5
DEGREES C
surface temperature: range for all stations
5/30
6/15
6/30
7/15
7/30
8/15
8/30
SUMMER 1973

the ambient water temperatures suitable for spawning in the species occurred. According to data by Forbes and Richardson (1909) the fertilized eggs of largemouth bass hatch in nine to ten days. This may be near the maximum time necessary for development from fertilization to hatching as later work by Carbine (1939) shows that hatching often occurs only three days after fertilization . The most recent research has shown that largemouth bass begin spawning when mean daily water temperatures at nesting depths was 14.4 C to 15.0 C (Miller and Kramer, 1971). Thus it is likely that a large number of largemouth bass fry were present in the lake by the time that the June, 1973 sample was collected. This is supported by the fact that large schools of M. salmoides fry were observed in the shallow near-shore areas of the lake in mid-June. In addition, collections made using ¼ inch mesh seines yielded a number of bass fry during the week of the June collections. The lowest spawning temperature reported for the bluegill, Lepomis macrochirus, Rafinesque is 17 C (Stevenson et. al., 1969). It is therefore likely that many young of the year bluegill were added to the available food items during this same two week period.

The preliminary study showed that, when available, small Centrarchidae are the preferred food of the

Figure 5. Relative Percent Frequency of Occurrence of Centrarchidae and Cyprinidae in the Stomach Contents of Largemouth Bass, Micropterus salmoides (May-August, 1973).


30
25
20
15
10
5
Centrarchidae
Cyprinidae
May
June
July
August
SUMMER
1973

largemouth bass population in Lake Anna as the population of Cyprinidae in the lake remained large and fairly constant throughout the summer of 1973 (Reed, 1974a). Espinosa and Deacon (1973) have also shown in controlled food choice experiments on M. salmoides that the golden shiner, Notemigonus crysoleucas, was rejected as a food item when other prey was also available. The largemouth bass is an euryphagous species and will adapt its feeding behavior to take adavantage of the most abundant food resource present and did accept N. crysoleucas as a second choice food item.

The dominance of Cyprinidae as prey items in May and August is probably due to a combination of their relative abundance and an inherent prey size limitation for the majority of the largemouth bass population of the lake. In comparing the total lengths of Centrarchidae utilized as food by the bass with the average lengths of centrarchid fry taken in seine samples, a distinct positive correlation is evident (Table 5). Of particular interest is the data for August, 1973 which shows a mean total length of 10.6 cm for all centrarchid young of the year collected while the mean lengths of Centrarchidae used as food items was only 10.2 cm ($P<0.05$). These data suggest that there may be a selection for the smaller members of the Centrarchidae population as prey by the largemouth bass. Throughout the study, the

Table 5. Average Lengths of Centrarchidae Fry Present in Stomachs of *Micropterus salmoides* Compared to the Average Total Length of *M. salmoides* Fry Collected From Lake Anna (1973).

	Average Total Length (Cm)		
	June	July	August
Average total lengths of *M. salmoides* fry collected from Lake Anna	2.8	5.8	10.6
Average lengths of *M. salmoides* and other Centrarchidae found in the stomachs of adult *M. salmoides*.	3.1	5.6	10.2

maximum total length for any prey fish found in the stomach of a largemouth bass was 10.5 cm. Under aquarium conditions Tarrant (1960) showed that there was a positive correlation between Micropterus salmoides size and the size of the forage fish preferred. The majority of the largemouth bass population in Lake Anna in the summer of 1973 were of such a size that 10.5 cm was approximately the maximum size of prey item tolerable. The majority of Notemigonus crysoleucas present in the lake during this time period were 10.0 cm or less in total length which allowed them to be utilized as a forage species when there was a lack of Centrarchidae of suitable prey size. Espinosa and Deacon (1973) have stated that the size of bait items did not interfere with the feeding preferences of M. salmoides but a review of their methods shows all prey items in their study to have been smaller than 10.5 cm in length with the majority ranging from 6.0 cm. to 10.0 cm.

Primary Study: December, 1973 to August, 1974.

The investigations of the food habits of the important species of game fishes which were begun in May, 1973 were continued and expanded throughout the period from December, 1973 through August, 1974. In the summer of 1973 the food habits of the largemouth bass, Micropterus salmoides was given primary attention as

this species was the most important in the lake from a sport fishing point of view. The food habits of adult chain pickerel, Esox niger, were also investigated to a lesser extent primarily to document the presumed position of this species as the top carnivore of the lake. The chain pickerel has long been known as a voracious predatory species as documented by other studies of its food habits (Johnson, 1969; Raney, 1942). Using the size separation proposed by Flemer and Woolcott (1966) the food habits of 166 chain pickerel of 74.0 mm or greater total length were investigated. The preliminary survey of the summer of 1973 showed that, as had been previously reported (Raney, 1942), E. niger of this size category were almost exclusively piscivorous. The main study of the food habits of this species was concentrated on identifying those prey species most frequently utilized and comparing these with the food preferences of the other major predator fish species in the lake, Micropterus salmoides.

The preliminary food habits study indicated the need for a sampling period covering a greater segment of the year as well as an increase in sample sizes. In addition, several sources (Lagler, 1956; Smith, 1974) suggested that two or more contiguous trophic levels should be investigated in any research of this general

type. Thus the food items of several of the forage fish species warranted investigation as well. Since members of the family Centrarchidae comprised the bulk of the food intake by both M. salmoides and E. niger in the summer of 1973, an examination of the stomach contents of small Centrarchidae (12.0 cm or less total length) was made throughout the summer of 1974. Gut contents of three species of this family--Lepomis macrochirus, Lepomis gibbosus, and Pomoxis nigromaculatus were investigated in order to develop a more complete picture of the food web of Lake Anna.

Largemouth Bass, Micropterus salmoides (Lacépède)

The stomach contents of Micropterus salmoides collected from Lake Anna from December, 1973 to August, 1974 are presented by month in Table 6. Food items for this species are listed as percent frequency of occurrence in an individual specimen. Lagler (1956) states that this method of stomach content analysis most accurately represents the food habits of dominant prey species. For all months the most abundant food item was the remains of other fishes. This supports data by Breder (1956) and Carlander (in press) stating that this species is known to be piscivorous at this size. Our studies on young of the year bass collected in the summers of 1973 and 1974 have shown M. salmoides individuals as small as 5.2 cm total length to have the remains of other

Table 6. Stomach Contents of Largemouth Bass, Micropterus salmoides, Collected From Lake Anna (December,1973-August, 1974). N=185

Food Item	Percent Frequency of Occurrence (By Month)						
	Dec. 1973	March 1974	April 1974	May 1974	June 1974	July 1974	August 1974
Fish Remains (total)	87.5	33.3	23.3	51.1	36.4	72.5	62.5
Unidentifiable	25.0	9.5	7.7	34.0	18.2	51.8	25.0
Centrarchidae (tot.)	50.0	14.3	15.4	10.0	18.2	13.8	13.0
Lepomis sp.	50.0	9.5	-	10.0	9.1	10.4	6.2
Pomoxis sp.	-	4.8	15.4	-	9.1	3.4	6.2
Cyprinidae	12.5	9.5	-	5.7	-	-	6.2
Percidae	-	-	-	-	-	3.4	-
Ictaluridae	-	-	-	1.4	-	-	6.2
Clupeidae (Dorosoma cepedianum)		-	-	-	-	6.9	13.0

Table 6. Stomach Contents of Largemouth Bass, Micropterus salmoides, Collected From Lake Anna (December, 1973-August, 1974). N=185

Food Item	Percent Frequency of Occurrence (By Month) Dec. 1973	March 1974	April 1974	May 1974	June 1974	July 1974	August 1974
Insecta (total)	-	4.8	23.1	8.6	18.2	3.4	-
Unidentifiable	-	-	7.7	-	-	-	-
Diptera	-	-	-	4.3	18.2	3.4	-
Odonata	-	-	-	-	-	-	-
Ephemeroptera	-	-	7.7	1.4	-	-	-
Plecoptera	-	-	7.7	2.9	-	-	-
Tricoptera	-	4.8	-	-	-	-	-
Plant material	12.5	-	-	5.7	9.1	6.9	-
Empty	-	61.9	53.8	34.9	36.4	13.8	38.0
Total	8	21	13	70	8	29	16

fish in their stomachs. This indicates that the largemouth bass of Lake Anna become piscivorous as little as two months after hatching.

For the 1974 sampling period, fish remains were found in 23.3% to 87.5% of the M. salmoides examined. Among the identifiable fish remains, the Centrarchidae were the dominant food item for all months with the exception of August, 1974 when the frequency of occurrence of centrarchids as a food item (13%) was equaled by that of the gizzard shad, Dorosoma cepedianum. The Centrarchidae forage species were composed of the genus Lepomis as well as the black crappie, Pomoxis nigromaculatus. Various Cyprinidae formed a smaller part of the diet being found in 12.5% of the fish from the mid-Winter sample and from 0 to 9.5% of the fish collected throughout the summer (Table 6).

The low frequency of occurrence of Cyprinidae in the stomachs of juvenile to adult bass represents a major change from the dietary habits exhibited by these fish in the summer of 1973. Cyprinidae comprised from 5.2% to 28.0% of the total food items of M. salmoides taken from Lake Anna from May through August, 1973. Of all identifiable species, members of the Cyprinidae were dominant in both May and in August of 1973 as a food item. In the 1974 sampling period, however, the

Cyprinidae remained a minor food item occurring from 5.7% to 9.5% of the time.

Two factors may be responsible for this change in the prey status of the Cyprinidae. The dominant member of this family in Lake Anna as shown by collections made during this study to be the golden shiner, Notemigonus crysoleucas. Our collections yielded a very small number of N. crysoleucas in the summer of 1974 as compared to the summer of 1973. This general decline in the population size may have been responsible for the reduction in the utilization of this species as a food item by the largemouth bass. Secondly, over 95.0% of the forage fish found in the stomachs of M. salmoides throughout the course of this study were found to be 10.3 cm or less in total length. As was suggested in the preliminary study, this may represent a size selectivity of prey items by the majority of the largemouth bass population of the lake. This is supported by the fact that all N. crysoleucas found in the stomachs of the bass collected in 1974 were of a total length of 10.1 cm or less. Measurement of over 200 individual golden shiners collected from Lake Anna in the summer of 1974 showed a range in total length of 9.8 cm to 16.7 cm with an average length of 14.8 cm (standard deviation = 1.4). This large collection

of N. crysoleucas indicates that this species is present in the lake in appreciable numbers, however, the majority of the population seems to be larger than the size food item optimally desired by the largemouth bass of TL ≥ 19.0 cm.

It should be noted that the gizzard shad, Dorosoma cepedianum appeared as a part of the food items of Micropterus salmoides for the first time in July, 1974 where it comprised 6.9% of the total number of food items. The frequency of occurrence of D. cepedianum increased to 13.0% by August, 1974. Although many adult gizzard shad were collected throughout the summer, no young of the year were collected until early in July, 1974. It is apparent from these collections that the gizzard shad population underwent a spawning and reproduction of high success in the early summer of 1974. This added an important forage fish resource to the lake and altered the food habits of the predatory species. As was noted for the other forage fish species, all gizzard shad found in the stomachs of M. salmoides were of a total length of 10.0 cm or less. Lewis (1967) and Nikolskii (1969) have observed that the feeding behavior of any predatory species tends to exploit the most abundant prey items. The data suggest that D. cepedianum may become the major forage fish for the largemouth bass in Lake Anna. In a similar reservoir in South Carolina,

Bennet and Gibbons (1972) found D. cepedianum to be the dominant food item of adult Micropterus salmoides.

Chain Pickerel, Esox niger LeSeur

The stomach contents of chain pickerel, Esox niger, are presented by month as percent frequency of occurrence in Table 7. The remains of other fishes were the principle food items of chain pickerel during each month of the study. Among the identifiable prey fishes, seven families representing a minimum of ten species were present. The chain pickerel is clearly the most voracious fish species in the lake and utilizes the greatest number of fish species as food items. Centrarchidae comprised from 8.7% to 34.5% of the diet of E. niger during the 1974 study (Table 7). The incidence of Catostomidae ranged from 3.7% to 6.9% while Cyprinidae were present in up to 20.7% of the stomachs dissected each month. Utilization of cyprinids as a food source is greater in the E. niger population than in the Micropterus salmoides population due to the lack of any observable prey size limitation as was evident in the largemouth bass. Gizzard shad appeared as a major food item in the pickerel diet in August of 1974 as they did in the largemouth bass. The Esox niger population in Lake Anna appears to be thriving (Reed, 1974b) and should continue to do so as abundant food

Table 7. Stomach Contents of Chain Pickerel, Esox niger, Collected From Lake Anna (March-August, 1974). N=166.

Food Item	Percent Frequency of Occurrence (By Month) March 1974	April 1974	May 1974	June 1974	July 1974	August 1974
Fish Remains(total)	49.8	47.9	76.0	45.6	48.1	62.9
Unidentifiable	22.7	26.1	10.4	21.6	22.2	25.9
Centrarchidae(Total)	9.0	8.7	34.5	18.6	14.8	22.2
Pomoxis sp.	4.5	-	6.9	5.4	11.1	14.8
Lepomis sp.	-	8.7	6.9	13.5	3.7	-
Micropterus sp.	4.5	-	-	-	-	7.4
Cyprinidae	-	8.7	20.7	5.4	3.7	-
Esocidae	-	-	3.5	-	3.7	-
Catostomidae	4.5	4.4	6.9	-	-	3.7
Ictaluridae	-	-	-	-	3.7	-
Percidae	13.6	-	-	-	-	11.1

Table 7. Stomach Contents of Chain Pickerel, Esox niger, Collected From Lake Anna (March-August, 1974). N=166.

Food Item	Percent Frequency of Occurrence (By Month) March 1974	April 1974	May 1974	June 1974	July 1974	August 1974
Clupeidae (Dorosoma cepedianum)	-	-	-	-	-	11.1
Insecta (total)	-	8.8	-	-	-	-
Diptera	-	-	-	2.7	-	-
Ephemeroptera	-	-	-	5.4	-	-
Odonata	-	4.4	-	5.4	-	-
Plecoptera	-	4.4	-	-	-	--
Amphibia (total)	4.5	4.4	-	2.7	-	-
Plant Material	-	-	-	2.7	3.7	-
Empty	45.5	39.1	24.1	40.5	48.2	40.7
Total in Sample	22	23	29	37	27	28

resources are available.

Large numbers of adult gizzard shad, Dorosoma cepedianum (LeSueur), began to be present in the gill net collections in early summer, 1974 (Reed, 1974b). After this species underwent an apparently successful reproduction during the summer of 1974, D. cepedianum were increasingly utilized as a food source by both Micropterus salmoides and Esox niger. By August of 1974 D. cepedianum was the dominant forage fish present in both of these species.

The appearance of D. cepedianum in Lake Anna was unexpected as this species was not present in the North Anna River prior to impoundment (Reed, 1973) and there is no record of any stocking of this species in the lake (J. Hoffman, personal communication). The Spotsylvania county, Virginia game warden who was present at one of the stocking operations, however, states that gizzard shad were present in a load of striped bass, Morone saxatilis that were delivered to the lake from the United States Federal Fish Hatchery located in Edenton, North Carolina. Gizzard shad were observed to have entered the lake during this stocking operation although no official record was made of their presence (L. C. Boggs, personal communication).

Bluegill, Lepomis macrochirus, Rafinesque

Throughout 1974 as in the summer of 1973, small members of the Centrarchidae family (especially Lepomis sp.) comprised one of the major food item categories for both Micropterus salmoides and Esox niger. To gain further information about the lower trophic levels of the food web of Lake Anna, fifty-three bluegills, Lepomis macrochirus, Rafinesque were collected for stomach content analysis. Specimens selected for examination were all 11.9 cm or less in total length as this was the size Centrarchidae most commonly ingested by the predatory species. The percent frequency of occurrence for each of the food items of the bluegills examined is listed in Table 8. Previous investigators, notably Flemer and Woolcott (1966), Seaburg and Moyle (1964), Gerking, (1962), and Pardue (1973) have documented the importance of insect larvae, particularly of the order Diptera, in the diet of L. macrochirus. Stomach analysis of Lake Anna bluegills confirms these earlier observations as various dipteran larvae were present in approximately 75% of all of the stomachs examined. In addition, small crustaceans representative of the Cladocera, Copepoda, and Ostracoda, play an important part in the diet of the

TABLE 8. BLUEGILL - GUT CONTENT (April - July, 1974)
N = 53, TL = 7.5 cm - 10.0 cm

ITEM	% FREQUENCY OF OCCURRENCE
ROTATORIA	
Kellicottia	5.66
Mytilina	1.89
Trichocerca	3.77
Dicranophorus	1.89
Notholca	1.89
Philodina	3.77
Ploesoma	1.89
Polyartha	1.89
PROTOZOA	
Chilomonas	1.89
Lacrymaria	1.89
Amoeba	1.89
Volvox	3.77
Multicilia	5.66
Spirostomum	1.89
Frontonia	5.66
ANNELIDA	
Naididae	1.89
GASTROPODA	
Amnicolidae	1.89
COELENTERATA	
Hydra	1.89

Table 8. Continued

INSECTA	
Diptera (unidentifiable sp.)	3.77
Chironomus sp.	26.42
Dixa sp.	15.1
Tabanus sp.	1.89
Phalacrocera sp.	11.32
Anopheles sp.	1.89
Culicinae	9.43
Psychoda sp.	1.89
Tanytarsus sp.	3.77
Simulium sp.	1.89
Hemiptera (unident.)	11.32
Notonectidae	1.89
Naucoridae	1.89
Coleoptera (unident.)	5.66
Erotylidae	3.77
Hydrophilidae	1.89
Zygoptera (unident.)	1.89
Coenagrion sp.	1.89
Ephemeroptera	3.77
Odonata (unident.)	1.89
Hymenoptera	3.77
Formicidae	1.89
Cladocera (unident. sp.)	1.89
Daphnidae	26.42
Eurycerus sp.	1.89
Polyphemus sp.	3.77
Ceriodaphnia sp.	7.55

Table 8. Continued

Diaphanosoma sp.	3.77
Chydorinae	3.77
Leptodora sp.	1.89
Acroperus sp.	1.89
COPEPODA	
Cyclopidae	58.49
Canthocamptus sp.	5.66
Limnocalanus sp.	7.55
Diaptomus sp.	1.89
OSTRACODA	
Eubranchipus sp.	20.75
Cypridopsis sp.	1.89
ALGAE	
Actinella	1.89
Anabena	1.89
Arthrospora	1.89
Chlorallanthus	1.89
Chlorococcum	11.32
Cladophora	3.77
Closterium	7.55
Cyclotella	11.32
Cymbella	1.89
Desmidium	13.20
Diatoma	1.89
Diogenes	3.77
Fragilaria	9.43
Frustulia	26.42

Genicularia	1.89
Groenbladia	1.89
Melosira	3.77
Micrasterias	1.89
Mougeotia	18.87
Navicula	18.87
Nostoc	1.89
Nitzschia	1.89
Oscillatoria	3.77
Pinnularia	1.89
Polycystis	3.77
Scenedesmus	1.89
Spirogyra	33.96
Spirostomum	1.89
Surirella	1.89
Tabellaria	16.98
Tetrapedia	1.89
Ulothrix	1.89
Zygnema	9.43

bluegill of Lake Anna. The most frequently found crustaceans were members of the Cyclopidae family which were present in 58.5% of the bluegill examined. Members of the Daphnidae were the second most frequently occurring crustacean being present in 26.4% of the stomachs of fish examined.

Various genera of unicellular and filamentous algae were found in nearly all of the Lepomis macrochirus examined. The rare overall frequency of occurrence of most of the genera indicates that many of them are probably ingested along with other food items and are not themselves a significant source of food. Two genera of filamentous algae, Spirogyra and Mougeotia, appear to be an important part of the diet of this sunfish. These two genera occurred in 34.0% and 18.9% of the bluegill stomachs respectively and were present in such large quantities that ingestion by chance is not a reasonable explanation for their appearance. Flemer and Woolcott (1966) have concluded that the bluegill is an opportune feeder and that selectivity in this species food habits operates only in favor of an animal diet. It should be noted, however, thattheir data show plant material to be present in only 9.5% of their bluegill sample while in this survey plant material occurred in appreciable quantities at least 34.0% of the time.

Howell, et al., (1941) postulated that the presence of large quantities of "second choice" food such as plant material in carnivorous fishes is indicative of an excessive number of fish competing for the available animal foods. Observation and seine collections showed very dense populations of small Lepomis macrochirus in the shallow, littoral areas of the lake. These fish may be pressured to exploit the filamentous algae in these areas as a food source due to the intense competition for animal food sources. It further appears that this large bluegill population will remain in the lake in large numbers as long as they are able to secure sufficient food. Beyerle (1971) reported that high densities of predators (in particular the northern pike, Esox lucius) will not by themselves controll an overabundance of small bluegills. The increasing presence of gizzard shad, Dorosoma cepedianum, may result in decreased predation on the bluegill population by the predatory fishes, further assisting the success of the bluegill population in Lake Anna.

Pumpkinseed, Lepomis gibbosus (Linnaeus)

The stomach contents of thirty-two pumpkinseed, Lepomis gibbosus (Linnaeus) are presented as percent frequency of occurrence in Table 9. The numerical occurrence (presence of a food item in number of individuals out of 32) is listed as well. The food

Table 9. Stomach Contents of Pumpkinseed Sunfish, *Lepomis gibbosus* Collected From Lake Anna, (April-July, 1974). N=32, Tl=7.2 Cm to 10.0 Cm.

Food Item	Numerical Occurrence	Percent Frequency of Occurrence
Algae (total)	31	96.9
Cladophora	1	3.1
Closterium	8	25.0
Cyclotella	4	12.5
Cymbella	3	9.4
Diatoma	2	6.2
Desmidium	1	3.1
Fragilaria	3	9.4
Frustulia	9	28.1
Melosira	3	9.4
Mougeotia	2	6.2
Navicula	19	59.4
Nitzchia	4	12.5
Nostoc	2	6.2
Oscillatoria	11	34.4
Pinnularia	2	6.2
Protococcus	10	31.2
Scenedesmus	1	3.1
Spirogyra	11	34.4

Table 9. Stomach Contents of Pumpkinseed Sunfish, Lepomis gibbosus, Collected From Lake Anna, (April-July, 1974). N=32, TL=7.2 Cm to 10.0 Cm.

Food Item	Numerical Occurrence	Percent Frequency of Occurrence
Algae (continued)		
Spirostomum	3	9.4
Surirella	2	6.2
Tabellaria	13	40.6
Zygnema	14	43.8
Anellida (total)	7	21.9
Oligochaeta	5	15.6
Naididae	4	12.5
Crustacea (total)	28	87.5
Cladocera (unident.)	5	15.6
Canthocamptus	6	18.8
Polyphemus	2	6.2
Copepoda (unident.)	4	12.5
Cyclopodidae	6	18.8
Diaptomus	2	6.2
Limnocalamus	2	6.2
Daphnia	2	6.2
Hydrocarina	1	3.1
Eurycerus	4	12.5

Table 9. Stomach Contents of Pumpkinseed Sunfish, *Lepomis gibbosus*, Collected From Lake Anna, (April-July, 1974). N=32, TL=7.2 Cm to 10.0 Cm.

Food Item	Numerical Occurrence	Percent Frequency of Occurrence
Insecta (total)	27	84.4
Chironomus	24	75.0
Culicinae	4	12.5
Dixa	7	21.9
Psychoda	2	6.2
Tipulidae	4	12.5
Tanytarsus	2	6.2
Odonata	2	6.2
Zygoptera	1	3.1
Unidentifiable	4	12.5
Plant Material (Macrophytes)	6	18.8
Protozoa (total)	11	34.4
Volvox	4	12.5
Lacrymaria	2	6.2
Chilomonas	2	6.2
Unidentifiable	7	21.9
Rotatoria (total)	11	34.4

Table 9. Stomach Contents of Pumpkinseed Sunfish, *Lepomis gibbosus*, Collected From Lake Anna, (April-July, 1974). N=32, TL=7.2 Cm to 10.0 Cm .

Food Item	Numerical Occurrence	Percent Frequency of Occurrence
Rotatoria (continued)		
Chromogaster	1	3.1
Dacranophorus	2	6.2
Kellicottia	5	15.6
Mytilina	1	3.1
Trichocerca	4	12.5
Unidentifiable	2	6.2

habits of this species differs greatly from those of the bluegill, Lepomis macrochirus, with which it is found in close association in the lake. Algae appear to play a more dominant role in the diet of the pumpkinseed than in the bluegill.

The percent frequency of occurrence of algae in the stomachs of L. gibbosus was found to be 96.9%. Several genera occur with such high frequency that casual ingestion of algae along with other foods is an unlikely possibility. The diatom Navicula occurs most frequently of all the genera of algae and was present in 59.4% of the pumpkinseed stomachs examined. High occurrences of Zygnema (43.8%), Tabellaria (40.6%), Spirogyra (34.4%), and Oscillatoria (34.4%) were also noted. In all, twenty-one genera of algae were present in specimens examined.

The high occurrence of algae is coupled with similarly high percent frequencies of occurrence of Insecta (84.4%) and Crustacea (87.5%). The pumpkinseed sunfish has previously been reported to be highly carnivorous. Flemer and Woolcott reported the majority of food items found in members of this species to be insect larvae. Pearse (1918), Ball (1948), Ball and Tanner (1951), and DeRyke (1922) all found snails to be a major item in the diet of Lepomis gibbosus. Although snails were

uncommon in Lake Anna during this study, the L. gibbosus population appeared quite large and many of the species were taken during seine collections of minimal time effort. The combined utilization of diverse food sources most likely allows such a large population to be supported even in the absence of a large quantity of snails. Of the insects used as food by the pumpkinseed, Chironomus larvae were the most abundant occurring in 75% of all of the fish stomachs examined. It should be noted that the majority of the specimens examined contained a minimum of four different food items often including Algae, Insecta, and Crustacea in a single stomach. Furthermore, none of the L. gibbosus were found to have empty stomachs when collected indicating an abundance of available food resources.

Black Crappie, Pomoxis nigromaculatus (LeSeur)

Of all of the smaller Centrarchidae whose food habits were examined, only the black crappie, Pomoxis nigromaculatus appeared to be totally carnivorous (Table 10). Analysis of the gut contents of sixty-three P. nigromaculatus showed insect remains to be present in 95.2% of all of the individuals examined. Dipteran larvae were present in 63.5% of the stomachs dissected and were the dominant insect food item. Dipteran larvae

Table 10. Stomach Contents of Black Crappie, Pomoxis nigromaculatus, Collected From Lake Anna. (July-August, 1974), N=63, TL= 8.8Cm to 10.9Cm.

Food Item	Numerical Occurrence	Percent Frequency of Occurrence
Insecta (total)	60	95.2
Unidentifiable	2	3.2
Coleoptera	7	11.1
Diptera (total)	40	63.5
Chaoborinae	2	3.2
Chironomidae	12	19.0
Culicinae	3	4.8
Dixa	6	9.5
other Diptera	17	27.0
Ephemeroptera	9	14.3
Odonata	2	3.2
Crustacea (total)	10	15.8
Copepoda (other than Cyclopidae)	3	4.8
Cyclopidae	2	3.2
Cladocera	2	3.2
Anostraca	3	4.8
Rotatoria (total)	1	1.6
Pisces (total)	22	35.0
Unidentifiable	21	33.3
Pomoxis nigromaculatus	1	1.6

Table 10. Stomach Contents of Black Crappie, Pomoxis nigromaculatus, Collected From Lake Anna. (July-August,1974), N=63, TL=8.8Cm to 10.9Cm.

Food Item	Numerical Occurrence	Percent Frequency of Occurrence
Plant material (total)	4	6.4
Algae	1	1.6
Macrophytes	3	4.8
Empty	3	4.8

were represented by members of the Chironomidae, Culicinae, and Chaoborinae families. In addition to the Diptera, other insect orders utilized as prey by P. nigromaculatus included representatives from the Coleoptera, Ephemeroptera, and Odonata.

Fishes also made up a substantial part (35.0%) of the food items found. Most fish present in P. nigromaculatus stomachs were small fry which could not be identified even to Family. It should be noted that a number of these fry were present in each stomach containing them and, when present, no other food items were found. The single identifiable prey fish was a black crappie, Pomoxis nigromaculatus.

The P. nigromaculatus population in Lake Anna and has increased in density over the past year (Reed, 1974b). This may be due to the large amount of available habitat as well as the lack of intense competition for food resources with other Centrarchidae. Although other centrarchids exploited insects as food items, none of the other species did so with as much regularity as did P. nigromaculatus. The fact that the black crappie does not appear restricted to an insectivorous feeding habit but also may utilize Crustacea as a food source assures it of securing a large food supply in the lake.

SUMMARY

This study illustrates that the food web of Lake Anna is a complex, dynamic system. The change in the dominant food habits of the top game fish species, Micropterus salmoides and Esox niger, indicate that the ecosystem of the lake is still undergoing many changes especially in the population dynamics of the fish species. In the first two years of this lake's existence large populations of these desirable sport fish species have flourished. The success of these fish populations is in a large part due to the abundance of successful forage fish populations and ability of the dominant predatory fishes to adapt their feeding so as to exploit the most abundant forage fish species. The data show that in a newly created reservoir the species available as forage fish change in relative abundance from one season to the next. In this particular ecosystem Cyprinidae appeared as the first family of prey fishes to be utilized. Once the individuals of the dominant cyprinid, Notemigonus crysoleucas, population grew to a size larger than that able to be used by one of the primary predators, Centrarchidae were substituted as the favored prey item. With the

appearance of a large gizzard shad (Dorosoma cepedianum) population, the predatory fishes began to utilize this species as a food item to a large extent. Thus, there are many changes in the predator/prey relationships between fishes in newly impounded lakes for at least the first two years of the lake's existence.

The examination of the food habits of the forage fish species documented the importance of aquatic insects, algae, and various crustaceans in the Lake Anna food web. It is obvious that the success of the larger game fish species depends directly on the success and availability of the forage fishes. In addition, the sport fishery which has developed around the smaller Centrarchidae is also dependant on the success of simpler organisms. Thus the fate of the entire game fish population of Lake Anna directly depends upon the maintainence of sufficient numbers of these organisms of the lower trophic levels. Any consideration of environmental impact on the lake must necessarily be concerned with the effects a particular action would have on the production of Algae, Insecta, and Crustacea if the ecosystem is to remain supportative of large populations of desirable game fishes.

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