CENTRARCHID FEEDING INTERACTIONS
IN A SMALL DESERT IMPOUNDMENT

by

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

ABSTRACT

The food habits of largemouth bass *Micropterus salmoides* (Lacepede), black crappie *Pomoxis nigromaculatus* LeSueur, green sunfish *Lepomis cyanellus* Rafinesque, and bluegill sunfish *Lepomis macrochirus* Rafinesque in Pena Blanca Lake were compared using reconstructed volume estimates of food items. Bass fed mainly on fish with green sunfish comprising the greatest part. The relative volume of fish consumed was high except in the winter when aquatic insects were dominant. Crappie fed almost entirely on zooplankton except in the spring when aquatic insects became dominant. Green sunfish ingested equal amounts of gastropods, aquatic insects and zooplankton. Bluegill sunfish ate primarily zooplankton, aquatic insects and terrestrial insects; however, zooplankton were most important. The food of the largemouth bass and green sunfish overlapped with respect to aquatic and terrestrial insects. Any food competition that might exist between the two would be for these foods. However, it is not considered extreme enough to have caused the recent decline in the bass catch. Large amounts of zooplankton were eaten by crappie and bluegills and it is surmised that they may compete with young bass for this food.

INTRODUCTION

The fishery in Pena Blanca Lake is supported primarily by largemouth bass Micropterus salmoides (Lacepede) and black crappie Pomoxis nigomaculatus Le Sueur. These species along with threadfin shad Dorosoma petenense (Gunther) and channel catfish Ictalurus punctatus (Rafinesque) were stocked when the lake was first filled in April, 1958. The bass, crappie and catfish provided excellent fishing in the first three years (McConnell, 1963). However, in recent years there has been a decrease in the numbers of largemouth bass caught. Black crappie fishing success, although erratic, has not declined to the same extent. These reductions in catch occurred after the accidental establishment of two additional centrarchids, green sunfish Lepomis cyanellus Rafinesque and bluegill sunfish Lepomis macrochirus Rafinesque. A coincidental diminution of the largemouth bass population and an increase in the sunfish population suggested that the sunfish might be the cause. The purpose of this research was to study food habits of the four centrarchids and attempt to determine the extent of food competition and predation among them.

Food habits of many fish species have been investigated; however, very few studies have compared the food habits of a fish population in an attempt to understand food competition. Food competition between various fish species has been shown. Green sunfish are said to compete for food with largemouth bass and other game species (Bennett, 1943; Miller and Alcorn, 1946; La Rivers, 1962). Abell and Fisher (1953) stated that a small bluegill population was better able to utilize the available food and caused decline of a much larger green sunfish population. Bennett (1962) found that largemouth bass competed with bluegills for insects when crayfish were not present. Competition was not extensive, however, as bass preferred adult insects. Calhoun (1966) stated that crappie compete with largemouth bass because of their piscivorous feeding habits. These studies concluded that food competition existed among fish species. Thus, it is also possible that food competition may exist in Pena Blanca Lake.

Pena Blanca Lake is located in Santa Cruz County, Arizona at an elevation of 3800 feet. The lake surface varies from 45-50 acres. It has an average depth of 20 feet and a maximum depth of 57 feet. It is warm monomictic lake and normally stratified from March to November (McConnell, 1963).

MATERIALS AND METHODS

Largemouth bass, black crappie, green sunfish, and bluegills were collected at night with a boat-mounted variable voltage electrofishing unit. All electrofishing was conducted near the shoreline. Crappie and bluegills were difficult to shock in the summer and fall; consequently, to supplement the electrofishing sample they were captured in fyke nets baited with cottonseed pellets in fine mesh bags. Captured fish were removed every two hours to insure a minimum of food digestion. All collections were made once a month from December 1966 through December 1967. Fifteen fish of each species was the desired sample size; however, this number was not always obtained (Table 1). All fish were immediately preserved in 10% formalin. No regurgitation was noted.

Total and standard lengths were determined to the nearest millimeter using a standard fish measuring board. The fish were weighed on a triple beam balance to the nearest 0.5 gram. Standard length and weight were used to calculate condition factors K_{SL} (Lagler, 1956).

The contents of the digestive tract from the esophagus to the pyloric valve were removed and examined with a dissecting microscope under low magnification.

Table 1. Monthly sample size (SS), number of empty stomachs (E) and total length range in millimeters (TL-R) of the four centrarchids.

		Largemouth Bass	Black Crappie	Green Sunfish	Bluegill Sunfish
Dec 66	SS	15	14	15	No Sample
	E	1	0	1	
	TL-R	152-265	90-124	93-142	
Jan 67	SS	15	11	15	No Sample
	E	1	0	1	
	TL-R	211-300	94-266	105-167	
Feb 67	SS	15	10	15	15
	E	2	0	0	1
	TL-R	160-267	110-254	118-164	129-180
Mar 67	SS	15	15	15	15
	E	3	0	2	0
	TL-R	184-270	108-140	131-178	136-177
Apr 67	SS	15	15	15	13
	E	3	0	0	1
	TL-R	170-270	110-137	125-173	142-180
May 67	SS	15	15	15	No Sample
	E	3	0	0	
	TL-R	175-228	116-142	120-175	
June 67	SS	15	12	15	No Sample
	E	3	0	0	
	TL-R	173-260	111-175	104-150	
July 67	SS	15	15	15	10
	E	1	0	0	0
	TL-R	155-285	156-184	113-144	97-133
Aug 67	SS	15	15	15	10
	E	5	0	1	0
	TL-R	160-283	167-209	107-134	107-138
Sept 67	SS	15	15	15	15
	E	3	2	0	0
	TL-R	152-242	192-217	104-150	112-148

Table 1. (Continued)

Oct 67	SS	15	15	15	15
	E	1	2	0	0
	TL-R	160-238	168-231	113-152	129-159
Nov 67	SS	15	15	15	15
	E	0	0	1	0
	TL-R	159-240	198-238	120-158	121-169
Dec 67	SS	15	15	15	15
	E	0	0	2	0
	TL-R	164-226	210-242	123-175	141-173
Total	SS	195	182	195	133
	E	26	4	8	2
	TL-R	152-300	90-266	93-178	97-180

When possible, insects were identified to family using the keys of Pennak (1953) and Usinger (1956). Crustaceans and mollusks were identified to order (Pennak, 1953). Most fish remains were identified to species. When this was not possible, threadfin shad were distinguished from centrarchids by vertebral differences.

Estimates were made of the pre-ingested volume of all insects remains. This was accomplished by comparing the remains to similar intact insects of known volume. Intact volumes were determined by water displacement in a graduated centrifuge tube.

Gastropod remains were identified to genus and estimates were made of the total volume by comparison to a snail of a known volume. The total volume was converted to biomass volume using a predetermined ratio of biomass to total volume. This ratio was determined by dissolving the shells of 35 various size snails of a known volume in 1.0 N HCl and measuring the remaining biomass by water displacement. The relative volume of biomass was found to be 25% for Gyraulus and 39% for Helisoma.

Crustaceans were identified to order and their volumes estimated by settling in a graduated centrifuge tube.

The volume of fish remains was measured directly by water displacement when the fish was only slightly digested, and the volume obtained was considered equal to the pre-ingested volume. When fish were partially digested, live volume was estimated from an established relation between intact volume and the combined length of the last five caudal vertebrae (McConnell and Gerdes, 1964). This was done for threadfin shad (Fig. 2) and green sunfish (Fig. 1) the only two species ingested.

The volumes of plant material and bryozoans were estimated by mounding the material into cone-shaped piles. These mounds were compared to similarly shaped clay piles of known volumes.

Foods of the four centrarchids studied were grouped into seven categories: aquatic insects, terrestrial insects, zooplankton, fish, gastropods, plant material and bryozoans. A breakdown of the organisms included in each category is given in Table 2. The volume of each food group in the fish stomachs was measured, and the relative volume that each group comprised of the total volume was determined. A monthly mean relative volume for each food group was than calculated for each centrarchid.

Seasonal mean relative volumes were calculated for each food group. Tukey's W procedure at the 95% confidence interval (Steel and Torrie, 1960) was used to detect significant differences among the seasonal relative volume of foods consumed by each of the centrarchids, and

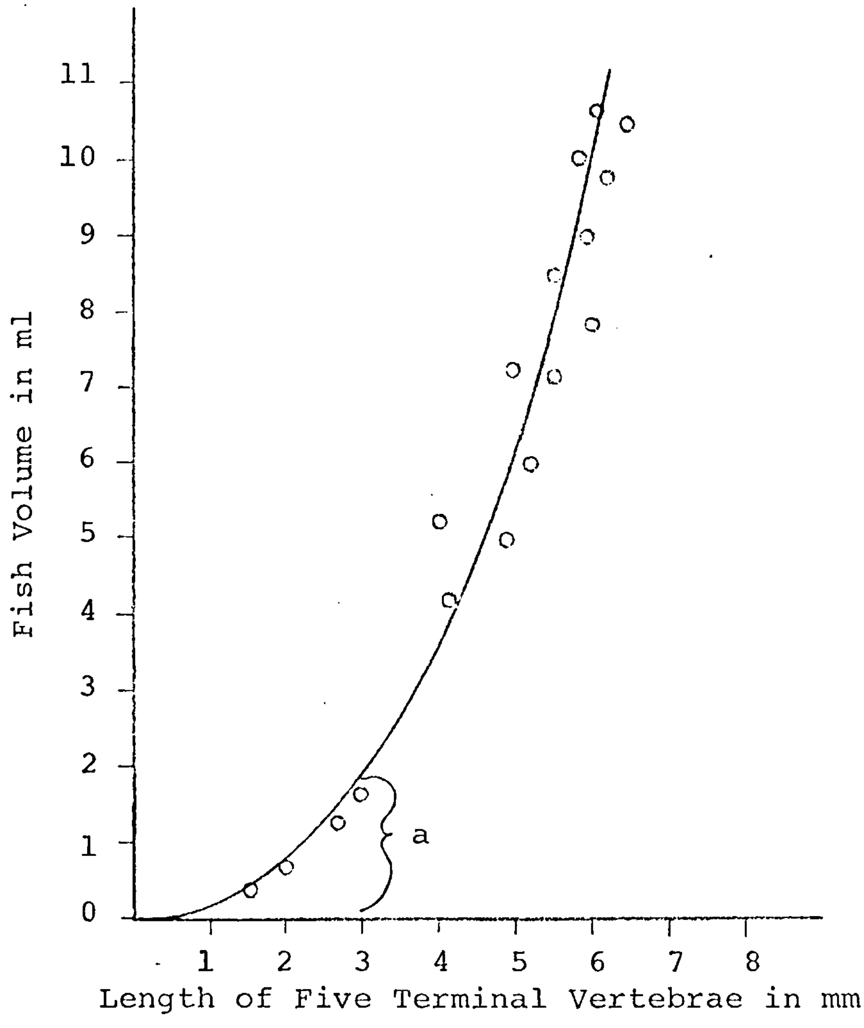

Figure 1. Relationship of fish volume to five terminal vertebrae of threadfin shad.

Source: a. Values taken from McConnell and Gerdes (1964).

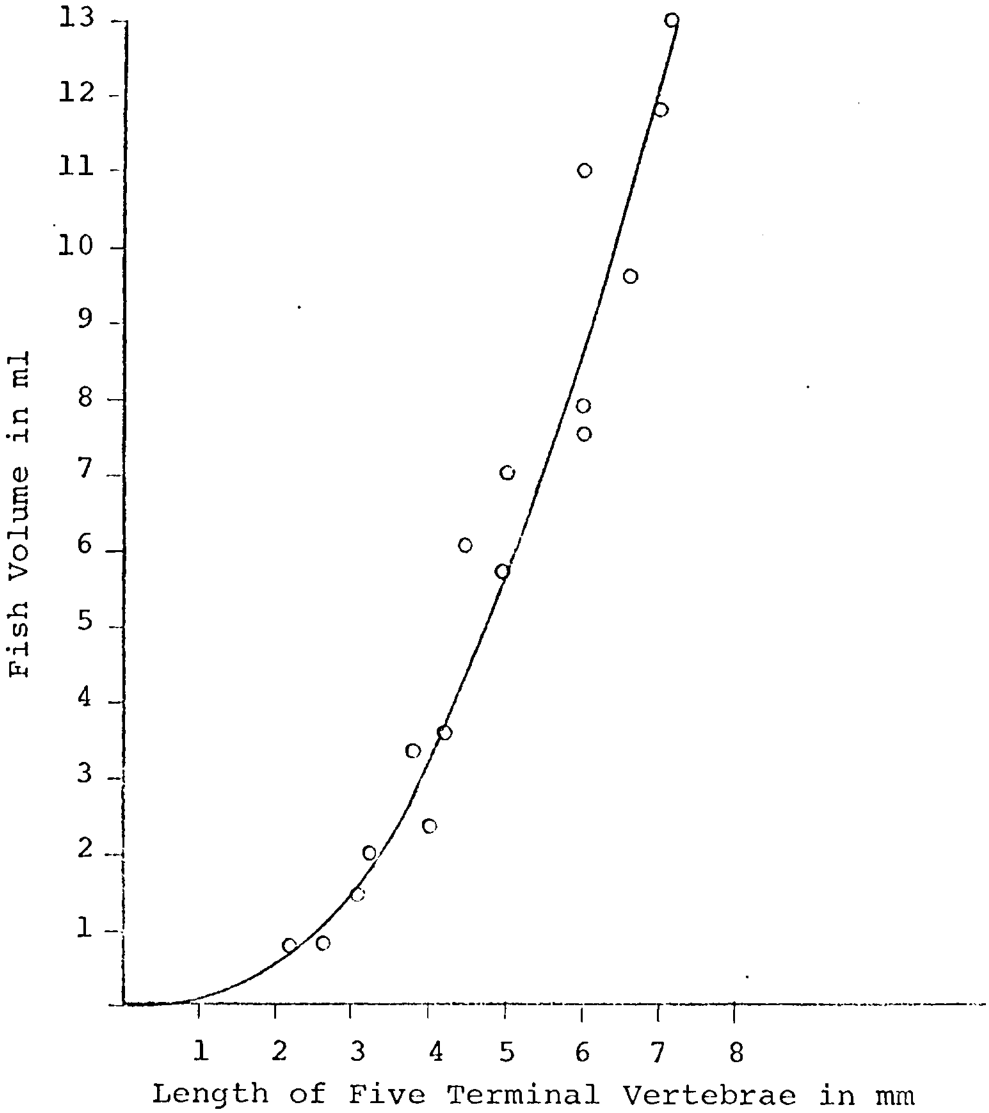

Figure 2. Relationship of fish volume to length of five terminal vertebrae of green sunfish.

Table 2. Major food items included within each food category.

- Aquatic Insects
  - Ephemeroptera:
    - Baetidae nymphs
  - Diptera:
    - Tendipedidae
      - Pupae and Larvae
    - Culicidae
      - Pupae and Larvae
  - Odonata:
    - Libellulidae
      - Nymphs
    - Coenagrionidae
      - Nymphs
  - Trichoptera:
  - Hemiptera:
    - Corixidae
    - Notonectidae
  - Coleoptera:
    - Dytiscidae
    - Hydrophilidae
- Gastropods
  - *Helisoma*
  - *Gyraulus*
- Plant Material
  - Vascular aquatics
  - Filamentous algae
- "Terrestrial Insects"[a]
  - Diptera:
    - Tendipedidae
      - Adult
  - Odonata:
    - Libellulidae
      - Adult
    - Coenagrionidae
      - Adult
  - Isoptera:
  - Hymenoptera:
  - Terrestrial Coleoptera:
  - Terrestrial Hemiptera:
- Zooplankton
  - Cladocera:
  - Eucopedoda:
  - Podocopa:
- Fish
  - Centrarchidae:
    - *Lepomis cyanellus*
  - Clupeidae
    - *Dorosoma petenense*
- Bryozoans
  - Bryozoans

[a] Includes all insects that are normally found on or above the water surface, true terrestrial insects and winged stages of aquatic insects.

to detect significant differences among the centrarchids for each food. Yearly relative volumes of each food ingested by the bass, crappie and green sunfish were calculated. The same statistical treatment was used on the yearly relative volumes as on the seasonal relative volume.

RESULTS AND DISCUSSION

Food Habits

Largemouth Bass

Fish were the major bass food, comprising 55.4% of the total yearly volume (Table 3). Fish were most important in the spring, making up 88.1% of the volume. Separate yearly relative volumes were not calculated for individual size groups as insufficient samples were obtained in some months, but a subsample indicated that bass from 150 to 180 mm and bass from 225 to 300 mm consumed 36.1% and 77.4% fish, respectively.

Goodson (1965) in a study in Pine Flat Lake, using reconstructed volumes, revealed 95.5% relative volume of fish in bass over 10 inches (252 mm) and, 84.9% in bass from 6.0 to 9.9 inches (150-249 mm). A high utilization of fish was maintained throughout the year. Bass in Pena Blanca Lake ranging from 150 to 300 mm ingested 88.1% relative volume of fish (Table 4), but did not consistently maintain this high utilization of fish. These comparisons suggest that bass in Pena Blanca Lake have a lesser supply of forage fish. This apparent shortage of forage fish appears to be caused by the lack of small fish in the

Table 3. Statistical comparison of the yearly mean relative volumes (percent) of food groups consumed by the four centrarchids.

	Largemouth Bass W=8.65 Relative Volume	Black Crappie W=6.71 Relative Volume	Green Sunfish W=8.29 Relative Volume	Bluegill Sunfish[c] Relative Volume
Aquatic Insect W[a]=7.70	27.1	23.2	27.4	10.8
Terrestrial Insect W=5.56	12.0	0.5	10.4	14.1
Zooplankton W=7.41	2.5	75.8	28.9	68.2
Fish W=8.70	55.4	0.0[b]	0.4	0.0[b]
Gastropod W=6.59	0.02	0.0[b]	24.6	0.4
Plant Material W=3.62	2.8	0.0[b]	4.9	6.4
Bryozoans	0.0[b]	0.0[b]	1.5	11.0
Mean Yearly Volume in Stomachs	2.31ml	1.81ml	0.34ml	

[a]Tukey's W procedure at the 95% confidence interval (Steel and Torrie, 1960).

[b]Food item never consumed and not included in calculation of W.

[c]Not a true yearly relative volume as insufficient samples were obtained in the winter and spring.

Table 4. Seasonal relative volume (percent) and occurrence of each food group consumed by largemouth bass.

		Aquatic Insect	Terrestrial Insects	Zooplankton	Fish	Plant Material	Gastropod	Mean Vol. in Stomach
Winter	Rel. Occ.	76	0.0	4	33	0.0	2	1.39ml
W[a]=18.3	Rel. Vol.	62.7	0.0	2.6	34.4	0.0	0.1	
Spring	Rel. Occ.	24	4	0.0	71	2	0.0	4.06ml
W=12.3	Rel. Vol.	10.4	0.5	0.0	88.1	1.4	0.0	
Summer	Rel. Occ.	18	27	2	43	18	0.0	2.26ml
W=21.0	Rel. Vol.	9.9	28.9	0.01	51.5	8.9	0.0	
Fall	Rel. Occ.	65	42	20	50	5	0.0	1.73ml
W=16.4	Rel. Vol.	25.4	18.6	7.2	47.5	0.8	0.0	
Mean	Rel. Occ.	45	18	6	49	6	0.5	2.31ml
W=8.6	Rel. Vol.	27.1	12.0	2.5	55.4	2.8	0.02	

[a]Tukey's W procedure at the 95% confidence interval (Steel and Torrie 1960).

winter, and the dense aquatic vegetation protecting small fish in the summer and fall.

Centrarchids, mainly green sunfish, comprised the greatest relative volume of fish eaten and occurred more frequently than did shad (Figs. 3 and 4). Shad were of minor importance in the winter and spring and were not consumed in the late summer and fall. It appears, as was concluded by McConnell and Gerdes (1964), that shad do not provide effective forage in Pena Blanca Lake.

Aquatic insects were the second most important bass food, making up 27.1% of the yearly total volume (Table 3). The bass subsample revealed that smaller bass ate a larger relative volume of aquatic insects (36.1%) than did the larger bass (17.3%). The highest seasonal relative volume of aquatic insects (62.7%) occurred in the winter. At this time, the volume of all food in bass stomachs was at its lowest point, 1.39 ml when the bass were generally larger. Apparently, aquatic insects were unable to supply the comparable volume of food that was supplied by fish during the rest of the year. However, this volume of food may have been sufficient as bass usually ingest less food in colder months. The relative increase in aquatic insect consumption may have been due to the lack of small fish in the winter.

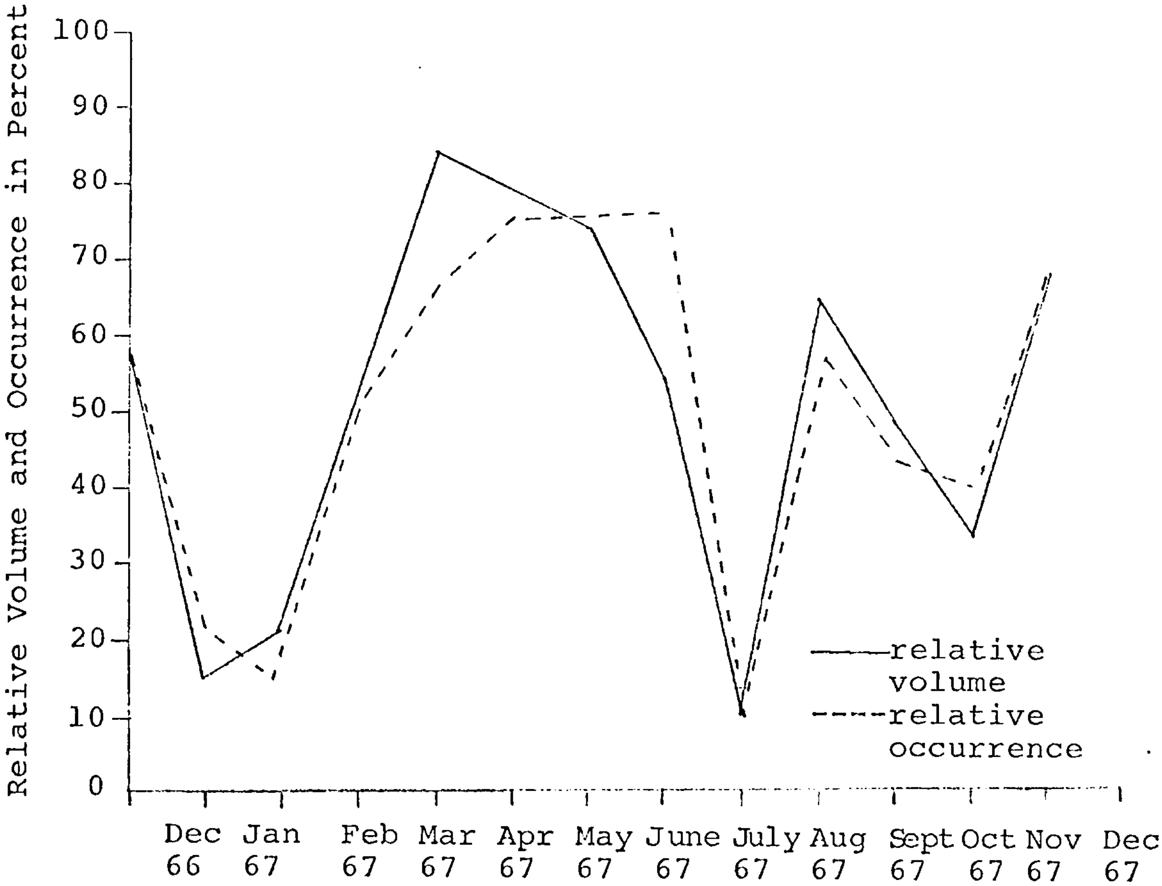

Figure 3. Monthly relative volume and occurrence of centrarchids in largemouth bass stomachs.

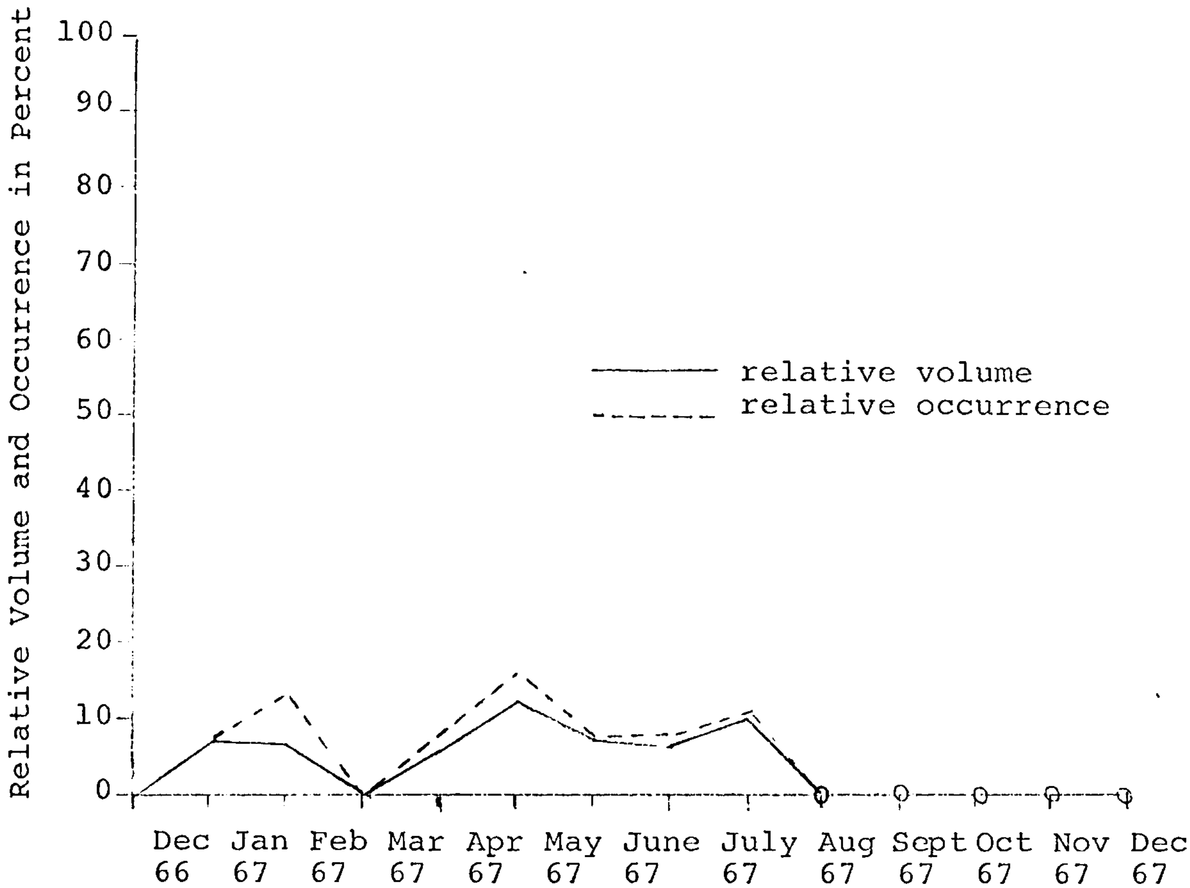

Figure 4, Monthly relative volume and occurrence of threadfin shad in largemouth bass stomachs. (o=0.0%)

The yearly relative volume of terrestrial insects (12.0%) was third in importance (Table 3). Most of the terrestrial insects were eaten in the summer and fall months (Fig. 5). This appears to have been caused by two factors: (1) an increase in the number of terrestrial insects available, and (2) an increase in aquatic vegetation may have given protection to forage fish. As there were large numbers of small fish observed while electrofishing, the lack of small fish was not considered a factor in the reduction in fish consumption during this period.

Black Crappie

Crappie fed almost entirely on zooplankton and aquatic insects (Table 5). Zooplankton, the most important food, comprised 75.8% of the yearly total volume (Table 3). McConnell and Gerdes (1964) report similar findings in Pena Blanca Lake in 1960 and 1961. However, they report that shad made up 35% of the total volume of food in 1960.

Many authors have reported that fish are an important crappie food (Parks, 1949; Kutkuhn, 1955; Seaburg and Moyle, 1964; Goodson, 1965 and Beers and McConnell, 1966). Goodson's study (1965) in Pine Flat Lake, using reconstructed volume, revealed that 99% of the total food volume consumed by 6.0 to 9.9 inch (150-249 mm) crappie was fish. Crappie in this study ranging from 90 to 266 mm

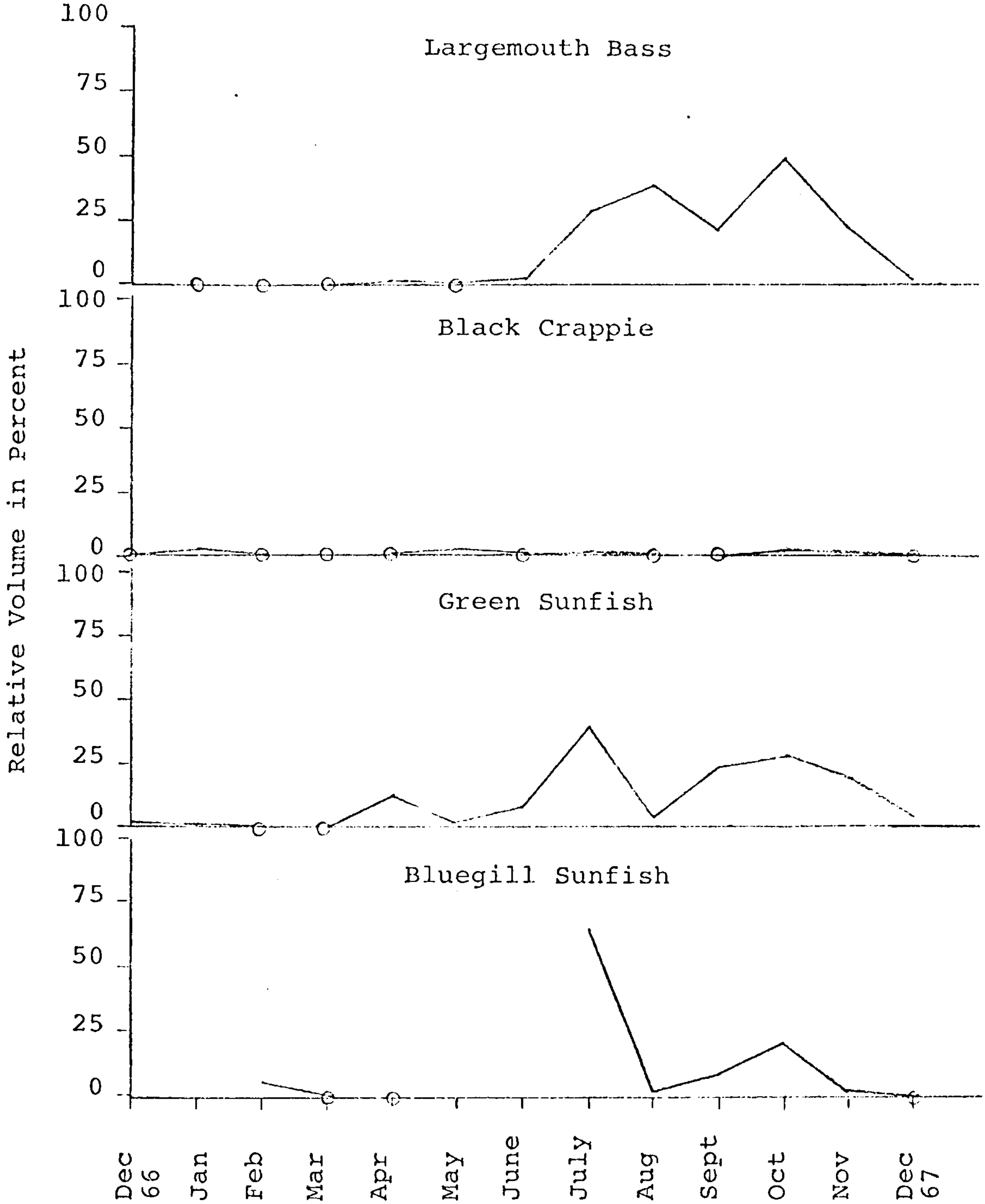

Figure 5. Monthly mean relative volumes of terrestrial insects consumed by the four centrarchids (o=0.0%)

Table 5. Seasonal relative volume (percent) and occurrence of each food group consumed by black crappie.

		Aquatic Insects	Terrestrial Insects	Zooplankton	Mean Vol. in Stomach
Winter	Rel. Occ.	89	3	100	1.19ml
W[a]=4.50	Rel. Vol.	9.3	0.4	89.3	
Spring	Rel. Occ.	95	5	86	0.64ml
W=14.7	Rel. Vol.	64.5	0.7	35.5	
Summer	Rel. Occ.	58	4	91	1.46ml
W=7.5	Rel. Vol.	5.1	0.3	94.4	
Fall	Rel. Occ.	86	9	98	3.05ml
W=6.5	Rel. Vol.	16.9	0.5	82.3	
Mean	Rel. Occ.	80	5	94	1.81ml
W=6.7	Rel. Vol.	23.2	0.5	75.8	

[a]Tukey's W procedure at the 95% confidence interval (Steel and Torrie, 1960).

did not eat fish. These comparisons point out the apparent scarcity of an acceptable forage fish in Pena Blanca Lake. However, the crappie have above average condition factors and good growth in spite of the lack of forage fish.

Crappie ranged in total length from 90 to 124 mm at the beginning of the study and 210 to 226 mm at the end of the study. Yet with the increase in size, the usual decrease in zooplankton ingestion (Seaburg and Moyle, 1964) was not observed (Table 5). This also seems to indicate the lack of forage fish availability.

During the spring, crappie changed their feeding habits (Figs. 6 and 7). Aquatic insects became most important as the total volume eaten was 64.5% (Table 5). At the same time the average volume of food in crappie stomachs declined, even though the crappie were larger than in prior samples. Though the relative volume of aquatic insects was high, it failed to supply a comparable volume of food generally supplied by the zooplankton.

Green Sunfish

Green sunfish relied on a wide variety of foods. Aquatic insects, zooplankton and gastropods were dominant (Table 6). The yearly relative volumes of these three food groups were all near 25% (Table 3). These findings are similar to the reports of others (Forbes and Richardson,

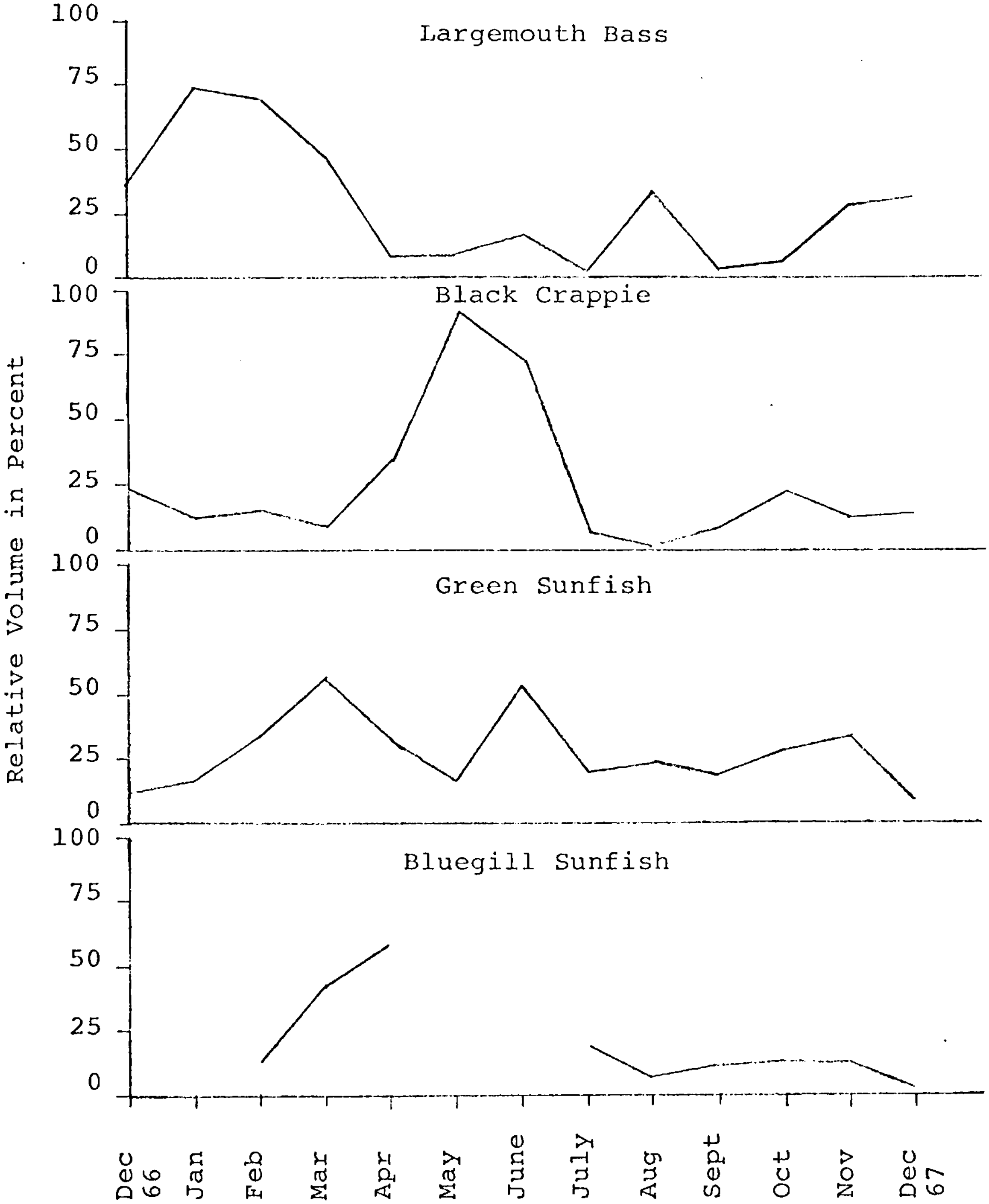

Figure 6. Monthly mean relative volumes of aquatic insects consumed by the four centrarchids.

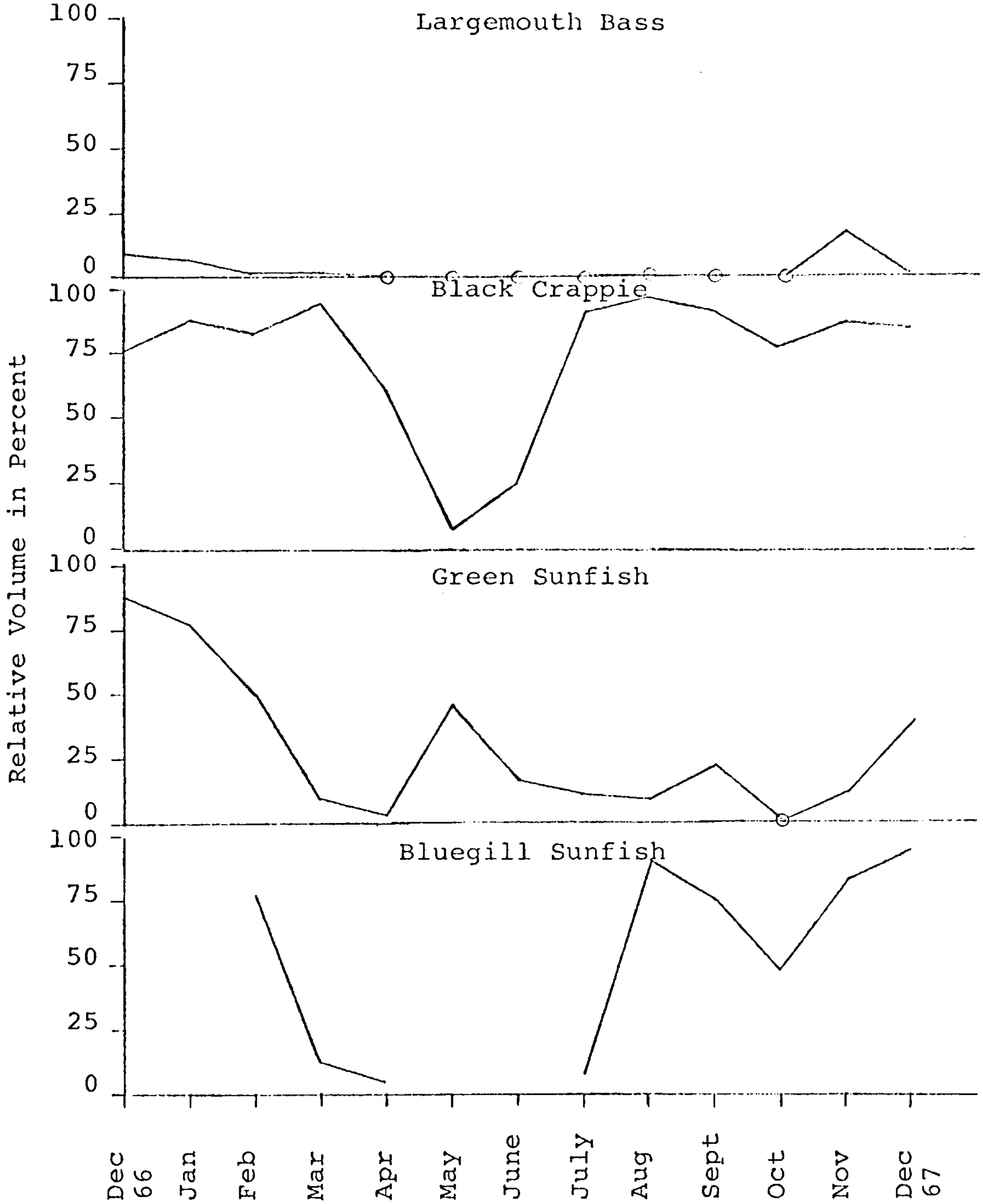

Figure 7. Monthly mean relative volumes of zooplankton consumed by the four centrarchids. (o=0.0%)

Table 6. Seasonal relative volume (percent) and occurrence of each food group consumed by green sunfish.

		Aquatic Insect	Terrestrial Insect	Zooplankton	Gastropod	Plant Material	Bryozoans	Fish	Mean Vol. in Stomach
Winter	Rel. Occ.	83	2	73	15	0.0	7	0.0	0.58ml
W[a]=17.0	Rel. Vol.	36.2	0.04	45.0	13.2	0.0	5.6	0.0	
Spring	Rel. Occ.	82	15	67	58	31	2	0.0	0.29ml
W=15.7	Rel. Vol.	32.8	7.5	22.0	22.0	11.7	0.07	0.0	
Summer	Rel. Occ.	64	45	36	59	18	0.0	0.0	0.13ml
W=16.0	Rel. Vol.	20.1	22.0	15.2	34.2	8.3	0.0	0.0	
Fall	Rel. Occ.	71	40	57	51	2	0.0	2	0.37ml
W=14.7	Rel. Vol.	22.5	12.7	33.0	29.3	0.7	0.0	1.9	0.30ml[b]
Mean	Rel. Occ.	78	26	58	45	12	2	0.5	0.34ml
W=8.29	Rel. Vol.	27.4	10.4	28.9	24.6	4.9	1.5	0.4	0.32ml[b]

[a]Tukey's W procedure at the 95% confidence interval (Steel and Torrie, 1960).

[b]Without volume of fish included.

1920; Koster, 1957; La Rivers, 1962; Sigler and Miller, 1963; Applegate, Mullan and Morais, 1966), except that they all report that green sunfish ate fish. Applegate's study (1966) in Bull Shoals Reservoir indicates that 16% of the total yearly food volume ingested by green sunfish was fish. This may be an under-estimation as food volume was not reconstructed. In Pena Blanca Lake fish were of little importance because the total yearly food volume was only 0.4% (Table 3).

Terrestrial insects were important in the summer and fall, where they comprised 22.0 and 12.5% of the relative food volume, respectively. During the period of greatest terrestrial insect use, green sunfish stomachs contained an average of 0.13 ml of food which was well below the yearly average of 0.32 ml. A possible cause in food volume decrease was the dense growth of aquatic vegetation which made finding food more difficult.

Bluegill

Bluegills fed predominantly on zooplankton and aquatic insects in Pena Blanca Lake (Table 7). These results generally agree with the results of other authors (Parks, 1949; Lux and Smith, 1960; Seaburg and Moyle, 1964; Goodson, 1965; and Applegate, et al., 1966).

Yearly mean relative volumes of food items were not calculated for bluegills because no samples were obtained in some winter and spring months.

Table 7. Seasonal relative volume (percent) and occurrence of each food group consumed by bluegill sunfish.

		Aquatic Insect	Terrestrial Insect	Zooplankton	Plant Material	Bryozoa	Gastropod	Mean Vol. in Stomach
Winter Only Feb & Mar	Rel. Occ.	90	10	70	0.0	43	13	1.32ml
W[a]=19.7	Rel. Vol.	24.9	2.6	45.0	0.0	25.0	2.1	
Spring Only Apr	Rel. Occ.	83	0.0	69	15	23	8	0.28ml
W=34.6	Rel. Vol.	58.5	0.0	5.3	9.6	19.2	7.2	
Summer	Rel. Occ.	66	43	95	20	0.0	3	0.91ml
W=17.4	Rel. Vol.	12.3	22.4	60.9	4.2	0.0	0.01	
Fall	Rel. Occ.	73	29	89	20	0.0	13	1.34ml
W=12.6	Rel. Vol.	9.3	5.8	75.4	8.5	0.0	0.8	

[a]Tukey's W procedure at the 95% confidence interval (Steel and Torrie, 1960).

Contrary to the findings of Applegate, et al., (1966) that bluegills used plant material heavily, the bluegills in Pena Blanca Lake ate only small amounts. The relative volume was generally less than 10% (Fig. 8).

Applegate (1966) in Bull Shoals Reservoir using direct water displacement found bryozoans to be a preferred food in the fall (75% of total volume), and that this dietary item was present throughout the year. The greatest amount of bryozoans eaten by bluegills in Pena Blanca Lake, 44%, occurred in March (Fig. 9). No bryozoans occurred as summer or fall foods (Table 7).

Comparison of Food Habits

Aquatic Insects

The greatest similarity in centrarchid food habits was their consumption of aquatic insects. Yearly relative volumes of aquatic insects ingested by bass, crappie and green sunfish (approximately 25%) were not significantly different (Table 3). Although yearly relative volumes of food taken in by bluegills were not calculated, in the summer and fall months bluegills and the other centrarchids ate similar relative volumes of aquatic insects (Fig. 6). However, observations suggest that feeding of bluegill and crappie does not overlap with bass and green sunfish for aquatic insects because: (1) both bluegill and crappie

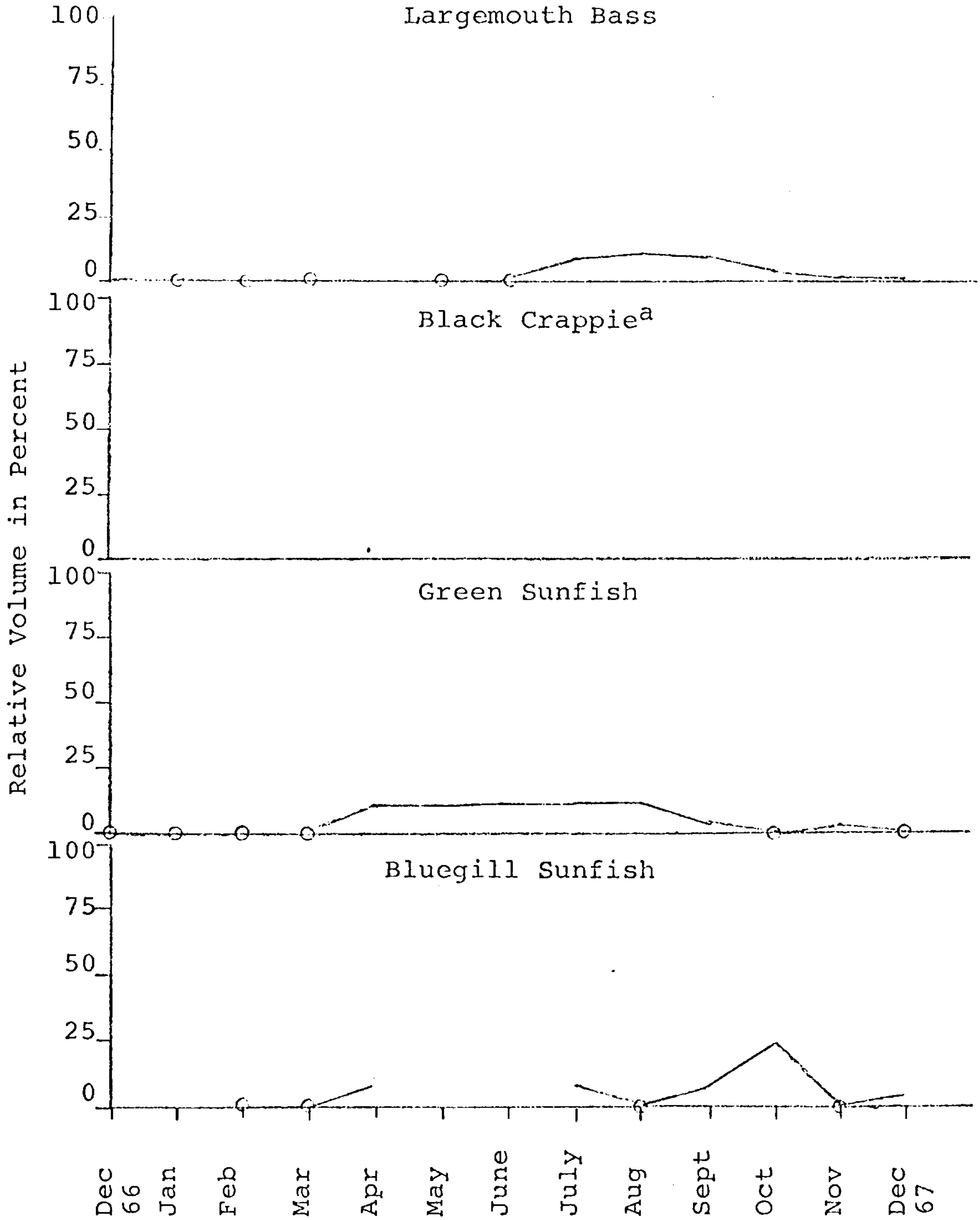

Figure 8. Monthly mean relative volumes of plant material consumed by the four centrarchids. (o=0.0%)

a. Species never consumed food item.

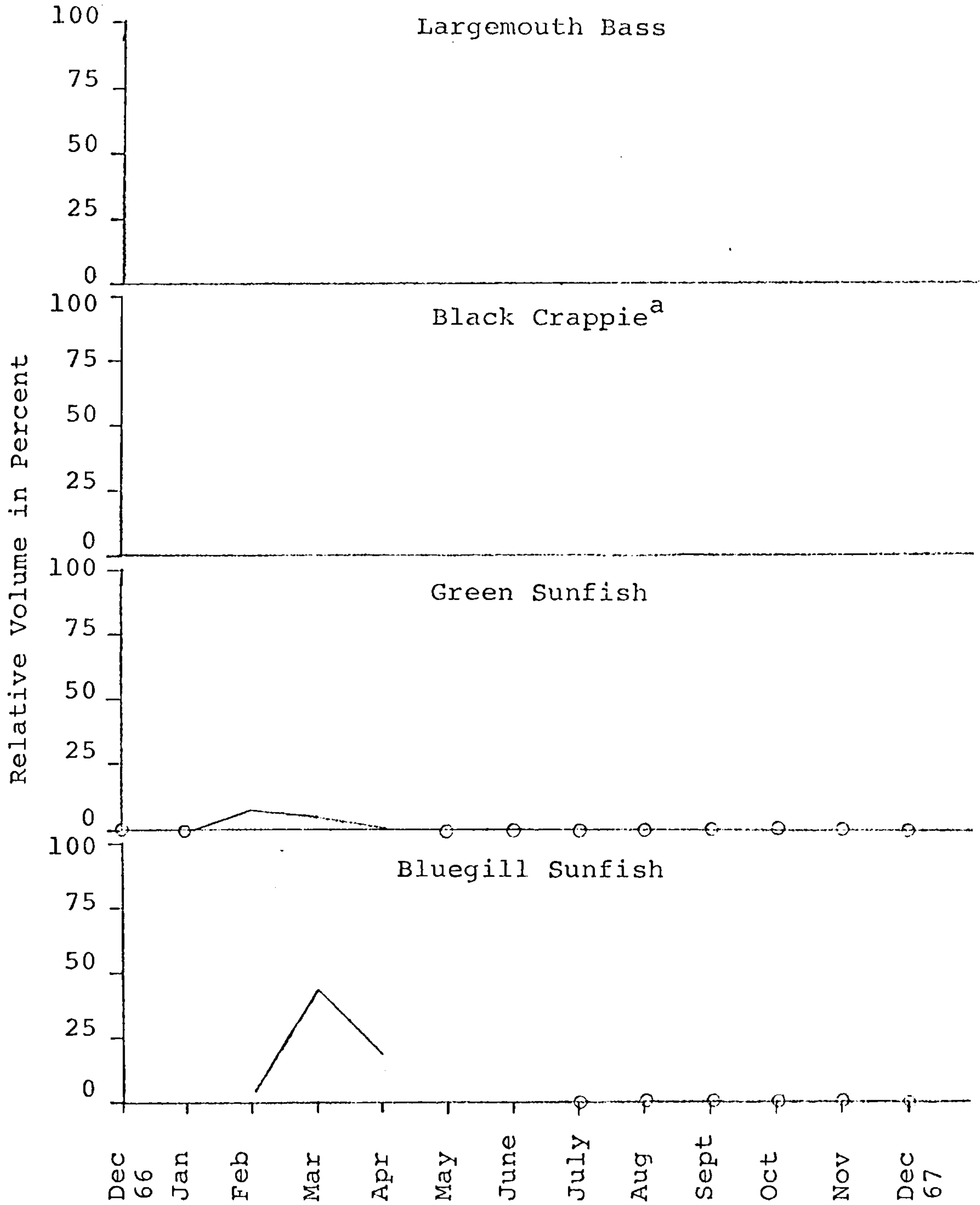

Figure 9. Monthly mean relative volume of bryozoans consumed by the four centrarchids. (o=0.0%)

a. Species never consumed food item.

were generally found farther off shore; (2) crappie ate more free-swiming insects such as tendipedidae pupae; and (3) the bluegill population is small.

Food overlap appeared to exist between green sunfish and small bass as they were normally found in close proximity to the shore and both fed on the same types of aquatic insects. A subsample revealed that bass between 150 and 180 mm consumed a greater relative volume of aquatic insects (36.1%) than bass of 225 to 300 mm (17.3%).

The most serious food overlap between the bass and green sunfish occurred during the winter. The highest relative volumes of aquatic insects eaten by bass (62.7%) and green sunfish (36.2%) occurred during this period (Table 8). Bass stomachs in the winter contained their smallest volume of food (1.39 ml) and green sunfish contained their largest (0.58 ml). This high ingestion of aquatic insects by green sunfish, coupled with a larger volume of food in their stomachs, probably decreased greatly the aquatic insects available to bass when they required them the most. A similar situation occurred in the fall (Table 8); however, aquatic insect intake by both species was not as high.

Zooplankton

Bluegill and crappie consumed high relative volumes of zooplankton in the summer and fall (Table 8), and a food

Table 8. Seasonal relative volume (percent) of food groups consumed by each of the four centrarchids.

Winter

	Largemouth Bass Rel. Vol.	Black Crappie Rel. Vol.	Green Sunfish Rel. Vol.	Bluegill Sunfish Rel. Vol.
Aquatic Insect W[a]=18.9	62.7	9.3	36.2	c
Terrestrial Insect W=.96	0.0	0.4	0.04	c
Zooplankton W=14.0	2.6	89.3	45.0	c
Fish W=14.3	34.4	b	0.0	c
Plant Material W=0	0.0	b	0.0	c
Gastropod W=10.2	0.0	b	13.2	c
Bryozoans	b	b	5.6	c

[a]Tukey's W procedure at the 95% confidence interval (Steel and Torrie, 1960).

[b]Food item never consumed.

[c]Insufficient sample to include in calculation of W.

Table 8. (Continued)

Spring

	Largemouth Bass Rel. Vol.	Black Crappie Rel. Vol.	Green Sunfish Rel. Vol.	Bluegill Sunfish Rel. Vol.
Aquatic Insect W[a]=20.9	10.4	64.5	32.8	c
Terrestrial Insect W=6.3	0.5	0.7	7.5	c
Zooplankton W=15.1	0.0	35.5	22.0	c
Fish W=9.3	88.1	b	0.0	c
Plant Material W=7.1	1.4	b	11.7	c
Gastropod W=13.3	0.0	b	22.0	c
Bryozoans	b	b	0.07	c

[a]Tukey's W procedure at the 95% confidence interval (Steel and Torrie, 1960).

[b]Food item never consumed.

[c]Insufficient sample to include in calculation of W.

Table 8. (Continued)

Summer				
	Largemouth Bass Rel. Vol.	Black Crappie Rel. Vol.	Green Sunfish Rel. Vol.	Bluegill Sunfish Rel. Vol.
Aquatic Insect W[a]=14.4	9.9	5.1	20.1	12.3
Terrestrial Insects W=18.0	28.9	0.3	22.0	22.4
Zooplankton W=14.8	0.01	94.4	15.2	60.9
Fish W=14.8	51.5	b	0.0	b
Plant Material W=11.6	8.9	b	8.3	4.3
Gastropod W=11.9	0.0	b	34.2	0.01
Bryozoans W=0	b	b	0.0	0.0

[a]Tukey's W procedure at the 95% confidence interval (Steel and Torrie, 1960).

[b]Food item never consumed.

[c]Insufficient sample to include in calculation of W.

Table 8. (Continued)

Fall

	Largemouth Bass Rel. Vol.	Black Crappie Rel. Vol.	Green Sunfish Rel. Vol.	Bluegill Sunfish Rel. Vol.
Aquatic Insect W[a]=14.4	25.4	16.9	22.5	9.3
Terrestrial Insect W=13.1	18.6	0.5	12.7	5.8
Zooplankton W=14.6	7.2	82.3	33.0	75.4
Fish W=12.8	47.5	b	1.9	b
Plant Material W=6.1	0.8	b	0.7	8.5
Gastropod W=10.8	0.02	b	29.3	0.8
Bryozoans W=0	b	b	0.0	0.0

[a]Tukey's W procedure at the 95% confidence interval (Steel and Torrie, 1960).

[b]Food item never consumed.

[c]Insufficient sample to include in calculation of W.

overlap appeared to exist. As the bluegill population was small at this time, the effects of the food overlap were not considered serious. If the bluegill population increases, crappie may be deprived of a measure of zooplankton now available.

Food overlap between bass and the bluegills and crappie for zooplankton was not shown in this study. Bass (150-300 mm) ate only small amounts of zooplankton. However, McConnell and Gerdes (1964) reported that zooplankton made up 25% of the volume of food consumed by young bass (109-195 mm) in Pena Blanca Lake. Their findings, along with the fact that crappie and bluegills are eating large amounts of zooplankton, suggest that food overlap may exist between young bass and the bluegill and crappie.

Fish

Bass and green sunfish, the only centrarchids that were found to eat fish, consumed significantly different yearly relative volumes of this item (55.4% and 0.4%, respectively). These relative volumes differ so greatly that food overlap is not considered to exist.

Gastropods

Green sunfish ingested the largest yearly relative volume of gastropods, 24.6% (Table 3). Bass and bluegill also ate gastropods but in much smaller amounts (Fig. 10). Sharing of this food item does not appear important.

Plant Material

Bass and green sunfish consumed similar yearly relative volumes of plant material, 2.8% and 4.9%, respectively (Table 3). Bluegills also took in small quantities of this food (Fig. 8). In all cases the quantities consumed were small and even though the amount of plant material available in the lake was high.

Bryozoans

Bryozoans were eaten by green sunfish and bluegills in the late winter and early spring (Fig. 9). As the volume consumed was small and duration of use short, food overlap was probably insignificant.

Predation

Largemouth bass were the only important piscivores and their predation concentrated primarily on green sunfish. The only other observed predation was limited to one green sunfish eating one fish in the winter. Fish predation by black crappie and bluegill sunfish was not observed. The possibility does exist, however, that crappie and sunfishes did prey on various species of fry, but as the samples were small and collected monthly this predation may have been overlooked.

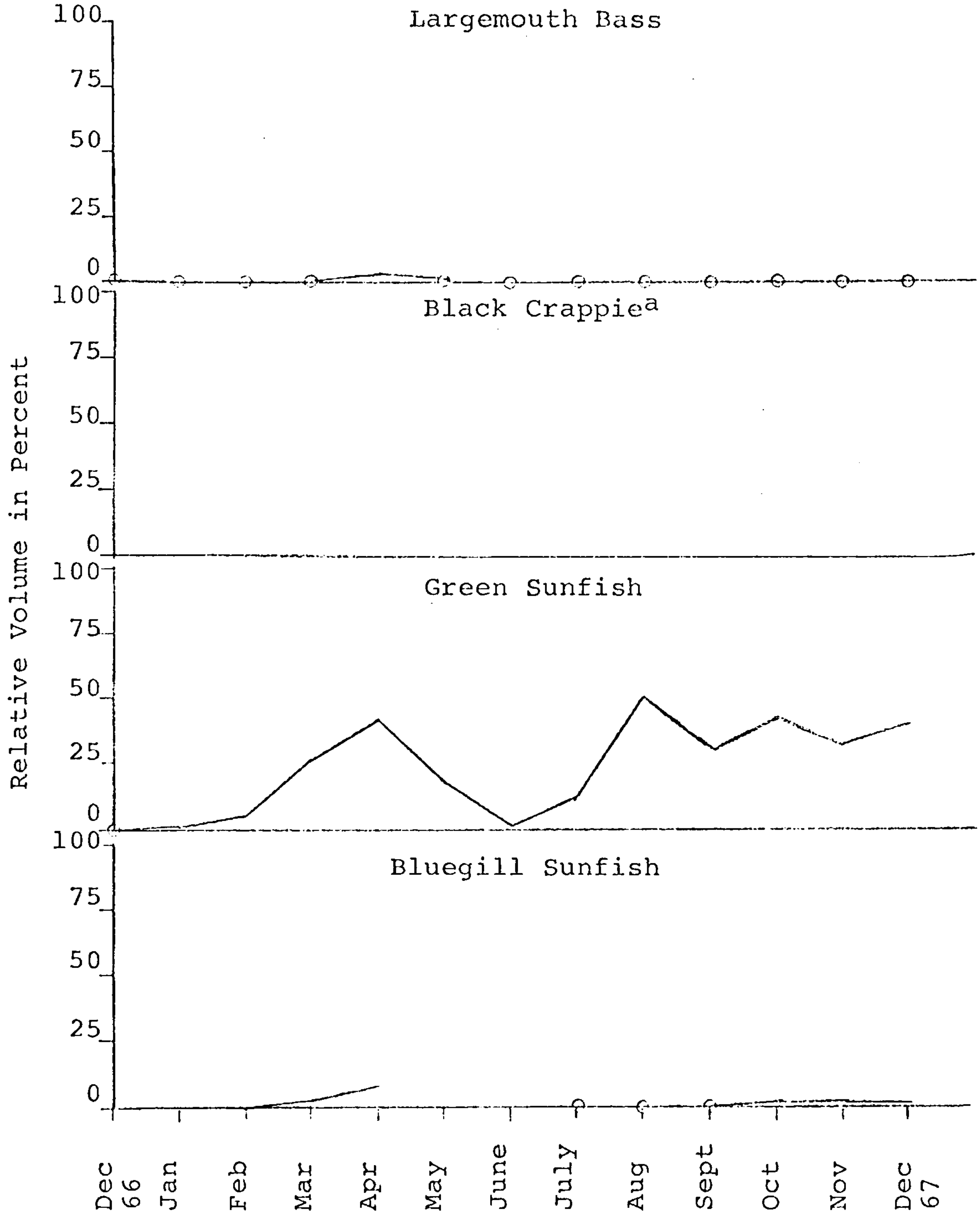

Figure 10. Monthly mean relative volumes of gastropods consumed by the four centrarchids. (o=0.0%)

a. Species never consumed food item.

Adequacy of Centrarchid Food Supply

The growth of the population and the condition factors K_{SL} were two parameters used to judge the adequacy of the food supply. Carlander (1944) considered bass under K_{SL} 2.00 poor, 2.25-2.50 average and over 2.65 excellent; crappie under 1.80 poor, 2.10-2.60 average and over 3.00 excellent; and bluegill under 3.0 poor, 3.30-4.00 average and 4.50 excellent. Carlander (1950) gives three condition factors determined in Minnesota waters for green sunfish 2.46, 3.46 and 3.66.

Bass in Pena Blanca Lake had a mean K_{SL} of 2.37 and a standard deviation of ± 0.44, which according to Carlander's figures was average. This may indicate that bass in Pena Blanca Lake get only an average supply of food. Crappie in Pena Blanca Lake had a mean condition factor of 3.12 ± .089 which is excellent according to Carlander's figures. Green sunfish and bluegills had high condition factors 3.87 ± .52 and 4.29 ± .36 respectively.

Length-frequency data collected during January 1967 in Pena Blanca Lake (Knipe, 1966) revealed that bass after two growing seasons attained a total length of nine inches. McConnell (1963) found that bass in the same lake between 1959 and 1961 were generally less than nine inches total length after two growing seasons. Bass have the same or maybe slightly better growth rate now. Apparently any competition for food with green sunfish has not affected the bass growth rate.

Crappie collected during the study appeared to be from one year class, and it was possible to determine their growth rate. Crappie at the beginning of the study were considered to have completed one growing season and averaged four inches total length. After two growing seasons they averaged nine inches total length. McConnell (1963) obtained similar results in Pena Blanca Lake. This crappie growth compares favorably with the growth figures given by Carlander (1950). This good growth by crappie in Pena Blanca Lake further supports the conclusion that the zooplankton supply an adequate diet, and that the lack of acceptable forage fish is not detrimental.

CONCLUSION

Competition as defined by Milne (1961), is the endeavor of two (or more) animals to gain the same particular thing, or to gain the measure each wants from the supply of a thing when that supply is not sufficient for both (or all). The supply in question in this study is food. Thus, to conclude that food competition exists the animals must eat the same food, they must inhabit the same area and the extent of the food supply must be known. The first two factors were determined; however, food supply estimates were not made in this study. Therefore, all conclusions concerning competition are based on similarity of food and habitat, and an assumption that food was not sufficient for both.

Competition between bass and green sunfish was considered minimal, except in the winter when aquatic insects were important foods for both. At this time competition was deemed moderate. Crappie and bluegill were not food competitors with bass. Thus, food competition does not appear to have been the cause of the recent decline in the numbers of bass caught.

Green sunfish supplies the bulk of the bass diet, and the bass exhibited growth comparable to the time when shad were the primary food. Thus, it is questionable whether control of the sunfish population at this time is desirable.

Crappie did not eat any fish; instead, they utilized zooplankton almost exclusively. Yet with the lack of fish in their diet they maintained high condition factors and good growth. No crappie--green sunfish competition was shown; however, crappie appeared to compete with bluegill for zooplankton. This competition was not believed important because of the small bluegill population involved. The bluegill population should be kept under observation as its increase may be detrimental to the crappie.

The lack of fish in the crappie diet and the paucity of shad in the bass diet points out the inability of shad to provide effective forage in Pena Blanca Lake. The apparent lack of fish in bass diets in the late summer and early fall may be attributed to the inability of bass to capture small green sunfish in the dense vegetation. This problem might be solved by aquatic vegetation control.

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