FEEDING INTERACTIONS OF THREE PLANKTIVOROUS FISHES IN TRINIDAD LAKE, TEXAS

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Abstract: Food habits of gizzard shad (*Dorosoma cepedianum*), threadfin shad (*D. petenense*), and blue tilapia (*Tilapia aurea*) were studied in summer and winter, 1975. Stomach contents of all 3 species consisted predominantly of organic detritus, followed by green algae, blue-green algae and diatoms. Occurrence of planktonic foods corresponded closely with the composition of the plankton. Although food habits differed between season, they were closely correlated among species within season. Similarities in food habits of the 3 planktivorous species suggest potential food competition.

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Introduction of exotic fishes has been considered in recent years for biological control, recreation, and food (Courtenay and Robins 1973). However, introduction of exotics presents the possibility of undesirable effects through interactions with native fishes (Noble *et al.* 1975). Competition for food is one such interaction which might be expected. Recent increase in the number of power plant cooling lakes, as well as the interest in the use of *Tilapia* species in aquaculture, has provided the impetus for tilapia to be introduced in the southern United States (Stickney 1979). Blue tilapia, which have been introduced and established in Florida and Texas, utilize planktonic food resources (McBay 1961). Overlap in food habits with native planktivorous species could consequently occur.

The blue tilapia, a subtropical fish native to Africa and Asia, cannot withstand prolonged water temperatures below 12 C (McBay 1961). Heated waters allow these fish to overwinter in Texas; established populations exist in several reservoirs. In these waters blue tilapia reproduce and grow rapidly. They serve as important prey when small, but may grow to more than 2 kg and represent a valuable food fish.

Threadfin shad and gizzard shad are the 2 most abundant planktivores in southern impoundments. Together they make up about 45% of the biomass in these waters (Jenkins 1967) and serve as important prey for piscivorous game fishes.

Ecological associations among fishes are often dominated by feeding interactions. Due to similar food habits, competition may occur among threadfin shad, gizzard shad, and blue tilapia. Although food habits of these 3 species have been investigated individually, no studies have compared the food habits of these species when they occur together. Studies on feeding interactions of blue tilapia and native threadfin and gizzard shads can provide information that will be useful when considering further introductions of tilapia.

In Trinidad Lake, Texas, seine and gillnet samples from 1972 through 1974 indicated that threadfin shad, gizzard shad, and blue tilapia were among the most abundant species (Germany 1977). This 305 ha impoundment, located in Henderson County, serves as a source of cooling water for a Texas Power and Light company fossil fuel electric

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generating plant. Temperatures in the lake sometimes exceeded 35 C in the summer but rarely fell below 13 C in the winter. The 50-year-old lake averages less than 3 m deep and is eutrophic. Twenty-eight species of fish were found in Trinidad Lake, but the only abundant planktivores were threadfin shad, gizzard shad, and blue tilapia. The objective of this study was to determine whether threadfin shad, gizzard shad, and blue tilapia utilize similar food resources in Trinidad Lake.

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MATERIALS AND METHODS

Three collections, consisting of 29 blue tilapia, 47 threadfin shad, and 30 gizzard shad, were made at Trinidad Lake during July, November, and December, 1975. All fish were within the range of 46-122 mm standard length. Continuation of the study was planned, but a complete die-off of tilapia occurred in January, 1976 (Germany and Noble 1977). Immediately after capture by seining or electrofishing, specimens were preserved in 10% formalin. Contents of each stomach were flushed into a Sedgewick-Rafter cell. Entire stomach contents were examined at 100X while subsamples were examined using 440X. Food organisms from stomachs were identified to recognizable taxa. Identification of phytoplankters was based on Prescott (1964), that of invertebrates on Pennak (1953).

Because of difficulty in making quantitative comparisons among numbers of individuals, numbers of colonies, organisms of different size, and animal parts, an index of dominance for food items was developed. This index of dominance was based on estimated relative volumes of various food items. Values of 0, 1 and 2 were assigned to each food item, with 0 indicating absence, 1 indicated presence in small amounts, and 2 indicating that the taxon was a major food item. In each stomach, 10 to 15 food items were usually of markedly greater volumes than all others, and were considered major food items. For each sampling period, frequency of occurrence and an average index of dominance were calculated for each food type, based on only those fish containing food.

Average indices of dominance were assigned to over 80 identifiable taxa of food items. Of these, 35 occurred frequently and formed the basis for comparison of food habits among species. The occurrence of these 35 principal food organisms within the species was similar during November and December, and data from these months were combined for analysis.

Plankton samples were collected from Trinidad Lake during November and December, 1975. Each month, 20 ml were filtered from a 600-ml water sample and preserved in 70% ethyl alcohol. Subsamples were examined qualitatively using a compound microscope at 100 to 440X. Plankters were identified to similar recognizable taxa as those used in stomach analyses.

RESULTS AND DISCUSSION

All stomachs of fish collected in July contained food. In November all threadfin shad examined contained food, but stomachs were empty in 20% of the gizzard shad and 27% of the blue tilapia. In December empty stomachs were found in 75% of the threadfin shad, 53% of the gizzard shad, and 65% of the blue tilapia. The power plant was not in operation during the December sampling period and water temperatures fell below 10 C. Blue tilapia were stressed during that time, and threadfin shad, which are also subject to mortality at low temperatures, may have been affected.

Detritus and organisms of planktonic origin made up most of the material found in the stomachs of threadfin shad, gizzard shad, and blue tilapia from Trinidad Lake. Organic detritus was the primary constituent of the diets of all three species. Its abundance and consistency of occurrence was represented by an average index of dominance of 2.0 in each fish species, although the index probably underestimated its contribution to the diets since it far exceeded in volume all other food items. Dalquest and Peters (1966) found detritus in gizzard shad, but dismissed it as having little or no food value. Baker and Schmitz (1971) found that a significant portion of the diet of threadfin shad was detritus. Fryer and Iles (1972) reported that some tilapias equipped for planktonic feeding may utilize deposit feeding when the plankton of the lake is dominated by unicellular green and blue-green algae.

Of the remaining constituents of the diets of the 3 planktivores, green algae (Chlorophyta), blue-green algae (Cyanophyta) and diatoms (Chrysophyta) predominated (Table 1). Unicellular green and blue-green algae also were predominant in

TABLE 1. Percentage frequency of occurrence (% FO) and mean index of dominance ($\overline{D}$) for 35 foods found in stomachs of three planktivorous fishes in Trinidad Lake, 1975.

	Threadfin Shad				Gizzard Shad				Blue Tilapia			
	Summer		Winter		Summer		Winter		Summer		Winter	
No. examined	8		39		10		20		7		22	
No. containing food	8		15		10		11		7		12	
Taxon	%FO	$\overline{D}$	%FO	$\overline{D}$	%FO	$\overline{D}$	%FO	$\overline{D}$	%FO	$\overline{D}$	%FO	$\overline{D}$
Blue-Green Algae												
Anabaena	62	1.12	6	0.13	40	0.50	0	0	86	1.40	16	0.16
Anabaenopsis	25	0.25	33	0.33	60	0.60	9	0.09	0	0	66	0.83
Gloeocapsa	50	0.88	53	0.73	70	0.70	72	1.27	28	0.28	50	0.75
Merismopedia	88	1.62	80	1.00	100	1.90	81	1.09	100	1.70	100	1.75
Nostoc	12	0.12	26	0.26	10	0.10	54	0.82	0	0	41	0.66
Oscillatoria	75	1.38	53	0.66	100	1.70	36	0.54	71	1.14	50	0.75
Spirulina	25	0.50	40	0.53	80	1.00	27	0.27	100	1.86	41	0.50
Colonial	62	1.25	80	1.40	70	1.20	36	0.54	43	0.43	83	1.33
Diatoms												
Cyclotella	0	0	33	0.33	50	0.50	27	0.27	0	0	58	0.75
Cymbella	38	0.50	13	0.13	90	1.30	9	0.09	14	0.14	50	0.50
Navicula	25	0.50	46	0.60	100	1.40	81	1.27	100	1.60	58	0.91
Synedra	25	0.50	13	0.13	0	0	45	0.63	14	0.28	66	1.00
Unidentified	25	0.38	53	0.73	50	0.90	27	0.27	0	0	25	0.33
Green Algae												
Ankistrodesmus	0	0	33	0.40	30	0.30	27	0.45	43	0.71	25	0.33
Arthrodesmus	0	0	73	1.13	70	1.30	82	1.27	71	0.86	100	1.66
Closteriopsis	12	0.12	40	0.60	30	0.30	36	0.54	28	0.57	50	0.66
Cosmarium	75	1.25	40	0.60	100	1.50	45	0.45	43	0.57	50	0.66
Dictyosphaerium	25	0.38	13	0.13	0	0	72	1.27	0	0	33	0.41
Gleotanium	0	0	26	0.33	20	0.20	54	0.81	14	0.14	25	0.25
Golenkinia	12	0.12	46	0.80	20	0.20	63	1.00	43	0.71	41	0.50
Oocystis	0	0	53	0.93	10	0.10	36	0.45	0	0	33	0.50
Pediastrum	75	1.38	86	1.20	100	1.70	100	1.81	100	1.80	100	1.83
Planktosphaeria	62	0.75	26	0.26	40	0.40	45	0.45	0	0	16	0.16
Scenedesmus	100	2.00	86	1.60	100	1.90	100	1.72	100	1.86	100	2.00
Tetraedron	25	0.38	53	0.53	0	0	27	0.27	43	0.57	83	0.83
filament	38	0.38	26	0.46	30	0.30	36	0.45	43	0.57	50	0.75
round green	88	1.75	100	1.66	100	2.00	63	1.27	28	0.57	75	1.41
oval green	88	1.62	93	1.73	100	1.50	81	1.54	14	0.14	75	1.50
Protozoans												
Chlamydomonas	38	0.62	33	0.66	20	0.20	27	0.54	0	0	33	0.66
Pandorina	38	0.38	0	0	80	1.60	0	0	28	0.28	0	0
Phacus	25	0.25	0	0	70	0.80	0	0	14	0.14	8	0.08
Colonial	75	0.88	33	0.40	80	0.90	9	0.09	43	0.43	41	0.58
Bryozoa	25	0.25	53	0.80	20	0.20	27	0.45	43	0.71	33	0.58
Rotataria	12	0.12	46	0.53	20	0.20	9	0.09	71	1.00	50	0.58
Ostracoda	0	0	73	1.20	10	0.10	18	0.18	14	0.14	25	0.25

the plankton samples (Table 2). Diatoms were represented by fewer taxa and were seldom abundant in the plankton. Zooplankton identified in the diets included Protozoa, Rotifera, Ostracoda, Cladocera, Copepoda, and Hydracarina, but no macrozooplankton occurred in the plankton samples. All 3 fish species occasionally included nematodes and bryozoans in their diets. Diptera larvae (chironomids) were rarely found in gizzard shad and threadfin shad stomachs. While food habits of the 3 species were generally similar, some differences were noted. These differences were analyzed by comparing frequencies of occurrence and average indices of dominance among species for major food categories.

Thirty genera of Chlorophyta were identified in the fish stomachs. Twenty-nine of these were present in blue tilapia and gizzard shad, while 25 genera were found in threadfin shad. Fifteen of these taxa had frequencies of occurrence greater than 25% and indices of dominance greater than 0.50 during at least 1 sampling period. These 15 taxa occurred in all 3 fish species. Green algae made up a greater part of the diets of all 3 fish species during winter. Desmids and unicellular algae made up most of the green algae found in gizzard shad, threadfin, and blue tilapia. Colonial and filamentous green algae were also present. Filamentous algae occurred more frequently in blue tilapia stomachs than in stomachs of gizzard or threadfin shads. Shad, particularly the threadfin, appeared to concentrate small unicellular green algae to a greater extent than did blue tilapia.

Blue-green algae made up a greater part of the diets of all three species during summer. For a given sampling period there appeared to be no differences in consumption of blue-green algae among the 3 species. Sixteen genera of blue-green algae were identified in the fish stomachs. Eight of these were major food items. Five taxa in summer and 4 taxa in winter had indices of dominance greater than 1.0 and frequencies of occurrence greater than 50%.

Diatoms showed the greatest differences in utilization among the 3 fish species. Thirteen genera of diatoms were identified in the stomachs, but only 4 of these occurred frequently enough to be considered major food items. Diatoms were more abundant in the blue tilapia and gizzard shad diets than in threadfin shad diets. Indices of dominance

TABLE 2. Genera of phytoplankton in Trinidad Lake, November, December, 1975.

Blue-green Algae	Diatoms	Green Algae
Anabaena	*Cyclotella*	*Ankistrodesmus*
Anabaenopsis	*Cymbella*	*Arthrodesmus*
Gloeocapsa	*Melosira*	*Closteriopsis*
Merismopedia	*Navicula*	*Cosmarium*
Nostoc	*Synedra*	*Crucigenia*
Oscillatoria	Unident. Diatom	*Golenkinia*
Spirulina		*Kirchnella*
Unident. Colonial		*Oocystis*
		Pediastrum
		Planktosphaeria
		Scenedesmus
		Tetraedron
		Tetrastrum
		Unident. round green
		Unident. oval green

for the 4 diatom taxa exceeded 1.0 in some season in blue tilapia and gizzard shad, but were always substantially less than 1.0 in threadfin shad.

Microzooplankton (protozoans and rotifers) were found in stomachs of all 3 fish. Eleven genera of protozoans were identified; frequency of occurrence of these 11 genera varied with fish species and sampling period, and only 4 were considered major food items. Rotifers were found in all 3 fish during both summer and winter sampling periods. They occurred most frequently in blue tilapia, and least frequently in gizzard shad.

Macrozooplankton, including copepods, cladocerans and ostracods, occurred more frequently in blue tilapia and threadfin shad than in gizzard shad. Copepods were identifiied only from blue tilapia and threadfin shad. In summer, copepods occurred in 28% of the blue tilapia with an average index of dominance of 0.28. In winter, copepods occurred in 8% of the blue tilapia with an average index of dominance of 0.08. Copepods occurred in stomachs of threadfin shad only in winter, with a frequency of occurrence of 13% and an average index of dominance of 0.13. Cladocerans occurred in all 3 species, but most frequently in blue tilapia. During summer, cladocerans occurred in 14% of the blue tilapia with an average index of dominance of 0.14. During winter, cladocerans occurred in 25% of the blue tilapia with an average index of dominance of 0.33. Of the macrozooplnkton, only ostracods were considered major food items. Ostracods were identified from the stomachs of all 3 species, but occurred in stomachs of threadfin shad only in winter. Threadfin shad had the maximum index of dominance for ostracods, 1.20, compared to values less than 0.25 for gizzard shad and blue tilapia in both summer and winter. Blue tilapia appeared to select zooplankton to a greater extent than either shad species. Although the importance of microcrustaceans in postlarval gizzard shad has been emphasized by Warner (1940), gizzard shad examined from Trinidad Lake rarely contained microcrustaceans.

Nematodes occurred in stomachs of all 3 species, but never had average indices of dominance greater than their frequencies of occurrence. In summer, nematodes occurred in 71% of the blue tilapia stomachs and 10% of the gizzard shad stomachs, but were not found in stomachs of threadfin shad. In winter, nematodes occurred in 12% of the blue tilapia stomachs, 27% of the gizzard shad stomachs, and 6% of the threadfin shad stomachs.

Diptera larvae were occasionally found in stomachs of gizzard and threadfin shad but not in blue tilapia. Chironomids occurred in 13% of the threadfin shad stomachs collected during winter. The presence of chironomids and sand grains in stomachs of shad seems to indicate that shad sometimes feed in the benthic zone. Bryozoan statoblasts (*Plumatella* sp.) were found in stomachs of all 3 fish species. Frequency of occurrence and mean index of dominance were consistently 20% or more. Fragments of animal material believed to be bryozoan tissue were also found, however positive identification was impossible.

Food habits of all 3 fishes changed markedly from summer to winter. For each species Spearman's rank correlation coefficients (Snedecor 1956) were calculated, based on the indices of dominance of all 35 principal food items. These correlations were low and non-significant between seasons (Fig. 1, diagonal values).

In contrast, diets were more similar among the 3 species during each sampling period. When average indices of dominance based on the 35 major food items were compared within seasons, significant correlation in food habits among all 3 species during the winter was demonstrated (Fig. 1, lower left). Similar analyses of the summer data resulted in significant correlation coefficients for threadfin shad--gizzard shad and gizzard shad--blue tilapia, while food habits of threadfin shad and blue tilapia were less closely correlated (Fig. 1, upper right). Winter correlation coefficients for gizzard shad--blue tilapia and threadfin shad--blue tilapia were higher than summer correlation coefficients for these pairs. Overlap in food habits of blue tilapia and native shad species may increase in winter when planktonic food resources are reduced. At the same time overlap in food

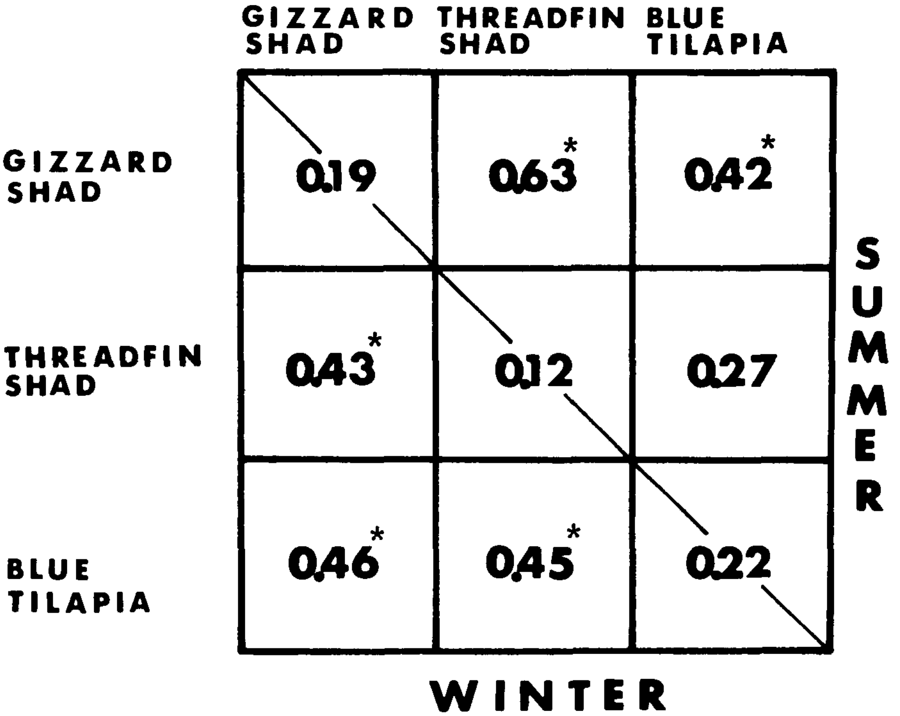

Fig. 1. Coefficients of Spearman's rank correlation between indices of dominance of 35 food items for three species of planktivores in summer and winter, Trinidad Lake, 1975. (Asterisks indicate significant correlation, p. <0.05).

habits of threadfin shad and gizzard shad was less in winter than in summer, possibly indicating behavioral and ecological differences which may help these sympatric species avoid competition.

Because the food habits of blue tilapia, threadfin shad, and gizzard shad overlapped, interspecific competition may occur if resources are in short supply. Trinidad Lake is highly productive and a rich phyoplankton bloom is maintained through the year. The major components of the plankton, unicellular green algae and blue-green algae, are seemingly in abundant supply. Diatoms, protozoans, and rotifers are less abundant in the plankton. Production of detritus is difficult to quantify, but the shallow lake has some marshy shoreline with abundant vegetation.

Blue tilapia, threadfin shad, and gizzard shad co-existed in Trinidad Lake depending upon many of the same food resources. In this highly porductive lake, it would seem that there is no shortage of most of the food items the 3 fish species consumed during July, November, and December 1975. However, the blue tilapia population exceeded 2000 kg per ha (Germany and Noble 1977), far in excess of average standing crop in most southern reservoirs. Their age and growth analyses indicated that stunting of blue tilapia occurred over the period 1973-1975. Gillnet and seine data from Trinidad Lake show a corresponding decrease in numbers of both gizzard shad and threadfin shad (Germany 1977). These changes indicate that food may have been in short supply.

The paucity of zooplankton in the plankton samples and in the stomach analyses may indicate that the fishes were in part limiting their food supply qualitatively. In the absence of such organisms, which other studies have indicated comprise a major portion of the diets of the shad species, greater similarity in food habits could occur. Such reliance on a common food resource, as indicated by the similarity in food habits of these three species, increases the chances for food competition.

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