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Food Habits of Bluegills from Heated and Unheated Areas of Coffeen Lake

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ABSTRACT

Food habits of bluegills collected from heated and unheated areas of Coffeen Lake were examined. Principal food items of bluegills from the heated station, in order of decreasing index of significance values, were plant material, terrestrial arthropods, gastropods, algae, and chironomids. A comparable list of principal food items from the unheated station included terrestrial arthropods, plant material, chironomids, other aquatic insects, and bryozoans. Diversity values, calculated to provide a qualitative assessment of feeding at heated and unheated locations, demonstrated that the diet of bluegills from the unheated station was consistently more diverse. Seasonal variations in diet reflected the bluegill's opportunistic feeding behavior, as seasonally abundant food resources (such as fish eggs, bryozoans, and terrestrial arthropods) were utilized as major food items. Other investigations have suggested that bluegills from heated locations feed more frequently than those from unheated waters. However, fullness indices calculated for this study indicated that stomach fullness was significantly higher at the heated station for only two of eight collection dates.

INTRODUCTION

A fundamental problem for all animals in an aquatic ecosystem is obtaining sufficient nutrition. For fishes inhabiting thermally enriched environments the problem may be exacerbated by accelerated rates of digestion and maintenance metabolism (Bennett and Gibbons 1972, Graham 1974). These fishes may exhibit several responses to mitigate these problems: migration to areas of cooler temperatures (Tranquilli et al. 1979), transitory forays into unpreferred temperatures to forage (Bennett and Gibbons 1972), or consumption of a larger daily ration. Alternatively, fishes may not be capable of mitigating those metabolic problems, and poor growth may ensue.

This investigation of bluegill feeding dynamics was initiated to increase our understanding of the ecological role of bluegills inhabiting cooling lakes. Specif-

ically, this study was designed to ascertain and compare the diet of bluegills (*Lepomis macrochirus*) from heated and unheated locations of Coffeen Lake.

STUDY AREA

Coffeen Lake was formed in 1963 by impounding McDavid Branch, a tributary of the East Fork of Shoal Creek. The normal operating level (590 MSL) was reached by late 1966, providing 446 hectares of lake surface area. Coffeen Lake is relatively deep compared with other Illinois reservoirs. The Illinois EPA (1978a, 1978b) listed selected parameters for 353 Illinois lakes and reported that Coffeen Lake had a greater mean depth (5.7 m) and maximum depth (17.7 m) than 95% of the lakes studied.

Coffeen Power Station, located in Montgomery County, Illinois, is owned and operated by Central Illinois Public Service Company (CIPS). The two coal-fired generating units produce a gross capacity of 945 MeW. These two units, based on a 70% load rate, have a maximum heat rejection of 4.36 BTU hr^{-1} and establish an average 12°C rise in water temperature across the condensors. The thermal effluent leaves the power station via a 0.9 km-long discharge canal and enters Coffeen Lake by flowing over a hot dam. The cooling loop is 6.6 km from discharge to intake, providing 324 hectares of effective cooling area. The unheated area (Station 4) was partially isolated from the main body of the lake by a railroad causeway which effectively blocked the heated water (Fig. 1). A more complete account of the Coffeen power facilities and lake environment may be found in Tranquilli and Larimore (1981).

MATERIALS AND METHODS

Bluegills were collected from heated (Station 1) and unheated (Station 4) areas (Fig. 1) of Coffeen Lake by means of a 230-volt AC electrofishing unit. All collections were made during daylight hours. The fish were placed immediately on ice and transported to the laboratory. Fish weight and total lengths were measured before the stomachs were removed and stored in 10% formalin. In order to obviate size-specific or age-related variations in the diet (Sarker 1975, Sule et al. 1981) only fish larger than 89 mm were included in the analyses.

Stomach contents were removed, identified, and weighed while moist on a Mettler balance (precision 0.1 mg). The composition of the diet was quantified using percent frequency of occurrence, the gravimetric method, and the index of significance as described by Windell (1971). The index of significance value, which represented the geometric mean of the frequency of occurrence and percent weight (gravimetric) values, allowed each food item to be ranked according to the combined assessment of weight and frequency of occurrence. Diversity indices, as described by Mathur (1977), were calculated for each data set using all identifiable food categories. The fullness index was defined as the wet weight (mg) of stomach contents divided by the weight (g) of the fish from which the stomach was taken.

Three sampling anomalies should be noted. First, collections made during June, July, and August 1979 were accidentally discarded; therefore, new collections were made during those months in 1980. Second, bluegills collected in July and August 1980 were not taken from the area of Station 1, as no fish could be

found there at that time. The collections were taken from areas near Station 1.5 (Fig. 1). Third, during January 1979, the unheated station was ice-covered, and no collection could be made.

RESULTS AND DISCUSSION

Index of significance values showed that food habits of bluegills collected from heated and unheated areas of Coffeen Lake were not greatly dissimilar (Tables 1 and 2). Differences in gastropod and bryozoan utilization were most pronounced, the former being more predominant in stomachs of fish from heated areas and the latter more predominant at unheated sites. Chironomids and other aquatic insects were more prevalent in stomachs from the unheated locations; the differences in use apparently reflected similar differences in abundance of those specific food resources. Another distinction between the two areas was the greater reliance of bluegills from the heated station on plant material and algae. Food items of nearly equal importance at both heated and unheated stations included terrestrial arthropods, microcrustaceans, and fish eggs.

Bluegills from both heated and unheated areas of Coffeen Lake consumed substantial quantities of terrestrial arthropods. However, that fact does not necessarily imply that bluegills were using that resource because autochthonous foods were scarce. Although authochthonous food resources were poor at the heated station, they were abundant at the unheated station (Swadener et al. 1980, Warren and Buckler 1981), and yet terrestrial arthropods were the most important food item of bluegills from unheated waters. Several factors may have contributed to the extensive use of terrestrial arthropods as food by bluegills. First, overhanging forest vegetation dominates the Coffeen Lake shoreline and thus provides an interface between aquatic and terrestrial habitats. Second, the feeding behavior and morphological adaptations of bluegills (Keast and Webb 1966), augment that fish's potential for capturing surface prey. Third, the opportunistic nature by which the bluegill feeds suggests that the most abundant and accessible food items are readily exploited. For instance, bluegills examined in this study from the September collections contained enormous quantities of aphids, almost to the exclusion of all other food items.

Diversity values were calculated to provide a qualitative assessment of feeding at heated and unheated locations (Table 3). Those values demonstrated that the diet of bluegills from the unheated station was consistently more diverse than that of bluegills from the heated area; only during October and November 1978 were diversity values higher at the heated station.

Food habits of bluegills from Lake Sangchris (Sule et al. 1981), a cooling lake in nearby Christian and Sangamon Counties, differed from those of bluegills examined in this study. Bluegills from Lake Sangchris relied more heavily upon microcrustaceans, chironomids, and other aquatic arthropods, whereas bluegills from Coffeen Lake consumed more terrestrial arthropods. In addition, gastropods, bryozoans, and fish eggs, all important components of the diet of Coffeen Lake bluegills, were not found in stomachs of bluegills from Lake Sangchris.

Empty stomachs were uncommon in this study, as only 1.0 and 4.5 percent of the stomachs from the heated and unheated stations, respectively, were empty. To further investigate differential feeding intensity at the two stations, a fullness index determined for each specimen showed that stomachs of bluegills from the

heated station contained significantly (P 0.05) more food by weight during March and June than did the stomachs of bluegills from the unheated areas, but there was no statistical difference between stations for the other six months. Differential feeding intensity of bluegills has been investigated in a cursory manner in other cooling lakes. Sarker (1977) and Sule et al. (1981) found that the percentage of empty stomachs was lower in samples taken from heated locations as opposed to those from unheated locations. That same trend held true for this investigation. Both Sarker (1977) and Sule et al. (1981) suggested that bluegills in heated waters fed more frequently because of higher digestive and metabolic rates. However, mean fullness indices calculated for this study were significantly higher (P 0.05) at the heated station for only two of eight collection dates.

Winter food habits did not differ between heated and unheated areas of Coffeen Lake, and the winter diet of bluegills from the heated station did not differ from published reports of the feeding habits of bluegills from lakes with normal winter water temperatures. Food items of increased importance during winter collections were microcrustaceans and plant matter, whereas utilization of chironomids declined and use of terrestrial arthropods declined precipitously (Fig. 2). Similar winter feeding regimes have been reported for several non-cooling lakes (Moffet and Hunt 1943, Goodson 1965). Probably unique to an Illinois lake was the appearance of fish eggs in the winter diet of bluegills, which were found in stomachs from the heated station in mid-March. At the same time fish eggs were not found in stomachs from the unheated area of the lake. This disparity can be related to the bimodal spawning periodicity of largemouth bass in Coffeen Lake. Largemouth bass from the heated area begin spawning approximately four weeks before bass in the unheated area (Tranquilli and Perry 1981).

During spring, fish eggs became the predominant food item of bluegills in Coffeen Lake. Ninety percent of the specimens from the heated station and 80 percent from the unheated waters contained fish eggs, but bluegills from the unheated station consumed a greater percentage weight and thus exhibited a higher index of significance value. Bryozoans were an important food item in spring at the unheated station but were not found in stomachs from the heated station. Food items which were used extensively during winter, microcrustaceans and plant matter, were less important in spring samples as other food resources became abundant. A distinct disparity existed between heated and unheated collections in the use of the major aquatic insect group, chironomidae larvae. The index of significance value for bluegills from the unheated station was 23.7 and only 4.0 for bluegills from the heated station. However, bluegills from the heated area were at the same time making much greater use of terrestrial arthropods as a food resource.

During the summer months water temperatures at the heated station often exceeded the upper avoidance temperature (33°C) of bluegills (Beitinger and Magnuson 1979) and thus may have altered feeding behavior. During this period, gastropods, which were uncommon during the other seasons, became an important component of the diet at the heated station but were much less important at the unheated station. Principal food items at the unheated station during the summer months were terrestrial arthropods, plant matter, bryozoans, and chironomids.

During autumn, plant matter and terrestrial arthropods were the predominant food items. Gastropods were uncommon, and bryozoans and fish eggs were completely absent from the diet of bluegills. Chironomids, which in other seasons

were more extensively utilized by bluegills from the unheated station, were used to a greater extent by bluegills from the heated area of Coffeen Lake.

Benthic food resources were sparse in the area of the heated effluent (Warren and Buckler 1981), and the major component of the littoral benthic community, oligochaetes, was rarely used as food by bluegills. Thus, bluegills from the heated station shifted to other food resources, some of which have been reported to be of limited value, e.g., algae (Kitchell and Windell 1970). Beitinger and Fitzpatrick (1979) stated that bluegills in natural populations are often food limited, and fish under such constraints can reduce maintenance metabolic costs by seeking lower water temperatures. In Coffeen Lake, intra- and interspecific competition for food and space is probably so severe that many fish were unable to occupy preferred temperature regimes. Multiple factors acting synergistically probably contributed to the stunted condition of bluegills (Perry and Tranquilli 1981) in Coffeen Lake. However, two of the more important factors limiting the growth and affecting the body condition of Coffeen Lake bluegills were the quality of the food resource and accelerated rates of maintenance metabolism.

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Table 1. Composition of the diet of 108 bluegills collected from the heated station of Coffeen Lake, October 1978-August 1980. Food items are listed in order of decreasing importance according to their index of significance value. Mean total length was 126 mm, range 90-154 mm.

Food item	Index of significance	Percent weight	Percent frequency of occurrence
Unidentified organic matter	55.2	35.8	85
Plant material	33.8	16.3	70
Terrestrial Arthropods	32.8	14.0	77
Gastropoda	16.8	13.5	21
Inorganic matter	13.0	5.3	32
Algae	12.3	6.6	23
Chironomidae	11.7	2.0	68
Microcrustaceans	7.6	1.1	52
Other aquatic insects	7.5	1.4	40
Fish eggs	6.3	2.5	16
Fish scales	2.6	0.3	22
Bryozoa	1.3	0.3	6
Astacidae	1.2	0.7	2
Oligochaeta	0.09	0.002	4
		99.8	

Table 2. Composition of the diet of 110 bluegills collected from the unheated station of Coffeen Lake, October 1978-August 1980. Food items are listed in order of decreasing importance according to their index of significance value. Mean total length was 126 mm, range 91-151 mm.

Food item	Index of significance	Percent weight	Percent frequency of occurrence
Unidentified organic matter	54.0	32.8	89
Terrestrial Arthropoda	34.7	18.8	64
Plant material	23.8	14.5	39
Chironomidae	19.6	5.2	74
Other aquatic insects	12.9	3.6	46
Bryozoa	12.1	9.1	16
Fish eggs	9.1	5.5	15
Microcrustaceans	7.1	1.0	51
Algae	6.4	4.5	9
Fish scales	4.7	1.5	15
Gastropoda	3.8	1.8	8
Inorganic matter	2.8	1.6	5
Oligochaeta	——	——	——
Astacidae	——	——	——
		99.9	

Table 3. Monthly diversity (D) of the diet values at heated and unheated stations in Coffeen Lake.

Date	Diversity (D)	
	Heated	Unheated
Oct. 1978	1.99	1.46
Nov. 1978	1.92	0.56
Jan. 1979	1.18	*
Mar. 1979	1.28	1.55
May 1979	1.61	2.46
Sept. 1979	1.78	1.84
June 1980	1.23	2.08
July 1980	2.27	2.77
Aug. 1980	1.95	2.08

*No collection due to ice cover.

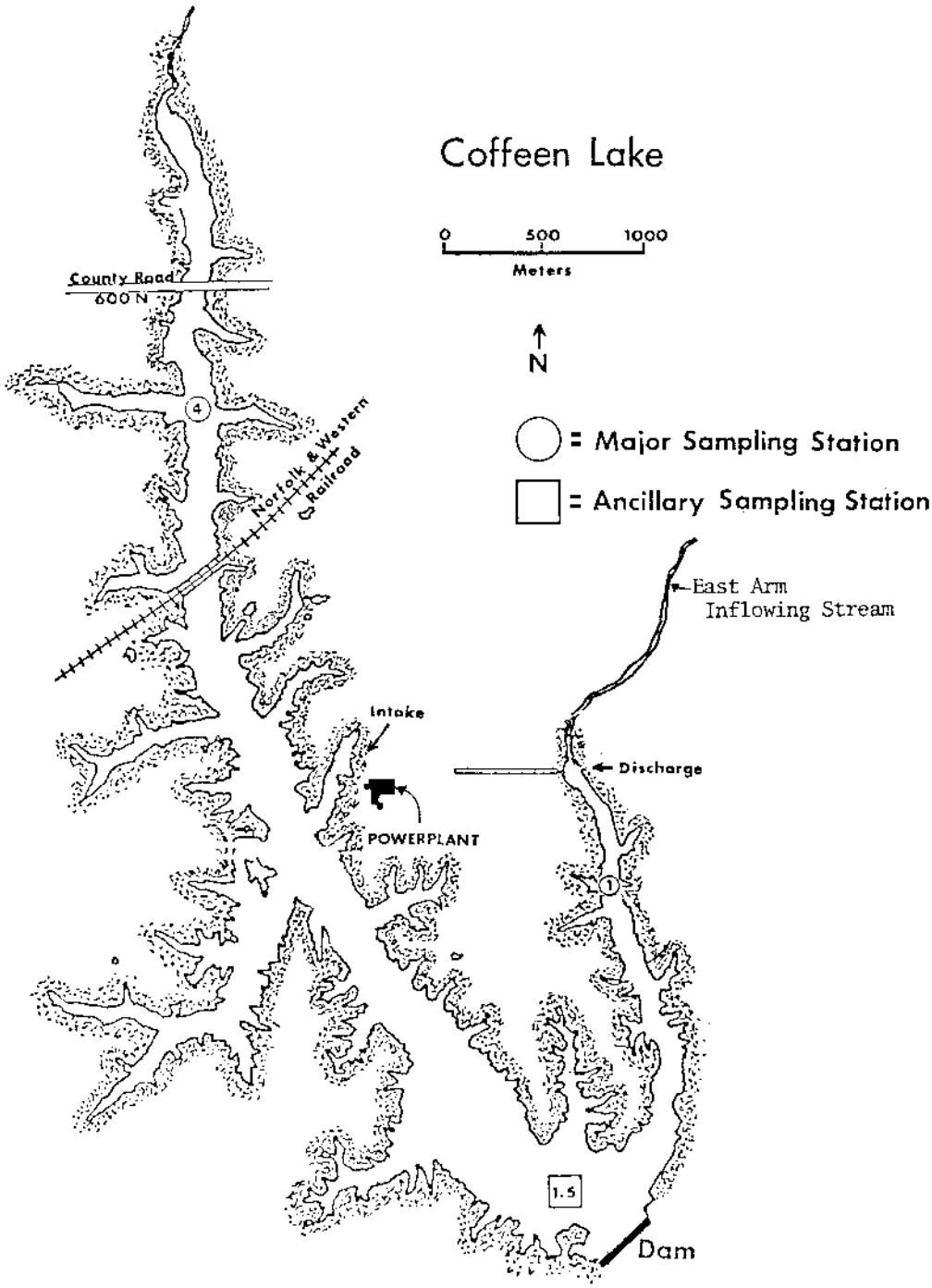

Fig. 1. Sampling stations on Coffeen Lake used during this study (Stations 1, 1.5 and 4).

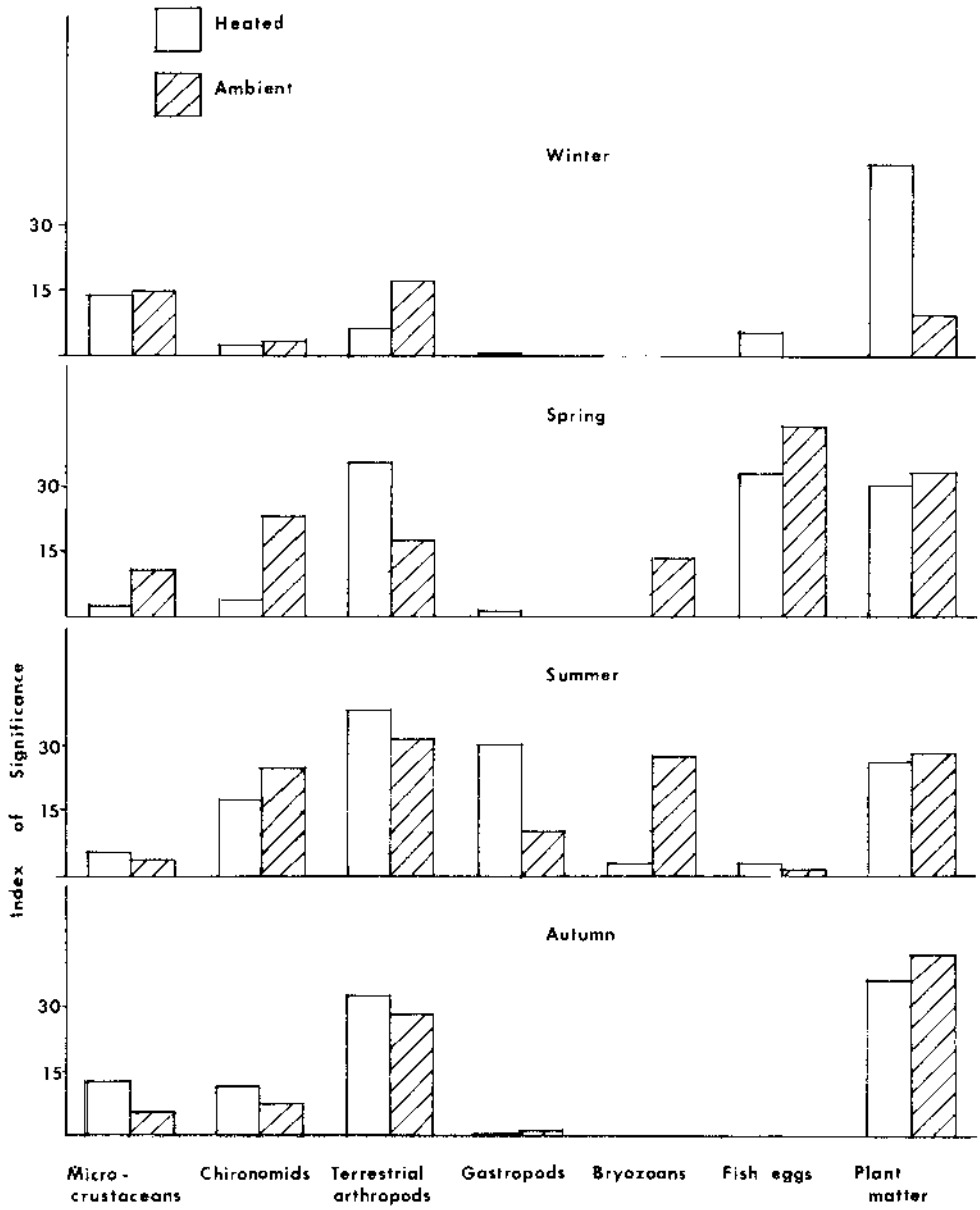

Fig. 2. Seasonal variations in the diet of bluegills from heated and unheated areas of Coffeen Lake.