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ABSTRACT

A three-year study was conducted to determine the possible effects of cage culture of fish on the environment of Crystal Lake, Arkansas. The investigation consisted of three periods: pre- (November 1971-October 1972), during- (November 1972-October 1973), and post- (November 1973-October 1974) cage culture.

Numbers and biomass of benthos per square meter for pre-, during-, and post-culture periods were 1353 (10.0g), 730 (8.8g), and 1028 (4.1g), respectively. Numerically, *Chaoborus* sp., Chironomidae, and Oligochaeta comprised more than 97%. *Chaoborus* was the most numerous organism before fish culture (>68%), but dominance shifted to the Oligochaeta (>58%) after culture.

INTRODUCTION

Rapidly increasing human populations have created a severe demand for increased production of food. Fish production has been recognized for its potential importance in subsidizing the world's protein needs. The great demand for fish as a protein source has resulted in overexploitation of natural fisheries. Therefore, the yield from natural fisheries must be supplemented by fish culture.

Production of fish by culturing them in cages suspended in reservoirs is becoming a common practice in many southern states. There is some concern about the effects caged fish culture may have on these reservoirs. Metabolic products of the fish, fish feces and excreta, and substances leached from the fish food might cause significant changes in the physicochemical characteristics and normal biota of a reservoir which could hasten eutrophication.

This study was conducted in three one-year phases for comparison: (1) pre-culture from November 1971 to October 1972, (2) during-culture from November 1972 to October 1973, and (3) post-culture from November 1973 to October 1974 (Kilambi et al. 1976). This report concerns the effects of fish cage culture on the macrobenthos population of Crystal Lake, Arkansas.

STUDY AREA

Crystal Lake, Benton County, Arkansas, is owned and operated by the Arkansas Game and Fish Commission as a public fishing lake. Crystal Lake has a surface area of 24 hectares (60 acres), an average depth of 4.5 m (15 ft), and a maximum depth of 9 m (30 ft). The watershed to lake area ratio is approximately 40:1, which, with an average annual rainfall of more than 152 cm (60 in.), produces a relatively high water exchange rate.

The lake undergoes the warm monomictic type of stratification characteristic of lakes in northwest Arkansas. Stratification begins in late April and is complete by early June. Destratification and fall turnover occurs by late November with continuous mixing of the entire water column through the winter and early spring.

MATERIAL AND METHODS

For sampling purposes the lake was divided into three sections, A, B, and C, representing the lower, middle, and upper regions, respectively (Fig. 1). One sampling station was used to represent each section.

Two benthos samples were taken at each station with an Ekman dredge (231 cm^2) twice a month between 0800 and 1100 hours. The contents were strained through a #30 (590 μm mesh) U.S. Standard Sieve. All material remaining in the sieve was placed in quart jars containing 5% formalin and transported to the laboratory where the organisms were separated from the detritus in white porcelain pans with the aid of an illuminated magnifying glass. Benthic organisms were identified to appropriate taxa as classified by Pennak (1953). The organisms then were preserved in 80% ethanol for future reference.

Significance of statistical tests was expressed at the 0.05 level.

RESULTS

Comparison of benthic organisms m^{-2} between stations within the study periods showed no significant differences (pre-cage $F_{2,54} = 1.28$; during-cage $F_{2,62} = 1.13$ post-cage $F_{2,34} = 1.28$). Therefore, the data for stations within periods were combined for further analysis.

During the pre-culture phase of the study the mean annual density of the total benthic macroinvertebrates was 1353 N m^{-2} with a biomass of 10.0 g m^{-2}. The most abundant benthic organism was larval *Chaoborus* sp. ($F_{3,69} = 4.42$). The average annual density of *Chaoborus* sp. was 847 N m^{-2} (Fig. 2) which represented 62.6% of the total benthic community. Chironomid larvae and oligochaetes had densities of 290 N m^{-2} (21.43%) and 173 N m^{-2} (12.79%), respectively (Fig. 2). The remaining portion of the benthos was composed of ceratopogonid larvae with 36 N m^{-2} (2.66%; Fig. 2), mollusks (Sphaeridae, *Physa* sp., and *Gyraulus* sp.) with 5 N m^{-2} (0.37%), and other taxa including Odonate nymphs (*Enallagma* sp. and *Chromagrion* sp.), dytiscid larvae, and coelenterates with 2 N m^{-2} (0.15%).

During the culture phase of the study no additional taxa of benthic organisms were present in the collections. The mean annual total was 730 N m^{-2} with standing crop biomass of 8.8 g m^{-2}. This phase showed

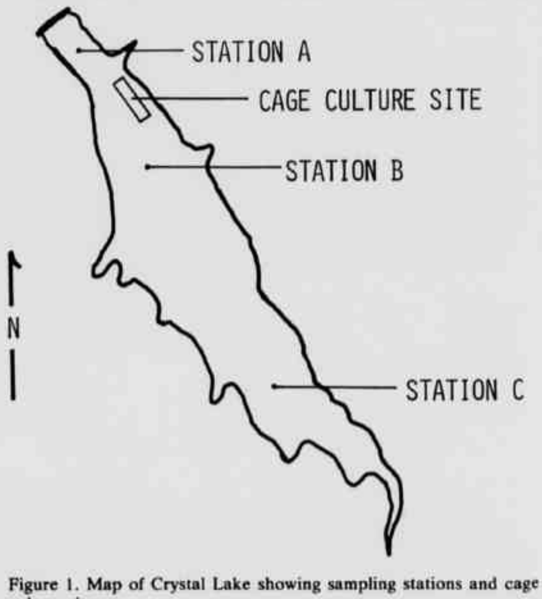

Figure 1. Map of Crystal Lake showing sampling stations and cage culture site.

no significantly ($F_{2,63} = 0.10$) dominant taxon; the average annual densities for *Chaoborus* sp., chironomid larvae, and oligochaetes were 217 N m^{-2} (29.73%), 247 N m^{-2} (33.84%), and 239 N m^{-2} (32.74%), respectively (Fig. 2). The remainder was composed of ceratopogonid larvae with 22 N m^{-2} (3.10%; Fig. 2), mollusks with 2 N m^{-2} (0.27%), and other taxa with 3 N m^{-2} (0.41%).

The post-culture phase mean annual density was 1028 N m^{-2} with a standing crop biomass of 4.1 g m^{-2}. During this phase the dominance shifted to Oligochaeta ($F_{1,38} = 4.82$) with an average annual density of 598 N m^{-2} (Fig. 2) comprising 58.17% of the total benthic community. *Chaoborus* sp., chironomid larvae, mollusks, and other taxa had densities of 333 N m^{-2} (32.39%; Fig. 2), 85 N m^{-2} (8.27%; Fig. 2), 9 N m^{-2} (0.88%; Fig. 2), 2 N m^{-2} (0.19%), and 1 N m^{-2} (0.10%), respectively.

The total density of organisms was 1353, 730, and 1028 N m^{-2} in the pre-, during, and post-culture periods, respectively. There were no significant differences in the total number of benthic organisms among the years ($F_{2,228} = 1.40$). Total biomass decreased each year; 10.0, 8.8, and 4.1 g m^{-2} were found in pre-, during-, and post-culture phases, respectively.

Several statistically significant changes among the dominant taxa of benthos were observed. *Chaoborus* sp. was the most abundant benthic organism (>62%) before fish culture ($F_{3,69} = 4.42$), no single taxon dominated the culture phase ($F_{2,63} = 0.10$), and the oligochaetes composed the bulk (>58%) of the post-culture ($F_{1,38} = 4.82$) standing crop. The number of oligochaetes increased significantly ($F_{2,58} = 11.24$) during the study, and chironomids decreased significantly ($F_{2,58} = 4.24$) from during-culture to post-culture. No significant shifts were observed either in the numbers of *Chaoborus* sp. ($F_{2,58} = 1.55$) or among ceratopodonids ($F_{2,45} = 1.03$) between culture phases. Mollusca and other taxa remained relatively unchanged during the study.

A single specimen of *Branchiura sowerbyi* Beddard was collected on 26 June 1974 in the lower end of the lake at a depth of 9 m. This gilled oligochaete was reported from two lakes in northwest Arkansas (Causey 1953), Lake Ft. Smith and Lake Atlanta.

DISCUSSION

The dominant taxa of benthic organisms according to density in Crystal Lake were Culicidae (*Chaoborus* sp.), Chironomidae, and Oligochaeta. Throughout the study they comprised 97.23% of the benthic community. This percentage agrees with the results found in three other northwest Arkansas lakes. Tatum (1951) found that in Lake Atlanta Oligochaeta, Chironomidae, and Culicidae constituted 99.68% of the total benthos collected. In Lake Wedington, Owen (1952) reported that 97.4% of the benthic population was Oligochaeta, Chironomidae, and Culicidae. Hulsey (1956) found that in Lake Fayetteville the structure of the benthic community was 97.1% Oligochaeta, Chironomidae, and Culicidae.

Throughout the study, Mollusca and other minor taxa represented a small portion of the benthos numerically; however, because of large individual mean weight they did comprise a significant fraction of the total biomass.

During the culture period, 17,444 kg of floating fish food was fed to a final weight of 13,185 kg of caged fish. Bottom samples from the cage site contained large quantities of fish feces composed of undigested cellulose from the fish chow. These deposits decreased appreciably through the post-culture phase, presumably as a result of decomposition and dispersal during mixis. Apparently nutrients bound in this material were released into the water and sediments. Of 13 physicochemical parameters monitored, ortho- and metaphosphate, nitrite and nitrate nitrogen, and turbidity showed significant increases during the study (Kilambi et al. 1976). This increase in nutrients produced larger annual standing crops of phytoplankton, zooplankton, and natural fish populations. The total benthos community did not increase as might have been expected. Apparently the residue resulting from fish culture was not used immediately by the macrobenthos and may have been responsible for their decrease during the study. This possibility is supported by the observation that the fish feces which accumulated were not immediately colonized by benthos. The fact that oligochaetes colonized this material at a faster rate than other taxa may account for their subsequent dominance.

Changes in the benthic community probably were caused by fish culture. However, this conclusion cannot be established definitely because there are no data covering several consecutive years in an Ozark reservoir that would establish normal fluctuations in these values for comparison. It is evident, therefore, that continuous monitoring of a reservoir for several year before and after fish culture would be necessary to record natural changes of benthos and to determine the precise effects of fish culture and the subsequent recovery rate.

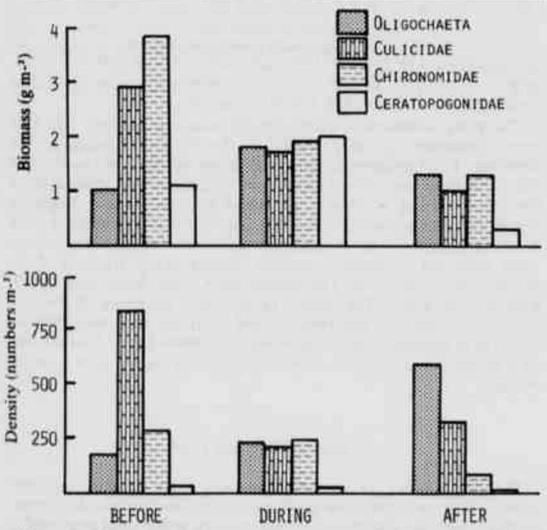

Figure 2. Biomass and density of major benthic macroinvertebrate taxa during each culture period.

ACKNOWLEDGEMENT

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