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Response of Zooplankton to Rotenone in a Small Pond

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To eradicate grass carp, *Ctenopharcyngodon idella*, from a pond, 6 *u*L/L of 2.5% rotenone was applied to the pond. Though fish are usually the target species of this toxin in aquatic systems, rotenone is also a highly effective insecticide. Rotenone, also called derris root, was originally derived from the roots of *Derris elliptica*. Current commercial sources include rosewood, *Tephrosa* spp., and Rabbit's pea, *Dalbergia paniculata* (Gaskins and Stone 1971). Though the toxin degrades rapidly (Loeb and Engstrom-Heg 1970) and bioaccumulation is not a hazard (Gunther and Turrell 1942) it can have a serious impact on aquatic ecosystems by affecting organisms other than target species. It may disrupt trophic structure of the system and limit restocking success.

Studies of the effect of rotenone on zooplankton, an important food source for fish fry, show variable sensitivity to the toxin. Most studies agree that zooplankton populations are reduced. The variation reported is in recovery rates and the degree to which different groups of zooplankton are affected (Almquist 1959; Anderson 1970; Hooper 1948). Several studies have suggested that rotenone is toxic to zooplankton at concentrations of 1 *u*L/L (Brown and Ball 1942) or less (Hooper 1948). The rate of recovery varies from 1 mon to 3 yr. Anderson (1970) reported that crustaceans and rotifers were destroyed and remained absent for 6 mon following rotenone treatment. In his study it took 3 yr for all zooplankton populations to reach pre-rotenone densities. Brown and Ball (1942) reported that copepods affected by rotenone recovered within 1 mon and cladocerans within 5 wk. Rotifers, while considerably reduced in numbers, remained present throughout Brown and Ball's (1942) study.

The objective of this study was to assess immediate and long term changes in zooplankton community structure after rotenone treatment in a small pond. Differences in recovery times among various groups of zooplankton would be expected due to differences in life history characteristics. The presence of resistant stages, resting eggs, reproduction by unaffected adults and duration of life cycle may all effect recovery (Lindgren 1960; Pennak 1978). In addition, decreased predation as a result of removal of fish and insect predators may hasten recovery (Brown and Ball 1942; Hooper 1948).

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MATERIALS AND METHODS

The study was conducted in two ponds located on the golf course of Western Illinois University. The experimental pond to which rotenone was added to remove grass carp and sunfish has a surface area of 0.48 ha, volume of 247,000 L, and a center depth of 2 m. The pond was rimmed with water primrose, *Jussiaea cepens*. Other aquatic macrophytes had been removed by the grass carp. The bottom substrate was silt-clay with some gravel areas. The second pond, approximately 150 m from the experimental pond, was slightly smaller, 0.32 ha, 165,000 L, and maximum depth of 1.8 m,but had similar morphometry and substrate. This pond, used as a control, did not contain fish but did contain some pondweeds, *Potamegeton* spp., and duckweed, *Lemna* sp. Both ponds drain into the Lamoine River and are nutrient enriched due to fertilizers in the runoff from the golf course.

Zooplankton samples were taken 15 min before, then 15 min, 1 hr, and 5 hr after rotenone was applied on the first day of the study. Subsequent sampling occurred every 3 d for 1 mon, then every 2 wk for 5 mon and then monthly for 8 mon. Some supplementary samples were taken during the first 6 mon because of environmental events which could have had a potential effect on zooplankton populations. One sample was taken immediately after a heavy rainfall, 7.62 cmover a 2 1/2 hr period, and a series of samples were taken during an algal bloom. Samples were collected in both the control and experimental pond.

Samples were collected with a 0.076-mm mesh plankton net. The net mouth had a diameter of 25.4 cm and nets were towed over a 3 m path. During periods when the ponds were frozen, Dec. through Feb., samples were collected by pumping water into the plankton nets from a hole cut in the ice. The pump used had a 0.832 L per stroke capacity and 30 strokes of water were pumped into the net at each station. Samples were collected from three stations on each pond. Samples were first treated with methyl crystals to anesthetize organisms and then preserved in 10% neutral buffered formalin. Half an mL of a 1:1 Biebrich Scarlet/Eosin B stain was added to each sample to facility enumeration (Williams 1974). Three 1 mL subsamples from each sample were examined for enumeration and species identification.

RESULTS AND DISCUSSION

No viable zooplankton were found 48 hr following rotenone application to the experimental pond (Figs. 1). Onset of recovery ranged from 1 to 6 mon with full recovery taking from 6 to 8 mon. Cyclopoid copepods were the first zooplankton to reappear followed by benthic rotifers. Caldocerans were not present until 6 mon following rotenone application. Considerable differences in zooplankton density and community composition occurred between the control and experimental ponds during the first 8 mon of the study. Control pond zooplankton population fluctuations are typical of zooplankton populations and have been reported in other studies (Hazelwood and Parker 1961).

Cyclopoid nauplii reappeared in experimental pond collections 30 d after rotenone application (Fig. 2). Their appearance coincided with an algal bloom which may have provided an abundant food supply. Copepoda have been the primary recolonizer in other zooplankton studies (Anderson 1970; Brown and Ball 1942; Claffey and Costa 1977; Hongue 1977) although recovery times reported by these investigators varied. The first zooplankters collected

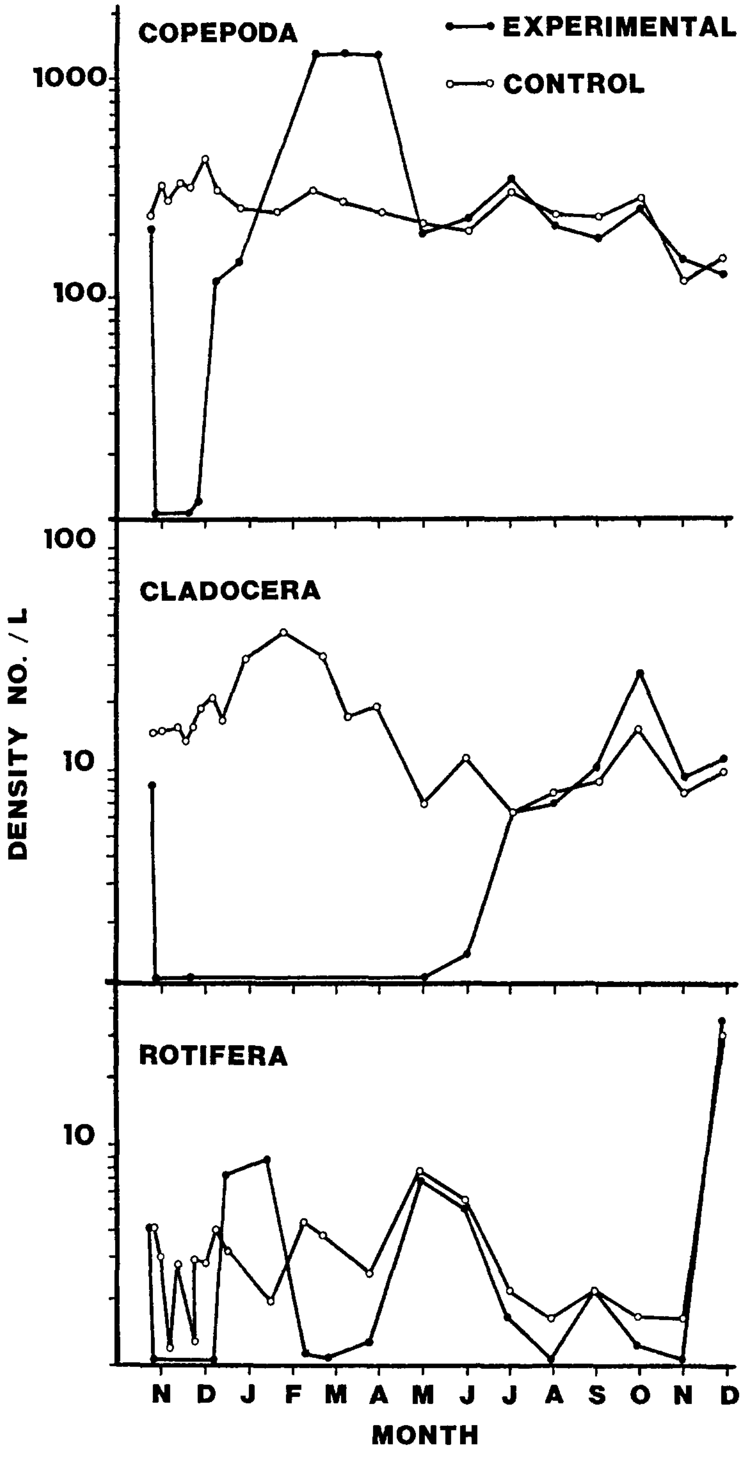

Figure 1. Zooplankton densities in experimental and control ponds.

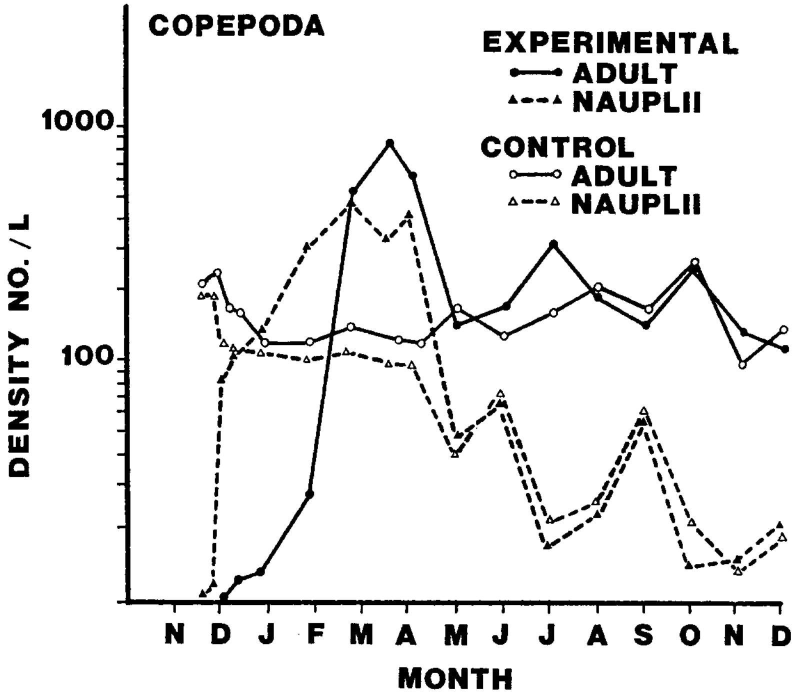

Figure 2. Comparison of adult versus nauplii densities in experimental and control ponds.

following poisoning were entirely copepod nauplii, identified when mature as *Acanthocyclops vernalis*. Although *Diaptomus pallidus*, *D. siciloides*, and *Paracyclops fimbriatus* were present prior to rotenoning, *A. vernalis* was the only copepod present in samples taken throughout the winter. *P. fimbriatus* reappeared in late Mar. and *D. pallidus* became the dominant copepod in May, persisting as the dominant copepod for the remainder of the study. *Diaptomuspallidus* was the dominant copepod in the control pond throughout the study with *A. vernalis* and *P. fimbriatus* also occurring abundantly. By May the copepod communities in the control and experimental ponds were very similar (Fig. 2). The reoccurrence of copepods was probably a result of repopulation from eggs that settled to the bottom when adults were killed. The eggs may have been protected by the sediment (Lindgren 1960) or have been specialized thick walled resting eggs produced as a result of heavy predation and high turbidity (Pennak 1978). Cyclopoid eggs have an incubation period of less than 1 mon with life cycles that are complete in 7 to 180 d (Pennak 1978). Copepod densities increased rapidly, reaching almost 1300/L (Fig 1). Control pond copepod densities did not exceed 500/L during the study period. The rapid growth pattern demonstrated by the experimental pond copepod population may have been a normal seasonal fluctuation, winter population expansion (Kerfoot and Peterson 1980), magnified by an abundant food supply and a lack of predators. Both fish and macroinvertebrates had been eliminated from the experimental pond by the rotenone (Beal 1985).

Rotifers were the second group of zooplankton to reoccur (Fig. 1) in the experimental pond. Though rotifers have been reported to tolerate rotenone at concentrations of 1 *u*L/L (Brown and Ball 1942) or may escape toxic effects by retreating into bottom sediments (Lindgren 1960), they were not present in zooplankton samples of the treated pond for 45 d. Rotenone concentrations used in this study were almost three times higher than in the Brown and Ball study. As with copepods, when rotifers did reoccur, their densities increased exponentially. However the populations also declined rapidly in late Jan. and remained low for 2 mon. This period corresponds to peak densities of copepods, and since copepods are primarily predaceous (Kerfoot and Peterson 1980), these high densities may have depressed rotifer populations. Rotifer populations increased when copepod populations declined and the rotifer communities were similar in the control and experimental pond by May. Rotifer densities were generally low (Fig. 1), usually less than 20% of the total zooplankton. However, in the last sample, rotifer populations had increased substantially, and they constituted 65% of the zooplankton community in both the control and experimental ponds.

Although initial rotifer densities were comparable between the two ponds, community composition was not. Benthic rotifers were dominant in the experimental pond while littoral species were predominant in the control. The effect of the grass carp in reducing aquatic macrophytes probably accounts for lower numbers of littoral species in the experimental pond. While *Keratella* sp. dominated pre-rotenone samples, the community was dominated by *Branchionus* sp. during, the recovery phase in the experimental pond. As aquatic vegetation increased, *Keratella* sp. populations increased so that by May it was the dominant rotifer in both ponds.

Pre-rotenone cladoceran densities in the experimental pond were approximately half that of the control pond, and they were eliminated immediately following rotenone application (Fig. 1). This group of zooplankton did not reoccur until May and did not recover to pre-rotenone densities until July. Composition of the cladoceran community prior to rotenone application showed major differences between ponds. The experimental pond contained *Bosmina longirostris*, *Daphnia parvula*, and *Ceriodaphnia reticulata*. While these species were also present in the control pond, *Daphnia pulex* was dominant. By contrast, *B. longirostris* was dominant in the experimental pond. This is probably a community response to predation since both grass carp and green sunfish present in the experimental pond are predators of cladocera (Etnier 1971; Watkins et al. 1981). According to Brooks (1968) and Zaret and Kerfoot (1975), size selectivity of larger cladocerans, especially mature *Daphnia* spp. allow smaller cladocerans, such as *B. longirostris*, to become dominant. Janicki et al. (1979) also found *B. longirostris* to be more likely to dominate in eutrophic or disturbed systems because of its shorter life cycle. By contrast, invertebrate predators, such as *Chaoborus*, which was abundant in the control pond, have been found to selectively remove smaller cladocera resulting in a community with abundant larger cladocerans (Fedorenko 1975). After cladoceran populations had recovered in the experimental pond, the community was composed of the codominants *B. longirostris* and *D. pulex*, as was the control pond.

Summarizing the results, rotenone eliminated all zooplankton from the water column. Recovery of the zooplankton community varied by particular group with copepods reoccurring first followed by rotifers and finally cladocerans. Zooplankton community composition did not recover, as compared with a control pond, until 8 mon after rotenone application. This indicated the general biocidal nature of this toxin. If rotenone is used in conjunction with a restocking effort in which naturally produced food items are depended on, the restocking needs to be delayed until the natural communities have been reestablished. This study indicated this would be particularly important if fry which depend on zooplankton as a food source are used in the restocking program.

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