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Effects of Fish on Zooplankton Community Structure in Chaney Lake, a Temporary Karst Wetland in Warren County, Kentucky

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ABSTRACT

Chaney Lake is an ephemeral karst lake in southern Kentucky (USA). Unlike most ephemeral lakes, Chaney often contains fish that can enter the lake through the underlying Lost River drainage system. The effects of introduction of golden shiners (*Notemigonus crysoleucas*) on zooplankton in Chaney were examined for a 2-week period in June and July 1997. Twelve fish were transplanted from an isolated region of the lake into each of three enclosures in an area of the lake where no fish had been observed. Three additional enclosures served as fish-free controls. Zooplankton samples and water chemistry and nutrient data were taken every 4 days. Water chemistry and nutrient data showed no significant differences in the measured parameters between enclosures with fish and those without fish. *Bosmina* and *Acanthocyclops* showed decreases in population growth rates in the presence of fish. The fish had no effect on the growth rates of the smaller zooplankton present such as the rotifers. Vertebrate predation in systems like Chaney Lake may pose significant ecological challenges for organisms adapted to temporary habitats.

INTRODUCTION

Fish can be important determinants of zooplankton abundance, species structure, and productivity in aquatic systems. Since the early work of Hrbacek et al. (1961) there have been numerous studies documenting the impacts of fish on zooplankton communities. Removal of zooplanktivorous fish from lakes has been shown to increase the densities of herbivorous zooplankton with concomitant effects on the phytoplankton (Carpenter et al. 1985, 1987; Vanni et al. 1990). This work has prompted research in the use of fish in "biomanipulation" to aid managers in controlling water quality in lakes (Shapiro and Wright 1984). There has been less research conducted on the effects of fish on zooplankton in wetland or forested lake communities, although fish have been shown to have significant effects on zooplankton in shallow, eutrophic, lakes that may be similar in many respects to wetlands (Hanson and Butler 1990). In a study of semipermanent Minnesota wetlands, Hanson and Riggs (1995) found that densities, biomasses, and taxa richness of zooplankton were significantly lower in wetlands that contained fish as opposed to similar ponds which did not contain any fish. In a study of another Minnesota prairie lake, a fish kill resulted in shift in zooplankton species composition from *Bosmina* and *Chydorus* to the larger *Daphnia galeata* and *D. pulex* (Hanson and Butler 1994).

Wetland areas may provide more refuges to zooplankton from fish predation than the open water column of a lake.In a pond-enclosure experiment where the density of vegetation was controlled, perch did not consume as much zooplankton biomass when vegetation was present in the enclosures as when vegetation was absent (Diehl 1992). In their study of a coastal marsh along Lake Erie, Kreiger and Klarer (1991) found that some copepods and cladocerans were more abundant near the sediments or near macrophytes than in the open-water column, which is consistent with earlier work suggesting that vegetation can provide an important refuge for zooplanktors from fish predation (Timms and Moss 1984).

While such biotic interactions between fish and zooplankton are important in structuring planktonic communities in permanent aquatic systems, in most temporary or ephemeral pond systems zooplankton are not subject to fish predation, although other vertebrates such as amphibians may have strong effects on zooplankton assemblages (Wilbur 1997). Indeed, taxa such as the large branchiopod Crustacea are thought to be successful in temporary systems because fish are often excluded from these habitats (Kerfoot and Lynch 1987). Organisms inhabiting ephemeral water bodies

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typically have life histories and ecological strategies that are synchronized to the hydrology of their habitat (reviewed in Wiggins et al. 1980) and that do not necessarily give these organisms any advantage in responding to predation from fish. In most transient water habitats, the threat of fish predation would be exceedingly small; in some ephemeral karst lakes, however, fish predation may be an important force structuring the zooplankton community.

Karst geology is characterized by extensive caves, sinkholes, sinking streams, and springs. Because of the many conduits leading into the subsurface in well-developed karst landscapes, surface water may be directed rapidly into the groundwater areas through a sinkhole, may rise again at a spring, and then sink into the subsurface again as a sinking stream. These points of exit and entrance of water are called estavelles. In many karst landscapes, standing surface water is uncommon, but variations in local geology can produce ephemeral karst lakes and wetlands such as Chaney Lake in south-central Kentucky. Chaney Lake is a 68-hectare state nature preserve located about 10 km south of Bowling Green in Warren County, Kentucky. The lake area is a shallow depression that is connected by fissures (estavelles) in the subsurface rock to the Lost River Cave system, which has a drainage basin of about 233 km^2. The lake is formed because of the Lost River Chert formation, which overlays the limestone under the lake and prevents the rapid return of water to the subsurface except where estavelles are located. When the capacity of the Lost River Cave system is exceeded during periods of high precipitation, groundwater enters Chaney Lake via the estavelles and also through one intermittent surface stream on the south edge of the preserve. As the water levels in the Lost River drop, water may leave the lake through the estavelles as well, leaving large numbers of smaller, isolated pools behind. The lake usually holds water from December through August, although from May on most of that water is in small pools (Jack, personal observation).

Historically, karst wetlands such as Chaney Lake were very important aquatic habitats in western Kentucky because they provided an important source of standing water in a terrain that had little surface water. Chaney Lake and another nearby karst lake, Rich Pond, host huge numbers of migrating birds in the spring and may be an important foraging area for a variety of waterfowl on their spring migrations (Mason, personal communication). Chaney Lake contains a variety of zooplankton species, including common ephemeral pond taxa such as the fairy shrimp *Streptocephalus*. However, the same estavelles that deliver water to support these communities can also serve as conduits for vertebrates such as the spring fish, *Chologaster agassizi*, to enter the lake. If fish can enter Chaney Lake, they may have a strong impact on zooplankton densities and community structure.

In early June 1997, a population of golden shiners (*Notemigonus crysoleucas*), which may have entered Chaney Lake via estavelles, was found in an isolated pool in the northeast corner of Chaney Lake. These fish were transplanted to experimental enclosures in another section of the lake to assess the effect of fish on the zooplankton communities in Chaney. We hypothesized that the fish would select the largest zooplankton species in the water column and, in turn, would cause a decrease in population growth rates of these larger species. We expected that the smaller zooplankton species such as rotifers would have no significant response to the fish or that they would increase in numbers if they are released from competition for resources with, or predation from, the larger macrozooplankton (see Gilbert 1988; Jack and Gilbert 1997).

MATERIALS AND METHODS

The study was conducted from 19 Jun 1999 to 1 Jul 1997 in a marsh area in the southeastern portion of Chaney (see Kelley et al 2000). This area was chosen as the study site because no fish had been observed there and it was unlikely to dry during the period planned for the experiment. The dominant vegetation in the marsh was buttonbush (*Cephalanthus occidentalis*), aquatic plants such as *Polygonum* sp. and a liverwort in the genus *Riccia*. The higher ground around the marsh area is ringed by tree species such as swamp white oak (*Quercus bicolor*), red maple (*Acer rubrum*) and sycamore (*Platanus occidentalis*). Large trees are not present in the marsh itself, perhaps because this part of Chaney consistently holds water for most of the year (>7 months in 1995–1998).

Six 1-m^3 enclosures were constructed using PVC piping for frames and plastic for the sides. The enclosures were then placed in the marsh, enclosing the water column and the associated zooplankton. They were anchored into the sediment of the marsh and were open at the top and at the bottom. Three enclosures were randomly selected to hold 12 fish each, with the other three serving as controls. The fish were caught by sweeping a net in the pool containing the fish and moving the fish into the appropriate enclosures in the marsh. These stocking densities were about ½ the estimated density of the fish in the original pool. This was determined by visually assessing the numbers of fish in the source pool and then taking transects through the pool to determine average depth and diameter, which were then used to estimate pool volume. Invertebrate and water chemistry samples were taken on the first day of the experiment and every 4 days afterward in each of the six enclosures for the duration of the project. Depth, turbidity, specific conductivity, temperature, pH, dissolved oxygen, and percent dissolved oxygen were recorded using a YSI 6250 multiprobe. One-liter nutrient grab samples were also taken in acid-washed bottles to measure nitrates, ammonia, and soluble reactive phosphorous using a Hach DREL 6000 water analysis kit. Nitrate was measured by the Cadmium Reduction method; ammonia was determined using the Nessler method; and soluble reactive phosphorus was measured using the Hach Phosver 3 method. Invertebrate sampling was conducted using a 7-cm-diameter coring device. Two 5-liter core samples were taken from each enclosure on each sampling date and filtered through a 20-μm mesh sieve. The material collected was then washed into a container and preserved in 90% ethanol.

All samples were counted in the laboratory by using an Olympus SZH 10 dissecting microscope. The samples were counted in their entirety and the dominant taxa (>95% of numerical abundance) were identified down to the lowest practicable taxon (usually genus). Population growth rates were calculated for the dominant taxa from the first and last experimental dates using the equation, $r = \ln N_f - \ln N_0 t^{-1}$, where r is equal to the population growth rate, N_f is equal to the final sampling date, No represents the beginning sampling date, and t stands for the total number of days in the experiment (Jack and Gilbert 1993). A Student's *t*-test was used to compare growth rates in the fish and fishless enclosures. A repeated measures ANOVA was calculated using SYSTAT version 7.0 to assess changes in the physical parameters in the enclosures.

RESULTS

The data met the assumptions of ANOVA so transformation was not needed before the data could be analyzed. Water chemistry and nutrient analysis data indicated no significant differences ($P > 0.07$) in measured parameters between treatments over time. The average temperature for all enclosures was 23.4 ± 0.84°C and the pH in the enclosures averaged 5.93 ± 0.57 (all data are presented as mean ± (standard errors). Turbidities were quite variable in all enclosures (39.4 ± 23.2 and 40.0 ± 24.3 for fish and non-fish respectively) and were higher after storm events. Dissolved oxygen levels ranged from just under 1 mg liter^{-1} to 3.3 mg liter^{-1} but there were no differences in oxygen levels between treatments. Average nitrate, ammonia and soluble reactive phosphorus concentrations were not different between treatments ($P > 0.15$; Figure 1).

The fish added to the enclosures had an initial average size (mouth to base of caudal fin) of 1.95 ± 0.21 cm; the average length at the end of the experiment was 2.46 ± 0.06 cm. The macrozooplankton assemblage in the marsh was dominated (>90%) by *Bosmina* sp. and *Acanthocyclops* sp., with smaller numbers of *Ceriodaphnia* sp., *Daphnia* sp., and at least two species of ostracods. The ostracods were similar in size and were grouped together for the purposes of the analysis. One isopod (*Caecidotea* sp.), one amphipod (*Hyalella azteca*), and at least one water mite (Hydracrina) species occurred in the samples. The latter three groups were considered to be accidentals in the plankton and were not included in the analysis. The microzooplankton assemblage was primarily composed of rotifers, with *Monostyla* sp., *Euchlanis* sp. and *Ascomorpha* sp. as the numerical dominants (>78%). There were also one species each of *Branchinous*, *Keratella, and Lecane*, and two *species of Polyarthra* species present in some samples. We

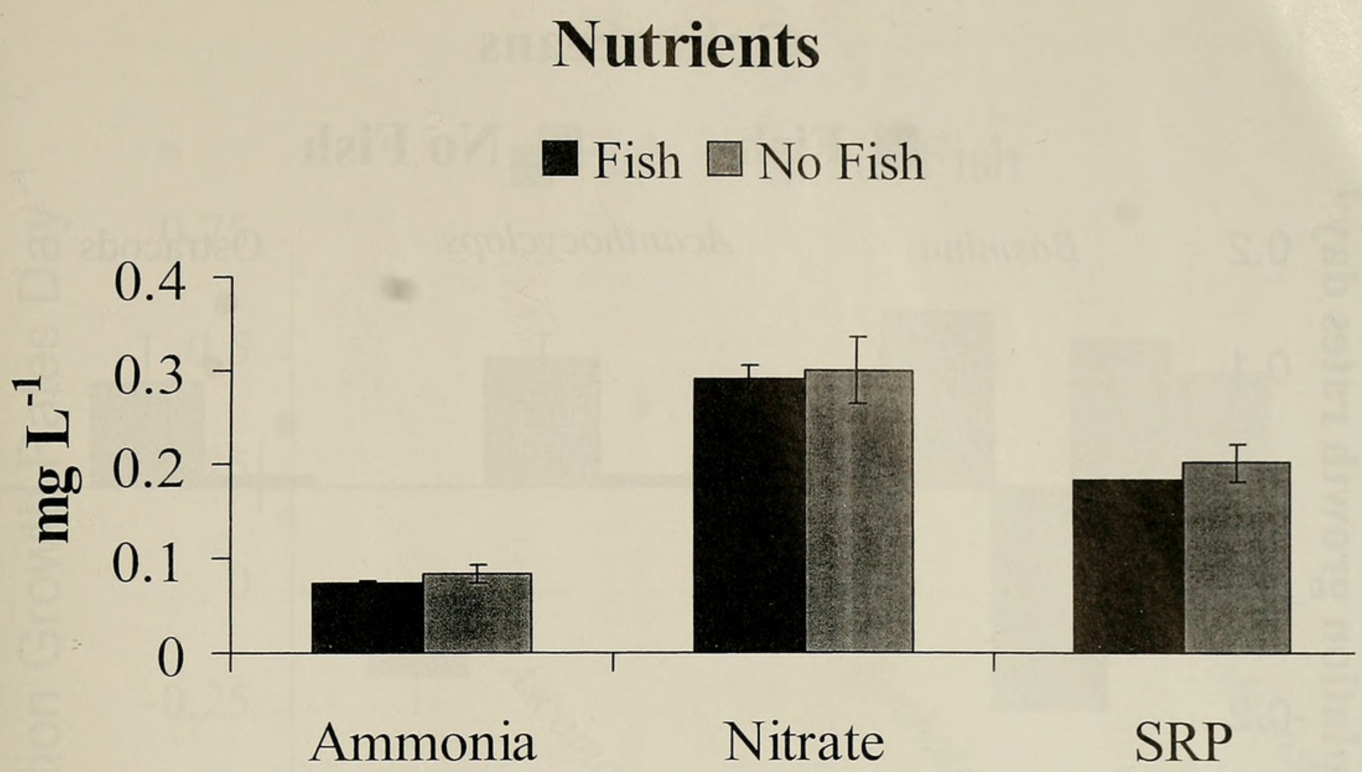

Figure 1. Ending concentrations of ammonia, nitrate, and soluble reactive phosphorous (SRP) in fish and fishless enclosures in Chaney Lake, Warren County, Kentucky (19 Jun 1999–1 Jul 1997). Bars show means and standard errors.

did not find any identifiable protists in our samples, but our filtering and fixation procedure may have prevented adequate sampling and recognition of these small organisms.

The presence of fish in the enclosures negatively affected the larger invertebrate taxa but showed no effect on the smaller taxa. The fish negatively affected the *Bosmina* sp. and the *Anthocyclops* sp. growth rates ($P < 0.006$; Figure 2). Ending mean densities of Bosmina were significantly higher in the fish-less enclosures (43 individuals liter^{-1}) compared to the fish enclosures (5.3 individuals liter^{-1}). *Acanthocyclops* sp. growth rates and ending mean densities were significantly higher in enclosures without fish (33 individuals liter^{-1}) than in enclosures with fish (7.3 individuals liter^{-1}). Ostracods as a group had a positive population growth rate when the fish were present and a negative growth rate without fish, but there was no significant difference between the two treatments ($P = 0.07$).

The presence of fish had no significant effect ($P > 0.07$) on the population growth rates of the three dominant rotifer species-*Ascomorpha, Euchlanis,* and *Monostyla* (Figure 3); however the densities of both *Euchlanis* and *Ascomorpha* decreased over time in all of the enclosures. Density of *Monostyla* sp. increased nearly 10 times over the same time period in all enclosures.

DISCUSSION

Our results confirmed that fish predation can affect aquatic invertebrate community structure in Chaney Lake.

Physical factors and nutrients assayed were not significantly different, so these factors probably did not contribute to the response of the zooplankton to fish. In enclosure experiments the effects of fish are sometimes the result of indirect mechanisms. Ammonia excreted by fish, for example, may enhance algal growth or the fish may feed on the algae, competing with the zooplankton. The golden shiners, however, are zooplanktivorous at this size (R. Hoyt, pers. comm.), and we found no differences in nutrient concentrations between the two treatments. The population growth rates we reported for our organisms were somewhat low compared to the instantaneous growth rates of related taxa in other ephemeral systems (Taylor et al. 1989), but this may be a reflection of a more constrained resource base in Chaney Lake.

Our data support the conclusion that fish predation in the enclosures was driving the suppression of large zooplankton in our study.

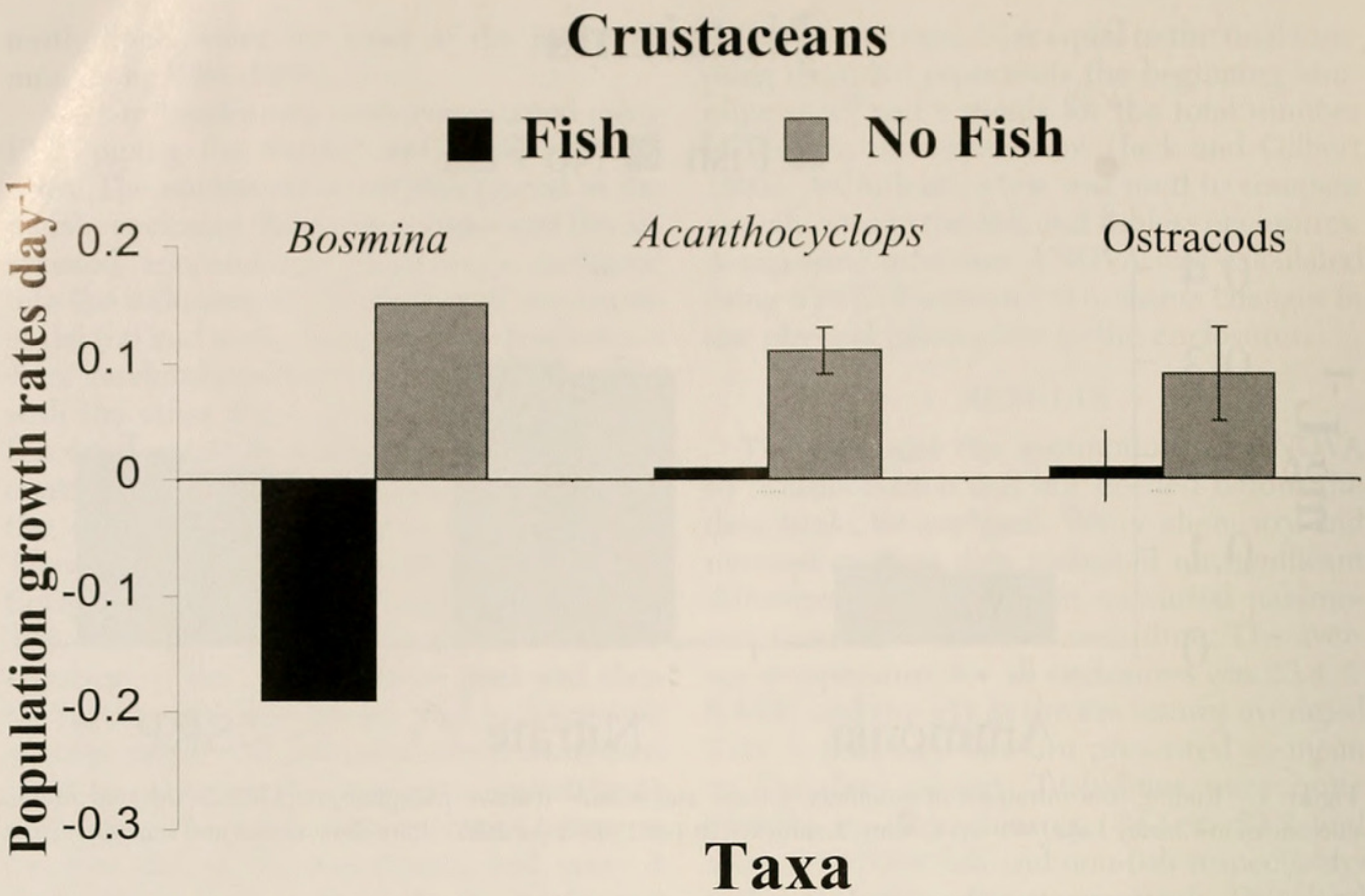

Figure 2. Population growth rates of the dominant crustacean species in fish and fishless enclosures in Chaney Lake, Warren County, Kentucky (19 Jun 1999–1 Jul 1997). Bars show means and standard errors.

Bosmina are not typically considered very vulnerable to fish predation because of their small size compared to other crustaceans, and many cyclopoids have well-developed escape responses that they may use to avoid fish predation. As the largest common zooplankton prey in the enclosures, however, one would expect that visually foraging fish would focus on *Bosmina* and the *Acanthocylops*. The ostracods were not significantly affected even though their mean size in the enclosures was comparable to that of *Bosmina* (0.65 vs. 0.44 mm, respectively). Ostracods are often found in association with vegetation or in benthic areas, where the golden shiners are unlikely to forage successfully on them. The ostracods present in our samples may not have been common in the plankton but may have been captured when the corer displaced them from the vegetation or the bottom.

Schneider and Frost (1996) found that in some cases the suppression of *Daphnia* in temporary ponds was associated with an increase in rotifer densities and taxon diversity. We did not see the increase in rotifer densities that we expected would occur once the macrozooplankton numbers were reduced; increases and decreases in rotifer numbers occurred across all enclosures regardless of treatment (see Results). This may indicate that the larger zooplankton are not significant predators on or competitors with the rotifers during this period in Chaney or that the rotifers were being more strongly limited by resource levels or other physiochemical factors in the lake. Previous research has indicated that small cladocerans like *Bosmina* are generally not effective predators on rotifers (reviewed in Gilbert 1988). The high densities of cyclopoid copepods in our study were also lower than those reported by Schneider and Frost (1996) in their study systems, so the impact of these crustaceans on the rotifers may have been too low to elicit a "release response" when the cyclopoid densities were reduced. The general increases and decreases in rotifer densities could also be the result of an unidentified "enclosure effect" affecting the rotifers. However, since this effect was expressed across all of the enclosures independently of treatment it should not affect our

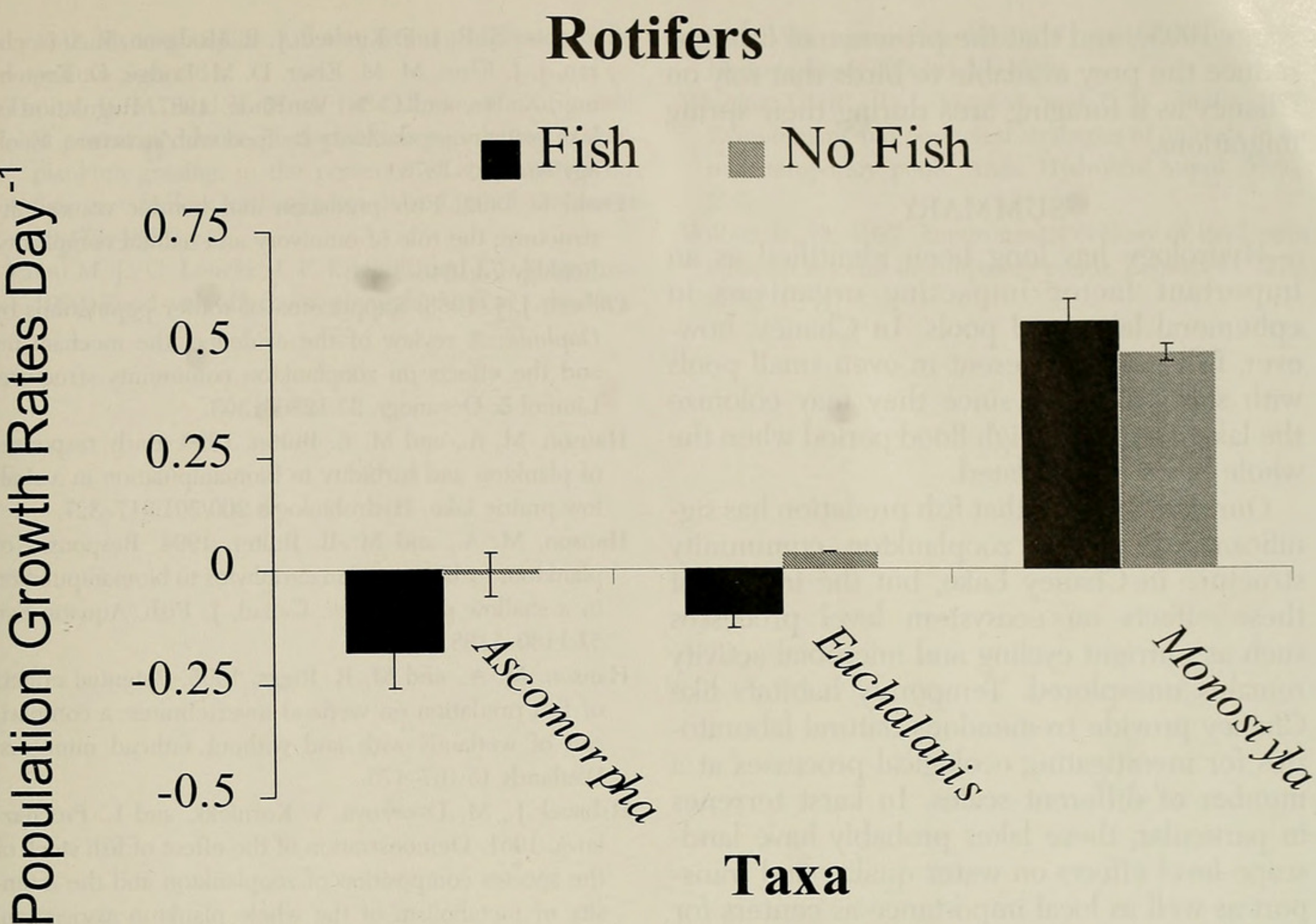

Figure 3. Population growth rates of the dominant rotifer species in fish and fishless enclosures in Chaney Lake, Warren County, Kentucky (19 Jun 1999–1 Jul 1997). Bars show means and standard errors.

interpretation of the fish effects in these enclosures.

The introduction of fish can have a profound impact on a system like Chaney. Early in the year, the entire Chaney basin is full, but as the year progresses it often dries to numerous smaller and disconnected ponds. If fish like the golden minnows are trapped in these pools, they could conceivably remove all of the large zooplankton from a particular pool. Many of the rotifers and crustaceans in these small pools appear to have multiple generations before they produce diapause eggs. If fish are introduced to a pool and severely reduce macrozooplankton densities, this could constrain the next year's recruitment in that pool. These pools may be colonized by zooplankton from other areas during periods of high water or there may be diapause eggs from previous years that could hatch, but that would be dependent on the vagaries of water level and on the natural histories of the organisms involved. If there are localized ecotypes adapted for the particular conditions in a pool or a closely associated group of pools, any unique genetic information in that population's gene pool may be lost as a result of fish predation. This information would probably not be replaced by colonists from other areas.

The path by which the fish enter Chaney may also be important. It is clear that fish may enter Chaney by the estavelles, but it may also be possible that they could enter the lake via overland flow during flood events. The area around Chaney contains at least one farm pond that may become connected to the lake during very high rainfall events. This would greatly expand the pool of potential fish colonists as fish that would be unable to survive in or travel through the Lost River system could enter Chaney in this manner. Very high densities of fish could be introduced this way; they could have an impact on the waterfowl and other vertebrate groups (e.g., amphibians) that use Chaney as breeding or feeding ground. Previous studies have already documented that waterfowl and fish are competitors for invertebrate prey in other wetlands (Hanson and

Riggs 1995), and that the presence of fish may reduce the prey available to birds that rely on Chaney as a foraging area during their spring migrations.

SUMMARY

Hydrology has long been identified as an important factor impacting organisms in ephemeral lakes and pools. In Chaney, however, fish may be present in even small pools with short duration since they may colonize the lake during the high flood period when the whole basin is inundated.

Our data indicate that fish predation has significant effects on zooplankton community structure in Chaney Lake, but the impact of these effects on ecosystem level processes such as nutrient cycling and microbial activity remains unexplored. Temporary habitats like Chaney provide tremendous natural laboratories for investigating ecological processes at a number of different scales. In karst terrenes in particular, these lakes probably have landscape-level effects on water quality and transport as well as local importance as centers for aquatic biological production and biodiversity. With many of these lakes threatened by development it is crucial that we continue to study these unique systems so that better management and preservation strategies can be devised to preserve the ecological integrity of these remarkable habitats.

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