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The Impact of Silver Carp \((Hypophthalmichthys molitrix)\) on the Rotifer Community in a Eutrophic Subtropical Chinese Lake

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ABSTRACT

From 29 April to 25 June in 1999, an enclosure experiment was conducted in Lake Donghu to assess the impact of planktivorous silver carp on the planktonic rotifer community. We set up four treatments with silver carp biomass at 0, 116, 176, and 316 g m\(^{-2}\). Total rotifer density was significantly higher in the no-fish enclosure than in fish-present enclosures. Fish predation on the rotifers alleviated zooplankton competition and resulted in dominance of small zooplankton species \((Anuraeopsis fissa, Trichocerca pusilla\) and \(Moina micrura\)) in fish-present enclosures. However, some relatively larger species \((Polyarthra vulgaris, Brachionus angularis, Brachionus calyciflorus,\) and \(Asplanchna spp.\)) showed higher densities in the no-fish enclosure than in fish-present enclosures.

INTRODUCTION

Planktivorous fish impacts on plankton communities have been studied with different experimental conditions (Mazumder et al. 1990, Hurlbert and Mulla 1981, Telesh 1993, He et al. 1994, Starling and Rocha 1990). Most of the studies showed that planktivorous fish (other than silver carp) suppressed the crustacean community but increased rotifer densities. Very few of these studies focused on the direct and indirect effects of silver carp on the rotifer community (Starling and Rocha 1990, Starling 1993, Burke et al. 1986).

The silver carp is one of the intensely stocked varieties fish, which, together with bighead carp, constituted 83-98% of total fish yield (Liu 1984, Huang and Xie 1996) in Lake Donghu. During the 1990s, several researchers discussed the filter-feeding planktivorous fish impact on zooplankton and phytoplankton communities in the whole lake (Xie et al. 2000, Yang et al. 1999) or in enclosure mesocosms (Yang and Huang 1992). However, all of these studies were carried out under conditions in which silver carp coexisted with bighead carp. In order to assess the effect of silver carp on the rotifer community alone, we designed this enclosure experiment.

MATERIALS AND METHODS

Study area and design

Lake Donghu is situated in the subtropical region of China \((30.33^\circ N; 114.23^\circ E)\) near the middle reaches of the Yangze River. It is a shallow (mean depth 2.5 m) eutrophic lake that covers approximately 32 km\(^2\) with a volume of about 80 x10\(^6\) m\(^3\). During the past several decades, eutrophication of this lake has continued to progress (Tang and Xie 2000, Xie and Xie 2002). For example, ammonium nitrogen concentration in the mid-lake has increased from 0.009 mg L\(^{-1}\) in 1956 to 0.15 mg L\(^{-1}\) in 1975 (Liu 1984) and to 0.26 mg L\(^{-1}\) in 1995 (Xie et al. 1996).

The experiment was conducted within eight enclosures (each 2.5 x 2.5 m by 2 m depth) constructed of polyethylene film bags that contained

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about 12.5 m³ lake water. They were sealed at the bottom to prevent fishes from moving in or out. The experiment was carried out from 29 April to 25 June in 1999, and was concluded prematurely as a result of flooding caused by heavy rain that allowed the fish to escape. About 10 cm of clay sediment from Lake Donghu were added to each enclosure several days before the fish were added.

Silver carp were collected from a nearby pond and were acclimated in a net cage set in the lake for several days before being put into the polyethylene enclosures. The enclosures were divided into four different silver carp biomass treatment groups with two replicates each. The numbers of fish of the four treatments were 0, 5, 12, and 20, providing four silver carp biomass levels of 0, 116, 176, and 316 g m⁻², respectively.

Quantitative zooplankton samples were taken weekly from the enclosures. The collection and laboratory methods for rotifer samples were the same as those in Shao et al. (2001). Crustacean zooplankton were sampled using a 5.0 L modified Patalas bottle sampler. Samples were obtained by straining 15-30 L of the lake water collected from the surface to the bottom at 0.5 m intervals through a 64 μm mesh plankton net and preserved with formalin. The laboratory procedures for crustacean zooplankton followed Yang et al. (1999).

Figure 1. Changes of total rotifer densities and biomass in different treatment enclosures (no-fish treatment to 316 g m⁻²) during the experimental period. Bars indicate total variation between duplicate enclosures. The numbers in the parentheses are the mean data. The dashed lines are trend-lines.
Data analysis
To identify statistically significant responses of the planktonic rotifer community to the fish treatments, a one-way analysis of variance (ANOVA) was used, with densities and biomass of rotifers from different fish treatment enclosures as dependent variables. Probability level was set at $\alpha = 0.05$. The data collected from the first and the second sampling times were excluded from the analysis because fish were only added after these sampling dates. Statistical analyses were conducted using Microsoft Excel™ spreadsheet models.

RESULTS

Rotifer density and biomass
The highest mean rotifer density and biomass were found in no-fish enclosures (Fig. 1). Total densities of rotifers were significantly higher in the no-fish enclosure than in fish-present enclosures ($df = 3$, $F = 3.810$, $p = 0.023$). However, there was no statistical difference between any two of the three fish-present enclosures ($df = 2$, $F = 1.496$, $p = 0.251$). No statistical difference was found in rotifer biomass between fish presence and absence enclosures ($df = 3$, $F = 1.731$, $p = 0.187$).

After fluctuating over the first two weeks, rotifer densities in all of the enclosures trended to a low level by the third sampling event on 13 May (Fig. 1). From then on, rotifer densities increased slightly in fish-present enclosures, while it declined in no-fish enclosure. However, with the increasing of the rotifer density, rotifer biomass had a slight decrease in all of the enclosures.

Some typical rotifer species
The number of rotifer species was similar in enclosures to that in the lake (about 30 species were found in each enclosure), although there were minor differences in species composition. Three major species in enclosures were *Anureaopsis fissa*, *Polyarthra vulgaris*, and *Trichocerca pusilla*. *A. fissa* and *T. pusilla* had lower densities in the no-fish enclosure than in the fish-present enclosures (Fig. 2). The difference of *A. fissa* density between no-fish enclosure

![Figure 2. Changes of some typical species densities in different treatment enclosures during the experimental time.](image_url)
and fish-present enclosures was significant \( p = 0.027 \), while it was not significant in \( T. \) pusilla density \( p = 0.133 \). However, \( P. \) vulgaris \( p = 0.016 \) and \( Brachionus angularis \) \( p = 0.029 \) had significantly higher densities in the no-fish enclosure than in the fish-present enclosures. The other two large-bodied species (\( Brachionus calyciflorus \) and \( Asplanchna \) spp.) showed no significant difference between the no-fish enclosure and fish-present enclosures. No statistical differences in densities of these species were found among fish-present enclosures.

**Crustacean zooplankton**

The total average biomass of crustaceans and the mean biomass of some main species were higher in no-fish enclosures than in fish-present enclosures (Fig. 3). In fish-present enclosures, the small-bodied species \( Moina micrura \) absolutely dominated the crustacean community during the experimental period. The increasing trend of \( Moina micrura \) biomass was in accordance with that of the fish stocking densities. However, the biomass of a large-bodied species \( Daphnia galeata \), which dominated in the fish-free enclosure, rarely exceeded biomass > 0.2 mg L\(^{-1}\) in fish-present enclosures. Copepod species such as \( Mesocyclop notius \), \( Cyclops vinctinus \), \( Thermocyclops tainokuensis \), and \( Thermocyclops brevisetus \) only dominated in the no-fish enclosure.

![Figure 3. Total average biomass and the mean biomass of some dominant crustacean species in different treatment enclosures during the experimental period.](image)

**DISCUSSION**

Most of the studies concerning impacts of planktivorous fish on zooplankton communities indicated that fish predation caused large increases in rotifer densities. However, in our enclosure experiment, total mean rotifer density was significantly higher in the no-fish enclosure than in fish-present enclosures. Similar results from predation of silver carp have been reported (Opuszynski 1979, Burke et al. 1986, Starling and Rocha 1990). Except for
some small-bodied species such as *A. fissa*, *T. pussila*, and *M. micrura*, most of the rotifer and crustacean species were greatly suppressed by silver carp. This might be explained by the food selectivity and feeding characteristics of the silver carp. Silver carp is a pump filter-feeder whose feeding rate is higher than tambaqui and tilapia on small prey such as rotifers and *T. decipiens* nauplii, and its feeding rate tends to decrease with particle size (Starling and Rocha 1990). These might also have been significant exploitative competition by larger-bodied rotifer and crustacean species. Burke et al. (1986) reported that gut contents of individual silver carp ranged from about 90% detritus to 99% algae, and the highest estimate for zooplankton was 5% in one fish, which was composed almost entirely of rotifers. Detritus and algae are also the main food of crustaceans. Even though silver carp may not directly prey on the large crustacean, the exploitative competition between the silver carp and the larger crustaceans maybe still exist. This competition may be the main reason for the marked decrease of the larger crustacean in fish-present enclosures.

During the experiment period, rotifer density increased slightly in fish-present enclosures after the third sampling event, although it was decreased in no-fish enclosure. These results indicate that silver carp may directly feed on rotifers. But silver carp also indirectly affected the dynamics of rotifer population by suppressing the macro-zooplankton. This indirect effect may be positive. Thus, we can presume if the indirect effects dominate over the direct feeding, the rotifer population will increase. During the latter period of our experiment, most of the relatively larger-bodied species, such as *Brachionus calyisflorus* and *Asplanchna* spp., almost disappeared, and the small-bodied species dominated in rotifer community. The effects of silver carp may gradually cause the zooplankton community to be dominated by small-bodied species.

These results indicate that silver carp stocking will suppress the whole zooplankton community and cause a shift from large species to smaller ones. Although silver carp may not directly prey on large cladocerans and copepods, this species of fish can still suppress these crustaceans by resource competition. Conversely, rotifers were released from the interference and exploitative competition by cladocerans and copepods, and were in turn suppressed by fish predation in fish-present enclosures. As a result of the equilibrium, the two small rotifer species with high growth rates, *A. fissa* and *T. pussila*, and the small-bodied cladoceran species, *M. micrura*, became dominant in fish-present enclosures. These results were similar to those observed in whole-lake studies (Yang et al. 1999, Shao et al. 2001).

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