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Particle-Grazing and Plankton Community Impact of an Omnivorous Cichlid

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Abstract

We determined selective ingestion of different sizes of suspended polystyrene particles by filter-feeding blue tilapia *Tilapia aurea*. Blue tilapias from 4.3 to 18.7 cm standard length selectively fed on particles larger than 25 μ m. We compared the plankton communities of pond quadrants with and without fish. Blue tilapias suppressed populations of the large-sized algae *Uroglenopsis* sp. and *Ceratium* sp. and the zooplankton *Keratella* sp. Populations of the small-sized algae *Rhodomonas* sp., *Chrysochromulina* sp., *Chlamydomonas* sp. and *Cyclotella* sp. and the zooplankton *Diaptomus* sp. were enhanced by the presence of blue tilapia. As an omnivorous filter feeder, blue tilapias act as size-selective phytoplankton grazers and escape-selective zooplankton predators.

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Many species of freshwater fish are omnivorous filter feeders that consume phytoplankton, zooplankton, and detritus. Although the selective use of zooplankton by filter-feeding fish has been studied (Starostka and Applegate 1970; Janssen 1976, 1980; Drenner and McComas 1980; Rosen and Hales 1981; Drenner, et al. 1982), we have little information about the role of fish as limnetic primary consumers (Drenner et al., in press). This paper focuses on the selective phytoplankton grazing of an omnivorous cichlid, the blue tilapia *Tilapia aurea*. Native to Africa and the Middle East, blue tilapias have become established in the United States since their introduction in the 1960s (Buntz and Manooch 1969; Hensley and Courtenay 1980).

Blue tilapias feed primarily on phytoplankton, zooplankton, and detritus but may also consume benthos and macrophytes (McBay 1961; Spataru and Zorn 1978; Hendricks and Noble 1980). Laboratory analysis showed that blue tilapias larger than 7.6 cm standard length (SL)

feed on plankton as filter feeders, using a series of rapid nondirected suction to draw prey and water into the buccal cavity. Smaller fish filtered, but visually located and attacked individual prey items as well (Gophen et al. 1983).

In this study, we examined the size-selective removal of plastic microspheres by blue tilapias in laboratory experiments. We also monitored changes in plankton communities after blue tilapias were introduced into quadrants of an experimental pond.

Methods

Blue tilapias were obtained from the Aquaculture Research Center at Texas A&M University. Fish used in laboratory trials were fed fresh zooplankton and acclimated 2 weeks in 25-30-liter aquaria prior to experiments.

Selective particle ingestion was determined from declines in densities of polystyrene microspheres (Ionics Incorporated, Watertown,

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Massachusetts) in aquaria as the fish fed. Microspheres ranging from 7 to 52 μm in diameter were added to aquaria containing 7–12 fish. The initial ranges of particle number per ml were: 7–10- μm spheres, 3,876–9,072; 10–13- μm , 1,028–3,874; 13–16- μm , 285–1,376; 16–19- μm , 93–424; 19–22- μm , 54–193; 22–26- μm , 36–213; 26–32- μm , 26–131; 32–38- μm , 8–99; 38–44- μm , 2–89; and 44–52- μm , 3–33. To examine the influence of fish size on selective particle ingestion, feeding trials were conducted on four sizes (cm SL) of fish: 4.3–4.5 (10 fish, 4 trials), 6.9–10.1 (12, 4), 11.7–13.9 (10, 6), and 15.4–18.7 (7, 7). Live zooplankton were added at densities of 2,000–19,000 organisms/liter to induce pump filter-feeding because the fish would not feed readily on microspheres alone.

Two replicate water samples containing microspheres were taken from well-stirred aquaria at 0 and 1.0 hours of feeding. A plexiglas tube was lowered quickly onto a randomly placed rubber stopper lying on the aquarium bottom (Drenner, et al. 1982). The column of water was strained through a 63- μm sieve to remove zooplankton, and the filtrate containing microspheres was poured into 125-ml bottles and preserved in 5% formalin to prevent bacterial growth. Particles ranging from 7 to 52 μm were counted in 10 channels of a model ZM Coulter Counter with a 200- μm aperture tube. We corrected for particle loss due to zooplankton grazing by monitoring the loss of microspheres from fishless control aquaria that contained microspheres and zooplankton. Only an average of 4.4% (SD = 7.3) of the microspheres were lost from the control aquaria. The percent loss for each particle size in the control was subtracted from the percent loss in the fish tank before feeding selectivity was computed. As an index of fish feeding selectivity, we used the normalized forage ratio (Lechowicz 1982).

Particles were kept in suspension by aeration through several airstones and movements of the fish. All feeding trials were conducted at 22–24 C under room fluorescent lighting. After completion of each trial, the fish were transferred to clean aquaria and fed fresh zooplankton for 24 hours to allow microspheres to pass from their guts. They then were starved for another 24 hours before the next feeding trial.

The field investigations were conducted in a pond divided by concrete partitions into four 0.006-hectare, 61- m^3 mud-bottomed quadrants

at the University of Kansas Nelson Environmental Study Area. Fifty percent of each quadrant bottom was covered by a plastic sheet to prevent excessive macrophyte growth in the center of the quadrant. One week before fish were introduced, the pond was filled above the concrete partitions to allow free mixing of water and plankton between quadrants. Initial plankton samples were taken on June 10, 1982, after we lowered the water level below the top of the concrete partitions.

Fifty fish between 12.5 and 19.0 cm SL were stocked in two of the quadrants at densities of 633.8 kg/hectare on June 11, 1982. This biomass lies between minimum and maximum standing crops reported for blue tilapia in Florida and Texas lakes (Germany and Noble 1979). We were careful not to stock fish that were mouth-brooding eggs or fry. Two quadrants were left as fishless controls. Quadrants were sampled throughout the experiment.

On August 2, we discovered that the fish had spawned and a few young fish had moved into the control quadrants through a 3.2-mm-mesh screen covering a pipe connecting the quadrants. To avoid the effects of the visually feeding young on the plankton community, we only present pond data through July 13, which is 2 weeks before fish were observed in the control quadrants. We drained the pond on August 28 and recovered 48 and 49 of the initial 50 fish stocked per quadrant, as well as hundreds of juvenile blue tilapias. We assume that few fish spawned before July 13 and that progeny effects were minimal.

Phytoplankton samples were collected throughout the experiment with an integrated column sampler (deNoyelles and O'Brien 1978) lowered to within 8 cm of the pond bottom. Replicate column samples were taken from each quadrant and mixed together. Two 125-ml subsamples from the mixture were preserved with Lugol's iodine. Phytoplankton samples were concentrated in 35-ml settling chambers and counted on a Wild inverted microscope at 400–600 \times magnification. Because of high silt content in some samples, aniline blue algae stain was added to the settling chambers to improve visibility of the phytoplankton cells.

Zooplankton were sampled with vertical tows of a 63- μm -mesh Wisconsin plankton net, one tow per quadrant on each sampling date. The vertical tows were made from the pond bottom.

Samples were preserved in 10% formalin and counted under a dissecting microscope.

Results and Discussion

Selective Particle Grazing

According to the normalized forage-ratio values, fish feeding selectivity increased with particle size (Fig. 1). Forage-ratio values above $1/n$ (n = number of particle-size categories) indicate selection, those below indicate avoidance (Lechowicz 1982). All four size classes of fish selectively fed on particles larger than $25 \mu\text{m}$. There is no apparent relationship of fish size to the size of particle selectively ingested.

Size-selective particle grazing by freshwater filter-feeding fish has only been studied for gizzard shad *Dorosoma cepedianum* (Drenner 1977; Mummert 1983; Drenner et al., in press). In similar feeding experiments, gizzard shad ingestion rates increased as a function of particle size, leveling off at $60 \mu\text{m}$. The particle-size-dependent ingestion rates were consistent with a model of filtering efficiency based on the cumulative frequency of interraker distances of gizzard shad gill rakers.

Blue tilapias not only strain particles with gill rakers, they also may filter with microbranchiospines. These small mucus-covered structures bear fine lateral spines and occur in a single row on the second, third, and fourth gill arches. The microbranchiospines may account for the efficient retention of small particles by cichlids (Gosse 1956; Fryer and Iles 1972).

Plankton Community Response

Because of only two-fold replication, the statistical power of the pond experiment is low. According to an analysis of variance for a two-factor experiment with repeated measures of one factor (Winer 1971), several species of phyto- and zooplankton show significant differences between fish and control quadrants at the $P \leq 0.1$ level (Figs. 2 and 3). Blue tilapias suppressed populations of the two largest algae *Uroglenopsis* sp. and *Ceratium* sp. Although our laboratory feeding experiments indicate that *Oocystis* sp. and *Navicula* sp. could be efficiently consumed by blue tilapia, they were not suppressed. The difference in the fish's impact on them versus *Uroglenopsis* and *Ceratium* may be because smaller algae have higher growth rates (Banse 1976; Schlesinger et al. 1981; Smith and

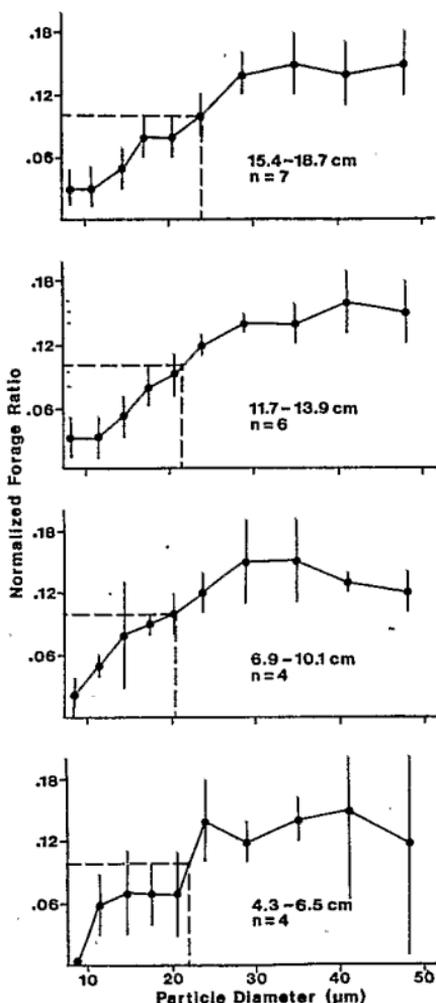


FIGURE 1.—Normalized forage ratio values of blue tilapia feeding on microspheres of different diameters. The microsphere diameter associated with a forage ratio of $1/10$ particle-size categories (0.1) is indicated by the dashed line. Vertical bars indicate ± 1 SD. Fish size range (SL) and number of experiments are shown.

Kalff 1982) and are, therefore, less susceptible to grazing pressure.

The smallest phytoplankters, *Rhodomonas* sp., *Chrysochromulina* sp., *Chlamydomonas* sp., and *Cy-*

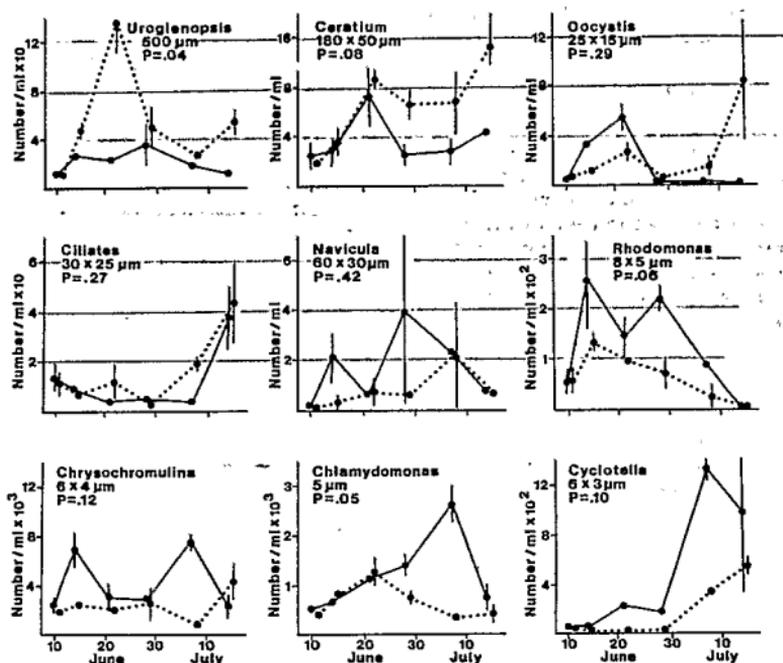


FIGURE 2.—Changes in densities of dominant phytoplankton and ciliates in pond quadrants containing blue tilapia (solid line) and control ponds without fish (dotted line). Points are means of two replicate quadrants; bars represent range of the densities for the replicate quadrants. Organism dimensions and the probability level for the analysis of variance are shown.

clotella sp., appear to be enhanced in the presence of blue tilapia. Our laboratory feeding experiments suggest that these small algal genera probably are not efficiently filtered by blue tilapia. Several factors may be responsible for their enhancement, including regeneration of nutrients by fish, algal enhancement during gut passage, and modification of the herbivorous zooplankton community. We have no information on nutrient release or digestion efficiency of blue tilapias during these experiments but Popma (1982) found that algal cells can be viable after passage through the digestive tract of blue tilapia.

Although all zooplankton in the pond were large enough to be filtered by blue tilapia, the fish suppressed only the rotifer *Keratella* sp. and enhanced copepodid and adult stages of the large copepod *Diaptomus* sp. (Fig. 3). *Keratella* has limited swimming ability whereas *Diaptomus* is the

most evasive zooplankton prey in the pond (Drenner, et al. 1982). Laboratory feeding trials have shown that blue tilapias are escape-selective predators, selectively feeding on nonevasive zooplankton prey such as *Bosmina* sp. and *Ceriodaphnia* sp. over more evasive prey such as *Mesocyclops* copepodids and adults (Gophen et al. 1983).

The impact of blue tilapia on the plankton community is, in general, like that observed for gizzard shad in a similar pond experiment. Gizzard shad are omnivores, filter-feeding on phytoplankton and zooplankton (Drenner et al., in press). Gizzard shad suppressed *Ceratium*, *Keratella*, and cyclopoid copepodids but enhanced species of *Ankistrodesmus* (dimensions, $20 \times 1 \times 1 \mu\text{m}$), *Cryptomonas* ($16 \times 6 \times 6$), *Cosmarium* ($10 \times 6 \times 5$), *Rhodomonas* ($6 \times 4 \times 4$), 2–4 μm algae and bacteria, and *Diaptomus* copepodids.

In conclusion, most studies of planktivore im-

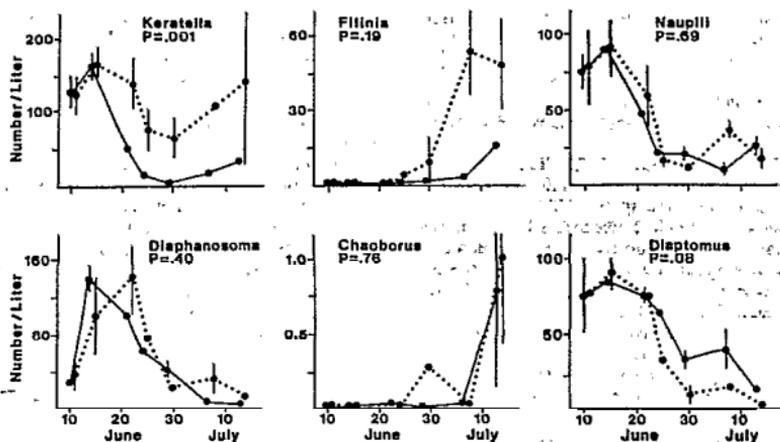


FIGURE 3.—Changes in densities of dominant zooplankton in pond quadrants containing blue tilapia (solid line) and control ponds without fish (dotted line). Points are means of two replicate quadrants; bars represent range of the densities for the replicate quadrants. Probability level for the analysis of variance is shown.

pact on plankton-community structure have focused on visually feeding fish. Visually feeding fish are size-selective zooplankton predators. They suppress populations of large zooplankton species, enhance the smaller zooplankton, and increase algal standing crops (for references, see Drenner, et al. 1982). Our studies of blue tilapia and gizzard shad show that omnivorous filter feeders have different community impacts than visually feeding planktivores. Filter feeders act as size-selective phytoplankton grazers and escape-selective zooplankton predators. They suppress populations of large phytoplankton and zooplankton species with limited escape abilities while enhancing abundances of small algae and evasive zooplankton.

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