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CLEARANCE RATES OF SUSPENDED PARTICULATE ORGANIC CARBON BY NILE TILAPIA WITH A DUAL PATTERN OF FILTER FEEDING

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Key words: Nile tilapia, feeding activity, organic carbon clearance rates

Abstract

The filter-feeding activity of Nile tilapia, *Oreochromis niloticus* L., was observed during a 24-h feeding cycle for five consecutive days. The feeding activity was high from afternoon to midnight, with a peak after dusk, and lowest from midnight to morning. The clearance rate of cyanobacteria dominated water was estimated during the low morning and high evening feeding periods. The tilapia cleared 34 mg C/l suspended particulate organic carbon in 4.5 h during the reduced morning period (beginning 07:00) and 45 mg C/l in 1 h during the peak evening period (beginning 20:30). Clearance rates of the cyanobacterial water were 13.4±1.2 l/kg fish/h in the morning and 66±3.6 l/kg fish/h in the evening.

Introduction

Filter-feeding fish are used to improve water quality and reduce algal biomass in culture ponds, wastewater lagoons and reservoirs (Henderson, 1983; Smith, 1985; Starling and Lazzaro, 1997; Drenner and Hambright, 1999; Mueller, 2001). Nile tilapia stocked in the Partitioned Aquaculture System (PAS) at Clemson University reduce the standing crop of phytoplankton and change the species composition through filtration (Mueller, 2001).

The filter-feeding kinetics of the Nile tilapia, *Oreochromis niloticus*, is described by a curvilinear relationship where the filtration rate increases with the suspended particular organic carbon concentration (Turker et al., 2003a). Nile tilapia filtration rates of green algae and cyanobacteria were significantly higher in warm

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water (26-30°C) than in cooler water (17-23°C; Turker et al., 2003b). Turker et al. (2003c) compared the filtration rates of Nile tilapia and silver carp, *Hypophthalmichthys molitrix*, and found that the Nile tilapia filtration rate of green algae was significantly higher than that of silver carp but the silver carp filtration rate of cyanobacteria was higher than that of Nile tilapia.

Light is one of the most important abiotic factors that influence the feeding behavior of fish because multiple properties of light (quality, intensity, daily and seasonal variations) interact with other environmental (e.g., temperature) and physiological factors (Houlihan et al., 2001).

Several investigations reported on the daily feeding activity of tilapia, notably Moriarty and Moriarty (1973), Saha and Dewan (1976), Caulton (1982) and Getachew (1989). These studies involved analysis of the gut contents in field-captured individuals. Algal filtration can be quantified by chlorophyll *a* analysis (Vinyard et al., 1988), the ^{14}C method (Moriarty and Moriarty, 1973) or algal cell counting (Northcott et al., 1991). However, the present study analyzed suspended particulate organic carbon (POC) in the algal rich PAS when Nile tilapia were stocked in static water to determine daily feeding activity and the clearance rate of the cyanobacterial-dominated water.

Materials and Methods

Two experiments were carried out using PAS water in mid-July, 2002, at the Calhoun Field Station at Clemson University, South Carolina. In the first experiment, the filter-feeding activity of the tilapia was monitored every two hours during a 24-h period to determine the periods of high and low activity. In the second experiment, the rate of clearance of POC was monitored twice a day during the high and low filter-feeding periods for five days.

In both experiments, the tanks received water for 24 hours prior to stocking the tilapia. An airstone helped maintain a mixed water column. Tanks were equipped with a screen to keep the tilapia off the tank bottom and prevent re-suspension of feces Water was discharged through a standpipe.

Dissolved oxygen and total ammonia-nitrogen were measured at the beginning and end of the experiment. Dissolved oxygen and temperature were measured with a YSI polarographic oxygen meter (Model 58, YSI Inc., Yellow Springs, Ohio). Total ammonia nitrogen was measured by the spectrophotometric method (APHA, 1992). Temperature was 27.8°C throughout the experiment.

To determine POC, a water sample was taken from a representative tank before stocking, centrifuged at 15,000 rpm for 15 min and decanted. The pellet representing the POC was re-suspended in a known water volume of the same hardness. Aliquots (n = 5) of the sample were rediluted and the POC was determined with a Total Organic Carbon Analyzer (Model DC-190, Rosemount Dohrman, Cincinnati, Ohio). The transmittance of each aliquot was determined at 750 nm with a spectrophotometer (APHA, 1992). The net change between POC in the incoming and POC in the outgoing water represented incidental settling and was used to correct filtration rates during the filter-feeding experiment.

Phytoplankton in water samples taken before the start of the experiment were identified to genus (Prescott, 1961) and the count was estimated with a hemocytometer. The water was dominated by *Microcystis* (92% by biovolume) and *Scenedesmus* (8%).

Daily filter-feeding pattern - experiment 1. Nile tilapia (avg wt 135±4 g) were stocked at 9 kg/tank in three tanks while a fourth tank without fish was used as a control. Individual timers and solenoid valves provided an intermittent water flow at 3.0 l/min to each tank during this experiment.

Water samples were taken every two hours for 24 hours and POC and transmittance were determined as described above. Standard curves of the POC and transmittance for the experimental period were determined by regression analysis. The coefficient of determination (r^2) for the linear regression models of the POC and transmittance values was 0.98.

The filtration rate (FR) of the POC was calculated as: FR (mg C/kg fish/h) = (POC_i -

POC_o) x flow rate/fish biomass, where POC_i is the suspended POC in the incoming water (mg C/l) and POC_o is the suspended POC in the outgoing water, flow rate was measured in l/h and fish biomass in kg tissue wet weight.

Controlled flow rates and tilapia filtering activity provided a set of POC concentrations for each tank in the experiment. Filtration rates and the associated POC concentrations were averaged for each tank.

Clearance of suspended POC - experiment 2. After determining the filter-feeding pattern of the tilapia, an experiment to determine the clearance of suspended POC was conducted. Six kg of Nile tilapia of similar size (143±7 g) were stocked into each of three replicate tanks without continuously running water. POC was tested twice a day - in the morning (during the low filter-feeding period) and in the evening (during the high filter-feeding period). Water samples were taken at 15-min intervals from 7:00 and from 20:30, until the POC reached near zero, and the POC and transmittance of each sample were determined as described above. The coefficients of determination (r^2) for the linear regression models of the POC and transmittance values were 0.96 in the morning and 0.95 in the evening.

The clearance rates (CR) were derived from the decrease in POC using the formula of Coughlan (1969): CR (l/kg fish/h) = V/(w x t) x (ln [POC_o/POC_t]), where V is the volume (l), w is the fish biomass (kg), t is the duration of the experiment (h), POC_o is the POC (mg C/l) at t = 0 and POC_t is the POC at time t. Clearance rates and the associated POC concentrations were averaged for each tank.

Results

Experiment 1. The filtration rate gradually increased from 14:00 until it reached a maximum at 22:00. Thereafter, it gradually decreased until the minimum was reached at 8:00 (Fig. 1). Mean (± SE) dissolved oxygen and total ammonia nitrogen values were 4.2±1.2 mg/l and 1.4±0.2 mg/l in the morning hours and 3.8±1.1 mg/l and 2.1± 0.2 mg/l in the evening hours, respectively.

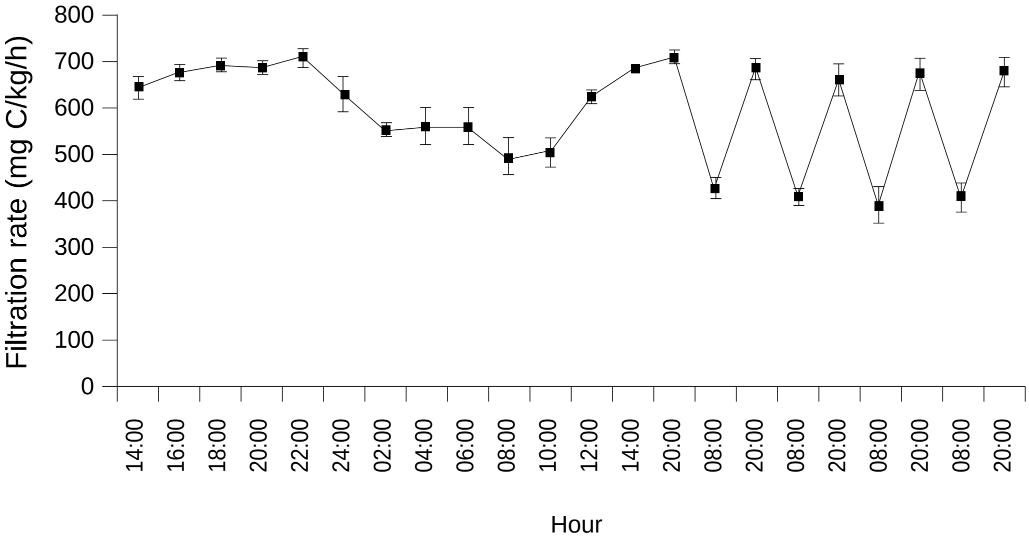

Fig. 1. Daily filter rate of 135±4 g Nile tilapia for six days in water dominated by *Microcystis* (92%) and *Scenedesmus* (8%).

Experiment 2. Filtration of suspended POC was slower in the morning than in the evening. Nile tilapia filtered 34 mg C/l suspended POC from the water column in 4.5 h during the low feeding period (beginning 07:00) and 45 mg C/l in 1 h during the high feeding period (beginning 20:30) under static conditions of no water exchange (Figs. 2 and 3, respectively). The average clearance rate (volume of water cleared) was 13.4±1.2 l/kg fish/h and 66±3.6 l/kg fish/h in the morning and evening, respectively. Mean total ammonia nitrogen values were 0.4 mg/l at the beginning and 2.2 mg/l at the end of the morning and 0.3 mg/l at the beginning and 1.4 mg/l at the end of the evening clearance experiments.

Discussion

Filter feeding of Nile tilapia followed a diel pattern with feeding slowing at night in the algal rich PAS water. Field observations of stomach contents reveal a similar variation in tilapia. Moriarty and Moriarty (1973) observed a diurnal cycle of acid secretion in the stomach of Nile tilapia which closely follows its feeding pattern. They concluded that feeding of Nile tilapia in Lake Georgia, Uganda, was restricted to daytime hours. In Nile tilapia from a fish farm in Jamalpur, Bangladesh, feeding activity increased from noon to midnight with a peak immediately after dusk and a decreased after midnight until early morning (Saha and Dewan, 1976). Caulton (1982) reported that

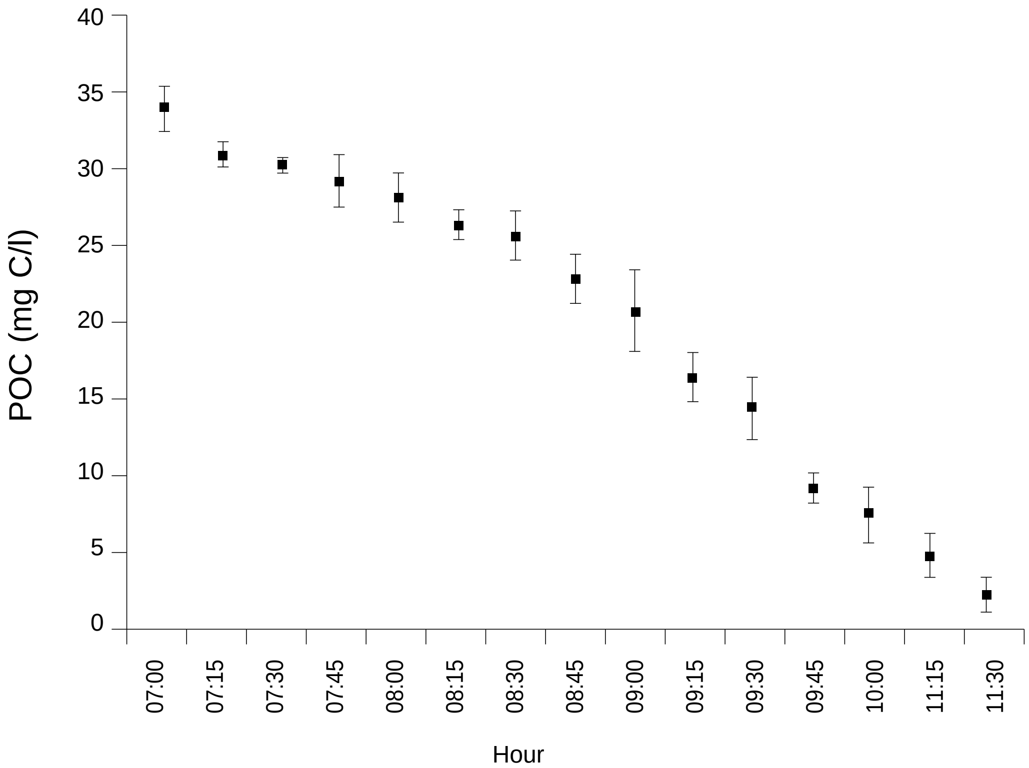

Fig. 2. Clearing of 33.8±1.4 mg C/l suspended particulate organic carbon (POC) in 4.5 hours during morning feeding hours in a static Partitioned Aquaculture System.

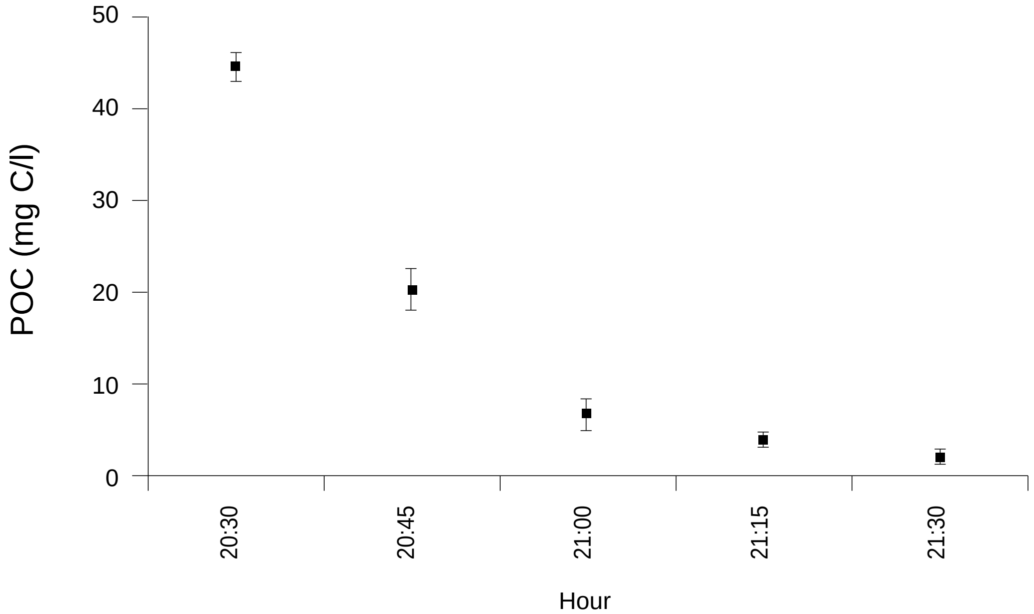

Fig. 3. Clearing of 44.6±1.5 mg C/l suspended particulate organic carbon (POC) in 1 hour during evening feeding hours in a static Partitioned Aquaculture System.

maximum feeding activity of *Tilapia rendalli* on the submerged plant coontail, *Ceratophyllum demersum,* in Lake Mclwaine, Zimbabwe, was restricted to daytime. The feeding pattern of Nile tilapia in Lake Awasa, Ethiopia, had a diel rhythm with the highest stomach fullness occurring in the late afternoon and evening (Getachew, 1989).

Although there are several studies in the literature on the filter-feeding rate of Nile tilapia (Moriarty and Moriarty, 1973; Getachew, 1989; Northcott et al., 1991), there are no studies on clearance rates. The filtration of cyanobacteria and green algae has proven a valuable tool for management of algal blooms in aquaculture ponds (Turker et al., 2003a,b,c). This study shows that Nile tilapia can be used to clean cyanobacteria, especially *Microcystis*, from the water column. It also shows that it is more beneficial to feed tilapia in the afternoon than in the morning.

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