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Effects of intra- and interspecific competition on diet, growth and behaviour of *Labeo calbasu* (Hamilton) and *Cirrhinus cirrhosus* (Bloch)

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Effects of intra- and interspecific competition on diet, growth, grazing, swimming, resting and social behaviour of two carps calbasu (*Labeo calbasu*) and mrigal (*Cirrhinus cirrhosus*) were examined in single and mixed species treatments. Three treatments (tanks with 4 *L. calbasu*, 4 *C. cirrhosus* or 2 *L. calbasu* plus 2 *C. cirrhosus*) were randomly assigned to six 1 m^2 glass-walled aquaria, in which pond conditions were simulated. Overall, both species preferred feeding on benthic macroinvertebrates, spending the majority of its grazing time near the tank bottom. Intraspecific food competition affected *L. calbasu* more than interspecfic food competition. The opposite was true for *C. cirrhosus* which was more affected by *L. calbasu* than by intraspecific competition. *L. calbasu* broadened its selection of food items and increased grazing time in response to intense (intraspecific) food competition. This behaviour allowed *L. calbasu* to maintain its food intake and hence growth. In presence of *L. calbasu*, *C. cirrhosus* continued to feed mainly on benthic macroinvertebrates, not changing its feeding behaviour. Therefore, *C. cirrhosus*' total food consumption and growth diminished in the presence of *L. calbasu*. In addition to food competition, direct interaction (interference competition from *L. calbasu*) also played an important role in the behaviour, diet, and growth rate of *C. cirrhosus*. From an ecological, economic and fish welfare point of view, it can be suggested that *C. cirrhosus* is deprived when cultured together with *L. calbasu* in aquaculture ponds.

1. Introduction

The interaction between fishes is influenced by feeding habits and food availability (Schoener, 1982). For example, when two species forage on the same limited food resources, interspecific competition for food will be intense. In this situation some species will broaden its feeding niche or switch to less preferred food items to maximize its food intake, while other species will not (Werner and Hall, 1979; Balcombe et al., 2005). Understanding how fish species will exploit a limited food resource in single or mixed species conditions, will broaden our understanding on fish ecology and allow improving aquaculture practices. For example, fish with a broad feeding niche can be cultured at higher densities than the fish with a narrow feeding niche.

Labeo calbasu (calbasu) and *Cirrhinus cirrhosus* (mrigal) are two important bottom feeder carps (cyprinids) stocked traditionally in south Asian polyculture ponds (Milstein et al., 2002; Rahman et al., 2006). In many cases, both species are stocked together. Many culturists believe that *L. calbasu* decreases the growth of *C. cirrhosus* while *L. calbasu* growth is not affected by the presence of *C. cirrhosus*, although there is no experimental evidence about it. Both *L. calbasu* and *C. cirrhosus* feed primarily on benthic macroinvertebrates (Islam et al., 1998; Kanak et al., 1999; Milstein et al., 2002)

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therefore, food competition between them may affect the growth of *C. cirrhosus*. However, insight in how both species compete for limited food resources is still lacking.

There are two common ways to quantify food competition. (1) Using growth and production data with the idea that winner will be more successful than the loser (Carpenter, 2005; Wuellner and Willis, 2008); or (2) observing changes in behavioural strategies and feeding patterns (Ward et al., 2006). However, each of these two methods cannot be used independently to explain the entire mechanisms involved in interactions among fishes. For example, growth data cannot distinguish between competition mediated by direct interaction (interference) or by resource depression. On the other hand, observations of behavioural strategies and feeding patterns cannot give a clear idea about the intensity of food competition. Therefore, combining fish behavioural observations with fish growth and production data will yield a more complete picture of the nature, intensity and mechanisms of interaction (Wuellner and Willis, 2008). In this experiment, growth, food selection and feeding behaviour of *L. calbasu* and *C. cirrhosus* were quantified in large aquaria in which pond conditions were simulated, stocking either single or mixed species groups. The objectives of this study were to investigate the effects of intra- and interspecific interaction on diet composition, growth and grazing, swimming and social behaviours of *L. calbasu* and *C. cirrhosus*.

2. Materials and methods

2.1. Experimental set-up

The experiment was carried out in outdoor rectangular tanks (size: 2.5 m × 0.4 m × 0.9 m) at Bangladesh Agricultural University, Bangladesh. The short sides were constructed from concrete and the long sides from glass, allowing direct observation of fishes throughout the tank. To establish pond conditions, tank floors were covered with pond sediment, and tanks were filled with pond water (supplied from the same pond). The sediment and water column heights in each tank were 10 and 70 cm, respectively. Each tank was further treated with agricultural lime ($CaCO_3$) at 25 g (250 kg ha^{-1}), semi-decomposed cow manure at 125 g (1250 kg ha^{-1}), urea at 3.1 g (31 kg ha^{-1}) and triple super phosphate at 1.6 g (16 kg ha^{-1}) one week before and again 2 weeks after fish stocking. Sunlight penetration through the glass walls was prevented by bamboo mat covers. The bamboo mats were only removed to record the fish behaviour.

Treatments consisted of three different fish group combinations stocked in each tank: 4 *L. calbasu* (LC treatment), 4 *C. cirrhosus* (CC) or 2 *L. calbasu* plus 2 *C. cirrhosus* (mixed). Duplicate treatments were randomly assigned to 6 tanks. All fishes were within a similar weight range (*L. calbasu*: 103.6–112.5 g and *C. cirrhosus*: 103.7–116.7 g). The experiment ran for four weeks, relying solely on the available natural food. Every week, half of tank water was replaced with less-turbid pond water. In addition, the tank water was also diluted partially with less-turbid pond water if turbidity prevented observations during video recording.

2.2. Measured variables

Water quality (temperature, dissolved oxygen, pH, nitrate nitrogen, total ammonia nitrogen, total nitrogen, phosphate phosphorus and total phosphorus) and total phyto- and zooplankton within experimental tanks were quantified weekly. Total benthic macroinvertebrates were only quantified at the end of the experiment. Procedures for water quality analyses (APHA, 1998) and total phytoplankton, zooplankton and benthic macroinvertebrates enumerations were similar as reported by Rahman et al. (2008a).

Fish behaviour was observed during the fourth week of the experiment during a full 24 h period starting at 08:00 h, video-recording the aquarium 15 min every 3 h (8:00, 11:00, 14:00, 17:00, 20:00, 23:00, 2:00 and 5:00 h). This system consisted of two analogue video cameras (model HEL30K1A000) connected with a Quard (model NB2010S), a video cassette recorder (SANYO, model TLS-9924P) and TV (SONY, model KV-TG21M80). The combined camera images covered the entire tank. The video cameras were sensitive enough to yield clear images also during night without artificial light. The individual fish behaviour was quantified by analysing video data using THE OBSERVER software (version 4.1, Noldus Information Technology, Wageningen, Netherlands). Fish behaviours were categorized as ‘grazing’ (in the water column, on the tank wall or on the bottom), ‘swimming’ (in the water column or <10 cm from the bottom), ‘resting’ (motionless) and ‘schooling’ (at least two fish <10 cm apart) according to Rahman et al. (2008b). All behaviours were expressed as percentage of total time, pooled over the whole day. The sum of grazing, swimming and resting is 100%. Fish behaviours were also categorized as schooling (intraspecific schooling: at least two individual of same species less than 10 cm apart and moving in same direction; interspecific schooling: at least two individual of different species less than 10 cm apart and moving in same direction) and scattering (all fish were scattered more than 10 cm apart). Because the sum of schooling and scattering time is 100%, scattering behaviour is not presented in the study.

At the end of the experiment all fishes were harvested and weighed individually up to the nearest 0.1 g. Specific growth rate (SGR, % body weight day^{-1}) was calculated from the natural logarithm of mean final mass minus the natural logarithm of the mean initial mass and divided by the total number of experimental days expressed as a percentage (Hopkins, 1992). After weighing, the body cavity of each fish was carefully opened and 5 cm of the anterior gut was removed and preserved immediately in 10% buffered formalin. The gut contents were analysed using a Sedgewick–Rafter cell and a microscope according to Rahman et al. (2006). The volumes of phyto- and zooplankton and benthic macroinvertebrates were also calculated according to Rahman et al. (2006).

2.3. Statistical analysis

All data were analysed using SPSS (version 14) after they were checked for normal distribution and homogeneity of variance. Only percent data had to be arcsine transformed