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Self-feeding behaviour and personality traits in tilapia: A comparative study between *Oreochromis niloticus* and *Sarotherodon melanotheron*

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ABSTRACT

Hybridization aims at combining valuable traits from two species into a single group. Nile tilapia *Oreochromis niloticus* (NT) and Black-chinned tilapia *Sarotherodon melanotheron* (BCT) are respectively characterized by fast growth and water salinity tolerance which attract the breeders who could take advantage of both species. The first step is to characterize both species behavior in different contexts. The aim of this study was to compare the self-feeding behaviour between NT and BCT with a design allowing to reveal individual and group feed demand behaviour and then to identify the individual specialization that builds around the device and the food dispenser. The second objective was to estimate the links between the individual specialization and personality traits. To this aim, we recorded feed demand behaviour of both species using a computerized self-feeding device (two tanks for each species containing 20 PIT-tagged individuals with a male-female ratio of about 47%). Personality traits of all individuals were subsequently characterized with an open field test (OFT). The links between feed-demand and personality were then analyzed. Growth performances were not significantly different between NT and BCT but there was a strong tank effect. The individual specialization was similar in NT and BCT and similar to that previously observed in sea bass i.e. 1–3 individuals responsible for most of the feed demand activity in the tanks. Most NT individuals stayed in the shelter during the open field test while most of BCT individuals moved out of it. Overall, NT were shyer than BCT or the OFT was not adapted to NT. Linking the results of the self-feeding experiment and OFT in BCT, we found a strong positive correlation between the triggering activity and females' shyness. Fish that spent more time inside than outside the shelter and which latency to emerge from shelter was longer, were characterized by a higher triggering activity (high-triggering fish). This study confirms the NT ability to use self-feeder devices and provides the first insight into the same ability in BCT and demonstrates links with personality traits. These results have a potential interest for the success of BCT and NT hybridization.

1. Introduction

Feed management is crucial for the economic performance of a fish farm. It involves avoiding either underfeeding, which inhibits growth and promotes competition (McCarthy et al., 1992), or overfeeding which increases food wastage (Thorpe and Cho, 1995) and feed conversion ratios (Talbot, 1993). Feeding behavior is a complex and flexible behavior that encompasses several behavioral responses associated with eating, including modes of feeding and feeding habits, mechanisms of food detection, frequency of feeding and food preferences (Volkoff and Peter, 2006).

Self-feeder devices have been developed to avoid both under- and over feeding with the fish obtaining food according to their nutritional needs (Covès et al., 2006). These devices have been widely used for studying feeding behaviour and especially feed palatability and nutrient selection (Boujard and Le Gouvello, 1997). When coupled with a computer and a PIT tag detection antenna, self-feeder devices give the possibility to reveal individual and group feed demand behavior. They allowed the assessment of

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numerous variables such as apparent group feed demand and consumption (when uneaten food is counted); feeding activity and feeding rhythms in Arctic char *Salvelinus alpinus* and European seabass *Dicentrarchus labrax* (Boujard et al., 1996; Rubio et al., 2004; Covès et al., 2006); circadian rhythms in rainbow trout *Oncorhynchus mykiss* (Alanärä, 1992; Boujard and Leatherland, 1992; Alanärä, 1996), and feed preferences in seabass (Paspatis et al., 2002). Most studies report the existence of individual specialization, also and hereafter called 'social structure' built around the device and the food dispenser. For example, social hierarchies have been observed in salmonids such as rainbow trout (Alanärä, 1996), or Arctic char (Brännäs and Alanärä, 1993), with dominant fish taking position near the feeder and the dispenser. These authors identified three fish categories (dominants, subdominants and subordinates): Dominant fish had the highest actuation level, followed by sub-dominants and then subordinates, resulting in higher specific growth rates for dominant fish. In European seabass and European cod (*Gadus morhua*), an intriguing individual specialization exists with three triggering categories coexisting: high-triggering (HT), low-triggering (LT) and zero-triggering (ZT) fish (Covès et al., 2006; Di-Poï et al., 2007; Millot et al., 2008; Millot and Bégout, 2009; Millot et al., 2014). In small populations composed of 50–100 fish, whatever the experimental conditions, the same pattern is always observed: HT fish are very few with only one or two animals being responsible for most of the triggering activity under a reward regime of 1 or 2 pellets per individual given after each actuation (Covès et al., 2006). On the other hand, the ZT status would be attributed to fish that never actuate the device while the rest of the population was composed of individuals that seldom actuated the trigger (LT) (Covès et al., 2006; Millot et al., 2008). This social structure is better and better understood in light of recent studies showing that the fish triggering activity is linked to personality traits (Benhaïm et al., 2012; Ferrari et al., 2014).

Animal personality can be defined as a correlated set of individual behavioural and physiological characteristics that are consistent over time and across situations (Wilson et al., 1994; Koolhaas et al., 1999; Sih et al., 2004). One of the main aspects of personality is the boldness–shyness continuum. Bold fish take more risks and explore their environment faster (less cautiously) when exposed to novelty (Øverli et al., 2006; MacKenzie et al., 2009). In contrast, shy individuals tend to be risk averse and are generally neophobic (Verbeek et al., 1994; Wilson et al., 1994), show a higher behavioural flexibility (Bolhuis et al., 2004) and are more responsive to their environment (Verbeek et al., 1994). Intermediate fish are in the middle of these two extremes. Among numerous behavioural tests assessing boldness, the open field test is widely used (Budaev et al., 1999a; Yoshida et al., 2005; Ferrari et al., 2014; Benhaïm et al., 2016).

Behind carps, tilapia is the second most farmed fish in the world. Even if the species is collectively called "tilapia", it includes in reality several genuses among which we find the black-chinned tilapia *Sarotherodon melanotheron* (BCT) and the Nile tilapia *Oreochromis niloticus* (NT), two species differentiated by their mode of parental care (oral incubation) (Trewavas, 1983). Today, 90% of these farmed fish are NT which grows particularly well but has a very low tolerance to salinity. Conversely, BCT has naturally low growth capacities but tolerates high salinity level (Whitfield and Blaber, 1979; Stickney, 1986). Fast growth of the first one and water salinity tolerance of the second species attract the breeders who could take advantages of both species characteristics by producing hybrids. This has been frequently attempted (Hopkins et al., 1989; Suresh and Lin, 1992) but seldom achieved although hybrids were produced in brackish waters recently (Amon et al., 2013). There are still concerns including interspecific aggressive behavior requiring further research on breeding conditions allowing hybridization (Akian et al., in preparation).

NT fish has also been used in studies addressing some themes of neuroscience and behaviour, such as stress (Volpato and Barreto, 2001; Barreto and Volpato, 2004; Moreira and Volpato, 2004); anxiety, emotionality and/or defence (Ide and Hoffmann, 2002; Barreto et al., 2003a); drugs affecting feeding behaviour (Delicio and Vicentini-Paulino, 1993) and personality traits (Martins et al., 2011a; Martins et al., 2011b). Despite a large number of reports on nutrition (Martins et al., 2011b; Ng and Wang, 2011; Teoh et al., 2011; Trung et al., 2011) very little characterization has, however, been done on self-feeding behaviour of NT and none on BCT. Previous studies showed that NT can use self-feeders efficiently to finely adjust food intake according to diet composition and contributions of nutrients from the diets (Fortes-Silva et al., 2010; Fortes-Silva and Sanchez-Vazquez, 2012) but the individual specialization based on the triggering activity and its link with personality traits has not been investigated so far.

The first aim of this study was to compare the self-feeding behaviour between NT and BCT with a design allowing to reveal individual and group feed demand behaviour and then to identify the social structure that builds around the device and the food dispenser. The second objective was to estimate the links between the individual specialization on the self-feeder and personality traits (boldness/shyness, exploration, activity).

2. Materials and methods

2.1. Experimental animals and housing conditions

Fish from both species (*Oreochromis niloticus* and *Sarotherodon melanotheron*) were hatched and reared at the experimental station of CIRAD (Montpellier, France). They were the first generation obtained in a recirculating system. NT were produced by the crossing of parents originating from the Bouaké strain in Ivory Coast while BCT were produced by the crossing of parents originating from the Ebrié lagune strain in Ivory Coast. NT growth is so much faster than that of BCT that we made the choice to compare them at similar size but not the same age in order to make the behavioural observations more relevant. A sample of 45 NT and 39 BCT was then transported at 1079 days post hatching (dph) and 1667 dph respectively to the Fish Ecophysiology Platform of La Rochelle (PEP, http://wwz.ifremer.fr/pep, France) and distributed in four 400 L tanks (T1–T4) located in a dedicated room: T1 (BCT, 11 females and 8 males), T2 (BCT, 11 females and 9 males), T3 (NT, 13 females, 10 males), T4 (NT, 13 females, 9 males).

At 1771 and 1183 dph, NT and BCT weighing 221.9 ± 97.9 g, 175.9 ± 22.0 g respectively were tagged with 12 mm conventional PIT tag to monitor each fish individually using a self-feeder equipped with PIT tag detection antenna.

The four tanks were supplied with filtered domestic water (Atlas cartridge) that removed organic matter and chlorine and further treated by a filter (flow rate of 300 L h^{-1} in each tank, and 20% water renewal per day). Tanks were surrounded by an opaque black curtain to avoid any disturbance of the fish. Nets were used to prevent the fish from jumping out of the tanks. A white light (LED, PAR 38, 120 W) was suspended above each tank. Light regime was 12:12 LD (light onset at 09:00 U.T. + 1). The physico-chemical properties of the water were monitored daily to guarantee optimum conditions. Water temperature was maintained at 24.8 ± 0.4 °C, O_2 saturation at 72.7 ± 12.9%, conductivity at 567.9 ± 57.2 µS cm^{-1}, pH at 6.59 ± 0.51. Ammonia, nitrite and nitrate concentrations were 0.26 ± 0.21, 0.58 ± 0.16 and 7.00 ± 5.84 mg L^{-1}, respectively. Fish were fed with commercial food (EFICO YM 868, 3 mm, BIOMAR®, France).