Applied Animal Behaviour Science 141 (2012) 79–90

Contents lists available at SciVerse ScienceDirect

Applied Animal Behaviour Science

journal homepage: www.elsevier.com/locate/applanim

Early life behavioural differences in wild caught and domesticated sea bass (*Dicentrarchus labrax*)

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ARTICLE INFO

Article history:
Accepted 9 July 2012
Available online 27 July 2012

Keywords:
Domestication
Swimming activity
Restocking
Selection
Coping styles

ABSTRACT

Behavioural studies comparing hatchery and wild-caught fish are useful to improve selection for aquaculture and restocking programmes. We examined swimming behaviour characteristics in wild captured and domesticated sea bass juveniles before and after eliciting a startle response at 8 different ages and always on naive individuals. We specifically investigated whether domestication impacts juvenile sea bass behaviour and whether the first months of captivity induce behavioural modifications in wild juveniles. An apparatus was designed to mimic a predator attack by presenting a sudden visual and mechanical stimuli simultaneously in 8 arenas where single individuals were placed and video recorded. The reactivity response was evaluated and different swimming variables including angular velocity, total distance travelled, mean velocity, immobility and distance from stimulus point were analysed from videos taken 5 min before stimulus actuation, 5 and 15 min after. Otolith readings showed that wild and domesticated juveniles were of similar age (~55 days at the start of the experiment and ~125 at the end of experiment). There were consistent behavioural differences (*e.g.* higher angular velocity and distance from stimulus point in wild fish) demonstrating that domestication reduces flight response behaviour. There were also similarities between both fish origins (similar response to stimulus actuation: decrease of total distance travelled and mean velocity, increase of angular velocity and immobility). A decrease over time in reactivity and variability in swimming responses among fish of both origins showed that captivity only does not fully explain wild fish behaviour changes and ontogenic modifications are likely interplaying.

1. Introduction

According to Price (1999) domestication is the process in which a population of animals becomes adapted to man and to the captive environment through genetic changes occurring over generation and environmentally induced developmental events recurring in each generation. This can lead to phenotypical changes, *e.g.* appearance of modified morphological and behavioural characters compared with the ancestral wild forms (Bilio, 2007). Some of these variations have been stabilized because of beneficial interests to humans. For example, chickens were selected to be larger, wild cattle (aurochs) to be smaller, and sheep to lose their bristly outer hairs (the kemp) and not to shed their soft inner hairs (the wool) (Diamond, 2002). Most wild animals that yielded valuable domesticates were large terrestrial mammalian herbivores and omnivores and their domestication started 10,500 years ago (Diamond, 2002).

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http://dx.doi.org/10.1016/j.applanim.2012.07.002

When compared to terrestrial agriculture, aquaculture is still a new industry. Fish domestication is so recent that most fish in culture are still exploited captives but a few are on the threshold of becoming domesticated (Balon, 2004). However it is also the fastest growing animal food-production sector and the number of farmed fish species has increased rapidly during the last few decades, some as food fish, others for stocking in the wild (Balon, 2004). Furthermore, the domestication process includes inadvertent and artificial selections (Price, 1999). Artificial selection is the process of changing the characteristics of animals by artificial means such as directional selection, genomic selection (Hamblin et al., 2011), or familial selection (Theodorou and Couvet, 2003). Artificial selection has substantially contributed to modern agriculture and animal husbandry, though aquaculture has yet to gain much from efficient breeding and selection programmes (Jobling, 2007). Furthermore, domestication may play a role in the distribution of individual characteristics such as behavioural and physiological responses which, if they are consistent over time and characteristic of a certain group of individuals, define a coping style (Koolhaas et al., 1999). For example, genetic selection of pigs that are more adapted to farming conditions may indirectly result in the selection for one type of coping style and a consequent reduction in individual variation (Ruis et al., 1999). Indeed, domestication and selection could rapidly impact fish behaviour, sometimes as soon as at the first generation of domestication (Vandeputte and Prunet, 2002; Bégout and Lagardère, 2004; Huntingford, 2004) and it is therefore important to check for the distribution of behavioural traits among populations, expecting bimodal distributions when coping styles are defined (Verbeek et al., 1994).

Among behavioural characteristics, several studies have implied that antipredator behaviour is highly sensitive to artificial rearing (Johnsson and Abrahams, 1991; Berejikian, 1995; Dellefors and Johnsson, 1995; Johnsson et al., 1996, 2001; Einum and Fleming, 1997; Fernö and Järvi, 1998). The single most important effect of domestication on behaviour is reduced emotional reactivity or responsiveness to fear-evoking stimuli (*i.e.* environmental change, Price, 2002). Behavioural measures of reactivity are also sensitive indicators of the complex of biochemical and physiological changes occurring in response to stress (Schreck et al., 1997). In particular, swimming performances in brook trout, *Salvelinus fontinalis* and in Guppy, *Poecilia reticulate* (Beamish, 1978; Walker et al., 2005) were reported to be better in wild stocks of fish *vs.* domestic stocks. Changes in swimming behaviour were good indicators of the effects of the domestication process on the stress response (Millot et al., 2009a,b). Standardized stimulation has been used to study the startle response in fish which is an important aspect of the swimming performances for escaping a predator (Wardle, 1993) and particularly the "C-start" response in relation to different environmental constraints: group *vs.* solitary response (Domenici and Batty, 1997); pollution (Faucher et al., 2006); water temperature (Johnson et al., 1996); and hypoxia (Lefrançois and Domenici, 2006).

Little is known about the antipredator behaviour of hatchery-reared and wild-caught juveniles of other non-salmon fish species (Malavasi et al., 2004) or on the behavioural response to fear evoking stimuli in the early life stages of fish. The European sea bass, *Dicentrarchus labrax* is a major species in Mediterranean aquaculture although little is known about the effects of the early phases of domestication or selection on growth apart from classical traits of commercial interest (Dupont-Nivet et al., 2008; Vandeputte et al., 2009). Attempts have been made to analyse behavioural responses to challenges in fish aged 12–24 months (Millot et al., 2010, 2011). Increased understanding of early behavioural swimming responses in sea bass should help determine early indicators that could be used for further domestication and selection programmes or for restocking.

The present study aimed at comparing the swimming behaviour characteristics of juvenile wild-caught sea bass with domesticated counterparts using an apparatus specifically designed to elicit a standardized and synchronized startle response in several arenas. The comparison between origins was done using always naive individuals over time to address the following questions:

(i) Does domestication have an impact on juvenile sea bass behaviour, especially regarding swimming activity before and after applying a visual and mechanical stimulus mimicking some aspects of a predator attack?
(ii) Do the first months of captivity induce behavioural modifications in wild juveniles?

2. Materials and methods

2.1. Experimental animals and housing conditions

Domestic sea bass larvae (five generations of domestication) were hatched at a farm in Aquanord SA (France). They were transferred on February 23rd, 2009 to the experimental station of INTECHMER (Cherbourg) when they were 3 days old (D3) and grown in a recirculated system. In total, 150,000 individuals were placed into a 1 m^3 cylindrical tank with conical bottom. All parameters were set according to the protocol used by the Aquanord hatchery. The tank was supplied with water treated by both sand and biological filters (flow rate between 150 and 500 $L\,h^{-1}$ and 10% water renewal per hour). Light regime was 12:12 LD (light onset at 08:00 U.T. + 1) and intensity was between 0 and 500 lx. Salinity was maintained at 35 $g\,L^{-1}$ except during the twenty first days where it was gradually decreased to 25 $g\,L^{-1}$ and increased again to 35 $g\,L^{-1}$ to facilitate the swimbladder formation. The oxygenation level was 7.8 ± 0.2 $mg\,L^{-1}$, temperature was 15.2 ± 0.53 °C. The temperature usually reaches 21 °C in a sea bass hatchery but here it was intentionally maintained lower to avoid creating large size differences with the wild stock that was thought to be captured later according to the natural conditions. Larvae were fed Artemia nauplii from D9 to D21 (5 nauplii per ml), a mixture of Artemia nauplii and enriched meta-nauplii (SUPER SELCO®) from D22 to D27 (2.5 nauplii and 2.5 meta-nauplii per ml) and enriched meta-nauplii from D28 to D54 (5 meta-nauplii per ml). Twenty-four hours before the arrival of