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Personality in the longsnout seahorse, *Hippocampus reidi* Ginsburg, 1933: Are males shyer than females?

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ABSTRACT

Individual responses, particularly based on personality, can have important consequences for individual fitness, based upon success in exploring new habitats, feeding on novel foods, and aggressiveness in competitive interactions. We conducted laboratory experiments to analyze individual responses to different artificial conditions that could suit specific male and female personalities in the endangered seahorse, *Hippocampus reidi*. Our experiments with *H. reidi* evaluated individual responses to a new habitat, novel objects, level of inactivity and social interactions. We demonstrate that approximately half of the seahorses have a bold personality, readily inspecting new habitats and objects and sporadically presenting social approaches. The remaining shy individuals had high levels of inactivity and did not check novelties in their habitats. Although we expected that males would have shyer personalities when compared with females, due to their ecological role in the provision of parental care, we found no statistical difference between the sexes in terms of these aspects of personality. The similar frequency of both types of personality in males and females suggests that these features may be balanced and evolutionarily stable in the sampled population.

1. Introduction

Many animal behaviour studies are based on behaviour of a specific population or group, but fail to consider the variability among individuals. However, the function of multiple behaviours in a population might be crucial for ecological fitness (Carter et al., 2013; Ogden, 2012). Behavioural diversification in a population is analogous to the concept of ecological niche, in which multiple behaviours can reflect individual specializations that diversify the use of resources, thus reducing inter-individual conflict (Bergmüller and Taborsky, 2010). The consistent behavioural differences between individuals across time and contexts is called personality (Dingemanse et al., 2010).

Variations in personality among individuals of a population are common and can be assessed by their reaction when faced with novelties, social interactions, breeding opportunities and habitat exploration, and may vary according to each stimulus (Corr et al., 2013; Dingemanse et al., 2012; Sih et al., 2004a). Understanding individual personality traits allows us to determine how animals may respond to environmental and ecological challenges (Reale et al., 2007; Sih et al., 2004b). Variations in personality may reduce conflicts among individuals and species, because distinct personalities result in different uses of resources (e.g. habitat, food), thus reducing competition and enhancing productivity (Bolnick et al., 2011). Populational variability in personality also leads to a wider exploration of resources, reducing density fluctuations in extreme situations (McCann, 2000). Intraspecific conflicts may instigate the occupation of different habitats and can lead to several dispersal strategies (Cote and Clobert, 2007). Depending upon each personality's ability to face new environments, individuals may or may not be able to tolerate high density populations. Therefore, the diversification of personality is an important feature for population health (Castanheira et al., 2013).

Recent studies show that the shy-bold axis of behaviour may have important consequences for an individual's lifespan and fitness, based upon success in exploring new habitats, feeding and mating opportunities and in coping with competition (Adriaenssens and Johnsson, 2010; Dall, 2004; Frost et al., 2007; Sinn et al., 2008). The bold-shy

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continuum has a strong effect in decision making, especially in unpredictable environments. Degree of boldness is usually assessed across several tests wherein bold individuals take more risks, learn faster, are more active and more explorative, while shy individuals present the opposite characteristics (Martins et al., 2012; Sneddon, 2003).

Male-female differences in personality also have been recorded in nature and are basically explained by their differences in ecological niche (Harris et al., 2010; Hedrick and Kortet, 2012; Vilela et al., 2017). Their ecological niche provides them with different experiences, driving the development of different traits (Piyapong et al., 2009; Schuett and Dall (2009)). There are few studies about sexual differences in personality types (Titulaeur et al., 2012; Zwoinska et al., 2013), but theory leads us to expect such differences. The risk-reward hypothesis suggests that females should be shyer than males due to reproductive traits (Jolles et al., 2015). For example, female guppies (*Poecilia reticulata*) have evolved to store sperm and thus avoid risky searching for mating partners (Laland and Reader, 1999; Harris et al., 2010). Males usually take more risks during breeding due to the possibility to improve reproductive success (Zwoinska et al., 2013). On the other hand, parental care appears to be associated with shy behaviours, as reported for the rhesus macaque *Macaca mulata* (Boissy, 1995; Maestripieri, 1993) and for the cichlid *Chiclasoma nigrofasciatum* (Budaev et al., 1999). Therefore, differences in male versus female ecological function may lead to variations in personality.

Seahorses are a type of fish distributed worldwide, inhabiting shallow waters of marine and estuarine ecosystems, such as mangroves, seagrass beds, rocky and coral reefs (Lourie et al., 1999). They have a unique division of reproductive roles, wherein courtship may take a couple of days and then females put their eggs inside the brood pouch of the males. Males are the ones that carry the eggs and provide protection, osmorregulation and nutrition to the fry (Vincent and Sadler, 1995). Seahorses have fascinated people for centuries due to their unique equine shape and unusual breeding habits. However, many species are currently threatened due to over-exploitation. They have been overharvested for use in traditional Chinese medicine, aquarium market and to be dried and sold as souvenir (Vincent, 1996).

In the present study we used seahorse *Hippocampus reidi* Ginsburg, 1933 as a model species, which is the most abundant seahorse in the Brazilian coast. Although this species is categorized as *Near threatened* by the IUCN Red List of Threatened Species (IUCN, 2017), regionally it is considered as *Vulnerable* (Mazzoni et al., 2000). The population decrease of this species in Rio de Janeiro occurs specially due to by catch and seahorse trading (Rosa et al., 2007). Seahorses are captured in nature for the aquarium trade, because it is difficult to develop an efficient protocol for rearing seahorse massively. Understanding how animals tend to react to captive conditions, it is possible to adapt a better condition for rearing the juveniles with the proper environmental enrichment and suitable aquarium partners, reducing capture of wild seahorses. Our objective was to examine the potential sex differences in personality, based upon the hypothesis that the ecological responsibility of carrying the fry might have led to shyer behaviour in males, while females would be bolder. This study examined differences in personality could potentially contribute towards management and conservation of seahorses in captivity, as a way to reduce pressure over natural populations.

2. Material and methods

This study was conducted in captivity and is part of a larger study of seahorse communication, authorized by the Brazilian Government, license number 25663-2 (Instituto Chico Mendes - ICMBio) and followed Animal Behaviour Society's Animal Care protocol (2012) and the Ethics Committee for Animal Care and Use in Experiments from Rio de Janeiro State University (number: 006/2015).

2.1. Animal sampling

Seahorses were manually collected at Urca beach (22° 56′ S and 043° 09′ O) using snorkeling equipment from November 2013 to September 2014. They were placed in plastic bags containing seawater and taken to the laboratory within 20–30 min. A maximum of five animals were collected per dive to prevent negative effects on the local threatened population, and our final sample size was limited due to the small populations that currently exist in the state of Rio de Janeiro. All animals were returned to the same sampling location after the experiments were conducted within a maximum period of one month. Before returning them to their natural habitat we took measure to determine that they were in good physical condition. These included assessments of skin and eye membrane color, behaviour pattern during feeding, and absence of sores, skin injuries and edemas. Pregnant males were not used for the experiments to prevent abortion. To avoid pseudoreplication during experiments, animals were individually identified and catalogued by photo-identification of the coronet, according to Freret-Meurer et al. (2013). No seahorses were recaptured during the study. Juveniles were not considered in trials, because we did not have a reasonable number for statistical analyses.

2.2. Behavioural assays

In the laboratory, seahorses were separated by gender and maintained in two 1.00 × 0.35 × 0.45 m aquariums. The salinity, temperature and pH were maintained at 34–35, 23–25 °C, 8.1–8.2, respectively. Nitrite was kept at 0–0.25 ppm and ammonia at 0 ppm. Photoperiod was kept at 10 day (0730 h–1730 h) and 14 night (1730 h-0730 h). The seahorses were fed twice a day (0800 h and 1600 h) with live *Artemia salina* enriched with higly unsaturated fatty acids for 24 h. The assays were conducted individually in a 0.80 × 0.30 × 0.40 m aquarium with two plastic plants used as substrate and holdfasts for the seahorses 35 cm apart from each other. All the behavioural trials were recorded with a Nikon Coolpix AW130 and later scored. Assays were divided into trials that evaluated exploratory behaviour, neophilia, anti-predatory response and sociability, detailed below.

2.2.1. Exploratory behaviour

Each seahorse was introduced individually into the experiment aquarium. After a period of 3 min acclimation restricted in a corner of the aquarium, the seahorse was released for the duration of the 20 min trial. The following behaviours were recorded: a) *inspection of the new habitat*: the animal swam throughout the aquarium; b) *protection:* the animal grasped the holdfast without exhibiting any other active behaviour, except for ocular movement. We scored the time elapsed until the animal grasped the holdfast.

2.2.2. Neophilia

After about 30 min of the end of the exploratory behaviour, we tested for neophilia/neophobia response. We introduced a red tube filled with live shrimp (*Artemia salina*) inside the aquarium in front of the seahorse. We scored for neophilia when seahorses approached the tube and for neophobia, when they moved away or remained motionless. Time was scored for 5 min.

2.2.3. Anti-predatory response

The anti-predatory behaviour was observed in the next 24 h of captivity. Seahorses usually remain attached to a holdfast using its tail to grasp the substrate. We simulated attempt of predation by using our hands to capture and retain the seahorse for 30 s, after which it was released. The *resistance to handler* was divided into four specific behaviours of the seahorse: a) grasping harder to aquarium plants while we try to capture it; b) swimming away from holdfast while we approach; c) grasping our hand hard trying to break free; d) wrapping our hand softly with its tale. We measured the time the seahorse took to get quiet

Table 1
Expected behavioural features that characterize shy and bold personalities. P = presence; A = absence.
Adapted from Hedrick and Kortet, (2012).

Personality features to be tested	Behavioural Features	Bold		Shy	
		P	A	P	A
Fear	Inspection of a new object	X			X
Fear	Inspection of new habitat	X			X
Fear	Inactivity		X	X	
Sociability	Social approach	X			X

in our hand, which we called *time of resistance*.

2.2.4. Sociability trial

For the next 48 h, four seahorses of the same sex were placed together and their behaviours were recorded using the *scan* method (Altmann, 1974), which was applied every two hours from 0730 to 1730 h. We used seahorses of the same sex to exclude sexual interactions. The following seahorse behaviours were recorded: a) *Social approach*: approaching a conspecific and (1) tangling of tails, (2) grasping the same holdfast and (3) color change; b) *Conspecific aggressiveness*: approaching a conspecific and exhibiting suction movements with the mouth, which produces a noise similar to a "click" (personal observation); c) no approach. We scored a positive sociability for the seahorses that displayed the *social approach* behaviours.

2.2.5. Data analyses

We considered the four features as variables to assess individual personality. We used the bold-shy axis for personality identification and quantified the presence or absence of the behavioural features (Table 1). The frequency of occurrence of shy and bold individuals was calculated, and we used Fisher's exact test to determine whether there was a preponderance of one or the other type of personality in the studied population. We used the same test to check for significant difference in personality between sex, by using *time of resistance*. We analyzed the shy-bold continuum behaviour with principal components analyses (PCA) of the three trials measured, excluding sociability trial. The PCA was basically used to extract personality traits, explaining variation among individuals. We ran the PCA on MultiVariate Statistical Package 3.22.

3. Results

A total of 27 seahorses were sampled for the experiments, 14 males and 13 females. When each behavioural feature was analyzed separately, discarding individual variations, we observed that 52% (N = 14) of the seahorses inspected the new habitat, while 48% (N = 13) of them instantly grasped a holdfast and remained inactive. Nonetheless, 74% (N = 20) of the seahorses inspected the new object (colored tube). In the sociability trials, inactive behaviour was exhibited by 48% (N = 14) of the observed animals and social behaviour was rare with only 22% (N = 6) of the seahorses exhibiting the approach behaviour. The other animals presented stereotyped behaviour during trials (30%, N = 7).

In terms of personality, the experiments showed that 48% (N = 13) of the analyzed seahorses presented a bold personality, inspecting new habitats and objects and sporadically presenting social approaches. Similarly, 52% (N = 14) were considered shy, presenting constant high levels of inactivity and ignoring novelties during the experiments. These values indicate that the number of bold and shy individuals in the population is in equilibrium (Fisher's LSD: p = 0.887). The shy-bold continuum axis analyzed by the PCA showed that the set of behavioural responses structured the personality (Table 2; Fig. 1). Axis 1 explained 97.2% of the behavioural responses and increasing positive values are

Table 2
Eigen explain in terms of behavioural responses of *Hippocampus reidi* to experiments conducted in the laboratory to assess individual personality.

	Axis 1	Axis 2
Eigenvalues	39025.15	1148.256
Percentage	97.055	2.856
Cum. Percentage	97.055	99.911

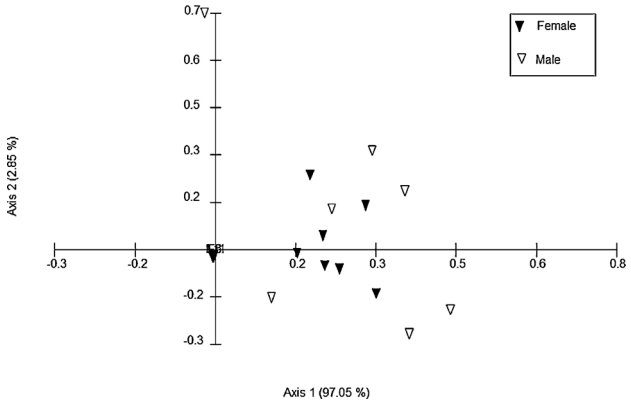

Fig. 1. Scatter plot for the Principal Component Analysis (PCA) of the individual set of behavioural responses of *Hippocampus reidi* seahorses to experiments conducted in the laboratory to assess individual personality. Males are represented by ▽ and females by ▼.

associated with a bolder personality. Decreasing values on this axis are associated with a shyer personality (Table 2). These results show that seahorses in general have a standardized response according to context and personality.

Males had higher percentage towards being shy (57%, N = 8), while females had towards a bolder personality (53.8%, N = 7). However, we did not find any statistical difference of personality between sexes (Table 3).

4. Discussion

The experiments of the present study showed that seahorses may have both bold and shy personalities, but the results did not support the hypothesis of sexual difference. The four tests for personality determination were well succeeded, but the response for *inspection of a new habitat* was not fully precise, because some animals became stressed by handling.

There was little social interaction. In nature, seahorses can be found in pairs, trios or quartets (Perante et al., 2002). The same studies report that the trios and quartets also include individuals of the same sex, but that social interaction of pairs is more stable, which is probably related to pairing for reproduction. As an example, Perante et al. (2002); Vincent (1994) and Vincent and Sadler (1995) described the behaviour of daily greeting of pairing seahorses (male and female), holding to each other. The low level of social interaction observed in the present study might be due to these kinds of interactions usually being more

Table 3
Types of personality percentages found for male and female *Hippocampus reidi* seahorses in laboratory experiments; N = sample sizes, P = probability of Fisher's exact test.

	Male		Female		P
	%	N	%	N	
Bold	42.8	6	53.8	7	0.395
Shy	57.1	8	46.1	6	0.671

common in the natural environment.

The studied population presented both types of personalities considered in this study. The presence of bold and shy personalities suggests that both provide fitness advantages. In general, boldness provides greater reproductive success, but tend to have a short life span, while shy individuals have reduced reproductive success, but longer life span (Smith and Blumstein, 2008). Variability in this kind of characteristic is extremely important in terms of population adaptability, as it helps to maintain the population evolutionarily stable (Monceau, 2015; Wolf and Weissing, 2012). Bold and shy personalities were found in equal proportions in the seahorses studied, and this scenario fits the ecological context described in some other studies with *H. reidi*. According to Freret-Meurer and Andreata (2008), the seahorse *H. reidi* is not a permanent resident of any specific site, especially females. Males usually remain for longer periods (about one year) in a specific place, but females remain for a shorter period of time (two/three months) in a specific patch and then disperse to other sites (Freret-Meurer and Andreata, 2008). The bold personality is extremely important for dispersion and settlement in new places (Carere and Locurto, 2011; Chapple et al., 2012). On the other hand, while residing at a specific site, this species is relatively sedentary and most of its time is spent either attached to a holdfast or foraging (Freret-Meurer et al., 2009, 2012).

Although no difference in terms of personality was detected between the sexes, a shyer personality in males would be expected, since they are the ones who carry the embryos inside the brood pouch, invest a lot of energy in parental care (Vincent and Sadler, 1995) and also present less active behaviour, especially during breeding (Freret-Meurer and Andreata, 2008; Freret-Meurer et al., 2012). The shyer personality would attribute to males a conservative behavior, avoiding exploration of novelties and exposure to possible danger. However, although males exhibit all these reproductive characteristics, seahorses do not have sex role reversal (Vincent, 1994; Wilson et al., 2003). Despite the fact that male seahorses are the ones that get pregnant, male-male mating competition occurs and males must invest considerable energy in female courtship. During courting, males exhibit several displays, such as nuptial coloration and sequential pumping (Mattle and Wilson, 2009). Male investment in female acquisition has probably led to bold males becoming as efficient as shy males for reproduction. The similar frequency of shy and bold males indicates that these features may be balanced and evolutionarily stable for the studied seahorses.

The present results also might contribute to improve management of seahorses in captivity. There are still many difficulties in maintaining and rearing seahorses in aquariums. Feeding and keeping seahorses healthy in captivity is a difficult issue, leading many individuals to death. They usually get stressed, do not eat properly and immune system fails, causing many diseases (Bombardini et al., 2006). Animals in captivity must be kept in ideal conditions to expand life time and develop their biological potential. Therefore, the present study on personality can contribute in understanding that these animals have several behavioural issues according to personality and it is possible to manage individuals differently to improve their potential (e.g. shy individuals tend to feed less in exposed landscapes).

On the other hand, the balance between shy and bold personalities in nature may be used as an indicator of a population potentially able to colonize other places. Bold fishes tend to spend more time in open habitats and have higher frequency of swimming (Sneddon, 2003), having great dispersal tendency (Brodin et al., 2013; Myles-Gonzalez et al., 2015). In this way, the present study tends to contribute for conservation from another point of view.

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