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Short Communication

Sexual Dimorphism in the Chinese White Fish *Hemiculter leucisculus*

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ABSTRACT

Divergent sexual selection in males and females can produce morphological and behavioural differences between the sexes. Numerous hypotheses have been proposed for the wide variation in the brain size of the two sexes. The Chinese white fish (*Hemiculter leucisculus*) is a common small fish, which displays differences in reproductive behaviour of the two sexes. The males display nuptial coloration during mating season, whereas the females produce eggs. Thus, the males may have larger brain size as a result of the divergent selection pressures hypothesis. Results showed that the average body mass and GSI was greater in the female, whereas male fish had slightly bigger brain. GIS and the relative brain size was larger in male than in the female. The male Chinese white fish with larger brain size might perform elaborate behavior for attracting females, so to increase reproductive success, whereas, the females with smaller brain size might save expensive resources to support the production of eggs.

Brain is often associated with information processing and interspecific variation in the size of brain regions is corresponded to the complexity of the behavior and society structure (Amiel *et al.*, 2011; Barton and Harvey, 2000). For most animals, the variation of brain size reflect differences in life history, diet, foraging technique, parental care, behavioral flexibility and habitat structure (Siddiqui *et al*., 1996; Garamszegi *et al.*, 2005; Zeng *et al.*, 2014). These factors are likely to shape the behavior of males and females, thus resulting in difference in size or structure of different brain regions in both sexes (Andersson, 1994).

Several hypotheses have been proposed to explain the sexual dimorphism in brain size. Sexual brain size dimorphisms have been reported in some taxon in relation to maternal investment (Gittleman, 1994; Burish *et al.*, 2004; Shumway, 2010; Kotrschal *et al.*, 2012; Zeng *et al.*, 2014). The most prevalent explanation is that sexually size dimorphic brains evolves through sexual selection (Maklakov *et al.*, 2011), whereby intense sexual selection drives the evolution of brain size in one sex, accompanied by weaker correlated selection on the size in another sex (Pitnick *et al.*, 2006; Kotrschal *et al.*, 2012). However, alternative hypotheses that do not invoke sexual selection have also been proposed (Aielloand and Wheeler, 1995). It is generally assumed that changes in the size of specific structures within the brain are the result of natural selection (Barton and Harvey, 2000). For instance, ecological factors appear to influence brain evolution in diverse taxon, for example diet correlates with brain size (Powell and Leal, 2012).

The Chinese white fish (*Hemiculter leucisculus*) is a common small fish living in the upper and middle water, widely distributed in rivers, lakes and ponds in eastern Asian. The characteristics of this species are green gray on the back, silver white on the lateral and ventral, without any other patternings, and the male in feeding season displays blue and red color in the body (Luo and Chen, 1998). There are several differences in reproductive investment and care behavior between the sexes, for instance, the males display nuptial coloration during mating season, whereas the females invest heavily in eggs production (FLIH, 1976). So the males may have larger brain size as a result of the divergent selection pressures. Thus, this species is well-suited for investigation of sexual size dimorphism in brain and testing the divergent selection pressures hypothesis. However, the difference of brain size between the sexes in this species is known very little. Our aims were to test whether the wild population of white fish (*H. leucisculus)* possesses significant differences in brain size dimorphism among the sexes.

Materials and methods

From 13 May to 3 June, 2012, the Chinese white fish (*H. leucisculus*) were collected at the downstream of

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the Xi-he River, in Nan-chong city in northeastern Sichuan, western China. All individuals were caught by hand nets. The brains were removed and weighted to the nearest mg, body mass was determined to the nearest 0.01g and standard length (SL, from the tip of the snout to the end of the caudal peduncle) was determined to the nearest 0.1 mm with digital calipers. Fish sex was judged by anatomical observation of fish gonad. A total of 78 males and females were recorded and all dissections and measurements were performed by one person.

A Chi-squared test was performed to test whether the mean population sex ratio equals 0.5. For controlling the effects of brain-to-body allometry, we used log transformation of relative brain size as our statistical variables. The relative brain size was recalculated as the ratio of brain size to the body weight. Meanwhile, the gonadosomatic index (GSI %), as gonad weight divided by fish weight with the viscera and gonads removed multiplied by hundred, was also calculated (Yin *et al*., 1993). The effects of sex on relative brain size and the total body mass (log transformed) of male and female, as well as GSI between the sexes were compared using unpaired t-test. All requirements for parametric analyses were conducted using R version 3.1.2.

Results

A total of 78 Chinese white fish (*H. leucisculus*), 41 males (SL, 13.46±1.51 cm) and 37 females (SL, 14.05±1.52 cm) were examined. Body mass (mg) and GSI of the Chinese white fish ranged from 19.67 to 21.53 and from 1.06 to 7.31 for male respectively; from 23.95 to 26.65 and from 4.17 to 30.14 for female respectively. Results of Chi-squared test showed that the Sex ratio was not statistically biased from 0.5 (chi-square values = 0.1154, p = 0.73) in wild population of the Chinese white fish (*H. leucisculus*).

We analysed the sexual size dimorphism in body mass, GSI and brain size, results of unpaired comparison showed that the body mass and GSI of the female (25.30±1.35, 13.88±1.09, respectively) were significantly larger than the male (20.60±0.93, 3.19±0.19, respectively) (t-test: t-body mass =2.86, t-GIS =10.12, d f= 65, p<0.05), however, the relative brain size of the male (0.0034±0.0001) were significantly larger than the female (0.0030±0.0001) (t-test: t=2.86, d f= 65, p<0.05) (Table I).

Discussion

Our results for the Chinese white fish *Hemiculter leucisculus* demonstrated that the sex ratio at population level did not depart from parity, but the average body mass and the relative brain size were significantly different between the sexes. These several differences in reproductive investment and care behavior among the sexes may have important impacts on the brain size of the Chinese white fish *Hemiculter leucisculus*, thus supporting the divergent selection pressures hypotheses. Previous finding has demonstrated that relatively larger brain in male may relate to the high cognitive ability, for males need to construct elaborate nests and care for offspring alone and during courtship perform elaborate displays (Kotrschal *et al*., 2012). We found a significant difference in brain and body size between the sexes in the Chinese white fish *Hemiculter leucisculus*. Although the sexual dimorphism in brain size have been confirmed in carnivorous mammals (Gittleman, 1994), bird (Burish *et al*., 2004). Our results provide an important evidence of the sexually size dimorphic brains in fish.

Table 1.- Sexual size dimorphism in body mass, GSI and brain size between the sexes of Chinese white fish using unpaired t test.

Static	Male (n=41)	Female (n=37)	*t*	P
Body mass (mg)	20.60±0.93	25.30±1.35	2.61	<0.05
GSI (%)	3.19±0.19	13.88±1.09	10.12	<0.05
Relative brain size	0.0034±0.0001	0.0030±0.0001	2.82	<0.01

Additionally, some studies have shown that the sex ratio population is related to physiological state (Aka *et al*., 2004), food resources allocation (Kruuk *et al*., 1999), differential breeding investment (Cordero *et al*., 2000). Our results showed that the sex ratio is 0.53 in Chinese white fish, which is not statistically different from 0.5. Future work will look at spatial changes in the sex ratio in relation to sexual selection in this fish.

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Statement of conflict of interest

Authors have declared no conflict of interest.

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