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SEXUAL DIMORPHISM IN BLACK JAW TILIAPIA (*Sarotherodon melanotheron*) AND BANDED JEWELFISH (*Hemichromis fasciatus*) FROM THE GREAT KWA RIVER, CALABAR, NIGERIA

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ABSTRACT

In this study, the pattern and magnitude of sexual dimorphic differences have been investigated in black jaw tilapia (*Sarotherodon melanotheron*) (n = 160; 74 males and 86 females) and banded jewelfish (*Hemichromis fasciatus*) (n = 120; 42 males and 78 females) from the Great Kwa River, Calabar, Nigeria. Fish samples were collected between July and December 2015. Fourteen morphometric variables, including body weight, total length, standard length, body depth, cheek depth, pre-orbital length, post-orbital length, pectoral fin length (right and left), pelvic fin length (right and left), head length, gonad weight, eye diameter and four meristic variables, including number of pectoral fins (right and left) and number of pelvic fins (right and left), were taken using standard methods. Size-adjusted morphometric measurements subjected to step-wise discriminant function analysis were used to determine predictor variables to morphologically differentiate sexes for both species; magnitude of dimorphism between sexes was estimated using percentage classification accuracy of the discriminant function analysis. From the discriminant function analysis, the pectoral fin length and gonad weight positively contributed significantly to morphometric dimorphism (magnitude=69.2%) in male and female *S. melanotheron* suggesting adaptation for reproductive function; while for *H. fasciatus* the body depth and standard length were important contributors to sexual dimorphism (magnitude=84.2%) suggesting size dimorphism for aggressiveness, territorial behavior and improving swimming performance. Overall, our results indicate that the different magnitude of sexual dimorphism between the two species could be attributable to the type and functional role of sexual dimorphic traits.

How to Cite

INTRODUCTION

Phenotypic diversification between sexes, also referred to as sexual morphometric dimorphism, is an ubiquitous phenomenon in animals and has been documented for a number of species both terrestrial and aquatic (Sullivan and Best, 1997; Herler et al., 2010; Nacua et al., 2010; Bhatta et al., 2012). These differences when present often manifest as structural specializations and adaptive mechanisms favouring sexual selection, dimorphic niches, food competition, locomotion, reproduction and other critical life processes of the species (Hedrick and Temeles, 1989; Bolinick and Doebeli, 2003). As such, the demands for survival experienced by each species trigger the emergence of morphological specialization of each sex (Camilleri and Shine, 1990; Collar et al., 2010), often to the advantage of the population (Lammers et al., 2001; Isaac, 2005; Sergio et al., 2007). For instance, if sexual dimorphism is evident in forage-related morphometric features, the likelihood of differing diet preferences and contrasting behavioural responses to a prey or food resource of each sex could be predicted on this basis. In addition, gape size has been used as a proxy for what prey a particular species consumed (Boubee and Ward, 1997), while tail dimensions have been used to estimate swimming capabilities (Fisher et al., 2005). More recently, Msing-Tsung (2015) demonstrated that visual fields and resolving power as indicated by the ganglion density and retina topography provide information on diet preferences, habitats and space usage.

The role of diverse environments and ecology on the magnitude of dimorphism expressed between the sexes has also been documented for a number of species; these differences have been attributed to habitat specific interactions/responses by each sex (Spooner et al., 2007; McPeek, 1996; McPeek and Brown, 2000; Frayer and Wolpoff, 1985; Post et al., 1999; Bonduriansky, 2007). Ecological reports have revealed that the extent of sexual dimorphism is constrained or regulated by the need to balance the demand for survival and the physiological cost for each sex and the population as a whole (Nur and Hasson, 1984; Rowe and Houle, 1996; Bonduriansky, 2007). This implies that the role of environmental factors, e.g. food abundance, temperature, presence of predators and anthropogenic effects, in determining the differing magnitudes of sexual dimorphism could be linked to the emergence of ecotype species, i.e. species adapted to particular environmental conditions with characteristic behavioural, structural or physiological traits (David et al., 1994; Post et al., 1999; Karan et al., 2000; Butler and King, 2004; Weladji et al., 2005; Alfaro et al., 2007; Rabosky et al., 2007; Collar et al., 2009).

It has been proposed that sexual dimorphism may evolve by ecological selection, thus favouring dimorphic niches and the emergence of certain dimorphic trophic traits (Hedrick and Temeles, 1989). The suitability of morphometric traits for predicting the adaptive aspects of sexual dimorphism could be largely attributed to their ability to overcome the limitation of taxonomic restrictions and provide information on the functional role of each sex within the habit range (Bremner, 2008; Enquist et al., 2015). The predictive value of traits for trophic niche description and locomotory capacity of a species has been documented (Childress, 1995; Trueman et al., 2014). Although a greater percentage of reports on sexual dimorphic traits have focused on humans, apes, birds and amphibian species (Blanckenhorn, 2005), many teleosts represent interesting models for studying sexual dimorphism (Parker, 1992). Cichlids are notable for their phenotypic diversity (Klingenberg et al., 2003) and are considered suitable for investigating adaptive radiation and wide spread distribution in the face of changing environmental resources (Kocher, 2004; Salzburger and Meyer, 2004; Elmer et al., 2009). Sexual dimorphism in cichlids has been reported to include the presence of body-spots, colour polymorphisms and pronounced sexual dichromatism, differential diet preferences among sexes (Fryer and Iles, 1972; Meyer, 1993; Galis and Metz, 1998; Kocher, 2004; Bhatta et al., 2012). Such records of sexual dimorphism are attributable to their taxonomic behavioural tendencies, i.e. division of labour among sexes (e.g. bi-parental mouth-brooding or guarding) and ability to harness a variety of ecological opportunities. Although cichlids are an undeniably widely studied group of species, very few studies have quantified the magnitude of dimorphic morphological traits between sexes and the application of such traits in predicting ecological possibilities of their habitat. This study was therefore aimed at investigating the patterns and magnitude of sexual morphometric dimorphism in black jaw tilapia (*S. melanotheron*) and banded jewelfish (*H. fasciatus*), which constitute one of the most available and ecologically important cichlid species in the Great Kwa River, Nigeria.

MATERIALS AND METHODS

Description of study area

The Great Kwa River is one of the major tributaries of the Cross River. It takes it course from the Oban Hill and flows southward where it discharges into the Cross River Estuary around latitude 4° 45' N and longitude 8° 20'E. It has an estimated length of 50 km and is about 2.8 km wide at the mouth where it discharges into the Cross River Estuary. The river is a source of drinking water and supports major fishing activities within the Cross River and Akwa Ibom States of Nigeria. The present study covered the entire length of the river and samples were collected along the length of the river at Calabar just before the river empties into the Cross River Estuary (Fig. 1).
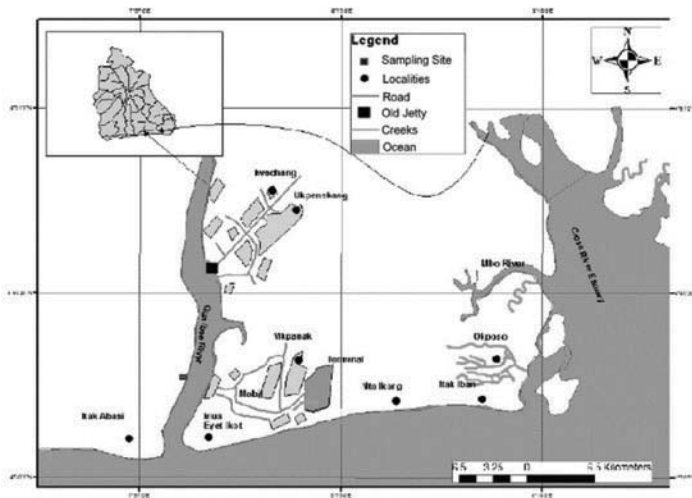
Fig 1. Map of Great Kwa River showing sampling point

Sample collection

Fish samples (*S. melanotheron* (n=160; 74 males and 86 females) and *H. fasciatus* (n=120; 42 males and 78 females) were collected between July and December 2015 from the Great Kwa River, Calabar, Nigeria with the aid of local fishermen using gill nets and cast nets of mesh sizes 50 − 55 mm. The fish samples were immediately preserved in ice chest and transferred to the laboratory. Collected fish samples were identified down to the species level using identification guide on freshwater fishes of West Africa (Paugy et al., 2003) and identification guide on freshwater fishes of Nigeria (Idodo-Umeh, 2003). Identified species include *S. melanotheron* and *H. fasciatus*.

Measurement of fish morphometric characteristics

Fourteen (14) morphological measurements were taken according to Neumann et al. (2011) method on all specimens. Morphometric traits were taken using absolute digital calliper (Mitutoyo 500-196-20) and all measurements were determined to the nearest millimeter, and body weight and gonad weight were taken with an Ohaus digital weighing balance (CS 200, Mettler Instruments). The morphometric characteristics measured include Body Weight (BW), Total Length (TL), Standard Length (SL), Body Depth (BD), Cheek Depth (CD), Preorbital Length (PreOrbL), Postorbital Length (PostOrbL), Pectoral fin Length (right and left) (PectLL and PectLR), Pelvic fin Length (right and left) (PelLR and PelLL), Head Length (HL), Gonad Weight (GW) and Eye Diameter (ED).

Measurement of fish meristic characteristics

Four (4) meristic characteristic were recorded according to

Neumann *et al.,* 2011 method. The meristic characteristics taken were Number of pectoral fins (left and right) (NoPectR and NoPectL) and Number of pelvic fins (left and right) (NoPelR and NoPelL).

Statistical analysis

All morphometric measurements of *S. melanotheron* and *H. fasciatus* from the Great Kwa River prior to transformation were described using measures of central tendency, i.e. mean and measures of dispersion (standard deviation). All measurements were corrected for size using residuals of regression, using morphological traits and standard length. Transformed morphometric data was further analyzed using step-wise discriminant analysis to determine the best combinations of morphometric and meristic variables that differentiate male and female sexes of each species. The significance of the discriminant function was established using the Wilks' lambda statistics ($p<0.05$). The discriminating power of each variable, i.e. ability to contribute maximally to group separation, was assessed using the standardized canonical discriminant function coefficient table where the values assigned to each variable provide an index of the importance of each predictor like the standardized regression coefficients (beta's) did in multiple regression. The sign indicates the direction of the relationship. Variables with the largest values are those which contribute mostly to differentiating the groups and as such were classified as most significant discriminating variables. In essence, predicting group membership from a linear combination of variables was achieved using discriminant analysis. The pattern, magnitude or degree of sexual dimorphic differences between males and females of each species were determined using the predicted group membership analysis of the discriminant test, classification accuracy and cross-validation.

RESULTS

Distribution and abundance of S. melanotheron and H. fasciatus from the Great Kwa River

A total of one hundred and sixty (n=160) *S. melanotheron* and one hundred and twenty (n=120) *H. fasciatus* were collected during the sampling period. For both sampled species, females dominated the populations with a percentage abundance of 53.7%, 65.0% for female, and 46.3% and 35.0% for male *S. melanotheron* and *H. fasciatus*, respectively.

Morphometric and meristic sexual dimorphism in S. melanotheron and H. fasciatus

Most morphometric characters in *S. melanotheron* and *H.*

fasciatus from the Great Kwa River showed sex specific significant increase in females compared with males, while no measured meristic variable showed sex related significant difference (Table 1a and b).

Table 1a. Morphometric variables of *S. melarotheron* from Great Kwa River

	Female	Male
BW	221.4±9.31*	179.2±14.45
TL	21.60±0.37*	19.34±0.84
SL	17.01±0.28*	15.34±0.65
BD	7.78±0.26	6.85±0.43
CD	2.79±0.06*	2.48±0.13
Pre OrbL	1.88±0.07	1.80±0.08
Post OrbL	2.40±0.06*	2.12±0.11
PectLR	6.87±0.23*	5.42±0.37
PectLL	6.87±0.23*	5.42±0.37
PelLR	5.30±0.13*	4.31±0.34
PelLL	5.30±0.13	4.31±0.34
NoPectR	13.33±0.13	13.4±0.12
NoPectL	13.33±0.13	13.4±0.12
NoPelR	5.73±0.27	5.67±0.33
NoPelL	5.73±0.27	5.67±0.33
HL	5.36±0.14	4.86±0.23
GW	3.04±0.65*	1.00±0.31
ED	1.36±0.03	1.26±0.05

Asterisk (*) denotes significant difference between (p<0.05) male and female. Body weight (BW). Total length (TL), Standard Length (SL), Body Depth (BD), Check depth (CD), Pre orbital length (Pre OrbL), Post orbital length (Post OrbL), Pectoral fins length right and left (PectLR and PectLL), Pelvic fin length right and left (PelLR and PelLL), Number of pectoral fins right and left (NoPectR and NoPectR), Number of pelvic fins right and left (NoPelR and NoPelL), Head length (HL), Gonad weight (GW) and Eye diameter (ED).

For *S. melanotheron*, a significant increase was observed in BW, TL, SL, CD, PreOrb, PectLR, PectLL, PelLR, PelLL and GW, while all measured meristic characters (NoPectR, NoPectL, NoPelR and NoPelL) showed no significant difference between sexes (Table 1a). In *H. fasciatus*, morphometric characters like BW, BD, CD, PreOrbL, PostOrbL, PectLR, PectLL and GW also showed a significant increase in females compared with males, while meristic variables (NoPectR, NoPectL, NoPelR and NoPelL) showed no significant difference between male and female (Table 1b).

Table 1b. Morphometric variables of *H. fasciatus* from Great Kwa River

	Female	Male
BW	220.9±9.47*	175.70±15.10
TL	21.47±0.49	19.16±0.94
SL	16.42±0.38	15.78±0.85
BD	7.41±0.32*	5.45±0.36
CD	2.91±0.25*	2.24±0.13
Pre OrbL	1.93±0.10*	1.58±0.11
Post OrbL	2.41±0.06*	2.15±0.11
RL Pect	7.06±0.19*	5.98±0.37
LLPect	7.06±0.19*	5.98±0.37
RL Pelvic	4.85±0.23	4.40±0.36
LL Pelvic	4.85±0.23	4.40±0.36
R No Pect	13.32±0.10	13.50±0.12
L No Pect	13.32±0.10	13.50±0.12
R No Pel	6.00±0.10	6.00±0.10
L No Pel	6.00±0.10	6.00±0.10
HL	5.40±0.18	4.40±0.31
GW	2.59±0.50*	0.57±0.20
ED	1.34±0.06	1.28±0.05

Asterisk (*) denotes significant difference between (p<0.05) male and female. Body weight (BW). Total length (TL), Standard Length (SL), Body Depth (BD), Check depth (CD), Pre orbital length (Pre OrbL), Post orbital length (Post OrbL), Pectoral fins length right and left (PectLR and PectLL), Pelvic fin length right and left (PelLR and PelLL), Number of pectoral fins right and left (NoPectR and NoPectR), Number of pelvic fins right and left (NoPelR and NoPelL), Head length (HL), Gonad weight (GW) and Eye diameter (ED).

Sexual dimorphic discriminant analysis in *S. melanotheron* and *H. fasciatus*

Standardized discriminant function coefficients for *S. melanotheron* (Table 2a) revealed three predictor variables, i.e. L_Pect_R, G_W and HL, while a closer analysis revealed only two significant predictors, i.e. L_Pect_R (r^2 =0.66) and G_W (r^2=0.03), were significant predictor variables (p<0.05) (Table 2b).

Wilks' lambda indicates the predictor variables with significant contribution to the discriminant function (Table 2b); cross validated classification showed that overall 69.2% of male and female *S. melanotheron* species were correctly classified. The standardized coefficients also reveal a positive relationship between the predictor variables (L_Pect_R =1.16, GW=0.59), indicating that with an increase in gonad weight of female fish there was a concurrent increase in the length of the right pectoral fin (Fig. 2).

Table 2a. Standardized coefficient of canonical variables in *S. melanotheron*

	Root 1
L_Pect_R	1.16
G_W	0.59
HL	-0.66
Eigen value	0.59
Cumulative Prop.	1.00

Pectoral fin length right (L_Pect_R), Gonad weight (G_W) and Head length (HL)

Table 2b. Discriminant function analysis summary of *S. melanotheron*

	Wilks's Lambda	Partial Lamdba	F-remove-(1.35)	p-level	Toler.	1-Toler.-(R-Sqr)
L_Pect_R	0.75	0.83	7.20	0.01	0.33	0.66
G_W	0.71	0.87	5.17	0.02	0.96	0.03
HL	0.66	0.94	2.06	0.15	0.33	0.66

Discriminant Function Analysis Summary (Step 3, N of vars in model: 3; Grouping: sex (2 grps) Wilks' Lambda: .62525 approx. F (3.35) = 6.9927 p< .0008. Bold values represent major discriminating variables. Pectoral fin length right (L_Pect_R), Gonad weight (G_W) and Head length (HL).
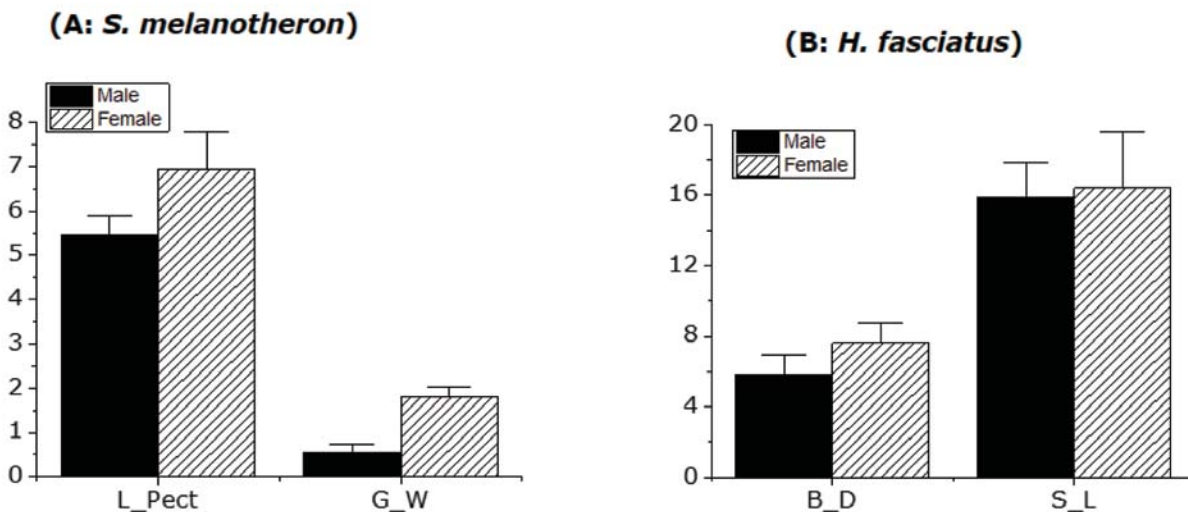

Fig 2. Discriminant features of cichlids from Great Kwa River, (A) *S. melanotheron* (Length of right pectoral fins (L_Pect) and Gonad weight (GW)), (B) *H. fasciatus* (Body Depth (BD) and Standard length (SL)). Length of pectoral fins, (L_Pect), standard length (SL) and body depth (BD) measured in centimeters (cm), while gonad weight was measured in grams (g)

Similarly, for *H. fasciatus* – although five predictor variables, i.e. BD, ED, SL, HL, GW, were listed in the table of standardized discriminant function coefficients (Table 3a), only two, i.e. BD (r^2=0.46) and SL (r^2=0.54), were significant predictor variables (p<0.05) (Table 3b); cross validated classification showed that overall 84.2% of male and female *H. fasciatus* were accurately classified.

Table 3a. Standardized coefficient of canonical variables in *H. fasciatus* from Great Kwa River

	Root 1
BD	1.01
ED	0.55
SL	-0.88
HL	0.43
G_W	-0.37
Eigen value	0.96
Cumulative Prop.	1.00

Body depth (BD), Eye diameter (ED), Standard length (SL), Head length (HL) and Gonad weight (G_W)

Table 3b. Discriminant function analysis summary of *H. fasciatus from Great Kwa River.*

	Wilk's Lambda	Partial Lambda	F-remove (1.32)	p-level	Toler.	1-Toler.-(R-Sqr.)
BD	0.69	0.73	11.75	0.00	0.53	0.46
ED	0.56	0.90	3.38	0.07	0.63	0.36
SL	0.61	0.82	6.80	0.01	0.45	0.54
HL	0.53	0.94	1.86	0.18	0.59	0.40
GW	0.53	0.95	1.46	0.23	0.63	0.36

Discriminant Function Analysis Summary Step 5, N of var. in model: 5; Grouping: sex (2 grups) Wilks' Lambda: .50959 approx. F (5.32) = 6.1591 p< .0004. Body depth (BD), Eye diameter (ED), Standard length (SL), Head length (HL) and Gonad weight (G_W).

From standardized coefficients, the predictor variables were negatively correlated (BD=1.01, SL=-0.88), indicating that the sex with a greater body depth was also the sex with the shorter body length (Fig. 2). Comparatively, discrimination of sexes in *H. fasciatus* using morphometric variable was significantly more successful (classification accuracy >75%) compared to *S. melanotheron* (classification accuracy <75%). This implies that a greater magnitude of morphometric divergence was detected between sexes in *H. fasciatus* compared to *S. melanotheron*.

DISCUSSION

Divergent dimensions or proportions of morphometric features between sexes of a species can be used to deduce the functional implication of those traits within the habitat (Mindel et al., 2016). In the present study, sexually dimorphic differences in *S. melanotheron* and *H. fasciatus* have been investigated using morphometric variables.

Generally, female *S. melanotheron* and *H. fasciatus* dominated the sampled population compared with males, suggesting a profound increase in the distribution and abundance of females compared with male fish population in the Great Kwa River; although this may imply a skewed sex ratio, this was not verified in this study. The discriminant function analysis showed that the right pectoral fin length and gonad weight were the major discriminating features between male and female *S. melanotheron*, with larger dimensions in females compared with males. While for *H. fasciatus* the body depth and standard length were the discriminating features between sexes, being significantly higher in females compared with males. Overall, our results indicate that certain morphometric trait relationships are sex-specific and such traits often highlight difference in reproductive physiology of male and female fish.

The observed larger/longer right pectoral fin in female *S. melanotheron* may suggest an adaptation for reproductive activities, i.e. for fanning the eggs and generating water current to supply oxygen to the eggs. This argument is supported by established knowledge indicating the important involvement of the pectoral fin in propulsion movement and balance within the water column of its habitat (Walker and Westneat, 2002; Drucker and Lauder, 2003). Conradsen and McGuigan (2015) reported that traits under selection, through their contributions to locomotive performance, might also be under selection because of their effects on other components, such as reproduction. The observed

significant increase in the right pectoral fins among most females may also be an important adaptation for territorial defense purpose. Reports have shown that pectoral fins and pelvic fins play prominent role in the speed, control of body position and stability, and in generating locomotor forces during propulsion and maneuvering features important for territorial display (Lauder et al., 2006; Higham 2007; Lauder and Madden, 2007). Furthermore, larger pectoral fins in females may not be unrelated to the natural selection of the females in this species for defending mating territory (Keremah and Ndah, 2013). The elongation of these fins, as observed, would increase the fin's total surface area, imparting on the sexes differing capabilities to manoeuvre.

In the present study, *S. melanotheron* gonad weight (GW) significantly increased in females compared with males suggesting that females had significantly heavier gonad weight than the males of this species, and this may be associated with the increased number of eggs in the female gonad and growth of ovaries via increased food storage ahead of spawning activities. Also the accumulation of vitellogenin (egg yolk precursor protein) in the oocytes of females may explain the higher gonad weight recorded in females compared with males. Previously it has been shown that ovarian development in female results in the accumulation of vitellogenin (Francolini et al., 2003) and this could also explain the significant increase in gonad weight in female *S. melanotheron* compared to males. Therefore, it may be suggested that the use of gonad weight as a distinguishing variable for male and female fish of this species may be considered reliable since tilapias are known to spawn all year round.

In *H. fasciatus*, body depth and standard length provided the greatest discriminance between sexes for this species. From the descriptive analysis, female *H. fasciatus* had larger body depth than males, this implies that females are generally larger than the males and this may also be a reflection of the ecological functions and division of labour in the wild. The broader and larger size in female *H. fasciatus* may also be attributed to their roles in defending spawned eggs from predators. Some other reports have shown that larger size is important for aggressiveness and territorial behavior. Previously, it has been reported that body depth influence swimming performance and can be a target of both natural and sexual selection (Webb, 1984; Taylor and McPhail, 1986; Taylor and Foote, 1991; Walker, 1997; Blake, 2004; Langerhans, 2009; Hendry et al., 2011). Furthermore, the increase in body depth and standard length in female *H. fasciatus* compared to males may suggest expanded distended body abdomen for egg-bearing female *H. fasciatus* and also an indication of deeper and wider bodies than males. The significant increase in BD in females may be related with fecundity (egg number and egg size), however, this remains to be evaluated. Elsewhere, Leris et al. (2013) quantified body shape variations between the sexes of *D. rerio* and reported that females had deeper body depth and width compared with males. Walker et al (2013) demonstrated that shallower body depth is thought to reduce drag during sustained swimming and thus is favoured in open water (pelagic) habitat and, in contrast, deeper body depth is also thought to increase manouverability and boost swimming speed, and thus is favoured in habitat with many hiding places. Therefore, sexual dimorphism of the observed species recorded in body depth in *H. fasciatus* from the Great Kwa River may probably have resulted as an adaptation for strong river current and defending of territory. Hence, it can be said that body depth is a critical dimorphic trait, suggesting that the sexes occupy different terrains within the habitat, with females probably occupying shallow water zone around the littoral areas of the river, while the male probably occupy open water areas. Furthermore, body depth and standard length are well documented as variables contributing to body shape of the fish, hence have been described as shape traits (Langerhans, 2009; Hendry et al., 2011; Conradsen and McGuigan, 2015). As such, the dimorphic patterns of body depth and standard length between sexes are expected to contribute to differing locomotor potential between female and male individuals of this species. Some authors have reported that body shape traits contribute to performance variations (Langerhans and Reznick, 2010; Walker et al., 2013), prolonged swimming speed and associated morphological performance (Arnold, 1983, 2003; Walker, 2007). Overall, the positive relationship between the right pectoral fin and increased gonad weight in *S. melanotheron* suggests that larger pectoral fins in females were more likely to be primarily affiliated with reproductive activity, while larger body depth of female *H. fasciatus* and its highlighted role in sexual dimorphism of this species is more suggestive of being primarily for locomotor function.

The differing magnitude of morphometric discrimination between sexes, i.e. 69.2% and 84.2% of *S. melanotheron* and *H. fasciatus* respectively, indicates that sexual dimorphism in *H. fasciatus* was more distinct compared to *S. melanotheron*. The lesser magnitude of sexual dimorphism recorded for *S. melanotheron* may be attributable to the lack of ecological opportunity compared to *H. fasciatus*. Spoljaric and Reimchen (2008) reported that ecology influences the magnitude of sexual dimorphism in dorsal fin length and posterior caudal depth. They suggested that a low magnitude of sexual dimorphism of fish living in shallow ponds might be attributable to limited niche availability. When distribution of a resource is limited, sexual dimorphism is less likely to evolve as a result of differential adaptation to divergent ecological resources by the sexes (Bolnick and Doebeli, 2003; Bolnick and Lau, 2008). In addition, this difference in magnitude of sexual dimorphism between the two species may also be explained based on the type of traits highlighted in sexual dimorphism of each species. For instance, the lower discriminant magnitude in *S. melanotheron* may be

due to the fact that the only traits highlighted for sexual dimorphism were traits with reproductive roles; as such dimorphism in reproductive traits may not warrant the sexes exploring different terrains or niches. As for *H. fasciatus*, the locomotory implication of wider body depth in females (i.e. inability to undertake long range or sustained swimming) by rule of thumb suggests that the males which have a narrower body depth were adapted for fast and sustained swimming which increases the likelihood to explore a different niche within the habitat compared to the females which were adapted for short bursts of swimming.

Results presented herein demonstrate the possibility of discriminating male and female cichlids based on morphometric traits. However, difference in magnitude of sexual dimorphism was also demonstrated between *Sarotherodon melanotheron* and *Hemichromis fassciatus*, and was attributable to limited niche availability to the species of smaller dimorphic magnitude and the type of traits highlighted in the sexual dimorphic role. In essence, sexual dimorphism linked or primarily anchored on reproductive traits may not result in a wide magnitude of dimorphism compared if the dimorphic traits were based on locomotor traits. Further research on a wider range of cichlid species is recommended to elucidate and validate the ecological possibilities highlighted by this study.

Sažetak

SPOLNI DIMORFIZAM CRNOBRADE TILAPIJE (*Sarotherodon melanotheron*) i DRAGULJASTOG CIKLIDA (*Hemichromis fasciatus*) IZ RIJEKE KWA, CALABAR, NIGERIJA

U studiji se istražuje obrazac i opseg spolnog dimorfizma crnobrade tilapije (*Sarotherodon melanotheron*) (n = 160; 74 mužjaka i 86 ženki) i draguljastog ciklida (*Hemichromis fasciatus*) (n = 120; 42 mužjaka i 78 ženki) iz rijeke Kwa, Calabar, Nigerija. Uzorci riba sakupljani su od srpnja do prosinca 2015. Ispitivano je četrnaest morfometrijskih varijabli: tjelesna masa, ukupna dužina, dubina tijela, dubina obraza, pre-orbitalna dužina, post-orbitalna dužina, dužina lijeve i desne prsne peraje, dužina lijeve i desne trbušne peraje, dužina glave, težina gonade, promjer oka i četiri merističke varijable koje uključuju broj lijevih i desnih prsnih peraja te broj lijevih i desnih trbušnih peraja, a dobivene su standardnim metodama. Morfometrijske mjere prilagođene veličini, koje su podvrgnute stupnjevitoj diskriminativnoj funkcijskoj analizi, korištene su za utvrđivanje prediktorskih varijabli za morfološku diferencijaciju spolova obiju vrsta. Izraženost dimorfizma među spolovima procijenjena je klasifikacijom postotka točnosti diskriminativne funkcijske analize. Iz diskriminativne funkcijske analize, dužine

prsnih peraja i težine gonada značajno su doprinijele morfometrijskom dimorfizmu (magnituda = 69,2%) kod mužjaka i ženki vrste *S. melanotheron* ukazujući na prilagodbu reproduktivnih funkcija, dok su za vrstu *H. fasciatus* dubina tijela i standardna dužina dali značajan doprinos spolnom dimorfizmu (magnituda = 84,2%), što upućuje na dimorfizam u veličini zbog agresivnog, teritorijalnog ponašanja i poboljšanja plivačkih sposobnosti. Naši rezultati ukazuju da se različita magnituda spolnog dimorfizma između dvije vrste može pripisati tipu i funkcionalnosti uloge svojstava spolnog dimorfizma.

Ključne riječi: morfometrijske mjere, spolni dimorfizam, ciklidi, rijeka Kwa, Nigerija

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