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Sexual Dimorphism in *Erpetoicthys calabaricus* from a Mangrove Creek, Nigeria

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Authors' contributions

This work was carried out in collaboration between both authors. Author IEA designed the work, performed statistical analyses and wrote the first draft. Author MAE wrote the final draft and managed literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

Sexual dimorphism of *E. calabaricus* is presented based on the examination of external morphology of the fish. Females had very pointed anal fins which joined the caudal fin smoothly with fewer than 10 spikes. Males had broader anal fin clearly separated from the caudal fin with between 9 and 12 spikes on the fin. Colour dimorphism in males tended towards an olive green, whereas the females had a light yellow-brown colour. Paired t-test showed that active females were slightly heavier than similarly-sized males. Length frequency distribution showed the largest fish was 39.9 cm TL female, while the smallest fish (TL_{min}) was 21 cm TL male. Sex ratio was in favour of males giving a male: female ratio of 1: 0.79 which was different from the expected 1: 1 ratio ($\chi^2 = 9.110$, df = 1, $p < 0.05$). The smallest female and male were 21.7 cm and 21 cm TL, thus delineating minimum sizes in the population. Largest female and male fishes measured 39.9 cm and 39.7 cm TL. Median sizes were 28.0 cm (females) and 29.0 cm (males).

Keywords: Dimorphism; sexual; male; female; colour.

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1. INTRODUCTION

Sexual dimorphism, the difference in size and morphology between males and females, is common throughout the animal kingdom and occurs frequently in various fish species, often involving differences in color [1,2]. This phenomenon is common in fishes and the differences between two sexes may involve secondary sex characters necessary for the accomplishment of copulation, oviposition or incubation or may be so–called accessory characters, which may not be directly involved in the mechanics of reproduction but are important to recognition, courtship or other reproductive behavior [3]. Morphological differences might be permanent or temporary related to the spawning season [4] or to growth stages and environment [5,6,7].

Studies interested in sexual dimorphism in Nigerian freshwater fishes are few, but universally many studies on this subject have recorded differences between males and females in terms of size, fins shape, jaws, snout and permanent extra autosomal structures including temporary characteristics observed during spawning season like nuptial tubercles, fin rays shape, body shape or color patterns and coloration [8,9,10,11,12].

According to Anderson [13], sexual dimorphism is a component of external morphological variation between the sexes, along with features such as the genital papilla, body pigmentation, fin shape and the most conspicuous difference between the sexes [14] and occurs in many fishes. Females are usually larger than males of the same age while in other species, males are larger than females [15]. Several authors have reported that the evolution of larger body size in male likely results from male-male competition associated with a polygynous mating system [16,14]. Hence, exploring the nature and extent of sexual dimorphism can aid in understanding social structure and adaptation, as well as species identification. Being a topic of lasting interest to biologists [17,18], the phenomenon is common in nature, and has the potential to increase intraspecific variation in performance and patterns of resource use [19]. Many vertebrate taxa exhibit sexual dimorphism, and explanations for its cause abound and are sometimes contradictory [20]. Typically, in any fish, sex can be determined by visual inspection of the gonads (primary sexual characteristics), which normally requires dissection, and in mature fishes, these characteristics are quite evident. The evolution of secondary sexual characteristics is usually the result of a disparity in the parental investment of males and females [21,13].

As in a phenotypic differentiation between males and females of the same species, differences could be observed in those who reproduce through sexual reproduction, with the prototypical example being for variations in characteristics of reproductive organs. Other possible examples are for secondary sex characteristics, body size, physical strength and morphology, ornamentation, behavior, and other bodily traits [22]. Traits such as ornamentation and breeding behavior found in only one sex imply that sexual selection over an extended period of time leads to sexual dimorphism [22]. Many teleost fishes do not exhibit any sexual dimorphism, even during the spawning season, and do not show sexual characteristics or permanent ornaments. On the other hand, some fishes show permanently dimorphic traits that are not necessarily associated with internal fertilization [23]. When present, sexual characteristics can be easily recognized in some species [24 and 25], whereas, in some others, a detailed examination is required for identification of these characteristics [26]. The present studies attempts to present baseline data on some aspects of sexual dimorphism in *Erpetoichthys calabaricus.*

The reed fish, *Erpetoichthys calabaricus* [27], is a member of the family Polypteridae which are small group of basal Actinopterigians restricted to few African fresh waters. Also known as rope fish, they live in slow moving waters with a lot of vegetation. They are rare species of freshwater fish in the bichir group first described 149 years ago after *Polypterus senegalensis* which is also a member of the family Polypteridae. The reed fish is the only member of the genus *Erpetoichthys,* though similar to *Polypterus senegalensis* from the genus *Polypterus* [28] and has been declared as “near threatened” [29].

2. MATERIALS AND METHODS

2.1 Study Area

The study was conducted in Ibikpe creek (Fig. 1) situated (latitude 05º 6´N and longitude 08º 11´E) within the rainforest zone of South-eastern Nigeria, located west of the lower reaches of the Cross River System. The creek is a perennial forest tributary system and drains a catchment area of 318.9 km^2 into the Cross River system, with which it maintains a permanent mouth, thus exposing the system to tidal ebb and flow. The area forms part of the Atlantic drainage system east of the Niger and empties into the Atlantic Ocean. The creek experiences tidal effects as manifested in many intrusive species. The area is considerably shaded by overwhelming canopy of riparian vegetation mostly *Elaeis guinensis, Raphia hookeri, R. venifera* and other tropical forest trees. Aquatic macrophytes are mainly *Nymphaea, Vossia and Musanga crinium sp.* It comprises dry (November-March) and wet (April - October) seasons [30,31,32].

2.2 Field Sampling and Laboratory Procedures

Samples of *E. calabaricus* were collected from designated fishers bi-monthly between April, 2013 and March, 2014 by means of non-return valve basket traps set on the fishing ground at locations which were 2 - 7 m deep and 10 m close to the shore at low tides and retrieved before high tides. Traps were 42 - 50 cm in length, 14 - 17 cm diameter of opening with mesh sizes of 0.2 - 0.5 cm.

Samples were immediately preserved in 10 % formalin solution for further analysis and transported to Department of Fisheries and Aquatic Environmental Management Laboratory, University of Uyo. Specimens were measured with a measuring board (scaled to ± 1 mm) to the nearest 0.1 cm to obtain total length (TL) and standard length (SL) and weighed on a top loading electronic meter (Hana Portugal 2010 model) balance (scaled to ± 0.01 g) to the nearest 0.00l g to obtain total weight (TW) [33].

2.3 Sexual Dimorphism

Each specimen was dissected and sex confirmed by inspecting its gonads. Colour, genital papillae and anal fin length were examined for possible dimorphism.

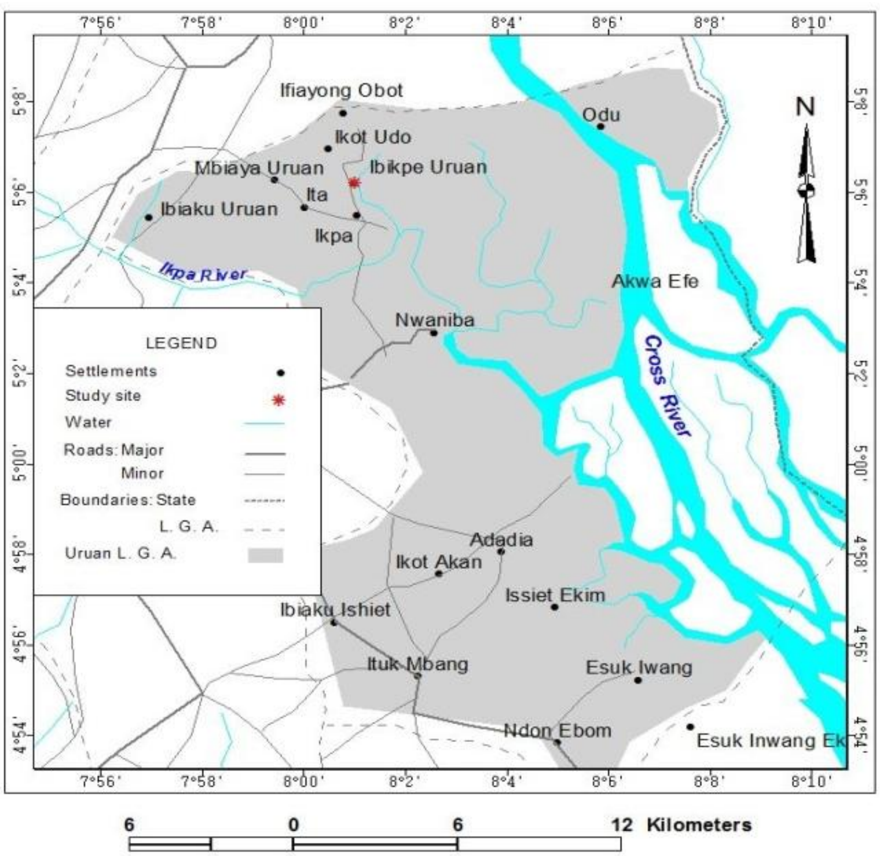

Fig. 1. Location of study area on Map of Uruan Local Govt. Area

2.4 Statistical Analyses

T - test statistic was used to evaluate sexual dimorphism in morphometric parameters while, Chi-square test was used to analyze sex ratio [34,35].

3. RESULTS

3.1 Visual Features

Females had very pointed anal fins which joined the caudal fin smoothly with fewer than 10 spikes. Males had broader anal fin clearly separated from the caudal fin with between 9 and 12 spikes on the fin. The genital papillae for both male and female were not too pronounced. Openings were shallow and concealed. Colour dimorphism in males tended towards an olive green, whereas the females had a light yellow-brown colouration. Table 1 shows that active females were slightly heavier than similarly-sized males ((a) maximum weight: paired t - test, t = 2.357, df = 12, $p < 0.05$; (b) mean weight: paired t - test, t = 2.846, df = 12, $p < 0.05$), weight difference being apparently to heavier ovaries *vis-à-vis* testes.

3.2 Population Structure

Length frequency distribution of females and males of *E. calabaricus* showed no significant difference (Fig. 2); both sexes occurred over the entire range of body size except the 36 cm and 37 cm groups where females were absent. At 38 cm group, both sexes were also absent. The largest fish (TL_{max}) examined was 39.9 cm TL female, while the smallest fish (TL_{min}) was 21 cm TL male. There were five and six size classes in each sex, the females and males respectively.

3.3 Sex Ratio

A total of 634 specimens of *E. calabaricus* were examined. Of this population, 355 (55.99 %) were males and 279 (44.01 %) females giving a male: female ratio of 1: 0.79 which was different from the expected 1: 1 ratio (χ^2 = 9.110, df = 1, $p < 0.05$) in favour of males. Figs. 3 and 4 illustrate variations in sex ratio with month and size. The wet season samples of 398 specimens consisted of 227 (57.04 %) males and 171 (42.96 %) females, giving a 1: 0.75 (χ^2 = 7.879, df = 1, $p < 0.05$) sex ratio in favour of the males. Similarly, of the 236 specimens caught in the dry season, males were 128 (54.24 %) and 108 (45.76 %) females, giving a sex ratio of 1: 0.84, which was significantly male biased (χ^2 = 1.694, df = 1, $p < 0.05$). Contingency χ^2 test indicated homogeneity between the seasonal sex ratios (χ^2 = 0.436, df = 1, $p < 0.05$) with males dominating during each season.

3.4 Median Sizes

The smallest female and male *E. calabaricus* were 21.7 cm and 21 cm TL respectively, thus delineating minimum sizes in the populations. The largest female and male fishes measured 39.9 cm and 39.7 cm TL, respectively. Median sizes were 28.0 cm (females) and 29.0 cm (males) (Fig. 5).

Table 1. Comparison of weights of similarly-sized females and males of *E. calabaricus* in Ibikpe creek

Total length	Females			Males		
(cm)	N	Min – Max	Mean	N	Min – Max	Mean
23.0	3	19.17 - 21.50	37.53	3	17.58 - 19.24	18.28
24.0	5	22.27 - 26.27	24.31	5	18.67 - 29.01	23.48
25.0	7	24.37 - 33.40	27.48	7	21.62 - 30.13	26.17
26.0	7	24.74 - 31.51	28.48	7	25.69 - 32.73	28.78
27.0	9	29.24 - 44.70	36.15	9	27.29 - 35.26	31.25
28.0	13	32.75 - 46.78	38.82	13	29.37 - 40.08	34.44
29.0	11	32.71 - 52.01	44.50	11	31.12 - 43.49	37.19
30.0	12	46.26 - 60.81	51.72	12	34.71 - 52.43	42.65
31.0	5	48.02 - 61.72	55.20	5	38.00 - 53.45	47.89
32.0	4	44.95 - 63.61	56.05	4	48.63 - 59.73	55.23
33.0	3	60.11 - 75.33	68.92	3	61.01 - 64.60	62.75
34.0	4	49.40 - 69.44	60.92	4	54.99 - 65.75	61.04
35.0	2	56.16 - 72.80	64.48	2	66.96 - 67.10	67.03

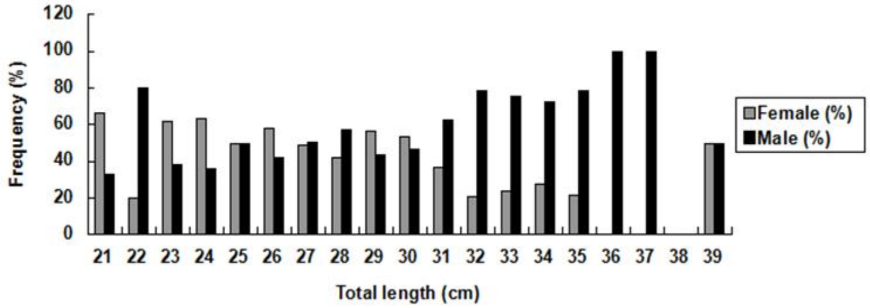

Fig. 2. Length-frequency distribution of *E. calabaricus* in Ibikpe creek

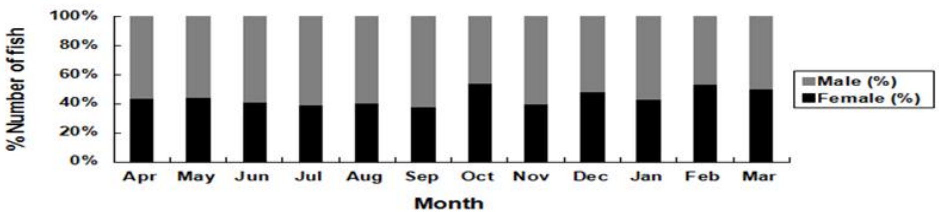

Fig. 3. Variations in sex ratio of *E. calabaricus* in Ibikpe creek with month

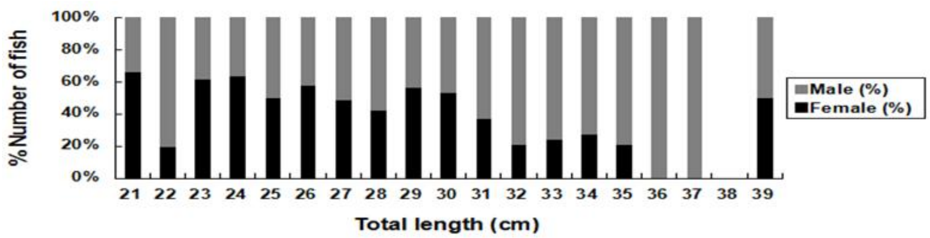

Fig. 4. Variation in sex ratio of the *E. calabaricus* in Ibikpe creek with size

4. DISCUSSION

The *E. calabaricus* could only be reliably sexed on dissection and examination of gonads. However, sexes could also be distinguished on the basis of the anal fin which was very pointed and joins the caudal fin smoothly in females. Males had broader anal fin clearly separated from the caudal fin, as well as between 9 and 10 spikes on the fin, while females had fewer than 10 spikes. Colour dimorphism which was clearly discerned tended towards olive green in males, whereas female had yellow-brown colouration. The significantly broader height of anal fin rays in male *E. calabaricus* may be a secondary sexual character [33] used during courtship. Paired t - test comparison also revealed that sexually active females were heavier than similarly-sized males. This is in agreement with the report of [36] who documented that mature females of *T. lepturus* in the Southern Brazil sub-tropical ecosystem were heavier than mature males, the observations also suggesting that females attain larger size than males in the same age and length class [37].

The unbalanced sex ratio reported in the study is difficult to explain. Probably, it could be attributed to behavioural differences between the sexes, which might have made the males more vulnerable and passive to gears such as traps than the females. The fishery therefore has a regulatory mechanism for sex ratio because populations of males present more growth without representing a risk situation for the fishery [38]. Male dominance maybe due to migration from spawning grounds after fertilization to feeding grounds in shallow parts (where they are easily captured) while females go towards submerged vegetation and rocky areas to avoid gears and carry out incubation and protection of offspring [39]. Wide disparities have been recorded for sex ratios of fluvial fishes [40] and have been shown to vary significantly

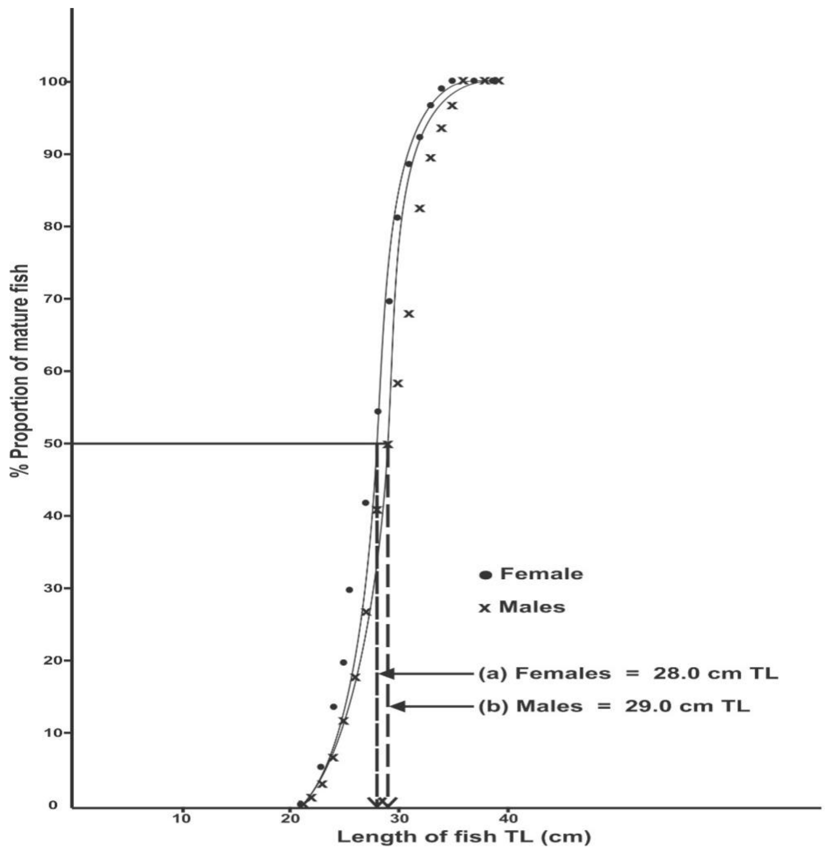

Fig. 5. Median sizes at maturity of female and male *E. calabaricus* in Ibikpe creek

according to the habitats [41]. It was similarly observed [42] that the sex ratio of *H. fasciatus* differed from the expected 1:1 ratio in their studies. The dominance of males over females owing to a greater number of males being hatched as documented for *T. leucosta* [43], or to the differential survival over certain environmental conditions [44]. [45], observed the dominance of males to females in the study of *P. jubelini* in the Lagos coast. Although for *O. niloticus,* preponderance of females has been attributed to sexual segregation during spawning activity, differences in gear type and fishing site [46]. Hence, further study is required to see if the same factors could be responsible for sex ratio results for *E. calabaricus*.

From the viewpoint that in organisms with 1:1 sex ratio, each female is expected to produce enough eggs during her life span to culminate in a mean of two additional adults [47], it can be inferred that in terms of investments, the male-biased sex ratio of *Erpetoichthys calabaricus* connotes a strategy evolved to ensure increase production of progeny [47]. Additionally, this male preponderance demonstrates that sufficient males are always available to maintain good population equilibrium [48]. There was a significant difference in sex ratio in October from the expected 1:1 ratio, in favour of females. It is however noteworthy that, these variations did not substantially influence the general male dominance, thus corroborating the notion of an "equilibrium population". The seasonal regimes in sex ratio of *E. calabaricus* probably reflect the natural dynamism in population structure [49].

Taking the median maturity size as a rough estimate of the optimum maturity size in the populations, the latter for *E. calabaricus* were 28.0 cm TL (female) and 29.0 cm TL (male), suggesting that females mature earlier than males. Since fish species that attain smaller maximum sizes mature at smaller size and where life spans of the fishes are small, they mature at very small sizes [50]; it is therefore possible to suggest that individuals of *E. calabaricus* grow more rapidly. However, considering that this species can grow to 39.9 cm TL as revealed in the present study, it is clear that individuals of the species reach sexual maturity early in life. Length of maturity in many fish species depends on demographic conditions, and is determined by genes and the environment [38]. The study showed that females mature at a relatively smaller length than males. This could be due to the fact that the on set of sexual maturity is more triggered in females than in males [40,51,46]. This result closely agrees with that of [52] who reported the length of 31.4 cm at maturity for the species from Cross River estuary.

5. CONCLUSION

Sexual dimorphism holds a special place in the history of evolution. By the application of geometric morphometrics, this study has demonstrated that populations of *E. calabaricus* have evolved subtle morphological differences. Observed findings and variations would be useful in prudent identification, management and maintenance of the species fishery as well serve as baseline data for further investigations on the species.

ETHICAL APPROVAL

As per international standard or university standard written ethical approval has been collected and preserved by the author(s).

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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