EGG PRODUCTION IN THE HAIRY TOADFISH, *Batrachoides liberiensis* (TELEOSTEI: BATRACHOIDIDAE) (STEINDACHNER, 1867) FROM OFFSHORE WATERS OF SOUTHEASTERN NIGERIA

Udo*, M. T., Udo, O. O., Offiong, U. S. and Essien, E. S.

ABSTRACT

*Department of Fisheries and Aquatic Environmental Management, Faculty of Agriculture. University of Uyo, PMB 1017 Uyo, Akwa Ibom State, Nigeria. *Correspondence: mfontudo@yahoo.com; +234 80 2890 1377*

Batrachoides liberiensis is one of the least studied ichthyofauna in both industrial and artisanal fish landings in Nigeria. The diminutive hairy toadfish lays very small number but large eggs; thus reproductive success of the egg batch in the stochastic marine habitat is important consequent upon its unique and ecological contribution lower in the food-chain. Therefore, the dynamics in the number and size of eggs produced by the hairy toadfish were investigated from offshore waters of southeastern, Nigeria. Fish samples were obtained from landings off distant water boats at Ibeno, Nigeria for twelve months. The samples were preserved in 10 % formalin and taken to laboratory for body identification, measurements, dissection and eggs counting. Average egg production in 31 screened toadfish was 58 eggs, for females measuring and weighing 8.0 – 13.0 cm TL and 7.700 - 29.700 g TW respectively. Egg production increased with morphometric correlates of lengths (total, standard and ovary) and weights (total, somatic ovary, total egg and individual egg). There was a trend with the population generally for individual egg weight, egg number and ovary weight to increase with female size as defined by body length and body weight. However, with use of partial correlation analysis to remove the effects of female size from the data, magnitude of some of the correlates changed but their directions did not. Thus, for females of the same size, the egg number increased with ovary weight (p<0.01), significant correlation was found between individual egg weight and ovary weight (p<0.05). Likewise, individual egg weight was positively correlated (p<0.05) with egg number. The toadfish is characterized by few but large eggs suggesting a population with parental-care guild. The possible significance of variations in individual egg weight on hatchlings/larvae survival and female reproductive success were also discussed.

Keywords*: Morphometric correlates; egg size; toadfish, Batrachoides liberiensis; offshore waters*

INTRODUCTION

The hairy toadfish, *Batrachoides liberiensis* appears to be the only species of the genus *Batrachoides* in West Africa. It is benthic, especially in littoral and coastal waters to about 30 meters and ambushes predators that favor sandy or muddy substrates where its cryptic coloration helps it avoid detection by predators. It inhabits also the brackish waters (FAO, 1981; Roux, 1990). Toadfishes and their relatives are classified in the order Batrachoidiformes, family Batrachoidinae, Porichthyi and Thalassophryninae sub-families are widely studied in waters of Europe and /or temperate regions with possible exception of the tropical species. The toadfish feed on fish and shrimps (Diouf, 1996; Essien, 2003; Udo and Udoh, 2015). They are usually scale-less with eyes set high on large heads; mouths are so large, with both maxilla and premaxilla, and often decorated with barbels and skin flaps. They range in size from 5.7 cm in the *Pacuma* toadfish to 7.5 cm length in *Thlassophryne megalops*. However, lengths of 23.3 cm TL (Udo and Udoh, 2015) to maximum length of 46.0 cm TL male / unsexed for some genera have been reported (Schneider, 1990).

In Nigeria, *B. liberiensis* is poorly represented in ecological studies and its reproductive strategies relatively undefined (Daniel, 2000). Udo and Udoh's (2015) report on the dynamics in diet regimes and habits showed female preponderance; the toadfish population off Qua Iboe River estuary (Nigeria) has no well-defined stomach; gut contents analysis of 360 specimens revealed piscivore-invertivore feeding habits, which exhibited affinity for fishes and crustaceans as major dietaries; length-weight data-pairs for the pooled, males and females showed the fish as a homogenous population that grows thinner as the length increases. Nevertheless, very little is published concerning the number of eggs including the morphometric correlates. The first aim of this study, therefore, was to determine egg number and egg production capacity of the hairy toadfish, *B. liberiensis*. It is therefore reasonable to say that due to paucity of literature, the second aim was to determine whether this variation in egg size and egg number also occurred in *B. liberiensis* and, if so, to compare it with that of other teleosts and discuss its significance in relation to reproductive success.

MATERIALS AND METHODS

The study was conducted at Qua Iboe River estuary at Ibeno, Akwa Ibom State, Nigeria (Fig.ure 1). The Qua Iboe River estuary is located in the rainforest zone with longitude $4^o27'$ - $5^o30'$ N and latitude 7^o 30' - 8^o 20' E. There are two major climatic seasons in the area – the wet (April to September) and the dry (October to March). Detailed description of the study area is contained in Tahal Consultants Ltd (1979). A total of 159 sexually, un-spawned, breeding females of *B. liberiensis* were collected between May 2003 and April 2004. The samples were obtained from fish merchants at Iwuochang / Upenekang fishing beach at Ibeno, Ibeno Local Government Area, Akwa

Ibom State (Nigeria), one of the major fishing settlements along the coastal waters of southeastern, Nigeria. The samples obtained were preserved in 10 % formalin. Each female was weighed to 0.001 g body weight (BW) on a top-loading electronic Mettler balance PS (165) and measured to 0.1 cm total length (TL) and standard length (SL) on a calibrated wooden board (50 cm). Each female was subsequently dissected and the ovaries removed and weighed to 0.001 g ovary weight (OW). The weight of the remaining body was also recorded and unless otherwise stated, is referred to as the somatic weight (SW). Measurement of the ovary length (OL) was also carried out. The eggs were preserved in vials containing Gilson's fluid to harden. During storage, ovaries containing the ripe ovaries were shaken periodically to enhance separation of eggs from the ovarian tissue. After two weeks, the fluid was decanted and the eggs washed, spread and air-dried for 24 hours on absorbent paper.

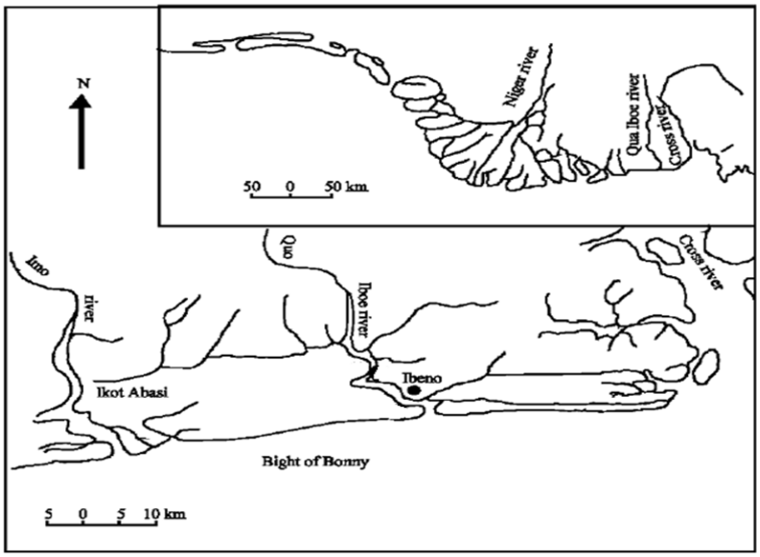

Fig. 1: Location of southeastern coast of Nigeria showing the Qua Iboe River estuary (Ibeno fish settlement). Inset: map of coast of Nigeria showing the location of Qua Iboe River.

Using the gravimetric method (Udo and Oribhabor, 2012), sub-samples were taken. Estimates for the dry weight of individual eggs from each female were obtained by taking three samples from each pair of ovaries. Each pair of ovaries measured a known weight (mean = 0.832 ± 0.673 mg; range: 0.59 – 1.20 g) and each contained a known number (mean = 58 ± 21.925; range 28 – 119) of eggs. Estimates for the number of eggs produced by each female were obtained by dividing the combined total egg weight (TEW) of each pair of ovaries by the mean of individual egg weight (IEW). Regression and correlation were used to evaluate relationships in egg production and morphometric correlates.

RESULTS

Out of 159 females dissected for egg production estimates, 31 (19.5%) were screened and used for the actual studying of the egg estimates. Mean absolute egg production of 31 specimens of the hairy toadfish (size 8.0 - 13.0 cm TL; 7.700 – 29.700 g BW) was 58 eggs. The relationships between egg production (EP) and independent morphometric correlates: total, standard and ovary length and body, somatic, ovary, total egg and individual egg weights were illustrated in Table 1. The correlation coefficients for each pair of transformed data was given in Table 2; it showed also that, the relationships between total length and standard length and between body weight and somatic weight produced the highest correlations respectively, for determining allometric variations in of the toadfish. The relationships between un-spawned female body weight and lengths (totals, standard, and ovary) were described by the following regression equations:

$BW = 0.0582\ TL^{2.3327;}$ $BW = 0.1369\ SL^{2.0579;}$ $BW = 1.9739\ OL^{0.1051}$

Correlations of the equations were 0.8466 ($p<0.001$), 0.4403 ($p<0.02$) and 0.3129 ($p<0.05$) respectively.

Similarly, the relationships between female somatic weight (SW) and lengths (total, standard, ovary) were represented by the regression equations:

$SW= 0.1040\ TL^{2.0148;}$ $SW = 0.0975\ SL^{2.1702;}$ $SW = 1.1951\ 0L^{0.3121}$

where N=31, and the respective correlations were 0.7995 ($P<0.001$), 0.9651 ($P<0.001$) and 0.5156 ($P<0.005$).

The difference between the unspawned weight (intact) and the body weight is approximately equal to the number of eggs produced (ovary weight) and this varied between 9.2 % of the unspawned weight in the smallest female (TL = 9.0) cm; BW = 7.7 g) and 16.5 % in the largest female (TL = 13.0 cm; BW = 24.200 g).

The relationship between unspawned body weight and ovary weight was described by the equation (r = 0.3696; p<0.05): $BW = 0.1873\ OW^{0.8554}$

Table 1: Relationships between egg production and morphometric correlates

Relationship	Regression equation ($Ep = aX^b$)
Egg production versus:	
Total length	$0.07918\ TL^{2.756}$
Standard length	$0.07638\ SL^{2.938}$
Ovary length	$0.06578\ GL^{1.320}$
Body weight	$4.94946\ BW^{0.895}$
Somatic weight	$6.06716\ SW^{1.012}$
Ovary weight	$46.80315\ OW^{0.227}$
Total egg weight	$62.28577\ TEW^{0.334}$
Individual egg weight	$146.10074\ IEW^{0}.^{222}$

Table 2: Correlation coefficients for pairs of variables using transformed data

	Ovary length	Ovary weight	Somatic weight	Body weight	Standard length	Total length	Egg weight
Egg number, EN	0.6993	0.6660	0.6835	0.7966	0.8892	0.8886	0.6659
Egg weight, EW	0.7263	0.6837	0.6137	0.7515	0.7125	0.8007	
Total length, TL	0.7257	0.6363	0.7905	0.8466	0.9756		
Standard length, SL	0.7739	0.5667	0.7971	0.4303			
Body weight, BW	0.3129	0.3696	0.9651				
Somatic weight, SW	0.4466	0.4466					
Ovary weight, OW	0.6801						

Similarly, the relationship between somatic weight and ovary weight was described by the equation (r = 0.4466, p< 0.02): $SW = 0.02798\ OW^{1.6536}$
The weight of egg produced was, however, only an approximation because the ovary membranes will have weight that is likely to vary according to the number and sizes produced. Because the two components of female size (body weight and total length) were so highly correlated (r≥0.7966 in each case), only the total length was used to show the relationships of ovary weight, egg weight and individual egg number against female body size.

Ovary weight

The correlation of ovary weight with body length (r = 0.6363; p<0.001) and body weight (r = 0.3696; P < 0.05) were moderately and minimally high respectively. Therefore, considerable variation in ovary weight with female size was expected. Surprisingly, the low value of the correlation between ovary weight and body weight improved rates than being reduced when the effect due to body length was removed (r = 0.4806; P < 0.005). It maintained its direction still and was highly significant (p<0.001).

Total egg weight

Even though the correlations of dry total egg weight with body length (r = 0.8007; p<0.001) and body weight (r = 0.7515; p<0.001) were high, there was still considerable variation in total egg weight with female size (i.e., if log of total egg weight, was plotted against female body length). Despite the correlations between total egg weight and body weight being reduced when the effect due to body length was removed (r = 0.8023; p<0.001), it was still highly significant. Thus, in toadfish of the same body length, heavy animals have larger ovaries than light animals.

Egg number

Similarly, the correlations of egg number against body length (r=0.8886; p<0.001) and body weight (r = 0.7966; p<0.001) were high. Interestingly, as with total egg weight, females of similar size showed considerable variation in the number of eggs they produced. Since total egg weight and egg number were both correlated with female size, the high correlation between them (r = 0.6659; p<0.001; N31) might be expected. The removal from this correlation of the effects due to body size, resulted in a lowering of value of the correlation coefficient (r = 0.6001; P < 0.001; N = 31). Thus, in females of the same size, an animal with a large ovary is expected to produce more eggs than one with a small ovary.

Individual egg weight

Although the correlations of individual eggs against female body length (r = 0.3427; p<0.05) were not significant whereas body weight (r = 0.4932; p<0.05) was, the results showed that females of similar size can produce eggs of variable weight. The overall trend, however, was for individual egg weight to increase with female size. Individual egg weight increased very significantly with dry total egg weight (r = 0.8660; p<0.001), so that the eggs produced by a large female were 1:4 times heavier than those produced by the smallest female. When the effects due to female size were removed, the correlation between individual egg and total egg weight became low (r = 0.4903; p<0.005) but significant. Therefore, toadfish of the same size showed significant correlation between individual egg weight and total egg weight.

Egg number versus individual egg weight

Since both estimated egg number and egg dry weight with female length, weight and total egg weight, a high positive correlation between egg number and individual egg might be expected. This positive correlation (r = 0.3882; p< 0.05) was, however, only just indicating that, for a given size of female, low egg number results in high individual egg weight and *vice versa*. An analysis using Spearman rank correlation was further conducted, to find out if there was any variation between female lengths against "mean" of individual egg weight per female per egg sample. The results (r = 0.8136; t = 7.5356; p< 0.001) of the analysis showed that variation did not only occur but that the variation depicted by the correlation was highly significant (p< 0.05).

DISCUSSION

The observation that about 16.2 % of the intact un-spawned mean body weight of small toadfish in the off-shore coastal waters of Qua Iboe River estuary is composed of ovary compares with the 16.4% reported for the same species at Qua Iboe River estuary (Essien, 2003). However, when the ratio of mean ovary weight to mean body of smallest fish (9.2%) and largest fish (18.5%) in this study, are compared with the Essien (2003) report of 0.1% (smallest) and 45.6% (largest fish), the results are different; indicating a higher rate of growth in ovary weight with female size in the latter's report. Toadfish from the offshore coastal waters are therefore producing relatively moderate ovary *vis-à-vis* the high and heavy ovary of those in the Qua Iboe River estuary. This difference between *B. liberiensis* from the two different habitats may be partly explained by the differences in food and environment. It is possible that both food supply and environmental conditions in the "deterministic" estuary are better than the "stochastic" coastal offshore ecosystem. The ecological implication is that female body condition of the estuarine samples may be regained more quickly after spawning, enabling gametogenesis (for the next year) to start earlier, thus, producing more ovaries (cf. Koskela and Pasanen, 1975). Since body weight, when related to body length, is an indication of body condition, the high correlation between ovary weight and body weight for a given female length would be expected. This correlation for *B. liberiensis* in the study, was also reported for the same species (Essien, 2003), *Periophthalmus barbarus* (Udo, 1995, 2002a, 2004), King and Udo (2001), *Ilisha africana* (King, 1991) and four tilapine cichlids (King, 1996). Despite this relationship, however, large ovary size need not necessarily result in high egg number, because individual egg weight may increase while egg number remains constant. The best strategy for a female would be such that results in her producing the most offspring surviving to sexual maturity. This is likely to be the result of a compromise between egg weight and egg number (Wilbur, 1977), since, when compared with small eggs, large eggs have the advantage of producing larger hatchlings (Kaplan, 1980).

When the female size in *B. liberiensis* is kept constant, there is a significant positive correlation between individual egg weight and ovary weight. This suggests that, for a particular size of female, any additional investment in reproduction is directed into producing fewer and bigger eggs. This explains reasons behind the large amount of variation found in the correlations between egg number and body size (length and weight). Thus, this study establishes positive relationships between ovary weight and fish length and weight. The implication here is that both morphometric correlates played identical roles in explaining the intra-specific variations in the ovary weight of the toadfish; the positive intraspecific correlations in the ovary weight–total body weight perhaps result from increased investment in egg quality relative to female body size. If egg weight is here considered as an index of egg quality, then the latter's association is buttressed by the positive relationship between egg weight and fish total length and body weight (King, 1996; Essien, 2003). Evidence of relationship between individual egg weight and number in the Amphibia is known (Reading, 1986) including those of teleosts (King, 1991; Udo, 1995, 2001, 2002b, 2004; King and Udo, 2001). In this study, *B liberiensis* exhibited a high positive correlation between individual egg weight and egg number. Even so, when variation due to female size was removed, the correlation became low but positive, indicating that females of the same size produce many small eggs or fewer large eggs. This finding contradicts results of inverse relationship reported for *Ilisha africana* (King, 1991), *P. barbarus* (Udo, 1995, 2002b, 2004; King and Udo, 2001), *Bostrychus africanus* (Udo, 2004) but in unison with the study of *Porogobius schlegelii* (Udo, 2004).

The negative relationship between individual egg weight and egg number is basically the outcome of estimating egg number by dividing the dry ovary weight by the mean dry egg weight. This would hold true if ovary weights were constant for females of similar size. However, they are usually not. The observed variation in ovary weight for females of similar size can be obtained and explained, if some produce low number of small eggs (small ovaries), some low number of large eggs (i.e. medium ovaries), some high number of large ones (i.e. large ovaries). Considering that combinations of egg size and egg number are plausible and, but each female is specimen–specific and/or unique, one would expect to find no correlation between egg weight and egg number over the entire range of female sizes, but not a negative one. Hence by implication, the inverse relationships between individual egg weights and egg number can be interpreted as trade-off between reproductive investment and growth. In another explanation, an inverse function between oocyte weight and egg number (cf. inverse egg number: egg size relationship in *Leuciscus leuciscus*: Mann and Mills, 1985) shows that less fecund females tend to produce heavier eggs than more fecund one.

The significance of the observation in this study that, *B. liberiensis*, directs its reproductive effort into producing large eggs (low number) can be seen when the effects of hatchling and/or fish larvae size and density on larvae growth are considered as follows; (1) At high density, those female fishes that produce fewer large eggs giving rise to large larvae that metamorphose early and at a large size (Wootton, 1973; Dajoz, 1977; Kaplan, 1980; Reading, 1986) will have a developmental advantage over those female fishes producing small eggs that result in small larvae with low growth rates; (2) On the reverse, at low density, females that produce many small eggs will have a numerical advantage over females producing large but fewer eggs, since larvae growth rates will all be similar and metamorphosis will not be delayed; (3) Still at low larvae density, it is reasonable to say that, the advantage of producing large eggs may be outweighed by the advantage of producing many eggs. Furthermore, (4) increase in egg number as a function of body length and weight suggests that large body size has favourable effects on reproductive output; and (5) Egg weights would increase with the condition indices of the toadfish, thus illustrating that egg quality was a function of the female's parent body condition, and the yolk content of fish eggs. Hence, their sizes are closely linked to the degree of parental care accorded to the eggs and/or young (Welcomme, 1976; Coates, 1988). On the basis of this framework, it is noteworthy that the coastal offshore population of the hairy toadfish, with relatively large eggs engages in various degrees of diverse forms of parental guarding of the eggs, larvae and/or the young. This observation is in line with reports on a temperate allied species, the oyster toadfish, *Opsamus tau* of the Western Atlantic. This is one of the most carefully studied Batrachiformes where the male guards the large eggs and young for about 3 weeks (Massiehe, 1998).

In brief mortality among deposited eggs differs widely within a spawning area. Studies have also shown that, one reason for large mortality is the high density of the eggs. For instance, in brown trout, *Salmo trutta*, mortality of alvins from small eggs is higher than for large eggs (Bagenal, 1969). According to Wootton (1980), rapid development of the eggs and subsequent rapid growth of the larval fish into size classes that are less vulnerable to predation will be advantageous. Thus, it would be reasonable to speculate that fish generally maintain a quality control over the eggs, which buffers the effect on egg quality of any change in composition of diet. Apart from some recent theoretical studies, the implication of egg size and quality for the reproductive success of individual fish is seldom reported (Wootton, 1980). The great natural mortality during egg and larvae phase is a fundamental aspect for the assessment of fish production. Finally, the demand by aquaculture industry for high quality eggs with predictive fertility and survival characteristic should act as stimulus and/or lend support for more research in this regard and which in this case, for *B. liberiensis* from coastal offshore water of Nigeria, is reported for the first time. Similar information for such small-bodied fish species (the mudskipper (*Periophthal barbarus*), Schlepel's gogy (*Porogobius schlegelii*), sleeper eleotrid (*Bostrychus africanus*) along the coastal waters of Nigeria have also been documented (Udo, 2002ab; Udo and Oribhabor, 2012; Udo and Udoh, 2015; Udo *et al*., 2008, 2009, 2016).

CONCLUSION

The study revealed that the mean egg production capacity of the toadfish was 58 eggs (range 28 – 119 eggs) per fish. The produced eggs were few but large in size; such a characteristic trait is typical of species with parental-care guild. Egg production in the fish correlated with the morphometric correlates as expected in fisheries science.

REFERENCES

Bagenal, T. B. 1969.The relationship between food supply and fecundity in brown trout *Salmo trutta* L. *Journal Fish Biology*, 1(1):169-82.

Coates, D. 1988. Length–dependent changes in egg size and fecundity in females, and brooded embryo size in males of fork-tailed catfishes (Pisces: Ariidae) from the Sepik River, Papua New Guinea, with some implications for stock assessment. *Journal Fish Biology*, 33:455-464.

Dajoz, R. 1977. Introduction to ecology. Hodder and Stoughton, London, 416 p.

Daniel, A. I. 2000. The intersexual variation in the aspects of the biology of the toadfish, *Batrachoides liberiensis* in the Qua Iboe estuary, Upenekang – Ibeno, Nigeria. B. Sc. Thesis, University of Uyo, Uyo, Nigeria. 31p.

Diouf, P. S. 1996. Les peuplements de poisons des milieu de l'Afrique de l'Quest: L'exemple de l'estuaife hyperhalin du Sine-Saloum. Universite de Montpellier II. Theses et Docoments Micrfiches No. 156, Paris. 267p.

Essien, E. S. 2003. Reproductive biology of the toadfish, *Batrachoides liberiensis* (Steindachner, 1967) in the Qua Iboe River estuary, Nigeria. B. Sc. Thesis, University of Uyo, Uyo, Nigeria. 22 p.

Food and Agriculture Organization (FAO), 1981. Species identification sheets for fisheries purposes. East Central Atlantic Fishing Area 34 and Part of 47. *Dept. of Fish and Oceans*. Canada II: 1-8.

Kaplan, R. H. 1980. The implication of the ovum size variability for off-spring fitness and clutch size within several populations of salamanders (*Ambystoma*). *Evolution, Lawrennce, Kansas*, 34:51-64.

King, R. P. 1991. Same aspects of the reproductive strategy of *Ilisha africana* (Bloch, 1995) (Teleostei: Clupeidae) in Qua Iboe estuary, Nigeria. *Cybium*, 15(3): 239-257.

King, R. P. 1996. Ecomorphological correlates of interspecific plasticity in reproductive investment and egg production of some cichlid fishes (Cichlidae) of a Nigerian rainforest stream. *Archive Hydrobiol*ogy, 136: 575 – 587.

King, R. P. and M. T. Udo. 2001. Fecundity of the mudskipper, *Periophthalmus barbarous* (Gobiidae) in Imo River estuary, Nigeria. *Archive of Fishery and Marine Research*. 4(2):117-124.

Koskela, P. and S. Pasanen. 1975. The reproductive biology of the female common frog, *Rana temporaria* L. in Northern Finland. *Aquilo (Zoology)*, 16: 1-2.

Mann, R. H. K. and C. A. Mills. 1985. Variations in the sizes of gonads, egg and larvae of dace, *Leuciscus leuciscus*. *Environment and Biology of Fishes*, 13 (4): 277.

Massiehe, F. D. 1998. Uncommon guide to common life of Narragansett Bay. Save The Bay, Incorporated. 254p.

Reading, C. J. 1986. Egg production in the common toad, *Bufo bufo. Journal of Zoology, London*. 208: 99-107.

Roux, C. J. 1990. Barachoididae. pp: 470-473. *In:* J. C. Hureau, C. Karrer, A. Post and L. Saldanha (eds). Check-list of the fishes of the eastern tropical Atlantic (CLOFETA). JNICT, Lisbon; SEI, Paris; and UNESCO, Paris. Vol. 1.

Schneider, W. 1990. FAO species identification sheets for fishery purposes. Field guide to the commercial marine resources of the Gulf of Guinea. Prepared and published with the support of the FAO Regional Office for Africa. Rome. 268p.

Tahal Consultants (Nigeria) Ltd. 1979. Qua Iboe Basin prefeasibility study. Cross River Basin Development Authority, Nigeria, 2, Annex II: A-1-14.

Udo, M. T. 1995. Some aspects of the biology of the mudskipper, *Periophthalmus barbarus* (Linnaeus, 1966) (Teleostei, Gobiidae) in the estuarine swamps of Imo River, Nigeria, M. Sc. Thesis, University of Uyo, Uyo, Nigeria. 145p.

Udo, M. T. 2002a. Intersexual plasticity in aspects of the biology of the mudskipper, *Periophthalmus barbarus* (Gobiidae) in Imo River estuary, Nigeria. *Journal of Environmental Sciences*, 14(1): 95 – 105.

Udo, M. T. 2002b. Morphometric relationships and reproductive maturation of the mudskipper, *Periophthalmus barbarus* from subsistence catches in the mangrove swamps of Imo Estuary, Nigeria. *Journal of Environmental Sciences*, 14 (2): 221-226.

Udo, M. T. 2004. The trophic, reproductive and growth biology of the gobiids (*Periophthalmus barbarus* Linnaeus, 1966 and *Porogobius schlegelii* Gunther, 1861) and eleotrid *Bostrychus africanus* Steindachner, 1880) in the Qua Iboe River estuary, Nigeria. Ph. D Dissertation, University of Uyo, Uyo, Nigeria. 384p.

Udo, M. T., Akpan, A.W and Ekwu. A. O. 2008. Observations of the indices of fecundity of the mudskipper, *Periophthalmus barbarus* (Gobiidae) in the Qua Iboe River estuary Southeastern Nigeria. *Ecology, Environment and Conservation*, 14(2-3): 255-262.

Udo, M. T., A. W. Akpan., B. J. Oribhabor and U. I. Daniel. 2009. Fecundity in the mudskipper in two estuarine (Mangrove Swamp versus Nipa swamp) creeks of Southeastern Nigeria. *Ecology Environment & Conservation*, 15(3): 455-460.

Udo, M. T. and P. E. Udoh. 2015. Dynamics in Diet Regimes and Habits of the Hairy Toadfish, *Batrachoides liberiensis* [Pisces: Batrachoididae] off Qua Iboe River Estuary, Nigeria. *The American Journal of Innovative Research and Applied Sciences*. 1(9): 351-355.

Udo, M. T.; N. O. Abiaobo and I. E. Asuquo. 2016. Aspects of the reproductive biology in Mudskippers, *Periophthalmus barbarus* (Gobiidae) (Linneaus, 1766) in mangrove swamps of Iko Estuary, Southeast, Nigeria. *Continental Journal of Biological Sciences*, 9 (1):1 – 14.

Welcomme, R. L. 1967. The relationship between fecundity and fertility in the mouth-broading cichlid fish, *Tilapia leucosticta*. *Journal Zoology London*, 51:453 – 468.

Wilbur, H. M. 1977. Propagule size, number, and dispersion pattern in *Ambystoma* and *Asclepias*. *American Naturalist*, 3: 43-68.

Wootton, R. J. 1973. The effect of size of food ration on egg production in the female three-spined stickle back, *Gasterosteus aculeatus* L. *Journal Fish Biology*, 5: 89-96.

Wootton, R. J. 1980. Ecology of Teleost Fishes. Chapman and Hall, London. Fish and Fisheries Series 1. 404p.