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Morphometric relationships and reproductive maturation of the mudskipper, *Periophthalmus barbarus* from subsistence catches in the mangrove swamps of IMO estuary, Nigeria

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Abstract: From April 1992 and March 1993, morphometric characteristics and reproductive maturation were studied in *Periophthalmus barbarus* from subsistence catches in the mangrove swamps of Imo estuary. Morphometric equations for males and females at different stages of ovarian maturation are presented. Generally males were significantly heavier in weight than females, but the latter were heavier than the former of the same body length. Females with developing and mature ovaries were generally heavier than immature females of the same length. Analyses of the gonadosomatic index and percentage of mature males and females indicate all year-round breeding such that: February-May was spawning, June-October postspawning and November to January recovery period. Fecundity varied between 900 and 23933 eggs per spawn and increased with fish size.

Keywords: *periophthalmus barbarus*; morphometric relationships; reproductive maturation; mangrove swamps; Imo estuary; Nigeria

Introduction

Nigerian mangrove swamps have great fisheries potentials and much is still needed to preserve the ecosystem in view of the potent prevalence and aggressive replacement of the mangrove (*Rhizophora*) by the exotic nipa palms (*Nypa*) (Moses, 1985; Wilcox, 1985; King, 1997). Among the common faunal components of the euryhaline intertidal mudflat ecosystem, is the amphibious gobiid *Periophthalmus barbarus*. It constitutes a source of protein to many communities throughout its geographic range but not object of any special fishery.

Morphometric relationships and spawning pattern are two important data inputs in fishery management. Length-weight relationships(LWRs) have been reported for quite a number of commercially important fishes in Nigeria(Olatunde, 1979; 1985; 1989; Oni, 1983; Marcus, 1984; Ajayi, 1993) and elsewhere. The breeding season of various fishes has also been documented in many localities(Olatunde, 1979; 1989; Marcus, 1982a; 1982b; Etim, 1989).

The mudskipper, *P. barbarus* is primarily fished at the subsistence and artisanal levels of the coastal waters of Nigeria. Moreover, the species is extensively cultured in some parts of the world for aphrodisiac value(Clayton, 1993). Recent studies on *P. barbarus* have focussed on population dynamics Etim *et al*. (Etim, 1996) and length-weight (King, 1996). *P. barbarus* from subsistence fisheries are available in the local markets throughout the year. The present study extends this line of investigation and reports the morphometric relationships and reproductive biology of *P. barbarus* have focussed on population dynamics (Etim, 1996) and length-weight(King, 1996). *P. barbarus* from subsistence catches over a period of 12 months.

1 Materials and methods

Between April 1992 and March 1993, not less than 50 *P. barbarus* were collected from subsistence catches on monthly basis. The sample was from African Trading Company (ATC) fishing settlement at Ikot Abasi, Akwa Ibom State, Nigeria (6°5′ - 7°40′E; 4°25′—6°25′N; Enplan, 1974). The mudskipper were caught by use of traditional non-return valved basket traps (Udolisa, 1994). The specimens were preserved in formalin (10%).

In the laboratory, specimens were sexed and morphometric characters measured. Total length (distance between tip of snout to end of caudal fin), standard length (distance between tip of snout and caudal peduncle) were measured to the nearest 0.1 cm TL by means of a measuring board. Each mudskipper was blotted dry and its body weight(BW) was measured to the nearest 0.001g. The length-weight relationship(LWR) was computed according to Lagler *et al*. (Lagler, 1997).

Liver and gonads were disserted and weighed to the nearest 0.001g. Hepatosomatic and gonadosomatic indices(*HSI* and *GSI*) were calculated by dividing the wet weight of the liver or gonad by the wet weight minus liver or gonad weight of the mudskipper, and expressed as a percentage value. The condition index(K) was determined by expressing somatic weight (i.e., body weight minus gonad weight) as a percentage of cube of total length.

The stage of gonadal development in both sexes were noted as described by Lagler *et al*. (Lagler, 1977) and Kock and Kellermann (Kock, 1991) based on external appearance of the ovaries. Six maturity stages were recognized: stage Ⅰ, immature; stage Ⅱ, early developing; stage Ⅲ, late developing; stage Ⅳ, mature; stage Ⅴ, ripe; stage Ⅵ, spent.

Absolute fecundity (Bagenal, 1978) was estimated in females of maturity stages Ⅳ and Ⅴ. Fecundity was estimated according to Wilkinson and Jones(Wilkinson, 1977). All statistical analyses, including regression of variance and t-test were based on Bailey (Bailey, 1959) and Parker (Parker, 1979).

2 Results

Table 1 Total length (TL), standard length (SL), body weight (BW), gonadosomatic index (*GSI*), gonad length (GL), condition index(K) and hepatosomatic index(*HSI*) of male and female *P. barbarus* sampled during a 12-month period

Parameters	Male	Female
TL, cm	9.3 ± 2.465	8.2 ± 1.814
SL, cm	7.5 ± 1.875	6.8 ± 1.524
BW, g	9.714 ± 6.288	6.996 ± 5.106
GSI, %	0.234 ± 0.142	0.989 ± 1.223
GL, % SL	16.499 ± 3.773	19.317 ± 5.057
K	1.432 ± 1.178	1.208 ± 0.449$^{(*)}$
HSI, %	1.544 ± 1.242	1.667 ± 1.187$^{(ns)}$
Sample size	258	429

notes: ns = not significant; * = $P < 0.05$; other values are significantly different at $P < 0.001$; values are expressed as mean ± *SD*

Morphometric data and organ indices of *P. barbarus* sampled in the study are shown in Table 1. Sex ratio was strongly biased towards females because males are believed to spend more time in the burrows guarding eggs and are less vulnerable to capture vis-á-vis the females. Except in the parameters *GSI* and *HSI*, males were generally longer and/or higher in length(total and standard), weight, and condition index. All correlation coefficients of regression equations fitted to morphometric data(Table 2) except one are highly significant ($P < 0.001$). Exponential (b) value for equation relating TL and BW of the sexes indicated isometry and were not significantly different from the same relationship between SL and BW ($P < 0.001$).

Table 2 Morphometric equations of male and female *Periophthalmus barbarus* during a 12-month period

Equations	Males (n = 181)			Females (n = 299)		
	a	b	r	a	b	r
$BW = a\ TL^b$	− 1.959	3.004	0.966	− 1.995	3.026	0.964
$BW = a + b\ SL$	− 15.323	3.110	0.947	− 13.584	3.057	0.846

Notes: BW = body weight, g; TL = total length, cm; SL = standard length, cm; r = correlation coefficient; n = number of specimen. All r values are significant at $P < 0.001$

Monthly variations in *GSI*, K and *HSI* of male *P. barbarus* (Fig.1) indicate that *GSI* values were higher in March and April; the index declined in September and October (lowest values). The value increased thereafter attaining a peak in February. No obvious pattern was apparent in monthly variation of K with *GSI*. However, *HSI* assumed a trend similar to that of *GSI* but lowest in values between January and March. The *GSI* values in female *P. barbarus* were lowest between June and December while highest from January to May (Fig.2). Similarly, no trend was decerned between the monthly changes of K and *GSI* whereas *HSI* values were apparently a reverse of the *GSI*. There was no significant seasonality in males *GSI* ($t = 0.414$, 213 df, $P > 0.05$) while a significant dry season increase in *GSI* ($t = 3.872$, 382 df, $P < 0.001$) was exhibited by females. The results suggest that higher breeding intensity occurred during the dry season than in the rains.

Monthly trend in mean *GSI*(Fig.1 and 2) and percentage occurrence of gonadal stages were used to

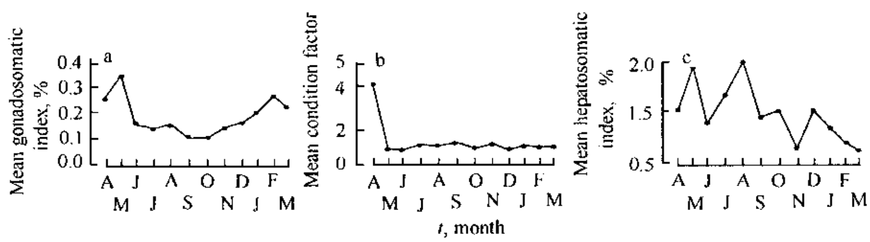

Fig.1 Monthly variation in mean (a) gonadosomatic index(*GSI*), (b) condition idex (*K*), and (c) hepatosomatic index(*HSI*) of male *Periophthalmus barbarus* during a 12-month period

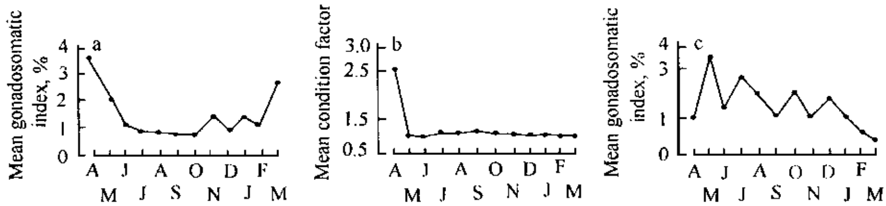

Fig.2 Monthly variation in mean (a) gonadosomatic index (*GSI*), (b) condition index (*K*), and (c) hepatosomatic index(*HSI*) of female *Periophthalmus barbarus* during a 12-month period

establish breeding seasonality in *P. barbarus*. Three major phases of gonadal cycle were established viz spawning, postspawning and recovery. Spawning in males occurred between February and May; postspawning period was from June-October and recovery phase was November to January. Females spawned between March and May; postspawning period spans June to October and the recovery period was November-February.

Seasonal variations in percentage of juvenile (stage Ⅰ to Ⅲ) and adult (stages Ⅳ to Ⅵ) males (size range: 35—15.6 cm TL) and females (size range: 34—13.6 cm TL) correlated with changes in *GSI*, with high percentage of mature and ripe males and females respectively collected in months with high *GSI* values.

The proportion of the stage Ⅳ males was 6.9%—30%. The stage Ⅴ specimens (2.9%—26.7%) were presented in all the months except May and June. The almost absence of stage Ⅵ (2.9%—99%) appears to suggest their immediate return to stage Ⅲ after spawning. Spawning in males occurred between February and May when *GSI* (0.221—0.347) was highest. The proportion of Ⅳ, 2.7%—25.0% and Ⅴ 2.7%—28.6% with both peaks in March, agrees with the earlier assertion that spawning in females was probably from March to May when *GSI* was highest 1.945—3.398. Stages Ⅵ was least in proportion (2.8%—3.0%); there was no stage Ⅵ female in April and June but their appearance in samples of July and August coincided with postspawning and recovery periods respectively. The proportion of occurrence of breeding males 6.7%—56.7% and females 5.4%—53.6% suggests that breeding was likely to have occurred throughout the year in *P. barbarus*.

Statistical analyses showed that morphometric parameters, total and standard lengths, body weight, gonadosomatic index, condition index and hepatosomatic index are significantly different between male and female *P. barbarus* at different stages of gonadal maturation (2 way ANOVA, $P < 0.05$; Table 3) indicating that there were increases in these parameters when the mudskipper became sexually mature.

Analyses of LWRs of male and female mudskipper at different stages of gonadal maturation (Table 4) show there was a trend of increasing *b* values with development in equations relating total length and body weight in each sex. This indicates that mature mudskipper were heavier than immature ones. Such a trend was not evident in males *b* values for maturity stage Ⅵ. It could also be inferred here that males mudskipper between stages Ⅰ and Ⅴ were heavier than their female counterparts of the same stages.

Table 3 Total length(TL), standard length(SL), body weight(BW), gonadosomatic index(*GSI*), condition index(*K*), and hepatosomatic index (*HSI*) of male and female *Periophthalmus barbarus* at different stages of gonadal maturation during a 12-month period

	Stages of gonadal maturation					
	I (n = 48)	II (n = 40)	III (n = 41)	IV (n = 42)	V (n = 21)	VI (n = 3)
a) Males:						
TL, cm	6.9 ± 1.272	8.8 ± 0.867	9.8 ± 1.230	10.6 ± 1.200	12.3 ± 1.228	12.9 ± 0.748
SL, cm	5.6 ± 1.073	7.2 ± 0.7755	8.2 ± 1.287	8.8 ± 1.003	11.2 ± 1.461	10.6 ± 0.602
BW, g	3.755 ± 1.730	7.615 ± 2.186	11.274 ± 4.613	14.167 ± 4.611	21.127 ± 5.957	23.377 ± 4.036
GSI, %	0.035	0.140 ± 0.125	0.195 ± 0.225	0.230 ± 0.185	0.360 ± 0.510	0.039 ± 0.026
K	1.084 ± 0.177	1.087 ± 0.118	1.140 ± 0.151	1.118 ± 0.120	1.127 ± 0.093	1.080 ± 0.797
HSI, %	1.356 ± 0.996	1.499 ± 1.037	1.429 ± 1.058	1.774 ± 1.414	1.474 ± 1.046	0.962 ± 0.866
b) Females:	(n = 64)	(n = 70)	(n = 65)	(n = 36)	(n = 23)	(n = 3)
TL, cm	6.2 ± 0.968	8.1 ± 1.345	9.9 ± 1.003	10.3 ± 1.351	11.0 ± 0.949	12.2 ± 0.814
SL, cm	5.1 ± 0.842	6.8 ± 1.214	8.2 ± 0.814	8.4 ± 1.174	9.0 ± 0.690	9.9 ± 0.525
BW, g	2.731 ± 1.325	6.121 ± 2.930	11.061 ± 3.482	12.960 ± 5.758	17.098 ± 4.860	23.182 ± 6.506
GSI, %	0.220	0.286 ± 0.247	0.704 ± 0.626	2.409 ± 1.412	4.671 ± 2.704	0.300 ± 0.073
K	1.086 ± 0.131	1.050 ± 0.077	1.087 ± 0.105	1.1109 ± 0.120	1.138 ± 0.200	1.147 ± 0.121
HSI, %	1.419 ± 0.869	1.432 ± 0.766	1.537 ± 0.961	1.378 ± 0.967	1.985 ± 1.066	3.813 ± 2.858

Table 4 Morphometric equations of male and female *Periophthalmus barbarus* at different stages of gonadal maturation during a 12-month period

		Stages of gonadal maturation					
		I (n = 46)	II (n = 38)	III (n = 66)	IV (n = 58)	V (n = 32)	VI (n = 3)
a) Males							
TW = a TL^b:	a	−2.047	−1.611	−1.861	−2.173	−2.241	−1.637
	b	3.063	2.630	2.910	3.206	3.271	2.702
	r	0.927	0.891	0.937	0.955	0.955	0.938
b) Females		(n = 43)	(n = 43)	(n = 42)	(n = 54)	(n = 42)	(n = 3)
TW = a TL^b:	a	−1.617	−1.617	−1.569	−1.944	−1.824	−3.658
	b	2.829	2.605	2.616	2.995	2.910	4.579
	r	0.956	0.872	0.928	0.961	0.924	0.998

The number of eggs per spawn in 71 females varied from 900—23933. Fecundity appeared to increase with TL ($r = 0.705$, $n = 69$, $P < 0.001$), SL ($r = 0.655$, $n = 69$, $P < 0.001$), BW ($r = 0.671$, $n = 69$, $P < 0.001$) and K ($r = 0.447$, $n = 69$, $P < 0.02$). There were no correlations between fecundity and *GSI* ($r = 0.159$, $n = 69$, $P > 0.05$) and *HSI* ($r = 0.140$, $n = 69$, $P > 0.05$). Larger females could have bigger ovaries, and thus bigger fecundity. However, the largest mudskipper was not necessarily the most fecund.

3 Discussion

King and Udo (King, 1996) gave a morphometric equation of *P. barbarus* of: log(TL) = 3.084 (TL) − 2.0044 for male while log(TW) = 3.013 log(TL) − 1.9547 female. From the equations *P. barbarus* with a TL of 12 cm would weigh 21.0g and 19.8g in male and female respectively. These values do not vary significantly from the present values of 19.2g males and 18.6g females for 12 cm TL fish estimated from equations shown in present study (Table 2). The results show that males are generally heavier than females. However, the slight high b value for female mudskipper is likely related to a high percentage of sexually mature females samples in the present study. Sexually mature females are heavier than immature females and males of same TL. A higher b value in LWR of females than males (Olatunde, 1979; Oni, 1983; Inyang, 1987; Farmer, 1986; Chu, 1993) and that of males over females (Olatunde, 1985) have been shown in fishes including shell fishes; reports of similar values between sexes are also available (Olatunde, 1979; Bradford, 1981; Ikusemiju, 1983; Marcus, 1984; Olatunde, 1989; Ajayi, 1993; Udo, 1995). It is most likely that the discrepancy is partially due to differences in the degree of sexual maturation in fish measured in the different studies.

The present study reveals a progressive increase in the size of males during sexual maturation, which is at variance with *Tilapia guineensis* (Etim, 1989) and *Penaeus merguiensis* and *P. ensis* (Crocos, 1983; Chu, 1993). However, as aforementioned, mature females are heavier than immature females and males of the same TL. This phenomenon may be related to the energy required of female reproduction. The large amount of reserves and food intake required for oocyte development is evident from the increase in gonadosomatic index during and after maturation. But the higher condition index of males compared with females is also consistent with high energy demand of the obligate-parental gobiid which usually is male-specific (Gibson, 1969; 1978) while the high but insignificant *HSI* of females over males appears another evidence of the high energy demand of the former's reproduction, as liver is the major organ for nutrient storage in fishes.

The process of gonad development requires energy which is usually drawn from visceral tissues, thus, the gonadal development and production are often associated with depletion of the soma (Wootton, 1979; Delahaunty, 1980); if energy reserves are used for gonad recrudescence, there is bound to exist an inverse relationship between gonad, condition and hepatosomatic indices (Delahuanty, 1980; Etim, 1989). Such relationship in the present study was more consistent with males than females (Table 3) where the values in *K* and *HSI* of males at maturity stages Ⅴ (ripe fish) and Ⅵ (spent fish) respectively declined significantly compared to the females. In females, gonadal development was not necessarily at the expence of hepatosomatic and body conditions.

The fecundity of 900-23933 eggs per spawn in *P. barbarus* is comparable with the results from the Chinese mudskipper (*Beleophthalmus pectinirostris*) of 10000—23000 eggs, but inconsistent and higher than the estimates reported for the Indian specimens, *B. Dussumieri* (= *B. dentatus*) with 1028—7197 and 970—4113 eggs from Bombay and Korangi districts respectively (Clayton, 1993). There was an increase in fecundity with body size of *P. barbarus*. This is as expected in fishes (Bagenal, 1978). This is apparently due to a higher ovary weight in bigger females, as observed in the study as well as other studies (Bagenal, 1967; Wootton, 1973; 1979). There were also increases in fecundity with total, standard and ovary lengths, somatic and ovary weights but decreased with increasing egg weight (Udo, 1995); no relationship was evident in fecundity versus condition and hepatosomatic indices.

The present study indicates that *P. barbarus* in the estuarine swamps of Imo River, Nigeria exhibits a year-round breeding comprising: spawning, post-spawning and pre-spawning seasons. The current results agree with reports on *B. dussumieri* whose active period of gonadal maturation spans February to May in males and March to June females and that the fish spawns once in a year; but it is slightly different from the Korangi specimens which spawn twice a year, first in April to May and July-September (Clayton, 1993). The present study reveals further that spawning commences towards end of dry season (March-April) and start of the rains (May). Spawning within this period in tropical equatorial region guarantees hatchlings into environment oferring food abundance and favourable progeny survival opportunities (Miller, 1979; Lowe-McConnell, 1987; Etim, 1989).

Although sexually mature *P. barbarus* could be found during most parts of the year, the data suggest that in Nigeria, the year-round breeding makes the species convenient for aquaculture. Considering also that *P. barbarus* in the study is detrivore-algivore, an index of lower trophic status; conversely, the relative small size at reproduction (Udo, 1995) has to be taken into account before intensive culture of *P. barbarus* can be considered. Thus, further research of the West African amphibious gobiids would provide scientific information not only for the proper management of this valuable fishery in the estuarine ecosystem of Imo River, but also for the development and improvement of aquaculture of this species in Nigeria.

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