SCIENTIA MARINA

Studies on some reproductive aspects of *Pseudotolithus elongatus* in the Cross River estuary, Nigeria*

SUNDAY BEN EKANEM, MARILYN-JOAN ACHIMA and MFON MICHAEL EKERE

Department of Biological Sciences, University of Calabar, P.M.B. 1115, Calabar, Nigeria. E-mail: sbe2005@yahoo.com

SUMMARY: To determine the spawning time of *Pseudotolithus elongatus* in the Cross River estuary, ovarian development, egg diameter, gonadosomatic index (GSI) and hepatosomatic index (HSI) of the female fish were studied from January to December 1998. All ovary developmental stages, including the spawning stage, were present every month, which indicated year-round spawning. High mean values of GSI and egg diameter in December-March and July-September indicated these as the two peak spawning periods for the species. The egg diameter ranged from 1 µm to 590 µm. The highest number of eggs found in an individual fish was 808911. Absolute fecundity of the species in The Cross River estuary can be calculated in relation to standard length using the formula $F = 17557SL^{0.768}$ or $F = 45532W^{0.277}$ in relation to weight. There were evidences to suggest that the species is an asynchronous partial spawner. The stock might be effectively conserved by the imposition of a closed fishing season during the two peak spawning periods.

Key words: *Pseudotolithus elongatus,* spawning, Cross River estuary.

RESUMEN: ESTUDIOS SOBRE ALGUNOS ASPECTOS REPRODUCTIVOS DE *PSEUDOTOLITHUS ELONGATUS* EN EL ESTUARIO DEL RÍO CROSS, NIGERIA. – Para determinar la época de puesta de *Pseudotolithus elongatus* en el estuario del río Cross, se estudió el desarrollo ovárico, el diámetro de los huevos, el índice gonadosomático (GSI) y el hepatosomático (HSI) en hembras desde Enero a Diciembre de 1998. Todos los estadios de desarrollo del ovario fueron presentes en cada mes, lo que indica que la época de puesta abarca a todo el año. Valores altos del GSI y del diámetro de los huevos en Diciembre-Marzo y Julio-Septiembre indican que estos son los dos periodos con un mayor número de puestas para esta especie. El diámetro de los huevos osciló entre 1 µm y 590 µm. El mayor número de huevos encontrado en un solo pez fue de 808911 huevos. La fecundidad absoluta de esta especie en el estuario del río Cross se puede estimar en relación a la longitud estándar mediante la fórmula $F = 17557SL^{0.768}$ o bien $F = 45532W^{0.277}$ en relación al peso. Se observaron evidencias que sugieren que esta tiene un modo de puesta parcialmente asíncrono. El recurso se podría conservar de forma efectiva mediante la imposición de vedas durante los dos periodos de mayor puesta mencionados anteriormente.

Palabras clave: *Pseudotolithus elongatus,* puesta, estuario del río Cross.

INTRODUCTION

The croakers or *Pseudotolithus* spp. are sciaenids found along the West African coast from Senegal to Gabon (Fisher *et al.,* 1981) where they are exploited by both the artisanal fishery (Uwe-Bassey, 1988) and the industrial fishery (Löwen-

berg and Künzel, 1991). Important *Pseudotolithus* species found here are *P. elongatus, P. typus* and *P. senegalensis.* Croakers are important food fish for Nigeria as they constitute about 40% of the total fish landing on the Nigerian coast (Gaffer, 1994). *Pseudotolithus elongatus* is the most economically important species in the Cross River estuary, where it constitutes 43.4% of the total catch by artisanal fishermen (Etim *et al.,* 1994).

The studies conducted on *Pseudotolithus* spp. include those on the growth, maturity and mortality of the Sciaenidae of the tropical West Africa and those on biological data of West African croakers carried out by Longhurst (1964 and 1966). The reproduction biology and production characteristics of three croaker species of the Guinea coast were studied by Zuyev and Giragosov in 1990. Isebor and Abohweyere (1995) studied the dynamics of *P. typus* in the Gulf of Guinea and pointed out that the fishing effort targeting the sciaenids is well over the sustainable level. Elliot (1995), while examining the status of croaker fisheries in Nigeria, noted that the future prospect of trawling in Nigeria depends on the conservation and adequate management of croakers. Studies conducted by Etim *et al.* (1994) alerted the public by stating that *P. elongatus* of the Cross River estuary, exploited at the rate of 0.44, was at the brink of over-exploitation. These warrant immediate conservation measures for the species, which the authors indicated could comprise a limited catch season and a limited catch area. Such measures require a good knowledge of the species' reproductive biology that hitherto is scarce. Tientcheu and Djama (1995) carried out some studies on the reproduction and feeding of *P. typus* and *P. senegalenis* of the Cameroons, but no such work has been done on the reproductive biology of *P. elongatus* in the Cross River estuary, except for the preliminary study by Achima in 1992. This may be due to the fact that the species is very delicate and difficult to study in captivity. This study is an attempt to document such reproductive aspects as fecundity of female *P. elongatus* in relation to its length and weight. The study also aims to determine the spawning time of the species using egg size, gonad development stages, gonadosomatic index (GSI) and hepatosomatic index (HSI) of fish specimens bought from artisanal fishermen.

MATERIALS AND METHODS

The fish used in this study were only female *Pseudotolithus elongatus.* Externally, female fish were distinguished from male fish by a round and serrated anal opening while a gravid female was recognised by the development of pinkish colouration on the abdomen and on the side stretching from the base of the pectoral fins down to the caudal peduncle, though the gonad developmental stage could not be determined till after dissection. Also,
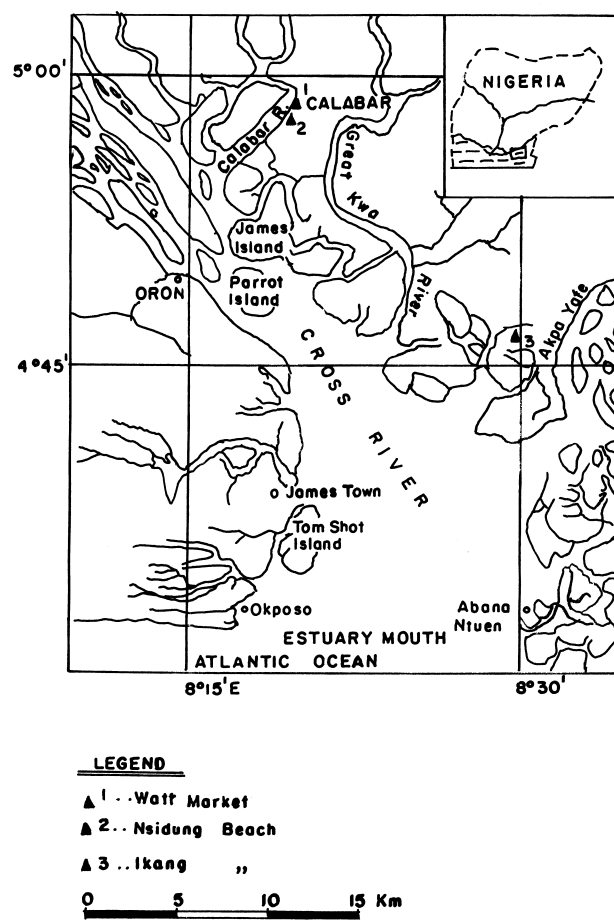

Fig. 1. – Map of Cross River estuary showing sample collection points at Nsidung beach, Ikang beach and Watt market.

the pectoral and the pelvic fins of a gravid female were brighter in colour than those of non-gravid female fish. The fish were bought from local artisanal fishers at Ikang and Nsidung beaches while some were bought from Watt market in Calabar. Locations of the fish collection points are shown in Figure 1.

Each month from January to December 1998 a minimum of 30 gravid female croakers were bought and examined. The 30 fish were obtained at two intervals of a fortnight apart for each month and taken to the laboratory, where the length and weight of individual fish were measured. The weight of the fish was measured to the nearest 0.5 g while the total length (TL) and standard length (SL), taken on the measuring board, were recorded to the nearest 0.1 cm. After measurements, each fish was dissected to remove the gonad, which was weighed and recorded. Gonads representing the different developmental stages were selected and fixed for sectioning while the others were pre-

served in the modified Gilson fluid (Simpson, 1951). This fluid helped to harden the eggs, break the ovarian tissue and liberate the eggs for counting and diameter measurement. Ovaries of each fish were preserved for a minimum of five days before counting the eggs to determine the fecundity. Schaefer (1996) cautioned against the use of Gilson fluid for processing ovaries, pointing out that it causes shrinkage of oocytes and introduces bias in fecundity estimation, but the method had merit in this study as it helped to bring out clearly the variations in egg sizes within each gonad.

A total of 44 fish at ovary development stage V and of standard length above 20 cm were used to determine the fecundity-length and fecundity-weight relationships after the standard length at first maturity for the species was calculated to be between 15 and 20 cm. Length at first maturity was estimated by the regression of percentage of ripe (stage V) females against standard length of the fish following the method of Longhurst (1964). The decision to use fish with stage V gonad in the fecundity-length analysis anchored on the argument by Schaefer (1996) that only the final stages of oocyte maturation provide a distinct hiatus in the distribution of oocytes from which batch fecundity can be determined. The remaining specimens were used in calculating the percentage occurrence of various gonad developmental stages.

Absolute fecundity, defined by Bagenal (1978) as the number of eggs in the ovaries of a fish prior to spawning, also referred to as batch fecundity by Schaefer (1996), was determined. To do this the preserved ovaries were washed several times to remove the fixative. The eggs were then separated from the follicle and placed on filter paper to remove excess water before being weighed to 1 mg precision. Eggs in a 1-gram subsample were counted. Countings were done for five similar subsamples, and the average for the five subsamples was taken as the number of eggs per gram weight of the eggs. Fecundity was calculated by multiplying the total weight of eggs by the number of eggs per gram weight of eggs. Relative fecundity was obtained as the number of eggs per kilogram (kg) of fish or number of eggs per centimetre length of the fish.

Scatter diagrams of fecundity against standard length of the fish were drawn. A regression line was fitted on the scatter diagram by the least squares method (Draper and Smith, 1966). The fecundity-length relationship was established using standard length in the exponential model:

$$\text{Fecundity} = A(L)^B$$

after Healey and Nicol (1975) and Schaefer (1996)

Similarly, the fecundity-weight relationship was derived in the form:

$$\text{Fecundity} = aW^b$$

where a, A, b, B are constants, L is the standard length in centimetres and W is the weight of the fish in kilograms.

The weight of each fish and of its gonad were used to determine the gonadosomatic index (GSI). Thus:

$$GSI = \frac{\text{Weight of gonad}}{\text{Weight of fish}} \; 100$$

The weight of each fish and its liver were used to determine the hepatosomatic index (HSI). Thus:

$$HSI = \frac{\text{Weight of liver}}{\text{Weight of fish}} \; 100$$

Ovaries for sectioning were fixed for 24 hours in formal saline (equal volumes of 10% formalin and 0.9% sodium chloride solution). Small samples taken from the middle portion of each gonad thus fixed were then dehydrated in alcohol, mounted in paraffin wax and sectioned at 8 µm thickness. The sections were stained with haematoxylin and eosin before photographs of the tissue were taken at x100 magnification. The criteria used in classifying the developmental stages of eggs in the gonad were the same as those described by Nikolsky (1963). This classification was also similar to that of Schaefer (1996), except that the postspawning gonad stage was not included or considered in this study. This exclusion was informed by the fact that Longhurst (1964) pointed out that only spawning females can be found close to inshore shallow water, the vicinity where artisanal fishermen operate, and that they move offshore as resting females after spawning. Stage I eggs were eggs at the formative stage without yolk, whereas eggs at stage V were matured and hydrated eggs measuring 401-590 µm in diameter and ready for spawning. Eggs at stage II development were partially yolked, stage III eggs were fully yolked while stage IV eggs were eggs at migratory-nucleus stage. Eggs at stages II, III, and IV had diameters varying from 1 µm to 400 µm.
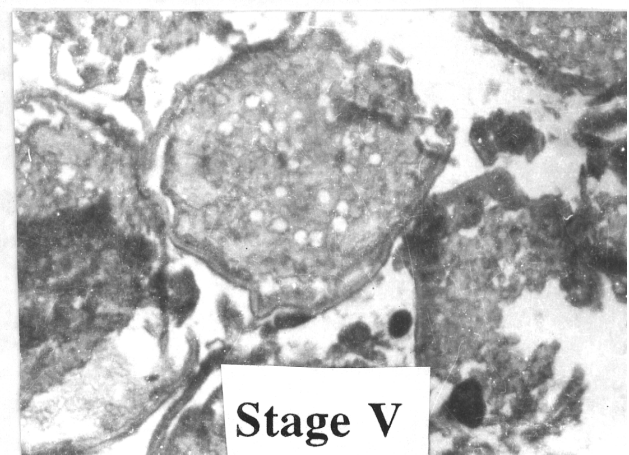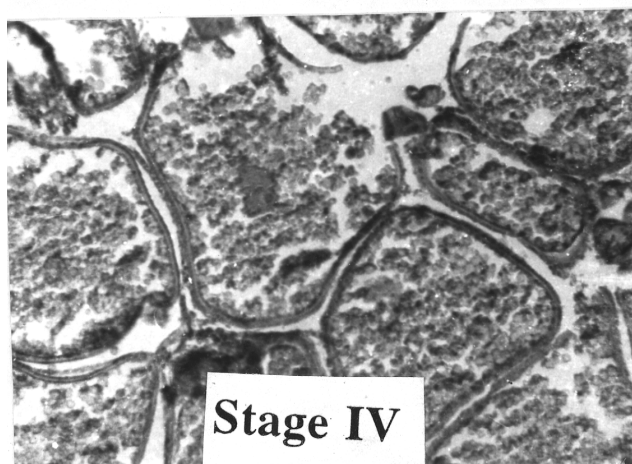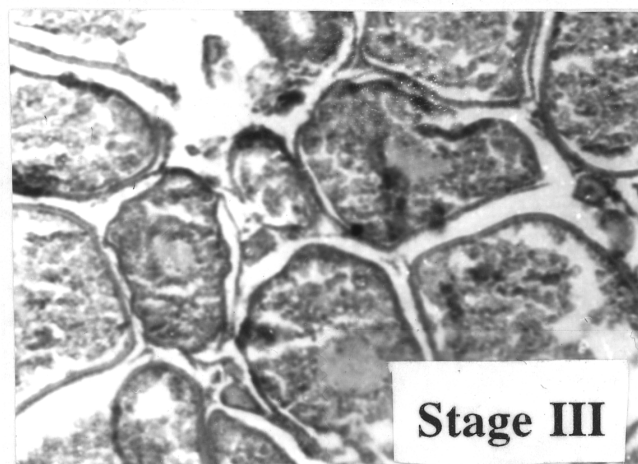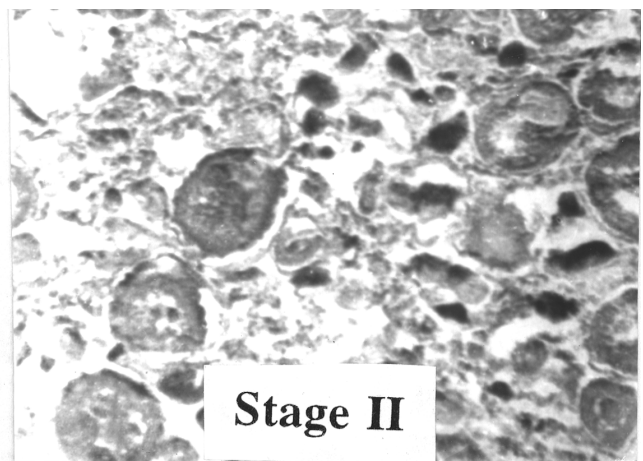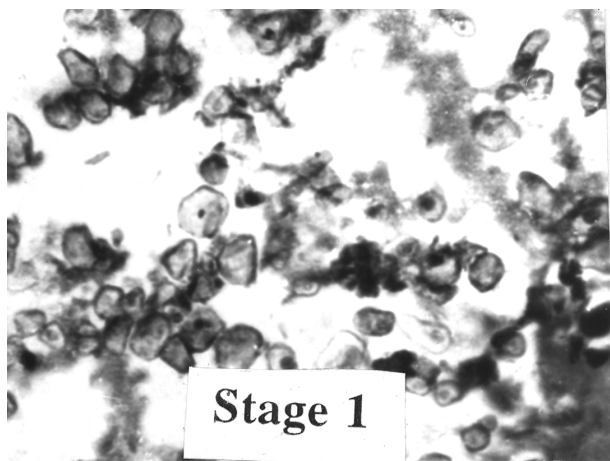
FIG. 2. – Ovarian sections showing development stages in female *Pseudotolithus elongatus*. Stage I: eggs at formative stage (unyolked); Stage II: partially yolked eggs; Stage III: fully yolked eggs; Stage IV eggs at migratory-nucleus stage; Stage V: matured and hydrated eggs.

The diameter of eggs which separated from the follicle was measured with an ocular micrometer on a light microscope. Diameters of 60 eggs were measured for each fish. Eggs for diameter measurements were taken at random after it was verified that there were no differences in egg sizes between the anterior, posterior and the middle parts of the ovary.

RESULTS

Gonad sections revealed five developmental stages as shown in Figure 2. All five stages of gonad development were present every month of the year and the monthly abundance (percentages) of the different gonad developmental stages is presented in

TABLE 1. – Monthly percentage occurrence of different egg developmental stages in the gonads of *Pseudotolithus elongatus* of the Cross River estuary

Month	Percentage of occurrence				
	Stage I	Stage II	Stage III	Stage IV	Stage V
January	33	27	11	16	13
February	66	7	7	14	6
March	56	10	14	12	8
April	50	24	11	9	6
May	50	38	6	4	2
June	40	40	4	12	4
July	23	35	28	10	4
August	18	31	33	12	6
September	46	14	16	17	7
October	50	20	20	6	4
November	66	10	8	13	3
December	50	5	23	12	10

TABLE 2. – Monthly mean values of Gonadosomatic Index (GSI), Hepatosomatic Index (HSI) and Egg Diameter of matured *Pseudotolithus elongatus* of the Cross River Estuary.

Month	Gonadosomatic Index (GSI)	Hepatosomatic Index (HSI)	Egg Diameter (μm)
January	3.59	1.99	275
February	3.27	1.17	326
March	1.34	0.55	291
April	1.16	0.62	208
May	0.91	1.66	183
June	1.16	0.81	263
July	2.05	1.8	239
August	2.22	1.18	251
September	2.18	1.28	265
October	1.53	1.45	203
November	1.80	0.99	247
December	3.75	2.31	249

Table 1. The presence of stage V ovary every month of the year (Table 1) indicated year-round spawning by this species. Table 2 shows monthly mean values of gonadosomatic index (GSI), hepatosomatic index (HSI) and egg diameter. The hepatosomatic index did not have a definite pattern to depict spawning seasons but the high mean GSI values in December, January and February are indicative of the highest spawning activities in these months. Another period of high spawning activity occurred in July, August and September. Spawning activity during this second period was lower than that of the earlier period as indicated by the gonadosomatic indices (GSI). The least spawning activity seemed to have occurred in May, which had the lowest mean GSI value.

Mean egg diameter did not show a clear pattern but high values were obtained in January, February and March, which were the same months in which the highest mean GSI values occurred, except for March. Individually, fish with stage V gonad (egg diameter = 590 μm) were collected in January; inci-
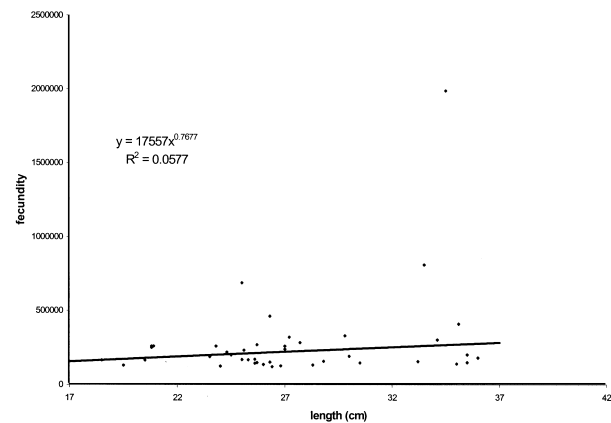

FIG. 3. – Fecundity-length relationship of *Pseudotolithus elongatus*.

dentally, fish with stage II gonad (egg diameter = 100 μm) were also collected in the same month.

Absolute fecundity of the species varied with individual fish. Many smaller fish were found to produce more eggs than bigger ones, but there were also bigger fish with more eggs than smaller ones, as expected. The fish with the highest fecundity of 808,911 eggs was collected in November. The fish had a standard length of 33.5 cm and weighed 613.3 g. This gave the fish a relative fecundity of 1,319,000 eggs/kg of fish. The fish with the lowest fecundity (1570 eggs) was collected in August; it weighed 220.0 g and had a total length of 31.7 cm and a standard length of 25.8 cm. The fish had a relative fecundity of 7000 eggs/kg of fish. The smallest gravid fish in this study with stage V eggs in the gonad was 18.5 cm in total length and 15 cm in standard length, and weighed 45 g.

The scatter diagram in Figure 3 shows the fecundity-length relationship of the species. It was derived from these relationships that the absolute fecundity of *P. elongatus* could be calculated in relation to the standard length by the formula: $F = 17557SL^{0.768}$ or $F = 45532W^{0.277}$ in relation to the fish weight. F is the fecundity or total number of eggs in the gonad prior to spawning, SL is the standard length of the fish in centimetres and W is the weight of the fish in kilograms.

DISCUSSION

The presence of all five stages of ovarian development, and stage V in particular, every month of the year, showed that *P. elongatus* of the Cross River estuary has no obligatory spawning season but spawns continuously all year round. Zuyev and

Giragosov (1990) made similar observation on this species along the Guinea coast. However, there are two preferred periods. All-year-round spawning confirms that recruitment takes place throughout the year, as stated by Etim *et al.* (1994); the peak spawning periods speculated by these authors also coincides with the findings in this study.

The peak spawning period of the species probably coincides with the temperature regime of the coastal waters. The peak in December-March coincides with the high temperatures of the dry season and that of July-September coincides with the high temperatures of August. Longhurst (1964) indicated that the peak spawning period for this species along the Nigerian coast occurs when the water temperature at 20 m depth is about 27°C. This author did not mention salinity, which might contribute to the spawning of the species.

The spawning time of *P. elongatus* in the Cross River estuary is similar to that of *P. senegalensis* and *P. typus* of the Cameroon, as reported by Tientcheu and Djama (1995); the only difference is in the peak spawning periods. *P. elongatus* of the Cross River estuary has its first peak in December, January and February and the second peak in July, August and September, whereas the first peak for *P. senegalensis* and *P. typus* of the Cameroon occurred in March, April and May and the second peak was in November and December. The high mean values of egg diameter for *P. elongatus* of the Cross River estuary, which extended from January to March, suggested that the first peak spawning period for this species actually terminates in March, indicating that the first peak spawning period of *P. elongatus* in the Cross River estuary is longer or more extensive than those of *P. senegalensis* and *P. typus* of Cameroon. Similar differences were found in the second spawning peak periods for these species in the two adjacent waters. It could be noted that as the first peak spawning period for *P. elongatus* terminated, that of *P. senegalensis* and *P. typus* commenced; this could be a strategy adopted by this genus to maximise the use of abundant food materials brought into the water by the early rains.

The lack of a definite pattern in the mean values of the hepatosomatic index (HSI) is probably due to the fact that continuous spawning is superimposed on one major and one minor spawning period of *P. elongatus* in the Cross River estuary. The hepatosomatic index shows an inverse relationship with the gonadosomatic index (GSI) when a species has a definite spawning season. This is because the process of gonad development requires energy, which is usually drawn from the visceral tissues such as the liver, as reported by Delahunty and de Vlaming (1980). An inverse relationship between the two indices showed up in May, when the mean GSI value reached its minimum (0.9), while the HSI mean value was very high (1.66), indicating a very low reproductive activity and a high energy reserve in the liver.

The regression statistics showed variability about the functional relationships between fecundity and length, and the same was observed between fecundity and weight. The correlation coefficient (r) for all regressions was significantly (P < 0.05) different from zero. This led to the functional relationship with size given in exponent form as $F = 17557SL^{0.768}$ or $F = 45532W^{0.277}$. Absolute fecundity calculated using standard length was closer to the actual total egg count than that calculated using weight of the fish; the formula based on weight should therefore be applied with caution, bearing in mind that somatic weight changes towards the spawning period can introduce some errors in the calculation. It was for this reason that Blaxter (1969) pointed out that it is more advantageous to relate fecundity to length rather than to weight of the fish.

An absolute fecundity of 1570 eggs obtained from a fish with a standard length of 25.8 cm and a weight of 229.0 g, which was the lowest absolute fecundity from a fish in this study, did not look real. By calculations a fish with a standard length of 25.8 cm and a weight of 229.0 g is expected to have between 205,000 and 213,000 eggs, which is about 130 times the number of eggs actually found in this specimen. A possible explanation for this is that the fish was caught after partial spawning. This is one evidence to show that this species is an asynchronous batch spawner. Additional evidence came from three fish each of 24.5 cm standard length with stage V gonads containing 198,764, 7470, and 10,334 eggs respectively. Similar differences were found in other fish of various sizes. Furthermore, variations in sizes of eggs (different egg developmental stages) were noted in the gonads of all specimens examined in this study and in particular egg sizes ranging from 100 to 590 µm were found in a fish with stage V gonad. All these findings suggest that ovulation in this species occurs in short succession as oocytes grow in size to produce several batches during the spawning season, as in other asynchronous batch spawners (Tyler and Sumpter, 1996). The smallest gravid fish with stage V gonad in this study was 15

cm in standard length (or 18.5 cm total length) and weighed 45 g. This is smaller than the smallest specimen of this species with eggs (stage V) obtained during a preliminary study in 1992 (Achima, 1992), which was 18.2 cm in standard length and weighed 76.7 g. This indicates that *P. elongatus* of the Cross River estuary starts to spawn at a smaller size and probably at a younger age six years after the preliminary studies. This observation is in conformity with the statement made by Echeverria (1987) that adjustment of age and size at maturity by a species are adaptive characteristics exhibited as a response to external pressures. In a heavily exploited stock one can expect the recruits to grow faster and mature earlier due to food abundance and reduced competition, as demonstrated by Bückmann (1963) in the case of plaice.

The findings from this study now provide guidelines for successful conservation of this species in the Cross River estuary. Etim *et al.* (1994) recommended among other measures the imposition of a closed area or closed fishing season. The area to be closed is not easy to demarcate as the fish keeps moving but a closed season imposed during the peak spawning periods, December-March and July-September, may effectively conserve the stock, though it could be difficult to enforce.

ACKNOWLEDGEMENTS

REFERENCES

Achima, M.N. – 1992. *Fecundity and spawning in Pseudotolithus elongatus of the Cross River estuary.* BSc thesis, Department of Biological Sciences, University of Calabar, Nigeria.

Bagenal, T.B. – 1978. Aspects of fish fecundity. In: S.D. Gerking (ed.), *Ecology of freshwater fish production*, pp. 75-95. Blackwells, Oxford, UK.

Blaxter, J.H.S. – 1969. Development: eggs and larvae. In: W.S. Hoar and D.J. Randal (eds.), *Fish Phisiology* Vol. 3, pp. 117-252. Academic Press, New York and London.

Bückmann, A. – 1963. Das Problem der optimalen Bufischung. Eine Darstellung zur Methodik der Fischerwiss 141 Beiheft 1: 1-107.

Delahunty, G. and V.L. de Vlaming. – 1980. Seasonal relationships of ovary weight, liver weight and fat stores with body weight in the gold fish, *Carassius auratus* (L). *J. Fish. Biol.*, 16: 5-13.

Draper, N. and H. Smith. – 1966. *Applied regression analysis.* John Wiley & Sons Inc. New York, London, Sydney.

Echeverria, T.W. – 1987. Thirty-four species of California rockfishes: Maturity and seasonality of reproduction. *Fish. Bull.,* 85(2): 229-250.

Elliot, O.O. – 1995. Present status of the croaker fisheries in Nigeria. In: Abstract of First Pan African Fisheries Congress on Sustainable Development of Fisheries in Africa held in Nairobi, Kenya 31 July-4 August 1995. p. 191.

Etim, L., B.U. Uwe-Bassey and T. Brey. – 1994. Population dynamics of the West African croaker *Pseudotolithus elongatus* in the Cross River Estuary, Nigeria. *Sci. Mar.*, 58(4): 315-321.

Fischer, W., G. Bianchi and W.B. Scott. – 1981. FAO species identification sheets for fishery area 34, 47, Vol. 7. Canada funds in trust, Ottawa, Canada, by arrangement with FAO.

Gaffer, J.A. – 1994. Fish production and the Nigerian environment, status, opportunities, threats. A keynote address presented at the 11th Annual Conference of Fisheries Society of Nigeria, Lagos 22-24 February 1994.

Healey, M.C. and R.A.W. Nicol. – 1975. Fecundity comparisons for various stocks of lake white fish *Coregonus clupeaformis. J. Fish. Res. Bd. Canada*, 32: 404-407.

Isebor, C.E. and P.O. Abohweyere. – 1995. Population dynamics of *Pseudotolithus typus* in the Gulf of Guinea. In: Abstract of First Pan African Fisheries Congress on Sustainable Development of Fisheries in Africa held in Nairobi, Kenya 31 July-4 August 1995. p. 135.

Longhurst, A.R. – 1964. Bionomics of the Sciaenidae of tropical West Africa. *J. Cons.*, CIEM 29: 93-114.

Longhurst, A.R. – 1966. A Synopsis of biological data on West African croakers, *P. typus, P. elongatus* and *P. senegalensis.* FAO *Fish. Synop.*, No. 35.

Löwenberg, U. and T. Künzel. - 1991. Investigations on the trawl fishery of the Cross River Estuary, Nigeria. *J. Appl. Ichthyol.,* 7: 44-53.

Nikolsky, G.V. - 1963. *The ecology of fishes.* Academic Press Inc. Berkeley Square London. p. 160.

Schaefer, K.M. – 1996. Spawning time, frequency and batch fecundity of yellow tuna, *Thunnus albacares,* near Clipperton Atoll in the eastern Pacific Ocean. *Fish. Bull.*, 94: 98-112.

Simpson, A.C. – 1951. The fecundity of plaice. UK Ministry of Agriculture, Fisheries and Food Investigation. Series 217: 3-27.

Tientcheu, J.Y. and T. Djama. – 1995. Biological aspects of two species of *Sciaenidae, Pseudotolithus typus* and *Pseudotolithus senegalensis* of Cameroon: Reproduction and feeding. In: Abstract of First Pan African Fisheries Congress on Sustainable Development of Fisheries in Africa held in Nairobi – Kenya. 31 July-4 August 1995. p. 29.

Tyler, C.R. and J. P. Sumpter. – 1996. Oocyte growth and development in teleosts. *Rev. Fish Biol. Fish.*, 6: 287 – 318.

Uwe-Bassey, B.U. – 1988. *The catch structure of the artisanal gillnet fishery of the lower Cross River*. M.Sc. Thesis. University of Calabar, Nigeria. 105 pp.

Zuyev, G.V. and V.E. Giragosov. – 1990. Reproduction biology and production characteristics of three species of croakers (*Sciaenidae*) along the Guinea coast (Abstract).

Scient. ed.: F. Piferrer