Biol. (1982) **21**, 485–496

Observations on the reproductive biology of the shad, *Ethmalosa fimbriata* (Bowdich), in the coastal waters of Cape Coast, Ghana

J. Blay Jr* and K. N. Eyeson†

Department of Zoology, University of Cape Coast, Cape Coast, Ghana

(*Accepted 15 December 1981*)

The gonads of *Ethmalosa fimbriata* have been classified according to five and four maturity stages in the male and female, respectively. The species appears to mature at 22·0 cm in Ghana waters. The fecundity and frequency distribution of oocytes have been determined. Monthly changes in the proportions of gonadal stages and gonadosomatic index indicate that the species spawns in the sea from October to March. The results have been compared with data on populations occurring in other West African countries.

I. INTRODUCTION

As previously communicated (Blay & Eyeson, 1982), there is a dearth of information on the biology of the shad, *Ethmalosa fimbriata*, found in the coastal waters of Ghana. This is probably because this fish species is poorly represented in the local fishery. According to Bainbridge (1963), the distribution of the species along the West African coast shows two main areas of concentration; one area stretches from the mouth of River Senegal to the coast of Sierra Leone, and the other occurs along the coasts of Nigeria and Cameroon to the mouth of River Congo. An isolated concentration is found in Abidjan area in Ivory Coast. Thus, most of the published works are based on observations in these countries where this fish is of commercial importance. The reports (Salzen, 1958; Bainbridge, 1957, 1961, 1963; Scheffers, 1971; Fagade & Olaniyan, 1972) indicated however, that there are differences in the biology of the local populations studied. The present investigation therefore attempts to add to these studies by focusing attention on the reproduction of the species in Ghana waters.

II. MATERIALS AND METHODS

Monthly samples of *E. fimbriata* were obtained from the fishermen at Elmina fishing harbour and by cast net in the Kakum River estuary (Blay & Eyeson, 1982). Some specimens were also caught by cast net in the Elmina lagoon, an open lagoon about 3 km west of the Kakum River estuary. This complex of coastal water systems in a small circumscribed area was sampled in an attempt to locate the spawning grounds of the species.

The standard and total lengths (S.L. and T.L.) and the weight of each fish were determined.

*Present address: University of Ilorin, Nigeria.

†All communications are to be sent to K. N. Eyeson.

0022–1112/82/110485+12 $03.00/0

The sex and maturity stage of each specimen were ascertained by the macroscopic and microscopic examination of the gonads. For the estimation of fecundity, ovaries containing clearly discernible eggs were considered ripe (Stage IV). These were cut into 4–6 pieces and fixed in modified Gilson's fixative (Simpson, 1951). After 2 weeks the bottles were shaken until the connective tissues were separated from the eggs. The eggs were then centrifuged thrice in Gilson's fixative to ensure thorough cleaning, and were counted using the Lowestoft electronic egg counter (Parrish *et al.*, 1960).

Samples of testes and ovaries in various stages of maturity were fixed overnight in Bouin's fluid and processed for histological examination. Transverse and longitudinal sections of 6–7 μm were prepared from the anterior, middle and posterior regions of the gonads to ascertain the distribution of germ cells, but since there were no differences only the transverse sections of the midregion were used. Five specimens of each maturity stage were studied, and in the ovaries the maximum diameters of the oocytes with visible nuclei were measured with a micrometer eyepiece.

III. RESULTS

MATURITY STAGES

On the basis of the appearance of the fresh gonads, five maturity stages were established for the males and four for the females. A histological examination of these stages showed distinct differences and these have been summarized in Table I below.

The maximum sizes of male and female fish in Stage I are 19·9 and 20·6 cm, respectively, few fish in the higher stages of maturity fell within these limits. On the basis of the criteria outlined in Table I, fish in Stage II could be classed as maturing while those in Stage IV were considered mature.

MONTHLY CHANGES IN FREQUENCY OF GONADAL STAGES

Only specimens in Stage II and above were used for this study. No estuarine nor lagoon specimens had developed to that stage and therefore did not form part of the samples analysed. The sample sizes are shown in Table II. These results have to be treated with caution because of the small sample sizes involved, but the trends can nevertheless be used as a guide. The variations in the proportions of the different gonadal stages are illustrated in Fig. 1.

(a) *Males*

High proportions of Stage II males were caught from February to June 1976 but there was a decrease from July 1976 to March 1977. Stage III males constituted 81·8% of the sample in August which suggests that the Stage II males of previous months were developing into Stage III. These matured into Stage IV which resulted in its high representation (50·0–70·6%) in the samples collected from September 1976 to January 1977. The appearance of Stage V fish in the October sample could indicate the onset of spawning activity which seemed to have continued until March 1977, as judged by the presence of Stage V specimens in the samples, except for January.

(b) *Females*

Stage II females did not show any regular pattern in the monthly proportions. A high percentage of Stage III however was recorded from April to August 1976, with a peak in June (84·2%). No Stage IV specimens were caught from June to August but they reappeared in September samples and increased in proportion

TABLE II. Monthly frequency changes in gonadal stages

Year	Month	Sex	Percentage frequency of gonadal stages			
			II	III	IV	V
1976	February	M	41·7 (5)*	8·3 (1)	50·0 (6)	–
		F	50·0 (5)	30·0 (3)	20·0 (2)	–
	March	M	57·1 (8)	–	42·9 (6)	–
		F	44·4 (4)	33·3 (3)	22·2 (2)	–
	April	M	71·4 (5)	14·3 (1)	14·2 (1)	–
		F	20·0 (1)	60·0 (3)	20·0 (1)	–
	May	M	52·9 (9)	23·5 (4)	23·5 (4)	–
		F	56·3 (9)	18·8 (3)	25·0 (4)	–
	June	M	69·2 (9)	15·4 (2)	15·4 (2)	–
		F	15·8 (3)	84·2 (16)	–	–
	July	M	31·3 (5)	37·5 (6)	31·3 (5)	–
		F	27·8 (5)	72·2 (13)	–	–
	August	M	–	81·8 (9)	18·2 (2)	–
		F	42·9 (3)	57·1 (4)	–	–
	September	M	16·7 (1)	33·3 (2)	50·0 (3)	–
		F	11·1 (1)	44·4 (4)	44·4 (4)	–
	October	M	5·6 (1)	16·7 (3)	50·0 (9)	27·8 (5)
		F	57·1 (8)	21·4 (3)	21·4 (3)	–
	November	M	20·0 (4)	15·0 (3)	50·0 (10)	15·0 (3)
		F	72·4 (21)	3·5 (1)	24·1 (7)	–
	December	M	11·8 (2)	5·9 (1)	70·6 (12)	11·8 (2)
		F	25·0 (3)	16·7 (2)	58·3 (7)	–
1977	January	M	27·3 (9)	18·2 (6)	54·6 (18)	–
		F	38·5 (5)	23·1 (3)	38·5 (5)	–
	February	M	–	–	6·3 (1)	93·8 (15)
		F	–	–	100·0 (14)	–
	March	M	24·0 (6)	–	36·0 (9)	40·0 (10)
		F	44·4 (4)	11·1 (1)	44·4 (4)	–

*Figures in parentheses refer to number of fish.

a monthly basis, except for January and March 1977, the ratio did not differ significantly from the expected 1 : 1 ratio. The spawning habits of the species are not known but it is possible that the spent females leave the spawning grounds before the males, hence a reduction in their relative numbers from January to March 1977, as compared to the pre-spawning period June to September, 1976.

GONAD WEIGHT AND LENGTH RELATIONSHIP

A hyperbolic relationship exists between the ovary weight and length of females (Fig. 3); this could be described by an equation:

$$GW = aL^n,$$

$$\text{or } \log GW = \log a + n \log L \text{ (Bagenal, 1957),}$$

where GW is gonad weight, L is total length, a is a constant and n is an exponent.

In the males also the gonad weight tended to increase with size but the mathematical relationship is less clear.

TABLE I. Maturity stages in *E. fimbriata*

Stages	Male	Female
I	Testes are small and weigh 0·03–0·08 g; spermatogonia are present but boundaries of tubules are not discernible.	Ovaries are very small and colourless, and weigh 0·07–0·60 g; oocytes are in protoplasmic phase, stain darkly and measure 0·02–0·09 mm.
II	Testes slightly enlarged, pale red and weigh 0·07–0·66 g; are firm to touch; inter-tubular tissues have developed, thus making tubular arrangement prominent; spermatogonia and primary spermatocytes are present.	Ovaries slightly enlarged, pale red and weigh 0·21–1·34 g; oocytes measure 0·02–0·18 mm and are still in protoplasmic phase.
III	Testes are creamy red and weigh 0·18–0·56 g; tubules are distinct, and spermatogonia, spermatocytes and spermatids are present; a few spermatozoa may be present.	Ovaries are deep red to purple due to large blood vessels in the wall; weigh 0·45–5·10 g; oocytes in early stages of vitellogenesis are present together with protoplasmic oocytes.
IV	Testes much enlarged, creamy white and soft; weigh 0·64–6·85 g; no milt produced on stripping but milt flows when testis wall is ruptured; tubules are well formed and cells in all stages of spermatogenesis are present; spermatozoa are abundant.	Ovaries much enlarged, pinkish or yellowish, and weigh 1·81–17·90 g; large number of yolky oocytes of different sizes are present; ova not extruded on stripping but separate readily when ovary wall is ruptured; non-yolky oocytes also present.
V	Milt flows when fish is stripped; testes are greyish white, large and weigh 1·42–9·269 g; tubules are enlarged and are fully filled with spermatozoa.	Not represented.

to a peak (100%) in February 1977. This pattern of changes shown by Stage IV samples seems to support the suggestion that spawning in the species probably started in October and continued until March.

SIZE AT MATURITY

The smallest Stage IV male fish had a total length of 20·3 cm while the smallest Stage IV female measured 21·2 cm. A length–frequency distribution of all the Stages IV and V specimens is shown in Fig. 2. Modal sizes of 23·0 cm and 22·0 cm were recorded for the males and females, respectively, which suggests that the females mature at a smaller size than the males.

SEX RATIO

The monthly sex ratios of the marine samples are shown in Table III. When all the samples are pooled a ratio of one male to 0·88 female is obtained. On

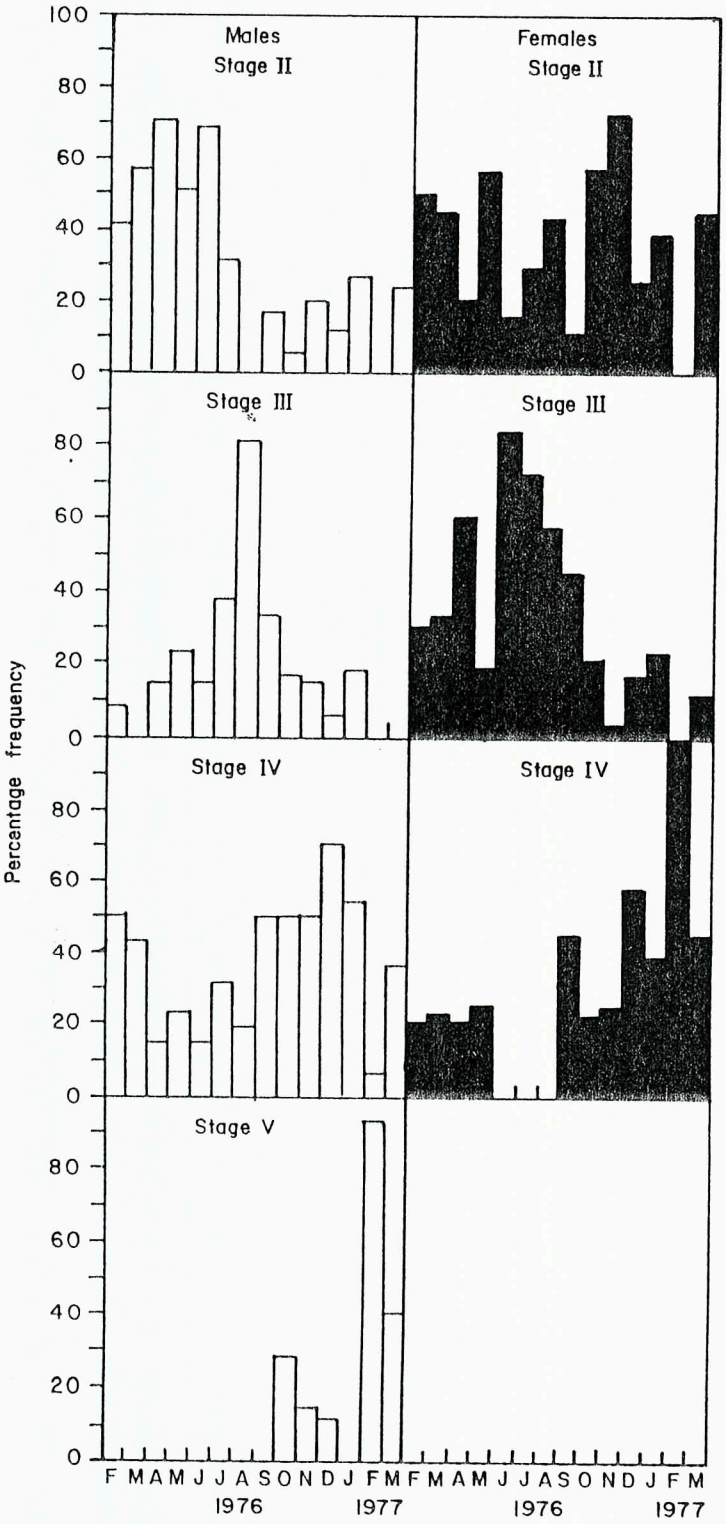

FIG. 1. Monthly frequency of gonadal stages in *E. fimbriata*.

FECUNDITY

Ovaries of 35 mature female fish were used for these estimates. The number of eggs ranged from 16 000 for a fish 21·2 cm long and weighing 88·0 g to 51 750 for a 30·4 cm specimen weighing 242·7 g. These relationships as illustrated in Fig. 4 indicate an increase in egg production with length and weight. The linear

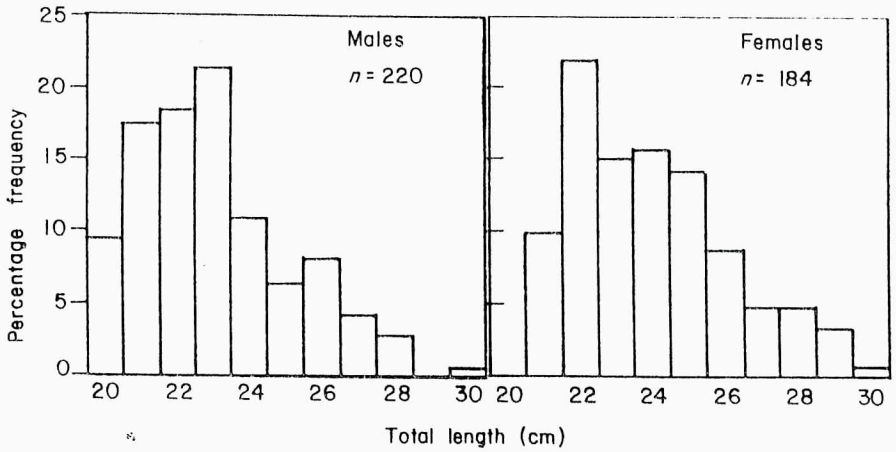

FIG. 2. Length frequency distribution of mature male and female *E. fimbriata* from the sea, (n = number of fish).

TABLE III. Monthly sex ratio of marine *Ethmalosa fimbriata*

Year	Month	No. of fish sexed	No. of males	No. of females	Sex ratio (male : female)	χ^2
1976	February	29	14	15	1 : 1·07	0·03*
	March	31	19	12	1 : 0·63	1·58*
	April	15	8	7	1 : 0·88	0·07*
	May	33	17	16	1 : 0·94	0·03*
	June	32	13	19	1 : 1·46	1·13*
	July	34	16	18	1 : 1·13	1·12*
	August	29	14	15	1 : 1·07	0·03*
	September	28	12	16	1 : 1·33	0·57*
	October	39	20	19	1 : 0·95	0·03*
	November	51	20	31	1 : 1·55	2·37*
	December	29	17	12	1 : 0·71	0·86*
1977	January	50	36	14	1 : 0·39	6·48**
	February	30	16	14	1 : 0·88	0·13*
	March	34	25	9	1 : 0·36	7·53**

*Not significant at the 5% level of probability.
**Significant at the 5% level of probability.

relationships can be represented by the equations:

$$F = 2788{\cdot}71L - 39351{\cdot}96 \ (r = 0{\cdot}84) \quad \text{(i)}$$

$$\text{and } F = 149{\cdot}77W + 8250{\cdot}28 \ (r = 0{\cdot}85), \quad \text{(ii)}$$

where F is fecundity, L is total length and W is body weight.

FREQUENCY DISTRIBUTION OF OOCYTES

The frequency distribution of different sizes of oocytes in the ovaries of the four maturity stages is shown in Fig. 5. In the Stage I fish a modal size of 0·04 mm was obtained and this increased to 0·07–0·08 mm in the Stage II ovary. This modal size was maintained in the advanced stages of maturity. The smallest oocyte measured 0·02 cm and the largest recorded in Stages I, II, III and IV ovaries

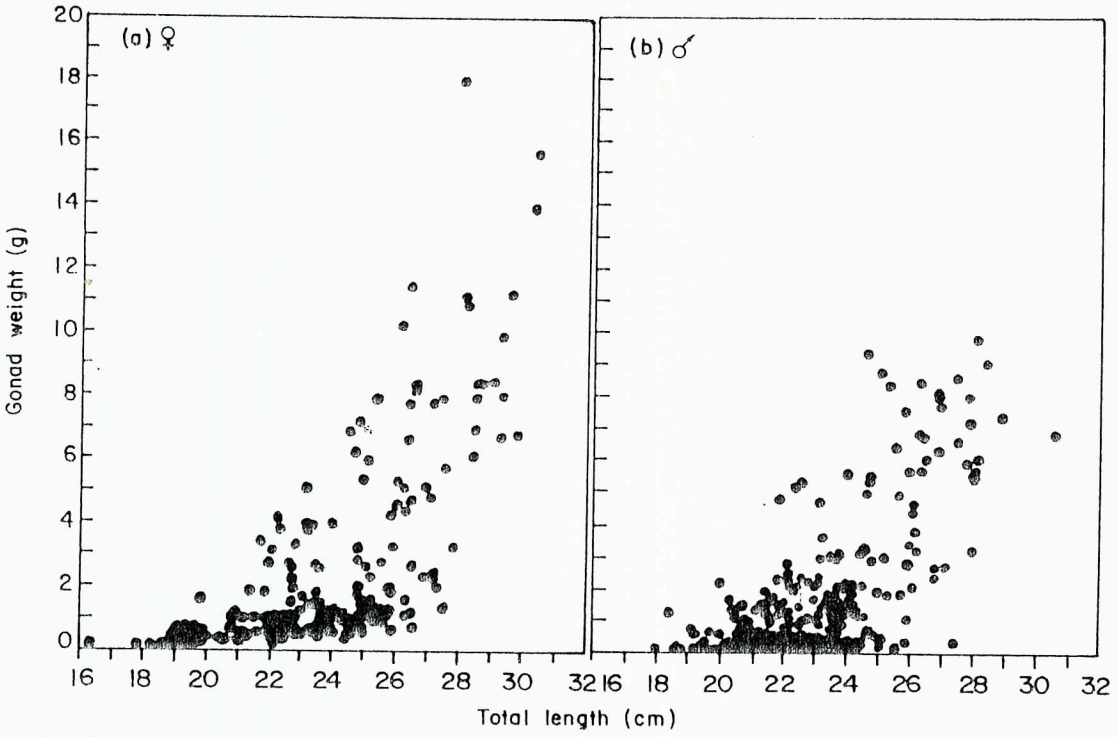

FIG. 3. Scatter diagram showing the relationship between gonad weight and total length of *E. fimbriata*.

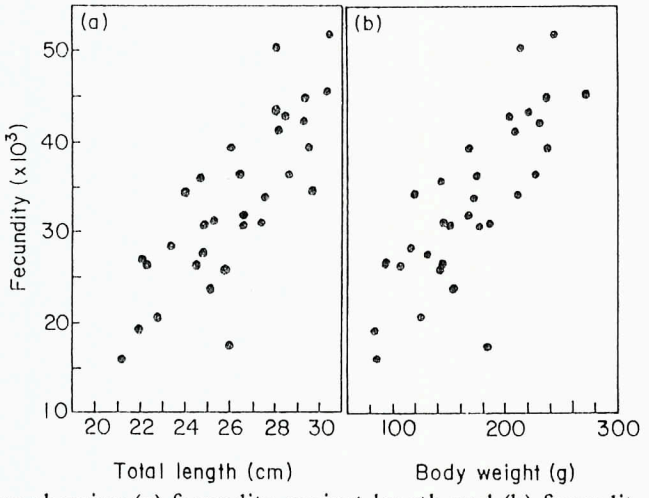

FIG. 4. Scatter diagrams showing (a) fecundity against length and (b) fecundity against body weight of *E. fimbriata*.

measured 0·09, 0·18, 0·35 and 0·54 mm, respectively. As shown in Table I, vitellogenesis begins in Stage III so that Stage IV ovaries which are considered mature would contain two populations of oocytes (yolky and non-yolky) of different size ranges. A regrouping of oocytes in Stage IV, at 0·05 mm intervals, gives a distribution illustrated in Fig. 6. Assuming that each of the two types of oocytes has a normal distribution, by plotting the frequencies as cumulative percentages on normal probability paper (Harding, 1949) an inflexion occurs at the midpoint of the 0·25–0·30 mm size classes. This point separates the two types of oocytes. The frequency distribution of ova in a ripe ovary has been used to predict the duration and pattern of spawning in fish (Hickling & Ruttenberg, 1936).

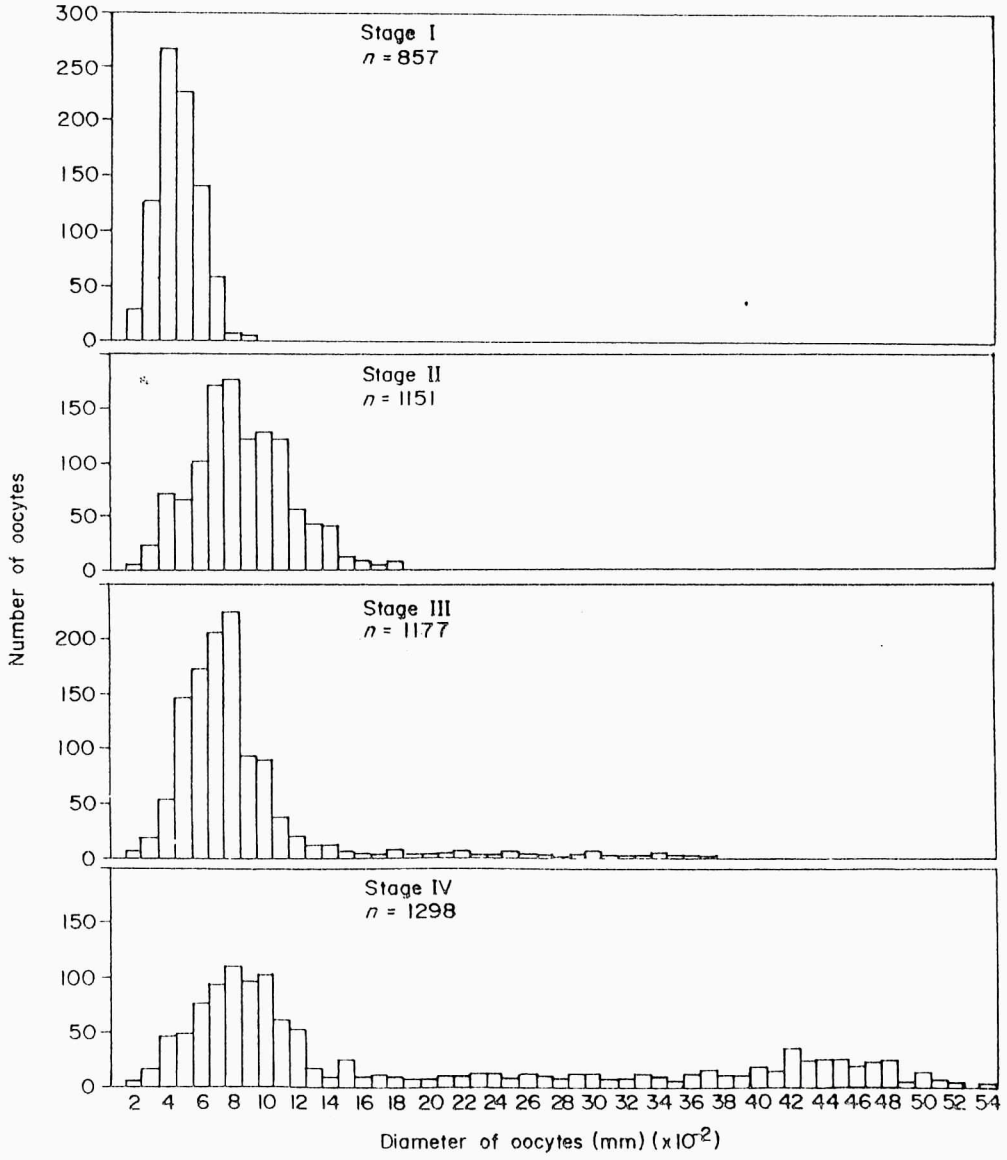

FIG. 5. Frequency distribution of oocytes at different stages of maturity in *E. fimbriata*, (n = number of oocytes).

VARIATIONS IN GONAD WEIGHT AND GSI

The gonadosomatic index (GSI) or the maturity coefficient was calculated from the formula:

$$\frac{GW}{BW} \times 100,$$

where GW is gonad weight and BW is body weight. Figure 7 shows the monthly variations in the gonad weight, in which the pattern is similar to the changes in the GSI as illustrated in Fig. 8 (a & b). A low GSI was recorded from February to September 1976, but this increased to a peak in October 1976 and was followed by a steady decline up to January 1977. A sudden increase was observed, however, in February 1977. The high GSI values seem to coincide with the spawning period as already inferred from the monthly variations in the maturity stages of the ovaries.

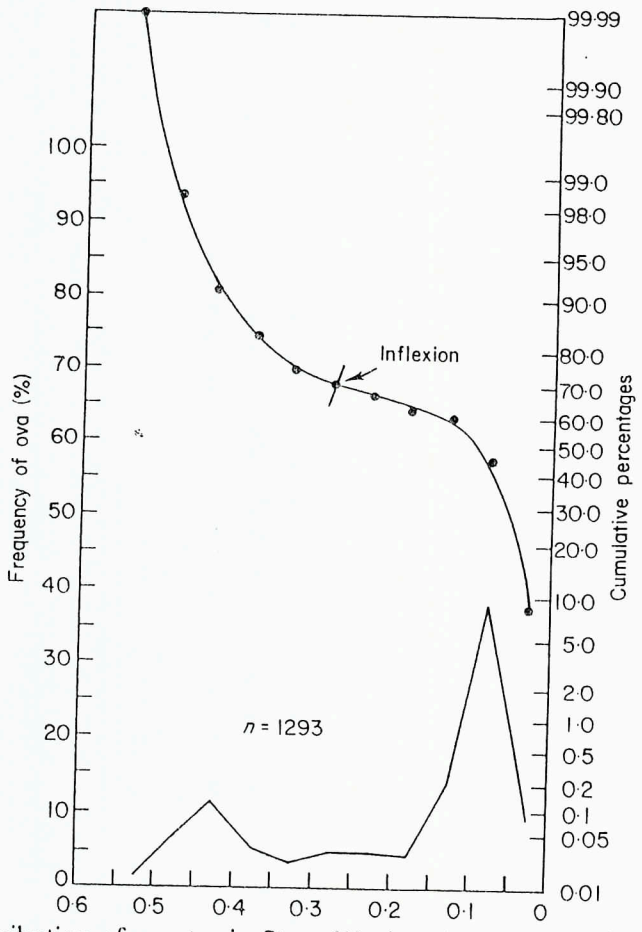

FIG. 6. Frequency distribution of oocytes in Stage IV plotted on a probability paper, (n = number of oocytes).

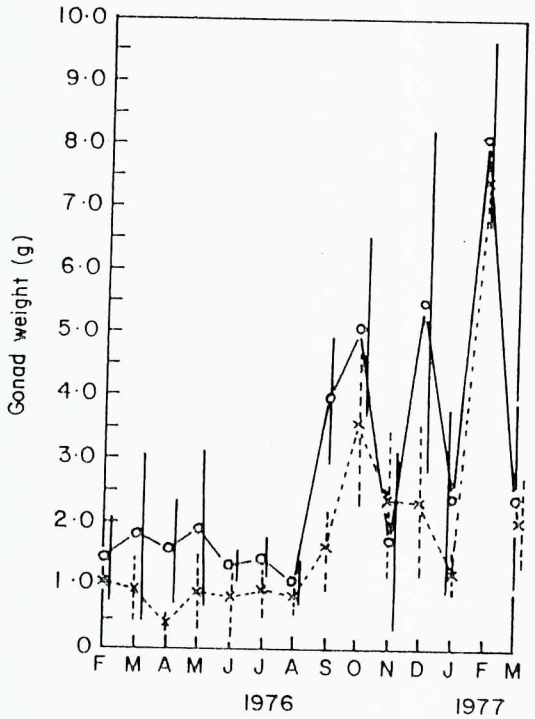

FIG. 7. Mean monthly gonad weight of male (×--×) and female (O——O) *E. fimbriata*. Vertical lines represent 2 S.E. (see Fig. 8 for number of fish).

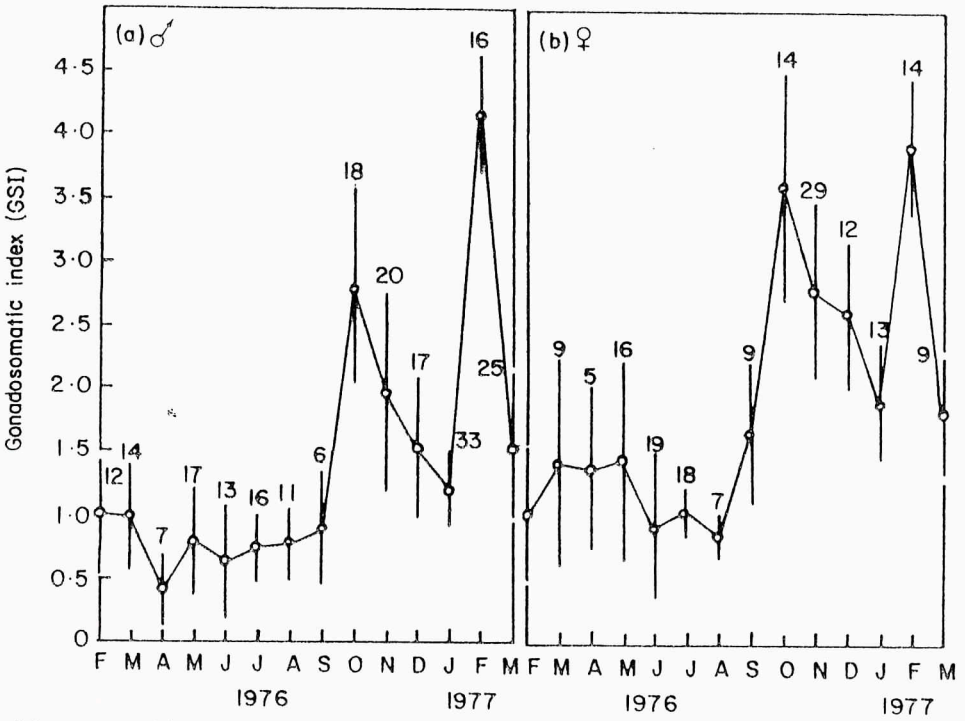

FIG. 8. Mean monthly GSI in (a) male and (b) female *E. fimbriata*. Vertical lines represent 2 S.E. The figures on top of the vertical lines represent number of fish in Stage II–IV/V.

IV. DISCUSSION

The maximum total length of mature *E. fimbriata* caught in Cape Coast waters measured 30·4 cm which is almost the same size (31·0 cm) as that caught in the Lagos lagoon (Fagade & Olaniyan, 1972). However, whereas the Cape Coast population seemed to mature at 22·0 cm, those of Lagos lagoon mature at much smaller sizes of 12·0 and 17·0 cm for the male and female, respectively. The population in the Sierra Leone river estuary, however, attain a maximum size of 39·0 cm and the male and female mature at about 27·0 cm and 28·0 cm, respectively. It would appear that these differences are ecologically conditioned.

Monthly variations in the sex ratio of Cape Coast samples, apart from those of January and March 1977, showed no significant difference from the expected 1 : 1 ratio as also observed by Salzen (1958) and Fagade & Olaniyan (1972) in other populations. Olsen & Lefevere (1969), however, recorded a sex ratio of one male to 2·08 female in the Midwest State of Nigeria. The significant increase in the number of males over females in January (1 : 0·39) and March (1 : 0·36) in the Cape Coast population could probably be attributed to an early departure of the females from the spawning grounds after shedding their eggs. Presumably, the males stay a little longer for the late spawners.

The fecundity of *E. fimbriata* in Cape Coast waters ranged from $1{\cdot}6 \times 10^4$ to $5{\cdot}1 \times 10^4$. This is low, compared with the $2{\cdot}38 \times 10^4$ to $1{\cdot}8 \times 10^5$ computed for the Lagos lagoon population (Fagade & Olaniyan, 1972), and it could be due to the relatively poor feeding in the population (Blay & Eyeson, 1982). Nevertheless, the increase in fecundity with length and weight is consistent with the observations made on fishes.

A study of the monthly percentages of ripe fish in the catch, and changes in gonadal weight and GSI have been used to determine the spawning period for the species. The peak gonadal weight and GSI observed in both male and female samples in October 1976, followed by the gradual decline until January 1977 and a second peak in February is suggestive of spawning beginning in October 1976 and continuing up to March 1977. This view is also supported by the presence of a high percentage of Stage V males in October, followed by the gradual reduction until January and a second peak in February. This second peak coincides with the peaks in gonadal weight and GSI. Although the monthly frequencies of Stage IV females suggest that ripe females might be available for spawning in September, the absence or inadequate numbers of Stage V males during the period would make spawning unlikely. Thus active spawning possibly occurred from October 1976 to March 1977. This period, coming shortly after the cold ' upwelling ' season was a dry period in Ghana and was characterized by increasing water temperatures from 23·0° C in October to 26·2° C in February (Blay, 1977). This dry season spawning agrees with the observations of Salzen (1958) and Fagade & Olaniyan (1972).

Other indications of spawning period can be obtained from monthly changes in the condition factor. There are reports (Hickling, 1945; Love, 1957; Halliday, 1969) that spawning fish tended to utilize the fat stored in the body as a source of energy and consequently there was a decline in the condition factor. Studies of *E. fimbriata* in Cape Coast (Blay, 1977) have shown that the condition factor started increasing from 2·00 in May 1976 and reached a peak of 2·42 in August 1976. This could possibly be due to the increasing feeding activity during the period (Blay & Eyeson, 1982). A decrease in the condition factor was observed, however, from November until the end of the study period in March 1977. This decrease has been interpreted as a consequence of intensive spawning and might support the suggestion of October to March as the spawning period. The occurrence of one mode in the distribution of yolky oocytes in the Stage IV ovaries and the presence of Stage V males only from October 1976 to March 1977 is a confirmation of the observation that *E. fimbriata* have a restricted spawning period.

The spawning ground of the species in Cape Coast waters was not located during the study period but, since no adult fish were found in the Kakum River estuary nor in the nearby Elmina lagoon, it is being suggested that they spawn exclusively in the sea. The eggs and juvenile fish are probably then washed into the lagoons and estuaries by tidal action. It seems therefore that, in different areas along the West African Coast, *E. fimbriata* could spawn either in the sea (Bainbridge, 1961), or in the estuaries and lagoons (Salzen, 1958; Scheffers, 1971; Fagade & Olaniyan, 1972). The characteristics of the coastline which influence the selection of spawning grounds of the species have not been investigated.

References

Bagenal, T.B. (1957). The breeding and fecundity of the long rough dab *Hippoglossoides platessoides* (Fabr) and associated cycle in condition. *J. mar. biol. Ass. U.K.* **36**, 339–373.

Bagenal, T. B. & Braum, E. (1968). Eggs and early life history. In *Methods for Assessment of Fish Production in Freshwater* (W. E. Ricker, ed.), pp. 159–178. Oxford: Blackwells.

Bainbridge, V. (1957). Food of *Ethmalosa dorsalis*. *Nature, Lond.* **179**, 874–875.

Bainbridge, V. (1961). The early life of the Bonga, *Ethmalosa dorsalis* (Cuvier and Valenciennes). *J. Cons. perm. int. Explor. Mer* **26**, 347–353.

Bainbridge, V. (1963). The food, feeding habits and distribution of the Bonga *Ethmalosa dorsalis* (Cuvier and Valenciennes). *J. Cons. perm. int. Explor. Mer* **28**, 270–283.

Blay, J. (1977). Aspects of the biology of the marine clupeid fish, *Ethmalosa fimbriata* (Bowdich), occurring in some coastal waters of Cape Coast district, Ghana. M.Sc. Thesis, University of Cape Coast, Ghana.

Blay, J. & Eyeson, K. N. (1982). Feeding activity and food habits of the shad, *Ethmalosa fimbriata* (Bowdich), in the coastal waters of Cape Coast, Ghana. *J. Fish Biol.* **21**, 403–410.

Fagade, S. O. & Olaniyan, C. I. O. (1972). The biology of the West African shad, *Ethmalosa fimbriata* (Bowdich) in the Lagos lagoon, Nigeria. *J. Fish Biol.* **4**, 519–533.

Halliday, R. G. (1969). Reproduction and feeding of *Argentina sphyraena* (Isospondyli) in the Clyde Sea area. *J. mar. biol. Ass. U.K.* **49**, 785–803.

Harding, J. P. (1949). The use of probability paper for the graphical analysis of polymodal frequency distributions. *J. mar. biol. Ass. U.K.* **28**, 141–153.

Hickling, C. F. (1945). The seasonal cycle in the Cornish pilchard, *Sardina pilchardus* Walbaum. *J. mar. biol. Ass. U.K.* **26**, 115–138.

Hickling, C. F. & Rutenberg, E. (1936). The ovary as an indicator of spawning period in fishes. *J. mar. biol. Ass. U.K.* **21**, 311–317.

Love, R. (1957). The bio-chemical composition of fish. In *The Physiology of Fishes*, pp. 401–418. New York: Academic Press.

Olsen, S. & Lefevere, S. (1969). Some observations on length and sex distribution and catch effort on Bonga, *Ethmalosa fimbriata* (Bowdich), at Beniboye (Midwest, Nigeria). *Proc. Symp. Ocean Fish. Resources Trop. Atl., F.A.O. Fish. Rep.* **51** (Art. 28), p. 54.

Parrish, B. B., Baxter, I. G. & Mowat, M. J. D. (1960). An automatic egg counter. *Nature, Lond.* **85**, 777.

Salzen, E. A. (1958). Observations on the biology of the West African shad, *Ethmalosa dorsalis*. *Bull. Inst. fr. Afr. noire.* (A) **20**, 1388–1426.

Scheffers, W. J. (1971). Note préliminaire sur quelques aspects de la biologie de '*Ethamalosa fimbriata*' (Bowdich) dans les eaux Sénégambiennes. *Programme des Nations Unies Pour le Developpement Fonds Special/FAO, Rapp.* 9/71, 1–4.

Simpson, A. C. (1951). The fecundity of the plaice. *Ministry of Agriculture (U.K.) Fish Invest. Ser. II* **17**, 1–27. Cited in Bagenal & Braun (1968).