An update of the reproductive biology of *Sardinellas* (Family: *Clupeidae*) in the coastal waters of Ghana.

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Abstract

Aspects of the reproductive biology of the round *sardinella Sardinella aurita* and flat *sardinella Sardinella maderensis*, the most important small pelagic fishes in the coastal waters of Ghana are reported in this paper. The information presented here is of management value considering recent observations which indicate that the stock is nearing collapse from overfishing. Samples of fish were randomly taken from commercial landings at Elmina (5˚06′ N; 1˚23′ W) between October 2013 and September 2014. *S.aurita* measured 11.0 cm to 27.9 cm TL and *S. maderensis* 9.8 cm to 28.2 cm TL. Maturity size (Lm50) of *S.aurita* males was 16.34 ± 0.21 cm TL and females 16.55 ± 0.19 cm TL, and *S. maderensis* males and females matured at 15.33 cm ± 0.24 cm TL and 15.09 cm ± 0.98 cm TL, respectively. Analysis of monthly Gonadosomatic Index (GSI) and percentage of spawning fish suggested that S. aurita spawned from February or March to September, with a major activity in July - September and a minor spawning in February - May. *S. maderensis* similarly bred within these periods with a major spawning in September and a smaller peak in March. Ova from ripe ovaries of both species were bimodal in diameter frequency distributions suggesting occurrence of restricted spawning periods in the species. Fecundity of S. aurita varied from 4,834 to 63,917 ova in fish of 19.3 cm TL and 65.92 g body weight to 63,917 ova in fish of 25.7 cm TL and weighing 145.82 g. Fecundity of *S. maderensis* ranged from 7,597 ova in fish of 23.6 cm TL and 112.51 g to 33,984 ova in fish measuring 27.5 cm TL and weighing 187.48 g. From the fecundity-body size equations, S. aurita was found to be more fecund than *S. maderensis*, which might partly explain the higher productivity of the former in Ghana waters. This study provides first-time information on the biology of *S. maderensis* in Ghana waters.

Keywords: *Sardinellas*, Size distribution, Maturity size, Fecundity, Spawning seasons.

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Introduction

The round *sardinella* (*Sardinella* aurita) and flat *sardinella* (*Sardinella maderensis*) are very important in the fisheries and nutrition of countries bordering the western Gulf of Guinea, including Ghana [1]. This has attracted investigations aimed at understanding the fishery dynamics and biology of the species in many countries. In Ghana, Mireku[2] and Zei [3] reported on the migration of S. aurita while Koranteng [4,5] dealt with their fishery, and Pezennec and Koranteng [6] examined the dynamics and biology of the common Ivorian-Ghanaian stock. The study by Quaatey and Maravelias [7] on the maturity and spawning pattern of S. aurita provides the most recent information on the biology of this species in Ghana. The biology of the flat *sardinella S. maderensis* has received little attention in the country, perhaps because of its relatively low significance in the fishery. Studies on *sardinellas* elsewhere in the Gulf of Guinea include those by Cury and Fontana [8] on competition and life-history strategies of the two species, Brainerd [9] who provided a synopsis of the *sardinella* fishery in the area, and Gabche and Hockey [10] on the growth, mortality and reproduction of *S. maderensis* in Cameroon.

A recent assessment of the small pelagic fishery in Ghana [11,12] indicated that the stock dominated by *sardinellas*, is on the verge of collapse and urgent measures would be required to resuscitate it. Chief among management considerations is institution of a closed season, which nonetheless should be based on sound knowledge of the biology of the species.

The current state of the small pelagic fishery in Ghana [11] could bring about changes in the biology of the species, which needs investigation to obtain up-to-date information to inform management of the fishery. The present study therefore sought to obtain contemporary information on the reproductive biology of *sardinellas* in Ghana for comparison with information earlier reported on the species in the country and elsewhere in West Africa.

Materials and Methods

Random samples of *sardinellas* were taken monthly between October 2013 and September 2014 from commercial landings at the Elmina fish landing quay near Cape Coast, Ghana (5˚06′ N; 1˚23′ W). After identification, round and flat *sardinellas* were measured for Total Length (TL) and Fork Length (FL) to the nearest 0.1 cm, and total Body Weight (BW) and Eviscerated Body Weight (BWE) determined to the nearest 0.01 g. Fish were dissected to determine the sex of individuals and developmental stage of gonads based on the classification of Holden and Raitt [13]. Gonads were weighed to the nearest 0.01 g and gonadosomatic index (GSI) computed as:

$$GSI = (GW / BWE) \times 100$$

Mean monthly GSI for each sex and monthly frequencies of

gonadal stages were plotted to establish the breeding pattern of the species. Visceral fat content was assessed based on a 5-point scale [14].

Ripe ovaries from each species were preserved in Gilson's fixative in specimen bottles over a week for later determination of fecundity. The bottles were agitated to separate ova from ovarian tissue, following which random measurements of the longest axis of ova from three ovaries of each species were made to the nearest 0.1 mm using a stage micrometer. The ova were further rinsed with water and decanted a few times to discard immature oocytes. Ova were filtered and dried in an oven at 105°C to constant weight to facilitate estimation of fecundity by the gravimetric method [15]. The total weight(W) of dried ova and weight(w) of three subsamples were determined; the number(n) of ova from each subsample was determined. The total number (N) of ova in an ovary based on each subsample was computed as $N = nW/w$ and the mean value from the three estimates was taken as the fecundity(F) of the fish.

The mean length at sexual maturity (Lm50), defined as the length at which 50% of individuals in the population mature was estimated for both sexes by fitting the logistic function to the proportion of mature fish at 1-cm size classes [16,17].

Results

The methodology section consists of two parts. The first part described sources of data and variables. Second section described empirical model adapted to examine the relationship between working capital management and company performance in Jordan. The third section described the statistical tools.

Length-frequency distribution

Figure 1 shows the length frequency distribution of the *sardinellas* from Ghana. A total of 746 specimens of S. aurita were examined and these measured 11.0 cm to 27.9 cm TL and weighed 9.6 g to 141.98 g. Males were 13.6 cm to 26.3 cm TL and females 12.0 cm to 27.9 cm TL. The length-frequency distributions of males, females and the combined specimens were unimodal, with the mode in the 19 cm length class.

S. maderensis measured 9.8 cm to 28.2 cm TL and weighed 10.85 g to 185.28 g. The length distribution of all specimens was polymodal with modes in the 11 cm, 15 cm, 18 cm and 25 cm TL classes. Males were 11.0 cm to 27.6 cm TL, with a modal size class of 18 cm TL, and females measured 10.0 cm to 28.2 cm TL with three modal size classes at 15 cm, 18 cm and 25 cm TL.

Fork length-total length relationship

Relationships were established for total length and fork length of the two sardinella species to facilitate length conversions of fish from other studies for comparison with the present results. The relationships were described by the equations:

TL = 1.17FL - 0.31 (r=0.99; P < 0.001) for S. aurita, and

TL = 1.23FL - 0.66 (r=0.99; P < 0.001) for *S. maderensis*.

Sex ratio

A total of 654 S. aurita specimens comprising 328 males and 326 females were sampled, indicating a clear 1:1 sex ratio in the population. On monthly basis (Table 1) the ratios were approximately 1:1 except in July when females significantly outnumbered males ($\chi 2 = 4.27$; $P < 0.05$).

S. maderensis specimens totalled 723 of which 383 were males and 340 were females, and the ratio did not also deviate significantly from 1:1 ($\chi 2 = 1.27$; $P > 0.05$). The monthly ratios (Table 2) were consistently 1:1 except in February when males were dominant ($\chi 2 = 4.27$; $P < 0.05$).

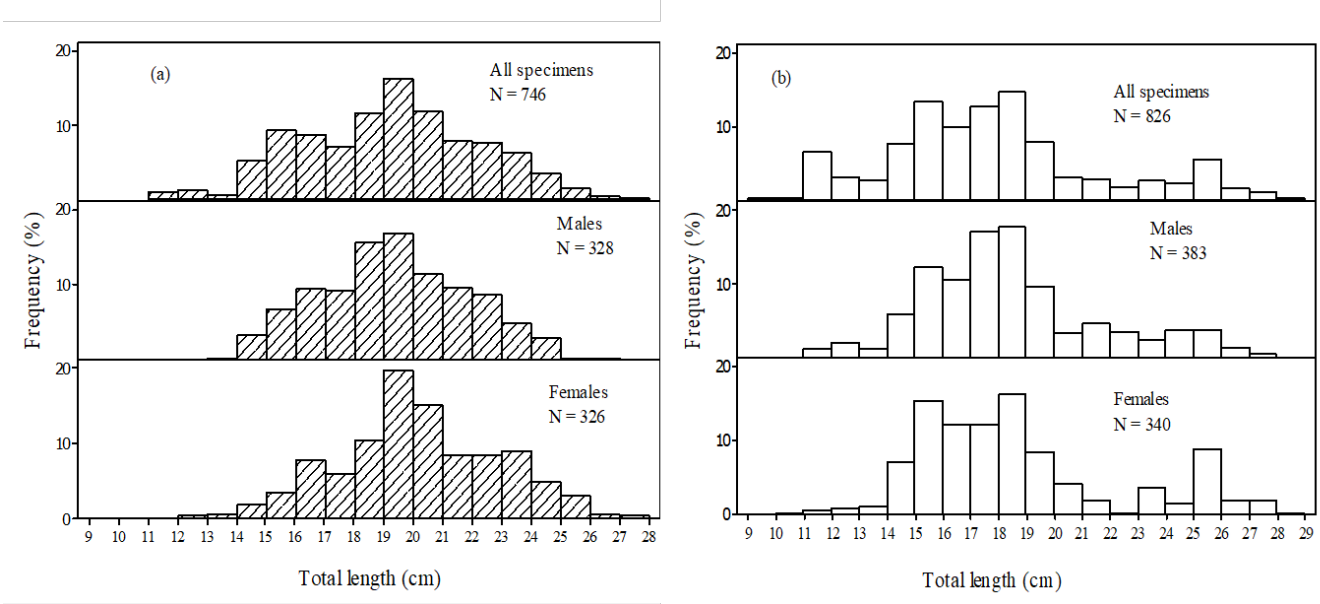

Figure 1. *Length-frequency distributions of (a) Sardinella aurita and (b) S. maderensis from the coastal waters of Ghana (N=sample size).*

Table 1. *Monthly sex ratios of Sardinella aurita samples from Ghana.*

Month	Number of specimens		Sex ratio	χ^2	P=0.05
	Male	Female			
October 2013	38	26	1:0.7	2.25	NS
November	23	18	1:0.8	0.16	NS
December	17	19	1:1.1	0.11	NS
January 2014	34	38	1:1.1	0.22	NS
February	25	27	1:1.1	0.07	NS
March	15	15	1:1	0.00	NS
April	37	41	1:1.1	0.10	NS
May	27	21	1:0.7	0.75	NS
June	39	25	1:0.6	3.06	NS
July	22	38	1:1.7	4.27	S
August	24	31	1:1.3	0.45	NS
September	27	27	1:1	-	NS
S= Significant; NS= Not Significant					

Table 2. *Monthly sex ratios of Sardinella maderensis samples from Ghana.*

Month	Number of specimens		Sex ratio	χ^2	P=0.05
	Male	Female			
October 2013	29	39	1:1.3	1.47	NS
November	25	23	1:0.9	0.08	NS
December	37	39	1:1.1	0.05	NS
January 2014	30	31	1:1.0	0.02	NS
February	64	36	1:0.6	3.92	S
March	37	26	1:0.7	0.96	NS
April	25	18	1:0.7	1.14	NS
May	17	10	1:0.6	1.81	NS
June	32	38	1:1.2	0.51	NS
July	31	23	1:0.7	1.19	NS
August	34	28	1:0.8	0.29	NS
September	22	29	1:1.3	0.48	NS
S= Significant; NS= Not Significant					

Maturity size

Figures 2 and 3 show maturity ogives for the sardinella species. The smallest mature male *S. aurita* (Stage III) was 15.4 cm TL with a body weight of 30.82 g; the smallest mature female measured 16.1 cm TL and weighed 37.82 g. The length at which 50% of the population attained sexual maturity (Lm50) was estimated as 16.34 ± 0.21 cm TL and 16.55 ± 0.19 cm TL for males and females, respectively.

In respect of *S. maderensis*, the smallest mature male (Stage III) was 14.3 cm TL and 25.81 g body weight, and the smallest mature female was 15.0 cm TL and 30.11 g body weight. The Lm50 was estimated to be 15.33 ± 0.24 and 15.09 ± 0.98 cm TL for males and females, respectively.

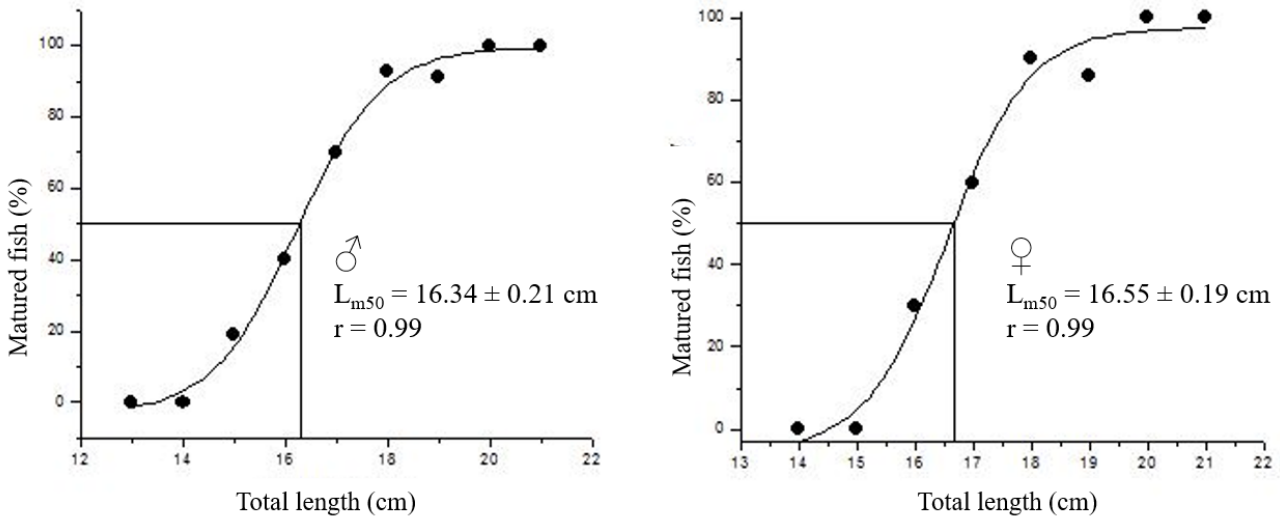

Figure 2. *Maturity ogives for male and female Sardinella aurita from Ghana (logistic curve constants a=-4.70, b=101.44 for males; a=-5.59, b=97.69 for females).*

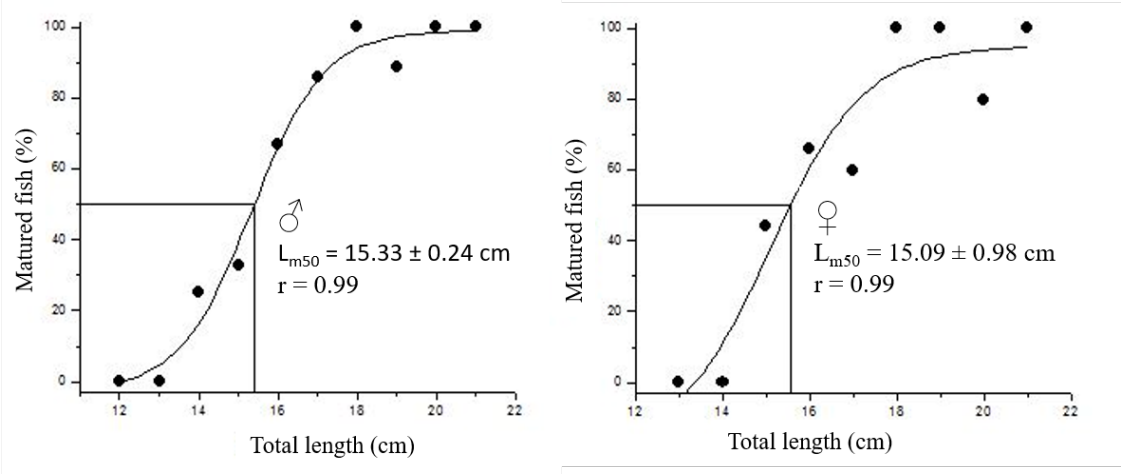

Figure 3. *Maturity ogives for male and female Sardinella maderensis from Ghana (logistic curve constants a=-2.78, b=99.17 for males; a=-19.09, b=95.08 for females).*

Fecundity

Figures 4 and 5 shows the relationships between Fecundity (F) and Total Length (TL), Body Weight (BW) and Gonad Weight (GW) of the *sardinellas* from Ghana. Fecundity of 93 ripe female S. aurita examined ranged from 4,834 to 63,917 ova in fish of total length 19.3 cm to 25.7 cm, body weight 65.92 g to 145.82 g, and gonad weight 1.17 g to 15.0 g. The following relationships were established for S. aurita:

F=3130.6TL – 48817 (r=0.56; P < 0.001)

F=274.7BW – 5162.6 (r=0.58; P < 0.001)

F=2708.8GW – 7194.8 (r=0.6; P < 0.001)

Fecundity of *S. maderensis* varied from 7,597 ova in fish of 23.6 cm TL and 112.51 g to 33,984 ova in fish measuring 27.5 cm TL and weighing 187.48 g. Gonad weight of these specimens varied from 1.45 g to 9.25 g. Fecundity was related to total length, body weight and gonad weight according to the following equations:

F=1240.9TL – 4402 (r=0.58; P < 0.001)

F=94.8BW + 3407.3 (r=0.55; P < 0.001)

F=1757GW + 8730.5 (r=0.61; P < 0.001)

By substituting a given length of fish in these equations, a higher

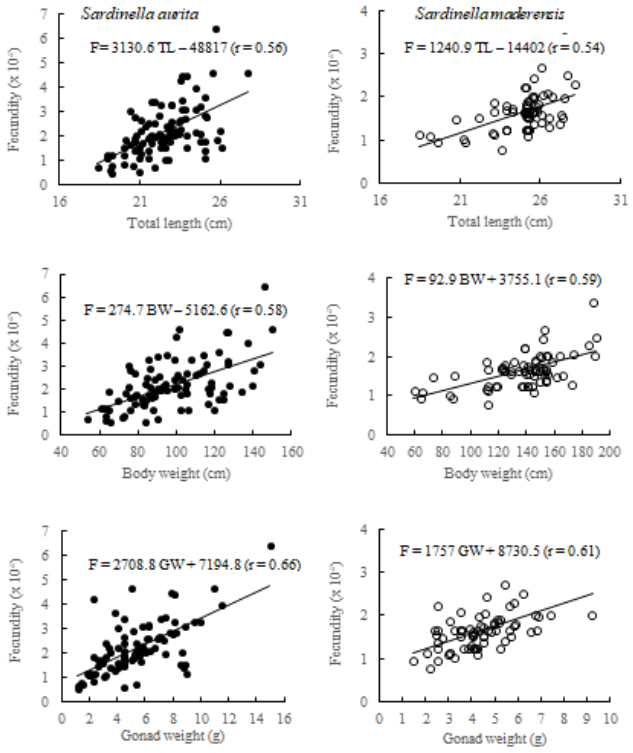

Figure 4. *Relationship between fecundity and total length, fecundity and body weight, and fecundity and gonad weight of Sardinella aurita and S. maderensis from the coastal waters of Ghana.*

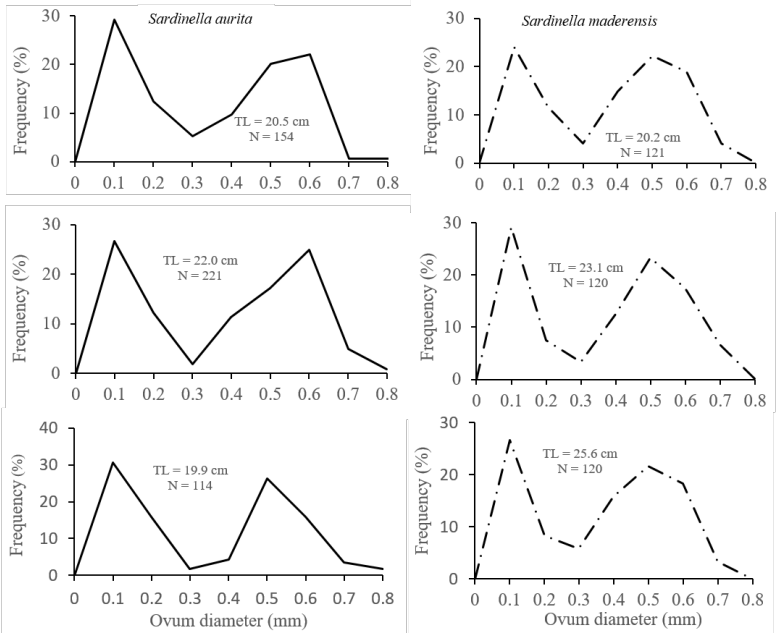

Figure 5. *Frequency distribution of diameters of ova from three ripe ovaries of Sardinella aurita and S. maderensis in the coastal waters of Ghana (N= number of ova).*

fecundity is extrapolated for S. aurita than *S. maderensis*.

Ovum diameter distribution

The diameter of ova of S. aurita and *S. maderensis* measured 0.1 mm to 0.8 mm, and their frequency distributions were bimodal with modes at 0.1 mm and 0.5 mm or 0.6 mm in the former, and 0.1 mm and 0.5 mm in the latter. Ova in the smaller size group were immature and the larger size group contained mature eggs. This suggests possible restriction of spawning to a given period.

Monthly variations in frequency of gonadal stages

Figure 6 shows the monthly variations in the proportions of S. aurita gonads at different developmental stages. Higher proportions of males (47.06% - 65.78%) and females (63.16% - 77.78%) at Stage II (resting or recovering) occurred in October-December. These may have developed into Stage III (pre-spawning) individuals in January-February, resulting in the prevalence of males (76.47% - 95.0%) and females (84.21% - 88.88%) at this stage. Spawning individuals (Stage IV) appeared in samples from February with higher proportions in March-April (40.00% - 48.65% for males and 60.00% - 60.90% for females), and July-September (44.10% - 81.82% for males and 77.80% - 89.50% for females). Post-spawning (Stage V) fish occurred sparsely from March to September with

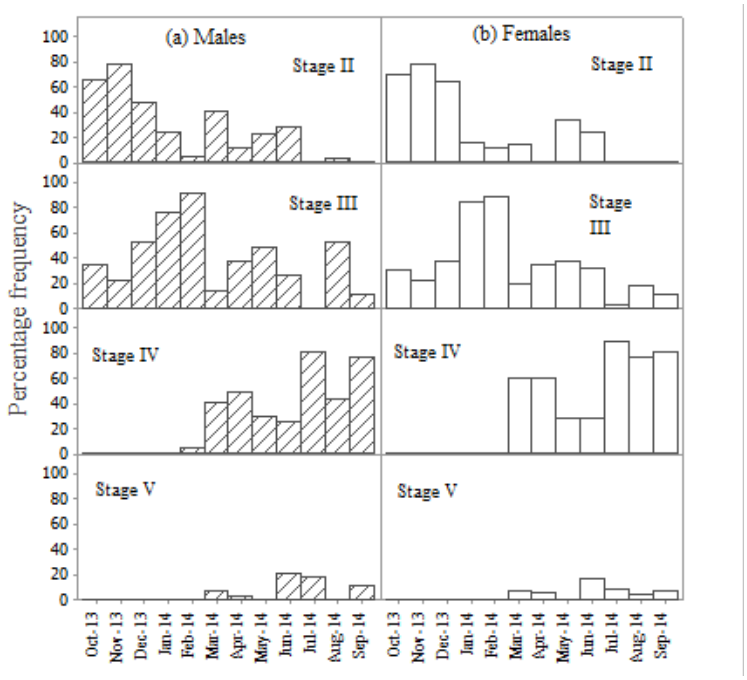

Figure 6. *Monthly frequency of gonadal stages of male and female Sardinella aurita from the coastal waters of Ghana..*

peak frequencies in June-July (18.18% - 20.51% for males and 7.89% - 16.00% for females).

Figure 7 shows the monthly variations in frequency of *S. maderensis* gonadal stages. Peak frequencies of males and females with gonads at Stage II occurred in May (82.35% for males and 70.00% for females) and October-November (64.0% - 94.82% for males, and 87.50% - 94.87% for females). Fish with gonads at Stage III reached peak frequencies in February-March (85.94% - 100% for males and 97.22% - 100% for females) and June-July (50.0% - 87.10% for males and 42.48% - 55.26% for females) while the frequency of spawning fish (Stage IV) increased steadily from February to September. Low frequencies of post-spawning individuals (Stage V) were found in the May to September samples.

Monthly variations in gonadosomatic index

Variations in the gonadosomatic index (GSI) of the two sardinella species are presented in Figure 8. In S. aurita, mean GSI of males ranged from 0.23 ± 0.04 to 6.56 ± 0.30 and in females from 0.24 ± 0.06 to 6.31 ± 0.31. Peak values occurred in February-March, and July-September.

The mean GSI of male and female *S. maderensis* varied from 0.11 ± 0.01 to 4.43 ± 0.66 and 0.51 ± 0.04 to 3.49 ± 0.33 respectively, with peak values in March and September. Generally, sexes of both species exhibited similar patterns in GSI fluctuations.

Monthly variations in visceral fat index

Variations in the mean visceral fat index of the *sardinellas* are illustrated in Figure 9. In S. aurita the index varied from 1.15

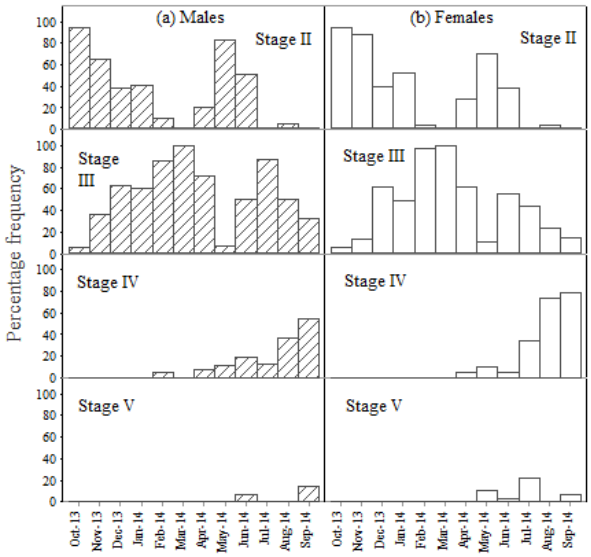

Figure 7. *Monthly frequency of gonadal stages of male and female Sardinella maderensis from the coastal waters of Ghana.*

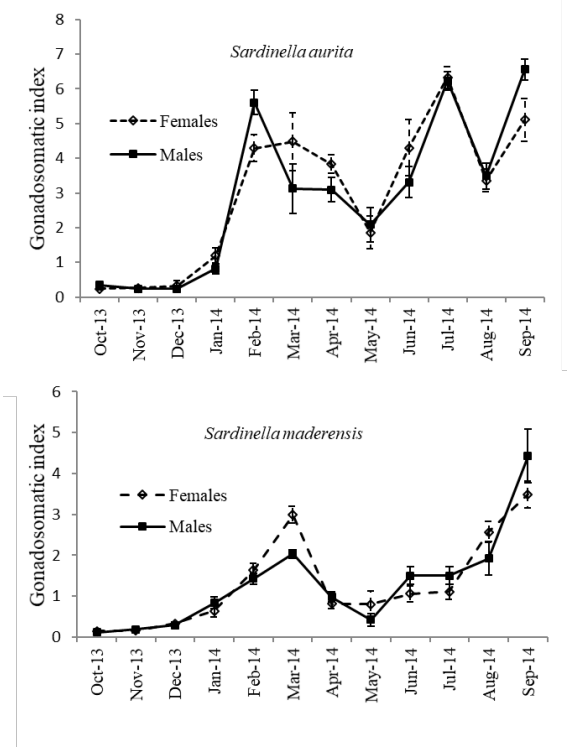

Figure 8. *Monthly gonadosomatic index (mean ± 2 SE) of Sardinella aurita and S. maderensis from the coastal waters of Ghana.*

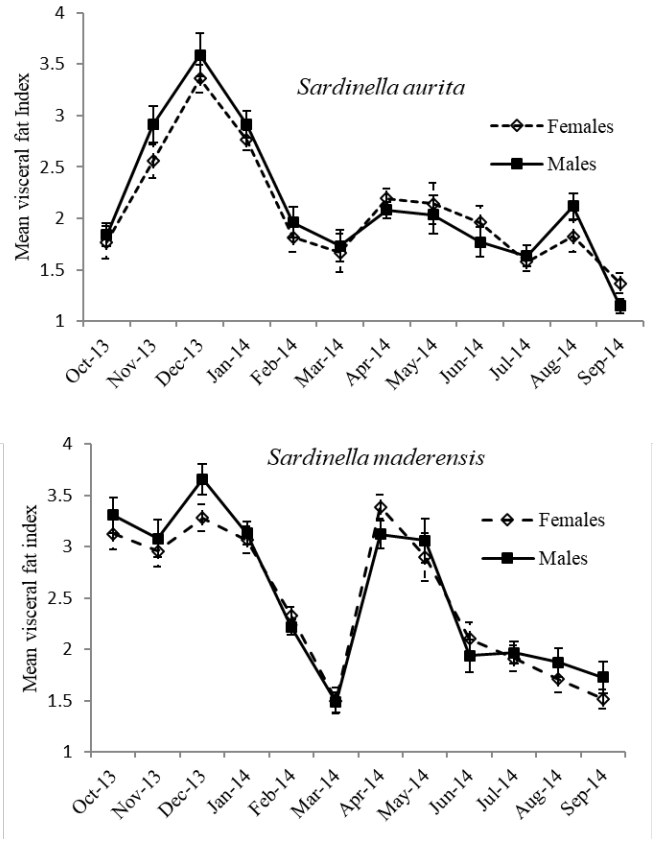

Figure 9. *Monthly visceral fat index (mean ± 2 S.E.) of Sardinella aurita and S. maderensis from the coastal waters of Ghana.*

± 0.07 to 3.59 ± 0.21 in males and 1.37 ± 0.09 to 3.36 ± 0.13 in females. A significant maximum of the index occurred in December, and a smaller peak in August.

The index in *S. maderensis* fluctuated between 1.49 ± 0.10 and 3.66 ± 0.15 in males, and 1.50 ± 0.13 and 3.39 ± 0.12 in females with higher values in October-January and April-May, while significantly low values occurred in March and June-September. The fluctuation patterns in males and females of both species were similar.

Discussion

Sardinella aurita from commercial fish landings in Ghana measured 11.0 – 27.9 cm TL with a modal size of 19 cm TL. Compared to specimens sampled in the early 1960s, it could be inferred that the size of fish caught has reduced over the last five or so decades, given that fish then [2] measured 16 - 24 cm FL (18.4 cm – 29.4 cm TL) with a modal size of 21.9 cm FL or 24.3 cm TL. Furthermore, the estimated lengths at sexual maturity (Lm50) of S. aurita males (16.34 ± 0.21 cm TL) and females (16.55 ± 0.19 cm TL) are slightly smaller than the size at which the fish matured (17.4 cm TL) in the late 1960s [18] and the late 1980s (16.7 cm TL for males and 17.1 cm TL for females) [7]. Increased fishing pressure and/or changes in environmental conditions during the interval may have accounted for the reduced maturity and landed size of the fish. Elsewhere in West Africa, maturity sizes of 21.0 cm TL [19] and 20.0 cm TL [20] have been reported for S. aurita off Senegal, which supports the likely influence of environmental factors on fish maturation.

S. maderensis in the landings measured 9.8 cm to 28.2 cm TL, and this size range did not differ appreciably from that of S. aurita. However, the maturity size of males (15.33 ± 0.24 cm TL) and females (15.09 ± 0.98 cm TL) was about 1 cm smaller than the estimate for the latter. There is no known report on the maturity size of flat *sardinella* in Ghana to compare with the present results, but it is reported [10] to mature at 17 cm TL off Cameroon which difference from the Ghana population may similarly be ecologically determined.

Judging from the monthly proportions of fish with Stage IV gonads, spawning may have lasted 7-8 months in S. aurita and 6-7 months in *S. maderensis*, which is close to the observed occurrence larval and juvenile S. aurita throughout the year [18]. However, two periods of enhanced spawning could be inferred for S. aurita from peaks in the gonadosomatic index (GSI) and proportion of gonads at Stage IV from February to March and July to September. This differed from Quaatey and Maravelias [7] conclusion from GSI variations and occurrence of eggs in plankton hauls that S. aurita in Ghana waters has three spawning peaks occurring in July to October, March and December. With exception of December, the other periods largely complemented the two spawning times found for the species in this study. Fluctuations in the GSI of *S. maderensis* also signified two peak spawning periods, namely March-April and September, although this was not explicitly supported by monthly representation of gonads at the spawning stage. It is however noteworthy that the peak spawning periods of both species coincided with upwelling events in the coastal waters of Ghana when their zooplankton food becomes abundant [3,7,21-24].

The 1:1 sex ratio found in S. aurita from Ghana is similar to that reported [25] for the species in Nigerian waters. While the

sex ratio of *S. maderensis* in Ghana was also 1:1, a male:female ratio of 1:1.5 was found in the population from Cameroon [10]. Deviations from a 1:1 ratio during the breeding season have, however, been reported in some species, e.g. Argentina sphyraena from Clyde Sea Area in the UK [26] and the West African shad Ethmalosa fimbriata from Ghana [27]. Similar changes in sex ratio may have manifested during the month of July in S. aurita and February in *S. maderensis* in Ghana when the fish were spawning. Presumably, males or females migrated from the breeding grounds soon after spawning, thereby reducing their availability in the fishing area. The presence of two distinct size groups of ova representing immature and mature ova in ripe ovaries of both *sardinellas* further portrayed restriction of spawning to a certain period of the year, as it would take some time for immature ova to develop to replace mature ova shed during the spawning season [28].

The relatively high fat index of S. aurita in December and *S. maderensis* from October to January may be an outcome of enhanced nutrition during preceding upwelling seasons in preparation for spawning. Fat may therefore have been used as an energy source for gonad maturation and breeding, in view of the coincidence of periods of low fat index with high GSI values and vice versa.

From the fecundity-body size relationships determined in this study, it may be surmised that round *sardinella* was more fecund than flat *sardinella* of comparable size, which might explain the dominance of the former in Ghana waters because of its expected higher recruitment rate and ultimately greater biomass. Comparing the fecundity-body weight relationship of S. aurita in the present study (F=274.7BW-5162.6) with the species in Congo waters (F=436.415BW–22076.4)[29], a slightly higher fecundity is deduced for the latter population. Also, the relationships established for *S. maderensis* in Ghana (F=94.8BW+3407.3) and Congo (F=418BW–18974.0), suggest that the latter's fecundity is about twice that of the Ghana population. These intraspecific and interspecific differences in fecundity of *sardinellas* may be attributed to genetic and physiological differences among the populations, and/or environmental conditions in their environments.

Conclusion

We conclude from results of this study that over the last five decades, the maturity size of S. aurita has reduced by approximately 1 cm in total length, while its maximum length and modal length have also reduced by about 2 cm and 5 cm respectively. The maturity size of S. aurita was about 1.0 cm to 1.5 cm longer than that of *S. maderensis*. Spawning may have lasted 7 to 8 months in S. aurita and 6 to 7 months in *S. maderensis* as indicated by the monthly occurrence of fish with gonads in the spawning condition. Restriction of spawning to a given period of the year was buttressed by the presence of two distinct crops of ova in mature ovaries of both species. It is alluded from fluctuations in gonadosomatic index (GSI) that both species had two spawning peaks, i.e. February-March and July-September for S. aurita, and March-April and September for *S. maderensis*. S. aurita was more fecund than *S. maderensis* which may partially explain the higher productivity of the former in Ghana waters.

Acknowledgements

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