Greener Journal of Agricultural Sciences
Vol. 9(1), pp. 23-31, 2019
ISSN: 2276-7770

DOI Link: http://doi.org/10.15580/GJAS.2019.1.011719017
http://gjournals.org/GJAS

Estimates of Population parameters for *Sardinella maderensis* (Lowe, 1838) in the coastal waters of Ghana

Samuel K.K. Amponsah [1]*; Patrick K. Ofori-Danson [2]; Francis K.E. Nunoo [3]; Godfred A. Ameyaw [4]

[1*] Department of Fisheries and Water Resources, University of Energy and Natural Resources, Box 214, Sunyani, Ghana. Email: samuel.amponsah@uenr. edu. gh
[2] Department of Marine and Fisheries Sciences, University of Ghana, Box LG 25, Legon, Ghana. oforidanson@ gmail. com
[3] Department of Marine and Fisheries Sciences, University of Ghana, Box LG 25, Legon, Ghana. Email: fkenunoo@ug. edu. gh
[4] Australian National Centre for Ocean Resources and Security, University of Wollongong, NSW 2522, Australia. Email: gameyawasiedu@ gmail. com

ARTICLE INFO

Article No.: *011719017*
Type**:** *Research*
DOI: *10.15580/GJAS.2019.1.011719017*

Submitted: *17/01/2019*
Accepted: *21/01/2019*
Published: *31/01/2019*

Corresponding Author
Samuel K.K. Amponsah
E-mail: *samuel.amponsah@ uenr.edu.gh*

Keywords: *Madeiran sardinella, population parameters, Ghana, MSY, VPA, overfishing*

ABSTRACT

This study examined some population parameters of *Sardinella maderensis* landed along the eastern coast of Ghana, based on length-frequency data from June, 2014 to January 2015. Overall, 1401 samples of *S. maderensis* were measured for standard length and resultant data analysed with FiSAT II. The asymptotic length (L_∞) and growth rate (K) were 23.63 cm SL and 0.61 yr^{-1} respectively. The theoretical age at birth (t_0) and growth performance index (ϕ) were -0.284 yr^{-1} and 2.532 respectively. The recruitment pattern was continuous with two recruitment pulses. Total mortality rate (Z), natural mortality rate (M) and fishing mortality rate (F) were 2.96 yr^{-1}, 1.30 yr^{-1} and 1.63 yr^{-1} correspondingly. Fishing mortality rate surpassed the optimum fishing rate which showed that the assessed fish species is under high fishing pressure. The estimated exploitation rate (E_{curr}) was 0.55, implying that the stock is over-exploitation. VPA outcome revealed higher harvesting rate on individuals with length between 10 – 11 cm. The spawning biomass which was below the 30% of unexploited biomass indicated future recruitment failure of the stock. As a result, urgent management interventions such as the application of biological reference points and mesh size regulations are urgently recommended for sustainable exploitation of *Sardinella maderensis*.

1.0 INTRODUCTION

Fishing is central to the livelihoods of both artisanal coastal and inland fishing households in Ghana (Sarpong *et al*., 2005). Marine artisanal fisheries are practiced within the EEZ of Ghana and account for 85% of the total fish catches in Ghana (Nunoo *et al*., 2014). Among these species, 65% are mostly small pelagics (Nunoo *et al.,* 2014). Ansa-Emmim (1973) reported that *Sardinella maderensis* and other species within the Clupeids family serve as important small pelagics exploited from the Ghanaian coast to fishing households in Ghana. Sardinellas including *Sardinella maderensis* accounts for more than 40% of the total domestic marine fish contribution. The abundance of these small pelagics is heavily linked to both minor and major upwelling activities in the Ghana-Ivorian marine ecosystem as well as rainfall (Koranteng, 1989; Binet, 1982).

Ecologically, juveniles of *Sardinella maderensis* are concentrated in the coastal waters from where they gradually move offshore as they grow older. A great majority of the adults remain confined over the shallow half of the continental shelf. Adults of *Sardinella maderensis* are much more sedentary with limited traveling distances along the coast (Gheno, 1970). They are most abundant in two regions to the north and south of the Gulf of Guinea respectively (FAO, 1971). Throughout the year, Sardinellas (particularly *Sardinella maderensis* and *Sardinella aurita*) supply the main part of the catch for the coastal artisanal fleets and they also form part of the catch of the long-distance fishery seiners when they operate sufficiently close to inshore (Brainerd, 1991). Despite having lower catches in the Ghanaian coastal fishery than *Sardinella aurita*, *Sardinella maderensis* which is said to be accessible for most months of the year are a very cheap source of animal protein to vulnerable fishing households (Nunoo et al., 2014; Muta 1964). Thus, its continuous occurrence in the coastal waters enhances household nutrition in vulnerable fishing communities. Its fishery also constitutes extreme economic activities of many fishers including fishermen, fish processors and traders in Ghana.

However, its population, together with *Sardinella aurita* currently suffers from declining catches due to the consistent application of light in fishing - an intervention introduced to ensure all-year-round supply of sardines and other unsustainable fishing practices. These aforementioned threats, as a result, make sustainable management of *Sardinella maderensis* stocks within Ghana's coastal waters problematic. As such, this study seeks to address some aspects of population parameters of *Sardinella maderensis* off the coast of Ghana with the aim of providing a basis for proper management.

2.0 MATERIALS AND METHODS

2.1 Study area

This study was carried out in four fish landing sampling stations, namely Vodzah, Denu, Jamestown and Tema based on two staged sampling criteria (Figure 1).

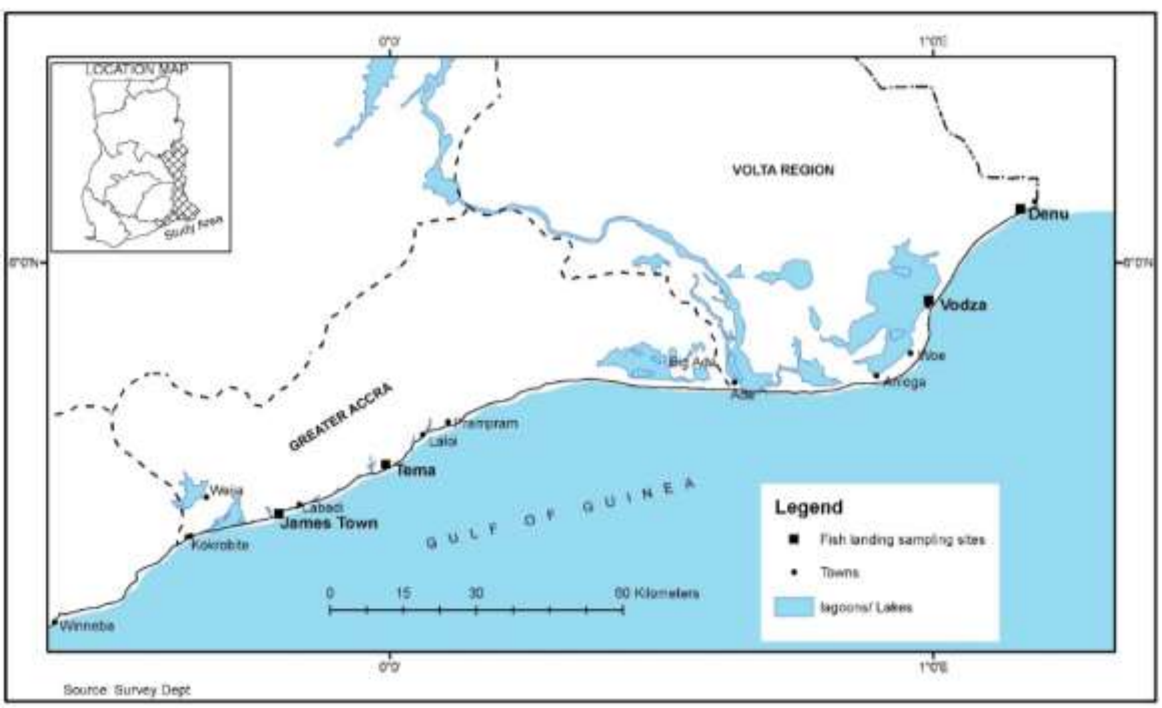

Figure 1: Map showing the sampling sites

2.2 Data collection

Fish samples were obtained on monthly basis from fishermen within the study areas from June 2014 to January 2015. Obtained samples were kept on ice blocks and sent to the laboratory at the Department of Marine and Fisheries Sciences, University of Ghana for analysis. Weight and standard lengths were obtained using electronic scale and the 100-cm measuring board respectively. Identification of samples was carried out using Fischer *et al*. (1981) and Kwei & Ofori-Adu (2005). In all, 1401 samples of *Sardinella maderensis* were assessed.

2.3 Methods

Monthly length frequency data was obtained and standard length (SL) measured throughout the study period to estimate the various population parameters.

2.3.1 Growth parameters

Growth indicators for the assessed fish species was carried out using the Von Bertalanffy Growth Function (VBGF). To ascertain growth or mortality dominated population, the Powell-Wetherell Plot was applied (Pauly, 1984). The equation: $Lt = L_\infty (1-e^{-K(t-t0)})$ (Pauly, 1979) was used in estimating the growth function. Age at birth (t_o), longevity (*Tmax*) and growth performance index (ϕ) were estimated following procedures outlined by Pauly (1983).

2.3.2 Mortality parameters

Mortality parameters including Total mortality rate (Z), Natural mortality rate (M) and Fishing mortality rate (F) were estimated using Pauly (1980). The mean surface temperature (T) of 25.7°C was applied in estimating natural mortality rate (M). The optimum fishing mortality rate (F_{opt}) and exploitation level (E) were estimated as 0.4M (Pauly, 1984) and F/Z (Gulland, 1969) respectively. Exploitation rates (E_{max}, $E_{0.1}$ and $E_{0.5}$) were computed following Ahmad et al. (2018). The impact of exploitation on yield was done based on the interrelationship between exploitation rate (E_{max}) and critical length ratio ($Lc_{50}/L\infty$).

2.3.3 Length at first capture (Lc_{50}) and maturity (Lm_{50})

The length at first capture of the assessed fish species was calculated from the length-converted catch curve. The length at first maturity (Lm_{50}) was estimated as 2*(L∞)/3 (Hoggarth *et al.,* 2006),

2.3.4 Recruitment pattern

Backward projection of the obtained length frequency data was used in establishing the recruitment pattern (Mudoidiong et al., 2017; Nurul-Amin *et al*., 2008). Midpoint of the smallest length interval was used as length at first recruitment (Lr_{50}) (Gheshlaghi *et al*., 2012).

2.3.5 Virtual Population Analysis (VPA)

Length structured VPA was performed using values of L∞, K, M, F, a (constant) and b (exponent) for the species as inputs (Gayanilo *et al.,* 2005). The t_0 value was approximated to be zero. The direct exponential relationship between the weight (W) and length (L) was used to obtain the values of the constants, a and b (exponent) (Pauly, 1984).

2.3.6 Maximum Sustainable Yield (MSY)

MSY was estimated as 0.5x (Y+MB), where B is the average biomass calculated from cohort analysis in the same year, M is the natural mortality and Y the annual yield. Annual yield (Y) was calculated as $\sum W_{L1,L2} * C_{L1,L2}$, where W is weight and C is the catch (Sparre and Venema, 1998).

2.4 Data Analysis

Obtained length frequency data were grouped and fed into FiSAT II (FAO-ICLARM Stock Assessment Tools) software for estimating the population parameters. Yield software package by Branch *et al*. (2000) was used in plotting length at age.

3.0 RESULTS

3.1 Growth parameters

Estimated growth parameters were 23.63 cm SL and 0.61 per year for asymptotic length (L_∞**)** and growth rate (K) correspondingly. The restructured Length frequency data superimposed with the estimated growth curve exposed three cohorts within the harvest (Figure 2).

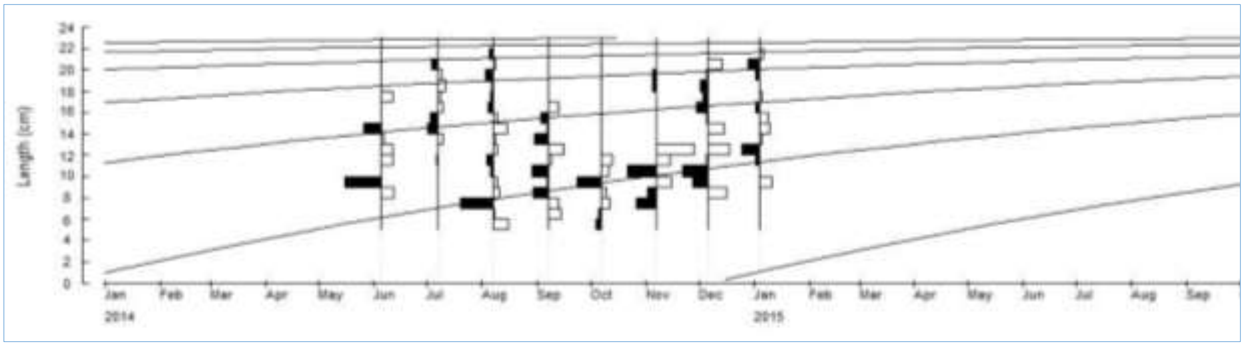

Figure 2: Reconstructed length frequency superimposed with growth curves

The growth function for the assessed species was $L_t = 23.63\ (1-e^{-0.61\ (t-(-0.284))})$. The growth performance index (ϕ) and Z/K ratio were 2.532 per year and 3.98 respectively (Figure 3a). Age at birth (t_o) and longevity (T_{max}) were -0.284 and 5 years respectively (Figure 3b).

3.2 Probability of capture and Length at first maturity (Lm_{50})

Length-at-first capture (Lc_{50}) and maturity were 5.3 cm and 15.7 cm respectively (Figure 3d). Critical length at first capture (Lc) was 0.22.

3.3 Recruitment pattern

Recruitment pattern was all year-round with minor peak in August-September and major peak took place in May-June (Figure 4a). The length at first recruitment (Lr_{50}) was 5.5 cm SL.

3.4 Mortality parameters

From the Jones and van Zalinge plot, Total mortality rate (Z) was estimated as 2.96 (Figure 3c). Natural and Fishing mortality rates were estimated as 1.33 (M) and 1.63 (F) per year respectively. Optimum fishing mortality rate and exploitation rate (E) were 0.53 per year and 0.55 respectively. E_{max}, $E_{0.1}$ and $E_{0.5}$ were 0.46, 0.36 and 0.28 respectively (Figure 4b).

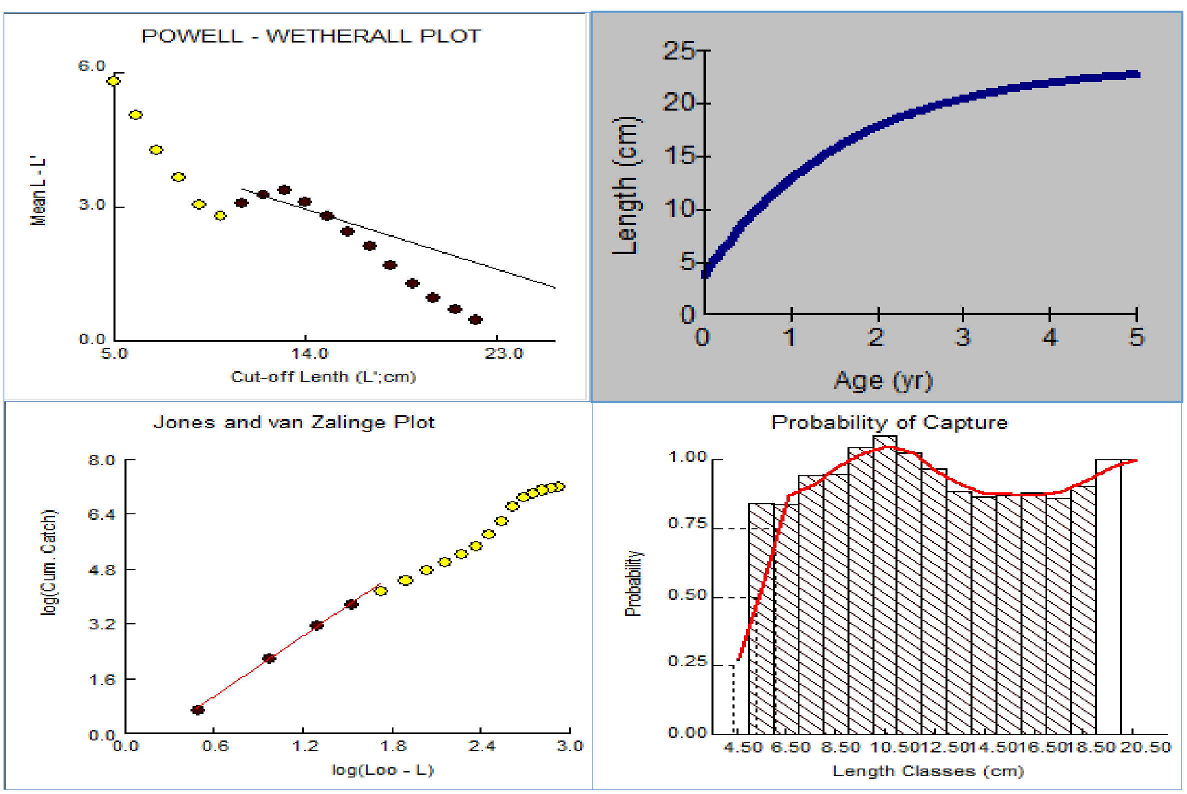

Figure 3: A) Powell Wetherell plot B); Length at age plot; C) Length-converted catch curve D; Length at first capture

3.5 Virtual population analysis (VPA)

Recruits estimated into the population was 6.54 x 10^7 with the highest harvesting intensity occurring within lengths, 10 cm and 11 cm with fishing mortality rate (F) of 0.27 yr^{-1} (Table 1). Peak of fishing mortality rate (1.33) ensued within the length range of 22 cm to 23 cm. Values of constants 'a' and 'b' were calculated as '0.0087' and '3.3'.

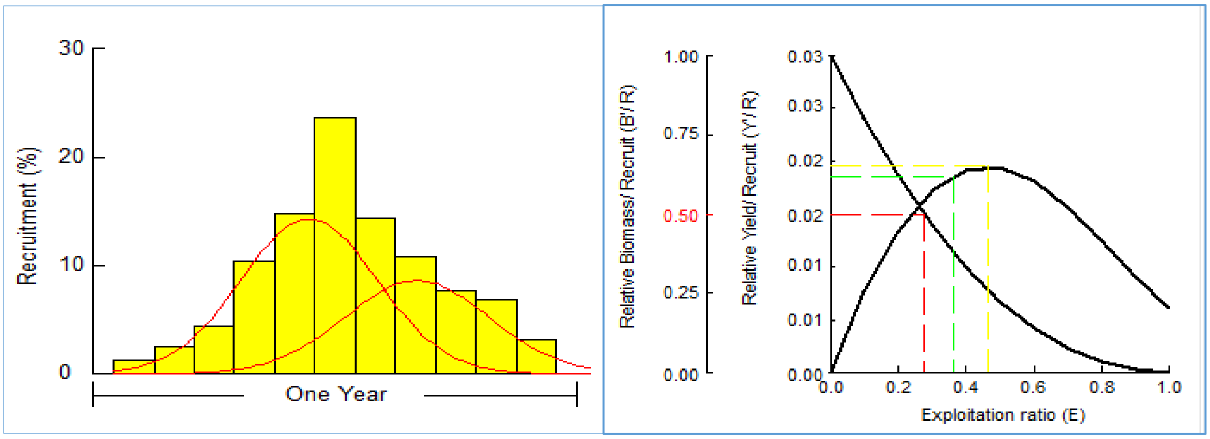

Figure 4: A) Recruitment pattern; B) Relative yield and relative biomass per recruit (B'/R)

Table 1: Survivors and catches of *Sardinella maderensis* from VPA output in FISAT II

Mid-Length	Catch (in numbers)	Survivors (N)	Fishing mortality (F)	Steady-state Biomass (tonnes)
5.5	25298	65450676	0.0045	13.6
6.5	79057	58008828	0.0152	21.99
7.5	366824	50999980	0.0759	32.64
8.5	354175	44207320	0.0797	45.31
9.5	720999	37943252	0.1785	59.42
10.5	980306	31849070	0.2719	73.74
11.5	499640	26073218	0.1564	88.14
12.5	338364	21325562	0.1196	102.8
13.5	199224	17223176	0.0799	116.75
14.5	170763	13707016	0.0785	128.96
15.5	177088	10641459	0.0948	137.83
16.5	148627	7981172	0.0949	142.16
17.5	126491	5748505	0.0988	141
18.5	126491	3919562	0.126	132.84
19.5	126491	2457690	0.1715	116.09
20.5	110680	1350241	0.2277	90.24
21.5	91706	592976	0.3554	56.04
22.5	79057	158114	1.33	15

3.6 Maximum Sustainable Yield (MSY)

Total biomass and yield were estimated as 3404.38 tons and 225.55 tons respectively. Using a mean body weight of 0.0745g, MSY was calculated as 2377 tons (Table 2).

Table 2: Estimates of the total biomass (tons), the yield (tons) and the MSY (tons) for *Sardinella maderensis*

Mid-Length	Catch	XL1, L2	N	E	F	Z	Biomass/kg	Body weight/kg	Yield
5.5	25298	1.06	65450676	0.003	0.0045	1.32	418826	0.0032	81.38
6.5	79057	1.07	58008828	0.011	0.0152	1.35	387483	0.0053	422.94
7.5	366824	1.07	50999980	0.054	0.0759	1.41	360058	0.0083	3049.12
8.5	354175	1.08	44207320	0.057	0.0797	1.41	331067	0.0123	4342.48
9.5	720999	1.08	37943252	0.118	0.1785	1.51	300921	0.0174	12515.67
10.5	980306	1.09	31849070	0.170	0.2719	1.60	268602	0.0238	23306.49
11.5	499640	1.10	26073218	0.105	0.1564	1.49	238000	0.0317	15829.76
12.5	338364	1.11	21325562	0.082	0.1196	1.45	210770	0.0413	13960.99
13.5	199223	1.12	17223176	0.057	0.0799	1.41	185759	0.0527	10497.41
14.5	170763	1.13	13707016	0.056	0.0785	1.41	162062	0.0662	11298.33
15.5	177088	1.15	10641459	0.067	0.0948	1.42	139167	0.0819	14497.84
16.5	148627	1.18	7981172	0.067	0.0949	1.43	116678	0.1000	14862.73
17.5	126491	1.21	5748505	0.069	0.0988	1.43	95380	0.1208	15274.91
18.5	126491	1.27	3919562	0.087	0.126	1.46	74790	0.1443	18258.54
19.5	126491	1.35	2457690	0.114	0.1715	1.50	54948	0.1710	21626.10
20.5	110680	1.52	1350241	0.146	0.2277	1.56	36213	0.2008	22228.54
21.5	91706.	2.00	592976	0.211	0.3554	1.69	19224	0.2342	21473.96
22.5	79057	0.04	158114	0.500	1.33	2.66	4428	0.0256	2024.24
							3404.38	**0.0745**	**225.55**
MSY		2377 tons							

4.0 DISCUSSION

The estimated growth rate was lower than 0.67 yr^{-1} with a short longevity period indicating that this species is a fast-growing organism that attains maximum length of 22.5 cm in less than 5 years (Kienzle, 2005). Mathews and Samuel (1990) documented that for short-lived species, maximum length (L_{max}) is lower than the asymptotic length (L_∞), a similar finding was observed from this study ($L_{max} < L_\infty$). The fast growth rate of the assessed fish species points to the equilibrium between fish density and food resources. The relative mortality-growth rate ratio (M/K = 2.18) was within the range for conducive marine environment (i.e. M/K = 1.5 – 2.5) as reported by Abowei *et al*. (2009). The estimated growth performance index from the study was slightly lower than estimates provided by other researchers (e.g. Sossoukpe et al., 2016). Potential reasons include computation procedure and the nature of the marine environment.

The lower length at first capture obtained from the study may be assigned to the use of small mesh sized fishing gears (Wehye and Amponsah, 2017a) as well as constant fishing within the nearshores along the Ghanaian coast which are areas noted to be active fish nursery grounds. Further to this, the estimated critical length at capture (Lc) fell below 0.5, showing that majority of the catch are juveniles (Pauly and Soriano, 1986). This finding signals the occurrence of the growth overfishing as they are not permitted to grow to the socially optimal size. The length at first capture was also found to be lower than lengths at first maturity and first recruitment - implying potential recruitment failure in the future. Diekert (2011) documented that recruitment overfishing largely involves capturing too any small sized fishes before they have matured. Hence, there is the need to implement and enforce mesh size regulations as this intervention will allow individuals of fish species to mature and spawn at least once before harvested.

Length of individuals experiencing high fishing intensity (10 cm – 11cm) was found to be lower than the minimum legal landing size (18 cm) enshrined in Ghana's Fishing Regulation (2010). This practice by fishermen fueled by consumer acceptance demonstrates poor enforcement of the fisheries law in Ghana by relevant authorities.

The observed continuous recruitment pattern was in agreement with findings by Pauly (1980) for tropical species, possibly due to the manifestation of more matured females (Deekae and Abowei, 2010). The presence of continuous recruitment pattern and a high number of survivors of individuals at the length at first recruitment (Lr_{50}) as shown in Table 1 indicate proper functioning of recruitment within the *Sardinella maderensis* stock. This finding shows that recruitment overfishing within the stock of the assessed fish species may be a critical issue in the future.

The higher Z/K ratio (>2) depicts intense exploitation (King and Etim, 2004). Comparatively, the lower natural mortality rate (M) estimated from the study confirms high fishing pressure on *S. maderensis* in Ghanaian coastal waters. Furthermore, fishing mortality rate (F) was found to be higher than the optimum fishing limit (F_{opt}), which re-echoes the incidence of intense fishing pressure on *S. maderensis* (Amponsah *et al.,* 2016b).

The exploitation rate (E) was higher than the optimum level of E = 0.5. This illustrates the existence of over-exploitation within the fishery of *S. maderensis* (Pauly, 1980). The relative biomass per recruit at E_{curr} and E_{max} were all lower than 30%, espousing the possible existence of recruitment failure in the future. Furthermore, the annual catch for *Sardinella maderensis* in 2014 (4895.76 tons) was found to be higher than the estimated MSY, reiterating the occurrence of overfishing within the fishery of the assessed stock.

5.0 CONCLUSION

S. maderensis within the coastal waters of Ghana is a fast-growing species with short doubling time, thus consequences of overfishing will be economic related than biological. Growth overfishing was found to be present due to the harvesting of small-sized individuals of the species. Recruitment within the stock was observed as active. However, recruitment overfishing within the stock was found to be a precarious issue in the future, especially with relative biomass per recruit below the threshold of 30%. Therefore, stringent management measures such as the use of biological reference points are urgently required for sustainable management.

ACKNOWLEDGEMENT

This study is the outcome of joint investigation between the Department of Marine and Fisheries Sciences, University of Ghana, Legon and the Australian National Centre for Ocean Resources and Security (ANCORS), University of Wollongong, Australia with resources from AusAID. The role of Professor Martin Tsamenyi AM and Dr. David Kirby of ANCORS, University of Wollongong, Australia and other colleges whose efforts facilitated this collaboration is duly valued. Further, this study is the product of supervisory work for the thesis M. Phil (Fisheries Science) degree at the Department of Marine and Fisheries Sciences, University of Ghana, of the corresponding author. Earnest appreciation goes to the technicians from Marine and Fisheries Department, University of Ghana for providing assistance during both field and laboratory work.

REFERENCES

Abowei, J.F.N., Davis, A.O. & Eli, A.A. (2009). Study of the length-weight relationships and condition factor of five fish species from Nkoro River, Niger Delta, Nigeria. *Current Research Journal of Biological Science*, 1: 94 – 98

Ahmad, I.M., Yola, I.D. and Suleiman, N. (2018). Mortality and Exploitation Rates of Challawa Gorge Dam Fishes, Kano State, Nigeria. J Fisheries Livest Prod 6: 262. doi: 10.4172/2332-2608.1000262

Amponsah, S.K.K., Ofori-Danson, P.K., Nunoo, F.K.E. & Ameyaw, G.A. (2017a). Population Dynamics of *Sardinella aurita* (Val., 1847) within Ghana's Coastal Waters. Vol. 4 (3), 237-248

Amponsah, S.K.K., Ofori-Danson, P.K., Nunoo, F.K.E. & Ameyaw, G.A. (2017b). Virtual population analysis and estimates of maximum sustainable yield of some commercially important fish species in the coastal waters of Ghana and management implications. *International Journal of Fisheries and Aquatic Research*, Vol 2 (3), pp 1 -7.

Amponsah, S.K.K., Ofori-Danson, P.K. & Nunoo, F.K.E. (2016a). Study of the population parameters of the bigeye grunt, *Brachydeuterus auritus* (Valenciennes, 1831) in Ghanaian coastal waters and its implications for management. *International Journal of Fisheries and Aquatic Studies*, 4: 413- 419.

Amponsah, S.K.K., Ofori-Danson, P.K. & Nunoo, F.K.E. (2016b). Population dynamics of *Engraulis encrasicolus* (Linnaeus, 1758) within Ghana's coastal waters. *International Journal of Fisheries and Aquatic Studies*, 4: 258 – 263.

Amponsah, S.K.K., Ofori-Danson, P.K. & Nunoo, F.K.E. (2016c). Fishing regime, growth, mortality and exploitation status of *Scomber japonicus* from catches landed along the eastern coastline of Ghana. *International Journal of Fisheries Aquatic Research,* 1: 5.

Amponsah, S.K.K., Ofori-Danson, P.K., Nunoo, F.K.E. & Ameyaw, G.A. (2016d). Aspects of population dynamics of Red Pandora, *Pagellus bellottii* (Steindachner, 1882) from the coastal waters of Ghana. *Journal of Scientific and Industrial Research*, 5: 215-224.

Amponsah, S.K.K. (2015). Assessment of coastal fishing operations in Ghana from the perspective of safety, poverty and catches. Masters Thesis, University of Ghana. 142 pp.

Ansa-Emmim, M. (1973). Pelagic Fisheries. In: *The Ghana Fishing Industry. Proceedings of Symposium on the Fishing Industry in Ghana*, May 4-5, 1972. Fishery Research Unit, Tema.

Beverton, R.J.H. (1963). *Maturation, growth and mortality of Clupeid and Engraulid stocks in relation to fishing.* Rapports et Proce´s-Verbaux des Re´unions, Conseil International pour l'Exploration de la Mer 154, 44–67.

Beverton, R.J.H. Holt, J.S. (1957) On the dynamics of exploited shrimp populations. *Shrimp . Invest. London, Ser.*, Vol 2 (19), 533 pp.

Binet, D. (1982). Influense des variations climatiques sur la peche de *Sardinella aurita* ivoiro-ghanéennes: relation secheresse-surpêche. *Oceanological Acta* 5: 443---452.

Brainerd, T.R (1991). The Sardinella Fishery off the Coast of West Africa; The Case of A Common Property Resource. *Paper presented at the Second Annual Conference of the International Association for the Study of Common Property (IASCP), September 26-29, 1991*, University of Manitoba, Winnipeg, Canada. 34 pp.

Branch, T.A., Kirkwood, G.P., Nicholson, S.A., Lawlor, B. & Zara, S.T. (2000). Yield Version 1.0, MRAG Ltd, London U.K.

Deekae, S.N. Abowei, J.N.F. (2010). Some growth parameters of *Macrobrachium macrobrachium* (herklots,1851) from Luubara Creek in Ogoni Land, Niger Delta, Nigeria. *Research Journal of Applied Sciences, Engineering and Technology,* 2: 558-567.

FAO (1971). *Working seminar on coastal pelagic resources of West Africa*. Tema, Ghana, 1-5 November 1971. Rome, FAO, 64p. (mimeo)

Fischer, W., Bianchi, G. & Scott, W.B. (Eds), (1981). *FAO species identification sheets for Fishery purposes. Eastern Central Atlantic; Fishing area 34, 47 (in part).* Canada Funds-in-Trust. Ottawa, Department of Fisheries and Oceans Canada, by arrangement with Food and Agriculture Organization of the United Nations, vols. 1-7,

Gayanilo, F., Sparre, P. & Pauly, D. (2005). *FAO-ICLARM Stock Assessment Tools II (FiSAT II).* Revised. User's guide. Computerized Information Series (Shrimp eries). No. 8. Revised version. FAO, Rome, 168 pp.

Gheno, Y. (1970). Note sur les sardinelles immatures de 1'estuaire du Gabon. Doc. Sci. Cent. Pointe-Noire ORSTOM (Nouv. Ser.). (12): 20p.

Gheshlaghi, P., Vahabnezhad, A. & Taghavi Motlagh, SA. (2012). Growth parameters, mortality rates, yield per recruit, biomass, and MSY of Rutilus frisii kutum, using length frequency analysis in the Southern parts of the Caspian Sea. *Iranian Journal of Shrimp Fisheries Science.* Vol 11(1), pp. 48 - 62.

Gulland, J. A. (1969): *Manual of methods for fish stock assessment.* Part Fish population. FAO Manuals in Fisheries Science, No. 4, 154 pp.

Hoggarth, D.D., Abeyasekera, S., Arthur, R.I., Beddington J.R., Burn R.W., Halls AS. et al. (2006). *Stock Assessment for fishery management - A framework guide to the stock assessment tools of the Fisheries Management Science Programme (FMSP).* Fisheries Technical Paper. No. 487. FAO. Rome. 261.

Kienzle, M. (2005). *Estimation of the population parameters of the Von Bertalanffy Growth Function for the main commercial species of the North Sea*. Fisheries Research Services Internal Report. No. 05/05.Aberdeen, 34 pp.

King RP. Etim, L. (2004). Reproduction, growth, mortality and yield of T. mariae (Boulenger, 1899) (cichlidae) in Nigeria rainforest wetland stream. Journal of Applied Ichthyology, 20: 502-510.

Koranteng, K. (1989). *The sardinella ("herring") fishery in Ghana: The past, recent developments and the years ahead*. Information Report 23, Fisheries Research and Utilization Branch, Tema. 20 p.

Kwei EA. Ofori-Adu, D.K. (2005). Fishes in the coastal waters of Ghana. Ronna Publishers, Tema.

Mathews, C.P. Samuel, M. (1990*). The relationship between maximum and asymptotic length in fishes*. Fish byte, 8(2): 14-16.

Muta, K. (1964). *Report on the biological survey of the sardine* (*Sardinella aurita*). Government of Ghana, Mimeo. 30 p

Mudoidiong, O., Ukpatu, J.E. and Udoh., J.P. (2017). Recruitment Pattern and Length-At-First-Capture of The Silver Catfish *Chrysichthys Nigrodigitatus* Lacépède: Claroteidae In Lower Cross River, Southeast Nigeria. International Journal of Fisheries and Aquaculture Research Vol.3, No.2, pp.10-18.

Nunoo, F. K. E., Asiedu, B., Amador, K.., Belhabib, D., Lam, V., Sumaila, U. R. & Pauly, D. (2014). Marine Fisheries Catches in Ghana: Historic Reconstruction for 1950 to 2010 and Current Economic Impacts. *Reviews in Fisheries Science and Aquaculture.* 22(4): 274-283.

Nurul Amin, S.M., Arshad, A., Bujang, J.S. and Siraj, S.S. (2008). Growth, Mortality and Yield-Per-Recruit of Sergestid Shrimp, *Acetes intermedius* Omori, 1975 (Decapoda: Sergestidae) from Length Frequency Analysis in the Coastal Waters of Malacca, Peninsular Malaysia. Pertanika J. Trop. Agric. Sci. 31(1): 55 – 66 pp.

Pauly, D. Soriano, M.L. (1986). Some practical extensions to Beverton and Holt's relative yield-per-recruit model. In: JL. Maclean, LB. Dizon, LV. Hosillos. (Eds.) *The First Asian Fisheries Forum,* Asian Fisheries Society, Manila, Philippines, 1986, pp. 491-496.

Pauly, D. Caddy, J. F. (1985). *A modification of Bhattacharya's method for the analysis of mixtures of normal distributions*. FAO Fish. Circ. (781): 16 pp

Pauly, D. (1984). *Fish population dynamics in tropical waters: a manual for use with programmable calculations*. ICLARM Stud. Rev.,8, 325 pp.

Pauly, D. Munro, J.L (1983). *Once more on the comparison of the growth of Fish and invertebrates*. Fish byte, 2(1): 21.

Pauly D. (1980). *A selection of simple methods for the assessment of tropical Fish stocks. FAO*. Fisheries Circular 729, FAO, Rome.

Pauly, D. (1979). *Gill size and temperature as governing factors in Fish growth: a generalization of von Bertalanffy growth formula*. Berichte des Instituts für Meereskunde an der University, Germany, 156 pp.

Sarpong, D., Quaatey, N. & Harvey, S. (2005). *The Economic and Social Contribution of Fisheries to Gross Domestic Product and Rural Development in Ghana.* FAO Sustainable Fisheries Livelihoods Programme (SFLP) GCP/INT/735/UK, Rome. 53 p.

Sossoukpe, E., Djidohokpin, G., & Fiogbe, E.D. (2016). Demographic parameters and exploitation rate of *Sardinella maderensis* (Pisces: Lowe 1838) in the nearshore waters of Benin (West Africa) and their implication for management and conservation. *Fisheries Research*, 4: 165-171.

Sparre, P. Venema, S.C. (1998). *Introduction to tropical Fish stock assessment. Part 1— Manual*. FAO Fisheries Technical Paper 306.1, FAO, Rome, 376 pp.

Wehye, A.S. & Amponsah, S.K.K (2017a). Growth, Mortality and Exploitation rates of Lesser African threadfin, Galeoides decadactylus (Bloch,1795) within the coastal waters of Liberia. *International Journal of Fisheries and Aquatic Research,* 2 (2), 43-49.

Wehye, A.S. & Amponsah, S.K.K (2017b). Aspects of population dynamics of Pseudotolithus typus (Bleeker, 1863) with management implications within the coastal waters of Liberia. *International Journal of Fisheries and Aquatic Studies,* 5(2): 583-589.

Wehye, A.S., Amponsah, S.K.K. & Jueseah, A.S. (2017). Growth, Mortality and Exploitation of Sardinella maderensis (Lowe, 1838) in the Liberian coastal waters. *Fisheries and Aquaculture Journal*, 8: 189. doi:10.4172/2150-3508.1000189.

Cite this Article: Amponsah SKK; Ofori-Danson PK; Nunoo FKE; Ameyaw GA (2019). Estimates of Population parameters for *Sardinella maderensis* (Lowe, 1838) in the coastal waters of Ghana. Greener Journal of Agricultural Sciences 9(1): 23-31, http://doi.org/10.15580/GJAS.2019.1.011719017.