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Fishing regime, growth, mortality and exploitation rates of *Scomber Japonicus* (Houttuyn, 1782) from catches landed along the eastern coastline of Ghana

*** Samuel KK Amponsah, Patrick K Ofori-Danson, Francis KE Nunoo**

Department of Marine and Fisheries Sciences, University of Ghana, Legon – Ghana

Abstract

Population parameters (growth, mortality and exploitation rates) and the fishing regime of *Scomber japonicus* along the eastern coastline of Ghana were assessed using FiSAT II software for samples collected from August, 2014 to January 2015. The asymptotic length ($L\infty$), growth rate (K) and length at first maturity (Lm_{50}) were 26.78 cm (standard length), 1.30 per year and 17.85 cm (standard length) respectively. The annual instantaneous rate of total mortality (Z), fishing mortality (F), the natural mortality (M) and the length first capture (Lc_{50}) were estimated at 5.02 per year, 2.92 per year, 2.10 per year and 13.19 cm respectively. The exploitation rate ($E_{current}$) was 0.58 with the $Lc/L\infty$ estimated at 0.49. The present study indicated that the maximum exploitation rate for *Scomber japonicus* could be achieved at E_{max} = 0.72. Results from the study showed relatively heavy exploitation for *Scomber japonicus* with its fishing regime as overfished. Such observations demand urgent implementation of management policies in order to ensure its sustainability for both future and present generation fish protein needs.

Keywords: Ghana *Scomber japonicus* Mortality Growth Exploitation

1. Introduction

Scomber japonicus (Houttuyn, 1782), commonly called 'Chub mackerel' of the Scombridae family is primarily a coastal pelagic species, found within a depth range of 0 – 300 m, however it is usually abundant at within 50-200m in subtropical waters of about 10 – 27ºC (Castro, 2000). Collette and Naunen (1983) wrote that Chub mackerel is widely distribution over the continental shelves of the tropical and subtropical regions of the Pacific, Indian and Atlantic Ocean and adjacent seas. Chub mackerel is known to feed on small pelagic organisms especially clupeids and pelagic invertebrates and are also schooling pelagic fish species in coastal waters (Fischer *et al.*,1981). 'Saman' as locally known in Ghana is a significant pelagic resource in Ghana's coastal waters with its abundance coinciding with the upwelling season in Ghana (Osei, 2008). Though Chub mackerel is highly appreciated in Ghana because of its high quality flesh, it is not popular in terms of abundance.

Chub mackerel forms one of the principal fish species of purse seine fishing operations in Ghana's coastal waters and usually, its catch is separated from the whole landed catch because of its high market value. Locally, it is marketed fresh, frozen, smoked, salted and occasionally canned as reported by Kwei and Ofori-Adu (2005). Despite the increasing fishing pressure on fish stocks due to the rising number of fishing crafts, fishermen operating in the coastal waters of Ghana and increase in demand for food and cash, information on population parameters and stock position for important commercial fishes are limited.

In view of this defect, the objective of the present study was to estimate some population parameters and identify the fishing regime of *Scomber japonicus* to ensure sustainable management of this species residing in Ghana's coastal waters.

2. Materials and methods

2.1 Study area

This study focused on the eastern coastline of Ghana comprising of four sampling stations namely; Jamestown, Tema, Vodzah and Denu Fig. 1. These four fish landing sampling stations are coastal areas with fishing as the primary source of livelihood complimented with some secondary livelihoods such as farming, trading and driving.

2.2 Data collection

Fish samples were purchased from local fishers at the selected landing sites for six months from August 2014 to January 2015 (a total of six months) who operated mostly with multifilament fishing gears. The samples were preserved in ice chest using ice blocks and transported to the laboratory at the Department of Marine and Fisheries Sciences, University of Ghana. At the laboratory, fish species were weighed to the nearest 0.01g using the electronic scale while the total and standard length were measured using the 100cm measuring board to the nearest 0.1cm. Fish samples were identified to the species level using identification keys by Fischer et al. (1981) and Kwei and Ofori-Adu (2005). In all, a total of 282 species of *Scomber japonicus* were sampled.

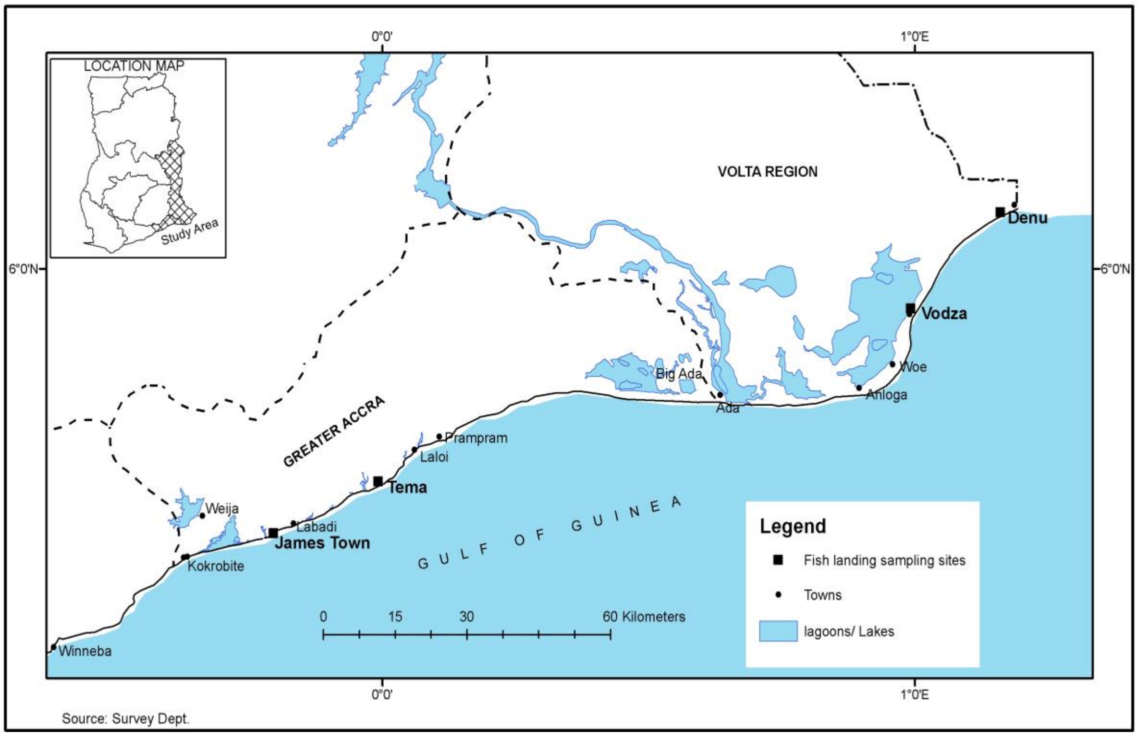


Fig 1: Map showing the sampling sites

2.3 Methods

2.3.1 Growth parameters

Growth parameters such as growth rate (K), asymptotic length (L_∞) and the growth performance index (ϕ) were obtained using the Von Bertanlaffy Growth Function (VBGF) fitted in FISAT II. According to VBGF as expressed below, individual fishes grow on average towards the asymptotic length at an instantaneous growth rate (K) with length at time (t) following the expression:

$Lt = L_\infty (1-e^{-k\,(t-to)})$ .... (Pauly, 1979).

The theoretical age at birth (t_o) was calculated independently, using the empirical formula:

$\log_{10}(-t_o) = -0.3922 - 0.275 * \log_{10}L\infty - 1.038 * \log_{10}K$ …………. (Pauly, 1979).

The longevity (Tmax) was estimated as: $Tmax = 3/K + t_o$ ………... (Pauly, 1983).

To compare the growth rate of the fish species for this study with published values, the growth performance index was generated as expressed in the equation:

$(ø) = 2\log L_\infty + \log K$………………. (Munro & Pauly, 1983)

2.3.2 Mortality parameters

Total mortality coefficient (Z) was estimated by using the Jones and van Zalinge plot incorporated in the FISAT II tool. Natural mortality rate, M, was computed by the empirical equation of Pauly (1980) expressed (below) using a mean surface temperature (T) of 25.7°C:

$\text{Log}\, M = - 0.0066 - 0.279\, 1og\, L_\infty + 0.6543 \log K + 0.4634 \log T$…………………….……………..…….. (Pauly, 1980)

Where M is the instantaneous natural mortality, L_∞ is the asymptotic length, T is the mean surface temperature and K refers to the growth rate coefficient of the VBGF.

Fishing mortality (F) was calculated using the relationship: $F = Z - M$…. (Gulland, 1969)

Where Z is the total mortality, F the fishing mortality and M is the natural mortality. The exploitation level (E) was obtained using the relationship: $E = F/Z$ ………... (Gulland, 1969)

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

To identify the fishing regime, the length at first capture (Lc_{50}) was estimated. The ascending left arm of the length-converted catch curve incorporated in FiSAT II tool was used to estimate the probability of length at first capture (Lc_{50}) in addition to the length at both 25 and 75 captures which corresponded to the cumulative probability at 25% and 75% respectively. The length at first maturity was estimated using the expression:

Length at first maturity (Lm_{50}) = $(2 * L_\infty)/\ 3$ ……………. (Hoggarth *et al.,* 2006).

2.3.4 Relative Yield per Recruit (Y'/R) and Relative Biomass per Recruit (B'/R)

The relative biomass per recruit (B'/R) was estimated as B'/R = (Y'/R)/F. Emax which implies exploitation rate producing maximum yield, $E_{0.1}$ suggesting exploitation rate at which the marginal increase of Y'/R is 10% of its virgin stock with $E_{0.5}$ indicating exploitation rate under which the stock is reduced to half its virgin biomass were computed using the procedure incorporated using the Knife-edge option fitted in the FiSAT II Tool.

2.3.5 Yield isopleths

Yield contours which characterize yield isopleths were plotted to identify the impact on yield of changes in exploitation rate (Emax) and critical length ratio $Lc/L\infty$ using the FiSAT II Tool.

2.4 Data Analysis
The length frequency data were pooled into groups with 1cm length intervals. Then the data were analyzed using the FiSAT II (FAO-ICLARM Stock Assessment Tools) software.

3. Results
3.1 Growth parameters
Figure 2 shows the restructured length frequency with superimposed growth curves. The presence of up to two peaks corresponds to two cohorts. The growth parameters were estimated as L∞ = 26.78 cm and K = 1.30 year $^{-1}$. Growth performance index (ø) and the theoretical age at birth (t_o) were estimated at 2.970 cm and -0.13 years respectively. Using the estimated growth parameters (L∞, K and t_o), the VBGF for length at time (t) was expressed as:

Lt =26.78 (1-e$^{-1.30\ (t-(-0.13))}$) for *Scomber japonicus.*

The longevity of *Scomber japonicus* (*Tmax*) was calculated as approximately 2 years.

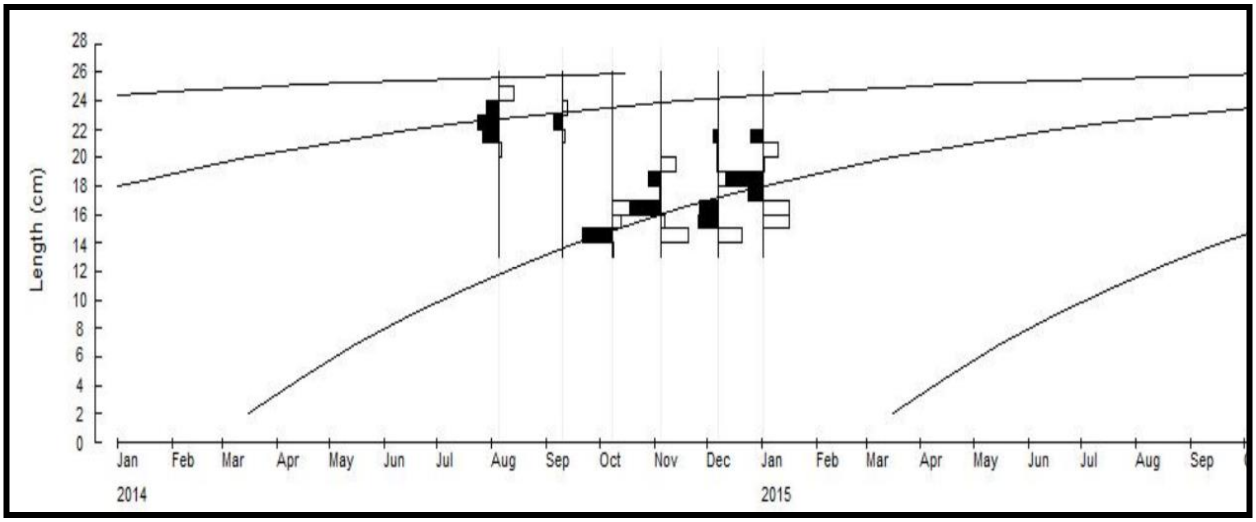


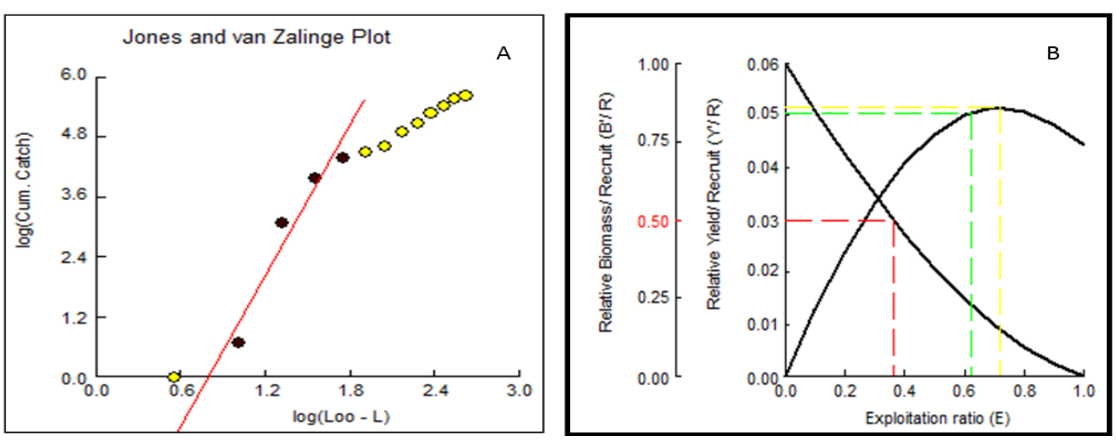
Fig 2: Reconstructed length frequency distribution superimposed with growth curve

3.2 Mortality Coefficients and Current Exploitation Rate
Using the Jones and van Zalinge plot as shown in Fig. 3a, the total mortality coefficient (Z) was calculated as 5.02 year^{-1}. The natural and fishing mortality were estimated at M= 2.10 year^{-1} and F = 2.92 year^{-1} respectively. The current exploitation rate ($E_{current}$) was obtained at 0.58.

3.3 Length at first capture (Lc_{50}) and Length at first maturity (Lm_{50})
Figure 3c shows the probability of capture as output from FiSAT. From Fig. 3c, the probability of capture at: L_{25} (25%) was 12.32 cm, L_{50} (50%) was 13.19 cm and L_{75} (75%) was 13.99 cm (Fig.3c) below. Therefore, the length at first capture (Lc_{50}) was 13.19 cm. The length at first maturity (Lm_{50}) was estimated at 17.85 cm.

3.4 Relative Yield per Recruit (Y'/R) and Relative Biomass per Recruit (B'/R)
Estimates of (Y'/R) and (B'/R) as graphically represented in Fig. 3b, were $E_{0.1}$ = 0.62, $E_{0.5}$ = 0.36 and E_{max} = 0.72. The optimum exploitation rate (E_{max} =0.72) is indicated by the broken yellow line. Comparatively, $E_{current}$ (0.58) was relatively lower than E_{max} (0.72).

3.5 Yield isopleth
The yield isopleths from which the yield contours predict the response of relative yield-per-recruit of the fish to changes in Lc (proportion of length at first capture to asymptotic length (Lc/L∞) = 0.49 and E_{max} = 0.72 is shown in Fig. 3d.



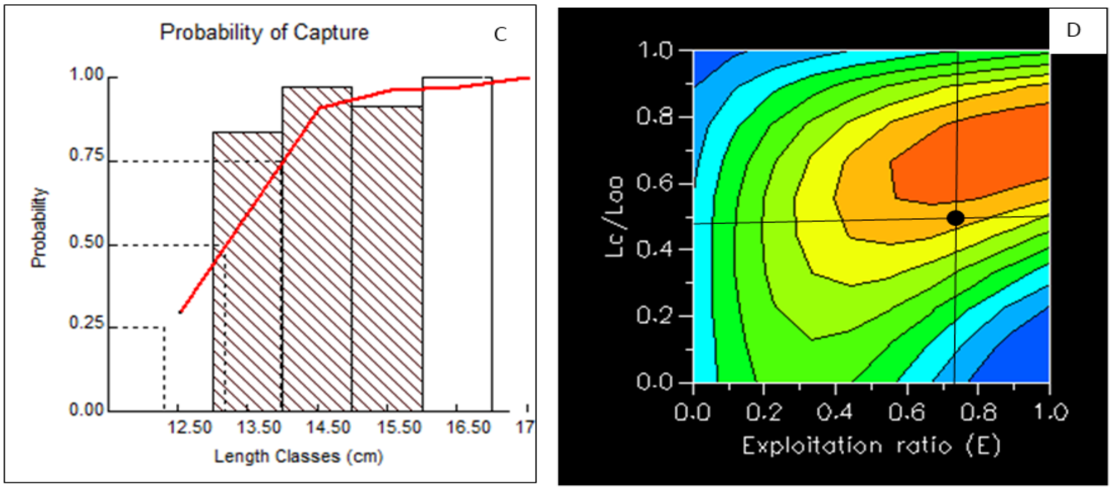


Fig 3: A) Jones and van Zalinge plot; **B)** Relative yield per recruit (Y'/R) and relative biomass per recruit (B'/R); **C)** Probability of capture; **D)** Yield isopleth diagram

4. Discussion

From the extant scientific literature, it is obvious that this is the first time in which population dynamics of *Scomber japonicus* has been reported from the coastal waters of Ghana, hence the result presented in this study will be a springboard for further research in this field.

Table 1: Comparison of growth parameters and growth performance indexes obtained from previous studies for S. japonicus

References	Locality	L ∞	k	Φ'
Tuggac (1957)	Marmara Sea	33.0	0.47	2.71
Carvalho *et al*. (2002)	Azores	57.5	0.20	2.82
Perrotta *et al*. (2005)	NE Mediterranean	39.7	0.29	2.66
Bayhan (2007)	Izmir Bay	29.8	0.20	2.25
Gang *et al*. (2008)	East Chine and Yellow Sea	40.4	0.49	2.90
Cengiz (2012)	Saros Bay	39.0	0.20	2.48
This study	eastern coastline of Ghana	26.78	1.30	2.97

The asymptotic length (L∞) of 26.78 cm (standard length) appeared to be lower than estimates reported in studies done elsewhere as indicated in Table 1. The differences in the asymptotic length can be attributed to the fact that maximum length obtained in this study was relatively lower than those obtained in other localities. Furthermore, the difference in maximum length can also be attributed to the fishing season, geographical reach of fishing activities and subsequently the dominating fish length during each fishing season, noise pollution from outboard motors and industrial activities, fishing pressure and environmental degradation (King, 1991).

The obtained growth rate (K) of 1.30 per year and longevity of 2 years both indicated that the species is fast growing pelagic or short lived. However, faster growth rates are defensive mechanisms against predators to enhance the sustainability of fish population within the marine environment. Using the growth performance index or phi prime (ø) which is the basis of comparing growth rates, the estimate of growth performance index or phi prime (ø) in this study (ø = 2.970) fell within the acceptable range by Munro & Pauly (1983). Though relatively higher than estimates reported by other authors from different locations (Table 1), the obtained growth performance index was favourable with estimates obtained in other studies. This observation shows that *Scomber japonicus* within the present study area and other study areas are of similar family or taxa.

Table 2: Results of earlier studies concerning mortality rates of S. japonicus in different localities

References	Locality	Z	M	F	E
Castello and Cousseau (1976)	Argentina	0.91	0.33	0.58	*
Serra (1983)	Northern Chile	0.30	*	*	*
Maxim *et al*. (1990)	Mauritania	0.40	0.38	*	*
Zhenbin *et al*. (1991)	Taiwan	1.02	0.63	0.39	*
Mendoza (1993)	Northeastern Venezuela	0.58	0.02	*	*
Carvalho *et al*. (2002)	Azores	0.19	*	*	*
Cengiz (2012)	Saros Bay	0.91	0.34	0.57	0.62
This study	eastern coastline of Ghana	5.02	2.10	2.92	0.58

The relatively high calculated mortality rates of *Scomber japonicus* in comparison with findings from different localities as presented in Table 2, could be linked to array factors such as the method used in estimating the mortality parameters, different ecological conditions and intensive fishing activities (Joksimović *et al*., 2009).

The estimated fishing mortality rate (2.92yr^{-1}) of *Scomber japonicus* was relatively higher than the estimated natural mortality (2.10yr^{-1}), implying that the assessed fish species is presently under relatively high fishing pressure. The relatively high fishing mortality rate observed in this study possess a challenge to the health of *Scomber japonicus* population. This is possible because such relatively high mortality rates may result in changes in size at maturity, decreased viability of juveniles making juveniles prone to predators with a subsequent downward plunge in abundance and catch (Pauly, 1983).

Beverton-Holt (1966) suggested that when the natural mortality and fishing mortality are equal (that is; exploitation rate (E) = 0.5), then the stock is in a healthy state and optimally exploited. The current exploitation rate (E= 0.58) calculated in this study indicated heavy exploitation though not intense as compared to the estimated exploitation rate reported by Cengiz (2012) in Table 2. From Fig. 3b, this assertion could be supported by the fact that the obtained $E_{current}$ (E=0.58) is much lower than the maximum allowable limit based on the yield-per-recruit calculation (E_{max}=0.72).

Nonetheless, the exploitation of this stock will soon approach the maximum fishing level if the current level of exploitation is not monitored accordingly. Therefore, the present level of fishing mortality (in terms of number of fishing vessels, especially artisanal canoes) should be of urgent concern for fisheries managers in Ghana.

A comparative look at the yield isopleths diagram (Fig. 3d) in relation to the quadrant rule by Pauly and Soriano (1986), the Lc /L∞ of 0.49 and exploitation rate (E_{max}) of 0.72 of *Scomber japonicus* fell within quadrant D (shown by the black dot in Fig. 3d). This category suggests that the *Scomber japonicus* fishery in Ghana is currently overfished with a fishing regime of catching smaller fishes at higher fishing effort. Furthermore, the length at first capture (13.19 cm) was found to be lower than the length at first maturity (17.85 cm), indicating that growth overfishing exists within the fishery of *Scomber japonicus*. Therefore, as a management intervention, mesh sizes should be increased along with decreasing fishing efforts.

Concluding, the results from this study leaves us little doubt that relatively heavy exploitation exist within the *Scomber japonicus* fishery in Ghana's coastal waters and it is subsequently, overfished. Hence the urgent need to protect this important commercial stock, possibly through the integrated effort of fishers, coastal communities, NGOs and governmental agencies.

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