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Assessing the Population Parameters of *Decapterus punctatus* (Cuvier 1829) from the Coastal Waters of Greater Accra, Ghana using TropFishR

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ABSTRACT

Population parameters provide important information and can be considered important indicators of the variability and sustainability of stocks. The population parameters of *Decapterus punctatus*, in the coastal waters of Greater Accra, Ghana were studied between July 2018 and June 2019. We employed a two-stage sampling criterion in selecting five important fishing communities. In all, a total of 1,116 samples were collected randomly from selected fishermen who use multifilament fishing gears. The von Bertalanffy parameters were estimated at asymptotic length ($L\infty$) = 29.8 cm, growth rate (K) = 0.35 per year and growth performance index (Φ') = 2.49. Mortality parameters were calculated as total mortality rate (Z) = 1.77 per year, the natural mortality rate (M) = 0.62 per year, and fishing mortality rate (F) = 1.15 per year. The current exploitation rate (Ecurrent) was lower than the maximum exploitation (Emsy), indicating that *D. punctatus* fishery on the coast of Greater Accra is in a sustainable state.

INTRODUCTION

Globally, fish stocks have been declining since the 1990s. The demand for fish for human consumption continues to upsurge reaching 179 million tonnes in 2018 mainly due to urbanization and expansion of the fish-consuming middle class in developing markets (**FAO, 2018)**. Fish continue to be an important component in the diets of majority of people, especially those living in low and middle income countries **(Delgado, 2003; Hassberg *et al.*, 2020)**. The share of fish production destined for human consumption is expected to continue to grow from 50% in 2020 to 89% by 2030 (**FAO, 2022**). Fisheries are an important source of livelihood and income for over 60 million people globally **(FAO, 2018)**.

The sustainability of fishery resources will help in attaining the targets of the 2030 UN Sustainable Development Goals, specifically Goal 2 “Zero hunger” and Goal 14

"Life below water". To achieve this, there is a need to better understand the population parameters of most fish species including the carangids.

Carangids are important pelagic fish species, and are widely distributed in the Atlantic, Indian and Pacific regions with 32 genera and 140 species reported around the world **(Edwards *et al*., 2001; Nelson, 2006; Panda *et al*., 2012).** Carangids are found in tropical and subtropical marine waters of the world, and some occur in temperate regions **(Bannikov, 1987; Honebrink, 2000; Souza and Mafalda Júnior, 2008).** Most species of the Carangidae are important for the commercial, recreational and aquaculture fisheries, thus helping to meet food security **(Katsuragawa and Matsuura, 1992)**.

Some reported genera in the family sighted in Ghana's coastal waters include *Elagatis, Alectis, Caranx, Carangoides, Oligoplites, Selene, Seriola, Selar, Chloroscombrus, Trachinotus* and *Decapterus* **(Edwards *et al*., 2001; Kwei and Ofori-Adu, 2005).** For the species in the *Decapterus* genus, only two main species exist in Ghana, these are *Decapterus rhonchus* and *Decapterus punctatus*. In Ghana, a time series analysis from FishStatJ shows rising production of scads from 263 tonnes in 2000 to 6,542 tonnes in 2018; and this could be attributed to the high harvesting rate by semi-industrial and artisanal fishermen in Ghana. The round scad (*D. punctatus*) is an economically and commercially important pelagic fish in Ghana as indicated in the Ghana Fisheries Regulation Act 625, 2009.

In Ghana, *D. punctatus* is mostly caught by fishing gears such as seines, hooks and gill nets **(Edwards *et al*., 2001).** Most of the *D. punctatus* harvested by gill net are to some extent of small sizes or at the juvenile stage which could trigger the possible collapse of the species, especially in wake of recruitment failure. Coupled with the above negative incidence confronting *D. punctatus*, there is no specific catch data on *D. punctatus* on major fish statistics websites including FishStatJ which compounds the inefficiency in managing *D. punctatus*. Again, there is no documented assessment of *D. punctatus* on the coast of Ghana, from the perspective of fish stock modeling which disrupts proper management of this commercially important fish species.

Currently, in Ghana, there is limited information on the population parameters of *D. punctatus*. However, the only information on population dynamics in existence for *Decapterus rhonchus* from the coast of Ghana was reported by **Forson and Amponsah (2020).** Therefore, the information from the present study will serve as a baseline for the sustainable management of the *D. punctatus* from the Ghanaian coastal waters. The objective of the study was to determine the growth, mortality and exploitation of *D. punctatus*, one of several Carangidae species on the coast of Ghana, to serve as a baseline for the formulation and implementation of future management measures and plans for the stock.

MATERIALS AND METHODS

Study area:

The study focused on five important fishing communities along the Greater Accra region of Ghana. These are Kpone, Prampram, Tema, Sakumono and Nungua as shown in Figure 1. A two-stage sampling criterion was used in selecting the sites which included geographical isolation from other sites included in the current study and the level of fishing activities. These sampling locations are noted for fishing with fishing contributing over 50% as a primary occupation.

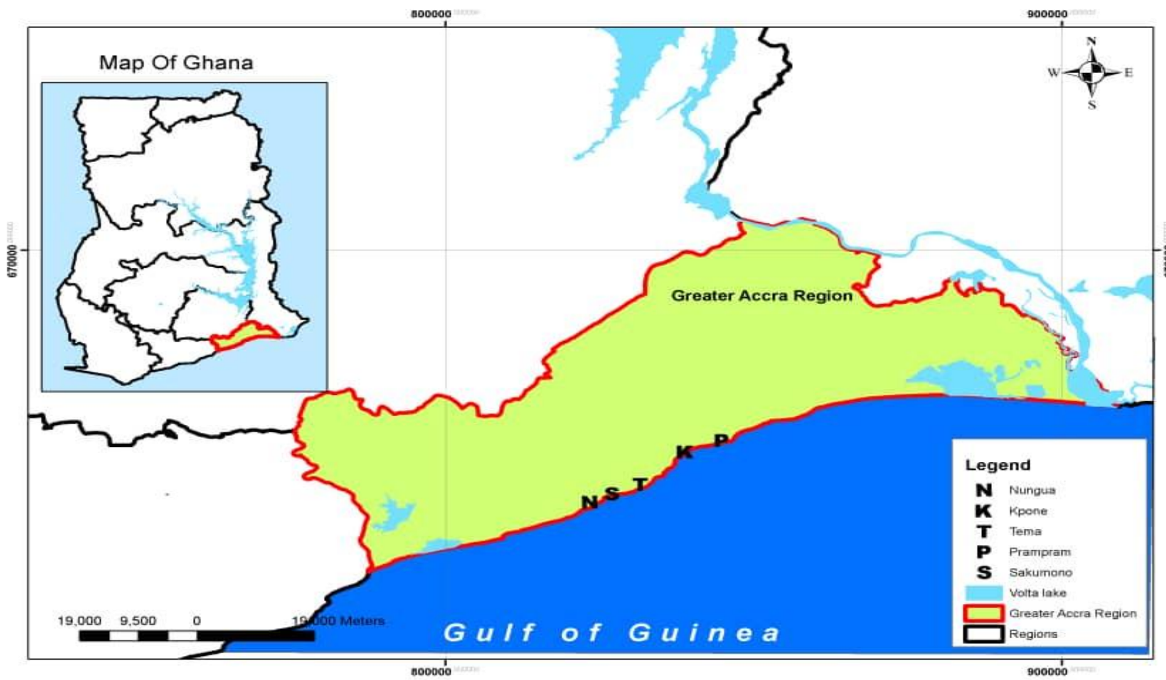

Fig. 1. A map of the study area showing sampling areas

Collection of Specimens and Sampling:

The species at the various sampling locations were identified to the species level using the identification keys by **Fischer *et al.* (1981).** Samples of *D. punctatus* were collected monthly from randomly selected fishermen who use multifilament fishing gears from fish landing sites for twelve months (July 2018 to June 2019). These fishermen predominantly use set nets and trawl nets with mesh sizes ranging from 0.013 m to 0.032 m. The samples collected were preserved on ice and transported to the laboratory where measurement for total length in centimeters was recorded. Measurement of total length was used for constructing length-frequency distribution with a length interval of 1 cm.

Growth parameters:

Growth parameters which follow the von Bertalanffy Growth Function (VBGF) including growth rate (K), asymptotic length (L_∞) and the growth performance index (Φ') were estimated using the Simulated annealing (SA) option of the Electronic Length

Frequency Analysis (ELEFAN) (Taylor and Mildenberger, 2017). Estimation of longevity (T_{max}) of the species was done using the method:

$T_{max} = 3/K$ **(Anato, 1999)**

The growth performance index was calculated using the formula:

$\Phi' = 2\log L_\infty + \log K$ **(Pauly and Munro, 1984)**

The theoretical age at length zero (t_0) followed the equation:

$\text{Log}_{10}(-t_0) = -0.3922 - 0.2752 \log_{10} L_\infty - 1.038 \log_{10} K$ **(Pauly, 1979)**

Mortality parameters:

Total mortality (Z) was computed using Linearized length converted catch curve **(Pauly and David, 1981; Spare and Venema, 1992)**

The natural mortality rate (M) was calculated using the procedure:

$M = 4.118K^{0.73}L\infty^{-0.333}$ **(Then *et al.*, 2015)**

Fishing mortality (F) was calculated as:

$Z - M$ **(Qamar *et al.*, 2016)**

The exploitation rate (E) was computed using the equation:

F/Z **(Georgiev and Kolarov, 1962)**

Length at first capture (Lc_{50}):

The probability of capture was estimated by backwards extrapolation of the descending limb of the length-converted catch curve. A selectivity curve was generated using linear regression fitted to the ascending data points from a plot of the probability of capture against length, which was used to derive values of the lengths at capture at probabilities of 50%, 75% and 95% **(Pauly, 1987).**

Estimated stock size:

The stock size was estimated using the Jones' length converted cohort analysis, which is a revision of Pope's virtual population analysis (VPA) for length data, integrated into TropFishR. This cohort analysis (CA) requires parameters a and b of the length-weight relationship, the estimated value of F and the terminal fishing mortality rate which was taken as the exploitation rate. The cohort analysis calculates the stock size using the total estimated catch (in numbers) as a reference point. The procedure followed in this study is provided by **Taylor and Mildenberger (2017).**

Yield per recruit:

The Thompson and Bell model was used to provide biological reference levels which is needed to deduce input control measures including reducing fishing effort. The fishing mortality needed to estimate the yield and biomass trajectories in the study was obtained by varying the parameter F in the Thompson and Bell model.

Data analysis:

The TropFishR package in R (**Taylor and Mildenberger, 2017)** was utilized for the assessment of the population parameters of specimens of *D. punctatus* that were encountered during the study period. The TropFishR is a package that contains the procedures such as Electronic Length Frequency Analysis (ELEFAN), length-converted catch curve (LCC) and cohort analysis (CA) for estimating the population parameters. These population parameters include the growth and mortality parameters as well as the biological reference points.

RESULTS

Length-frequency distribution

The length distribution for the *D. punctatuts* from the study ranged from 8 – 24 cm with an interval of 1 cm (Table 1). The estimated mean length of a total of 1,112 specimens was 14.1 cm.

Table 1: Length-frequency distribution of *D.pucntactus* specimen

Length Class	Jul., 2018	Aug., 2018	Sept., 2018	Oct., 2018	Nov., 2018	Dec., 2018	Jan., 2019	Feb., 2019	Mar., 2019	Apr., 2019	May, 2019	Jun., 2019
8	0	6	1	0	0	0	0	0	0	0	0	8
9	0	5	5	0	0	0	0	0	0	0	0	14
10	2	1	9	2	10	1	3	3	15	0	0	14
11	1	7	26	11	24	6	2	17	16	2	3	29
12	8	6	38	20	12	13	2	25	20	9	5	28
13	10	11	22	19	10	18	11	36	17	21	10	10
14	15	16	11	17	11	7	8	8	4	21	4	8
15	12	5	13	8	10	10	6	4	1	12	13	9
16	26	3	6	2	4	6	4	2	0	10	17	7
17	27	1	1	1	0	10	0	0	0	5	15	5
18	7	0	2	2	0	6	2	0	0	7	2	5
19	3	2	1	5	0	7	0	0	0	1	4	3
20	1	1	0	3	0	3	0	0	0	2	8	1
21	0	1	1	1	0	2	0	0	0	0	9	1
22	0	1	1	4	0	0	0	0	0	0	2	0
23	0	0	0	1	0	0	0	0	0	0	0	0
24	0	0	0	1	0	0	0	0	0	0	0	0
Total	112	66	137	97	81	89	38	95	73	90	92	142

Growth parameters

Restructured length-frequency of *D. punctatus* with superimposed growth curves is shown in Figure 2. The asymptotic length (L_∞) was 29.8 cm with a growth rate (K) of 0.35 yr^{-1}. The growth performance index (Φ') and Rn score were 2.49 and 0.31, respectively. The longevity (t_{max}) was calculated as approximately 8 years. The age at zero length (t_o) was estimated as – 0.4.

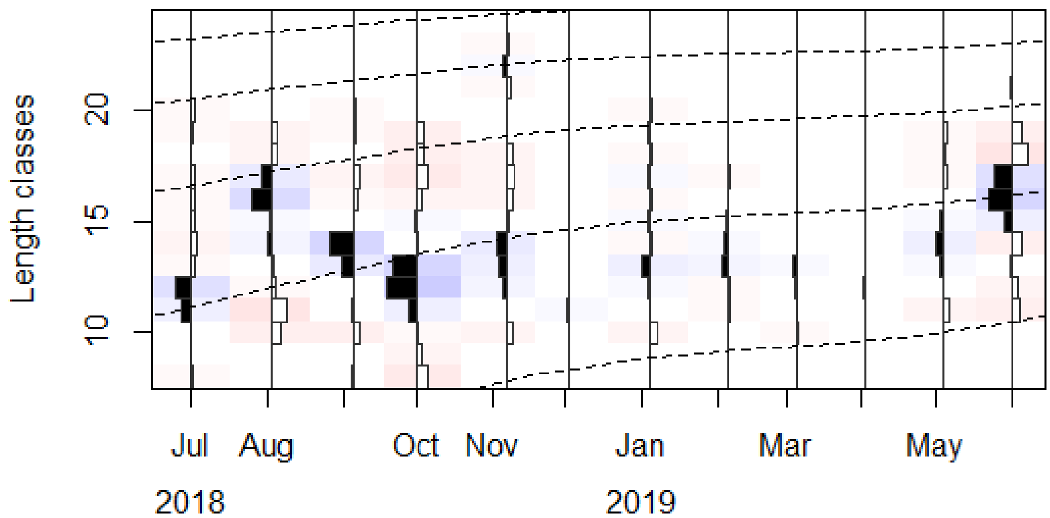

Fig. 2. Length-frequency histograms with the growth curves (dashed lines) obtained through the bootstrapped ELEFAN with SA analysis superimposed for *D. puntactus* ($L\infty$ = 29.8 cm and K = 0.35 yr^{-1}, t_0 = -0.47)

Length at capture

From Figure 3, the age at capture is tc_{50} = 1.31 years, tc_{75} = 1.43 years and tc_{95} = 1.64 years. The corresponding lengths at capture (Lc) were estimated as Lc_{50} = 11.0 cm, Lc_{75} = 11.7 cm and Lc_{95} = 13.0 cm (Fig. 3). About 215 samples (19.6% of the total sample) had lengths lower than the length at first capture (Lc_{50} = 11.0 cm).

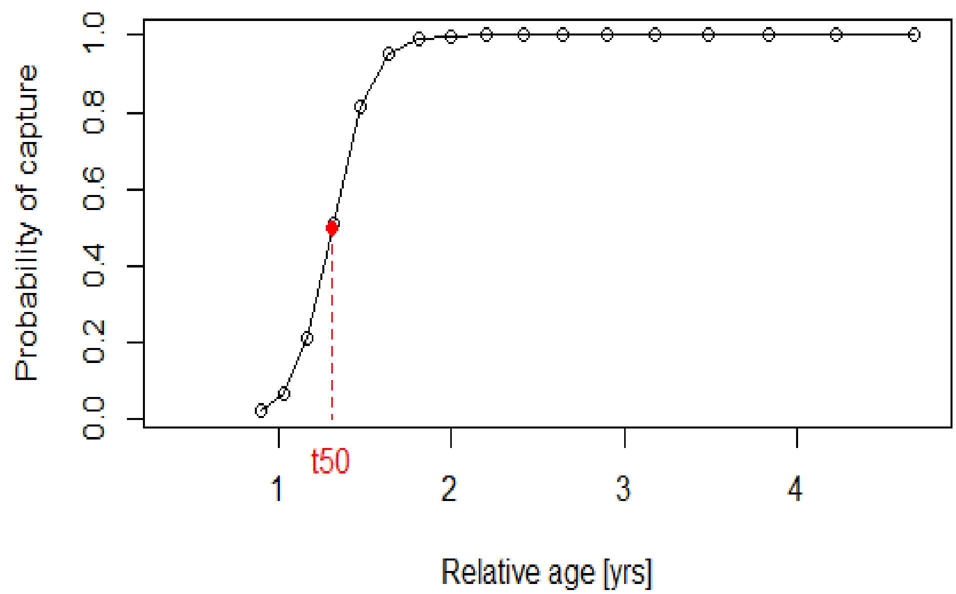

Fig. 3. The catch curve's selectivity function estimated a length at first capture at 11.0 cm

Mortality parameters

The Linearized length-converted catch curve was used for the estimation of instantaneous total mortality (Z) as shown in Figure 4. The total mortality rate (Z) was calculated as 1.77 yr^{-1}. The natural and fishing mortality rates were estimated at M = 0.62 yr^{-1} and F = 1.15 yr^{-1}, respectively. The current level of exploitation rate had E value of 0.65.

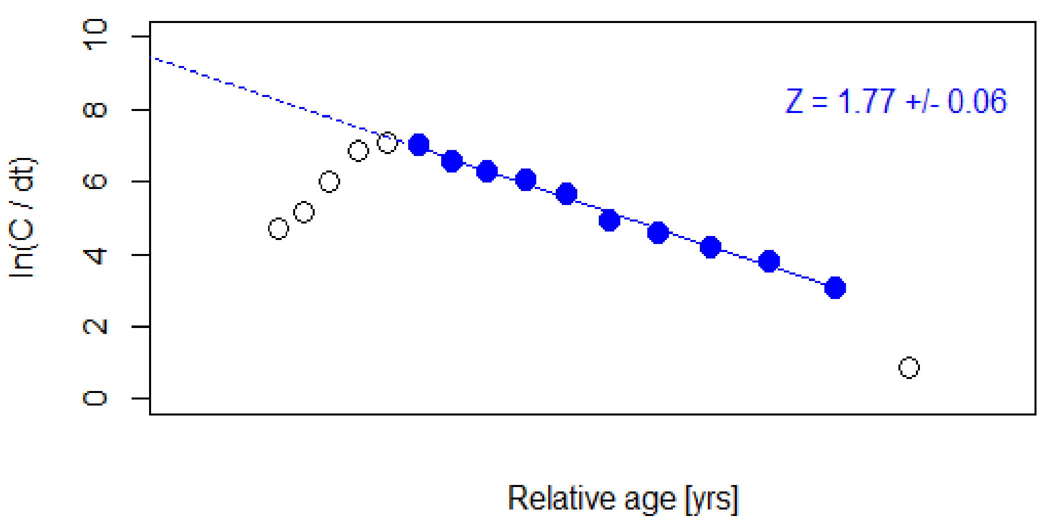

Fig. 4. Linearized length-converted catch curve for the estimated total mortality (Z = 1.77 yr^{-1})

Estimated stock size

Figure 5 shows the sigmoid-shaped fishing pattern across length classes (red line in CA plot). Fishing mortality was also witnessed throughout all mean size classes. Specimen with midlength group of 13 cm were more exposed to the fishing gear whereas the fishing mortality rate was higher for midlength group of 22 cm.

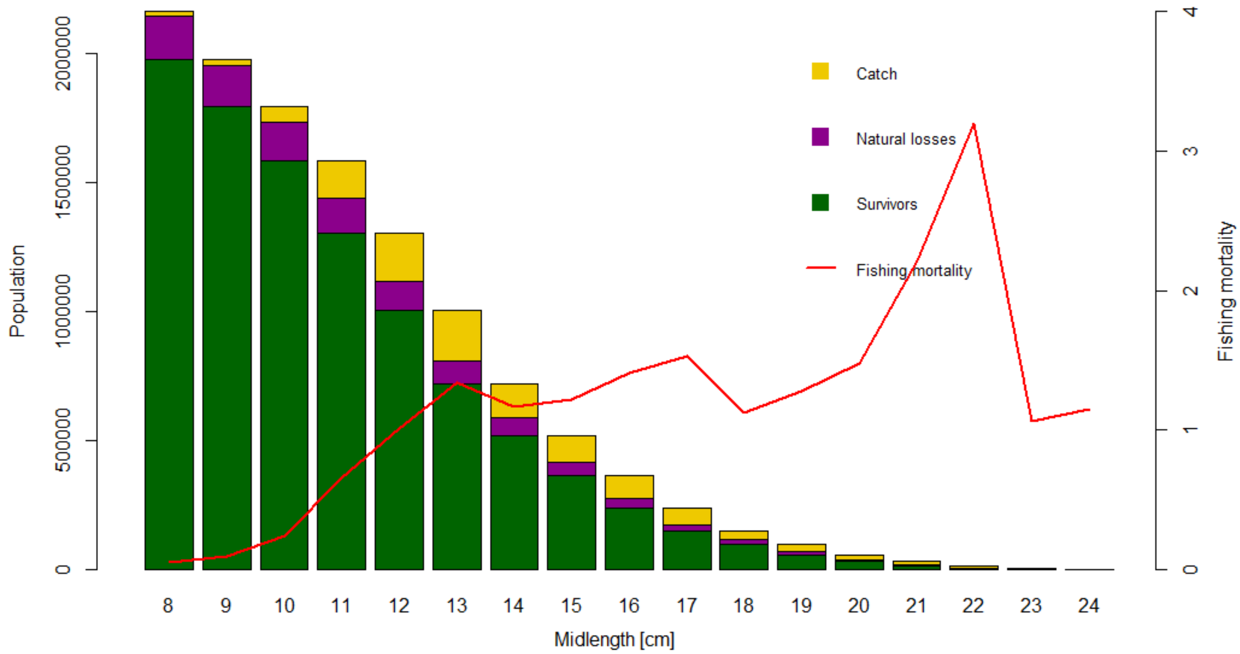

Fig. 5. Jones' cohort analysis (CA) of *D. punctatus* fishery with fishing mortality rate by length classes and resulting reconstructed population structure (survivors, natural losses and catch) in numbers per length class

Relative yield per recruit (YPR)

The plot of relative yield per recruit against exploitation ratio showed that the indices for sustainable yield were 0.52 for the optimum sustainable yield ($E_{0.5}$) and 0.74 for the maximum sustainable yield (E_{msy}) as indicated in Figure 6. The fishing mortality for exploitation at sustainable yield (E_{msy}) was 1.76yr^{-1} while for the optimum sustainable yield ($E_{0.5}$), the corresponding fishing mortality was 0.66 yr^{-1}

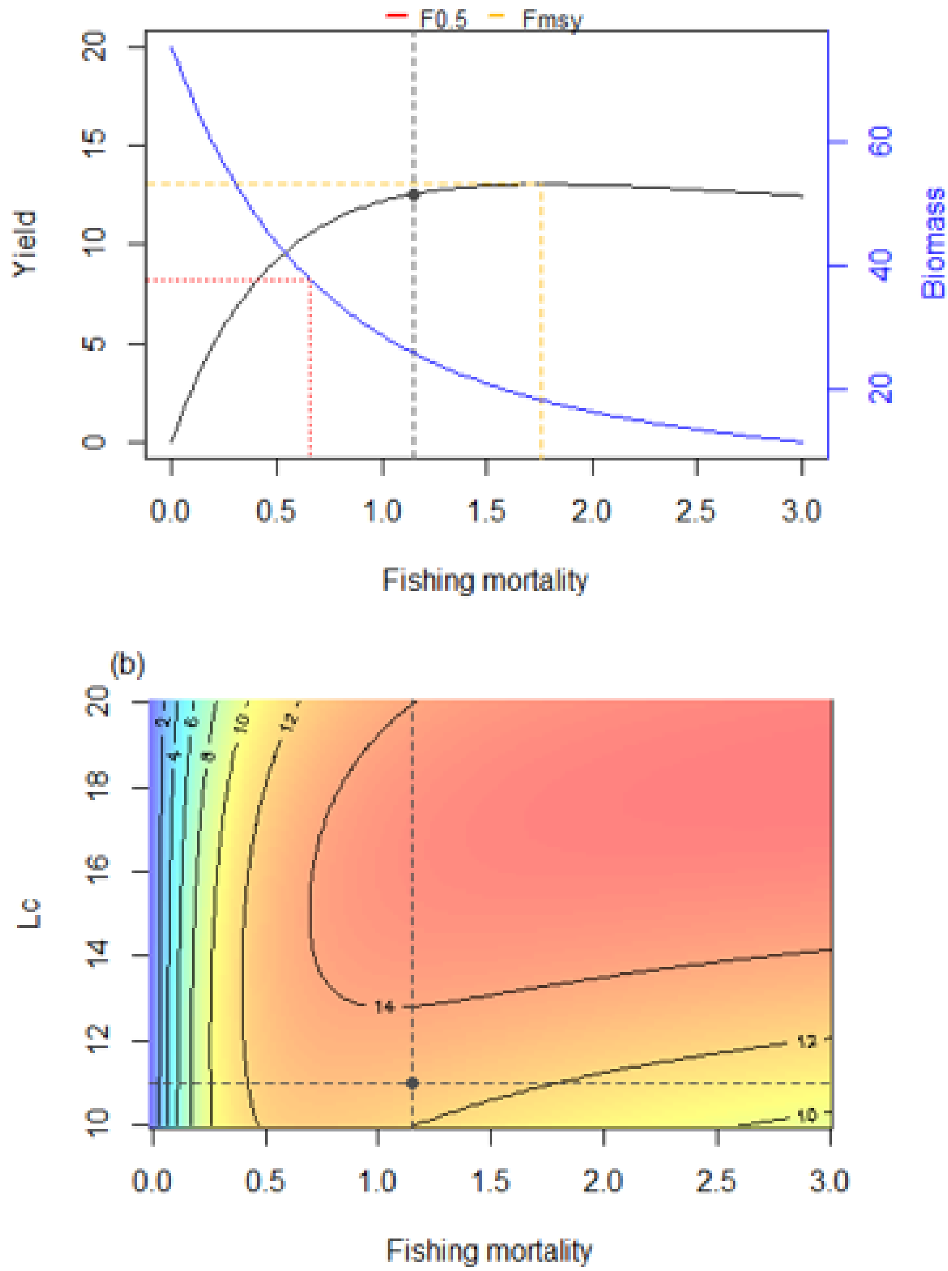

Fig. 6. Thompson and Bell model: Curves of yield and biomass per recruit plot of *D. punctatus* in the Ghanaian coast. The black dot represents yield and biomass under the current fishing pressure. The yellow and red lines represent maximum allowable fishing mortality (F_{msy} = 1.76 yr^{-1}) and fishing mortality with a 50% reduction related to the virgin biomass ($F_{0.5}$ = 0.66 yr^{-1})

DISCUSSION

The growth constant of the fish in the present study ($K = 0.35yr^{-1}$) was higher than the estimate for the *D. rhonchus* ($K = 0.14yr^{-1}$) from the coastal waters of Ghana **(Forson and Amponsah, 2020).** Overall, *D. punctatus* from the coast of Ghana exhibits signs of slow growth. The lower maximum theoretical length ($L\infty$ = 29.8 cm TL) of the fish in Ghana's waters compared to *D. russelli* in Pakistan ($L\infty$ = 32.65 cm) and *D. rhonchus* in Ghana's waters ($L\infty$ = 40.6 cm) could portray the impact of poor environmental conditions for the growth of *D. punctatus* from the coast of Ghana. More so, the differences in asymptomatic length may be a result of the differences in productivity, the analysis method utilized, or fishing pressure **(Park *et al.*, 2008; Sequeira *et al.*, 2009).**

The index of growth performance is considered a useful tool for comparing the growth curves between populations of the same species and/or different species that belong to the same family **(Park *et al*., 2013).** From the study, the growth performance index was in line with estimates from **Forson and Amponsah (2020)** for *D. rhonchus* in Ghana and **Poojary *et al*. (2011)** for *D. russelli* in Indian waters that reported growth performance of 2.37 and 2.90, respectively.

Hales (1987) documented the length at first maturity for *D. punctatus* from the South Atlantic Bight to be 11.0 cm. From the present study, the estimated length at first capture was also 11.0 cm. This reveals that *D. punctatus* from the coast of Ghana are harvested exactly at the same size as they mature which could lead to two key forms of overfishing; namely growth and recruitment overfishing. However, with approximately 19% of the samples assessed having length below the length at first capture, it suggests that overfishing is far from occurring within the stock of the assessed species. It is, therefore, prudent for fisheries managers to consider mesh size that correlates with selectivity at 95% length at capture (Lc_{95} = 13.0 cm) to avoid any future collapse of the *D. punctatus* fishery in Ghana. The collapse of the fishery will have severe effects on food security, income generation and revenue for the coastal communities.

From the present study, *D. punctatus* within the coast of Greater Accra was found to be confronted with a relatively higher fishing mortality rate ($F = 1.146\ yr^{-1}$) than the natural mortality ($M = 0.624\ yr^{-1}$). This reveals fishing as the main contributor to the loss of *D. punctatus* rather than naturally induced mortality within the coast of Greater Accra. However, the fishing pressure exerted on this species was found not to be extreme as it was lower than the fishing mortality rate required at the maximum sustainable yield ($F_{ms\ y} = 1.76\ yr^{-1}$).

The exploitation rate of the species was above the optimum level of 0.5, suggesting intense fishing pressure on the stock. There are over 2 600 canoes in addition to 25 000 fishermen in the Greater Accra region of Ghana. These put pressure on fish stocks in order to meet protein needs.

The results obtained from the cohort analysis support claims by other researchers; that is the rate of fishing varies with changing the length of the stock with large-sized individuals experiencing higher rate of fishing mortality (**Peixoto *et al.*, 2021)**. Furthermore, the higher number of survivors presupposes that recruitment overfishing is far from the stock of this species found on the coast of Ghana. *Decapterus punctatus* in Ghana's coast is in a sustained state because the current fishing rate is smaller than F_{msy} but slightly higher than $F_{0.5}$ (target reference point). The possible reason for this observation may be that the stock of this species is caught before reaching the first maturity stage. The YPR analysis revealed that the MSY of the stock would be realized at an exploitation rate of E_{msy} = 0.74. Despite, the high fishing pressure on the stock, the value of E_{msy} was higher than the present estimated exploitation rate (0.65), indicating that the fishery of the stock is in a sustainable state, which could be attributed to the high rebuilding rate of the species.

CONCLUSION

Decapterus punctatus from the coastal waters of Ghana exhibits signs of slow growth at a rate of 0.35. The exploitation rate (E = 0.65) was lower than the E_{msy} which indicated that the species is not experiencing overfishing in Ghana's marine waters. Based on the findings of the study, harvesting species at a length less than the length at first maturity may alter the recruitment potential of the stock which in turn may result in the collapse of the stock. The length 95% capture is recommended to ensure the continuous presence of recruits into the stock of *D. punctatus* which can be achieved through mesh size regulations. The implementation of sustainable fisheries management measures is needed to ensure the continuous contribution of the stock of *D. punctatus* to food and nutrition security, and income generation in Ghana.It is also recommended that further biological and long-term data be collected to better understand the stock status of the species and its role in the ecosystem.

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