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Assessing the population characteristics of Carangids in the Coast of Ghana, West Africa

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Abstract

The population parameters of three Carangidae species from the marine waters of Ghana were examined between July 2018 and June 2019. Length and weight measurement of 1020 samples were collected from some selected coastal communities along the Greater Accra region of Ghana and analyzed using TropFish R. The asymptotic length (L_∞) for *C. crysos, C. hippos, and T. trecae* was 37.6 cm, 35.3 cm and 26.1 cm respectively. The growth rate (K) was 0.41, 0.44, and 0.75 yr^{-1} for *C. crysos, C. hippos,* and *T. trecae* respectively. The exploitation rate (E) estimate revealed overexploitation for *C. crysos,* and *T. trecae* (E>0.5) while *C. hippos* was underexploited (E<0.5). The findings of YPR analysis proved that the Ghanaian stock of these fish species is in a steady-state with the current exploitation rate lower than the exploitation rate at maximum sustainable yield (E_{msy}).

Keywords: *Caranx crysos; Caranx hippos; Trachurus trecae;* growth; mortality; Ghana.

1. Introduction

Carangids are a widely distributed pelagic fish species in the Atlantic, Indian, and Pacific regions with 32 genera and 140 species reported around the world (Panda *et al.,* 2012; Nelson, 2006; Edwards *et al.,* 2001). It consists of a group of fishes known by common names such as jacks, scads, trevallies, queenfishes, runners, amberjacks, pilotfishes and pampanos (Smith-Vaniz, 1999). Members of the family generally have compressed (but ranging from very deep to fusiform) bodies with most species possessing small cycloid scales and ctenoid scales in a few species (some scales on the lateral line are modified into spiny

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scutes in many species) (Nelson, 2006). The family contains some very important food species and its members form some of the most economically important fisheries in the world due to their wide distribution, high value and demand (Mohd Azim *et al.,* 2017). Carangids are found in all tropical and subtropical marine waters of the world with some occurring in temperate regions (Honebrink, 2000). The juveniles of some species of the family could also be found in estuarine environments.

According to Edwards *et al.* (2001), twenty-two species from the Carangidae family occur on the mainland coast of tropical West Africa. Some reported genera in the family sighted in Ghana's coastal waters include *Elagatis, Alectis, Caranx, Carangoides, Oligoplites, Selene, Seriola, Selar, Chloroscombrus* and *Trachinotus* (Kwei and Ofori-Adu, 2005; Edwards *et al.,* 2001). In Ghana, members of this family are caught by seines, hooks, mullet net, ali and watsa nets (Edwards *et al.,* 2001). With the increasing fishing pressure on fish stocks along Ghana's coast, knowledge of the current status of fish stocks is an essential tool for sustainable management. As such, the present study on the population dynamics of some species of the Carangidae family is aimed at providing vital information for the sustainable management of the stock of these fish species.

2. Materials and methods

2.1. 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 and the level of fishing activities. These sampling locations are noted for fishing with fishing activities contributing over 50% as a primary occupation.

2.2. 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 *Caranx crysos, Caranx hippos* and *Trachurus trecae* were collected monthly

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

from randomly selected fishermen who use multifilament fishing gears from fish landing sites for twelve (12) months (i.e., from July 2018 to June 2019). These fishermen predominantly use set nets and trawl nets with mesh size ranging from 0.5 inches to 1.25 inches. The samples collected were preserved on ice and transported to the laboratory where measurement for total length in centimeters and body weight in grams using a measuring board and electronic scale respectively, was undertaken.

2.3. 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 ELEFAN_ SA. 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:

$\Phi' = ٢ \log L_\infty + \log K$ (Pauly and Munro, 1984)

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

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

2.4. Mortality Parameters

Total mortality (Z) was computed using the linearized length-converted catch curve (Pauly and David, 1981; Sparre 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:

F/Z (Georgiev and Kolarov, 1962)

2.5. Length at First Capture (Lc50)

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 at 50%, 75% and 95% (Pauly, 1987).

2.6. Estimated stock size

The stock size was estimated here, 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 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 (E). 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 as provided in Taylor and Mildenberger (2017)

2.7. Yield per recruit

The Thompson and Bell model was used to provide biological reference levels that are 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.

2.8. Data analysis

The TropFishR package in R programming was utilized for the assessment of the population parameters of specimens of *Caranx crysos, Caranx hippos, and Trachurus trecae* that were encountered during the study period (Taylor and Mildenberger, 2017).

3. Results

3.1. Growth parameters

Restructured length-frequency for the three species with superimposed growth curves is shown in Figure 2. The asymptotic length (L_∞) for *C. crysos, C. hippos* and *T. trecae* was 37.6 cm, 35.3 cm and 26.1 cm respectively, with a corresponding growth rate (K) of 0.41 yr^{-1}, 0.44 $yr^{-1}$and 0.75 yr^{-1} (Table 1). The growth performance index (Φ′) was 2.76, 2.74, and 2.71 while the age at zero-length (t_o) was -0.38 years, -0.36 years and -0.23 years for *C. crysos, C. hippos* and *T. trecae* respectively. Furthermore, the R_n value was 0.37, 0.66, and 0.73 for *C. crysos, C. hippos,* and *T. trecae* respectively.

3.2. Length and age at capture

From Figure 3, the corresponding lengths at capture (Lc) were estimated as Lc_{50} = 14.9 cm, Lc_{75} = 16.4 cm and Lc_{95} = 18.7 cm for *C.* crysos. C. *hippos* recorded 13.2 cm, 14.9 cm, and 17.6 cm for length at 50%, 75% and 95% capture. The length at 50%, 75%, and 95% capture for *T. trecae* was 15.3 cm, 15.9 cm and 16.8 cm respectively (Table 1). Moreover, the age at first capture ($tc_{50\%}$) for *C. crysos, C. hippos, and T. trecae* was 1.24 years, 1.07 years, and 1.18 years, respectively.

3.3. Mortality parameters

The linearized length-converted catch curve was used for the estimation of instantaneous total mortality (Z) as shown in Figure 3 and Table 1. For *C. crysos*, the total mortality (Z), natural (M) and fishing (F) mortalities were 1.39 ± 0.05 yr^{-1}, 0.65 $yr^{-1}$and 0.74 yr^{-1}, respectively. In addition, *C. hippos* recorded Z, M and F to be 1.22 ± 0.13 yr^{-1}, 0.70 $yr^{-1}$and 0.52 yr^{-1}. The Z, M and F values for *T. trecae* were 4.74 ± 0.51 yr^{-1}, 1.14 $yr^{-1}$and 3.60 yr^{-1}, correspondingly. The current exploitation rate (E) for *C. crysos, C. hippos, and T. trecae* was 0.53, 0.42, and 0.76, respectively.

3.4. Estimated stock size

Figure 4 depicts the logistic shaped fishing pattern across length classes (red line in CA plot) which revealed varying fishing mortality throughout all mean size classes. For *C. crysos* and *C. hippos*, the specimens with a mid-length group of 19 cm and 20 cm were more exposed to removal by fishing gears whereas, for *T. trecae*, specimen within the mid-length of 16 cm experienced high fishing pressure. A high number of survivors were observed for *C. crysos, C. hippos and T. trecae* which portrays the recruitment potential of these species are still functional.

3.5 Yield-per-recruit (YPR)

The plot of relative yield per recruit against exploitation ratio showed that the indices for $E_{0.5}$ and E_{msy} are 0.55 & 0.76, 0.51 & 0.74, and 0.58 & 0.80 for *C. crysos, C. hippos, and T. trecae* respectively (Figure 5). F_{msy} and $F_{0.5}$ were 2.1 yr^{-1}& 0.80 yr^{-1}, 1.96 yr^{-1}& 0.74 yr^{-1}, and 4.60 yr^{-1} & 1.56 yr^{-1} for *C. crysos, C. hippos and T. trecae,* respectively.

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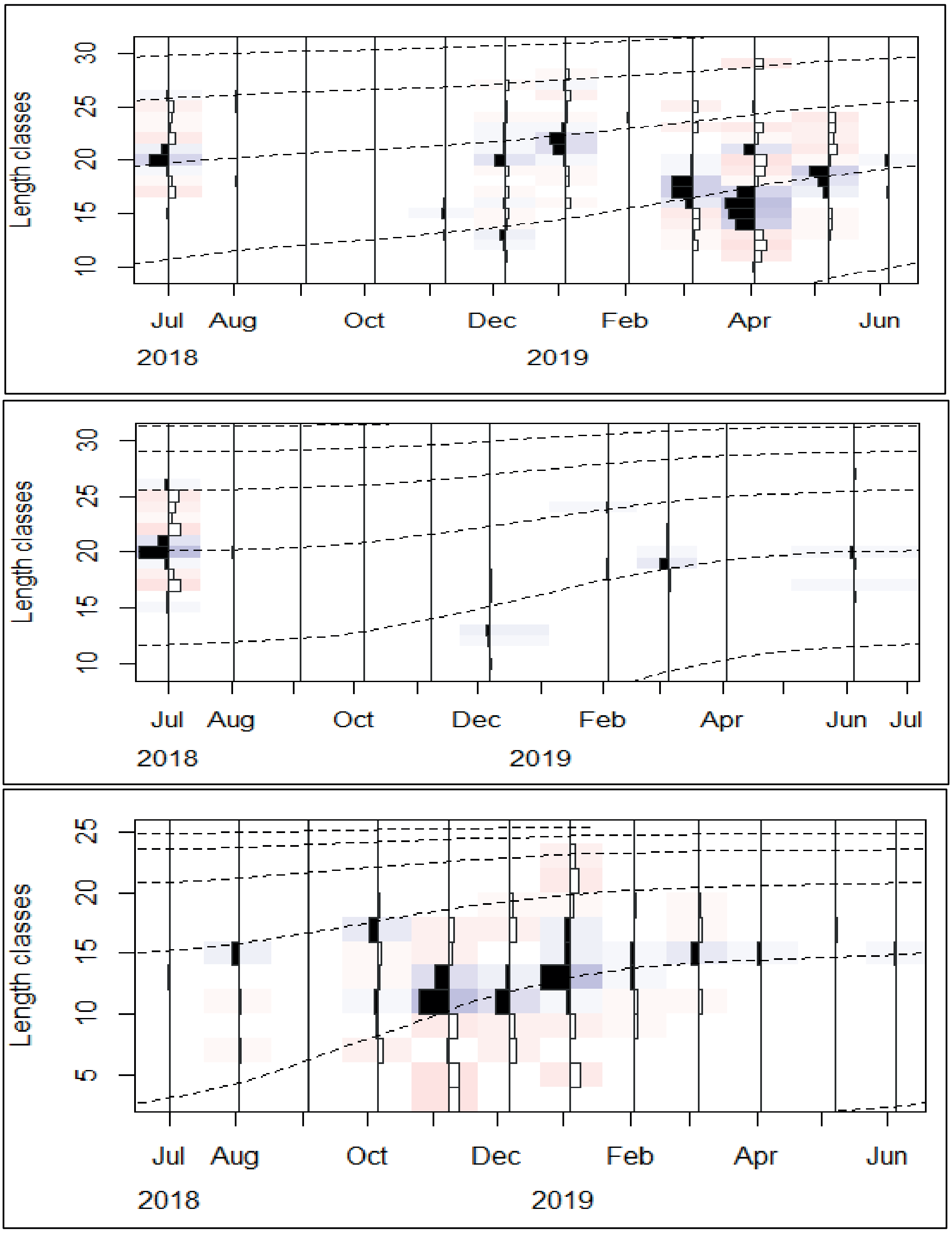

Figure 2. Reconstructed length-frequency distribution with growth curves for *C. crysos, C. hippos* and *T. trecae respectively* (July 2018 – June 2019, Ghana)

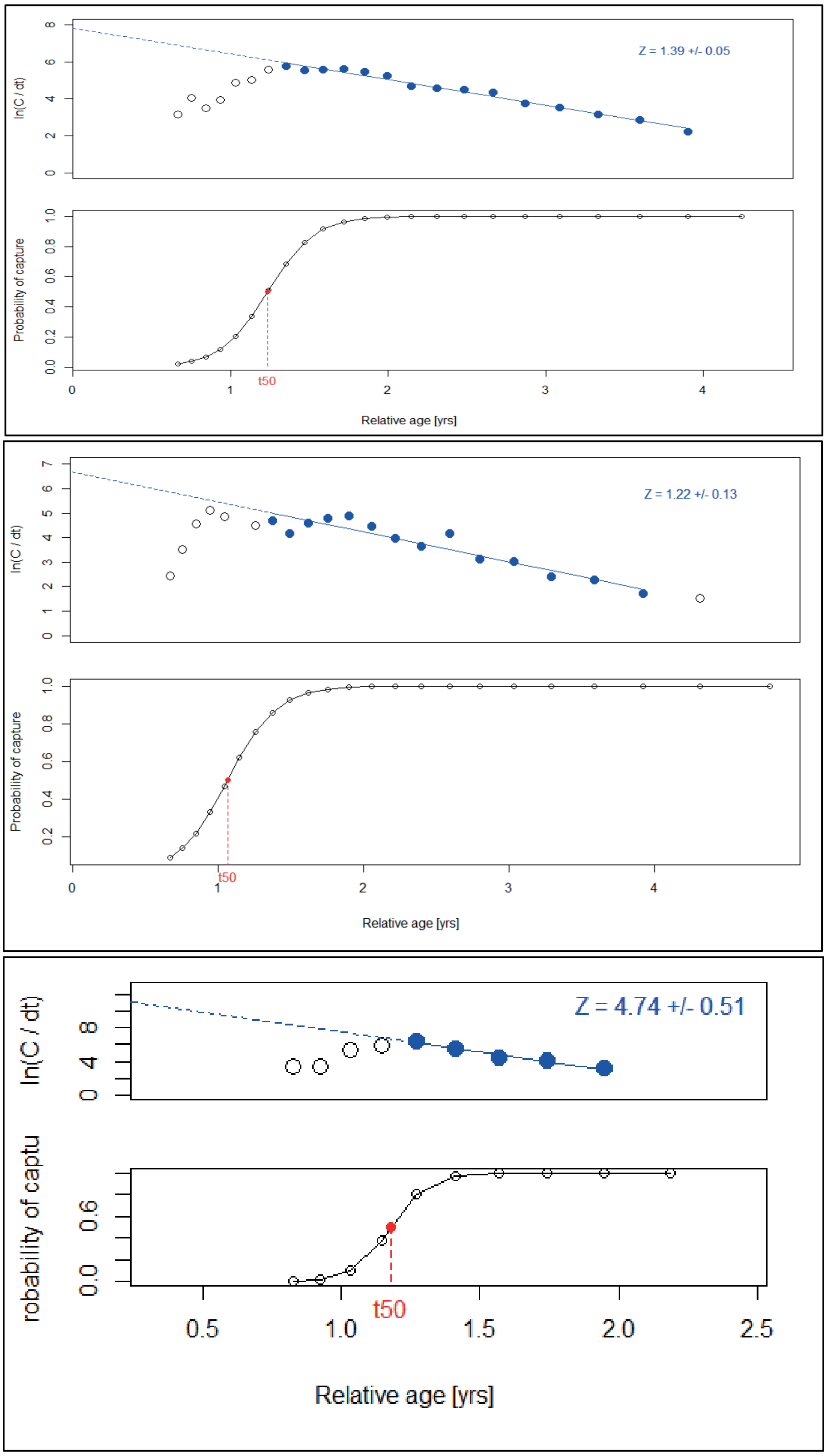

Figure 3. Linearized length-converted catch curve for the estimated total mortality and the Catch curve's selectivity function estimated a length at first capture for *C. crysos, C. hippos and T. trecae respectively* (July 2018 – June 2019, Ghana)

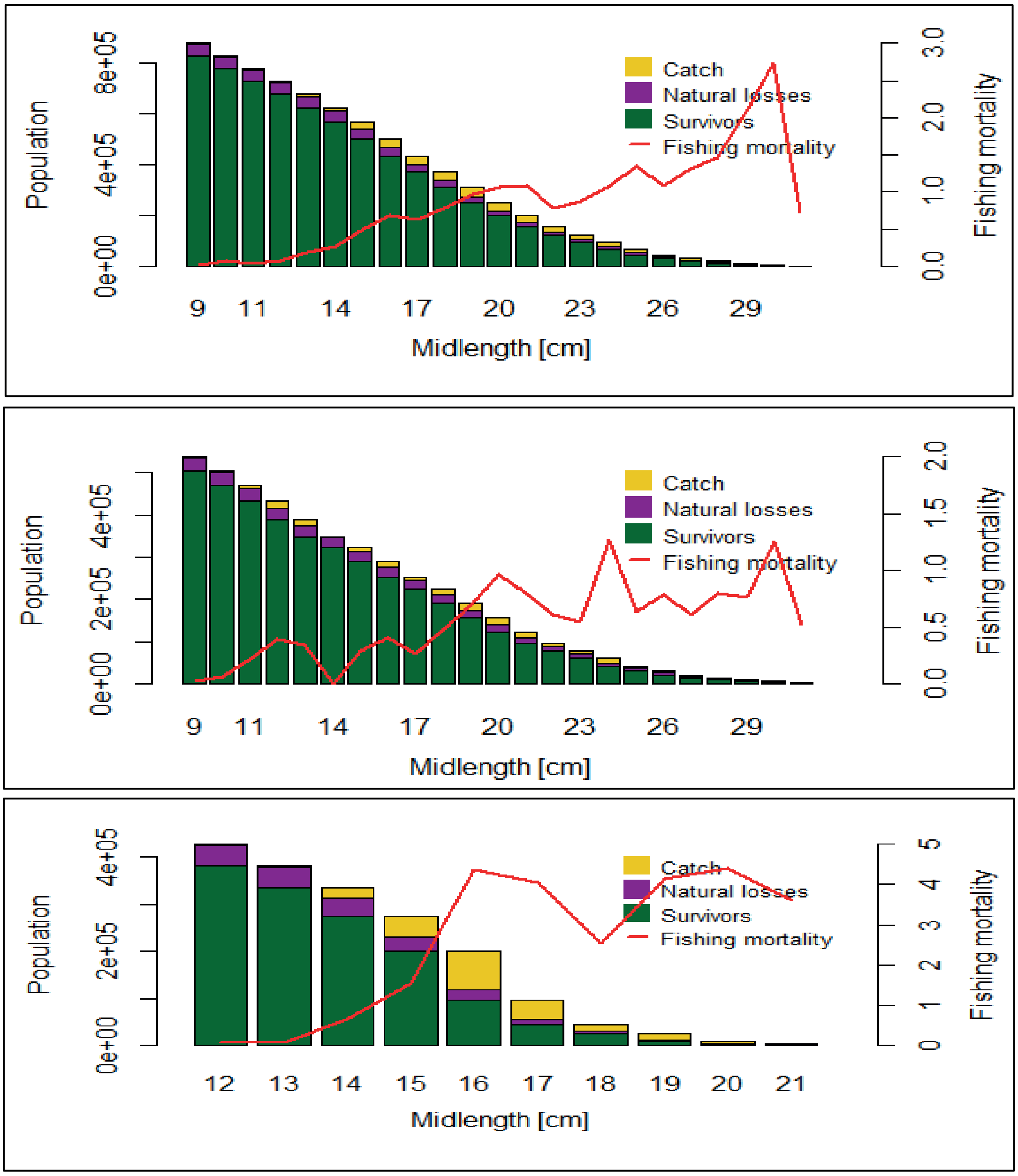

Figure 4. Jones' cohort analysis (CA) of *C. crysos, C. hippos and T. trecae* fishery with fishing mortality rate by length classes and resulting reconstructed population structure (survivors, natural losses and catch) in numbers per length class (July 2018 – June 2019, Ghana)

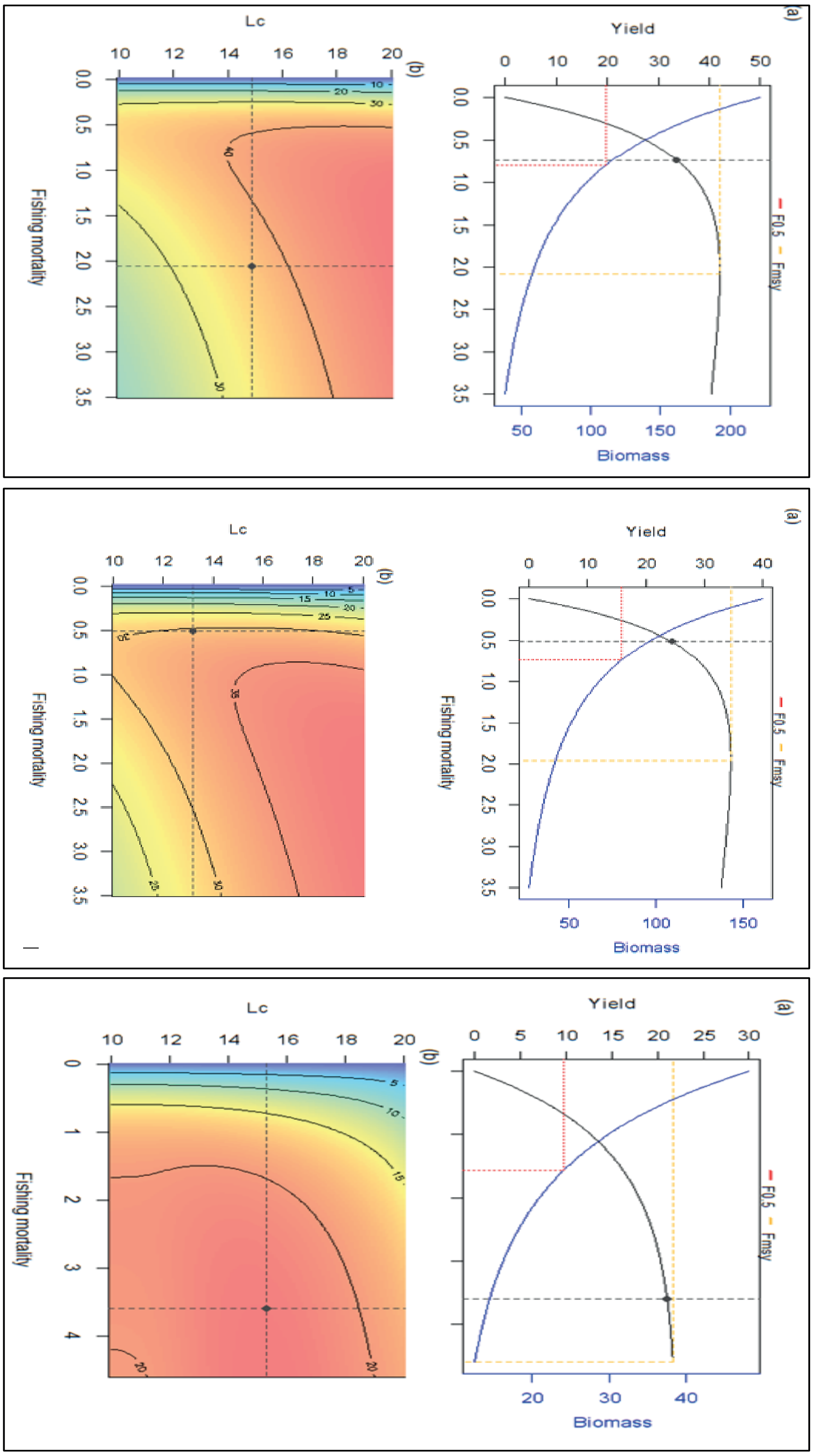

Figure 5. Thompson and Bell model: Curves of yield and biomass per recruit plot of *C. crysos, C. hippos and T. trecae* in the Ghanaian coast. The black dot represents yield and biomass under the current fishing pressure. The yellow and red lines represent maximum allowable fishing mortality and fishing mortality with a 50% reduction related to the virgin biomass (July, 2018 – June, 2019, Ghana)

Table 1. Population parameters of the *C. crysos*, *C. hippos* and *T. trecae*

Parameters	Unit	*C. crysos*	*C. hippos*	*T. trecae*
Asymptotic length (L_∞)	cm	37.6	35.3	26.1
Growth rate (K)	per year	0.41	0.44	0.75
Growth performance index (Ø)		2.76	2.74	2.71
Longevity (t_{max})	years	6.94	6.46	3.78
Theoretical age (t_o)	years	-0.38	-0.36	-0.23
Total mortality rate (Z)	per year	1.39 ± 0.05	1.22 ± 0.13	4.74 ± 0.51
Fishing mortality rate (F)	per year	0.74	0.52	3.60
Natural mortality rate (M)	per year	0.65	0.70	1.14
Exploitation rate (E)		0.53	0.42	0.76
$F_{0.5}$	per year	0.8	0.74	1.56
F_{msy}	per year	2.1	1.96	4.60
$E_{0.5}$		0.55	0.51	0.58
E_{msy}		0.76	0.74	0.80
Length at first capture (Lc_{50})	Cm	14.9	13.2	15.3
Length at 75% capture (Lc_{75})	Cm	16.4	14.9	15.9
Length at 95% capture (Lc_{95})	Cm	18.7	17.6	16.8
Age at first capture (Lc_{50})	Year	1.24	1.07	1.18
Age at 75% capture (Lc_{75})	Year	1.40	1.25	1.25
Age at 95% capture (Lc_{95})	Year	1.67	1.56	1.38
Critical length at capture (Lc)		0.40	0.37	0.46
T_anchor		0.77	0.72	0.09
C		0.46	0.84	0.80
Rn		0.37	0.66	0.73
Total number (N)		428	365	227

4. Discussion

Due to the scanty information on population dynamics for species in Ghana's marine waters, findings from the present study will serve as a baseline for the sustainable management of species within the Carangidae family. The growth constant of *C. crysos* and *C. hippos* in the present study was less than 0.5 yr^{-1} which depicts that these species are showing signs of slow growth. However, *T. trecae* from the current study recorded a growth rate above 0.5 yr^{-1}, indicating that it is a fast-growing species. Under high fishing pressure, species with a slow growth rate are more likely to rebuild at a slower pace than fast-growing species. The index of growth performance is considered as 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 estimated for *C. crysos, C. hippos, and T. trecae* were relatively similar which suggests that these species are a paraphyletic group.

The length at first capture (Lc_{50}) from the present study for *C. crysos, C. hippos, and T. trecae* was markedly below the estimated length at first maturity obtained from García-Cagide *et al.* (1994), Reuben *et al.* (1992) and CECAF (1979) who reported 26 cm, 22 cm and 31.5 cm for *C. crysos, C. hippos, and T. trecae* respectively. This situation presents a doom picture for the future generation in terms of food security, as the continuous harvesting of juvenile or immature species may be the recipe for growth overfishing. Repercussions are that, this may result in recruitment failure if appropriate measures are not taken. To buttress this finding, the critical length at capture (Lc) a ratio of the length at first capture and the asymptotic length was lower than 0.5, implying the abundance of juveniles than adult individuals of the various fish stocks. It is, therefore, imperative for fisheries managers in Ghana to consider reviewing the legal mesh size as well as the implementation and enforcement of reviewed mesh-size regulation.

Relatively, the fishing mortality rate (F) of *C. crysos,* and *T. trecae* was higher than the corresponding natural mortality rate (M), showing the superior impact of fishing activities on the decline of these fish stocks along the coast of Ghana. However, for *C. hippos*, the natural mortality rate (M) was higher than the fishing mortality rate (F) along the coast of Ghana. The dynamics of the fishing and the natural mortality rate of the fish species show that the mortality rates are not balanced. Overall, the fishing mortality rate for the species was not that intense because it was lower than the fishing mortality rate required at the maximum sustainable yield (F_{msy}). Furthermore, the exploitation rate for both species (i.e., *C. crysos* and *T. trecae*) was above the optimum level of 0.5, suggesting that these species are overexploited along the coast of Ghana. On the contrary, the exploitation rate was slightly below the optimum level of 0.5, indicating the stock of *C. hippos* along the coast of Ghana is underexploited.

The results obtained from the Cohort Analysis show that varying mid-length are exposed to changing fishing mortality rate. Again, it shows that the recruitment potential of the species is still functional due to the higher number of survivors at the lowest mid-length. From this observation, recruitment overfishing is far from occurring in the stock of these fishes.

The YPR analysis revealed that the exploitation at maximum sustainable rate (E_{msy}) for the fish species is higher than the exploitation rate (E) which signifies the steady-state of stock of these species stock and that, the collapse of these species is far from imminent.

Conclusion

C. hippos and *C. crysos* exhibited a slow growth rate while *T. trecae* showed a fast growth rate from the coastal waters of Ghana. Based on the YPR results, the stock of these species is in a steady-state ($E_{curr}<E_{msy}$). Despite the high number of survivors from the result of the cohort analysis for the assessed fish species, there is a need to implement proper management measures to reduce the harvesting of juvenile fish species. Preferably, mesh-size regulation should be enforced to ensure the continuous contribution of the stock of these fish species to food security and the achievement of SDG 1, 2 and 14.

Credit authorship contribution statement

Amponsah Samuel Kweku Konney: Conceptualization, Formal analysis, Investigation, Methodology, Resources, and Software. Nana Ama Boadu Afranewaa and

Samuel Henneh: Writing - original draft. Patrick Ofori-Danson: Conceptualization, Validation, Roles/Writing – review & editing. Selasi Yao Avornyo: Supervision, Methodology and Project administration.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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