Science | Technology | Development

Ghana Journal of Science, Technology and Development | Vol. 8, Issue 2, December 2022
e-ISSN: 2343-6727
Received: June 28, 2022
Accepted: September 14, 2022
DOI: https://doi.org/10.47881/344.967x

Length-Weight Relationship and the Condition Factor of some Important Estuarine Fish Species from Kakum Estuary of Ghana

Kezia Baidoo[1], Noble Kwame Asare[2], Seth Mensah Abobi[1]

[1]*Department of Fisheries & Aquatic Resources Management, Faculty of Biosciences, University for Development Studies, P. O. Box TL 1882, Tamale-Ghana*

[2]*Department of Fisheries and Aquatic Sciences, School of Biological Sciences, University of Cape Coast, Ghana*

Corresponding author: *baidookezia327@gmail.com*

ABSTRACT

This study assessed the length-weight relationships and the condition factors of nine commercial and abundant fish species namely Liza dumerilli, Mugil curema, Liza falcipinnis, Mugil bananensis, Lutjanus goreensis, Lutjanus fulgens, Sardinella aurita, Caranx hippos, and Eucinostomus melanopterus from the Kakum River Estuary. This study was conducted from November 2016 to April 2017 to provide primary information about the biometrics, the length-weight model parameters, and the state of well-being of fish species inhabiting the Kakum Estuary. Sampling was done monthly using a mini boat of 9 m long with a depth of 1.5 m for both diurnal (06:00, 10:00, 14:00, 18:00, 06:00 h) and nocturnal (22:00, 02:00 h) periods with a medium-mesh cast net of 20 mm stretched. Sampling was done within thirty (30) minutes on all sampling times. The total length of the species from the estuary ranged from 2.2 cm in Liza dumerilli to 29.8 cm in Mugil curema while the total weight ranged from 0.2 g to 251 g in Mugil curema. The slope b values of the species varied from 2.3787 for Liza dumerilli to 3.1009 for Eucinostomus melanopterus. Three species from the Kakum Estuary exhibited negative allometric growth and 6 species were growing isometrically. The mean condition factors of the fish species ranged from 0.82 ± 0.36 (SD) in Sardinella aurita to 1.82 ± 0.23 (SD) in Lutjanus goreensis. The results of the present study provide essential input parameters for further assessment of the species standing stock biomass.

Keywords: Assessing, Estuarine, Fishes, Length, Population, Kakum

INTRODUCTION

Estuaries are recorgnised to be one of the utmost valued and productive aquatic systems (Salas *et al*., 2015) and are identified worldwide as a vital component of the continental coasts in terms of their biological status as well as its utilization by humans (Marques *et al*., 2004). Numerous research have emphasised on the significance of estuarine systems and their related coastal systems. These studies focused on estuaries' critical servces such as feeding and nursery grounds for most marine fishes, as well as their role in supporting economically treasured offshore fish stocks (Blaber *et al*., 2000; Beck *et al*., 2001; Gillanders *et al*., 2003; Able, 2005).

Estuaries are mostly used by the juveniles of several fish species for the possible advantages they provide for their survival and growth (Beck *et al*., 2001) and serve as a refuge from predators and good environmental conditions for these species (Matich *et al*., 2020). Molina *et al*. (2020) stated that fish using Southern African estuaries are categorised into functional groups such as marine estuarine opportunists. This includes large species that spawn at sea, enter estuaries primarily as juveniles, and habitually return to the sea prior to attaining sexual maturity. Fishes are the major integral component of estuarine ecosystems and are characterised by the largest and most motile elements of these ecosystems (Scapin *et al*., 2018). Ecologically, estuaries are considered among the most transformed and threatened systems (Blaber *et al*., 2000). Lepage et al., (2022) mentioned that estuaries display a wide variety of influences through anthropogenic activities that clash with their ecological purposes, which threatens the long-term viability and health of these vital ecotones. Historically, fisheries managers have recorded that anthropogenic activities are the most threatening factors impacting fish population s and their distribution in estuarine systems (King, 2013). Domestic and industrial discharges, pollution as well as overfishing have significantly impacted the abundance, distribution, and structure of estuarine communities (Kennish, 2002). Therefore, current studies focus on habitat loss as a greater problem than poll ution itself (Cattrijsse *et al*., 2002; Kennish, 2002).

According to Elliot *et al*. (2007), some estuaries have been studied for several years while others have occasionally been studied in terms of their fish assemblages. Concurrently, these ecosystems are sturdily overexploited and are impacted by most anthropogenic activities (Bettencourt and Ramos, 2003). The Kakum River Estuary plays a critical role as a nursery area for several species of commercially important fish species, while its importance has not yet been comprehensively assessed according to Blay (1997). Therefore, there is a need to generate a baseline study and collect data from multiple sources for the establishment of a strong scientific background to promote management plans for the sustainability of the coastal system. Fishes inhabiting these ecosystems serve as a cheap source of animal protein full of nutrients and play a vital role in the growth of a nation. Asare and Javier (2022) identified that fishes from the families Mugilidae, Carangidae, Lutjanidae, Clupeidae, Gerreidae, Gerreidae, and Bothide are the most important species of brackish systems in Ghana. They mainly comprise marine/estuarine-opportunistic species that exploit the estuaries specifically as spawning, nursery, and feeding grounds (Molina *et al.,* 2020). These fish species occupying these systems are considered the most economically essential species as they contribute significantly to national food security, provide employment, and revenue for the larger number of the Ghanaian populace. Available scientific data and resource surveys conducted in Ghanaian waters indicated that some pelagic and demersal fish resources are overexploited (Mensah *et al.,* 2002). Consequently, coherent management of these resources demands in-depth knowledge of their ecology and the well-being of the species occupying this system. Some scientific studies have investigated the status of brackish systems and their environments. Such investigations include structural parameters and above-ground biomass of mangrove tree species around the Kakum estuary of Ghana (Aheto *et al.,* 2011); assessment of the environmental conditions and benthic macroinvertebrate communities in two coastal lagoons in Ghana (Aggrey-Fynn *et al.*, 2011); and the occurrence and diversity of juvenile marine fishes in two brackish water systems in Ghana (Blay, 1997).

Data on the length and weight of fish provides a significant parameter in assessing and estimating fish population dynamics (Methot and Wetzel, 2013), mortality rates, growth, and well-being of the fish (Ogbonna and Chinomso, 2010). Knowledge on the natural history of fish species and the length-weight relationship is critical in assessing the stock biomass and relating the progress history of the fish population from different areas (Morato *et al.*, 2001; Haimovici and Velasco, 2000; Ozaydin *et al.*, 2007). Schneider *et al.* (2000) specified that condition factor offers an understanding of the lifecycle of fish concentrating on the coefficient values resulting from data on length-weight relationship. Data on the well-being of fish aids in assessing the standing stocks or biomass thereby establishing the yield by adapting one variable into another as field studies, calculating condition indices, and comparing the growth of fish populations from dissimilar areas and in trophic studies. Nevertheless, data on the state of well-being of commercial species such as *Liza dumerilli, Liza falcipinnis, Mugil bananensis*, *Mugil curema*, *Sardinella aurita*, *Eucinostomus melanopterus*, *Lutjanus fulgens*, *Lutjanus goreensis*, and *Caranx hippos* in the brackish water of Ghana is very inadequate (Ofori-Danson *et al*., 2003).

Therefore, this study provides an assessment of the Length-weight relationship and condition factor of selected commercial fish species in the Kakum river estuary of Ghana.

It is hypothesised that the *b* values (the slope) and the *a* values (intercept) of the length-weight relationship of the fishes from Kakum river estuary are significantly different from those estimated from the coastal marine waters.

MATERIALS AND METHODS

Study Area

The study was conducted in the Kakum river estuary (Figure 1). The Kakum river estuary is formed by the Kakum river, and the Sweet river which are a twin river system, habitually fringed by a pristine mangrove system in some areas and highly degraded in other areas. The estuary (1° 19' W, 5° 05' N) is located close to Elmina and is about 5 km west of Cape Coast (the regional capital).

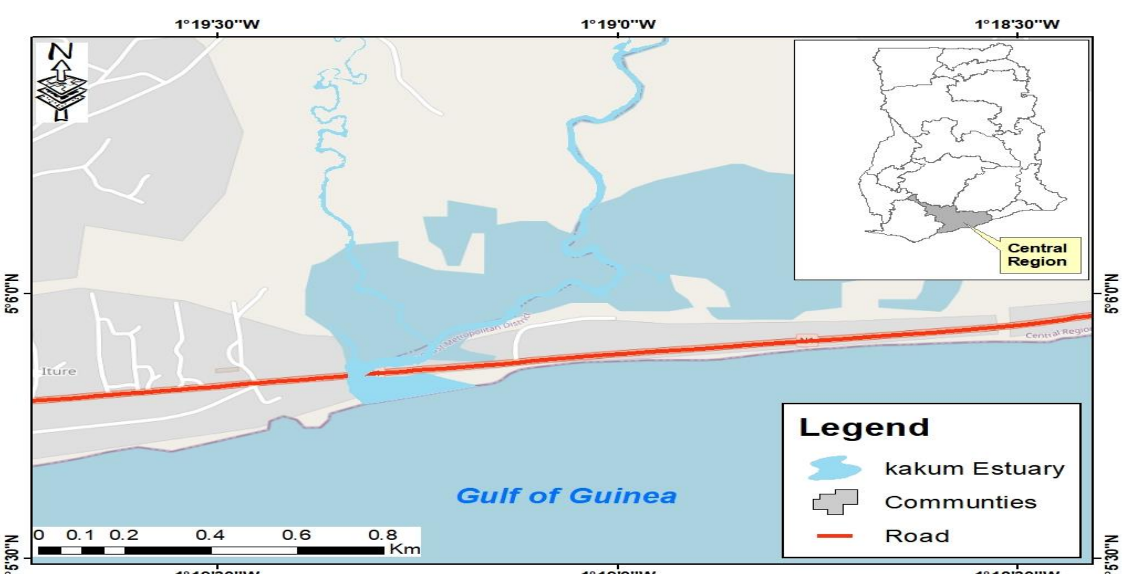


Figure 1: Map of Ghana with inset of Kakum Estuary

Fish sampling and measurement

Fish sampling was done monthly from November 2016 to April 2017 using a mini boat of 9 m long with a depth of 1.5 m for both diurnal (06:00, 10:00, 14:00, 18:00, 06:00 h) and nocturnal (22:00, 02:00 h) periods with a medium-mesh cast net of 20 mm stretched. Sampling was done within thirty (30) minutes on all sampling times. Each sampling covered 100 m to standardise the sampling effort. Casting was done in a manner to attain species occurring during low as well as high tides. On each sampling date, ten casts were made during the day and ten at night given a total of serventy castings each month across the estuay.

In the laboratory, fish caught were sorted and identified to their family and species levels using a fish identification manual (Kwei and Ofori-Adu, 2005). Individuals were measured for their total length (TL, cm) and body weight (BW, g) to the nearest 0.1 cm and 0.01 g respectively. The specimens were categorised into size groups based on total body weight (g) and total lengths (cm).

Data Analysis

Determination of dominant marine fish species composition

The percentage composition of each fish species was estimated as the number of each species, then divided by the total number of fish caught, and the resulting value expressed as a percentage.

Determination of condition factor

STATISTICA 8.1 was used to analyze catch, length and weight data. The analyses included regression analysis for length-weight relationships means, frequencies, percentages, and condition factors of fish species.

Determination of the length-weight relationship

The length and weight of the species were estimated using the equation: $\mathbf{W= aL^b}$ as defined by Ricker (1975) to establish the length-weight relationship of the measured species, where; W represents the body weight (g), L is the total length (cm), *a* is a constant determined empirically and *b* is the slope of the equation. The slope *b* has a numerical value that is generally within the range of 2.5 and 3.5 and is often close to 3 (Froese, 2006). Under isometric growth, *b* is equal to 3. However, isometric growth in fish is intermittent (Soykan and Kinacigil, 2021). The equation concerning length-weight specifies the state of well-being of a fish in a population recognised as the condition factor. A higher condition factor value represents good condition and those with lower values signify poor condition. The condition factor (K) is well-defined as: **K= weight (g) /length (cm) b × 100**. This is modified from Fulton's (1902) formula of $\boldsymbol{K}: \frac{\boldsymbol{W}}{\boldsymbol{L3}}$ (W: weight and L: Total length). After weighing and measuring hundreds of the selected fish species from the Kakum estuary, the condition factor (K) was multiplied by 100 to bring the K value close to unity.

RESULTS AND DISCUSSION

Percentage IRI and composition of abundant marine species

In the Kakum estuary, the grey mullet *Mugil curema* was the most abundant fish with an IRI of 22.7 % followed by *Liza dumerilli*, *Mugil bananiensis*, *Caranx hippos*, and *Liza falcipinnis* at 18.0 %, 17.8 %, 15.0 % and 12.6 % IRI respectively. The remaining species had an Index of Relative Importance (IRI) of less than 5% biomass. (Figure 2).

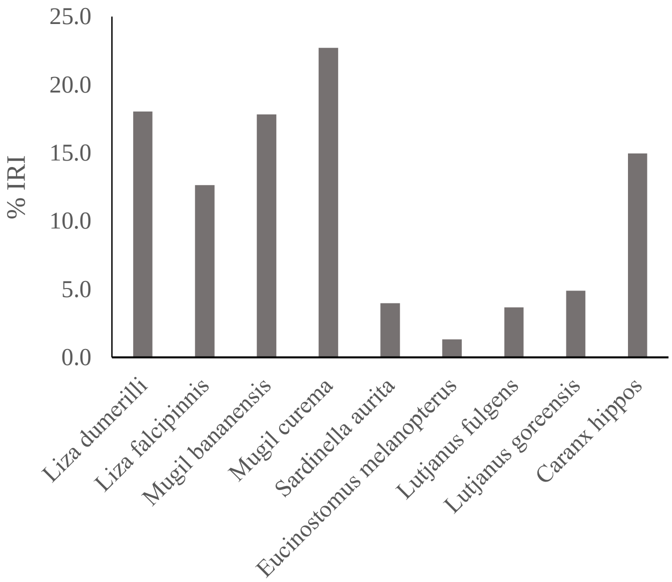


Figure 2. Index of Relative Importance of dominant fish species in Kakum River Estuary

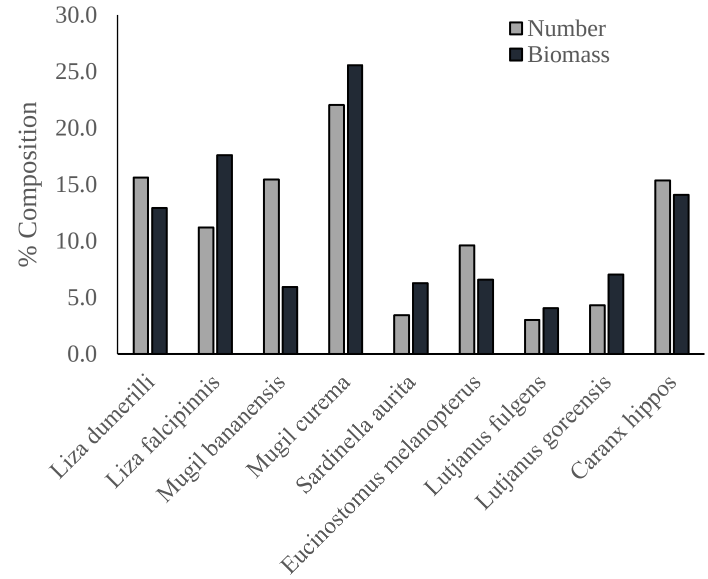


Figure 3: Percentage composition of dominant marine fish species in Kakum River Estuary

The grey mullet *Mugil curema* emerged as the most abundant fish with a composition of 25.1 % of the total biomass followed by the *Liza falcipinnis*, *Caranx hippos*, and *Liza dumerilli* with 17.6 % and 14.1 %, and 12.9 % biomass compositions respectively. The remaining species had a composition of less than 10 % biomass. However, *Mugil curema* was the most common fish with a composition of 22.0 % of the specimens. *Liza dumerilli* were the second most common fish with compositions of 15.6 %, while the grey mullets *Mugil bananensis*, *Caranx hippos*, and *Liza falcipinnis* made up 15.4 %, 15.3 %, and 11.2 % respectively. The remaining species constituted less than 10 % (Figure 3).

Morphometric determination of abundant species

Overall, 23 species belonging to 16 families were encountered. However, the nine most abundant species, belonging to 5 families have been selected for this study. The number of individuals varied from 32 in *Lutjanus fulgens* to 250 in *Mugil curema*. The species in the estuary measured 2.2 cm in *Liza dumerilii* to 29.8 cm in *Mugil. curema* in total length and from 0.2 g to 251 g body weight for *Mugil curema* (Table 1).

Condition of fish species

The condition factors of the abundant species from the estuary were not very distinct. The mean condition factors ranged from 0.82 ± 0.36 (SD) in *Sardinella aurita* to 1.82 ± 0.23 (SD) in *Lutjanus goreensis*. The K-values for *Liza dumerili*, *Mugil curema*, *Liza falcipinnis*, and *M. bananensis*, were 1.33, 1.16, 0.88, and 1.17 respectively. The highest K-value was calculated for *Lutjanus goreensis*, while the lowest K-value was recorded for *Sardinella aurita* (Table 1).

The size ranges of the most common marine species such as *Liza falcipinnis, Liza* *dumerilii*, *Mugil cephalus, Mugil curema, Mugil bananensis* (Mugilidae), *Sardinella aurita* (Clupeidae), *Lutjanus goreensis*, *Lutjanus fulgens, Lutjanus agennes* (Lutjanidae), *Caranx hippos* (Carangidae) were mostly smaller than their standard reported sizes. The length, and weight as well as the smaller specimens of individual species of the fish community encountered throughout the study were much smaller in the estuary and are attributed to the mesh size (20 mm stretched mesh) of the cast net used for sampling. This community structure is similar to a study made by some researchers who reported the dominance of a few species of brackish water environments (Green *et al.*, 2009, Okyere *et al.*, 2011). A similar situation was recorded for the fish biota of a creek studied by Emmanuel & Onyema (2007) in South-Western Nigeria.

According to Whitfield (1990), the observation of juvenile fishes in the estuary gives an indication that the water body is mainly used by marine juvenile fish species purposely as feeding and nursery grounds. Because of the commercial importance of most of these fish species and the ongoing anthropogenic activities in the estuary, enforcement of fisheries management regulations concerning conservation regulations to prevent the impact of anthropogenic practices that affect marine juvenile fishes using the estuary as a nursery and feeding ground will be necessary. However, the observation of a highly rich and diverse fish biota in the estuary indicates a highly productive system that merits management planning and possible conservation status.

Length-frequency distribution

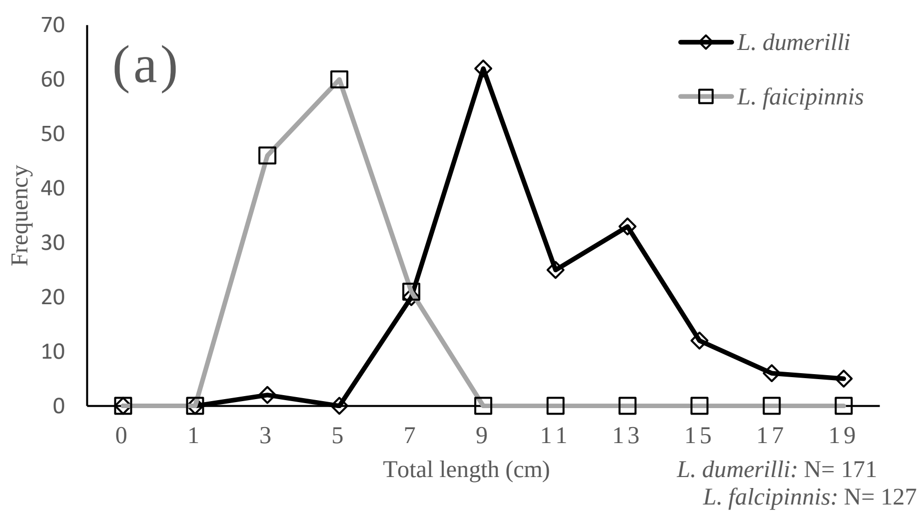
The length-frequency distribution for *Liza dumerilli, Liza facipinnis, Mugil curema, Sardinella aurita, Eucinostomus melanopterus, Lutjanus fulgens, Lutjanus goreensis, and C. hippos* is presented in Figure 4. Over the six-month study, *Mugile curema* had the largest sample size of 250. The total length of *Mugil curema* ranged from 4.0 cm to 29.8 cm. While 2 cohorts of *Liza dumerilli* and *Eucinostomus melanopterus* species were observed (Figure 4a and c), only 1 cohort occured in the remaining species throughout the period of the study. In *Liza dumerilli,* the first cohort had total lengths of 7 to 11 cm and the second cohort was between 11 to 15 cm and the first cohorts in *Eucinostomus melanopterus* ranged from 3 to 6 cm and 9 to 11 cm.

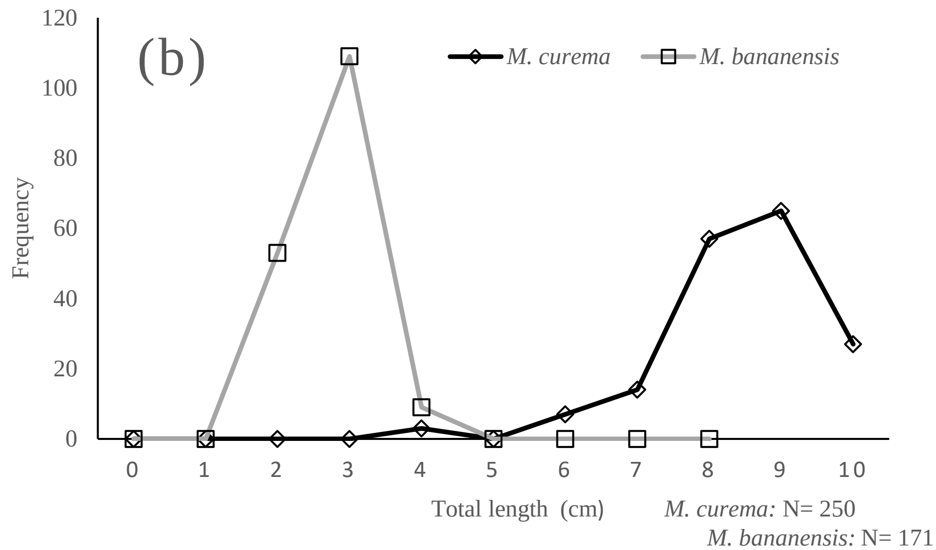
The modal progressions of length-frequency polygons of the species, suggest that fish species at diverse ages are occurring in the estuary. Chang *et al.* (2000) reported that, various cohorts of grey mullet were recorded in the Tanshui estuary, and these grey mullets formed transient populations of fish whose numbers were regulated by the immigration of 0+ group fish from the sea and the emigration of older groups (Arruda *et al,* 1991). In the present study, the occurrence of mullets of different species with similar ranges in modal class size suggest a possible schooling habit of the mullets. However, the most abundant species selected for this study were the sub-adults or juveniles. This study is similar to the results of Lawson *et al.* (2010) who reported on the dominance of the sub-adults of *Liza falcipinnis* in the Badagry creek, Lagos, Nigeria. The occurrence of table-sized mullets in the sample indicates a good possibility for brackish water culture in the estuary and a source of protein to the surrounding coastal communities.

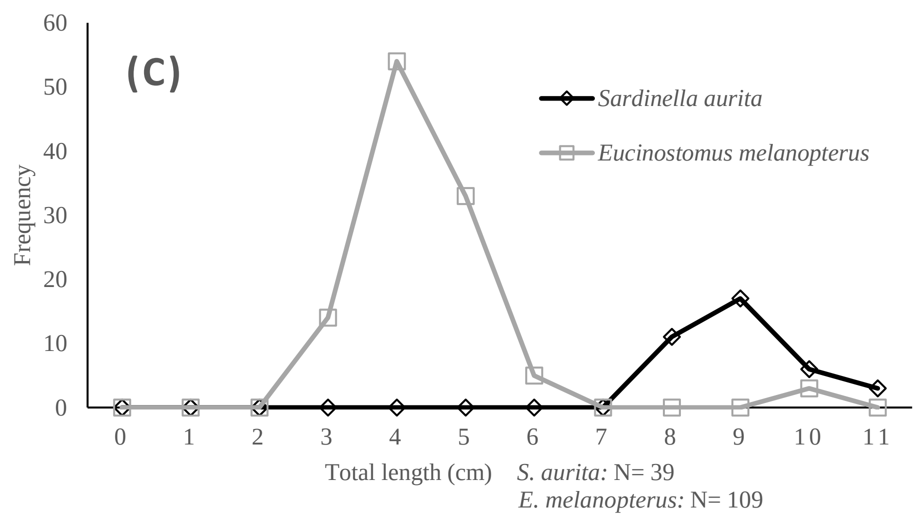
Table 1: *The length, weight, and condition factor of 9 abundant fish species collected from the Kakum River Estuary.*

		TL (cm)			BW (g)							
	n	**Min**	**Max**	**Mean ±SD**	**Min**	**Max**	**Mean ±SD**	**K**	**SD of K**	**a**	**b**	**r**
Liza dumerilli	171	2.2	20.9	10.2±4.4	1.76	87.3	13.94±22.0	1.3	0.31	0.04	2.38±0.08	0.84
Liza falcipinnis	127	5.1	16.6	11.8±3.9	1.52	77	18.96±22.4	0.9	0.33	0.02	2.72±0.14	0.93
Mugil bananensis	171	4.4	15.5	9±1.8	1.9	35.6	6.4±5.9	1.2	0.31	0.03	2.48±0.14	0.92
Mugil curema	250	4	29.8	9.8±3.7	0.2	251	15.3±34.3	1.2	0.34	0.02	2.72±0.18	0.78
Sardinella aurita	39	7.1	17.6	9±2.5	2.8	49.6	7.5±12.1	0.8	0.36	0.01	3.07±0.21	0.96
Eucinostomus melanopterus	109	4.6	18.5	7.9±3.1	0.97	104	8.9±24.6	1.1	0.26	0.01	3.10±0.10	0.97
Lutjanus fulgens	34	5.1	16	11.1±2.8	3.01	65.8	11.1±16	1.6	0.18	0.02	2.97±0.20	0.96
Lutjanus goreensis	49	5.1	15.8	13.1±2.6	3.02	76	13.1±17.5	1.8	0.23	0.02	2.85±0.22	0.96
Caranx hippos	174	3.4	14.4	5.6±1.5	0.58	9.04	2.8±2.1	1.4	0	0.03	2.53±0.11	0.91

Note: *Total length (TL), n (Number), WB (Bodyweight), SD (Standard deviation), and K (Condition factor)*




(b)
M. curema
M. bananensis
Frequency
Total length (cm)
M. curema: N= 250
M. bananensis: N= 171


(c)
Sardinella aurita
Eucinostomus melanopterus
Frequency
Total length (cm)
S. aurita: N= 39
E. melanopterus: N= 109

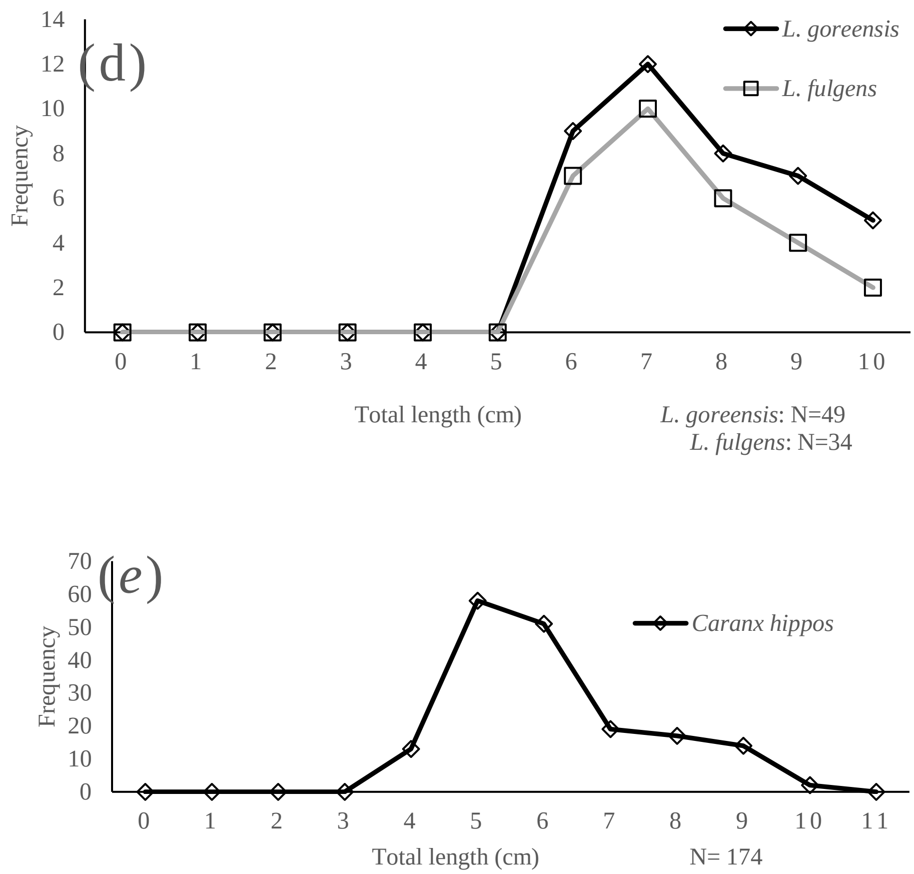
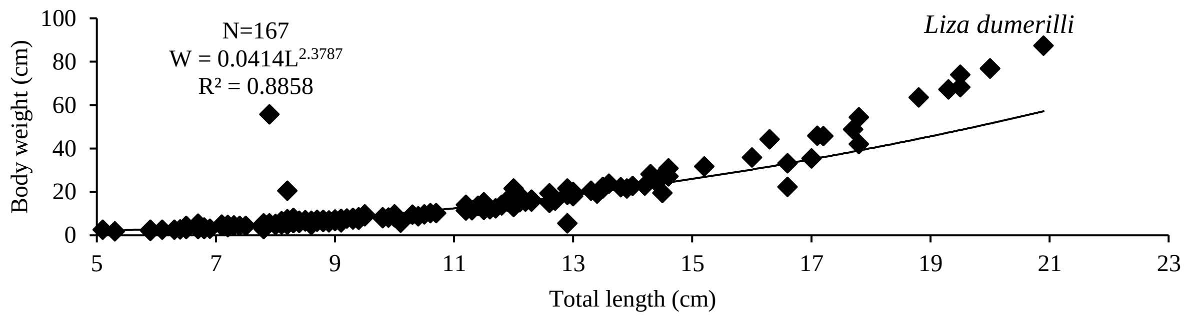
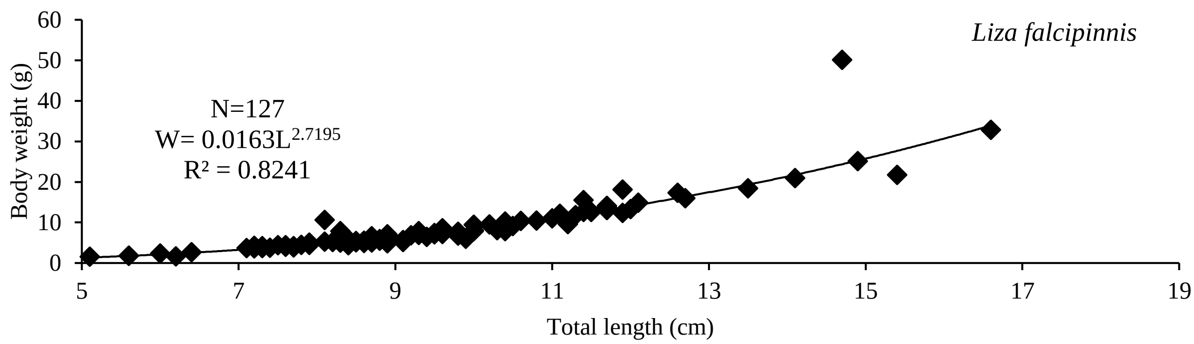


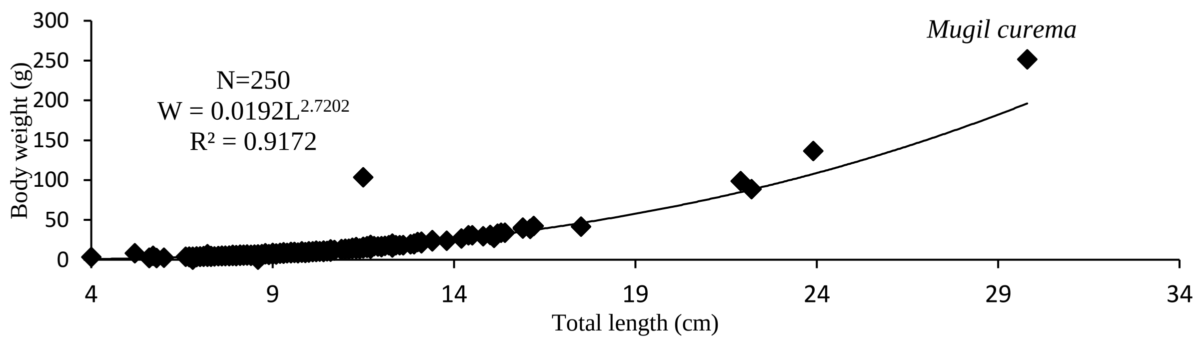
Figure 4. Total length-frequency distribution of dominant marine species from Kakum River Estuary (November 2016 to April 2017)

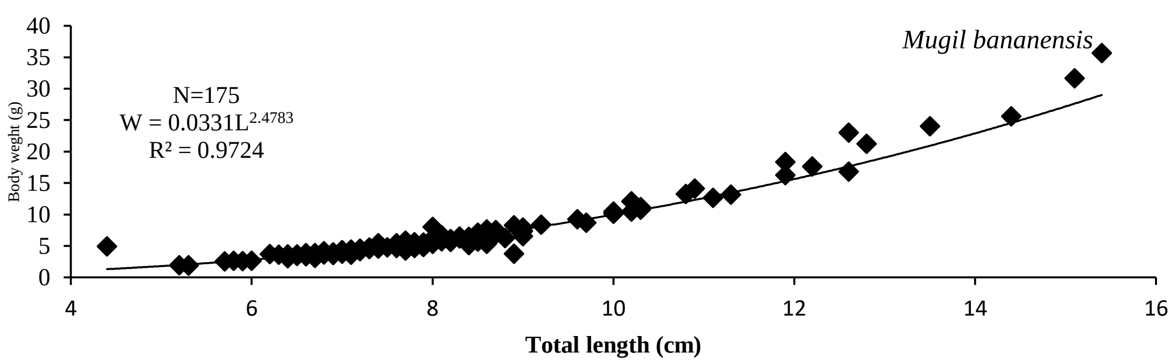
Length-weight distributions of the abundant fishes

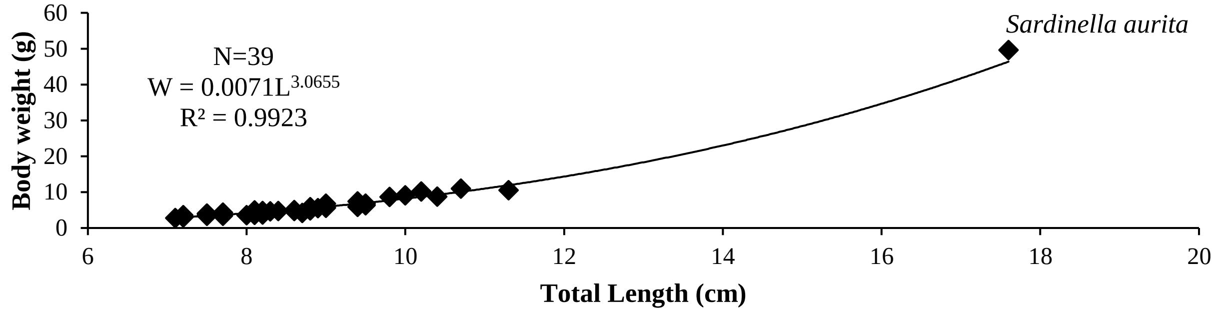
A strong correlation of (r = 0.84 to 0.97) was documented for the length and weight relationships of the nine (9) abundant species studied in the estuary (Figure 4). The regression coefficient *b* was significantly lower than the hypothetical value of 3.0 for the *C. hippos* (2.527), *Mugil bananensis* (2.4783), and *Liza dumerilli* (2.3787) stock in the estuary signifying species with negative allometric growth. The coefficient *b* was significantly higher than 3.0 for *Sardinella aurita* (3.1009), and *Eucinostomus melanopterus* (3.0655), indicating that the species are growing isometrically but *L. goreensis* (2.8471), *Mugil curema* (2.7202), *Lutjanus fulgens* (2.9743), and *Liza falcipinnis* (2.7197) stock in the estuary showed isometrically growth since the regression coefficient *b* was significantly closer to the hypothetical value of 3.0 (Figure 5).

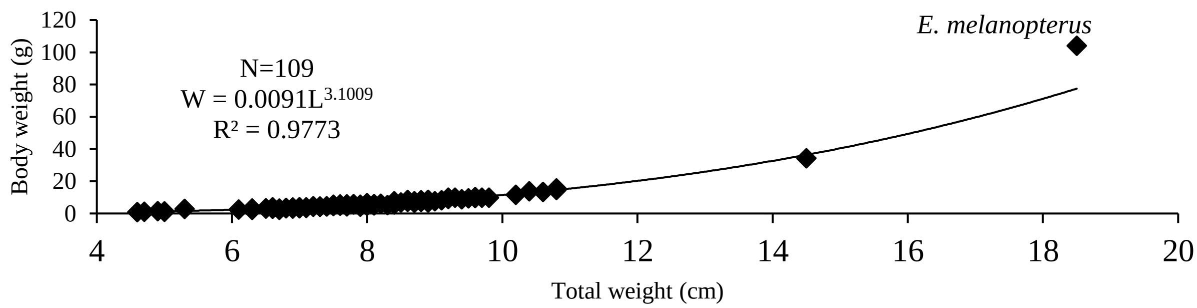

N=167
W = 0.0414L^2.3787
R² = 0.8858
Liza dumerilli
Body weight (cm)
Total length (cm)

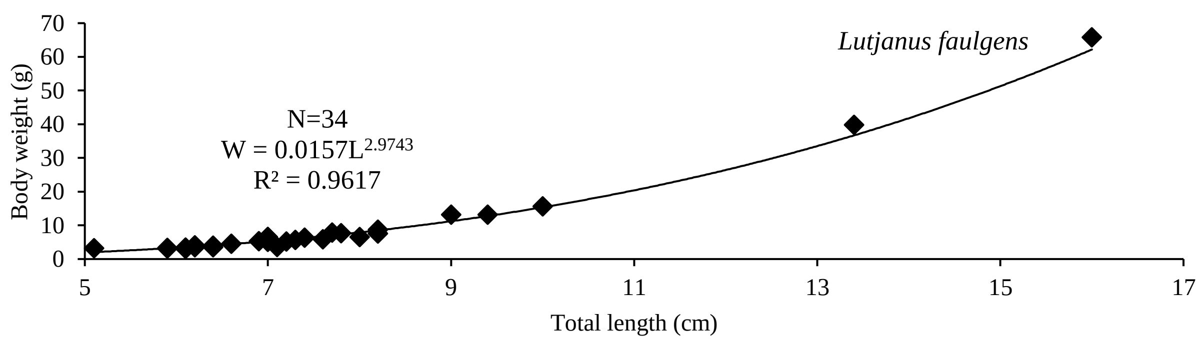

N=127
W= 0.0163L^2.7195
R² = 0.8241
Liza falcipinnis
Body weight (g)
Total length (cm)

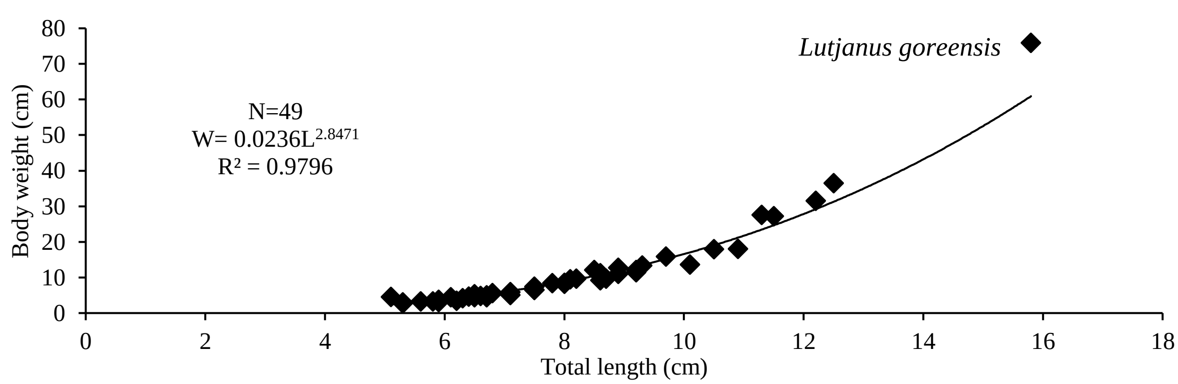

N=250
W = 0.0192L^2.7202
R² = 0.9172
Mugil curema
Body weight (g)
Total length (cm)


N=175
W = 0.0331L^2.4783
R² = 0.9724
Mugil bananensis
Body weght (g)
Total length (cm)


Sardinella aurita
N=39
W = 0.0071L^3.0655
R² = 0.9923
Body weight (g)
Total Length (cm)


E. melanopterus
N=109
W = 0.0091L^3.1009
R² = 0.9773
Body weight (g)
Total weight (cm)


Lutjanus faulgens
N=34
W = 0.0157L^2.9743
R² = 0.9617
Body weight (g)
Total length (cm)


Lutjanus goreensis
N=49
W= 0.0236L^2.8471
R² = 0.9796
Body weight (cm)
Total length (cm)

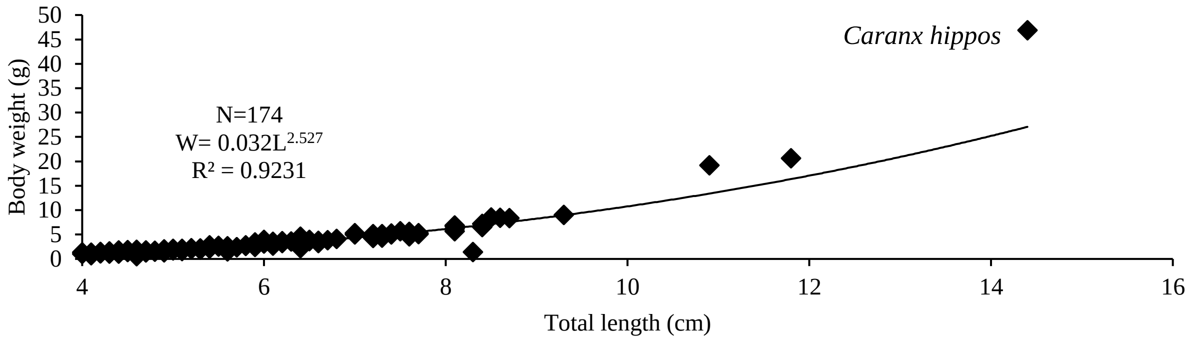


Figure 5. Length-weight relationship of the dominant fish species in the Kakum River Estuary from November 2016 to April 2017). N= Number of fish

The length-weight relationships for the selected species captured from the Kakum river estuary were highly significant ($p < 0.05$). The coefficient of determination (r^2) for the length-weight relationships was found to be higher for all the selected species ($r^2 = 0.82 - 0.99$) which signifies that the length of fish increases with an increase in weight and again suggesting a strong relationship between the length and the weight of fishes recorded from the estuary. This is in agreement with past studies on fishes of diverse species from similar systems: (eg: Konan *et al*., 2007; Koffi *et al*., 2014; Tah *et al*., 2012; Ndiaye *et al*., 2015). Ndiaye *et al*., (2015) reported r^2 of 0.72 - 0.99 for 31 species of fish. The estimated value *b* in the present study ranged from 2.38 in *Liza dumerilli* to 3.10 in *Eucinostomus melanopterus* with a 95% confidence interval of *b* for all the nine fish species examined which ranged from 0.08 to 0.22 in the estuary. However, *Sardinella aurita* and *Eucinostomus melanopterus* had exponents *b*, which statistically were significant to 3.0 representing possible isometric growth in the species. The exponents *b* for the remaining seven were not significant statistically to 3.0 indicating possible allometric growth.

The recorded values for the fish species being isometric in the length-weight relationship indicated that fish species did not increase in weight faster than the cube of their total length. However, those recorded to be allometric infer that the species increased in weight faster than in total length. This indicates that fish weight increases with the increasing length and this result is in accordance with the observations of Ndiaye *et al.* (2015) with a reported *b* values from 2.17 to 3.60 for 31 fish species (which comprised Clupeidae, Mugilidae, Carangidae, Gerreidae, and Lutjanidae) sampled from Saloum Delta, Senegal. The differences observed in *b* values might be correlated to differences in geographical areas with varying environmental conditions (Warren *et al.*, 2008).

The parameters (α, and b) of the relationship between Length-weight and the “K” value of the fishes are influenced by several factors such as availability of food, feeding intensity, age, size of fish, their sex, period, maturation stage, gut fullness, degree of muscular growth, and the amount of accumulated fat as well as the life history of the species (Gupta and Banerjee, 2015; Ujjania *et al.*, 2012)

CONCLUSION

In conclusion, the length-weight relationships, length-frequency distribution, and condition factors of this study provide valuable information for the management of the fisheries industry as well as the population dynamic of the fishes. Again, the LWR and K in the Kakum river estuary were presented for the first time for the selected species. Therefore, the results of the present study can be employed as baseline information for the studied species and compared with further studies.

ACKNOWLEDGMENTS

This study is part of the M.Phil. research work of the first author. The authors acknowledge USAID/UCC Fisheries and Coastal Management Capacity Building Support Project for sponsoring this work.

REFERENCES

Able, K.W. (2005). A re-examination of fish estuarine dependence: evidence for connectivity between estuarine and ocean habitats. Estuary Coast Shelf Sci;64:5–17

Aggrey-Fynn, J., Galyuon I., Aheto D. W. and Okyere I. (2011). Assessment of the environmental conditions and benthic macroinvertebrate communities in two coastal lagoons in Ghana. Ann. Biol. Res. 2(5): 413–424

Aheto, D.W., Aduomih, A.A. O. and Obodai, E.A. (2011). Structural parameters and above-ground biomass of mangrove tree species around the Kakum river estuary of Ghana. Ann. Biol. Res. 2(3): 504–514

Arruda, L.M., Azevedo, J.N., & Neto, A.I. (1991). Age and growth of the grey mullet (Pisces, Mugilidae) in Ria de Aveiro (Portugal). Sci. Mar., 55 (33): 497 – 504.

Asare, N. K., & Javier, J. L. (2022). Tidal influence on fish faunal occurrence and distribution in an estuarine mangrove system in Ghana. *African Journal of Aquatic Science*, *47*(1), 88-99.

Beck, M.W., Heck, K.L., Able, K.W., Childers, D.L., Eggleston, D.B., & Gillanders, B.M., et al. (200). The identification, conservation, and management of estuarine and marine nurseries for fish and invertebrates. Bioscience;51:633–41.

Blaber, S.J.M., Cyrus, D.P., Albaret, J.J., Ching, C.V., Day, J.W., & Elliott, M., et al. (2000). Effects of fishing on the structure and functioning of estuarine and nearshore ecosystems. ICES J Mar;57:590–602

Bettencourt, A., & Ramos, L. (2003). Estuários Portugueses. Instituto da Água;. 317 pp.

Blackwel, B.G., Brown, M.L., & Willis, D.W. (2000). Relative weight (Wr) status and current use in fisheries assessment and management. Reviews in Fisheries Science, 8, 1-44.

Blay, J. Jr. (1997). Occurrence and diversity of juvenile marine fishes in two brackish water systems in Ghana. In Biodiversity Conservation: Traditional Knowledge and Modern Concepts. (D. S. Amlalo, L. D. Atsiatorme and C. Fiati, eds), pp. 113–119. UNESCO-BRAAF Proceedings, Cape Coasts

Chang, C.W., Tzeng, W.N., Lee, Y.C. (2000). Recruitment and hatching dates of grey mullet (Mugil cephalus L.) juveniles in the Tanshui estuary of northwest Taiwan. Zoological Studies, 39(2): 99 – 106.

Costa, M.J., & Bruxelas, A. (1989). The structure of fish communities in the Tagus estuary, Portugal, and its role as a nursery for commercial fish species. Sci Mar;53(2–3):561–6

Elliott, M., Whitfield, A. K., Potter, I. C., Blaber, S. J., Cyrus, D. P., Nordlie, F. G., & Harrison, T. D. (2007). The guild approach to categorizing estuarine fish assemblages: a global review. *Fish and fisheries*, *8*(3), 241-268.

Emmanuel, B.E., & Onyema, I.C. (2007). The plankton and fishes of a tropical creek in south-western, Nigeria. Turk. *J. Fish. Aquat. Sci*. 7:105-114

Froese, R. (2006). Cube law, condition factor and weight-length relationships: history, meta-analysis and recommendations. J. Appl. Ichthyol. 22:241-253.

Fulton, T. (1902). Rate of growth of seas fishes. Sci. Invest. Fish. Div. Scot. Rept. P. 20.

Gillanders, B.M., Able, K.W., Brown, J.A., Eggleston, D.B., & Sheridan, P.F. (2003). Evidence of connectivity between juvenile and adult habitats for mobile marine fauna: an important component of nurseries. Mar Ecol Prog Ser;247:281–95.

Green, B.C., Smith, D.J., Earley, S.E., Hepburn, L.J., Underwood GJC. (2009). Seasonal changes in community composition and trophic structure of fish populations of five salt marshes along the Essex coastline, United Kingdom. Estuarine, *Coastal and Shelf Science*, 85(2), 247-256.

Gupta, S., & Banerjee, S. (2015). Length-weight relationship of Mystus tengara (Ham.-Buch., 1822), a freshwater catfish of Indian subcontinent. International Journal of Aquatic Biology, 3(2), 114-118.

Haimovici, M., & Velasco, G. (2000). "Length-weight relationships of marine fishes from southern Brazil", NAGA, ICLARM 23, 19-23.

Kennish, M. J. (2002). Environmental threats and environmental future of estuaries. *Environmental conservation*, *29*(1), 78-107.

King, M. (2013). *Fisheries biology, assessment and management*. John Wiley & Sons.

Koffi, B.K., Berté, S., & Koné, T. (2014). Length-Weight Relationships of 30 Fish Species in Aby Lagoon, Southeastern Côte d"Ivoire. Curr. Res. *J. Biol. Sci.* (Sous presse).

Konan, A.K.F., Ouattara, M., Ouattara, A., & Gourène, G. (2007). Weight-length relationship of 57 fish species of the coastal rivers in south-eastern of Ivory Coast. *Ribarstvo*, 65(2): 49-60.

Kwei EA, Ofori-Adu DW. 2005. Fishes in the coastal waters of Ghana. *Ronna Publishers*, Tema.108 pp.

Lawson, E.O., Akintola, S.O., & Olatunde, O.A. (2010). Aspects of the Biology of Sickle fin mullet, Liza falcipinnis (Valenciennes, 1836) from Badagry creek, Lagos, Nigeria, Nature, and Science, 8(11): 168 – 182.

Lepage, M., Capderrey, C., Elliott, M., & Meire, P. (2022). Estuarine Degradation and Rehabilitation. *Fish and Fisheries* *in Estuaries: A Global Perspective*, *1*, 458-552.

Marchand, J. (1980). Seasonality abundance and diversity of the ichtyofauna of the lower Loire Estuary in 1977–1978 (France). Ann Inst Oceanogr Paris ;56:127–37.

Marques, M., da Costa, M.F., Mayorga, M.I.D., & Pinheiro, P.R.C. (2004). Water environments: anthropogenic pressures and ecosystem changes in the Atlantic drainage basins of Brazil. Ambio 2004;33:68-77

Matich, P., Nowicki, R. J., Davis, J., Mohan, J. A., Plumlee, J. D., Strickland, B. A., ... & Fisher, M. (2020). Does proximity to freshwater refuge affect the size structure of an estuarine predator (Carcharhinus leucas) in the north-western Gulf of Mexico?. *Marine and Freshwater Research*, *71*(11), 1501-1516.

Mensah, M. A., & Quaatey, S. N. K. (2002). 17 An overview of the fishery resources and fishery research in the gulf of guinea. Large Marine Ecosystems, 11, 227-iii.

Methot Jr, R. D., & Wetzel, C. R. (2013). Stock synthesis: a biological and statistical framework for fish stock assessment and fishery management. *Fisheries Research*, *142*, 86-99.

Molina, A., Duque, G., & Cogua, P. (2020). Influences of environmental conditions in the fish assemblage structure of a tropical estuary. Marine Biodiversity, 50(1), 1-13.

Morato, T., Afonso, P., Lourinho, P., Barreiros, J.P., & Santos, R.S. (2001). Length-weight relationships for 21 coastal fish species of the Azores, north-eastern Atlantic. Fisheries Research, 50(3), 297-302.

Ndiaye, W., Sarr, A., Diouf, M., Faye, A., & Mbodji, A. (2015). Length-weight relationships of some fish species from the Saloum Delta, Senegal. *International Journal of Advanced Research*, Volume 3, Issue 4, 132-138

Ofori-Danson, P. K., Van Waerebeek, K., & Debrah, S. (2003). A survey for the conservation of dolphins in Ghanaian coastal waters. *Journal of the Ghana Science Association*, (2).

Ogbonna, J., & Chinomso, A. (2010). Determination of the concentration of ammonia that could have lethal effect on fish pond. *Journal of Engineering and Applied Sciences (Asian Research Publishing Network)*, *5*, 1-5.

Okyere, I., Aheto, D.W, & Aggrey-Fynn, J. (2011). Pelagia Research Library. *European Journal of Experimental Biology*, 1(2), 178-188.

Ozaydin, O., Uckun, D., Akalin, S., Leblebici, S., Tosunoglu, Z. (2007). Length-weight relationships of fishes captured from Izmir Bay, Central Aegean Sea.

Tah, L.G., Gooré, B.G., Dacosta, K.S. (2012). Length-weight relationships for 36 freshwater fish species from two tropical reservoirs: Ayamé I and Buyo, Côte d‟Ivoire. *Int. J. Trop. Biol. Cons*., 60(4): 1847-1856.

Ricker, W.E. (1975). Computation and interpretation of biological statistics of fish populations. Bulletin of the Fisheries Research Board of Canada .191:382

Ujjania, N.C, Kohli, M.P.S, & Sharma, L.L. (2012). Length-weight relationship and condition factors of Indian major carps (Catla catla, Labeo rohita, and Cirrhinus mrigala) in Mahi Bajaj Sagar, India. Research Journal of Biology, 2(1), 30-36.

Salas, P. M., Sujatha, C. H., & Ratheesh Kumar, C. S. (2015). Fate and source distribution of organic constituents in a river-dominated tropical estuary. *Journal of Earth System Science*, *124*(6), 1265-1279.

Saliu, J.K. (2001). "Observation on the condition factor of Brycinus nurse (Pisces: Cypriniformes, Characidae) from Asa Reservoir, Ilorin, Nigeria", Tropical Freshwater Biology 10, 9-17.

Scapin, L., Zucchetta, M., Sfriso, A., & Franzoi, P. (2018). Local habitat and seascape structure influence seagrass fish assemblages in the Venice Lagoon: The Importance of conservation at multiple spatial scales. *Estuaries and Coasts*, *41*(8), 2410-2425.

Schneider, J.C., Laarman, P.W., & Gowing H. (2000). "Length-weight relationships", In Schneider, James C. (Ed.). Manual of fisheries survey methods II: with periodic updates. Michigan Department of Natural Resources, Fisheries Special Report 25, Ann Arbor

Soykan, O., & Kınacıgil, H. T. (2021). Length–Weight Relationship of some Discarded Fish Species with Emphasis on Length at Maturity from the Central Aegean Sea, Turkey. *Thalassas: An International Journal of Marine Sciences*, *37*(2), 505-511.

Warren, D.L., Glor, R.E., & Turelli, M. (2008). Environmental niche equivalency versus conservatism: quantitative approaches to niche evolution. *Evolution: International Journal of Organic Evolution*, *62*(11), 2868-2883.

Whitfield, A.K. (1990). Life history styles of fishes in South African estuaries. *Environmental Biology of Fish*. 28: 295-308.