

THE STATUS OF FISH DIVERSITY AND FISHERIES OF THE KETA LAGOON, GHANA, WEST AFRICA

M. A. LAMPTEY* AND P. K. OFORI-DANSON

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

*Corresponding author's email: amlamptey@ug.edu.gh or angela.lamptey@yahoo.com

Abstract

The fish and fisheries of three fish landing sites around the Keta lagoon in Ghana have been studied. A total of 18 fish species belonging to 13 families were encountered in the study. Four of the species were found to be commercially important notably, the cichlids (*Tilapia guineensis* and *Sarotherodon melanothron*), the Bonga shad, (*Ethmalosa fimbriata*) and the blue-swimming crab, (*Callinectes amnicola*). The most important shell fish was the blue swimming crab (*Callinectes amnicola*). All the fishes showed isometric growth values from 2.6 to 3.0. Mean monthly condition factor (K) was between 0.3 ± 0.5 and 13.9 ± 1.8 . Occurrence of fish species caught in commercial fishing was 32.3 per cent for *Callinectes amnicola*, 18.5 per cent for *Tilapia guineensis* and 13.9 per cent for *Sarotherodon melanothron*. Total weight of fish caught in experimental fishing was 2.7 tonnes. From experimental fishing with cast nets, *Ethmalosa fimbriata* accounted for 41.8 per cent (percentage of occurrence) of the total catch, whilst *T. guineensis* accounted for 29.2 per cent, *Sarotherodon melanothron* accounted for 23.3 per cent and *Callinectes amnicola* accounted for 5.7 per cent. Shannon-Wiener species diversity of fish species was highest in Woe (0.76), followed by Anloga (0.46) and least in Anyanui (0.14). The Keta lagoon was found to be an important nursery ground for some juvenile marine species including Clupeidae, Mugilidae, Lutjanidae, Peneidae, Carangidae, Sciaenidae and Pomadasysidae. The most occurred fishing gears were the brush parks (Acadja) (29.1 %) and basket traps (23.2 %), whilst the least occurred gear was the encircling net (1.8 %). There is the deployment of multiplicity of fishing gears which was highly pronounced at Anloga where fishing appeared to be a daily source of income. Fisheries in the Keta lagoon are threatened from irresponsible fishing and environmental degradation. Management strategies that could be applied to enhance fishery productivity include re-establishment of estuarine conditions, preservation of vital habitats such as vegetation cover around the lagoon, and the development of aquaculture.

Introduction

Lagoons are a class of aquatic environment linked by the common characteristic of having a single (or more) restricted connection(s) to the ocean (Hansen & Rattray, 1966; Odum & Copeland, 1972; Fairbridge, 1980; Day, Blaber & Wallace, 1981). The lagoons are of utmost importance as nursery grounds for marine and freshwater fin and shellfish, which often sustain significant fisheries (Kapetsky, 1984). Kapetsky (1984) in a com-

parative study of fishery yields from lagoons and other exploited marine and freshwater ecosystems concluded that coastal lagoons are, overall, more productive than the marine and freshwater ecosystems. The productivity of lagoons is variable (Ben-Tuvia, 1983; Ardizzone, 1984; Kapetsky, 1984). Fisheries yield may range from about two to over 800 kg ha⁻¹ yr⁻¹ and is 10-20 times higher per unit primary production in lagoons than lakes (Nixon, 1982), suggesting either a

greater conversion efficiency or greater harvest efficiency, or both. The low diversity of species and the relatively shallow water in lagoons could contribute to either. Much of the variability in yield among lagoons is due to varying intensity of harvest (Kapetsky, 1984). Large fraction of this variability is attributable to differences in hydrodynamics which may directly affect catchability (Corsi & Ardizzone, 1985; Chauvet, 1988) of which the Keta lagoon of Ghana is no exception.

The coastal waters of Ghana comprise over 90 lagoon systems and estuarine flood-plains of rivers (Ofori-Danson, Entsua-Mensah & Biney, 1999). These coastal lagoons have historically supported artisanal fisheries, and comprise a significant proportion of the economic and dietary resources of the human populations clustered around the various lagoons. In such areas, fishing pressure is usually very intense, and data on existing fish stocks suggest that over-exploitation has had both direct and indirect impact on the population dynamics of the fishery (Koranteng, Ofori-Danson & Entsua-Mensah, 2000; Dankwa, *et al.*, 2004).

The main objective of the study was to investigate the current mode of fishing and the status of the Keta Lagoon fishery, over the years in terms of species diversity, level of catches and sizes of landed fishes due to the growing concern of dwindling catches.

Experimental

Site description

Keta lagoon (Fig.1) with co-ordinates 5° 55'N 0° 59'E lies in the far south-east of Ghana, east of the international frontier with Togo. The lagoon is about 140 km east-northeast of Accra, on the south coast of the

Volta Region, southeast Ghana (Sorensen *et al.*, 2003; Armah *et al.*, 1997). The lagoon is connected to the open sea through a tributary of the Volta lake at Anyanui (Sorensen *et al.*, 2003). The lagoon is an extensive, brackish water-body situated to the east of the Volta river estuary, with an average depth of 0.8 m and an average salinity of 1.87 ‰ (18.7 PSU) (Sorensen *et al.*, 2003; Anon., 1993). The surrounding flood-plain consists of marsh, scrub, farmland and substantial mangrove stands, which are heavily exploited for fuelwood (Ofori-Danson, Entsua-Mensah & Biney, 1999). Keta lagoon was designated a Ramsar site under the Ghana Coastal Wetlands Management Project in 1999 (Ofori-Danson, Entsua-Mensah & Biney, 1999). Inflow into the lagoon is from three main sources: from the Todzie river, the Aka and Belikpa streams and, to a limited extent, from the Volta river itself at Anyanui (Armah *et al.*, 1997) with an unknown discharge rates. Currently, the commonest economic activities are agriculture, fisheries/aquaculture, means of transport and conservation, with fishing and farming being the main occupations of the population in the area (Ofori-Danson, Entsua-Mensah & Biney, 1999). A major threat is coastal erosion (Piersma & Ntiamo-Baidu, 1995; Ofori-Danson, Entsua-Mensah & Biney, 1999) and urbanisation, therefore, conservation efforts and management interventions have been suggested to concentrate on those parts of the lagoon supporting artisanal fisheries

Fishing activities at the various sampling sites were monitored to investigate the fish species composition, catch per unit effort and the various fishing modes deployed at



Fig. 1. Map of Ghana showing the Keta lagoon and the sampling stations (Survey Department Ghana, 2010).

the sites. These included 1) gear type and mesh size, 2) key fish species landed commercially by local fishermen at each landing site, 3) experimental fishing using a cast net (average diameter = 4 m, mesh size = 25 mm) for Anloga, and 4) monofilament net (mesh size = 10 mm) at both Woe and Anyanui, deployed quarterly to compare catch composition to commercial catches, after sorting the catch to species level using taxonomic guides (Schneider, 1990; Dankwa, Abban & Teugels, 1999; Paugy, Leveque & Teugels (2003). During the experimental fishing, a fisherman was contracted to fish for one hour at each of the sampling sites, and the number of throws per hour recorded. The catch per unit effort (CPUE, equation 1) of commercial fishers in each of the sampling months was calculated as catch/fisher/hour, that is:

$$CPUE = \frac{\text{Weight of fish catch (Kg)per fisher}}{\text{Effort (duration of fishing)(hr)}} \quad (1)$$

(Koranteng, Ofori-Danson & Entsua-Mensah, 2000).

The individual body weights and standard lengths (length-frequency data) (carapace length in the case of crabs) of the fish were measured and recorded. The estimated values of the above indicators were compared with similar results obtained from fisheries monitoring studies, undertaken by Ofori-Danson, Entsua-Mensah & Biney (1999) in the Keta lagoon under the Ghana Coastal Wetlands Management Project. The exponential equation of fish length and weight relationship is;

$$W = aL^b \quad (\text{Roff, 1986}) \quad (2)$$

where W = weight of fish in grams, L = standard length of fish in cm, b = exponent

of growth and a = a constant determined empirically. The growth of the fishes were analysed and identified as allometric growth ($b < 3$) or isometric (b is equal to or close to 3) growth by plotting the logarithmic form of equation 2 in order to get a linear relationship in the form:

In $W = \ln a + b \ln L$ (King, 1992) (3) where b (growth constant) = slope of the line of best fit (Imam *et al.*, 2010). The physiological well being of the key fish species was determined through estimation of their monthly mean condition factor (K).

$$K = \frac{\text{Body weight (g)}}{[\text{Standard length (cm)}]^3 \times 100} \quad (4)$$

(Sparre, Ursin & Venema, 1989).

The fish species biodiversity indices was determined using the Shannon-Wiener Diversity Index (H), Margalef species richness index (d) and Pielou's evenness (J) which are defined as:

$$H = - \sum_{i=1}^s p_i \ln p_i \quad (5)$$

(Magurran, 1988; Zar, 1974)

where H = Shannon-Wiener diversity index, s = number of species and p_i = proportion of individuals of each species belonging to the i th species of the total number of individuals. $d = ((S-1)/(\ln N))$ (6)

(Magurran, 1988; Zar, 1974).

where S = number of species recorded and N = total number of individuals summed over all the S species.

$$J = H/(\ln S) \quad (7)$$

(Magurran, 1988; Zar, 1974).

where H = Shannon-Wiener's species diversity index, and S = the number of species diversity.

Results

Species composition

Table 1 shows the species list of fish encountered during the study. A total of 4,408 individual fish specimen comprising 18 fish species belonging to 13 families were collected from commercial catches from August 2010 to March 2012 at the three sampling sites (Table 1). Four of the species *Tilapia guineensis* (763;17.3 %), *Sarotherodon melanotheron* (570;12.9 %), *Ethmalosa fimbriata* (491; 11.1 %), *Callinectes amnicola* (1,107, 25.1 %) were found to be commercially important in the Keta lagoon. Although *P. leonensis* was abundant, it is not of commercial importance in the Keta area and, therefore, was not considered in the data analysis.

Table 2 shows the diversity indices of fish species from the keta lagoon. The highest number of species (11) was recorded in Woe, followed by Anyanui (8) and Anloga (6). Total number of fishes recorded during the study period was highest in Woe (1,969), followed by Anloga (1,327) and Anyanui (1,112). Shannon-Wiener diversity index followed the order $0.76 > 0.46 > 0.14$ for Woe, Anloga and Anyanui, respectively. The most even of species was recorded in Anloga, whereas the least even was recorded in Woe.

Fig. 2 shows the mean monthly percentage compositions of dominant fish species which varied across the months. The least was recorded for *S. melanotheron* except for December 2011 and January 2012.

Fig. 3 shows the length frequency analysis of the dominant fish species. Fig. 3a shows that 50 per cent of *S. melanotheron* and *T. guineensis* (Fig. 3b) specimens had

TABLE 1
Fish species encountered during the study from August 2010 to March 2012 compared to previous study

Family	Species	Common name	Exptal. Fishing	Present study	GCWMP, 1999 (Shenker et al., 1999)
Cichlidae	<i>Sarotherodon melanotheron</i> (Ruppell, 1852)	Black-chin tilapia	+(114)	+(570)	+
	<i>Tilapia guineensis</i> (Günther, 1862)	Red-chin tilapia	+(143)	+(763)	+
	<i>Oreochromis niloticus</i> (Linnaeus, 1758)	Nile tilapia		+(101)	+
	<i>Tilapia zillii</i> (Gervais, 1848)	Red-belly tilapia		+(47)	+
	<i>Hemichromis fasciatus</i> (Peters, 1857)	Jewel fish		+(28)	+
	<i>Hemichromis bimaculatus</i> (Gill, 1862)	Jewel cichlid		+(122)	+
	<i>Hyporhamphus picarti</i> (Valenciennes, 1847)	African halfbeaks			+
	<i>Porogobius schlegelii</i> (Günther, 1861)	Schlegel's gobid		+(243)	+
	<i>Mugil cephalus</i> (Linnaeus, 1758)	Grey mullet	+(5)	+(65)	+
	<i>Liza falcipinnis</i> (Cuvier & Valenciennes, 1836)	Sicklefin mullet			+
	<i>Eucinostomus melanopterus</i> 1 (Bleeker, 1863)	Mojarra		+(63)	+
	<i>Farfantepenaeus notialis</i> 1 (Pérez-Farfante, 1967)	Pink shrimp		+(17)	+
<i>Callinectes amnicola</i> 1 (Rochebrun, 1883)	Blue swimming crab	+(23)	+(1,107)	+	
<i>Clarias gariepinus</i> (Burchell, 1882)	Catfish		+(57)	+	
<i>Pseudotolithus typus</i> 1 (Bleeker, 1863)	Cassava fish		+(32)	+	
<i>Brachydeuterus auritus</i> 1 (Valenciennes, 1832)	Burrito			+	
<i>Eihmalosa fimbriata</i> 1 (Bowdich, 1825)	Bonga Shad	+(205)	+(491)	+	
<i>Sardinella maderensis</i> 1 (Lowe, 1838)	Flat Sardine			+	
<i>Ilisha africana</i> 1 (Bloch, 1795)	West African Ilisha			+	
<i>Pellomula leonensis</i> (Boulenger, 1916)	Guinean sprat		+(800)"	+	
<i>Cynoglossus</i> spp.1 (Hamilton, 1822)	Tongue sole			+	
<i>Alectis alexandrina</i> 1 (Saint Hilaire, 1817)	African threadfin		+(1)	+	
<i>Lutjanus fulgens</i> 1 (Valenciennes, 1830)	Red snapper		+(1)	+	
Total		490	4,408		

+ = species found; * = Most dominant species; " = not of commercial importance; | = marine fishes using lagoon for breeding or as nursery grounds.

TABLE 2

Diversity indices of fish encountered during the study period

Diversity indices	Anyanui	Anloga	Woe	Total
N	1,112	1,327	1,969	4,408
S	8	6	11	17
H'	0.14	0.46	0.76	-
J'	0.60	0.73	0.15	-
d'	1.00	0.70	1.32	-

S = species; N = number; H = Shannon-Wiener diversity index; J = Pielou's species evenness; d = Margalef species index;

standard lengths ranging from 75 to 85 mm, whilst 50 per cent of *E. fimbriata* (Fig. 3c) had standard lengths ranging from 55 to 65 mm and 50 per cent of *C. amnicola* (Fig. 3d) had carapace lengths ranging from 85 to 95 mm. Lots of dead shells of molluscs, *Tympanotonus fuscatus* and bivalves were found mostly at Anyanui and Anloga.

Table 3 shows the length ranges of the four dominant species. Length ranges for the dominant fish species showed larger sizes in terms of length and weight as compared to earlier studies. In the study, standard length ranges recorded were from 48 to 170 mm,

whereas length ranges of 25 to 157 mm were recorded in previous studies. Similarly, higher weights were recorded in the study as compared to earlier studies.

Fig. 4 shows the length-weight relationship of the dominant fish species. *Ethmalosa fimbriata* and *C. amnicola* showed isometric growth (Fig. 4ad) pattern of value close to 3.0, whereas these same species showed allometric growth during the GCWMP in 1999. *S. melanotheron* and *T. guineensis* showed allometric growth in the study as well as in the previous study. This could be attributed to the poor water quality of the Keta lagoon (Lamprey *et al.*, 2013).

Fig. 5 shows the mean Condition factor (K) of fish specimen which was similarly higher in the present study with 13.4 recorded for *E. fimbriata*, 3.9 for *T. guineensis*, 3.6 for *S. melanotheron* and 6.9 for *C. amnicola*. This could be attributed to a change in gear selectivity. Smaller mesh size (< 25 mm) gears are being used currently, therefore, both juvenile and adult fishes are caught together.

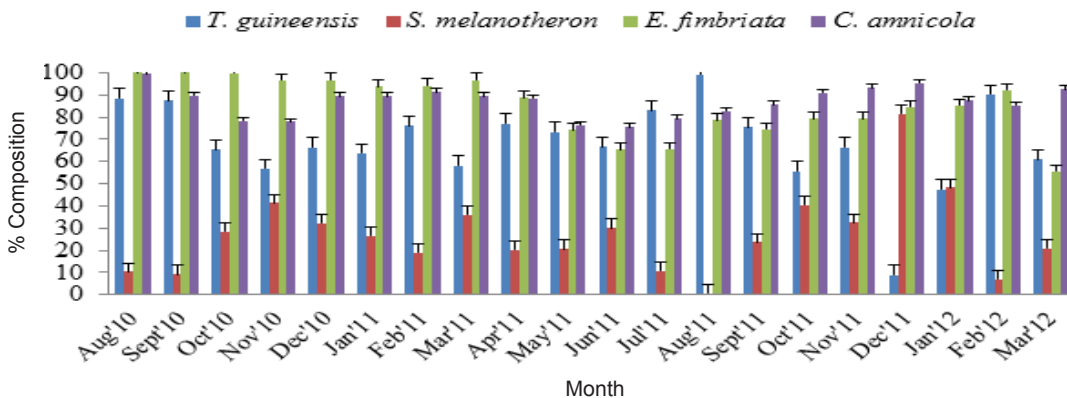


Fig. 2. Percentage composition of dominant fish species of Keta lagoon from August 2010 to March 2012.

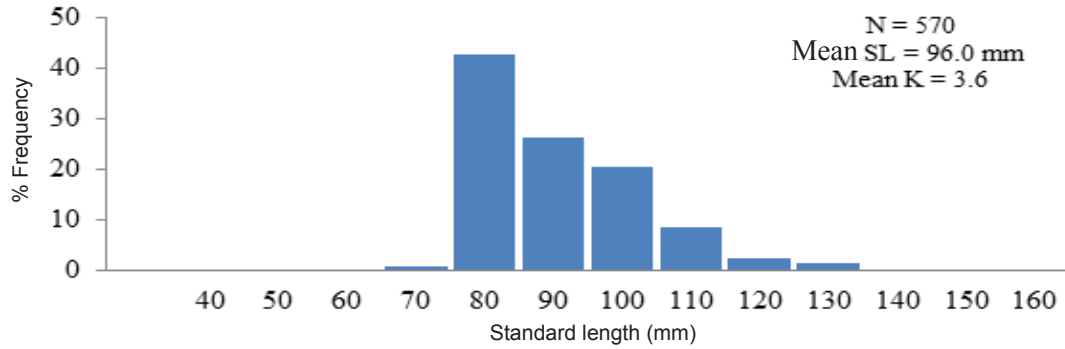


Fig. 3a. Length frequency distribution of *S. melanotheron* from August 2010 to March 2012

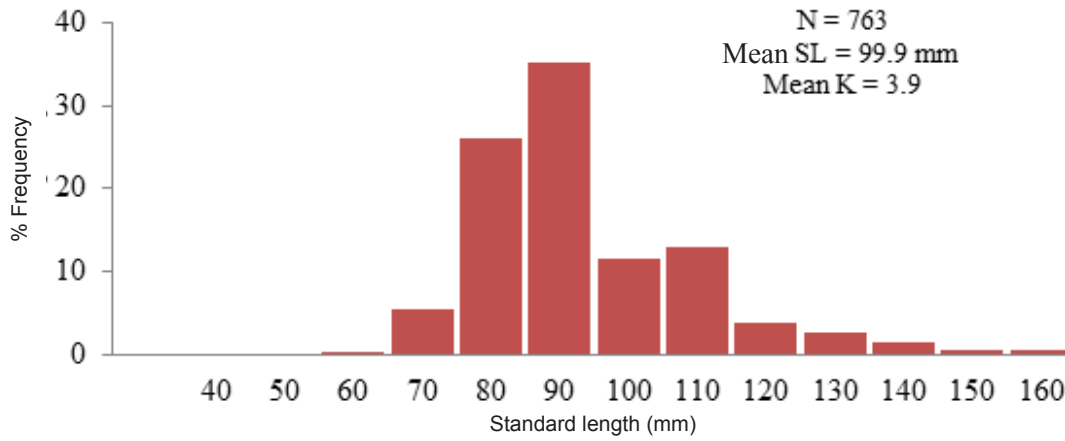


Fig. 3b. Length frequency distribution of *T. guineensis* from August 2010 to March 2012

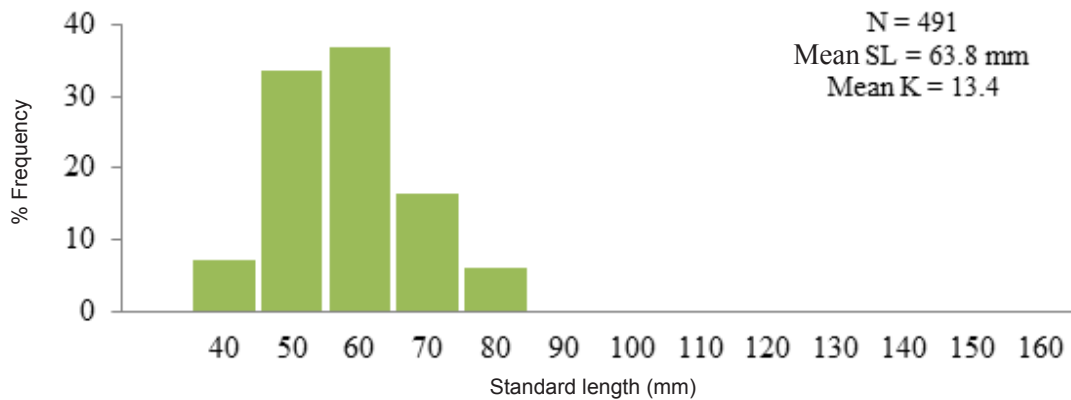


Fig. 3c. Length frequency distribution of *E. fimbriata* from August 2010 to March 2012

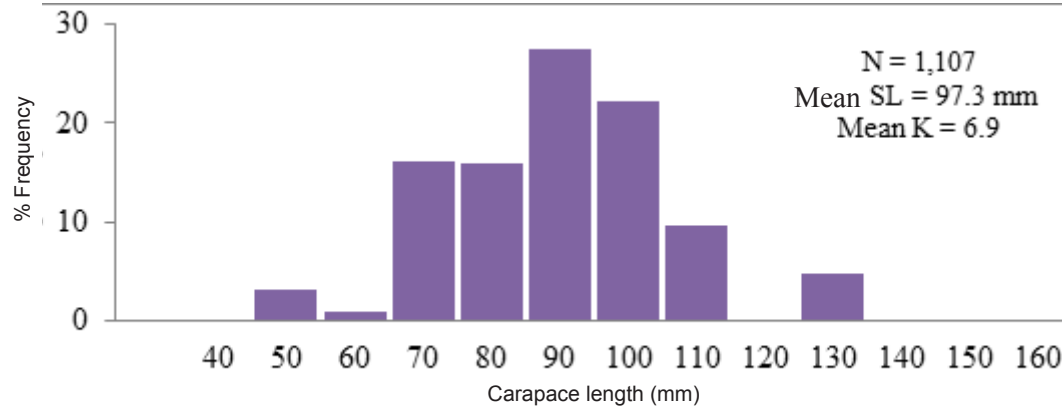


Fig. 3d. Length frequency distribution of *C. amnicola* from August 2010 to March 2012.

TABLE 3

Length range, modal length and maximum weight of fish recorded during the study compared to earlier study

Species	Present study			GCWMP, 1999		
	Length range (mm)	Modal length (mm)	Maximum weight (g)	Length range (mm)	Modal (mm) length (mm)	Maximum weight (g)
<i>S. melanotheron</i>	78 - 140	75	131.4	38 - 121	70	73.0
<i>T. guineensis</i>	69 - 170	85	190.8	25 - 157	60	147.0
<i>E. fimbriata</i>	48 - 85	55	83.8	30 - 90	75	15.0
<i>C. amnicola</i>	50 - 140	85	200.7	30 - 127	80	143.0

Fishing gears, catch rates and catch per unit effort

Table 4 shows fishing gears found in use during the study. The importance of each gear or fishing method, in terms of contribution to estimated catches made at the various sampling sites were as follows: 'Acadja' 29.1 per cent, basket traps 23.2 per cent, monofilament gill net 18.4 per cent, drag net 10.2 per cent and the rest 19.1 per cent. Encircling net was not in use as at 1999, but was found in use during the current study, and also rope fishing, barrier fishing and bottle traps were not found in use during the study, although fishers affirmed their use in previous years. Mostly, women were en-

gaged in handpicking. The most preferred fishing method was the Brush park system or 'Acadja' for fishes followed by the basket traps for crabs.

Catch, effort and catch per unit effort

Table 5 shows the characteristics of the Keta lagoon fishery from August 2010 to March 2012. The mean number of fishers per day for all the sampling stations was estimated as 87, with mean hours fished per fisher per day as 13 h, and estimated total catch/fisher/day of 477.0 kg. Total catch during the study was 267.1 t and CPUE was 96.1 kg/fisher/h. Total weight of fish recorded in the experimental fishing was 2700 kg

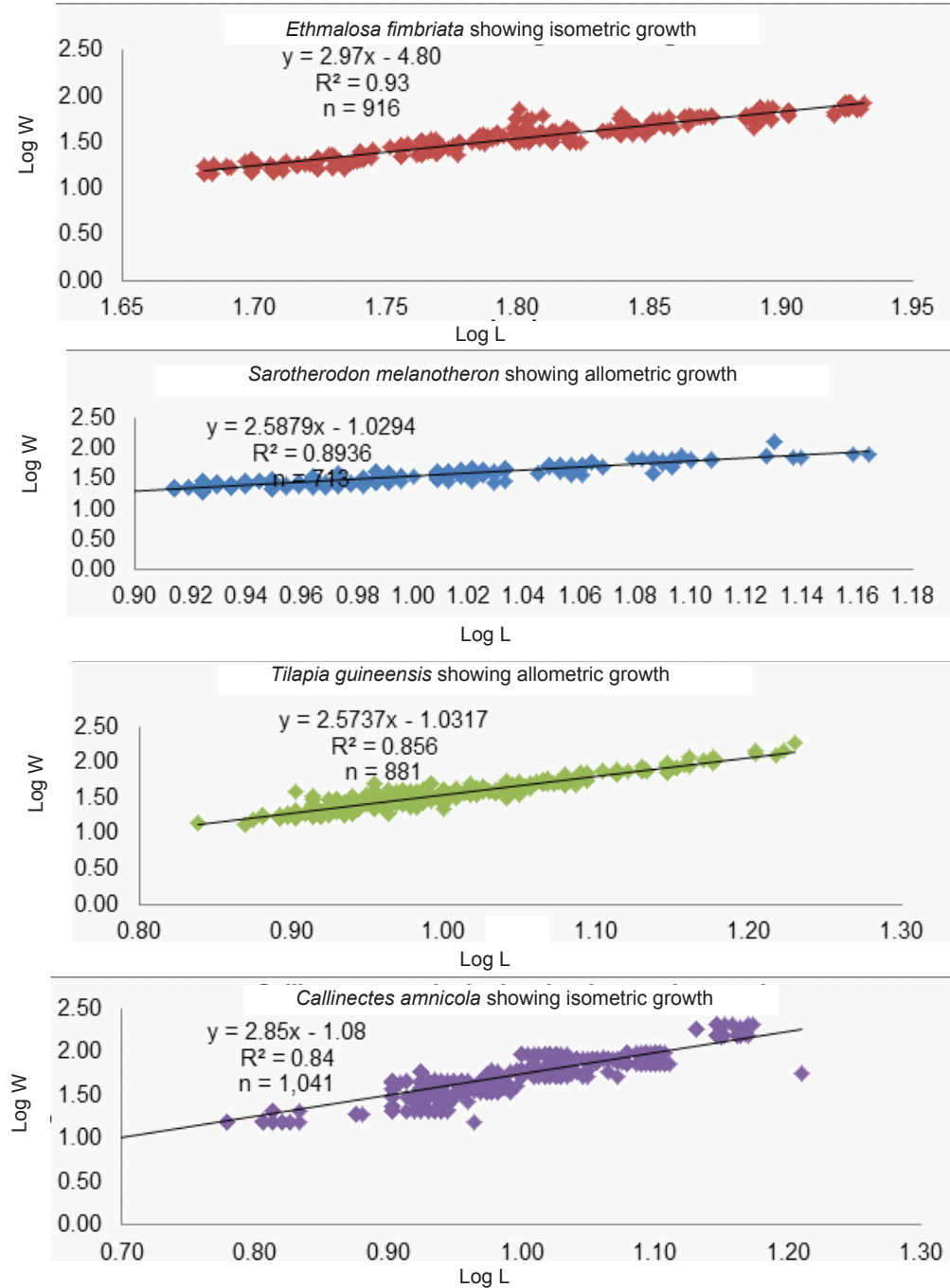


Fig. 4. Length-weight relationship of a) *S. melanotheron*, b) *T. guineensis*, c) *E. fimbriata* and d) *C. amnicola* in the Keta lagoon during the study

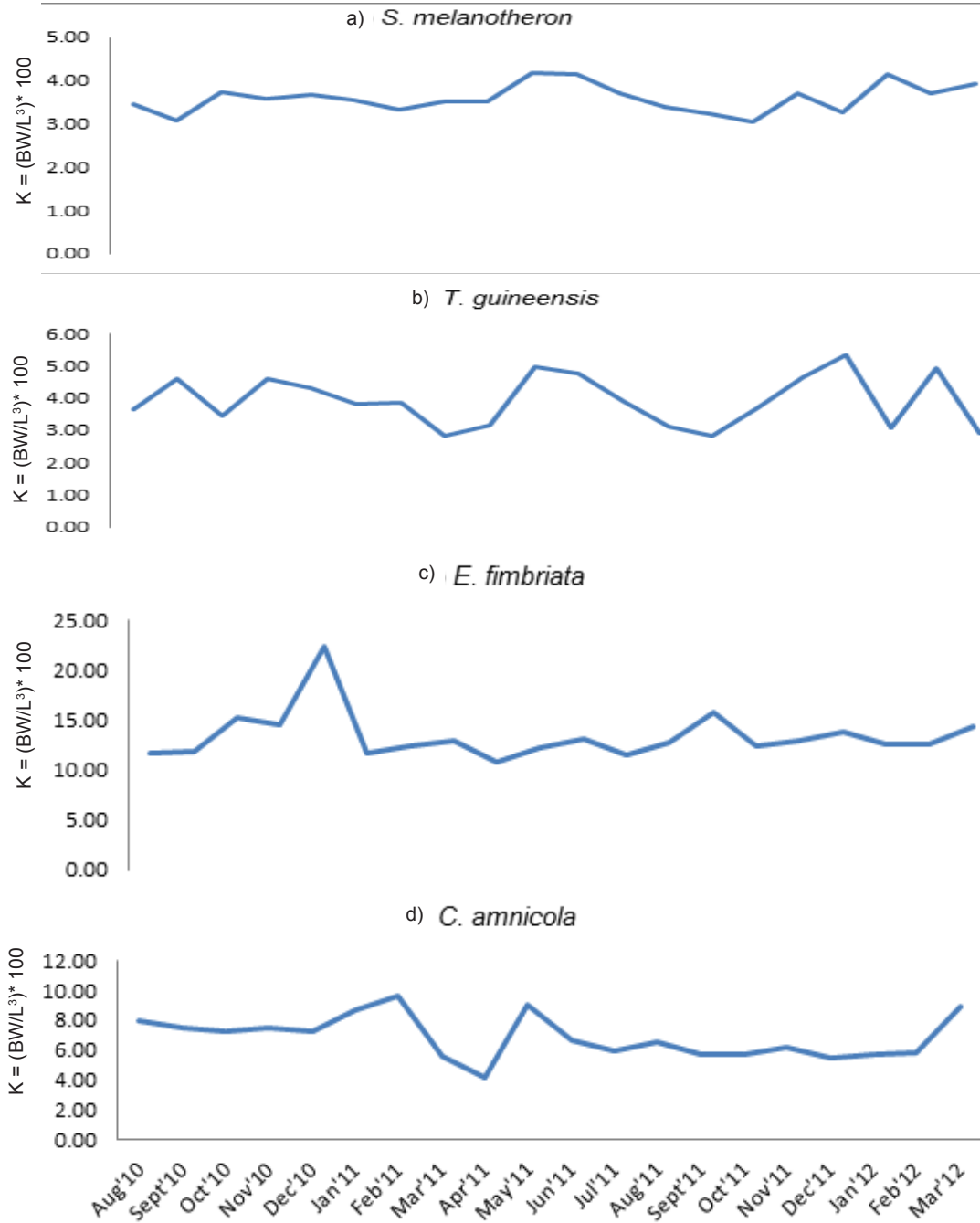


Fig. 5. Mean monthly condition factor (K) for dominant fish species (all gears) from August 2010 to March 2012.

TABLE 4
Total number of fishing gears deployed during the study compared to previous study

Fishing gears	Present study			GCWMP, 1999 (Shenker <i>et al.</i> , 1999)	Abundance	% Composition	
	Anloga	Woe	Anyanui				
Drag net	+	+	+*	+	420	10.2	
Brush parks ("Acadja")			+*	-	+	1200	29.1
Basket trap	+	+	+	+*	+	954	23.2
Encircling net	+	+	+	+	-	76	1.9
Cast net	+	+	+	+	269	6.5	
Monofilament net	+	+	+	+	+	757	18.4
Hook-and-line	+	+	+	+	121	2.9	
Mosquito net	-	+	-	+	199	4.8	
Handpicking	+	-	-	+	122	3	
Bottle trap	-	-	-	+	0	0	
Rope fishing ("Tekali")	-	-	-	-	+	0	0
Barrier fishing	-	-	-	+	0	0	
Total					4118	100	

TABLE 5
Characteristics of the fishery from August 2010 to March 2012 during the study period

Stations	Mean nos. of fishers/day (a)	Mean hrs fished/ fisher/day (Hrs) (b)	Mean Catch/ fisher/day (kg) (c)	Estimation of total catch/fisher/day (kg) (d = a × c)	Estimation of total catch/ fisher/month (d × 28 days) (kg)	Estimation of total catch during the study (20 months) (t)	CPUE (kg/fisher/hr) (d/b)	Total catch for experimental fishing (t)
Woe	31	5	7	217	6,076	121.5	43.4	0.8
Anloga	51	5	5	255	7,140	142.8	51.0	1.7
Anyanui	5	3	1	5	140	2.8	1.7	0.2
Total	87	13	13	477	13,356	267.1	96.1	2.7

Total fish catch per fisher per annum (all sites together) 3,205.2 tons

(2.7 t). The estimated total catch per fisher per annum was estimated to be 3,205.2 t.

Discussion

Despite the close geographical proximity, and the fact that all the three sites are located within the Keta lagoon, they supported different assemblages of fish species and fisheries. The most abundant species in

Keta lagoon have evidently changed over time compared with the records of the Ghana Coastal Wetlands Management Project which was undertaken in 1999 (Shenker *et al.*, 1999; Ofori-Danson *et al.*, 1999). For instance, the current dominant species included *T. guineensis* and *S. melanothron*, *Porogobius schlegeli*, (*C. amnicola*, *Mugil* spp., *Ethmalosa fimbriata* and *Chrysichthys*

spp.) have become very rare (Dankwa *et al.*, 2004). Fishers blamed the decreased species diversity in the Keta lagoon on the limited fresh and sea water inflow, which inhibits the free movement of marine and fresh water fish species to restock the lagoon (Allan & Flecker, 1993). The fluctuations in the condition factors of the dominant species calculated from monthly samples, for instance, may be due to seasonal variations in food abundance, and the average reproductive stage of the fish stocks.

In addition, fish catches were generally very low in Anyanui because, fishing activities were usually low and were mostly carried out at night when transport activities had ceased. During the day most activities revolved around transporting people and goods from Ada Foah and surrounding villages to Anyanui. Even though the second highest number of fish species was recorded at Anyanui, fishes were generally of biggest sizes and the least abundant. The possible increase in population and intense fishing pressure in Anloga and Woe, presumably contributed to the small sizes of fishes caught, since most of the fishers use unapproved gears and mesh sizes, relative to the sparsely-populated Anyanui township.

The preference for 'Acadja' and gill net at Anloga and Woe (Table 4) was possibly attributed to the fact that the catch levels were higher as compared to the other gears. Seine nets were preferred in Woe possibly due to the fact that they caught *Pellonula leonensis* in very large quantities, and only the seine net made of mosquito netting could capture them due to their very small sizes. Also the preference for basket traps in Anyanui was possibly attributed to the fact that the sea

brought in a lot of *C. amnicola* during high tide. Cast nets were also preferred in Anloga and Woe possibly due to the shallow water of the lagoon at these two sites.

The mesh size of most of the fishing gears used was far below the minimum recommended size of 25 mm (stretched mesh) by the Fisheries Commission of Ghana. In addition, unapproved gears such as the drag net were also used. This apparently permitted the capture of very large numbers of juvenile fishes, and the possible destruction of the epi-benthic substrates and fauna (in the case of the drag net). The relative lack of large adult fishes in the catches demonstrates that the intense fishing effort could create an evolutionary pressure that selects for reproduction between smaller fishes. The ultimate response to this heavy fishing pressure is the generation of a population of small, low-value fishes. Allowing fish to attain a large body size before capture may allow a large number of eggs to be carried, or the production of large eggs, with correspondingly higher chances of larval survival before they are recruited into the fishery, thereby, reducing growth and recruitment overfishing (King, 1992). From a fisheries point of view, growth and recruitment influence the sustainable catch weight that could be taken from a stock (King, 1992). Thus, the present harvest levels and fishing gears if allowed to continue would apparently contribute to a long-term reduction in the fishery potential of the Keta lagoon.

The use of drag nets is not permitted at all the various sites, yet fishers still use them. Fishing goes on throughout the week and throughout the year except during floods and for a few days during the annual 'Hog-

betsotso' festival of the Anlo people. In Anyanui, fishing is not done during the day on Wednesdays because it is their market day. Activities are centered on transportation during the day. However, fishing is done every day at Anloga and Woe.

Conclusion and recommendations

Commercial catches recorded higher species diversity compared to experimental fishing probably because, the experimental fishing had a shorter duration and limited gears compared to commercial fishing. Moreover, most of the fishers moved to nearby lagoons, floodplains, and streams to fish overnight and land finally at their respective landing sites, whilst experimental fishing was done within the catchment (a few meters radius) of the landing site in question. For instance, in Woe, some of the fishers through informal interviews claimed they went to nearby streams and floodplains to fish. The red-chin tilapia (*T. guineensis*) and the black-chin tilapia (*S. melanotheron*) were the most dominant species in Anloga, whilst the Guinean sprat (*P. leonensis*) and the blue swimming crab (*C. amnicola*) were the most important fishery at Woe and Anyanui, respectively. Although *H. picarti*, *Sardinella maderensis*, *Ilisha africana*, *Liza* spp., and *Cynoglossus* spp. were recorded in 1999 during the Ghana Coastal Wetlands Management Project (Shenker *et al.*, 1999), they were completely absent during the study.

Also, *Alectis alexandrinus* and *Lutjanus* spp. recorded during the study, were completely absent during the GCWMP in 1999. Despite the lack of catch statistics, fishers attested to the trend that catches have declined over the years, to the extent that some of the

species have either become rare or gone extinct from the Keta lagoon, due to the construction of the Akosombo dam on the Volta river (Shenker *et al.*, 1999). This was attributed to the limited influx of fresh and sea water, which has inhibited the free movement of both marine and fresh water fishes into the lagoon (Allan & Flecker, 1993). A wide variety of fishing methods and gears were employed to catch the different fish species available. Brush parks ('Acadja'), basket traps, monofilament gill nets and drag nets were the most dominant gears.

Over-fishing, use of under-size mesh (< 25 mm), use of unapproved gears and limited exchange of fresh and sea water, were some of the factors limiting fish productivity at the various sites. Moreover, the spawning and nursery grounds of these fishes could possibly be degraded through the use of drag nets, encircling nets and the brush parks ('Acadja') which are generally destructive. This perhaps explains why they have been banned in the case of lagoon fishery under the Fisheries Act 625 of Ghana. Also, the 'acadja' stumps decay and contribute to nutrient loads in the lagoon when they stand in the water over years, thus, forcing the fishes that cannot adjust to move away to more favourable environments.

For sustainable exploitation of the fishery, it is necessary to regulate fishing methods such as mesh size, net size, type of net or gear, limit access to the fishery by prohibiting fishing on certain days or during certain periods (closed seasons), and limiting the efficiency of certain gears in order to facilitate recruitment of juvenile and immature fishes to the stocks, in order to produce abundant progeny each year. This is critical since the

fisheries depend on the successful recruitment of juvenile fishes. Also, management strategies that could be applied to enhance fishery productivity including re-establishment of estuarine conditions, preservation of vital habitats such as mangrove afforestation, and engaging in alternative livelihoods such as the development of aquaculture, livestock farming and craftsmanship are recommended.

Acknowledgements

The authors are most grateful to DANIDA for funding the study through the SIFA Project which forms part of a research project carried out in collaboration with University of Ghana and the University of Copenhagen, Denmark. They are also grateful to the Head of Department of Marine and Fisheries Science, University of Ghana for facilitating the study. Also, the authors wish to thank technicians of the Department of Marine and Fisheries Sciences for helping out on the field and in the laboratory.

References

- ALLAN, J. D. & FLECKER, A. S. (1993) Biodiversity conservation in running waters. Identifying the major factors that threaten destruction of riverine species and ecosystems. *Bio-Science* **43**(1), 32 – 43.
- ANON. (1993) *Ramsar library: The directory of wetlands of international importance*, 4th edition.
- ARDIZZONE, G. D. (1984) Biological characteristics, exploitation and management of fishery resources in coastal lakes of central Italy. *Stud. Rev. GFCM/Etud. Rev. CGPM* **61** (2), 462 – 476. FAO, Rome, Italy.
- ARMAH, A. K., AWUMBILA, M., CLARK, S., SZIETROR, A., FOSTER-SMITH, R., PORTER, R., & YOUNG, E. M. (1997) Coping responses and strategies in the coastal zone of south-eastern Ghana. A case study in the Anloga area. In *the coastal zone of West Africa - problems and management. Proceedings of an international seminar 23-28 March 1996* (S.M. Evans, C.T. Vaqnderpuye and A. K. Armah eds), Accra, Ghana. Penschaw Press, UK.
- BEN-TUVIA, A. (1983) An Indo-Pacific goby *Oxyurichthys papuensis* in the eastern Mediterranean. *Isr. J. Zool.* **32**(1), 37 – 43.
- CHAUVET, C. (1988) *Manuel sur l'aménagement des pêches dans les lagunes côtières: la bordigue méditerranéenne*. FAO Document Technique sur Les Pêches 290. FAO, Rome. 77 pp.
- CORSI, F. & G. D. ARDIZZONE (1985) Some environmental conditions affecting yellow eels catchability. *Oebalia IX* **2**, 561 – 571.
- DANKWA, H. R., ABBAN, F. K. & TUEGELS, F. (1999) *Freshwater fishes of Ghana: Identification, distribution, ecological and economic importance*. Royal Museum for central Africa, Tervuren. 53 pp.
- DANKWA, H. R., SHENKER, J. M., LIN, J., OFORIDANSON, P. K. & NTIAMOAH-BAIDU, Y. (2004) Fisheries of two tropical lagoons in Ghana, West Africa. *Fisheries Management and Ecology* **11**, 379 – 386.
- DAY, J. H., BLABER, J. M. & WALLACE, J. H. (1981) Estuarine fishes. In *Estuarine ecology with particular reference to southern Africa* (J. H. Day ed.) A. A. Balkema, Rotterdam. 197–221 pp.
- FAIRBRIDGE, R. W. (1980) The estuary; its definition and geochemical role. In *Chemistry and biogeochemistry of estuaries* (E. Olausson and I. Cato eds). Wiley, New York. 1 – 35 pp.
- HANSEN, D. V. & RATTRAY, M. JNR. (1966) New dimensions in estuary classification. *Limnology and Oceanography* **11**, 319 – 326.
- IMAM, T. S., BALA, U., BALARABE, M. L. & OYEYI, T. I. (2010) Length-weight relationship and condition factor of four fish species from Wa-

- sai reservoir in Kano, Nigeria. *African Journal of General Agriculture* **6**(3), 319 – 326.
- KAPETSKY, J. M. (1984) Coastal lagoon fisheries around the world: Some perspectives on fishery yields and other comparative fishery characteristics. In *Management of coastal lagoons* (J. M. Kapetsky and G. Lasserro eds). FAO Stud. Rev. GFCM No. 61, Vol. 1, 97 – 139.
- KING, M. (1992) *Fisheries biology, assessment and management*. Fishing News Books, Blackwell Science Ltd., Oxford, UK. 352 pp.
- KORANTENG, K. A., ENTSUA-MENSAH, M. & OFORI-DANSON, P. K. (1997) The current status of the fishery of Sakumo II lagoon in Ghana. *Ghana J. Sci.* **37**, 59 – 66.
- KORANTENG, K. A., OFORI-DANSON, P. K. & ENTSUA-MENSAH, M. (1998) Comparative study of the fish and fisheries of three coastal lagoons in West Africa. *International Journal of Ecology and Environmental Science* **24**, 371 – 382.
- KORANTENG, K. A., OFORI-DANSON, P. K. & ENTSUA-MENSAH, M. (2000) Fish and Fisheries of the Muni lagoon in Ghana, West Africa. *Biodiversity and Conservation* **9**(4), 487 – 499.
- LAMPTEY, A. M., OFORI-DANSON, P. K., ABBENEY-MICKSON, S., MADSEN, H. B. & ABEKOE, M. K. (2013) The influence of land-use on water quality in a tropical coastal area: Case study of the Keta lagoon complex, Ghana, West Africa. *Open Journal of Modern Hydrology* **3**, 188 – 195.
- MAGURRAN, A. E. (1998) *Ecological diversity and its measurement*. Princeton University Press, Princeton. 179 pp.
- NIXON, S. W. (1982) Nutrient dynamics, primary production and fisheries yields of lagoons. *Oceanologica Acta Suppl.* **4**, 357–372.
- OFORI-DANSON, P. K., ENTSUA-MENSAH, M. & BINEY, C. A. (1999) Monitoring of fisheries in five lagoon Ramsar sites in Ghana. *Final report to the department of Wildlife under the Ghana Coastal Wetlands Management Project*. 116 pp.
- ODUM, H. T. & COPEL, B. J. (1972) Functional classification of the coastal ecological system of the United States. In *Environmental framework of coastal plain estuaries*. (B. Nelson, ed.). *Geological Society of America Memoir* **133**, 9 – 28.
- PAUGY, D., LEVEQUE, C. & TEUGELS, G. G. (2003a) *The fresh and brackish water fishes of West Africa*, Volume I. MRAC, Tervuren, Belgium. 457 pp.
- PIERSMA, T. & NTIAMOA-BAIDU, Y. (1995). Waterbird ecology and the management of coastal wetlands in Ghana 12. *NIOZ – Report 1995 – 1996*. 105 pp.
- ROFF, D. A. (1986) Predicting body size with life history models. *Bioscience* **36**, 316 – 323.
- SCHNEIDER, W. (1990) *FAO species identification sheets for fishery purpose. Field guide to the commercial marine resources of the Gulf of Guinea*. FAO, Rome. 268 pp.
- SHENKER, J. M., DANKWA, H. R., LIN, J., OFORI-DANSON, P. K. & NTIAMOA-BAIDU, Y. (1999) Fisheries of Keta and Songhor lagoons. Ghana Coastal Wetlands Management Project. *Environmental Baseline Studies. Final Report*. 116 pp.
- SORENSEN, T. H., VOLUND, G., ARMAH, A. K., CHRISTENSEN, C., JENSEN, I. B. & PEDERSEN, J. T. (2003) Temporal and spatial variations in concentrations of sediment nutrients and carbon in the Keta Lagoon, Ghana. *West Afri. J. appl. Ecol.* **4**, 91 – 105.
- SPARRE, P., URSIN, E. & VENEMA, S. C. (1998) *Introduction to tropical fish stock. Part I. Manual*. FAO Fisheries Tech. Paper 306: 1. FAO, Rome. 337 pp.
- ZAR, J. H. (1974) *Biostatistical analysis*. Library of Congress Cataloging in Publication Data. U.S.A. 718 pp.