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The fisheries and primary productivity of the Keta Lagoon

Addo C.[1], Ofori-Danson K. P.[1], Mensah A.[1] and Takyi R.[1]

[1]*Department of Marine and Fisheries Sciences, University of Ghana, Legon.*

Abstract

The Keta Lagoon in Ghana supports artisanal fisheries which comprise significant proportion of economic and dietary resources of the people. The state of the fisheries and primary productivity of the Keta Lagoon based on the two sites, Anloga and Woe, were studied from August, 2010 to March, 2011. A total of 22 finfish species belonging to 12 genera and 10 families were encountered in the Keta Lagoon. Fish species diversity based on Shannon-Wiener's index (H'), Species Richness based on Margalef's index (D) and Species Evenness based on Pielou's index (J) were generally low at both Anloga site at 1.27, 1.07 and 0.19, respectively and Woe site at 1.84, 1.75 and 0.25, respectively. The length-weight regression co-efficient (b) indicated that *Tilapia zillii* (3.12) and *Tilapia guineensis* (2.90) from Anloga sampling site as well as *Sarotherodon melanotheron* (2.66), *Tilapia zillii* (3.03), *Tilapia guineensis* (2.92) and *Gerres melanopterus* (3.13) from Woe sampling site grow isometrically. The condition factor (K) indicated that the fish species from Anloga site were in better condition than those from Woe. The Trophic Status Index based on Chlorophyll *a* estimation indicated that the lagoon was hypereutrophic. The high primary productivity was attributable to the high concentration levels of nutrients especially nitrate (95.31 mgl^{-1}, 79.44 mgl^{-1}) and phosphate (0.007 mgl^{-1}, 0.005 mgl^{-1}) for Anloga and Woe sites respectively contributed from farmlands situated around the lagoon through leaching. This was evident in decreased dissolved oxygen levels. Chloride levels were however at concentrations lethal to most of the fish species.

Keywords: Fisheries, Keta Lagoon, diversity, trophic status, chlorophyll *a*, Ghana

Corresponding author's email*: cyndyorka@yahoo.com*

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Introduction

Coastal lagoons are environments suitable for human activities (Zhuang, 1992). The lagoons form important vulnerable ecosystems, housing a wide variety of fish, shrimps, crabs, mollusc and polychaete species. The Keta Lagoon is the most extensive brackish water-body in Ghana, which has also been designated as a Wetland of International importance (Ramsar site). It is separated from the Atlantic Ocean by a large sandbar, the Keta sand spit. The lagoon supports artisanal fisheries that comprise significant proportions of economic and dietary resources of the human populations clustered around the lagoons. The Lagoon fishing serves an important source of income for people in the communities living around it (Dankwa *et al.*, 2004). The lagoon is of utmost importance as it serves as nursery grounds for fin fishand shell-fish, which often sustain significant fisheries. Lack of job opportunities has pushed many people from the communities surrounding the lagoon into fishing for a living, resulting in intense fishing pressure (Dankwa *et al*., 2004).

Shenker *et al.* (1998), identified a total of 20 finfish species in the Keta Lagoon. The Keta Lagoon is dominated by the Cichlids (Ofori-Danson *et al*., 1999; Armah *et al*., 1997; Dankwa and Entsua-Mensah, 1996). *Sarotherodon melanotheron* is the dominant fish species in the Keta Lagoon and comprises about 33 % of the total fish catch (Entsua-Mensah *et al.* (2000) and *Tilapia guineensis*, 14 % (Dankwa *et al*., 2004). *Pellonula leonensis* comprises about 32 % of the total fish catch (Dankwa *et. al*., 2004).

Chlorophyll *a* is the most abundant form of chlorophyll within photosynthetic organisms and, for the most part, gives plants their green colour. In the photosynthetic reaction below, carbon dioxide is reduced by water, and chlorophyll assists this transfer (YSI-Environmental, 2005). Phytoplankton (especially algae) are beneficial to aquatic organisms and increase phytoplankton growth can be as a result of increased nutrients into the lagoon such that water bodies with low levels of nutrients have low levels of chlorophyll whereas waters with high nutrient contents have high levels of chlorophyll (Chapman and Kimstach, 1996).These nutrients can as a result, be potential sources of pollution when in abnormal concentrations and may result in eutrophication evident in increased phytoplankton growth (Pelley, 1998). Increase phytoplankton growth (Algal blooms) limit sunlight available penetration affecting the quality of water and subsequently on the aquatic organisms (Paerl, 1997). A collaborative effort between the Danish International Development Agency or DANIDA and the Ecological Laboratory of the University of Ghana, has established the Sustainable Food Production through Irrigated Intensive Farming systems in West Africa, or the SIFA Project. PhD and MPhil students are supported financially and logistically to carry out various research work to help achieve the aims of the project. The primary objectives of the SIFA Project is to introduce drip irrigation as water saving technique including assessing the possibilities of using wastewater in the irrigation system. The project seeks to also increase the number of job opportunities by increasing sustainable vegetable production in an intensive savannah semi-arid production system using the Keta sand spit pilot. Data will also be obtained on the fisheries to provide a reference base for future monitoring and enable appropriate management options for sustainable exploitation of the Keta Lagoon fishery. This study forms part of the SIFA project. One major influence on the productivity and diversity of coastal freshwater systems is the expanding practice of irrigated agriculture. At the Keta sand spit, irrigation is practiced mainly by the use of bucket watering from wells and sprinkling. This agricultural system is environmentally sensitive because of possible leaching of nutrients to the aquifers (Nguyen-Khoa *et al*., 2003). The study will assess the state of the Keta Lagoon fisheries and the effect of the leaching of nutrients on the primary productivity.

Materials and methods

1.1. Study area

The Keta Lagoon is located alongside the delta of the Volta River in eastern Ghana (Fig.1). Keta Lagoon is about 140 km east-northeast of the south coast of the Volta region, southeast Ghana with coordinates 5°55' N 0°59' E. The two sites selected for sampling, Anloga and Woe have the GPS coordinates: 5^{O} 47'50' N 0^{O} 53'55.8' E and 5^{O} 50' N 0^{O} 57'13.2' E.

Keta Lagoon is an important habitat for many aquatic species of animals and has been recognized as internationally important under the Ramsar Wetlands convention.

1.2. Field sampling and analysis

The sampling was undertaken once a month from August 2010 to March 2011. The sampling sites were divided into three zones namely: (i) the littoral (station 1), (ii) the open water (station 2) and (iii) the lower end of the lagoon (station 3). Fish samples were collected monthly from commercial fishers using gears and fishing methods such as set net or gillnet, drag net, hand cast net and mosquito net. Water samples for analysis was collected by immersing Nansen sampling bottles at the three selected stations and allowing free flow of water. Temperature was measured insitu with a hand held Mercury-in-glass Thermometer and pH measured with portable pH meter.

Nitrate, chloride and salinity were analyzed using the Ion-selective electrode ELIT probe. The electrical conductivity was measured using the sensitive probe, E587 conductometer.

The method for phosphate determination was according to APHA (1998). A modification of the Winkler method of titration was used for dissolved oxygen concentration determination. Chlorophyll *a* was determined by estimating pigment concentration in the water column using the spectrophotometric (trichromatic) method of APHA (1995). The fishes were identified individually using identification keys from Edward *et al*. (2001) and Dankwa *et al.* (1999). The weights of the fish specimens caught were read to the nearest 0.1 g using an electronic weighing scale and the standard length (SL) of individuals of fish measured to the nearest 0.1 cm.

1.3. Statistical analysis

Length-weight relationships of fish specimens were determined using the exponential equation (Roff, 1986).

$W = aL^{b}$

1.3.1. Condition factor

The condition factor (K) of the fish was calculated using the formula below (Tesch, 1971)

$K = W \times 100\ L^{3}$

where K= condition factor,

W = weight of fish in grams and L = length of fish in centimeters.

1.3.2. Determination of growth parameters

The ELEFAN 1 module in FISAT II was used to estimate the growth parameters (L_∞ and K) of VBGF (Pauly, 1984; Sparre and Venema, 1992). The growth performance index (ø), was estimated using these growth parameters (L_∞ and K), where $ø = \log_{10} K + 2 \log_{10} L_\infty$ (Pauly and Munro, 1984).

1.3.3. Fish species diversity

Fish species diversity was determined by: (i) Shannon-Wiener's Index (H') of species diversity (Shannon and Wiener, 1963); $H' = -\sum P_i \ln P_i$, where P_i = Proportion of the total number of individuals occurring in i (ii) Margalef's Index (D) for species richness (Margalef, 1968); $D = (S - 1)/ \ln N$, where S = number of species and N = number of individuals (iii) Pielou's Index (J) for species evenness (Pielou, 1966); $J = H'/\ln S$, where H' = species diversity index and S = number of species.

Results

1.4. Fish species composition and relative abundance

The various fish species encountered were caught with set net or gillnet, drag net, hand cast net and mosquito net. A total of 15 fin-fish species belonging to 17 genera and 10 families were collected. A total of 8 fish species belonging to 5 genera and 3 families were encountered at Anloga site whilst a total of 14 species, 12 genera and 10 families were encountered at Woe (Table 1). This implies that the species at Anloga contained 29 % of the overall 22 species encountered at both sites. Compared to Woe site, which represents 71% of the entire species encounter, there is less diverse assemblage of fishes at Anloga site. Of the key species of finfish encountered in Anloga *Sarotherodon melanotheron* contributed 49.4 % and was the most abundant, *Tilapia zillii,* 30.8 and *T. guineensis* 12% of total numbers caught. Other species of importance included *Hemichromis fasciatus* and *Elops lacerta*. *H. bimaculatus, S. galilaeus* and *Porogobius schlegelii* observed at low abundance (less than 1%) in Fig.2. In Woe however *Pellonula leonsis*, *T. zillii*, *S. melanotheron, Gerres melanopterus* and *T. giuneensis* dominated the catch contributing 30.7 %, 20.4 %, 18.7 %, 11.7 % and 8.8 % of the total numbers caught respectively (Fig. 3).

Other species of importance included *Hemiramphus brasiliensis*, *S. galilaeus* and *P. schlegelii*. *H fasciatus*, *Mugil cephalus*, *E. lacerta*, *Ctenopoma pecherici*, *Ablennes hians* and *Epiplatys spilargyreius* had low abundance (less than 1 %). Species diversity, richness and evenness were low at 1.27, 1.07 and 0.19 respectively for Anloga site compared to Woe site with values of 1.84, 1.75 and 0.25 respectively as shown in Table 2. The regression co-efficient (b) which predicts the growth pattern indicated that *T. zillii* (3.12) and *T. guineensis* (2.90) (Table 3a & b) from Anloga site had isometric growth as well as *S. melanotheron* (2.66), *T. guineensis* (2.92), *G. melanopterus* (3.13) from Woe site. *S. melanotheron* (2.33) and *P. leonensis* (1.07) indicated allometric growth.

1.5. Growth parameters

From Tables 4 and 5, $L\infty$, K and $W\infty$ for *S. melanotheron*, *T. zillii* and *T. guineensis* were generally higher in Anloga site than Woe site. *S. melanotheron* had a high ø in Anloga site (1.96) than Woe site (1.85) whiles *T. zillii* and *T. guineensis* had a lower ø in Anloga site (1.54 and 1.86) than Woe site (2.02 and 1.94). In Woe site, *G. melanopterus* had the lowest ø of 1.67. The asymptotic weights of *S. melanotheron* (143.90 g), *T. zillii* (86.63 g) and *T. guineensis* (36.47 g) from Anloga site were generally higher than *S. melanotheron* (32.44 g), *T. zillii* (35.45 g) and *T. guineensis* (20.43 g) from Woe site. *G. melanopterus* (45.45 g) had the highest asymptotic amongst the key fish species and *P. leonensis* (10.49 g) had the lowest asymptotic weight. Using the equation for the length-weight relationship, when L_∞ was substituted,

Table 1: List of fish species encountered in Anloga and Woe from August 2010 to March 2011

Anloga			Woe	
Family	Genus	Species	Genus	Species
1. Cichlidae	1. *Sarotherodon*	1. *melanotheron*	1. *Sarotherodon*	1. *melanotheron* (Rüppell, 1852)
		2. *galilaeus*		2. *galilaeus* (Günther, 1903)
	2. *Tilapia*	3. *zillii*	2. *Tilapia*	3. *zillii* (Gervais, 1848)
		4. *guineensis*		4. *guineensis* (Bleeker, 1862)
	3. *Hemichromis*	5. *fasciatus*	3. *Hemichromis*	5. *fasciatus* (Peters, 1852)
		6. *bimaculatus*		
2. Elopidae	4. *Elops*	7. *lacerta*	4. *Elops*	6. *lacerta* (Valenciennes, 1846)
3. Gobiidae	5. *Porogobius*	8. *schlegelii*	5. *Porogobius*	7. *schlegelii* (Günther, 1861)
4. Clupeidae*			6. *Pellonula*	8. *leonensis* (Boulenger, 1916)
5. Mugilidae*			7. *Mugil*	9. *cephalus* (Linnaeus, 1758)
6. Gerreidae*			8. *Gerres*	10. *melanopterus* (Bleeker, 1863)
7. Anabantidae*			9. *Ctenopoma*	11. *petherici* (Günther, 1903)
8. Belonidae*			10. *Ablennes*	12. *hians* (Valenciennes, 1846)
9. Hemiramphidae*			11. *Hemiramphus*	13. *brasiliensis* (Linnaeus, 1758)
10. Cyprinodontidae*			12. *Epiplatys*	14. *spilargyreius* (Dumeril, 1861)
TOTAL = 10	**5**	**8**	**12**	**14**

*= families not encountered at Anloga site

Table 2: Species diversity of fish species for Anloga and Woe

Site/Index	Diversity (H')	Richness (D)	Evenness (J)
Anloga	1.27	1.07	0.19
Woe	1.84	1.75	0.25

Table 3a: Summary of the length-weight relationship of the major species found at Anloga August 2010-March 2011

	Anloga	
Species	**N**	**Length-weight relationship**
S. melanotheron	347	$BWT = 0.168L^{2.33}$
T. zillii	216	$BWT = 0.034L^{3.12}$
T. guineensis	82	$BWT = 0.0500L^{2.90}$

Table 3b: Summary of the length-weight relationship of the major species found at Woe August 2010-March 2011

	Woe	
Species	**N**	**Length-weight relationship**
S. melanotheron	322	$BWT = 0.0755L^{2.66}$
T. zillii	350	$BWT = 0.0355L^{3.03}$
T. guineensis	151	$BWT = 0.0440L^{2.92}$
P. leonensis	528	$BWT = 0.7802L^{1.07}$
G. melanopterus	201	$BWT = 0.0197L^{3.13}$

Table 4: Summary of growth parameters of major fish species at Anloga from August 2010-March 2011

Growth parameter	*S. melanotheron*	*T. zillii*	*T. guineensis*
L_∞ (cm)	18.11	12.34	9.71
K	0.28	0.23	0.76
Ø (yr/1)	1.96	1.54	1.86
W_∞ (g)	143.90	86.63	36.47

Table 5: Summary of growth parameters of major fish species at Woe from August 2010-March 2011

Growth parameter	*S. melanotheron*	*T. zillii*	*T. guineensis*	*G. melanopterus*	*P. leonensis*
L_∞ (cm)	9.77	9.77	8.19	11.87	11.34
K	0.74	1.10	1.30	0.57	0.36
Ø (yr/1)	1.85	2.02	1.94	1.67	1.90
W_∞ (g)	32.44	35.45	20.43	45.45	10.49

Table 6: Monthly mean physicochemical data at Anloga from August 2010-March 2011

	Months								
Parameters	**August**	**September**	**October**	**November**	**December**	**January**	**February**	**March**	**Mean**
Chlorophyll a (mgl^{-1})	0.06	0.46	0.45	0.09	0.32	0.29	0.15	0.10	0.24
Phosphate (mgl^{-1})	0.005	0.006	0.004	0.008	0.01	0.019	0.005	0.001	0.007
Nitrate (mgl^{-1})	41.62	90.00	44.11	59.62	53.06	157.27	263.03	53.76	95.31
Conductivity (μScm^{-1})	1945.0	2085.8	1033.3	2065.0	3228.3	2893.3	3296.7	3310.0	2482.18
Temperature (°C)	26.1	26.1	27.3	30.8	30.0	26.6	29.8	29.7	28.30
pH	7.46	7.54	7.47	7.43	7.95	9.73	7.74	9.88	8.15
Dissolved Oxygen (mgl^{-1})	7.96	6.10	11.43	6.78	1.69	6.10	11.01	4.57	6.96
Salinity (ppt)	11.25	13.25	7.20	13.37	26.92	14.90	145.64	90.01	40.32
Chloride (mgl^{-1})	6213.3	7311.9	3972.2	7386.4	14888.9	8231.6	8063.3	4982.8	7631.30

Table 7: Monthly mean physicochemical data at Woe from August 2010-March 2011

	Months								
Parameters	**August**	**September**	**October**	**November**	**December**	**January**	**February**	**March**	**Mean**
Chlorophyll a (mgl^{-1})	0.09	0.49	0.41	0.06	0.14	0.14	0.10	0.13	0.20
Phosphate (mgl^{-1})	0.013	0.012	0.002	0.004	0.004	0.005	0.001	0.001	0.005
Nitrate (mgl^{-1})	49.66	73.76	55.65	59.68	57.59	122.02	167.82	49.37	79.44
Conductivity (μScm^{-1})	2921.7	2412.9	1371.7	2174.2	3098.3	2670.8	3183.3	3416.7	2656.20
Temperature (°C)	27.3	27.3	29.4	31.2	30.9	26.7	30.3	30.1	29.15
pH	7.63	7.58	7.53	7.84	8.22	9.99	7.95	10.07	8.35
Dissolved Oxygen (mgl^{-1})	11.26	8.3	10.5	6.95	2.54	5.42	9.82	4.23	7.38
Salinity (ppt)	13.77	18.25	10.78	15.28	24.86	13.71	170.91	113.69	47.66
Chloride (mgl^{-1})	7607	10082.2	5952.4	8439.7	13750	7579	10213	6625	8781.04

Table 8a: Trophic status index based on chlorophyll *a* estimation

	Anloga	Woe
Trophic status index (TSI)	71.13	73.17

The scale and hierarchization produced from the Carlson indices, specifically for this study is:

TSI (Carlson, 1977)	Trophic status index and water quality
70-80	Heavy algal blooms; dense macrophyte blooms; hypereutrophic

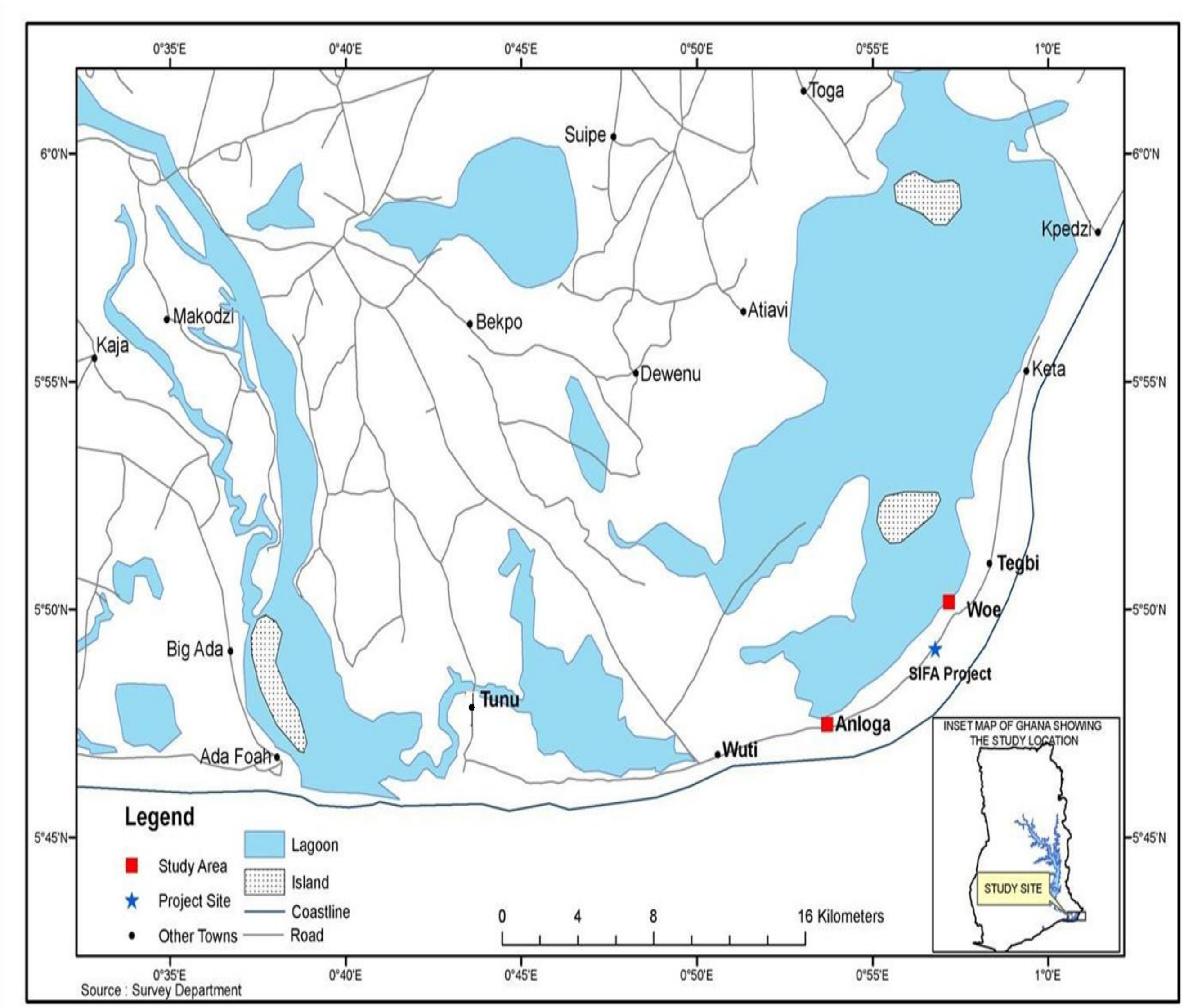
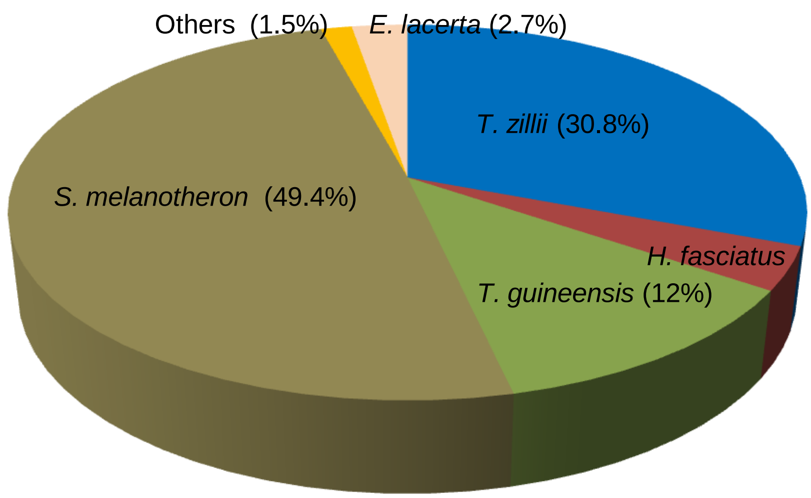


Figure 1 Map showing study sites



Figgure 2: Species composition of catches by numbers in Anloga, August 2010-March 2011

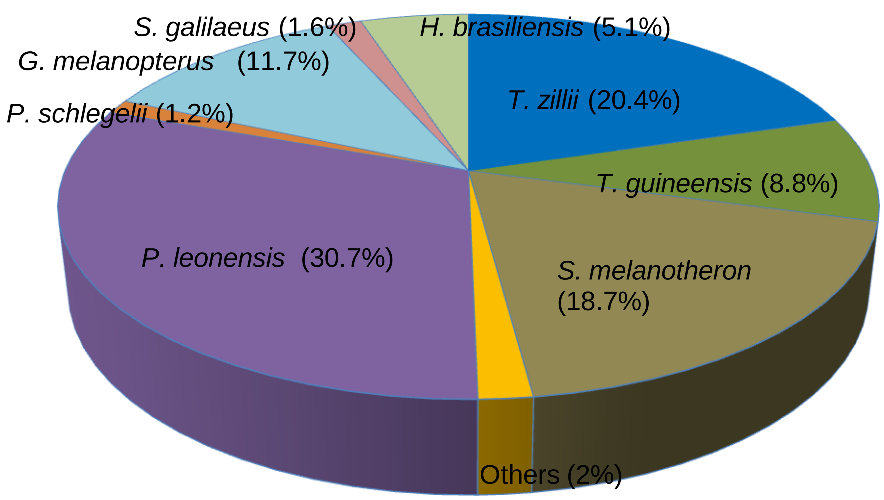


Figure 3: Species composition of catches by numbers in Woe, August 2010-March 2011

the asymptotic weight of the fish was 143.90 g, 86.63 g and 36.47 g for *S. melanotheron*, *T. zilllii* and *T. guineensis* respectively for Anloga site (Table 4). When L∞ was substituted, the asymptotic weight of the fish was 32.44 g, 35.45 g, 20.43 g, 10.49 g and 45.45 g for *S. melanotheron*, *T. zilllii* and *T. guineensis, P. leonensis and G. melanopterus* respectively for Woe Sampling site (Table 5).

The lowest value (0.06 mgl^{-1}) for Anloga site occurred in August, while Woe site's lowest value (0.06 mgl^{-1}) was in November. Highest Phosphate value (0.019 mgl^{-1}) occurred in January and the lowest (0.001 mgl^{-1}) in March for Anloga site, while the highest value (0.013 mgl^{-1}) for Woe site occurred in August and the lowest (0.001 mgl^{-1}) in February and March. Mean values were 0.007 mgl^{-1} for Anloga site and 0.005 mgl^{-1} for Woe site. The mean value for nitrate was 95.31 mgl^{-1} and 79.44 mgl^{-1} for Anloga and Woe sites, respectively. Highest nitrate value (263.03 mgl^{-1}, 167.82 mgl^{-1}) for Anloga and Woe sites, respectively occurred in February and the lowest (44.11 mgl^{-1}) for Anloga site in August whilst the lowest (49.37 mgl^{-1}) for Woe site occurred in March. Highest Conductivity value (3310 μScm^{-1}, 3416.7 μScm^{-1}) for Anloga and Woe sites respectively occurred in March and the lowest (1033.3 μScm^{-1}, 1371.7 μScm^{-1}) in October. Mean conductivity values for Anloga and Woe sites were 2482.18 μScm^{-1} and 2656.20 μScm^{-1}, respectively. Mean temperature value recorded was 28.3 °C for Anloga site and 29.15 °C for Woe site. Highest temperature value (30.8 °C, 31.2 °C) for Anloga and Woe sites respectively occurred in November and the lowest (26.1 °C) for Anloga

In Tables 8a Woe recorded highest trophic status index (TSI) (73.17) while Anloga recorded the least TSI (71.13) (Table 7a).

Discussion

The Keta Lagoon fisheries are an important source of protein and income for the indigenous people. A total of 15 fin-fish species belonging to 17 genera and 10 families were collected throughout the study period from August, 2010 to March, 2011 at the two sites of study. Compared to earlier studies by Ofori-Danson *et al*. (1999), who had a total of 20 fin-fish species, the fish species encountered were rather low. This can be as a result of fishing pressure or unfavourable environmental conditions. In order of importance by numbers, these consisted of the black-chin tilapia, *Sarotherodon melanotheron,* which dominated the catches; the red belly tilapia, *Tilapia zillii* and the red chin tilapia, *Tilapia guineensis.* However, the Guinean sprat,

1.6. Primary productivity and physicochemical parameters

The mean Chlorophyll *a* value was 0.24 mgl^{-1} and 0.20 mgl^{-1} for Anloga and Woe sites respectively. Highest Chlorophyll *a* values (of 0.46 mgl^{-1}, and 0.49 mgl^{-1}) for Anloga and Woe sites respectively occurred in September (Tables 6 and 7)

site in August and September with the lowest (26.7 °C) for Woe site occurring in January. pH had the highest value (9.88, 10.07) for Anloga and Woe sites respectively in March and the lowest value (7.43) for Anloga site in November and the lowest value (7.53) for Woe site in October. The mean pH value was 8.15 for Anloga site and 8.35 for Woe site. Mean values for Dissolved Oxygen were 6.96 mgl^{-1} and 7.38 mgl^{-1} for Anloga and Woe sites respectively. Dissolved oxygen had the highest value (11.43 mgl^{-1}) for Anloga site in October and the lowest value (1.69 mgl^{-1}) in December while Woe site had the highest value (11.26 mgl^{-1}) in August and the lowest value (2.54 mgl^{-1}) in December. Highest Salinity (145.64 ppt, 170.91 ppt) and Chloride (8063.3 mgl^{-1}, 10213 mgl^{-1}) values for Anloga and Woe sites, respectively occurred in February and the lowest salinity (7.20 ppt) and chloride (3972.2 mgl^{-1}) values for Anloga site occurred in October. For Woe site, the lowest salinity (10.78 ppt) occurred in October and chloride (7607 mgl^{-1}) values occurred in August. Mean salinity values were 40.32 ppt for Anloga site and 47.66 ppt for Woe site and mean chloride values of 7631.30 mgl^{-1} and 8781.04 mgl^{-1} for Anloga and Woe sites, respectively.

Pellonula leonensis was found to be numerically the most abundant fish at Woe site (Shenker *et al.,* 1998), followed by *Sarotherodon melanotheron, Tilapia zillii, Tilapia guineensis and Gerres melanopterus*. The fish diversity study indicated that the Woe site had a greater number, H' (1.84), J (0.25) and D (1.75) of fish species present and the numbers of individuals in the community were distributed equitably among these species than at Anloga site, H' (1.27), J (0.19) and D (1.07). Generally, the fish diversity (diversity index, richness and evenness) of the Keta Lagoon at the two sites, Woe (1.84, 1.75 and 0.25) and Anloga (1.27, 1.07 and 0.19) indicates that this was rather low. Harsh environmental factors and higher fishing pressure could also account for this low fish diversity (Entsua-Mensah *et al*., 1997). For instance nutrients will initially increase the productivity of a water body leading to high species diversity until beyond a certain level, where additional inputs become a stress and productivity is decreased resulting in low diversity (Kilham and Mavuti, 1990). Bagenal (1978) explained that when co-efficient of regression (b) is greater and or less than 3, then growth is allometric but when equal to 3, then the growth is isometric. With the exception of *P. leonensis* (1.1) from from Anloga site and *S. melanotheron* (2.7)*, T. zillii* (3.0)*, T. guineensis* (2.9) and *G. melanopterus* (3.1) from Woe site exhibited isometric growth.

Data on growth studies are very important in fishery management. It is the growth of individuals in the population that determines the amount of stock available for the fishery (King, 1995). The asymptotic lengths (L_∞) of *S. melanotheron* (18.11 cm)*, T. zillii* (12.34 cm) and *T. guineensis* (9.71 cm) from Anloga site and *S. melanotheron* (9.77 cm), *T. zillii* (9.77 cm), *T. guineensis* (8.19 cm), *G. melanopterus* (11.87 cm) and *P. leonensis* (11.34 cm) from Woe site, suggest suggest smaller fish species caught at Woe site compared to Anloga site. But this was generally low as compared by the asymptotic lengths of 39.5 cm SL reported by Paugy *et al.* (2003a) for the species in major lagoons of West Africa. The smaller values of the asymptotic lengths observed in this study suggest possible intense fishing pressure or poor environmental conditions of the species in the Keta Lagoon. The growth performance index was slightly higher for species from Woe site than Anloga site. These values imply slightly fast growth of species from Woe site than

Woe site and *S. melanotheron* (2.3) from Anloga site which showed allometric growth, the rest of the species namely *T. zillii* (2.9) *and T. guineensis*

Anloga site. This fast growth rate of the fish has been attributed to "r-selected" mode of life caused by unstable ecological conditions in environmental parameters and high natural and fishing mortalities (Blay and Asabere-Ameyaw, 1993). Despite harsh environmental conditions and fishing pressure, reproduction and recruitment continue to sustain the fishery. The length at first maturity of a species is important life history information for fish resource management. For instance mesh size can be regulated so that the reproductive or spawning stocks are not targeted. The size at which *S. melanotheron* (7.1 cm) and *T. zillii* (6.1 cm) must reach before they are capable of reproduction was higher in Anloga site compared to *S. melanotheron* (7.6 cm) and *T. zillii* (6.6 cm) from Woe site. L_m of *T. guineensis* (5.1 cm) was the same in Anloga and Woe site (Table 4 & 5). *G. melanopterus* reached the highest size of (8.5 cm) amongst all the species and this is the size they must attain before they are capable of reproduction. This means that *S. melanotheron, T. zillii, T. guineensis* and *P. leonensis* will be in reproductive stage for the first time at small sizes than *G. melanopterus*. The implication of this is that, increased fishing effort as well as

the use of small sized nets in fishing may possibly be responsible for the smaller sizes of fish caught as fishes in their reproductive or spawning stage are targeted. This may possibly manifest in a decline of the fishery.

The mean chlorophyll *a* values for both Anloga site (0.24 mgl^{-1}) and Woe stite (0.20 mgl^{-1}) were rather high according to Chapman and Kimstach (1996) who reported that chlorophyll *a* levels of < 2.5 μgl^{-1} was low and levels of 5-140 μgl^{-1}high. This is evident in the high nitrate and phosphate levels recorded. This high nutrients possibly indicates the increasing applications of artificial fertilizers on farmlands around the lagoon. The weak correlation between phosphate and chlorophyll *a* might be as a result of the binding nature of phosphate to sediments, where the concentration in the sediment may be high. Chlorophyll *a* which was used as a measure of primary productivity in this study was used to estimate the Trophic Status Index (TSI). The TSI of the lagoon at Anloga (71.13) and Woe sites (73.17) according to the scale by Carlson (1977) implies that the lagoon was hypereutrophic, with dense macrophyte growth and anoxic hypolimnion. This hypereutrophic state might be as a result of the increasing agricultural activities around the lagoon, domestic activities

and rivers contributing nutrients to the lagoon. These nutrients are used by photosynthetic plants for growth and when in excess can lead to eutrophication detrimental to fish growth. Some of these excess algae die and decompose using oxygen for this process and may subsequently result in oxygen depletion. The pH values from the results indicate that the lagoon was slightly alkaline (8.15 and 8.35) for Anloga and Woe sites respectively meaning more saline water intrusion. This confirms the assertion that shallow lentic environments which favour the growth of phytoplankton are more influenced by activities which increase pH values (Symoens *et al*., 1981). Temperature (28.3°C and 29.2 °C) for Anloga and Woe sites respectively was within the optimal range of 20°C-30°C (DWAF, 1996) suitable for fish growth. Chloride levels at both Anloga site (7631 mgl^{-1}) and Woe site (8781 mgl^{-1}) were rather lethal to the health of fishes. This is in conformity to the assertion by Tucker (1998) who that chloride levels above 1000 mgl^{-1} was lethal to fish. Hence factors such as sewage disposal and leaching from farmlands around the lagoon which help to increase chloride levels in the lagoon should be minimized. Diversity index, richness and

evenness were high at Woe site than Anloga site. On the whole, fish diversity was low in the Keta Lagoon meaning that there was less number of fish species present and the numbers of individuals in the community were not distributed equitably among these species. The length-weight relationship indicates that most of the fish species

growth was isometric. The fish species occurred at small sizes and this was evident in the smaller asymptotic lengths. The length at first maturity also indicate possible reduction in the size of fish species and the use of small mesh nets would deprive the fishery of the spawning stock and hence recruitment into the fishery (Table 5 & 6).

The trophic status index of the Keta Lagoon based on chlorophyll *a* content ranged from 70-74 and fell within the Carlson's Trophic status index range scale of 70-80, which implies that the lagoon is hypereutrophic. This hypereutrophic state of the lagoon may possibly be attributed high nitrate and phosphate concentration brought into the lagoon from farmlands around it and resulting in increased primary productivity. Existing regulations on mesh size should be enforced while traditional conservation practices, such as non-fishing days and closed seasons are promoted so that fish at first maturity which can sustain the fishery through spawning and juvenile fishes are not captured. Farms should be sited far away from the lagoon coupled with the adoption of good irrigation practices such as drip irrigation to minimize the leaching of nutrients into the lagoon.

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