Available online at www.pelagiaresearchlibrary.com

Pelagia Research Library

European Journal of Experimental Biology, 2011, 1 (2):178-188

ISSN: 2248 –9215

Comparative ecological assessment of biodiversity of fish communities in three coastal wetland systems in Ghana

Isaac Okyere, Denis W. Aheto and Joseph Aggrey-Fynn

Department of Fisheries and Aquatic Sciences, School of Biological Sciences, University of Cape Coast, Ghana

---

ABSTRACT

The species diversity, richness and composition of fish communities as well as some physico-chemical conditions were analyzed in order to establish baseline data inventory in three wetland systems in Ghana. Water quality checker was used to measure five physico-chemical parameters while a pole-seine net was used for fish sampling. Results showed that dissolved oxygen content of Essei lagoon was critically low (averagely 0.7 mg/L) while temperature was significantly higher in Butuah lagoon, with the Whin estuary maintaining moderately good conditions. Twenty-six (26) species of shell- and finfishes belonging to 18 families from freshwater, brackishwater and marine sources were encountered in the water bodies. Whin had the most rich and diverse fish community (d= 3.21, H'= 1.62), followed by Butuah (d= 1.54, H' = 1.56), with Essei recording the least (d= 0.99, H' =1.02). The moderately good environmental conditions, together with the higher richness and diversity of fish biota in the Whin estuary generally reflect a highly productive system that merits management planning and possible conservation status. The lower richness and the correspondingly lower diversity of fish community in the Essei and Butuah Lagoons with most of the fish being juveniles require serious and realistic management interventions to be enforced.

Key words: Fish biodiversity conservation; coastal wetlands; ecological indices; environmental conditions; wetland management.

INTRODUCTION

Wetland ecosystems are the most productive ecosystems of the world [1]. The pivotal role played by wetland ecosystems in providing many goods and services in support of the human economy and societal well-being throughout the world have been underscored [2]. The Convention on Wetlands defines wetlands as areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres. It could also be extended to incorporate riparian and coastal zones adjacent to the wetlands, and islands or bodies of marine water deeper than six metres at low tide lying within the wetlands [3].

In Ghana, wetland ecosystems constitute about 10% of the country's total land surface area [4] with lagoons and estuaries classified as being the country's most valuable wetlands since they are closely tied to salt marshes, mangroves swamps and tidal flats which constitute significant features of Ghana's coastline providing critical habitats for many fish and wildlife species that support the country's economy [5]. For instance, the support provided by lagoons and estuaries in terms of eco-tourism, storage of runoff, denitrification and detoxification of polluted water, prevention of shoreline erosion, as well as providing important breeding and feeding grounds for commercially important fish species, reptiles, birds, and their use as areas of recreation have been well documented in literature [6][7].

Despite these benefits, wetlands in the country are reported to have come under severe threat and are being degraded at an alarming rate within the last decades [8][9]. For instance, the increasing misuse of lagoons and estuaries by man through widespread exploitation of juvenile fish stocks and pollution poses a grave danger to the biodiversity and communities of these habitats. Fisheries resources from these ecosystems are intensively exploited for sustenance [10]. Also, the use of explosive devices and nets of small mesh sizes have been observed to deplete juvenile fish stocks [11]. Poor sanitation around the wetland areas has also been widely acclaimed as a contributory factor to its fisheries decline [9]. Now, with global climate change, it is also feared that sea level rise may further exacerbate the anthropogenic impacts on these wetlands [12]. The situation is worrying because estuaries and lagoons have been classified as the most biologically productive ecosystems in the country [13]. Unfortunately, information on the biodiversity of wetland systems in the country is insufficient, largely constraining any possible management interventions [14]. In view of the on-going changes in environmental conditions, and the continued utilization of wetland resources in the country, periodic monitoring of biodiversity of these ecosystems needs to be vigorously pursued to assess their status [10].

This study presents the status of species diversity, richness, composition and size distribution of fish biota in three coastal wetland systems namely the man-made open Essei lagoon, the closed Butuah lagoon and the Whin river estuary in the Western Region of Ghana including an assessment of aspects of their environmental relationships. These data are crucially relevant to inform policy-makers, resource users, managers and other stakeholders on the ecological status of the resources that could be used to strengthen the management of coastal wetlands for food security and biodiversity conservation in the country.

MATERIALS AND METHODS

2.1 Study area

The study was carried out in July 2010 within the Sekondi-Takoradi Metropolis of the Western Region of Ghana (Long. $1^o\ 42^1$ W and $1^o\ 48^1$ W; and Lat. $4^o\ 52^1$ N and $4^o\ 56^1$ N). The three wetlands are shown in Fig. 1. Essei lagoon is a "man-made open" lagoon that maintains a permanent contact with the sea as a result of human intervention while the Butuah lagoon is a "classical closed" lagoon which gets cut off from the sea by a sand bar for greater part of the year, but open for a short period during the rainy season [15]. The Whin estuary by virtues of its funnel shape allows for a large seawater-freshwater interchange.

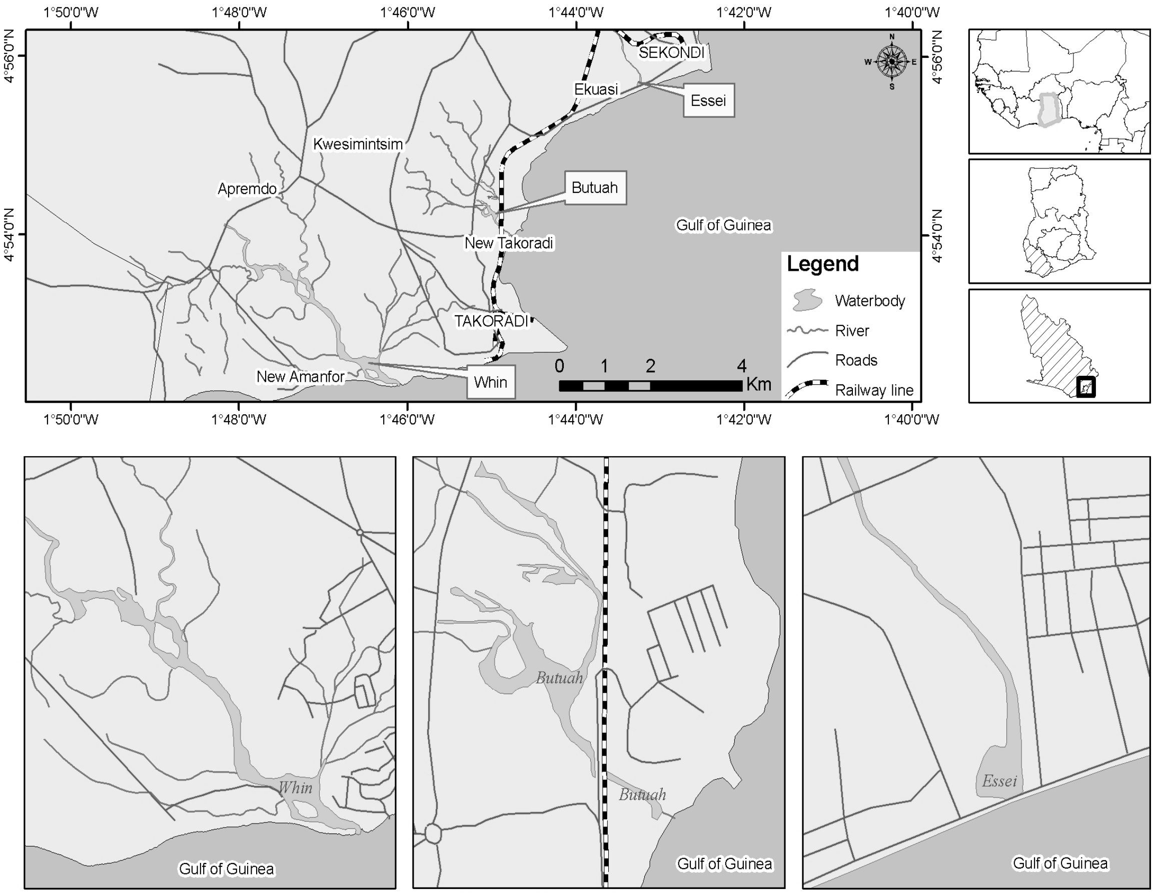

Fig. 1*:* Map showing the Whin, Butuah and Essei wetlands in the Western Region of Ghana

2.2 Measurement and analysis of physico-chemical factors

Water quality was assessed relative to predetermined standards for critical concentrations for certain environmental factors and pollutants. The parameters measured were: Temperature, Salinity, Dissolved Oxygen, pH and Turbidity, and these were recorded using the Water quality checker (Model: Horiba U-10). Three replicates were recorded from seven different areas of each of the water bodies by immersing the probe into the water and recording the readings as we switched the mode from one parameter to another. The environmental data were analysed for their means, after which the F-test (Analysis Of Variance) was used to determine the statistical significance of the differences in the physico-chemical parameters among the water bodies [16].

Where significant differences were observed, Duncan's Multiple Range Test was further used for pair-wise comparisons to determine which water bodies differ in environmental conditions [16].

2.3 Fish sampling and data analysis

A pole-seine net of 7 m long and 1.5 m deep with stretched mesh size of 5 mm was used for the fish sampling. The fishes were preserved in 10% formalin and sent to the laboratory for further examination. The fish were sorted and identified to their various families and species using fish identification manuals [17][18][19][20][21]. The total length (TL) of fish specimens was measured to the nearest 0.1cm.

Fish samples were analysed for species composition, richness and diversity. Species richness was determined using Margalef index (*d*) given as $\frac{(s-1)}{\ln N}$, where *s* is number of species in the sample, and *N* is the number of individuals in the sample [22]. Diversity of the communities was ascertained by the Shannon-Wiener index (H′) given as $H' = -\sum_{i=1}^{s} P_i(\ln P_i)$, where *s* is the number of species in the community and P_i is the proportion of individuals belonging to species *i* in the community [22]. The evenness or equitability component of diversity was calculated from Pielou's index given as $J' = H'/H_{max}$ where $H_{max} = \ln s$ [23]. The degree of similarity between the communities in the different water bodies was determined as $C_s = \frac{2j}{a+b}$ [22], where C_s is Sorensen's index, *j* is the number of species common to a given pair of water bodies, and *a* and *b* are the number of species occurring in either of the pair. The size range of the fish from each of the wetlands was also analysed.

RESULTS

3.1 Environmental conditions

Table 1 shows the means of the aquatic environmental parameters for the three water bodies, as well as the statistical significance of their differences at the 5% level. Butuah had extremely higher temperature, averaging 32.9°C ($F_{2,18}$= 64.10; P < 0.05), and a significantly higher turbidity around 180 ppm ($F_{2,18}$= 4.85, P < 0.05). Of the three wetlands, Essei lagoon recorded the least average dissolved oxygen concentration (0.7 mg/l) and was the significantly lower ($F_{2,18}$= 13.36; P < 0.05) among the three. Whin was the most alkaline with the highest salinity of 3.7 ‰.

Table 1: Means of physico-chemical parameters of the three water bodies shown (each value is a mean of 21 measurements; same alphabets represent homogenous means)

Parameter	Mean (± Standard Error)			*F*-value	$P_{(0.05)}$
	Essei	Butuah	Whin		
pH	7.7 (± 0.02)a	7.6 (± 0.05)a	8.1 (± 0.04)b	33.20	S
Temperature (°C)	22.8 (± 0.3)a	32.9 (± 0.8)b	22.4 (± 0.2)a	64.10	S
Salinity (‰)	1.9 (± 0.3)a	1.9 (± 0.2)a	3.7 (± 0.1)b	16.45	S
Turbidity (ppm)	57.8 (± 4.7)a	180.1 (± 33.5)b	42.3 (±11.5)a	4.85	S
Dissolved Oxygen (mg/L)	0.7 (± 0.1)a	3.7 (± 1.3)b	3.1 (± 0.1)b	13.36	S

'S' denotes significant

3.2 The Fish Communities

3.2.1 *Occurrence and Size range of fish species*

A total of 26 species of shellfishes and finfishes from 18 families comprising freshwater, brackishwater and marine fishes were collected from the three water bodies. The 8 species recorded from Essei comprised 5 finfishes and 3 crab species. The fish community in Butuah was made up of 14 species, of which 10 were finfishes and 4 were crabs. From the Whin Estuary, 20 species were collected with 16 being finfishes; most of which were marine species, and the remaining 4 being crabs. The lagoon tilapia *Sarotherodon melanotheron*, mudskipper *Periophthalmus barbarus*, sickle fin mullet *Liza falcipinnis*, swimcrab *Callinectes amnicola* and land crab *Goniopsis cruentata* were present in all the three wetlands. The other species occurred in one or two of the water bodies.

The size range of the finfishes, together with their habitat of origin (freshwater, brackishwater and marine) is presented in Table 2. Specimens of the common species such as *Liza falcipinnis* ranged from 2.9 cm - 5.0 cm TL in Essei, 5.6 cm - 10.1 cm TL in Butuah and 9.0 cm – 27.0 cm in Whin estuary. *S. melanothreron* specimens measured 4.0 –7.1 cm, 1.4 – 10.5 cm and 8.0 cm – 15.5 cm TL in Essei, Butuah and Whin respectively. The second dominant species in Whin, *Lutjanus goreensis* had a total length range of 8.9 – 12.3 cm.

3.2.2 *Richness, diversity and similarity of fish communities*

Table 3 shows that Whin estuary had the most rich and diverse fish community (d = 3.21, H' = 1.62), followed by Butuah (d = 1.54, H' = 1.56), with Essei having the least (d = 0.99, H' = 1.02). Distribution of the individuals among the various species was more even in Butuah (J' = 0.68) than Essei and Whin (J' = 0.57 each). The fish communities of Essei and Butuah lagoons were highly similar (C_s = 0.64), but these communities were not much similar to the Whin community (C_s = 0.36 and 0.53 with the Essei and Butuah lagoons respectively).

Table 2: Occurrence and size range of finfish species in the three water bodies in the Sekondi-Takoradi Metropolis

Family	Species	Essei			Butuah			Whin		
		No.	Min. TL(cm)	Max. TL(cm)	No.	Min. TL(cm)	Max. TL(cm)	No.	Min. TL(cm)	Max. TL(cm)
Mugilidae	*Liza dumerilii****	-	-	-	12	5.0	10.4	14	7.2	16.9
	*Liza falcipinis****	78	2.9	5.0	20	5.6	10.1	16	9	27
	*Mugil bananensis****	-	-	-	17	4.3	12.1	12	7.5	14.3
	*Mugil cephalus****	-	-	-	-	-	-	3	6.9	14.2
	*Mugil curema****	-	-	-	21	5.2	11.4	10	9.3	15.1
Clupeidae	*Odaxothrissa mento**	2	-	5.6	168	11	27.1	-	-	-
	*Sardinella maderensis****	-	-	-	-	-	-	17	4.3	7.3
Cichlidae	*Oreochromis niloticus**	-	-	-	12	5.4	18.5	-	-	-
	*Sarotherodon melanotheron***	12	4.0	7.1	56	1.4	10.5	53	8	15.5
Gobiidae	*Bathygobius soporator****	-	-	-	-	-	-	1	10.9	-
	*Periopthalmus barbarous***	53	4.6	5.1	-	-	-	11	6.2	16.3
Serranidae	*Serranus accraensis****	2	3.6	7.0	-	-	-	-	-	-
Acanthuridae	*Acanthurus monroviae****	-	-	-	-	-	-	1	-	7.3
Labridae	*Thalassoma pavo*****	-	-	-	-	-	-	1	-	16.4
Bothidae	*Scyacium micrurum****	-	-	-	-	-	-	1	-	7.1
Haemulidae	*Plectorhynhus mediterraneus****	-	-	-	-	-	-	5	4.1	4.2
Lutjanidae	*Lutjanus goreensis****	-	-	-	-	-	-	26	8.9	12.3
Eleotridae	*Eleotris senegalensis**	-	-	-	-	-	-	5	9.3	10.6
Gerreidae	*Eucinostomus melanopterus****	-	-	-	-	-	-	12	8.2	11.1
Clariidae	*Clarias gariepinus**	-	-	-	-	-	-	-	-	-
	*Heterobranchus longifilis**	-	-	-	6	-	8.3	-	-	-

* *Freshwater species that occasionally enter brackishwater*

** *Truly estuarine/lagoon that spend their entire lives in estuary/ lagoon.*

*** *Marine species that use estuaries and lagoons primarily as nursing and spawning grounds, spending adult life at sea and returning occasionally to estuaries and lagoons.*

**** *Occasional visitors occurring irregularly (ornamental)*

Table 3: Richness, diversity, evenness and similarity indices for the fish communities

Water body	Margalef's Richness (d)	Shannon – Wiener diversity (*H'*)	Pielou's evenness (*J'*)	Sorensen's similarity (C_s)	
				Essei	Butuah
Essei	0.99	1.02	0.57		
Butuah	1.54	1.56	0.68	0.64	
Whin	3.21	1.62	0.57	0.36	0.53

3.2.3 *Composition of fish communities*

The two main fish species which dominated the Essei fish community were *Periophthalmus barbarus* (51.3 %) and *Liza falcipinnis* (34.3%) while *Odaxothrissa mento* dominated the Butuah community (49.1 %), followed by *Sarotherodon melanotheron* (16.3 %) (Figure 2). The Whin community was dominated by *S. melanotheron* (26.5 %) and the snapper *Lutjanus goreensis* (Lutjanidae) (13 %). Compositions of the remaining species varied between 0.5 % and 8.5 % in the communities in which they occurred.

DISCUSSION

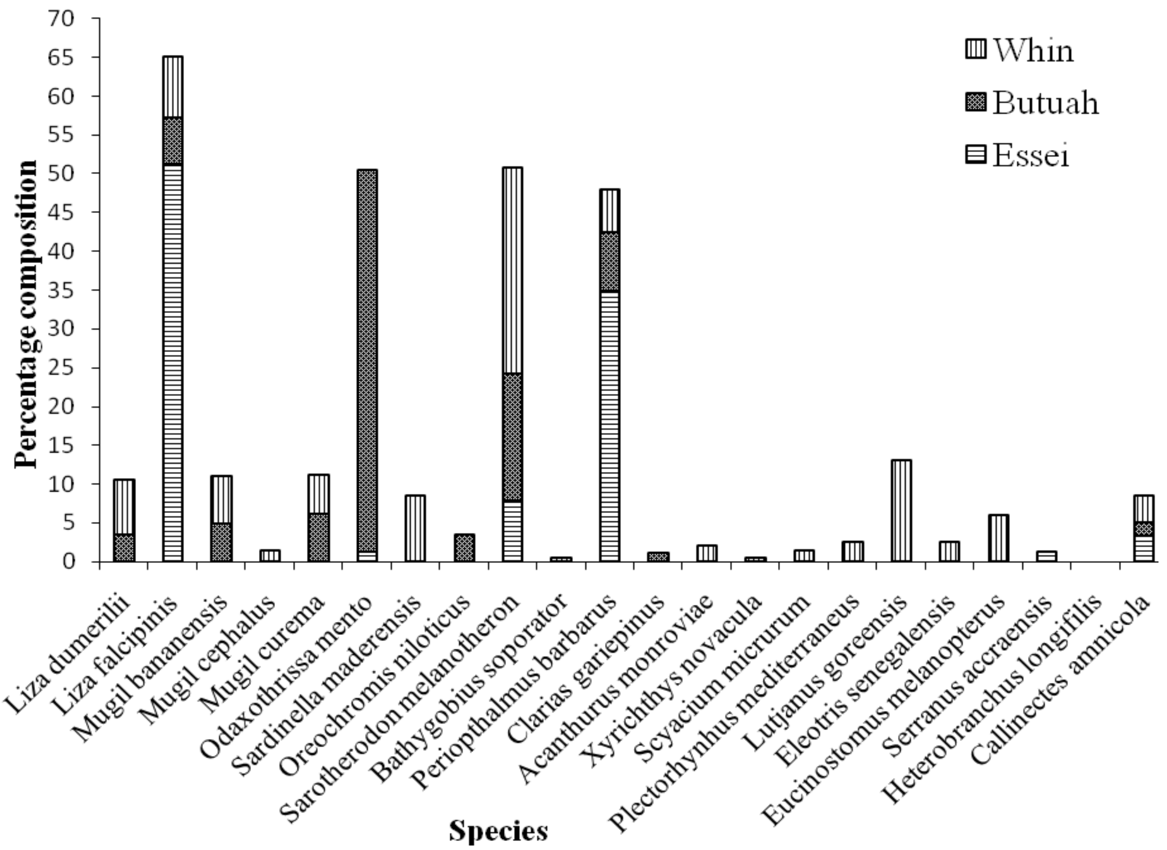

Figure 2: Percentage composition of fish species in the Essei, Butuah and Whin brackishwater systems

This section analyses the diversity of fish species in the three water bodies in relation to the physico-chemical conditions of the water bodies. It is discussed within the context that a high level of biodiversity is desirable and provides indications of relative good health status of the ecosystem. Therefore, maintaining biodiversity is necessary in order to assure the survival and productivity of ecosystems and assure livelihoods as a whole.

4.1 Fish diversity, richness and composition of the wetlands

Fish is the most important biota of brackish water ecosystems contributing as an essential and beneficial food item [24]. Therefore, a study of data on fish biota gives indication of state of ecosystem health.

4.1.1 *The Whin estuary*

The Whin estuary indicated a high diversity of fish community with most of the fish biota being dominated by marine species. These include *Liza falcipinnis, Liza dumerilii, Mugil bananensis, Mugil cephalus, Mugil curema, Sardinella maderensis* among others (Table 2). It is probable that most of these fish species primarily use the estuary as nursing or spawning grounds and spend their adult life at sea and occasionally returning to the estuary in their adult life. This is in agreement with other authors who earlier confirmed that marine species such as *Liza falcipinnis, Mugil cephalus* and *Lutjanus goreensis* live and reproduce from nearly freshwater to hypersaline conditions [25][26]. The observed high diversity of fish species may also be attributable to the fairly good environmental conditions of the estuarine environment favourable for fish survival and growth.

The physico-chemical parameters recorded in the estuary in terms of mean temperature, turbidity, dissolved oxygen and salinity were optimal. Also, the significantly alkaline pH averaging 8.1($F_{2,18}$= 33.2, $P < 0.05$) suggest that the water body has a reasonably good buffer capacity implying optimally good pH levels adequate for supporting a range of aquatic life. Hydrogen ion concentration (pH) range of 6.5 to 8.5 is generally suitable. Acidity is detrimental to aquatic macroinvertebrates and fish [27]. Therefore, the pH values measured implies that the estuary provides very good conditions for fisheries development. Truly estuarine species identified include *Periophthalmus barbarus, Sarotherodon melanotheron* and *Uca tangeri.* Only one freshwater species *Eleotris senegalensis* was found in the estuary. The estuary was also found to be a suitable habitat for some ornamental fish species namely *Thalassoma pavo.*

Despite the high diversity of fish species encountered, the size ranges of the most common marine fishes such as *Liza falcipinnis, Liza dumerilii, Mugil curem* (Mugilidae), *Lutjanus goreensis* (Lutjanidae) *Sardinella maderensis* (Clupeidae) were generally smaller than reported normal maturity sizes [17][20]. The observation of juvenile fishes suggests that the estuary is utilized by juvenile marine fish species as nursery and feeding grounds as also observed in estuaries in South Africa [6].

In view of the commercial importance of majority of the fish species and the active fishing activities ongoing in the estuary, it would be necessary to enforce fisheries management regulations, especially with respect to fishing gear regulation to avert the exploitation of juvenile fishes in the estuary. The recognition of a highly rich and diverse fish biota in the Whin estuary reflects a high productive system that merits management planning and possible conservation status.

4.1.2 *The Butuah lagoon*

The Butuah lagoon is a "Classical closed" lagoon that gets cut off from the sea by sand bar for greater part of the year, but open for a short period during the rainy season [15]. Despite the physical feature, it is worthy to note that the lagoon is mainly dominated by fisheries of marine origin (Table 4). These fish species have probably adapted to live under brackish water conditions during the closed periods. These include *Liza dumerilii, Liza falcipinnis, Mugil bananensis, Mugil curema* and *Callinectes amnicola.* Freshwater species found in the lagoon may be regarded as invasive species or were artificially introduced into the water body. These include *Oreochromis niloticus, Odaxothrissa mento, Clarias gariepinus and Heterobranchus longifilis.* Extremely very few lagoon species were encountered namely *Periophthalmus barbarus* and *Sarotherodon melanotheron.*

The fish community encountered in the lagoon was made up of 14 species, of which 10 were finfishes and 4 crabs could be described as generally low in diversity. In comparison with Whin as a brackishwater system, the species diversity and species richness in Butuah was estimated to be lower (d = 1.54, H' = 1.56). Low fish diversity is confirmed to be a good indicator of a possibly stressed ecosystem and the higher the fish diversity the more stable the fish community [32]. The lower fish diversity may be attributable to the significantly high water temperatures of the lagoon system (mean = 32.9^{o}C; $F_{2,18}$= 64.10; P < 0.05) which could be described as considerably high for aquatic life. The possible impacts of high average temperature of the lagoon should be of great concern because aquatic organisms are dependent on certain temperature ranges for optimal growth and health. Temperature affects many other parameters in the water, including the amount of dissolved oxygen available, the types of plants and animals present, and the susceptibility of organisms to parasites, pollution and disease.

While further research could provide in-depth answers, possible reasons could be related to minimal shade due to widespread destruction of watershed including associated mangrove and other riparian vegetation around the lagoon. It is also possible that hot water discharges into the water from near urban industrial enterprises or simply attributable to chemical processes or groundwater inflows. In addition high turbidity indicated record high values that may have impacted negatively on the productivity of the system in general. This observation may also be linked to intense human activities around the lagoon such as agricultural releases from adjacent farms and organic effluent discharges from homes. Also, further investigations into the occurrence of freshwater species discussed in this context as potentially invasive e.g. *Oreochromis niloticus* in the Butuah lagoon needs to be vigorously pursued.

4.1.3 *The Essei lagoon*

The Essei lagoon is a man-made open lagoon [28][15]. In terms of fish species composition, richness and diversity, data from the Essei lagoon generally recorded very low values. In total, 7 species of fish were encountered belonging to 7 families. Essei recorded the least indices in terms of fish species diversity and richness (d = 0.99, H' = 1.02). This observation could be attributed to several reasons. First, intense artisanal fishing activities in these lagoons cannot be ruled out as a major impact on the lagoon fisheries. Such impacts have been reported elsewhere notably in South Africa [29] and the Gulf of Thailand [30]. Water quality in the lagoon was also rated to be very poor. For example, the oxygen concentration amounting to 5 mg/l is ideal for fish survival and growth [31][27]. Oxygen content recorded in the Essei lagoon could be described to be at critically very low levels with an average of 0.7 mg/L which was the significantly lowest among the water bodies ($F_{2,18}$= 13.36; P < 0.05). This may be regarded as near deoxygenation and may have also accounted for the very low fisheries content of the lagoon.

In addition, the sizes of fish recorded in the Essei lagoon were much smaller than those recorded in the Butuah and Whin estuary. Hence the Essei lagoon may be acting as a nursery ground for juvenile marine fish species such as *Liza falcipinnis* and *Serranus accraensis* (Table 4). However, *Sarotherodon melanotheron* and *Serranus accraensis* had relatively larger sizes, possibly demonstrating their capability to adapt to stressful conditions, growing at the expense of other species. Similar finding has been reported for the Ebrie lagoon in West Africa [25]. Therefore, the generally lower size ranges of similar fish species encountered in the Essei and Butuah lagoon is worrying. The presence of *Liza falcipinnis* and *Serranus accraensis* known to be largely marine species may indicate they are opportunistic species. No freshwater species were encountered in the lagoon probably because of the very low dissolved oxygen content.

We conclude that the Whin estuary reflects a highly productive system that merits management planning and possible conservation status relative to data on richness and diversity of fish biota as well as the environmental conditions. The lower richness and low diversity of fish species, primarily occurring as juveniles in the Essei and Butuah lagoons require very serious and realistic management interventions to be enforced.

Acknowledgements

This research was supported with funds from the United States Agency for International Development (USAID), accessed through a collaborative research grant from the Coastal Resources Center (CRC) and Friends of the Nation (FoN), Ghana. The authors are particularly grateful to the fishing communities where the research was undertaken and the Department of Fisheries and Aquatic Sciences of the University of Cape Coast for providing most the materials for this study.

REFERENCES

[1] Millennium Ecosystem Assessment, Ecosystems and Human Well-being: Synthesis, **2005**, Island Press, Washington, DC.

[2] M. King, S. King; The Oceans and Coastal Areas and their Resources, UNESCO-UNEP International Environmental Education Programme, **1995**, Paris.

[3] Ramsar Convention; The Convention on Wetlands of International Importance especially as Waterfowl Habitat, **1971**, Ramsar, Islamic Republic of Iran.

[4] Ministry of Lands and Forestry; *Managing Ghana's wetlands: a national wetlands conservation strategy*, **1999**, GEF/World Bank-funded Coastal Wetlands Management Project.

[5] D. K. Attuquayefio, F. Gbogbo, *W. Afr. J. Appl. Ecol.*, **2001**, 2, 65-75.

[6] A. K. Whitfield, *Environ. Biol. Fish.*, **1990**, 28, 295-308.

[7] J. M. Ryan, Y. Ntiamoa-Baidu, *Biodiversity Conserv.* **2000**, 9, 445-446.

[8] C. A. Biney, *Oceanol. Acta*., **1982,** 4 suppl. (vol. special), 39-43.
[9] A.Y. Karikari, K.A. Asante, C.A. Biney, *W. Afr. J. Appl. Ecol.* **2006**, 10, 73-85.
[10] J. Jr. Blay, In: D.S. Amlalo, L. D. Atsiatorme, C. Fiati (Ed.), Biodiversity Conservation: Traditional Knowledge and Modern Concepts, **1997,** BRAAF Proceedings, Cape Coasts, 113-119.
[11] P. Bannerman, R. Quartey, Report on the observations of commercial light fishing operation in Ghana, February-June, **2004**, Marine Fisheries Research Division, Tema, 8.
[12] Ghana's initial national communication under the United Nations Framework Convention on Climate Change, Accra: Environment Protection Agency of Ghana, Ministry of Environment, Science and Technology, **2000**.
[13] C. Gordon, *Biodiversity Conserv*., **2000**, 9, 465-478.
[14] E. A. Obodai, C. A. Nsor, *Ethiopian J. Environ. Stud. Manag*., **2009**, 2, 56-62.
[15] K. Yankson, E. A. Obodai, *J. Ghana Sci. Ass.* (Special Edition), **1999**, 2, 26 - 31.
[16] J. H. Zar; Biostatistical Analysis, (4th ed). Upper Saddle River, Prentice Hall, USA. , **1999**.
[17] W. Schneider; FAO species Identification for Fishery Purposes: Field Guide to the Commercial Marine Resources of the Gulf of Guinea. FAO pbl. RAFR/F1/90/2, Rome, **1990**.
[18] M. Holden, W. Reed; West African Freshwater Fish. Harlow, Longman Group Ltd., UK. **1991**.
[19] H. R. Dankwa, E. K. Abban, G. G. Teugels; Freshwater Fishes of Ghana, Annales Sciences Zoologiques, Vol. 283, **1999.**
[20] D. Paugy, C. Lévêque, G.G Teugels; The Fresh and Brackish Water Fishes of West Africa. Vol. II. IRD Editions, Publications Scientifiques du Muséum, MRAC, **2003**.
[21] E.A. Kwei, D.W. Ofori-Adu; Fishes in the Coastal Waters of Ghana, Ronna Publishers, Tema, Ghana, **2005**.
[22] C. J. Krebs; Ecological Methodology, Addison-Welsey Educational Publishers Inc., Canada, **1999**.
[23] E.C. Pielou, *J. Theoret. Biol*., **1966**, 13, 131-144.
[24] I. F. Pailwan, D.V. Muley, S. Maske; Proceedings of Taal 2007: The 12th World Lake Conference, **2008**, India, 1643-1649.
[25] B. E. Emmanuel, I. C. Onyema, *Turk. J. Fish. Aquat. Sci.*, **2007**, 7, 105-113.
[26] J. Albaret, R. Lae, *Aquat. Living Resour*., **2003**, 16, 1-9.
[27] T. V. R. Pillay; Aquaculture and the Environment (2nd Ed.), Blackwell Publishing Ltd., Oxford, U K, **2004**.
[28] C. A. Biney, *Trop. Ecol.*, **1986**, 27, 147–156.
[29] B.J. Tomlin, R. Kyle, *S. A. J. Zool.*, **1998**, 11, 1-10.
[30] A. C. Simpson, In: D. Pauly, G. L. Murphy (Ed.), Theory and Management of Tropical Fisheries (ICLARM and CSIRO, Cronulla, Australia, **1982)** 5-32.
[31] H. B. N. Hynes; The ecology of running waters, Liverpool University Press, Liverpool, **1970.**
[32] C. Lévêque, *Aquat. Living Resour*., 1995, 8, 59-78.