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Seasonal Dynamics of Physico-chemical Characteristics in Wetlands of Northern Region (Ghana): Implications on the Functional Status

Collins Ayine Nsor*[1], Emmanuel Acquah[2] and Clifford A. Braimah[3]

1) Department of Fisheries and Aquatic Sciences, University of Cape Coast, University Post Office, Cape Coast-C/R, Ghana
2) Department of Ecotourism and Forest Recreation, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana
3) School of Engineering, Tamale Polytechnic, P. O. Box 3 ER, Tamale, Ghana

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Abstract: Seasonal variations of 11 water quality, namely; pH, TDS, Conductivity, Turbidity, surface water temperature, DO, NH_3, PO_4, NO_3-N, Ca^{2+} and Mg^{2+}, were assessed in six wetlands, in the dry (December - April) and wet (July–October) seasons for two years, using standard APHA Four major environmental disturbances (farming activities, bushfires, grazing activity, illegal fishing methods) were quantified using *Battisti* and *Salafsky models*. Although physical parameters values showed an increase in the dry season compared to the wet season, they were not statistically significant ($p>0.05$). However, hydro-chemical parameters showed significant seasonal variations ($p< 0.05$). With the exception of NH_3 that was in far excess of the required levels acceptable for aquatic life, in Nabogo and Bunglung sites, the remaining hydro-chemical variables were at tolerable levels necessary for aquatic life. Elevated levels of NH_3 and turbidity in these sites were linked to surface run-off from nearby agricultural fields, while turbidity levels showed appreciable levels in Kukobila (395±2.7 NTU) in the wet seasons, compared with the remaining sites. DO levels were lower beyond acceptable limit and partly influenced by surface water temperature. Our results revealed that farming practices and bushfires directly influenced water quality. Consequently, wetlands functional status could degrade further in the near future if current disturbances intensify. Thus managers of wetlands could institute conservation measures, in order to curb future disturbances and enhance.

Keywords: water quality, environmental disturbance, seasonality, cluster analysis

Introduction

Each freshwater system has an individual pattern of physical and chemical characteristics largely determined by the climatic, geomorphological and geochemical conditions prevailing in the drainage basin, distance from ocean and the underlying aquifer and the soil cover (Chapman, 1996). Water pollution has become a growing threat to human society and natural ecosystems in the recent decades (Garizi *et al.* 2011). Assessment of seasonal changes in surface water quality is an important aspect for evaluating temporal variations of river pollution due to natural or anthropogenic inputs of point and non-point sources (Ouyang *et al.* 2006). Anthropogenic influences such as urban, industrial and agricultural activities, increasing consumption of water resources and natural processes (e.g., changes in precipitation inputs, erosion, weathering of crustal materials), degrade surface waters and impair their use for domestic, industrial, agricultural, recreation or other purposes (Carpenter *et al.* 1998; Javie *et al.* 1998). Due to the sensitive reaction of fauna species to spatio-temporal variations of surface water physico-chemical characteristics, constant monitoring of will provide a reliable estimation of the water quality and the management measures to be instituted for species survival. Jonnalagadda and Mhere (2001) argued that, many variables in natural ecosystems, simultaneously change with time and location with little opportunity to control them. Thus measuring as many parameters as possible, may contribute to the understanding of their interactions and to assess the sustainability of the environment (Hopke, 1985). Anthropogenic activities have been identified as easy source of water pollution in most freshwater systems in Nigeria (Akintola and Nyamah, 1978; Ayoade, 1994, Ayoade and Oyebande, 1983; Obasi and Balogun, 2001; Ovrawah and

(✉) ayineus@yahoo.com

Hymore, 2001).

In Ghana, most scientific studies on wetlands water quality, have been carried-out in the Southern coast and forest zones (e.g., Ameka *et al.* 2000; Ansa-Asare and Asante, 2000; Bosque-Hamilton *et al.* 2004**;** Asante *et al.* 2008). Inspite of the numerous role of wetlands in rural livelihood support and enhancement of biological integrity (e.g. Nsor *et al.* 2014; Nsor and Alhassan, 2015), in Northern savanna zone, they have not attracted similar scientific investigation on seasonal wetlands physico-chemical dynamics. Even the few study conducted in this area, have focused on water quality on riverine systems, in the context of safe drinking water (e.g., Abdul-Razak *et al.* 2009). Land use activities which directly influences wetlands water quality in Northern Region of Ghana, are seasonally specific (i.e., wet and dry seasons). This is because human-led activities such as farming practices, bushfires, grazing and fish harvest, vary along the two seasons and hence physico-chemical characteristics may fluctuate in line with the two seasons, in space and time. Giving the high conservation concern of wetlands in Northern Region of Ghana (Nsor *et al*. 2014), there is the need to investigate whether water quality of these wetlands are at acceptable limits necessary to support aquatic life or have degraded.

Materials and methods

The study was carried out in six wetlands located in the Northern region of Ghana, with their co-ordinates as follows: (i) Wuntori (N09˚08.335' W00˚109˚.685'); (ii) Kukobila (N10˚08.723' W000˚48.179'); (iii) Tugu (N09˚22.550' W000˚ 35.004'); (iv) Bunglung (N09˚35.576'W000˚47.443'); (v) Adayili (N09˚41.391' W000˚41.480') and (vi) Nabogo (N09˚ 49.941' W000˚.51.942') (Fig. 1). The six sites lie on the extensive floodplain along the course of the White Volta River, which has overtime become incised and modified through meandering and aligning along various topographic features. This has led to the development of streams that have diverted from the main White Volta (Slaymaker and Blench, 2002). All six wetlands were classified as close shallow marshes (Wuntori and Tugu wetlands), open deep marsh (Kukobila wetland), riparian wetlands (Adayili and Nabogo wetlands) and artificial wetland (Bunglung wetland). The hydrological regimes of the six wetlands under study were typical of permanent wetlands, whose depth at low tide did not exceed 2 m on average. Sizes of the wetlands were computed through on-screen digitizing of Landsat aerial images, obtained from google earth platform. The areas are as follows: (a) Wuntori = 7.7 ha; (b) Kukobila = 5 ha, Tugu (c) 2.7 ha; (d) Nabogo = 7.9 ha; (e) Adayili = 6.7 ha and (f) Bunglung = 11.5 ha.

Water quality sampling procedure and analyses

Since the wetlands are a zone of intense human-led activities, such as farming, grazing and fish exploitation by rural duelers, sampling strategy was designed to cover a wide area of key sites that accurately represent the water quality of the different wetland types. Four sample plots of size 50 x 20 m (1000 m^2) were randomly demarcated in each of the six sites, bringing the total plots to 24. In all, 11 physico–chemical parameters, namely; pH, Turbidity, surface water temperature, Conductivity, TDS, Nitrate-N (NO_3--N), Phosphate (PO_4^{3-}), Ammonia (NH_4-N), Calcium (Ca^{2+}), Magnesium (Mg^{2+}) and Dissolve Oxygen (DO), were taken from upper, mid and downstream in all sites on the same day. Monthly sampling was carried-out to monitor changes in the dry and wet seasons, over a 2-year period and to determine whether water quality parameters were of acceptable standard necessary to sustain aquatic life, we compared the results of our data to the International Water Quality Standards for Surface Water and Wetlands (e.g., Chapman 1992, 1996; Carr and Rickwood, 2008).

We sampled four months in the dry (December-April) and wet seasons (July-October), respectively. Sampling, preservation and analytical protocols were conducted following standard methods for surface waters outlined in APHA (APHA) (1998) and Voutsa *et al.* (2001). With the exception of pH and water temperatures that were measured *in situ* using a Hach 2000 pH meter and a mercury-in-glass thermometer respectively, the remaining samples were stored in ice chest and transported on the same day to the Water Research Institute laboratory, for analysis of their physico-chemical parameters.

Environmental assessment

Identifying how many and which types of human-induced disturbances or threats are present and their

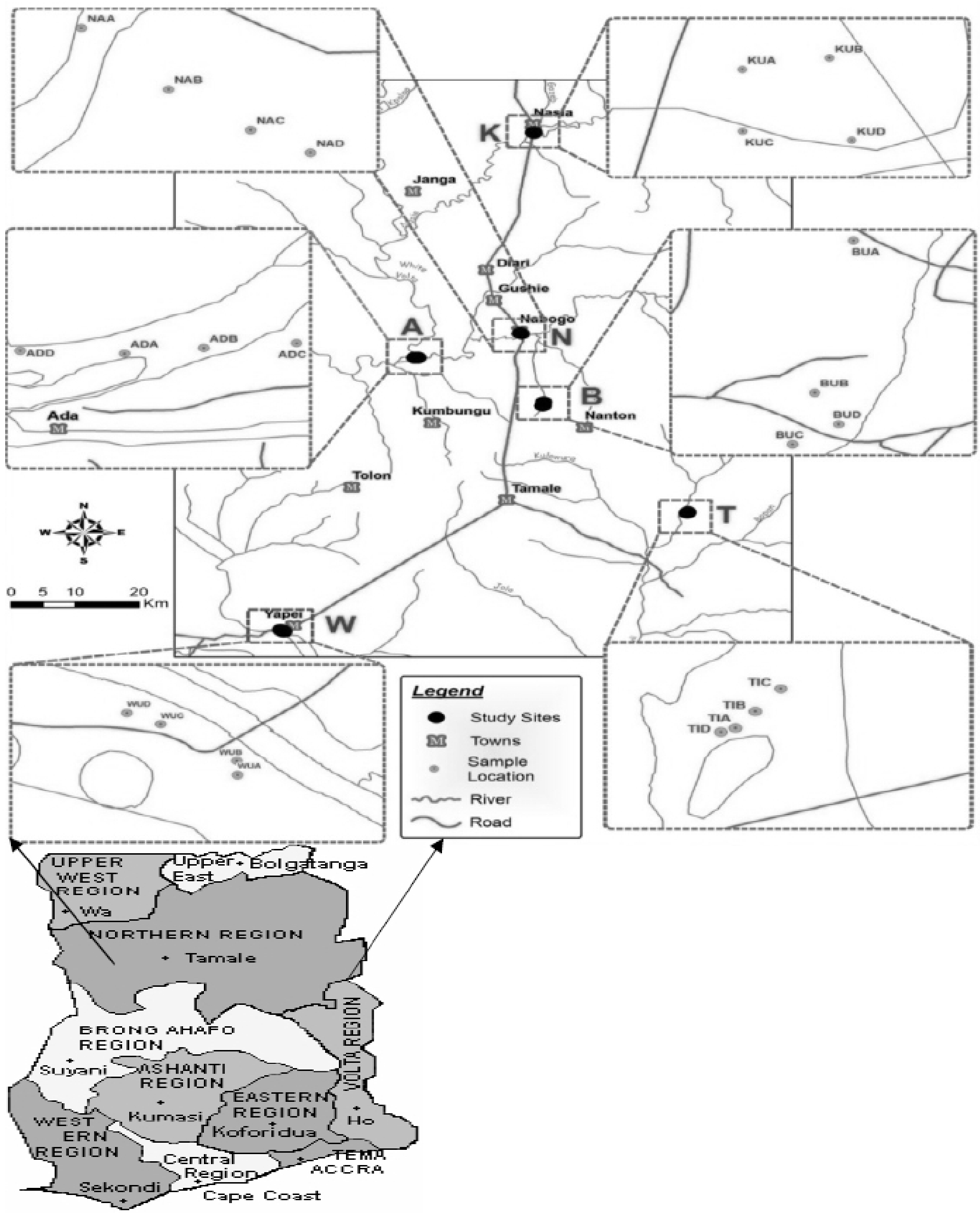

Fig. 1 Map of the study areas, showing the location of the wetlands in the floodplains of the White VoltaRiver catchment, Northern Region. The alphabets represents names of the wetlands; K = Kukobila, N = Nabogo, A = Adayili, B = Bunglung, T = Tugu and W = Wuntori

regime is important when assessing the water quality status of wetlands of high conservation concern for efficient management. In this regard, three major environmental drivers of change (bushfire, farming activities, crude fishing method and grazing pressure), were assessed to determine their influence on nutrient load (i.e. orthophosphate (PO_4^{3-}), Nitrate-N (NO_3-N, Ammonia (NH_4-N). We used the hierarchical classification of threats (HCT) developed by Salafsky *et al.* (2003). The model explains that all threats identified and comprehensively documented (contains all possible items, at least at higher levels of the hierarchy), consistent (ensures that entries at a given level of the classification are of the same type), expandable (enables new items to be added to the classification if they are discovered) and exclusive (allows any given item to only be placed in one cell within the hierarchy). A score ranging 1–4 was used to assess the scope and severity of every threat. A "*scope*" hereby referred to as the percentage ratio of the study area affected by a specific threat within the last 5 years (where 100% correspond to total site area: χ ha) Battisti *et al.* (2009). The scores were assigned as follows: 4 = the threat is found throughout (50%) the site; 3 = the threat is spread in 15–50% of the site; 2 = the threat is scattered (5–15%); and 1= the threat is much localized (<5%). Assessment of the area disturbed was carried out well beyond the delineated zone of wetlands, where most land use activities take place.

Statistical analyses

Cluster analysis (Complete-linkage clustering) (Sneath and Sokal, 1973) was applied to aggregate sites of similar pysico-chemical characteristics, using Statistica software package ver. 11. The degree of matching between each pair of sub-plots was computed, using the coefficient of squared Euclidean distance (Noest and Van der Maarel, 1989). Hydro-chemical parameters were initially log transformed, before we subjected them to further analysis. A linear regression model was applied to evaluate the influence of surface water temperature on dissolved oxygen. A One-way ANOVA was used to determine if environmental variables and water quality data differed significantly among the six sites in the wet and dry season using Statistica software package ver. 11. A Student T-test was used to determine differences between sites physico-chemical characteristics.

Results

A total of 11 water quality characteristics were presented in Table 1. Water quality results in this study generally appear to be at tolerable levels in line with international standards for aquatic life (Tabs. 1 and 2). Seasonal variations in water quality showed no significant difference in the six sites ($p > 0.05$). Although physical parameters values showed an increase in the dry season compared to the wet season, they were not statistically significant ($p>0.05$) (Fig. 2). However, hydro-chemical parameters differed significantly ($p<0.05$) in the six sites, but seasonal variations in each site, showed no significant difference in Wuntori (*Student t-test*, p = 0.083), Kukobila (p = 0.33), Tugu (p = 0.12), Nabogo (p = 0.37), Adayili (p = 0.88) and Bunglung (p = 0.1). Turbidity varied significantly on a seasonal basis ($p<0.05$), with the highest recorded in Kukobila in the dry season (395±2.7 NTU), and Bunglung in the wet season (123.3±1.1 NTU) (Fig. 2, Tab. 1). Mean pH values for all sites varied marginally and showed a rather weak acidic to neutral condition during the wet (6.7±0.03–7.8±0.6) and dry (6.5±0.3–6.9±0.07) seasons. Mean surface water temperature did not significantly differ ($p>0.05$) among sites and ranged between 30.1±0.2ºC-31.3 ± 0.9ºC and 29.8 ± 0.5ºC-31.3 ± 0.2ºC in the dry and wet seasons respectively. Mean temperature was highest in the Nabogo riparian system and lowest in Kukobila in the dry season. However, this trend did not markedly vary across sites in the wet season. Dissolved oxygen concentration was averagely < 3 mg/L in all sites, with the exception of Tugu wetland that recorded DO levels > 3 mg/L (3.5±0.09 mg/l) in the wet season (hypoxic condition). Overall, mean temperature values (x) did not significantly influence dissolved oxygen concentration (y) in the dry ($r^2 = 0.012$, p= 0.84) and wet ($r^2 = 0.436$, p = 0.15) seasons (Figs. 3 and 4). Consequently, linear regression was used to develop the following model to predict future dissolved oxygen concentration (y) as a function of water temperature data (x) in the dry: $y = -0.0814x + 4.7326$ and wet: $y = -0.6868x + 23.537$ seasons. Conductivity was consistently highest only in the shallow marshes of Wuntori in the dry (197±2.7 μS/cm) and wet (153±3 μS/cm) seasons (Fig. 5, Tab. 1).

Nutrient loads such as nitrates-nitrogen (0.2-2.4 mg/L) and phosphates (0.003-0.7 mg/L) concentration levels were generally low throughout the year. Elevated levels of ammonia (>2mg/L) above acceptable limits, were observed in two sites (Nabogo and Bunglung constructed wetlands). Notwithstanding these increased levels, they did not affect the functional status of the wetlands, due to the fact that weak acid to neutral pH (6.5–7.8) and surface water temperatures in the range of 29.8±0.5ºC–31.3±0.2ºC, negate the toxic effect on aquatic life. Major cations like calcium (Ca^{2+}) and magnesium (Mg^{2+}) did not follow any incremental sequence from the wet to the

Tab. 1: Results of mean (±*S.E.*) water quality parameters from six wetlands in the dry (Dec.-April) and wet seasons (July-Oct.). Concentration units in mg/L or mg/L, conductivity in μS cm^{-1} and Turbidity in NTU

Season	Parameters	Wuntori	Kukobila	Tugu	Nabogo	Adayili	Bunglung
Dry season	Conductivity	197±2.7	62.3±1.1	146.8±1.5	56.8±0.6	53.7±0.9	65.7±0.1
	TDS	120±1.3	38.1±0.6	88.2±0.7	33.4±0.6	30.7±0.6	40±0.1
	pH	7.8±0.6	6.7±0.3	6.8±0.09	6.8±0.1	6.9±0.2	6.7±0.03
	Turbidity	74.5±1.3	395±2.7	23.8±0.9	147.5±0.6	126.5±0.6	119.3±1.3
	Nitrate-N	1.3±0.03	0.74±0.02	2.4±0.09	2.1±0.06	0.07±0.009	1.6±0.02
	Phosphate	0.04±0.01	0.29±0.04	0.2±0.01	0.06±0.02	0.7±0.07	0.5±0.3
	Ammonia	1.5±0.03	1.5±0.03	0.8±0.009	1.8±0.5	1.1±0.2	2.2±0.4
	Calcium	7.9±0.4	12.9±0.7	5.7±0.09	9.6±0.1	5.9±0.2	6.1±0.1
	Magnesium	7.3±0.2	2.2±0.09	7.9±0.1	6.1±0.1	6.1±0.1	6.2±0.1
	DO	2.4±0.08	2.5±0.09	2.1±0.1	1.7±0.1	1.9±0.1	2.9±0.1
	Temperature	30.9±0.2	29.8±0.5	30.2±0.4	31.3±0.2	30±0.3	30.8±0.3
	Parameters	**Wuntori**	**Kukobila**	**Tugu**	**Nabogo**	**Adayili**	**Bunglung**
Wet season	Conductivity	153±3	63.7±0.8	116.8±0.9	62.6±0.9	90.05±1.6	54.1±0.8
	TDS	86.4±2.1	39.9±1.3	74.1±1.6	37.7±1	54.8±1.1	31.6±0.9
	pH	6.6±0.2	6.7±0.1	6.5±0.3	6.7±0.2	6.9±0.1	6.9±0.07
	Turbidity	6.5±0.6	13.7±0.6	20.5±0.6	72.3±1.3	78.8±1.4	123.3±1.1
	Nitrate-N	0.2±0.009	0.5±0.02	0.73±0.03	0.7±0.02	1.2±0.03	1.9±0.009
	Phosphate	0.14±0.009	0.03±0.006	0.05±0.006	0.7±0.02	0.08±0.006	0.07±0.005
	Ammonia	0.15±0.009	0.3±0.03	0.39±0.02	2.3±0.6	0.6±0.08	1.3±0.09
	Calcium	7.9±0.5	6.2±0.5	6.9±0.4	6.7±0.5	7.5±0.2	1.8±0.07
	Magnesium	5.5±0.2	3.6±0.3	2.9±0.09	2.4±0.01	2.5±0.1	2.2±0.1
	DO	2.5±0.1	2.5±0.2	3.5±0.09	2.4±0.1	2.7±0.1	2.3±0.09
	Temperature	31.3±0.9	30.6±0.3	30.1±0.4	30.9±0.2	30.2±0.5	30.1±0.2

dry season, as their concentrations varied substantially in the sites ($p<0.04$). Sites like Wuntori and Tugu wetlands, with dolomitic bedrock, were high in magnesium cations, they did not contribute to water hardness and alkalinity, since they were within acceptable limits necessary for aquatic life. Total dissolved solids (TDS) were generally at optimal levels, but did not differ significantly (*Student t-test*, $p = 0.60$) among sites in the two seasons.

Tab. 2: International Water Quality Standards for Surface Water and Wetlands

Water parameters	Standard acceptable levels for aquatic life
Conductivity	500 μS cm^{-1} (Carr & Rickwood, 2008)
TDS	50 - 250 mg/L (Chapman, 1992)
pH	6.5 – 9.0 (CCME, 1999)
Turbidity	1 – 1000 NTU (Chapman, 1996)
Nitrate-N	0.5 mg/L (Carr & Rickwood, 2008)
Phosphate	0.025 mg/L(Carr & Rickwood, 2008)
Ammonia	0.05 mg/L (Carr & Rickwood, 2008)
Calcium	0 to 100 mg/L (Chapman, 1992)
Magnesium	[a]Ni
DO	6 - 9.5 mg/L (CCME, 1999)
Temperature	30° C (Chapman, 1996)

[a]Ni: No information

Site similarity in water quality parameters in relation to environmental disturbances

For the dry season, all six sites were clustered in two groups, comprising of all three marshes in cluster I (Wuntori, Tugu and Kukobila) and riparian/constructed wetlands in cluster II (Nabogo, Adayili and Bunglung) (Fig. 6). These sites were clustered on the basis of their similarity in physico-chemical parameters. Grazing pressure, bushfire, illegal fishing and farming activities, were the key environmental drivers of change in these sites (Fig. 6, Tab. 3). While grazing pressure and bushfire disturbances were more severe in the three marshes than the riparian sites, illegal fishing was widely practiced across the six sites. Farming activities was more intense in Bunglung site than the remaining five sites, in the dry season. Among all documented disturbances, farming the most practiced activity. Disturbances in these sites recorded high turbidity levels in Kukobila (395±2.7 NTU**)** and Bunglung (123.3±1.1 NTU). While high ammonia concentration in Bunglung (2.2±0.4 mg/L) and Nabogo (2.3±0.6 mg/L). Although, farming activities, grazing and bushfires were severe, they did not influence nutrient loads concentrations in the six

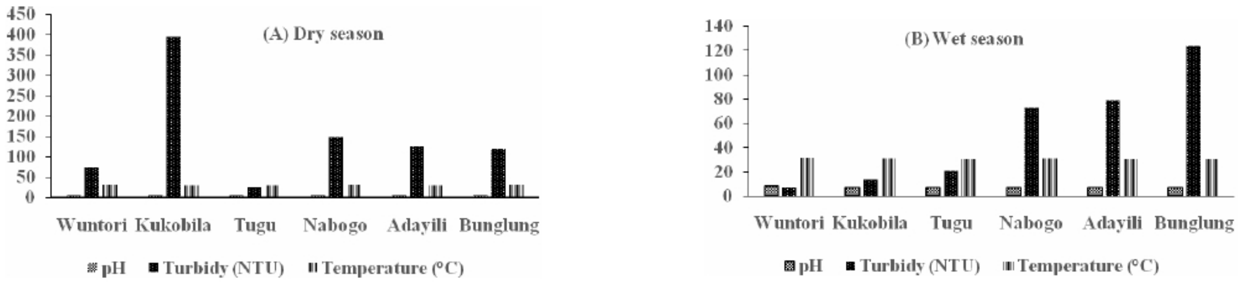

Fig. 2: Seasonal variations of mean physical parameters across the six wetlands in the (A) wet season (July-Oct.) and (B) dry season (Dec.-April) (All axes were re-scaled to log10).

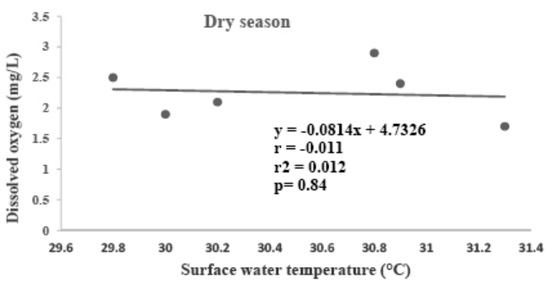

Fig. 3: Relationship between surface water temperatures on dissolved oxygen among the six wetlands in the dry season

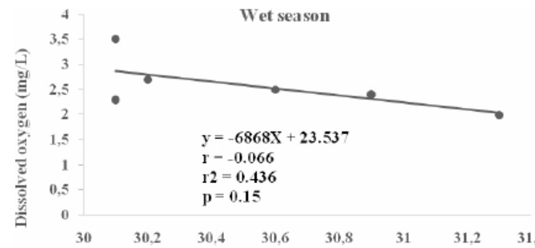

Fig. 4: Relationship between temperature and dissolved oxygen among the six wetlands in the wet season

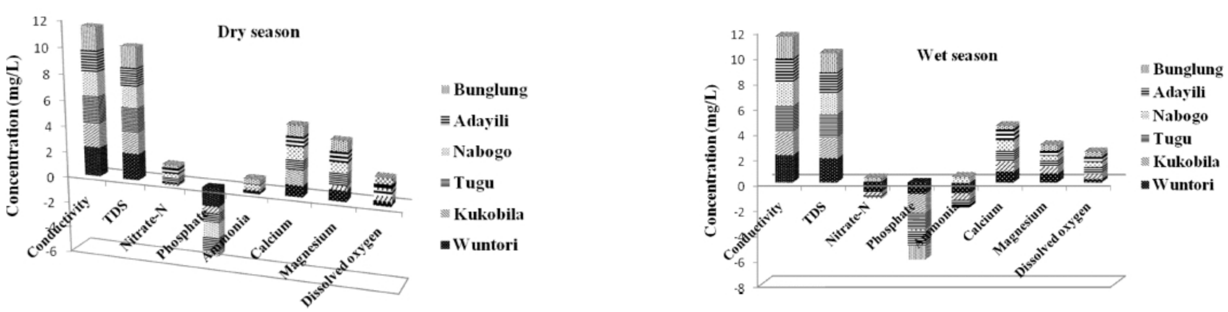

Fig. 5: Seasonal variations of mean hydrochemical parameters in the six wetlands in the dry season (Dec.-April) and wet season (July-Oct.) (All axes were re-scaled to log10).

sites, as their levels were low and within tolerable limits for aquatic life.

For the wet season, three clusters were produced and consisted of Wuntori and Tugu in cluster I; Nabogo, Adayili and Bunglung in cluster II and Kukobila in Cluster III (Fig. 7). Farming activities was the predominant disturbance in four sites (Wuntori, Kukobila, Nabogo and Bunglung constructed wetlands) (Tab. 4) and this reflected in high concentrated levels of ammonia reported in Nabogo (2.3±0.6) and Bunglung (1.3±0.09) (Fig. 3, Tab. 1). Bushfire and grazing pressure, was the least driver of change across the six sites.

Discussion

The quality of surface water within a region is governed by both natural processes (such as precipitation rate, weathering processes and soil erosion) and anthropogenic effects (such as urban, industrial and agricultural activities and the human exploitation of water resources) (Mahavi *et al.* 2005; Liao *et al.* 2007; Nouri *et al.* 2008). And these processes play a critical role in determining the health

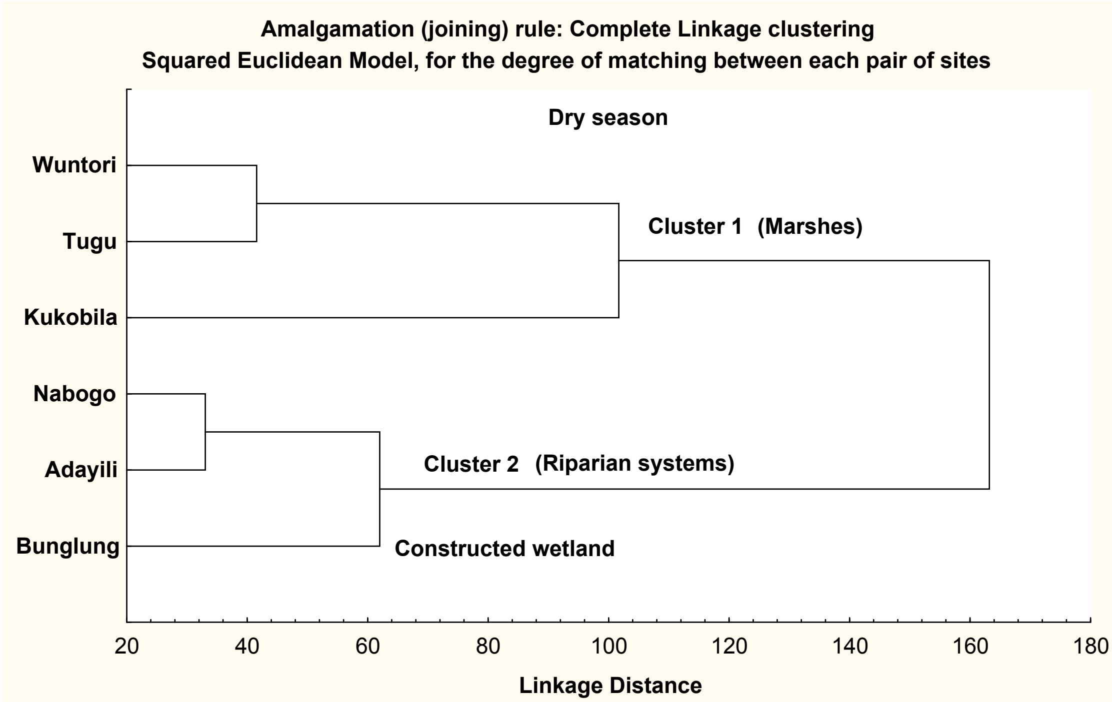

Fig. 6: Hierarchical Cluster Analysis (HCA) dendrogram showing three clusters of similar water quality characteristics, in the six sites in wet season

Tab. 3: Rank of environmental disturbances identified on the basis of severity across the six wetlands of the Wetland classes in wet season

Treats	Close shallow marshes		Open deep marshes	Riparian systems		Constructed wetlands
	Wuntori	*Tugu*	*Kukobila*	*Adayili*	*Nabogo*	*Bunglung*
Grazing pressure	4	4	4	3	1	4
Bushfire	4	3	4	3	4	3
Farming activities	1	2	2	1	1	4
Illegal fishing methods	4	2	4	4	3	3

[a]Status of disturbances severity: 4 = the threat is found throughout (50%) the site; 3 = the threat is spread in 15–50% of the site; 2 = the threat is scattered (5–15%); and 1, the threat is much localized (<5%). Source of ranking after Battisti *et al.* (2009) and Salafsky *et al.* (2009).

of a watershed and to make necessary management decisions to control current and future pollution of receiving water bodies (Khadam and Kaluarachchi, 2006). In this study, seasonal variations in water quality partly influenced anthropogenic disturbances, such as farming activities, bushfires and illegal fishing methods. Increased levels of NH_3 in Nobogo (2.3±0.6 mg/L) in the dry season and Bunglung (2.2±0.4 mg/L) in the wet season, was probably due to run-off of fertilizer application from farmlands. Rivers in watersheds with substantial agricultural and urban land use, experience increased inputs and varying compositions of organic matter (Sickman *et al.* 2007) and excessive concentrations of nutrients from fertilizer application and watershed releases (Easton et al. 2007). Documented levels of NH_3 were far more than the maximum allowable limit for aquatic life (0.08–0.73 m/L), at pH of 6.5–9.0 and 30 º C (US-EPA, 1985). Although, ammonia levels were high in this study, they did not affect the functional status of the wetlands, due to the fact that weak acid to neutral pH (6.5-7.8) and surface water temperatures in the range of 29.8±0.5ºC - 31.3±0.2ºC, negate any toxic effect on aquatic life. Chapman (1996) argue that elevated levels of (NH_3) at low pH levels and surface water temperature above 36ºC, are toxic to aquatic life and therefore, detrimental to the ecological balance of water bodies at low pH levels. Johnson *et* *al.* (1997) observed similar increase in ammonia concentration in the summer than autumn in Mid-western stream ecosystems. Low concentrated levels of nitrate-nitrogen (0.2–2.4 mg/L) and phosphate (0.003–0.7 mg/L) in the six sites, suggest that the six were not eutrophied. This is confirmed by Chapman (1996) who stated that Concentrations in excess of 5 mg/L NO3-N usually indicate pollution by human or animal waste, or fertilizer run-off, while natural concentration levels, seldom exceed 1 mg l/L. Pajman *et al.* (2009) stated that nitrate and total phosphate with positive strong loading value as the most significant parameters contributed to water quality variations in four and three seasons.

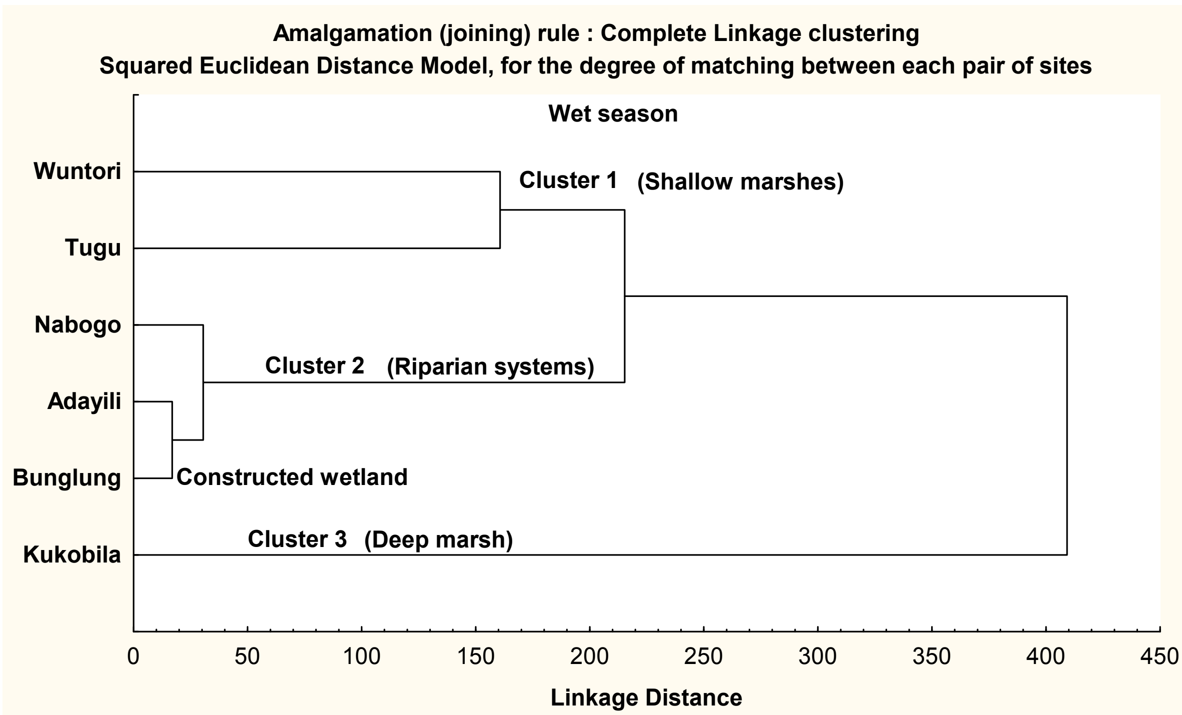

Fig. 7: Hierarchical Cluster Analysis (HCA) dendrogram showing three clusters of similar water quality characteristics, in the six sites in wet season.

Tab. 4: Rank of environmental disturbances identified on the basis of severity across the six wetlands of the Wetland classes in wet season.

Treats	Close shallow marshes		Open deep marshes	Riparian systems		Constructed wetlands
	Wuntori	*Tugu*	*Kukobila*	*Adayili*	*Nabogo*	*Bunglung*
Grazing pressure	1	1	2	2	1	3
Bushfire	1	1	1	2	1	1
Farming activities	4	3	4	3	4	4
Illegal fishing methods	3	2	2	2	3	2

[a]Status of disturbances severity: 4 = the threat is found throughout (50%) the site; 3 = the threat is spread in 15–50% of the site; 2 = the threat is scattered (5–15%); and 1, the threat is much localized (<5%). Source of ranking after Battisti et al. (2009) and Salafsky et al. (2009).

Though DO levels were generally low, values were higher in the wet season and similar to values recorded in the Haraz River Basin in Iran in winter and autumn than summer (Pejman *et al.* 2009). Low DO levels in the six sites (3.5±0.09–1.7±0.1 mg/L), showed a general hypoxic condition and this is in part attributed to increase in surface water temperature (30.1±0.2ºC-31.3±0.9ºC), brought about by burning of aquatic macrophytes. Other studies suggest that low DO can occur when there is addition of organic pollutants and nutrients that fuel bacterial and algal production and respiration, leading to the net consumption of oxygen in the water column (Correll, 1998; Barton and Tayler, 1996). Kramer (1987) and Chapman (1996) conclude that hypoxic condition usually occur when DO concentrations are < 5 mg/l, and this adversely affect the functioning and survival of biological communities. While below 2 mg/L, may lead to the death of most aquatic life. Chapman (1996) further indicated that in fresh-waters dissolved oxygen (DO) at sea level ranges from 15 mg/L at 0°C to 8 mg/L at 25°C. Thus water quality guidelines for dissolved oxygen concentration levels of 5.5- 6 in warm water and 6.5 – 9.5 in cold water, are necessary for the protection of freshwater aquatic life (Canadian Council of Resources and Environment, 1987; Truelson, 1997). Increased in turbidity in Kukobila during the wet season (395±2.7 NTU), were within tolerable range of 1 – 1000 NTU provided by Chen *et al*. (2012). Although turbidity was within the acceptable level, its relative increase in Kukobila, was probably due to intense farming activities, leading to surface run-off and deposition of the transformed soil structure into the water column. Chapman (1996), argue that turbidity vary seasonally according to biological activity in the water column and surface run-off carrying soil particles. Major ions (Ca^{2+} and Mg^{2+}) in this study did not contribute to water hardness and alkalinity, since they were within acceptable limits necessary for aquatic life. This findings is supported by Chapman (1996), who indicated that Calcium and magnesium concentrations in natural waters are typically < 15 mg/L and > 100 mg/L, respectively, while waters associated with carbonate-rich rock concentrations may reach 30-100 mg.

Conclusion

Overall, seasonal variations in water quality were not significant across the six sites. Nutrient load were at tolerable levels necessary for aquatic life. Ammonia concentration and turbidity were high and linked to nutrient run-off from nearby farmlands, especially in Nabogo and Bunglung wetlands. Dissolved oxygen concentration, was well below optimal levels in the dry and wet seasons. This has the potential to impact on aquatic life. Our findings in this study suggest that the current functioning status of the six wetlands are generally goodcompared with some coastal swamp and mangrove wetlands in Ghana. However, emerging disturbances such as farming activities, bushfire and grazing activities, could potentially affect their ecological integrity. Thus, strict enforcement of conservation measures will be vital in curbing any possible future degradation of the wetlands, giving that the livelihood support of most rural dwellers in Northern Ghana, are derived from these wetlands.

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