An Integrated Assessment of the Ecological Health Status of Coastal Aquatic Ecosystems of Ada in Ghana

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Abstract

This paper aims at assessing the ecological health status of aquatic ecosystems in the coastal area of Ada in Ghana. Healthy aquatic ecosystems are characterized by high species diversity, good water and habitat quality among others. An ecological assessment was conducted to describe the landuse pattern, water quality and habitat quality of critical aquatic ecosystems. Physicochemical parameters of water were monitored for three months each in the dry and wet seasons. Biological components which composed of macroinvertebrate and aquatic macrophyte were studied to determine the biodiversity status. The results revealed that 70% of the sampled aquatic ecosystems have concentrations of water parameters within the limits of natural background levels. However, the concentrations of nitrates and phosphates were significantly higher than the recommended World Health Organization (WHO) standards for healthy aquatic ecosystems. With regards to landuse and habitat quality, seventy percent (70%) of the sampled ecosystems were found to be in poor condition. Increasing effort on awareness programmes is needed to improve community participation to ensure proper disposal of domestic and industrial waste.

Introduction

The main components of natural ecosystems have been categorized as biological, physical and chemical components and comprise several different subsystems interacting together (Thom and O'Rourke, 2005). In a healthy ecosystem, there is balanced interaction among the various components and the whole natural system functions together to provide the necessary ecosystem services which support life (Myers *et al.*, 2013). The direct and indirect influence of natural and anthropogenic factors could compromise the resilience and functions of ecosystems (Lu *et al.*, 2015). Climate change has influenced the composition and dynamics of biodiversity. Expansion of agricultural lands and settlement areas has led to a reduction of biodiversity (Wheeler and Von Braun, 2013). The negative implications of these stressors have had a greater impact on the phenology of biodiversity. The result has been gradual reduction of ecosystem services rendering ecosystems less productive or unhealthy (Lu *et al.*, 2015).

There is now abundant evidence that many natural ecosystems have been over-exploited by humans. Various biophysical systems at regional and global levels have become highly stressed and performing poorly (Allan *et al.*, 2013, Costanza *et al.*, 1992). The rapid deterioration of the world's major ecosystems has strengthened the need for effective ecosystem monitoring and the development of an integrated approach for assessing ecosystem status and condition.

Ecosystem health is usually defined in terms of non-appearance of pathological signs in a particular natural system. For example, lakes, ponds and rivers are healthy if they show no signs of diseased condition such as contamination, loss of aquatic species or algal blooms (Rapport *et al.*, 2001). Costanza (2012) defined ecosystem health as a natural system which is healthy and free from 'distress syndrome', stable, sustainable, active and maintains its organization and autonomy overtime and is resilient to stress. In broad sense, healthy ecosystems have the capacity of maintaining biological and social functions which contribute to the sustainable goals of humanity.

There is close similarity between the definitions of ecosystem health and the concepts of stress ecology. Stress ecology defines ecological health in terms of 'system vigor, organization and resilience, as well as the absence of signs of ecosystem distress (Rapport *et al.*, 1999). Both concepts highlight presence of essential functions and key attributes that sustain life systems. Vigor or productivity is the capacity of the natural system to sustain the growth and reproduction of living things (Costanza and Mageau, 1999). The vigor of a system is simply a measure of its activity, metabolism or primary productivity. Examples include gross primary productivity in ecological systems and gross national product in economic systems. Organization is the capacity of the natural system to support different living organisms and the complex interactions that sustain them (Costanza and Mageau, 1999). For example, dissolve oxygen concentrations in a natural environment is described as a very important factor for organization in ecosystem health because oxygen is needed to support animal and plant life (Costa & Hughes, 2012). Resilience of the natural system is the capacity to withstand perturbations (Costanza and Mageau, 1999). In this effect, it determines how the natural system is able to rebound after disturbances such as floods, fire and storms. In practical terms, these attributes interconnect within both concepts of ecosystem health and stress ecology. Arthington et al., (2010) summarizes a healthy ecosystem as one that is sustainable. It has the ability to maintain its structure (organization) and function (vigor) over time in the face of external stress (resilience).

The holistic and effective approach for ecosystem assessment considers an approach which takes into account all the major components of the natural ecosystem categorized as chemical, physical and biological components. It is also important to know the objective of assessment which will determine the much relevant parameters or subcomponents to test or monitor for an ecosystem investigation. This study focused on landuse, water and habitat investigations. It tested and monitored physicochemical parameters of water and compared macroinvertebrate and plant diversities in various aquatic ecosystems in the coastal area of Ada in Ghana. The reason was to develop a fair knowledge of the aquatic ecosystems with regards to the components, productivity and risk in the Ada coastal area. This objective is in connection with a broader research project that seeks to propose an educational model to enhance community stewardship of aquatic ecosystems in the coastal communities.

Challenges in the coastal areas of Ghana

Studies by Jonah (2014) indicate that there is lack of proper management interventions and poor monitoring systems to understand what is really happening in the coastal areas of Ghana. One crucial thing about the coastal area is that, the number of people moving into and settling in the coast keeps increasing (Moller-Jensen and Knudsen, 2008). The situation is partly attributed to economic gains particularly fishing and tourism (Otoo *et al*, 2006). The coastal areas have a number of attractions which make them a desirable place for many people especially migrants from the hinterlands. People like the beaches and they move to live there. These activities are increasing human footprint along the coast of Ghana (Olympio and Amos-Abanyie, 2013).

The increasing rate of human activities on ecosystems without proper management measures comes with negative multiple effects which eventually lead to ecosystem degradation: a threat to human health, loss of biodiversity, new diseases among organisms, harmful algal blooms, siltation and reduced water quality (Ansari *et al*., 2010). A study by Lawson *et al*., (2015) highlights the major environmental challenges along the coast of Ghana to be open defecation, pollution, poor waste management and the use of unsustainable fishing methods. The coastal areas of Ghana have not been given the needed attention to harness the full potential for economic, social and environmental gains. However, current trends keep subjecting many of the rich coastal ecosystems to degradation beyond restoration. Proper management systems are relevant now to keep resilient and productive ecosystems.

The impacts of sea level rise and poor sanitation were common observable environmental challenges in the Ada coastal zone in Ghana (Otoo *et'al,* 2006). Many structures and properties have been eroded by the rising sea level. According to the Ada East District Assembly, coastal erosion has been undertaken by the Government of Ghana, under the Ada Coastal and Volta Estuary Defense Project. Work was progressively steady and it was expected that, the project would solve the increasing loss of beaches to the sea, estimated to be 2.5 metres per annum (AEDA, 2016).

The challenge now is to tackle the issue of excessive pollution of the environment with waste which affects coastal ecosystems. A recent environmental impact assessment conducted by Dredging International revealed that environmental management is poor in the District (AEDA, 2016). Most of the corridors of the plains are highly engulfed with filth especially with materials such as sachet rubbers, polyethylene bags, plastic bottles and metallic materials which are not easily degradable. Excessive livestock grazing and indiscriminate felling of trees have rendered most parts of the coastal area bare. This is gradually causing damage to the coastal ecosystems (AEDA, 2016). Ecological investigations, biotic and abiotic components studies will provide a baseline data for effective monitoring of the ecosystems.

Abiotic and biotic influence on aquatic ecosystem health

Aquatic ecosystems are described as ecologically diverse ecosystems with several physical and biological interactions. However, human activities continue to negatively affect the biological and physical processes of these natural sites. For example, wetland ecosystems regarded as one of the productive ecosystems of the world have increasingly been affected by poor water quality due to human activities. The quality of water in the natural environment depends on various abiotic and biotic constituents and their interactions, which are mostly influenced by the immediate surroundings of the particular region. Industrial waste and the municipal solid waste have emerged as the leading causes of pollution of surface water (Patil *et al*., 2012). Physicochemical parameter studies have been very important in the process of investigating the quality of aquatic systems. Aftab et al., (2005) studied various physicochemical parameters and determined higher quantities of electrical conductivity (EC), total dissolve solids (TDS), total suspended solids (TSS), biological oxygen demand (BOD), chemical oxygen demand

(COD) and ammonia than permissible limits in water bodies which was traced to untreated fertilizer effluent which is carried by run-offs. Pawar *et al.*, (2006) studied physicochemical parameters in bore well and dug well water samples and attributed high concentration to industrial pollution. Dey *et al.*, (2005) studied physiochemical parameters of water samples drawn from the River Koel, Shankha and Brahmani and concluded that dilution during rainy season decreases the metal concentration level to a considerable extent. Poonkothai and Parvatham (2005) studied physicochemical and microbiological contents of automobile wastewater and their results indicated higher values than permissible limits which render the waste water unsafe in the natural environment. These research works were important in determining the health of aquatic ecosystems. They provided information such as sensitive degradation hotspots which would guide the design of awareness creation programmes.

A category of physicochemical parameters have been described as key parameters directly related to water quality and ecosystem health (Costa and Hughes, 2012). In an aquatic ecosystem, the water temperature controls the rate of all chemical reactions and affects growth, reproduction and development. Drastic temperature changes can be fatal to the living organisms as it disrupts the physiological processes (Edjere *et al.*, 2016). pH is most important in determining the corrosive nature of water. The lower the pH value, the higher the corrosive nature of water and can cause stress to many aquatic species (Gupta *et al.*, 2009) Dissolved oxygen (DO) correlation with water parameters gives several direct and indirect information e.g. bacterial activity, photosynthesis, nutrients availability and stratification (Premlata, 2009). An excess of nitrogen and phosphorous in coastal waters lead to eutrophication (Ansari *et al.*, 2010). Most of the nitrogen that enters coastal waters is from anthropogenic sources (Premlata, 2009). The inputs originate primarily from wastewater, runoff and atmospheric deposition (Costa and Hughes, 2012). Turbidity measures water clarity or how much the material suspended in the water column decreases light penetration. High levels of turbidity can result from natural disturbances such as storms, wave action and bottom feeding animals as well as anthropogenic disturbances such as urban runoff, waste discharge, dredging and boating (Costa and Hughes, 2012). Salinity is a key factor especially in intermediary saline aquatic environment like an estuary. It affects the variety and well-being of the various aquatic organisms living in an estuary (NCCF, 2000).

Seasonal variation of physicochemical factors is important to consider in ecological assessment because it helps to determine the trend of spatio-temporal changes of important abiotic factors and their effects on the biotic components. A resilient ecosystem is able to function as a waste receptacle, clean and absorb the type and quantity of contaminants in a particular locality and in different seasonal conditions of the year. Thus, to effectively study the health of ecosystems, it is recommendable to monitor physicochemical parameters and biological components as well as investigating the relationship between these two parameters and how they impact on each other (Patil *et al.*, 2012). Macroinvertebrates are an important food source for many fish. They are also good indicators of ecosystem health, because some species are extremely sensitive to water quality (Yazdian *et al.,* 2014). A lack of macroinvertebrates in what appears to be a healthy ecosystem can indicate the presence of short-term, but disastrous water quality issues, such as extremely hot temperatures. Another criterion for healthy ecosystem is the kind of macrophyte and the environmental quality of the area where they grow naturally. Macrophytes act as a refuge and nursery for juvenile fish and shellfish (Costa and Hughes, 2012) eg. Volta clams (*Galatea paradoxa*), many of which are commercially important species in the coastal area of Ada in Ghana. Attributes of the natural environment of a plant or plant community give an idea of their tolerance limits to various environmental conditions (Yazdian *et al*., 2014), and of the physical, chemical, and microbiological processes involved in their establishment and development (Iliopoulou-Georgudaki *et al*., 2003). In particular, healthy ecosystems capable of serving both ecological and economic functions would require a diversity of macroinvertebrates (Barbosa *et al*., 2001). Such ecosystems have different plants including annuals, perennials, common and abundant, with a high removal capacity, tolerant to local conditions like climate, pests, and diseases. These plants are usually readily propagated and established within the locality (Pérez-López *et al*., 2009).

Materials and Methods

Study area

The study focused on aquatic ecosystems located at Ada, in the Eastern coasts of Ghana. The area spans about 45km lengthwise of the Gulf of Guinea. The Ada coastal environment is one of the ecological zones of Ghana with wetlands of international importance, especially as waterfowl habitat. The protected area known as the Songhor Ramsar site contains wetlands which provide natural habitats to diverse species of plants and animals. The coastal stretch is described as an open reserve area by the Wildlife Division of the Forestry Commission of Ghana. This means that even though the coastal zone is protected, inhabitants are allowed to take resources in the ecosystems for their livelihoods under certain regulations. Recent reports by the Ada East District Assembly (AEDA) indicated that the coastal ecosystems are under degradation as a result of increasing human and economic pressure. Figure 1 shows map of Ghana, Greater Accra Region and the study area. Fifteen communities span the coastal area which stretches from Pute to Azizanya (Figure 1).

Sampling Locations

Aquatic ecosystems were located on aerial photographs of the study area and their coordinates were taken with a GPS during ground truthing (Table 1). These areas were marked as sampling locations. The data was incorporated into GIS software (ARCGIS) and plotted on aerial photographs to show the clear locations of these ecosystems. The sites were designated as S1 to S13 (Figure 2). Aerial photographs of the study area were acquired from the Marine and Fisheries Science Department of the University of Ghana.

Ecological investigations

Rapid ecological survey was undertaken to assess the landuse pattern, water quality and general habitat characteristics of the aquatic ecosystems. The concepts which guided the ecological survey were adapted from generic models including protocols provided by the Coalition for Buzzards Bay (Coalition for Buzzards Bay, 2015) and the North

TABLE 1
Sampled ecosystems in the coastal communities

Sitecode	Site description	GPS reading	
		Latitude	Longitude
S1	Upstream of Futue Stream	5.811694	0.613972
S2	Downstream of Futue Stream	5.789139	0.623778
S3	Western bank of the River Volta	5.784417	0.638444
S4	Eastern Bank of the River Volta	5.783403	0.633451
S5	Ditch	5.776833	0.646
S6	Mangrove Swamp	5.783466	0.633462
S7	Intertidal zone	5.775306	0.627361
S8	Pond	5.766782	0.650046
S9	Creek	5.773694	0.654972
S10	Creek	5.772722	0.657861
S11	Lagoon	5.771806	0.660222
S12	Lagoon	5.774925	0.663856
S13	Estuary	5.773222	0.668167

Fig. 1. Map of study location (Coastal stretch from Pute to Azizanya)

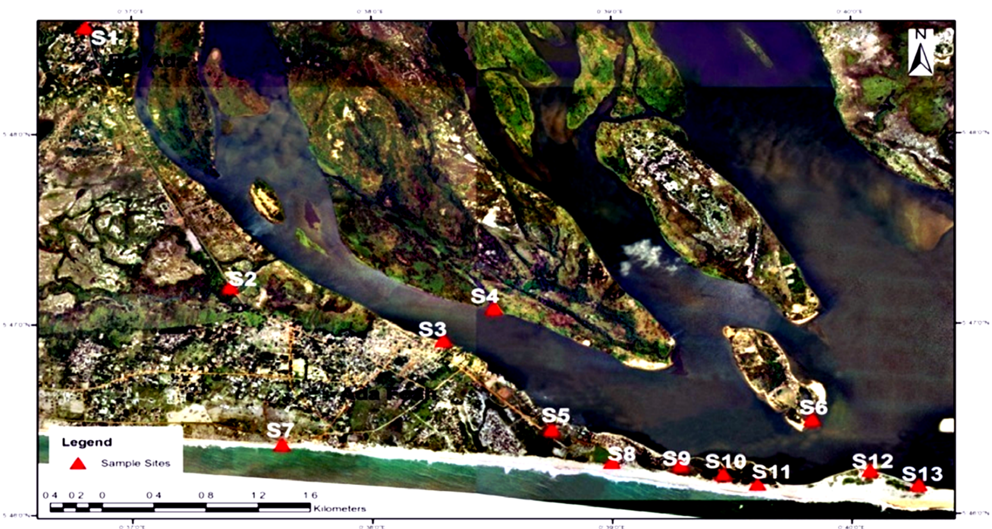

Fig. 2. Aerial photograph showing location of sampling sites
Source: Department of Marine and Fisheries, UG

Carolina Coastal Federation (NCCF, 2000). It included standardized parameters required for ecosystem assessments and acceptable levels, concentrations and natural limits for aquatic species as recommended by the World Health Organization (WHO).

The NCCF model uses a reference description in relation to the health of the particular aquatic ecosystem. The reference descriptions were in the form of a four-point scale ranging from excellent condition (5), good condition (3), bad condition (1), and very bad condition (0). The numeric score graded the condition in the location as assessed by the researcher. The scores were totaled to determine the final score. The maximum score was 35 (5 x 7) and the minimum score was 0 (0 x 7) for each of the three ecological investigations. The final scores were then grouped into two categories. Scores ranging from 25 to 35 represented a good ecosystem health whilst scores less than 25 indicated poor ecosystem health (Adapted from NCCF, 2000).

Landuse investigations

A tape-measure was used to determine the size of buffer zones along waterways at three different places in each sampling location. The average of the three measurements were taken and scored based on the NCCF guideline. Drainage ditches or culverts in waterways were noted around sampling sites and scored.

In order to determine whether dirt and pollution are threats for the water in the ecosystems, a test for compaction or hardness of the soil was conducted. A wooden peg was used to test the hardness of the soil. Starting at the edge of the waterway in a straight path, a stop was made at every three metres and the wooden peg was pushed into the ground as far as possible. The depth at which the wooden peg goes into the ground was recorded. The average was computed and scored according to the NCCF guideline. Observational approach was used to figure out if landuse around the waterways is negatively affecting the structure and water quality of the ecosystems. Sampling locations with pipes, culverts or drainage ditches were noted. Their sources and leakages were assessed visually and scored. The percentage of the water that was shaded was estimated and scored. This was so because stable temperature is vital for the survival of many living organisms in the ecosystems. Furthermore, the land type which makes up the watershed in each sampling location was visually assessed and scored based on the NCCF framework.

Water quality investigations for ecosystem quality

Chemical and Physical parameters of water were measured at the sampling locations to aid in ecosystem quality determination according to the NCCF framework (NCCF, 2000). The parameters measured included dissolved oxygen (DO) pH, percentage saturation of oxygen, nitrate and phosphate. The quantity and type of trash in the ecosystems were visually assessed. These parameters were scored based on the NCCF guidelines (NCCF, 2000). The percentage saturation was calculated to find out how much oxygen each sampling location contains and compared to how much oxygen the place should have at different temperatures (NCCF, 2000). The percentage saturation was calculated from (Equation 1):

$$\frac{\text{Measured dissolved oxygen} \times 100}{\text{Potential dissolved oxygen}} = \%\ \text{Saturation (Eq 1)}$$

Habitat investigations

The banks of waterways were described

and scored according to NCCF framework (NCCF, 2000). In addition, sediment build-up along water ways was visually assessed and scored as sediment could reduce channel of water flow and also smothering aquatic species and plants during heavy rainfall. The various kinds of habitats, the curvature of waterways, percentage of water on waterway in the ecosystems and blockages were visually assessed and scored at each sampling location (NCCF, 2000).

Physicochemical characteristics of water

Physicochemical parameters were also assessed to observe seasonal trends. Monitoring was performed for the two seasons (dry and wet). Sampling was done in May, June and July, 2016 for the wet season and in the dry season, it was conducted in the same locations in November, December, 2016 and January, 2017. Water samples were taken at thirteen different sites using random grab sampling method. At each site, waterproof handheld instrument, HORIBA Series was used on-site to measure the following parameters: pH, temperature, TDS and electric conductivity (EC), salinity, dissolved oxygen and turbidity. Additional water samples were collected at each of the sampling locations designated W1 to W13 and stored in clean 500 ml plastic bottles for analyses of nitrate and phosphates. These parameters were selected because they are directly linked to water attributes that are important for the health of aquatic ecosystems (Pesce & Wunderlin, 2000). The methods outlined in the Standard Methods for the Examination of Water and Wastewater (APHA, 1998) and HACH Company Ltd. (1996) DR/2010 Spectrophotometer Procedure Manual was followed for the analyses of nitrates and phosphates.

Macroinvertebrate study

The procedure by Perkins and Ramberg (2004) was followed for the macroinvertebrate sampling. Sweep net samples were taken with 10 sweeps at fringe vegetation sites in the sampling locations. The collected samples were preserved with formaldehyde and Rose Bengal as a staining agent to help sort organisms. The samples were preserved in an ice chest at 4°C and taken to the Ecological Laboratory of University of Ghana for immediate analysis. Each invertebrate sample was washed and placed on white trays, sorted, identified and counted. A hand lens was used for the identification of smaller invertebrates that were difficult to identify by eye. The identification key by Macan (1979) was used. Analysis for macroinvertebrates was done using biological diversity indices.

Aquatic macrophyte study

For the macrophyte inventory, twelve out of thirteen sites were sampled. Sampling site S13 had no macrophytes. Macrophytes found in the waterways or on the margins and inner banks of the sampling sites were collected and identified by means of random quadrat throws. Ten throws of 1m^2 quadrat were conducted at each site and plants in each quadrat were inventoried. Counts were done and population density was estimated for each species as (number of plants of the species “x” / 10 throws). Samples were collected and identified at the Ecological laboratory of the University of Ghana.

Data analysis

Both qualitative (observational) and quantitative data were scored according to NCCF framework (NCCF, 2000) similar to a Likert scale. The Likert scale allows the

TABLE 2
Health indices used to assess the sampling locations

Health index rating	Landuse score	Water quality score	Habitat score
Good	25 to 35	25 to 35	25 to 35
Poor	Less than 25	Less than 25	Less than 25

researcher to make personal responses to a series of statements which are related to the study objectives (Dunlap and Van Liere (1978, Schultz and Zelezny, 1999, Tweneboah, 2009). However in the present study, the scoring was aided by guidelines based on observed status of ecosystem, human activities or quantitative determination of a parameter in question. Each sampling station was categorized as 'good' or 'poor' based on the guidelines given in Table 2. Green circle were used to mark areas which fell in the good category and red circle marked areas which fell in the poor category with respect to ecological health.

Descriptive statistics were used to describe results from monitoring physicochemical parameters of water, macroinvertebrate and aquatic macrophyte studies. Mean values of physicochemical parameters were compared with recommended WHO guideline values using the t-test paired two samples for mean using Microsoft Excel 2007. All measurements were done at 5% level of significance.

The richness and evenness of species were computed to describe biodiversity in the study area (Leinster and Cobbold, 2012; Bibi and Ali, 2013). The Shannon-Weiner Index (Shannon and Weaver, 1949) and Simpson Index (Simpson, 1949) were also used to evaluate the macroinvertebrate and macrophyte diversity. Shannon diversity is a widely used index for comparing diversity among various habitats (Clarke and Warwick, 2001). It was calculated to compare species diversity in the different sampling locations based on the formula below:

$$H' = - [\sum Piln Pi] \qquad (Eq2)$$

Where, H' = Diversity Index; Pi = is the proportion of each species in the sample; lnPi = natural logarithm of this proportion. The value of Shannon Weiner Diversity Index usually falls between 1.5 and 3.5. Values outside these ranges are usually computed in rare cases. Higher values close to 4.6 give an indication that the numbers of individuals are evenly distributed between all the species (Bibi and Ali, 2013). Simpson index (D) was computed to determine the probability that any two individuals randomly selected from a sample will belong to the same species. It was measured by the formula:

$$D = 1 - \{\sum n\,(n-1)/N\,(N-1)\} \qquad (Eq3)$$

Where n = the total number of macroinvertebrate /macrophyte of a particular species. N = the total number of macroinvertebrates/macrophyte of all species.

Results

Ecosystem health index

Table 3 below presents the results from the ecological investigations conducted in the study area. Categorized under landuse, water and habitat quality, conditions in sites S4 (eastern bank of the River Volta), S6 (mangrove swamp) and S13 (estuary) were favourable for living organisms in the ecosystem. This could be attributed to the fact that these zones were relatively far from human influence. The mangrove swamp for instance help to sieve out pollutants from running waters before entering the main waterways in the aquatic ecosystems. Sites S5 (ditch), S8 (pond) S11 and S12 (lagoons) were poor in landuse, water and habitat quality. The water from the ditch and lagoons were polluted as inhabitants living close by, continue to dispose of garbage into the water bodies. For habitat investigations, ten sites rated poor which is not a good signal for ecosystem health. These ecosystems have eroded banks, blockages, lots of trash and poor habitable locations for biotic conditions.

Sampling site S2 (downstream of the Futue stream), indicated a high-water quality and landuse score but a low habitat quality score. This is an indication of poor habitat condition which is not resulting from the immediate landuse. Site S3 (western bank of river) shows a high-water quality score but indicated a low landuse score which is an indication that landuse problem is not affecting ecosystems within the period of sampling. Such problem in the ecosystem might be seasonal or periodical. Site S2 (downstream of the Futue stream) presented a low habitat score and a high landuse score. This could be attributed to the fact that the problems in the habitats of the ecosystem were not caused by nearby landuse but could be the result of landuse up stream. Site S1 (upstream of the Futue stream) indicated a low score for both habitats and landuse which reflects that landuse is negatively affecting the habitats in the ecosystems.

Seventy percent (70%) of the sampling areas were found to be in the poor condition of landuse impact on aquatic ecosystems. Generally, areas away from the settlement zones indicated a good landuse score. These were S1 (downstream of the Futue stream), S4 (western bank of the river), S6 (mangrove swamp) and S13 (estuary). Seventy percent (70%) of the sampling areas indicated good water quality. However, water in the lentic

TABLE 3
Landuse, Water quality and Habitat Assessment

	Sampling areas	Landuse score	Rating	Water quality score	Rating	Habitat score	Rating
S1	Stream	20	🔴	33	🟢	13	🔴
S2	Stream	28	🟢	31	🟢	21	🔴
S3	River	17	🔴	29	🟢	19	🔴
S4	River	29	🟢	35	🟢	25	🟢
S5	Ditch	18	🔴	23	🔴	11	🔴
S6	Mangrove Swamp	30	🟢	31	🟢	29	🟢
S7	Intertidal zone	15	🔴	25	🟢	18	🔴
S8	Pond	20	🔴	23	🔴	19	🔴
S9	Creek	20	🔴	29	🟢	15	🔴
S10	Creek	19	🔴	31	🟢	17	🔴
S11	Lagoon	19	🔴	23	🔴	19	🔴
S12	Lagoon	17	🔴	23	🔴	11	🔴
S13	Estuary	28	🟢	31	🟢	25	🟢

ecosystems were found to be of poor quality. The poor water quality sites were S5 (ditch), S8 (pond), S11 (lagoon) and S12 (lagoon). Close to 80% of the sampling areas were poor with respect to habitat quality. It was realized that the aquatic ecosystems in the eastern side of the River Volta presented good habitats quality for living organisms. These sites were S4 (eastern bank of the river), S6 (mangrove swamp) and S13 (estuary).

Seasonal variation of physicochemical parameters

Mean water temperature for the various sampling locations did not show significant variation for both dry and wet seasons. The highest temperature was recorded in site W8 (pond) during the dry season at 33°C.

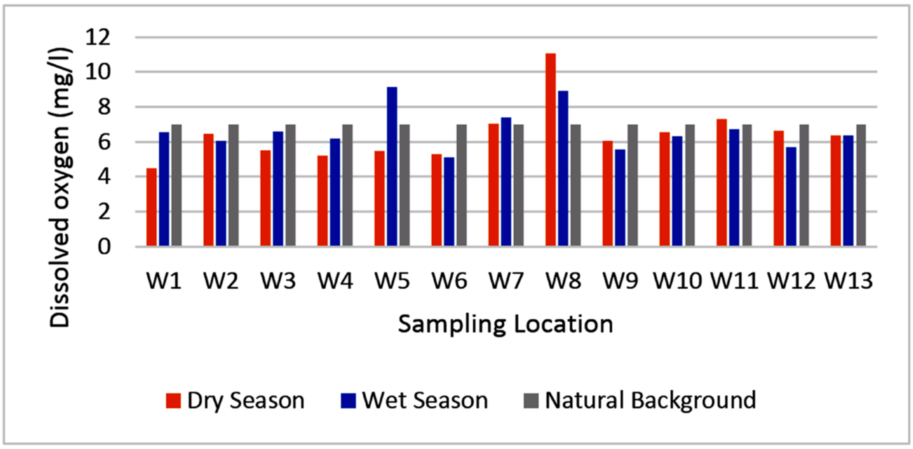

Fig. 3. Mean dissolved oxygen concentrations at the sampling locations

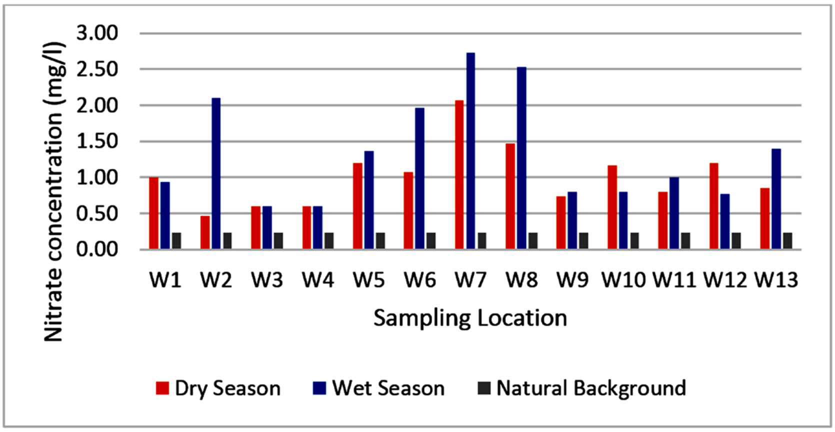

Fig. 4. Mean Nitrate concentrations at the sampling locations

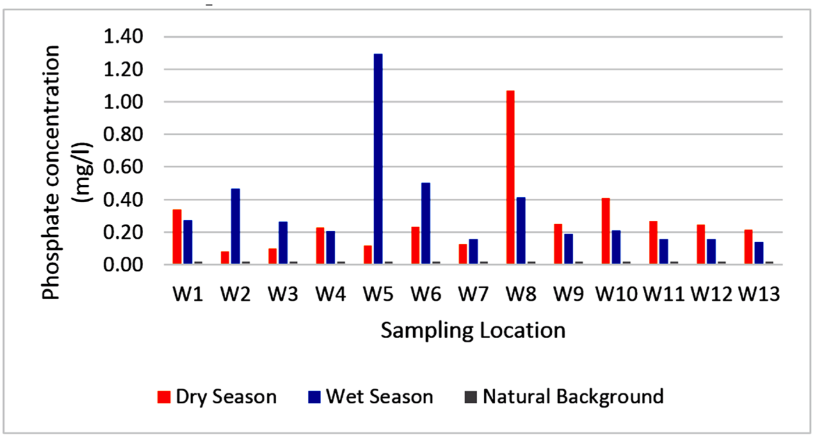

Fig. 5. Mean Phosphate concentrations at the sampling locations

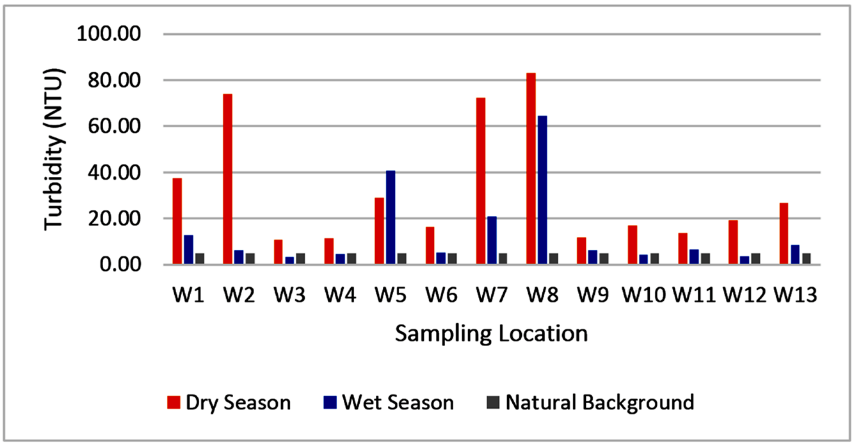

Fig. 6. Mean Turbidity at the sampling locations

For both wet and dry season salinity values recorded indicated slight differences. The salinity levels recorded at sites W7 (intertidal zone) and W13 (estuary) were within range of natural background levels of 35mg/l and 0.5 to 35mg/l respectively. Site W7 is an intertidal zone containing marine water and W13 is estuarine which is influenced by both marine and fresh waters.

Figure 3 presents the mean DO for the sampling locations. The sites which were close to the marine environment did not show significant variation for both dry and wet seasons for mean DO concentrations (P=0.35). However, for the inland areas within the coastal zone, the wet seasons recorded relatively higher values than the dry season. In all, DO concentrations for both the dry and wet seasons were above 4mg/l which is the minimum required for the survival of the biological components of the ecosystems (Begum, 2008). The highest mean DO was recorded at site W8 (pond) at 11mg/l.

Nitrate levels at the various sampling locations were relatively very high compared to the natural background of 0.23mg/l (APHA, 1998). Similar trends were recorded for both dry and wet seasons. The highest nitrate concentration was recorded in site W7 (intertidal zone) at 2.75mg/l in the wet season (Figure 4).

Mean phosphate concentrations at the various sampling locations were also relatively high compared to natural background of 0.02mg/l (APHA, 1998). Higher levels were recorded at the sites close to marine environments compared to inland areas and site W5 (ditch) indicated the highest concentration of phosphate in the study area at 1.30mg/l (Figure 5).

The mean total nitrogen concentrations in the wet season were significantly higher than in the dry season (P=0.01; $p<0.05$). For total phosphorous concentration, the levels in the dry season were relatively higher but no significant variations (P=0.12). However, site W5 (ditch) recorded the highest level at 3.5mg/l which was in the wet season. The total dissolved solids (TDS) indicated higher level towards the near shore areas than the inland area of the study area. Mean conductivity increases from the inland areas towards the marine environments. There were no significant variations between the levels recorded in both seasons (P=0.37). Turbidity was relatively high compared to natural background concentration of 5NTU. Figure 6 shows the highest turbidity which was recorded in the dry season in site W8 (pond) at 83NTU. The dry season recorded higher values with significant variations (P=0.001).

The pH levels in all the sampling locations were slightly above the natural background level of 7. However, the recordings were within the range of survival (6 – 8) for aquatic organisms in ecosystems.

Macroinvertebrates and ecosystem health

Table 4 below shows macroinvertebrate diversity in the sampling locations. Results indicated relatively low diversity in the study area. Shannon diversity index revealed very low species diversity in the study area. The highest recorded was 1.5 at site S8 (pond). Simpson's diversity index also confirmed site S8 as most biodiverse. Species evenness index was very low in the study area. The highest was recorded at site S8 (Pond). Species richness also indicated relatively low values in all sampling locations. In terms of species abundance, sampling site S9 (creek) recorded the highest number of 101 for six different species identified in the location. Species variety (total number of different species) of macroinvertebrate was highest in site S9 and S4 with six varieties each.

Aquatic macrophytes and ecosystem health

Table 5 shows the aquatic macrophyte diversity description in the sampling locations. In total, 20 macrophyte species were recorded in the study area. Shannon-Weiner Diversity Index (H′) and Simpson's Diversity Index (D) were relatively higher in the areas with less human influence. For example, site 4 located in the western bank of the River Volta is away from human impact and site 6 which is also in the mangrove swamp recorded the highest scores for diversity. From the random quadrat sampling technique, *Pycreus sp* was found to

TABLE 4
Number of Macroinvertebrate per ten sweeps and diversity indices in the sampling locations

Class/Order	**Family/Species**	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**	**S11**	**S12**	**S13**
Gastropoda	Ampullariidae/Pomacea											3		
Decapoda	Ocypode quadrata	11						3	11	3				
Diptera	Chironomidae/ Chironomus		8						4					6
Diptera	Culicidae/Anopheles		9											4
Osteichthyes	Juvenile fish	3				14						6		
Odonata	Calopterygidae/Phaon iridipennis				2									
Bivalvia	Etheriidae/Etheria							1		1				
Crustacea	Penaeidae/Penaeus		7		5	64	9		7	9	8	14	17	
Gastropoda	Potamididae/ Tympanostonus fuscatus	7							7	27	7	6	12	4
Gastropoda	Lymnaeidae/Lymnaea		2		18		10			56	16			
Gastropoda	Pleuroceridae/ Pleurocera			4				4						
Polychaeta	Capitellidae/Capitella				5									
Polychaeta	Nephtyidae/Nephtys				8					5	9			
Ephemeroptera	Baetidae/Centroptilum				1									
Odonata	Libellulidae/Zygonyx								4					
Species abundance (n)		21.0	26.0	4.0	39.0	78.0	19.0	8.0	33.0	101.0	40.0	29.0	29.0	14.0
Simpson Diversity index		0.38	0.27	1.00	0.27	0.70	0.47	0.32	0.21	0.39	0.26	0.31	0.50	0.30
Evenness		0.64	0.83	0.00	0.95	0.31	0.45	0.64	1.00	0.78	0.87	0.81	0.44	0.70
Species Richness		0.66	0.92	0.00	1.37	0.23	0.34	0.96	1.14	1.08	0.81	0.89	0.30	0.76
Shannon Diversity index		0.98	1.28	0.00	1.45	0.47	0.69	0.98	1.54	1.19	1.33	1.24	0.68	1.08
Species variety (S)		3	4	1	6	2	2	3	5	6	4	4	2	3

TABLE 5
Population density of Aquatic macrophyte species and diversity indices in the sampling locations

Family	Species	Growth form	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
Pontederiaceae	*Eichhornia crassipes*	Free-floating	6.1	6.2	0.3	16.2		7.9			16.7			0.2
Cyperaceae	*Scirpus cubensis*	Emergent	2											
Nymphaeaceae	*Nymphaea lotus*	Floating-leaved	2.2					0.8						
Poaceae	*Vossia cuspidata*	Emergent	16.9		7.2	2.8		4		3		3		5.4
Alismataceae	*Sagittaria guayanensis*	Floating-leaved	1.7											
Cyperaceae	*Pycreus mundtii*	Emergent	1		0.3		84							
Acanthaceae	*Avicennia germinans*	Shrub	0.2				0.5			0.4		0.2	0.2	
Poaceae	*Panicum maximum*	Herb	1.5				9.8		20.9	23	2.8			3
Fabaceae	*Acacia*	Tree	0.3	1.4										
Fabaceae	*Mimosa pudica*	Emergent		4.9										
Lentibulariaceae	*Utricularia reflexa*	Submerged		7.9			0.3							
Meliaceae	*Azadirachta indica*	Tree			0.3									
Convolvulaceae	*Ipomoea aquatica*	Emergent				3.4								
Solanaceae	*Solanum lycopersicum*	Herb			0.3									
Polygonaceae	*Polygonum lanigarum*	Emergent				3		4.8						
Ceratophyllaceae	*Ceratophyllum demersum*	Submerged				5.4		0.5			0.9			
Hydrocharitaceae	*Vallisneria aethiopica*	Submerged				19		1			33.2			
Commelinaceae	*Commelina diffusa*	Emergent						0.3						
Typhaceae	*Typha domingensis*	Emergent								11		1.9	11.8	
Salviniaceae	*Salvinia molesta*	Free-floating						0.2	2.3					
Species abundance (n)			31.9	20.4	8.4	49.8	94.6	19.5	23.2	37.4	53.6	5.1	12	8.6
Simpson Diversity			0.67	0.70	0.26	0.73	0.20	0.73	0.18	0.53	0.52	0.51	0.03	0.48
Evenness			0.68	0.91	0.38	0.83	0.28	0.73	0.47	0.66	0.64	0.74	0.12	0.68
Species Richness			2.31	1.00	1.88	1.28	0.66	2.36	0.32	0.83	0.75	1.23	0.40	0.93
Shannon Diversity			1.50	1.26	0.61	1.49	0.39	1.53	0.32	0.91	0.88	0.81	0.09	0.75
Species variety (S)			9	4	5	6	4	8	2	4	4	3	2	3

be highest in population density which was located in sampling site S5 (Vegetation along the ditch). According to the population size within the 50m^2, *Pycreus sp* was still found to be the most abundant estimated at 4200 species. *Eichhornia crassipes* was the most frequent macrophyte in the study area. However, species like *Vossia, Nymphea*, *Ceratophyllum*, *Vallisneria* and *Typha species* were found to be common along the aquatic systems. It was observed that *Eichhornia crassipes* which has been described as an exotic plant is taking over the niche of the local plant species. There were no organisms recorded in site 13 which was along the estuary.

Discussion

It is necessary to conduct periodic ecological investigations to monitor pollution of aquatic environment (Adjei-Boateng *et al*., 2010; Bengraine and Marhaba, 2003). The study has revealed a couple of challenges concerning landuse, water and habitat quality in the aquatic ecosystems in the Ada coastal environment of Ghana. Threats to the aquatic ecosystems are primarily due to human activities in the settlement areas of the coastal zone. The area continues to develop over the years with increasing population and economic pressures (AEDA, 2016). The study indicates that poor landuse is having a negative impact on habitat quality which results in the loss of macroinvertebrates and macrophytes. The general observation that buffer zones were devoid of vegetation is key to understanding some of the factors contributing to the degradation of ecosystems in the study area. Buffer zones are characterised by natural sites typically vegetation which separate human activities from water bodies. They thus help to sieve out pollutants from running water before ending up in streams, lakes, rivers and the sea (Costa and Hughes, 2012). Improper landuse due to habitat destruction as reflected in the findings suggest activities such as illegal felling of trees within the buffer zones contribute to the state of the ecosystem quality. Improper landuse activities, declining water quality and habitat destruction are gradually affecting the resilience of aquatic ecosystem in the coastal area of Ada. Owusu *et al*., (2016) highlights that various water resources are in a decrease as a result of declining water quality in Ghana. The situation also poses danger to the human health and the overall sustainability of the environment. Studies by Addo *et al.*, (2015) recommends that water bodies running through industrial and settlement sites should be monitored and treated before public use.

The seasonal variations of physicochemical parameters during the monitoring period indicated slightly higher values in the wet season (May, June and July, 2016) compared to the dry season (November, December 2016 and January, 2017). This observation reflected in parameters like conductivity, TDS, nitrate, and total nitrogen in the aquatic ecosystems. Parameters such as phosphate, total phosphorous and turbidity did not show clear variation in the two seasons. However, compared to the natural background level, they were found to be higher. Conductivity values were in direct relationship with the concentrations of TDS in the water samples from the study locations. The elevated levels of the conductivity, TDS, total phosphorous, total nitrogen and turbidity in both seasons could be attributed largely to leachates that were flushed into the various aquatic ecosystems by run-off. A similar situation has been explained by Murwira *et al*., (2014) and Wilson and Tisdell (2001). The situation is also aided by other human actions like vegetation removal which may expose soil to erosion. High phosphate and nitrate levels in the water samples from the various sampling locations could be attributed to influx of domestic waste as inhabitants wash along the rivers and lagoons. Also, residue from fertilizers may be carried by the run-offs from farmlands into the aquatic environments. An earlier study by Karikari and Ansah-Asare (2006) and Aglanu and Appiah (2014) suggested human, animal and agricultural activities as the main sources of pollution in the aquatic ecosystems.

The analysis indicated that macroinvertebrate diversity of the aquatic ecosystems was poor. Simpson diversity and Shannon diversity indices for all the sampling stations indicated low levels of diversity, rendering the aquatic ecosystems unsuitable for most biotic components. Highly sensitive macroinvertebrates such as mayfly nymph and stonefly nymph which are proxy indicators of good water quality were not recorded in any of the samples taken which is an indication of significant levels of pollution in the aquatic ecosystems. However, diverse macroinvertebrates recorded at the mangrove swamp zone indicates suitability for the growth and development of other aquatic species like fish. Two most abundant macroinvertebrates within the sampling areas were the *Penaeus* and the *Lymnaea sp*. From the classification of the sampled macroinvertebrates, it was realized that gastropods are the most abundant class of species within the study area. Low biodiversity in the study area could be attributed to human impacts such as release of pollutants and domestic wastes from the communities. A similar study in Tanzania by Shimba *et al.*, (2018) has proven these actions to be the major causes.

Conclusion

The study has established that landuse patterns are relatively poor and human activities such as improper waste disposal are continuously having a negative impact on the coastal aquatic ecosystems. Water quality parameters of the aquatic ecosystems outside the settlement areas were within their natural limits. However, the water quality of streams, creeks and the ponds in the settlement areas were of poor quality. These water bodies need immediate interventions to regenerate their natural ability to sustain biotic components. Majority of the aquatic ecosystems are vulnerable to eutrophication due to high levels of nitrate and phosphate concentration.

There is the need to enhance community stewardship of aquatic ecosystems which will expose inhabitants to the current situation and human disturbances which are degrading the natural sites. It is important to find ways to enable community members personalized the issues described. Environmental awareness programmes should be designed to make people take ownership and be responsible for the ecosystems on which their livelihoods depend. An integrated approach which is sustainable is therefore recommended to enhance the stewardship sensitization programmes. The approach focuses on empowering community members with the necessary skills to control landuse activities which negatively impact on aquatic ecosystems. Community members should be well-informed about proper waste disposal systems, correct methods of fertilizers, herbicides and pesticides application which will enhance water and soil quality. Inhabitants should also be exposed to the issues of habitat destruction which is continuously threatening wildlife in the coastal zone. An integrated approach that takes into consideration the indigenous natural and human systems, action strategies which involve local community members and promotes the values of sustainability is proposed. The strategy will complement efforts to recover and enhance the resilience of aquatic ecosystems in the coastal area of Ada.

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