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Influence of human activity on diversity and abundance of insects in three wetland environments in Ghana

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Abstract. *Mensah BA, Kyerematen R, Annang T, Adu-Acheampong S. 2018. Influence of human activity on diversity and abundance of insects in three wetland environments in Ghana. Bonorowo Wetlands 2: 33-41.* The Wetland environment is unique with unique biota that includes insects. Insects serve as indicators of environmental health, nevertheless, the recent spate of human encroachment on wetlands is likely to affect its unique biotic composition, and this phenomenon poses a threat to the wetland environment. The physical and chemical quality of studied habitats in this research provided background information for comparison against the established quality standard of the wetland environment. The study involved reconnaissance surveys, insect trapping and social surveys on the impact of anthropogenic activities on insect diversity and abundance in and around the wetland environment. Twenty-two insect orders belonging to 112 families were sampled from different sites along the Sakumono, Kpeshie, and Muni-Pomadze wetlands. Species diversity and abundance were significantly different among the various locations with the most diverse being Kpeshie. Water within wetlands in Kpeshie was the most polluted although it had a positive correlation with insect diversity and abundance. Results of a survey of selected communities showed that majority of the residents had a low level of education with less appreciation of issues involving the environment including pollution. Majority of people within the surveyed communities were unable to access decent toilet facilities and publicly demarcated waste disposal sites. There was no coordinated and concerted effort to manage these three wetlands two of which are designated Ramsar sites. Activities such as farming, discharge of domestic garbage, improper fishing practices, improper disposal of industrial and human waste are increasing the pollution risk of these wetland environments.

Keywords: Abundance, diversity, insect, lagoon, wetland

INTRODUCTION

Wetlands are highly diverse habitats and are known to be among the earth's most productive ecosystems (Barbier et al. 1997). Wetlands can be classified based on their (i) components (biotic and abiotic features), (ii) functions (the interactions between the components such as nutrient cycling), and (iii) attributes such as species diversities. These characteristics of wetlands support human existence and their related economic activities. "Wetlands" is an elastic term which includes large variety of landforms. Some cold climate wetlands are unique and thus have no tropical equivalence, and vice versa. Tundras and mangroves, for instance, are unique to the temperate and tropics respectively.

Wetland resources comprise of the water, land, soils, plants, and animals, which may be exploited for subsistence, income, and employment. While wetland services such as maintenance of hydrological and biogeochemical cycles, act as management schemes for silt and other materials, erosion control plays a dominant role in maintaining the general ecological balance. For instance, it has been reported that rivers and wetlands around Lake Victoria act as natural purifiers (Scheren et al. 2000). Besides supplying local communities with resources for subsistence, wetlands support distant communities with ecological services such as flood and water flow regulation and drought alleviation, ground-water recharge, water quality protection and purification, drinking water supply and storage, erosion and sediment control, wastewater treatment, carbon retention and climate modification (Seyam et al. 2001). The New Partnership for Africa's Development (NEPAD) has identified six sectoral priorities that include the Environment Initiative in Africa which included wetland conservation which is recognized as one of the eight sub-themes for priority intervention (Anon 2001).

Insects are vital for ecosystems functioning (Samways et al. 2010). They can inhabit all conceivable habitats from the pole to the equator and occupy all trophic niches more than the level of primary producers (Resh and Carde 2003). Insects are known to be the most abundant and diverse organisms present in most environments. Insects may be used as indicators of environmental quality (Kyerematen et al. 2014 a, b; 2018 a, b; Acquah Lamptey et al. 2013 a, b, Adu-Acheampong et al. 2016) due to their short life cycles and sensitivity to perturbations. In most terrestrial ecosystems, insects are the dominant herbivores. They may significantly influence the plant community as well as reflect the variety of plant resources available to them (Barbour et al. 1998; Groves 2002). Insects in wetlands are abundant and diverse because wetlands have too shallow water depths to support the lives of many fish species and thus exerting little or no pressure on insect species which act as fish prey. The absence of many fish and other insect predators within wetlands create convenient habitats which enable insects to survive and persist especially in swampy areas.

Insects are for the large part, responsible for the breakdown of organic material such as plant, animal and animal remains, the elimination of animal waste, the aeration of the soil and the vastly important task of plant pollination. They are an essential food source for many fishes, birds, amphibians, and reptiles. Furthermore, in some parts of the world, they also constitute a significant portion of the human diet. Rare insects are sometimes used as indicators of endangered mammal species. In spite of that, insects and such related indicator species are given little attention despite their importance in the overall ecological balance (Constanza et al. 1997).

In this study, we investigated insect diversity of wetlands in three wetland environments in relations to human activities. We also investigated the impact of anthropogenic activities on wetland within the study areas using the relationship between pollution and insect diversity in these wetlands. The aim was to use the presence or absence and abundance of key insect species as proxy measures for degradation or otherwise of the wetland environments within the study areas. We hypothesize that the presence (diversity and abundance) of some insects groups is dictated by pollution within these wetlands.

MATERIALS AND METHODS

Study areas

Winneba

Winneba is located on the south coast (56 km west of Accra and 140 km east of Cape Coast). The Muni-Pomadze wetland in Winneba in the Central Region of Ghana, (Figure 1.A) is one of five internationally-recognized coastal wetlands (Ramsar sites) in Ghana under the Convention on Wetlands of International Importance (Ramsar Convention), thanks to its importance as a breeding and nesting site for migratory and resident waterbirds, insects, and terrestrial vertebrates (Collar et al. 1994; Ryan and Attuquayefio 2000; Kyerematen et al. 2014a).

The wetland is particularly vital to the local Effutu people, serving as their traditional hunting grounds, especially during their annual "Aboakyer" Festival. The swamp falls within the Coastal Savanna Vegetation Zone of Ghana, with a characteristic bimodal rainfall distribution and a low mean annual rainfall of about 854 mm. According to Gordon and Cobblah (2000), the dominant rainy season occurs from March/April to July/August with a peak in June, while the minor season runs from September to November. The dominant dry season runs from December to March and the minor dry season from August to September. Mean annual temperature ranges from 24^{o}C in August to 29^{o}C in March with a relative humidity range of 75-80% (Gordon and Cobblah 2000). The site selected for the survey lies within the boundaries of the proposed Muni-Pomadze Ramsar site. The principal sampling area was located near Mankoadze, a fishing village west of Winneba.

In recent times, the previously diverse fauna of this area including mongooses, have dwindled, with some of the animals presumed locally extinct or rare (Ryan and Attuquayefio 2000). Current evidence suggests that the degradation of the wetland could be attributable primarily to neglect and unsustainable human activities such as bushfires, farming, hunting, fuelwood harvesting and estate development (Ntiamoa-Baidu and Gordon 1991; Ryan and Ntiamoa-Baidu 1998; Kyerematen et al. 2014a).

Sakumo Lagoon

The Sakumo Lagoon is situated on the eastern part of Accra along the Accra-Tema coastal road 3 km west of Tema (Figure 1.B). The lagoon is located within latitudes 5^{o} 36.5‵‵ N and 5^{o} 38.5‵‵ N and between the longitudes 1^{o} 30’ W and 2^{o} 30’ W. The district stretches from Madina to Oyarifa on the west and the Aburi highlands in the north. It is bounded by an approximate north-south line on the east, which also defines the western boundary of Tema (Biney 1995b). The surface area is 2.7 km^2 and its catchment area covers a total area of 350 km^2 although the active catchment area is 127 km^2 because of damming of the streams leading towards the lagoon (Tumbulto and Bannerman 1995).

There are two rainy seasons with the major season starting in March and peaking in mid-July and the minor season beginning in mid-August and ending in October. The average annual rainfall is about 753 mm, and relative humidity varies from an average of 65% in mid-afternoon to 95% at night. The mean monthly temperatures range from a minimum of 24.7^{o}C in August to a maximum of 28.1^{o}C in March. The lagoon and its neighboring wetlands have been labeled as one of the five coastal Ramsar sites in Ghana (Kwei 1974).

Sakumo Lagoon is still a vast birding destination despite its position in the heart of a sprawling metropolis. Extending about 20 km east of Accra and covering up to 350 ha, Sakumo Lagoon is ideally situated for birding from the city in either the morning or afternoon. The main attraction at Sakumo is the open shallow estuary and flooded reedbeds which between September and April can support thousands of waders and an impressive list of estuarine birds. The surrounding savanna also hosts many species from dry country species and birds of prey. A couple of hours birding in the morning or afternoon at Sakumo between October and April should produce upwards of 80 species (Ryan 2005, Ntiamoa-Baidu and Gordon 1991). It was labeled as a Ramsar site on the 14th of August 1992, and it is managed by the Wildlife Division of the Forestry Commission on behalf of the state.

Figure 1. Map of the study area in Muni-Pomadze Lagoon (Winneba) (A), Kpeshie Lagoon (B), Sakumono Lagoon (C) and Ghana

Kpeshie Lagoon

The Kpeshie lagoon catchment area lies between latitude 5º 33′0 N and 5º 36′20 N and stretches between longitude 0º 9‟30‟ W′and 0º 7′10‟ W (Figure 1.C). The catchment area occupies almost 47.391551 ha. The Kpeshie lagoon is less than 1km^2 in surface area, and it is situated along the outskirts of La, a peri-urban township. The Municipal Assembly share boundaries with the following Sub Metros: Osu Clottey towards the east, Ayawaso towards the north, and Teshie to the west (Kpanja 2006).

Methods

Sampling points

Sampling points capture the main activities carried out along the stretch of the lagoons which would affect the water quality and insect diversity.

Sampling design and technique

The following trapping techniques were used to capture insects: malaise traps, yellow pan traps, light traps, fruit-baited charaxes traps, pitfall traps, flight interception traps, sweep nets and aerial nets. A regular, perpendicular walk was undertaken from predetermined sites to all the selected locations along the lagoons. To ensure that the traps were proportionally spaced, a meter tape was used to measure the distance between them. The smallest intersite distance was 50m with the largest being 250m. Where necessary a hoe and machete were utilized to cut through grass or mangrove to gain access. Sampling was done monthly during the rainy season (April to June) and the dry season (December to February) and the temperature was recorded during these seasons.

Malaise trap

This trap has been designed to collect flying insects. This rectangular tent-like trap made of black nylon netting directs the flying insects into a collecting bottle containing 70% alcohol at the top end of one side. Insects were collected after 3-5 days for subsequent identification.

Pitfall trap

This is used for trapping ground inhabiting insects and is a straight-sided container that is sunk level with the surface of the neighboring substratum. Ten traps were set at 20m intervals along the 200m transect in each area. Each trap contained a soapy solution to break the surface tension so that trapped insects would not be able to fly or crawl out. Trapped insects were collected after 3-5 days and emptied into a container containing 70% alcohol for subsequent identification.

Yellow pan trap

Yellow pan traps collect insects that are attracted to the yellow color filled with soapy water. Ten traps were set at 20m intervals along the 200m transect in each area. Trapped insects were collected after 3-5 days and emptied into plastic bottles containing 70% alcohol for subsequent identification.

Flight interception trap

This trap is commonly used to intercept flying insects which are not likely to be drawn to baits or light and is assembled of brightly colored netting. Intercepted insects fall into the trays at the bottom that contain a killing agent. One trap was set in each area. Trapped insects were collected after 3-5 days and emptied into bags containing 70% alcohol for subsequent identification.

Charaxes trap

This trap is made up of a net with a rectangular cross-section with a string attached to the four corners at the closed top and a flat wooden board connected at the open end. Bait made up of mashed rotten banana mixed with palm wine was placed on the board. Alcohol-loving insects are mostly trapped by this method. Individual traps within areas were separated from each other by at least 50m and by no more than 250m (Oduro and Aduse-Poku 2005). Standard field handling of specimens captured from charaxes traps consisted of firmly squeezing the thorax to disable the sample (Oduro and Aduse-Poku 2005).

Sweep net

The sweep net consists of a circular metallic rim with a cloth attached to form a sac with the rim as the opening with a wooden handle attached to the rim. It was swung through the vegetation with the alternating forehand and backhand strokes about 10 times and the content carefully emptied into a killing jar. The catches were later transferred into a bag containing 70% alcohol for subsequent identification.

Aerial net

The aerial net consisted of a metallic rim with a wooden handle and a fine mesh forming a sack. Swarming butterflies, dragonflies and moths were spotted and collected. The butterflies caught were placed in glassine envelopes with wings folded together. This technique prevented the insects from losing their scales, a feature very vital for identification. The other insects were transferred into killing jars containing ethyl acetate and kept in glassine envelopes for later identification.

Visual observation and direct counts

Visual counts were done whenever an insect was spotted that was out of reach to be collected or trapped. At each site, random walk sampling was used for a minimum of two hours to sample each site twice daily. This was done under sunny conditions mostly between the hours of 8:00 hours GMT and 16:00 hours GMT. The butterflies were identified by their wing patterns and colors as well as flight patterns.

Social survey

Sampling technique

This study employed a purposive sampling technique, the non-probability sampling technique.

Questionnaire administration

Questionnaires were administered in the major towns/settlements where water samples were collected in a purposive sampling and non-probability technique. A total of 280 questionnaires were administered in Winneba, Sakumono, and Kpeshie. An effort was made to interview women and men equally in each locality.

Interview

Interviews were conducted by interacting with some of the locals in sensitive areas such as the small-scale industries and the lagoon sites.

Non-participatory observations

Non-participatory observations were also undertaken to enable the interviewer to generate initial information to complement the data obtained from respondents.

Sorting and species identification

All insects sampled were either placed in containers containing 70% alcohol or envelops and labeled for further identification. All insects were identified to specific level with reference to Museum collections in the Biodiversity Museum of the Department of Animal Biology and Conservation Science, University of Ghana, Legon, Scholtz and Holm (2005), Carter et al. (1992), Gullan and Craston (2005), and Boorman (1981).

Statistical analyses

Several statistical analyses were performed using SPSS (Vol.16.0) to determine if some of these environmental factors affected insect diversity within the wetlands. Data obtained from the traps at a given sampling point on a specific date were pooled to generate a single sample for each site-data combination. Data from all the traps were combined to get total insect diversity per study site and sampling period. Simpson's Index (D) Shannon-Weiner Index (H), Margalef index and the Pielou"s Evenness index ("J") were computed for measuring insect diversity.

A one-way ANOVA of insect diversity between groups of wetlands was performed to test whether there was a difference in insect diversity among the three sites (Muni-Pomadze, Sakomo lagoon, and Kpeshie lagoon). Simpson/Shannon diversity indices and Margalef richness index were calculated. Nonparametric richness estimators were applied to estimate total species richness at a site: ACE (Abundance-based coverage estimator), ICE (Incidence-based coverage estimator), Chao1 (Abundance-based coverage estimator), Chao2 (Incidence-based coverage estimator), Jack1 (First-order jackknife estimator) and jack2 (Second-order jackknife estimator).

RESULTS AND DISCUSSION

Relative abundance of insects

As many as 5,541 individual insects were recorded from all the three sites combined. Muni-Pomadze recorded 1,883, Sakumo wetlands recorded 1,530 and Kpeshie recorded 2,128. Four hundred and twenty-nine species of insects, belonging to 22 orders and 112 families were collected from all three sites. Insects belonging to the orders Hymenoptera, Diptera, Hemiptera, and Coleoptera were the most abundant and diverse in all three areas (Table 1). Hymenoptera and Diptera had the highest relative abundances of 34% and 30% respectively during the dry season. Meanwhile, Hymenoptera and Hemiptera were dominant with relative abundances of 25% and 19% respectively for the wet season.

There was no significant difference between Sakumo and Kpeshie sites, but Muni-Pomadze was significantly different from the two. The average of at least two groups of the analysis differed significantly ($p>0.05$). The abundance of insects did not vary much between Kpeshie and Sakumo, but that of Muni-Pomadze was relatively less than both Kpeshie and Sakumo, however, there was a significant difference in the relative abundance of insects sampled during the dry and the wet season. At all sampling sites, the number of individual insects collected in the wet season was higher than the dry season (Table 1). Hymenoptera was the richest order in both seasons at Sakumono with a relative abundance of 29.9% for the wet season and 9.0% for the dry season. Kpeshie recorded an overall relative abundance of 88% in the wet season and 12% in the dry season with Muni-Pomadze recording a total relative abundance of 84% in the wet season and 15.6% in the dry season.

Species richness and diversity indices

Species richness in terms of Margalef and Pielou indices were higher in the wet seasons at all three sites than the dry seasons, but the Shannon Weiner and Simpsons diversity indices were somewhat higher in the dry season than that of the wet season (Table 2).

Observed species richness

Table 3 shows that the observed species richness (Sobs) was higher at Kpeshie than the rest of the sites. The species accumulation curves were approaching an asymptote, an indication that species saturation had been reached and sampling efforts were adequate.

Social survey: Respondent information

Sex

The questionnaires were administered in Sakumono, La Trade Fair Area (Kpeshie) and Mankoadze (Muni-Pomadze) in Winneba. The distribution of the polls was done to ensure that there were an almost equal number of men (137) and women (143). The population tested in each of these locations was categorized according to the level of activities carried out by residents in these catchment areas. There were 100 respondents each from Sakumono and Mankoadze constituting 71.4% of the total respondents for each of the two sites. The rest of the respondents were from the Trade Fair Area (Kpeshie), representing 28.6% of the 280 people sampled for the study. Forty-six percent and 42% of respondents from Trade Fair and Mankoadze respectively disposed of their refuse indiscriminately (Figure 2).

Table 1. Relative abundance of individual insects captured by order from the three wetlands

Order	Sakumono	Kpeshie	Muni-Pomadze	Relative abundance %
Coleoptera	93	218	372	12
Diptera	256	524	299	20
Hymenoptera	595	518	400	27
Hemiptera	188	415	214	15
Lepidoptera	105	112	145	7
Orthoptera	89	69	96	4.6
Dictyoptera	33	36	36	2
Collembola	51	54	79	3
Dermaptera	3	3	14	0.4
Odonata	15	14	33	1
Ephemeroptera	6	6	17	0.5
Mallophaga	0	0	9	0.1
Embioptera	3	0	14	0.3
Psocoptera	26	17	43	1.5
Neuroptera	18	18	16	0.9
Trichoptera	6	23	26	0.9
Thysanopter	18	58	43	2.2
Mecoptera	0	4	5	0.1
Isoptera	10	21	5	0.7
Anoplura	0	4	0	0.07
Homoptera	14	4	14	0.6
Plecoptera	1	0	3	0.07
Total individual number (N)	1530	2118	1883	100

Table 2. Diversity and richness indices for each season in and around each lagoon

Sites	Simpson (I/D)		Shannon-Weiner (H)		Margalef (D)		Pielou (J)	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Sakumono	10.8	13.10	4.15	3.57	131.9	58.8	0.8	0.87
Kpeshie	21.32	51.19	4.87	4.33	152.9	60.8	0.97	1.05
Muni-Pomadze	4.84	14.94	2.55	3.65	139.9	55.8	0.52	0.9

Table 3. Species richness estimates at all three sites

Sites	Total Species Trapped (Sobs)	Singleton/ doubleton	Unique/duplicates	ACE/ ICE	Chao 1/ Chao 2	Jack 1/ Jack 2
Sakumono	199	79/48	19/35	246/785	264/204	218/202
Keshie	214	94/51	25/56	268/814	231/219	239/212
Muni-Pomadze	196	81/67	19/51	192/598	244/199	215/183

Table 4. Educational level breakdown

Educational Level	Sakumono	La Trade Fair	Mankoadze	Percentage (%)	Total
Primary	15	8	23	16.4	46
Middle/JHS	24	18	25	23.9	67
Secondary/SSS	22	20	20	22.14	62
Voc/Com/Tech	16	15	14	16.1	45
Tertiary	14	17	9	14.3	40
No formal education	9	2	9	7.14	20
Total	100	80	100	100	280

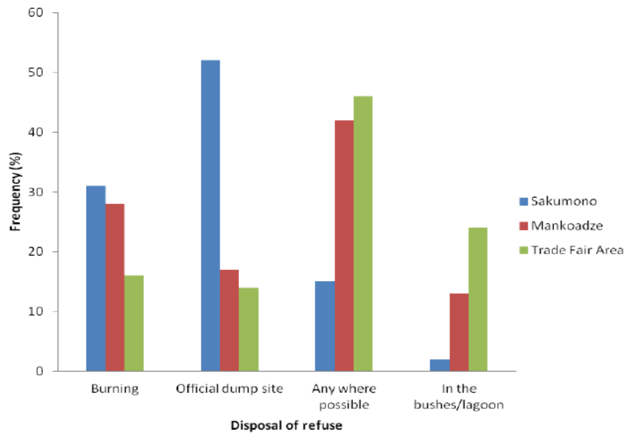

Figure 2. Mode of disposal of refuse

Educational level

Table 4 summarized the educational level of respondents. Sixty-seven individuals (23.9%) sampled had Middle or Junior High School education, 22.14% had Secondary School Education, and 16.1% had Vocational, Commercial and Technical Education.

Discussion

Insect abundance

Of the 5541 individual insects sampled, a total of 22 orders belonging to 112 families were collected and identified from distinct sites along the Sakumo, Kpeshie, and Muni-Pomadze lagoons. The most abundant order at Kpeshie was Diptera followed by Hymenoptera, Hemiptera, Coleoptera, and Lepidoptera.

Hymenoptera was the most abundant insect order followed by Diptera and Hemiptera at Sakumo, whiles Muni-Pomadze had Hymenoptera as the most abundant, followed by Coleoptera and Diptera. Insects constitute more than half of the world's known animal species (Wilson 1992) of which Lepidoptera is the second largest and most diverse order (Benton 1995). The highest number and far more varied order recorded at all the three sites was the Hymenoptera with Kpeshie being the most diverse.

The abundance and diversity of insects at a specific habitat depends on a wide range of factors including climatic conditions, food availability for both adults and larvae and suitable nesting sites (Allan et al. 1973; Pollard and Yates 1993). Diptera was the most abundant and diverse group at Kpeshie because the site had a varied vegetation structure and botanical composition (Struhsaker 1998; Nummelin 1996). It is very likely that the same factors accounted for the differences in species composition within the area. Insect numbers from Kpeshie were higher than those at Muni-Pomadze. This may likely have been as a result of the diversity of plants as well as the thick mangroves in the catchment area of the Kpeshie lagoon which have more food resources and habitats for the persistence of insects. Hymenopterans were the most abundant insects at both Sakumono and Muni-Pomadze. Ants, which constituted the majority of hymenopterans sampled are more abundant in grassy areas than mangroves. The predominant vegetation type at both Sakumo and Muni-Pomadze is grass with few patches of mangroves. Economic activity (e.g., fishing) is very high in these areas, subjecting the lagoons to intensive fishing activity throughout the year. These human activities disturb the breeding and other naturally instinctive behaviors of insect. Many cattle were observed grazing in and around the vast grassland areas around the lagoons. Sakomono and Muni-Pomadze are designated Ramsar sites with the convergence of thousands of birds from all over the world. These birds voraciously feed on insects and other invertebrates, greatly influencing the number and diversity of insects sampled from these sites.

Very few butterflies species were recorded at Sakumo because of its grassy nature with few flowering plants where butterflies find their nectar. Kpeshie lagoon is highly polluted (Plate 8), with its surrounding area creating ideal conditions for breeding mosquitoes, thus the very high numbers of Culicidae. The many heaps of waste provided ideal breeding sites for these mosquitoes. Many dipterans such as the Muscidae and Calliphoridae thrive on rotten matter which was also in abundance. Simulidae were found where there were ripples created by the presence of large boulders at Kpeshie. This was not the case at Sakumono and Muni-Pomadze.

Observed species richness

The fact that Kpeshie had higher species diversity is not consistent with the theoretical expectations of the species-area relationship, where smaller cities tend to support fewer species (May and Stumpf 2000). Despite the fact that Kpeshie had the highest human influence due to encroachment from a large number of both individuals and businesses, it recorded the highest indices for Simpson (1/D) and Shannon Weiner (H), Margalef (D) and Pielou (J) for both seasons. The lagoon has been partially filled with sand for development and this has drastically reduced the natural size of the lagoon, to a fraction of what it used to be. Due to the proximity of residential and commercial buildings to the lagoon, solid wastes easily finds its way into the lagoon while liquid waste is discarded directly into the lagoon from drains from all the nearby settlement as well as those around the lagoon. All these notwithstanding, the Kpeshie lagoon recorded the highest insect numbers with the most dominant species being *Odontomachus* spp (Formicidae), *Aedes vexans* (Culicidae) and *Simulium venustum* (Simuliidae).

Relatively fewer insect species were collected at Sakumo. Although the lagoon is in the middle of a vast wetland, vegetation is very sparse, with grass covering almost the entire catchment area. The variations of temperature recorded in the dry and wet seasons were high compared to Kpeshie which has more mangroves.

Social survey

Sex of respondents

A higher percentage of the 280 respondents, 143 (51%) were women, with the remaining 137 (49%) being men.

Educational level

Approximately 24% of the respondents had middle School or Junior High School (JHS) level of education, while 22.14% of the respondents had secondary or Senior High School (SHS) level education. Fourteen percent (14%) had tertiary education while 7.14% had no formal training. Due to the new infrastructural development around the Kpeshie and Sakumo lagoons, urban dwellers are fast moving into these sites, hence, the number of respondents sampled for tertiary education was 14% for Sakumono and 17% for La Trade Fair area (Kpeshie) respectively with Mankoadze having the least with only 9%. Mankoadze observed the highest number of middle and JHS leavers with 25% respondents followed by 24% of people for Sakumono and 18% of people for La Trade Fair. Sakumono and La Trade Fair area had the highest number of respondents with vocational, commercial and technical educational status. It is obvious from these figures that formal education did not translate into prudent sanitation and waste disposal habits since about 97% of all respondents had at least some form of formal education.

Waste disposal and sanitation

Waste disposal and sanitation are significant challenges in Ghana, and this was manifested in all the study sites. For instance, the La Pleasure Beach Hotel (adjacent to the Kpeshie Lagoon) transports its wastewater to an activated sludge system located near the lagoon. Kpeshie Lagoon is the receiving water body for various drains in the Kpeshie catchment area (Figure 2). Water that enters the lagoon has its sources from communities within Burma Camp, La, Tebibiano, Teshie Camp, Africa Lake (all communities in the catchment area) and from the mangrove swamp surrounding the lagoon. Wastewater from Burma Camp is channeled through sewers into a waste stabilization pond near the Kpeshie lagoon (Kpanja 2006). This situation introduces a lot of solid matter and pollutants into the Kpeshie lagoon with its long-term impact on biodiversity including insects within the lagoon.

The social survey showed that a substantial number of inhabitants within the study area had no access to necessary sanitation facilities such as toilets and appropriate waste disposal mechanisms. As indicated in Figure 2, 71% of the respondents admitted that they had no access to private toilet facilities. About 45% of the respondents use bushes, river banks and refuse dumps as defecating grounds due to the absence of toilets facilities in their homes. Fifty percent (50%) of public toilet users expressed dissatisfaction with the unhygienic state of those facilities. During sampling, there was indiscriminate human fecal matter scattered all over most of the sampling sites especially Kpeshie and parts of Mankoadze. Only a few of the sampled communities had official refuse dump sites, and some of these official sites were located close to the wetland environments and not well maintained. For example, at Mankoadze and Trade Fair areas, one of such official dumping sites had been located extremely close to the lagoons. This observation supports the findings of a study by Noye-Nortey (1990) and Akuffo (1998), who reported that sanitation is the least managed problem in developing countries with much of the pollution coming from domestic rather than industrial sources. The neglect of good hygiene practices makes it extremely difficult in controlling water pollution in developing countries. Such situations further put undue stresses on biodiversity within these wetlands. The presence of some insect species is an indicator of pollution within water environments. In this study, the many insects sampled within the wetlands indicated various degrees of pollution as a result of the impact of anthropogenic activities, coupled with environmental conditions within these wetlands.

Conclusion

We conclude from this study that biodiversity within the three studied wetlands have been impacted negatively by human activity. This is because our sampled taxa (insect diversity within these wetlands) showed groups that prefer highly polluted environments. Our observations and results can be attributed to the dire human conditions in communities in which these wetlands are located. This is further aggravated by the lack of decent toilet facilities and managed refuse damping sites in most of these communities forcing the inhabitants to openly defecate and dump refuse in sensitive places such as along the banks of these lagoons. This situation is further compounded by the lack of or unwillingness of local governments to manage or protect the three studied wetlands two of which are designated Ramsar sites. Bad farming practices, improper domestic and industrial waste disposal and bad fishing practices were identified as the main sources of pollution of these wetland environments. If the trend is not arrested, there are indications of further destruction of these wetlands and other such wetlands in Ghana due especially to rapid urbanisation and socioeconomic changes. Some of these threats from urbanisation especially in the Sakumo wetland environment and its catchment area come from building developers who build close to the catchment area of the lagoon.

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