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FORAGE POTENTIAL, MICRO-SPATIAL AND TEMPORAL DISTRIBUTION OF GROUND ARTHROPODS IN THE FLOOD PLAIN OF A COASTAL RAMSAR SITE IN GHANA

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ABSTRACT: *Despite the critical roles played by arthropods in ecosystem functioning and nutrient cycling, a general lack of information about the ecology of many arthropods in West African coastal wetlands persists. An investigation into the abundance, distribution and forage potential of ground arthropods to waterbirds inaWest African Coastal Ramsar site, indicated that the distribution and abundance of the arthropods were similar along both the latitudinal and longitudinal axes of the lagoon's flood plain. Agelenidae (house spiders), Formicidae (ants) and Gryllidae (True crickets) respectively constituting 52.68%, 36.58% and 5.85% of the total arthropod abundance, dominated the 23 families of arthropods. On the basis of percentage biomass and per capita biomass compositions, Gryllidae and Agelenidaewere of the most important to waterbird foraging. Although Formicidae occurred in large numbers, the small-size nature of the individuals indicated that they wereof little importance to waterbird foraging. Ocypodidae (Ghost and Fiddler crabs) (0.3%) and Acrididae (short- horned grasshoppers) (0.3%) constituted a negligible fraction of the arthropod abundance buthad the highest per capita biomass and would be the most profitable forage.The low abundance of Ocypodidae and Acrididae were attributed to marginalisation of the sampling method employed in the study.*

INTRODUCTION

The importance of West African coastal wetlands in the support of Palearctic migrant waterbirds of the African-Eurasian flyways has been noted (Reneerkens *et al*., 2009; Ajonina *et al*,. 2007; Gbogbo 2007; Blomert *et al*., 1990; Ntiamoa-Baidu and Grieve, 1987, Ntiamoa–Baidu and Hepburn, 1987). Over the past few decades, the flyway's populations of waterbirds have faced steady declines (Abdourahamane 2010, Underhill *et al*. 2000, Tripet & Yesou 1998, Zwarts *et al*. 1998) and several investigations have since commenced. In Ghana, wetland studies have focused largely on flora (Oteng-Yeboah, 1999), fisheries (Gbogbo *et al*., 2008; Ahulu *et al*., 2006; Entsua–Mensah, 2000), waterbirds (Gbogbo and Attuquayefio, 2010; Ntiamoa-Baidu *et al*.,1998; Ntiamoa–Baidu,1991) and benthic invertebrates consisting largely of annelids and molluscs (Gordon, 2000).

Arthropods are by far the most important herbivores in many ecosystems and are valuable food sources for many species of animals (Siemann *et al*., 1998; Schmidta *et al*. 2005). Despite these roles played by arthropods in ecosystem functioning and nutrient cycling, a general lack of information about arthropods in West African coastal wetlands persists. Waterbird population declines in coastal West Africa have been linked to several factors, including competition between birds and humans for fisheries (Gbogbo et al. 2008, Van der Winden *et al*., 2000). Nevertheless, arthropods may be an important food source for waterbirds in coastal West Africa and may supplement the nutritional demands of waterbirds, particularly under such competitive conditions. Besides, wetlands are sensitive ecological areas, and data on the abundance and distribution of arthropods on wetlands can serve as a source of reference in assessing changes in wetland ecological status resulting from human use, climate change and pollution. This paper examines the forage potential, micro-spatial and temporal distribution of ground arthropods in the flood plains of the coastal Ramsar site in Ghana as a step to identifying their contribution to waterbird support in coastal West Africa.

MATERIALS AND METHODS

Study area

The study was carried out at the coastal wetland of Sakumo II Lagoon (generallycalled Sakumo Lagoon). Sakumo II Lagoon (Fig. 1), located in the Tema Metropolitan Area in Ghana, is about 15km East of the capital of Ghana –Accra.It is one of the five coastal Ramsar sites (Wetland of International Importance) in Ghana, with a total conservation area of 13.4km^2. About 7km^{2}of the Sakumo II Lagoon is made up ofalluvial plain and this surrounds thebrackish water lagoon of 3.5km^2 (Wetland International, 1998). The area of the brackish water lagoon is however reduced to about 1 km^2 during the dry season (Sep./Oct. to Mar./Apr.) (Pauly, 1975).The Lagoon is linked to the sea by a sluice which allows exchange of water with the sea depending on the tides and rains. The surrounding flora includes low-lying grasses such as *Cyperus* sp. and *Paspalum*that invade most of the estuary bed,and *Avicennia* sp. (white mangrove) which hasbasically been lost due to commercial and household activities that resort to it as a source of fuel wood (Oteng-Yeboah, 1999).Many waterbird species forage in the flood plains and marginal waters of the lagoon with few species making use of the open water. According to BirdLife International (2012), Sakumo II Lagoon serves as a habitat for about 70 species of waterbirds, with an estimated maximum number of 30,000. Flocks are usually dominated by Black-wing Stilts (*Himantopus himantopus*), Ringed Plovers (*Charadrius hiaticula*), Curlew Sandpipers (*Calidris ferruginea*), Greenshanks (*Tringa nebularia*), Common Tern (*Sterna hirundo*), Black Terns (*Chlidonias niger*) and Little Egrets (*Egretta garzetta*).

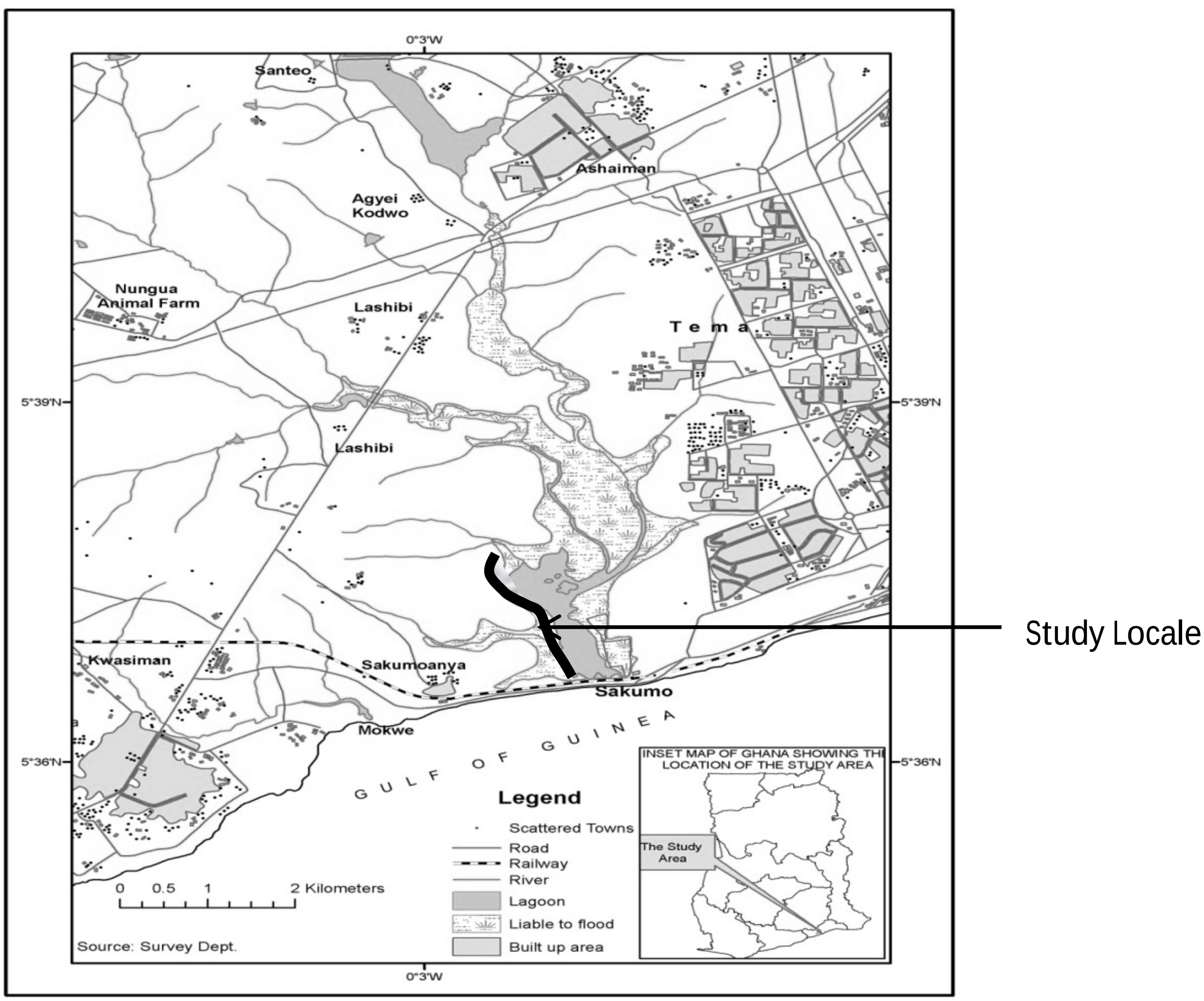

Figure 1: Map of Study Area

Demarcation and trap layout

The flood plain area in thewestern bank of the lagoon, constituting the core area used by foraging waterbirds, was divided into three (3) zones based on proximity to the sea (Study Locale, Fig 1). These included the Southern zone(5°36'57.26"N, 0° 2'6.64"W -closest to the sea), the Northern zone (5°37'41.04"N, 0° 2'27.76"W - the farthestfrom the sea) - and the Middle zone (5°37'19.16"N, 0° 2'12.49"W – lying between the two). Each zone was further divided into three areasbased on proximity to the main body of the lagoon. These included (i) the marshy shoreline area with pockets of sedges and rushes (closest to the lagoon waterfront), (ii) the extensive intertidal area adjoining the marshy shoreline area (which was either abare mudflat or covered with pockets of *Sesuvium portulacastru),* and (iii) the dry grassy semi-terrestrial area marking the maximum water edge of the lagoon (farthest from the lagoon waterfront). The Southern zonehowever,hadseveral scattered pools of water and its demarcation into shoreline, intertidal and dry grassy area was not pronounced.

In each of the months of October and December 2011 and February 2012, twenty-eight (28) pitfall traps were set in each zone in four rows of seven traps. Rows were positioned parallel to the long axis of the lagoon. The Southern zone was however, not sampled in February because of difficulties with accessibility. As a result of differences in the size of the sampling areas, two of the rows of traps were set in the intertidal area adjoining the marshy shoreline of each zone while a row each was set in the marshy shoreline and dry grassy semi-terrestrial areas. Traps consisted of shallow plastic buckets with 13 cm rim diameter and 750ml volume. To minimize depletion effects that can occur with pitfall trapping (Digweed *et al*.1995), traps were set at 10m apart but in the intertidal area adjoining the marshy shoreline, the two rows of traps were 15m apart. Each pit-fall trap was buried to its rim and the space around it filled and smoothened with the dug-out soil. Traps were about one-third filled (250-300 ml) with water and a little detergent added to reduce the surface tension of the water so that capture organisms would sink and drown in the traps. The top lid coverings of the traps were raised with sticks to serve as shelter over the traps to prevent excessive desiccation or flooding from rains. Traps were checked for catches at 3-7 day intervals, depending on climatic conditions (either too much rain that would flood the contents away or high temperatures that would dry the contents). Catches from individual traps were sieved through 0.5mm mesh and stored in 70% alcohol in labelled plastic vials for further processing in the laboratory.

Laboratory processing and identification

Specimens were sorted into their respective families, counted and identified using literature and identification keys (Katson, 1978; Roth,1993; Jackman, 1997; Ubick *et al*, 2005), under a Leica EZ4 D microscope. Individual families of organisms were placed in Petri dishes and dried in a laboratory at 55oC for 3 days. The dry weights of the specimens were then taken with a sensitive electronic scale for analysis.

Data analysis

Abundance, biomass and distribution data were analysed on the basis ofthe lagoon's source-to-mouth andshoreline-to-land dimensions, as well as temporal factors. Because of the several scattered pools of water in the Southern zone that limited its demarcation into shoreline, intertidal and dry grassy areas, data from the Southern zone was discountedin the shoreline-to-land distributional analysis. Relative abundance (RA) of individual families of arthropods was calculated as follows:

RA = Number of individuals in a family/
Number of trap nights (Vodzogbe *et al*., 2005)

where onetrap night was defined as one trap set successfully for one night.

In calculating the RA, trap nights were only based on traps that successfully passed all nights in the trapping session. Traps that were overturned, removed, destroyed by animalsor wetland users, or which got completely submerged in the lagoon water were not considered to be successful.

The Shannon-Wiener index was used to determine the within-habitat diversity, whereas the Pielou's index E measured the within-habitat evenness (Magurran, 1988). Sorensen's index (C_s) was used to measure the multivariate family overlaps among sample areas (Magurran, 1988).

RESULTS

General occurrence and biomass of ground arthropods

A total of 3,037 individual arthropods belonging to three (3) classes, eleven (11) orders and 23 familieswere captured by the pitfall traps (Table 1). Arachnida constituted 52.68% of the total catch, compared to Insecta (47.29%) and Crustacea (0.03%). All the captured Arachnida belonged to the family Agelenidae in contrast to 21 families of Insecta

Table 1: Occurrence and biomass of ground arthropod taxa in Sakumo II Lagoon

Class	Order	Family	Family Common Name	Total Occurrence (%)	Total Biomass (%)	Per capita Biomass (g)
Arachnida	Araneae	Agelenidae	House spiders	52.68	42.42	0.01
Insecta	Hymenoptera	Formicidae	Ants	36.58	4.67	<0.00
		Apidae	Common Bees	0.49	0.24	<0.00
		Sphecidae	Thread-Waisted Wasps	0.3	0.4	0.01
		Pompilidae	Spider Wasps	0.07	0.12	0.02
	Orthoptera	Gryllidae	True Crickets	5.85	11.49	0.02
		Tetrigidae	Pygmy Grasshoppers	0.72	0.79	0.01
		Acrididae	Short-horned grasshoppers	0.3	10.65	0.22
		Tettigonidae	Long-horned Grasshoppers	0.36	0.59	0.01
	Coleoptera	Gyrinidae	Whirligig Beetles	0.3	4.04	0.11
		Coccinnelidae	Ladybird Beetles	0.03	0.08	<0.00
		Carabidae	Ground Beetles	0.16	0.12	0.04
		Belidae	Primitive Weevils	0.1	0.28	0.02
		Staphylinidae	Rove Beetles	0.03	0.28	0.07
	Blattaria	Blattidae	Cockroaches	0.07	0.55	0.07
	Diptera	Sciomyzidae	Marsh Flies	0.26	2.06	0.07
		Sepsidae	Black Scavenger Flies	0.2	0.67	0.03
		Mydidae	Mydas Flies	0.07	0.24	0.03
	Hemiptera	Naucoridae	Creeping Water Bugs	0.73	5.82	0.07
	Isoptera	Termitidae	Termites	0.23	<0.00	<0.00
	Lepidoptera	Cossidae	Miller Moths	0.07	0.16	0.02
	Trichoptera	Leptoceridae	Long-horned Caddis Flies	0.03	0.04	0.01
Crustaceae	Decapoda	Ocypodidae	Ghost and Fiddler Crabs	0.03	13.7	3.46

and one family of Crustacea. The most dominant families of insects were the ants, Formicidae, and the True crickets, Gryllidae - constituting 36.58% and 5.85% respectively of the arthropod catches.

Total biomass of the captured arthropods was 25.25g, of which Arachnida constituted 42.42% compared to 43.88 and 13.7% respectively, for Insecta and Crustacea. Among the insects, Orthoptera contributed 23.52% of the total arthropod biomass, followed by Hemiptera(5.82%), Hymenoptera (5.43%) and Coleoptera (4.8%). The remaining five orders of insects constituted only 9.11% of the total arthropod mass. Data on the per capita mass indicated Ocypodidaeas arthropods with the highest mass per individual, followed by Acrididae. Although Formicidae occurred in high numbers, its per capita biomass was very small.

Source-to-Mouth distribution

The relative abundance of the individual families across the three zones is presented in Table 2. No significant differences existed among the relative abundance of the arthropods in the Northern, Middle and Southern zones (ANOVA, $F = 0.001$, $F_{Critical\ 2,51} = 3.187$, $p > 0.05$), a Shannon Diversity Indexvalues(Table 3) indicating particularly low family diversity in the Southern zone while Pielou index values (Table 3) suggestedpronounced species dominance in the Southern zone. Indeed, Table 2shows the relative abundance of Agelenidaeto beparticularly higher than that of the remaining families in the Southern zone and thus confirming its exceptional dominance in the Southern zone.

The most dominant families in the Northern zone were Formicidae (1.99), followed by Agelenidae (1.5). These two species also dominated the Middle zone, but in a reversed order (Table 2). Sorensen's Index value of 0.79 was obtained for the Northern and Middle zones, 0.56 for the Northern and Southern zones and 0.28 for the Middle and southern zones. Thus, arthropod family composition of the Northern and Middle zones were more similar (79%)than that of the Northern and Southern zones (56%) andthe Middle and Southern zones (28%), indicating that the arthropod community composition changed with distance from the mouth of the lagoon.

Table 2: Source-to-mouth distribution of ground arthropod in the Sakumo II Lagoon

FAMILY	Relative Abundance		
	Northern Zone	Middle Zone	Southern Zone
Agelenidae	1.5	2.31	1.21
Formicidae	1.99	1.06	0.01
Apidae	0.02	0.01	0.02
Sphecidae	0.02	0.01	-
Pompilidae	0.01	-	0.01
Gryllidae	0.17	0.26	0.12
Tetrigidae	0.02	0.04	-
Acrididae	0.02	0.01	0.01
Tettigonidae	0.02	< 0.01	0.01
Gyrinidae	0.01	0.01	-
Coccinnelidae	0.02	0.01	-
Carabidae	0.01	0.01	-
Belidae	-	0.01	-
Staphylinidae	< 0.01	< 0.01	-
Blattidae	-	0.01	-
Sciomyzidae	0.01	0.01	0.01
Sepsidae	0.01	0.01	-
Mydidae	-	0.01	-
Naucoridae	0.01	0.05	-
Termitidae	-	0.02	-
Cossidae	0.01	-	-
Leptoceridae	-	< 0.01	-
Ocypodidae	-	< 0.01	-
TOTAL	**3.87**	**3.83**	**1.39**

SHORELINE-TO-LAND DISTRIBUTION

The total relative abundance of arthropods in the marshy shoreline habitat was 4.63 compared to 3.28 and 4.34 in the

Table 3: Ecological diversity values on spatial and temporal scale

Ecological diversity	Source-to-Mouth distribution			Shoreline-to-land distribution			Temporal Distribution		
	Northern Zone	Middle zone	Sourthern zone	Marshy Shoreline	Intertidal area	Dry grassy semi-terrestrial area	October	December	February
Shannon-Weiner	1.1	1.15	0.42	1.12	1.04	1.17	0.1	1.12	1.35
Pielou	0.4	0.38	0.19	0.44	0.37	0.39	0.35	0.44	0.45

intertidal area and dry grassy – semi terrestrial area respectively (Table 4).These values are statistically the same (ANOVA, F =0.104, $F_{Critical\ 2,\ 45}$ = 3.211, P > 0.05). Relative abundance of the individual families indicated the dominance ofAgelenidae and Formicidae in each of the demarcations. Shannon Weiner diversity and Pielou's Index values for the Marshy shoreline, Intertidal area and the dry grassy semi-terrestrial area, are shown in Table 3 and further confirms family dominance. All the three demarcations had similar community composition of ground arthropods with the Marshy shoreline and the Intertidal areas scoring a Sorensen's index of 0.63. Similarly the marshy shoreline and the dry grassy semi-terrestrial area scored Sorensen's index value of 0.76, while the intertidal area and the dry grassy semi terrestrial area had 0.69.

TEMPORAL DISTRIBUTION

Agelenidae and Formicidae dominated the arthropods throughout the period (Table 5). This observation is supportedby the Pielou's Index values(Table 3). Shannon Diversity values also remained fairly stable over time (Table 3). Similar to the spatial distribution of the arthropods, the relative abundance data again indicated the dominance ofAgelenidae and Formicidaethroughout the period. The abundance of the arthropods (Table 5) over the study period however remained statistically similar (ANOVA, F = 0.396), $F_{critical\ 2,45}$ = 0.3211). Sorensen's Index values showed similar community composition of arthropod families between October and December (0.67), December and February (0.62) and October and February (0.60).

Table4: Shoreline-to-land distribution of ground arthropod inthe Sakumo II Lagoon

Family	Relative Abundance: Marshy Shoreline	Intertidal area	Dry grassy semi-terrestrial area
Agelenidae	2.06	2.01	1.59
Formicidae	1.93	0.99	2.19
Apidae	0.05	0.01	0.01
Sphecidae	0.02	0.01	0.01
Pompilidae	<0.01	-	-
Gryllidae	0.31	0.1	0.36
Tetrigidae	0.02	0.03	0.04
Acrididae	0.05	0.02	0.03
Tettigonidae	0.02	-	0.03
Gyrinidae	0.04	0.02	-
Coccinnelidae	0.01	0.02	0.01
Carabidae	0.01	0.01	-
Belidae	0.02	-	-
Staphylinidae	0.01	-	-
Blattidae	0.01	-	-
Sciomyzidae	<0.01	-	0.02
Sepsidae	0.02	-	0.02
Mydidae	<0.01	-	0.01
Naucoridae	0.02	0.05	0.01
Termitidae	0.02	0.01	-
Cossidae	<0.01	-	0.01
Leptoceridae	<0.01	-	-
Ocypodidae	0.01	-	-
TOTAL	4.61	3.29	4.32

Table5: Temporal distribution of ground arthropod in the Sakumo II Lagoon

Family	Relative Abundance October	December	February
Agelenidae	2.01	1.78	1.14
Formicidae	1.71	1.71	0.11
Apidae	0.02	0.02	0.01
Sphecidae	-	0.02	0.01
Pompilidae	-	-	0.01
Gryllidae	0.13	0.15	0.47
Tetrigidae	<0.01	0.02	0.08
Acrididae	0.02	0.03	0.06
Tettigonidae	0.01	0.01	0.02
Gyrinidae	0.02	-	0.01
Coccinnelidae	0.01	0.02	-
Carabidae	<0.01	0.01	0.01
Belidae	0.01	-	-
Staphylinidae	-	<0.01	-
Blattidae	<0.01	<0.01	-
Sciomyzidae	<0.01	-	0.04
Sepsidae	-	0.02	-
Mydidae	<0.01	-	-
Naucoridae	0.04	-	0.01
Termitidae	<0.01	-	0.02
Cossidae	-	-	0.01
Leptoceridae	<0.01	-	-
Ocypodidae	-	-	0.01
Total	4	3.79	2.07

DISCUSSION

This study established Agelenidae,Formicidae and Gryllidae as the most dominant ground arthropod families in Sakumo II Lagoon. However, on the basis of percentage biomass composition, Agelenidae, Ocyporidae, Gryllidae, and Acrididae were the highest contributors. Although Formicidae constituted 36.58% of the total arthropod abundance, its per capita biomass was negligible and comparable to that of Apidae, Coccinnelidae and Termitidae each of which constituted lees than 0.5% of the total arthropod abundance. The Optimum Foraging Theory predicts foraging organisms to reject small prey items if they are less profitable (Charnov, 1976; Yahnke, 2006). This implies that although Formicidae occurred in large numbers in Sakumo II Lagoon it might not be an important food source for waterbirds because of their small sizes.

Ocypodidae might be the most profitable prey to waterbirds among the arthropods. However, pitfall traps are not the best for sampling decapods and thus the sampling method employed in this study would largely under-represent the occurrence of Ocypodidae. Much as this family potentially appears to be the most profitable prey to waterbirds in this study, it should be borne in mind that predators usually have some critical maximum size of food items above which handling time and energy expended becomes unprofitable. So the suitability of the Ocypodidae as the most profitable family will also depend on the range and sizes of waterbirds found at the study site. The abundance and importance of decapods to waterbirds' foraging activities have earlier been noted using specialised traps (Gbogbo et al., 2008). Other families of arthropods that might be under-represented in this study as a result of the employed sampling methods include Acrididae, Sciomyzidae, Mydidae, Sepsidae, Coccinnelidae, Cossidae, Tettigonidae, Tetrigidae, Pompilidae, Sphecidae and Apidae. However, the fact that these families occurred in the pitfall traps suggest that they might abound in the study area and the biomass data indicates that Acrididae in particular, may constitute a significant food source for the waterbirds. Among the typical ground arthropods however, Gryllidae and Agelenidae appeared to have higher potential as food sources for waterbirds based on the product of their occurrence and per capita biomass.

In structuring waterbird foraging habits and diets in coastal Ghana, species belonging to guilds 2, 3 and 4 have been noted as the only waterbirds that feed on invertebrates (Ntiamoa-Baidu *et al*., 1998). Foraging microhabitats used by theses pecies ranged from the dry grassy boundary of the flood plain to water depth of 14cm but with different species exhibiting different limits and preferences (Ntiamoa-Baidu et al.,1998). The fact that the abundance of ground arthropods was similar among the shoreline, intertidal area and the dry grassy terrestrial areas, as well as among the lagoon's source, middle and mouth, are indications that the entire flood plain of the lagoon is of the same forage quality to waterbirds. Thus, abundance and/or distribution of ground arthropods did not appear to be the major factors determining the choice of foraging area by the waterbirds.

The low similarity between the arthropod community composition between the Southern and Middle zones,as well as the Northern and southern zones is however an indication that the arthropod community composition indeed changes with distance from the mouth of the lagoon. Hypersaline conditions in lagoons and estuaries often characterise lower reaches of many estuaries and lagoons and are known to impact negatively on invertebrate populations (Gordon, 2000). Piersma and Ntiamoa-Baidu (1995) conceptualised the population of benthic invertebrate to fall drastically under hypersaline conditions, and that many such populations are restored with the influx of rains (Gordon, 2000). The mouth of the lagoon may be characterised with similar hypersaline condition since this study was carried out during the dry season. There is therefore the need to investigate seasonal changes in ground arthropod communities in West African coastal lagoons to ascertain possible influences of salinity.

In relation to temporal distribution, many Palearctic migrant waterbirds arrive in coastal West Africa by September / October and depart by March/April (Ntiamoa-Baidu, 1991). The similarity in the community composition and relative abundance of the arthropods throughout the months of the study however indicated that the presence of the birds neither affected the community composition nor depleted the abundance of the arthropods.

In recognition of the diverse ground arthropod family and their abundance in the study area, there is the need to investigate their utilisation by waterbird species on the coast. Several species of egrets and herons described as exclusive fish-eating in coastal Ghana (Ntiamoa-Baidu et al., 1998), were reported to feed on morediverse organisms, including arthropods in some other part of the world (Liordos, 2010). This work is however part of a more diverse study aimed at investigating the importance of ground arthropods and aerial insects to foraging waterbird in coastal Ghana. Further studies should be designed to identify selectivity of the arthropod family and their utilisations as forage, particularly by waterbird species that feed on both invertebrates and fish.

CONCLUSIONS

Distribution and abundance of ground arthropods were similar along both the latitudinal and longitudinal axis of the flood plains of Sakumo II Lagoon. The occurrence of ground arthropods in the flood plains of the lagoon was dominated by Agelenidae and Formicidae, but,the small sizes of the Formicidae indicated that they were of little importance to waterbird foraging. Ground arthropod families in the lagoon that may be of importance to waterbird foraging were Gryllidae and Agelenidae. Acrididae and Ocypodidae also had forage potential to waterbirds, but recorded low abundance values which were attributed to marginalisation by the sampling method employed.

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