EFFECTS OF RAINFALL PATTERN ON DISTRIBUTION OF *Callinectes amnicola* AND *Macrobrachium vollenhovenii* FROM INTERCONNECTING LAGOONS LAGOS, NIGERIA

***AKINWUNMI M.F.[1], AYENI A.O.[2], LAWAL-ARE A.O.[1]**
[1]Department of Marine Sciences, Faculty of Science, University of Lagos, Nigeria
[2]Department of Geography, Faculty of Social Sciences, University of Lagos, Nigeria.
*Corresponding author: Email: mfakinwunmi@gmail.com

ABSTRACT
Crustaceans form a very popular food items in the diet of coastal communities in West Africa. In Nigeria, there is paucity of information on the effect of rainfall pattern on shellfishes found in these aquatic environments. C. amnicola and M. vollenhovenii were collected monthly from four interconnecting lagoons between 1999-2000 and 2013-2015. The rainfall data for the periods were collected from Nigerian Meteorological Agency, Oshodi Lagos. The sizes of crabs/prawns ranged from 3.5-8.4 cm/4.5-10.4 cm (small-sized), 8.5-13.4 cm/10.5-16.4 cm (medium-sized) and 13.5-18.4 cm/16.5-22.4 cm (large-sized) respectively. The relationship between the sizes of the species and the rainfall pattern were assessed based on onset and offset of rainfalls. The results showed that during high rainfall, the small-sized crabs dominated Badagry and Lagos Lagoons, medium-sizes were more in Badagry and Lekki Lagoons while the large ones were more in Lekki Lagoon. Small sized prawns were noted to be in abundance during the rainy seasons from Badagry, Lagos and Epe Lagoons while the large-sized prawns were dominant in Epe Lagoon. The changes in rainfall pattern could be said to have significant effect on the size variations and distribution of these shellfishes. Hence, effective conservation should be adequately enhanced by prohibiting the fishing of these organisms especially during the rainy season. This information would assist Biologist on the population dynamics of these aquatic species and its implication for the management of the fisheries and culturability of their uses as a commercially important species.

Keywords: Abundance, *Callinectes amnicola*, Distribution, Lagoon, *Macrobrachium vollenhovenii*, Rainfall pattern

INTRODUCTION

Climate change is one of many sources of disturbance that can trigger stress in aquatic ecosystems (Pletterbauer *et al*., 2018). These disturbances and stress occur concurrently at multiple temporal and spatial scales due to variation in global climate change (Vargas *et al*., 2008; Pletterbauer *et al*., 2018; Ayeni *et al*., 2015; 2016). Climate change disrupts land-water connections in ways that influence biogeochemical and hydrologic cycles and affect the plants and animals living there as well as the entire ecosystems (Hädera and Barnes, 2019; Ayeni *et al*., 2019). For instance, increase in water temperatures will affect essential components of ecological processes as well as the geographic distribution of aquatic species. On continental, regional and local scales, some climate change stress manifest slowly over decades while some can occur rapidly and cause significant impacts to lagoons (Dale *et al*., 2001). Warming may force species to migrate to where temperatures are more conducive to their survival while some key species may be forced to relocate and/or die (Fletcher, 2019). In addition, seasonal changes in precipitation and runoff alter hydrologic characteristics of aquatic systems, thereby, affecting ecosystem productivity and species structure (Woodward *et al*., 2010).

Aquatic ecosystems remain one of the critical components of the global environment which have long been threatened by human-natural induced stressors (Staudt *et al*., 2013; Hädera and Barnes, 2019). Though, aquatic ecosystems provide a variety of services for human populations which include: drinking water, habitat for fisheries, irrigation as well as recreational opportunities (Pletterbauer *et al*., 2018; Talbot *et al*., 2018). Lagoon water quantity and quality is influenced by the water loses or gains from evaporation, precipitation, groundwater input, surface runoffs and exchange with the ocean which could be intensified with climate change and allied resultant impacts (Anthony *et al*., 2009; Momou *et al*., 2017). Coastal lagoons are highly productive ecosystems which support a range of natural services that are highly valued by society. It contributes to the overall productivity of coastal waters by supporting a variety of habitats including salt marshes, fisheries productivity, storm protection, tourism, sea grasses and mangroves and also provide essential habitat for many fish and shellfish species (Anthony *et al*., 2009). Lagoon water quality deterioration mainly comes from excessive nutrient inputs, eutrophication, acidification, heavy metal contamination, organic pollution and obnoxious fishing practices (Emmanuel and Chukwu, 2010). Coastal lagoons are formed and maintained through sediment transport processes which are carried by rivers, waves, currents, wind and tides (Anthony *et al*., 2009; Momou *et al*., 2017) which accumulates in river and tidal deltas, on marshes and flats where submerged aquatic vegetation slows currents and on washover fans. Lagoon barriers are constantly eroded by waves and wind, requiring continuous sediment deposition to maintain them (Anthony *et al*., 2009; Momou *et al*., 2017).

The relationship between environmental factors and organism's distribution within aquatic environments has received considerable attention in which

Callinectes amnicola and *Macrobrachium vollenhovenii* are one of the dominant organisms due to their high economic values. Numerous parameters influence the spatial distribution of these organisms while relative importance of each factor differs according to the species (Bruno *et al*., 2013). Salinity is a major factor that distinguishes these lagoons from one another and could be said to have a profound effect on the distribution and abundance of these organisms (Akinwunmi and Lawal-Are, 2018).

Though, there is little information regarding the effect of climatic variables coupled to water properties on these species distribution but rainfall could be an important factors affecting the distribution of *C. amnicola* and *M. vollenhovenii* in coastal lagoons due to the dilution of the salinity of the aquatic media from the rain water (Onyema, 2013). It is on this aforementioned, that this study aimed to study the effects of rainfall pattern on the distribution of *C. amnicola* and *M. vollenhovenii* from interconnecting coastal lagoons in Nigeria.

MATERIALS AND METHODS

Description of the Study Sites

The Badagry Lagoon (Fig. 1), with source in River Queme in the Republic of Benin to the west of Nigeria, is located in Lagos State (Southwest Nigeria) and opens into the Atlantic Ocean via the Lagos harbour. It lies between longitudes 3°54″ and 4°13″E and latitudes 6°25″ and 6°35″N (Lawal-Are and Kusemiju, 2000). It is part of a continuous system of lagoons and creeks lying along the coast of Nigeria from the border with the Republic of Benin to Niger Delta, with the depth of water ranging from 1-3 m (Ndimele and Jimoh, 2011). The area is characterized by thick shrubs and small trees. The major ecological factors operating in the Badagry Lagoon have been documented by Ezenwa and Kusemiju (1985) and Solarin (1998). The temperature of Badagry Lagoon ranged from 26-30°C (Ezenwa and Kusemiju, 1985). The authors also observed an increase in salinity from July to September (rainy season) in the Badagry Lagoon due to the intrusion of salt water from the Cotonou Lagoon in the Republic of Benin.

Lagos Lagoon (Fig. 1) is located between longitudes 3°23″ and 3°53″E and latitudes 6°26″ and 6°37″N. It is an open tidal estuary situated within the low-lying coastal zone of Nigeria. This coastal terrain is dominated by a maze of estuaries, lagoons, creeks and rivers. Out of the total land area covered by Lagos State, one-quarter is water surface: lagoons, creeks and coastal river estuaries

(Ndimele, 2003). These water bodies act as sinks for the disposal of wastes from about 2000 medium and large-scale industries located in the Lagos metropolis (Anetekhai *et al*., 2007). The lagoon is fed in the north by Ogun River. The lagoon opens into the Atlantic Ocean via the Lagos Harbour. River Ogun its major source of water discharges a large volume of water into the lagoon and as a result of this, the salinity is very low during the rainy season (Solarin, 1998; Lawson, 2001). Characteristically, Lagos Lagoon has a seasonal fluctuation in salinity and high brackish water during the dry season (from December to May), while freshwater condition exists in the rainy season (June – November) (Kusemiju, 1975; Ugwumba and Kusemiju, 1992; Solarin, 1998; Lawal-Are, 2006). Lagos Lagoon receives freshwater from Lekki Lagoon via Epe Lagoon in the North-east and discharges from Majidun, Agboyi and Ogudu creeks as well as Ogun River in the North-west (Soyinka, 2008; Lawal-Are *et al*., 2010, Lawal-Are and Nwankwo, 2011). Lagos Lagoon is shallow in depth and in most places; it is a little more than 1.5 meters deep (Solarin and Kusemiju, 2003).

Lekki Lagoon, located in Lagos and Ogun states of Nigeria covers an area of nearly 247 km^2 and lies between longitude 4˚00'E and 4˚15'E and latitude 6˚22'N and 6˚37'N (Akinsanya *et al*., 2007; Opadokun and Ajani, 2015). Lagos Lagoon links Lekki Lagoon at the upper part while Mahin creeks link the lagoon at the lower part. River Oni flows into Lekki Lagoon in the north eastern side while Rivers Oshun and Saga flow in from the north western parts (Fawole, 2002; Kuton, 2006). The lagoon is surrounded by many beaches.

Epe Lagoon (Fig. 1) lies between latitudes 6º29″N and 6º38″N; and longitudes 3º30″E and 4º05″E (Agboola and Anetekhai, 2008) and is fed by River Oshun. With a surface area of about 225 km^2 and a maximum depth of 6 m, the lagoon is sandwiched between the Lagos and Lekki Lagoons. However, a large area of the lagoon is relatively shallow with a minimum depth of 1m, and the vegetation surrounding the lagoon is of the mangrove swampy type (Balogun, 1987). The lagoon opens into the Gulf of Guinea via the Lagos harbour and it is one of the four major lagoons in Lagos State, Nigeria (Kumolu-Johnson *et al*., 2010).

Field studies

The rainfall data between year 1999-2000 and 2013-2015 were collected from Nigerian Meteorological Agency (NIMET), Oshodi Lagos. These rainfall data year were acquired because they correspond to the two periods of sampling of the crustaceans. Besides, the study is also to observe the variation that might occur over the years (13years) after the first sampling.

Collection of samples

The sampling of the crustaceans was randomly collected using basket (Plate 1). *C. amnicola* were collected monthly using Artisanal fisheries from Badagry, Lagos and Lekki Lagoons from May, 1999 to October, 2000 (18 months) while *M. vollenhovenii* were collected monthly from Badagry, Lagos and Epe Lagoons (Fig. 1) between June, 2013 and May, 2015 (24 months) from traps which were set near the shore of the lagoons.

The samples were immediately preserved in an ice-chest and subsequently transported into a deep freezer at temperature of -20 ^{o}C in the laboratory of the Department of Marine Sciences for further biological analysis.

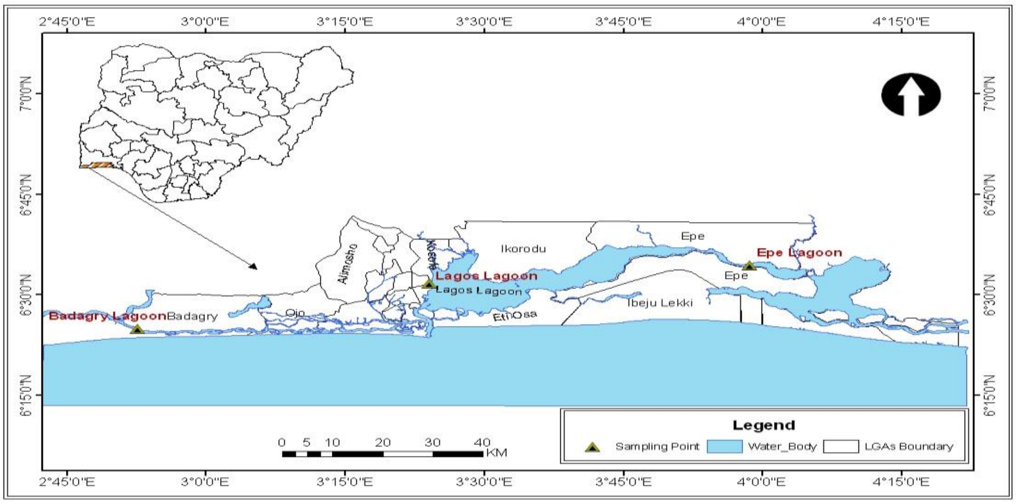

Fig. 1: Map showing the sampling stations
Source: Akinwunmi *et al.* (2019a)

Plate 1: Trap (Igun) used in the collection of the samples
Source: Akinwunmi and Lawal-Are (2019b)

LABORATORY PROCEDURES

Length-Weight measurement of the samples

The samples were removed from the freezer and allowed to thaw. Excess water was removed from the specimens using a pile of filter papers. The Total Length (TL) of the prawn was measured to the nearest 0.1 cm from the tip of the rostrum to the end of the telson with a tape rule. The Carapace Length (CL) of the crab was measured to the nearest 0.1 cm from the edge of the frontal region to the tip of the carapace back wall. The total body weight of the samples was measured on an electronic weighing balance (Model: DT 1001A) to the nearest 0.01 gram.

The samples were grouped into varied sizes of small, medium and large and the frequency of each class size were recorded.

Crabs	Small sizes:	3.5 – 8.4 cm
	Medium sizes:	8.5 – 13.4 cm
	Large sizes:	13.5 – 18.4 cm
Prawns	Small sizes:	4.5 – 10.4 cm
	Medium sizes:	10.5 – 16.4 cm
	Large sizes:	16.5 – 22.4 cm

Statistical Analysis

The data from the rainfall and the sizes of the crabs and prawns were analyzed using one-way analysis of variance (ANOVA). The correlation and regression values were tested for significance at 5% confident interval ($P < 0.05$). Further analysis was carried out using Descriptive statistics and Microsoft Excel for windows (2007), Predictive Analytics SoftWare (PASW) Statistics version 18 and PAleontological STatistics (PAST) version 2.

RESULTS

The rainfall pattern ranged from 0.3 - 436.6 and 2.1 – 325.2 during the period of the crab and prawn collections respectively. The result showed that the rainfall records was lowest in January, 2000 and January, 2015 for the period of crab and prawn collections respectively. While the rainfall records were highest in September, 2000 and July, 2014 for the period of crab and prawn collections respectively as shown in Tables 1 and 2 respectively.

A total of 4177 crabs were collected from the three lagoons during the period of study, 2042 from Badagry Lagoon, 1417 from Lagos Lagoon and 718 from Lekki Lagoon. Out of the total number of 4177 crabs collected, 1825 were small-sized, 2115 were medium-sized while 237 were large-sized. The frequency of occurrence of various sizes of crabs from the three lagoons showed that the small-sized crabs dominated Badagry and Lagos Lagoons, medium-sized crabs were dominant in Badagry and Lekki Lagoons while the large-sized crabs were more in Lekki Lagoon as presented in Table 1.

A total of 4728 prawns were collected from the three lagoons, 1770 from Badagry Lagoon, 924 from Lagos Lagoon and 2034 from Epe Lagoon. From the total number of 4728 prawns collected, 4305 were small-sized, 416 were medium-sized while 7 were large-sized. The frequency of occurrence of various sizes of prawns from Badagry, Lagos and Epe Lagoons showed that the small-sized prawns predominate in the three lagoons while Epe Lagoon recorded the highest for all the various size groups with values of 1757, 271 and 6 (small, medium and large sizes) respectively as presented in Table 2.

The Pearson correlation value for the crab is -0.035 with the statistical significant value (P-value) of 0.016 while the Pearson Correlation value for the prawn is -0.025 with the statistical significant value (P-value) of 0.081 as shown in Tables 3 and 4. These indicates that as one variable increases, so the other decreases, and vice versa. Hence, increase in rainfall pattern do not necessarily translate to the increase in sizes of *Callinectes amnicola* and *Macrobrachium vollenhovenii* from the lagoons.

Table 1: Frequency of Occurrence of various sizes of Crabs from Badagry, Lagos and Lekki Lagoons

S/N	MONTH/YEAR	RAINFALL (cm)	BADAGRY			LAGOS			LEKKI		
			SMALL SIZED	MEDIUM SIZED	LARGE SIZED	SMALL SIZED	MEDIUM SIZED	LARGE SIZED	SMALL SIZED	MEDIUM SIZED	LARGE SIZED
1.	May-1999	88.6	45	50	1	68	24	6	2	20	7
2.	Jun-1999	338.4	92	109	17	52	55	7	35	47	17
3.	Jul-1999	223	98	66	4	23	37	1	22	7	1
4.	Aug-1999	148.6	63	54	1	51	42	3	23	67	25
5.	Sep-1999	113.3	104	88	0	31	49	1	6	27	24
6.	Oct-1999	221.1	10	17	0	24	15	1	0	11	12
7.	Nov-1999	92.1	6	0	0	10	10	0	0	33	9
8.	Dec-1999	26.9	34	73	2	6	20	0	0	13	4
9.	Jan-2000	0.3	46	68	5	108	76	0	0	0	0
10.	Feb-2000	12.5	74	158	8	75	28	0	0	0	0
11.	Mar-2000	21	52	160	2	132	37	0	0	0	0
12.	Apr-2000	77.9	35	144	14	109	19	0	0	0	0
13.	May-2000	138.8	16	43	2	21	58	3	12	18	0
14.	Jun-2000	244.4	46	38	1	21	22	3	29	12	0
15.	Jul-2000	103.8	34	27	10	6	21	13	11	31	7
16.	Aug-2000	86.4	14	16	0	5	25	0	101	8	1
17.	Sep-2000	436.6	6	8	0	21	16	2	8	15	8
18.	Oct-2000	133.6	13	67	1	24	36	0	1	30	14
			788	**1186**	**68**	**787**	**590**	**40**	**250**	**339**	**129**
	Total			**2042**			**1417**			**718**	
							4177				

Table 2: Frequency of occurrence of various sizes of Prawns from Badagry, Lagos and Epe Lagoons

S/N	MONTH/YEAR	RAINFALL (cm)	BADAGRY			LAGOS			EPE		
			SMALL SIZED	MEDIUM SIZED	LARGE SIZED	SMALL SIZED	MEDIUM SIZED	LARGE SIZED	SMALL SIZED	MEDIUM SIZED	LARGE SIZED
1.	Jun-2013	108	103	3	0	0	0	0	76	25	0
2.	Jul-2013	190.8	100	2	0	0	0	0	99	3	0
3.	Aug-2013	8.4	98	2	0	94	6	0	86	14	0
4.	Sep-2013	162	102	3	0	91	9	0	87	18	0
5.	Oct-2013	110.2	98	2	0	100	2	0	81	19	0
6.	Nov-2013	264.9	98	3	0	63	9	0	91	19	0
7.	Dec-2013	47.9	100	2	0	0	0	0	0	0	0
8.	Jan-2014	90.7	24	21	0	0	0	0	48	12	0
9.	Feb-2014	32.5	0	0	0	0	0	0	77	1	0
10.	Mar-2014	76.9	99	1	0	0	0	0	103	9	0
11.	Apr-2014	199.6	103	1	0	0	0	0	85	19	0
12.	May-2014	305.7	110	0	0	0	0	0	110	15	0
13.	Jun-2014	291.7	142	3	0	0	0	0	152	9	0
14.	Jul-2014	325.2	117	3	0	98	2	0	79	15	0
15.	Aug-2014	217.4	110	7	0	98	4	0	90	11	0
16.	Sep-2014	240.8	133	8	0	90	12	0	80	12	0
17.	Oct-2014	177.6	0	0	0	73	26	1	85	19	0
18.	Nov-2014	149.3	0	0	0	46	10	0	0	0	0
19.	Dec-2014	9.7	0	0	0	90	0	0	0	0	0
20.	Jan-2015	2.1	0	0	0	0	0	0	0	0	0
21.	Feb-2015	141.3	0	0	0	0	0	0	85	4	0
22.	Mar-2015	113.9	0	0	0	0	0	0	77	7	0
23.	Apr-2015	67.5	90	2	0	0	0	0	79	22	3
24.	May-2015	72.4	78	2	0	0	0	0	87	18	3
	Total		**1705**	**65**	**0**	**843**	**80**	**1**	**1757**	**271**	**6**
				1770			**924**			**2034**	
							4728				

Table 3: The Pearson correlation value for the crabs (*Callinectes amnicola*)

Correlations			
		Rainfall	**Crabs**
Rainfall	Pearson Correlation	1	-0.035*
	Sig. (2-tailed)		0.016
	N	4177	4177

*. Correlation is significant at the 0.05 level (2-tailed).

Table 4: The Pearson correlation value for the prawns (*Macrobrachium vollenhovenii*)

Correlations			
		Rainfall	**Prawns**
Rainfall	Pearson Correlation	1	-0.025
	Sig. (2-tailed)		0.081
	N	4728	4728

DISCUSSION

It was evident from this study that crabs and prawns were available and well distributed in all the lagoons all through the period of study. Though, there were exceptions of non-availability in some months (especially the dry months) in some of the lagoons. This could be due to the fact that during rainfall, the aquatic media is expected to be rich in nutrients as a result of the surface and underwater mixing in which these species feed on and thereafter enhances their distribution in the lagoons. The work of Lawal-Are (2003) on the aspect of the biology of Lagoon crab corroborated with the findings in this work. The work revealed that crabs are found all the year round but there is reduction in the collection in the months of October and November (dry months) while there is population abundance between May and September.

The results showed that during high rainfall, small and medium-sized crabs dominated Badagry Lagoon; Lagos Lagoon had all the sizes distributed while Lekki Lagoon had mainly large-sized crabs. Small sized prawns were noted to be in abundance during the rainy seasons from Badagry, Lagos and Epe Lagoons with the highest from Epe Lagoon. The variation in these sizes from the different lagoons could also be attributed to the pattern of rainfall. This is in agreement with the work of Akinwunmi and Lawal-Are (2018), which revealed that *Macrobrachium vollenhovenii* were more in Epe Lagoon than other interconnecting lagoons. These findings conform to the work of Emmanuel and Chukwu (2010) who reported that high number of shellfishes (*Macrobrachium vollenhovenii* and *Callinectes amnicola*) were found in Lekki Lagoon between March, 2006 and February, 2008.

Despite the weak and negative relationship between rainfall and the distribution of the crabs and prawns from the Pearson correlation value, the statistical significant value (P-value) for the crab is less than 0.05 ($P<0.05$) and thus suggested that the effect of rainfall on crab production is statistically significant at 5% confident interval. For the prawns, the statistical significant value (P-value) is greater than 0.05 ($P>0.05$). Hence, the effect of rainfall on prawn production is not statistically significant at 5% confident interval or there is no significant relationship between rainfall and prawn distribution in the lagoons.

Rainfall pattern in this study, was observed to serve as the major contributing factor to upwelling (resuspension of nutrients) within the aquatic ecosystems which influences the distribution and diversity of the crustacean community of the study areas. The major source of these nutrients as to the inflow from land-based source was documented by Onyema (2013), while Bruno *et al.* (2013) reported increase in freshwater organisms influenced by rainfall pattern.

Though, Woodward *et al*. (2010) revealed that most aquatic habitat are generally vulnerable to climate change because most species within these particular habitats have limited abilities to disperse as the environment changes and many systems are already exposed to numerous anthropogenic stressors. However, it could be inferred from this research that rainfall plays a major role in the distribution of crustaceans, due to direct influence on salinity variations as observed in tropical lagoons (Akinwunmi and Lawal-Are, 2018).

CONCLUSION

The study gave an addition to knowledge on the effect of rainfall pattern on the distribution of *Callinectes amnicola* and *Macrobrachium vollenhovenii* from interconnecting lagoons in Nigeria.

Rainfall pattern in this study was observed to serve as the major contributing factor to the resuspension of nutrients within the aquatic ecosystems which influences the distribution and diversity of the crustacean community of the study areas.

The study therefore suggested that the changes in rainfall pattern could be said to have significant effect on the size variations and distribution of these shellfishes. Hence, effective conservation should be adequately enhanced by prohibiting the fishing of these organisms especially during the rainy season. This information would assist Biologist on the population dynamics of these aquatic species and its implication for the management of the fisheries and culturability of their uses as a commercially important species.

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