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INFLUENCE OF RAINFALL ON THE DYNAMICS OF TWO PRAWN POPULATIONS IN THE CROSS RIVER ESTUARY, NIGERIA.

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ABSTRACT

The influence of rainfall on the population dynamics of the prawns, *Macrobrachium macrobrachion* Herklots 1851 and *Nematopalaemon hastatus* Aurivillius 1898, in the Cross River Estuary, Nigeria, was investigated. Rainfall accounted for a significant portion of the variations in catch rate, spawning and recruitment indices of *M. macrobrachion*. This is because the processes of migration to the estuary, and the spawning of the prawns there, are presumably not only triggered off by rainfall but also progressively influenced by it. With significant relationships also among the population variables (catch rate, spawning and recruitment indices) at appropriate lags, it was possible to chart the time steps from rainfall through catch rate, to spawning and recruitment. A certain amount of rainfall in a given month leads to a given abundance of adult population (catch rate) in the estuary two months later, which is followed in another one month by spawning. Recruitment takes place 4 to 5 months after spawning. Thus the time span from rainfall to recruitment of the young of a given cohort is 7 to 8 months. For *N. hastatus*, the catch rate in the estuary does not seem to proceed linearly with rainfall because after the early rains, the prawns migrate offshore for spawning purposes. However, from the analyses the time span from rainfall through spawning to recruitment of the young was estimated at 6 months. There is still room for studies aimed at clarifying the recruitment processes of these prawn populations in order to enhance their effective management.

KEYWORDS: Rainfall, Catch rate, Spawning, Recruitment, *Macrobrachium*, *Nematopalaemon*, Cross River Estuary, Nigeria

INTRODUCTION

Understanding the processes mediating the dynamics of tropical prawn populations is an important step towards their effective management (Garcia, 1985; Rothlisberg, Staples and Crocos, 1985). Garcia (1988) emphasized the influence of environmental variability on the dynamics of tropical prawn populations; and advised that such environmental influences must be taken into account in the management of the prawn stocks. The role of the parental stock on tropical prawn recruitment has largely been discountenanced (Garcia and Le Reste, 1981). In a few cases where stock-recruitment relationships have been demonstrated in prawns, they have been regarded as artefacts and misinterpretations (Garcia, 1983; 1984). The latter author argued that because tropical prawns are short-lived species (completing life-cycle within one year), the observed relationships may be actually recruitment-stock relationships and not vice versa. Among environmental factors affecting tropical prawn recruitment, abundance and catchability, rainfall appears to be the most important. Rainfall has been shown to be a good predictor of prawn catch and recruitment in the Gulf of Carpentaria, Australia (Staples, 1985), in the Casamance estuary, Senegal (Le Reste, 1980), and in Cote D'Ivoire (Garcia and Le Reste, 1981).

In the present study, relationships were sought between rainfall, prawn catch rate (as an index of abundance), and the indices of spawning and recruitment, for two prawn populations: (1) Brackish River Prawn (*M. macrobrachion*) and (2) Estuarine Prawn (*N. hastatus*), in the Cross River Estuary, Nigeria. The aim was to assess the influence of rainfall on these prawn populations from the abundance of adults through the spawning process to the recruitment of the young; and possibly to identify the pathway of such influences, especially through the influence of rainfall on the variability of salinity. Populations of these two prawns form the bases of important artisanal fisheries in the lagoons, estuaries and the mangrove creeks of Nigeria. They have been the subject of quite a few studies including Marioghae (1982, 1990), Powell (1983) and Enin (1998) for *M. macrobrachion*, and Sagua (1980), Marioghae (1980), Enin *et al.* (1991, 1996) for *N. hastatus*.

MATERIALS AND METHODS

The area for this study is shown in Fig. 1 along with the sampling locations, from which prawn samples were obtained from the artisanal fisheries. The data series used in this study are given in Table 1 (for *M. macrobrachion*) and Table 2 (for *N. hastatus*). The catch rate data and the methods for obtaining them had earlier been described by Enin (1998) for *M. macrobrachion* and it represents simply the amount of prawns caught per canoe per day's outing (Kg canoe-day^{-1}). Those for *N. hastatus* were described by Enin, Löwenberg and Künzel (1991), and here catch rate represents the amount caught per net per day's outing (Kg net-day^{-1}). The derivation of the spawning and recruitment indices for both prawns had been described by Enin (1997). In both cases, the spawning index represents the percentage of the prawns bearing eggs in the total monthly sample. The recruitment index is the percentage of juveniles (< 4 cm total length for *M. macrobrachion* and < 4.2 mm carapace length for *N.*

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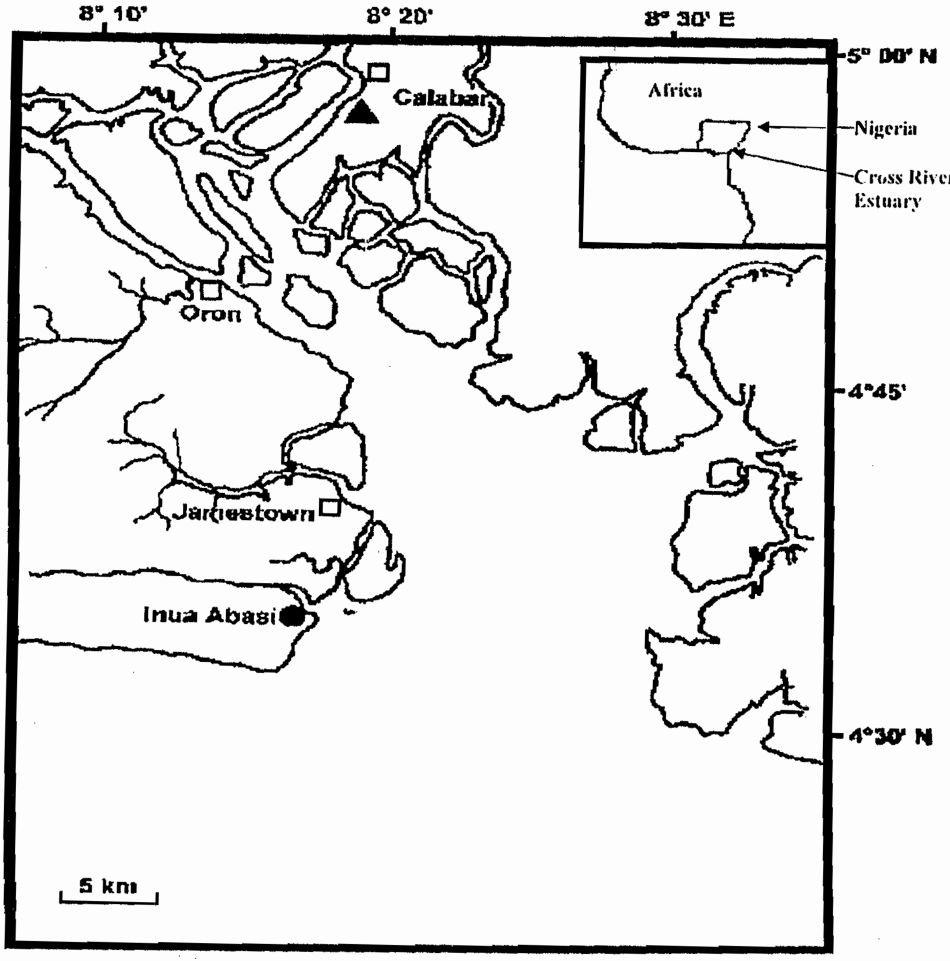

Fig. 1. The Cross River estuary with indication of the sampling locations: Inua Abasi (•) and Nsidung Beach, Calabar (▲).

hastatus) in the total monthly length-frequency samples. For the present analysis, these percentages were converted into integers by arc sine transformation. All rainfall (mm) data for Calabar, Nigeria, were obtained from the Meteorological Unit, Department of Geography, University of Calabar, Nigeria. Salinity data (Table 3) for the Cross River Estuary, Nigeria, were taken from Löwenberg and Künzel (1992).

Linear relationships were then sought between total rainfall and the variables obtained from the prawn populations (catch rate, spawning index, recruitment index), and also among those population variables themselves. Furthermore, the linear relationship between monthly total rainfall and monthly maximum salinity was quantified. All the relationships were established using the method of ordinary least square (OLS) with lags of up to 6 months. The maximum lag of six months was adopted because each of the two prawn species has two cohorts per year, which in each case is separated by a period of about six months. In all correlations involving rainfall, the lagging procedure did not result in loss of data points or reduction in sample size (n) because extensive rainfall data previous to the start of our study were available. The significance of the coefficients of correlation was tested under the null hypothesis that these were zero. The observed marginal significance levels (p - values) were used to indicate significance. It should be mentioned that non-significance does not necessarily mean that there is no relationship. It only means that there is probably no linear relationship as the coefficient of correlation is a measure of linear relationship. Thus, when we use the expression 'relationship' in the following we mean 'linear relationship'.

RESULTS

Rainfall and salinity patterns

The Cross River Estuary is located in the humid tropical rain forest belt of Nigeria with its typical double-peaked rainfall pattern (Fig. 2). In Fig. 2, a long term mean total rainfall for Calabar is presented covering the years 1977 to 2000. The dry season lasts from November to March and during this period total rainfall remains generally below 100 mm per month. The wet or rainy season extends from April to October and here rainfall increases to peak values > 500 mm between June and October. A period of decreased rainfall occurs in the middle of the rainy season, mostly in August (giving the name 'August break') but this shifts to September in some years. Surface salinity in the estuary showed a similar but inverse seasonal pattern to that of rainfall, reaching a flood-stage peak of 21 ‰ in March, when rainfall is least, and decreased with increased

Table 1: Data on *Macrobrachium macrobrachion* of the Cross River Estuary, Nigeria, and total rainfall in the area, used in the study.

Month/ Year	Total Rainfall (mm)	Catch Rate (kg canoe-day^{-1})	Spawning Index	Recruitment Index
Apr. 91	275.8			
May	205.4			
Jun.	468.6			
Jul.	477.7			
Aug.	485.6			
Sep.	136.5			
Oct.	293.2	26.51	34.79	
Nov.	75.4	30.23	37.90	
Dec.	5.2	4.2	18.28	56.51
Jan. 92	0.4	4.1	27.41	49.42
Feb.	1.3	1.5	13.00	43.28
Mar.	262.9	0.9	22.94	41.55
Apr.	242.3	2.2	18.92	32.23
May	173.2	5.7	14.26	55.96
Jun.	321.4	4.2	22.65	44.23
Jul.	418.1	6.1	36.50	32.58
Aug.	420.9	2.7	28.39	40.94
Sep.	449.7	3.6	36.52	28.06
Oct.	453.8	6.7	23.87	35.87
Nov.	102.3	3.8	28.42	43.78
Dec.	0.0	3.3	24.47	44.92
Jan. 93	56.3	1.4	32.11	38.21
Feb.	14.7	2.3	16.93	50.03
Mar.	182.9	1.6	21.02	31.91
Apr.	137.4	2.6	10.80	40.70
May	217.5	3.5	24.57	44.44
Jun.	309.8	5.0	20.16	40.15
Jul.	302.3	6.0	27.69	35.02
Aug.	500.9	3.9	38.93	27.18
Sep.	418.9	4.1	43.42	25.13
Oct.	275.3	5.5	34.64	26.70
Nov.	153.7	8.4	36.88	36.59
Dec.	5.2	5.1	29.35	48.34

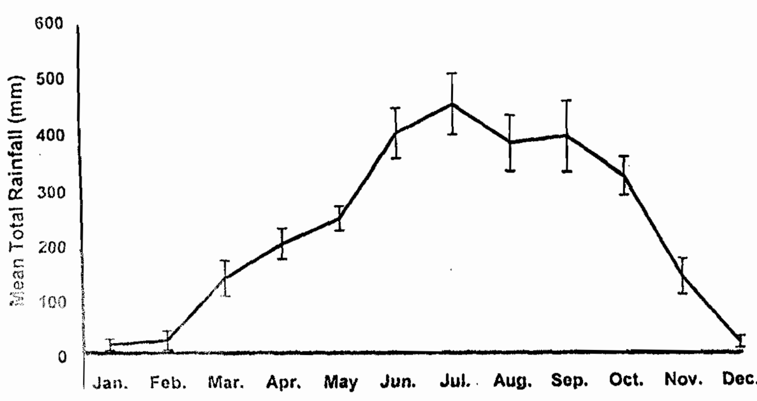

Fig. 2. Mean total rainfall (mm) in Calabar, 1977 to 2000, and the 95 % confidence intervals.

rainfall to about 5 ‰ in October when rainfall is at its peak (Fig. 3). Surface salinity at ebb-stage shows a similar annual pattern, with zero salinity in October.

Macrobrachium macrobrachion

The coefficients of correlation together with the regression parameters among total rainfall and the variables from *M. macrobrachion* population are provided in Table 4. Rainfall in one to three previous months were significantly related to prawn catch rates, with the two months lag being the most important. With spawning index, rainfall was significantly correlated at No lag and upto three months lag, the latter being the strongest. Against recruitment index, rainfall was

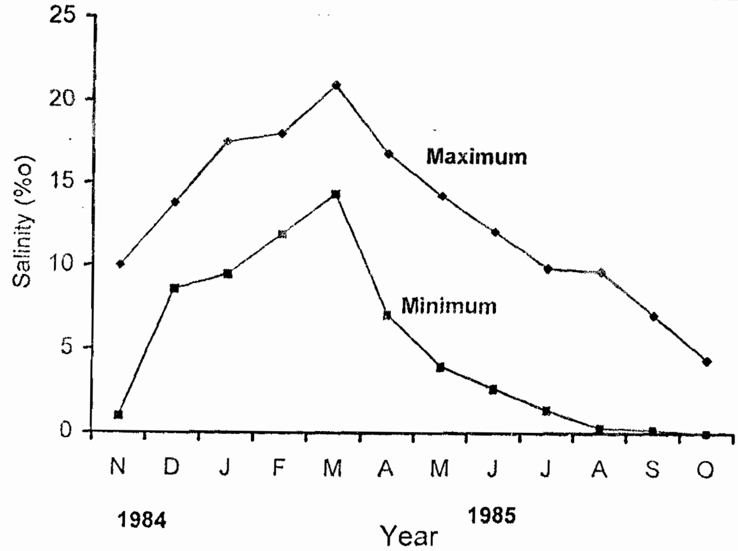

Fig. 3. Annual salinity (‰) regime in the Cross River estuary, Nigeria (Data from Löwenberg and Künzel, 1992).

Table 2: Data on *Nematopalaemon hastatus* of the Cross River Estuary, Nigeria, and total rainfall in the area, used in the study.

Month/ Year	Total Rainfall (mm)	Catch Rate (kg net-day^{-1})	Spawning Index	Recruitment Index
May 86	245.6			
Jun.	161.9			
Jul.	434.3			
Aug.	228.2			
Sep.	401.2			
Oct.	404.1			
Nov.	62.1	1.8	25.57	
Dec.	0.0	1.6	19.22	
Jan. 87	20.0	1.8	9.46	20.57
Feb.	49.8	1.6	9.72	18.25
Mar.	203.8	2.2	9.97	15.93
Apr.	240.9	3.2	5.74	39.61
May	306.9	3.4	10.78	7.06
Jun.	376.0	3.8	14.54	16.29
Jul.	371.1	1.9	16.00	10.39
Aug.	515.7	2.5	15.68	8.27
Sep.	291.6	2.1	17.44	12.91
Oct.	485.1	1.7	19.19	17.54
Nov.	79.4	1.7	18.63	22.03
Dec.	80.0	2.1	10.94	37.61
Jan. 88	69.0	2.6	14.42	23.14
Feb.	18.0	3.3	11.24	14.77
Mar.	117.6	5.5	14.42	36.67
Apr.	194.0	1.4	14.54	28.39
May	272.6	1.7	9.63	11.49
Jun.	516.2	1.2	8.13	12.41
Jul.	390.4	1.0	11.09	12.84
Aug.	144.3	0.8	14.67	14.67
Sep.	517.6	1.5	18.24	16.49
Oct.	237.5	2.4	20.09	34.93
Nov.	113.0	2.5	9.46	21.39
Dec.	84.4	1.9	6.55	24.86

Table 3. Data used for correlation between total rainfall (mm) and salinity (‰) in the Cross River Estuary, Nigeria (only maximum salinity was employed in the correlation).

Month/Year	Total Rainfall (mm)	Salinity (‰)	
		Maximum	Minimum
May 84	312.1		
Jun.	397.9		
Jul.	300.2		
Aug.	134.6		
Sep.	397.3		
Oct.	293.2		
Nov.	229.4	10.0	1.0
Dec.	0.0	13.8*	8.6
Jan. 85	23.6	17.5	9.5
Feb.	0.0	18.0	11.9
Mar.	106.2	21.0	14.4
Apr.	236.9	16.8	7.1
May	402.5	14.3	4.0
Jun.	407.5	12.1*	2.7*
Jul.	281.3	9.9	1.4
Aug.	309.1	9.7	0.3
Sep.	309.6	7.1*	0.2*
Oct.	334.7	4.4	0.0

* Interpolated missing values

significantly correlated only without lag and at one month lag, but those relationships were negative (Table 4).

The correlation between spawning index and catch rate was significant at one to three months lags, but was strongest at the two months lag. Between recruitment index and spawning index, correlation was significant at No lag, 4-month and 5-month lags. It was strongest at No lag but negative. The highest positive correlation at the 5-month lag was only slightly stronger than that at the 4-month lag. Correlation between recruitment index and catch rate was significant only at the 6 months lag (Table 4).

Nematopalaemon hastatus

Quantified relationships among rainfall and variables from *N. hastatus* population are given in Table 5. The correlation between catch rate and total rainfall was insignificant at all lags and was mostly negative except for the 5 and 6 months lags. Between spawning index and total rainfall, significant relations were found at 1 month lag and at 3 months lag; the latter being only slightly higher than the former. Relations between recruitment index and rainfall were significant at No lag and at 6 months lag, with the latter only being the positive one.

Spawning index and catch rate exhibited no significant relationship. No significant relations were shown also between recruitment index and spawning index. In this case only at No lag was the correlation negative, the rest were positive. Again between recruitment index and catch rate no significant correlation was found. At No lag, 1 month lag and 6 months lag the relationships were positive, while at 2 to 5 months lags they were negative.

DISCUSSION

Rainfall is probably the most important climatic factor driving environmental processes in the tropical rain forest belt of Nigeria. Its role in determining the flood regime in the Cross River system, which in turn influences fish catch and fish communities had been demonstrated by Moses (1987). Amadi (1990) asserted that seasonal salinity fluctuations is the key factor determining the dynamics of animal populations in the Nigerian estuaries. It is clear that the observed salinity pattern is closely related to or in fact significantly determined (besides river in-flow) by the seasonal rainfall pattern in the area. As Table 6 shows, an inverse correlation exists between salinity in the Cross River Estuary and total rainfall in the area, which is strongest at the 1 month lag. Here, rainfall explained about 68% of the variation in salinity. Given this scenario, the underlying objective in the present analysis was to assess the influence of rainfall on the dynamics of the prawn populations, from catch rates as an index of abundance of the adult population, through spawning and recruitment; and to assess the linkages in an exploratory and step-wise manner.

The prawn *M. macrobrachion* is a freshwater species but similar to other members of the genus, brackish-water conditions are required for larval survival (Willfuhr-Nast *et al.*, 1993). In some species larval mortality ensue when hatched in freshwater, if they fail to reach brackish-water within a few days (New and Singholka, 1985). Spawning adults thus migrate into estuaries to spawn and thus become the target of artisanal fishery in that zone. Both the catch rates and spawning activities of this prawn in the Cross River

Table 4. Coefficients of correlation (r) and regression parameters (a, b) among the various variables of *Macrobrachium macrobrachion* of the Cross River Estuary, Nigeria, and total rainfall (mm), with lags (n = sample size).

Lag	r	a	b	n
Catch Rate (kg canoe-day^{-1}; y) on Total Rainfall (x)				
No lag	0.257	3.321	0.003	25
1 month	0.519**	2.654	0.006	25
2 months	0.602** 2.410	0.007	25	
3 months	0.452*	2.824	0.005	25
4 months	0.090	3.717	0.001	25
5 months	-0.297	4.663	-0.003	25
6 months	-0.414*	4.940	-0.004	25
Spawning Index (y) on Catch Rate (x)				
No lag	0.365	19.403	1.698	25
1 month	0.469*	18.007	2.162	24
2 months	0.649**	13.472	3.493	23
3 months	0.448*	18.516	2.344	22
4 months	0.004	27.091	0.021	21
5 months	-0.327	33.517	-1.663	20
6 months	-0.401	35.241	-2.022	19
Recruitment Index (y) on Spawning Index (x)				
No lag	-0.631**	56.328	-0.641	27
1 month	-0.267	46.744	-0.270	26
2 months	-0.103	42.527	-0.108	25
3 months	0.079	37.078	0.078	24
4 months	0.452*	26.702	0.485	23
5 months	0.458*	25.565	0.537	22
6 months	0.150	34.062	0.176	21
Spawning Index (y) on Total Rainfall (x)				
No lag	0.459*	21.270	0.023	27
1 month	0.531**	20.187	0.028	27
2 months	0.505**	20.431	0.025	27
3 months	0.583**	19.570	0.028	27
4 months	0.246	23.448	0.012	27
5 months	0.072	25.435	0.004	27
6 months	-0.376	30.531	-0.019	27
Recruitment Index (y) on Total Rainfall (x)				
No lag	-0.676**	46.966	-0.035	27
1 month	-0.518**	45.515	-0.027	27
2 months	-0.214	42.012	-0.011	27
3 months	-0.191	41.722	-0.009	27
4 months	0.131	37.983	0.006	27
5 months	0.221	36.931	0.011	27
6 months	0.267	36.410	0.014	27
Recruitment Index (y) on Catch Rate (x)				
No lag	-0.069	41.031	-0.326	25
1 month	0.021	38.697	0.091	24
2 months	-0.317	44.333	-1.550	23
3 months	-0.390	45.428	-1.951	22
4 months	0.034	37.628	0.170	21
5 months	0.313	33.026	1.544	20
6 months	0.496*	29.814	2.268	19

* significant at p = 0.05
** significant at p = 0.01

Table 5. Coefficient of correlation (r) and regression parameters (a, b) among the various variables of *Nematopalaemon hastatus* of the Cross River Estuary, Nigeria, and total rainfall (mm), with lags (n = sample size)

Lag	r	a	b	n
Catch Rate (kg net-day^{-1}; y) on Total Rainfall (x)				
No lag	-0.113	2.347	-0.001	26
1 month	-0.257	2.552	-0.002	26
2 months	-0.313	2.646	-0.002	26
3 months	-0.293	2.617	-0.002	26
4 months	-0.164	2.436	-0.001	26
5 months	0.193	1.921	0.001	26
6 months	0.145	1.992	0.001	26
Spawning Index (y) on Catch Rate (x)				
No lag	-0.031	13.219	-0.125	24
1 month	0.038	12.603	0.151	24
2 months	-0.019	13.106	-0.075	24
3 months	-0.021	13.266	-0.080	23
4 months	0.108	12.319	0.417	22
5 months	0.307	10.608	1.219	21
6 months	0.334	10.831	1.254	20
Recruitment Index (y) on Spawning Index (x)				
No lag	-0.071	22.065	-0.164	24
1 month	0.222	12.747	0.542	23
2 months	0.302	9.912	0.752	22
3 months	0.186	13.658	0.499	21
4 months	0.343	8.058	0.870	20
5 months	0.443	6.185	1.075	19
6 months	0.355	9.005	0.862	18
Spawning Index (y) on Total Rainfall (x)				
No lag	0.303	11.171	0.008	24
1 month	0.504*	10.117	0.012	24
2 months	0.358	10.974	0.009	24
3 months	0.508*	10.126	0.012	24
4 months	0.360	10.908	0.009	24
5 months	0.049	12.658	0.001	24
6 months	-0.310	14.716	-0.007	24
Recruitment Index (y) on Total Rainfall (x)				
No lag	-0.441*	25.375	-0.024	26
1 month	-0.238	23.089	-0.013	26
2 months	-0.179	22.444	-0.010	26
3 months	0.046	19.526	0.003	26
4 months	0.210	17.378	0.011	26
5 months	0.356	15.430	0.019	26
6 months	0.565**	12.730	0.031	26
Recruitment Index (y) on Catch Rate (x)				
No lag	0.316	13.805	2.874	26
1 month	0.116	17.585	1.051	25
2 months	-0.293	25.778	-2.655	24
3 months	-0.335	26.582	-3.044	23
4 months	-0.368	27.481	-3.372	22
5 months	-0.264	25.951	-2.520	21
6 months	0.042	18.316	0.379	20

* significant at p = 0.05
** significant at p = 0.01

Table 6. Coefficient of correlation (r) and parameters of regression (a, b) of maximum salinity (‰) of the Cross River Estuary, Nigeria, on total rainfall (mm) in the area, with lags (n = sample size).

Lag	r	a	b	n
No lag	-0.610*	17.253	-0.020	12
1 month	-0.825***	18 791	-0.027	12
2 months	-0.764**	18.289	-0.024	12
3 months	-0.505	16.233	-0.016	12
4 months	-0.282	14.756	-0.009	12
5 months	-0.010	12.948	-0.0003	12
6 months	0.448	9.838	0.015	12

* significant at p = 0.05
** significant at p = 0.01
*** significant at P = 0.001

Estuary are highest during the rainy season especially between July and November (Enin, 1997, 1998). It is conceivable that increased rainfall in the catchment area leading to depressed salinity in the estuary, provide suitable conditions for the spawning and for larval survival.

It probably takes two months on the average for rainfall in the drainage basin of the Cross River to make maximum impact on the salinity in the estuary. This may explain the strongest correlation obtained in the present analysis between catch rates and rainfall at the two months lag (Table 4). However, the time required for the prawns to migrate from the freshwater zones into the estuary may partly account for this 2-month delay. So it can be argued that the dilution process of rainfall might take one month, as indicated by the strongest correlation between salinity and rainfall at one month lag (Table 6), while the migration process of the prawns might take another month, making a total of two months delay between rainfall and prawn catch rates. It should be noted however, that the rainfall data used for correlation with salinity (Tables 3 and 6) represent rainfall in the local area and as such may make a faster impact on the salinity in the estuary (i.e in one-month period) than rainfall from the entire drainage basin of the Crcss River, which extends even to the Camerouns. Rainfall from the entire drainage basin of the Cross River, may require two months to make significant impact on the salinity of the estuary. Hence, the significance at the two months lag. The 'proximate factors' (Payne 1986) that trigger off prawn migration in the first place may include elavated water levels and current speed, and changes in the chemical constitution of the river water, resulting from rainfall and drainage from land.

Spawning index and total rainfall had the strongest correlation at 3 months lag. This indicates that the prawns having arrived the estuary in response to rainfall two months earlier, require another one month before embarking on spawning activity. Correlation between recruitment index of *M. macrobrachion* and total rainfall were significant only at No lag and one month lag. But those correlations were negative making it difficult to interpret the results. Between spawning index and catch rate, correlation was strongest at 2 months lag. This would indicate a total of 4 months lag between total rainfall and spawning (two months between rainfall and catch rate and two months between catch rate and spawning). But the strongest correlation at the 3 months lag between rainfall and spawning index indicates that this is not the case. It may however, show that the time span between rainfall and spawning can be 3 or 4 months.

Correlation between recruitment index and spawning index were significant at No lag and at 4 and 5 months lags. The negative correlation at No lag can be disregarded. The positive ones at 4 and 5 months lags indicate that recruitment takes place four to five months after spawning. The spawning activity of *M. macrobrachion* is highest in September while recruitment of the young into the population peaks in December/January (Enin 1997). This approximates to the four to five months lag between spawning and recruitment. The relationship between recruitment index and catch rate was significant at six months lag. It is difficult to say if this indicates a relationship between the spawning stock and recruitment. But it is noteworthy that the prawn catch rates are highest in July and in October/November while recruitment is highest in December/January and in May (Table 1; Enin, 1997). The time difference separating the adult population in July and recruitment in December/January, and that between the adult population in October/November and recruitment in May, both approximate to a 6-month interval. But it must be noted that the catch rates data includes some recruitment term since newly recruited individuals are also harvested by the fishery.

For *Nematopalaemon hastatus*, no significant linear relationship was found between catch rate and total rainfall, between spawning index and catch rate, between recruitment index and spawning index, and between recruitment index and catch rate (Table 5). Significant correlations were however, established between spawning index and total rainfall at one month and three months lags; and between recruitment index and total rainfall at No lag and 6 months lag. The lack of relationship between catch rate and other variables in the series may be associated with the complicated migratory pattern of *N. hastatus*. The prawn is abundant in the estuary and the near shore coastal waters in the dry season, coming to a peak between March and June. Thereafter, it decreases in abundance with increased rainfall to the lowest values in July to September before increasing again to a smaller peak in October and

November (Marioghae, 1980; Enin *et al.* 1991). The low catch rates in the high rainy season months is due to emigration of the prawns from the estuary into the deeper continental shelf waters during its main spawning season (Longhurst, 1965, 1971; Sagua, 1980). Therefore, despite that rainfall may be the trigger for its offshore migration leading to good catches in the estuary during the early rains as the fishery takes advantage of the migratory schools, prawn abundance during the rest of the year in relation to rainfall is non-linear.

This nonlinearity in the relation between catch rate and rainfall probably explains why catch rate also has no significant correlation with spawning index and recruitment index. These latter two variables seem to proceed linearly with rainfall (Table 5). The spawning index of *N. hastatus* and total rainfall had the strongest correlation at three months lag similar to the situation in *M. macrobrachion*. Prawn spawning in the estuary therefore responds to rainfall with 3 months delay, associated with the need for the spawning populations to reach suitable grounds. Between recruitment index and total rainfall, correlation was strongest at 6 months lag. This means an interval of 3 months between rainfall and spawning and another 3 months between spawning and recruitment. Given the peaks of recruitment in March/April and in Ocotober - December (Table 2; Enin 1997), it means that rainfall in April - June and in September/October are important to the recruitment of *N. hastatus*. Because the indices of adult population abundance, spawning and recruitment used here are only approximate, the present analysis can be regarded as merely exploratory (without postulating any hard cause and effect hypothesis). There is therefore the need for research effort clearly directed to effect a detailed modelling of the recruitment processes in the populations of the two prawns considered here, which are of immense value to the artisanal fisheries in Nigeria. This would greatly enhance the effective management of the prawn stocks.

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