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INVESTIGATION OF COMMUNITY PATTERNS IN MANGROVES USING CORRELATION ANALYSIS

I. E. Ukpong
Department of Geography and Regional Planning
University of Uyo, Akwa Ibom State, Nigeria.
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Abstract

Pearsons correlation coefficients were used to analyse the interrelationship between mangrove species. The aim was to investigate ecological associations among species with a view to understanding the community structure and spatial zonation in mangroves. Three groups of ecological associations were discerned and explained in terms of positive and negative relationships to each other. These groups reflect spatial distributional patterns based presumably on species dynamic relationships to each other and to the swamp landscape. Hence zonation patterns are probably determined by species competition, which make the simple spatial schemes often discussed in mangrove literature ecologically unrealistic.

1. Introduction

The term mangrove generally applies to an association of trees which live in wet, loose soils in tropical tide waters (Davis 1940). The term also applies to certain species of trees which occur in such an association. For this latter application, mangrove is normally

restricted to those species of trees which possess either pneumatophores or viviparous fruits or both (Macnae and Kalk 1962). Often the word "mangrove" is used when reference is made to individual kinds of trees, while the word "mangal" is used with reference to the swamp forest community (Walsh 1974, Chapman 1976).

On shorelines the occurrence of mangroves has often been explained in terms of the invasion of suitable habitats by pioneer species. The most adapted species establish close to the shores while the least adapted ones occur inshore. Hence the vegetation occurs in zones of species from the shores inland. Mangrove zonation has therefore been attributed to several environmental factors to which the species show varying adaptations. The factors are salinity (Scholander 1968, Giglioli and King 1966, Rabinowitz 1978); tidal range (Thom *et al* 1975, Semeniuk 1983); mangrove soils (Van Steenis 1958, Naidoo 1980, Semeniuk 1983). These studies were extensively discussed by Walsh (1974), Chapman (1976), Tomlinson (1986) and need not be elaborated here. However, one pertinent question that has not been sufficiently addressed is: *What is the role of the mangrove vegetation itself in giving rise to the perceived zonation patterns?* The answer to this question lies in elucidating the interrelationships between the mangrove species themselves in the course of ecological succession in mangrove ecosystems. Previous studies merely indicated the possible relationship of species distribution to each other without really exploiting the nature of the interrelationships.

2. Dynamic Equilibrium in Mangrove Swamps

The mangrove swamps had been thought of as a simple ecosystem where the occurrence of plant species relates directly to salt concentrations, shore topography and soil properties. This may be true since mangroves tend to occupy brackish or saline shores where fresh water species intolerant of salt cannot exist. However the simplicity of the ecosystem has perhaps been over stressed when considered within the concept of direct vegetation - environment relationships. Mangroves may occur in fairly defined zonation in littoral areas of marked wet and dry spells of the macroclimate, which correspond to low and high salinites. But in ever-wet areas, fluctuations in salinity may be marginal especially in estuaries that have abundant freshwater inputs from inland streams.

An alternative to the classical vegetation/environment zonation concept, which seems to offer a more satisfactory approach to the analysis of mangrove patterns is the concept of dynamic equilibrium. The dynamic equilibrium does not only relate to a changing vegetation, but also to a landscape constantly influenced by active fluvial processes. In mangrove swamps, sediment accretion may initiate, the establishment of new vegetation while erosion may destroy the vegetation along a degrading shore. By modifying the mangrove habitats, fluvial processes influence the distribution of the flora. The plant therefore develop adaptations in relation to the constantly disturbed landscape e.g the possession of trailing stems for easy rooting in the sands, the development of props in species occurring along flooded channel margins or the possession of salt filtering mechanism to regulate salt concentrations in tissues. These imply that the species constantly adjust to varying processes of landscape evolution and stress factors and their banded structure may be viewed as a community characteristic arising from adaptation and competition with each other as they strive to maintain a dynamic equilibrium situation with the ever changing swamp landscape.

3. Aim of the Study

The aim of this study is to analyse the interrelationships between the mangrove species with a view to understanding the community structure and spatial variation of the species in mangrove swamps. To achieve this aim, it is proposed to analyse the floristic characteristics of the vegetation and validate the issue of species zonation along shorelines based on the species measurements from a large number of stands.

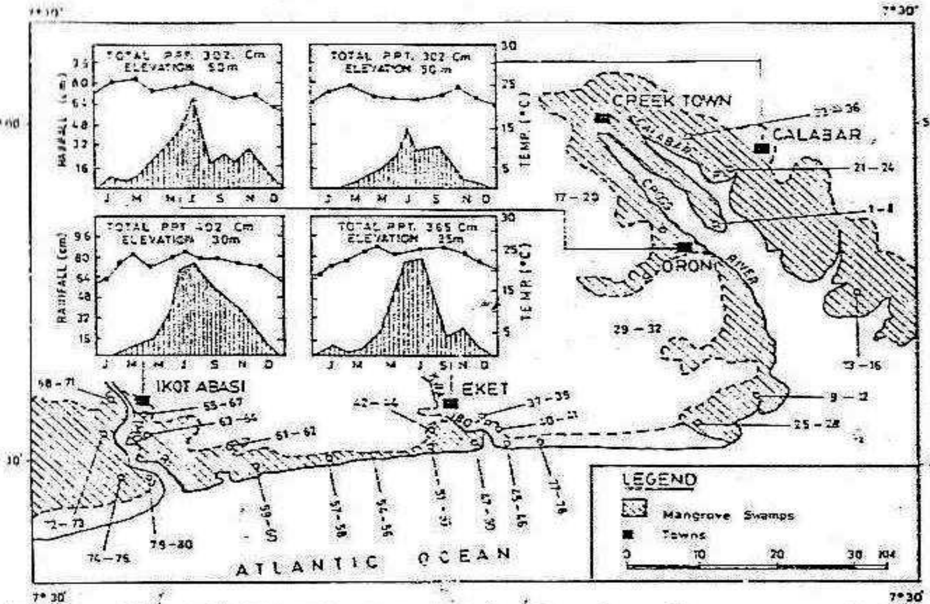

Fig. 1: **Map of the study area showing location of transects and climatic condition for the swamp.**

4. Study Area

The study area for this investigation is the southeastern coast of Nigeria. It consists of the marginal estuaries of the Rreek Town Creek/ Calabar River, Cross River, Kwa Iboe and Imo Rivers lying between longitude 73°0' to 8°0' East with a 170km stretch of coastline. These estuaries may be regarded as an eastward extension of the River Niger delta since they are connected to each other and to the, Niger delta by means of interriverine creeks. The most extensive mangrove growth occurs in the estuaries of the Cross River and Imo River. Species occurring in the swamps are *Avicennia africana, Rhizophora mangle, Rhizophora harrisonii* and *Laguncularia racemosa.* The non-mangroves are *Nypa fruticans, Raphia hookeri, Conocapus erectus, Pandanus candelabrum, Phoenix reclinata* and *Acrostichum aureum.* The succession and zonation scheme for these mangroves in Nigeria was discussed by Chapman (1976) (see Ukpong 1998).

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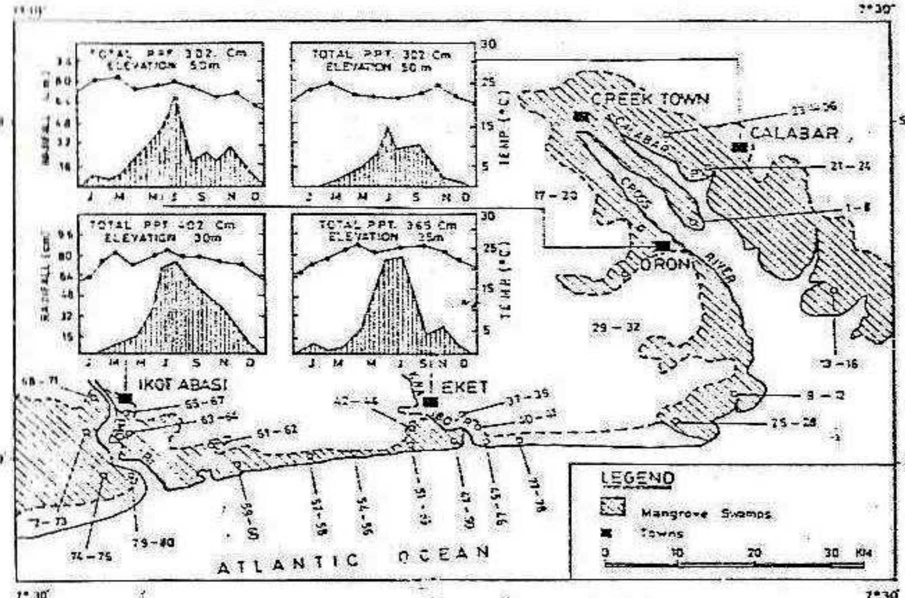

Fig. 1: **Map of the study area showing location of transects and climatic condition for the swamp.**

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5. Method

The unit for sampling was the quadrat. For each swamp the mangrove coverage were selectively obtained in 10 x 10m quadrats established from the shores along transects at 20-m intervals. The $100m^2$ quadrats were considered most appropriate. Although a larger quadrat would have raised the number of mangroves encountered, it would also have demanded a much longer sampling time. Each $100m^2$ quadrat was subdivided into four $25m^2$ subquadrat in order to facilitate coverage estimates of the understorey, and another $1m^2$ subdivisions allowed for the determiantion of seedling coverage and other groundlayer species. A total of eighty quadrats were sampled in all the swamps. Coverage was defined as the proportion of the ground surface covered by the perpendicular projection onto it of the foliage (Greig-Smith 1975). To determine crown cover for the over-storey, the crown-diameter method was used. The computational formula is:

$$\text{Crown cover} - \frac{(D_1 + D_2)^2}{4}\pi \text{ where}$$

D_1 and D_2 are the first and second crown diameter measurements projected onto the swamp surface (Mueller-Dombois and Ellenberg 1974).

Coverage values for the understorey and ground layer were determined by visual estimates in the $25m^2$ and $1m^2$ subquadrats respectively. The relative coverage values for each species was computed as:

$$\frac{\text{Relative coverage of species x 100}}{\text{Total \% coverage in quadrat}}$$

Coverage measurement is essential in determining the abundance and consequently the relative importance of the species with respect to their spatial distribution. The crown cover data of species were very slightly negatively skewed but more closely approximated to normal distribution after square root transformations.

5.1 Synthesis of Data

Pearsons product moment correlations were employed to analyse the data. Two methods may by used to derive the correlation coefficients r (i) Graphical representation - in which the two axes of the graph Y and X represent variables measured at interval or ratio scale, Y being the variable of interest for which an explanation is being sought and (ii) computational derivation - which determines the strength of the relationships using the formula:

$$r = \frac{(X_i - \overline{X})(Y_i - \overline{Y})}{\sqrt{(X_i - X)^2 (Y_i - Y)^2}}$$

where r = correlation coefficient and X and Y represent variables the relation of which are being sought. In this study the r - values have been computational derived. Those proving significant on applying the t-test have been reported.

To establish the relationship between the different species, the bivariate correlation analysis was performed on their relative coverage values. The coefficients (r) enabled an assessment of the nature of the relationship between the species, identifying those species whose distribution may be strongly influenced by others.

The correlation coefficient however has some pitfalls. The coefficients are limited to the area for which the data are used and cannot be extrapolated to other areas. Also, a statistically significant relationship does not necessarily mean that the variables are causally related. A significant relationship merely serves as an indication of a relationship most unlikely to have occurred by chance. Dalton *et al* (1972) list the following possibilities as to the meaning of a correlation: (i) direct causal relationship or partial causal relationship, (ii) indirect casual relationship when the link between the two variables must be south i.e mutual interaction of the variables, (iii) both variables may be dependent upon a common factor i.e two variables may be spurious and (iv) the relationship could be a chance occurrence going contrary to reasonable expectation.

For all correlations reported in this study, if r> 0.21, P<0.05; r>0.26, P<0.01; r>0.34; P<0.001. The levels of ecological associations between the species were categorized into the following groups:

(i) r = > -0.50 = moderately strong to strong negative relationship (- -);

(ii) r = > + 0.50 = moderately strong to strong positive relationship (+ +);

(iii) r = < -0.50 = weak negative relationship (-);

(iv) r = < + 0.50 = weak positive relationship (+)

The above categorization aimed at simplifying interpretations of the correlation rather than to investigate directly the causal factors of the ecological relationship.

6. Results

The matrix of the correlation coefficient is given in Table 1. True mangroves (species with pneumatophores or viviparous fruits) show mostly negative relationships with each other, which is a tendency to exclude competition for the range of environmental factors to which each species is most adapted. The strongest negative correlations exist between *Avicennia africana* and *Rhizophora mangle* (r=-0.51) and *Rhizophora racemosa* and *R. mangle* (r=-0.57). Non mangroves

Table 1: Correlation matrix of species (Reporting correlations above -0.17 and +0.17.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1.	*A. africana*	1.00	-.51	-.33	-.19	-.64	-.50	-.45	-.24	-.17	-.52	+.52	-.16	-.11	-.21	-.13	.12	.18
2.	*R. mangle*		1.00	-.57	-.21	-.26	-.13	-.31	-.18	-.02	.63	.19	.17	.10	.15	.18	.08	.14
3.	*R. racemosa*			1.00		-.22	-.12	-.07	-.17	-.07	.16	.10	-.12				-.01	
4.	*R. harrisonii*				1.00	-.09	.11	-.05		-.10		.18	.14	.18	.11	.08	-.05	-.03
5.	*N. fruiticans*					1.00	.85	.48	-.32		.52		.20	.17	.16	.08		-.07
6.	*R. vinifera*						1.00		.25	-.05	-.55	.54	.18	.05	.04			-.58
7.	*C. erectus*							1.00	-.65	.15	.08		-.45	.07			-.11	.09
8.	*P. candelabrum*								1.00		.68	-.41	-.09	.11	.08	.02	-.07	-.12
9.	*D. lunatus*									1.00	-.37	.45	.39	.62	.15	.08	.03	.31
10.	*P. reclinata*										1.00	.61	.58		.02	.11	.08	.08
	A. aureum											1.00		.51	.19	.48	.51	.05
11. 12.	*S. portula- eastrum*												1.00	.38	.11	.15	.17	.02
13.	*C. articulans*													1.00	.62	.13	.68	.01
14.	*T. rhomboldeae*														1.00	.05		.09
15.	*H. tilaceus*															1.00	.54	.05
16.	*Selaginellaspp*																1.00	.12
17.	*Cactus afer*																	1.00

show negative correlations with the mangroves e.g *Nypa fruticans* and *A. africana* (r = -0.64), *Phoenix reclinata* and *A. africana* (r =- 0.52) and *Conocarpus erectus* and *A. africana* (r =-o.45). *N. fruticans* is positively correlated with other non-mangroves e.g with *Raphia vinifera* (r = 0.85). The non-mangroves show mostly positive correlations with each other.

Three groups of ecological associations may be said to exist in the swamps (Tables 2):

Groups 1: This group consists of mangrove species and associes that display mostly negative relationships with each other;

Table 2: Extracted matrix for 54 stand pairs from the mangrove swamps showing positive and negative species relationships:

-- Strong to moderately stromg negative relationship;
- Weak negative relationship;
+ Weak positive relationship;
++ Strong to moderately strong positive relationship.

Group	Species	*Avicennia africana*	*Rhizophora mangle*	*Rhizophora racemosa*	*Rhizophora harrisonii*	*Nypa fruiticans*	*Raphia vinifera*	*Concocarpus erectus*	*Pandanus candelabrum*	*Drepanocarpus lunatus*	*Phoenix reclinata*	*Acrostichum aureum*	*Sesuvium portulacastrum*	*Cyperus articulans*	*Triumfetta rhomboideae*	*Hibiscus tilaceus*	*Selaginella spp*
GROUP 1 (Tidal)	*Rhizophora mangle*	--															
	Rhizophora racemosa	-	-														
	Rhizophora harrisonii	-	+														
	Nypa fruiticans	--	-	-													
	Raphia vinifera	-	-			++											
	Concocarpus erectus			-		+											
	Pandanus candelabrum			-		-	+										
	Drepanocarpus lunatus				-		-										
GROUP 2 (Semi-tidal)	*Phoenix reclinata*	-	++			+	--		+	-							
	Acrostichum aureum	+	+		+		++		-	+	++						
	Sesuvium portulacastrum	+	+	-	+		+	--		+	++						
	Cyperus articulans									+			++				
GROUP 3 (Ecotonal)	*Triumfetta rhomboideae*										+	+		++			
	Hibiscus tilaceus											-		+			
	Selaginella spp										+	+	+	++		++	
	Cactus afer						--		-	+					+		+

Group 2: This group consist of non-mangroves that display mostly positive relationships with each other and with species in the first group;

Group 3: The third group consists of species that show no relationship with those in the first group but positive relationships with species in the second group.

The communities show a correspondence with areas of regular tidal flooding, semi-tidal areas reached frequently by tides but may not be on a regular basis, and ecotonal or upland areas reached by the highest tides or storm waves on an irregular basis. However, since the three groups of communities are constantly under marine influence, the exclusivity of one species by another in its own zone of maximum adaptation can only be idealized. For instance, *Cyperus articulans, Sesuvium portulascastrum* and *Triumfetta rhombiodeae* which are non-mangroves in the third group show negative relationship with *Avecennia africana* and positive relationship with *Rhizophora mangle* which are true mangroves in the first group. Thus there can be no sharp zonation of species in the mangrove swamps.

7. Observations

The mangrove species *R.racemosa, R. mangle, R. harrisonii, A. africana, Laguncularia racemosa. Conocarpus erectus* and numerous brackish/freshwater associes constitute the mangals of the study area. The species in most instances appear to be organized into zones following the shorelines. Each zone is often occupied by one of the mangrove community types or by a combination of more than one community type. Then, there are areas characterised by mosaics of various community types due to variations in the local topography.

Field observations show that:

1. In the Creek Town Creek/Calabar River swamp, high forest species such as *Ripogonum* spp, *Cactus afer, Selaginella* spp, *Elaeis guineensis* and *Raphia vinifera* are ecotonal, occurring mostly at the landward edge of the swamp proper. *Raphia hookeri* is dominantly a brackish water species but its occurrence in mixed stand with *Raphia vinifera* which is dominantly a

freshwater species is an indication that salinity of the swamp is seasonal. (Fig. 2). Within the diurnally flooded areas, *Cyperus papyrus, Vossia, cuspidata* and *Acrostichum aureum* occupy microtopographic variations, with *A. aureum* showing greater preference for topographic mounds. The occurrence of *Vossia cuspidata* which is dominantly a freshwater species is a further indication that seasonal salinity variations encourage competition among species since *V. cuspidata* is dominantly a freshwater plant.

2. In the Kwa Iboe River and Imo River estuaries, the coastal strand vegetation consists mainly of *Hibiscus tiliaceous, Paspalum vaginatum, Cyperus articulans, Imperata cylindrica* and *Cynodon dactylon.* The strand vegetation shows defined zonation patterns especially of the mangrove species *R. racemosa* and *A. africana* which fringe the ebbflood channels (Fig 3 and 4). On the estuarine shores, spatial zonation patterns appear not to be so well defined as on the beachridges.

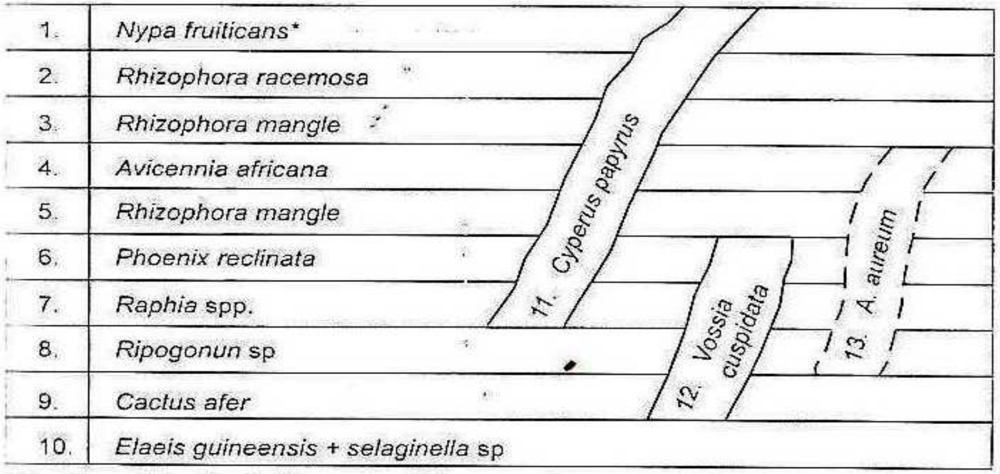

Fig. 2: Idealized diagram of the zonation pattern in the mangals of the Creek Town Creek/Calabar River swamps. 1-10 represent sequence from the shoreline to the lowland forest. 11-13 represent species associated with microtopographic variations across the zonation. * = introduced species.

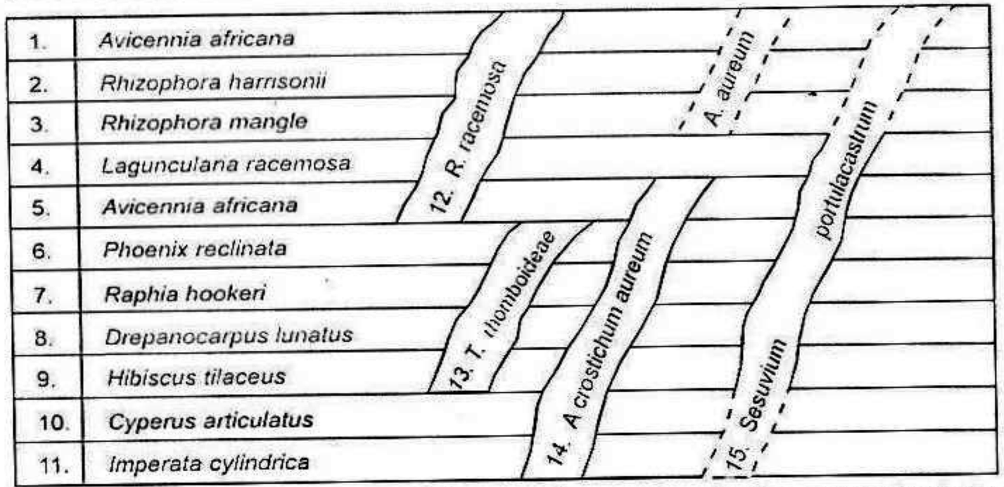

Fig. 3: **Idealized diagram of the zonation pattern in the mangals of the Kwa Ibo River estuary. 1-11 represent sequence from the shoreline across ebbflood channels to the old sand dunes. 12-15 represent species associated with microtopographic variations across the zonation. Dash lines - infrequent occurrence.**

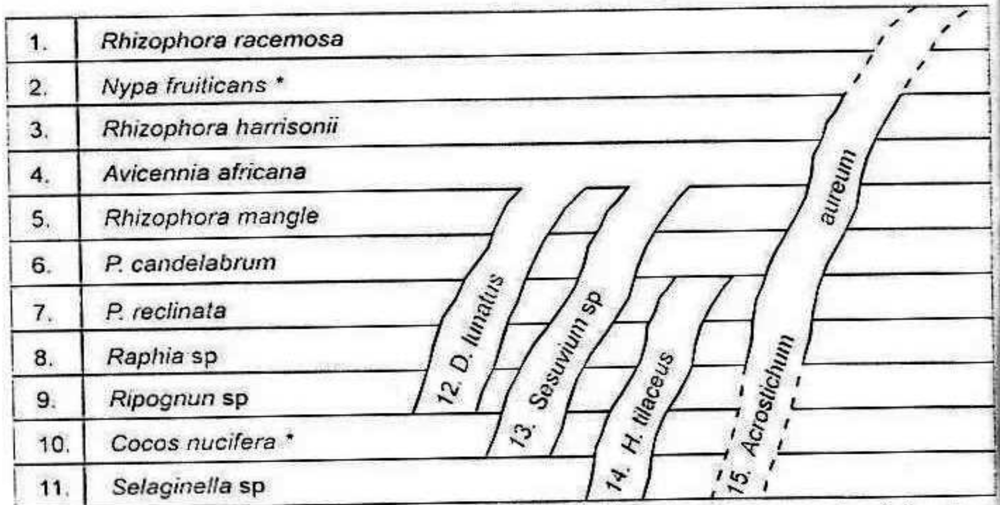

Fig. 4: **Idealized diagram of the zonation pattern in the mangals of the Imo River estuary. 1-11 represent sequence from the shoreline landward. 12-15 represent species associated with microtopographic variations across the zonation.**
*** = introduced species.**

8. Conclusion

It is clear that in the marginal swamps, mangrove species zonation can only be idealized. The extracted matric of correlation coefficients (Table 2) indicates that the level of species associations may be primarily due to competition leading to a display of each species niche relations. This is in consonance with field observations for particular locations of swamps.

The simple structures (schemes) of species zonation often discussed in the literature (Chapman 1976, Walsh 1974, Tomlinson 1986) do not appear to represent the community situation in the swamps. Hence the concept of zonation has limitations since it does not reflect the dynamic conditions in which mangrove communities interact and compete with each other.

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