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SEDIMENTS AND BIONOMIC MAPPING ON SOFT BOTTOMS IN THE SOUTH-WESTERN LAGOON OF NEW CALEDONIA.

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ABSTRACT

The south-western lagoon of New Caledonia covers an area of 5 550 sq.km. composed largely of soft bottoms. As part of the identification of the soft bottom biotopes of the New Caledonian lagoons that is being carried out, a study of the distribution of sediments and communities has also been undertaken. Sampling has been done with a 2 nautical miles grid, using a dredge for the benthos and a grab for the sediments. Mapping of the muds and a multivariate analysis have made it possible to define the sedimentological structure of these bottoms. A qualitative inventory of the benthic macrofauna communities has been drawn up in respect of the main zoological groups. Mud distribution is governed by the morphology of the shore, bathymetry and hydrodynamics. Sediments are divided according to two gradients, one relating to grain size, the other to siltation, which reflect a twofold influence, from the land and from the reef. One of the main factors affecting the distribution of benthic communities is the mud content of the sediment, which influences the wealth of species and the composition of the fauna. For herbivorous species however, this relationship is indirect, for their distribution is primarily associated with the presence of vegetative cover, which itself is dependent on the nature and the texture of the sediment. Examples of species distribution concerning the Strombidae and Cerithiidae molluscs are described.

INTRODUCTION

Several studies have already been carried out on New Caledonia's south-western lagoon - on its geomorphology (Thomassin 1984, Coudray *et al.* 1985), its sedimentology (Launay 1972, Dugas 1974, Dugas & Debenay 1978, 1980, 1981, 1982, Debenay 1985, Chevillon 1985, 1986) and its ecology (Salvat 1964, Thomassin 1981, Chardy *et al.* 1987, Chardy *et al.* in press, Chardy & Clavier in press, Richer de Forges *et al.* 1987).

All these authors have described a lagoon that is bordered by an outer barrier reef extending from the coast towards the south (figure 1). In this part of the lagoon, an area of 5 550 km² (Testau & Conand 1983), several zones can be distinguished according to standard criteria : a coastal zone with broad bays, characteristic of a submerged coast, representing a particular environment that is sheltered and receives terrigenous deposits, a broad central plain scattered with coral reefs and islets roughly following three lines parallel to the extension of the lagoon (Thomassin 1984); the inner slope hydraulic sand bank of the barrier reef, known locally as the 'inner reef white sand bottom'; and lastly, the barrier reef proper, 400-500 m. wide. Furthermore, from north to south the lagoon is divided into three parts by the sills of the Noumea peninsula and of the Ile Ouen. These separate parts become progressively larger and deeper towards the south. In the most southerly part, the lagoon is no longer enclosed by a continuous barrier reef and through a very broad submarine valley (Anglada 1975) it communicates extensively with the ocean. Here there are therefore two gradients, one terrigenous, from the coast towards the barrier reef, and the other oceanic, from the south towards the north.

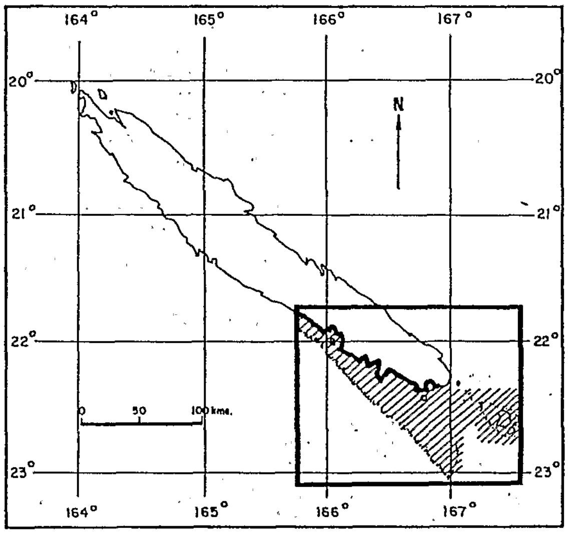

Figure 1. Location map.

The sedimentological and bionomic mapping work described in this paper forms part of the reconnaissance and characterization of the main lagoon biotopes of New Caledonia, a survey which was started by ORSTOM in 1984 as part of its 'lagoon' programme.

EQUIPMENT AND METHODS

The south-western lagoon was covered by systematic sampling using a sampling grid of two nautical miles, representing a total of 489 stations (figure 2). Two types of collection were made at each station : one using a Smith-McIntyre grab to take samples of sediments, the other using the Charcot dredge to sample the benthos.

The sediments were examined by conventional sedimentology methods as described by Buchanan (1984). The sieve-shaker used had 6 sieves with meshes of 20, 2.5, 1, 0.5, 0.25 and 0.063 mm. respectively. The mud content of the samples and the distribution of grains in the various granulometric fractions were thus obtained. The data regarding the carbonated or terrigenous origin of the sediments was taken from work done by Debenay (1985) and Chevillon (1985, 1986).

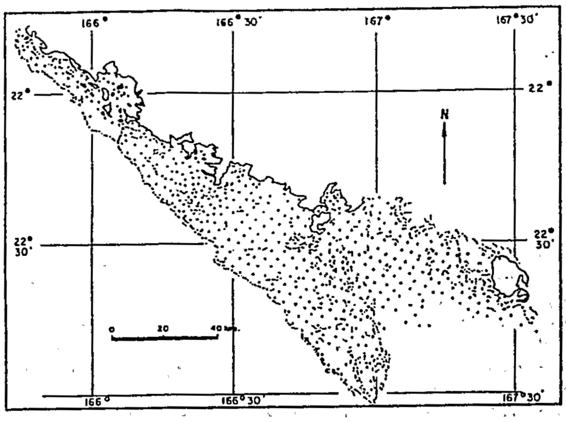

Figure 2. Location of samples.

A principal components analysis was applied to the granulometric data. Correlations were calculated on the weighted percentages of all the different grain size fractions. The data were centred and reduced for each fraction in order to allow a balanced representation of the variables.

The benthic samples collected with the Charcot dredge were washed through five and two millimetre sieves and then sorted into groups and fixed in alcohol and formalin. Identification of the organisms was entrusted to the relevant specialists for each group. The results described here relate only to two groups of molluscs, the Cerithiidae and the Strombidae.

RESULTS

Mud distribution

Mapping of the mud content in the sediment was inspired by Maxwell's work (1968) on the Australian Great Barrier Reef. Five classes have thus been selected : less than 5 % (non mud facies), 5 to 25 % (low mud), 25 to 50 % (moderate mud), 50 to 75 % (high mud) and more than 75 % (dominant mud facies). Figure 3 shows that the greatest mud content (high and dominant mud facies) is found in the broad bays with which the coast is indented. The mud rate then decreases, describing successive contours, until it reaches the barrier reef where the mud content of the sediments is no more than 0 to 5 % (non mud facies).

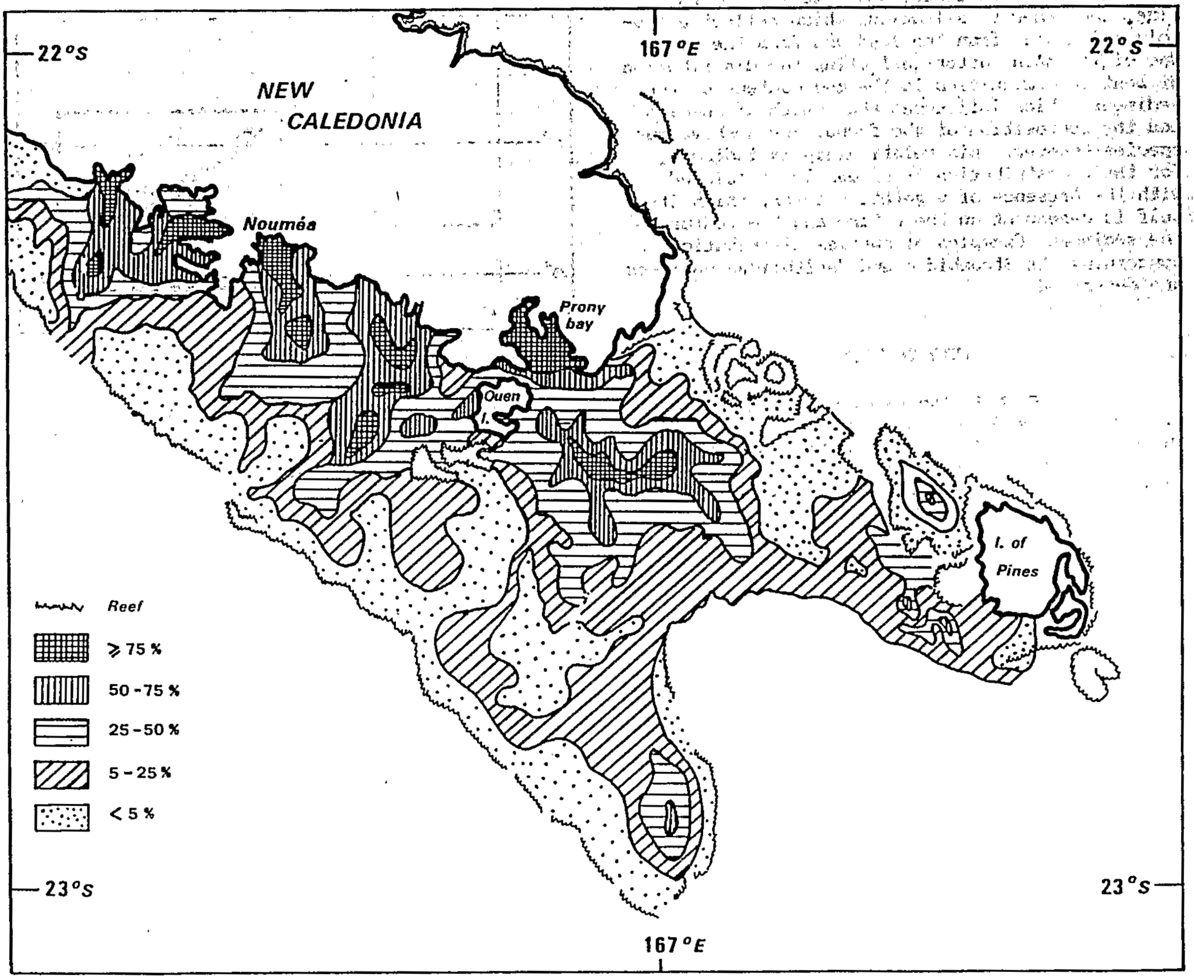

Figure 3. Distribution of mud in sediments

The presence of the submarine valleys described by Coudray (1982), Thomassin (1984) and Debenay (1985) interrupts this general trend; these vestiges of a former submerged drainage pattern provide communication between the passes in the outer barrier reef and the mouths of the principal present-day rivers. Around theses valleys the very muddy sediments overflow into the lagoon and may spread out until they nearly reach the passes.

South-east of Ile Ouen a large, deep accumulation basin (> 80 m.), in which there is a concentration of sediments that have probably come from the Prony Bay, indicates a connection between this bay and the very broad submarine valley by which the most southerly part of the lagoon opens into the ocean. In the approaches to the Ile of Pines and in the south-western tip of the lagoon, other zones of concentration are observed; their presence is not related to the coastal bays or the submarine valleys, but solely to the bathymetry of these sectors.

The calcium carbonate content of these muds shows that they come almost exclusively from carbonated sources (more than 85 % $CaCO_3$). They are thus clearly distinguishable, by the zones where they are deposited and by their origin, from the muds observed in the bays and in the submarine valleys, which indicate terrigenous transports deposited by the rivers of the west coast.

Grain size structure

The results of the principal components analysis are summarized in the first two axes of inertia (figure 4) which extract 73 % of the total variance (44.78 and 28.22 % respectively). The third axis, which explains 12.43 % of the variance, will not be described here.

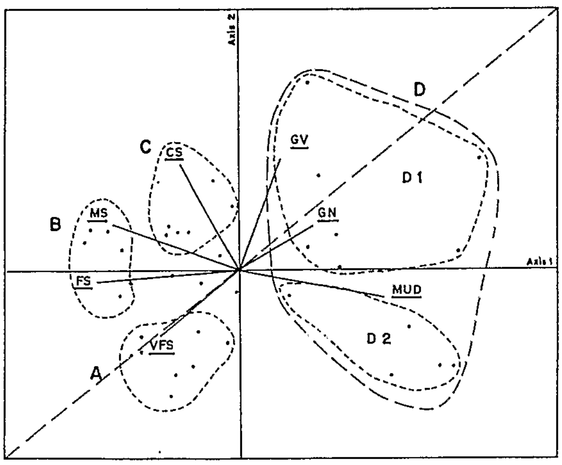

Figure 4. Principal component analysis: projection of the end of the station vectors (·) and variables vectors (underlined) in the first factorial plane (VFS: very fine sand, FS: fine sand, MS: medium sand, CS: coarse sand, GV: gravel, GN:granule).

The MUD and FINE SAND variables show, respectively, a marked affinity with the positive and negative poles of axis 1, while the VERY FINE SAND variable is projected on the negative pole of the first bisectrix. Examination of the 2nd factorial plane (axes 2-3) (not presented here) and of the relative contributions confirms the assignment of the variables COARSE SAND and GRAVEL to axis 2. We can then interpret axis 1 as a gradient of siltation and axis 2 as a gradient of grain size.

Projection of the stations in the variables space brings out 4 distinct groups (A,B, C and D). Examination of the grain size distribution and of the places where the samples were taken made it possible to define the characteristics of these sets. The first group (A) corresponds to the 'inner reef white sand bottoms' characterised by a mode in the very fine sands and a mud rate lower than 7 % . The B group is formed by a shift of the mode towards the fine and medium sands; the distribution becomes progressively bimodal (FINE SAND and MEDIUM SAND). It corresponds to an extension of the white sand bottoms as described by Debenay (1985). The stations in the third group, which are projected around the COARSE SAND variable, represent the sediments of the lagoonal plain and are characterised by a multimodal distribution. For these first three groups, situated to the left of axis 2, the mud rate never exceeds 25 % (low mud facies). The last group (D), to the right of axis 2, represents all the muddy bottoms. Within it there are two sub-groups : the sediments with unimodal distribution (D2) (mode in the muds) and the muddy sediments that have, in addition, a second mode towards the coarse fractions (granule of gravel) (D1) which is usually due to the presence of the shells of oysters living in this habitat.

There are thus, in fact, two clearly differentiated environments, the muddy bottoms (pure muds and heterogeneous muddy material) which are found in the bays or nearby (submarine valleys) and the white sand bottoms situated immediately against the outer reef. The other two result from the interpenetration and mixing of the two preceding environments, and they constitute the greater part of the grey sand bottoms of the lagoonal plain. As this mixing takes place there is a shift of the mode of distribution from the very fine sands towards the gravels and simultaneously an increase in the mud rate. This analysis confirms the structure described by Debenay (1985) and by Chardy *et al.* (in press).

Species distribution

On the basis of the benthos samples collected by dredging, lists of species were drawn up and comparative examination of them has made it possible to define the characteristics of the communities. Three main communities have been recognised from the qualitative studies done (Richer de Forges *et al.* 1987) and from the quantitative studies (Chardy *et al.* in press). These three are : the muddy botttoms community, the grey bottoms community and the white bottoms community.

Species distribution maps were drawn for molluscs, which are a major component of the communities. For this group, and more especially for the gastropod molluscs group, which comprises numerous families (45) found in all biotopes, a map showing the wealth of species is given (figure 5). The richest zones (where there are more than 40 species per station) are situated in the inner reef slope zones, with low mud sediments and a high degree of hydrodynamic effect. The muddy coastal zone has many fewer species (less than

20); the intermediate zones, with between 20 and 40 species per station, are situated either on the grey bottoms or on the white bottoms. The scarcity of species in the southern part of the lagoon is explained by the depth, which is more than 50 metres.

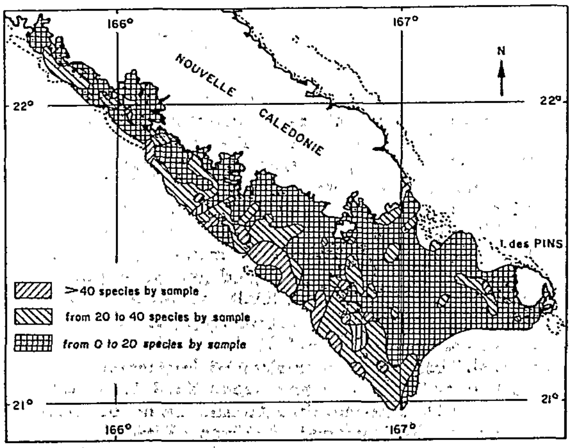

Figure 5. Number of mollusc species collected by dredgings.

If one considers certain families of herbivorous and detritus feeding gastropods that are very common in the south-western lagoon, the Strombidae and the Cerithiidae, it will be seen that their distribution on the soft bottom is related to sediment. Thus, of the 16 species of *Strombus* present in the lagoon (table 1), the distribution of the three most abundant, *S. erythrinus*, *S. luhuanus* and *S. gibberulus*, is related to the mud content of the sediment (figure 6). None of these species lives in the very muddy bay heads; *S. erythrinus* occupies the sandy and muddy bottoms where there are *Halimeda* sea-grass beds; *S. luhuanus* is more closely restricted to the grey and white bottoms, and *S. gibberulus* is associated with the inner reef coral bottoms.

Table 1. Frequency of Strombidae species collected by dredgings in the S.W. lagoon of New Caledonia.

Species of Strombidae in the SW lagoon	Number of stations	% occurrence
Strombus (Canarium) erythrinus Dillwyn, 1817	138	28
Strombus (Conomurex) luhuanus Linné, 1758	62	13
Strombus (Gibberulus) gibbosus (Roeding, 1798)	49	10
Strombus (Canarium) mutabilis Swainson, 1821	27	5
Strombus (Dolomena) plicatus Reeve, 1851	24	5
Strombus (Dolonema) dilatatus Swainson, 1821	15	3
Strombus (Labiostrombus) epidromus Linné, 1758	12	2
Strombus (Dolonema) variabilis Swainson, 1820	12	2
Strombus (Euprotomus) vomer vomer (Roeding, 1798)	11	2
Strombus (Canarium) haemastoma Sowerby, 1842	7	1
Strombus (Canarium) wilsoni Abbott, 1967	4	1
Strombus (Canarium) dentatus Linné, 1758	3	< 1
Strombus (Tricornis) thercites Swainson, 1823	1	< 1
Strombus (Canarium) labiatus labiatus(Roeding,1798)	1	< 1
Strombus (Dolomena) minimus Linné, 1771	1	< 1
Strombus (Canarium) fragilis (Roeding, 1798)	1	< 1

It is possible to define the affinity of each of these species of the sediment by observing the percentage of their occurrence in terms of the mud content of the sediment (figure 7). *S. erythrinus* is found on all types of bottom having up to 75 % and more mud; *S. luhuanus* does not occur on bottoms with more than 50 % mud and *S. gibberulus* is found only on the slightly muddy bottoms (less than 25 % mud).

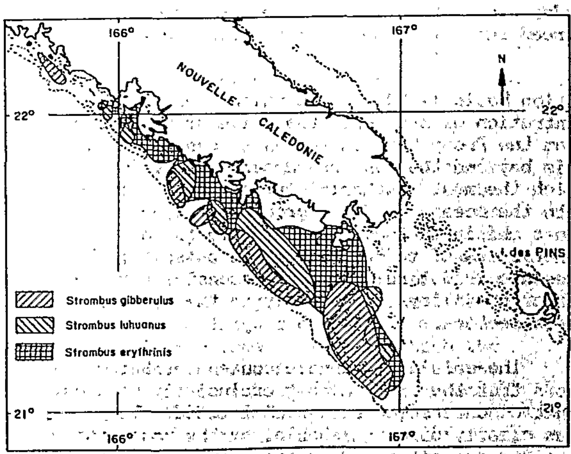

Figure 6. Repartition of the principal mollusc species of the Strombidae family in the S.W. lagoon.

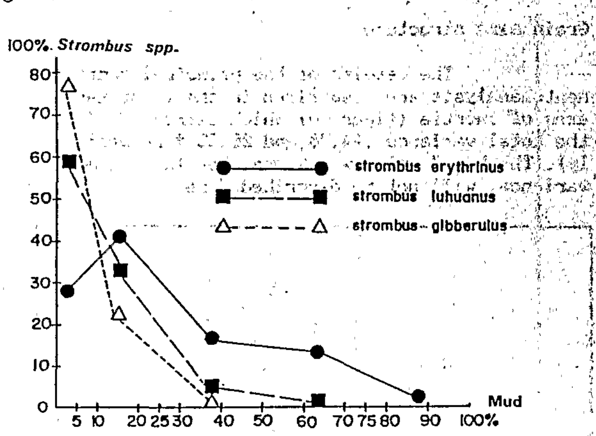

Figure 7. Percentage of occurence of the main Strombidae species in relation with mud in sediments.

20 species of the herbivorous and detritus-feeding Cerithiidae[1] are found in the south-western lagoon (table 2). A map of the 4 most common species *Rhinoclavis sordidula*, *Rhinoclavis articulata*, *Rhinoclavis fasciata* and *Cerithium rostratum*, shows the preferences of each (figure 8). The presence of *R. sordidula*, which is a detritus feeder, is related to the presence of muds, while *R. fasciata* prefers bottoms where there is little mud. The two other species are distributed on the grey bottoms and on the white bottoms.

Graphs indicating the distribution of the Cerithiidae in terms of rates of mud in the sediment (figure 9) show how affinity for different types of sediment differs according to the species. *Rhinoclavis sordidula* is found on the muddy bottoms (40-70 % mud content in the sediment); on the other hand, the two oher species of the same genus *R. articulata* and *R. fasciata* prefer less muddy bottoms; *Cerithium rostratum* is most frequently found on the inner reef white bottoms.

Table 2. Frequency of the observations of Cerithiidae species collected by dredging in the S.W. lagoon.

Species of Cerithidae in the SW lagoon	Number of observations	% occurrence
Rhinoclavis (Proclava) sordidula (Gould, 1849)	99	20
Rhinoclavis articulata (Adams et Reeve, 1854)	79	16
Rhinoclavis fasciata (Bruguière, 1792)	35	7
Cerithium rostratum Sowerby, 1855	27	5
Cerithium novaehollandiae Adams, 1855	19	4
Cerithium salebrosum Sowerby, 1855	15	3
Rhinoclavis (Proclava) kochi Philippi, 1848	14	3
Varicopeza pauxilla (Adams, 1894)	9	2
Cerithium columna Sowerby, 1834	7	1
Pseudovertagus nobilis (Reeve, 1855)	5	1
Cerithium minutum Sowerby, 1855	5	1
Rhinoclavis aspera (Linné, 1758)	4	< 1
Bittium sp.	2	< 1
Plesiotrochus sp.	2	< 1
Gourmya gourmyi (Crosse, 1861)	2	< 1
Cerithium zonatum (Wood, 1828)	2	< 1
Cerithium nodulosum Bruguière, 1792	1	< 1
Pseudovertagus aluco (Linné, 1758)	1	< 1
Rhinoclavis sinensis (Gmelin, 1791)	1	< 1
Cerithium tenellum Sowerby, 1855	1	< 1

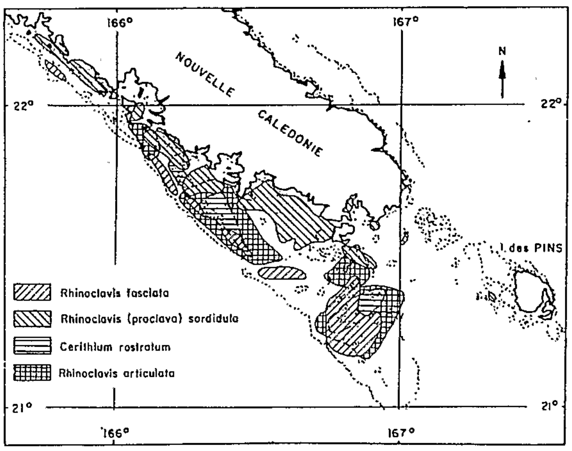

Figure 8. Repartition of the principal mollusc species of the Cerithiidae family in the S.W. lagoon

DISCUSSION

The multivariate analysis effected here confirms the structure of the soft bottoms of the south-western lagoon described by Debenay (1985) in regard to the sedimentology and also by Chardy *et al.* (in press) who worked on the basis of groups of species. There is thus a definite concordance between the sedimentology of the soft bottoms and the distribution of benthic species. As regards the species referred to in this paper, the herbivorous and detritus-feeding gastropod molluscs, the nature of the sediment and more especially its mud content, appears to be the principal factor of its distribution. In the case of *R. sordidula*, which is a real detritus-feeder, there is a direct relation with the nature of the sediment; regarding the other species, which depend on plant matter for their food, their distribution reflects that of the macrophytes. Garrigue (1985, 1987) has shown that the distribution of the principal species of macrophyte is dependent on the nature of the sediment. Whether this relationship between certain benthic organisms is direct or not, the presence of the species in question has precise ecological significance. The organisms studied are found to be distributed according to species on the three types of bottom of the south-western lagoon : the white bottoms, the grey bottoms and the muddy bottoms. These species are thus good biological indicators.

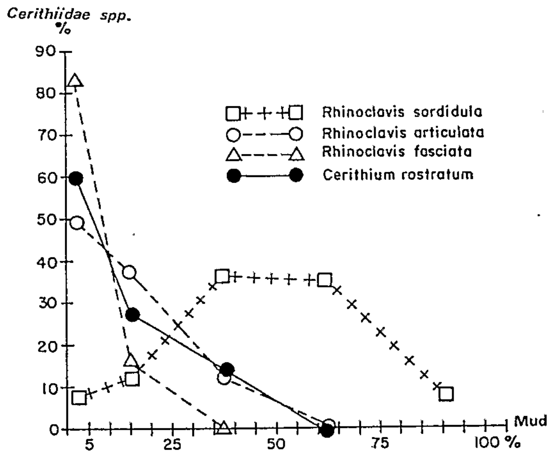

Figure 9. Percentage of occurence of the Cerithiidae species in relation with mud in sediments.

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