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THE ROLE OF *Mya arenaria* L. POPULATIONS IN COASTAL SEDIMENTARY PROCESSES

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ABSTRACT:

The observations and measurements carried out at Mamaia (the Romanian Black Sea coast) between 1977-1981 led to the conclusion that every year the storms transport and deposit on a 1 metre beach length an average quantity of nearly 7 tons of Mya arenaria (out of them 2.4 tons of calcarous shells) which accumulate on the shore and modify the chemical and granulometric composition of sediments. So far as the supply of mineral sediments carried by the Danube mainly, has diminished, the role of Mya arenaria populations in sedimentary processes has become predominant on the beaches North of Constanţa.

The penetration, settlement and massive development of Mya arenaria bivalve in the Black Sea during the past 10-15 years is certainly an ecologic event of great importance (8, 9). As we have already asserted (11, 12) the first and most eloquent proof of the strong consolidation of Mya at the Romanian shore consists in the beach deposits. Thus in the past few years great quantities of Mya arenaria shells have been deposited to the North of Constanţa, all along the coast from Mamaia to Sulina, on the beaches with fine sand and poor in shells until 1970-Corbula mediterranea COSTA was the only one more abundant (1, 2). In some zones the shell deposits of Mya form real "waves" 1 m high along several kilometres.

The formation of these beach deposits has been poorly studied (6). Only in 1975, I first estimated the amounts of Mya shells deposited on the beaches lying between Mamaia and the Danube mouths;on these beaches covering an area about 120 km long and 0.25 - 20 m wide (5.5 m on the average), a total amount of only 1,017 tons was estimated, which represented 0.22% of the whole Mya stock registered in 1975 at the Romanian littoral down to 30 m depth. At that time we considered the beach deposits to be surprisingly scarce. However it was found that the greatest part of the stock destroyed by the "red tide" with Exuviaella cordata OSTF. (10,14) lay "in situ" embedded in the sediment; the short time passed since the mortalities as well as the lack of great storms to disturb the sea bottom and carry Mya shells landwards,explained the scarcity of beach deposits to a great extent. The prognosis,I then made concerning the beach deposits (in a scientific report submitted to the National Council of Science and Technology I asserted: "We consider that the beach deposits will enrich in future, so that the raw material for the factories producing fodder meal will be provided") was fully confirmed later on.

The present paper based on the monthly observations and measurements performed on the beach at Mamaia between 1977-1981, represents a first contribution that helps to know the role of Mya arenaria shells in the formation of littoral sediments.

MATERIALS AND METHODS OF WORK

The northern sector of Mamaia beach (from Mamaia Sat to the North of the Tourist Resort, around the parallel 44°18'N) was controlled on 2,500 m length monthly between 1977-1981, after storms especially (2-3 days after the storm had broken out); observations were made on the shell deposits and quantitative samples were collected.

On the beach, mollusc shells and other vegetal and animal remains are ununiformly spread. They usually form smaller or larger deposits of smaller or bigger quantities like a continuous or interrupted strip of variable width running more or less parallel to the shore. Such a disposition of shells on the beach lessens the possibilities of their quantitative evaluation.

In order to collect quantitative samples, a transverse profile was established on the beach along the line of a fixed guide mark. The profile length, or the beach width (between the fixed guide mark and the sea edge) as well as the width of the strips with shell deposits varied from one month to another according to the sea level. The settling of new shells and the formation and transformation processes of the deposits occur rather irregularly both in time and space. Sometimes, the shell deposits cover a continuous band, 15-20 m wide, which starts from the very sea edge, at other times the deposits spread on strips running either parallel to or in a zigzag line on the shore depending on wave action. By observing the shell distribution on both side of the profile, deposits bearing similar characteristics were delimited and their width was noted. We present here an example to illustrate the way in which the various shell strips were delimited starting from the sea edge to the fixed guide mark:

- 0-2 m: forming deposits consisting mainly of small-sized Mya, then of Cardium lamarckii, etc.;
- 2-9 m: zone with lots of Mya shells with decaying flesh;
- 9-13 m: zone without shells, covered by moist, green sand (in the laboratory we determined the species Chlamydomonas Reinhardi DANGEARD - it looks like a pure culture invaded by ciliates);
- 13-16 m: zone with scarce Mya valves and few Rapana thomasiana shells;
- 16-60 m: zone with old Mya deposits, thinly broken shells and sand.

The beach deposits consist of isolated valves or/and of joined valves with or without flesh. If we refer to the isolated valves only, it is difficult to assert whether they have been recently carried and deposited on the beach or they originate in older deposits uncovered by storms from under the layer of sand. However we can certify that when there are numerous joined valves with or without flesh in the deposits, they have been recently dislocated from the substratum and carried on to the beach.

In each zone with mollusc deposits quantitative samples were collected from varying surfaces (100-2,500 cm^2) in accordance with the shell abundance.

The collected samples were sorted completely, all the species in the deposit composition being registered. Mya arenaria shells were sorted out per classes of length into the following three categories: 1. entire individuals live or having died recently (the two valves either with or without flesh, were joined by the ligament still elastic); 2. the right valve and 3. the left valve. The total number of Mya belonging to the class which was estimated, was established by totalizing the number of individuals with joined valves and the greatest number of individuals out of the right or left valves.

The quantitative evaluation of Mya deposits was based on the number of individuals belonging to each class of length from a sample and the average weight of the individuals, in accordance with the equation (8):

$$q_t(g) = 0.89 \times 10^{-4} L^{3.08}$$

where $q_t(g)$ is the total weight (shell + flesh + intervalve water) of an individual, and L (mm) is the length of individuals. Mention must be made that on the average the valve weight (calcareous part) represents only about 34% of the total weight of the individuals.

RESULTS AND DISCUSSIONS

The formation of shell deposits on the beach is a complex process which depends on a multitude of variable factors. Among them we mention first the shell supply source of the beach, that is the natural populations which potentially form deposits; the shell source depends on the state, size and distribution of the populations of benthal organisms, especially the bivalve ones. It is obvious that these populations can be dislocated from their biotope and carried towards the beach only when dynamic factors are present - waves, swell, currents, etc.; the intensity of these factors can very much enough and they reach the maximum at the Romanian littoral during the storms caused by the winds blowing from the North-East sector. Considering that all the above-mentioned factors are extremely variable, it is obvious that the shell quantities in deposits as well as their spreading on the land will permanently vary, from one month to another.

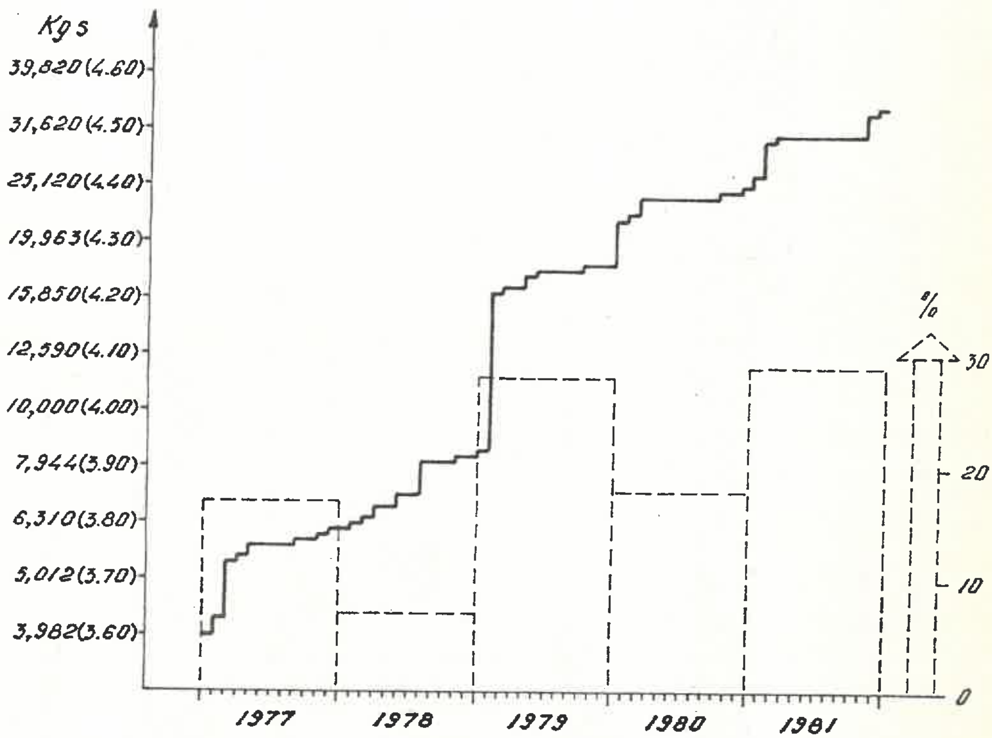
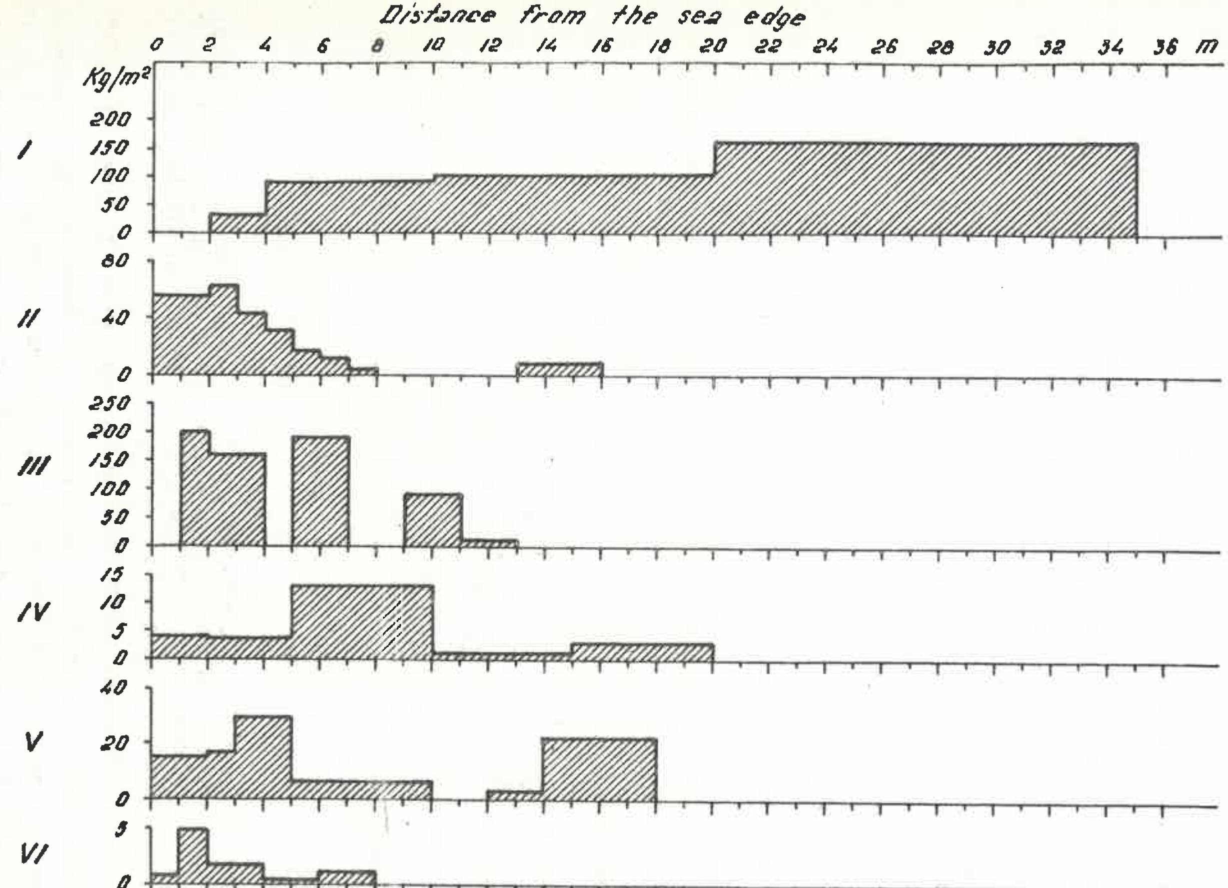


Fig.1 - Cumulative curve of the total quantities of Mya arenaria deposited monthly on a 1 m beach length at Mamaia; annual percentage distribution of total quantities deposited between 1977 - 1981

Between 1977-1981 on a one metre length of beach at Mamaia there have been accumulated 35 tone of Mya arenaria (7 tons per year on an average); this means about 12 tons of calcareous shells entering the sedimentary processes. As we can read on the cumulative curve of the total quantities of Mya deposited on


Distance from the sea edge
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36 m
Kg/m²
200
150
100
50
0
I
80
40
0
II
250
200
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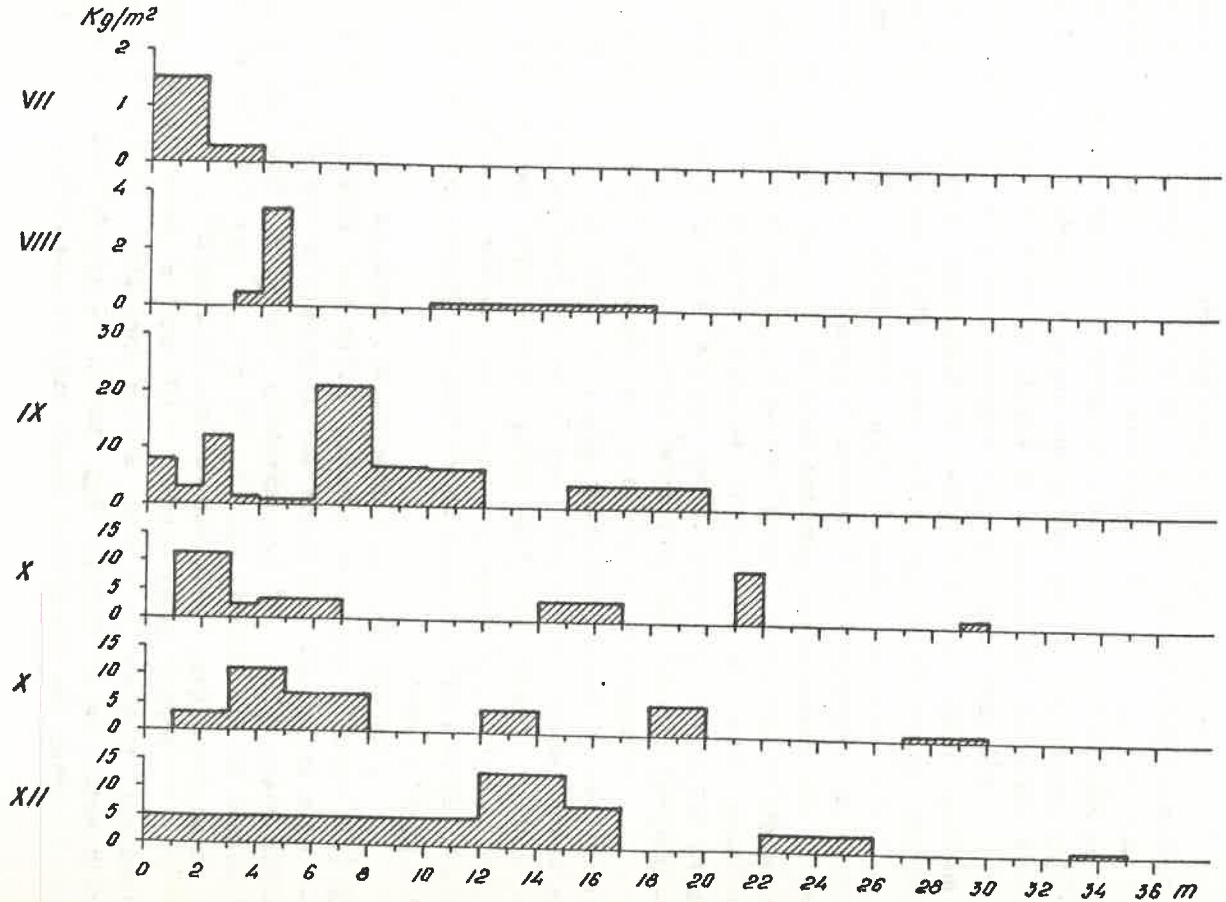

Fig.2 - Monthly dynamics of the total quantities of Mya arenaria deposited on Mamaia beach in 1977

the beach (Fig.1), during the five years of observations and measurements, the accumulations took place irregularly: 6.1 tons (17%) in 1977, 2.2 tons (6%) in 1978, 9.9 tons (28%) in 1979, 6.7 tons (19%) in 1980 and 10.1 tons (29%) in 1981.

The monthly level of accumulations was also irregular; it varied between the maximum of 7.85 tons - recorded in February 1979 and the minimum of only about 2 kg - registered in August 1979 or September 1981 (Fig.1). In order to better understand how the Mya quantities on the beach can vary, we present as an example the evolution of the deposits at Mamaia in 1977 (Fig.2).

The data show that all through the year from one month to another, both the quantities of organisms deposited on the beach and their spreading on the beach width varied as follows:

- January: 4 tons of Mya (65% fresh, with flesh) were carried and deposited on a medium fragment of a one metre beach length; the shells were disposed on a continuous strip 30 m wide; the height of the shell "waves" gradually grows from the sea edge landwards, from 30 kg/m^2 up to 160 kg/m^2 (Fig.2); on the average Mya in the deposits counts 15,800 sps./m^2 and 122.0 kg/m^2 (out of which 6,700 sps./m^2 and 76.9 kg/m^2 live);

- February: relatively low deposits (319 kg/1 m beach length, out of which 35% fresh Mya), arranged in two strips on the beach, whose total width was 11 m; the maximum abundance, in the richest "wave" of Mya lying 2-3 m from the sea edge, is 10,400 sps./m^2 and about 63 kg/m^2; the medium abundance was of only 4,100 sps./m^2 and 29.0 kg/m^2 (out of which 1,200 sps./m^2 and 10.1 kg/m^2 fresh);

- March: the beach deposit was estimated to 1.1 tons of Mya (16% fresh), spread on a beach width that totalizes 9 m; in the 1-2 m strip and 5-7 m one the biomasses of the deposited bivalves reach values of approximately 200 kg/m^2, but the medium abundance in the deposit was 20,200 sps./m^2 and 123.0 kg/m^2 (out of which fresh Mya, 1,900 sps./m^2 and 20,2 kg/m^2);

- April: small deposit - 107 kg/1 m beach length (8% - fresh Mya) disposed in 4 main strips spreading over 20 m of the beach width; on an average Mya has 1,200 sps./m^2 and 5.3 kg/m^2 (out of which the fresh ones count only 70 sps./m^{2}and 0.5 kg/m^2);

- May: deposit estimated to 232 kg/1 m beach length (19% fresh Mya), disposed in several strips whose width totalizes 18 m; on the average Mya has 2,210 sps./m^2 and 12.9 kg/m^2 (out of which fresh Mya 284 sps./m^2 and 2.5 kg/m^2);

- June, July and August: very small deposits (4-13 kg/1 m beach length) ununiformly spread on strips that totalize 4-10 m; in the summer months only empty valves of Mya were deposited on the beach, without any fresh sample containing flesh (so no double joined valves were found); on an average the Mya in the deposits had densities of 129 - 666 sps./m^2 and biomasses of 0.5-1.6 g/m^2;

- September: deposit of only 117 kg (31% fresh Mya) distributed in several strips that totalize 17 m width; on an average, Mya had 7,870 sps./m^2 and 6.9 kg/m^2 (out of which 6,120 sps./m^2 and 2.1 kg/m^2 were recently dead individuals, with flesh;

- October and November: poor deposits - 54-69 kg/1 m beach length (24-65% fresh biomasses), disposed in discontinuous strips whose total width was 11-14 m; the average abundance estimated was about 4,200 sps./m^2 and nearly 5.0 kg/m^2 (out of which 3,700 - 3,600 sps./m^2 and 1.2-3.2 kg/m^2);

- December: relatively small deposit - 122 kg/1 m beach length (68% fresh Mya) distributed in two zones totalizing 23 m width; on an average 2,400 sps./m^2 and 5.3 kg/m^2, out of which 2,000 sps./m^2 and 3.6 kg/m^2 fresh Mya (with flesh).

Special mention must be made on the structure per size classes of Mya populations which formed beach deposits in 1977 (Fig.3). During the first months the deposits were mostly formed by medium and long-sized individuals, so that the medium length of the shells was about 35 mm; in the latter half of the year small-sized Mya prevailed so that the medium length falls to about 13-14 mm. If, instead of taking into account the length, we consider the medium weight of the individuals in deposits, it varied in 1977 from one month to another as follows (the medium weights expressed in g/individual, calculated both for the whole deposit and for the fresh fraction will be registered below, the former as the numerator, the latter as the denominator): I - 7.9/11.5; II - 7.0/8.2; III - 6.1/10.8; IV - 4.5/7.1; V - 5.1/8.8; VI - 2.4/-; VII - 1.9/-; VIII - 4.2/-; IX - 0.9/0.3; X - 1.1/0.3; XI - 1.2/0.9; XII - 2.2/1.8.

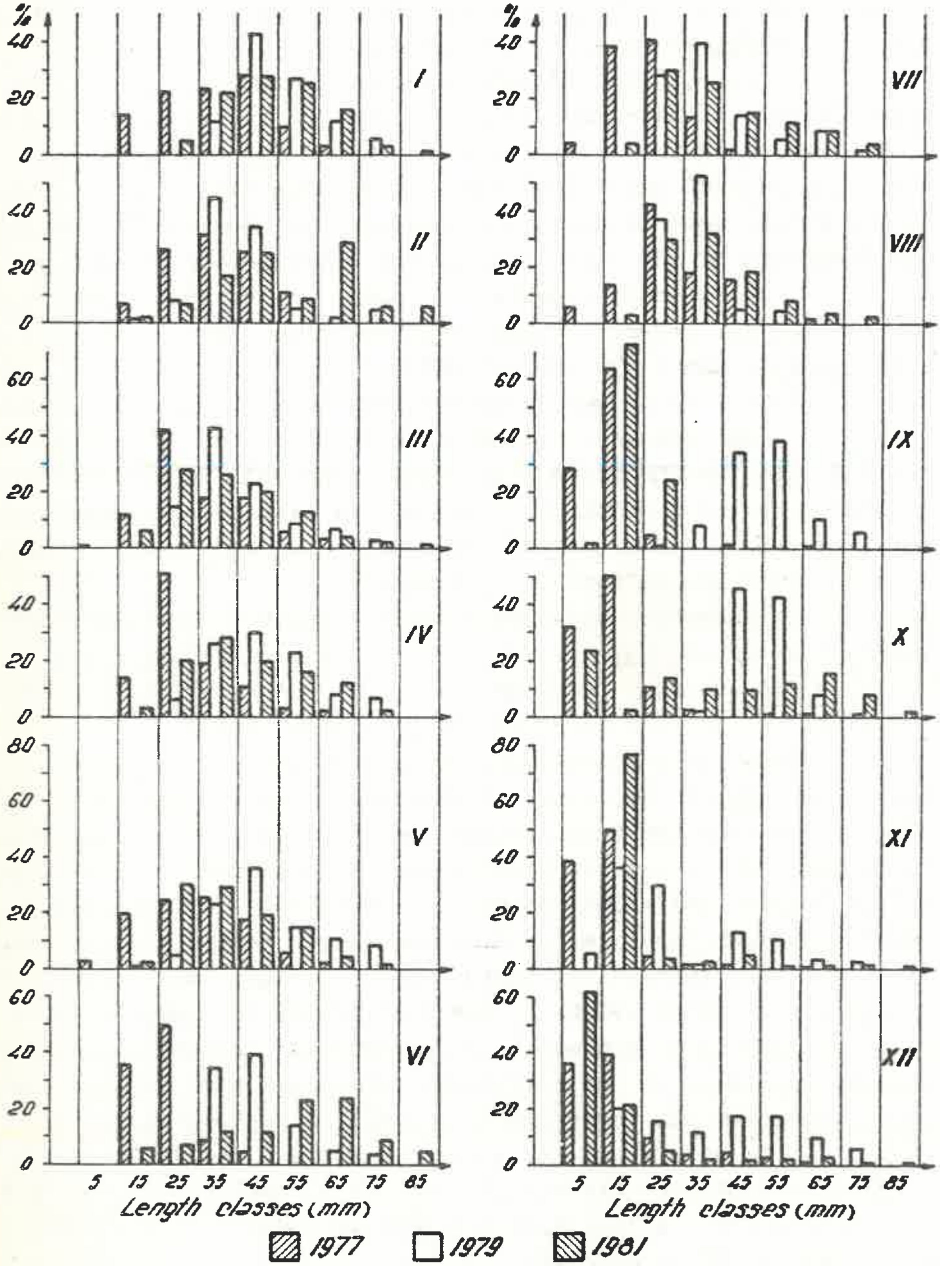

Fig.3 - Monthly variations of structure per size classes of Mya arenaria populations from beach deposits

The structure of *Mya* populations in the beach deposits of 1977 was common for the other studied years too (Fig.3).Consequently the prevalence of *Mya* adults in the first half of the year, when more than 80% of the total annual quantity of shells is accumulated, and of juveniles in the latter half of the year represents a major characteristic in the structure dynamics of beach deposits.

By analyzing the data from 1977,we can observe that the quantities of *Mya* shells and other molluscs deposited on the beach vary much enough from one month to another, but according to the average values for 1977-1981 these quantities are usually bigger during the first months of the year then they greatly decrease until summer and then a slight increase may be observed towards the end of the year. On an average, out of the *Mya* quantities annually accumulated on the beach, more than 72% are deposited during the storms that take place in January through March. On the Romanian coast generally and on Mamaia beach especially, because of its eastern exposition, the most destructive storms, that are at the same time involved in the formation of shell deposits, are the storms caused by winds blowing from the North and North-East sectors;but the greatest frequency of these winds and their speed too, as the multiannual monthly average data illustrate, were registered in January - March (Fig.4), that is the same period when the greatest quantities of *Mya* on the beach were recorded. The great storms also cause an increase in the width of the beach zone where take place active processes of shell accumulation, of erosion, or the rolling and "grinding" of the shells, of sedimentation and resedimentation of old deposits. We underline the fact that the percentage of *Mya* individuals in deposits, with joined valves and flesh, increases during unusually great storms. Thus, the average annual value of the percentage of recently dead individuals represents almost 60% of the deposit; it rises to over 78% during the storms in January, February and March. During the summer months only isolated, empty *Mya* shells, without flesh, appear on the beach. However there were a few exceptions: July 1981 - 3 kg = 12% and especially August 1978 - 995 kg = 100% *Mya* with flesh (the latter value greatly alters the average of August - Fig.4).

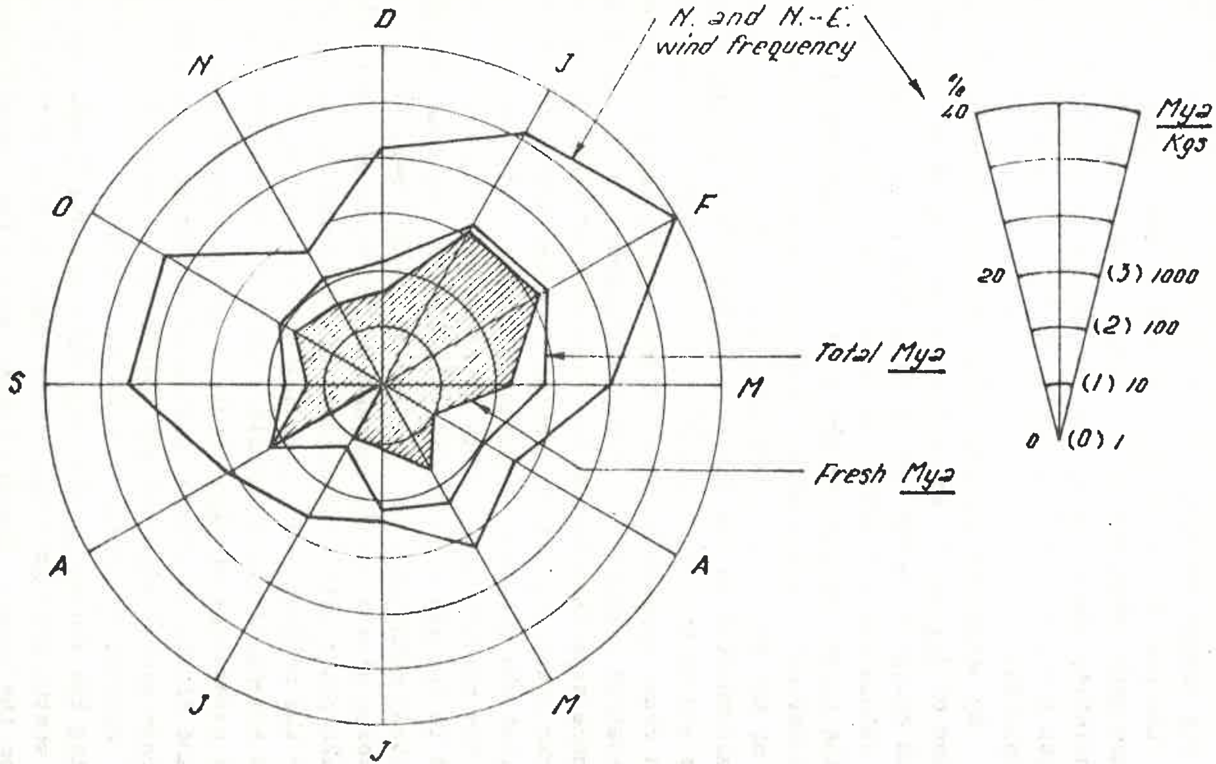

Fig.4 - Monthly variations of Mya arenaria on Mamaia beach according to North (N) and North-East (NE) wind frequency; multiannual monthly average values for 1977 - 1981

Besides Mya, all species of molluscs from the neighbouring sedimentary sectors were found in the deposits of the supralittoral zone, but their quantities were extremely poor, negligible. Only in certain sectors of the beach sometimes appear small"islands" formed by shells of Cardium edule lamarcki (almost 15,000 sps./m^2), Corbula mediterranea (35,000 sps./m^2), Mytilus galloprovincialis (3,500 sps./m^2 - of course very few in comparison with their quantities on the beaches situated South of Constanţa), Hydrobia ventrosa (715,400 sps./m^2), etc.

The great quantities of Mya shells which accumulate yearly on the beaches of the Romanian littoral cause great changes in the structure of the sediments. The researches carried out on the beaches North of Constanţa (5, 7, 18) have shown that they consist of fine, mineral (quartz-mica) sands. Before Mya arenaria bivalve had penetrated into the Black Sea the shell deposits formed after storms did not change the granulometric and chemical pattern of the sediments present on the beaches North of Constanţa, because the species carried by storms and deposited on the beach were low in quantity and their shells having a low content of conçhioline (organic nitrogen) (15) dissolved relatively quickly. In addition, the Danube supplied the beaches with sufficient quantities of sediments represented by fine sands.

But in the last years,because of Mya arenaria deposits, the granulometry and chemistry of sands have changed.The analysis of two cores collected at Mamaia, 5 m (CA) and 20 m (CB) distance from the sea edge (Fig.5), reveals that the superficial beach sediments (30-50 cm layer) have a medium diameter of the granules which places them among medium and coarse sands.The participation of coarse fractions, resulted from the breaking of Mya arenaria shells, in the building up of the sediment is very clearly illustrated by the cumulative granulometric curve of the studied sands (Fig.6).

The structure of the Mamaia beach sediments in 1977 is greatly changed in comparison with the one registered 10-16 years ago (7), a fact well pointed out by the cumulative granulometric curves (Fig.6). It is significant that the granulometry is changed in all the fractions of the studied cores.We mention that the actual developing sediments also have another chemical structure because the medium and coarse fractions which changed their granulometry are calcareous, of organic origin.

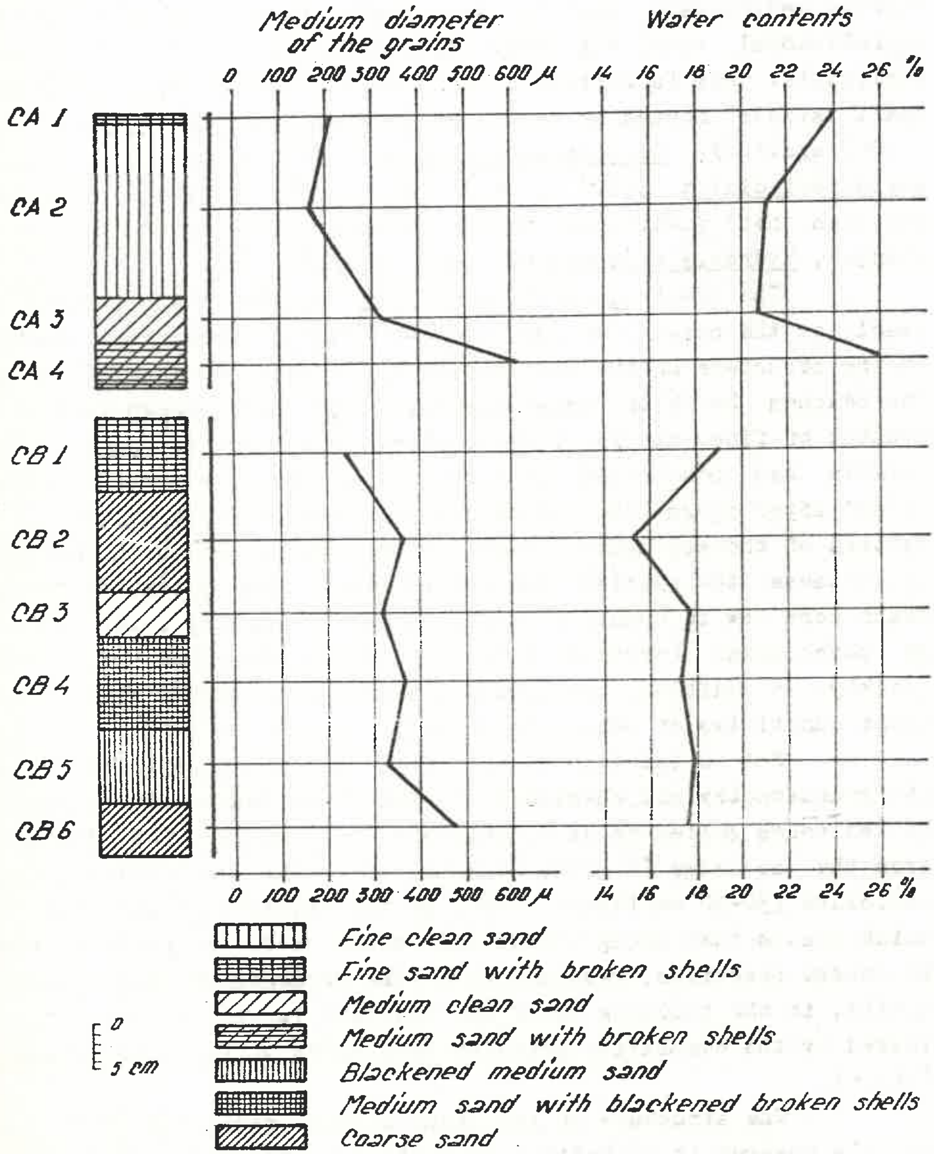

Fig.5 - Characteristics of sediments from Mamaia beach; core CA - 5 m distance from sea edge and core CB - 20 m distance from sea edge (collected in 1977)

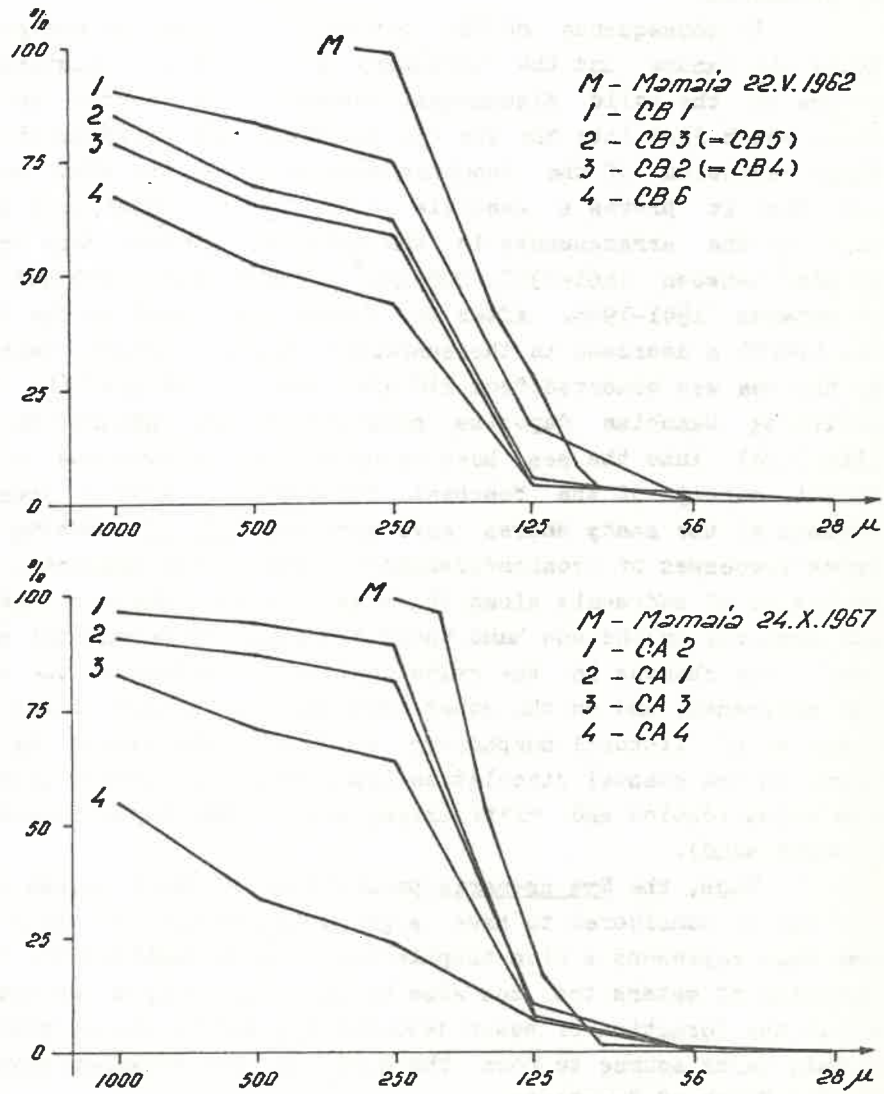

Fig.6 - Cumulative selilogaritmic granulometric curves of sediments on Mamaia beach

Under the present conditions, when changes and important damages of the coastal ecosystems (13) are registered under the influence of man-made ecological pressure, we also witness changes in the morphology and coastal morpho-dynamics, including sedimentary processes.

In consequence of the building of numerous energetic dams on the Danube and the tributary rivers, was registered a decrease in the solid discharges, suspended or dragged on the bottom, which flow into the sea (3, 4). Thus, the analysis of the secular variation of the Danubian turbidity at the river mouth shows that it proves a sensible tendency to diminishing as a result of the arrangements in the afferent hydrographic basin (232 g/m^3 between 1861-1900, 202 g/m^3 between 1901-1940 and 179 g/m^3 between 1941-1968. After the Danube was dammed at the Iron Gates (1970) a decrease in the suspended alluvial deposits carried into the sea was observed,from 218 g/m^3 down to 199 g/m^3 (4). The diminishing Danubian deposits parallel to the advance of the Sulina Canal into the sea have brought about a decrease in the sediment supply of the beaches; consequently, active erosion processes of the sandy shores have appeared (16, 17). During the complex processes of erosion/transport/accumulation appears a redistribution of sediments along the coast and over the continental shelf seaward; on the one hand these processes represent one more cause of the changes in the granulometric structure of the submerse sediments, and on the other hand they contribute to the modification of littoral morphology which is also caused by the changes in the coastal circulation (as a result of port-building, shore consolidation and cliff arrangement or the exploitation of the beach sand).

Thus, the Mya arenaria populations of the Romanian littoral can be considered to have a great importance not only because they represent a rich trophic base which realizes the best filtration of waters too, but also because they play a prominent part in the formation of beach deposits. Mya shells are at present the only major source to form the sands on the Romanian beaches situated North of Constanţa.

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