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Impact of the Pollution on the Benthic Community

Environmental impact of the pollution on the benthic coralligenous community in the Gulf of Fos, northwestern Mediterranean

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A bionomic study of the coralligenous concretionary hard bottom in the northwestern Mediterranean was carried out at four stations: three stations(Arnette, Laurons, Auguette) under the influence of intense multisource pollution(gradient decreasing from north to south) in the Gulf of Fos, west of Marseille, France, and one control station(Moyade islet) in an unpolluted area near Riou island, east of Marseille.

Along the increasing pollution gradient from the outer to the inner part of the Gulf of Fos, there is a qualitative and quantitative impoverishment of the fauna. On the whole, the species richness, the numerical abundance, and the species diversity index are all on the decrease. Accordingly, the innermost station in the Gulf of Fos(Auguette) is most heavily affected by the industrial, and to a lesser extent by the domestic wastes, from the nearby industrial complex and urban areas.

The impact on the benthic coralligenous community of this serious alteration has been analysed in view of community composition, functional aspect, and ecological stocks. The faunal affinity between stations has been studied by means of the two coefficients: fourfold point correlation coefficient and Jaccard's community coefficient. The upper layer and inferior face communities of the coralligenous concretionary structures are also compared.

Introduction

The coralligenous concretionary substrates in the northwestern Mediterranean are important biogenous formation in which the infralittoral "corniche" of Melobesiae is also situated close to the mean tide mark in the vicinity of Marseille, France.

The conditions of initiation, evolution, structure, and the processes of consolidation of this circalittoral formation have previously been investigated intermittently to understand the geomorphological phenomenon entangled with the activity of calcareous organisms. In addition, various ecological researches on this diversified climax benthic community have been carried out to elucidate, in particular, the community structure and their function with physiognomical remarks, and the characteristic organisms associated(Pérès et Picard, 1951, 1964; Laborel, 1961; Laubier, 1966; Sarà, 1958, 1969; Hong, 1980).

The immense development of this circalittoral biological formation in the Mediterranean is characterized by a consolidation of calcareous algae principally belonging to the family Corallinaceae. This creates new ecological conditions not only for the flora and the sessile fauna by the extension of a utilisable surface for this attachment, but also for the sedentary or vagile

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animals by the creation of cryptic habitats from the irregular growth of the algae and the holes many boring animals leave after their death. The fragmentation of substrate by lithophagous organisms and the pulverization of concreted masses by the many holes of boring animals, such as sponges of the genus *Cliona*, polychaetes of the genus *Polydora*, many pelecypods, etc... adds to this complexity.

In the Gulf of Fos, the benthic community of the coralligenous bank generally occurred between 10—20*m* in depth due to relatively turbid waters from the river Rhône which is now seriously affected by industrial and domestic pollution from a nearby coastal large-scale industrial complex. Thus, a synecological study was undertaken to obtain baseline information on the benthos of the circalittoral hard substrate in this region.

Materials and methods

Site characteristics

The Gulf of Fos, a marine embayment about 30*km* north-west of Marseille has a complex hydrology due to the freshwater inflow from the river Rhône and the Etang de Berre(Blanc, Leveau et Kerambrun, 1975; Blanc, Leveau et Bonin, 1975, 1976; Benon *et al.*, 1976). Moreover, the Mediterranean south of Fos is directly influenced by the waters of the Rhône which derive from the east and penetrate into the interior of the bay to the south-west. Thus the centre of the bay is characterized by terrigenous mud(Fig. 1). Data from the meteorological station of Cap Couronne located at the entrance of the bay shows two dominant winds, the N-W Mistral and the east wind(Hong, 1980). Their opposed orientation in the region of Fos produces two principal hydrological conditions. The Mistral, which is the most important dominant wind in the region, tends to drive the superficial waters offshore, which entrains bottom Mediterranean waters into the bay. This phenomenon is inver sely observed for the east wind which provokes an afflux of water masses in all the northern part of the bay.

The Gulf of Fos is surrounded by an important industrial complex containing a big port, oil-refineries and petrochemical plants. Moreover, the associated increase of the urban population has produced a great increase of domestic effluent discharged to the sea. Additional perturbations originate in the local natural pollution from a submarine sulfur spring near the region of Arnette, the effluent of a thermal power-station, and the inflow of significant quantities of freshwater through the river Rhône and indirectly by way of the canal of Port Saint-Louis du Rhône and Etang de Berre. These all become more intense and confounded towards the innermost part of the bay, and produce a very complex pollution stress which influences various areas of the bay according to the meteorological conditions.

The bottom types in the Gulf of Fos situated between Auguette and Arnette show some homogeneity in their bathymetric profile in the zone of 0—25*m* which is essentially a border of hard substrate. The distribution of benthic communities of this border shows through its remanent features that it was very homogeneous, before the degradation of the milieu, so that the same aspect of bionomic profile existed from the north to the south of this region. This fact is used to justify comparison between the different sectors at the present time and facilitate the evaluation of impact of degrading agents on this portion of the bay.

The general schema of the distribution of bottom types is: (i) Principally muddy and muddy sand bottoms from the open sea to a depth of 14*m* in the north-west and 28—30*m* in the south-east. (ii) In shallower waters a mosaic of concretionary masses("the coralligenous bottom") alternating with islets of more or less well-developed meadows of *Posidonia oceanica* Delile living or either residual as a dead mat, along with muddy sand. (iii) From 8—10*m*, the seagrass or its dead mat is more extensive and stretches to

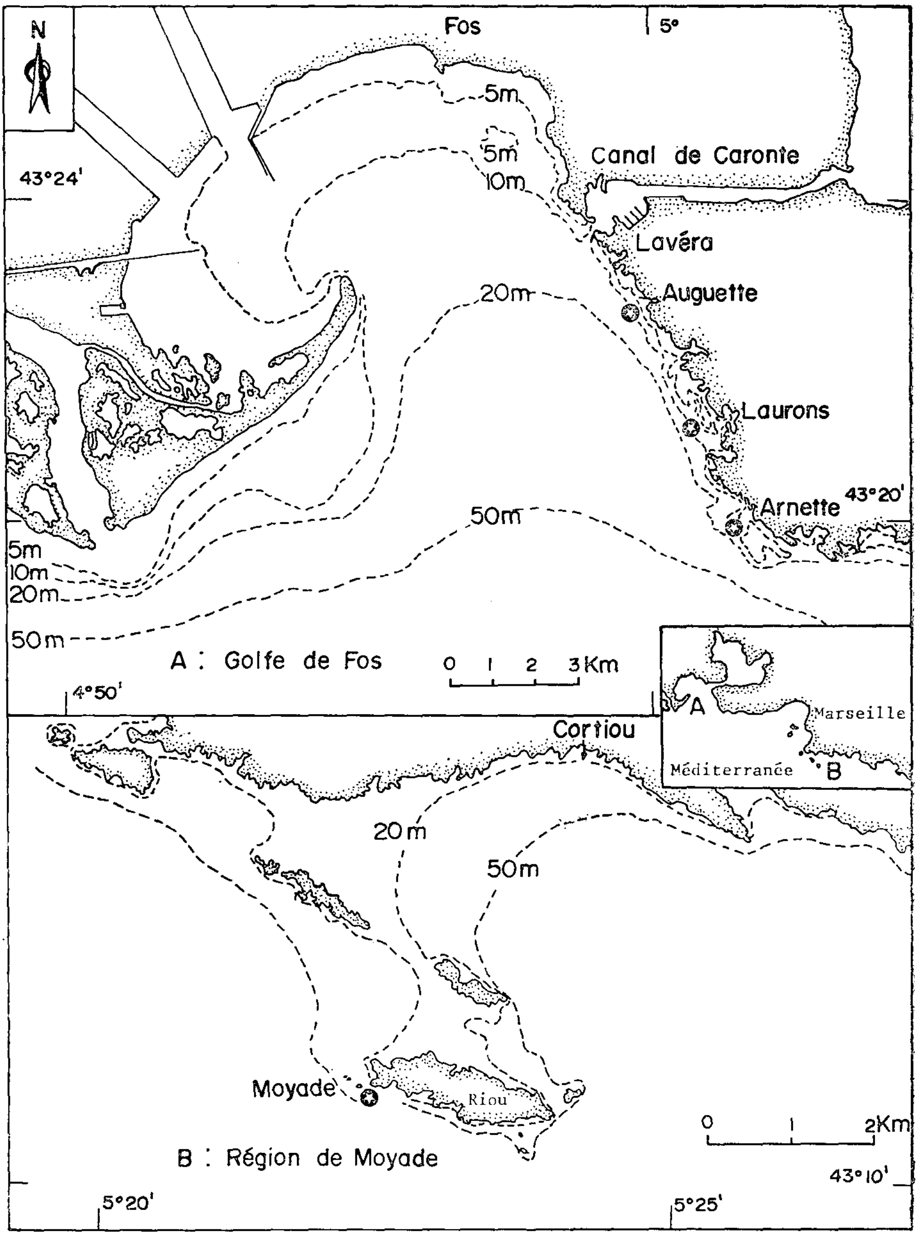

Fig. 1. Sites of the sampling stations(A: Gulf of Fos; B: Region of Moyade).

the shore where the rocky bottom is absent at a depth of 5*m*(Harmelin et Hong, 1979).

Sampling area

Three stations were sampled in the Gulf of Fos along a gradient of environmental stress that decreases from north to south(Fig. 1).

Auguette(AU): This station is located in the innermost of the bay and receives the most serious effect of the pollution.

Laurons(LA): This intermediate station in the middle part of the bay lies between Auguette and Arnette.

Arnette(AR): This region is situated at the entrance of the Gulf where environmental perturbation is least apparent.

An additional station was chosen as a control in the Moyade islet, immediately adjacent to Riou island, east of Marseille. This site is characterized by its oceanic environmental regime, with high and relatively unvarying salinity, stable temperature, and low turbidity(Lacombe et Tchernia, 1960).

Moyade(MO): This station is situated between the west point of the Riou island and the Moyade islet at a depth of about 34*m* where the coralligenous community is the best around Marseille.

Sampling procedure

Benthic samples were collected by means of SCUBA diving during the winter of 1978. Five successive quadrats each of approximately 400cm^2 were taken from each station on a relatively physiognomically homogeneous area. By using a hammer and a graver, the concretionary masses were sampled to a thickness of about 10*cm* to include endofauna inhabiting the interior. The samples were then put into plastic bags and preserved in 10% neutralized formalin-seawater. All macrofauna retained on a 1*mm* mesh was sorted, identified to species, and counted in the laboratory.

Analysis of data

The analysis of data used the method of Picard (1965) adapted for the benthic community of hard bottom by Bellan-Santini(1969). This method compares species of different ecological groups in terms of a number of bionomic coefficients. Thus, in this study each species was characterized by a triple numbering, i. e. presence, mean abundance, and partial mean dominance. Major difficulties were encountered in ascribing individual counts to colonial species such as sponges and bryozoans. These were therefore categorized as:

+ =rare, ++ =abundant, +++ =very abundant, and for these groups the qualitative codes were classified quantitatively as:

+ =3, ++ =6, +++ =10.

The Shannon-Weaver information function(H') was used as a diversity index(Shannon and Weaver, 1963; Pielou, 1975):

$$H'=-\sum_{i=1}^{S}\frac{n_i}{N}\log_2\frac{n_i}{N},$$

Where N is the total number of the individuals, S the total number of species per site and n_i the number of individuals of the ith species.

The degree of equality of the different species abundances was calculated in the sense of "evenness" of Pielou(1966). The actual evenness value , "E" of the community is then

$$E=\frac{H'}{H'\max}=\frac{H'}{\log_2 S}$$

Faunal affinity between stations was calculated by means of the fourfold point correlation coefficient(Φ) using binary data(i. e. species presence-absence), namely

$$\Phi=\frac{ad-bc}{(a+b)(a+c)(b+d)(c+d)}$$

where a is the number of species present at both station, b is the number of species present at the first station only, c is the number of species at the second station only, and d is the number of species absent at both station. Affinity values vary from +1(when the same species are present and absent; $b=c=0$) to −1(when there is no common species present or absent; $a=d=0$). Independence between samples was tested by χ^2 calculated on contingency tables and given by the formula $\chi^2=(a+b+c+d)\Phi^2$.

Jaccard's coefficient of community(1908) was also used to compare coefficients:

$$J(\%)=\frac{a}{a+b+c}\times 100 \qquad (0\leqq J\leqq 100)$$

Hierarchical classifications of faunal similarities between stations were constructed on the data obtained from the two coefficients using the method of Mountford(1962).

Impact of the pollution on the benthic community

The concretionary masses present a very complicated morphological structure with various ecological habitats so that this fauna is highly diversified. It is characterized by a mixture of many ecological groups from infralittoral to bathyal communities(Hong, 1982). The analyses of the upper layer concretionary structures are presented here along with five samples per station, but the faunal studies of the inferior face are based on one sample per station for comparison. It should be mentioned that for the better understanding of the ecological structure, the ecological significations of the associated fauna have been determined from the various literatures, personal observations in the field, and the communications with the specialists for certain zoological groups(Hong, 1980, 1982).

Results and discussion

General trends

The qualitative and quantitative differences between stations are analysed by the zoological groups, functional roles, and various ecological groupings in the four stations surveyed(Hong, 1980, 1982).

A total of 526 species was recorded. The fauna associated with the concretionary masses was dominated by bryozoans, molluscs, and polychaetes which together comprised 54.5% of the species recognized. Other well-represented groups were crustaceans and sponges. These five groups comprised about 80% of the total number of species encountered.

The interstationary comparative analyses show (Fig. 2) that the number of species decreases with a remarkable regularity towards the pollution input sites: 387 species were found in the station of Moyade, 310 species in Arnette, 260 species in Laurons, and 214 species in Auguette. The same holds nearly true in respect of the number of individuals. The control station showed the highest species richness and numerical abundance,

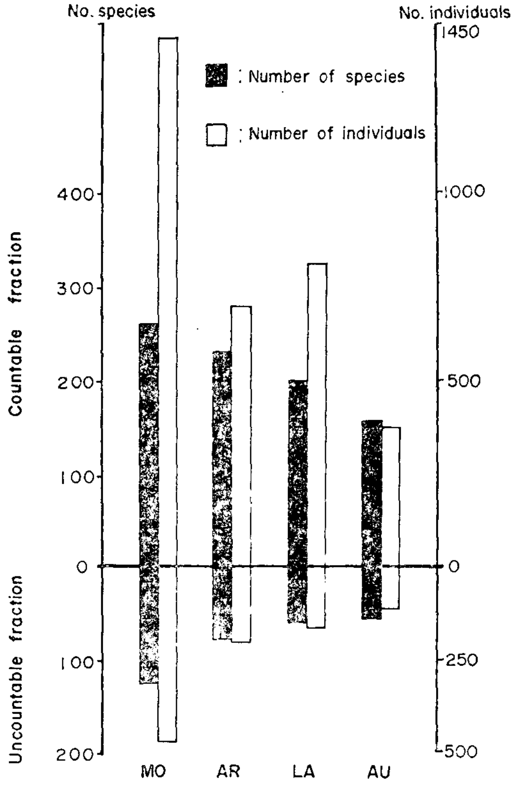

Fig. 2. Numbers of species and individuals found in the upper layer communities.

whereas these values were lowest in the Auguette station, which comes under the serious influence of the pollution. In the Moyade station 1,416 individuals were found in the countable fraction and 482.4 in the uncountable fraction but in the Auguette station 381 individuals in the countable fraction and 115 in the uncountable fraction.

Spatial evolution of the community composition according to the zoological groups

Species richness of different zoological groups mostly follows the same impoverishment towards the pollution inputs except for some minor groups, such as foraminifera protozoans and sipun-

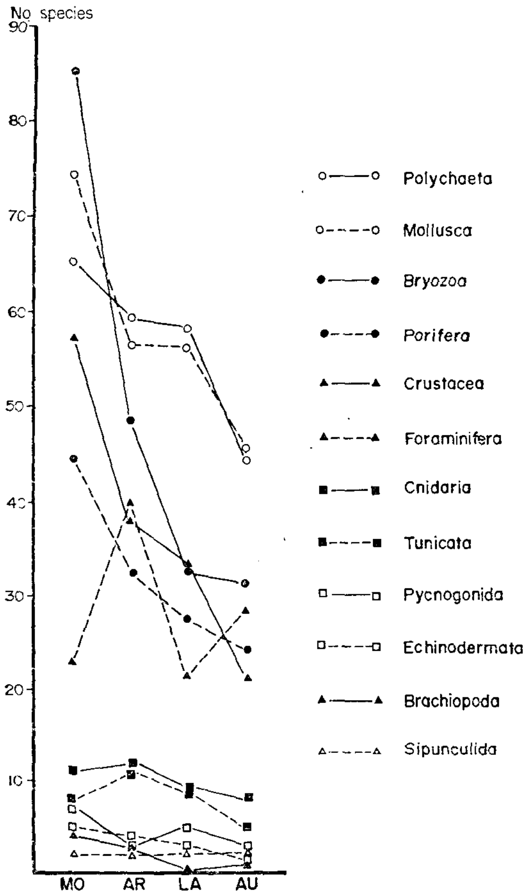

Fig. 3. Spatial variations in species number of different taxonomical groups.

culans(Fig. 3).

The most sensitive groups to environmental alteration are in the order bryozoans, crustaceans, sponges, and echinoderms. Harmelin *et al.* (1981) previously suggested that in the region of Provence, northwestern Mediterranean the species numbers and the overall density of macro-echinoderms are very important ecological parameters, which can assist with the assessment of industrial as well as of domestic pollution.

Except for the molluscs and sipunculids most zoological groups showed decreases in the number of individuals counted or estimated quantitatively as the pollution increased(Table 1).

Remarkably the partial mean dominance of molluscs in the Auguette station represented more than 50%, remaining between 18% and 25% in other stations. This quantitative increase in the polluted area is essentially due to the species, *Arca lactea* Linné which shows ecologically widespread distribution in various hard substrates. This species contributes then 31.6% to the partial mean abundance in the Auguette station.

Spatial variations of the functional groups classified by their roles in the biological formation

The important algal fraction of the coralligenous community, especially species of the family Corallinaceae, e.g. *Pseudolithophyllum cabiochae* Boudouresque et Verlaque, *P. expansum*(Philippi), *Mesophyllum lichenoides*(Eylis), *Neogoniolithon mamillosum*(Hauch), *Archaeolithothamnium mediterraneum*, etc..., play the fundamental role of primary construction building the framework of the concretionary masses. However, only the animal fraction was examined in this study.

These were categorized in three groups in terms of their role as reef builders: frame-builders, destructors, and utilizers of the constructed substrate(Hong, 1980, 1982). Species utilizing the concretionary structure of the reef consisted of more than 75% of the species recognized during the study, of which 8—11% are assigned to the cryptofauna*. The calcareous frame-building species varied from 21% to 24%, whereas destructive organisms including borers, burrowers, raspers, and substrate crushers, ranged between 2.8% and 1.3% according to the station.

Both constructive organisms and utilizers(exclusive of the cryptofauna) had lower species richness and were numerically less abundant with increasing environmental pollution. Des-

* This term is used here to include all organisms living generally in gaps, pores, and micro-caverns within the hard substrate.

Table 1. Distribution of different taxonomical groups of the coralligenous community in the four stations studied (Am=Mean Abundance; Ame=Estimated Mean Abundance for uncountable species; S=Number of species)

Taxononmical groups	Moyade		Arnette		Laurons		Auguette	
	S	Am-Ame	S	Am-Ame	S	Am-Ame	S	Am-Ame
Foraminifera	23	120.6	39	63.8	21	33.4	28	25.2
Porifera	44	122	32	74	27	58	24	51.5
Cnidaria	11	52	12	24.4	9	96.8	8	7.5
Bryozoa	85	360.4	48	129.8	32	109.2	31	63.4
Brachiopoda	4	68.4	3	2.6	0	0	1	0.6
Polychaeta	65	538.4	59	376.2	58	346.2	44	80.0
Sipuncula	2	6.8	2	8.6	2	13.2	2	8.8
Mollusca	74	359.2	56	127.8	56	203.0	46	204.8
Pycnogonida	7	9.4	3	4.0	5	3.8	3	0.6
Crustacea	57	172.8	38	68.2	33	110.0	21	47.8
Echinodermata	5	78.6	4	18.0	3	3.6	1	1.4
Ascidiacea	8	8.2	11	7.4	9	4.4	5	2.2
Fishes	0	0	1	0.2	2	0.6	0	0
Others	2	1.6	2	1.2	3	3.2	1	1.8
Total number of species	387		310		260		214	

* Hydrozoans were not included in the analysis.
* Numerical abundances of Porifera and Bryozoa are assessed by Ame.
* Species lists accompanied with the numerical abundance are available from the author.

tructive organisms and cryptofauna did not show this trend(Fig. 4).

Although the number of species of destructive organisms varys little between stations, their quantitative abundance at three stations in the Gulf of Fos showed much higher dominance values than at the Moyade station.

The number of species of cryptofauna show little spatial variations, but most individuals were found at the Moyade station. Among three stations in the Gulf of Fos, the Arnette region in the periphery of the bay is most quantitatively impoverished, whilst the Auguette station, under the most severe influence of the pollution, shows on the other hand high numerical abundance and dominance values. This may be due to the significant sedimentation at the Auguette station of fine particles in the numerous crevices that constitute shelter. The numerical impoverishment of sciaphilic cryptofauna in the Arnette station, can be attributed to the intensive illumination received because this station is located at a shallow depth and washed by distinctly less turbid waters than in other inner stations in the Gulf of Fos(Benon *et al.*, 1977).

Spatial evolution of various ecological stocks

The classification of species by ecological innction helps to explain the environmental responses of various ecological groups to the progressive extension of the pollution. The general tendency was first analysed for the five following ecological ensembles, i.e. circalittoral hard substrate species, infralittoral hard substrate species, soft substrate species including indicator species for fine sediment, wide-spread species, and the last group containing species of unknown ecology.

Fig. 5 shows a general trend for a gradual decrease in species richness with increasing pollution except for the infralittoral hard substrate species. The number of individuals did not show this clear trend.

Circalittoral hard bottom species are well-

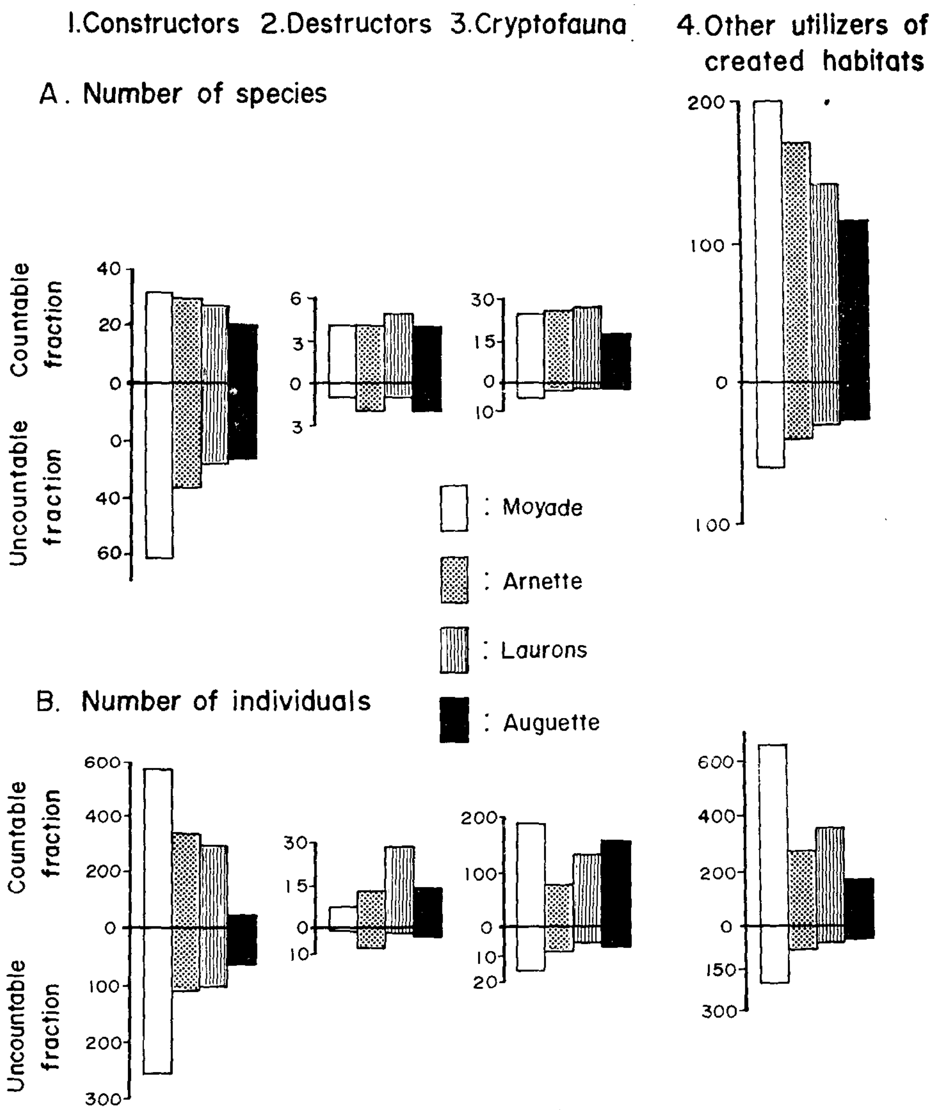

Fig. 4. Numbers of species and individuals according to the functional aspect.

represented consisting of 26—35% of all species encountered and the trend is most conspicuous in those species which occur more frequently in deeper waters. This group of species, generally characterized by sciaphilic organisms, is composed of the following four ecological groups; circalittoral hard bottom species *sensu lato*(SDC* *sensu lato*), coralligenous species(C*), species

* French initials referring to the mediterranean benthic biocenoses are conserved here and they are respectively as follows:
SFBC: Biocoenosis of fine well-sorted sand
VTC: Biocoenosis of the terrigenous mud
SGCF: Biocoenosis of the coarse sands and find gravels under bottom currents
DC: Biocoenosis of the coastal detritic
GSO: Biocoenosis of the semi-obscure caves
GO: Biocoenosis of totally dark caves and tunnels
GO-GSO: Aspect showing species group occurring in two above submarine cave biocoenoses
SU: Ubiquitous sciaphilic species group
C: Coralligenous biocoenosis
B: Bathyal biocoenosis
SDC: Species group of circalittoral hard bottom

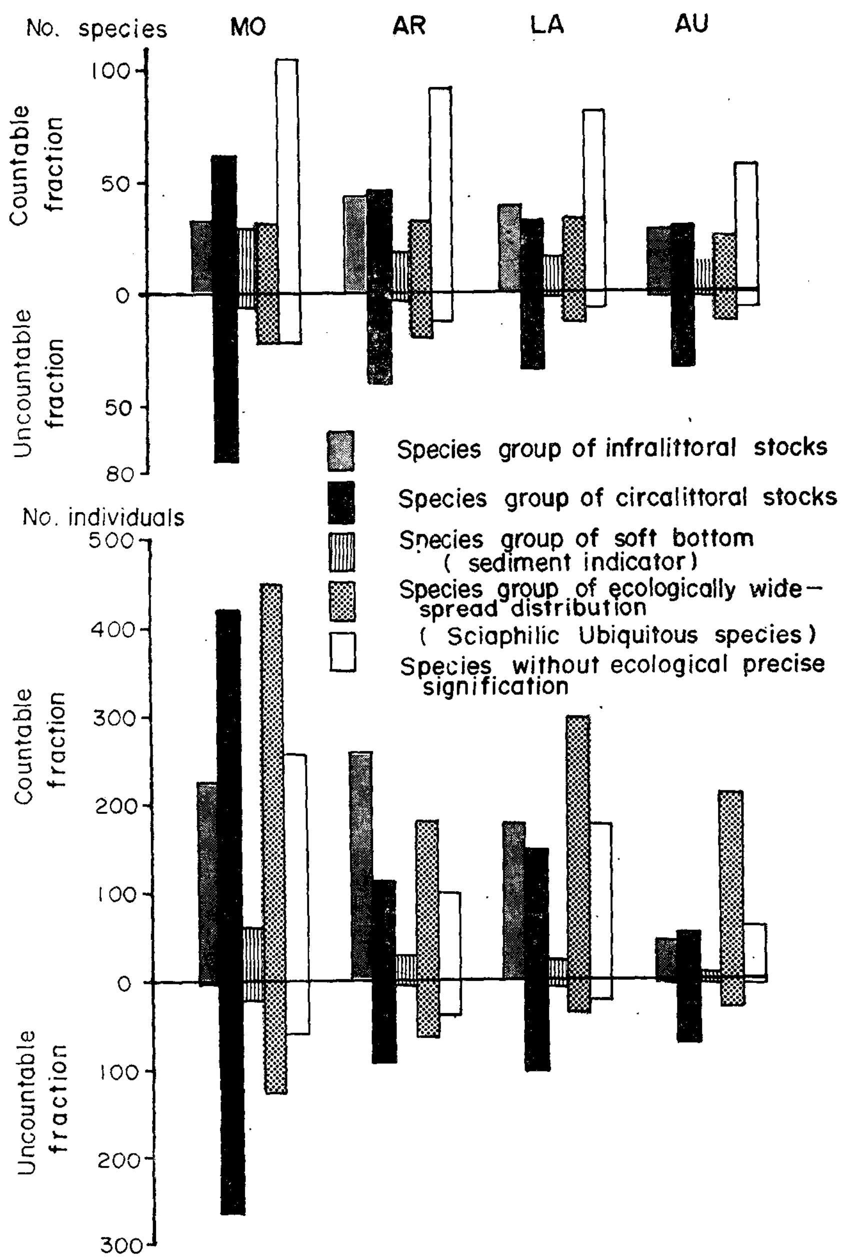

Fig. 5. Numbers of species and individuals of five global ensembles in various ecological stocks of the coralligenous community.

inhabiting submarine caves(GSO*, GOGSO*, GO*), and bathyal species(B*). The qualitative and quantitative predominance of this group from the others is due to the major contribution of species group, "SDC *sensu lato*", comprising 14% of the total species recognized. The other groups which usually prefer a lower illumination, remain in the Fos region in spite of the shallower depth. Probably due to increased turbidity decreasing the light penetration and the proliferation of small interstices from the irregular growth of the calcareous algae and the holes many boring animals leave after their death. Certainly, these shade-loving species are better represented in the Moyade region. So although the bathyal species are nearly negligible or absent in the region of Fos not only in quantitative abundance but also in species richness, twelve species of this stock are found in significant abundance in the Moyade region.

Compared with the control station, their abundance in the Fos region is strongly diminished at the Arnette station, slightly increased at the Laurons station, and decreased again in the innermost station in the Gulf of Fos. These variations can be interpreted because there is a great difference in illumination available at the bottom between the two stations, Moyade and Arnette, as the latter is half the depth of the former. Slight increase at the Laurons station in number of individuals may have resulted from the diminution of light by increased turbidity. However, at the Auguette station the turbidity is too great resulting in a general impoverishment.

A different change in faunal distribution is seen in the infralittoral hard bottom species. Namely, the three stations lying along the Gulf of Fos contained nearly 15% of the species recognized, while at the Moyade station 9% occurred. The species richness of these species shows a maximal value at the Arnette station, diminishing progressively to the inmost station of the Gulf of Fos. By contrast, the control station had an intermediate value between Laurons and Auguette. As suggested above, this result is in agreement with the bottom illumination, which depends in general upon depth and turbidity. The quantitative results showed the same type of distribution to species richness, with a very accentuated impoverishment at the Auguette station and a comparatively high value at Moyade due to one or two dominant species. Bryozoans and sponges in the uncountable fraction were almost absent in infralittoral regions. This suggested that these two zoological groups are largely sciaphilic.

Sediment trapping by concretionary structures results in the appearance of species inhabiting soft substrata or sediment indicator species. Ecological groups of soft substrate species around the coralligenous community in the region of Marseille, contain four biocoenotic units(SFBC, VTC, DC, SGCF*) along with the species group requiring the presence of fine sediment. Although these ecological groups seem, on the whole, less significant qualitatively as well as quantitatively(Fig. 5), their constant presence at all stations indicates the ecological importance of sediment in the constitution of coralligenous community. Three stations in the region of Fos held approximately 7% of the total number of the species found, but 9.3% were found at the Moyade station. At all stations the sediment indicator species were usually dominated both qualitatively and quantitatively with about 5% of the total number of species. Maximal species richness and quantitative abundance of this group occurred at the control station and decreased towards the inmost station of the Gulf of Fos. But, a few species of the characteristic species of three biocoenoses of soft bottom(SFBC, VTC, SGCF) occurred occasionally, as juvenile forms. Characteristic species of the coastal detritic biocenosis(DC) constantly occurred even at the Fos stations and at the Moyade station. This biocenosis constituted one of the most important associated with the concretionary coralligenous community. The numerical significance of the species exclusive or preferential to DC suggests either that DC is, in general, established adjacent to the coralligenous community in the region of Marseille, or that the nature of sediment trapped is mainly detritic, and then offers a suitable sediment for these species.

Little spatial variation in the number of species occurs in the countable fraction of species of widespread distribution, but a slight diminution with increased pollution in the uncountable fraction was observed. These species were numerous at all stations, but most particularly so at the control station. Analysis of mean dominance of this group shows: an increase in dominance with approach to the innermost station of the Gulf of Fos, where it reaches a surprising 55.5% in the countable fraction. This accords well with a frequently observed principle that in a disturbed area the disappearance of characteristic species of the biotope allows species possessing ecologically large potentials to invade producing "the subnormal zone" defined by Bellan(1967). This group is quantitatively and qualitatively important at the Moyade station suggesting the probable intervention of polluted water under certain meteorological conditions from the sewage drain of Marseille-Cortiou about 5*km* distant. In 1975, bionomic mapping of the area affected by this source showed an impact on the bottom around the Riou island with the exception, due to the protective role of this islet, of the southwest sector where the Moyade station is situated(Picard, 1976). It is likely that the hard substrate fauna react more rapidly to the influence of polluted water than the soft substrate fauna. Animals inhabiting this biogenous concretionary substrate comprise mostly of filter feeders or feeds on suspended particles. Consequently, it may be that they directly capture various particles charged with organic materials that had been previously contaminated(absorbed or adsorbed according to the nature of pollutants) by chemical pollutants, in particular by detergents.

The faunal group without precise ecological signification representing approximately 30% of all the species recognized at each station as shown in Fig. 5, demonstrates the paucity of our knowledge on the ecology of the hard bottom fauna in the region.

Faunal aspect of the inferior face of concretionary structures

The faunal aspect of the inferior face of concretionary structures has been much less thoroughly examined, because only one sample per station was taken to compare with the upper layer. Even though this sample size is not satisfactory,

Table 2. Numbers of species and individuals found in the inferior face concretionary structures

Station	Number of species	Number of individuals	
		A*	Ae**
Moyade	163	989	355
Arnette	167	487	203
Laurons	132	667	142
Auguette	91	515	107

* A: Abundance for countable fraction

** Ae: Estimated abundance for uncountable fraction

it appeared that the distribution of the associated fauna in species composition, functional groupings, and ecological groups, is similar to that of the upper layer samples, showing general impoverishment with pollution(Table 2).

In the functional analysis, however, the specific and numerical dominance of cryptofauna is curiously high in the stations at Auguette and Laurons. This is probably because this ecological group occupies a cryptic habitat protected from the exterior environment, while the other groups are constantly in direct contact with various *factors fluctuating* on the exterior.

Analysis of the number of species in various ecological groups shows that there are two general tendencies: the circalittoral groups(SDC *s. l.*, G, C, and even SU) which comprise generally sciaphilic species, tended to decrease in species richness toward the inner part of the Gulf of Fos on the one hand, whilst the infralittoral groups(INF *s. l.*, AP, HP), the soft substrate groups including indicator species of fine sediment, and the group showing a widespread distribution(exclusive of SU), were more diversified in the region of Fos than at Moyade. All of these stocks showed a lowest species richness at Auguette.

Dominance analysis showed a strong increase in species of widespread distribution in the inner part of the Gulf of Fos, a maximum of soft substrate species at Auguette the most turbid station, a maximum of infralittoral species at

Arnette where the waters are clearer and shallower, and the distinct predominance of circalittoral species at the Moyade station.

Evolution of the diversity and faunal affinity between stations

a) Diversity and evenness

It is generally hoped that the diversity in a given community may characterize the degree of structural evolution, the maturity, and the stability of an ecosystem or more exactly of a taxocenosis. For an ecosystem tends to evolve towards an increasing complexity, as it becomes more mature(Margalef, 1968; Travers, 1971). Therefore, for a understanding of the structure of a community the Shannon index of diversity has been employed. It can be calculated in this study from the mean abundance for the countable fraction and the estimated mean abundance for the uncountable fraction of each species in the case of the upper layer samples. For the calculation of the inferior community, it is the abundances or estimated abundances that are considered.

As shown in Fig. 6, it is apparent that the values of the index(H') are very high. In particular, for the samples of upper layer community, they remain between 5.1 and 6.6 bits whatever the station or the fraction may be. This confirms the structuralo-biocoenotic complexity of the coralligenous community. Furthermore, Pérès & Picard(1964) had already suggested that the coralligenous bottom constitutes a "climax" biocoenosis in the circalittoral zone of the Mediterranean.

A second tendency is for a decrease in the diversity index as it becomes more distant from the Moyade station. This is particularly clear in the uncountable fraction which parallels to results on the numbers of species and individuals.

The comparison between upper layer and inferior face can not be made due to differences of sample sizes. However, the Shannon index, which is independent of sample size, may be

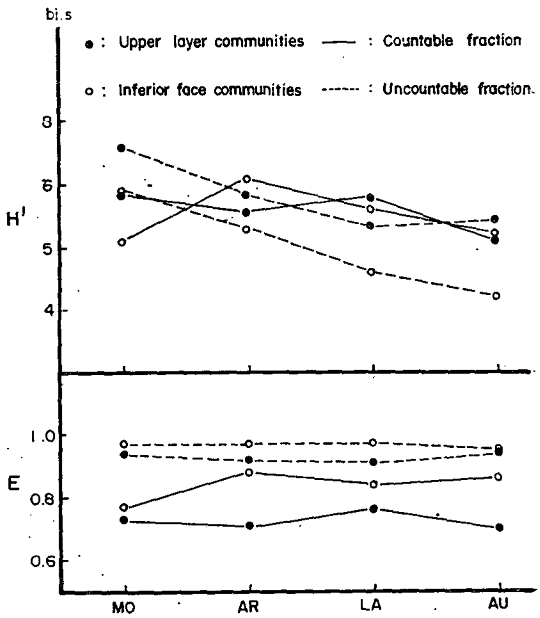

Fig. 6. Variations of the diversity index(H') and evenness(E).

more appropriate(Daget, 1976). Consequently, for countable fraction and uncountable fraction together the mean value of the index is always higher on the upper layer than in the inferior layer. Accordingly the benthic coralligenous community of the upper layer appears more structured.

The stability of the ecosystem examined by analysis of Pielou's "evenness"(1966), shows some ecological features(Fig. 6): The uncountable fraction was distributed relatively evenly, without important variation of individual numbers of different species in the upper layer communities or in the inferior face. This may be have resulted partly from the method used for the evaluation of the abundance.

b) Affinity

Affinity for faunal comparisons between the four collecting areas were estimated by means of the two qualitative coefficients of similarity: fourfold point correlation coefficient and Jaccard's community coefficient. These coefficients allowed

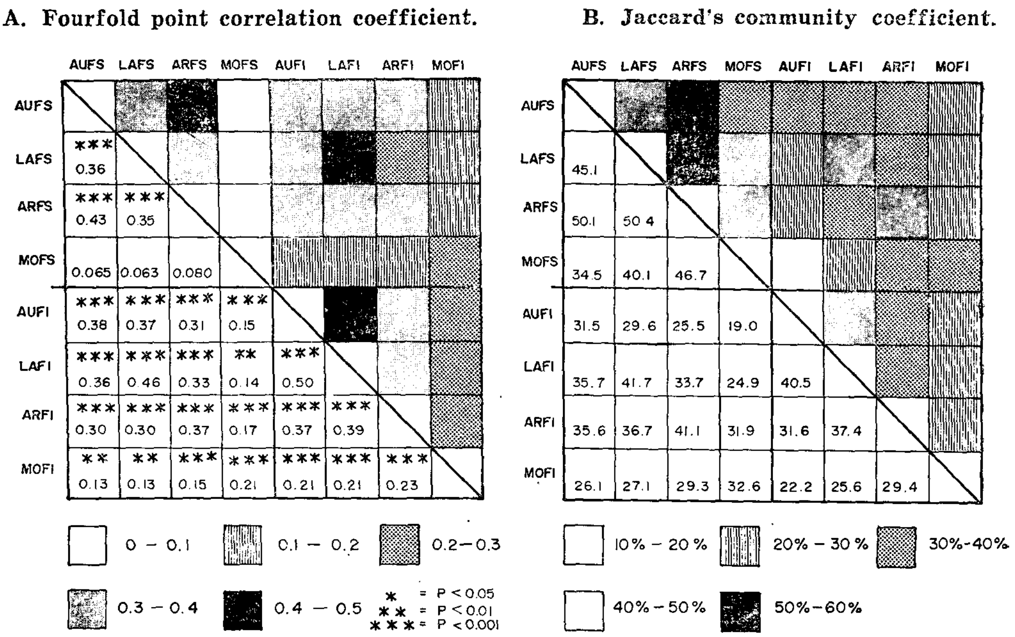

Fig. 7. Trellis diagrams from the fourfold point correlation coefficient and Jaccard's community coefficient.

the construction of correlation matrices between different stations and dendrogram for the better interpretation.

All the stations examined by the Φ coefficient had some interstational affinity, since only the positive values are observed($0.0625<\Phi<0.43$), while Φ varies in principle from -1 to $+1$. The values relating to the Moyade station(MO) are particularly low, especially in the upper layer samples between Moyade(MOFS) and those in the region of Fos: MOFS-AUFS, MOFS-LAFS, MOFS-ARFS. In addition, the χ^2 test concludes that the hypothesis of independence for these three values can not be rejected. In contrast, the hypothesis of independence for the following pairs may be completely rejected:

(1) three pairs between the upper layer samples in the region of Fos: AUFS-LAFS, LAFS-ARFS, AUFS-ARFS.
(2) nine pairs between the samples of upper layer and those of inferior face in the region of Fos: AUFS-AUFI, AUFS-LAFI, AUFS-ARFI, LAFS-AUFI, LAFS-LAFI, LAFS-ARFI, ARFS-AUFI, ARFS-LAFI, ARFS-ARFI.
(3) three pairs between the upper layer samples in the region of Fos: AUFI-LAFI, AUFI-ARFI, LAFI-ARFI.

suggesting that there is a faunal correlation between these fifteen pairs.

The last group of which the hypothesis of independence is rejected, show less significance. These were:

(1) three pairs between the upper layer samples of Moyade(MOFS) and the samples of inferior face of the region of Fos: MOFS-AUFI, MOFS-LAFI, MOFS-ARFI.
(2) four pairs between the samples of inferior face of Moyade(MOFI) and the upper layer samples of all the stations: MOFI-AUFS, MOFI-LAFS, MOFI-ARFS, MOFI-MOFS.
(3) three pairs between the inferior face sample of Moyade(MOFI) and the samples of inferior face of the region of Fos: MOFI-AUFI, MOFI-LAFI, MOFI-ARFI.

Some additional explanation can be made: 1/Even if the upper layer samples of Moyade (MOFS) are independent of those of the region of Fos(AUFS, LAFS, ARFS), the same does not hold true in respect of the communities of inferior face of the region of Fos, which show little association($0.135 \leq \Phi \leq 0.166$). 2/While the sample of inferior face of Moyade(MOFI) presents a low correlation($0.131 \leq \Phi \leq 0.145$) with the upper layer samples of the region of Fos(AUFS, LAFS, ARFS), but a more important affinity($0.206 \leq \Phi \leq 0.231$) with those of the inferior face of the region of Fos(AUFI, LAFI, ARFI). Therefore, it may be easily concluded that the community of the inferior face has high interstational affinity, even with the upper layer aspects of the community. This was already observed in the analysis of evenness, and allows the supposition that the fauna of the inferior face is more stable and less sensitive to the alteration of the milieu than that of the upper layer. 3/In a given station, the association between faunal aspects of two different faces is more significant than the comparison between the same upper layer or inferior face communities of other station: Ex. LAFS-LAFI>>LAFS-ARFI.

Jaccard's coefficient for community similarity demonstrates another ecological grouping(Fig. 7). It is due to the fact that this index does not count the double absence of species between samples. Generally, the values of this index range between 18.95% and 50.4%. Contrary to the phi coefficient, there is a high affinity between samples of the upper layer at all the stations, including that at Moyade. On the whole, this coefficient separates the communities of the inferior face from the upper layer samples in different stations. Four groups with a close faunal relationship can be made: 1/the pairs between the upper layer community of Moyade and the inferior face communities of the four other stations, present a faunal affinity decreasing toward the inner part of the Gulf of Fos: MOFS-MOFI, MOFS-ARFI, MOFS-LAFI, MOFS-AUFI.

2/the affinity between the communities of the upper layer and those of the inferior face whatever the stations may be, is an inverse function of the distance between stations: sixteen pairs between AUFS, LAFS, ARFS, MOFS and AUFI, LAFI, ARFI, MOFI.

3/the relations between the inferior face communities are the higher as the distance from their stations is reduced: six pairs between AUFI, LAFI, ARFI, and MOFI.

4/the in ferior face community of Moyade (MOFI) always has a low affinity with all other stations and layers except the upper layer of the same station(MOFS).

c) Hierarchical representation

The dendrograms made from the two different matrices synthesize the results with a minimal loss of information, and allow the schematization of the affinity existing between stations. Each coefficient relates to the faunal grouping accor-

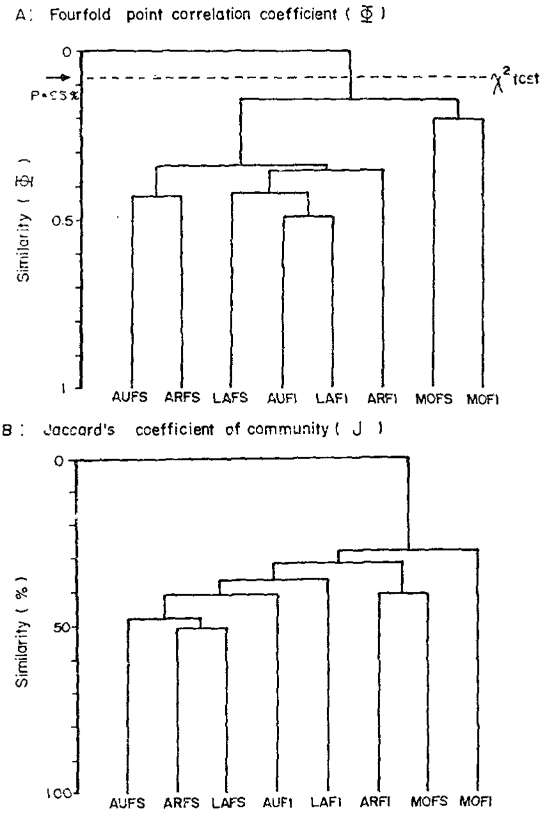

Fig. 8. Dendrograms constructed from the fourfold point correlation coefficient and Jaccard's community coefficient.

ding to their characteristics. The fourfold point correlation coefficient(Φ) devides the community studied into three subgroups(Fig. 8): 1/first group is composed of the upper layer communities in the region of Fos: AUFS and ARFS.
2/a second group joins the inferior face communities in the region of Fos: LAFS, AUFI, LAFI, ARFI constructing the nucleus by AUFI and LAFI. 3/a third completely isolated group consists of the Moyade community: MOFS and MOFI. This illustrates an isolation of the control station(station of Moyade) and is fairly well adapted to our results in spite of the unexpected liaison of the upper layer community of Laurons (LAFS) to the faunal groups of the inferior face.

On the contrary, Jaccard's coefficient of community establishes rather two eventual subdivisions(Fig. 8): 1/the first division regroups the upper layer communities, consisting of the nucleus LAFS-ARFS. 2/the second division less clearly constitutes the communities of the inferior face focused on the AUFI-LAFI. But, because of the double absence problem chaining occurs rendering the Jaccard's coefficient inappropriate to our data.

Conclusion

An impoverishment in the total number of species found was accentuated as it approached toward the pollution source: Control(387 species), Arnette(310 species), Laurons(260 species), Auguette(214 species). Specific impoverishment is particularly apparent in the bryozoans, crustaceans, and the echinoderms. On the other hand, the number of species of molluscs and polychaetes varies little from station to station.

The total number of individuals sampled decreased more or less regularly with the pollution. This diminution is particularly clear in the uncountable fraction and is composed of bryozoans and poriferans: Control(482.4), Arnette(203.8), Laurons(167), Auguette(115). However, in respect of the countable fraction, this diminution is not so regular, but a maximum numerical abundance at the Moyade station and a minimum at the Auguette station have been noted: Control (1,416), Arnette(702.4), Laurons(818.2), Auguette(380.7). The remarkable difference in numerical abundance between Moyade and the other stations in the Gulf of Fos, is probably due to the pollution, but also to the effect of greater depth at the Moyade station, which favours the coralligenous community.

The impact of the pollution is also found by a diminution of the diversity index: the Auguette station had a minimum value, while the maximum value occurred at the Moyade station.

Species grouped by function showed that on the whole the constructive species group and the utilizers of the created habitats were well represented at the Moyade station not only in species richness but also in numerical abundance, while the destructive species group was slightly more well-represented at the stations of the Gulf of Fos than in Moyade. Thus, the dominance of sipunculids increases highly with the pollution. The cryptofauna showed a maximum mean dominance at the most altered station, probably due to their relative protection from to the exterior milieu.

In general, the progressive impoverishment, qualitative and quantitative, of all the ecological stocks as a function of the intensity of pollution is notable, however:

1/The ecological stocks of the infralittoral hard bottom are more important qualitatively as well as quantitatively at the stations in the Gulf of Fos than at the Moyade station where the depth is more important. In the three stations of the Gulf of Fos, these stocks show a clear progressive decrease in species richness and numerical abundance with the increase of the pollution.

2/Conversely, the ecological group of species of circalittoral hard substrate are better represented at the Moyade station than in all of the stations in the Gulf of Fos. For the same bathymetric reason due to the ascent("la remontée") of the deep-sea species where it constitutes 3.1%

of the species richness of the community studied.

3/The species of the soft substrate including the indicator species of fine sediment show decrease with the pollution. These species are much less important quantitatively than qualitatively.

4/The species group of ecologically widespread distribution constitutes, in respect of the species richness, 17—18% of the community at the stations of the Gulf of Fos and 14% at Moyade. However, it should be pointed out that the dominance of this stock generally demonstrates a considerable increase with the pollution: thus, at the most altered station its dominance reaches 55% in the countable fraction, while it presents only 26% at the least altered station in the Gulf of Fos.

As far as the faunal comparison of the upper layer community with that of the inferior face of the concretionary structures is concerned, the community composition, functional aspect, and the structure of ecological stocks are nearly identical for the two different faces. The fauna of the inferior faces differs from that of the upper layer by a qualitative and quantitative impoverishment.

The faunal affinity shows different results according to the coefficient used. Whilst the fourfold point correlation coefficient(Φ) is well adapted for the isolation of the control station from to the other stations of the Gulf of Fos, the Jaccard's coefficient of community(J) regroups the samples according to the upper layer or the inferior face. The hierarchical schematization shows that in view of the chaining effect of the Jaccard's coefficient, the phi coefficient is better for our data.

So due to a low species richness, a high dominance of the species group showing a widespread distribution, the nearly complete disappearance of certain taxonomic groups, and the rarefaction of the large forms of the epifauna, the station of Auguette situated in the proximity of the industrial complex in the Gulf of Fos, may be regarded as the equivalent in the hard bottom of the "subnormal zone" defined by Bellan(1967) for the heavily polluted soft substrate.

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北西 地中海 Fos해역의 海洋汚染이 海洋底棲生物群集 Coralligenous Community에 미치는 영향

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북서 지중해 Fos 해역에서의 해양 오염이 해양 저서 생물에 미치는 영향을 조사하기 위하여 Fos 지역의 해저에 발달하고 있는 저서생물군집 Coralligenous Community의 공간분포를 군집생태학적 측면에서 분석하였다.

Fos 임해공업단지의 영향하에 있는 3개의 정점을 環境勾配에 따라 설정하고(Arnette, Laurons, Auguette) 마르세이유 동남쪽 Riou섬 서편 Moyade에 한 개의 對照定點을 택하여 분석한 결과 오염이 심한, Fos 해역의 내만으로 들어갈수록 출현종의 수나 개체수가 감소하는 현상을 관찰할 수 있었다. 또한 種의 多樣度, numerical abundance, 多樣性 指數 등의 생태학적 諸 指數도 오염의 진전에따라 함께 감소하고 있다. 특히 Fos 해역 가장 안 쪽에 위치하고 있는 Auguette 정점은 인근 대단위 Fos 공업단지의 산업폐수는 물론 도시의 생활하수로부터 심각할 정도로 영향을 받고 있음이 밝혀졌다.

이렇게 산업 폐수와 도시 하수가 복합적으로 작용하여 해양 저서생물에 미치는 영향을 Community Composition, Coralligenous Community 특유의 기능적 측면, 生態群別에 의한 분석 등을 통하여 조사하였다. 기타 Fourfold Point Correlation Coefficient와 Jaccard's Community Coefficient를 이용하여 정점간의 種類似度를 비교 검토하였으며 Coralligenous Community의 下部動物相과의 관계도 아울러 고찰하였다.