NOTE ON THE MACROZOOBENTHOS OF THE UPPER LEVEL SEDIMENTS OF PORTO SÀNTO ISLAND (MADEIRA, PORTUGAL)

By LUÍS CANCELA DA FONSECA[1], JOSÉ GUERREIRO[2] & JOÃO GIL[3]

With 9 figures & 1 table

ABSTRACT. Soft bottom macrobenthic fauna of Porto Santo Island is poorly documented, nevertheless following the "Preliminary Assessment of the Effects of the Aragon oil spill in Porto Santo Island" during an intensive survey on May 1991, several data were recorded on upper level surface sediments, both intertidal and subtidal (from 0 to -20m) as well as its faunal composition. All the analyzed soft bottom substrate's samples can be classified as sands, varying from medium to fine sands. The macrobenthic fauna is clearly dominated by three taxonomic groups: polychaetes, bivalves and amphipods. Polychaetes are the dominant group on intertidal zones while bivalves dominate at the deepest level prospected (-20m), between these extreme levels amphipods are the major group at least at -10m, while at -5m there is no clear group dominance and gastropods and tanaids are present. Cluster analysis on the global matrix of sediment parameters and taxonomic data came out with two major groups of stations , the first including the finest sands, and the second one grouping stations with the coarser sediments. Evidence of the oil spill impact is mainly assessed by values concerning the microphytobenthos and the macrozoobenthic community dominance and specific diversity.

INTRODUCTION

Little information is available on oil spill effects in open sea islands in addition to particular recruitment patterns of bottom organisms, and intense coastal water renewal make the Porto Santo case quite interesting. The major killing effects promoted by this kind of disasters on soft bottom communities are due to settlement of crude (physical disturbance and stifling phenomena) and poisoning by toxic compounds (ICES, 1989). Unfortunately,

[1] U.C.T.R.A.- Universidade do Algarve, Campus de Gambelas, P-8000 Faro, Portugal
[2] Dept.Zool. Antropol. - F.C.U.L. and Lab. Marítimo da Guia, Estrada do Guincho, P-2750 Cascais, Portugal
[3] Lab. Marítimo da Guia, Estrada do Guincho, P-2750 Cascais, Portugal

Bol. Mus. Mun. Funchal, Sup. no. 4: 233-252, 1995 ISSN 0870-3876

soft bottom communities of Porto Santo Island (Madeira Archipelago) are rather unknown. Only the marine algae have been studied (LEVRING, 1974; AUDIFFRED & PRUD'HOME VAN REINE, 1985). Nevertheless an intensive survey was carried out during May 1991 - "Preliminary Assessment of the Effects of the 'ARAGON' Oil Spill in Porto Santo Island" (SBMOB-DZA, 1992) - in which upper level surface sediments, both intertidal and subtidal (from zero to -20 Mt.), as well as its faunal composition, have been studied.

According to CHASSÉ & MORVAN (1978), decontamination of clean sands surface could be done in six months; which means that this survey may have been carried out too long (more than one year) after the real impact of the "Aragon" crude oil on the soft bottom communities of Porto Santo Island, mainly medium to fine sands communities. Also, different metabolic reactions and responses to oil among benthic organisms (TEAL & FARRINGTON, 1977) can promote differences in the response of benthic communities to crude oil impact. Although a direct assessment of the "Aragon" oil spill effects is not possible, and comparisons between previous and actual condition of the communities are not allowed, data obtained permit a preliminary description of those communities, as well as a first approach to the effects of the oil spill on benthic soft bottom communities. Although natural differences between habitats may be present, affected and presumably unaffected places are studied and compared in the present work, which constitutes a first note on soft bottom substrata of Porto Santo Island both, on the benthic habitat and fauna, and on the presumable impact of the "Aragon" oil spill on those communities.

METHODS

Soft bottom was sampled at five locations (A, I, H, G and E, Fig. 1), along transects from the intertidal zone to the -20 Mt. bathymetric level, in which missing levels correspond to rocky areas. Location of sampling stations was established from the apparently most impacted area by the oil spill (A - Serra de Fora) towards a clean zone (E - Zimbralinho), including the inside of the harbor (I) and two transects in front of the beach (H - Cais, a minor impacted to clean area and G - Calheta, a major impacted area). The number affecting each station emphasizes its level (1: intertidal; 2: -5 Mt.; 3: -10Mt.; 4: $\geq$ -15 Mt.). Intertidal sediment were sampled with a stainless steel hand corer (0.02 m^2). A modified hand operated Van Veen grab (0.05 m^2 - model Sousa Reis/ LMG 1983) was used for subtidal samples. For macrobenthos ($\geq$1 mm) study, 10 intertidal and 6 subtidal replicates were collected. From each sampling point two more sub-samples were separated: i) a 10 cm section for grain-size studies; ii) the upper layer (1 cm) for water content, organic matter and phytopigments analysis. All the samples were frozen at -20°C, till the analysis were done.

For grain-size purposes mud (< 62μ , >4 ϕ), sand (62μ-2000μ, 4ϕ to-1ϕ) and gravel (>2000μ, <-1ϕ) were separated by wet sieving (BULLER & McMANUS, 1979). Sand grain-size distribution (phi level) was also analyzed. The sediment organic matter content (%OM) was estimated by loss on ignition (±500 °C, 24 hr. period) after the estimation of sediment water contents (%H20) by 24 hour drying at ±70 °C, and then converted to g/m² values. The concentration of the sediment phytopigments was evaluated by spectrophotometry, after a 24 hour cool extraction in 90% acetone. Concentrations (µg/g dry sediment) of chlorophyll a (Chl. a), phaeopigments (Phaeop.) and carotenoids (Car) were calculated by modified Lorenzen (Chl. a, Phaeop.) and Parsons and Strikland (Car) equations (PLANTE-CUNY, 1974), as well as the Margalef index and the Chl. a % degradation (PLANTE-CUNY, 1978). The Moss (MOSS, 1967) index was also calculated. To obtain phytopigment values per unit area (mg/m²) from phytopigment values per weight (µg/g), a sediment specific weight was used (CANCELA DA FONSECA et al, 1987; BERNARDO, 1990).

For the study of the macrobenthic organisms, samples were sieved in place by 1 mm² square mesh sieves (each replicate being treated separately) and frozen at -20 °C until their study could be performed. At the laboratory, samples were unfreeze in a 10% formalin solution and stained with Bengal rose. Next, the organisms have been sorted, identified, whenever possible to the species level, and counted (species richness). Densities of organisms (number/m²), Shannon-Wiener diversity, eveness (PIELOU, 1975) and McNaughton community dominance index (McNAUGHTON, 1968) were calculated.

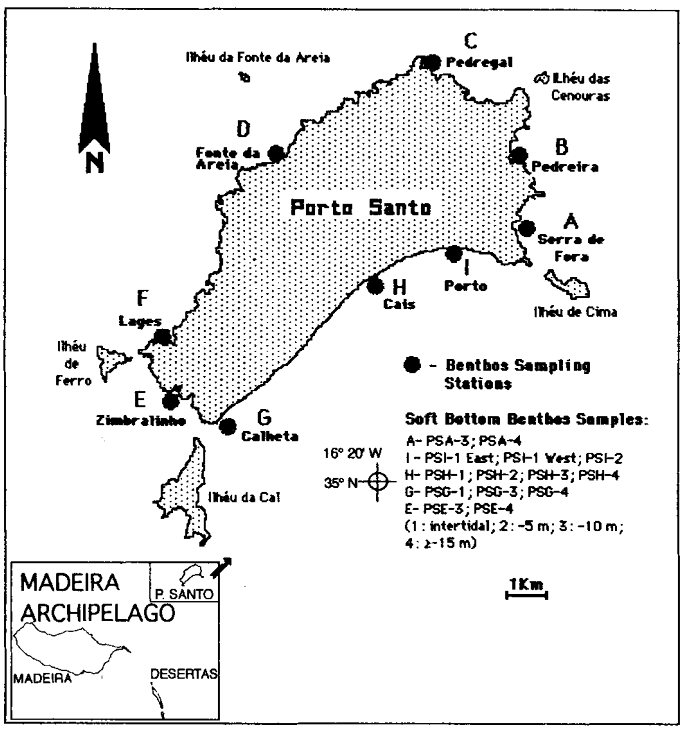

Figure 1 - Porto Santo Island: Benthos sampling stations

Cluster analysis (Bravais-Pearson correlation coefficient) with the UPGMA clustering method (SNEATH & SOKAL, 1973; LEGENDRE & LEGENDRE, 1984) was used to group stations. In order to summarize the information, principal component analysis (PCA- SNEATH & SOKAL, 1973) was also applied. PCA and cluster analysis was performed using programs by ANDRADE (1986).

RESULTS

All the collected sediment samples were classified as sands. Considering only sand percentages, and reporting stations on triangular Shepard diagrams (BULLER & McMANUS, 1979), a series from medium to fine sands was obtained, showing a decrease in grain-size, as follows: PSI-1 (East) → PSG-1 (Medium sands) - PSH-2 → PSA-4 → PSE-3 → PSI-1 (West) → PSH-1 → PSE-4 → PSA-3 → PSH-3 (Medium to fine sands) → PSG-3 → PSH-4 → PSG-4 → PSI-2 (Fine sands). Grain-size distribution per station (Fig. 2) illustrates that sequence. The finest sands were found in the Harbor (PSI-2) and in the deepest levels facing the South Coast beach (PSH-4, PSG-3, PSG-4).

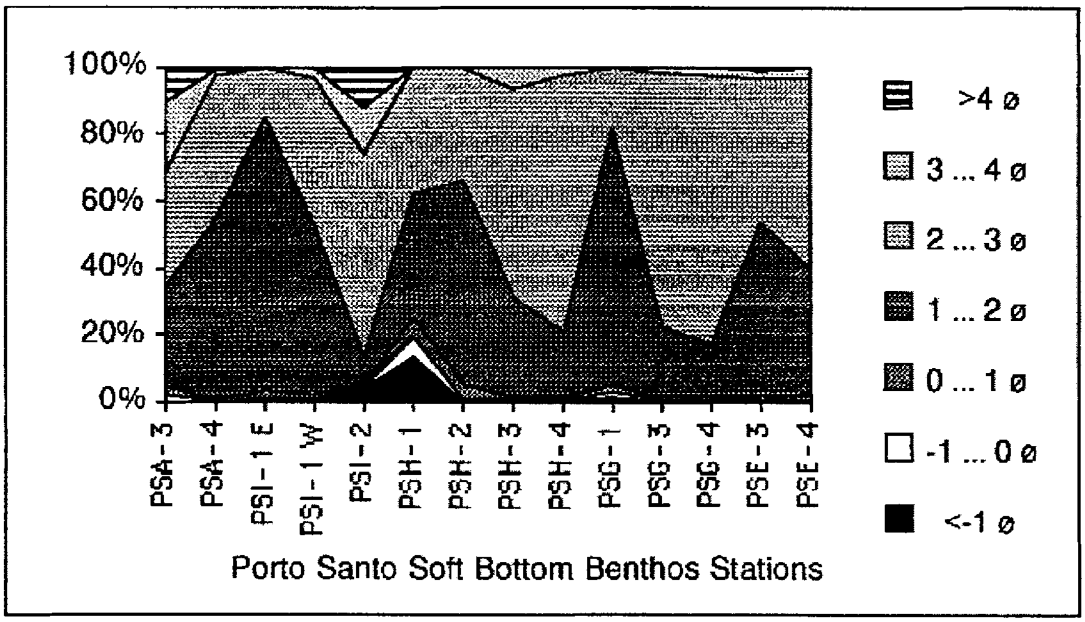

Figure 2 - Porto Santo: Grain-size Distribution per Station. Wentworth PHI scale - Ø:
Mud: >4 Ø; very fine sand: 3 ι 4 Ø; fine sand: 2 to 3 Ø; medium sand: 1 to 2 Ø; coarse sand: 0 to 1Ø; very coarse sand: -1 to 0 Ø; G ιve' <-1 Ø.

Surface sedimen present low organic matter contents (between 1.14 and 2.05%). Values of organic matter und in the sites of the oil spill major impact (PSA-3 and PSA-4) are not markedly different from those of the other stations. The highest organic matter content where recorded in the clean zone (PSE-4).

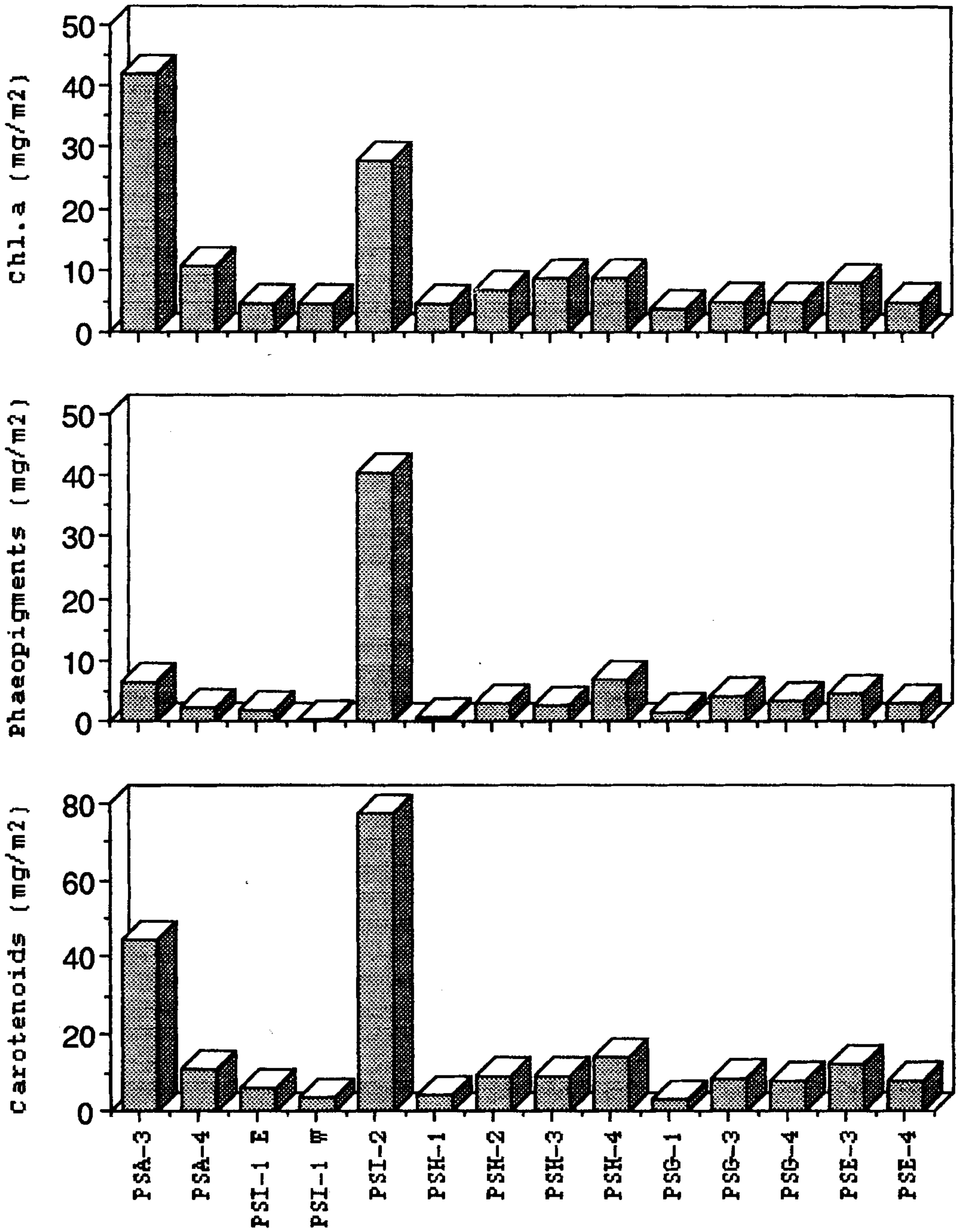

Figure 3 - Porto Santo Microphytobenthos: Chlorophyll a, Phaeopigments and Carotenoids contents of the upper layer of the sediment.

Values of the phytopigments of the sediment show that the largest quantities of functional chlorophyll a appear in the area directly impacted by the oil spill, which presents also low values of Margalef and chlorophyll degradation indexes (Figs. 3 and 4). The values of phytopigments recorded at PSI-2 seem to indicate that the harbor is the main zone of accumulation for the organic material.

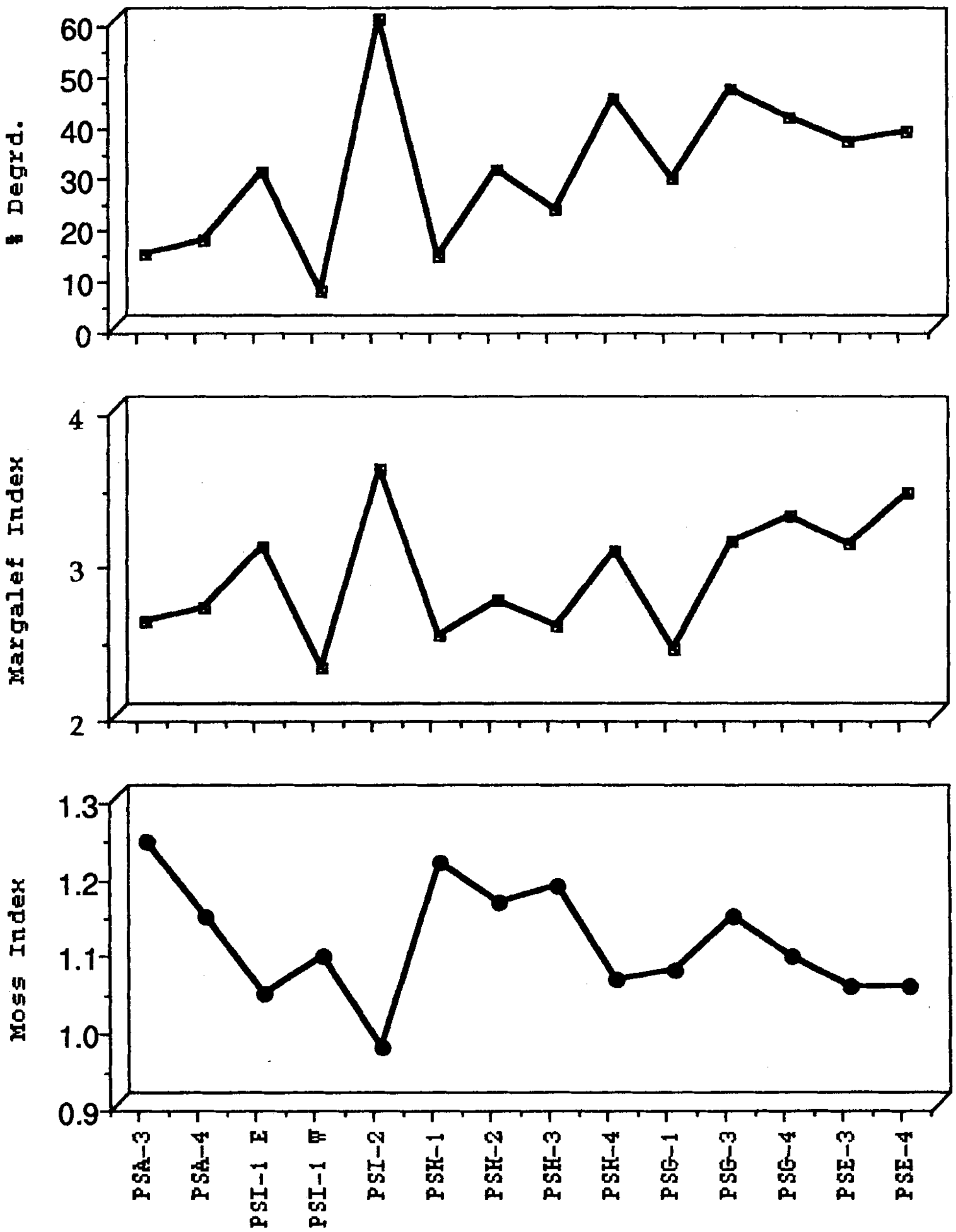

Figure 4 - Porto Santo Microphytobenthos: Variation of the % Degrad., Margalef and Moss indexes in the upper layer of the sediment.

A PCA performed on the data of the sediment, in which axis 1 and 2 concentrate 67% of the total variability (Fig. 5), plots OTU's (stations) from finest to coarser sands along the axis 1. Its distribution mainly suggests a grain-size gradient, and probably a bottom circulation gradient (cf. ANDRADE & CANCELA DA FONSECA, 1982). Accordingly, stations PSI-2 and PSA-3 (points 5 and 1) are those where the percentage of mud (silt + clay) is higher. The following assemblage of stations groups the deeper stations (≥ -10 Mt.); and the series terminates with the station showing the higher percentage of coarse sediment, PSH-1 (point 6).

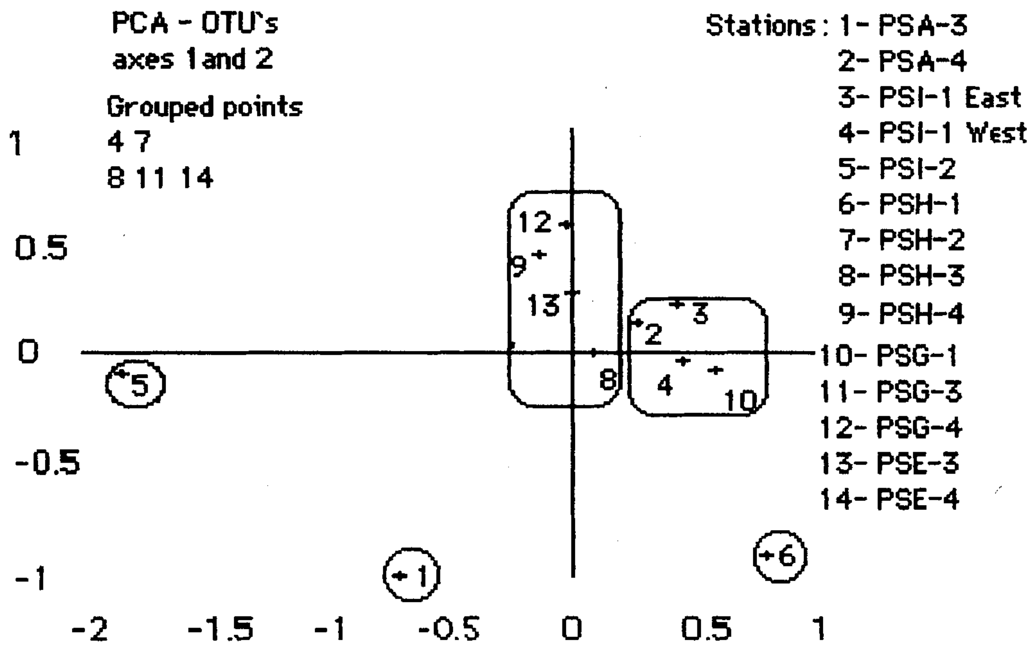

Figure 5 - Principal Component Analysis (PCA): Stations ordination based on the sediment variables data.

The benthic soft bottom macro-organisms collected from the Porto Santo Island, represent 29 major taxonomic groups (Table 1), and 198 different species were identified. Polychaetes constitute the major group with at least 70 species, followed by crustaceans (40 species) and by mollusks (37 species). Densities by bathymetric level reveal the differences in *taxa* distribution between intertidal and subtidal locations, the former clearly dominated by polychaetes while mollusks and crustaceans are the dominant groups in the latter.

Maximum densities of organisms were recorded in the transect H (Cais), in the middle of Porto Santo beach at -10 m depth. The higher densities were observed in the deeper stations of the H and G (Calheta) transects (Fig. 6). The highest number of taxa was recorded at the deepest point in transect H, followed by (Fig. 7) the subtidal station in the inner harbor (PSI-2), the most sheltered area. The lower densities and number of taxa occurred in transect A, the area of the major crude oil impact.

TABLE 1 - Porto Santo soft bottom benthic survey (May 1991): Density of the different *taxa* (ind./m^2) per station

MAJOR TAXA/SPECIES	A-3	A-4	I-1E	I-1W	I-2	H-1	H-2	H-3	H-4	G-1	G-3	G-4	E-3	E-4
FORAMINIFERIDA														
Massilina sp.	0	0	0	0	4	0	0	0	0	0	0	0	0	0
Mineacinea mineacea	0	0	0	0	0	0	3	0	3	0	0	0	0	0
Quinqueloculina cf. bicornis	0	0	0	0	228	0	0	0	3	0	0	3	0	0
Spiroloculina excavata	0	0	0	0	0	0	0	0	3	0	0	0	0	0
PORIFERA														
Porifera n.i.	0	0	0	0	4	0	0	0	0	0	0	0	0	0
CNIDARIA														
HYDROZOA														
Halecium liouvilley	0	0	0	0	4	0	3	0	0	0	3	0	0	0
Hebella parasitica	0	0	0	0	4	0	0	0	0	0	0	0	0	0
Perigonimus repens	0	0	0	0	0	0	0	0	7	0	0	0	0	0
Theocarpus distans	0	0	0	0	0	0	3	0	0	0	0	0	0	0
ANTHOZOA														
Edwardsia sp.	0	0	0	0	0	0	0	0	3	0	0	7	0	0
NEMERTINA														
Amphiporus bioculatus ?	0	0	0	0	0	0	0	3	0	0	0	27	0	0
Cephalothrix linearis	0	0	0	0	0	0	0	0	3	0	0	0	0	0
Cephalothrix rufifrons ?	0	0	0	0	0	0	0	0	3	0	0	0	0	0
Cerebratulus fuscus ?	0	0	0	0	0	0	0	0	3	0	0	0	0	0
Drepanophorus rubrostriatus	0	0	0	0	24	0	0	0	0	0	0	0	0	0
Tubulanus banyulensis ?	0	0	0	0	0	0	3	0	0	0	0	0	0	0
Valencinia longirostris	0	0	0	0	0	0	0	0	13	0	3	0	0	0
Nemertina n.i.	0	0	0	0	16	0	33	17	20	0	0	10	0	0
NEMATODA														
Nematonema sp.	0	0	0	0	0	0	0	0	3	0	0	0	0	0
ANNELIDA														
POLYCHAETA														
Aglaophamus rubella	0	0	0	0	0	0	0	7	3	0	0	0	0	0
Amphitritinae n.i.	0	0	0	0	0	0	0	0	3	0	0	0	0	0
Aricidea cerrutii	0	0	0	10	24	0	0	0	0	0	0	3	0	0
Armandia polyophthalma	0	0	0	10	0	0	0	20	53	0	13	53	7	0
Capitomastus minimus ?	0	0	0	0	0	0	3	0	0	0	0	0	0	0
Caulleriella alata	0	0	0	0	4	0	0	0	0	0	0	0	0	0
Chone collaris	0	0	0	0	24	0	0	0	3	0	0	0	0	0
Chone duneri	0	0	0	0	0	0	3	3	7	0	0	0	0	0
Chone cf. duneri	0	0	0	0	0	0	0	0	3	0	0	0	0	0

MAJOR TAXA/SPECIES	A-3	A-4	I-1E	I-1W	I-2	H-1	H-2	H-3	H-4	G-1	G-3	G-4	E-3	E-4
Chone filicaudata	0	0	0	0	0	0	0	10	33	0	0	10	0	0
Chone cf. filicaudata	0	0	0	0	4	0	0	0	10	0	0	3	0	0
Chone infundibuliformis	0	0	0	10	4	0	3	0	0	0	0	0	0	0
Chone sp.	0	0	0	0	0	0	3	0	7	0	0	0	0	0
Chrysopetalum debile	0	0	0	0	4	0	0	0	0	0	0	0	0	0
Cirratulus cirratus	0	0	0	0	8	0	0	0	0	0	0	0	0	0
Cirratulus sp.	0	0	0	0	8	0	0	0	0	0	0	0	0	0
Clymenura clypeata	0	0	0	20	0	0	0	0	10	0	0	0	0	0
Dasybranchus gajolae	0	0	0	0	0	0	3	0	0	0	0	0	0	0
Ditrupa arietina	0	0	0	0	0	0	0	0	347	0	10	413	0	0
Eteone sp.	0	0	0	0	0	0	0	0	0	0	0	3	0	0
Eunice vittata	0	0	0	0	0	0	0	0	3	0	0	0	0	0
Eunicidae n.i.	0	0	0	0	0	0	3	0	0	0	0	0	0	0
Fabricia sabella	0	0	0	0	4	0	0	0	0	0	0	0	0	0
Filograna sp.	0	0	0	0	44	0	0	0	0	0	0	0	0	0
Glycera rouxii	0	0	0	0	0	0	0	0	3	0	0	0	0	0
Hala cf. parthenopeia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hala parthenopeia ?	0	0	0	0	0	0	3	0	3	0	0	0	0	0
Hyalinoecia bilineata	0	0	0	0	0	0	0	0	3	0	0	0	0	0
Jasmineira cf. caudata	0	0	0	0	0	0	0	0	3	0	0	0	0	0
Langerhansia cf. cornuta	0	0	0	0	4	0	0	0	0	0	0	0	0	0
Lanice conchilega	0	0	0	0	0	0	0	0	47	0	0	0	0	0
Lepidonotus clava	0	0	0	0	0	0	3	0	3	0	0	0	0	0
Lumbrinereis gracilis	0	0	0	0	0	0	0	0	7	0	0	0	0	0
Lumbrinereis cf. gracilis	0	0	0	0	4	0	0	0	7	0	0	0	0	0
Lumbrinereis cf. tetraura	0	0	10	10	0	3	7	0	0	0	0	0	0	0
Lumbrinereis sp1	0	0	0	0	0	0	0	0	3	0	0	7	0	4
Maldanidae n.i.	0	0	0	10	0	0	0	0	17	0	0	0	0	0
Mystides limbata	0	0	0	0	0	0	0	0	7	0	0	3	0	0
Nainereis sp.	3	3	0	0	0	0	0	0	0	0	3	0	0	0
Nephthys hombergii	0	3	0	0	116	0	0	3	17	0	0	37	60	52
Nephthys cf. hombergii	0	0	0	0	0	0	0	0	0	0	0	3	0	0
Nerine mesnili	0	143	0	0	0	120	0	0	0	205	0	0	0	0
Nerine sp.	0	7	0	10	0	0	0	0	0	0	0	0	0	0
Nicolea venustula	0	0	0	0	0	0	10	0	0	0	0	0	0	0
Notomastus cf. latericeus	0	0	0	0	0	0	0	3	7	0	0	0	0	0
Odontosyllis ctenostoma	0	0	0	0	0	0	0	0	7	0	0	0	0	0
Odontosyllis dugesiana	0	0	0	0	0	0	0	0	0	0	0	3	0	0
Ophelina acuminata	0	0	0	0	0	0	0	0	7	0	0	0	0	0
Owenia fusiformis	0	0	0	0	20	0	0	0	0	0	0	0	0	0
Paradoneis armata	0	0	0	0	16	0	0	0	0	0	0	0	0	0
Paradoneis lyra	0	0	0	0	12	0	0	0	0	0	0	0	0	0
Perinereis sp.	0	0	0	0	0	0	0	0	0	5	0	3	0	0
Phyllodocidae n.i.	0	0	0	0	0	0	0	3	0	0	0	0	0	0
Pista cristata	0	0	0	0	8	0	0	0	3	0	0	0	0	0
Platynereis dumerilii	0	0	0	0	12	0	20	0	0	0	0	0	0	0
Polycirrus haematodes ?	0	0	0	0	0	0	0	0	0	0	0	3	0	0

MAJOR TAXA/SPECIES	A-3	A-4	I-1E	I-1W	I-2	H-1	H-2	H-3	H-4	G-1	G-3	G-4	E-3	E-4
Pomatoceros lamarckii	0	0	0	0	12	0	0	0	0	0	0	0	0	0
Praxillella affinis	0	0	0	0	0	0	0	0	3	0	0	0	0	0
Prionospio cf. ehlersi	0	0	0	0	0	0	0	0	0	0	0	3	0	0
Prionospio malmgreni	0	0	0	0	0	0	0	20	113	0	0	13	0	4
Prionospio cf. malmgreni	0	0	0	0	0	0	0	0	0	0	0	7	0	0
Prionospio sp.	0	0	0	0	0	0	0	0	0	0	0	17	0	4
Psammolyce inclusa	0	0	0	0	0	0	0	0	13	0	3	10	0	0
Sabellidae n.i.	0	0	0	0	0	0	0	0	0	0	0	3	0	0
Scalisetosus pellucidus	0	0	0	0	0	0	0	0	7	0	0	0	0	0
Scolelepis girardi ?	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Scolelepis cf. squamata	0	20	20	20	0	0	3	7	0	0	13	0	43	16
Scolelepis sp. ?	0	0	0	0	0	0	3	0	0	0	0	0	0	0
Scoloplos armiger	0	0	0	10	0	0	0	0	7	0	0	0	0	0
Semivermilia cf. torulosa	0	0	0	0	4	0	0	0	0	0	0	0	0	0
Spio filicornis ?	0	0	0	0	0	0	0	20	0	0	3	0	0	0
Spio sp. ?	0	0	0	450	0	0	123	17	0	0	0	0	0	0
Spiochaetopterus madeirensis	0	0	0	0	8	0	0	0	3	0	0	0	0	0
Spionidae n.i.	0	3	0	130	0	0	890	13	50	195	7	7	3	8
Spiophanes bombyx ?	0	0	0	0	0	0	0	0	0	75	0	0	0	0
Syllidia armata	0	0	0	0	4	0	0	0	7	0	0	0	0	0
Syllinae n.i.	0	0	0	0	0	0	3	0	0	0	0	0	0	0
Thelepus sp.	0	0	0	0	0	0	0	0	0	0	0	3	0	0
Typosyllis variegata	0	0	0	0	4	0	0	0	0	0	0	0	0	0
OLIGOCHAETA														
Tubificoides sp.1	0	0	0	0	0	0	0	0	3	0	0	0	0	0
Tubificoides sp.2	0	0	0	0	0	0	0	7	0	0	0	0	0	0
SIPUNCULIDA														
Aspidosiphon muelleri	0	0	0	0	0	0	0	0	300	0	0	3	0	0
Golfingia papillifera	0	0	0	0	4	0	0	0	0	0	0	0	0	0
ECHIURIDA														
Thalassema cf. arcassonense	0	0	0	0	0	0	0	0	3	0	0	0	0	0
Thalassema cf. neptuni	0	0	0	0	0	0	0	0	0	0	0	3	0	0
Thalassema sp.	0	0	0	0	0	0	0	0	3	0	0	0	0	0
MOLLUSCA														
APLACOPHORA														
Entonomenia atlantica	0	0	0	0	0	0	13	0	0	0	0	0	0	0
GASTROPODA														
Akera bullata	0	0	0	0	40	0	0	7	0	0	0	0	0	0
Alvania cancellata	0	0	0	10	0	0	0	0	0	0	0	0	0	0
Bittium latreillei	0	0	0	0	692	0	13	0	0	5	0	0	0	0
Bivonia cf. semisurreta	0	0	0	0	32	0	0	0	0	0	0	0	0	0
Cylichna cylindracea	0	0	0	0	0	0	0	0	0	0	0	3	0	0
Cytharella smithi	0	0	0	0	0	0	0	0	3	0	0	0	0	0
Gibbula candei	0	0	0	10	0	0	0	0	0	0	0	0	0	0
Hedylopsis cf. spiculifera	0	0	0	20	0	0	0	0	0	0	0	0	0	0
Jujubinus ruscurianus	0	0	0	0	4	0	0	0	0	0	0	0	0	0
Jujubinus sp.	0	0	0	0	4	0	0	0	0	0	0	0	0	0

MAJOR TAXA/SPECIES	A-3	A-4	I-1E	I-1W	I-2	H-1	H-2	H-3	H-4	G-1	G-3	G-4	E-3	E-4
Monodonta atrata	0	0	10	0	0	0	0	0	0	0	0	0	0	0
Nassarius cuvierii	0	0	0	0	20	0	10	0	0	0	0	0	0	0
Natica furva	0	0	0	0	0	3	0	0	0	0	0	0	0	0
Nitidella ocellina	0	0	0	0	0	0	7	0	0	0	0	0	0	0
Ocinebrina edwardsi	0	0	0	0	0	0	0	0	3	0	0	0	0	0
Philine scabra	0	0	0	0	0	0	7	0	0	0	0	0	0	0
Pseudovermis sp.	0	0	0	0	0	0	0	3	0	0	0	0	0	0
Semiretusa tornata	0	0	0	0	0	0	0	0	3	0	0	0	0	0
Setia beniamina innominata	0	0	0	0	0	0	33	0	0	0	0	0	0	0
Setia punctifera	0	0	0	0	0	0	10	0	7	15	0	0	0	0
Skeneopsis planorbis	0	0	0	0	0	3	0	0	0	65	0	0	0	0
Turbonilla lactea	0	0	0	0	0	0	0	0	3	0	0	0	0	0
Turbonilla sp.	0	0	0	0	0	0	0	0	3	0	0	0	0	0
Weinkauffia semistriata	0	0	0	0	116	0	0	0	0	0	0	0	0	0
BIVALVIA														
Abra alba	0	0	0	0	4	0	0	0	13	0	0	0	0	0
Donax vittatus	0	7	0	0	0	10	0	0	3	5	10	3	47	16
Ervilea nitens	43	0	0	0	0	10	1070	2500	3906	5	540	3713	57	128
Gaffrarium minimum	0	0	10	20	0	0	13	263	183	5	7	167	40	44
Lima subauriculata	0	0	0	0	0	0	0	0	123	0	0	40	0	0
Notirus irus	0	0	0	0	4	0	0	0	0	0	0	0	0	0
Parvicardium ovale	0	0	0	0	0	0	0	0	7	0	0	3	0	0
Parvicardium papillosum	0	0	80	0	128	0	3	0	10	0	3	13	47	4
Tellina fabula	0	0	20	0	4	0	207	110	3	0	0	0	0	0
Tellina tenuis	0	0	20	0	0	0	0	10	0	0	10	0	13	0
Thracia papyracea	0	0	0	0	0	0	0	0	3	0	7	3	0	0
Venerupis aurea	0	0	0	0	0	0	0	0	7	0	0	0	0	0
ARTHROPODA														
PANTOPODA														
Anoplodactylus petiolatus	0	0	0	0	0	0	0	23	3	0	3	3	0	0
CRUST. OSTRACODA														
Cythere albomaculata	0	0	0	0	0	0	0	0	3	0	0	0	0	0
Philomedes sp.	0	0	0	0	0	0	0	0	3	0	0	0	0	0
CRUST. COPEPODA														
Harpaticoida	0	0	0	0	0	0	3	0	0	0	0	0	0	0
Notodelphyoida	0	0	0	0	0	0	0	0	3	0	0	0	0	0
Poecilostomatoida	0	0	0	0	44	0	0	0	0	0	0	0	0	0
CRUST. MISYDACEA														
Anchialina agilis	0	0	0	0	0	0	0	0	7	0	0	3	0	0
Erythrops cf. elegans	0	0	0	0	0	0	0	0	0	0	0	3	0	0
Gastrosaccus normani	0	0	0	20	8	0	10	400	83	0	147	270	7	8
CRUST. TANAIDACEA														
Apseudes latreilli	0	0	0	10	0	0	0	0	0	0	0	0	0	0
Leptochelia cf. savignyi	0	0	0	0	876	0	0	0	150	0	0	0	0	0
Parasimelobus chevreuxi	0	0	0	0	28	0	0	0	0	0	0	0	0	0
Tanais cf. dulongii	0	0	0	0	16	0	0	0	0	0	0	0	0	0
Tanais cf. cavolinii	0	0	0	0	0	0	7	0	0	0	0	0	0	0

MAJOR TAXA/SPECIES	A-3	A-4	I-1E	I-1W	I-2	H-1	H-2	H-3	H-4	G-1	G-3	G-4	E-3	E-4
CRUST. ISOPODA														
Campecopea hisurta	0	0	0	0	0	0	0	3	0	0	0	0	0	0
Cymodoce truncata	0	0	0	0	0	0	0	0	0	0	0	0	3	0
Dynamene cf. toreilliae	0	0	0	0	56	0	0	0	0	0	0	0	0	0
Eurydice cf. affinis	0	0	10	0	0	20	0	0	0	10	0	0	0	4
Eurydice spinigera	0	3	0	0	0	53	30	0	0	5	0	0	0	8
Paranthura cf. nigropunctata	0	0	0	0	4	0	0	0	0	0	0	0	0	0
Synisoma cf. bellonae	0	0	0	0	0	0	0	0	0	0	0	0	3	0
CRUST. AMPHIPODA														
Amphitoe sp.	0	0	0	0	0	0	10	0	0	0	0	0	0	0
Caprella sp.	0	0	0	0	4	0	10	23	17	0	0	0	0	0
Erichtonius brasiliensis	0	0	0	0	4	0	7	0	543	0	0	0	10	0
Erichtonius sp.	0	0	0	0	0	0	0	0	480	0	0	0	0	0
Gammaropsis maculatus	0	0	0	0	0	0	10	0	0	0	0	0	0	0
Gammaropsis sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Harpinia crenulata	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jassa marmorata	0	0	0	0	8	0	0	0	0	0	0	0	0	0
Jassa sp.	0	0	0	0	12	3	27	0	0	0	0	0	0	0
Megamphopus longicornis	0	0	0	0	0	0	0	0	13	0	0	0	0	0
Microdeutopus sp.	0	0	0	0	0	0	0	0	0	0	0	3	50	0
Photis longipes	0	10	0	0	728	0	40	2396	0	0	2246	0	0	0
Photis reinhardi	0	0	0	0	0	0	0	0	0	0	0	327	0	0
Photis sp.	0	0	0	0	28	0	90	6409	553	0	2903	613	7	0
Phtisica marina	0	0	0	0	640	0	0	1590	1377	0	37	367	7	0
Podocerus variegatus	0	0	0	0	44	0	7	0	3	0	0	0	0	0
Other Amphipoda n.det.	0	80	0	0	0	0	20	57	20	0	217	43	0	0
CRUST. DECAPODA														
Crangon crangon	0	0	0	0	0	0	0	0	0	0	0	0	7	4
Cryptosoma cristatum	0	0	0	0	0	0	0	0	0	0	3	0	0	0
Macropodia sp1	0	0	0	0	0	0	0	0	3	0	0	0	3	0
Philocheras bispinosus	0	0	0	0	0	0	0	0	3	0	7	3	7	32
Philocheras cf. fasciatus	0	0	0	0	0	0	3	0	0	0	0	0	0	0
Pottumnus latipes	0	0	0	0	4	0	0	0	3	0	0	3	0	0
Xanthus pilipes	0	0	0	0	0	0	3	0	0	0	0	0	0	0
INSECTA DIPTERA														
Chironomidae	0	0	0	0	0	0	0	0	0	10	0	0	0	0
PHORONIDA														
Phoronopsis harmeri	0	0	0	0	0	0	0	0	57	0	0	7	0	0
BRYOZOA														
Arthropoma cecilii	0	0	0	0	0	0	0	0	0	0	0	0	3	0
Buskea dichotoma	0	0	0	0	0	0	0	0	0	0	0	3	0	0
Caberea boryi	0	0	0	0	0	0	3	0	0	0	0	0	0	0
Cribilaria innominata	0	0	0	0	0	0	3	0	0	0	0	0	0	0
Escharina johnstoni	0	0	0	0	0	0	0	0	0	0	0	0	3	0
Mollia rosselii	0	0	0	0	0	0	0	0	0	0	0	3	7	0
Parellisina curvirostris	0	0	0	0	0	0	0	0	0	0	0	0	3	0
Schizoporella longirostris	0	0	0	0	0	0	0	0	0	0	0	0	3	0

MAJOR TAXA/SPECIES	A-3	A-4	I-1E	I-1W	I-2	H-1	H-2	H-3	H-4	G-1	G-3	G-4	E-3	E-4
Schizoporella unicornis	0	0	0	10	0	0	0	0	0	0	0	0	0	0
Scrupocellaria cf. scrupea	0	0	0	0	4	0	0	0	0	0	0	0	0	0
Scrupocellaria cf. scruposa	0	0	0	0	4	0	0	0	0	0	0	3	0	0
Setosella vulnerata	0	0	0	0	0	0	0	0	0	0	0	0	3	0
Watersipora complanata	0	0	0	0	0	0	0	0	0	0	0	0	10	0
ECHINODERMATA														
HOLOTUROIDEA														
Leptosynapta inhaerens	0	0	0	0	0	0	0	0	0	0	0	0	0	4
ASTEROIDEA														
Astropecten platyacanthus	0	0	0	0	0	0	0	3	0	0	0	0	0	0
OPHIUROIDEA														
Amphipholis squamata	0	0	0	0	432	0	100	0	23	0	0	0	0	0
Ophiura cf. africana	0	0	0	0	4	0	0	0	3	0	0	0	0	0
Ophiura grubei	0	0	0	0	0	0	0	0	7	0	0	0	0	0
ECHINOIDEA														
Arbaciella elegans	0	0	0	0	0	0	3	0	0	0	0	0	0	0
Echinocardium cf. cordatum	0	0	0	0	0	0	0	0	3	0	3	3	0	8
Echinocardium cf. flavescens	0	0	0	0	0	0	0	0	13	0	10	7	0	0
Echinocyamus pusillus	0	0	0	0	0	0	0	0	17	0	0	3	0	4
Genocidaris maculata	0	0	0	0	8	0	0	0	0	0	0	0	0	0
CHORDATA														
TUNICATA														
Molgula cf. occulta	0	0	0	0	4	0	0	0	137	0	0	83	0	0
Polycarpa cf. gracilis	0	0	0	0	0	0	0	0	97	0	10	0	0	0

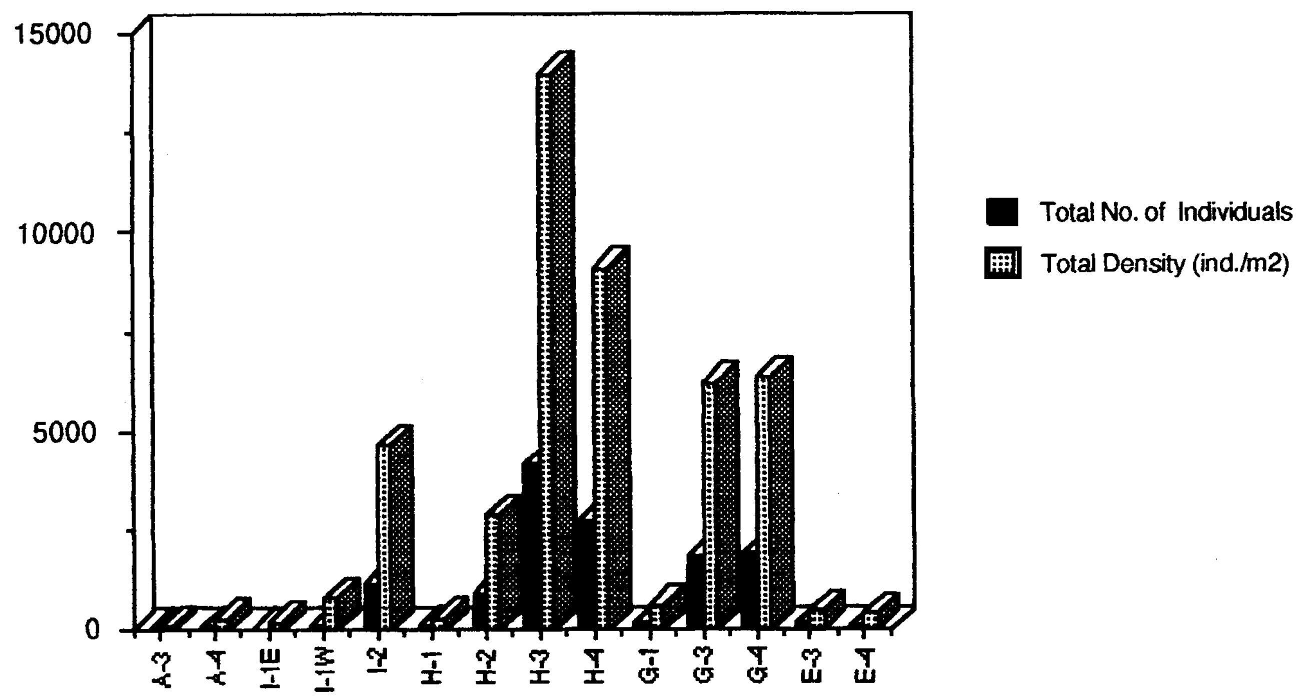

Figure 6 - Variation of soft bottom macrofauna: number of individuals and densities per station.

Values of McNAUGHTHON community dominance index, Shannon-Wiener diversity (H') and eveness for each station (Figs. 7 and 8) point out some disturbance at PSA-3 station: the lowest value of H' and a 100% dominance are surely related with the highest impact of oil spill of all the studied soft bottom stations. According to this fact are the values of the same indexes obtained for the PSG-3 station located in the other heavily impacted area. This also agrees with the presence of crude in the bottom, observed by scuba diving at the time the samples where obtained - May 1991.

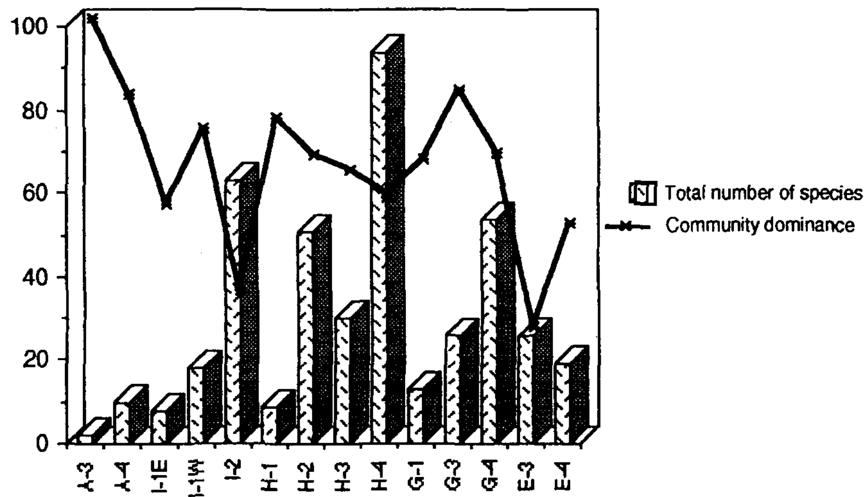

Figure 7 - Number of species sampled from the soft-bottom macrobenthos and McNAUGHTON community dominance index.

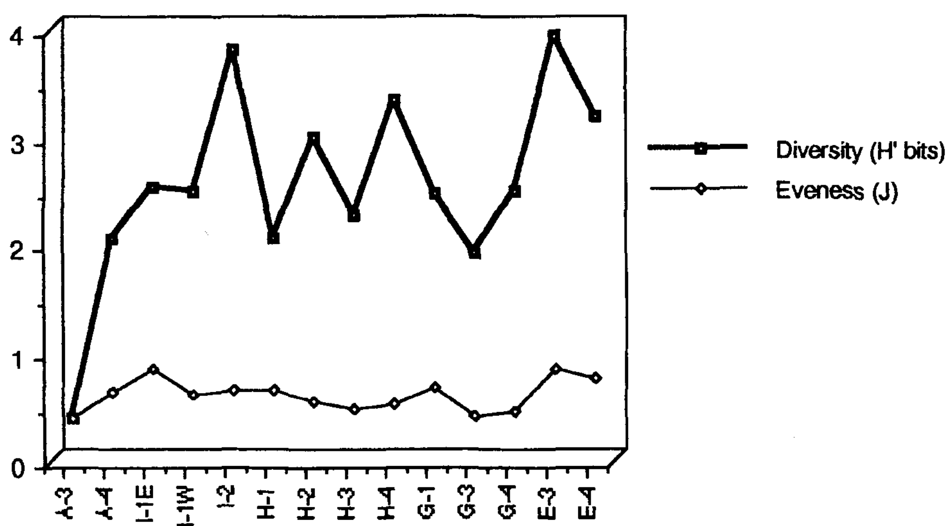

Figure 8 - Variation of Shannon-Wiener diversity and eveness per station.

Cluster analysis using the Bravais-Pearson correlation coefficient was performed on a global matrix of sediment parameters and the distribution of major *taxa* per station. In Q mode analysis a separation was obtained (Fig. 9), between PSH-3, PSG-3, PSH-4, PSG-4, the deepest stations in the H and G transects, and the other stations, certainly the more unstable habitats, due to its lower depths. Those four stations were also the ones where the higher numbers of individuals and total densities were recorded. These stations were included in the intermediate group obtained with the sediment characteristics (cf. Fig. 5). Stations PSE-3 and PSE-4 were excluded from that group by the addition of the taxonomic data to the sediment characteristics of each station. In fact, cluster analysis including taxonomic data emphasize the number of individuals rather than its distribution by the different species. The group {PSH-3, PSG-3, PSH-4 and PSG-4} includes the stations with the higher densities. Otherwise, the other group reveal a gradient among the other stations, in what concerns the number of organisms (and perhaps also of disturbance), rather than the differences in the sediment parameters.

DISCUSSION

The results on the macrozoobenthos of the Porto Santo near shore soft-bottom communities are an important contribution to the knowledge of the benthos of the Madeira Archipelago and they show that only 41% of the identified species are refered in the revision of the soft bottom invertebrates of the Portuguese benthos (DEXTER, 1992) and can be considered common to the fauna of the European continental coast of Portugal. The evaluation of differences in community structure suggest that "Aragon" oil spill has had considerable effects, both on faunal and microphytobenthic composition of the bottom. However, it should be stressed that pre-impact information are not available to aid the interpretation of the obtained data.

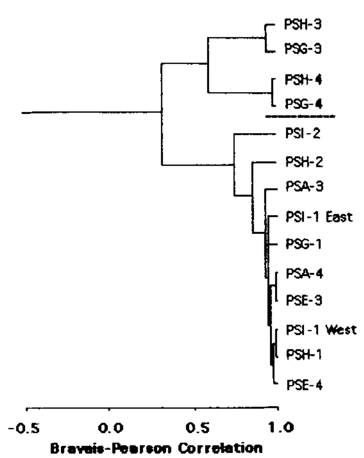

Figure 9 - Stations grouping (cluster analysis - Q mode), based on the values of sediment parameters and *taxa*, per station.

At the macrofaunal level, diversity data points out that the site A is the most disturbed area. The lower values of diversity and eveness matched the main area of the oil spill impact (PSA-3 station). Other low values of these community parameters (PSG-3 station) reveal also a major impacted area. On the other hand, maximum diversity and eveness occurred at the non affected area (PSE-3 station). Thereafter, from the observation of the species list, and according with the scale of the Survival Index proposed by CHASSÉ (1978), the distribution of the macrofauna strongly suggests the occurrence of a major impact by the "Aragon" oil spill at Serra de Fora (A transect). All the most sensible organisms noticed for that index (CHASSÉ, 1978; CHASSÉ & MORVAN, 1978), such as Echinodermata, Tanaidacea and Decapoda, are excluded from that zone. Only organisms of two of the most resistant groups quoted by those authors were founded at the higher polluted suspected area (PSA-3): Polychaeta and Bivalvia.

Otherwise, results regarding the microphytobenthos seem to corroborate this hypothesis and suggest that site A is in a earlier seral stage of succession. Data on microphytobenthos indicate that the more productive area is the Eastern coast directly affected by the crude. Values for Moss, Margalef, and chlorophyll degradation indexes emphasize this fact, as shown for other places (CANCELA DA FONSECA *et al.*, 1987; BERNARDO, 1990). Otherwise, and excepting the harbor (PSI stations), the shape of the curves in Fig. 4 stress a progressive impoverishment of microphytobenthos production and an increase of its community structure, from East stations (PSA-3 and PSA-4) to West stations (PSE-3 and PSE-4); that means, from the supposed most affected area (Serra de Fora) to that considered as a clean area (Zimbralinho). One may speculate about this, and several possibilities can be considered: i) greater amounts of nutrients are free in the area, due to one or both: the mortality that probably occurred with the oil spill and the decomposition that followed; and the products used to emulsionize oil; ii) the death and extinction or great reduction of the herbivores and/ or deposit-feeders, permits greater densities of microphytobenthos; iii) greater amounts of nutrients will be free for the benthic micro-algae due to the eventual regression of macro-algae.

According to ICES (1989), settlement of crude oil seems to act like a physical disturbance. In that case, one may remember the grouping of the most affected subtidal stations with the intertidal stations of the other areas (cf. Fig. 9), the most physically disturbed. Facing the results of this cluster analysis the impact assessment of the "Aragon" oil spill is rather difficult, because the separation between the clean area (E transect) and the polluted one (A transect) is not clear. But as it was stressed above, cluster analysis heighten the number of individuals which is reduced in physically disturbed areas like the A and the E sites naturally are, due to the water flow that are usually stronger in these sides of the Porto Santo island.

So, and as HYLAND (1978) pointed out for the “Amoco Cadiz” oil spill, the observed variations in community structure also stress the natural variation in environmental conditions between contrasting habitats (e.g. protected vs. ocean-exposed sand). As emphasized by the ICES report (1989), at present levels of understanding of ecosystem responses to impacts, significance of observed changes may only be judged against natural fluctuations of community structure and composition. This is also highlighted by the comparison of the frequencies of macrobenthic faunal *taxa* in each station, showing that polychaetes are the dominant group on intertidal zones while bivalves dominate at the deepest level prospected. Between these levels amphipods are the major group at -10 Mt., while at -5 Mt. there is no clear dominance of no one of these groups that are here joined by gastropods and tanaids. Applying the CHASSÉ's survival index without knowledge about the community composition one may be tempted to say that the -5 Mt. bathymetric level was the less impacted one.

To try to assess an impact without a reference state for the benthic communities composition and structure is a very hard and delicate task and, as pointed out by AUGIER (1985), the knowledge of the Madeira Islands benthic communities is very poor. The “Aragon” oil spill at Porto Santo Island (Madeira Archipelago) enhance the absolute priority of the existence of extensive surveys and defined baselines in all habitats and geographical areas, in order to establish the natural spatio-temporal variability. This work, only possible after the oil spill, intends to be a note on the macrobenthic soft bottom fauna of Porto Santo Island but it emphasizes the priority of this kind of studies and even more to ecosystems like these-one, located in the Mid-Atlantic and separated from the nearest similar system by depths exceeding 3000 meters.

ACKNOWLEDGEMENTS

Thanks are due to ISABEL HENRIQUES, MARIA MANUEL ANGÉLICO, RICARDO ARAÚJO, ANTÓNIO FREITAS, LUÍS SILVA, PEDRO PEREIRA, MIGUEL MOREIRA AND FRANCISCO ANDRADE for assistance in the field sampling, and to CARLOS ALVES for sorting out the organisms from samples. Thanks are also due to TERESA LOPES for help during the preparation of the campaign, to DOMINGOS ABREU for the identification of the gastropods, to JOÃO CARLOS MARQUES for the revision of the amphipods, and to LUIZ SALDANHA for the help on the cnidarians, bryozoans and tunicates. This work was supported by the EEC Contract B6612-90-8831.

REFERENCES

ANDRADE, F.,
1986. *O estuário do Rio Mira: Caracterização geral e análise quantitativa da estrutura dos macropovoamentos bentónicos*. Tese de Doutoramento, Fac. Ciências de Lisboa, 393p.

ANDRADE, F. & CANCELA DA FONSECA, L.,
1982. The coenotic structure of the Sado estuary (Setúbal, Portugal). Numerical treatment using a multivariate analysis. Preliminary approach. *Actual problems of Oceanography in Portugal* : 109-119. JNICT and NATO Marine Sciences Panel, Lisboa.

AUDIFFRED, P. A. J. & PRUD'HOME VAN REINE, W. .,
1985. Marine algae of Ilha do Porto Santo and Deserta Grande (Madeira Archipelago). *Bol. Mus. Mun. Funchal,* 37 (168): 20-51.

AUGIER, H.,
1985. Première contribution à l'étude et à la cartographie des biocenoses marines benthiques de l'ile de Madere. *Bol. Mus. Mun. Funchal,* 37 (168): 86-129.

BERNARDO, J. M.,
1990. *Dinâmica de uma Lagoa Costeira Eutrófica (Lagoa de Santo André).* Tese de Doutoramento, Fac. Ciências de Lisboa, 322p.

BULLER, A. T. & MCMANUS, J.,
1979. Sediment sampling and analysis. *in*: K. R. DYER (Ed.), *Estuarine hydrography and sedimentation. A handbook*: 87-130. Cambridge Univ. Press, London.

CANCELA DA FONSECA, L.; COSTA, A. M.; BERNARDO, J. M.; FONSECA, R.,
1987. Lagoa de Santo André (SW Portugal): Phytopigments as sedimentary tracers. *Limnetica,* (2): 299-306.

CHASSÉ, C.,
1978. Un indi malacologique pour mesurer l'impact ecologique de la marée noire de 'Amoco Cadiz' sur le litoral. *Haliotis*, **9**: 127-135.

CHASSÉ, C. & MORVAN, D.,
1978. Six mois après la marée noire de l' "Amoco Cadiz", bilan provisoire de l'impact écologique. *Penn ar Bed* , 11(93): 311-338.

DEXTER, D. M.,
1992. Soft bottom invertebrates of the Portuguese benthos. *Bol. Inst. Nac. Invest. Pescas*, **17**: 61-88.

HYLAND, J. L.,
1978. Onshore survey of macrobenthos along the Brittany Coast following the 'Amoco Cadiz' oil spill. *Actes de Colloques C.N.E.X.O.*, **6**: 175-192.

I.C.E.S.,
1989. Report of the ICES Advisory Committee on marine pollution. *ICES Cooperative Research Report*, No. 167.

LEGENDRE, L. & LEGENDRE, P.,
1984. *Écologie Numérique. I - Le traitement multiple des données écologiques. II - La structure des données écologiques.* (2ème ed.). Masson Ed. Paris. 260+335p.

LEVRING, T.,
1974. The marine algae of the Archipelago of Madeira. *Bol. Mus. Mun. Funchal,* 28 (125): 1-111.

MCNAUGHTON, S.J.,
1968. Structure and function in California grasslands. *Ecology*, 49(5): 962-972.

MOSS, B.,
1967. A spectrophotometric method for the estimation of percentage degradation of chlorophylls to phaeopigments in extracts of algae. *Limnol. Oceanogr.*, 12 (2): 335-340.

PIELOU, E. C.,
1975. *Ecological diversity*. Wiley-Interscience Pub., John Wiley & Sons, N.Y. 165p.

PLANTE-CUNY, M. R.,
1974. Evaluation par spectrophotométrie des teneurs en chlorophylle a fonctionelle

et en phéopigments des substrats meubles marins. *Doc. Sci. Mission O.R.S.T.O.M.*, Nosy-Bé, **45**: 1-76.

PLANTE-CUNY, M. R.,
1978. Pigments photosynthétiques et production primaire des fonds meubles néritiques d'une région tropicale (Nosy-Bé, Madagascar). *J. Rech. Oceanogr.*, 3 (1): 1-14.

SBMOB-DZA,
1992. *Preliminary assessment of the effects of the 'Aragon' oil spill in Porto Santo island*. Final Report of EEC Contract B6612-90-8831, SBMOB-DZA, FCUL, Laboratório Marítimo da Guia, Cascais (Mimeo).

SNEATH, P. H. & SOKAL, R. R.,
1973. *Numerical Taxonomy. The principles and practice of numerical classification.* Freeman and Co., San Francisco. XV+573p.

TEAL, J. M. & FARRINGTON, J. W.,
1977. A comparison of hydrocarbons in animals and their benthic habitats. *Rapp. P.-v. Réun. Cons. int. Explor. Mer*, **171**: 79-83.