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Ecology of the benthic communities of the deep North East Atlantic[1]

L. Laubier[2] and M. Sibuet[2]

Abstract

– Deep benthic communities of the Bay of Biscay (North East Atlantic) have been thoroughly sampled during seven cruises between 1972 and 1974. Some 200 samples using three main types of gear (corer, epibenthic sled and beam trawls) have been performed. Sediment characteristics (granulometry, organic content) and faunal densities for each size assemblage are given. Continental influences appear to increase macrofaunal density. Compared with other areas, the central part of the Bay of Biscay appears to have a low faunal density. This fact can be related to the existence of a mesoscale gyre of the upper layer, which could be responsible for a low primary productivity. –

Introduction

For some thirty years one of the main objectives in deep sea benthic ecology was to try to quantify the density of the fauna living on the bottom, in number of individuals as well as in biomass for a given area.

The Soviet scientists, using the large Okean grab, tried to obtain an estimate of biomass, trophic distribution and amount of organic carbon in the sediment (1, 2, 3). One of the main results was to distinguish two main areas in the deep sea in terms of their eutrophic and oligotrophic conditions (over and below 0.25% of organic carbon in the sediment), for depths below 3000 m in the Pacific Ocean (1).

In the USA, the same trend to quantify the biological data led to the improvement of sampling gears, with the development of the epibenthic sled (4) and the utilisation of the USNEL spade corer (5). These gears, well designed for sampling on smooth bottom were used for successful investigations on the density and the diversity of the deep sea fauna.

The deep sea biological research program, set up at the "Centre Océanologique de Bretagne" in 1969, begun with a series of cruises undertaken in the North and South East Atlantic Ocean and in the Mediterranean Sea between summer 1969 and spring 1972. Four large scale exploration cruises (Noratlante (6), Polymède I (7), II (8), Walda) were conducted with faunistic and biogeographic objectives and some 200 sampling operations were performed. During these cruises sampling methods have been improved with the view of obtaining for each station a complete figure of the different size components of the fauna, using three distinct types of gear (Reineck corer, epibenthic sled and beam trawl, here abreviated respectively KR, DS, and CP). The sieving was standardized too, in order to obtain distinct size categories of fauna. The importance of the sieving and of the choice of the mesh size was pointed out in France a few years before in the early 1960's for shallow water fauna.

Between 1972 and 1974 a series of 7 cruises were undertaken, and more than 200 sampling operations were performed in the Bay of Biscay (9). This sampling program has made possible an ecological survey from different stations chosen at established depths between 2000 and 4700 m in the northern and southern parts of the Bay of Biscay. In the south, the stations were located a short distance from the coast (20–30 miles) and were obviously subjected to terrestrial input; stations from the northern part of the Bay of Biscay are far from the land (200–250 miles from the western part of Brittany). The results given here deal with general data about the characteristics of sediment and the estimation of faunal densities. We wish to thank the "Centre national de tri d'oceanographie biologique in Brest"; M. Segonzac, P. Briand and Mrs J. Galeron, for the sorting of the collections.

Even if this quantitative approach does not reach exact absolute values (and should be called a semiquantitative study) it was found that the values obtained make it possible to compare distinct areas of the Bay of Biscay, and also some other areas, for instance the deep Norwegian Sea more recently explored with the same methods during the French-Swedish expedition NORBI in 1975 (10). It must be specified that the general faunistic information is discussed with respect to higher taxa. With regard to the recent studies on diversity in the deep sea (11) our results are restricted, at the present stage, to an estimation of macrofaunal densities from the higher taxa sorted and counted in the laboratory. Just a few groups have been fully identified by specialists (12 to 18) and the species diversity cannot be calculated for the total fauna, as identifications are not yet available. They are currently undertaken by different French scientists, who took part in this program, and by foreign specialists who have received our collections for study.

Material and Methods

The six stations explored during the Biogas cruises are located in the North of the Bay of Biscay at depths of 2000, 3000, 4000, 4700 m, and in the south of the Bay, where terrigenous influences were expected, two stations were chosen at 2000 and 4500 m respectively (Fig 1). For each station, pictures of the bottom have been obtained using a troika sled equipped with Edgerton flash and

[1] Contribution N° 612 du Département Scientifique du Centre Océanologique de Bretagne
[2] Centre Océanologique de Bretagne B.P. 337 F-29273 Brest Cedex France

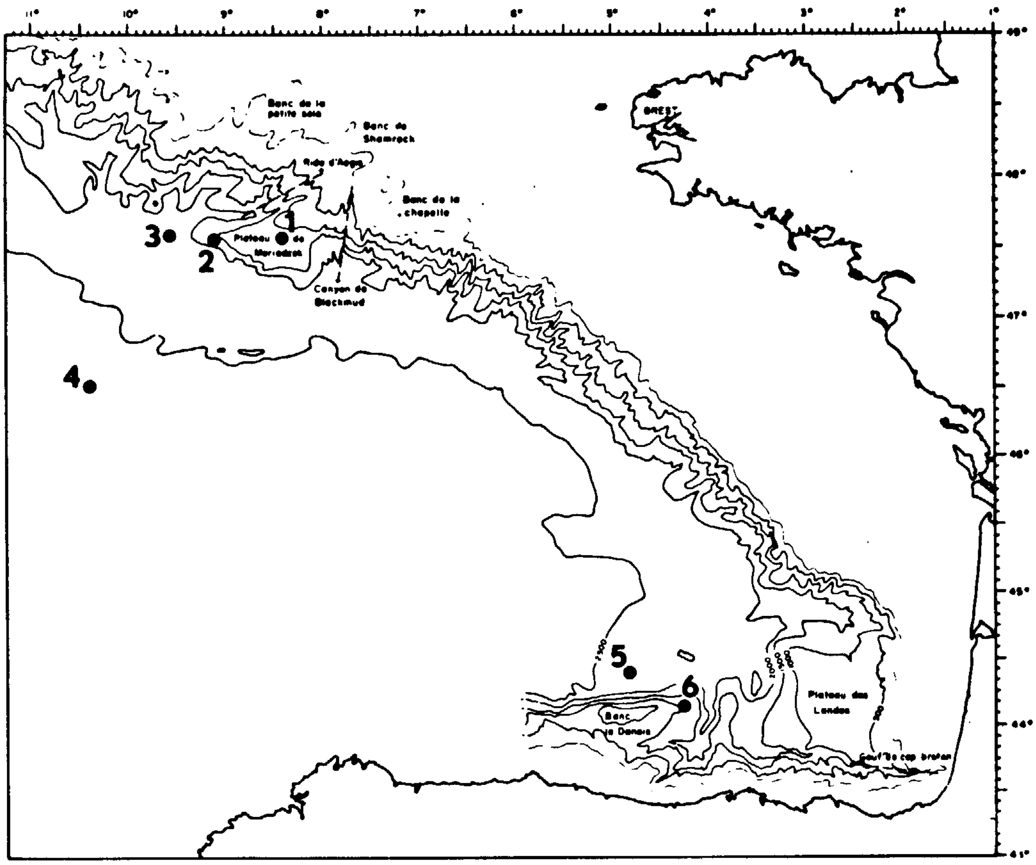

Fig 1. Stations localization in the Bay of Biscay.

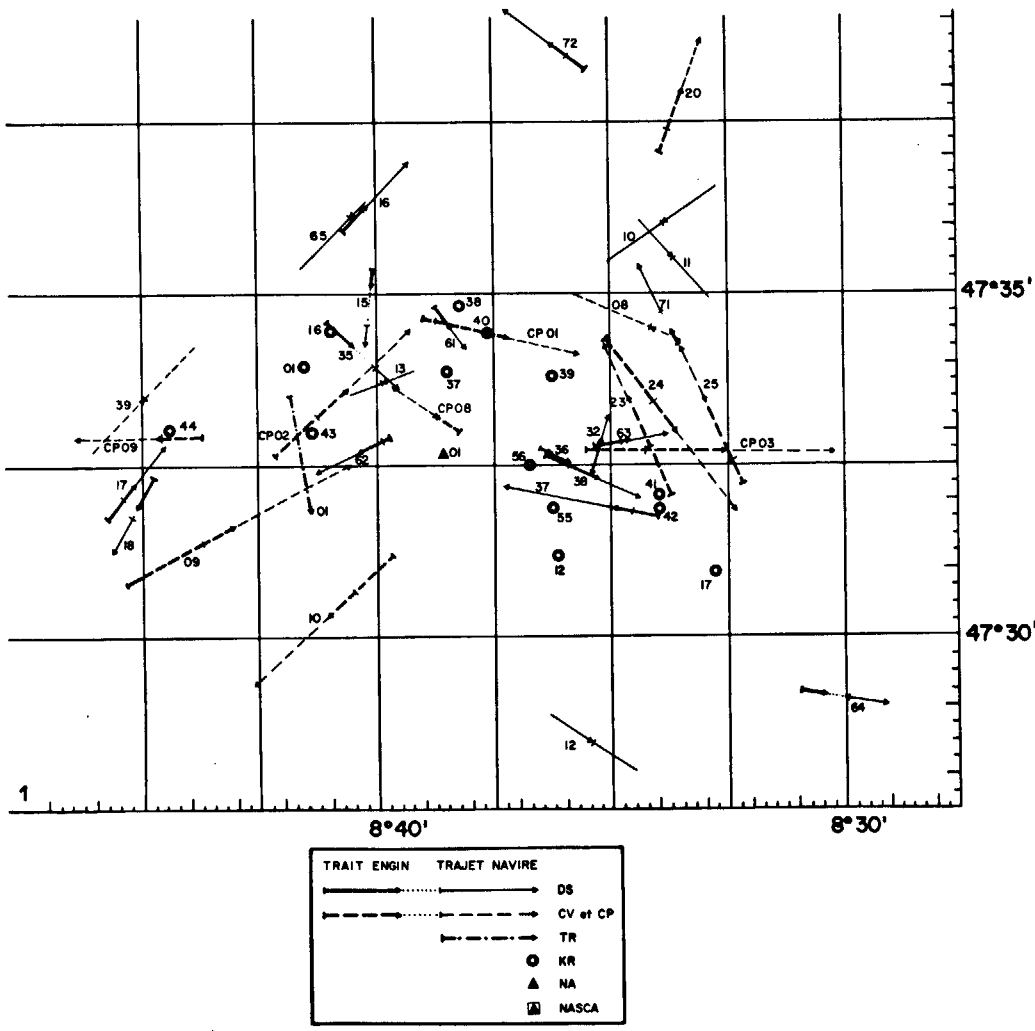

Fig 2. Samples localization with length of the hauls on the bottom for station 1.

camera system. Undisturbed sediment samples were obtained with a Reineck corer.

Analyses of the two first cms of sediment were undertaken for the evaluation of the amount of the sediment fraction coarser than 63 μ, and – for the evaluation of the amount of organic matter – nitrogen and organic carbon.

The different size categories of fauna are based on the sample analyse obtained from three types of gear: a Reineck corer for the macrofauna greater than 250 μ (the meiofauna being studied by A. Dinet); a modified epibenthic sled; a double beam trawl of 3 meters width or a single beam trawl of 5 meters width for large macrofauna and megafauna retained on the 500 μ screen. These two last devices can only give a rough estimate or minimum value of densities by the evalution of the sampled area. The method described (19) based on satellite navigation and ultrasonic pinger is used for that evaluation. As an example of the result, Fig 2 shows for station 1 the distance of each haul on the bottom and the distribution of all the samples in the area. A complete account of the sample location is given in the Biogas preliminary results (9).

Results and discussions

Bottom pictures

The photographs obtained at each station bring some descriptive information on bottom conditions. At station 1 and 6 for example the existence of currents is shown by the orientation of the Gorgonaria *Acanella arbuscula*. Station 2 is characterized by well developed ripple marks. The deepest stations 3, 4 and 5 are calm, smooth bottom with numerous hillocks surrounded by holes.

Analyses of sediment – faunal density

The results of analyses of sediment and counts of fauna are all expressed in terms of mean values with the indication of standard deviation obtained for each station (Table 1).

The granulometry of the sediment (21) shows a striking difference between the composition of the sediment from the deepest stations (station 4, 4700 m, and station 5, 4500 m) and station 6 at 2000 m in the south of the Bay of Biscay, where the percentage of coarse fraction greater than 63 μ is low (13.5%), and that of stations 1, 2 and 3 in the Northern part of the area (28% at 2100 m), (table 1).

The analyses of organic matter indicates some decrease with depth of the percentage of organic carbon and nitrogen in dried sediment. At station 5 and 6 in the south of the Bay of Biscay, the high values of N and org. C are related to a higher percentage of fine particles in the sediment. This relationship can be due to organic supply coming from the continent. In several samples obtained in the south and particularly at station 5 large quantities of plant debris have been found. Station 3 appears rather rich for such a depth, compared with stations 2 and 4. It is also the most homogeneous station if we consider the moderate values of the standard deviation.

The total densities of counted organisms (Table 2) obtained for each station and for type of gear show in general a decrease with depth. We must notice the exception of station 2 at 3000 m which is the richest with respect to the smaller macrofauna collected with the

Table 1. Sediment analyses for each station.

BIOGAS Stations	1		2		3		4		5		6	
Depth in m (mean value)	2100		3000		4200		4700		4500		2000	
Mean value: M̄ Standart deviation: σ	M̄	σ	M̄	σ	M̄	σ	M̄	σ	M̄	σ	M̄	σ
% > 63 μ	28,03	17,6	30	25,6	25,5	11,8	14,9	13,7	15,9	17	13,5	10,8
% ORG. C	0,51	0,10	0,40	0,10	0,44	0,03	0,39	0,11	0,60	0,09	0,85	0,13
% N	0,059	0,012	0,044	0,010	0,047	0,005	0,039	0,015	0,058	0,011	0,085	0,009
% ORG. C/N	8,73	0,8	8,7	1,3	9,4	1,1	10,7	1	11,3	0,9	9,8	0,7

Table 2. Faunal density at each station for each type of gear.

BIOGAS Stations	1		2		3		4		5		6	
Depth in m (mean value)	2100		3000		4200		4700		4500		2000	
M̄: Mean value σ: standard deviation	M̄	σ	M̄	σ	M̄	σ	M̄	σ	M̄	σ	M̄	σ
Nb ind./m² Reineck corer	1750	590	2008	366	919	438,8	505	142,80			995	412
Nb ind./m² Epibenthic sled	3,60	3,86	2,84	2,59	1,86	2,98	1,32	1,54	0,26	0,30	0,02	7,28
Nb ind./m² Trawl	0,123	0,098	0,034	0,024	0,054	0,6504	0,030	0,032	0,043	0,034	0,147	0,099

Table 3. Density of higher taxa in each station.

BIOGAS stations			1						2						3			
Depth in m. (mean value)			2100						3000						4200			
Gear code	KR		DS		C		KR		DS		C		KR		DS		C	
Number of Samples	4		11		10		5		6		7		5		9		7	
Density M̄: mean value σ: standard deviation	M̄ Nb Ind./m²	σ	M̄ Nb Ind./m²	σ	M̄ Nb Ind./Ha	σ	M̄ Nb Ind./m²	σ	M̄ Nb Ind./m²	σ	M̄ Nb Ind./m²	σ	M̄ Nb Ind./Ha	σ	M̄ Nb Ind./m²	σ	M̄ Nb Ind./m²	σ
Anthozoa			0,007	0,01	368	497			0,005	0,006	6,6	8,5					72	114,8
Nemertinea					1	2	8	17					8	17				
Nematoda	740	641	0,24	0,31			772	467	0,17	0,15			252	115	0,14	0,15		
Polychaeta	600	223	1,38	1,85	214	197	544	248	0,56	0,29	72,4	74,9	408	254	0,62	0,77	95,8	156
Sipuncula	45	42	0,046	0,054			340	55	0,05	0,04	8,11	17,5	60	56	0,033	0,032	33	36,7
Echiura											0,92	1,25						
Brachiopoda					0,6	0,9			0,008	0,017	21,20	34,3					20,07	46,2
Priapulia																		
Aplacophora			0,093	0,17	3,8	9,1	16	21	0,02	0,03			8	11	0,012	0,022		
Gasteropoda	20	28	0,08	0,17	34,2	59			0,024	0,023	9,37	7,9			0,020	0,048	32,5	21,6
Scaphopoda			0,019	0,02	14,1	16	8	17	0,028	0,026	8,34	10,9	4	8	0,032	0,08	61,9	73,1
Bivalvia	44	68	0,20	0,15	37	58	68	68	0,31	0,19	24,40	35,5	36	26	0,49	0,90	64,5	99,7
Cephalopoda																		
Pycnogonida			0,013	0,043	2,3	3,3			0,005	0,004	0,88	1,26						
Ostracoda	20	16	0,32	0,57			68	70	0,048	0,07			36	32	0,009	0,012		
Copepoda	80	43					28	30					36	26				
Cirripedia			0,001	0,003	5,2	8,09					11,7	16,8			0,005	0,015	7,70	8,3
Mysidacea																		
Tanaidacea	90	62	0,19	0,11			76	41	0,08	0,08	8,18	12,8	40	37	0,10	0,17		
Cumacea	15	10	0,35	0,52	14,7	34,4	5	10	0,30	0,38	6,8	10,6			0,12	0,23		
Isopoda	50	47	0,23	0,30	4,9	12,9	44	43	0,25	0,26	9,9	14,9	4	8	0,13	0,19	8,05	16,5
Amphipoda	30	20	0,22	0,36	10,4	16,7	16	16	0,23	0,22	12,22	14,4	16	16	0,039	0,070	13,3	23,8
Macrura			0,002	0,003	7,1	7,3					11,79	10,4					3,7	3,3
Anomura			0,001	0,004	19,6	22,5					5,89	6,1					6,14	3,5
Crinodea			0,005	0,012	33,4	92,1												
Holothuroidea			0,008	0,012	125	91,8	8	10	0,011	0,009	47,2	34,2	4	8	0,035	0,079	60	69
Asteroidea	5	10	0,05	0,08	30	26,7			0,025	0,019	20,6	21			0,005	0,011	11,4	5,5
Ophiuroidea			0,14	0,21	255	223	4	9	0,72	1,63	45,05	40,7	4	9	0,039	0,091	26,3	42,4
Echinoidera			0,004	0,008	46	40,7					9,08	11,1			0,012	0,002	3,5	6,6
Tunicata			0,001	0,003	2,1	4,6	3	9			1,33	2,08	3	9	0,037	0,09	24,1	45,9
Pisces					7,8	5,9					4,28	3,21					2,3	2,2

corer, whereas the density of large macrofauna collected with the trawl is the smallest.

In connection with this, the sediment characteristics indicate a very low amount of organic matter and a high percentage of sand fraction (coarser than 63 μ). The existence of ripple marks on some pictures clearly establishes the importance of the bottom currents at this section.

In the south of the Bay of Biscay (station 6 and 5), the high amount of organic matter in the sediment is not clearly linked to a faunistic richness (in terms of density) for any size category of fauna.

The density values obtained in the south for the corer are relatively low at 2000 m compared with the corresponding northern station; the densities of macrofauna obtained for sled and trawl samples are higher. As the standard deviation for the sled at st 6 is very close to the mean value, no great attention can be paid to the high number, 9.02 ind/m^2, obtained. The organic matter seems, here, to have much more influence on fauna of large size than on very small animals collected with the corer. But it can also be suggested that the corer fails to show the existence of spatial heterogeneity. At station 5 where plant debris has often been observed, the fauna is not very dense. We wish to emphasize the difficulty of concluding from chemical analyses the exact fraction of organic matter which can be assimilated by the different animals.

An analysis of the variation of densities of the different zoological classes or orders collected by the different samplers brings some information on the composition and major changes of the fauna with increasing depth or environment variation (Table 3).

The decrease of density with depth is generally observed for all the higher taxa but exceptions must be pointed out:

The Amphipoda, in the trawl only, show a notable increase between st 1 and 4.

The ascidians appear in numbers only at the deepest stations from more than 4000 m, st 3–4–5.

We can also draw attention to station 3 at 4200 m where the scaphopods, bivalves and tanaids show the greatest density in the trawl.

The relatively low density observed in the south for the corer at st 6 is mostly due to the smaller number (near one half of the density observed at st 1) of nematodes and polychaetes. The highest densities in the trawl and sled of st 6 are due to a general increase of the fauna and particularly the scaphopods, the peracarids, the decapods and the holothurians.

The very poor st 5, where a few "azoic" samples have been obtained, is remarkable as one of the stations where the ophiuroids show a great density in relation to the depth.

Several zoological groups do not show a noticeable decrease of density with depth, but a great variation of abundance and size of animals in the different stations considered occurs.

This could be considered as the result of a difference in adaptation to the environmental conditions. Another explanation could be the difference in trophic structure, but our knowledge about nutritional aspects is still at the beginning.

Table 3. (continued)

BIOGAS stations	4						5						6					
Depth in m. (mean value)	4700						4500						2000					
Gear code	KR		DS		C		KR		DS		C		KR		DS		C	
Number of Samples	4		3		7				3		6		3		6		6	
Density M̄: mean value σ: standard deviation	M̄ Nb Ind./m²	σ	M̄ Nb Ind./m²	σ	M̄ Nb Ind./m²	σ	M̄ Nb Ind./m²	σ	M̄ Nb Ind./m²	σ	M̄ Nb Ind./m²	σ	M̄ Nb Ind./m²	σ	M̄ Nb Ind./m²	σ	M̄ Nb Ind./m²	σ
Anthozoa			0,005	0,009	15,6	14,7					15,15	19,1			0,16	0,20	89,1	56,1
Nemertinea															0,02	0,02	1,9	1,9
Nematoda	170	38	0,086	0,050					0,025	0,026	28,9	47	306	94,5	0,48	0,33	4,6	9,3
Polychaeta	135	93	0,30	0,37	64,2	71,9			0,10	0,11	74,3	79,6	386	277	1,64	0,99	109,2	125,1
Sipuncula			0,017	0,015	10,4	8,5			0,018	0,012	9,5	3,6	13	11	0,05	0,04	19,9	19,4
Echiura											0,5	0,7						
Brachiopoda					5,2	8,4					1,9	3,9					4	9
Priapulia									0,002	0,001								
Aplacophora			0,008	0,010	1,1	1,9			0,002	0,003	2	3			0,08	0,07	16,7	19,4
Gasteropoda	10	11	0,027	0,038	18,5	17,1					13,3	10,6			2,06	2,69	86,3	126,1
Scaphopoda	10	20	0,020	0,034	2,3	3,1			2,6	2,9	2,6	2,9	6	11	0,32	0,39	91,3	93,7
Bivalvia	40	36	0,34	0,30	46,2	39,1			0,011	0,011	13,7	16,5	13	11	1,17	0,73	53,7	41,9
Cephalopoda																	0,3	0,6
Pycnogonida															0,003	0,006	22,2	38,8
Ostracoda	30	38	0,26	0,046	5,8	8,7			0,003	0,001	7,5	12,1	13,3	11	0,17	0,15	56,7	107,7
Copepoda	40	36	0,060	0,10	6,0	12,8					26,8	42,5	33	57	0,02	0,03	35,1	79,2
Cirripedia					5,5	7,4					0,3	0,5					2	3,5
Mysidacea			0,014	0,025	1,6	1,8					5,2	8,3			0,007	0,014	31,2	47,0
Tanaidacea	20	28	0,023	0,020	3,0	4,7			0,019	0,022	2,4	2,7	120	60	0,57	0,51	22,1	26,6
Cumacea			0,076	0,11	2,9	3,6			0,008	0,013	6,1	10			0,65	0,65	150	235
Isopoda	45	64	0,23	0,31	5,3	8,5			0,014	0,015	44,3	73,9	73	80	0,60	0,47	127,7	173,7
Amphipoda	5	10	0,043	0,086	20,7	34,9			0,002	0,001	14,2	20,4	26	11	0,43	0,34	94,2	144
Macrura					6,3	3,9					3,5	3,9					34,2	61,7
Anomura											1,7	2,3			0,02	0,02	26,5	38,1
Crinodea																		
Holothuroidea			0,008	0,013	23,5	20,2					65,4	67,6			0,098	0,107	207	152
Asteroidea					13,1	9					5,8	5,0			0,015	0,012	9,6	5,2
Ophiuroidea			0,009	0,016	19	15			0,058	0,093	62	81,1	6	11	0,42	0,37	138,9	105,6
Echinoidera															0,03	0,043	23,2	31,9
Tunicata			0,028	0,048	21,5	37,3					20,3	44			0,002	0,001		
Pisces					5,9	5,3					3,7	3,8					14,8	17,6

Table 4. Comparison of sediment analyses and faunal density between station 2 in the Bay of Biscay and Norwegian Sea basins.

	Sediment analyses			Faunal densities in mean Nb Ind./m²		
	% Org. C	% N	% Org. C/N	Corer KR	Epibenthic sled DS	Trawl C
BIOGAS (~ 3000 m)	0,40 σ = 0,10	0,044 σ = 0,010	8,7 σ = 1,3	2008 σ = 366	2,84 σ = 2,74	0,034 σ = 0,024
NORBI (~ 3000 m)	0,66 σ = 0,22	0,09 σ = 0,03	8,09 σ = 1,48	1584,5 σ = 1883	13,40 σ = 17,72	1,25 σ = 0,87

Discussion

Only a very few comparisons of these results with other abyssal basins in the Atlantic or in the other oceans can be made, due to the disparity of sampling and sorting methods which have been used in the past. Even the comparison of the Reineck corer with the USNEL spade corer is not completely valid, partly due to the size of the samples (4 times greater for the spade corer), and partly to the sieving method (297 μ screen mesh or 250 μ screen mesh.

Still it can be noted that the mean value of 374 ind/m² obtained in the Central North Pacific in a oligotrophic area at 5500 m is not too far from the Biogas figure at the deepest stations (4700 m) where we obtained 505 ind/m². Even if Bay of Biscay conditions can be expressed as eutrophic using the arbitrary limit of 0.25% org. C, it must be emphasized that recent observations of drifting buoys tracked by satellite have demonstrated the existence of mesoscale gyre (21). This observation supports the hypothesis of a low productivity in this part of the Bay of Biscay.

The comparison with the Norwegian Sea, explored in 1975 by the same methods, is more valid. The data published recently (10) give the possibility of comparing mean values of density from the same depth of 3000 meters in the two basins. Table 4, summarizes the mean values and the dispersion around the mean (standard deviation) for st 2 of Biogas and for the 46 operations (18 KR, 12 DS, 16 CP) obtained in the four deep Norwegian basins at the same depth between 2500 and 3700 m.

The organic matter (organic carbon and nitrogen) shows similar values with slightly higher figures in the Norwegian Sea. Similar values are obtained (8.7 and 8.0%) for the ratio C/N.

A noticeable difference of density of the fauna is observed for the great macrofauna only, collected with sled and trawl. The trawl caught a considerable number of animals and indicates the richness of large-sized animals (the holothurian species *Elpidia glacialis*, for instance, is dominant and has been caught in enormous number).

If we consider the difference of selection of size categories of fauna collected by trawl and sled, we must point out the great difference of density between trawl and sled obtained in the Bay of Biscay (with a ratio $\frac{DS}{CP} = 88$), whereas in the Norwegian Sea the density ratio between the two gears is not as high ($\frac{DS}{CP} = 10$). This confirms the dominance of large size animals and probably a higher biomass in the Norwegian Sea.

In conclusion of this general ecological survey of the North East Atlantic, it can be stated that the variations in richness and in size categories of fauna have been demonstrated inside the Bay of Biscay (which is not very homogeneous) and between the Norwegian basin and the Bay of Biscay.

As very few comparisons can be carried out with previous studies and recent cruises undertaken by other countries, we fell that some kind of progress in our knowledge should come from improvements of sampling and sieving methods, together with the regular use of some standardized gear.

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