Abyssal benthic oxygen consumption in the Northeastern Atlantic: measurements using the suspended core technique

Northeast Atlantic
Abyssal sediments
Oxygen uptake
Corer
Benthos

Atlantique Nord-Est
Sédiments abyssaux
Consommation d'oxygène
Carottier
Benthos

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ABSTRACT

Knowledge of rates of decomposition of organic material at the benthic boundary layer of abyssal sediments would provide us with one of the last links in our understanding of the oceanic carbon cycle. Relatively few measurements exist in the literature and these are insufficient to obtain an overall assessment of benthic metabolism. In this paper we present measurements of sediment community oxygen uptake, made *in situ* at two locations in the northeastern Atlantic Ocean, using a novel system involving a multiple corer. Measurements were made at depths of 4,980 m and 2,880 m in the Porcupine abyssal plain and Rockall Trough respectively. The stations were visited in April-May over a period of four years (1979-1982). Measurements were made on two occasions from the Porcupine abyssal plain (station A-1) where the mean sediment community oxygen uptake rate was 67 μmoles $O_2.m^{-2}.hr^{-1}$ (range 58-77 μmoles $O_2.m^{-2}.l^{-1}$); three measurements were made in the Rockall trough (station A-2) where the mean figure was 149 μmoles $O_2.m^{-2}.hr^{-1}$ (range 99-203 μmoles $O_2.m^{-2}.hr^{-1}$). A comparison with previously published data shows that these results were higher than those predicted for the north Atlantic Ocean. Reasons for this are discussed.

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RÉSUMÉ

Utilisation de l'oxygène du benthos abyssal dans le nord-est de l'Atlantique : mesures obtenues sur place en utilisant le système de la « carotte pendue »

La connaissance des taux de décomposition du matériel organique au niveau de la couche benthique des sédiments abyssaux est essentielle pour la compréhension du cycle océanique du carbone. Relativement peu de mesures sur ce point ont été publiées, et elles sont insuffisantes pour obtenir une idée globale précise du métabolisme benthique. Dans cet article, nous présentons des mesures de consommation d'oxygène par la communauté sédimentaire, faites *in situ* dans deux localités du nord-est de l'Atlantique, obtenues par une nouvelle méthode utilisant un carottier multiple. Les mesures ont été prises respectivement à des profondeurs de 4980 et 2880 m dans la plaine abyssale du Golfe de Gascogne et le bassin de Rockall. Les stations ont été visitées en avril-mai pendant quatre ans (1979-1982). Deux mesures ont été prises dans la plaine abyssale du Golfe de Gascogne (station A-1), où le taux moyen d'utilisation de l'oxygène par la communauté sédimentaire était de 67 μmoles $O_2.m^{-2}.hr^{-1}$ (variation de 58 à 77 μmoles $O_2.m^{-2}.l^{-1}$); trois mesures ont été effectuées dans le bassin de Rockall (station A-2) où le taux moyen était de 149 μmoles $O_2.m^{-2}.hr^{-1}$ (variation de 99 à 203 μmoles $O_2.m^{-2}.hr^{-1}$). En comparaison avec les données déjà publiées, il apparaît que ces résultats sont plus élevés que ceux prévus pour le nord de l'Océan Atlantique. Les raisons possibles de cette différence sont discutées dans cet article.

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INTRODUCTION

The bathyal benthic boundary layer may be defined biologically as the sediment community and the organisms in the overlying water column associated with the bottom (Smith, Hinga, 1983). It represents a distinct niche in the oceanic biosphere driven, essentially, by sedimenting organic material formed originally in the euphotic zone. Remineralisation of this material in turn releases the nutrients used, ultimately, in the photosynthetic process. Smith (1982) has remarked that "knowledge of biological processes decreases precipitously with increased water depth"; thus, relatively few measurements have been made of rates of organic decomposition in sediments at bathyal and abyssal depths.

Degradation of organic carbon by the sediment biosphere is typically determined from rates of oxygen uptake across the sediment/water interface. This approach, although suffering from several limitations as a measurement of total organic degradation (Pamatmat, 1977), appears at present to be the best direct means of measuring decomposition rates. Other approaches, such as measuring electron transport activity (Wieser, Zech, 1976; Christensen, Packard, 1979) and radiotracer techniques (Christian, Hall, 1977; Jannasch, 1979) may best be regarded as measures of the standing level of sediment metabolic potential rather than providing actual rates of overall decomposition.

Sediment oxygen uptake has been measured using isolated cores incubated on board ship (Pamatmat, 1971). This technique is of doubtful use in the deep sea due to the effects of decompression and temperature changes occurring during core retrieval (Smith, 1978). To overcome these problems, *in situ* techniques have been developed by Hinga (Hinga *et al.*, 1979) and Smith and their co-workers (Smith *et al.*, 1976; Smith *et al.*, 1979; Smith *et al.*, 1983). These respirometers are positioned by manned submersibles or free fall vehicles. *In situ* measurements of abyssal benthic respiration at depths greater than 500 m have, so far, been restricted to 21 sites studied by the groups cited above. Nine sites lie along a transect in the northwest Atlantic from Gay Head (Cape Cod) to Bermuda (Smith, 1978). In the Atlantic, five further sites have been investigated, four off the Eastern seaboard of America (Smith, cited *in* Wiebe *et al.*, 1976; Hinga *et al.*, 1979) and one off the coast of equatorial west Africa (Hinga *et al.*, 1979).

Studies in other oceans are at present restricted to seven sites off the California coast in the northeast Pacific (Smith, 1974; Smith *et al.*, 1979; Smith *et al.*, 1983). This limited coverage of the global seabed clearly inhibits any overall assessment of the role of sediment community activity in the oceanic ecosystem and may be said to be due, in part, to the difficulties in procuring and deploying the sophisticated apparatus used at present.

In this paper we present the first *in situ* measurements of benthic respiration carried out in the deep waters of the temperate northeast Atlantic to the west of the British Isles. These measurements were carried out by a method ("suspended core technique"; Patching, Raine, 1983) employing an unmodified corer, routinely used for obtaining deep sea samples, rather than dedicated respirometers.

METHODS

Rate measurements were carried out at two sites routinely sampled by the Scottish Marine Biological Association (SMBA), stations A-1 and A-2 (Fig. 1) at depths of 4980 and 2880 m respectively. The corer used in this study was that developed and used by members of the SMBA for obtaining undisturbed cores of oceanic sediments for meiofaunal and other studies (Barnett *et al.*, 1984). The corer retrieves up to twelve sediment cores in a characteristic pattern (Fig. 2). The overall length of each core tube was 61 cm, with an internal diameter of 5.77 cm and cross-sectional area of 26.2 cm^2. Sediment core lengths ranged from 20 to 34 cm, with overlying water columns of 27 to 34 cm.

The corer operates on the principle of the Craib (1965) corer: the coring assembly is supported from a framework resting on the seabed. Penetration is controlled by a system of weights and a hydraulic damper, thus minimising disturbance to the sediment surface. After penetration, the core tubes are automatically sealed at the top and bottom. When coring at depth an acoustic "pinger" was mounted immediately above the corer. This, in conjunction with a precision depth recorder on board ship, enabled precise monitoring of the distance of the corer from the sea bed.

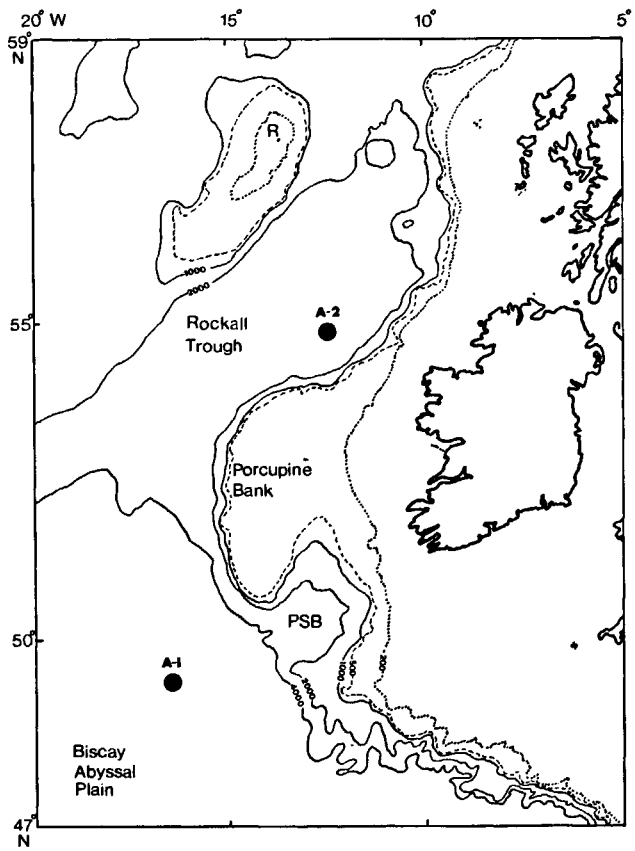

Figure 1

Locations of sediment community oxygen consumption stations. R = Rockall and Rockall plain; PSB = Porcupine sea bight. Mercator projection, bathymetry in metres.

To obtain a rate measurement, normal coring was first carried out, with cores hauled to the sea surface as soon as possible, and the overlying water from the cores siphoned off for analysis. Several such deployments were carried out on each occasion.

The mean of these measurements was recorded as the "time-zero" level (T_0). The corer was then lowered, and another set of cores taken which were then raised to only 50 m above the bottom. The cores were left to incubate at what were essentially *in situ* conditions of temperature, salinity and pressure for 15 to 36 hours. Monitoring depth with the precision depth recorder ensured that the coring assembly did not foul the bottom during this period. At the termination of the incubation period, the corer was recovered, and the overlying water of each core removed and analysed. This value was taken as the final (T_t) oxygen concentration.

Oxygen determinations were carried out by the precise Winkler technique of Bryan *et al.* (1976). Determinations carried out on replicate samples under routine conditions confirmed their reported precision for the method (coefficient of variation 0.05-0.1%).

The oxygen uptake rate (μmoles $O_2.m^{-2}.hr^{-1}$)

$$= \frac{10.H.(T_t - T_0)}{P},$$

where H was the height of the overlying water column (cm) and P was the incubation period (hr.).

Bottom water temperatures were taken by reversing thermometers attached to the corer frame. Cores were sectioned into 2 cm thick layers for subsequent chemical and microbiological analyses. Some sections were frozen immediately and subsequently dried at a temperature of 90°C. Sediment organic carbon and nitrogen levels were then measured using a Perkin Elmer 240B CHN analyser after phosphoric acid treatment to remove carbonates. Sediment samples for bacterial counts were preserved by the addition of formalin to give a final concentration of 7% w/v. After suitable dilution, total microbial counts were estimated by the method of Jones (Jones, 1974; Jones, Simon, 1975). The frequency of dividing cells (Hagstrom *et al.*, 1979; Newell, Christian, 1981) was noted. Results provided for microbiological and chemical analyses represent the mean for the top 12 cm of sediment.

RESULTS

The sediment at stations A-1 and A-2 (Fig. 1) consisted of light grey globigerina ooze. No evidence of reducing conditions was found to a depth of at least 10 cm at either site (Stanley *et al.*, 1978). Environmental data for both sites are presented in Table 1. No significant change of total bacterial count or frequency of dividing cells (FDC) with depth was noted. Although theoretical and experimental evidence suggests a relationship between FDC and the growth rate of bacterial populations, considerable difficulties exist in defining this and determining the overall applicabilities of algorithms linking the two (Hagstrom *et al.*, 1979; Newell, Christian, 1981). Applying the relationship:

$$\ln \mu = 0.299\,(\mathrm{FDC}) - 4.961$$

determined by Newell and Christian (1981) produces values of μ (the instantaneous growth rate) of 0.013 hr^{-1} for station A-1 and 0.017 hr^{-1} for station A-2. These are equivalent to instantaneous generation times of 76 and 60 hours respectively. It should be noted, however, that this relationship was derived using bacterial cultures and natural populations in temperate coastal marine waters. Its applicability to abyssal benthic populations has not been shown.

Table 1
Environmental parameters of sites studied.

	A-1 (48°50'N; 16°30'W)	A-2 (55°02'N; 12°03'W)
Depth (m)	4,980	2,880
Distance from shore (km)	555	185
Primary production[a] ($gm\ C.m^{-2}.yr^{-1}$)	100	100
Bottom water temperature (°C)	2.6	2.8
Dissolved oxygen of bottom water[b] ($\mu moles.l^{-1}$)	252	260
Benthic abundance[c] ($No.m^{-2}$)	—	4,980
Benthic biomass[c] ($mg\ wet\ wt.m^{-2}$)	—	4,610
Abundance: biomass (No. (mg wet wt.)$^{-1}$)	—	1.08
Total bacterial counts (counts $\times 10^9$.ml sediment^{-1})	6.9	7.5
Frequency of dividing bacterial cells (% of total cells)	2.1	2.9
Sediment organic carbon (mg C.gm dry wt.$^{-1}$)	2.3	3.2
Sediment organic nitrogen (mg N.gm dry wt.$^{-1}$)	0.26	0.40
Carbon: nitrogen	6.85	8.00

[a] Koblenz-Mishke *et al.* (1968) cited in Gage (1977).
[b] 1.0 $ml.l^{-1}$ = 44.6 $\mu moles.l^{-1}$ dissolved oxygen.
[c] From Gage (1979); results from material retained on a 420 μm sieve.

Determinations of sediment community oxygen consumption (SCOC) were carried out twice at station A-1 (Tab. 2) and three times at station A-2 (Tab. 3). In each case several deployments provided material for the T_0 determinations. Although standard deviations were calculated for the cores within each deployment these should be treated with caution since the cores were non-randomly distributed (Fig. 2). However, the variation between cores was small; the range averaged only 0.57% of each mean T_0 value at station A-1 and 0.33% at station A-2.

Since each deployment yielded a cluster of non-random cores it was regarded as a single sample (*see* discussion) with the mean oxygen value for the cluster as the best estimate for the sample. There were only very small variations in the mean values for the T_0 deployments on any one date. A standard deviation for all the T_0 deployments on each occasion was calculated from the mean oxygen value for each deployment; these were 0.10 and 0.59 at station A-1 for mean concentrations of 254.26 and 251.62 μmoles $O_2.l^{-1}$ in May 1980 and April 1982 respectively (Tab. 2). At station A-2 stan-

Table 2
Oxygen contents of the water overlying the cores and estimated sediment community oxygen uptake at station A-1.

Deployment	Number of cores	Oxygen concentration (μmoles O^2/l) Mean	Minimum	Maximum	Standard deviation	Sediment community O^2 consumption (μmoles $O^2/m^2/hr$) Mean	Standard deviation
15-17 *May* 1980							
Time Zero (T_0):							
1	5	254.70	254.52	254.98	0.18		
2	5	254.00	253.30	254.70	0.15		
3	5	254.25	253.91	255.03	0.45		
4	3	254.07	253.61	254.33	0.40		
All	18	254.26	253.30	255.03	0.31		
Post incubation (36 h: T_t)	11	246.93	243.28	252.16	2.44	58	19
12-14 *April* 1982							
Time Zero (T_0)							
1	9	251.35	250.42	252.20	0.58		
2	9	252.30	251.25	254.16	0.83		
3	5	251.21	250.68	251.88	0.56		
All	23	251.62	250.42	254.16	0.59		
Post incubation (20 h: T_t)	11	246.32	243.26	248.31	1.68	77	24

Standard deviations on individual deployments (T_0 and T_t) are calculated from a cluster of non-randomly dispersed cores and are therefore unreliable. Mean and standard deviations for pooled time zero deployments are calculated from the T_0 random deployment values, for each of which the best estimate is the mean of the cluster of cores.

Table 3
Oxygen contents of the water overlying the cores and estimated sediment community oxygen uptake at station A-2.

Deployment	Number of cores	Oxygen concentration (μmoles O^2/l) Mean	Minimum	Maximum	Standard deviation	Sediment community O^2 consumption (μmoles $O^2/m^2/hr$) Mean	Standard deviation
4-5 *May* 1979							
Time Zero (T_0)							
1	5	258.47	258.22	258.50	0.15		
2	10	258.23	257.85	258.69	0.29		
3	4	258.10	257.85	258.31	0.20		
All	19	258.27	257.85	258.69	0.19		
Post incubation (24 h: T_t)	7	249.18	243.96	252.44	3.29	144	52
12-13 *May* 1980							
Time Zero (T_0)							
1	5	259.93	258.85	260.69	0.70		
2	5	260.23	259.94	260.53	0.25		
3	5	260.04	260.04	259.30	0.47		
All	15	260.07	258.85	260.69	0.22		
Post incubation (24 h: T_t)	8	253.36	251.39	255.97	1.55	99	23
17-18 *April* 1982							
Time Zero (T_0)							
1	4	261.16	260.22	262.06	0.83		
2	4	251.56	261.33	261.82	0.26		
3	4	261.55	261.22	261.75	0.23		
4	4	260.92	260.74	261.33	0.28		
5	4	260.81	260.21	261.11	0.42		
All	20	261.20	260.21	262.06	0.35		
Post incubation (15 h: T_t)	6	253.42	250.79	256.19	2.07	203	54

Standard deviations on individual deployments (T_0 and T_t) are calculated from a cluster of non-randomly dispersed cores and are therefore unreliable. Mean and standard deviations for pooled time zero deployments are calculated from the T_0 random deployment values, for each of which the best estimate is the mean of the cluster of cores.

dard deviations were 0.19, 0.22 and 0.35 for means of 258.27, 260.07 and 261.20 μmoles $O_2.l^{-1}$ in May 1979, May 1980 and April 1982 respectively (Tab. 3).

As expected, the T_t deployments all showed lower mean oxygen values than those for T_0. However, because of the non-random nature of each cluster of cores it is

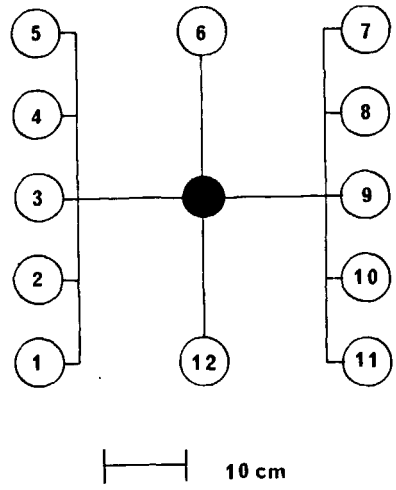

Figure 2
Plan showing the arrangement of the core tubes on the multiple corer.

not possible to estimate reliably the variation of each T_t mean. The standard deviations were all considerably larger than the corresponding values for each T_0 deployment suggesting different rates of oxygen consumption between cores. The SCOC's observed at the shallower A-2 station (144, 99, 203; mean 149 μmoles $O_2.m^{-2}.hr^{-1}$ Tab. 3) were higher than those observed at station A-1 (58, 77; mean 67 μmoles $O_2.m^{-2}.hr^{-1}$ Tab. 2).

DISCUSSION

The suspended core technique was developed to allow opportunistic measurements of sediment community oxygen consumption during cruises utilising the SMBA multiple corer. Because of this, it differs from the respirometer-based systems of Smith's and Hinga's groups in two major respects, firstly in size and number of enclosures deployed and secondly in the lack of stirring of the overlying water during the incubation. In this study, the number of replicate enclosures was 11 at station A-1, and 7, 8 and 6 at station A-2 giving total coverages of 0.028 8, 0.018 3, 0.021 0 and 0.015 7 m^2 respectively. These compare with areas of 0.292 m^2 for Smith's bell-jar respirometer (Smith *et al.*, 1976), 0.165 m^2 for Smith's grab respirometer (Smith *et al.*, 1979; Smith, Baldwin, 1983) and 0.177 m^2 for the respirometer described by Hinga *et al.* (1979). Given that the total area monitored for any one deployment of the corer is significantly less than the three other techniques just mentioned, the larger number of smaller replicate cores used does, however, allow information to be amassed concerning patchiness on a smaller scale. The "between-core" variability of the oxygen concentrations in the water overlying the cores was much greater in the T_t deployments than in those for T_0 (Tab. 2 and 3). The uniformity of the core values within each T_0 deployment would suggest that the higher T_t variability is not introduced during core retrieval and handling or oxygen determination, but reflects a real core to core variation in metabolic activity. This variability cannot be compared directly to that found by the other *in situ* techniques outlined above, in which the individual incubation chambers were significantly larger and the number of replicate chambers was much smaller (four in each case) than in the present investigation. For the stations with depths in excess of 500 m studied by Hinga *et al.* (1979), however, the standard deviations from replicate grabs were 44 and 37% (stations 77F and 76D respectively) and when only two chambers were used, the range (± mean) was 26 and 12% (stations 77D and 77E). Similar variability exists in the data of Smith (1978) for his stations along the Gay Head to Bermuda transect, and also for stations across the eastern Pacific (Smith *et al.*, 1983). In the present work, standard deviations for the sediment community oxygen uptake were calculated from the results for individual cores within each T_t deployment (Tab. 2 and 3). These showed, in general, a standard deviation of the order of 30% on each occasion. It is difficult to understand why the "between replicate chamber" variability should be similar for those of cross-sectional area ranging from 26 cm^2 (this study) to 708 cm^2 (Smith *et al.*, 1976; Smith, 1978).

It should be emphasised, however, that standard deviations calculated from a cluster of non-randomly dispersed cores (this work), grabs or chambers (other workers) must be treated with caution. Because of its design, the multiple corer has the inherent characteristic of providing, for each deployment, a cluster of systematically positioned cores (Fig. 2). Greig-Smith (1964) has pointed out that systematic sampling can have the advantage that, in some circumstances, the mean may deviate less from the true value than that given by random samples, although there is no evidence of this in the present work. The oxygen concentration of the water overlying the sediment in each deployment was taken to be the mean value of all the non-random cores, but although standard deviations of these means are given in the results (Tab. 2 and 3) they are probably unreliable and are given only to provide a comparison with similar standard deviations in results from other workers. There is no trustworthy method of estimating the variability of the cluster of non-random cores from each deployment (Cochran, 1953).

There are, therefore, difficulties in testing the significance of the difference between a group of T_0 deployments and that for a single T_t. Since several deployments provided data for each time-zero (T_0) determination then the mean oxygen values from each deployment may be used to calculate the mean and a reliable standard deviation for that series of deployments. However, because of the duration, only a single deployment was carried out for each of the subsequent final (T_t) oxygen determinations and no comparable, reliable standard deviation was available. One can only check whether the T_t deployment mean (O_2) lies outside appropriate confidence limits calculated for the T_0 mean. In all cases, the mean T_t value lay below the lowest 99.5% confidence internal for the T_0 deployments (Tab. 2 and 3). There seems little doubt, therefore, that significant amounts of oxygen were consumed during the incubation periods.

A major difference between our technique and the other *in situ* techniques is the lack of stirring of the overlying water in the cores during the incubation. It has been

suggested that lack of stirring in cores may result in stratification with low oxygen levels over the sediment surface and a consequent suppression of the rate of oxygen uptake (Rybak, 1969; Davies, 1975). Movement of the suspended corer may have provided some mixing. No evidence of stratification was found when the system was recovered after incubation, but this may have been due to the increased movement and thermally induced currents caused by the recovery process.

It should be stressed, however, that the net effect of lack of stirring, if any, means that our measurements were underestimates of sediment community oxygen consumption.

Though Smith and Hinga (1983) stated recently that there is "an insufficient data base on which to make more than an approximate estimation of sediment community oxygen uptake for areas of the ocean floor for which no measurements exist", Smith and his co-workers have made successive attempts to generate predictive equations by multiple regression analysis (Tab. 4). Initially, results from deep stations in the Atlantic Ocean on a transect from Gay Head to Bermuda yielded an equation (equation 1; Tab. 4) in which oxygen consumption was a function of depth, sediment nitrogen content, carbon to nitrogen ratio, temperature and biomass. Subsequent reanalysis of these results produced another equation (equation 2; Tab. 4) expressing oxygen consumption in terms of depth and surface primary production. Insufficient data exists to enable the application of equation 1 (Tab. 4) to site A-1. In all other cases, however, both equations 1 and 2 underpredict our observed oxygen uptake results by up to two orders of magnitude, even though they were based on results from the same ocean and similar latitudes. Smith (1978) found that, for equation 1, depth was the most important variable, accounting for 83.1% of the variation in sediment oxygen uptake. This would appear to hold only for the Gay Head to Bermuda transect and may be partially due to the negative correlation between depth and surface productivity along this line.

Subsequent *in situ* measurements in the eastern Pacific Ocean (Smith *et al.*, 1983) do not comply with predictive equations for the northwestern Atlantic. Smith and his co-workers have presented two possible predictive equations based on these data. One (equation 3; Tab. 4; Smith *et al.*, 1983) accounts for 99.1% of the observed variability in oxygen consumption in terms of depth and macrofaunal abundance. Though depth again is an important variable, it should be noted that, for station A-2, where enough environmental data exists to make a comparison, our measured sediment oxygen consumption is extremely close to that predicted by this equation. Smith and Hinga (1983) have also derived an equation (equation 4; Tab. 4) based on their data set for the eastern Pacific Ocean and predicting oxygen consumption in terms of depth and primary productivity. This equation again underpredicts our results, by approximately half an order of magnitude.

Clearly, existing predictive equations based on a certain area generally fail when applied to results obtained outside that area, even when, as in our case, they are from the same ocean. Smith and Hinga (1983) have attempted to produce a global equation to predict abyssal sediment oxygen uptake in terms of primary productivity and bottom water dissolved oxygen (equation 5; Tab. 4) but this fails to predict our observed oxygen uptake rates. Further, higher rates of oxygen consumption than those predicted have been measured at four out of five stations not included in their regression analysis (Smith, Hinga, 1983). It would seem that some variable, or variables, not yet incorporated into the data set used for regression analysis, and at least partially independent of it, exerts significant influences on deep sediment community oxygen consumption. For example, Smith *et al.* (1983) point out that for a deep station in the Tongue of the Oceans, Bahamas, where sediment oxygen consumption was underpredicted by approximately an order of magnitude, evidence of terrestrially-derived organic matter was observed (Wiebe *et al.*, 1976). This material may influence oxygen uptake locally, yet is not a parameter in any of Smith's multiple regression analyses.

One factor that must ultimately influence rates of organic decomposition in marine sediments is the supply of organic matter to them. At present, insufficient data exists to quantify the relationship between these two

Table 4

Equations used to predict deep-sea sediment oxygen uptake (Y). Note that the units of Y in equation 3 are μmoles $O_2.m^{-2}.hr^{-1}$. In all other equations Y is expressed in ml $O_2.m^{-2}.hr^{-1}$. This has been done to enable a direct comparison with the equations in the review of Smith and Hinga (1983), where the same confusion in units exists. It has been assumed that 24% of fauna retained on a 297 μm sieve is retained on a 420 μm sieve for site A-2 in equations 1) and 3) (Smith, Hinga, 1983). Z: depth (m); C:N: carbon to nitrogen ratio: N: sediment total nitrogen ($mg.gm^{-1}$); T: temperature (°C); MA: macrofaunal abundance ($no.m^{-2}$); PP: primary production ($gm\ C.m^{-2}.yr^{-1}$); DO: bottom water dissolved oxygen ($ml.l^{-1}$); B: biomass ($gm.m^{-2}$).

	Predictive equation	Area	Y			
			A-1 (predicted)	A-1 (observed)	A-2 (predicted)	A-2 (observed)
1)[a]	$\ln Y = 2.93 - 0.001\,Z + 0.15\,(C:N) + 0.11\,(1/N) - 0.65\,T + 142.7\,(1/B)$	Northwestern Atlantic	—	1.50	0.75	3.32
2)[b]	$Y = 0.9421 - 0.000\,162\,10\,Z - 0.001\,25\,PP$	Atlantic Ocean	0.08	1.50	0.35	3.32
3)[c]	$Y = 115.0 - 0.020\,0\,Z + 0.004\,3\,MA$	Eastern Pacific	—	67	147	149
4)[b]	$Y = 0.3508 - 0.000\,114\,20\,Z + 0.007\,680\,PP$	Pacific Ocean	0.42	1.50	0.79	3.32
5)[b]	$Y = 0.3789 + 0.007\,755\,PP - 0.146\,9\,DO$	All Oceans	0.32	1.50	0.26	3.32

[a] Smith (1978).
[b] Smith and Hinga (1983).
[c] Smith *et al.* (1983).

processes in oceanic environments. Deuser and co-workers (Deuser, Ross, 1980; Deuser *et al.*, 1981) have shown through use of sediment traps that seasonality exists in the rate of supply of organic material to sediments of the northwestern Atlantic. A key question lies in whether this seasonality results in a corresponding seasonality in rates of abyssal benthic oxygen uptake. Smith and Baldwin (1984) have noted an apparent seasonal variability in sediment community oxygen uptake at stations in the East Pacific. Our results were typically taken during a period immediately subsequent to the spring phytoplankton bloom in the overlying surface waters, and the relatively high rates observed may be a response to a short-term input of organic material. Studies in the region of station A-1 (Porcupine Sea Bight; Fig. 1) have shown a seasonal input to the sea bed of phytodetritus apparently linked to the surface spring bloom (Billett *et al.*, 1983). A sampling programme involving measurements of sediment oxygen uptake through this period of phytodetritus deposition is now underway.

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