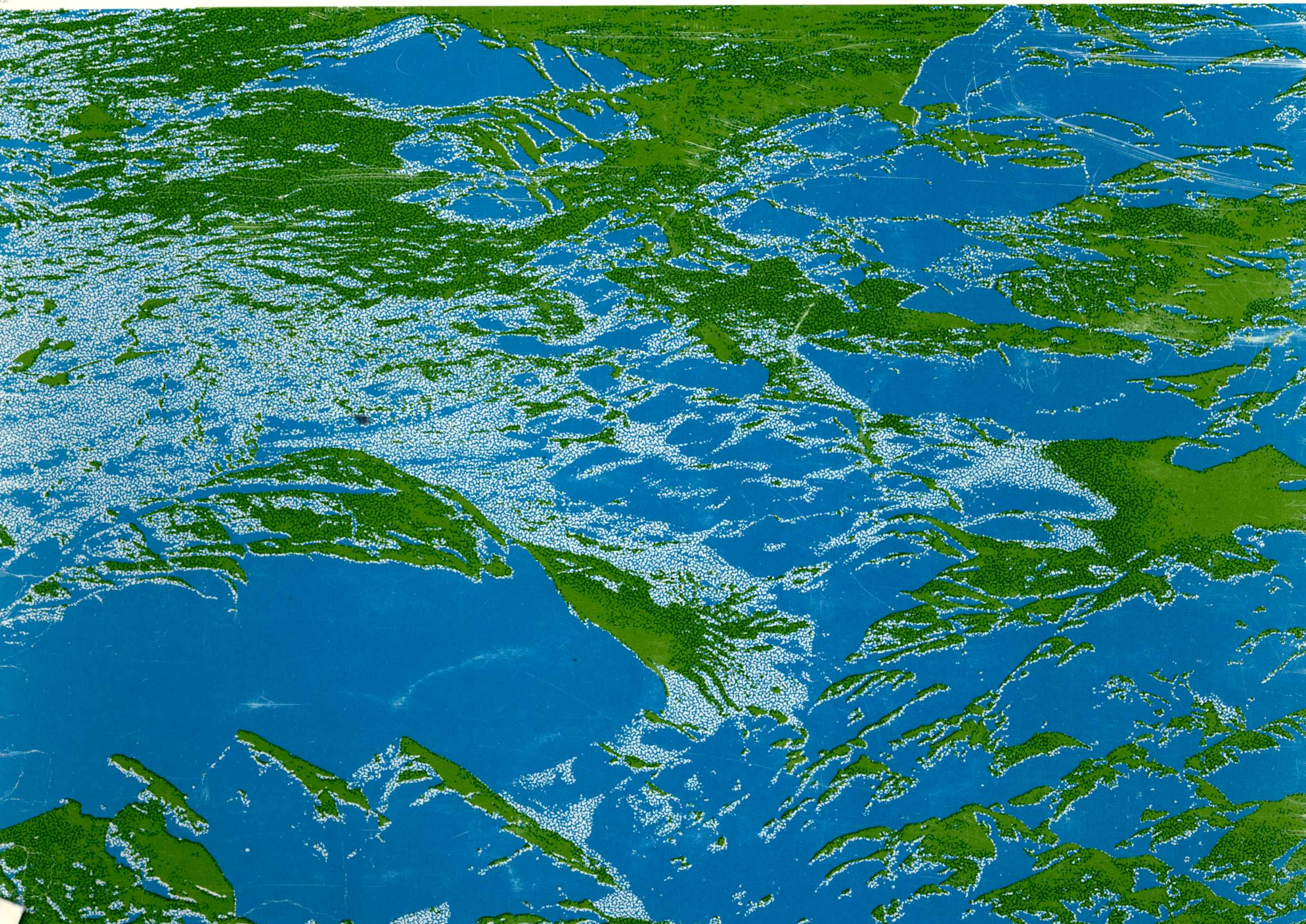
THE ROLE OF BENTHOS IN THE GRAND BANKS ECOSYSTEM - INFORMATION OVERVIEW AND FIELD STUDY

Final Report For:
Fisheries and Oceans Canada

February 1986



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THE ROLE OF BENTHOS IN THE GRAND BANKS ECOSYSTEM - INFORMATION OVERVIEW AND FIELD STUDY

Final Report
for
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INFORMATION OVERVIEW

INTRODUCTION

The benthos in marine shelf ecosystems have been shown in recent years to be important and vital. The concept that benthos represents a dead end in the processing of energy rich materials produced by plants, has been replaced by one which links the benthos closely with the primary producers, through significant feedback loops chiefly in the form of nutrient regeneration, but also via consumption and processing of benthos by fishes. But the significant role of the benthos in energy and nutrient cycling is not mirrored by an equivalent understanding, primarily because it is so complex. Consequently only simple benthic systems in accessible locations have been studied and then in comparatively few cases. The state of knowledge is illustrated by the fact that despite the potential usefulness of estimates of benthic production, no actual measurements have been attempted on any continental shelf system.

The benthic communities of the Grand Banks of Newfoundland are not unlike those in most areas. Two surveys of the Banks, Nesis (1965) and Hutcheson et al (1982) provide the only distribution and standing crop data. With recent interest in development of undersea hydrocarbon resources there, scientists with the Federal Department of Fisheries and Oceans have undertaken to produce an ecosystem model of the Grand Banks which will predict responses of the living resources to an oil spill. Such a model requires rate information on benthic processes to complement those known or estimated for the other components of the Grand Banks ecosystem. However, no direct measurements have been made of critical benthic processes such as production, respiration and nutrient recycling.

To fill this need Atlantic Oceanics Company Ltd. (now Seakem Oceanography Ltd.) was contracted to provide information on the benthic environment of the Grand Banks of Newfoundland to be incorporated into the ecosystem oil spill model for the area. The information to be provided was to be derived from existing data for the Grand Banks and literature for other continental shelf systems. Major processes that were to be considered were production by benthic organisms, the role of the benthos in nutrient cyclying, feeding relationships of dominant benthic organisms and energy budgets for characteristic communities. The results of this study are contained in the enclosed report.

METHODS

Atlantic Oceanics conducted a computer literature search in relevant data bases and used papers thus located and those in personal reference files as a source of information on benthic-pelagic coupling world-wide. The information was used in conjuction with the results of Hutcheson et al. (1981) (a benthic survey of the Grand Banks conducted for Mobil Oil Canada, Ltd. in support of their Grand Banks EIS), to estimate the likely rates of benthic processes, specifically nutrient regeneration, respiration and production.

The results of the survey are presented in tabular form, accompanied by a brief text pointing out useful generalities. Where possible, unifying mathematical relationships describing benthic processes also have been included.

Certain estimates and features of Grand Banks benthic communities i.e. production, community composition, have been presented for subareas of the Grand Banks designated by the Grand Banks modelling workshop: Northern Grand Banks, Southwestern Bank and Southeast Shoal and Bank. The Labrador current, identified as a modelling compartment, has not been included as a benthic compartment because of the absence of benthic data for it.

RESULTS AND DISCUSSION

Predominant Grand Banks Benthic Communities

Species composition and dominance relationships of benthos in the major Grand Banks compartments are presented in Table 1. Data are based on the results of Hutcheson et al. (1981). In general, the infrequent sampling (4 times per year) prevents assessment of annual trends in numbers and data presented in Table 1 are annual averages.

In addition, no biomass data were available for individual species on the Grand Banks (except *Mesodesma deauratum*, a bivalve dominating standing crop on Southeast Shoal). Thus annual trends in species biomass are not extractable from the data.

Food Sources of Major Benthic Invertebrate Species

Most of the dominant infaunal invertebrates fed near the sediment water interface (Table 2). Suspension feeders were the largest group with surface deposit feeders and carnivores important in most model compartments. Subsurface infaunal deposit feeders were predominant only on the northeast Grand Banks slope (Station 3). Epibenthic invertebrates were predominantly surface deposit feeders and carnivores (Table 3).

Benthic Oxygen Demand

A tabular summary of published data on total oxygen demand of marine sediments is presented in Table 4. Values presented represent ranges of values measured in single studies throughout the year or single values at one time of the year. All data have been standardized to the same units of mg O_2 m^{-2} h^{-1}. Total oxygen consumption includes the components of biological and chemical oxygen demand.

On a world-wide basis, total oxygen demand values range between 4.2 and 170.8 mg O_2 m^{-2} h^{-1}. Rates are somewhat temperature dependent (Figure 1). Within the annual bottom temperature range on the Grand Banks (approx. -2-7°C), rates are generally less than 20 mg O_2 m^{-2} h^{-1} and average 9.7 mg O_2 m^{-2} h^{-1} (n=22). Within this temperature range, there is no obvious relationship between sediment oxygen demand and water temperature.

A summary of the relationships between total oxygen demands and bottom water temperatures for individual studies is presented in Table 5. The best curve fits are generally linear with intercepts ranging between -0.27 and 20.56 for curves of the form: $O_2=a+bT$. Slopes range between 0.51 and 3.83. The curve equation for the single values compiled from the literature summary is:

$$O_2 = -11.0 + 3.17T, \quad r=0.73$$

The relationships summarized in Table 5 from works by Hale (1976), Florek and Rowe (1983), and Nixon et al. (1976) are probably most applicable to the Grand Banks because of the types of waters in which the studies were carried out, i.e., north temperate/boreal or continental shelf. Temperature coefficients that could reasonably be applied to the Grand Banks would therefore range between 2.25 and 3.0 with intercepts between 10 and 20.

The overall relationship between total oxygen demand and water depths is illustrated in Figure 2. Within the compartmental boundaries specified for the Grand Banks model, water depths are greater than about 70 m. The few literature data available for these water depths (70-200 m), have sediment oxygen consumption values between 4 and 50 mg O_2 m^{-2} h^{-1}.

Another measure of the relationship between oxygen demand and temperature change is the Q_{10} statistic which is a measure of the relative change in the rates of a process over a ten degree temperature interval. Q_{10} values derived from studies summarized in Table 4 are shown in Table 5. The average Q_{10} for all data reviewed is 2.88 between 0 and 10°C. The range of values from individual studies is 1.18-4.48. There are few data for the lower temperature ranges of the Grand Banks.

Benthic oxygen demand is a reflection of the metabolism of organic matter by benthic communities. The amount of carbon remineralized by bottom sediments and associated fauna and flora represents a portion of the carbon produced by primary production in the overlying water column and other organic carbon inputs. In shallower waters, where more production usually reaches the bottom, the percentages of carbon remineralized by the benthos can be higher whereas in deeper waters the percentages may be lower (Figure 3). This relationship probably stems from the relatively clear linear relationship between amount of organic matter produced and/or imported and the amount of organic matter consumed on the bottom (Nixon, 1981). Benthic remineralization can account for between approximately 15 and 50% of carbon fixed by primary production (Figure 3) at water depths greater than about 60 m. The value of 87% for 60 m shown is for Bedford Basin, a partially enclosed body of water.

Nixon (1981) noted the following relationship between benthic remineralization (gC m^{-2} y^{-1}) and organic input from primary production and other sources (gC m^{-2} y^{-1}):

$$B.R. = 15 + 0.238\ (P + I),\ r^2 = 0.94$$

Benthic Nutrient Flux

Benthic nutrient fluxes measured from marine environments are presented in Table 6. Diagenesis of various forms of nitrogen in marine sediments generally leads to high accumulations of dissolved inorganic nitrogen (usually ammonium and sometimes nitrate) in the pore waters of marine sediments. The diffusion gradient between sediments and overlying waters would generally predict a flux of these nutrients into the overlying waters. The majority of direct measurements of benthic nutrient fluxes have been restricted to finer-grained nearshore and estuarine sediments, with the exception of papers such as those of Rowe et al. (1977a,b) and Florek and Rowe (1983) (Table 6).

Ranges of measured values for the fluxes of specific nutrients are:

	ug-at m^{-2} h^{-1}
NH_4	-4.3 to 400
NO_3	-428 to 216
NO_2	-1.96 to 14
PO_4	-14.9 to 50

It is more difficult to generalize about appropriate rates for nutrient flux than it is for oxygen demand data since release rates of different organic nutrients are not uniform. The connection between organic matter consumed (measured as oxygen consumed) and nutrients released is not well documented for marine bottom communities (Nixon, 1981). There may be some relationship between the amount of inorganic nitrogen released and the oxygen demand of coastal marine sediments in the summer months as seen in Nixon's (1981) equation of $NH_4 = -140.3 + 80.4\ O_2$ ($r^2 = 0.94$) derived from the data of eight different experiments. Ammonia release appears to dominate the inorganic nitrogen species released from sediments, particularly during the summer months (Hale, 1976; Boynton et al., 1980; Pomeroy et al., 1983). Relationships between the release rates of ammonia and temperature are summarized in Table 7. At 0°C, which would be typical of bottom waters over the Grand Banks throughout much of the year, these equations would predict ammonia flux rates of from -343.3 to 6.69 ug-at m^{-2} h^{-1}. The net flux of the majority of ammonia at very low water temperatures would therefore be into the sediments. Boynton et al. (1980) summarized benthic ammonium flux values from a variety of studies and noted that annual means range between about 10 and 150 ug-at N m^{-2} h^{-1} for the colder, coastal waters. The geometric mean of the summarized values is approximately 49 ug at N m^{-2} h^{-1}.

Few authors have quantitatively established the relationship between nitrate flux and temperature. However, the importance of nitrate appears to be system specific. In Narraganett Bay, nitrate sediment fluxes were usually undetectable and the benthic community was not thought to participate directly in the seasonal nitrate cycle in the water (Nixon et al., 1976). Alternatively, the pattern at some deep water stations in the Atlantic

Ocean (approx. 2000 m) was uptake of nitrate and phosphate by the benthic community and release of ammonia (Smith et al., 1978). Nitrate fluxes are almost always less than ammonia rates and greater than nitrite fluxes (e.g., Boynton et al., 1980; Pomeroy et al., 1983). In the Patuxent Estuary in winter, the majority of nitrogen flux is into the sediments in the form of nitrite plus nitrate at rates between 100 and 674 ug-at N m^{-2} h^{-1}.

Phosphate flux from marine sediments has ranged from about -15 to 50 ug-at m^{-2} h^{-1} (Table 6). Equations relating phosphate release to temperature have been published (Hale, 1976; Kremer and Nixon, 1978):

PO_4 (ug-at m^{-2} h^{-1}) $= 1.208\ e^{0.13T}$ (Kremer and Nixon, 1978)
PO_4 $= -14.34 + 2.28T$ (Hale, 1976)
PO_4 $= -4.99 + 1.27T$ (Hale, 1976)
PO_4 $= -9.04 + 1.01T$ (Hale, 1976)

Hale (1976) noted that on an annual basis, phosphate was released from the sediments at higher temperatures and taken up at lower temperatures.

Benthic Production

Benthic production and P/B ratios for communities observed world wide are presented in Table 8. In general production has never been measured on an open shelf environment such as the Grand Banks and attempts at modelling shelf ecosystems (e.g. Steele, 1974; Mills, 1980) have relied heavily on assumptions of production to biomass ratio (P/B) and mean generation times of benthos. Most of the time these approaches do not account for recyling of production within the benthos, i.e. the sum of the production of all the benthic organisms amount to more than what is available to fish because some is consumed and energy lost in respiration, mortality, etc. This has seldom been accounted for in studies where benthic community production has been measured (an exception is Ankar 1978) and thus estimates of production in general are greater than what is actually available to other trophic levels.

For the purposes of calculating production from Grands Banks, P/B's and standing crop data for individual invertebrate taxa have been used which are representative of the values observed in Tables 8 and 9. However, an alternate approach would be to take a P/B calculated from an entire community. Several community P/B's have been calculated in Table 8. Although there is no reason to suppose that widely varying benthic communities should have similar community P/B's, this seems in part to be the case, with values ranging from 0.4 to 1.6 (mean 0.9±0.47) (0.4, Buchanan and Warwick, 1974; 0.56, Warwick et al., 1978; 0.78, Miller et al., 1971; 0.9, Ankar, 1980; 1.0, Warwick and Price, 1975; 1.6, Cederwall, 1977; 1.6, Wolff and deWolf, 1977).

Production estimates for Grand Banks model compartments using benthic standing crops measured in Hutcheson et al. (1981), and wet weight to flesh dry weight (and flesh dry weight to Kcal) conversions of, for crustaceans, 0.20 (3.8); polychaetes, 0.17 (3.7); echinoderms 0.05 (2.3); molluscs 0.10 (4.3) and others 0.2 (3.6) are as follows (see also Tables 8 and 10).

Dry Weight   Carbon

Northeast Grand Banks Slope
$P = 7.8$ gC $m^{-2}y^{-2}$, $B = 5.80$ gC, $P/B = 1.28$, $P/B = 1.33$

Northeast Grand Banks Shelf
$P = 17.0$ gC $m^{-2}y^{-1}$, $B = 13.59$ gC, $P/B = 1.14$, $P/B = 1.25$

Southwest Grand Banks Shelf
$P = 8.25$ gC $m^{-2}y^{-1}$, $B = 6.75$ gC, $P/B = 1.11$, $P/B = 1.22$

Southeast Grand Banks Shelf
$P = 160.3$gC $m^{-2}y^{-1}$, $B = 229.45$gC, $P/B = 0.71$, $P/B = 1.43$

The calculation of production from standing crop and P/B ratios for these areas is outlined in Tables 11 A-D.

P/B ratios above determined for dry weights are in agreement with P/B's measured in other studies (above and in Table 8). The P/B's in terms of carbon from data in Hutcheson et al. (1981) are about the same as those determined from flesh dry weight except on the southeast Grand Banks Shelf (Station 48) where P/B in terms of carbon is higher. This is because the dominance in terms of standing crop of molluscs with their low turnover decreases P/B. But other groups with higher turnover make more significant contributions in terms of energy, hence the P/B elevation. Note that the high production estimated in Hutcheson et al. (1981) for Southeast Shoal (Table 8 and above) is not as great as has been reported in benthic communities consuming phytoplankton directly, i.e. barnacles (Wu and Levings, 1978).

Benthic Standing Crop

Benthic standing crops for benthos communities world wide and for Grand Banks model compartments are shown in Table 9.

Hargrave and Peer 1973 noted that total biomass in inshore shallow water sediments seems to depend on the level of primary production, but have no mathematic relation for it. There was a linear relationship between benthic macrofauna biomass (g m^{-2}) and spring bloom chlorophyll concentration (mg m^{-3}) of $B = 1.97 + 1.35\ P$, $r = 0.89$. Hutcheson et al. (1981) observed a good correlation, albeit for only four points, between macrobenthic standing crop (g m^{-2}) and integrated annual primary production (gC $m^{-2}\ y^{-1}$) of $\log B = 1.67 + 0.0049\ P$, $r = 0.99$.

Benthic Community Respiration

Miller and Mann (1973) found a universal Q_{10} relationship for north Atlantic poikilotherms of 2.05. The annual population respiration rate of sea urchins could have been predicted from a respiration rate measurement on a single occasion.

Macrobenthic community respiration ranged from 463. gC m^{-2} y^{-1} for a sand dollar community in the Sea of Japan (Ryabushko et al., 1982) to a total biological community respiration (macro, meio, microbenthos and bacteria) of 364 gC m^{-2} y^{-1} in Kiel Bight (Graf et al., 1982).

Production (Kcal m^{-2} y^{-1}) of a species may be estimated from respiration (Kcal m^{-2} y^{-1}) using the following:

$$P = 0.6440\ R^{.8517}$$ (McNeill and Lawton, 1970)

Several authors have tried this equation and got reasonable agreement with their estimates of production. However, the estimate of total production in Miller et al. (1971) in a herbivore community in St. Margarets Bay is quite small relative to other herbivore communities (Table 8) and possibly this reflects a failing in the equation.

A few values of ratio of community respiration to standing crop are available, 8.1 for total biological respiration (Ankar, 1977) and 1.2-1.3 for a sand dollar community containing Echinarachius parma (Ryabushko et al., 1982), the species present on Hibernia and biomass of the same order of magnitude as on Hibernia [396 versus 440 g (wet) m^{-2} (Hutcheson et al., 1981).

At 17.6°C the total annual community O_2 consumption in the Sea of Japan sand dollar respiration study (Ryabushko et al., 1982) was 46.3 gC m^{-2} y^{-1} (Table 12). Standing crop of sand dollars was 396 g wet m^{-2}. The sand dollar respiration was only 28% of community respiration.

It is possible to calculate respiration for this community at the Hibernia temperature and then use this respiration rate and standing crop at Hibernia to calculate community respiration at Hibernia and then calculate production from McNeill and Lawton's (1970) relationship. Taking the sand dollar community respiration rate (per gram wet weight) (Ryabushko et al., 1982) for the Sea of Japan at 17.6°C (0.1169 gC) and converting it on the basis of a Q_{10} of 2.0 to the annual mean temperature at Hibernia (2.4°C, Hutcheson et al., 1982) gives a rate of 0.042 gC (0.48 Kcal (g wet wt)$^{-1}$)

for the sand dollar community at Hibernia. Total respiration for the Hibernia community is then 18.48 gC (210.67 Kcal) m^{-2} y^{-1}. Using this value with McNeill and Lawton's (1970) equation for calculating production from respiration of small poikilotherms gives a value for sand dollar community production of 61.4 Kcal m^{-2} y^{-1} (5.4 gC) which amazingly is in the same ball park as the production actually estimated for Hibernia elsewhere in this report (2.89 gC m^{-2} y^{-1}, Table 11-C). All this calculation suggests is that the values we are considering may be of the right order of magnitude. Ryabushko's (1982) total community respiration of 46.3 gC m^{-2} y^{-1} (16.5 gC m^{-2} y^{-1} converted to the Hibernia temperature) may be a comparable system.

Further, the components of respiration from that study were sand dollars (28%), other infauna (23%) and "microphytomicrobenthos" (translation) including respiring diatoms, bacteria and protozoans. The rest may be a reasonable approximation of the respiration and production to be expected in the Hibernia system.

A wide range of weight specific oxygen consumption rates of benthic invertebrates makes estimation of respiration rate of other invertebrates in the benthic community at Hibernia a touchy proposition. For polychaetes at 7.5 to 10°C the range is 0.08 to 0.30 mL O_2 h^{-1} (g dry)$^{-1}$ and for bivalves 0.06 to 1.06 (Table 12). The rate for Glycera dibranchiata (a cogener of G. capitata which occurred at Hibernia) was 0.08 mL O_2 h^{-1} (g dry)$^{-1}$ at 7.5°C (Coyer and Mangum, 1973). Macrobenthos account for varying percentages of total benthic community respiration (12-35%, Tarasov, 1982; <5% Graf et al., 1982; macrofauna 51%, Ryabushko et al., 1982).

Components of Benthic Biomass, Respiration and Production

A breakdown of the contributions of benthic components to production, respiration and biomass is presented in Table 13.

Energy Budgets

Consumption rates of organisms feeding on benthos are presented in Table 14 and annual population consumption rates and energy flow of benthic invertebrates and fish on other food sources are presented in Table 15.

Assimilation efficiency of benthic organisms feeding and of other organisms feeding on benthos are presented in Table 16.

Feeding rates of benthic invertebrates are presented in Table 17. Ingestion rates for organic matter by deposit feeders and detritivores are a function of organism weight with organic matter ingestion rate (C) (mg dry) day^{-1} dependent on mg dry weight (W) by the relationship:

$$C = 0.381\ W^{0.742}$$ (Cammen, 1980)

Fecal production rates of benthic invertebrates are presented in Table 18.

Ecological transfer efficiencies (ratio of production in one level to that in another) (Table 19) for benthic communities to the next higher trophic level ranged from 1.3% to 23%, but the distribution was skewed to lower values. A value of 24-34% was observed in the transfer of energy from benthos to epibenthos, which included two fish species, a goby and a flatfish, and a shrimp (*Crangon crangon*) (Evans, 1984). The epibenthos were very efficient at transferring benthic productivity to higher trophic levels. This is interesting if we consider the Grand Banks benthos has an important epibenthic component and especially has a benthic epibenthic fish species (Sand lance) and many shrimp species as transfer agents. In the Wadden Sea, 60% of shirimp production was consumed by predators (Kuipers and Dapper, 1981). The energy budget in carbon units from Evans (1984) is presented in Table 20.

A transfer efficiency from food to benthos of 23% was observed in a west coast barnacle population (Wu and Levings 1978) (Table 13). This illustrates the high transfer that occurs in suspension feeding communities and the level of transfer that could be occurring on Southeast Shoal to support the high mollusc and barnacle densities there. Growth efficiences of benthic carnivores range from 6% to 75% (Table 5:21 of Conover, 1978). One study cited in Evans (1984) (Baird and Milne, 1981) indicated that a fish population consumed 54% of the benthic production.

The lower ecological transfer efficiences averaged 4.6%.

Role of Bacteria

Bacteria contributed more than 70% to total benthic community production in the Baltic (Ankar, 1977). Bacterial oxygen consumption accounts for 8-40% of community oxygen consumption in Smith (1973). Graf et al. (1982) found that 95% of benthic heat production (respiration) was accounted for by organisms other than macrofauna, and bacteria were a large component. In the Sea of Japan sand dollar community, bacteria and protozoans did 49% of the respiration with sand dollars doing 28% and other infauna 23% (Ryabushko et al., 1982). Bacteria and plant material make up 82% of benthic food requirements in Keil Bight (Gerlach, 1978).

Dissolved Organic Matter Loss

Although not measured for infaunal benthic communities as a whole, dissolved organic matter loss may be substantial. *Hyalella azteca* (a benthic amphipod) loses 36% of assimilated calories as organic excretion (Hargrave from Conover, 1978) and the green sea urchin loses 40-80% (Miller and Mann, 1973).

Production of Single Benthic Invertebrate Species

Production of a number of benthic invertebrate species in the literature is presented in Table 21. This information cannot be used to estimate community production on the Grand Banks because the data collected in Hutcheson et al. (1981) do not include a breakdown by size of invertebrates collected.

Components of Benthic Biomass and Production by Trophic Group

Ankar and Elmgren (1978) divided the soft bottom benthic community of the Baltic on the basis of feeding affinities. Biomass was split between carnivores (6.7%), planktivores (26.1%) and detritivores (67.2%) and production between carnivores (8.9%), planktivores (20.0%) and detritivores (71.1%).

Role of Direct Input of Phytoplankton to Benthos

Smetachek (from Graf et al., 1982) noted that spring bloom in Kiel Bight may account for 1/3 of the yearly total input of organic matter from the pelagic to benthic system.

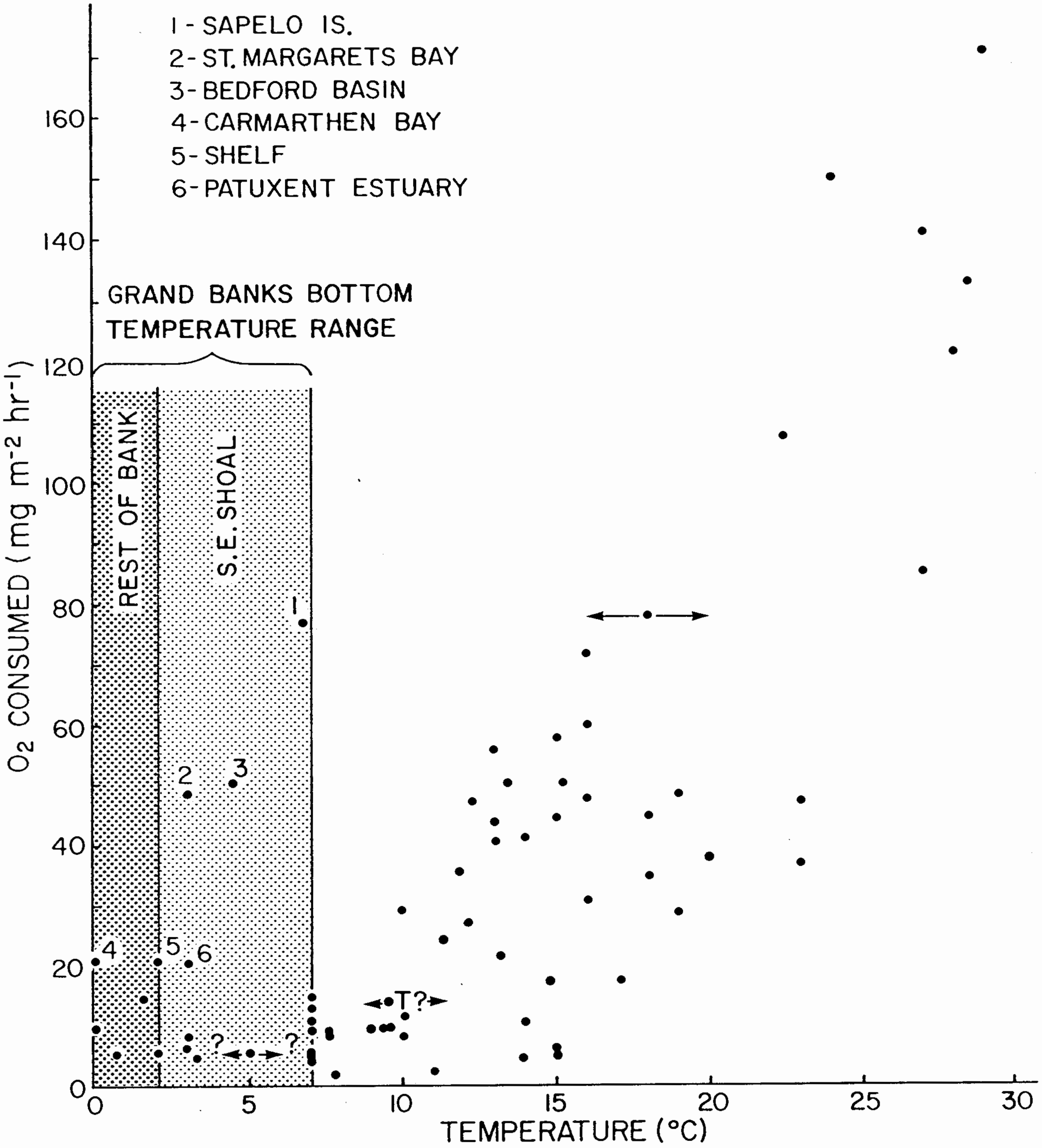


Figure 1. Total sediment oxygen demand vs temperature.

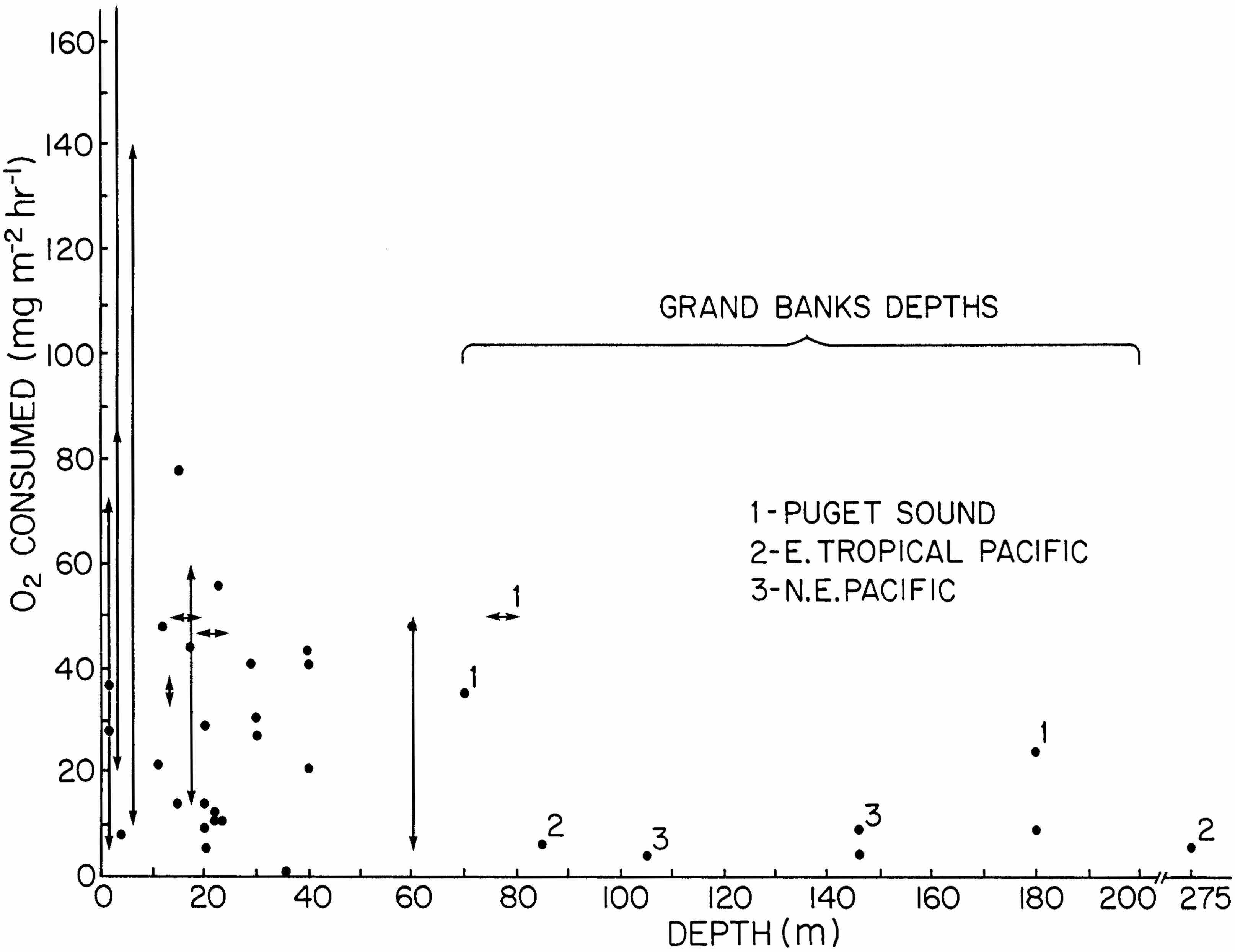
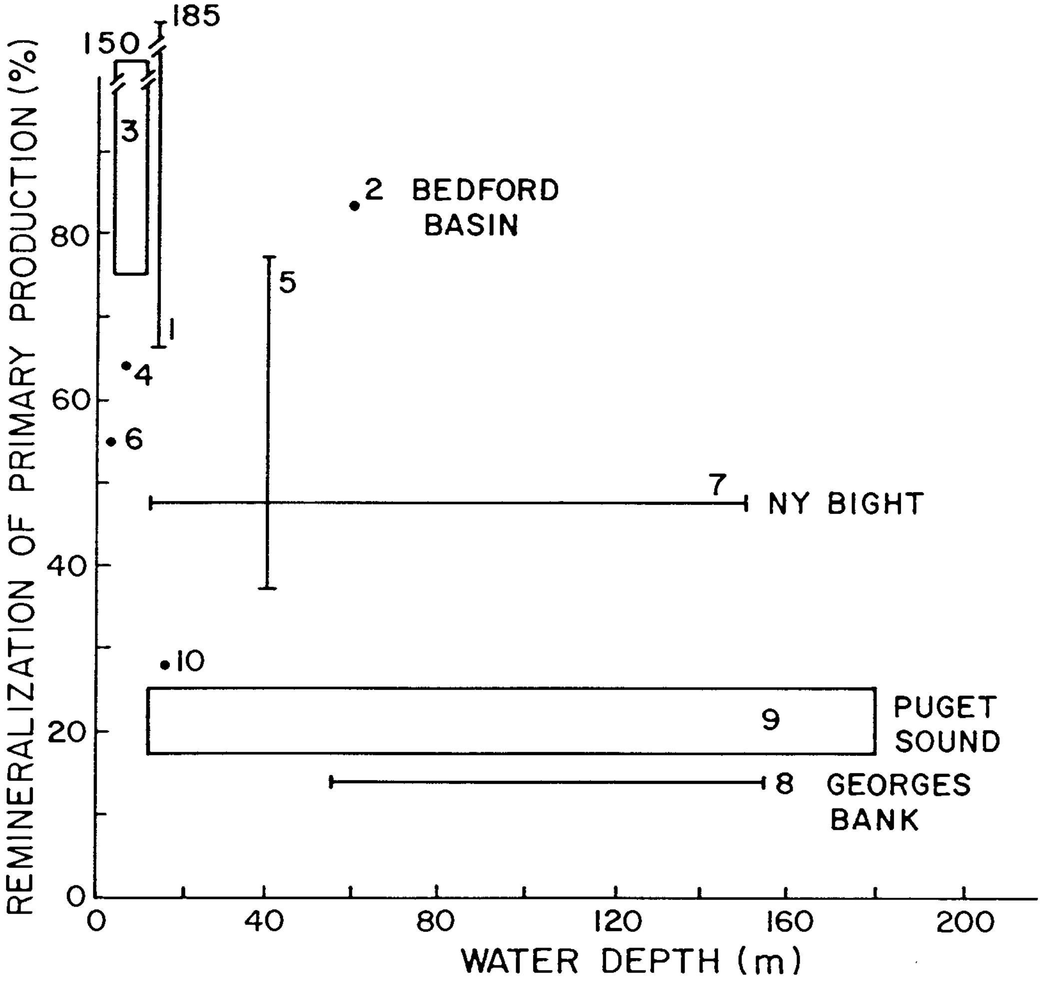


Figure 2. Total sediment oxygen demand vs depth.



1	Rowe et al., 1975	6	Hopkinson and Wetzel, 1982
2	Hargrave, 1978	7	Florek and Rowe, 1983
3	Jorgensen, 1977	8	Florek and Rowe, 1983
4	Nixon et al., 1976	9	Pamatmat and Banse, 1969
5	Smith, 1978	10	Hartwig, 1976

Figure 3. Percentage of primary production remineralized by benthic communities.

TABLE 1. DOMINANCE IN BENTHIC COMMUNITIES OF GRAND BANKS SPATIAL COMPONENTS [Polychaetes (P), Crustaceans (C), Molluscs (M), Echinoderms (E)]

NORTHERN GRAND BANKS - SLOPE

A. GRAB DATA

ABUNDANCE

Species	Mean Annual Number m^{-2}
Prionospio steenstrupi (P)	205
Eudorellopsis integra (C)	93
Harpinia plumosa and *sp.* (C)	99
Onuphis conchylega (P)	23
Macoma calcarea (M)	19
Astarte elliptica (M)	14
A. borealis (M)	15
Ophiura sarsi (E)	12
Ammotrypane sp. (P)	15

	495
Total	612±207

STANDING CROP

Taxon	Mean g m^{-2}	S.E.	n	%
Molluscs	99.4	28.5	12	54.7
Echinoderms	70.6	27.1	12	38.9
Polychaetes	8.8	3.2	12	4.8
Other	1.4	0.6	12	0.8
Nematodes	0.8	0.8	12	0.4
Crustaceans	0.7	0.3	12	0.4
	-----	----	--	-----
Total	181.7	48.8	12	100.0

B. SLED DATA

Species	Mean Annual # Per Tow	Density (Number m^{-2})
Monoculodes intermedius	316.8	0.83
Paroediceros lynceus	34.3	0.09
Meterythrops robusta	23.8	0.06
Westwoodilla megalops	22.5	0.06
Erythrops elegans	18.8	0.05
Rhachotropis oculata	17.3	0.05
Bathymedon obtusifrons	16.8	0.04
Oediceros saginatus	16.5	0.04
Syrrhoe crenulata	13.5	0.04
Monoculodes kroyeri	12.8	0.03
	-----	----
	493.1	1.29

Taxon	Mean Annual # Per Tow	Density (Number m^{-2})
Cnidaria	0.5	<0.01
Molluscs	6.0	0.02
Polychaetes	9.0	0.02
Crustacea	575.0	1.50
Echinoderms	16.0	0.04
Sipunculida	0.5	<0.01
	-----	----
	607.0	1.58

Table 1 (cont'd)

NORTHEAST GRAND BANKS - SHELF

A. GRAB DATA

ABUNDANCE

Species	Mean Annual Number m^{-2}
Exogone hebes (P)	291
Parapionosyllis longicirrata (P)	165
Pholoe minuta (P)	61
Streptosyllis arenae (P)	44
Chiridotea tuftsi (C)	43
Ophelia limacina (P)	37
Glycera capitata (P)	37
Prionospio steenstrupi (P)	36
Chaetozone setosa (P)	32

	746
Total	880±69
Ammodytes dubius	7.4

STANDING CROP

Taxon	Mean g m^{-2}	S.E.	n	%
Echinoderms	382.9	35.2	127	66.3
Molluscs	165.2	30.4	127	28.6
Polychaetes	8.5	1.2	127	1.5
Crustaceans	7.7	6.3	127	1.3
Other	7.0	2.1	127	1.2
Barnacles	4.6	2.7	127	0.8
Nematodes	2.3	0.3	127	0.4
	------	----	---	-----
Total	577.5	45.2	127	100.0

B. SLED DATA

Species	Mean Annual # Per Tow	Density (Number m^{-2})
Monoculopsis longicornis	72.9	0.19
Rhacotropsis oculata	53.6	0.14
Oediceros saginatus	33.8	0.09
Syrrhoe crenulata	32.6	0.09
Amphiporeia lawrenciana	27.5	0.07
Westwoodilla megalops	19.4	0.05
Balanus crenatus	17.2	0.04
Monoculodes kroyeri	15.3	0.04
Cylichna gouldi	12.7	0.03
Monoculodes intermedius	4.5	0.01

Taxon	Mean Annual # Per Tow	Density (Number m^{-2})
Cnidaria	0.5	<0.01
Molluscs	235.0	0.61
Polychaetes	64.0	0.17
Crustacea	2240.0	5.85
Echinoderms	52.0	0.14
Ascidacea	0.8	<0.01
Pisces	10.0	0.03
Ammodytes sp.	1.0	<0.01
Others	1.4	<0.01
	------	----
	2606.0	6.80

Table 1 (cont'd)

SOUTHWESTERN BANK

A. GRAB DATA

ABUNDANCE

Species	Mean Annual Number m^{-2}
Glycera capitata (P)	308
Prionospio steenstrupi (P)	112
Exogone hebes (P)	84
Pholoe minuta (P)	59
Aonides gracilis (P)	53
Exogone dispar (P)	39
Ophiura robusta (E)	34
Laphania boecki (P)	20
Chaetozone setosa (P)	17

	726
	820.7±132
Ammodytes dubius	1.8

STANDING CROP

Taxon	Mean g m^{-2}	S.E.	n	%
Echinoderms	204.4	73.1	11	68.6
Molluscs	71.0	47.5	11	24.1
Polychaetes	14.4	4.0	11	4.9
Other	4.8	4.2	11	1.6
Nematodes	1.6	0.4	11	0.5
Crustaceans	0.7	0.2	11	0.2
	-----	----	--	-----
Total	294.9	84.7	11	100.0

B. SLED DATA

Species	Mean Annual # Per Tow	Density (Number m^{-2})
Syrrhoe crenulata	88.0	0.23
Rhacotropis oculata	48.1	0.13
Monoculopsis longicornis	30.0	0.08
Amphiporeia lawrencia	17.0	0.04
Onuphis conchylega	16.9	0.04
Monoculodes edwardsi	10.1	0.03
Oediceros saginatus	9.9	0.03
Idotea phosphorea	9.1	0.02
Monoculodes tuberculatus	6.9	0.02
	-----	----
	236.0	0.62

Taxon	Mean Annual # Per Tow	Density (Number m^{-2})
Molluscs	9.0	0.02
Polychaetes	59.0	0.15
Crusteaceans	333.0	0.87
Echinoderms	14.0	0.04
Ammodytes sp.	7.0	0.02
Others	4.0	0.01
	-----	----
	426.0	1.11

Table 1 (cont'd)

SOUTHEAST SHOAL & BANK

A. GRAB DATA

ABUNDANCE

Species	Mean Annual Number m^{-2}
Mesodesma deauratum (M)	2193
Balanus crenatus (C)	1845
Scolelepis squamata (P)	122
Exogone hebes (P)	101
Glycera capitata (P)	56
Micronephtys minuta (P)	39
Pleustidae (C)	41
Harmothoe imbricata (P)	31
Acanthohoustorius spinosus (C)	32
Priscillina armata (C)	30

	4488
Total	5140±1654
Ammodytes dubius	2

STANDING CROP

Taxon	Mean g m^{-2}	S.E.	n	%
Molluscs	7115.0	4130.8	17	97.0
Barnacles	146.8	134.0	17	2.0
Echinoderms	53.6	32.5	17	0.7
Polychaetes	9.1	3.6	17	<0.1
Other	8.5	1.9	17	<0.1
Crustaceans	4.5	1.6	17	<0.1
Nematodes	1.3	0.9	17	<0.1
	------	------	--	-----
Total	7338.8	4124.8	17	100.0

B. SLED DATA

Species	Mean Annual # Per Tow	Density (Number m^{-2})
Monoculodes edwardsi	934.4	2.44
Pontogenela inermis	473.8	1.24
Balanus crenatus	453.8	1.18
Mesodesma deauratum	178.5	0.47
Pleustidae	59.8	0.16
Unciola irrorata	55.5	0.14
Oediceros saginatus	44.3	0.12
Ischyrocerus megalops	25.1	0.07
Phoxocephalus holbolli	22.1	0.06
	------	----
	2247.3	5.88

Taxon	Mean Annual # Per Tow	Density (Number m^{-2})
Molluscs	8.0	0.02
Polychaetes	9.0	0.02
Oligochaetes	0.1	<0.01
Crustaceans	145.0	0.38
Echinoderms	4.0	0.01
Fish	0.9	<0.01
	-----	----
	167.0	0.44

Table 1 (cont'd)

FOOT NOTES

1. Northern Grand Banks slope data taken from Station 3 (48°,30'N, 51°,30'W) of Hutcheson et al. (1981).

2. Northeast Grand Banks shelf data taken from all Hibernia area stations of Hutcheson et al. (1981).

3. Southwestern Bank data taken from Station 33 (46°N, 51°W) of Hutcheson et al. (1981).

4. Southeast Shoal and Bank data is that of station 48 (44°N, 49°30'W) of Hutcheson et al. (1981).

5. Species mean annual densities calculated as means of all grabs (sleds) taken at station(s) over the year.

6. Sum of mean densities of dominant species in grabs presented followed by annual mean macroinvertebrate density ±1 standard error of mean.

TABLE 2. FEEDING TYPE OF DOMINANT BENTHIC INVERTEBRATES IN VAN VEEN GRAB SAMPLES.

Numbers under stations refer to rank of species listed in order of overall dominance in grabs in this study. Asterisk (*) denotes feeding type determined in this study. Double asterisk (**) denotes dominance on St. Pierre Bank. Question mark where feeding type surmised. Bracketed letters indicate animal type: polychaete (P), mollusc (M), crustacean (C), echinoderm (E). Adapted from Hutcheson et al. (1981).

		Rank in Abundance			
		Station			
Species	Feeding Classification	3 Northeast Banks - slope	Hibernia Northeast Banks - shelf	33 Southwestern Grand Banks	48 Southeastern Grand Banks
Exogone hebes (P)	surface herbivores		1	3	5
Exogone dispar (P)(genus)	"			7	
Lepeta caeca (M)*	"			11	
Mesodesma deauratum small(M)*	suspension feeders				1
Mesodesma deuuratum large(M)*	"				4
Balanus crenatus (C)	"				2
Prionspio steenstrupi (P)	"	1	13	2	
Aonides gracilis (P)	"		10	5	
Scolelepis squamata (P)	"				3
Euchone papillosa (P)(genus)	"		8	14	
Amphiporeia lawrenciana (C)	"				14
Liocyma fluctuosa (M)*	"		12		
Cyrtodaria siliqua (M)**	"				
Spio filicornis (P)	"			10	
Laphania boecki (P)	"			6	
Polydora sp. (P)**	"				
Euchone sp. (P)(genus)**	"				
Macoma calcarea (M)	surface deposit feeder	6			
Ophiura sarsi (E)	"	9			
Stereoderma unisemita (E)	"				12
Acanthohaustorius spinosus (C)	"				11
Pleustidae (C)	"			8	
Aricidea jeffreysii (P)**	"				
Eudorellopsis integra (C)*	"	2			
Chaetozone setosa (P)	"		5	8	
Unciola irrorata (C)?	"			12	
Priscillina armata (C)?	surface deposit feeder,		11		10
Chiridotea tuftsi (C)	carnivore		9		
Echinarachnius parma (E)	"		7	16	
Ophiura robusta (E)	"		15	9	
Astarte borealis (M)	subsurface deposit feeder	8			
Thyasira flexuosa (M)?	"	11			
Astarte elliptica (M)	"	7			
Harpinia plumosa (C)	"	3			
Capitella capitata (P)	"			15	
Ophelia limacina (P)*	"		4		
Harpinia sp. (C)	"	5			
Streptosyllis arenae (P)	carnivore		3		
Micronephtys minuta (P)(genus)	"				7
Ammotrypane sp. (P)	"	10			
Harmothoe imbricata (P)	"				9
Paraplonosyllis longicirrata (P)	"		2	13	
Glycera capitata (P)	"		6	1	6
Pholoe minuta (P)	"		14	4	
Onuphis conchylega (P)	"	4			
Anonyx nugax (C)	"				13

TABLE 3. FEEDING TYPES OF DOMINANT BENTHIC INVERTEBRATES CAPTURED IN EPIBENTHIC SLED SAMPLES AT ALL STATIONS ON THE GRAND BANKS AND AROUND HIBERNIA (from Hutcheson et al, 1981)
Polychaete (P), Crustaceans (C), Echinoderms (E).

Species	**Feeding Type**
Monoculopsis longicornis (C)	Surface deposit feeder/detritivore
Syrrhoe crenulata (C)	"
Monoculodes intermedius (C)	"
Amphiporeia lawrenciana (C)	"
Westwoodilla megalops (C)	"
Pleustidae (amphipods) (C)	"
Monoculodes borealis (C)	"
Unciola irrorata (C)	"
Monoculodes edwardsi (C)	"
Ecinarachnius parma (E)	"
Cucumaria frondosa (E)	"
Rhachotropis oculata (C)	Surface deposit feeder/detritivore & carnivore
Oediceros saginatus (C)	"
Spirontocaris spinus (C)	"
Lebbeus polaris (C)	"
Balanus crenatus (C)	Suspension feeder
Ischyrocerus megalops (C)	"
Harmothoe imbricata (P)	Carnivore
Onesimus edwardsi (C)	"

TABLE 4. TOTAL OXYGEN DEMAND OF MARINE SEDIMENTS. SUMMARIZED FROM LITERATURE.

Rate (mgO_2 m^{-2} h^{-1})*	Location	T (°C)	Depth (m)	Core/In Situ (C/I.S.)	Reference
3.7-100.4 (av=26.1)	-	-	0-200	-	Zeitzschel, '81
14.8 - 59.8	Buzzards Bay	1.5-16	17	I.S.	Rowe et al., '75
77.97	Buzzards Bay	July, Aug	15	I.S.	Smith et al., '73
34.6 - 37.8	Buzzards Bay	18-20	12-14	C	Florek & Rowe, '83
9.6-4.96	Kiel Bight	9.5-13.9	20	I.S.	Balzer et al., '83
13.87	Kiel Bight	8-13	20	I.S.	Balzer, '84
5.54	Kiel Bight	4.9	20	I.S.	Balzer, '84
9.58	Kiel Bight	9.5	20	I.S.	Balzer et al., '83
5.7-49.98	Bedford Basin	2-4.5	60	C	Hargrave, '78
5.71-71.4 (av=29.3)	Eastern Passage	0.7-16	0.5-2	I.S.	Hargrave & Phillips, '81
48.6	St. Margarets Bay	3	60	C	Mann, '72
6.56	Randers Fjord	3		C	Revsbech et al., '80
11.68	Estuary	10		C	Revsbech et al., '80
44.8	Estuary	18		C	Revsbech et al., '80
8-48	Limfjorden, Denmark	3-19	4-12	C	Jørgensen, '77
21.4	Eckernforde Bight (S.W. Baltic)	13.2	11	I.S.	Pamatmat et al., '81
20.8-85	Chesapeake Bay	0-27	3	I.S.	Kemp & Boynton, '81
10-141	Chesapeake Bay	0-27	6	I.S.	
20.8-170.8	Patuxent Estuary	3-29	3	I.S.	Boynton et al., '80
10-150 (av=4.1)	Narragansett Bay	0-24	5.8-7.3	I.S.	Nixon et al., '76
4.7-107.3 (av=37.8)	Narragansett Bay	3.2-22.4	5.8-7.3	I.S.	Hale, '76
20.8	Gay - Head Burmuda	2	40	I.S.	Smith, '78
43.4	Transect	13	40	I.S.	Smith, '78
40.8	Transect	14	40	I.S.	Smith, '78
0.7-4.8 av=1.4	Spanish Continental Shelf	20	94-238	C	Tenore et al., '84
28.4	Castle Harbor, Bermuda	19	1.5	I.S.	Smith et al., '72
36.8	Castle Harbor, Bermuda	23	1.5	I.S.	Smith et al., '72
55.8	Baja, California	13	23	I.S.	Smith et al., '74
40.4	Baja, California	13	29	I.S.	Smith et al., '74
30.6	Spanish Sahara	16	30	I.S.	Smith et al., '76
6.2	E Trop. Pacific	15	85	C	Pamatmat, '71
5.4	E Trop. Pacific	15	275	C	(In Hargrave, '73)
44.1	La Jolla, Cal.	15	17	I.S.	Smith et al., '78
76.97-132.4	Sapelo Is, Georgia	6.8-28.5	7	C	Smith, '73
121	Georgia Bight	28	3.8	I.S.	Hopkinson & Wetzel, '82
1.86	Christiaensen Basin (N.Y. Bight)	7.8	35.5	I.S.	Rowe et al., '77
2.86-47.1	N.Y Bight	11-23	13-28	I.S.	Florek & Rowe, '83
8.14-47.6	E.N.Y. Bight	10-16	20-150	C	Florek & Rowe, '83
5.43-10.6	Georges Bank	6-14	55-155	C	Florek & Rowe, '83
8.7-17.24	Carmarthen Bay, UK	7.6-17.1	9.8-17.3	C	Pomeroy et al., '83
29.1	Long Is. Sound	10	20	C	Carey, '67
9.6	Puget Sound	9	180	C	Pamatmat, '71a
11.0	Puget Sound	7	23	C	Patatmat, '71a
11.0	Puget Sound	7	22	C	Patatmat, '71a
12.8	Puget Sound	7	22	I.S.	Patatmat, '71a
5.7-57.1	Puget Sound	7-15	11-180	I.S.	Pamatmat & Banse, '69
27.1	Puget Sound	12.2	30	I.S.	Pamatmat & Banse, '69
50	Puget Sound	15.2	15-18	I.S.	Pamatmat & Banse, '69
50	Puget Sound	13.5	75-80	I.S.	Pamatmat & Banse, '69
47.1	Puget Sound	12.3	20-23	I.S.	Pamatmat & Banse, '69
24.2	Puget Sound	11.3	180	I.S.	Pamatmat & Banse, '69
35.7	Puget Sound	11.9	70	I.S.	Pamatmat & Banse, '69
9.6	N.E. Pacific	7	146	C	Pamatmat, '71b
4.2	N.E. Pacific	7	105	C	Pamatmat, '71b
4.86	N.E. Pacific	7	146	C	Pamatmat, '71b
8.7	Camarthen Bay	7.6	10	C	Pomeroy et al., '83
17.24	Camarthen Bay	14.8	10	C	Pomeroy et al., '83
14.17	LaJolla Bight	-	18.3	I.S.	Hartwig, '76

* 1 mg O_2 m^{-2} h^{-1} = 1.43 mL O_2 m^{-2} h^{-1}

TABLE 5. SUMMARY OF RELATIONSHIPS BETWEEN TOTAL OXYGEN DEMAND OF SEDIMENTS AND WATER TEMPERATURES

Equation	r	Q10	Reference
$O_2 = 11.19 + 2.25T$	0.73	2.50_{0-22}	Hale, '76
$O_2 = e^{0.15\ r\ +\ 2.09}$	0.78	4.48_{0-10}	Nixon et al. '76
$O_2 = 20.56 + 2.99T$	0.81	2.23_{15-25}	Florek & Rowe, '83
$O_2 = 10.77 + 1.16T$	0.61	1.70_{5-15}	Hargrave & Phillips, '81
$O_2 = 6.05 + 3.63T$	0.85	2.76_{4-14}	Jorgensen, '77
$O_2 = 23.50 + 3.83T$	0.82	2.10_{3-13}	Boynton et al., '80
$O_2 = ? + 0.51T$	-	-	Smith, '73
$O_2 = 107.6 + 2.14T - 5.48[O_2]$	-	1.18_{6-16}	Smith, '73
$O_2 = -0.27 + 1.06T$	0.57	2.48_{7-17}	Pomeroy et al., '83
$O_2 = -11.00 + 3.17T$	0.73	2.88_{0-10}	Lit. Summary
$\log O_2 = 0.52 + 1.01 \log_e T$	0.57	-	Lit. Summary

TABLE 6. BENTHIC NUTRIENT FLUX

NH_4*	NO_3*	NO_2*	P*	Location	T (°C)	Depth (m)	Core/In Situ (C/I.S.)	Reference
25-400	-	-	-	-	-	5-30	I.S.	Zeitzschel, '81
2.6-124	.15-4.8	-1.96-4.3	-14.9-5.2	Buzzards Bay	1.5-16	17	I.S.	Rowe et al., '75
27.8			3.0	Kiel Bight	9.5-13.9	20	I.S.	Balzer et al., '83
9.7	NO_3+NO_2=10.1		2.63	"	8-13	20	I.S.	Balzer, '84
εN:5.6			0.7	"	4.9	20	I.S.	"
99	40	n.d.	20	Narragansett Bay	0-24	5.8-7.3	I.S.	Nixon et al., '76
259	NO_3+NO_2=-141		DIP:43	Patuxent Estuary	3-29	3	I.S.	Boynton et al., '80
DON:	-428-216		DOP:-11-34					
36-191				New York Bight	11-23	13-23	I.S.	Florek & Rowe, '83
20-204				"	"	"	C	"
138				E.N.Y. Bight	14	28	I.S.	"
53				"	14	28	C	"
-4.3-276	-66.3-43.4		-9.4-41.6	Narragansett Bay	3.2-22.4	5.8-7.3	I.S.	Hale, '76
av=84.5	av=-1.2		av=9.6					
		0-10.4			3.2-19		I.S.	Hale, '76
		av=1.66						
165	5	5	36.7	Georgia Bight	28	3.8	I.S.	Hopkinson & Wetzel, '82
DON: -3.3			DOP:0					
εInorg N:175			εInorg P:36.7					
εN:172			P:36.7					
16.5-191.2	7.9 (May)			Carmarthen Bay	Summer	9.8-17.3	C	Pomeroy et al., '83
av=77.03								
2.4-32.1	11.66 (Aug)				Winter	"	C	"
av=21.57	32.8 (Oct)							
εN:23				Loch Thurnaig, Scotland	6-13	30	I.S.	Davies, '75
			7.9-8.9	Eastern Passage	.7	1-2	I.S.	Hargrave & Connolly, '78
27.8			2.3	Baltic		20		Balzer, '78
εN:16.2								
εN:28				Harrington Sound (Bermuda)		9		Balzer & Keller, '78
εN:18						18		"
εN:20						24		"
235	160	14	50	Cape Blanc, Spanish Sahara	-	25	I.S.	Rowe et al., '77
57.9	2.5	-0.8	0.4	New York Bight	7.8	35.5	I.S.	Rowe et al., '77

* ug-at m^{-2} h^{-1}

TABLE 7. LITERATURE DERIVED RELATIONSHIPS BETWEEN NUTRIENT RELEASE RATES (ug at-m^{-2} h^{-1}) OF MARINE BENTHIC SEDIMENTS AND TEMPERATURE

Species	r^2	n	Source
$NO_x = -343.3 + 12.84T$	0.29	12	Boynton et al., '80
$NH_4 = -183.48 + 25.10T$	0.83	12	"
$NH_4 = e^{0.16T} + 1.90$	0.8		Nixon et al., '76
$NH_4 = -48.78 + 12.26T$	0.91		Hale, '76
$NH_4 = -19.7 + 6.52T$	0.95		"
$NH_4 = -34.09 + 8.66T$	0.86		"
$NH_4 = 8\ e^{0.15T}$	-		Kremer and Nixon, '78

TABLE 8. SECONDARY PRODUCTION OF BENTHOS

		Production (m^{-2} y^{-1})					Kcal = 4.184 KJ	Kcal = 1/11.4 gC
Geographic Area	Taxon	Wet Weight(g)	Dry Weight(g)	AFDW(g)	Energy(KJ)	P/B	Carbon gC m^{-2} y^{-1}	Authority
Georges Bank								
winter	Polychaetes			5.1[1]	115	2.64	2.4	Maurer & Leathem '80
spring	"			5.5[1]	124	"	2.6	"
Nantucket Shoals & Georges Bank								
winter	"			6.5[1]	146	"	3.1	"
spring	"			6.4[1]	144	"	3.0	"
Southern Slope								
winter	"			5.3[1]	119	"	2.5	"
spring	"			4.8[1]	108	"	2.3	"
Northern Slope								
winter	"			5.1[1]	115	"	2.4	"
spring	"			4.5[1]	101	"	2.1	"
Southwestern Shelf								
winter	"			2.9[1]	65	"	1.4	"
spring	"			5.1[1]	115	"	2.4	"
Gulf of Maine								
winter	"			2.7[1]	60.7	"	1.3	"
spring	"			3.4[1]	76.4	"	1.6	"
B.C. Intertidal	Barnacles				12119		263.3	Wu & Levings '79
	Oyster (*C. virginiana*)				17288		362.5	Dame '76
	Oyster (*C. gigas*)				6464		135.5	Bernard '73
	Scrobicularia					>4y 0.29		
	plana (Bivalue)				73-519	<4y 0.67	1.6-10.9	Hughes '70
	Littorina irronata (Gastropod)				170		3.6	Odum & Smalley '59
	Tegula funebralis (Gastropod)				897		18.8	Paine '71
	Fissurella barbadensis (Limpet)				213		4.5	Hughes '71a

Table 8 (cont'd)

Geographic Area	Taxon	Production (m^{-2} y^{-1}) Wet Weight(g)	Dry Weight(g)	AFDW(g)	Energy(KJ)	Kcal = 4.184 KJ P/B	Carbon gC m^{-2} y^{-1}	Kcal = 1/11.4 gC Authority
Washington	Polychaete-*Pectinaria californiensis*					3.3-5.5		Nichols '75
	Polychaete-*Harmothoe sarsi*					2.4-3.1		Sarvala '71
Boreal European estuaries	Deposit feeders		10				3.9	Warwick '80
Boreal European cont. shelf 80m	Deposit feeders		1.7				0.7	"
Scotia Shelf 0-90m	Benthos				120.5	2.0	2.6	Mills '80
90-180m	"				138.4	2.5	2.9	"
Mid Atlantic Shelf	"	50				0.5	3.0	Walsh '81
Wadden Sea	*Macoma balthica*					0.3-0.8		Beukema '80
Northern Baltic - soft bottom	*Macoma balthica*		10.2		190	4.0	4.0	Ankar '80
"	"					0.4		Bergh '73
"	"					0.4		Ostrowski '76
"	Macrobenthos				230	0.9	4.8	Ankar '80
Bay of Fundy	Corophium-tide flats					7.2		Peer (unpub.)
"	Amphipod - *Haploops fundienses*	0.764			3[2]	1.3	<0.1	Wildish '84
"	*Photis reinhardi*	0.370			1.6[2]	2.8	<0.1	"
"	*Casco bigelowi*	1.210			5.4[2]	2.5	<0.1	"
"	*Harpinia propinqua*	0.066-0.083			0.3-0.5[2]	3.8	<0.1	"
Baltic	Amphipod-*Pontoporeia*					0.7-2.1		Cederwall '77
Arachon Bay - France	*Macoma balthica*			0.7-3.2		0.6-2.0	0.2-1.1	Bachelet '82
"	*Scrobicularia plana*			0.6-25.2		0.8-5.7		"

Table 8 (cont'd)

		Production (m^{-2} y^{-1})					Kcal = 4.184 KJ	Kcal = 1/11.4 gC
Geographic Area	**Taxon**	**Wet Weight(g)**	**Dry Weight(g)**	**AFDW(g)**	**Energy(KJ)**	**P/B**	**Carbon gC m^{-2} y^{-1}**	**Authority**
Buzzards Bay	Nephtys		9.34[3]		140.9		3.0	Sanders '56
Carmathen Bay, S. Wales	Macrobenthos mashly susp. feeders			25.8		0.56	10.2	Warwick et al. '78
Grevelingen estuary	Macrobenthos			41.3		1.6	16.3	Wolff & de Wolf '77
Baltic	Macrobenthos			6.8		1.6	2.7	Cederwall '77
Northumberland Coast	Macrobenthos (*Brissopsis-Amphiura*)			1.7		0.4	0.7	Buchanan & Warwick '74
Buzzards Bay	Macrobenthos (*Nephtys-Yoldia*)			29.6		2.5	11.7	Sanders '56
Godhavn	Polychaetes	158[4]		21.0		1.4	10.1	Curtis '77
Lyngmarksbugt	"	44[4]		5.9		1.4	2.8	"
Fungsthytten	"	5[4]		0.7		1.4	0.3	"
Tut	"	12[4]		1.6		1.4	0.8	"
Nova Scotia	Sea Urchins				209	0.8	4.4	Miller & Mann '73
Northern Baltic	Benthos (macro, meio, micro & bacteria)					5.4	29.4	Ankar '77
"	Net-Avail to fish					0.3-0.5	1.3-2.1	"

Table 8 (cont'd)

			Production (m^{-2} y^{-1})				Kcal = 4.184 KJ	Kcal = 1/11.4 gC
Geographic Area	**Taxon**	**Wet Weight(g)**	**Dry Weight(g)**	**AFDW(g)**	**Energy(KJ)**	**P/B**	**Carbon gC m^{-2} y^{-1}**	**Authority**
Baltic	*Pontoporeia affinis*				103		2.2	Ankar & Elmgren '76
"	*Pontoporeia femorata*				13		0.3	"
"	Macrobenthic carnivores			20	20		0.4	"
"	Macrobenthic planktivores			45	45		0.9	"
"	Macrobenthic detritivres			160	160		3.4	"
"	Macrobenthos total			225	225		4.7	"
"	Meiobenthos total			112	112		2.3	"
NE Atlantic - off France	*Myrthea spinifera* (bivalve)			0.0174^5			<0.1	Bourcier '78
"	*Tellina serrata* (bivalve)			0.102^5			<0.1	"
"	*Venus ovata* (bivalve)			0.014^5			<0.1	"
"	*Ophiura albida*			0.031			<0.1	"
"	*Venus gallina*			20^5			9.5	Masse '71 from Bourcier '78
"	*Spisula subtruncata*			9.8^5				"
Biscayne Bay, Fla	*Macoma tageliformis*			0.54			4.7	Moore '72
"	*Tellina versicolor*			2.4			1.1	"
"	*Codakia orbicularis*			1.56			0.6	"
Northumberland Coast	Macrobenthos			1.74	32.7	0.4	0.7	Buchanan & Warwick '74
Western Sweden	*Carcinus maenus*		0.5	0.4^6	10.6		0.2	Pihl & Rosenberg '82
"	*Crangon crangon*			2.4^7	54.1		1.1	Kuipers & Dapper '81

Table 8 (cont'd)

		Production (m^{-2} y^{-1})					Kcal = 4.184 KJ	Kcal = 1/11.4 gC
Geographic Area	**Taxon**	**Wet Weight(g)**	**Dry Weight(g)**	**AFDW(g)**	**Energy(KJ)**	**P/B**	**Carbon gC m^{-2} y^{-1}**	**Authority**
Lyngmarksbugt	Benthos				292.88		6.1	Petersen & Curtis '80
Fangsthytten	Shallow sheltered benthos				71.5	0.4	1.5	"
Godhaven	Shallow exposed "				1082.8	0.6	22.7	"
Tut	Deep sheltered "				69.5	0.4	1.5	"
Lyngmarks bugt	Deep exposed "				269.0	0.9	5.6	"
Ellesmere Is. fjord	Benthos				62.8		1.3	Curtis (pers. comm) in Petersen & Curtis '80
NE England coast	Benthos -20m fine sand			3.4-7.4	63.4-138.9	0.9-1.7	1.3-2.9	Rees '83
"	*Spiophanes bombyx*					1.5-4.9		"
"	*Magelona mirabilis*					1.1-2.7		"
"	*Magelona minuta*					5.9-6.2		"
"	*Nephtys hombergi*					1.15		"
"	*Tellina fubula*					0.9-1.8		"
"	*Nucula turgida*					0.5-0.8		"
"	*Venus striatula*					1.4-3.4		"
Everywhere	Polychaetes					2.2		Robertson '79
"	Gastropods					2.2		"
"	Bivalves					1.9		"
"	Crustucea					3.0		"
"	Echinoderms					1.3		"
Grevelingen estuary	Macrobenthos			41.3[8]	775.3	1.6	16.3	Wolff '77
"	*Littorina*					2.0		Wolff & deWolf '77
"	*Hydrobia*					2.0		"
"	*Arenicola*					1.2		"
"	*Macoma*					1.0		"
"	*Cardium*					1.7		"
"	*Mytilus*			110.99	2554.1[9]		53.5	"

Table 8 (cont'd)

Kcal = 4.184 KJ **Kcal = 1/11.4 gC**

Geographic Area	**Taxon**	**Production (m^{-2} y^{-1})** **Wet Weight(g)**	**Dry Weight(g)**	**AFDW(g)**	**Energy(KJ)**	**P/B**	**Carbon gC m^{-2} y^{-1}**	**Authority**
Firemore Bay, Loch Ewe, Scotland	Benthos			4.5				McIntyre & Eleferiou '68
"				1.7				Warwick '74
Irish Sea	Mytilus edulis - new set				12552-25104		263-526	Dare (unpub. m.s.) from Miller & Mann '73
St. Margarets Bay	Benthic herbivores				391.2	0.78	8.2	Miller et al. '71
Georgia salt marsh	Modiolus				69.9		1.5	Kuenzler '61
Intertidal estuarine Ythan estuary	Mytilus edulis				2928.8		61.4	Milne & Dunnet '72
Morecamb Bay, England	Mytilus edulis				149.1	2.5-3	3.12	Dare '75
Tamar estuary, England	Benthos			13.3		1.0	5.2	Warwick & Price '75
Northeast Grand Banks - Slope	Macrobenthos		22.6			1.28	7.8	Hutcheson et al '81 & this study
- Shelf	"		53.5			1.14	17.0	"
Southwest Grand Banks	"		26.5			1.11	8.3	"
Southeast Grand Banks	"		438.9			0.71	160.3	"

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1 Used alcohol preserved wet wt and Lie's (1968) conversion of 0.133. To convert AFDW to Kcal used average of energy values for polychaetes from Atkinson and Wacasey i.e. Kcal = 5.462 x AFDW (g).

2 Used Brawn et al. '68 1.058 Kcal (g live weight)$^{-1}$

3 AFDW = 0.66 DW (Ankar and Elmgren '78)

4 Used Lie's polychaete wet weight to AFDW = 0.133

5 Used AFDW = 5.418 Kcal (Atkinson & Wacasey '76)

6 Used energy content of Hyas araneus from Tyler. DW = 1.28 AFDW

7 Crangon crangon energy content 17.6 KJ (g dry wt)$^{-1}$. DW = 1.26 AFDW

8 AFDW to Kcal = 4.487 (Wissing et al. '73)

9 Caloric content 5.5 Kcal (g AFDW)$^{-1}$ (Dare '75)

TABLE 9. STANDING CROP OF BENTHOS

Geographic Area	Taxon	Standing Crop Wet Weight(g)	Dry Weight(g)	AFDW(g)	Energy(KJ)	Carbon(g)	Authority
Georges Bank							
- winter	Polychaetes	14.4 15.5[1]		1.92[1]	43.9	0.9[2]	Maurer & Leathem '80
- spring	"	15.6 14.8[1]		2.07[1]	47.3	1.0	"
Nantucket shoals							
& Georges - winter	"	18.7 21.2[1]		2.48[1]	56.7	1.2	"
- spring	"	18.4 20.0[1]		2.44[1]	55.8	1.2	"
Southern slope							
- winter	"	15.0 16.5[1]		1.99[1]	45.5	1.0	"
- spring	"	13.6[1]		1.80[1]	41.1	0.9	"
Northern slope							
- winter	"	14.7 1.7[1]		1.95[1]	44.6	0.9	"
- spring	"	12.9 8.1[1]		1.71[1]	39.1	0.8	"
Southwestern shelf							
- winter	"	8.3 6.7[1]		1.10[1]	25.1	0.5	"
- spring	"	14.8 5.6[1]		1.96[1]	44.8	0.9	"
Gulf of Maine							
- winter	"	7.8 6.9[1]		1.03[1]	23.5	0.5	"
- spring	"	9.8 0.9[1]		1.3[1]	29.7	0.6	"
Georges Bank	All taxa	>100g m^{-2}				5.6	Wigley '61
South of Martha's Vinyard	"	295.7				16.6	Wigley & Maurer '75 from Maurer & Leathem '80 Monterey
Bay, Calif.	Barnacles		2100g m^{-2}	1449		699.0	Glynn from Wu and Levings '78
Scotian Shelf (0-90m)	Macrobenthos	24.0[3]				1.3	Mills '80
Grand Banks (0-50m)	"	1455[3]				81.7	Nesis '65
(50-100m)	"	312[3]				17.5	"
US Atl. Cont. Shelf(0-100)	"	4-5[3]				0.2-0.3	Rowe et al. '74
US Mid Atlantic Bight							
(0-50m)	"	266[3]				14.9	Wigley et al. '76
(50-100m)	"	189[3]				10.6	"
Davis Strait-Hudson Strait							
(100-200m)	"	276[3]				15.5	Stewart '83

Table 9 (cont'd)

Geographic Area	Taxon	Standing Crop				Carbon(g)	Authority
		Wet Weight(g)	Dry Weight(g)	AFDW(g)	Energy(KJ)		
Fraser R. estuary	*Macoma balthica*		2.96	2.4 [4]		0.9	McGreer '83
St. Margarets Bay	Macrobenthos				318	6.7	Brawn et al. '68
Isle of Man	"				111-577	2.4-12.1	Jones '56
US Continental Shelf	"				70-3749	1.5-78.6	Wigley & McIntyre '64
St. Margarets Bay	Macrobenthos sand		2.7 [5]			0.9	Hargrave & Peer '73
"	Silt clay		1.9 [5]			0.6	"
"	Sand - mud		4.2 [5]			1.4	"
"	Sand		5.3 [5]			1.8	"
US Outer Continental Shelf	Polychaetes	10-30 [6]		1.3-4.0	29.7-91.4	0.6-1.9	US Outer Continental Shelf Study, Anon.
"	Molluscs	50-100					"
"	Crustacea	<10-50					"
"	Echinoderms	50-300					"
Carmathen Bay, S. Wales	Macrobenthos			45.8			Warwick et al. '78
Grevelingen Estuary	Macrobenthos (*Macoma* comm)			41.3			Wolff & de Wolf '77
Baltic	"			4.3			Cederwall '77
Northumberland Coast	Macrobenthos (*Brissopsis*-*Amphiura* comm)		4.0 [5]			1.3	Buchanan & Warwick '74
Buzzards Bay	Macrobenthos (*Nephtys*-*Yoldia*)		11.9			4.0	Sanders '56
Gulf of St. Lawrence							
- unsorted gravel	Macrobenthos		6.2			2.1	Peer '63
- fine sand	Macrobenthos		21.5			7.2	"
Northern Baltic	Bacteria		2				Ankar '77
" soft bottom	Benthos				260	5.5	"
Coastal Baltic	Macrobenthos	102				5.7	Segerstrale '33
"	"	138.6				7.8	Jarvekulg '70
"	"	137				7.7	Bergh '74
Bothnian Sea	"	163				9.2	Elmgren et al., in press
Open Baltic	"	45				2.5	Shurin '61
"	"	42				2.4	Shurin '62
"	"		41 [5]			13.7	Demel and Mulicki '54

Table 9 (cont'd)

		Standing Crop					
Geographic Area	**Taxon**	**Wet Weight(g)**	**Dry Weight(g)**	**AFDW(g)**	**Energy(KJ)**	**Carbon(g)**	**Authority**
Kiel Bight	Benthos	660 [7]				37.0	Arntz '71
Bothnian Sea	Meiobenthos	65				3.6	Elmgren et al. (in press) from Ankar & Elmgren '76
Cont. Shelf NW Spain	Macrobenthos			2.2	41.3	0.9	Tenore et al. '82
Offshore mud, Northumberland coast	"			3.98	74.7	1.6	Buchanan & Warwick '74
Swedish West Coast	Polychaetes		2 [8]	1.3	30.2 [9]	0.6	Evans '84
"	Meiofauna				12	0.3	"
"	Macrofauna				81	1.7	"
Kiel Bight	Benthos		7.2			2.4	Graf et al. '82
Fangothytten	"				166.9	3.5	Petersen & Curtis '80
Godhaven	"				1717.5	36.0	"
Tut	"				169.5	3.6	"
Lyngmarhabugt	"				288.3	6.0	"
NE English Coast	"			2.0-6.6	37.5-123.9	0.8-2.6	Rees '83
Sea of Japan	Sand dollar community	893				50.1	Ryabushko et al. '82
St. Margarets Bay	Herbivores				503.8	10.6	Miller et al. '71
Georgia salt marsh	*Modiolus*		11.5			4.3	Kuenzler '61
Grevelingen Estuary	Macrobenthos			25.93		10.2	Ankar '77
Tamar estuary-England	Macoma community			13.2		5.2	Warwick & Price '75
Northeast Grand Banks - slope	Macrobenthos		17.7 [5]			5.9	Hutcheson et al. '81 & this study
- shelf	"		47.1 [5]			15.7	"
Southwest Grand Banks	"		23.9 [5]				"
Southeast Grand Banks	"		614.4 [5]				"

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1 Used alchohol preserved wet wt and Lie's (1968) conversion of 0.133.

2 Polychaete 5.462 Kcal $(gAFDW)^{-1}$

3 Wet weight to Kcal = 0.64 (Brawn et al. '68)

4 AFDW = 4.049 Kcal g^{-1} (Gilbert '73)

5 Used dry weight = 3.0x carbon (average of values from Hutcheson et al. '81 and calculations for this report, see table 6)

6 Lie's conversion for polychaetes AFDW = 0.133 wet wt

7 570 gm^{-2} in one large susp. feeding bivalve, *Cyprina islandica*

8 Polychaete DW to AFDW = 0.66 (Athinson & Wacasey '78)

9 4.487 Kcal $(gAFDW)^{-1}$ (Wissing '73)

TABLE 10. ENERGETIC CONVERSION FACTORS

	CONVERSION VALUES (Weights in g, Energy in Kcal)							
Taxon	Wet Wt to Flesh Dry Wt	Wet Wt to AFDW	Flesh Dry Wt to AFDW	Wet Wt to Kcal	Dry Wt to Kcal	AFDW to Kcal	Dry Wt to Carbon	Authority
Zooplankton							0.14	Platt et al. '69
							0.32	Wiebe et al. '75
Benthos general				1.0				Steele '74
				0.6				Mills & Fournier '79
				0.5				Crisp '75
				0.64				Brawn et al. '68
						4.487		Wissing et al. '73
Polychaetes	0.128		0.66		3.604	5.462		Atkinson & Wacasey '76
		0.23						Lappalainen & Kangas '75
		0.133						Maurer & Leathem '80
	0.173		0.90					Ankar & Elmgren '76
				0.663	3.132			Brawn et al. '68
				0.674	3.388			Tyler '73
	0.207				4.789			Thayer et al. '73
Amphipods	0.16-0.17							Fradette & Bourget '80
	0.21							Lappalainen & Kangas '75
	0.21				5.346			Ankar & Elmgren '76
					4.002			Cummins & Wuycheck '71
	0.18		0.60		3.526	5.901		Atkinson & Wacasey '76
				0.448	2.444			Tyler '73
				1.058	3.761			Brawn et al. '68
Isopods	0.22							Lappalainen & Kangas '75
	0.25				4.439			Ankar & Elmgren '76
	0.19				2.697	5.167		Atkinson & Wacasey '76
Mysidacea	0.19							Lappalainen & Kangas '75
Crustacea (minus barnacles)	0.18		0.56		2.969	5.270		Atkinson & Wacasey '76
				0.867	4.175			Tyler '73
				1.154	4.482			Brawn et al. '68
planktonic			0.83		4.803	5.379		Wissing et al. '73
benthic			0.79		3.546	4.277		Wissing et al. '73
Barnacles	0.03	0.02	0.69			5.391		Atkinson & Wacasey '76
						5.0-5.6		Wu & Levings '78
					7.1			Turpayeva & Galperin '80a
	0.06-0.07							Fradette & Bourget '80
Oligochaetes	0.13-0.19				5.290			Ankar & Elmgren '76
Echinoderms								
sea urchin		0.05				5.652		Atkinson & Wacasey '76
general	0.11				2.253			Atkinson & Wacasey '76
	0.17			0.369	2.315			Brawn et al. '68
	0.12							Fradette & Bourget '80
Molluscs	0.10		0.80		4.343	5.418		Atkinson & Wacasey '76
	0.07			0.302	4.213			Tyler '73
	0.12			0.537	4.390			Brawn et al. '68
Bivalves	0.07		0.79		4.285	5.437		Atkinson & Wacasey '76
Gastropods	0.12		0.81		4.400	5.399		Atkinson & Wacasey '76
Bivalves	0.11			0.524	4.671			Brawn et al. '68
Gastropods	0.13			0.550	4.108			Brawn et al. '68
Bivalves	0.09-0.17							Fradette & Bourget '80
Gastropods	0.07							Fradette & Bourget '80
<u>Macoma balthica</u>			0.17		4.254			Ankar '80
"					4.256	4.049		Gilbert '73
"	0.06-0.07							Ankar & Elmgren '76
<u>Mytilus edulis</u>		0.16						Wolff & de Wolf '77
<u>Scobicularia plana</u>						5.197		Gilbert '73
<u>Cardium hauniense</u>	0.07				3.701			Ankar & Elmgren '76
Hydroids	0.18							Fradette & Bourget '78
Nudibranchs	0.25							Fradette & Bourget '78
Flatworms	0.22							Lappalainen & Kangas '75
Nematodes	0.23		0.80					Ankar & Elmgren '76

TABLE 11A. ANNUAL PRODUCTION OF BENTHIC MACROINVERTEBRATES ON SOUTHEAST GRAND BANKS SHELF (STATION 48, HUTCHESON ET AL., 1981). (N = 17 SAMPLES)

	Crustaceans	Polychaetes	Echinoderms	Molluscs	Other	Macrofauna Total	Meiofauna, Oligochaetes, and Nematodes
Formalin preserved wet weight standing crop (g m^{-2})	151.3	9.1	53.6	7115.0	8.5		1.3
Standing crop corrected for preservation (g m^{-2})	174.00	10.47	61.64	8182.25	9.78		1.50
Flesh dry weight (g m^{-2}) (conversion factor bracketed)	34.8(0.20)	1.78(0.17)	3.08(0.05)	572.74(0.07)[1]	1.96(0.2)	614.36	0.3(0.2)
Production							
Dry weight (g $m^{-2}y^{-1}$, P/B bracketed)	104.4(3.)[2]	4.09(2.3)[3]	2.0(0.65)[4]	326.46(0.57)[5]	1.96(1.0)	438.91	
Energy (Kcal m^{-2} y^{-1})	396.72	15.15	4.60	1403.79	7.06		
Carbon (gC m^{-2} y^{-1})	34.8	1.33	0.40	123.14	0.62	160.29	
					Total:	160.29	P/B 0.71

TABLE 11B. ANNUAL PRODUCTION OF BENTHIC MACROINVERTEBRATES ON SOUTHWEST GRAND BANKS SHELF (STATION 33, HUTCHESON ET AL., 1981). (N = 11 SAMPLES)

	Crustaceans	**Polychaetes**	**Echinoderms**	**Molluscs**	**Other**	**Macrofauna Total**	**Meiofauna, Oligochaetes, and Nematodes**
Formalin preserved wet weight standing crop (g m^{-2})	0.7	14.4	202.4	71.0	4.8		1.6
Standing crop corrected for preservation (g m^{-2})	0.81	16.56	232.76	81.65	5.52		1.84
Flesh dry weight (g m^{-2}) (conversion factor bracketed)	0.16(0.20)	2.82(0.17)	11.64(0.05)	8.17(0.10)	1.10(0.2)	23.89	0.37(0.2)
Production							
Dry weight (gm^{-2} y^{-1}, P/B bracketed)	0.48(3)[2]	6.49(2.3)[3]	7.57(0.65)[4]	10.87(1.33)[6]	1.10(1.0)	26.51	
Energy (Kcal m^{-2} y^{-1})	1.82	24.00	17.40	46.72	3.96		
Carbon (gC m^{-2} y^{-1})	0.16	2.11	1.53	4.10	0.35	8.25	
					Total	8.25	P/B 1.11

TABLE 11C. ANNUAL PRODUCTION OF BENTHIC MACROINVERTEBRATES ON NORTHEAST GRAND BANKS SHELF (HIBERNIA STATIONS, HUTCHESON ET AL., 1981). (N = 127 SAMPLES)

	Crustaceans	**Polychaetes**	**Echinoderms**	**Molluscs**	**Other**	**Macrofauna Total**	**Meiofauna, Oligochaetes, and Nematodes**
Formalin preserved wet weight standing crop (g m^{-2})	12.3	8.5	382.9	165.2	7.0		2.3
Standing crop corrected for preservation (g m^{-2})	14.15	9.78	440.34	189.98	8.05		2.65
Flesh dry weight (g m^{-2}) (conversion factor bracketed)	2.83(0.20)	1.66(0.17)	22.02(0.05)	19.0(0.10)	1.61(0.2)	47.12	0.53(0.2)
Production							
Dry weight (gm^{-2} y^{-1}, P/B bracketed)	8.49(3)[2]	3.82(2.3)[3]	14.31(0.65)[4]	25.27(1.33)[6]	1.61(1.0)	53.50	
Energy (Kcal m^{-2} y^{-1})	32.26	14.13	32.92	108.66	5.80	193.77	
Carbon (gC m^{-2} y^{-1})	2.83	1.24	2.89	9.53	0.51	17.00	
					Total	17.00	P/B 1.14

TABLE 11D. ANNUAL PRODUCTION OF BENTHIC MACROINVERTEBRATES ON NORTHEAST GRAND BANKS SLOPE (STATION 3, HUTCHESON ET AL., 1981). (N = 12 SAMPLES)

	Crustaceans	Polychaetes	Echinoderms	Molluscs	Other	Macrofauna Total	Meiofauna, Oligochaetes, and Nematodes
Formalin preserved wet weight standing crop (g m^{-2})	0.7	8.8	70.6	99.4	1.4		0.8
Standing crop corrected for preservation (g m^{-2})	0.81	10.12	81.19	114.31	1.61		0.92
Flesh dry weight (g m^{-2}) (conversion factor bracketed)	0.16(0.20)	1.72(0.17)	4.06(0.05)	11.43(0.10)	0.32(0.2)	17.69	0.18(0.2)
Production							
Dry weight (gm^{-2} y^{-1}, P/B bracketed)	0.48(3)[2]	3.96(2.3)[3]	2.64(0.65)[4]	15.2(1.33)[6]	0.32(1.0)	22.60	
Energy (Kcal m^{-2} y^{-1})	1.82	14.64	6.07	65.37	1.15	89.05	
Carbon (gC m^{-2} y^{-1})	0.16	1.28	0.53	5.73	0.10	7.80	
					Total	7.80	P/B 1.28

[1] Used 0.07 in conversion; determined in Hutcheson et al. (1981) for Mesodesma deauratum which dominated mollusc standing crop.

[2] P/B averaged from Warwick (1980) and Wildish (1984)

[3] P/B averaged from Warwick (1980)

[4] P/B averaged from Robertson (1979)

[5] Used P/B calculated in Hutcheson et al. (1981).

[6] P/B averaged from Warwick (1980)

TABLE 12. RESPIRATION RATES OF BENTHIC ORGANISMS

Location	Organism	T°	Indiv Weight	Standing Crop Kcal	O_2 mL h^{-1} g^{-1}dry	Kcal m^{-2} y^{-1}	gC m^{-2} y^{-1}	Annual Respiration/ Standing Crop	Authority
U.K.	*Mytilus edulis*				0.1-0.3				Widdows '73
St. Margarets Bay	sea urchin	8				178.5	15.7		Miller & Mann '73
U.K. mud flat	*Neanthes virens*			27.7		16.7	1.5	0.60	Kay & Brafield '73
Northern Baltic, muddy	Benthos	5 [8]		62.1		501.9	44.0	8.1 [8]	Ankar '77
Continental Shelf, N.W. Spain	Benthos	20		9.9 [2]		42.0	3.7 [1]	4.2	Tenore et al. '82
Sandy Pt., Virginia	*Glycera dirbranchiata*	25			0.06 [3,4]				Coyer & Mangum '73
Sandy Pt., Virginia	"	7.5			0.08 [3,4]				"
Sandy Pt., Virginia	"	12.5			0.11 [3,4]				"
Sandy Pt., Virginia	"	17.5			0.15 [3,4]				"
Sandy Pt., Virginia	*Amphitrite ornata*	5			0.12 [3,4]				"
Sandy Pt., Virginia	"	10			0.13 [3,3]				"
Sandy Pt., Virginia	"	15			0.17 [3,4]				"
Kiel Bight	*Pectineria koreni*	10			0.38 [5]				Graf et al. '82
Kiel Bight	*Nephtys ciliata*	10			0.23 [5]				"
Kiel Bight	*Macoma balthica*	10			0.07 [5]				"
Kiel Bight	*A. borealis*	10			0.05 [5]				Graf '77 (Graf et al. '82)
Kiel Bight	macrofauna	10				87.2	7.7		Graf et al. '82
Kiel Bight	benthos	10				4144.4	363.5		"
Chesapeake Bay	*Mya arenaria*	1			0.43-0.82				Kennedy & Mihursky '72
Chesapeake Bay	"	10			0.67-1.90				"
Chesapeake Bay	"	20			1.90-3.48				"
Chesapeake Bay	*Macoma balthica*	4			0.29				"
Chesapeake Bay	"	10			0.46				"
Chesapeake Bay	"	20			0.62				"
Chesapeake Bay	*Mulinia lateralis*	2			0.14				"
Chesapeake Bay	"	10			0.82				"
New England	*Glycera dibranchiata*	23	3g		0.93-1.5 [6]				Mangum & Miyamoto '70
Sea of Japan	Sand dollar	17.6		9.8		147.9 [7]	13.0	1.32	Ryabushko et al. '82
	Sand dollar community	17.6		37.7		528.1 [2,7]	46.3	1.23	"
Georgia Salt Marsh	*Modiolus modiolus*					39	3.4		Kuenzler '61

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[1] 1 mL O_2 = 4.8 cal

[2] average caloric value of benthos 4.487 Kcal (g AFDW)$^{-1}$ (Wissing '73)

[3] used wet weight/dry weight conversion of 0.20 from Tyler '73

[4] used geometric mean of active and resting metabolism

[5] 1 mL O_2 = 20.1 J

[6] polychaete weight to dry weight conversion = 0.20

[7] sand dollar caloric calculated value assuming AFDW = 0.05 wet weight and caloric content is 5.652 Kcal (g AFDW)$^{-1}$ (Atkinson & Wacasey '78 for sea urchin)

[8] Value for entire benthic community, i.e. macro-, micro- and meiobenthos

TABLE 13. COMPONENTS OF BENTHIC BIOMASS (B), RESPIRATION (R) AND PRODUCTION (P).

Location – Community	Bacteria %				Meiofauna %				Macrofauna %				Authority
	B	R	P	P/R	B	R	P	P/R	B	R	P	P/B	
Mediterranean – sandy mud					70*				20*				Gerlach '78
Scotland – 5 m					50*				70*				"
North Sea – 35 m, fine sand					35*				180*				"
Baltic – 9-50 m					60*				210*				"
Baltic – 30 m, silty sand	20.5		81.9	21	14.2		8.6	10	65.2		9.4	2	"
Northern Baltic	15.4	46.7	76.9	30	7.7	13.3	7.7	4.6	77.9	40.0	15.4	1.2	Ankar '77
Southern Baltic – 6 m, sand					1*				6*				Arlt '73
Gulf of Finland					1*				3*				Elmgren & Ganning '74
Bothnian Sea					1*				10*				"
Bothnian Bay					2.5*				1*				"
Northern Baltic – soft bottom					1*				8*				Ankar & Elmgren '76

* Relative units, bacteria not estimated

TABLE 14. CONSUMPTION RATES OF ORGANISMS FEEDING ON BENTHOS

Consumer	Food	Location	Annual Consumption Rate	Gross Production Efficiency[1]	Consumption as % of Benthic Production	Authority
Carcinus maenas	animals & detritus	Western Sweden	0.5 gC m^{-2}	30%	5%	Klein Breteler '76
Crangon crangon	benthos	Western Sweden	24.4 gC m^{-2} [2]	32-45%	3%	Meixner '68 from Evans '84
Crangon crangon	benthos	Western Sweden	2.0 gC m^{-2}			Evans '84
Plaice	benthos	Western Sweden	0.4 gC m^{-2}		15%	Evans '84
Benthos	detritus & other benthos	Western Sweden	91.1 gC m^{-2}			Evans '84
Epibenthos	benthos	Western Sweden	2.6 gC m^{-2}		24-34%	Evans '84
Fish	benthic invertebrates	Ythan estuary, Scotland			54% [3]	Baird & Milne '81
Herbivores	macroalgae	St. Margarets Bay	58.2 gC m^{-2} y^{-1}	14%	9%	Miller et al. '71

[1] production as a percentage of consumption

[2] energy content of *Crangon crangon* = 17.6 KJ $(g\ dry\ wt)^{-1}$

[3] the highest value ever reported (Evans '84)

TABLE 15. ENERGY BUDGETS OF BENTHIC COMMUNITIES

Consumer Group	Producer Group	Community Type	Location	Population Consumption gC m^{-2} y^{-1}	Energy Budget Parameters (% of Annual Consumption)				Energy Flow[5] gC m^{-2} y^{-1}	Authority
					P(G)[1]	R^2	F^3	A^4		
Benthos (barnacles)	Phytoplankton	Rocky Intertidal	BC coast	600.4	48.4	49.0	2.6	97.4	585	Wu & Levings '78
Macrofauna	Phytoplankton & Detritus	Middle Atlantic Shelf	Middle Atlantic Shelf	20						Walsh '81
Benthos (barnacles)	"	Intertidal Barnacles (1st 30 days)	Sea of Azov						17737	Turpayeva & Galperin '80
Crabs			Black Sea						23.9-16.2	Abolmasova '76
Macoma balthica	Detritus & sediments							70		Budnova '72, '74
Portlandia arclica	"							50		Budnova '72, '74
Holothurian	"							22		Yingst '76
Orchestia bottae	"							37.8		Sushchenya '68
Mysis relicta	Daphnia							52-87		Lasenby & Langlord '73
Idotea balthica	Animals, Detritus & Algae			0.015[6]				28-76		Tsikhon-Lukanina '70
Sphaerosoma pulchellum	"			0.00079[6]						"
Strongylocentrotus droebachiensis	Macroalgae	Rocky Intertidal		978	7.0	25.0	68	62	606	Miller & Mann '73
"	"	"		32.8	21.8	78.2		61	20	"
Scrobicularia plana	Detritus, benthic microalgae	Tidal flat		41.9	27.2	102.1		54	22.8	Hughes '70
Intertidal gastropods	Scrapings	Rocky Intertidal		8.3-93.9				39	3.3-32	Hughes '71b
"	"	"		8.2-93.9				70	5.8-65.7	"
Neanthes virens	Benthos	Mudflat		6.6	70.9	26.1	17.6	85	5.6	Kay & Brafield '73
Fish	Benthos	Soft bottom		2.1						Arntz & Brunswig '76
Fish (plaice)	Benthos	Wadden Sea		2.3						deVlas '79
Fish (flounder)	Benthos	"		0.3						"
Meiofauna	Detritus							70		Hargrave '70; Kofoed '75
Macrofauna	Animals							77-85		Kay & Brafield '73
Macrofauna	Detritus							29		Tenore & Gopalan '74
Epibenthic preds	Polychaetes			0.2						Evans '84
"	Benthos			0.4[7]						"
Meiofauna	Microfauna	Epibenthic	W. Sweden	14.8	15.6[8]	54.4[8]	30.0[8]			"
Macrofauna	Micro - Meiofauna	"	"	91.1	13.3[8]	40.0[8]	46.7[8]			"
Epibenthos	Benthos	"	"	2.6	27.6[8]	35.1[8]	36.6[8]			"

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[1] Production of body tissue, eggs and shell (% of consumption)
[2] Respiration (% of consumption)
[3] Feces production (% of consumption)
[4] Assimilation (% of consumption)
[5] Energy flow = carbon assimilation by population
[6] gC $animal^{-1}$ y^{-1}
[7] Used DW to AFDW of polychaetes (0.9) (Ankar & Elmgren '78)
[8] As % of consumption, net of A

TABLE 16. ASSIMILATION EFFICIENCES OF MACROBENTHOS

Consumer Group	Producer Group	Community Type	Location	Assimilation Efficiency (%)[1]	Authority
Benthos (barnacles)	Phytoplankton	Rocky/intertidal	Pacific Coast	92.5%	Wu & Levings '78
Sea urchins	Macroalgae	"	Atlantic Coast	62.0%	Miller & Mann '73
Macro & meiobenthos	Bacteria	Soft bottom	Northern Baltic	80.0%[2]	Ankar '77
"	Dead planktonic organic matter	"	"	70.0%[2]	"
"	Dead organic matter	"	"	10.0%[2]	"
Fish	Macrobenthos	"	"	90.0%	"

[1] Amount assimilated as percentage of amount consumed.

[2] Estimate only, used in energy budget.

TABLE 17. BENTHIC INVERTEBRATE FEEDING RATES (% BODY WT DAY^{-1})

Consumer	Food	Feeding Rate %	Authority
Dexamine spinosa (amphipod)	diatoms	17-200	Greze '63
Idotea balthica (isopod)	normal animal plant & detrital foods	45-140	Tsikhon & Lukanina '70
Idotea balthica	-	19-239	Sushchenya & Khmeleva '69
Orchestia bottae	-	18-180	"
Idotea balthica	algae	24-32	de la Cruz '63
Sea stars	animal prey	0.09-1.91	Hatanaka & Kosaka '59

TABLE 18. FECAL PRODUCTION RATES

Consumer Group	Producer Group	Community type	Location	Fecal Production (Unit Body Wt)$^{-1}$	Fecal Production (m^{-2})	% Body Wt Day^{-1}	Authority
Benthos (barnacles)	Phytoplankton	Rocky intertidal	BC Coast	0.25-170 mg dry body wt^{-1} mo^{-1}			Wu & Levings '78
Spionids - *Streblospio benedicti*	Detritus-meiobenthos			12-19 mg h^{-1} worm^{-1}			Dauer et al. '81
Paraprionospio pinnata							
- small				40-52 "			"
- large				91-233 "			"
Polydora ligni				35-66 "			"
Spio setosa				7-20 "			"
Scolecolepides viridis							
- small				59-177 "			"
- large				99-207 "			"
Spiophanes bombyx				4-14 "			"
Pectinarea	Deposits					7500	Gordon '66
Amphitrite	"					566	Rhoads '67
Cymenella torquata	"					2550	"
Nereis diversicolor	"					1004-2046	Vel'tishcheva & Karzinkin '70
Abarenicola pacifica	Sediment					180	Hobson '71
A. claparedi	"					550	Hobson '67
Arenicola grubi	"					125-317	Kiseleva & Vityuk '70
A. marina	"					723	Jacobsen '67
Yoldia limatula	"					1800	Rhoads '63
Scrobicularia plana	"					11-39	Hughes '69
Tegula funebralis	Algae					3.2	Paine '71
Susp. feeding molluscs	Seston					2-34	Haven & Morales-Alamo from Conover '78
Neanthes virens (carnivore)	*Nephtys hombergi*	Mud flat			1.0gC m^{-2} y^{-1}		Tenore & Gopalan '74
Arenicola marina (deposit feeder)	Sand fauna					1000	Gordon et al. '78

TABLE 19. ECOLOGICAL TRANSFER EFFICIENCIES

Consumer Group	Producer Group	Community Type	Location	Transfer Efficiency[1] %	Gross Production Efficiency[2] %	Gross Growth Efficiency[3] %	Producer Productivity gC $m^{-2}y^{-1}$	Consumer Productivity gC $m^{-2}y^{-1}$	Authority
Benthos (Barnacles)	Phytoplankton	Rocky, intertidal	Pacific Coast	23.0					Wu & Levings '78
Macrobenthos	Phytoplankton	Shallow, soft bottom	Baltic	3.7			150.0	4.6	Ankar '77
Fish (groundfish)	Benthos	Muddy, soft bottom	N. Baltic	3.0			4.6	0.1	"
Macrobenthos	Phytoplankton	Soft bottom	North Sea	6.0			75.5	4.2	Steele '74
Fish	Benthos	Soft bottom	North Sea	5.0			4.2	0.2	"
Macrobenthos	Phytoplankton	Soft bottom	Kiel Bay	4.8			192.9	0.2	Arntz & Brunswig '78
Fish	Benthos	Soft bottom	Kiel Bay	6.5			9.2	0.6	"
Molluscs	*Spartina* & *Zostera*	Shallow, subtidal	Nova Scotia	4.7					Burke & Mann '74
Crangon crangon	Benthos	Soft bottom	Sweden		39				Meixner '68
Macrobenthos	Bacteria & meiofauna	Soft bottom	Shelves		10-30				Pace et al. '84
Macrobenthos	Bacteria & meiofauna	Grevelingen estuary	Netherlands	5-8					Wolf & deWolf '77
Sea urchins	Macroalgae	St. Margarets Bay	Nova Scotia		4-13				Miller & Mann '73
Benthic invertebrate	Micro & meiodetritus	Shelf	General						Pomeroy '79
Nereis diversicolor	Animals					14-43			Ivleva from Pomeroy '
Asterias	Animals					55			Hempel '70
Herbivores	Macroalgae	Intertidal	Nova Scotia	1.3	9		614.0	8.2	Miller et al. '71
Modiolus	Phytoplankton	Salt marsh	Georgia			25			Kuenzler '61
Epibenthos	Benthos			5.8	28		12.1	0.7	Evans '84

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[1] Ratio of production in given tropic level to production in tropic level of food items

[2] Production as percentage of consumption

[3] Growth as a percentage of total consumption

TABLE 20. ANNUAL ENERGY BUDGETS FOR THE SHALLOW WATER COMMUNITY IN KVARNBUKTEN BAY 1976-1977, EXPRESSED IN gC m^{-2} y^{-1} (BIOMASS VALUES IN gC m^{-2}) (FROM EVANS, 1984)

	Consumption (C)		Production (P)		Respiration (R)		Excretion (F)		Mean Biomass (B)	
	1976	1977	1976	1977	1976	1977	1976	1977	1976	1977
Benthic Community:										
Meiofauna	14.85	14.85	2.31	2.31	8.09	8.09	4.45	4.45	0.25	0.25
Macrofauna:										
Polychaetes	43.81	41.31	6.01	4.47	15.90	16.17	21.88	20.64	0.95	0.65
Bivalves	0.97	8.90	0.13	0.57	0.46	2.25	0.38	6.09	0.02	0.46
Crustaceans	4.62	10.52	0.84	1.62	1.93	4.70	1.85	4.22	0.19	0.36
Others	24.42	18.23	3.40	2.58	8.82	6.53	12.20	9.11	0.32	0.23
Total	88.67	93.81	12.68	11.55	35.20	37.74	40.76	44.52	1.72	1.70
Epibenthic Community:										
Crangon crangon (brown shrimp)	1.66	2.37	0.50	0.57	0.50	0.78	0.65	1.03	-	-
Pleuronectes platessa (plaice)	0.34	0.48	0.08	0.15	0.19	0.23	0.06	0.11	-	-
Pomatoschistus minutus (goby)	0.15	0.17	0.04	0.08	0.08	0.06	0.02	0.02	-	-
Total	2.14	3.02	0.63	0.80	0.78	1.07	0.74	1.16	-	-

TABLE 21. ANNUAL PRODUCTION OF MACROBENTHOS (PRODUCTION IN DRY WEIGHT UNLESS OTHERWISE STATED) (FROM WARWICK, 1980)

Conversions: Kcal = 4.184 KJ
Kcal = 0.0877 gC

Species	Production m^{-2} y^{-1}	P/B	Production gC m^{-2} y^{-1}	Max. Age Yrs	Locality	Reference
Nephtys incisa	9.34 g	2.16	2.9*	3	Long Island Sound, USA 4-30 m	Sanders, 1956
Cistenoides gouldii	1.70 g	1.94	0.5*	2	"	"
Yoldia limatula	3.21 g	2.28	1.2*	2	"	"
Pandora gouldiana	6.13 g	1.99	2.3*	2	"	"
Moira atropos	2.52 g	0.70	1.0**	6	Biscayne Bay, Fla, USA 3 m	Moore and Lopez, 1966
Tagelus divisus	21.0 g	1.78	7.9*	2	Biscayne Bay, Fla, USA L.W.S.	Fraser, 1967
Ampharete acutifrons	0.719 g (wet)	4.58	0.3*	1	Long Island Sound, USA 9-17 m	Richards and Riley, 1967
Neomysis americana	36.2 mg	3.66	<0.1**	1?	"	"
Crangon septemspinosa	0.519 g	3.82	0.2***	3	"	"
Asterias forbesi	4.52 g	2.64	1.0***	3	"	"
Tellia martinicensis	0.23 g	2.4	0.1*	2	Biscayne Bay, Fla, USA 3 m	Penzias, 1969
Chione cancellata	8.9 g	0.42	3.3*	7	Biscayne Bay, Fla, USA M.L.W.S.	Moore and Lopez, 1969
Dosinia elegans	0.13 g	1.25	<0.1*	2	Biscayne Bay, Fla, USA 3 m	Moore and Lopez, 1970
Pectinaria hyperborea	10.6 g	4.6	3.4*	2	St. Margaret's Bay, NS 60 m	Peer, 1970
Scrobicularia plana	60 Kcal	0.29	5.3	7?	North Wales, Lower shore	Hughes, 1970
" "	13.3 Kcal	0.67	1.2	4	North Wales, Upper shore	"
Anodontia alba	14.09 g	1.43	5.3*	4+(?)	Biscayne Bay, Fla, USA Low water	Moore and Lopez, 1972
Strongylocentrotus droebachiensis	401.0 Kcal	0.80	35.2	6	St. Margaret's Bay, NS Intertidal	Miller and Mann, 1973
Neanthes virens	45.2 Kcal	1.62	0.4	3	Thames estuary, UK Intertidal	Kay and Brafield, 1973

Table 21 (cont'd)

Species	**Production m^{-2} y^{-1}**	**P/B**	**Production gC m^{-2} y^{-1}**	**Max. Age Yrs**	**Locality**	**Reference**
Ammontrypane aulogaster	359 mg	2.08	0.1*	?	Northumberland, UK 80 m	Buchanan and Warwick, 1974
Heteromastus filiformis	297 mg	1.01	0.1*	2	"	"
Spiophanes kroyeri	196 mg	1.40	<0.1*	3	"	"
Glycera rouxi	192 mg	0.37	<0.1*	5	"	"
Calocaris macandreae	142 mg	0.12	<0.1*	9.5	"	"
Abra nitida	118 mg	1.11	<0.1*	3	"	"
Lumbrineris fragilis	78 mg	1.34	<0.1*	3	"	"
Chaetozone setosa	50 mg	1.28	<0.1*	3	"	"
Brissopsis lyrifera	108 mg	0.30		4	"	"
Mya arenaria	11.6 g	2.54	4.4*	3	Petpeswick Inlet, Canada Intertidal	Burke and Mann, 1974
Macoma balthica	1.93 g	1.53	0.7*	3	"	"
Littorina saxatilis	3.25 g	4.11	1.2*	1	"	"
Macoma balthica	10.07 g	2.07	3.8*	6	Ythan Estuary, Scotland Intertidal	Chambers and Milne, 1975
Nephtys hombergi	7.34 g	1.9	2.3*	3	Lynher Estuary, UK Intertidal	Warwick and Price, 1975
Ampharete acutifrons	2.32 g	5.5	0.7*	1	"	"
Mya arenaria	2.66 g	0.5	0.8*	8	"	"
Scrobicularia plana	0.48 g	0.2	0.2*	9	"	"
Macoma balthica	0.31 g	0.9	0.1*	6	"	"
Cerastoderma edule	0.21 g	0.2	0.1*	7	"	"
Ampelisca brevicornis	4.26 g (wet)	3.95	0.2*	1.25	Helgoland Bight, 28 m	Klein et al., 1975
" "	2.43 g (wet)	3.68	0.1*	1.25	"	"
Pectinaria californiensis	2.02 gC	5.3	2.0	1.2	Puget Sound, Wash., USA 34 m	Nichols, 1975
" "	2.798 gC	3.3	2.8	2.1	Puget Sound, USA, 203 m	"
" "	3.471 gC	4.1	3.5	1.8	Puget Sound, USA, 254 m	"
" "	1.386 gC	5.5	1.4	1.9	Puget Sound, USA, 207 m	"
" "	4.816 gC	3.4	4.8	2.4	Puget Sound, USA, 71 m	"

Table 21 (cont'd)

Species	**Production** m^{-2} y^{-1}	**P/B**	**Production** gC m^{-2} y^{-1}	**Max. Age Yrs**	**Locality**	**Reference**
Cerastoderma edule	29.25 g	1.59	11.0*	5	Southhampton Water, UK Intertidal	Hibbert, 1976
" "	71.36 g	1.10	26.8*	5	"	"
" "	46.44 g	2.61	17.5*	5	"	"
Mercenaria mercenaria	3.99 g	0.52	1.5*	8	"	"
" "	14.00 g	0.28	5.3*	8	"	"
" "	6.19 g	0.17	2.3*	9	"	"
Venerupis aurea	0.70 g	1.11	0.3*	5	"	"
" "	1.25 g	1.10	0.5*	5	"	"
Crassostrea virginica	3828 Kcal	1.87	335.7	?	South Carolina, USA Intertidal	Dame, 1976
Littorina littorea	6.13 g	0.61	2.3*	?	Grevelingen Estuary, Netherlands, Intertidal	Wolff and de Wolf, 1977
Hydrobia ulvae	7.23 g	1.78	2.7*	1	"	"
" "	8.80 g	1.24	3.3*	1	"	"
" "	12.79 g	1.36	4.8*	2	"	"
Cardium edule	10.32 g	0.69	3.8*	3.5	"	"
" "	119.82 g	2.56	44.9*	3.5	"	"
" "	51.76 g	1.13	0.7*	3.5	"	"
Macoma balthica	3.40 g	1.93	1.3*	8.1	"	"
" "	0.95 g	1.00	0.4*	8.1	"	"
" "	0.07 g	0.30	<0.1*	8.1	"	"
" "	-0.74 g	-0.25	<0.1*	8.1	"	"
Arenicola marina	3.79 g	1.14	1.2*	3	"	"
" "	6.26 g	0.72	2.0*	3	"	"
" "	3.32 g	0.99	1.0*	3	"	"
Pontoporeia affinis	3.17 g	1.90	1.0*	3	North Baltic, 64 m	Cederwall, 1977
Pontoporeia femorata	3.03 g	1.43	0.9*	3	"	"
Harmothoe sarsi	0.23 g	1.99	0.1*	3	"	"
Pharus legumen	16.12 g	0.56	5.1*	6	Carmarthen Bay, S. Wales 13.5 m	Warwick et al., 1978

Table 21 (cont'd)

Species	**Production** $m^{-2}\ y^{-1}$	**P/B**	**Production** $gC\ m^{-2}\ y^{-1}$	**Max. Age Yrs**	**Locality**	**Reference**
Spiophanes bombyx	3.35 g	4.86	1.1*	?	"	"
Ensis siliqua	1.37 g	0.27	0.5*	10	"	"
Donax vittatus	0.72 g	2.10	0.3*	2.5	"	"
Magelona papillicornis	0.69 g	1.10	0.2*	3	"	"
Venus striatula	0.62 g	0.41	0.2	10	"	"
Ophiura texturata	0.46 g	0.68		3	"	"
Tellina fabula	0.29 g	0.90	0.1*	6	"	"
Glycera alba	0.28 g	0.97	0.1*	3	"	"
Sigalion mathildae	0.17 g	0.44	<0.1*	?	"	"
Tharyx marioni	0.015 g	0.79	<0.1*	2	"	"
Astropecten irregularis	0.0004 g	0.005	<0.1*	?	"	"
Echinocardium cordatum	-0.012 g	-0.02		3	"	"
Harmothoe sarsi	0.376 g	2.4	0.1*	2	Gulf of Finland, 33-35 m	Sarvais (in press)
" "	0.401 g	3.1	0.1*	3	"	"

* conversion from Atkinson and Wacasey (1978)

** conversion from Tyler (1973)

*** conversion from Brawn et al. (1968)

PART 2

FIELD STUDY

INTRODUCTION

The Grand Banks Ecosystem Modelling Project has been synthesizing data from the Grand Banks and other continental shelf systems to serve as the basis of a model of that important fishery area. One area in which original data are lacking for the Grand Banks is benthic-pelagic coupling. Indeed, rate estimates and process descriptions for nutrient and carbon exchange between the sediments and overlying waters are few for offshore continental shelf and slope waters. The studies summarized in Part 1 reveal that most work has been at water depths less than 50 m. Some work (e.g., Smith, 1978; Smith et al., 1978) has been done at deepsea depths but those results are not applicable to the Grand Banks.

In the absence of actual data for the Grand Banks and in order to provide data that can serve as a reference point for extrapolations drawn from the literature, a field project on the Grand Banks was conducted from March 27 to April 2, 1985. The objectives of the study were to: determine flux rates for nitrogen and phosphorus between water and sediment; determine the oxygen demand of the sediments; determine the sediment macrofaunal, meiofaunal and bacterial standing crops where the rate measurements were taken; and assess the spatial variability in these variables.

MATERIALS AND METHODS

The field program was conducted on cruise number 27 of the RV Wilfred Templeman. Four stations on the northeastern and eastern portion of the Grand Banks were occupied. The station locations and a summary of the sampling conducted are presented in Table 22. Stations were chosen to be representative of the Northern Grand Banks compartment of the model and the biologically active shelf break region.

Grab samples for standing crop determination were taken with a 0.1 m^2 Van Veen bottom grab. Between 5 and 15 replicate samaples were taken at each station. An approximately 500 g sediment subsample was removed from each sample, bagged and frozen for later determination of total carbon and nitrogen content and grain size analysis. Two replicate cores of 67 mm diamter were removed for meiofaunal and bacterial analysis from up to 5 of the replicate grabs at each station. The macrofaunal samples were then washed through a 0.64 cm mesh wire sieve, and material which passed through was collected in a 20 L bucket. This sample was then elutriated through a 0.42 mesh size sieve ten times with a vigorous wash of seawater. All fauna collected on both meshes were retained and preserved with 10% formalin buffered with marble chips. The efficiency of this procedure for these types of samples had been previously checked by Hutcheson et al. (1981). The elutriated sediment was given a final short visual examination for heavier organisms after which it was discarded.

The core samples were placed in containers and covered with a 2% magnesium chloride solution in distilled water. The samples were left standing for 1 hour and then sufficient glutaraldehyde added to give a 5% solution. Sample bottles were capped and refrigerated at approximately 4°C within 4 weeks of sampling. Surficial subsamples (approx. 1-2 mL) were removed from these samples and frozen for later determination of bacterial biomass.

Sediment samples for grain size analysis have been given to the Atlantic Geoscience Center of the Bedford Institute of Oceanography.

Total carbon and nitrogen were determined with a Perkin-Elmer CHN

Analyzer Model 240B. The sediment was dried at 60°C for 40 hours. Subsamples (<1 g) were weighed into preweighed scintillation vials. The sediment was acidified with 3 mL of 1N HCl to remove inorganic carbon. The vials were placed in an oven at 60°C under vacuum for 92 hours, then reweighed. The total C and N remaining in the sample was determined on the CHN analyzer. Subsamples of approximately 100 mg were placed in ashed platinum boats, weighed and combusted. Peak heights were compared to those obtained for the standard cyclohexanone-2, 4-diphenylhydrazone (51.79% C, 20.14% N). The amount of C or N in each sample was calculated using the formula:

$$\text{ug g}^{-1} = \frac{[\text{Peak Ht of Sample (uV)} - \text{Peak Ht of Blank (uV)}] \times \frac{\text{ug}}{\text{uV}} \text{ (from Standard)}}{\text{Wt of Acidified Sample (g)} \times \frac{\text{Wt Before Acifification}}{\text{Wt After Acifification}}}$$

A 0.15 m^2 Van Veen grab was used at Stations 6 and 8 to obtain sediment samples for onboard determination of nutrient flux and oxygen demand of the sediments. Ports in the top of the grab were opened on deck and 67 mm diameter acrylic core tubes pushed all the way into the sediment. The sediment core was extracted intact with any overlying water, the bottom capped and the top temporarily sealed with a cap. Twelve replicate cores were obtained by repetitive sampling with the grab. The cores were flushed with 1-2 volumes of filtered (1.2 um glass fiber filter) seawater at ambient temperature. They were then capped to exclude any air bubbles. Half the caps at each station had a freely pivoted magnetic stirring bar hanging from them. The sealed cores were placed in a water bath with ambient temperature seawater at 0-2°C pumped through continuously. The cores were arranged in a circle in the water bath and magnets on the end of a rotating arm turned the stirring bars with each pass, about once every second. The bath was kept covered in near darkness. Controls were also run, consisting of 2 stoppered 300 mL BOD bottles filled with the filtered seawater. At the start of incubations, triplicate 50 mL water samples were taken in disposable syringes from the filtered seawater stock for dissolved oxygen concentration determination. A fourth 50 mL sample was taken in another syringe. An in-line Gelman filter (12 mm diameter) assembly containing a 0.8 um glass fiber filter was attached to the tip of the syringe. Several millilitres of water were expelled from the syringe to wash the filter and then triplicate water samples of approximately 2 mL each were dispensed into 2 mL polystyrene conical beakers with snap top closures. These samples were used for nitrate, nitrite and phosphate analysis. Triplicate 10 mL water samples for ammonia analysis were dispensed into glass scintillation vials with screw caps. The vials had been previously rinsed with deionized water, capped, transported and stored on the ship in a sealed polyethylene bag. A 0.4 mL portion of phenol solution was added to each sample. The caps were closed tightly and samples kept cool and in the dark until they were analyzed ashore. The phenol hypochlorite method for ammonia was used (Strickland and Parsons, 1972). The solution of phenol in ethanol had been prepared ashore and stored in separate tightly capped containers. A separate container was opened at sea for each series of samples. The other nutrient samples were kept frozen until analysis ashore when the automated methods of Strickland and Parsons (1972) with a Technicon Autoanalyzer were used.

Dissolved oxygen concentrations were determined with a micro-Winkler titration using an adaption of methods given in Strickland and Parsons (1972). The method was adapted for 50 mL water samples taken in disposable plastic syringes. The syringes served as fixation chambers. The volume of each syringe was determined by repeatedly weighing distilled water drawn into the syringe. A small pin stop drilled through the upper part of the syringe bore stopped the barrel as it was withdrawn at the same place each time. The variation in the calibrated volume was 0.06% standard error of the mean (n=6). The method used is presented in Appendix A.

After incubation periods of 85-102 hours, triplicate water samples for dissolved oxygen, nitrate, nitrite, phosphate and ammonia were withdrawn by syringe from each core. Flux rates of each of these variables were calculated from initial and final concentration values by:

$$\left[\frac{F_E - I_C}{T_E} - \frac{F_C - I_C}{T_C}\right] \times \frac{V}{A}$$

where F_E = final experimental concentration
I_C = initial control (and experimental)
F_C = final control
T_E = experimental incubation time
T_C = control incubation time
V = water volume in core (mL)
A = core cross-sectional area (m^2).

The sign convention is that negative flux rates represent consumption by the sediments and positive values represent release.

RESULTS

The numbers of samples taken and their disposition are listed in Table 23. Quantitative sediment bacterial, macro- and meiobenthos samples were not analyzed at the Scientific Authority's request. The availability and locations of these samples have been made known to Dr. Peter Schwinghammer of the Marine Ecology Laboratory.

The oxygen consumption and nutrient flux rates of individual relicate samples from Stations 6 and 8 are presented in Tables 24 and 25. The means of these values for stirred and unstirred cores are presented in Table 26. Differences between stirred and unstirred cores were not major although they have not been tested statistically.

Sediment oxygen flux rates were very low and ranged between 6.0 mg O_2 consumed m^{-2} h^{-1} and 3.3 mg O_2 released m^{-2} h^{-1}. Values for Station 6 generally indicated slight release of oxygen (mean value 1.95 mg O_2 m^{-2} h^{-1}). Values at Station 8 were closer to zero.

Nitrite plus nitrate were released very slowly by the sediments at Stations 6 and 8 at mean rates of 2.1 and 4.9 ug-at N m^{-2} h^{-1} respectively. Nitrate accounted for almost all of the nitrogen flux. The mean flux rate at Station 8 was approximately double that at Station 6.

Ammonia flux rates were quite low. The mean trend was for consumption of ammonia by the sediments at Station 6 (-0.5 ug at N m^{-2} h^{-1}), and almost no activity at Station 8 (-0.05 ug at N m^{-2} h^{-1}).

Phosphate was consumed by the sediments at both stations at rates generally less than 1 ug at P m^{-2} h^{-1}. The mean rate at Station 6 was double that at Station 8. Phosphate measurements showed the most variability of all the nutrients between the three replicates for each core.

Total organic carbon and nitrogen values for sediments are presented in Table 27. Organic nitrogen contents ranged from 52-136 ug C g^{-1}, carbon from 219-723 ug N g^{-1} and the C/N ratio from 4.11 to 6.02. Station 7 had the highest organic carbon and nitrogen concentrations in sediments. **Overall means were 86.5 ug N g^{-1} for organic nitrogen, 415.2 ug C g^{-1} for organic carbon and 5.16 for the C/N ratio.**

Bottom photographs at Stations 5,6, and 8 are shown in Figures 4, 5 and 6. Medium sands containing some fine pebbles appeared to predominate at Station 5. Macrofauna visible include sand dollars and an unidentified hydroid-like form which was also obtained in grab samples. Station 6 was primarily cobble which is characteristic of the northeastern Grand Bank. The cobble pavement was not sampled by the grabs and samples obtained from this station were from areas containing sand with cobble and gravel mixed in. Sea urchins were the predominant epifaunal species observed in photographs. The bottom at Station 8 appeared to be a silty sand with large numbers of epifauna. Sand dollars, brittle stars and tubes probably cast by the polychaete worm Onuphis sp. are the most easily identifiable forms.

DISCUSSION

Oxygen flux on the Grand Banks in late March was very low and at the low end of the range of values for other shelf systems (Figure 1). The slight production of oxygen at the two Grand Banks stations may have been an experimental artifact due to the release of oxygen from interstitial waters associated with the slight warming of core samples from *in situ* temperatures of approximately -1.7°C to incubation temperatures onboard ship of 0-2°C.

Nitrate was the primary species involved in nitrogen flux between sediments and water. It was released at rates of about 2-5 ug-at N m^{-2} hr^{-1}. These rates are within the range of previously reported values for shallower water marine systems. This situation contrasts with that in other areas where ammonia release may be the predominant form of nitrogen cycling (see Part 1, Results - Nutrients).

The flux of phosphate was into the sediments at an average rate of less than <1 ug-at P m^{-2} h^{-1}. This direction of flux and low flux rate are in agreement with other observations on phosphate flux summarized in Part 1.

TABLE 22. STATION PARAMETERS FOR GRAND BANKS BENTHIC SAMPLING CRUISE. R.V.W. TEMPLEMAN CRUISE 27. MARCH/APRIL 1985

Station Number	Position		Bottom Depths (m)	Near Bottom Water Temperature °C (Depth Measured)
	Latitude	Longitude		
5	46°59.9'N	50°0.0'W	86	-1.65 (83.7m)
6	47°0.0'N	48°59.9'W	91	-1.68 (82.7m)
7	47°0.0'N	48°15.0'W	123	-1.64 (111.0m)
8	46°27.8'N	47°27.8'W	200	-1.21 (192.6m)

TABLE 23. NUMBER OF BENTHIC SAMPLES TAKEN FOR ANALYSIS AT EACH STATION

Station Number	Grain Size	C/N	Macrofauna	Meiofauna	Bacteria	Oxygen Demand	Nutrient Flux	Bottom Photos	TOC
5	5	5	5	6	5	0	0	no	1
6	15	13	15	10	15	12	12	no	0
7	5	5	5	4	5	0	0	no	0
8	15	15	15	12	15	12	12	yes	2
Sample Status	At AGC/BIO	Done	Stored at Seakem & F&O, St. John's	Stored at BIO	Stored at Seakem	Done	Done	Negatives at Seakem	

TABLE 24. STATION 6. FLUX RATES OF OXYGEN AND NUTRIENTS BETWEEN WATER AND GRAND BANKS SEDIMENTS IN INCUBATED CORE TUBES. NEGATIVE VALUES = CONSUMPTION BY SEDIMENTS. POSITIVE = RELEASE. S = STIRRED, U = UNSTIRRED. REPLICATE VALUES, MEANS ± 1 STANDARD ERROR OF MEAN SHOWN.

Core	O_2	$NO_2 + NO_3$	NO_2	NO_3	NH_3	PO_4
	mg m^{-2} h^{-1}			ug at m^{-2} h^{-1}		
1S	1.147	6.124	-0.099	6.223	-0.045	-0.201
	3.270	4.818	-0.120	4.938	-0.015	-0.375
	1.580	5.253	-0.120	5.374	0.037	-0.331
	1.999±0.648	5.398±0.384	-0.113±0.007	5.511±0.377	-0.007±0.024	-0.302±0.052
1U	0.376	2.033	-0.012	2.045	-0.020	-1.630
	0.837	3.592	0.055	3.537	-0.080	-1.274
	-	2.924	-0.034	2.958	-0.046	-0.873
	0.607±0.231	2.850±0.452	0.003±0.027	2.847±0.434	-0.048±0.017	-1.259±0.219
2S	3.883	7.109	-0.092	7.201	-0.052	1.068
	2.916	4.276	-0.173	4.449	-0.070	-0.348
	2.993	3.467	-0.152	3.619	0.096	-0.227
	3.264±0.310	4.951±1.104	-0.139±0.024	5.089±1.083	-0.009±0.013	0.164±0.453
2U	1.963	0.848	-0.052	0.900	-7.773	-0.353
	3.374	0.438	-0.052	0.490	-0.122	-0.846
	2.123	3.723	-0.031	3.755	-7.490	-0.230
	2.487±0.446	1.670±1.033	-0.045±0.007	1.715±1.027	-5.789±2.505	-0.477±0.188
3S	3.178	-1.634	-0.011	-1.623	-0.108	-0.482
	3.138	-0.803	0.010	-0.813	-0.083	-0.357
	3.041	0.027	-0.032	0.059	-0.027	-0.191
	3.119±0.041	-0.803±0.480	-0.011±0.012	-0.792±0.486	-0.072±0.024	-0.344±0.084
3U	1.275	-0.496	-0.019	-0.477	-0.028	-0.007
	1.419	0.303	0.004	0.300	-0.014	-0.646
	1.193	0.874	-0.031	0.905	0.054	-0.555
	1.296±0.066	0.227±0.397	-0.016±0.010	0.243±0.400	0.004±0.025	-0.402±0.200

Core	**O_2**	**NO_2 + NO_3**	**NO_2**	**NO_3**	**NH_3**	**PO_4**
	mg m^{-2} h^{-1}	**ug at m^{-2} h^{-1}**				
4S	1.188	1.445	-0.132	1.578	-0.050	0.401
	1.492	3.067	-0.132	3.199	-0.018	-0.714
	-	0.432	-0.132	0.564	0.055	-1.160
	1.340±0.152	1.648±0.767	-0.132±0.000	1.781±0.767	-0.004±0.031	-0.491±0.464
4U	2.131	-1.693	-0.027	-1.666	-0.012	-0.075
	2.293	-2.509	-0.060	-2.449	-0.061	-0.793
	1.949	-0.878	0.022	-0.899	-0.086	-0.499
	2.124±0.099	-1.693±0.471	-0.022±0.024	-1.671±0.477	-0.053±0.022	-0.456±0.208
5S	0.932	4.342	-0.141	4.483	-0.004	-0.932
	2.241	2.185	-0.141	2.326	-0.062	-1.407
	1.525	5.636	-0.162	5.799	0.249	-1.407
	1.566±0.378	4.055±1.007	-0.148±0.007	4.203±1.012	-0.061±0.095	-1.248±0.158
5U	2.343	1.683	0.006	1.678	-0.050	-1.166
	3.083	4.308	-0.012	4.320	-0.020	-1.061
	2.596	3.258	0.023	3.235	-0.046	-0.466
	2.674±0.217	3.083±0.763	0.006±0.010	3.078±0.767	-0.039±0.009	-0.897±0.218
6S	1.090	0.396	-0.196	0.592	-0.033	-0.804
	1.369	1.141	-0.196	1.336	-0.041	-0.990
	-	3.745	-0.196	3.941	-0.003	-0.506
	1.230±0.081	1.761±1.015	-0.196±0.000	1.957±1.015	-0.026±0.012	-0.767±0.141
6U	1.548	3.488	0.006	3.482	-0.086	-1.078
	1.656	2.954	-0.030	2.984	-0.037	-0.971
	1.836	-0.068	0.006	-0.073	-0.061	-0.509
	1.680±0.084	2.125±1.107	-0.006±0.012	2.131±1.111	-0.061±0.014	0.852±0.175

TABLE 25. STATION 8. FLUX RATES OF OXYGEN AND NUTRIENTS BETWEEN WATER AND GRAND BANKS SEDIMENTS IN INCUBATED CORE TUBES. NEGATIVE VALUES = CONSUMPTION BY SEDIMENTS. POSITIVE = RELEASE. S = STIRRED, U = UNSTIRRED. REPLICATE VALUES, MEANS ± 1 STANDARD ERROR OF MEAN SHOWN.

Core	O_2	$NO_2 + NO_3$	NO_2	NO_3	NH_3	PO_4
	mg m^{-2} h^{-1}			ug at m^{-2} h^{-1}		
7S	-6.221	5.307	-0.091	5.398	-0.102	-0.340
	-5.914	3.931	-0.045	3.976	-0.001	-0.432
	-5.944	4.160	0.001	4.160	-0.067	-0.890
		8.848	-0.022	4.871		-0.799
	-0.627±0.098	4.562±0.316	-0.040±0.020	4.601±0.328	-0.057±0.030	-0.615±0.135
7U	1.080	2.020	-0.088	2.108	-0.136	-0.283
	1.033	2.241	-0.132	2.373	-0.133	-0.416
	-	3.567	-0.132	3.699	-0.065	-0.328
	1.056±0.024	2.609±0.483	-0.117±0.015	2.727±0.492	-0.111±0.023	-0.342±0.039
8S	0.764	5.025	-0.094	5.119	-0.089	-0.352
	0.781	4.549	-0.047	4.596	0.199	-0.210
	0.481	5.025	-0.094	5.119	-0.029	-0.828
	0.675±0.097	4.866±1.159	-0.079±0.016	4.945±0.174	0.027±0.088	-0.463±0.268
8U	0.776	5.779	-0.001	5.778	0.017	0.762
	0.756	4.996	-0.052	5.047	-0.095	-1.326
	-	2.908	-0.156	3.064	-0.011	-1.588
	0.766±0.010	4.561±0.857	-0.069±0.046	4.630±0.811	-0.030±0.034	-0.717±0.747
9S	0.649	9.734	-0.105	9.839	-0.091	0.979
	0.569	4.876	-0.079	4.956	-0.057	0.570
	0.258	2.831	-0.156	2.987	-0.124	-1.577
	0.492±0.119	5.814±2.047	-0.113±0.023	5.927±2.037	-0.091±0.019	-0.009±0.793
9U	-1.021	4.400	0.533	3.866	-0.098	-0.285
	-1.025	9.999	0.533	9.465	-0.110	-1.356
	-1.113	4.643	0.533	4.110	-0.115	-1.064
	-1.053±0.030	6.347±1.827	0.533±0.000	5.814±1.827	-0.105±0.005	-0.901±0.320

Core	O_2	$NO_2 + NO_3$	NO_2	NO_3	NH_3	PO_4
	mg m^{-2} h^{-1}	ug at m^{-2} h^{-1}				
10S	0.432	4.906	-0.200	5.094	-0.048	-0.272
	0.514	5.837	-0.250	6.072	0.071	-0.179
	0.244	7.467	-0.225	7.679	-0.087	-0.365
	0.397±0.080	6.070±0.748	-0.225±0.014	6.282±0.754	-0.021±0.048	-0.272±0.054
10U	0.724	5.459	0.047	5.412	-0.021	0.453
	0.835	5.211	-0.052	5.263	-0.085	-1.674
	0.630	2.986	-0.027	3.013	-0.058	-0.784
	0.730±0.059	4.552±0.786	-0.011±0.030	4.562±0.776	-0.055±0.019	-0.668±0.617
11S	0.883	5.033	0.154	4.879	-0.072	-0.219
	0.907	1.066	0.154	0.911	-0.080	-0.060
	-	3.446	-0.057	3.503	-0.043	-0.325
	0.895±0.012	3.181±1.153	0.084±0.070	3.098±1.163	-0.065±0.011	-0.201±0.077
11U	-0.228	11.072	0.023	11.049	-0.050	0.270
	-0.212	7.714	0.048	7.667	-0.041	0.196
	-0.187	10.699	0.023	10.676	-0.013	-0.924
	-0.209±0.012	9.829±1.063	0.031±0.008	9.798±1.071	-0.035±0.011	-0.153±0.386
12S	-0.723	3.258	0.088	3.170	0.052	0.397
	-0.628	3.110	0.058	3.052	0.003	0.220
	-0.549	3.184	0.088	3.096	-0.018	-0.357
	-0.633±0.050	3.184±0.043	0.078±0.010	3.106±0.034	0.012±0.021	0.087±0.228
12U	-0.621	3.011	0.016	2.995	-0.024	0.015
	-0.653	3.699	0.033	3.666	-0.052	-0.191
	-0.723	3.355	-0.001	3.356	-0.018	-0.346
	-0.666±0.030	3.355±0.199	0.016±0.010	3.339±0.194	-0.031±0.010	-0.174±0.105

TABLE 26. MEAN CORE FLUX RATES OF OXYGEN AND NUTRIENTS BETWEEN WATER AND GRAND BANKS SEDIMENTS IN INCUBATED CORE TUBES. NEGATIVE VALUES = CONSUMPTION BY SEDIMENTS. POSITIVE = RELEASE. S = STIRRED, U = UNSTIRRED, N = 3. STATION MEANS ± 1 STANDARD ERROR OF MEAN SHOWN.

Stn. No.	Core No.	Type	O_2	$NO_2 + NO_3$	NO_2	NO_3	NH_3	PO_4
			mg m^{-2} h^{-1}			ug at m^{-2} h^{-1}		
6	1	S	1.999	5.398	-0.113	5.511	-0.007	-0.302
6	1	U	0.607	2.850	0.003	2.847	-0.048	-1.259
6	2	S	3.264	4.951	-0.139	5.089	-0.019	0.164
6	2	U	2.487	1.670	-0.145	1.715	-5.789	-0.477
6	3	S	3.119	-0.803	-0.011	-0.792	-0.072	-0.344
6	3	U	1.296	0.227	-0.016	0.243	0.004	-0.402
6	4	S	1.340	1.646	-0.132	1.781	-0.004	-0.491
6	4	U	2.124	-1.693	-0.022	-1.671	-0.053	-0.456
6	5	S	1.566	4.055	-0.148	4.203	0.061	-1.248
6	5	U	2.674	3.083	0.006	3.078	-0.039	-0.897
6	6	S	1.230	1.761	-0.196	1.957	-0.026	-0.767
6	6	U	1.680	2.125	-0.006	2.131	-0.061	-0.852
			1.949±0.235	2.106±0.623	-0.077±0.022	2.174±0.632	-0.504±0.481	-0.611±0.119
8	7	S	-6.027	4.562	-0.040	4.601	-0.057	-0.615
8	7	U	1.056	2.609	-0.117	2.727	-0.111	-0.342
8	8	S	0.675	4.866	-0.079	4.945	0.027	-0.463
8	8	U	0.766	4.561	-0.069	4.630	-0.030	-0.717
8	9	S	0.492	5.814	-0.113	5.927	-0.091	-0.009
8	9	U	-1.053	6.347	0.533	5.814	-0.105	-0.091
8	10	S	0.397	6.070	-0.225	6.282	-0.021	-0.272
8	10	U	0.730	4.552	-0.011	4.562	-0.055	-0.688
8	11	S	0.895	3.181	0.084	3.098	-0.065	-0.201
8	11	U	-0.209	9.829	0.031	9.798	-0.035	-0.153
8	12	S	-0.633	3.184	0.078	3.106	0.012	0.087
8	12	U	-0.666	3.355	0.016	3.339	-0.031	-0.174
			-0.298±0.558 (0.233±0.220)*	4.911±0.567	0.007±0.054	4.902±0.562	-0.047±0.012	-0.303±0.077

* without -6.029 value

TABLE 27. TOTAL ORGANIC CARBON AND NITROGEN CONTENT OF GRAND BANKS SEDIMENT

Station	ug N g^{-1}			ug C g^{-1}			C/N		
	x	S.E.	n	x	S.E.	n	x	S.E.	n
5	52	6	5	219	21	5	4.25	0.56	5
6	68	22	12	243	80	12	4.11	0.71	12
7	136	29	5	723	40	5	5.99	0.81	5
8	96	10	15	515	71	15	6.02	0.84	15
Overall Mean	86.5	9.8	37	415.2	48.4	37	5.16	0.45	37

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APPENDIX A

Micro Winkler Titration Method

APPENDIX A

MICRO WINKLER TITRATION METHOD

BLANK RUN - Before Each Series of Analyses

1. Pipette 1 ml potassium iodate into a 125 ml flask and add 50 ml distilled water.
2. Add 1/2 ml conc. sulfuric acid and 1/2 ml alkaline iodide.
3. Stir for 1 minute and add 1/2 ml manganous sulfate and 1 ml starch.
4. Place flask under delivery tip and titrate until solution is just colorless.
5. Record volume added.
6. Pipette 1 ml potassium iodate into this same solution and stir for 1 minute.
7. Titrate until just colorless and record volume added.
8. The difference between the 2 titrations (1-2) is the reagent blank (±0.0010 ml). It may be positive or negative.

STANDARDIZATION - Before Each Series of Analyses

1. Pipette 5 ml potassium iodate into a flask and add 50 ml distilled water.
2. Add 1/2 ml conc. sulfuric acid and 1/2 ml alkaline iodide and stir for 1 minute.
3. Titrate until pale yellow and add 1 ml starch. Continue titrating until solution is just colorless. Record volume.
4. Run 2 more standardizations (±0.0005 ml).

SAMPLE TITRATION

1. To each syringe add 1/2 ml manganous sulfate and 1/2 ml alkaline iodide, seal with parafilm and shake.
2. Let syring stand until precipitate has settled a bit, then add 1/2 ml conc. sulfuric acid, seal again and shake until all precipitate has dissolved, empty contents into flask.
3. Add stirring bar and titrate with sodium thiosulfate until pale yellow color.
4. Add 1 ml starch.
5. Continue titrating to end point (just colorless).
6. Record volume added.
7. Reset buret and do next sample.

NOTE: All samples should be acidified before starting the series of titrations.

FIGURE 4

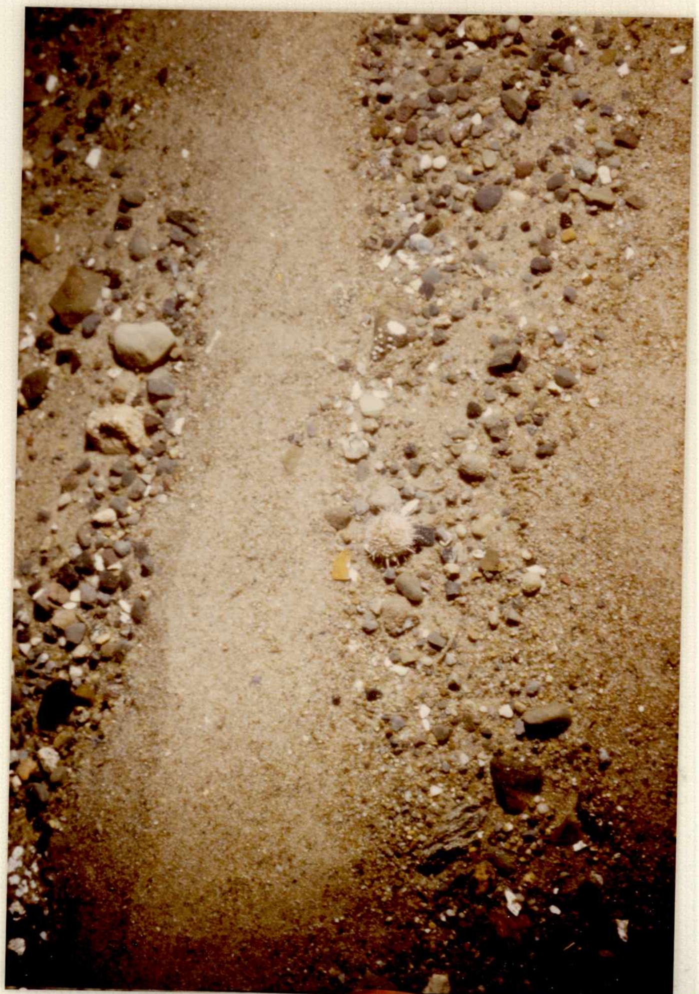
Bottom Photos - Station 5

FIGURE 5

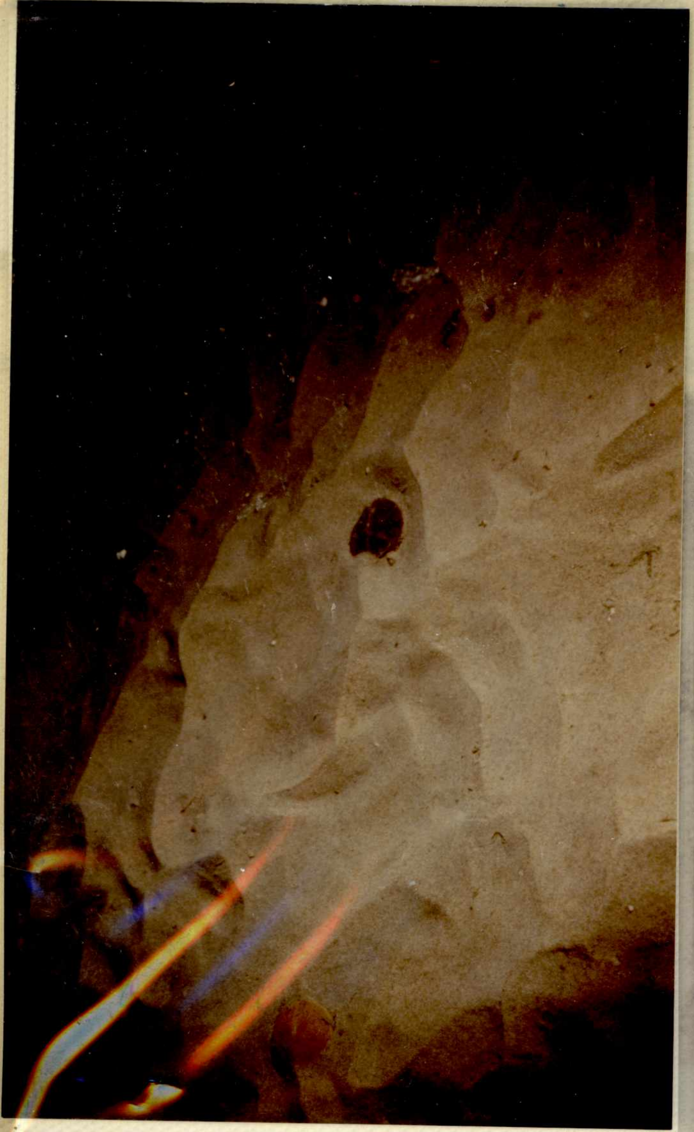
Bottom Photos - Station 6

FIGURE 6

Bottom Photos - Station 8



STA 5



ADDENDUM

Add to References:

Smith, K.L., Jr., G.T. Rowe and J.A. Nichols. 1973. Benthic community respiration near the Woods Hole sewage outfall. Estuarine and Coastal Mar. Sci. 1:65-70.