A Description of Arctic Nearshore Meiobenthos from Oiled and Unoiled Sediments at Cape Hatt, Northern Baffin Island

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A DESCRIPTION OF ARCTIC NEARSHORE MEIOBENTHOS FROM OILED AND UNOILED SEDIMENTS AT CAPE HATT, NORTHERN BAFFIN ISLAND

by

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This is the 199th Technical Report

from the Western Region, Winnipeg

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PREFACE

This is one of two final reports (the first being Technical Report 1434) of work conducted under the terms of a Department of Supply and Services contract issued to LGL Ltd., environmental research associates (DSS Contract No. OSF84-00100). The scientific authority was B.W. Fallis, Freshwater Institute, 501 University Crescent, Winnipeg, Manitoba, R3T 2N6.

This study was funded in part by the Northern Oil and Gas Action Program (NOGAP), through the Department of Fisheries and Oceans, Western Region, and by the Arctic Resource Assessment Section, Freshwater Institute, Department of Fisheries and Oceans, Winnipeg. It is one of a series of studies being executed under NOGAP Project B.2, to assess the implications of hydrocarbon development and production on critical estuarine and marine habitats of the Canadian Arctic Coastal Shelf. The assistance of G.D. Koshinsky in facilitating the initiation of the contract, and of B.W. Fallis in overseeing its execution, is greatly appreciated.

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Martin, C.M., and W.E. Cross. 1986. A description of Arctic nearshore meiobenthos from oiled and unoiled sediments at Cape Hatt, northern Baffin Island. Can. Tech. Rep. Fish. Aquat. Sci. 1468: iv + 24 p.

Benthic meiofauna from shallow nearshore waters at Cape Hatt, northern Baffin Island, were dominated by nematodes (68.4% of individuals collected), foraminiferans (10.1%), and copepods (7.7%). Densities were high (overall average of 582.5 individuals•cm^{-2}) relative to most other Arctic and boreal locations studied. Analyses of variance revealed several types of systematic variability in the densities of dominant meiofaunal groups: variability among depths, bays, and years. Possible effects of oil released during the Baffin Island Oil Spill (BIOS) project in 1981 were indicated in a posteriori comparisons between reference bays and one bay where sediment oil concentrations were elevated. In the oiled bay, (1) nematode densities were lower than in four other bays during 1982, (2) copepod densities decreased at 6 m depth between 1982 and 1983, and (3) depth distributions of ostracods and foraminiferans differed from those in the reference bay in 1983. Each of these differences was consistent with differences in measured (or presumed) oil concentrations among depths, bays, and years. However, the lack of pre-spill data and replicated oil treatments precludes unequivocal conclusions; factors other than oil (e.g. substrate or exposure) may have been responsible for the observed patterns of distribution. Mean nematode:copepod (N/C) ratios and among-replicate variability in those values were high in two reference bays but not in the oiled bay, supporting recent evidence that N/C ratios are not reliable pollution indicators.

Key words: Arctic; meiobenthos; oiled sediments; Cape Hatt; Baffin Island; nematode:-copepod ratios.

RÉSUMÉ

Martin, C.M., and W.E. Cross. 1986. A description of Arctic nearshore meiobenthos from oiled and unoiled sediments at Cape Hatt, northern Baffin Island. Can. Tech. Rep. Fish. Aquat. Sci. 1468: iv + 24 p.

La méiofaune benthique des eaux peu profondes près des côtes à Cape Hatt, dans le nord de l'île de Baffin, se compose surtout de nématodes (68,4% des sujets recueillis), de foraminifères (10,1%) et de copépodes (7,7%). Les densités étaient élevées (moyenne globale de 582,5 sujets par cm^2) par rapport à la plupart des autres endroits dans l'Arctique et le Nord où des études ont été faites. Des analyses de la variance ont permis de dégager plusieurs types de variabilité systématique dans les densités de groupes méiofauniques dominants: variabilité entre les profondeurs, les baies et les années. Les effets qui pourraient être attribuables au projet de déversement de pétrole à l'île de Baffin (BIOS) en 1981 ont été relevés dans des comparaisons a posteriori entre les baies-témoins et une autre baie où les concentrations de pétrole dans les sédiments ont été élevées. Dans cette baie, (1) les densités de nématodes étaient plus basses que dans quatre autres baies au cours de 1982; (2) la profondeur à laquelle se retrouvaient les densités de copépodes est passée à 6 m entre 1982 et 1983; et (3) la distribution des ostracodes et des foraminifères selon la profondeur n'était pas la même que dans la baie-témoin en 1983. Ces différences concordaient toutefois avec les différences dans les concentrations d'hydrocarbures mesurées (ou estimées) entre les profondeurs, les baies et les années. L'absence de données antérieures au moment des déversements et les reprises de traitement au pétrole nous empêchent de tirer des conclusions formelles; ainsi, d'autres facteurs que le pétrole (p. ex. substrat; exposition) expliquent peut-être les modèles de distribution observés. Les rapports moyens des nématodes et des copépodes (N/C) et la variabilité des valeurs lors des reprises de traitement étaient élevés dans deux baies-témoins, mais pas dans la baie où il y avait eu déversement de pétrole, ce qui corrobore la position établie récemment selon laquelle les rapports N/C ne constituent pas un indicateur fiable de la pollution.

Mots-clés: Arctique; méiobenthos; sédiments chargés de pétrole; Cape Hatt; île de Baffin; rapports nématodes - copépodes.

INTRODUCTION

The possibility of accidental oil releases into Arctic and subarctic marine habitats is increasing with the acceleration of oil exploration and development. In the event of an oil spill or blowout in Arctic or subarctic waters, hydrocarbons will most likely accumulate in the under-ice, intertidal and shallow subtidal habitats. Data concerning the effects of treated and untreated oil on the biota of these habitats would be of use in decisions regarding the use of chemical countermeasures for oil spills.

One component of the benthos, the meiofauna, comprises the smallest metazoans (e.g. rotifers, foraminiferans, copepods, nematodes). For the purpose of this study, we have followed the taxonomic approach toward meiofauna classification described by McIntyre (1969). The term "permanent meiofauna" refers to those taxa that are usually less than 1 mm in length at the adult stage. "Temporary meiofauna" are comparable in size, but consist of juveniles of macrofauna. The lower size limit for meiofauna is determined by the mesh size used in sample processing, which in this case was 76 µm.

Although considerable effort has been directed recently toward studies of oil effects on nearshore macrobenthic communities (e.g. Cross et al. 1984), no such information is available on meiofaunal communities in the benthos of the eastern Canadian Arctic. The only previous study of oil effects on Arctic meiofauna concerned the responses of meiofauna that inhabit the bottom layers of Arctic sea ice to oil and dispersed oil (Cross and Martin 1983). The lack of information on intertidal and subtidal meiofauna "is a serious knowledge gap in view of the tendency of oil to accumulate and persist for extended periods in the sediment" (Percy 1982).

In fact, little information of any kind is available on Arctic meiofauna. Arctic meiobenthos have been previously described as both diverse and abundant in subtidal sediments of West Greenland (Kristensen and Nørrevang 1982) and of Stefansson Sound, Beaufort Sea (Carey and Montagna 1982). There have been a few recent publications on meiofauna inhabiting the undersurface of Arctic sea ice (Cross 1982; Carey and Montagna 1982; Kern and Carey 1983).

In other latitudes, meiobenthos have become a focus of pollution studies in recent years. Intertidal and benthic meiofauna have been increasingly used as indicators of pollution of various types. Although there is conflicting evidence concerning the effects of oil on meiofauna, the sensitivity of some meiofaunal groups to pollution and the insensitivity of others has led to a recent postulation that simple ratios of abundances (e.g. nematode:copepod ratios) may be useful as pollution indicators (Raffaelli and Mason 1981; Warwick 1981). The use of such simple ratios is attractive because of the great reduction in effort and cost required to detect pollution.

The role and importance of meiofauna in any benthic ecosystem are still not well understood. They recycle nutrients, increase bacterial activity by grazing larger organic material, and provide a source of food for macrofaunal predators and some benthic fish (Elmgren 1976; Alheit and Scheibel 1982; Fabijan 1983). Watzin (1983) has suggested that meiofauna may also have a significant effect on the community structure of macrofauna by interacting with their juvenile stages, primarily through competition for organic material found in the surface layers of sediment and through predation from carnivorous turbellarians and nematodes. In Arctic food webs, where bivalves are of high importance in the diets of bearded seals and walrus, the small and easily overlooked meiofauna may be very important by virtue of this competition. Perturbations that increase the competitive ability of the short-lived meiofauna over that of the long-lived and slow-growing macrofauna may have some repercussions on higher trophic levels.

Any study of pollutant effects must also consider natural factors whose effects may be confused with those of the pollutants. Physical factors affecting meiobenthos in temperate waters include sediment grain size (Willems et al. 1982), temperature (Harris 1972), tidal cycle currents (Palmer and Brandt 1981), and food availability (Elmgren 1976). In nearshore Arctic waters, where seasonal variations of temperature and salinity are extreme and food availability is seasonal, environmental factors may be very important in regulating meiobenthic communities.

The present study examines the distribution and composition of subtidal meiobenthos present at the Baffin Island Oil Spill (BIOS) project site at Cape Hatt, N.W.T. During 1982 and 1983, samples were collected in uncontaminated areas and in areas that were treated with oil and dispersed oil during the BIOS experimental oil releases in 1981. The distribution of meiofauna was studied in relation to sediment grain size, organic carbon content, temperature, and the distribution of oil in subtidal sediments.

MATERIALS AND METHODS

STUDY AREA

Field studies were carried out during 21-31 August 1982 and 26-27 August 1983 from the BIOS project base camp located at Cape Hatt, Baffin Island. The study area consisted of five shallow embayments in Ragged Channel, some 5-8 km SSW of Cape Hatt, Eclipse Sound (72°27'N, 79°51'W; Fig. 1).

In late August 1981, 15 m^3 of untreated Lagomedio oil was released within booms on the surface of Bay 11, and an additional 15 m^3 of the same oil treated with the dispersant Corexit 9527 (10 oil:1 Corexit) was released underwater in Bay 9 (Fig. 1). Currents carried the dispersed oil into Bay 10, which had originally been designated as a reference bay. For several days following the dispersed oil release, low levels of oil were also found throughout Ragged Channel, including the new BIOS reference bay, Bay 7, and an additional reference bay, Bay 13 (Fig. 1). Levels of oil contamination in the water column and sediments are given in a later section.

FIELD PROCEDURES

Subtidal meiofauna were hand-collected by scuba divers using core samplers constructed from 50 mL polyethylene syringes (inside diameter of 2.5 cm). Vertical depth of penetration varied according to substrate characteristics, but at least 5 cm of sediment was collected. The numbers of replicate samples taken at each station are given in Table 1.

In August 1982, replicate samples were randomly collected in an area of approximately 25 x 25 m at a depth of 6 m in each of the four BIOS study bays (Bays 7, 9, 10, and 11), and in an additional reference bay (Bay 13). These sampling sites were the same as those of Cross and Martin (1983), who studied epibenthic amphipods and under-ice fauna. In August 1983, sampling was conducted on two consecutive days in Bay 13, and on one day in Bay 11, where relatively high levels of crude oil occurred in shallow subtidal sediments (Boehm et al. 1984). In both bays, replicate samples were collected at each of four depths (3, 6, 9, and 12 m); in Bay 11 these depths corresponded with the sampling locations of other BIOS studies, including the biochemical and microbiological components. In conjunction with meiofaunal sampling, water temperatures were recorded, and one sediment sample was collected at each station for each of organic content and granulometric analysis.

LABORATORY PROCEDURES

All samples were processed in the field within 10 h of collection; samples for organic content determinations were kept frozen until laboratory analysis, and all other samples were preserved in 5-10% formalin in seawater. Prior to laboratory analysis, Rose Bengal (concentration of 1 $g \cdot L^{-1}$ of formalin) was added to each sample to facilitate the sorting of animals from detritus and sediment.

Meiofauna initially were separated from sediment by decantation (10x), and the residue subsequently was sieved through nested fine mesh filters (212 µm and 76 µm). The larger fraction (>212 µm) was examined in its entirety under a binocular microscope, and major taxonomic groups of animals were counted. The finer fraction was subsampled by adding 1 litre of water, agitating the mixture and extracting 10 mL with a Hensen-Stempel pipette. Extractions were repeated until at least 100 animals were counted.

Copepods were identified to species and life stages whenever possible. Unidentified or tentatively identified copepod species were sent to an appropriate authority for identification or verification (see ACKNOWLEDGMENTS). In cases where it is generally recognized that additional species descriptions or revisions of higher taxonomic levels are required, questionable species or genera were pooled at the next highest taxonomic level. In some cases, species identification was precluded by the condition of the animals.

Methods used in granulometric analysis were the sand-silt-clay determination procedures of McDonald and Kelly (1968). The percent contribution of the coarse fraction (>1 mm in diameter) was determined for entire samples, but was excluded from all other calculations (percent composition of sand, silt, and clay). Total organic carbon content (% C) was determined at the Arctic Biological Station by the method described in Bunch et al. (1985).

DATA PROCESSING AND ANALYSIS

All results from laboratory analyses were coded for computer processing on an Apple II microcomputer. Computer programs developed by LGL were used to generate the sample by sample and station by station tabulations. Other LGL programs were used to organize the data into a format acceptable to packaged statistical programs. Prior to statistical analysis, a logarithmic transformation ($\log(x+1)$) was applied in order to reduce the skewness inherent in such data.

To determine which factors affected particular variables, fixed-effect analyses of variance (ANOVA) were performed. Variables analysed were densities (number per sample) of five major taxonomic groups of permanent meiobenthos, and the density of all permanent meiobenthos combined. Four types of ANOVA were performed: one factor ANOVA (bays), used to examine differences among the five bays (Bays 7, 9, 10, 11, 13) sampled in 1982; two factor ANOVA (depths, days), applied to 1983 data from the reference bay (Bay 13) in order to assess the effects of depth (3, 6, 9, 12 m) and of small scale time differences (26, 27 August 1983); two factor ANOVA (bays, years), applied to data from the two bays (Bays 11, 13) sampled in 1982 and 1983 in order to examine yearly differences in these two bays; and two factor ANOVA (bays, depths), applied to 1983 data in order to determine whether depth effects were consistent in the two bays (Bays 11, 13) sampled in 1983.

The last two types of analysis were used to examine possible oil effects. Concentrations of oil in Bay 11 (surface oil release bay) varied among depths and between 1982 and 1983 (see Boehm et al. 1984), whereas oil concentrations in Bay 13 were presumably at or near background levels at all depths in both years. If trends in meiofauna abundance were similar to those in oil concentration, this would indicate an oil effect; such trends (i.e. inconsistent depth or year effects between Bays 11 and 13) would be indicated in the above ANOVAs by significant interaction terms (bay x depth or bay x year). This design is similar to that of the BIOS project (Cross et al. 1984; see also Green 1979), except that no pre-spill data on meiofauna are available. The results of these analyses have been interpreted taking into account Eskin and Coull's (1984) recommendation that a posteriori studies comparing data from polluted areas with reference areas must be interpreted with great caution, particularly when oil effects and recovery rates are not known.

RESULTS AND DISCUSSION

SITE DESCRIPTION

Information on the nearshore geology of the study area was reported by McLaren et al. (1981). In general, the five study bays were similar in substrate characteristics. The beaches and intertidal zones were composed of a gravel/cobble pavement overlying sand with scattered rocks and boulders. At depths of 1-2 m, a relatively flat, predominantly sand bottom occurred in each of the study bays, and between 2 and 3 m depths a steep, rocky slope occurred in each of three shallow embayments in Ragged Channel (Bays 7, 9, and 10). With increasing depth, an unconsolidated silt veneer overlying the substrate became more predominant, and sparsely distributed boulders occurred.

Sediment data based on samples taken in conjunction with meiobenthic sampling are given in Table 2. At all depths in all bays, sand comprised at least 60% of the fine fraction (<1.0 mm) of the substrate. The clay and fine silt content each represented about 5% or less of the fine fraction, whereas coarse silt (1/16-1/64 mm) varied between 4.7 and 27.9% of the fines. The amount of cobble, pebble, and coarse sand in the whole sediment sample was also quite variable.

In general, the clay content was relatively constant over the depth range studied (3-12 m), whereas with increasing depth the cobble, pebble, and sand content decreased, and the silt content increased (Table 2). Variability among the study bays was more apparent in the cobble, pebble, and coarse sand fractions than in the fine components of the substrate. The lowest content of cobble, pebble, coarse sand, and silt, and the highest content of sand were found in Bay 9, whereas the converse was true for each of these characteristics in Bays 7 and 11. Because of the small sample sizes, apparent differences in substrate characteristics among depths and bays may be partly attributable to small scale variability. These sediment data are, however, comparable to data based on larger sample sizes reported by Cross et al. (1984) for the BIOS study bays (7, 9, 10 and 11).

Determinations of total organic carbon (TOC), based on one sediment sample per station during 1983 sampling, are shown in Fig. 2. Total organic carbon ranged from 0.8 to 2.4%, and increased slightly with depth in both locations (Bays 11 and 13). The percentages in Bay 11 (surface oil release) are comparable to those reported by Bunch and Cartier (1984), viz. between 0.8 and 2.2% at 2-11 m depths on 10 and 17 August 1983. Bunch and Cartier (1984) found no correlation between concentrations of total organic carbon and depth or between TOC and hydrocarbon concentrations in Bay 11.

In all bays in Ragged Channel, a relatively fresh, warm surface layer of water was present during August 1982 and 1983. On many occasions a boundary was observed at 3-4 m depths, whereas at other times the pycnocline was apparent as deep as 7 or 8 m. Periodic measurements of salinity in 1982 ranged from 19-26 in shallow waters and 25-30 in deeper waters. These salinity differences were probably attributable to the influx of fresh water from ice melt and numerous small streams. Water temperatures also varied greatly with depth; during the sampling period in August 1983, temperatures ranged from 2.5 to 3.0°C at 3 m depth and from 0 to 1.0°C at 12 m depth (Fig. 2).

MEIOBENTHOS

The depth of sediment sampled for meiofauna was variable, but in all cases at least 5 cm of sediment was collected. In subtidal sediments of Oslofjord, Norway, 89.6% of meiofaunal numbers occurred in the upper 5 cm (Amjad and Gray 1983). Over 90% of the meiofaunal numbers collected in the intertidal zone of Port Valdez, Alaska, were found in the top 3 cm of sediment (Feder and Paul 1980). The present results, therefore, likely underestimate total meiofaunal abundance by no more than 10%.

The following descriptions of group composition and abundance are based on samples collected in the reference bays only. In 1982, two reference bays were sampled (Bays 7 and 13), whereas in 1983 only Bay 13 was sampled.

Group and species composition

Permanent meiobenthos collected at Cape Hatt during August 1982 and 1983 included large protozoans (foraminiferans, radiolarians, and tintinnids), kinorhynchs, nematodes, mites, and small crustaceans (ostracods, copepods, and tanaidaceans). These permanent meiobenthos contributed 93.4% of total numbers collected in the reference bays (Table 3). Nematodes, the numerically dominant taxa, comprised 68.4% of total meiofauna collected during the study. Foraminiferans and copepods made up 10.1% and 7.7% of total numbers, respectively. Radiolarians, kinorhynchs, and mites usually represented less than 0.1 % of total numbers, and were present in few samples.

Temporary meiobenthos (juveniles of macrobenthos) comprised only 6.6% of total animals collected (Table 3). Small polychaetes were relatively abundant, representing 92.5% of total identified temporary meiobenthos. Isopod juveniles were also present in the study area, but were not collected in the reference bays.

A total of 41 taxa of meiobenthic copepods (excluding nauplii and copepodites) were identified in samples from the two reference bays (Table 4). Most numerous were unidentified harpacticoid and cyclopoid nauplii and copepodites; together, these juvenile stages comprised from 69.2 to 75.9% of total copepod numbers collected, depending on date and bay (Table 4). Unidentified harpacticoid copepods of the families Diosaccidae and Ameiridae were subdominant, together comprising 4.0-12.2% of total copepod numbers. With the exception of Ectinosoma finmarchicum, most identified species or genera were present in low numbers, usually less than 1% of the total (Table 4).

Distribution of major groups

Total meiofaunal densities in the study area at Cape Hatt (all reference samples combined) averaged about 582.5 individuals per square centimetre; nematodes alone contributed 398.6 individuals per square centimetre (Table 3). Densities were high relative to a number of Arctic and boreal locations (Table 5).

The smallest scale of variability in our data is that among replicate samples within stations. Distributions of major meiofaunal groups ranged from relatively even to relatively patchy, and even greater extremes of variability were observed for the many uncommon species in the study area. However, total numbers of permanent meiobenthos were relatively evenly distributed on a small scale; the standard deviation was less than the mean at all stations during 1982 and 1983 (Tables 6 and 7). Identified taxa of temporary meiofauna, on the other hand, were more patchy in small scale distribution (i.e. within stations). This variability was likely attributable to the settlement patterns of macrofauna juveniles, which depend on many environmental variables such as current, substrate characteristics, and food availability. In the Arctic, settlement of macrofaunal juveniles may be periodic and may result in patchiness on small spatial scales (e.g. Thorson 1936; Curtis and Petersen 1977; Petersen 1978).

In the following sections, the abundances of five major groups of permanent meiobenthos and of total permanent meiobenthos are examined; each of the five groups comprised >1% of total meiofaunal numbers and occurred in over 85% of the samples. Factors that are examined are large-scale spatial effects (depths and bays), temporal effects (days and years), and oil effects.

Depth effects: Depth effects per se were examined only in the reference bay (Bay 13) during 1983. Variability among the depths studied (3, 6, 9, and 12 m) was evident for each of the five major meiofaunal groups examined. This variability is represented by the "depth" term in Table 8, which gives the results of two-factor (days, depths) analyses of variance. When all permanent meiofaunal groups were combined, however, total abundance did not differ significantly among depths (Table 8).

In the reference bay, progressive changes in density with depth occurred in all groups except nematodes (Table 6; Fig. 3). Densities of foraminiferans were similar at 3, 6, and 9 m depths and increased markedly at 12 m depth. Densities of all copepods, harpacticoid copepods, and ostracods, on the other hand, decreased progressively from 3 to 12 m depth (Fig. 3). Nematodes showed a slight density increase at 9 m depth relative to 3, 6 and 12 m depths.

The major physical factors affecting foraminiferan abundance may be temperature and salinity. In the Arctic spring and summer, the salinity of shallow water is reduced by snow and ice melt; in summer, the temperature of surface water is increased by solar heating. At Cape Hatt, the greatest temperature difference occurred between 9 and 12 m depth (Fig. 2), and reduced salinity was observed as deep as 8 m (see SITE DESCRIPTION). Thus, the occurrence of high numbers of foraminiferans only at the deepest depth sampled may have been a result of more constant temperature and salinity conditions. According to Murray (1979), variation in salinity is the main factor limiting foraminiferan distribution in brackish water. Substrate characteristics may also affect foraminiferan abundance (Murray 1979).

The abundance patterns of meiobenthic copepods and ostracods at Cape Hatt suggests that these taxa may be tolerant of changes in salinity. The decrease in crustacean densities with depth may be related to temperature or substrate characteristics. Temperature at Cape Hatt decreased with increasing depth, and Thomson et al. (1986) have previously reported that Arctic intertidal amphipods were more abundant at higher temperatures (based on multiple regression analyses). The changes in substrate characteristics with depth at Cape Hatt (increase in silt and decrease in sand content) may also have affected the distribution of these small crustaceans (Table 2). Copepods previously have been reported to prefer coarse substrates (e.g. Raffaelli 1982; Witte and Zijlstra 1984). Another possible explanation of the depth distribution of meiobenthic crustaceans is the higher abundance in shallow water of filamentous algae and kelp (Cross et al. 1984), which may provide food or shelter.

Bay effects: Bay effects per se were examined only for data collected in 1982, when five bays were sampled at 6 m depth. There were no significant differences among bays in the densities of foraminiferans, ostracods, harpacticoid copepods, all copepods, and all permanent meiobenthos (one factor ANOVAs, $P>0.1$). Densities of nematodes, on the other hand, varied significantly among bays (one factor ANOVA; $F = 5.85$; $df = 4,36$; $P<0.001$). Nematode densities averaged 160.6 individuals per square centimetre in Bay 11, whereas mean densities in the other study bays were 352.6-441.8 individuals per square centimetre (Table 6). This difference may be attributable to the high percentages of cobble, pebble, and coarse sand found in Bay 11 relative to the other bays (Table 2). Furthermore, the subtidal zone of Bay 11 slopes very gently compared to that in the other bays (Cross et al. 1984); distance from shore may be a factor affecting nematode distribution. Nematode distribution is considered further below (see OIL EFFECTS).

Temporal effects: Two types of temporal variability were examined: variability on two consecutive days in August 1983 (Bay 13 only), and variability between August 1982 and 1983

(Bays 11 and 13). There was no day-to-day difference in the density of any of the permanent meiofaunal taxa examined (Table 8). Therefore, data from the two days were pooled for further analysis.

Year-to-year differences were evident in two taxa: nematodes and ostracods (Table 9). In both cases, the temporal change involved an increase in density from 1982 to 1983 (Fig. 4). Year effects were also evident for copepods, but between 1982 and 1983, density increased in one bay and decreased in the other (Fig. 4, Table 9).

Year to year variability in macrobenthos was also evident at Cape Hatt (Cross et al. 1984). Abundance in a number of macrofaunal species increased from 1981 to 1983. Cross et al. (1984) suggested that increases in abundance may have been evidence of recovery from some disturbance to the system (e.g. high input of fresh water) during or prior to 1980, that caused widespread, albeit species-specific, mortality.

OIL EFFECTS

Levels of oil contamination

On 19 August 1981, 75 drums (15 m^3) of slightly aged Lagomedio crude oil were released on the surface in Bay 11. Approximately half of this amount was recovered on the day following the release. During the six hour release and during the 30 hour monitoring period that followed, oil concentrations in the top metre of water were low (<3 ppm) and concentrations below a depth of 1 m were below the detection limit of 0.25 ppm (Green et al. 1982). When oil levels in the water of Bay 11 were integrated over time (i.e. concentration x time exposed), the total oil exposure was 1.2-2.1 ppm-h (Green et al. 1982). Approximately one third of the oil was deposited on the beach during the falling tide, and concentrations in the intertidal area reached 36 000 ppm (Green et al. 1982). This oil did not immediately become incorporated into Bay 11 sediments at 3 and 7 m depths (Boehm et al. 1982), but oil concentrations began to rise a few weeks following the release and were still rising one and two years thereafter. Mean oil concentrations in the sediment after one and two years were 7-9 ppm and 16-46 ppm, respectively (Boehm 1983; Boehm et al. 1984). During both years the distribution of oil was patchy, and highest concentrations were found at the southern end of the study area (up to 150 ppm in 1983). Oil was largely confined to the upper 2 cm of sediment throughout the study period.

On 27 August 1981, an additional 15 m^3 of aged Lagomedio crude oil mixed with 1.5 m^3 of Corexit 9527 dispersant and with seawater (5:1,water:oil) were introduced into Bay 9 from a diffuser pipe that was about 1 m from the bottom and extended from the shore to a depth of 14 m. Concentrations in the water column were high (>50 ppm) following the release. Horizontal diffusion was rapid, and after four days the dispersed oil was found throughout Ragged Channel at concentrations of 30-50 ppb at depths of 5-15 m. Total exposure to dispersed oil (based on 36 h observation) was 300 ± 100 ppm-h in Bay 9, approximately 30 ppm-h in Bay 10, and 0.5 ppm-h in Bays 7 and 11 (Green et al. 1982). Oil was still detectable in the water of the study bays (generally less than 5 ppb) more than two weeks after the dispersed oil release (Boehm et al. 1982, Tables 3.4 to 3.7).

Oil was quickly incorporated into the sediments in Bay 9 and, to a lesser degree, in Bays 7 and 10 (Boehm et al. 1982). Concentrations in Bay 9 sediments reached a maximum of 4-6 ppm a few weeks (or later) following the release and were considerably lower one year later. Low concentrations apparently persisted in Bay 7 and 10 sediments through 1982 (0.8-1.2 ppm). In the second post-spill year, however, oil concentrations had increased considerably in sediments of Bay 9 (averages of 3.8 and 7.7 ppm at 3 and 7 m depths, respectively). This oil may have been transported into the study area from the southern part of the bay where the dispersed oil was released in 1981. Levels had also increased somewhat in sediments of Bay 7, although oil in 3 m sediments was not petrogenic, and only one of five samples from 7 m depth contained a relatively high concentration of petroleum (12.8 ppm; Boehm et al. 1984).

The oil levels in the sediments at Cape Hatt were relatively low when compared with values reported in the literature. Levels were <10 ppm on a dry sediment weight basis, with the exception of concentrations in Bay 11 during 1983. Following an oil spill in Chedabucto Bay, N.S., Scarratt and Zitko (1972) reported that sediment hydrocarbon concentrations (based on wet sediment weight) were 10-20 ppm at lightly oiled stations, and 160-1240 ppm at heavily oiled stations. Sanders et al. (1980) found 10-20 ppm hydrocarbon content (based on dry sediment weight) in lightly oiled stations, and 1300-12 400 ppm (dry sediment) in heavily oiled stations after an oil spill in Buzzards Bay, Mass. Chronically oiled areas can contain similar sediment hydrocarbon concentrations: 4-60 ppm in lightly oiled areas and 820-6000 ppm in heavily oiled areas (Farrington and Quinn 1973; Koons and Thomas 1979; both based on dry sediment weight).

Distribution of meiobenthos

Possible effects of oil on meiofauna at Cape Hatt were evident in three types of analysis of variance (ANOVA): one factor ANOVA (bays) applied to data from the five study bays sampled in 1982, two factor ANOVA (bays, years) applied to data from the two bays sampled in 1982 and 1983 (Bays 11 and 13), and two factor ANOVA (bays, depths) applied to data from the two bays sampled in 1983 (Bays 11 and 13). Meiofauna were not sampled before the BIOS experimental oil releases in 1981. Hence, the use of the above-mentioned types of analysis is based on differences in the observed or presumed levels of oil contamination (1) among the five study bays sampled during 1982, (2) between 1982 and 1983 in one oiled bay (Bay 11) and one reference bay (Bay 13), and (3) among the four depths sampled in Bays 11 and 13 during 1983. A posteriori studies comparing polluted areas with reference areas must be interpreted with great caution (Eskin and Coull 1984). Also, because the BIOS oil treatments were not replicated, effects of natural factors (e.g. substrate composition) may be confounded with effects of oil, and therefore it is not possible to reach unequivocal conclusions about oil effects (Hurlbert 1984).

The first evidence of a possible effect of oil was from one factor ANOVAs (bays) for data collected in 1982. Of the six taxa or groups tested, only nematode densities differed significantly among the five bays sampled; nematode density in the surface oil release bay (Bay 11) was 2-3 times lower than in the other four bays (two reference and two dispersed oil bays). Bay 11 also differed from the other bays in that concentrations of oil in subtidal sediments during 1982 were higher in Bay 11 than in any other bay, at both 3 and 7 m depths (Boehm et al. 1984). Hence, it is possible that nematode densities decreased in Bay 11 as a result of oil in subtidal sediments.

The second type of evidence about a possible effect of oil was the significant interaction term between bay and year factors in two factor ANOVAs for densities of all copepods and harpacticoid copepods (Table 9). Interaction terms were not significant in analyses of densities of total meiobenthos, foraminiferans, nematodes, and ostracods (Table 9). Between 1982 and 1983, copepod density at 6 m depth increased in the reference bay (Bay 13) and decreased in the oiled bay (Bay 11) (Fig. 4). This difference may have been a result of increased oil concentrations in the subtidal sediments of Bay 11 (see Boehm et al. 1984). Although oil concentrations were not measured in Bay 13, they presumably were at or near background levels in both years, as was the case in another reference bay (Bay 7). Thus it is possible that densities of copepods (primarily harpacticoid copepods) were adversely affected by increasing oil concentrations in sediments between the first and second post-spill years. The probable source of this oil was stranded oil in the intertidal zone of Bay 11 (Cross et al. 1984).

The third type of evidence about a possible effect of oil was found in two factor ANOVAs (bay, depth) for data collected in 1983. Interaction terms were significant for densities of foraminiferans, ostracods, all copepods, and harpacticoid copepods, but not for densities of nematodes or total meiobenthos (Table 10). The significant interaction term means that depth distributions were not consistent between the two bays, and the possibility of an oil effect arises because the depth distribution of oil also was not consistent between the two bays. In Bay 11, oil concentrations decreased with increasing depth (e.g. 300, 13, 7.4, and 3.5 ppm near 3, 6, 9, and 12 m depths on one transect; Boehm et al. 1984, Table 3.5), whereas in Bay 13, oil concentrations at all depths were presumably at or near background levels (see above).

In the reference bay, densities of meiofaunal crustaceans (ostracods and copepods) decreased with increasing depth, whereas foraminiferan densities were similar at 3, 6, and 9 m, and an order of magnitude higher at 12 m depth (Fig. 3; Table 7). In Bay 11, the surface oil release bay, foraminiferans were less abundant at 3 m and more abundant at 6 and 9 m depths; ostracods were least abundant at 3 m and 'naturally' distributed between 6 and 12 m; total copepods and harpacticoid copepods were least abundant at 6 m and of similar abundances at 3, 9, and 12 m depths. In the last case, there is no apparent relationship between the distribution of oil and the way in which depth distributions differed between the bays. In the first and second cases, however, the densities are consistent with a dose-dependent relationship. High oil concentrations at 3 m may have adversely affected densities of foraminiferans and ostracods in Bay 11, whereas low oil concentrations at 6 and 9 m either may have resulted in density increases (foraminiferans) or had no effect (ostracods).

Thus, in all three types of analysis that compared densities in Bay 11 with those in other bays, possible oil effects were indicated for one or more of the meiofaunal taxa examined. Oil in the subtidal sediments of Bay 11 may have been responsible for (1) low nematode densities at 6 m during 1982, (2) decreases from 1982 to 1983 in densities of total copepods and harpacticoid copepods at 6 m, and (3) low densities of foraminiferans and ostracods at 3 m during 1983, and high densities of foraminiferans at 6 and 9 m depths in that year. It has already been pointed out, however, that such a posteriori comparisons between polluted and reference bays must be interpreted with caution. Among the bays studied, Bay 11 was unique not only in its high concentrations of oil, but also in its substrate composition (Table 2), slope (much less steep), and exposure (more protected). One or more of these factors, or other unknown factors that differed among bays, may have been responsible for the observed differences in meiofaunal abundance.

To our knowledge, the only previous study of oil effects on Arctic meiofauna was that of Cross and Martin (1983), who studied effects of chemically dispersed oil (6-37 ppm) released onto the under-ice surface during spring. Nematodes were not affected, whereas densities of copepods and polychaetes were reduced by more than 80%. In other latitudes, apparently conflicting results concerning effects of oil on meiofauna have been reported, both for laboratory studies (see Decker and Fleeger 1984) and field studies. In the latter case, differences in results are probably a result of uncontrolled factors that varied among studies; such factors included species, locations, substrates, tide levels, and types and concentrations of oil. Under this widely varying set of conditions, reported effects of oil on meiofauna have included (1) no effects (Boucher 1980), (2) adverse effects on all taxa (Alongi et al. 1983), (3) proliferation of some taxa, including nematodes (Fricke et al. 1981; Fleeger and Chandler 1983), copepods (Naidu et al. 1978; Fleeger and Chandler 1983), and foraminiferans (Frithsen et al. 1985), and (4) adverse effects on only some taxa. In the last case, crustaceans generally have been found more sensitive than nematodes (Giere 1979; Fricke et al. 1981; Elmgren et al. 1983; Frithsen et al. 1985; see also Raffaelli and Mason 1981), although the opposite also has been reported (Bakke and Johnsen 1979; Boucher 1980, 1985; McLachlan and Harty 1982). Reported recovery rates also have varied, from two months (Frithsen et al. 1985) to more than two years (Elmgren et al. 1983). Because of this variability in reported results, previous literature concerning oil effects on meiofauna is of little use in interpreting results of the present study.

Nematode:copepod ratios

Raffaelli and Mason (1981) suggested that the ratio of numbers of nematodes/copepods in marine sediments could be a useful tool for monitoring pollution, basing the theory on the generalization that copepods are more sensitive to pollution than are nematodes. This suggestion is attractive because small samples of meiobenthos provide large numbers of individuals, and because nematodes and copepods can be differentiated and enumerated quickly without taxonomic expertise; effort and cost required to monitor pollution are thereby reduced substantially. Raffaelli and Mason (1981) urged caution in the use of the ratio, however, and since that time its attractiveness has largely been removed either through attempts to elaborate the approach or through critical evaluation of its reliability (e.g., Coull et al. 1981; Warwick 1981; Raffaelli 1982; Lambshead 1984; Boucher 1985; Shiells and Anderson 1985; cf. Amjad and Gray 1983). The major concerns are that the ratio oversimplifies a highly complex set of relationships, and that nematodes and copepods may react independently to a variety of environmental factors, of which pollution is only one (Lambshead 1984). Furthermore, a number of exceptions to the generalization that copepods are more sensitive to pollution than nematodes have been reported (see above).

Mean nematode:copepod (N/C) ratios for each bay, depth, and date sampled at Cape Hatt are shown in Table 11. In most cases, among-replicate variability was low, and mean N/C ratios were lower than the high values (>100) found at all polluted sites examined by Raffaelli and Mason (1981). At Cape Hatt, mean N/C ratios exceeded 100 at three locations; these included both reference bays (Bays 7 and 13), but not Bay 11, where the highest concentrations of oil in sediments were found (see Levels of oil contamination). In these cases, variability among replicates was high, and the high mean values were largely a result of very high N/C ratios in only a few samples (Fig. 6).

Thus, high mean N/C ratios at Cape Hatt were associated with high sample-to-sample variability, but not with high levels of oil contamination. High variability among replicate samples is apparently characteristic of nematode:copepod ratios, indicating contagious distributions in one or both taxa (Coull et al. 1981; Shiells and Anderson 1985). This variability, together with evidence of inconsistency in the variation of the N/C ratio in relation to the level of sewage pollution, "would seem to cast doubt on the validity of the N/C ratio as a tool to detect organic pollution" (Shiells and Anderson 1985). Results of the present study concerning oil pollution in the Arctic provides further evidence that N/C ratios are not reliable pollution indicators.

In conclusion, analyses of variance revealed several types of systematic variability in the densities of dominant meiofaunal groups in nearshore waters at Cape Hatt, northern Baffin Island: variability among depths, bays, and years. A posteriori comparisons between oiled and unoiled bays indicated possible effects of oil on foraminiferans, nematodes, ostracods, harpacticoid copepods, and all copepods. Effects included decreases and increases in density, and the observed density differences were consistent with measured or presumed levels of oil contamination in subtidal sediments. However, the lack of pre-spill data and replicated oil treatments precludes unequivocal conclusions concerning oil effects; factors other than oil may have been responsible for the observed patterns of meiofaunal distribution. Mean nematode: copepod (N/C) ratios and among-replicate variability in those values were high in two reference bays but not in the oiled bay, supporting recent evidence that N/C ratios are not reliable pollution indicators.

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Table 1. Summary of meiobenthic samples taken in the study bays at Cape Hatt, northern Baffin Island, during August 1982 and 1983.

Bay	Oil Treatment (BIOS 1981)	Sampling Date	Depth	No. Samples
7	Reference	25/08/82	6 m	8
13	Reference	31/08/82	6 m	9
		26/08/83	3 m	6
			6 m	6
			9 m	5
			12 m	6
		27/08/83	3 m	6
			6 m	6
			9 m	6
			12 m	6
9	Dispersed oil release[a]	24/08/82	6 m	8
10	Dispersed oil contamination[a]	23/08/82	6 m	9
11	Surface oil release	21,22/08/82	6 m	7
		27/08/83	3 m	6
			6 m	6
			9 m	6
			12 m	5

[a] Experimental release of 15 m^3 oil premixed with 1.5 m^3 Corexit 9527 resulted in heavy contamination of Bay 9 and light contamination of Bay 10.

Table 2. Sediment characteristics of sampling stations at Cape Hatt, northern Baffin Island, during August 1982 and 1983. Data for cobble, pebble, and coarse sand are expressed as a percent of entire sample; data for sand, silt, and clay are expressed as a percent of the fine fraction.

			Coarse fraction (≥1.0 mm)			Fine fraction (<1.0 mm)				
Depth	Bay	Size (mm)->	Cobble >5.6	Pebble 2.8-5.6	Coarse Sand 1.0-2.8	Sand 1/16-1.0	Coarse Silt 1/64-1/16	Fine Silt 1/256-1/64	Clay <1/256	Sample Size
3 m	11		21.3	10.9	8.2	75.7	12.8	1.4	10.1	1
	13		9.0	4.5	4.1	91.1	4.7	1.4	2.9	2
	(All)		(13.1)	(6.6)	(5.5)	(86.0)	(7.4)	(1.4)	(5.3)	(3)
6 m	7		12.0	0	2.4	69.1	18.5	3.4	9.0	1
	9		0	0.3	0.9	91.5	5.7	0	2.8	1
	10		0	0.6	1.3	79.5	15.2	2.2	3.2	1
	11		16.8	10.1	6.4	66.5	24.8	3.6	5.1	2
	13		10.2	0.3	3.0	85.2	9.1	1.9	3.9	3
	(All)		(9.5)	(2.8)	(3.3)	(78.6)	(14.5)	(2.3)	(4.6)	(8)
9 m	11		7.3	3.0	4.8	73.2	15.9	5.8	5.2	1
	13		0	0.2	1.6	85.9	9.9	1.4	2.9	2
	(All)		(2.4)	(1.1)	(2.7)	(81.7)	(11.9)	(2.9)	(3.7)	(3)
12 m	11		4.4	0.4	2.9	61.3	27.9	5.8	4.9	1
	13		3.5	0.1	0.7	74.6	18.7	2.9	3.8	2
	(All)		(3.8)	(0.2)	(1.4)	(70.2)	(21.8)	(3.9)	(4.2)	(3)

Table 3. Mean density (no·cm^{-2}) and percent contribution of major taxa to total permanent meiofaunal numbers in two reference bays[a] at Cape Hatt, northern Baffin Island, during August 1982 and 1983. Data are based on 4.9 cm^2 core samples (n = 64).

Taxon	Density (mean ± SD	% of total numbers collected	% occurrence in 64 samples
Permanent meiobenthos[b] (total)	(543.96 ± 297.05)	(93.4)	
Foraminifera	58.91 ± 105.18	10.1	86
Radiolaria	0.06 ± 0.51	<0.1	2
Tintinnida	14.51 ± 15.09	2.5	77
Kinorhyncha	0.27 ± 1.14	<0.1	5
Nematoda	398.57 ± 220.46	68.4	100
Halacarida	0.02 ± 0.15	<0.1	2
Crustacea (nauplii)[c]	19.22 ± 36.01	3.3	69
Ostracoda	7.21 ± 8.11	1.2	95
Copepoda	44.72 ± 70.73	7.7	98
Tanaidacea	0.37 ± 0.64	0.1	45
Temporary meiobenthos[d] (total)	(38.58 ± 52.57)	(6.6)	
Polychaeta juveniles[e]	7.81 ± 37.71	1.3	27
Pelecypoda juveniles	0.40 ± 0.72	0.1	59
Gastropoda juveniles	0.02 ± 0.07	<0.1	8
Nemertinea	0.02 ± 0.06	<0.1	5
Oligochaeta	<0.01	<0.1	2
Unidentified[f]	30.33 ± 31.15	5.2	95
Total no cm^{-2} or %	582.54	100	

[a] Bays 7 and 13 (reference).
[b] Taxa usually >1 mm in length at the adult stage.
[c] Includes mainly unidentified copepod nauplii.
[d] Juveniles (<1 mm) of macrofauna (>1 mm at the adult stage).
[e] Only includes those polychaetes retained on the smallest sieve (76 um).
[f] Includes turbellarians and unidentified (damaged) juveniles.

Table 4. Species composition (%) of meiobenthic copepods collected in two reference bays at Cape Hatt, northern Baffin Island, during August 1982 and 1983.

	Taxon	1982 Bay 7 6 m	1982 Bay 13 6 m	1983 Bay 13 3,6,9,12 m
Harpacticoida	Unidentified nauplii	22.0	45.5	30.1
	Unidentified copepodites	29.4	23.7	19.9
	Unidentified adults	1.9	0	1.4
Ectinosomidae	Ectinosoma finmarchicum	1.0	3.1	3.8
	Ectinosoma neglectum	0.5	0.6	<0.1
	Bradya confluens	0.1	0.6	0.3
	Pseudobradya spp.	0.5	0.9	0.3
Harpacticidae	Zaus sp.	0.4	0.3	<0.1
	Harpacticus uniremus	0	0.3	0.1
	Unidentified	0.6	0	0
Tisbidae	Tisbe angusta	0.1	1.1	0.5
	Tisbe furcata	0	0.9	0
	Zosime sp.	0	0	<0.1
	Unidentified	0	0	<0.1
Thalestridae	Parathalestris jacksoni	0	0	<0.1
	Diarthrodes sp.	0	0	<0.1
	Dactylopodia sp.	0.3	0.9	0.3
	Dactylopodia vulgaris	0.1	0.3	0.1
	Dactylopodia micronyx	0	0	<0.1
	Dactylopodella sp.	0.1	0	<0.1
Parastenheliidae	Parastenhelia cf. spinosa	0	0	0.1
Diosaccidae	Stenhelia sp.	2.9	0	0
	Stenhelia gibba	1.6	0.6	1.3
	Stenhelia longicauda	0.1	0.9	0.1
	Stenhelia eflexa	0	0	<0.1
	Amphiascus sp.	0	0	<0.1
	Unidentified	1.0	4.3	0.4
Ameiridae	Ameira sp.	0	0	0.7
	Proameira sp.	0.8	0	0.1
	Proameira arenicola	0.1	0	0
	Sarsameira sp.	0	0	<0.1
	Unidentified	3.0	7.9	6.0
Cletodidae	Rhizothrix curvata	0.8	0	0.7
	Unidentified	0.1	0.3	0.1
Laophontidae	Paralaophonte cf. hyperborea	0.4	0	0.6
	Echinolaophonte horrida	0.3	0	0.2
Ancorabalidae	Arthropsyllus sp.	0	0	<0.1
Cyclopoida	Unidentified nauplii	18.4	0	25.5
	Unidentified copepodites	0	0	0.4
	Unidentified adults	0	0	0.1
Cyclopinidae	Cyclopina gracilis	0	0	0.2
	Cyclopina cf. schneideri	0	0	0.1
	Cyclopina sp.	0	5.7	<0.1
Oncaeidae	Unidentified	0	0	<0.1
Copepoda	Unidentified	13.7	2.6	6.4
Total numbers collected		1783	352	11,827

Table 5. Comparison of meiofaunal densities in subtidal sediments of various arctic and boreal locations.

Location	Substrate	Depth (m)	Density ($no \cdot cm^{-2}$) Nematoda	Copepoda	Total	Reference
Cape Hatt, Baffin Island[a]	sand	3-12	398.6	44.7	582.5	this study
Beaufort Sea	soft clay - silt	5-6	54.6	2.0	58.4	Carey and Montagna (1982)
a Copenhagen, Denmark	mud	5.5	2.5-7.1	0.1-0.8	5.9-14.7	Krogh and Sparck (1936)[b]
Waddensea, W. Denmark	sand	2-3	4.2-23.4	0.3-40.0	-	Smidt (1951)[b]
Baltic Sea[a]	-	44-45	600.8	12.6	642.1	Elmgren et al. (1983)
Belgian Coast, North Sea	-	-	36.6	16.1	56.2	Willems et al. (1982)

[a] Reference bays only.
[b] As cited in McIntyre (1969).

Table 6. Mean density (no·cm^{-2}) of meiobenthos in five bays at Cape Hatt, northern Baffin Island, during August 1982. Data are expressed as mean ± standard deviation and are based on 4.9 cm^2 core samples (sample sizes given in Table 1).

Taxon	Bay 7	Bay 13	Bay 9	Bay 10	Bay 11
Permanent meiobenthos (total)	(467.05 ± 239.99)	(403.76 ± 164.28)	(500.58 ± 116.52)	(530.70 ± 177.17)	(404.56 ± 269.30)
Foraminifera	65.46 ± 94.45	26.77 ± 29.47	20.00 ± 24.23	44.49 ± 31.24	128.91 ± 197.12
Radiolaria	0	0	0	0.07 ± 0.20	0.97 ± 2.56
Tintinnida	17.95 ± 13.00	10.43 ± 10.66	20.43 ± 15.46	31.19 ± 24.41	4.12 ± 5.00
Kinorhyncha	0.64 ± 1.80	0.21 ± 0.62	0	0	0
Nematoda	317.96 ± 169.49	352.62 ± 145.60	441.79 ± 98.28	396.22 ± 154.38	160.63 ± 120.41
Halacarida	0	0	0	0	1.14 ± 2.77
Crustacea (nauplii)[a]	14.10 ± 18.75	2.51 ± 4.22	3.65 ± 9.27	18.84 ± 18.02	25.53 ± 42.85
Ostracoda	5.46 ± 3.95	2.74 ± 3.35	3.77 ± 3.36	5.27 ± 4.33	3.12 ± 3.41
Copepoda	45.43 ± 50.40	7.98 ± 7.51	10.90 ± 16.17	34.57 ± 26.37	80.08 ± 100.20
Tanaidacea	0.05 ± 0.09	0.50 ± 0.83	0.03 ± 0.07	0.05 ± 0.09	0
Temporary meiobenthos (total)	(22.25 ± 14.88)	(20.53 ± 18.50)	(27.46 ± 20.35)	(55.33 ± 39.96)	(39.75 ± 50.72)
Polychaeta juveniles[b]	1.20 ± 2.23	4.53 ± 13.58	1.27 ± 2.36	7.23 ± 15.75	0
Pelecypoda juveniles	0.10 ± 0.15	0.45 ± 0.42	0.28 ± 0.43	0.27 ± 0.39	0.06 ± 0.15
Gastropoda juveniles	0	0.02 ± 0.07	0	0.05 ± 0.14	0.09 ± 0.23
Nemertinea	0.03 ± 0.07	0	0.03 ± 0.07	0.20 ± 0.48	0
Oligochaeta	0.03 ± 0.07	0	0	0	0.12 ± 0.31
Unidentified[c]	20.89 ± 15.27	15.53 ± 12.52	25.89 ± 19.50	47.58 ± 31.51	39.49 ± 50.67

[a] Includes mainly unidentified copepod nauplii.
u [b] Only includes those polychaetes retained on the smallest sieve (76 um).
[c] Includes turbellarians and unidentified (damaged) juveniles.

Table 7. Mean density (no·cm^{-2}) of major meiobenthic taxa in two bays at Cape Hatt, northern Baffin Island, during August 1983. Data are expressed as mean ± standard deviation and are based on 4.9 cm^2 core samples (sample sizes given in Table 1).

Taxon	Depth (m)	Bay 11 27 August	Bay 13 26 August	Bay 13 27 August	Bay 13 26, 27 August
Permanent meiobenthos (total)	3	642.76 ± 434.29	798.21 ± 623.85	410.14 ± 201.38	604.18 ± 486.22
	6	513.37 ± 313.51	523.18 ± 186.85	549.92 ± 94.52	536.55 ± 141.87
	9	886.92 ± 374.64	616.70 ± 340.81	708.00 ± 337.50	666.50 ± 325.10
	12	656.24 ± 161.90	443.49 ± 231.17	627.05 ± 227.39	535.27 ± 238.71
Foraminifera	3	1.84 ± 2.58	41.72 ± 45.76	21.72 ± 24.31	31.72 ± 36.46
	6	179.98 ± 196.12	17.94 ± 33.81	24.11 ± 30.18	21.03 ± 30.72
	9	190.67 ± 138.05	13.23 ± 14.26	18.17 ± 29.89	15.92 ± 23.12
	12	126.57 ± 120.25	105.68 ± 108.23	260.57 ± 212.33	183.12 ± 179.89
Nematoda	3	516.55 ± 346.13	525.64 ± 388.61	293.04 ± 126.06	409.34 ± 301.03
	6	258.56 ± 121.58	355.69 ± 135.80	425.48 ± 64.65	390.58 ± 107.75
	9	543.56 ± 185.30	571.36 ± 333.93	589.05 ± 257.08	581.01 ± 278.80
	12	414.52 ± 116.21	312.40 ± 214.48	321.13 ± 88.88	316.76 ± 156.60
Ostracoda	3	6.18 ± 9.39	23.30 ± 13.21	9.57 ± 6.03	16.43 ± 12.14
	6	17.30 ± 14.53	5.13 ± 2.13	11.24 ± 9.07	8.18 ± 7.05
	9	12.10 ± 9.85	5.43 ± 4.53	5.50 ± 4.64	5.47 ± 4.35
	12	9.11 ± 9.64	2.81 ± 2.85	3.46 ± 4.04	3.13 ± 3.35
Copepoda	3	58.70 ± 52.04	144.41 ± 182.80	51.78 ± 49.92	98.10 ± 136.31
	6	27.30 ± 16.36	79.72 ± 40.30	52.55 ± 31.85	66.14 ± 37.43
	9	87.78 ± 56.03	17.00 ± 10.03	32.36 ± 36.54	25.38 ± 27.79
	12	69.55 ± 74.61	12.50 ± 11.45	17.01 ± 14.93	14.76 ± 12.90
Harpacticoida	3	48.73 ± 46.68	90.13 ± 114.79	28.21 ± 29.05	59.17 ± 86.13
	6	15.87 ± 12.82	60.94 ± 32.27	35.42 ± 20.69	48.18 ± 29.08
	9	50.43 ± 29.83	12.96 ± 10.08	22.40 ± 17.51	18.11 ± 14.77
	12	53.82 ± 47.42	9.70 ± 8.47	15.75 ± 13.38	12.72 ± 11.14

Table 8. Two factor analyses of variance for densities of major meiobenthic taxa at four depths in the reference bay (Bay 13) at Cape Hatt, northern Baffin Island, on 26 and 27 August 1983. F-values are shown with significance levels (ns = $P>0.05$; * $P\leq0.05$; ** $P\leq0.01$; *** $P\leq0.001$).

	Source of Variation (df)		
Taxon	Day (1,39)	Depth (3,39)	Day x Depth (3,39)
Permanent meiobenthos (total)	0.05 ns	0.47 ns	1.49 ns
Foraminifera	0.10 ns	6.89 ***	0.41 ns
Nematoda	0.00 ns	2.99 *	1.24 ns
Ostracoda	0.01 ns	10.08 ***	1.83 ns
Copepoda	0.35 ns	6.55 **	0.46 ns
Harpacticoida	0.07 ns	3.93 *	0.39 ns

Table 9. Two factor analyses of variance for densities of major meiobenthic taxa at 6 m depth in Bays 11 and 13[a] at Cape Hatt, northern Baffin Island, during August 1982 and 1983. F-values are shown with significance levels (ns = $P>0.05$; * $P\leq0.05$; ** $P\leq0.01$; *** $P\leq0.001$).

	Source of Variation (df)		
Taxon	Day (1,30)	Depth (1,30)	Day x Depth (1,30)
Permanent meiobenthos (total)	0.94 ns	2.79 ns	-0.02 ns
Foraminifera	8.70 **	0.38 ns	1.24 ns
Nematoda	12.33 **	4.44 *	1.81 ns
Ostracoda	2.43 ns	21.93 ***	0.04 ns
Copepoda	-[b]	-[b]	6.37 *
Harpacticoida	-[b]	-[b]	8.14 **

[a] Samples taken in Bay 13 and 26 and 27 August were pooled.
[b] F-values are not shown for main effects because of the significant interaction term.

Table 10. Two factor analyses of variance for densities of major meiobenthic taxa at four depths in Bays 11 and 13[a] at Cape Hatt, northern Baffin Island, during August 1983. F-values are shown with significance levels (ns = $P>0.05$; * $P\leq0.05$; ** $P\leq0.01$; *** $P\leq0.001$).

Taxa	Source of Variation (df) Bay (1,62)	Depth (3,62)	Bay x Depth (3,62)
Permanent meiobenthos (total)	0.90 ns	1.54 ns	0.70 ns
Foraminifera	-[b]	-[b]	10.03 ***
Nematoda	0.03 ns	3.52 *	2.05 ns
Ostracoda	-[b]	-[b]	8.65 ***
Copepoda	-[b]	-[b]	4.84 **
Harpacticoida	-[b]	-[b]	5.09 **

[a] Samples taken in Bay 13 on 26 and 27 August were pooled.
[b] F-values are not shown for main effects because of the significant interaction term.

Table 11. Ratios of nematodes : copepods in macrobenthic samples collected in the study bays at Cape Hatt, northern Baffin Island, during August 1982 and 1983.

Bay	Date	Depth (m)	Mean ± SD	Range	n
7	25 Aug 1982	6	114 ± 281	1-809	8
9	24 Aug 1982	6	176 ± 178	9-476	8
10	23 Aug 1982	6	74 ± 180	4-553	9
11	21-22 Aug 1982	6	25 ± 52	1-142	7
	27 Aug 1983	3	10 ± 3	7-13	6
		6	12 ± 7	6-25	6
		9	7 ± 3	3-11	6
		12	14 ± 12	2-28	5
13	31 Aug 1982	6	57 ± 28	22-95	8[a]
	26 Aug 1983	3	10 ± 8	1-23	6
		6	5 ± 3	3-10	6
		9	38 ± 21	23-75	5
		12	47 ± 34	11-93	6
	27 Aug 1983	3	14 ± 15	3-44	6
		6	11 ± 6	4-18	6
		9	35 ± 27	7-77	6
		12	254 ± 451	10-1137	6

[a] One sample, in which no copepods were found, was not considered.

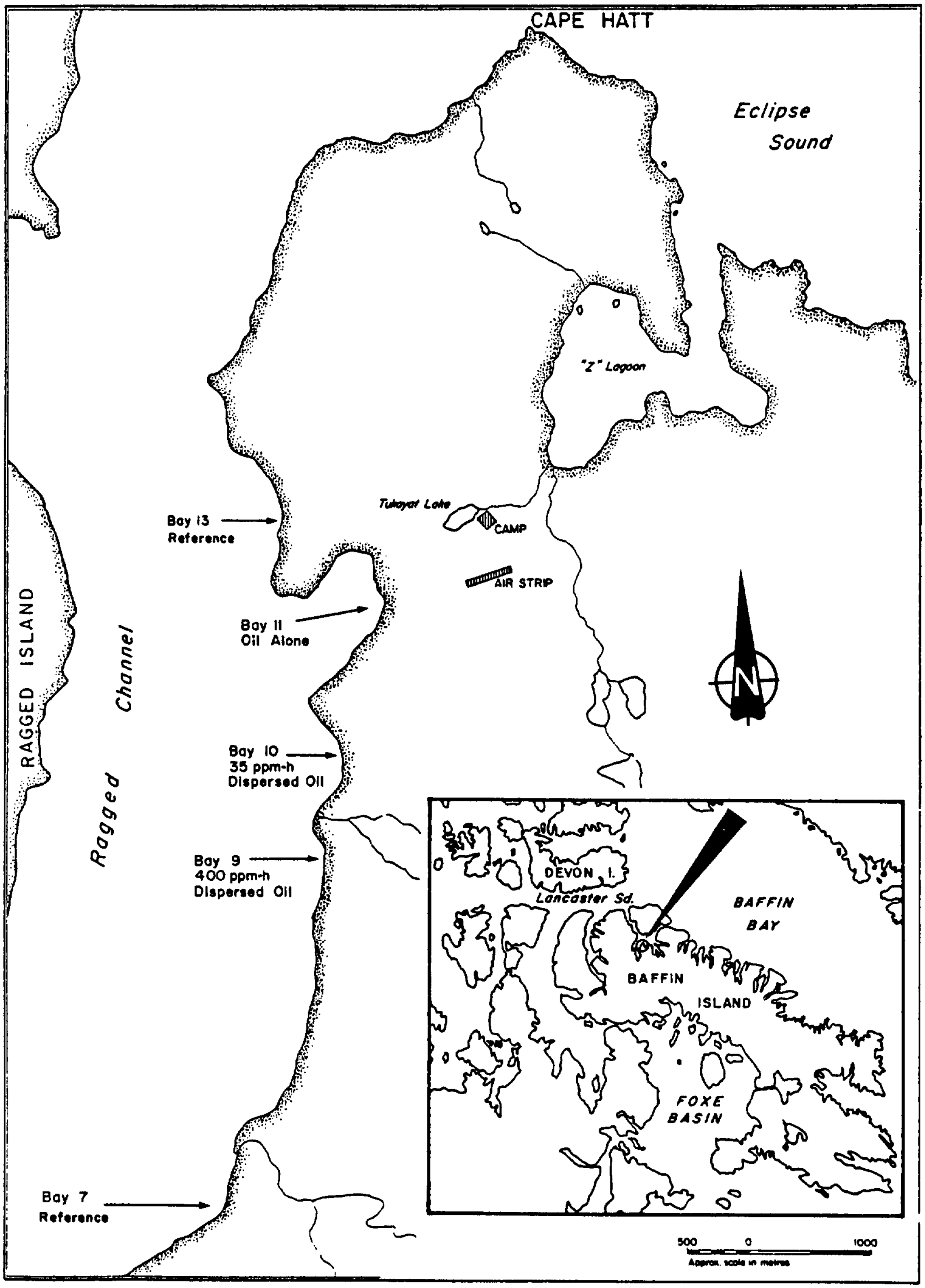

Fig. 1. Locations of study bays at Cape Hatt, northern Baffin Island, and oil treatments applied in August 1981.

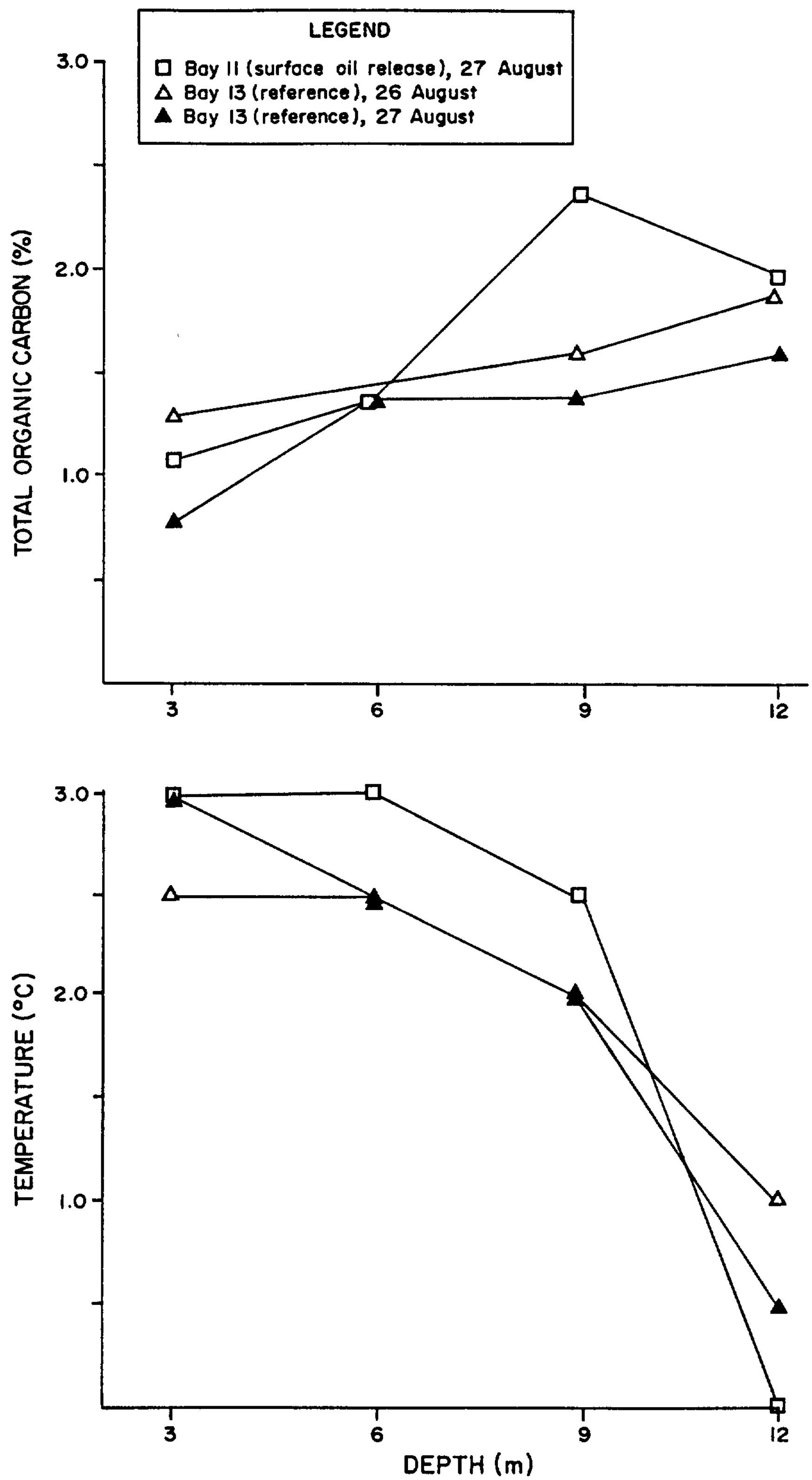

Fig. 2. Water temperatures and total organic carbon in sediments at four depths in two bays at Cape Hatt, northern Baffin Island, during 26-27 August 1983.

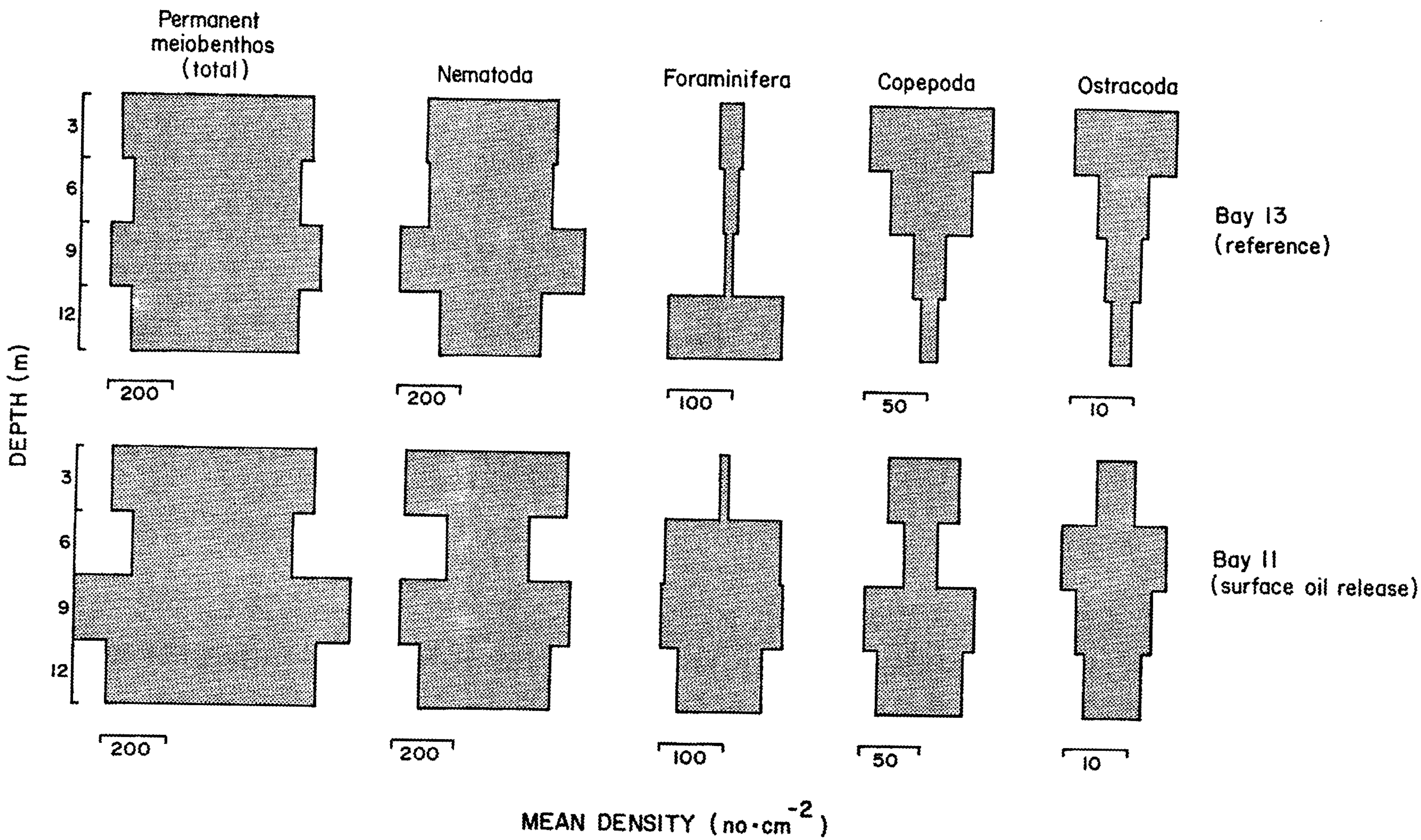

Fig. 3. Mean densities of major meiobenthic taxa at four depths in two bays at Cape Hatt, northern Baffin Island, during 26-27 August 1983.

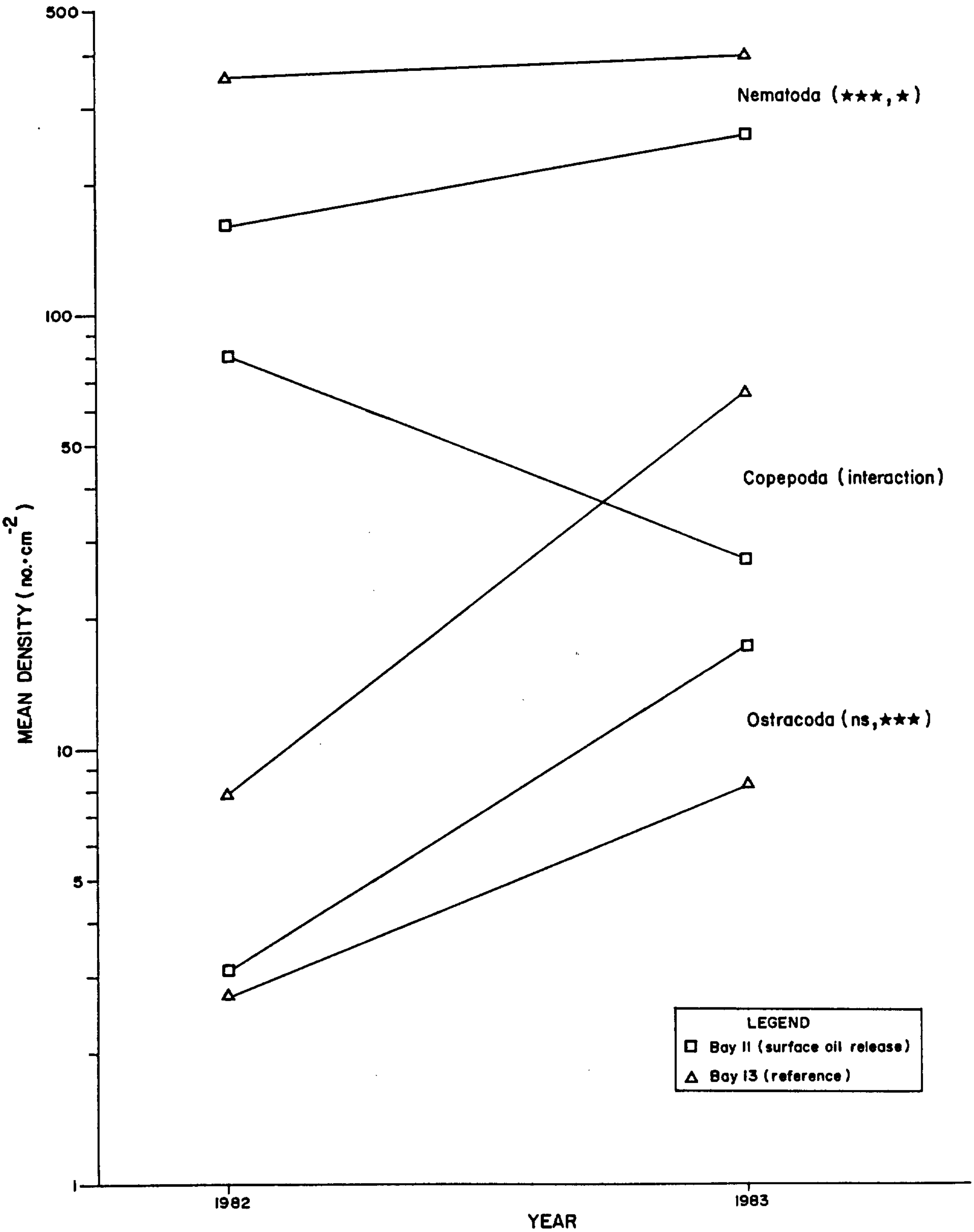

Fig. 4. Mean densities of major meiobenthic taxa at 6 m depth in two bays at Cape Hatt, northern Baffin Island, during August 1982 and 1983. Significance levels are shown for bay, followed by period, effects (see Table 9).

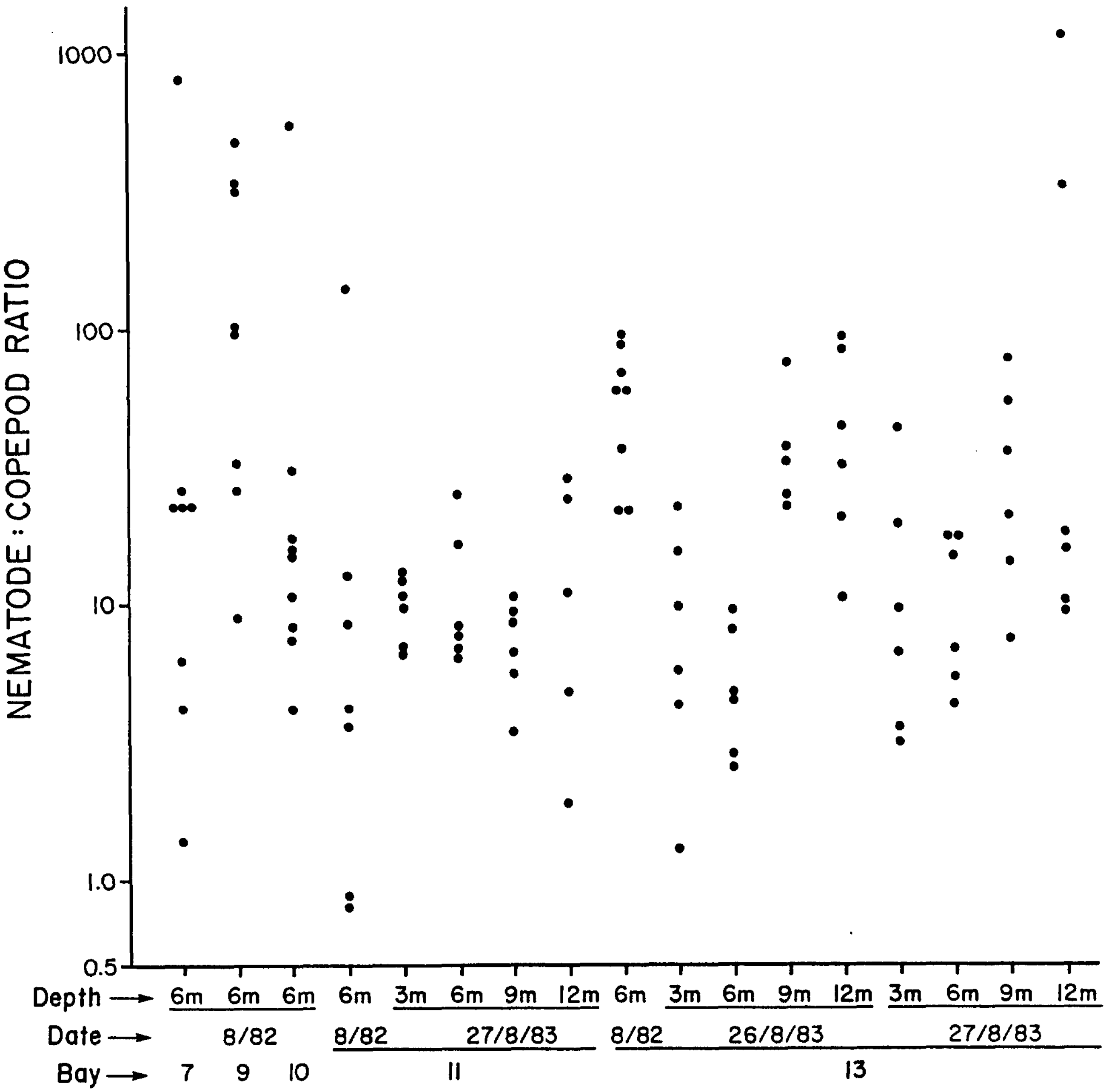

Fig. 5. Ratios of nematodes: copepods in meiobenthic samples collected in the study bays at Cape Hatt, northern Baffin Island, during August 1982 and 1983.

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