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The Biological Setting of the BIOS Site at Cape Hatt, N.W.T., Including the Sampling Design, Methodology and Baseline Results for Macrobenthos

N.B. SNOW,[1] W.E. CROSS,[2] R.H. GREEN[3] and J.N. BUNCH[4]

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ABSTRACT. The Baffin Island Oil Spill (BIOS) Project was carried out in nearshore shallow waters at Cape Hatt, northern Baffin Island. Observations and limited data on phytoplankton, zooplankton, fishes, birds and mammals at Cape Hatt and more detailed information on microheterotrophs indicate that the BIOS site is typical of the majority of eastern and central High Arctic coastal areas. Detailed baseline information on nearshore macrobenthos (infauna, epibenthos and macroalgae) is, in general, similar to that previously reported for other eastern and central arctic locations; comparisons were hindered by a scarcity of detailed studies elsewhere, differences in sampling methods and complexity in infaunal community structure.

Infaunal density (means from 1119 to 3981 individuals·m^{-2} in different study bays and sampling periods) was dominated by polychaetes, especially *Pholoe minuta*, whereas infaunal biomass (59-2267 g·m^{-2}) was dominated by bivalves, primarily *Mya truncata*. Epibenthic crustaceans (207-2527 individuals·m^{-2}) were dominated by ostracods, amphipods (notably *Guernea* sp.) and cumaceans (*Lamprops fuscata*). The sea urchin *Strongylocentrotus droebachiensis* (up to 10 individuals·m^{-2}) and the seastar *Leptasterias polaris* (up to 2 individuals·m^{-2}) were the large and conspicuous echinoderms on study transects. Macroalgal biomass was from 178 to 1112 g·m^{-2} (not including a *Laminaria* zone); communities at 3 m depth were dominated by loose-lying understory algae, particularly *Stictyosiphon tortilis*, *Pilayella littoralis* and *Dictyosiphon foeniculaceus*. The deeper transects (7 m) supported a considerably higher infaunal biomass and density of epibenthos than did 3 m transects in both sampling periods, whereas depth differences in macroalgal biomass varied from September 1980 to August 1981.

An evaluation of the sampling design and procedures used in this study (including efficiency of the diver-operated airlift sampler; the area, location and number of replicate samples collected; and bias, efficiency and consistency in laboratory analysis) indicated that representative samples of the nearshore macrobenthic communities were obtained. The study design and analysis of variance procedures used to analyze the data provided a rigorous framework within which oil effects were evaluated.

Key words: Arctic, benthos, phytoplankton, bacteria, benthic sampling design, sediment, experimental oil releases, Baffin Island, baseline, microheterotroph

RÉSUMÉ. Le projet de déversement de pétrole à l'île Baffin (BIOS) a été mené dans les eaux peu profondes près du littoral du cap Hatt, au nord de l'île Baffin. Des observations et des données limitées sur le phytoplancton, le zooplancton, les poissons, les oiseaux et les mammifères du cap Hatt, ainsi que des renseignements plus détaillés sur les micro-organismes hétérotrophes, indiquent que le site du projet BIOS est représentatif de la plupart des zones littorales de l'est et du centre de l'Extrême-Arctique. Des renseignements détaillés formant une base de référence sur le macrobenthos près de la côte (endofaune, épibenthos et macro-algues) sont, en général, semblables à ceux qu'on a rapportés précédemment dans d'autres endroits de l'est et du centre de l'Arctique; mais on n'a pas pu établir facilement des comparaisons, à cause du manque d'études détaillées menées à d'autres endroits, de différences dans les méthodes d'échantillonnage et de la complexité de la structure de la communauté endofaunique.

La densité de l'endofaune (moyennes de 1119 à 3981 individus·m^{-2} dans différentes baies expérimentales et au cours de différentes périodes d'échantillonnage), était dominée par des polychètes, surtout les *Pholoe minuta*, alors que la biomasse endofaunique (de 59 à 2267 g·m^{-2}) était dominée par des bivalves, en particulier les *Mya Truncata*. Les crustacés de l'épibenthos (de 207 à 2527 individus·m^{-2}) étaient dominés par les ostracées, les amphipodes (notamment l'espèce *Guernea*) et les cumacés (*Lamprops fuscata*). Dans les sections étudiées, les gros échinodermes facilement repérables étaient l'oursin de mer *Strongylocentrotus droebachiensis* (jusqu'à 10 individus·m^{-2}) et l'étoile de mer *Leptastenas polaris* (jusqu'à 2 individus·m^{-2}). La biomasse des macro-algues était de 178 à 1112 g·m^{-2} (sans compter une zone de *Laminaria*); à une profondeur de 3 m, les communautés étaient dominées par des algues sous la couche de surface et peu ancrées, surtout les *Stictyosiphon tortilis*, les *Pilayella littoralis* et les *Dictyosiphon foeniculaceus*. Les sections plus profondes (7 m) renfermaient une biomasse endofaunique et une densité de l'épibenthos beaucoup plus importantes que les sections à une profondeur de 3 m, tandis que les différences de profondeur de la biomasse des macro-algues variaient entre septembre 1980 et août 1981.

Une évaluation du plan et des méthodes d'échantillonnage utilisés lors de cette étude (y compris l'efficacité de l'appareil d'échantillonnage à ascencion par air, opéré par un plongeur; la zone, l'emplacement précis et le nombre d'échantillons identiques, ainsi que l'efficacité, l'erreur statistique et l'uniformité dans l'analyse en laboratoire), ont indiqué qu'on avait recueilli des échantillons représentatifs des communautés du macrobenthos situées près du littoral. Le plan de l'étude et les méthodes d'analyse de variance dont on s'est servi pour analyser les données, ont fourni un cadre bien défini, à l'intérieur duquel on a évalué les effets du pétrole.

Mots clés: Arctique, benthos, phytoplancton, bactéries, plan de l'échantillonnage du benthos, sédiments, déversements de pétrole expérimentaux, île Baffin, base de référence, micro-hétérotrophe

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INTRODUCTION

Many biological studies have been carried out in the Canadian Arctic during the past 15 years largely in response to increased industrial activity, primarily oil and gas exploration, although mining has also contributed. Much of this work has been undertaken by the federal government (e.g., the biological study components of the Beaufort Sea Project) or industry (e.g., the biological components of the Arctic Pilot Project and the Eastern Arctic Environmental Studies program). Such studies have been primarily descriptive and are considered to be "baseline" or "inventory" data acquisition. Much of the earlier, pre-industry work carried out in the Arctic was similar in nature, e.g., the *Calanus* series (Dunbar, 1956). In more recent years, an effort has been made to design, implement and integrate experimental studies into the "inventory" framework, and the Baffin

[1]Box 2120, Inuvik, N.W.T., Canada X0E 0T0
[2]LGL Ltd., 22 Fisher Street, P.O. Box 280, King City, Ontario, Canada L0G 1K0
[3]Department of Zoology, University of Western Ontario, London, Ontario, Canada N6A 5B7
[4]Arctic Biological Station, 555 boul. St-Pierre, Ste-Anne-de-Bellevue, Québec, Canada H9X 3R4

Island Oil Spill (BIOS) Project is a significant example of such effort.

Most reports of environmental impacts of oil spills have been based on follow-up studies after an unanticipated oil spill (e.g., Gilfillan and Vandermeulen, 1978; Krebs and Burns, 1978; Sanders, 1978; Sanders *et al.*, 1980). Experimental studies have also been carried out, but usually on a small scale, whether in laboratory microcosms or field mesocosms (e.g., Percy, 1976, 1977, 1978; Busdosh and Atlas, 1977; Bayne *et al.*, 1979). Uncontrolled field studies suffer from the defect that there is no true experimental replication or manipulation of treatment effects (Green, 1984; Green, in press). On the other hand, small-scale experiments lack realism, especially in relation to impacts of oil spills in the High Arctic.

The biological component of the BIOS Project was planned to fill the gap between these approaches by carrying out an experimental oil spill in the field, using a balanced design of nested spatial scales of sampling effort within realistic treatment conditions applied to different shoreline bays. Effects of chemically dispersed crude oil were compared with the effects of a similar quantity of the same crude oil that was not dispersed and allowed to strand on the shoreline. Any subsequent re-introduction of this oil into the marine environment was by natural processes (see Sergy and Blackall, 1987). The results of studies on the effects of chemically dispersed oil and untreated oil on target communities (microheterotrophs and macrobenthos) are provided elsewhere in this volume (Bunch, 1987; Cross and Thomson, 1987; Cross *et al.*, 1987 a,b).

Because the intended practical use of BIOS results is to assist in the selection of appropriate oil spill countermeasures for arctic nearshore environments, it is important to understand the extent to which the results can be extrapolated. The purpose of this paper is to provide such an understanding in two ways. First, by discussing study design and methodology, this paper evaluates the degree to which the samples collected are representative of the communities studied. Secondly, by briefly describing the Cape Hatt ecosystem and providing detailed baseline information on the shallow marine subtidal benthos at the study site, this paper evaluates the geographic extent to which the study results can be extrapolated.

A harsh climate and high logstics costs combine to make arctic research a formidable proposition. In spite of the major increase in arctic studies during recent years and the concomitant increase in basic knowledge, the Arctic is still a vast area about which relatively little is known in a detailed biological sense. In the Canadian Arctic, the presence of bacteria in marine waters was first reported by Kriss (1963:31-34) and Boyd and Boyd (1963). Later references were made by Glaeser (1971) and Bunch (1974). A sediment flora was classified by McDonald *et al.* and reported in 1963. Since these early studies, several investigations have been initiated in arctic marine waters, of which the BIOS Project is one.

To date, studies of arctic macrobenthos have been of short duration, either single-sample surveys (Ellis, 1960) or wide-area surveys for one or two years (e.g., Thomson and Cross, 1980). The BIOS Project provided an opportunity to collect nearshore benthos data systematically from the same area over a four-year period. Such data are unique for any arctic area (in or outside Canada) and have yielded useful information on growth rates and life cycles. These data will be reported elsewhere, as they are outside the scope of the present volume.

METHODS

Study Area

The study area (Fig. 1) for the nearshore component of the Baffin Island Oil Spill Project consisted of four shallow embayments in Ragged Channel, some 5-8 km SSW of Cape Hatt, Eclipse Sound (72°27′N, 79°51′W). Bays 9 and 10 (dispersed oil release and dispersed oil contamination bays respectively)

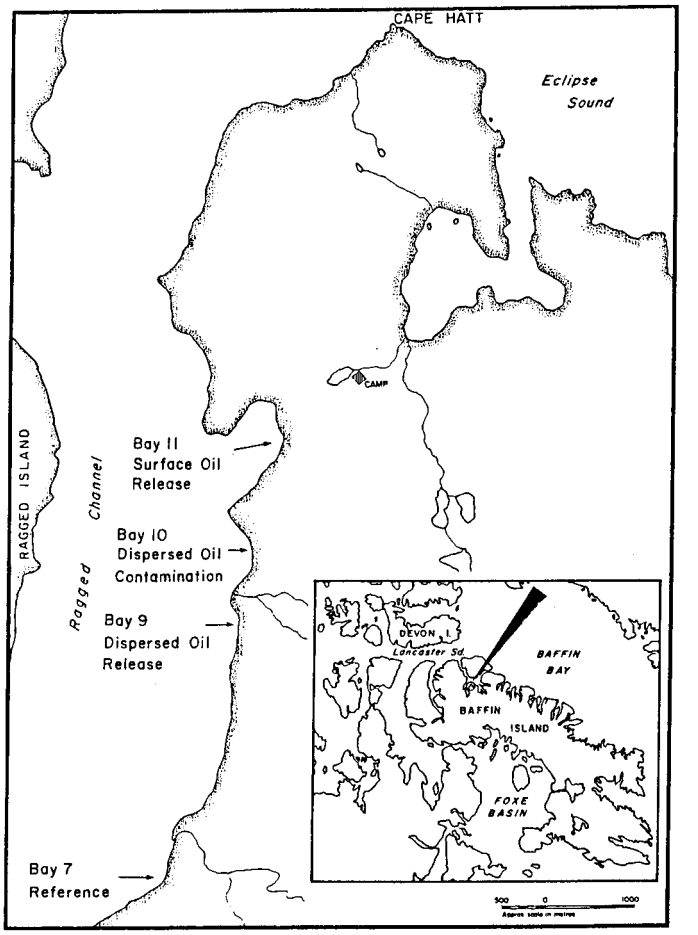

FIG. 1. BIOS site at Cape Hatt, northern Baffin Island, showing the locations of study bays and oil treatments applied in August 1981.

are shallow indentations in the coastline, each about 500 m in length, separated by the delta of a small stream and a distance of somewhat less than 500 m. Bay 7 (reference bay) is similar in size and configuration, located about 6 km to the south, and just south of another small stream. Bay 11 (surface oil release bay) has been designated as the lower half (and Bay 12 as the upper half) of a deeper embayment approximately 1 × 1 km in dimension, located approximately 1 km north of Bay 10.

Field Procedures for Macrobenthos

Observations were made using SCUBA in the study bays during 7 August-17 September 1980, 5 August-20 September 1981, 30 July-13 September 1982 and 3-29 August 1983. Divers monitored each oil release in 1981 and the condition of each bay on the first day following the dispersed oil release. Systematic sampling was carried out during 29 August-17 September 1980,

6-17 August 1981, 29 August-10 September 1981, 8-15 August 1982, 3-12 September 1982 and 6-10 August 1983 from the BIOS Project camp located at Cape Hatt, Baffin Island (Fig. 1). Additional sampling for other studies continued between the two periods in 1981 and 1982 and until 20 September 1981, 13 September 1982 and 29 August 1983. All sampling was carried out by divers working from inflatable boats. Processing and preservation of samples were performed in tents erected on the beach in Bay 12. During September 1980, systematic sampling was carried out in Bays 9, 10 and 11, and during August and September 1981 and 1982 and August 1983, systematic sampling was carried out in Bays 7, 9, 10 and 11 (Fig. 1).

Sampling Locations: Three contiguous 50 m transects were set parallel to the shoreline at each of two depths (3 m, 7 m) in each of the study bays (Fig. 2). Transect locations at each depth in each bay were marked underwater during the first sampling period by driving steel rods approximately 1 m into the substrate at 50 m intervals along a 150 m line. In each bay, sighting lines at the ends of the transects were established on the shore by placing pairs of markers on the beach. Transects were located in subsequent periods using the surface and underwater markers.

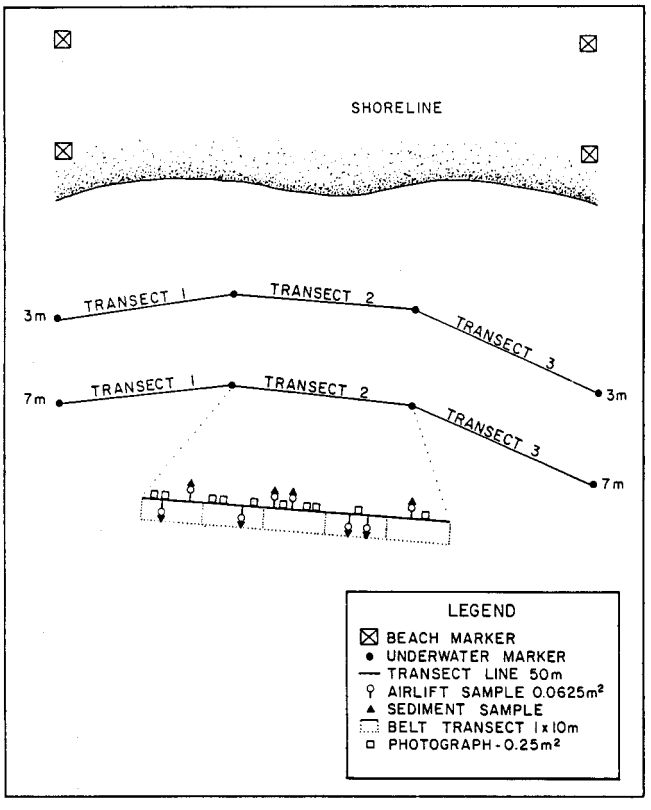

FIG. 2. Schematic representation of sampling design for BIOS benthic study.

A 150 m transect rope marked at 1 m intervals was set between the permanent stakes before (and removed after) sampling at each bay/depth/period combination in 1980 and 1981. Transect lines were left in place from August 1982 until August 1983. The 150 m transect rope marked the locations of three 50 m transects at each depth in each bay. Airlift sampling locations 1 m^2 in area immediately seaward or shoreward of the line were selected using a random numbers table, and the exact location of the 0.0625 m^2 sample within each of these 1 m^2 areas was selected to avoid large rocks on the surface of the sediment. Photograph locations along each transect were also randomly selected and were indicated on a list attached to the camera. Sample locations for airlifts and photographs were re-randomized for each transect and period; on any given transect, randomly selected airlift locations were rejected if they had been used during a previous period. *In situ* counts and supporting collections were made within 1 × 10 m belts along each transect line.

Airlift Sampling: Infauna, epibenthic crustaceans and macroalgae were sampled by means of a self-contained diver-operated airlift. Eight replicate samples were obtained on each of three 50 m transects at each of two depths in each of three bays in September 1980 (total of 144 samples), in each of four bays in each of August and September in 1981 and 1982 (total of 384 samples in each year) and in each of four bays in August 1983 (192 samples).

The airlift consisted of a weighted 2 m length of pipe 8 cm in diameter fitted at the top with a 1 mm mesh net, which retained the sample and could be removed quickly and capped. Air was supplied from a 20 MPa air cylinder fitted with the first stage of a diving regulator, which reduced air pressure to approximately 860 kPa above ambient. Areas to be sampled were demarcated by a ring containing an area of 0.0625 m^2.

The ring was placed on the bottom and pushed as far as possible into the substrate to contain shallow infauna. The airlift was inserted into the ring, the air was turned on and the mouth of the airlift was moved around to thoroughly cover the area within the ring. The air was turned off when all visible organisms had been collected. The net on the airlift was then removed, capped and replaced, and the depth of penetration of the airlift into the substrate was measured to the nearest cm. A sample of surface sediment was collected in a polyethylene jar immediately beside the excavated area during the first sampling period in each bay. After three or four airlift samples had been taken, they were raised to the boat and rinsed in the collecting bags from the side of the boat in order to remove fine sediments. Immediately after each dive, all samples were delivered to the field laboratory.

Quantitative Photography and in situ *Counts:* A photographic record of each transect during each period was obtained on colour slide film using a Nikonos camera with a 15 mm lens, paired Vivitar electronic flashes and a fixed-focus framer covering a bottom area of approximately 0.25 m^2. Ten photographs were taken at randomly located intervals along each 50 m transect line during each period. In addition to providing a permanent visual record of each study area, photographs were used to estimate densities of visible surface fauna that were too sparsely distributed to be represented adequately in airlift samples. In order to obtain quantitative information on effects that were apparent immediately after the dispersed oil release, an additional six randomly located photographs were taken on each transect in Bays 9 and 10 on the second day following the release. Photographs were also taken in Bays 7 and 11 on the fourth and fifth days following the release. (No immediate effects were apparent in these bays.)

Those macrophytes and invertebrates too large and sparsely distributed to be sampled representatively by airlift or camera were counted *in situ*. On each 50 m transect during each period, counts of urchins, starfish and individual kelp plants were made within five 1 × 10 m strips parallel to and immediately adjacent to the transect line. Collections of representative plants and animals were also made for species identification. Additional counts of urchins and starfish were made after the dispersed oil

release in 1981 using both *in situ* and photographic techniques (see above).

Laboratory Analysis Procedures for Macrobenthos

All samples were processed in the field within 12 h of collection. Samples were emptied into large plastic trays, and nets were carefully rinsed and picked clean. Entire samples (minus large rocks and gravel) were labelled and preserved in 10% formalin:90% sea water. Macrophytic algae other than those in airlift samples were pressed on herbarium paper and dried at room temperature.

Detailed laboratory processing and analysis of the samples was carried out within six months of collection. All samples collected (1104) were analyzed except for (1) the 48 samples collected in Bay 10 during 1983, and (2) four samples that were inadvertently mixed during laboratory analysis in 1981. The resultant loss in data was one of eight replicates at each of 3 m and 7 m in Bay 10 during Pre-spill Period 2 and at each of 3 m and 7 m in Bay 11 during Post-spill Period 1.

Samples initially were rinsed to remove formalin and sediment and then were separated into five fractions. The first fraction, consisting of all material passing through a 1 mm mesh screen and retained on a 0.45 mm mesh screen, was preserved in alcohol for future reference. The second fraction, separated by rinsing, contained algae, detritus and most soft-bodied animals. This fraction was examined under a binocular microscope, and animals >1 mm in length were sorted into major taxonomic groups; the remaining algae and detritus was blotted dry and weighed on a Mettler PT 200 balance. In 52 samples that contained large volumes of algae (>500 ml), large and conspicuous organisms were picked from the entire sample, but only a subsample of known weight was examined microscopically.

Fractions 3-5 were obtained by using nested sieves to separate the balance of the sample into three different size fractions (1-2.8 mm; 2.8-5.6 mm; >5.6 mm) containing sand, gravel, bivalves and some soft-bodied animals. The large fraction was sorted in a glass tray into major taxonomic groups. Shell fragments and entire bivalve shells were separated, labelled and stored for future reference.

The 1-2.8 mm and 2.8-5.6 mm fractions from 1980 and 1981 samples were routinely sorted under a binocular microscope. Careful checking of a number of these samples indicated that approximately 10% of the smaller organisms remained in the sand and gravel and were excluded from analysis. Hence a more efficient method using differential specific gravity (Sellmer, 1956) was used in 1982 and 1983. During 1983, this improved method was also applied to sand and gravel from the 1980 and 1981 samples. The 1 mm and 2.8 mm sieves were placed on paper towelling to remove excess moisture, and the contents were then emptied into a plastic pail containing a 70% solution (by weight) of $ZnCl_2$ (s.g. = 2.0). The mixture was gently stirred, and organisms that floated to the surface were removed with a 1 mm mesh net. The procedure was repeated a minimum of two times. The specific gravity of the solution was measured before each sample was processed and was kept relatively constant (s.g. = 1.8-2.0) by adding $ZnCl_2$ as necessary. The combined net contents were sorted into major taxonomic groups, and entire bivalve shells were separated and stored in labelled plastic bags for future reference.

All animals were identified to species level whenever possible; unidentified or tentatively identified species were sent to appropriate authorities for identification or verification. In cases where verifications indicated that additional taxonomic effort was required on previous years' samples, the taxa in question were re-examined during the final year (1983). 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 prior to analysis. For each taxon identified, individuals were counted, gently blotted dry and weighed together to the nearest milligram on a Mettler PT 200 or PC 220 balance. Unless otherwise specified, all weights are preserved (10% formalin) wet weights, including mollusc shells but excluding polychaete tubes. Lengths of individuals of all bivalve species and diameters of the calcareous oral rings of the holothurian *Myriotrochus rinkii* were measured to the nearest mm. After laboratory examination, all taxa were stored in 75% ethanol; a solution of 3% propylene glycol in 75% ethanol was used for crustaceans.

For each of four common bivalve species (*Mya truncata*, *Astarte borealis*, *Macoma calcarea* and *Serripes groenlandicus*), the relationships between length, wet weight and dry weight were derived as follows: for each bay and period, approximately 50 undamaged individuals of each species were selected (where possible) from airlift samples taken along the middle transect at 7 m depth; *S. groenlandicus* was selected only from 1981, 1982 and 1983 samples. If necessary to obtain a sample size of 50 per bay, animals from the inner ends of the outer two 7 m transects were also used. For each individual the length, wet weight including shell, wet meat weight and dry (constant) meat weight were determined. Constant dry weight was obtained by drying at 60°C in a Fisher Isotemp Oven Model 301 for 24-48 h (depending on species), time periods that were established by weighing at daily intervals until constant weight was found.

Airlift samples of algae and detritus from 3 m depths were weighed (see below), and 524 of the 526 samples were analyzed in detail. Large and conspicuous species were sorted from each of these samples and weighed; in 33 cases (samples that had been subsampled for invertebrate sorting), only the subsample was examined. A subsample of approximately 2 g wet weight was separated from the balance of the sample and sorted completely into the following categories: *Stictyosiphon tortilis*, *Dictyosiphon foeniculaceus*, *Sphacelaria* spp., a mixture of *Pilayella littoralis* and tubular diatoms, other species and detritus (non-algal material). An appropriate subsample factor was then applied to extrapolate these results to the unsorted portion of the sample. Formalin wet weights were determined by rinsing in water, removing water by vacuum filtration in a Buchner funnel using Whatman #1 Qualitative filter paper until drops were 30 seconds apart and weighing immediately to the nearest milligram on a Mettler PC 220 balance.

Methods used in sediment analysis were identical to those of McLaren *et al.* (1981). The sand fractions (<4 Φ) were separated using 0.5 Φ interval sieves in the range of −1.0 Φ to 4.0 Φ. Silt and clay (>4.0 Φ) were determined using the pipette method. Gravel content was determined for entire samples but was excluded from all other calculations (grain size, sorting coefficient and percent composition of sand, silt and clay).

Study Design

This study was designed so that classical analyses of variance (ANOVA) procedures could be used. Data from each depth sampled were analyzed by three-factor fixed-effects ANOVA using the GLM procedure of the SAS computer program pack-

age (Helwig and Council, 1979; Freund and Littell, 1981). The three factors, transects (nested within bays), bays and periods, had three, four and six levels respectively. In statistical terms, a significant interaction between spatial and temporal effects indicated a possible oil effect (Green, 1979). Because of the nested design, the among-transects term rather than the residual error term was used to test the significance of main effects (periods, bays) and of the interaction between the main effects. When interaction terms involving transects were non-significant ($P>0.05$), they were pooled with the transect term before testing for main effects. When interactions involving transects were significant ($P\leq0.05$), they were not pooled with the transect term, which was used alone as the denominator in the tests.

Further details of analytical procedures are given in other papers in this volume (Cross and Thomson, 1987; Cross *et al.*, 1987a,b). The study design is discussed further in a later section of this paper.

RESULTS AND DISCUSSION

Evaluation of Sampling Efficiency and Laboratory Techniques

It is of particular importance in a structured study such as the BIOS Project to ensure that the community studied is representatively sampled, i.e., to collect an adequate number of samples of a size appropriate to the organisms' distributions and to collect all organisms of a specified minimum size within the sampling unit. Clearly, it is desirable to collect a large number of samples and to use a small mesh size in sample collection and processing, but there are always logistic constraints to consider (Green, 1979). The sampling design in the present study was in general decided *a priori*, whereas some of the options (e.g., mesh size and therefore minimum organism size; sample unit area; matched vs. re-randomized sampling in different periods) were evaluated during preliminary sampling in 1980. In this section, we discuss the above considerations and present data in order to evaluate sampling efficiency and point out possible sources of error.

Mesh size of sampling and sample processing equipment determines the minimum size of organisms that are quantitatively sampled, although some individuals smaller than the mesh size are retained. Birkett and McIntyre (1971) suggested that a 0.5 mm mesh size should be used for macrofauna but pointed out that in coarse sediments this size may retain too much material. Elsewhere, 1 mm has been used as the minimum mesh (and organism) size for macrofauna (e.g., Ankar and Elmgren, 1978). During preliminary sampling at Cape Hatt in 1980, it was found that the use of a 0.5 mm mesh collecting bag increased the amount of sand collected by about five times over that retained in a 1 mm mesh bag. Because 0.5 mm mesh would have greatly increased sample collection and processing time, 1 mm was used as the lower limit.

Penetration depth of sampling devices is of particular concern where deeply burrowing animals occur, and the inadequacy of most grab samples in this respect is well known (e.g., Holme, 1971; McIntyre, 1971). The problem is particularly acute when the substrate consists of hard-packed sand or sediments with high gravel or rock content. The latter type of substrate occurs in each of the study bays at Cape Hatt, and an airlift sampler was chosen for this reason. Preliminary sampling in August 1980 indicated that all of the species and most of the individuals found in the Cape Hatt benthic community could be sampled adequately with a sampler penetration depth of no more than 8-10 cm. However, a large proportion of the benthic biomass was contributed by large individuals of the bivalve *Mya truncata*, which occurred to depths of 15 cm in the sediment.

Mean depth of penetration of the airlift sampler used in the present study was from 12.0 to 17.1 cm at 7 m depth in each of the bays and periods (Table 1). Analysis of variance indicated that penetration depth on 7 m transects did not vary significantly among bays or periods, nor was there any significant bay-by-period interaction (Table 2). Furthermore, visual and tactile inspection of sampling plots by divers during and after sampling ensured that all large individuals of *Mya truncata* were collected by the sampler. Sampler penetration was shallower at 3 m depth in all bays (6.0-14.6 cm; Table 1) because a consolidated sediment layer and/or rock was present. At this depth, bay and period differences were ambiguous in two types of analysis of variance (Table 2) because of significant ($P>0.01$) interactions between bay and period factors. In the third analysis type, period and bay differences were significant (Table 2). Again, however, inspection of the sampling plots ensured that all large individuals of *M. truncata* were collected.

The available data on highly motile epibenthic crustaceans at Cape Hatt were from the same airlift samples upon which infaunal results were based. Estimates for epibenthic crustaceans likely are not as accurate as those for infauna, however, because of escape of organisms from the area sampled and inclusion of those inadvertently drawn into the airlift from outside the 0.0625 m^2 sampling areas. A modification to the sampler, developed for EAMES studies to overcome this shortcoming (see Thomson and Cross, 1980), was not practical in the present study because of difficulties in operating the airlift in the mixed sediment-rock substrate. No quantitative estimates are available for the extent to which epibenthic crustaceans were over- or underestimated in the present study. There is only one reason to expect differences among bays or periods in the accuracy of our estimates. Crustaceans that may have been immobilized by dispersed oil would not have escaped from the area sampled, and those outside the sampling area would not have been included.

The area of the airlift sampling unit employed in the present study (0.0625 m^2) was somewhat smaller than the 0.1 m^2 area

TABLE 1. Penetration depths (cm) of the airlift samples in four bays[1] at Cape Hatt, northern Baffin Island, during September 1980, August and September 1981 and 1982 and August 1983;[2] data are expressed as mean ± standard deviation and are based on eight replicate 0.0625 m^2 samples on each of three transects for each depth, period and bay

Water depth (m)	Period	Bay 7	Bay 9	Bay 10	Bay 11
3	Pre-spill 1	—	10.7 ± 2.7	11.2 ± 2.7	8.0 ± 2.8
	Pre-spill 2	7.6 ± 2.5	10.5 ± 3.3	10.3 ± 2.4	10.4 ± 3.9
	Post-spill 1	8.1 ± 2.8	14.6 ± 3.7	11.4 ± 3.2	11.7 ± 4.2
	Post-spill 2	6.0 ± 3.1	14.1 ± 3.3	11.5 ± 3.7	9.3 ± 4.6
	Post-spill 3	7.3 ± 2.3	11.4 ± 3.9	13.3 ± 3.0	10.0 ± 5.3
	Post-spill 4	8.7 ± 1.7	12.9 ± 4.2	—	12.5 ± 4.1
7	Pre-spill 1	—	16.4 ± 2.7	15.8 ± 3.7	16.9 ± 3.0
	Pre-spill 2	12.0 ± 2.8	13.0 ± 3.3	14.5 ± 3.4	12.9 ± 2.2
	Post-spill 1	13.6 ± 2.7	15.9 ± 2.7	14.7 ± 2.4	17.1 ± 6.2
	Post-spill 2	15.0 ± 3.4	14.6 ± 2.9	13.5 ± 2.8	14.3 ± 2.9
	Post-spill 3	13.0 ± 3.4	12.9 ± 4.5	15.3 ± 4.5	14.3 ± 4.2
	Post-spill 4	15.5 ± 3.7	14.9 ± 2.5	—	14.5 ± 3.0

[1]Bay 7 (reference), Bay 9 (dispersed oil release), Bay 10 (dispersed oil contamination), Bay 11 (surface oil release).
[2]Pre-spill Periods 1 and 2 (September 1980, August 1981) and Post-spill Periods 1, 2, 3 and 4 (September 1981, August 1982, September 1982, August 1983).

TABLE 2. Three-factor analyses of variance for penetration depth of airlift samples in four bays[1] at Cape Hatt, northern Baffin Island, during September 1980, August and September 1981 and 1982 and August 1983[2]

Analysis	Depth (m)	Source of variation				
		Period	Bay	Period by bay	Transect (bay)[4]	Per by trans (bay)[5]
Bays 9, 10, 11 1980-82	3	—[3]	—[3]	2.36* (8,30)	4.16*** (6,311)	0.79 ns (24,311)
	7	2.42 ns (4,6)	0.23 ns (2,6)	0.49 ns (8,6)	4.32*** (6,310)	2.76*** (24,310)
Bays 7, 9, 10, 11 1981, 1982	3	—[3]	—[3]	2.31* (9,32)	4.00*** (8,332)	0.66 ns (24,332)
	7	2.04 ns (3,8)	0.72 ns (3,8)	0.73 ns (9,8)	3.80*** (8,331)	2.10** (24,331)
Bays 7, 9, 11 1981-83	3	3.75* (4,30)	44.99*** (2,30)	1.84 ns (8,30)	4.27*** (6,313)	0.70 ns (24,313)
	7	3.49 ns (4,6)	0.68 ns (2,6)	0.78 ns (8,6)	2.51* (6,313)	2.00** (24,313)

F-values are shown with significance levels (ns = $P>0.05$; * $P\leq0.05$; ** $P\leq0.01$; *** $P\leq0.001$) and degrees of freedom.
[1]Bay 7 (reference), Bay 9 (dispersed oil release), Bay 10 (dispersed oil contamination), Bay 11 (surface oil release).
[2]Pre-spill Periods 1 and 2 (September 1980, August 1981) and Post-spill Periods 1, 2, 3 and 4 (September 1981, August 1982, September 1982, August 1983).
[3]Interpretation of main effects confounded by significant interaction of period-by-bay term.
[4]Transects are nested within bays.
[5]Where period-by-transect (bay) interaction was ns, it was pooled with transect (bay) effect to test bay, period and period-by-bay effects; where period-by-transect (bay) was significant ($P<0.05$), transect (bay) alone was used to test main effects.

that is generally recommended (e.g., McIntyre, 1971), although this recommendation is based primarily on the performance of grab samplers. The size of our sampler appears to be adequate, however, based on Green's (1979:38) rule of thumb that the ratio of the volume of the organism to the volume of the sample unit should be 0.05 or less. The largest organism in our samples, *Mya truncata*, was at most about 50 cc in volume, whereas the volume sampled was approximately 10 *l* (ratio of 0.005). Furthermore, our samples contained an average of more than 200 infaunal individuals per sample; those species included in analyses of community structure (those contributing 0.9% or more to total numbers), therefore, averaged about two individuals per sample. The epibenthic taxa considered for analysis were less abundant, but the least abundant taxon considered at each depth still averaged about one individual per sample. Animals more sparsely distributed, including many small species and some large species (e.g., the bivalve *Clinocardium ciliatum*, the gastropod genus *Buccinum*, the polychaete genus *Phyllodoce* and the decapod *Sclerocrangon boreas*), were excluded from analysis.

The number of replicate samples collected (8 per transect and 24 per bay during each period), in conjunction with the size of the sampling unit, appears to have been adequate to obtain a representative sample of the communities present. Species-area curves are useful in determining the area that must be sampled in order to yield a representative estimate of the number of species present. The curves in Figure 3 show the cumulative number of species of infauna and of epibenthos collected in various numbers of samples at each depth in each bay. At both depths the curves flattened after 0.5-1.0 m^2 of substrate had been sampled (i.e., 8-16 samples). Depending on depth and bay, the number of infaunal species found in 8 samples represented 73-85% of the total number of species collected in all 24 samples; 90-95% were found in 16 samples (1 m^2). The corresponding percentages for epibenthos were 78-96% in 8 samples and 89-100% in 16 samples.

The airlift sampling locations 1 m^2 in area were selected along the transect lines using random numbers, but the exact location of the sample within the 1 m^2 area was selected to avoid large rocks on the substrate surface. Also, samples were not collected in areas where there was evidence of recent ice scour. Thus our samples are biased toward areas of higher faunal abundance, and to some extent our data overestimate the actual abundance and biomass of benthos in the study bays. However, this bias was consistent in all bays and periods and does not affect conclusions about oil effects.

One possible source of sampling error resulted from the loss, and subsequent replacement, of one of four transect markers at 3 m depth in each of Bays 9 and 10 in August 1981. The same marker was also lost and replaced in Bay 10 in August 1982. It is possible, therefore, that transect locations in these cases were not identical from year to year; hence, confounding of temporal and spatial variability may have occurred. However, these few transect markers were replaced as close to the original locations as possible by measuring depth, so their locations likely do not differ greatly from year to year. There were no obvious trends in the data for several species of infauna and macroalgae (i.e., no apparent transect-by-period interactions in Bays 9 and 10 between the appropriate sampling periods) to indicate that locations had differed greatly.

In the laboratory, samples were analyzed in random order during all years to ensure that no among-bay or among-period bias occurred. Possible sources of error for which bias was avoided were progressive changes in procedure or operator error over the 2- to 4-month periods of laboratory analysis and, more importantly, in biomass of benthic plants and animals. Mills *et al.* (1982) have shown that bivalves lose weight in 10% formalin and that all taxa tested lose weight in alcohol. Relative stability in weights was reached after one or two months in preservative. There may be some year-to-year variability in our biomass data, as laboratory analysis was completed about one month earlier in 1980 (September samples only) and two

months earlier in 1983 (August samples only) than in 1981 and 1982 (August and September samples). This variability is likely small, however, as all samples had been preserved for at least one month before wet weights were determined. Mills *et al.* (1982) concluded that "Precision, though not accuracy, of wet weights can only be achieved after specimens have been in preservation for a month or more."

The use of differential specific gravity (using $ZnCl_2$; Sellmer, 1956) increased accuracy (by at least 10%) and precision in separating animals from the substrate; this procedure eliminated human error in sample sorting. This technique was used in 1982 and 1983, and in 1983 was applied to 1980 and 1981 samples (the sand and gravel had been retained). The 1980-83 results are, therefore, directly comparable.

Year-to-year consistency in species identification was ensured in 1983. The results of verifications of species identifications were incorporated, and samples from previous years were re-analyzed where necessary. Furthermore, all bivalve samples were re-analyzed in 1983 to correct any inconsistencies among years that resulted from analysis by different technicians in different years. All other major groups (polychaetes, gastropods, echinoderms and amphipods) were identified by permanent staff.

Dry weights of bivalves used in weight-length analyses were based on specimens initially preserved in 10% formalin and transferred to 75% alcohol after samples were sorted. Thus, the measured dry weights underestimate actual dry weight. Length of time in each preservative varied among samples, but samples were analyzed in random order to eliminate bias among bays and periods. Bias was introduced in 1983, however, when dry weight determinations were carried out 2-3 months earlier than in previous years. The effect of increased time in alcohol (10 vs. 125 days) was, therefore, tested for *Macoma calcarea* from one bay (Bay 7). Analysis of covariance showed a highly significant difference in regression line slopes for samples of 50 individuals that were in 75% alcohol for 10 and 125 d ($F = 13.88$; $df = 1,96$; $P = 0.0003$). After preservation for 125 d, the mean dry weight of an average-sized *Macoma* was 87.8% of the mean after 10 d. This bias is considered in the presentation of results (Cross and Thomson, 1987).

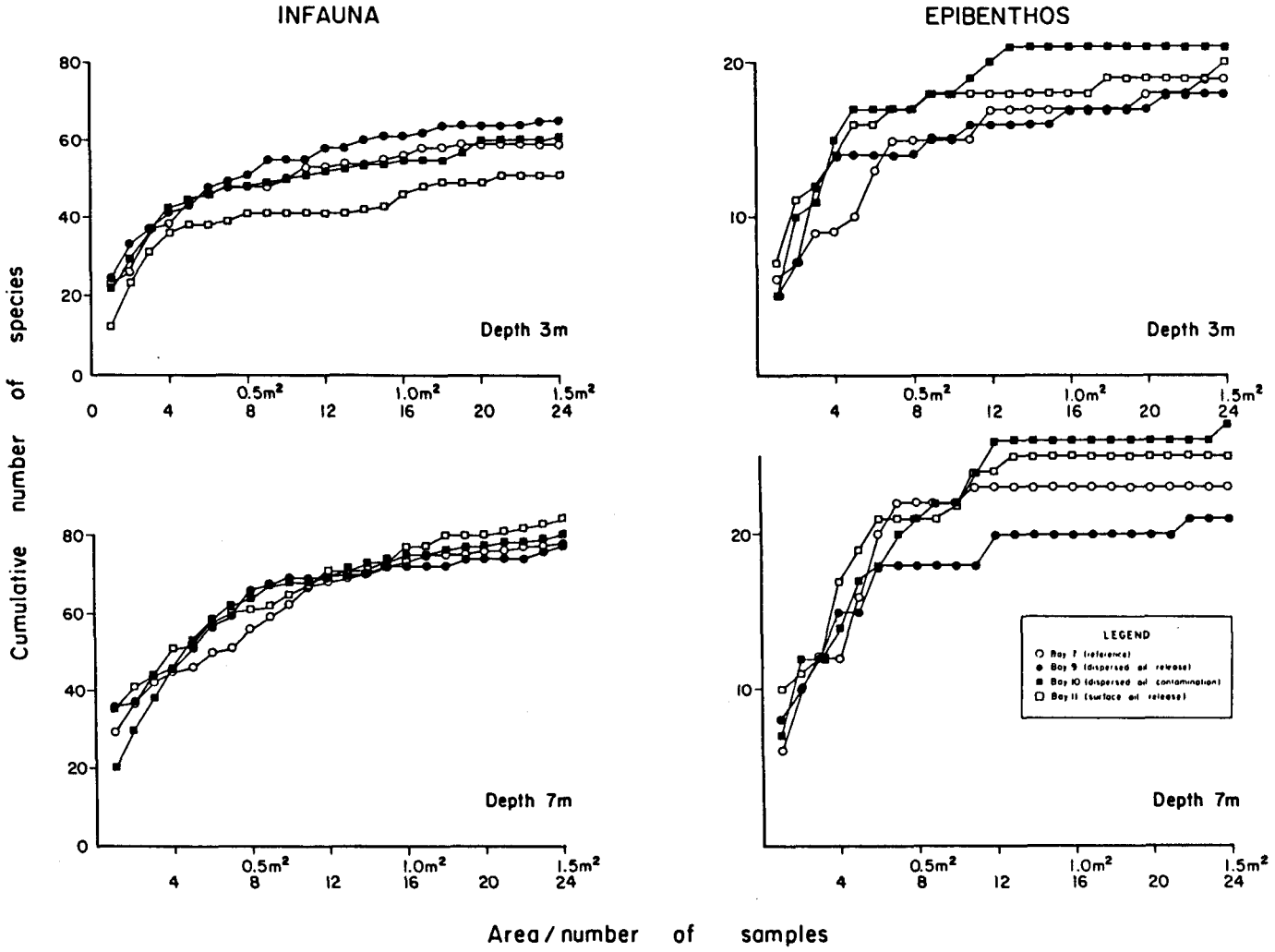

FIG. 3. Species-area curves for infauna and epibenthos in four bays at Cape Hatt, northern Baffin Island, during September 1980 and during August 1981.

Study Design

The original study design had both virtues and defects, and some unforeseen events during the execution of the study added some more defects. The virtues were that there was a planned experimental design, with treatments (including a control) crossed with pre- and post-treatment observations, and a balanced spatial and temporal nested array of samples within those treatment place-and-time combinations. Elegant and powerful classical statistical procedures for testing effects of oil-related treatment conditions (analyses of variance and covariance) followed from the design.

The defects of the original design were (1) that there were not replicate bays within treatments, (2) that the three bays were not randomly assigned to the treatments and (3) that there was only one pre-spill year; therefore no among-year variation could be estimated for the "baseline" condition. The first of these was unavoidable on the grounds of cost and logistic constraints. Even two replicate bays per treatment condition would have doubled cost, diver time and labour-intensive operations such as sorting and taxonomic identification of organisms. Although the "one bay per treatment condition" design was necessary for these reasons, it is unfortunate because it results in a lack of true experimental replication (Hurlbert, 1984). The "pseudo-replication" represented by among-transect (within-bay and within-time) variation must suffice as an error term in statistical tests of oil-related impact on biota. The second point is that the treatment conditons were assigned to each of the three bays partly based on their locations to make the logistics of applying dispersed and undispersed oil easier and to minimize cross-contamination. A random allocation of treatments to bays would have been better on purely statistical grounds. Thirdly, there is no temporal replication for the temporal control. We have no measure of year-to-year variation under natural conditions, except by using pre- *and* post-spill years in the control bay.

Defects added during the execution of the study were (1) contamination of the original control bay (Bay 10) with dispersed oil after the experimental release, (2) adding a new "control" bay (Bay 7) at the time of the second (August 1981) pre-spill sampling and (3) in the final year of sampling (1983) not analyzing Bay 10 samples. The consequences of these three intentional or unintentional changes are that the design became unbalanced and could not be analyzed in a single ANOVA. For example, all four bays could only be analyzed from August 1981 (Bay 7 was not sampled in September 1980) to September 1982 (Bay 10 samples collected in 1983 were not analyzed). A second analysis was done using data from the beginning of the study (September 1980) through September 1982, with Bay 7 omitted. A third analysis was done using data from August 1981 to August 1983, with Bay 10 omitted. Fortunately the results and interpretations from these three overlapping analysis designs were largely in agreement, but there is no doubt that the power and clarity of the original design were partially lost.

Subtidal Sediments

The four study bays were generally 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 the shallow embayments in Ragged Channel (Bays 7, 9 and 10). The 3 m transect lines were just seaward of this slope. The substrate on 3 and 7 m transects consisted of a mixture of silt, sand, gravel and larger rocks (Table 3). With increasing depth, an unconsolidated silt veneer overlying the substrate became more predominant, and sparsely distributed boulders occurred.

Grain size data (Table 3) are expressed in logarithmic units (Φ). Large numbers mean fine grain. Gravel consists of particles greater than 2 mm across and for present purposes is excluded from all calculations except where % gravel is discussed. Sand falls in the range of −1.0 Φ (2 mm) to 4.0 Φ (0.0605 mm), silt in the range of 4.0 Φ to 9.0 Φ (0.002 mm), and clay is finer than 9.0 Φ.

Sediments at 3 m depth were generally fine to very fine sand (2-4 Φ). In all but four samples, sand constituted at least 75% of the fine fraction of the substrate. The clay content was generally less than 5%. Sediment differences among bays were small, as was within-bay variability in mean grain size, sorting coefficient and percent sand, silt and clay (Table 3). Percent gravel was considerably more variable within bays, and a much higher gravel content occurred in Bay 7 than in the other three bays. At 7 m depth, sediments were slightly finer (higher mean Φ) and more poorly sorted than at 3 m depth. The percentages of sand and gravel were lower, and percentages of silt and clay were higher than at 3 m (Table 3). As was the case at 3 m depth, among-bay differences in mean grain size and sorting coeffi-

TABLE 3. Sediment characteristics at two depths in four bays[1] at Cape Hatt, northern Baffin Island, during September 1980 and August 1981[2]

Depth (m)	Bay	Mean grain size (Φ)	Sorting (Φ)	Gravel[3] (%)	Sand (%)	Silt (%)	Clay (%)	Sample size
3	7	2.66 ± 0.53	2.40 ± 0.30	76.15 ± 14.76	81.45 ± 7.84	15.53 ± 6.45	3.03 ± 1.58	23
	9	3.10 ± 0.30	2.29 ± 0.44	42.88 ± 22.00	83.27 ± 5.45	12.10 ± 4.29	4.63 ± 1.21	24
	10	3.34 ± 0.38	2.33 ± 0.28	33.73 ± 17.45	77.27 ± 7.77	17.61 ± 5.96	5.12 ± 1.95	24
	11	2.84 ± 0.24	2.35 ± 0.33	37.88 ± 16.95	82.95 ± 3.99	12.84 ± 3.10	4.21 ± 1.12	24
	All	3.00 ± 0.46	2.34 ± 0.34	47.36 ± 24.34	81.23 ± 6.79	14.51 ± 5.49	4.26 ± 1.67	95
7	7	4.09 ± 0.68	2.70 ± 0.28	66.96 ± 11.65	60.94 ± 13.19	32.14 ± 10.86	6.92 ± 3.19	24
	9	3.50 ± 0.17	2.14 ± 0.10	7.59 ± 5.25	80.54 ± 3.00	14.28 ± 2.46	5.18 ± 0.67	10
	10	3.78 ± 0.30	2.28 ± 0.16	18.41 ± 17.46	69.34 ± 6.88	24.96 ± 5.95	5.70 ± 1.08	14
	11	3.76 ± 0.51	3.18 ± 0.26	19.94 ± 11.05	65.56 ± 7.14	23.75 ± 4.60	10.67 ± 2.92	21
	All	3.84 ± 0.54	2.68 ± 0.45	34.20 ± 27.27	66.90 ± 11.21	25.54 ± 9.42	7.56 ± 3.30	69

Data are expressed as mean ± standard deviation.
[1]Bay 7 (reference), Bay 9 (dispersed oil release), Bay 10 (dispersed oil contamination) and Bay 11 (surface oil release).
[2]Pre-spill Period 1 (September 1980) for Bays 9, 10 and 11; Pre-spill Period 2 (August 1981) for Bay 7.
[3]Gravel is expressed as % of entire sample and excluded from all other calculations.

cient were small at 7 m, and most sediment characteristics differed little within bays. Sediments had a lower percentage of gravel and silt and a higher content of sand in Bay 9 than in the other bays. The converse was true for each of these characteristics in Bay 7. Clay content in Bay 11 was considerably higher than in the other three bays.

General Biological Characteristics

This section provides information on aspects of the Cape Hatt ecosystem not described elsewhere in this issue; this information was gathered as a result of ancillary studies, observations and measurements made during the four-year course of the project. Also included is information on nearshore macrobenthos that is supplementary to the more detailed description of benthos at 3 and 7 m depths given in a later section. Baseline data on bacteria and microheterotrophic activity are more fully described in another paper in this issue (Bunch, 1987). Supporting chemical and physical data were reported by Green (1981) and Bunch *et al.* (1985).

Microorganisms: Measurements of microorganisms in the water column in the BIOS study bays were made during 1980. Following the oil releases in 1981, the emphasis shifted exclusively to sediment microorganisms during 1982-83, because that was where chronic effects were expected.

Total counts of bacterial cells in the water column at Cape Hatt during 1980 were in the range 3-10 $\times$ 10^8 cells$\cdot l^{-1}$. Microheterotrophic activity in the water column during the same period (measured as maximum velocity of ^{14}C glutamic acid uptake — V_{max}) was in the range 3-6 $\mu g \cdot l^{-1} \cdot d^{-1}$ (Bunch *et al.*, 1981). In the surficial sediments of the BIOS study bays during 1981-83, total counts of bacteria were in the range 3-20 $\times$ 10^8 cells$\cdot g^{-1}$ dry sediment, whereas activity (V_{max}) was in the range 6-40 μg glutamic acid$\cdot g^{-1} \cdot d^{-1}$ (Bunch, 1987).

Data based on direct counts of bacterial cells using epifluorescent microscopy as described by Watson *et al.* (1977) are available for many marine areas. Enumeration by this procedure does not distinguish between metabolically active or inactive cells or dead cells but provides an accurate assessment of bacterial abundance. The application of the direct count technique to arctic waters is demonstrated by the data in Table 4, where the abundance of bacteria is presented for various depths, seasons and locations in the Arctic, including Cape Hatt. The data suggest a seasonal uniformity of bacterial abundance in arctic regions. Moreover, this seasonal abundance is comparable to that obtained in more southerly latitudes (Williams, 1981; Zimmerman, 1977). In northern regions, however, the period of high bacterial numbers is limited to the duration of the open water season.

TABLE 4. Bacterial abundance in arctic regions by season

Season	Location	Date	Depth (m)	Total count (no. $l^{-1} \times 10^8$)	Reference
Formed ice	Beaufort Sea	14 May 81	10	1.7	Bunch *et al.*, 1983b
	Cape Hatt	6-16 June 80	10	0.6-1.1	Bunch *et al.*, 1981
Post-ice breakup	Beaufort Sea	25 July 81	5	8.4	Bunch *et al.*, 1983b
	Cape Hatt	17 July 81	5	2.6-5.2	Bunch *et al.*, 1983a
Mid-open water	Davis Strait	18 Aug 78	20	3.5	Bunch, 1979
	Cape Hatt	15-21 Aug 80	10	3.3-5.9	Bunch *et al.*, 1981
Pre-ice formation	Cape Hatt	12-16 Sept 80	10	2.0-6.7	Bunch *et al.*, 1981

Microheterotrophic activity is taken here to mean the measurement of the rate of incorporation of ^{14}C-glutamic acid. Although bacteria predominate, the microheterotrophic flora may also include yeasts and other marine fungi. The measurement of this activity includes the determination of the maximum velocity (V_{max}) of uptake of glutamic acid. The technique does not reveal what proportion of the flora is incorporating glutamic acid or whether various groups are incorporating the substrate at the same rate. It does allow relative comparisons to be made, both spatially and seasonally, in various geographic locations. It must be borne in mind that glutamic acid is only one of numerous organic and biologically reactive substrates found in sea water, and the measurement of its uptake constitutes only a small proportion of heterotrophic incorporation of various components of dissolved organic carbon (DOC) in sea water and sediments.

Glutamic acid uptake at several stations occupied during cruises in Davis Strait off Baffin Island during spring and summer of 1977 and 1978 is seen in Figure 4 (Bunch, 1979). A bloom of phytoplankton was occurring at Station 41 in open water, whereas "winter" conditions still prevailed at the time of the spring sampling. V_{max} ranged from 0.05 to 5.51 $\mu g \cdot l^{-1} \cdot d^{-1}$ in water samples collected at 1-200 m from these stations. The microheterotrophic response to primary production was seen in high values of V_{max} at the bloom station in the upper waters as opposed to very low levels of activity throughout the water columns of "winter" stations. Summer (August 1978) values of V_{max} at the same latitudes (60°, 61°, 62° and 63°N) are also seen in the figure. Although the open water bloom of phytoplankton was observed during June (MacLaren Marex Inc.,

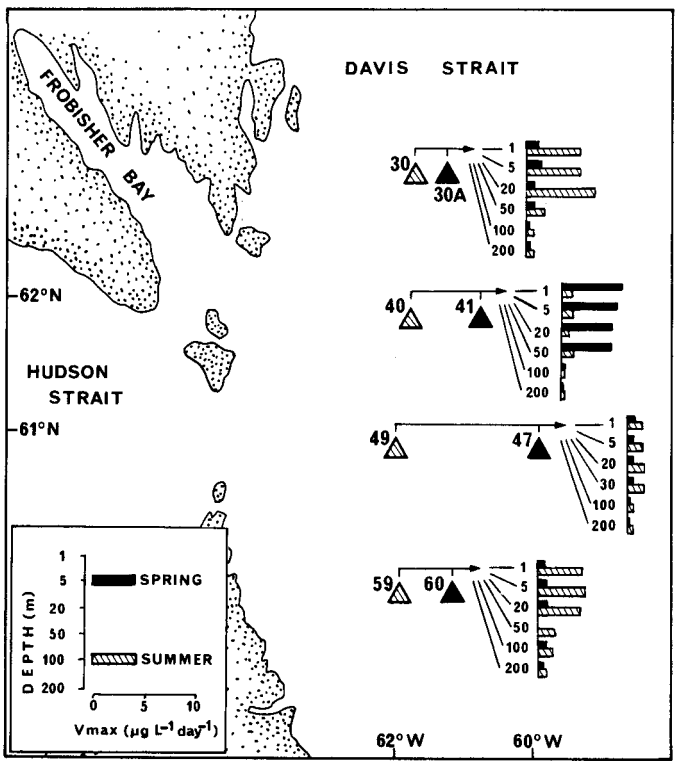

FIG. 4. Comparative seasonal microheterotrophic activity at stations occupied in Davis Strait, offshore from Baffin Island, during 1977 and 1978 (from Bunch, 1979). Refer to the inset of Figure 1 for the geographical location.

1979), coastal upwelling of nutrients may have sustained phytoplankton populations in the upper waters of Stations 30 and 59. This sustained level of primary production was also suggested by high values of V_{max} at the same stations. Values of V_{max} below 50 m were uniformly low during spring and summer occupations, and these values corresponded to the low numbers of bacteria (Bunch, 1979). A similar range of nearshore values has been obtained in the western Beaufort Sea (Bunch *et al.*, 1983b; Griffiths *et al.*, 1978). During the first years of the BIOS Project at Cape Hatt, Bunch *et al.* (1981) found values of V_{max} of glutamic acid uptake to be in the same range as those previously reported.

Phytoplankton: Phytoplankton samples collected at Cape Hatt during August 1980 were dominated by the diatom *Chaetoceros socialis* and unidentified microflagellates. Total cell concentrations were in the range 1.5-5.3 $\times$ $10^5 \cdot l^{-1}$ (M. Foy, pers. comm. 1981). Chlorophyll *a* concentrations, measured at the same time, averaged 0.48 $\mu g \cdot l^{-1}$ (Green, 1981). The major phytoplankton bloom in 1981 occurred in July, during ice break-up, with chlorophyll *a* concentrations in the range 5-10 $\mu g \cdot l^{-1}$ (Bunch *et al.*, 1985).

The few phytoplankton data we have from Cape Hatt are from inshore areas, whereas most other data are from the open ocean. Nevertheless, the composition and abundance at Cape Hatt are within reported ranges for most other arctic areas. The dominance of diatoms (especially *Chaetoceros socialis*) and microflagellates appears to be typical of arctic phytoplankton assemblages (Milne and Smiley, 1978). Phytoplankton densities for other eastern arctic areas are in the range of 3.5-4.1 $\times$ 10^5 cells$\cdot l^{-1}$ (Bursa, 1961; Sekerak *et al.*, 1976a). Higher values have been reported from arctic areas that are enriched by glacial outflow, a condition that does not occur at Cape Hatt.

Similarly, phytoplankton biomass at Cape Hatt was comparable with published data from other arctic locations. Chlorophyll *a* concentrations from other areas include 0.17-0.35 $\mu g \cdot l^{-1}$ in Frobisher Bay (Grainger, 1971) and 0.04-9.51 $\mu g \cdot l^{-1}$ in the High Arctic (Bain *et al.*, 1977). Harrison *et al.* (1982) determined an average chlorophyll *a* concentration of 1.26 $\mu g \cdot l^{-1}$ for the euphotic zone of Baffin Bay in later summer 1978.

It was noted that spring blooms occurred in melt pools and tidal cracks at Cape Hatt in advance of the spring water-column bloom. A similar event was noted in leads between ice floes by Bursa (1963).

Zooplankton: With the exception of a single peripheral study of macrozooplankton in Ragged Channel during 1982 (J. Carolsfeld, unpubl. data) and studies of ice-associated fauna (Cross and Martin, 1983, 1987), no systematic sampling of zooplankton occurred during the BIOS Project. Macrozooplankton were obvious to divers throughout the study, however, and the following observations were made.

Under landfast ice during spring, the most conspicuous macrozooplankton were coelenterates. There were usually large numbers of medusae and ctenophores, such as *Mertensia ovum*, *Bolinopsis infundibulum* and *Beroe cucumis*. Large numbers of small calanoid and cyclopoid copepods were apparent, whereas abundance of the large *Calanus hyperboreous* was low. Vast numbers of *Mysis litoralis* and *M. oculata* were also present under the ice in spring, often appearing in concentrated patches in the top metre of the water column. More than 10 species of gammarid amphipods were associated with the underside of the ice in 1981 and 1982 (Cross and Martin, 1983); these included species that occurred in the plankton or in subtidal or intertidal benthic habitats during the open water period. Meiofauna (primarily copepods and nematodes) in and near the under-ice surface are described in Cross and Martin (1987).

During the open water period (late July-September), small calanoid and cyclopoid copepods were still present, and the large copepod *Calanus hyperboreous* became abundant in the upper few metres of the water column. The pteropods *Limacina* (= *Spiratella*) *helicina* and *Clione limacina* also appeared in the bays during the open water season, together with increased numbers of the trachymedusan *Aglantha digitale*. *Clione limacina* was present slightly before *Limacina helicina*, and the growth rate for the former species was from 1 cm to 5 cm total length in approximately two months. Pairing in this species usually occurred during mid- to late August, although it was noted as early as July in 1982.

J. Carolsfeld (unpubl. data) observed that in 1982 the nearshore bays had a different assemblage of macrozooplankton than did the offshore channel. *Clione limacina*, *Limacina helicina* and *Parathemisto* sp. were more abundant in Ragged Channel, whereas *Aglantha digitale* was more abundant in the bays. Pteropods were concentrated in the upper 10 m at both nearshore and offshore locations. The above species did not exhibit any clear diurnal behaviour, although there was evidence of this for copepods and chaetognaths.

The available data on zooplankton in the Cape Hatt area are qualitatively similar to those reported for other arctic areas. The species present and the overwhelming numerical dominance of copepods in net samples (J. Carolsfeld, unpubl. data) are similar to those previously reported (e.g., Grainger, 1965).

Direct observations by scuba divers are of recent and as yet limited application in zooplankton studies, particularly in polar waters. However, the observations of macrozooplankton at Cape Hatt, reported here and by Cross and Martin (1983), are consistent with diver observations in a number of other arctic locations, both under the ice and in open water (e.g., Bell, 1973; Turnbull, 1974; Buchanan *et al.*, 1977; Thomson *et al.*, 1978; Cross, 1980). Noteworthy are observations of the abundance of mysids and gelatinous zooplankton in most of the locations studied during spring, summer, or both, because both of these groups are difficult to sample using conventional surface-operated methods. Mysids avoid nets and are often patchily distributed in dense swarms near the ice or the bottom, whereas gelatinous zooplankton can be large, sparsely distributed (relative to, say, copepods) and very fragile. The importance of both of these types of plankton in arctic ecosystems has undoubtedly been underestimated (see also Buchanan *et al.*, 1977; Thomson *et al.*, 1978; Griffiths and Dillinger, 1981).

Benthos: The intertidal zone at Cape Hatt was extremely depauperate, probably as a result of a combination of freezing sea ice, sediment conditions and freshwater run-off and seepage. Organisms characteristic of the intertidal at lower latitudes were either absent (beyond their northern distribution limit) or occurred subtidally, below the influence of ice. Mobile species, such as amphipods and young sculpins, moved in and out of the intertidal zone with the tide, and a few remained in small pools between tidal cycles. Intertidal amphipod communities at Cape Hatt (see Cross, 1982; Cross and Martin, 1983) were similar to those found in other eastern and central arctic locations, although density and biomass tended to be higher in the central Arctic (Thomson *et al.*, 1986).

Observations of subtidal benthos were largely confined to

visible macroalgae and epibenthic organisms (see Figures 5-8). Several relatively distinct vertical zones were apparent. The shallowest was largely barren, rippled sand. The tunicate *Rhizomolgula globularis* was found only in this zone, together with gammarid amphipods and sculpins. At depths of 1-3 m, boulders were common, many of which were used by whelks for the attachment of egg cases. This zone was usually characterized by *Fucus distichus evanescens* and filamentous algae (e.g., *Dictyosiphon foeniculaceus* and *Pilayella littoralis*). This fucoid zone was followed by a zone of muddy sand covered by dense filamentous algae, within which large numbers of sculpins occurred. The next zone consisted of kelp (mainly *Laminaria saccharina*), which extended down to approximately 5 m depth. This kelp zone was occupied by the nudibranch *Dendronotus* sp. for egg mass deposition.

Beyond the kelp zone, the deeply burrowing bivalve *Mya*

FIG. 5. Bay 7 sediment at 4 m depth. Urchins, anemones, fucoid algae and the siphons of *Mya truncata* are apparent.

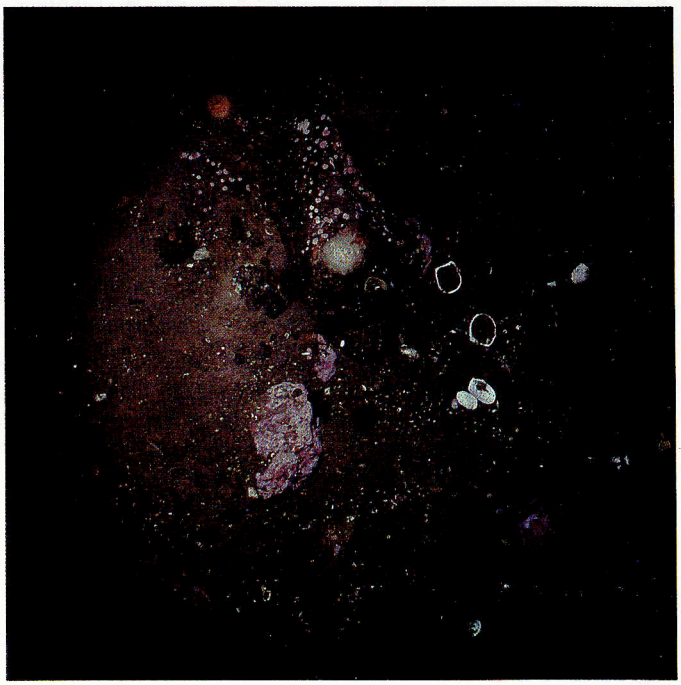

FIG. 7. Bay 10 sediment at 8 m depth. A whelk egg-mass can be seen on the largest rock, in addition to an anemone, urchins and the siphons and shells of *Mya truncata*.

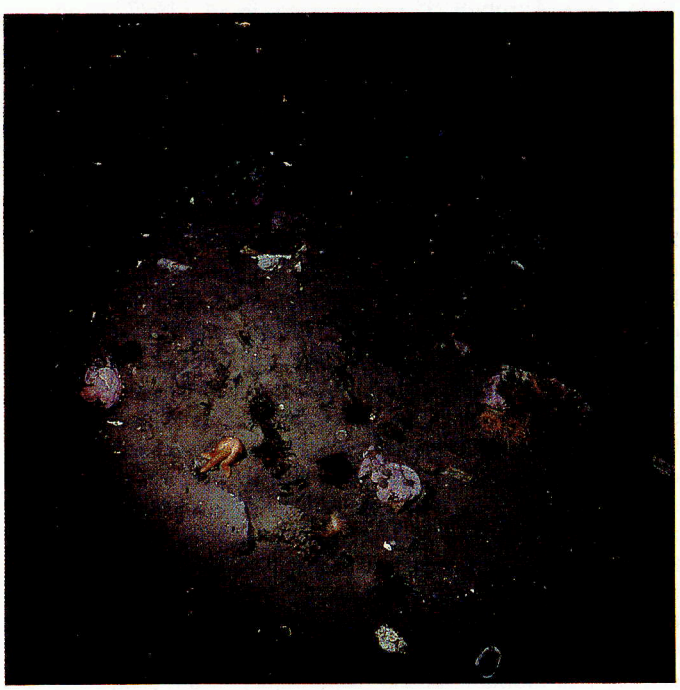

FIG. 6. Bay 11 sediment at 6 m depth. A starfish (*Leptasterias polaris*) can be seen feeding upon a large individual *Mya truncata*.

FIG. 8. The holothurian (*Psolus* sp.) and brittle-stars (*Ophiura sarsi*) at a depth of 10 m in Bay 9.

truncata was the most conspicuous infaunal organism. It first became obvious at depths of 6 m and increased in abundance with increasing depth. At depths of 6-10 m the visible benthos was diverse, consisting of anemones, fan-worms, chitons, whelks, limpets and echinoderms. Echinoderms were particularly conspicuous, including the seastars *Leptasterias polaris* and *Stephanasterias albula*, the urchin *Strongylocentrotus droebachiensis*, the holothurian *Myriotrochus rinkii* and the brittle stars *Ophiura sarsi* and *Ophiocten sericeum*.

At 10-30 m depths, the dominant macroalga was *Agarum cribrosum*, which occurred in clumps scattered among, or on, large boulders. These clumps harbored large numbers of mysids (predominantly *Mysis oculata*), juvenile fishes, arctic cod and several species of shrimp of the genera *Lebbeus*, *Spirontocaris* and *Sclerocrangon*. Dense *Mya truncata* beds also characterized this zone, and densities of ophiuroids noticeably increased. Coralline algae (*Lithothamnion* spp.) were evident on rocks and shells. At approximately 20 m depth, the sedentary holothurians *Psolus fabricii* (usually entirely exposed on rocks) and *Psolus phantapus* (invariably buried with only the feeding introvert exposed) became quite numerous. A large crinoid (*Heliometra glacialis*) also occurred at this depth, together with small numbers of scallops (*Chlamys islandica*), usually encrusted (and often cemented to the substrate) by sponges and coralline algae.

During the study period, feeding observations were made for several echinoderm species. The large starfish *Leptasterias polaris* co-occurred with the bivalve *Mya truncata* between 5 and 30 m+ depths. It was undoubtedly the major invertebrate predator in the area. Large (>15 cm diameter) starfish fed primarily on large (4 cm shell length) *Mya truncata* and *Serripes groenlandicus*, and to a lesser extent on the whelks *Buccinum* spp. and the polychaete *Pectinaria* (= *Cistenides*) *granulata*. Medium-sized seastars (7-15 cm) fed mainly on smaller bivalves, including *Astarte borealis*, *A. montagui*, *Macoma* spp. and small *Mya truncata*. Small starfish (<7 cm) fed mainly on *Macoma* spp. and *Nuculana minuta*.

The sun-star, *Crossaster* sp., was relatively uncommon at depths shallower than 10 m. Its only prey at Cape Hatt was the sea urchin *Strongylocentrotus droebachiensis*. The urchins themselves invariably consumed filamentous algae, especially *Stictyosiphon* sp. and *Pilayella littoralis*, and detritus.

Several observations of reproductive phenomena were made. During August of most years, several *Leptasterias polaris* were curled up on rocks, brooding their young. At the end of July 1982, a single observation was made of five urchins (four males, one female) releasing gametes. These were extruded from the gonopores and settled on the substrate around the urchin as a "halo." No urchin was closer than 1 m to any other at that time.

Fishes: The only abundant pelagic fish observed at Cape Hatt was the arctic charr (*Salvelinus alpinus*). Relatively high numbers were present during August and September, both in Z-Lagoon and in Ragged Channel (see Fig. 1). Most charr from both locations had guts full of mysids, fish larvae, gammarid amphipods and hyperiid amphipods (*Parathemisto* spp.), mostly in the length range 2-3 cm. The presence of *Parathemisto* spp. in the guts indicates at least some of the feeding was not inshore. Two noteworthy exceptions to the above feeding pattern were (1) an 8 kg charr, taken from Z-Lagoon, that had consumed 170 sculpins and a single liparid, and (2) a 6 kg charr, taken from a Ragged Channel bay, that had eaten seven 14-15 cm sand lances (*Ammodytes* sp.) (LGL Ltd., unpubl. data). These were the only sand lances observed or collected in the area during 1980-83.

Benthic fish at Cape Hatt were examined in an ancillary study (Fabijan, 1983). Sixteen species of benthic fish were collected. Diets, habitat associations, behaviour, age-length-weight data, reproductive biology and parasite loads were determined for eight of these species, which included several sculpins, a gymnelid and an eel-pout.

All the benthic species studied used some form of cover (algal canopy, rocks, crevices or sediment burrowing). The only species that showed no particular habitat association was the largest size class of arctic staghorn sculpin. Similar habitat associations have been described in general terms for other areas of the Canadian Arctic (e.g., Buchanan *et al.*, 1977; Thomson *et al.*, 1978; Thomson and Cross, 1980).

Interestingly, the planktonic pteropod *Limacina helicina* constituted 50% of prey biomass in shorthorn and staghorn sculpins, a gymnelid and a liparid. Fourhorn sculpin fed almost exclusively on intertidal amphipods, and fish were found only in the diets of fourhorn and shorthorn sculpins. Variable amounts of benthic polychaetes, gastropods and crustaceans were found in the guts of all species. The dominance of mysids and amphipods in diets of benthic fish elsewhere in the Arctic (e.g., Buchanan *et al.*, 1977; Craig and Griffiths, 1978) was not observed at Cape Hatt.

Birds and Mammals: Avian life in the vicinity of Cape Hatt was not spectacular. A few pairs of oldsquaw used the melt pools and tidal cracks in springtime. Oldsquaw and eiders nested in the general area during summer, and a pair of Arctic loons nested on Tukayat Lake near the camp (Fig. 1) each year of the project. Snowy owls, jaegers, gulls and ravens also frequented the general area.

Terrestrial mammals observed in the vicinity of Cape Hatt included red fox, arctic hare and lemmings. No polar bears (or bear tracks) were seen during the study period. Several ringed seals (<100) were seen hauled out in Ragged Channel during spring, and solitary narwhals and ringed seals were seen during the summer. One bearded seal was seen during the study period, in Bay 9 during August 1981. No evidence of feeding by bearded seals or walrus was observed in the study area.

Utilization of the Cape Hatt area by birds and mammals was not extensive, which is characteristic of the majority of eastern arctic coastal areas. There are no major concentrations such as colonies or haul-outs in the immediate vicinity.

Infauna

The term "infauna" is used here to refer to those animals that are either incapable of motion or are able to move only slowly in the sediment or on the sediment surface. This group includes bivalves, polychaetes, gastropods, priapulids, nemerteans and some echinoderms. The results presented below are based on pre-spill sampling at two depths (3 and 7 m) in three or four bays during September 1980 and August 1981.

Group and Species Composition: At both depths, bivalves accounted for most of the biomass — 87.0 and 94.2% at 3 and 7 m depths respectively. Mollusc wet weights in this study include shell weight. The dominance of infaunal biomass by bivalves is reduced to approximately 75% and 85% at 3 and 7 m depths respectively when only tissue weight is considered (LGL Ltd., unpubl. data). Numbers of infauna, on the other hand, were dominated by polychaetes at 3 m depth and by bivalves at 7 m depth; together these two groups accounted for 80.5 and 90.2% of infaunal animals collected at 3 and 7 m depths respectively.

The ten most common infaunal taxa at each depth at Cape Hatt in terms of numbers and biomass are shown in Table 5. The ten dominant species accounted for more than 60% of numbers and 90% of the biomass of infauna at both depths. The four lists of ten species include eleven bivalves, six polychaetes, two gastropods and one holothurian (Table 5). Relatively few species were dominant (i.e., among the top ten species) in terms of both density and biomass: the bivalves *Mya truncata* and *Astarte borealis* (both depths), the holothurian *Myriotrochus rinkii* (3 m depth only), the polychaete *Pectinaria* (= *Cistenides*) *granulata* and the bivalves *Astarte montagui*, *Macoma calcarea* and *Nuculana minuta* (7 m depth only). The contributions of *Astarte* spp. and *M. calcarea* to density, and to a much lesser extent to biomass, are underestimated in Table 5 because unidentified juveniles of these two genera are not included.

Distribution of Species: The smallest scale of variability apparent in our data was that among replicate samples within transects. Distributions of major groups and dominant species were patchy (Tables 6 and 7), and extremes of variability were observed for the many uncommon species in the study area. The next smallest scale of variability, that among 50 m transects, was considerable for most of the species and groups examined, particularly at 3 m depth. Relatively few species were evenly distributed on a 50 m scale in the study bays: the gastropod *Retusa obtusa* at 3 m depth; and at 7 m, the polychaetes *Praxillella praetermissa* and *Spio* spp., the gastropod *Moelleria costulata* and juvenile bivalves of the genera *Astarte* and *Macoma* (see Cross and Thomson, 1987).

The greatest variability in infaunal distribution was that between bays. At both depths, the highest total biomass and density of infauna were found in Bay 9 (about 600-2300 $g \cdot m^{-2}$ and 3500-4000 individuals$\cdot m^{-2}$). At 7 m depth, total biomass and density were similar in the other three bays (about 900-1500 $g \cdot m^{-2}$ and 2500-3000 individuals$\cdot m^{-2}$); at 3 m depth, total biomass and density of infauna were consistently lower in Bay 11 (<100 $g \cdot m^{-2}$ and <1500 individuals$\cdot m^{-2}$) than in the other three bays (see Tables 6 and 7).

In shallow water (3 m depth), bay differences were consistent (ranking of bays was 9>10>7>11) for most of the groups and species studied (Tables 6 and 7). Notable exceptions were the polychaetes *Nereimyra punctata*, *Eteone longa* and *Chaetozone setosa* and the bivalve *Musculus discors* (most abundant in Bay 10).

At 7 m depth, bay differences were much less consistent (Tables 6 and 7). As was the case at the shallower depth, Bay 9 supported the highest numbers and biomasses of bivalves and total infauna; several bivalve species (Thyasiridae spp., *Nuculana minuta*, *Musculus niger*, and *Serripes groenlandicus*), together with the dominant polychaete *Pholoe minuta*, reached their highest numbers in this bay. However, several taxa reached their highest densities or biomasses in Bay 11, in contrast to results from the shallower depth: the bivalves *Mya truncata* and *Astarte montagui* and the gastropod *Trichotropis borealis*. Bay 7 was lowest ranked in terms of infaunal biomass, but several important species, including *Macoma calcarea* and the gastropod *Cingula castanea*, were most abundant in this bay. As at 3 m depth, Bay 10 ranked in an intermediate position for most taxa.

In general, temporal change was a much smaller component of variability in the abundance and biomass of infauna than was spatial variability. Biomass of dominant infauna, in particular, was relatively constant between September 1980 and August 1981. Densities of infaunal species were somewhat more variable in time than were biomasses, particularly at 7 m depth. For both densities and biomasses, the most common type of tempo-

TABLE 5. Percent contribution of dominant taxa to total infaunal numbers and biomass (wet weight) at each of two depths in four bays at Cape Hatt, northern Baffin Island, during September 1980 and August 1981

Depth (m)	Dominant taxon by numbers		% of total infaunal numbers	Dominant taxon by biomass		% of total infaunal biomass
3	*Pholoe minuta*	(P)	14.91	*Mya truncata*	(B)	40.89
	Nereimyra punctata	(P)	13.07	*Astarte borealis*	(B)	23.23
	Euchone analis	(P)	6.82	*Astarte montagui*	(B)	6.35
	Myriotrochus rinkii	(H)	6.40	*Hiatella arctica*	(B)	5.47
	Mya truncata	(B)	5.75	*Musculus discors*	(B)	5.46
	Cingula castanea	(G)	5.32	*Pectinaria granulata*	(P)	2.21
	Thyasiridae spp.	(B)	3.85	*Macoma calcarea*	(B)	2.08
	Eteone longa	(P)	3.49	*Serripes groenlandicus*	(B)	1.98
	Astarte borealis[a]	(B)	3.36	*Myriotrochus rinkii*	(H)	1.94
	Chaetozone setosa	(P)	2.41	*Trichotropis borealis*	(G)	1.18
	Total % contribution		65.38	Total % contribution		90.79
	Total infaunal density (no$\cdot m^{-2}$)		2580.1	Total infaunal biomass ($g \cdot m^{-2}$)		317.3
7	Thyasiridae spp.	(B)	13.60	*Mya truncata*	(B)	44.44
	Pholoe minuta	(P)	11.56	*Astarte borealis*	(B)	18.94
	Astarte borealis[a]	(B)	10.98	*Serripes groenlandicus*	(B)	12.22
	Astarte montagui[a]	(B)	7.52	*Astarte montagui*	(B)	5.28
	Mya truncata	(B)	5.25	*Macoma calcarea*	(B)	5.15
	Macoma calcarea[a]	(B)	4.84	*Clinocardium ciliatum*	(B)	1.98
	Nuculana minuta	(B)	3.15	*Hiatella arctica*	(B)	1.93
	Pectinaria granulata	(P)	2.07	*Pectinaria granulata*	(P)	1.22
	Cingula castanea	(G)	2.04	*Musculus niger*	(B)	1.07
	Trichotropis borealis	(G)	1.95	*Nuculana minuta*	(B)	0.84
	Total % contribution		62.96	Total % contribution		93.07
	Total infaunal density (no$\cdot m^{-2}$)		3029.6	Total infaunal biomass ($g \cdot m^{-2}$)		1418.0

Based on 167 airlift samples, each covering 0.0625 m^2, from each of 3 and 7 m depths.
B = bivalve, P = polychaete, G = gastropod, H = holothuroid.
[a]Unidentified *Astarte* juveniles (≤3 mm) and *Macoma* juveniles (≤5 mm) are not included.

ral change was a decrease from September 1980 to August 1981. It is not known whether this variability was annual (1980-81), seasonal (August-September), or both.

Comparison with other locations: Thomson *et al.* (1986) examined infaunal benthos from 25 sites in the eastern and central Canadian Arctic, including Cape Hatt. Nine species assemblages were defined by factor analysis, of which the first three (accounting for 32% of variance in the analysis) were abundant at Cape Hatt. However, ordination of the sites studied indicated that the distribution of infaunal species assemblages was complex and was dependent on depth, substrate and a number of other interrelated environmental factors.

In general, however, the composition of the benthos at Cape Hatt appears to be typical of that in other High Arctic areas. Several of the dominant infaunal species, including several of those contributing most to biomass (*Mya truncata*, *Macoma calcarea*, *Astarte borealis*, *A. montagui*, *Serripes groenlandicus* and *Pectinaria granulata*), belong to the arctic *Macoma* community (Thorson, 1957; Ockelmann, 1958; Ellis, 1960; Thomson, 1982). This community is a widespread and common feature of nearshore High Arctic areas and is displaced only under local circumstances (e.g., under estuarine influences).

Abundance and biomass in the study bays at Cape Hatt during pre-spill sampling averaged 2580 individuals·m^{-2} and 317 g·m^{-2} at 3 m depth, and 3030 individuals·m^{-2} and 1418 g·m^{-2} at 7 m depth (Table 5). Densities at Cape Hatt were near the upper end of the range of values reported by Thomson *et al.* (1986) for 25 sites in the central and eastern Arctic. Biomass at Cape Hatt was considerably higher than that found in the eastern and central Arctic (Ellis, 1960; Thomson *et al.*, 1986), in the Alaskan

TABLE 6. Mean density (no·m^{-2}) of major taxa and dominant species of infauna in four bays at Cape Hatt, northern Baffin Island, during September 1980 and August 1981

		3 m depth				7 m depth			
Taxon	Period	Bay 7	Bay 9	Bay 10	Bay 11	Bay 7	Bay 9	Bay 10	Bay 11
Total infauna[1]	Sept 1980	—	3980.7±1024.7	3288.0±1323.6	1487.3±911.4	—	3706.0±1258.9	3020.7±919.6	3045.3±605.8
	Aug 1981	1753.3±881.5	3977.3±1759.5	2459.7± 796.0	1118.8±561.3	2552.7±796.9	3436.7± 973.4	2445.9±638.6	2927.3±851.8
Polychaeta	Sept 1980	—	2045.3± 585.3	1746.0± 743.4	893.3±507.1	—	920.0± 343.1	988.7±333.5	971.3±267.5
	Aug 1981	865.3±522.9	1916.0± 838.3	1479.0± 545.3	779.0±369.4	766.7±302.1	1006.7± 392.1	795.8±291.5	982.0±335.2
Pholoe minuta	Sept 1980	—	546.7± 254.5	303.3± 251.9	228.0±226.1	—	408.7± 234.8	390.7±235.4	283.3±200.3
	Aug 1981	316.0±350.0	834.0± 652.1	297.0± 162.3	164.7±164.6	339.3±163.8	451.3± 244.3	317.9±175.4	258.7±141.9
Nereimyra punctata	Sept 1980	—	290.7± 351.4	610.0± 451.1	286.0±268.1	—	2.7± 6.1	40.7± 50.6	42.7±166.6
	Aug 1981	235.3±200.1	183.3± 193.8	477.7± 372.1	282.8±252.5	14.7± 20.0	6.7± 11.5	39.0± 38.5	6.7± 8.1
Euchone analis	Sept 1980	—	464.7± 490.2	142.7± 139.1	80.7± 94.8	—	4.7± 13.7	6.0± 14.8	12.7± 33.4
	Aug 1981	63.3± 66.0	346.7± 275.6	107.8± 75.4	23.3± 41.7	10.7± 20.4	10.0± 17.5	14.6± 27.7	7.3± 11.5
Eteone longa	Sept 1980	—	88.7± 71.6	110.7± 103.3	93.3± 83.8	—	12.0± 13.6	21.3± 18.1	31.3± 18.6
	Aug 1981	55.3± 49.5	42.0± 28.6	135.5± 207.4	106.2± 65.7	25.3± 47.6	14.7± 17.0	22.3± 15.8	25.3± 22.1
Chaetozone setosa	Sept 1980	—	105.3± 92.3	148.7± 197.5	50.0± 63.2	—	23.3± 41.7	4.7± 11.0	12.7± 52.1
	Aug 1981	0.7± 3.3	68.7± 79.2	92.5± 95.4	22.8± 30.8	0	24.7± 25.8	2.1± 7.3	0.7± 3.3
Pectinaria granulata	Sept 1980	—	30.7± 25.4	22.0± 27.4	13.3± 19.3	—	45.3± 39.7	89.3± 41.1	61.3± 37.6
	Aug 1981	15.3± 18.0	38.0± 25.8	18.1± 35.2	6.0± 10.4	62.0± 45.3	63.3± 37.9	68.9± 47.6	49.3± 29.1
Bivalvia	Sept 1980	—	1160.7± 639.2	1022.7± 616.8	317.3±300.5	—	2458.0± 852.7	1856.0±764.3	1732.0±496.0
	Aug 1981	299.3±208.7	1250.7± 863.9	633.6± 257.6	144.7±211.4	1406.0±692.7	2130.0± 647.5	1449.7±643.4	1608.7±540.0
Mya truncata	Sept 1980	—	278.0± 160.1	226.0± 215.7	57.3± 58.5	—	185.3± 87.9	161.3± 95.2	202.7± 96.9
	Aug 1981	58.0± 42.4	258.0± 161.4	136.3± 80.8	24.7± 43.7	128.7± 75.9	121.3± 74.1	102.3± 51.9	190.0±105.3
Thyasiridae spp.	Sept 1980	—	243.3± 255.5	124.0± 90.3	9.3± 23.1	—	662.7± 269.8	506.7±268.3	81.3± 88.5
	Aug 1981	20.7± 33.2	204.0± 179.8	91.0± 65.8	2.7± 7.7	412.7±261.4	699.3± 228.5	444.5±272.7	77.3± 72.6
Astarte borealis	Sept 1980	—	192.0± 154.0	32.0± 41.9	21.3± 30.8	—	437.3± 257.2	368.0±207.7	384.0±204.0
	Aug 1981	54.7± 59.7	240.7± 245.9	51.4± 55.1	14.0± 17.2	160.7±129.0	291.3± 168.3	304.7±186.6	382.0±174.9
Astarte montagui	Sept 1980	—	144.7± 177.3	6.7± 23.1	2.0± 7.2	—	199.3± 151.5	160.7±129.9	448.0±258.8
	Aug 1981	16.0± 32.3	224.7± 239.3	9.0± 23.5	1.3± 4.5	44.0± 45.1	131.3± 85.1	165.6±132.7	443.3±208.2
Macoma calcarea	Sept 1980	—	36.7± 42.1	25.3± 27.9	6.7± 14.1	—	208.7± 71.6	114.7± 44.2	72.7± 35.9
	Aug 1981	8.0± 14.2	46.7± 47.4	14.6± 15.9	0	262.0±138.8	194.0± 99.0	105.0± 49.2	68.0± 40.9
Musculus discors	Sept 1980	—	0	183.3± 183.1	81.3±108.2	—	0	0.7± 3.3	5.3± 18.1
	Aug 1981	30.7± 25.4	0	93.9± 111.2	39.3± 67.4	4.7± 19.7	0	1.4± 4.6	0.7± 3.3
Musculus niger	Sept 1980	—	8.7± 17.0	2.0± 7.2	2.0± 7.2	—	78.7± 58.9	26.0± 45.5	24.0± 24.5
	Aug 1981	0	16.7± 24.7	0.7± 3.3	0.7± 3.3	19.3± 20.6	58.7± 51.4	18.1± 29.1	19.3± 24.0
Nuculana minuta	Sept 1980	—	0.7± 3.3	3.3± 9.4	0	—	122.0± 71.5	80.0± 50.2	84.7± 38.5
	Aug 1981	3.3± 8.1	0.7± 3.3	2.8± 7.9	0	76.7± 46.0	156.7± 68.5	58.4± 32.9	87.3± 42.7
Serripes groenlandicus	Sept 1980	—	24.7± 48.6	1.3± 4.5	0.7± 3.3	—	84.0± 57.8	33.3± 35.9	13.3± 23.9
	Aug 1981	0	29.3± 52.5	0	2.7± 10.2	44.7± 31.6	58.7± 45.9	26.4± 25.8	17.3± 23.6
Gastropoda	Sept 1980	—	399.3± 221.5	358.0± 200.6	174.0±145.1	—	234.0± 159.8	163.3± 77.8	304.7±157.2
	Aug 1981	468.0±278.0	498.0± 253.4	253.9± 157.8	93.8±104.0	334.7±158.1	252.0± 109.3	168.3± 77.0	318.7±194.1
Cingula castanea	Sept 1980	—	182.7± 150.1	143.3± 101.2	15.3± 22.4	—	86.0± 100.1	38.7± 39.7	26.7± 33.9
	Aug 1981	303.3±226.1	224.7± 149.2	83.5± 72.8	5.5± 11.9	116.0±108.0	100.0± 79.5	37.6± 40.2	26.0± 47.4
Trichotropis borealis	Sept 1980	—	36.7± 41.0	4.0± 19.6	12.7± 62.1	—	29.3± 24.8	49.3± 42.2	117.3± 81.1
	Aug 1981	12.7± 18.3	67.3± 66.9	7.0± 13.5	0	63.3± 41.3	38.7± 32.0	36.2± 31.0	78.7± 60.8
Myriotrochus rinkii	Sept 1980	—	351.3± 174.7	146.0± 141.6	93.3± 80.3	—	86.0± 105.6	0.7± 3.3	26.7± 67.3
	Aug 1981	106.7±106.1	279.3± 160.9	81.3± 59.6	96.0± 83.2	26.0± 57.4	32.0± 44.0	10.4± 26.7	5.3± 12.2

Data are expressed as mean ± standard deviation and are based on 8 replicate 0.0625 m^2 airlift samples on each of three transects for each depth, period and bay.
[1]All taxa but nemerteans and epibenthic crustaceans and echinoderms.

TABLE 7. Mean biomass ($g \cdot m^{-2}$) of major taxa and dominant species of infauna in four bays at Cape Hatt, northern Baffin Island, during September 1980 and August 1981

Taxon	Period	3 m depth				7 m depth			
		Bay 7	Bay 9	Bay 10	Bay 11	Bay 7	Bay 9	Bay 10	Bay 11
Total infauna[1]	Sept 1980	—	590.6±407.6	308.0±234.7	83.1±110.1	—	2267.3±1049.6	1530.5±578.7	1232.3±638.6
	Aug 1981	169.1±176.4	675.2±484.1	336.5±272.6	58.5± 61.8	932.8±707.4	1411.2± 839.1	1213.2±669.6	1335.8±786.1
Bivalvia	Sept 1980	—	529.5±400.7	264.3±220.4	54.3± 88.5	—	2194.8±1053.3	1439.8±581.7	1128.9±626.7
	Aug 1981	138.4±162.1	609.2±469.7	300.9±261.3	35.2± 58.0	869.9±695.8	1332.7± 835.4	1122.1±684.3	1261.4±776.2
Mya truncata	Sept 1980	—	235.6±172.5	134.7±167.3	17.3± 48.3	—	1120.8± 753.6	661.4±476.6	513.8±444.7
	Aug 1981	60.6±103.5	248.5±215.4	190.2±177.5	21.2± 48.8	481.5±494.8	541.7± 479.8	544.7±407.1	547.5±540.8
Astarte borealis	Sept 1980	—	171.7±182.7	32.3± 67.2	11.0± 27.4	—	316.9± 291.8	355.0±308.5	330.3±243.0
	Aug 1981	40.1± 49.3	210.4±236.3	46.8± 93.6	3.6± 6.5	45.3± 47.4	221.0± 164.2	222.4±214.5	389.2±212.5
Astarte montagui	Sept 1980	—	51.2± 65.9	3.6± 11.6	0.7± 3.6	—	61.3± 59.0	51.5± 47.1	146.6± 94.3
	Aug 1981	3.5± 8.2	77.3± 81.7	3.3± 7.2	1.3± 4.3	9.7± 11.1	36.9± 22.0	59.6± 65.0	158.6± 93.8
Serripes groenlandicus	Sept 1980	—	13.6± 26.3	1.2± 5.7	2.2± 10.8	—	360.6± 367.3	186.6±206.8	28.4± 61.1
	Aug 1981	0	26.8± 48.2	0	0.1± 0.6	132.9±145.6	290.7± 286.0	156.3±182.1	57.8±113.5
Hiatella arctica	Sept 1980	—	37.3± 53.9	28.1± 61.6	3.4± 12.3	—	126.7± 194.2	7.9± 19.7	7.6± 24.9
	Aug 1981	16.9± 35.0	18.0± 30.1	17.8± 47.0	<0.1	5.3± 15.6	20.6± 39.6	3.0± 7.8	20.1± 45.8
Macoma calcarea	Sept 1980	—	10.5± 16.6	5.1± 6.7	3.1± 7.5	—	83.9± 48.7	72.8± 44.1	53.8± 44.8
	Aug 1981	4.0± 8.6	16.4± 20.3	7.0± 15.5	0	111.4± 74.4	78.5± 47.4	74.2± 61.8	36.5± 39.8
Musculus discors	Sept 1980	—	0	55.1± 63.7	15.1± 26.9	—	0	0.1± 0.4	2.6± 8.9
	Aug 1981	11.6± 16.0	0	31.9± 36.4	7.5± 16.4	1.8± 9.0	0	2.3± 9.2	<0.1
Musculus niger	Sept 1980	—	1.3± 2.5	0.1± 0.3	0.2± 0.7	—	31.7± 41.9	12.1± 21.8	14.5± 23.5
	Aug 1981	0	2.6± 4.0	<0.1	<0.1	3.8± 6.6	27.4± 48.7	12.9± 25.7	3.7± 4.5
Clinocardium ciliatum	Sept 1980	—	0	0	0	—	27.4± 104.3	50.5±171.7	0
	Aug 1981	0	0	0	0	23.2± 77.7	52.6± 184.5	20.1± 96.2	22.5± 76.9
Nuculana minuta	Sept 1980	—	<0.1	<0.1	0	—	21.3± 12.1	5.8± 5.6	7.7± 6.1
	Aug 1981	0.2± 0.7	0.1± 0.7	<0.1	0	13.8± 10.8	22.7± 10.6	5.1± 4.9	7.1± 4.2
Polychaeta	Sept 1980	—	40.0± 13.8	34.0± 22.6	18.6± 14.0	—	53.1± 33.9	63.9± 42.5	54.1± 28.7
	Aug 1981	15.5± 12.6	43.1± 21.4	24.7± 14.2	13.8± 7.5	33.1± 26.9	43.6± 28.7	37.5± 19.5	45.1± 29.9
Pectinaria granulata	Sept 1980	—	9.5± 8.4	7.7± 9.9	7.3± 11.1	—	10.1± 9.5	25.8± 12.0	17.2± 12.1
	Aug 1981	5.5± 7.4	10.8± 8.9	6.1± 11.3	2.1± 3.8	15.5± 14.5	20.5± 12.4	18.6± 15.3	13.7± 10.7
Gastropoda	Sept 1980	—	9.3± 8.5	4.0± 5.3	3.6± 11.9	—	9.9± 8.4	11.9± 13.3	44.1± 44.1
	Aug 1981	5.1± 5.4	14.4± 12.6	3.8± 5.0	0.5± 0.6	10.1± 7.8	15.8± 22.8	20.2± 25.0	16.4± 13.3
Trichotropis borealis	Sept 1980	—	7.2± 7.9	1.1± 5.3	2.3± 11.3	—	5.5± 7.1	7.5± 7.7	21.5± 18.3
	Aug 1981	1.9± 3.1	12.3± 11.8	1.5± 3.3	0	6.6± 5.1	5.6± 5.4	5.5± 5.5	11.9± 9.9
Holothuroidea									
Myriotrochus rinkii	Sept 1980	—	8.3± 4.5	4.9± 4.8	5.1± 6.7	—	4.9± 5.1	0.1± 0.3	1.4± 3.2
	Aug 1981	4.2± 3.6	6.8± 3.5	5.4± 4.4	8.6± 9.2	1.7± 3.0	2.2± 2.8	0.5± 2.0	0.2± 0.7

Data are expressed as mean ± standard deviation and are based on 8 replicate 0.0625 m^2 airlift samples on each of three transects for each depth, period and bay.
[1]All taxa but epibenthic crustaceans and echinoderms.

Beaufort Sea (Carey *et al.*, 1974; Carey, 1978) and in west Greenland (Vibe, 1939; Ellis, 1960). This difference is, at least in part, attributable to the effectiveness of the airlift sampler used in this study. About half of the biomass found at 7 m depth at Cape Hatt represented the deeply burrowing bivalve *Mya truncata*. Buchanan *et al.* (1977) compared results of quantitative underwater photographs with those of shallow penetrating samplers and found that their shallow samples underestimated infaunal biomass by as much as 960 $g \cdot m^{-2}$. Many of the other low values previously reported may also be biased by inadequate sampling.

Epibenthos

For the purposes of this study, the term "epibenthos" refers to motile members of the benthic community. Included are those animals capable of rapid movement through the lower part of the water column (e.g., crustaceans) and those that move relatively slowly on the sediment surface but are capable of covering relatively large distances because of their large size (e.g., urchins, starfish).

Crustaceans: Epibenthic crustaceans collected in the study bays at Cape Hatt included ostracods, amphipods, cumaceans, isopods, decapods and nebaliaceans. Ostracods, the numerically dominant taxon, constituted 73.0% of total crustaceans collected during September 1980 and August 1981. Amphipods and cumaceans made up 19.5% and 7.2% of total numbers respectively. Isopods, decapods and nebaliaceans were present in very small numbers. Percent contributions of dominant crustaceans to total epibenthic density at each depth are shown in Table 8.

TABLE 8. Percent contribution of dominant crustaceans to total epibenthic density at each of two depths in four bays at Cape Hatt, northern Baffin Island, during September 1980 and August 1981

3 m depth			7 m depth		
Taxon		% of total epibenthic numbers	Taxon		% of total epibenthic numbers
Guernea sp.	(A)	13.8	Ostracoda (Myodocopa)		73.0
Lamprops fuscata	(C)	11.6	*Guernea* sp.	(A)	6.8
Monoculodes spp.	(A)	9.2	*Lamprops fuscata*	(C)	4.8
Stenothoidae spp.	(A)	8.3	*Anonyx* spp.	(A)	3.9
Orchomene minuta	(A)	7.7	*Pontoporeia femorata*	(A)	1.5
Protomedia fasciata	(A)	7.0	*Brachydiastylis resima*	(C)	1.5
Pontoporeia femorata	(A)	4.9	*Monoculodes* spp.	(A)	1.3
Ostracoda (Myodocopa)		4.3	*Paroediceros lynceus*	(A)	1.1
Paroediceros lynceus	(A)	4.1	*Boeckosimus plautus*	(A)	0.5
Ostracoda (Podocopa)		3.9	*Orchomene minuta*	(A)	0.4
Total % contribution		74.8	Total % contribution		94.8
Total epibenthic density ($no \cdot m^{-2}$)		320.1	Total epibenthic density ($no \cdot m^{-2}$)		2073.5

(A) = amphipod; (C) = cumacean.

Ostracods, one species of cumacean and seven amphipod taxa accounted for 74.8% of total numbers at 3 m depth. The three most abundant taxa of epibenthic animals were the amphipod genera *Guernea* and *Monoculodes* and the cumacean *Lamprops fuscata*. At 7 m depth, the ten most dominant taxa made up 94.8% of numbers of animals collected, and myodocopid ostracods alone contributed 73.0% of total numbers. *Guernea* sp. and *Lamprops fuscata* were also important community members at this depth, ranking second and third in terms of density.

There was little indication that densities of total epibenthos varied among bays, but for most specific taxa that were examined, spatial variation on this scale was considerable at both depths. At 3 m depth, *Guernea* sp. and *Lamprops fuscata* were most abundant in Bay 9 (dispersed oil release bay). In contrast, Bay 9 supported the lower densities of amphipod families Stenothoidae and Oedicerotidae (*Monoculodes* spp. and *Paroediceros lynceus*). Densities of *Orchomene minuta* were highest in Bay 10 and similar in the other three bays (Table 9). At 7 m depth, Bay 11 supported the highest density of total amphipods and cumaceans (Table 8). Densities of myodocopid ostracods were highest in Bay 7, whereas *Paroediceros lynceus* was most abundant in Bays 10 and 11 and was rare in the other two bays.

Differences in epibenthic crustacean densities between September 1980 and August 1981 varied among species and bays. At both depths, densities tended to increase between the two sampling periods in Bay 9 and to decrease in Bays 10 and 11 (Table 9). Two amphipod taxa (*Anonyx* spp. and the family Stenothoidae) were notable in that densities decreased at each depth in each bay.

All of the crustacean species collected at Cape Hatt are common in nearshore arctic waters (Steele, 1961; Sekerak *et al.*, 1976b; Buchanan *et al.*, 1977; Thomson *et al.*, 1978; Thomson and Cross, 1980). Overall densities of epibenthic crustaceans at Cape Hatt were higher than those found in two central arctic locations by Buchanan *et al.* (1977) and Thomson *et al.* (1978) and were similar to those found in NW Baffin Bay and E Lancaster Sound by Thomson and Cross (1980). Amphipod densities at Cape Hatt were lower than at most other eastern and central arctic locations studied by Thomson *et al.* (1986), whereas ostracod densities at Cape Hatt were unusually high when compared with those at similar depths in the studies cited above.

Echinoderms: The two large epibenthic echinoderms in the study area were the urchin *Strongylocentrotus droebachiensis* and the starfish *Leptasterias polaris*. Because of their large size and sparse distribution, density data are based on *in situ* counts in 10 m^2 areas, rather than on airlift samples.

Very few urchins or starfish were present at 3 m depth (Table 9). At 7 m depth, both *Strongylocentrotus droebachiensis* and *Leptasterias polaris* were most abundant in Bay 7 and least abundant in Bay 11. For both species, there was a trend of decreasing densities from south to north in Ragged Channel, i.e., toward the mouth of the channel. Urchins were more abundant in August 1981 than in September 1980, whereas densities of starfish were similar at both times (Table 9). Both echinoderm species are characteristic of arctic waters. *Strongylocentrotus droebachiensis* is widely distributed and often relatively abundant (up to 14 individuals$\cdot m^{-2}$) in the Lancaster Sound area, whereas the distribution of *Leptasterias polaris* is more restricted, and its abundance elsewhere in the Arctic is lower than that at Cape Hatt (Thomson and Cross, 1980; Thomson *et al.*, 1986).

Macroalgae

Macroalgal studies at Cape Hatt were focused on understory and canopy algae collected at 3 m depth in airlift samples; baseline data are given together with post-spill data in Cross *et al.* (1987b). This paper contains a summary of the species composition of those algae on 3 m transects and additional data on total macroalgal biomass collected at 7 m depth in airlift samples and on kelp densities counted *in situ* at 3 and 7 m depths (Table 10).

Macroalgae at 3 m depth were dominated by loose-lying understory algae, primarily *Stictyosiphon tortilis* (38.2% of total biomass in September 1980 and August 1981), *Pilayella littoralis* and the colonial diatom *Berkeleya rutilans* (29.8%; it was impractical to separate these two species), *Dictyosiphon foeniculaceus* (12.1%) and *Sphacelaria* spp. (1.6%). Dominant canopy species included *Neodilsea integra* (4.7%), *Fucus distichus* (3.7%) and *Chorda* spp. (1.6%). *Laminaria* spp. (1.6% of algal biomass in 3 m airlift samples) primarily consisted of fragments but also included some small plants.

Total algal biomass varied considerably among depths, bays and sampling periods (Table 10). Biomasses were consistently higher at 3 m than at 7 m depth in September 1980, whereas the opposite was true in three of four bays in August 1981. Biomass

TABLE 9. Mean density (no·m^{-2})[1] of major taxa and dominant species of epibenthos in four bays at Cape Hatt, northern Baffin Island, during September 1980 and August 1981

Taxon	Period	3 m depth				7 m depth			
		Bay 7	Bay 9	Bay 10	Bay 11	Bay 7	Bay 9	Bay 10	Bay 11
Total crustacea	Sept 1980	—	302.0±186.8	437.3±311.5	306.7±188.8	—	1390.0±869.0	2523.3±941.0	2064.7± 815.2
	Aug 1981	206.7±123.5	440.0±689.4	298.0±292.0	248.8±306.6	2526.7± 957.3	2138.7±857.2	1900.5±669.3	1963.3±1269.3
Ostracoda	Sept 1980	—	50.7± 51.2	46.0±101.4	10.0± 15.5	—	977.3±736.6	1741.3±864.0	1144.0± 726.6
	Aug 1981	10.0± 19.9	49.3± 87.2	13.9± 18.2	3.3± 8.1	2103.3±1030.7	1744.7±746.4	1570.1±621.0	1310.7± 973.6
Myodocopa spp.	Sept 1980	—	18.0± 26.0	30.7± 94.0	4.7± 10.0	—	965.3±740.9	1726.0±887.9	1099.3± 751.9
	Aug 1981	9.3± 19.4	19.3± 27.1	11.8± 15.4	2.7± 7.7	2102.0±1031.3	1742.7±747.4	1570.1±621.0	1308.7± 971.4
Cumacea	Sept 1980	—	26.7± 36.4	38.0± 84.9	10.7± 27.8	—	142.0±110.0	135.3± 96.8	319.3± 169.4
	Aug 1981	18.7± 30.8	140.7±375.6	20.8± 33.0	24.0± 48.6	72.7± 68.0	96.0± 94.0	55.7± 40.9	214.0± 155.5
Lamprops fuscata	Sept 1980	—	24.0± 36.2	22.7± 62.4	10.7± 27.8	—	108.7± 98.4	110.0± 84.0	192.0± 146.0
	Aug 1981	18.7± 30.8	139.3±376.0	20.8± 33.0	23.3± 48.8	59.3± 61.8	83.3± 94.5	40.3± 36.4	104.7± 97.7
Brachydiastylis resima	Sept 1980	—	0.7± 3.3	0	0	—	9.3± 24.0	3.3± 9.4	80.7± 62.3
	Aug 1981	0	0.7± 3.3	0	0	11.3± 20.3	3.3± 10.5	9.7± 15.8	94.0± 93.2
Amphipoda	Sept 1980	—	224.7±141.7	353.3±267.6	286.0±178.9	—	270.7±244.7	644.0±369.0	600.0± 301.1
	Aug 1981	176.7±110.4	248.0±364.2	261.9±272.2	218.2±272.4	345.3± 224.5	296.0±157.3	266.4± 99.4	426.0± 269.3
Guernea sp.	Sept 1980	—	72.7± 63.3	43.3± 62.7	14.0± 25.5	—	92.0± 65.1	112.7± 78.9	163.3± 99.0
	Aug 1981	15.3± 19.2	98.0±125.5	53.5± 45.9	11.3± 18.6	117.3± 48.7	179.3±115.4	125.2± 73.6	196.7± 166.7
Orchomene minuta	Sept 1980	—	5.3± 9.0	37.3± 59.4	8.7± 10.5	—	2.7± 7.7	6.7± 12.4	10.0± 27.0
	Aug 1981	17.3± 29.4	29.3± 44.2	70.7±219.2	5.3± 19.8	4.7± 11.0	5.3± 10.2	11.1± 14.0	19.3± 23.6
Anonyx spp.	Sept 1980	—	8.0± 11.6	18.0± 40.4	40.7± 97.3	—	91.3±220.1	300.0±307.7	95.3± 81.8
	Aug 1981	5.3± 10.2	2.0± 7.2	2.8± 6.2	7.3± 14.9	29.3± 56.9	29.3± 56.9	11.8± 19.4	26.0± 30.5
Pontoporeia femorata	Sept 1980	—	3.3± 6.6	2.0± 5.4	15.3± 31.8	—	10.0± 16.2	2.7± 6.1	72.7± 92.3
	Aug 1981	3.3± 6.6	1.3± 4.5	4.2± 8.7	80.0±181.1	72.0± 59.5	20.0± 26.4	9.7± 15.1	37.3± 90.0
Monoculodes spp.	Sept 1980	—	16.7± 31.1	54.0± 78.4	49.3± 35.9	—	2.0± 9.8	6.7± 16.3	14.7± 33.0
	Aug 1981	19.3± 34.0	8.7± 14.1	24.3± 48.5	32.0± 46.5	30.7± 30.9	21.3± 20.4	19.5± 19.9	35.3± 45.7
Stenothoidae spp.	Sept 1980	—	8.7± 11.5	44.7± 66.2	32.0± 45.0	—	1.3± 4.5	13.3± 17.4	29.3± 45.2
	Aug 1981	56.0± 62.6	3.3± 8.1	19.5± 25.0	20.2± 31.9	3.3± 6.6	0.7± 3.3	4.9± 10.2	12.7± 19.4
Protomedia fasciata	Sept 1980	—	59.3± 86.9	4.7± 13.7	8.7± 22.1	—	4.7± 10.1	0	0
	Aug 1981	0.7± 3.3	62.0±163.1	11.1± 19.0	9.3± 18.2	0	2.0± 7.2	2.8± 6.2	0
Paroediceros lynceus	Sept 1980	—	5.3± 12.2	34.0± 72.4	11.3± 13.7	—	5.3± 10.2	42.0± 49.4	76.0± 92.1
	Aug 1981	2.7± 6.1	1.3± 4.5	18.8± 25.4	19.3± 35.0	4.7± 8.8	3.3± 8.1	13.9± 12.1	18.7± 28.2
Strongylocentrotus droebachiensis	Sept 1980	—	0	0	0	—	4.4± 1.5	1.6± 0.7	1.0± 0.4
	Aug 1981	0.1± 0.1	0.1± 0.1	<0.1	<0.1	10.0± 3.4	7.6± 2.2	1.9± 0.9	1.3± 0.5
Leptasterias polaris[1]	Sept 1980	—	0	0	0	—	1.0± 1.1	1.9± 1.3	0.7± 1.1
	Aug 1981	0.1± 0.3	0	0	0.1± 0.3	3.3± 2.5	1.1± 0.9	1.3± 0.9	0.5± 0.8

Data are expressed as mean ± standard deviation and are based on 8 replicate 0.0625 m^2 airlift samples (crustaceans) or 5 replicate 10 m^2 *in situ* counts (echinoderms) for each of three transects for each depth, period and bay.
[1]Densities of *L. polaris* expressed as no·10 m^{-2}.

TABLE 10. Biomass of all macroalgae and densities of Laminariales at 3 and 7 m depths in four bays at Cape Hatt, northern Baffin Island, during September 1980 and August 1981

	Date	Depth	Bay 7	Bay 9	Bay 10	Bay 11
Total biomass[1]	Sept 1980	3 m	—	474±242	1112± 576	630± 616
		7 m	—	242±139	443± 325	218± 222
	Aug 1981	3 m	278± 154	178±168	355± 266	1110±1568
		7 m	859±2973	218±190	747±1746	211± 216
Laminaria saccharina[2]	Aug 1981	3 m	0	0	14.3±18.3	10.7±11.3
		7 m	0	0	1.5± 2.3	0
Agarum cribrosum[2]	Aug 1981	3 m	0	0	0	0
		7 m	0.1±0.4	0.2±0.6	1.1±1.4	1.7± 2.1

[1]Mean ± s.d. formalin wet weight (g·m^{-2}); based on 24 airlift samples (0.625 m^2) for each bay, depth and period. Methods for removing surface water from algae were less precise and less effective than those in Cross *et al.* (1987b); at 3 m, weights in this table are 1.8 × those in the later paper.
[2]Mean ± s.d. no·m^{-2}; based on 15 *in situ* counts (10 m^2) for each bay and depth. Counts were not made during September 1980.

differences between September 1980 and August 1981 may reflect annual or seasonal differences in growth. Because a large proportion of the biomass was loose-lying, however, differences may also be spatial effects caused by waves or currents.

Kelp densities were also quite variable (Table 10). *Agarum cribrosum* was present in low numbers at 7 m in each bay and was absent at 3 m depth. *Laminaria saccharina* was present in only one and two bays at 7 and 3 m depths respectively. In Bays 7 and 11, *L. saccharina* at 3 m depth primarily consisted of small plants (<30 cm long), many of which were newly settled sporophytes. As previously mentioned, kelp densities were considerably higher in a zone between the 3 and 7 m depths.

A comparison of macrophytic algae at Cape Hatt with those in other arctic locations is hindered by the scarcity of available quantitative data. Species present in the loose-lying understory community at 3 m at Cape Hatt were found by Wilce (1973) among attached understory algae in the upper band (1-4 m) of the *Laminaria* zone at five moderately exposed rocky coastal sites in Greenland and the eastern Canadian Arctic. Most species from Cape Hatt were not among the loose-lying algae found by Lee (1973), however, on soft bottoms in the western Canadian Arctic. Algal biomass at Cape Hatt was higher than the biomass of algae other than kelp at most of the 5 and 10 m stations in the Lancaster Sound area studied by Thomson and Cross (1980). Kelp biomass in other parts of the Arctic (e.g., Thomson and Cross, 1980; Chapman and Lindley, 1981; Busdosh *et al.*, 1985) was higher than that reported for Cape Hatt (Cross *et al.*, 1987b),

but samples at Cape Hatt were not collected in the *Laminaria* zone that occurred at 3-5 m depth. Densities of kelp at Cape Hatt were not as high as in some Lancaster Sound locations (pers. obs.) but were considerably higher than those in mixed boulder/silt substrates in the Alaskan Beaufort Sea (Busdosh *et al.*, 1985).

CONCLUSIONS

One of the primary objectives of this paper was to evaluate the adequacy of the sampling design and field and laboratory procedures in providing representative samples of nearshore macrobenthic communities. In consideration of the airlift sampler that was used (mesh size, penetration depth, sampling efficiency), the area sampled and number and location of replicate samples collected, and attempts to avoid bias, to increase sample sorting efficiency and to ensure consistency in laboratory analysis, it was concluded that representative samples of the communities were collected. Despite some flaws discussed in this paper, the study design provided a rigorous and objective framework within which results on oil effects were evaluated.

Another objective was to evaluate the geographic extent to which the study results could be extrapolated. A relatively large number of arctic marine studies have been conducted in recent years, but basic biological data for all but a few species are still lacking, as is information regarding many aspects of trophic interrelationships. The Arctic is also very large, and the area surveyed at any level of activity is still small. Furthermore, detailed studies have shown that the distribution of benthic communities in the Arctic is dependent on a number of interrelated factors. However, the available data indicate that the Cape Hatt ecosystem is typical of those in much of the eastern and central Canadian Arctic. Results of the BIOS Project may also be extrapolated to the western Arctic, the west coast of Greenland, Labrador and perhaps Newfoundland, but further data on nearshore habitats and benthos would be required to do so with any degree of certainty.

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