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INTRODUCTION

In spring, a dense growth or bloom of **microalgae** occurs on and in the soft bottom layer of arctic sea ice. This algal layer begins to develop in April and the bloom peaks in May (Homer 1976, 1977). Productivity of ice algae during the relatively short bloom in April and May can be quite high. The bloom has been estimated to provide between 6 and 33% of the total annual primary production in various arctic locations (Alexander 1974; Homer et al. 1974; Welch and Kalff 1975). In addition, this bloom is important because its production occurs before there is significant production by **planktonic** and benthic algae during the open water season (Apollonio 1965). Thus, ice algal production is available to herbivores earlier in the season than is **planktonic** production (Dunbar 1968). This availability is further enhanced by the concentration of ice algae in two dimensions on the bottom of the ice and, near the end of the bloom, by their occurrence as macroscopic 'detrital' masses on the under-ice surface and in the water column (Cross 1982a).

In addition to the photosynthetic activity of its **microalgae**, the under-ice community also shows considerable heterotrophic activity. The heterotrophic component includes a number of microscopic organisms that can occur in abundance, including bacteria, fungi, colorless flagellates and ciliated protozoans (Homer 1976, 1977). The existence of an active microbial population is suggested both by the abundance of bacteria (Homer 1976) and by the uptake of **labelled** organic substrates (Homer and Alexander 1972). Considerable grazing activity among micro-organisms (e.g. flagellates ingest diatoms; ciliated protozoans graze on diatoms, bacteria and other

organic material--Horner and Alexander 1972) further indicates the existence of an efficient system of in situ nutrient regeneration and inorganic carbon cycling. Inorganic nutrient concentrations in the bottom layer of ice are usually about an order of magnitude higher than in the water below (Homer 1976, 1977), in spite of the high algal concentrations occurring there. In addition to in situ nutrient regeneration, nutrient sources include drainage from the ice above and exchange with the water below (Meguro et al. 1967; Alexander et al. 1974).

The under-ice community also includes a wide variety of metazoans that graze on ice algae (Homer and Alexander 1972; Bradstreet and Cross 1982; Grainger and Hsiao 1982) and, presumably, on bacteria as well. The smallest of these **metazoans--copepods**, nematodes, **polychaetes** and turbellarians--are termed **meiofauna**. Interest in this community has increased in recent years. The existing literature is largely limited to sublittoral and intertidal habitats, but quantitative data on under-ice **meiofaunal** communities in arctic waters are becoming increasingly available (Thomson et al. 1978; Carey and Montagna 1982; Cross 1982a; Grainger and Hsiao 1982; Kern and Carey 1983). The impact of these grazers on ice-algal production, and their contribution to higher **trophic** levels (e.g. arctic **cod--Bradstreet** and Cross 1982), are not well understood. In consideration of their high abundances (on the order of 10^5 **individuals/m²**), however, they may be extremely important in both respects.

The largest and most conspicuous invertebrates inhabiting the under-ice surface are **gammarid amphipods**. Dominant species on the undersurface of the ice have included, at various places and times, **Onisimus litoralis** or

Onisimus glacialis (Green and Steele 1975; Buchanan et al. 1977; Thomson et al. 1978; Cross 1980, 1982a; Grainger and Hsiao 1982), Gammarus setosus (Thomson et al. 1978), Ischyrocerus anguipes (Cross 1980, 1982a,b), Apherusa glacialis (Golikov and Scarlato 1973; Cross 1980, 1982a) and Weyprechtia pinguis (Cross 1982b). Most of these species are herbivores that consume ice algae (e.g., Homer and Alexander 1972; Buchanan et al. 1977; Bradstreet and Cross 1980, 1982); Onisimus litoralis is also known as a scavenger of dead animal material (e.g., MacGinitie 1955). The habitats of these species in the absence of landfast ice include the undersurface of pan ice, the water column, and shallow sublittoral and intertidal areas. In the absence of ice, Apherusa glacialis and Onisimus glacialis are generally considered to be pelagic species (Dunbar 1954; Barnard 1959). However, Apherusa glacialis often associates with pan ice in late summer (e.g., Stephensen 1942; MacGinitie 1955; Divoky 1978; Thomson et al. 1978) and Onisimus glacialis is also an epibenthic species in some locations (Griffiths and Dillinger 1981). Onisimus litoralis and Gammarus setosus occupy intertidal or nearshore sublittoral habitats in the open water season (Dunbar 1954; MacGinitie 1955; Steele and Steele 1970; Thomson and Cross 1980; Cross 1982b).

Distributional and dietary information indicates that the ice habitat is important to amphipods during spring. However, the relative importance and seasonal utilization of pelagic, **benthic** and under-ice habitats by these species is not known. Although the abundance and biomass of nearshore amphipods have been reported for intertidal, sublittoral and under-ice habitats in the eastern Arctic, simultaneous sampling of under-ice and benthic substrates and consecutive sampling of one area through the season (i.e. under fast ice and during the open water season) have not been carried out.

Ice-associated invertebrates (**copepods** and amphipods) are important food items for arctic cod (**Bain** and Sekerak 1978; Bradstreet and Cross 1980, 1982; Craig et al. 1982), various marine birds (Bradstreet 1976, 1980; Divoky 1978; Johnson and Richardson 1981; Bradstreet and Cross 1982), and ringed seals (Finley 1978) . In addition, the arctic cod is a major prey species of marine mammals and birds in the Canadian Arctic (Dunbar 1941, 1949; McLaren 1958; Bradstreet 1976, 1977, 1979, **1980**, 1982; **Finley** 1976; Davis and Finley **1979**; Finley and Gibb 1982, in press; Finley et al. 1982) and elsewhere. Thus , under-ice communities may be critical elements of arctic marine food webs. Damage to the under-ice communities could have effects on the mammals and birds that occupy the higher trophic levels of the food webs.

Studies of plant and animal communities inhabiting the undersurface of arctic sea-ice, and in particular studies allowing direct observations by use of SCUBA methods, have become a focus of attention only recently. To date, few quantitative studies of this type have been conducted. Recent reviews of published research on under-ice biota in the Arctic and Antarctic are given by Homer (1976, 1977). These include details of research carried out by a group from the University of Alaska who used surface-operated and SCUBA methods to study **microalgae** and primary productivity during 1972-1974. SCUBA-based quantitative studies of under-ice communities in the central and eastern parts of the Canadian Arctic are those of Buchanan et al. (1977), Thomson et al. (1978) and Cross (1980, **1982a,b**).

In the event of a marine oil spill or blowout, large quantities of **oil** are most likely to accumulate in the under-ice, intertidal and shallow sublittoral habitats. Data on the effects of treated and untreated oil on

the **biota** of these habitats would be of use in decisions regarding the use of chemical countermeasures for oil spills in ice-covered waters. Productivity and biomass of phytoplankton under oiled ice have been reported (e.g. , Adams 1975), and laboratory experiments concerning effects of oil and dispersed oil on arctic **phytoplankton** have been carried out (e.g. , Hsiao 1978). To our knowledge, the only previous study of oil effects on ice algae is that of Cross (1982b).

Oil effects on arctic **meiofauna** have not been studied, but this group has become a focus of pollution studies in recent years. Raffaelli and Mason (1981) and Warwick (1981a) have postulated that nematode to copepod ratios in **meiobenthic** communities could be potentially useful in the monitoring of pollution. Presumably, the ratio would increase in polluted areas because of greater availability of food to nematodes, and the greater sensitivity of copepods to pollutants (Bodin and Le Meal 1982; McLachlan and Harty 1982). Under-ice **meiofaunal** communities might be useful for oil spill monitoring in arctic regions where ice is present most of the year.

Laboratory studies concerning the acute toxicity of oil to arctic marine invertebrates have been conducted using animals from both the Beaufort Sea (Percy 1974, 1976, 1977a,b; Percy and Mullin 1975, 1977; Busdosh and Atlas 1977) and the eastern Arctic and sub-Arctic (Fey 1978, 1979). These studies have provided useful information on the relative sensitivities of a range of organisms, including some species of under-ice amphipods, but laboratory studies cannot be used to predict the effects of oil contamination in a natural field situation (Fey 1978, 1979). In situ studies of oil effects on nearshore arctic **benthos** were initiated in 1980 (Cross and Thomson 1981,

1982), but similar studies have not previously been carried out in arctic intertidal or under-ice habitats.

In the first year of this study, Cross (1982b) examined effects of in situ applications of oil and dispersed oil on under-ice algae and amphipods at Cape Hatt, Baffin Island, during May 1981. Oil and dispersed oil were added to chambers in the under-ice surface, productivity was measured, and the results were compared with those from simultaneous controls. Oil at low concentrations had little effect on productivity, but oil at the highest level tested caused significantly reduced uptake of radioactive carbon. Dispersed oil at the lowest level tested appeared to stimulate photosynthesis, but at the highest level there was near zero productivity. Distributions and population structures of under-ice and intertidal amphipods in the BIOS (Baffin Island Oil Spill Project) study bays were described. Data were collected prior to the experimental release of oil at Cape Hatt in August 1981, and the intertidal habitat was sampled again following the release of oil. Numbers of Gammarus setosus in the intertidal area of the surface oil release bay decreased by almost an order of magnitude, whereas those in Bays 9 and 10 (dispersed oil bays) decreased by 15 to 40%. These measured decreases were consistent with direct observations made during the oil releases.

The present study is a continuation of that of Cross (1982b). Distribution and life history data were collected for amphipods occupying under-ice, intertidal and shallow sublittoral habitats in the BIOS study bays one year after the release of oil. Similar data collected during 1981 (pre- and 2-4 weeks post-spill) are included in the present report. Productivity

studies described herein address the effects of oil, solidified oil and dispersed oil (three different chemical dispersants) on productivity of ice algae and on associated variables, and also on meiofaunal communities. By using spatial and temporal controls we examine the initial impact on and subsequent recovery of under-ice communities subjected to a single application of these treatments.

MATERIALS AND METHODS

Field studies were carried out during 16-31 May, 10-19 August and 7-8 September 1981, and during 8 May - 2 June, 20-25 August and 6-11 September 1982 from the BIOS (Baffin Island Oil Spill) project base camp located at Cape Hatt, Baffin Island. The study area consisted of five shallow embayments in Ragged Channel, some 5-8 km SSE of Cape Hatt ($72^{\circ}27'N$, $79^{\circ}51'W$). Bays 9 and 10 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. Bays 13 and 7 are similar in size and configuration; the former is located about 3 km to the north and the latter is about 6 km to the south, and just south of another small stream. Bay 11 has been designated as the lower half of a deeper embayment approximately 1 km x 1 km in dimensions, located approximately 1 km north of Bay 10 (Fig. 1).

All under-ice and sublittoral sampling and experimental work was carried out by SCUBA divers working through holes in the ice (May) or from small inflatable boats (August and September). Studies on amphipod distribution and population structure were conducted in Bays 7, 9, 10 and 11 (Fig. 1), at a depth of 3-5 m or on the ice undersurface at the same locations. Intertidal sampling was carried out on the beach between two markers, 150 m apart, which demarcated the sampling locations within the BIOS study bays. Experimental studies on ice algae and **meiofaunal** communities were conducted on the under-ice surface in Bay 13 over a water depth of 10 m.

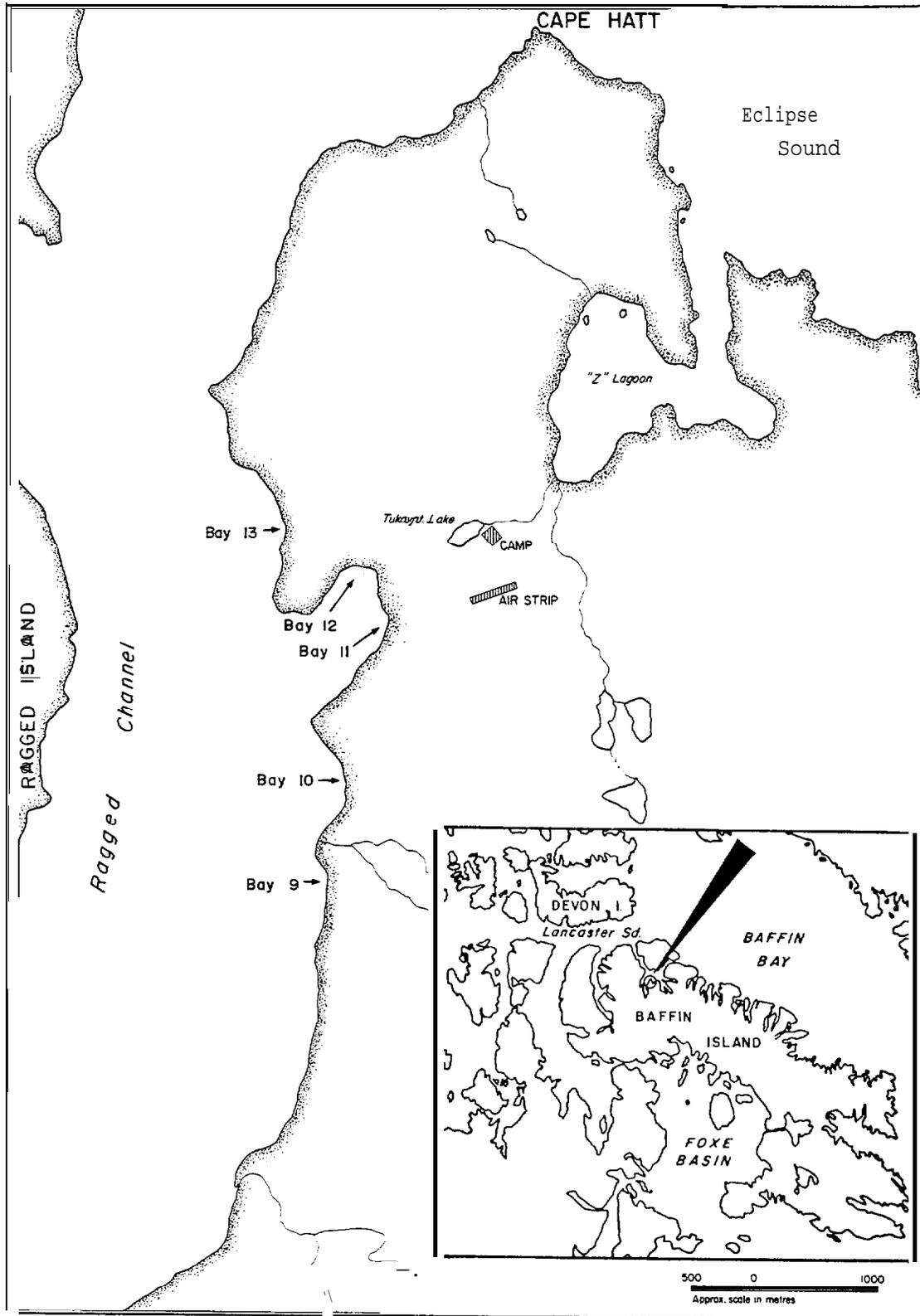


FIGURE 1. Locations of study bays at the BIOS project site at Cape Hatt, Baffin Island.

Amphipod Distributions and Population Structures

Quantitative samples of amphipods were collected in under-ice, intertidal and shallow (3-5 m) sublittoral habitats in each of BIOS study Bays 7, 9, 10 and 11 (Fig. 1). The under-ice surface was sampled during 17-19 **May** and 31 May 1981, and during 8-11 and 30-31 May 1982 (10-16 replicates per bay per time). The intertidal habitat was also sampled at two times in each year: during 17-19 August and on 7 September 1981, and during 20-24 August and 6-9 September **1982** (10 replicates). The shallow sublittoral habitat was sampled at three times in each year: during 17-19 May and on 10 August and 8 September 1981, and during 30-31 May, 21-25 August and 8-11 September 1982 (10 replicates). Sampling in Bay 7 was not carried out in May 1981. Sampling locations selected in 1981 were relocated as closely as possible in 1982.

In late August 1981, 15 m³ of untreated Lagomedio oil was released within booms on the surface of Bay 11, and an additional 15 m³ of the same oil treated with the dispersant Corexit 9527 (10 **oil:1 Corexit**) was released underwater in Bay 9 (Fig. 1). Currents carried the dispersed oil into Bay 10, which had originally been designated as the control bay. This resulted in a relatively high level of contamination of Bay 10--approximately one order of magnitude lower than that in the dispersed oil release bay. For several days following the dispersed oil release, low levels of oil (average maximum of 50 ppb) were also found in the new control bay--Bay 7--and also throughout Ragged Channel (Fig. 1).

All systematic sampling on the under-ice surface was at least 5 m from the entry hole to avoid disturbance artifacts. **Macrofauna** (mainly **amphipods**) on the under-ice surface were sampled by scraping fine mesh (1 mm) dip nets with a 40 cm flat top for 10 m distances along the under-ice surface in areas not previously disturbed by respired SCUBA air. These 10 m transects extended radially from the entry hole (5-15 m, 15-25 m) and were relatively evenly distributed in the semi-circle seaward of the hole. Entry holes were located just seaward of major tide cracks, and the area sampled consisted only of relatively flat, smooth ice. **Meiofauna** and **microalgae** were sampled only in 1982. **Meiofauna** were collected with 10 cm diameter plexiglass chambers inserted 2-3 cm into the soft ice, and **microalgae** were collected with 2.5 cm diameter stainless steel corers driven 10 cm into the ice (5 replicates of each type of core per bay per time).

Intertidal sampling was carried out at or near **low** tide. A 0.25 m² aluminum **quadrat** was placed in the water with its shoreward edge 0.5 m seaward from the water line, the substrate was manually disturbed, and all of the enclosed animals were removed by using a small aquarium net. Sampling locations were randomly selected along 150 m segments of the bays that corresponded with the **benthic** transects sampled during the BIOS Study. Substrates consisted of mixed sand, pebble and cobble.

Sublittoral sampling was carried out using 'a' self-contained diver-operated airlift. The airlift consisted of a weighted 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 an aluminum ring containing an area of 0.15 m². Motile **epibenthos** within the 0.15 m² area were contained, and those outside were excluded, by 1 mm mesh netting covering the top of each ring. The netting over each ring contained a capped central receptacle to receive the 'mouth' of the airlift.

The airlift frame was placed on the bottom and pushed as far as possible into the substrate to contain shallow infauna. The airlift was attached to the net, the air was turned on, and the mouth of the airlift was moved around to cover thoroughly the area within the ring. The net on the airlift was then removed, capped and replaced.

In May, sublittoral sampling locations were randomly selected at a depth of 3-5 m within an area on the bottom below the under-ice sampling area. In August and September, samples of **epibenthic** and shallow **infaunal amphipods** were again collected at the same depths. In 1981, these areas only approximately corresponded to those sampled in May, whereas in 1982 locations were marked in May and relocated in August and September. The substrate consisted of coarse to fine sand with pebbles and cobble (up to 10 cm); data on substrates in Bays 9, 10 and 11 were reported by Cross and Thomson (1981).

All samples were preserved in 10% **formalin**. Amphipods were identified, counted and weighed at species level (whenever possible) and **amphipod** lengths were measured to the nearest mm. **Amphipods** of the genus Onisimus were not identified to species if <6 mm long; most Ischyrocerus collected were damaged

and hence were only identified to generic level. Wet weights of each species or group in each sample were obtained by gently blotting dry and weighing on a **Mettler** PT200 balance to the nearest milligram. Amphipods were transferred to a solution of 3% propylene glycol in 75% ethanol for storage.

The resulting data were analyzed with one- and two-factor analyses of variance, using the SAS general linear models (GLM) program (Helwig and Council 1979). Variables analyzed included abundance (nos./m²) and biomass (mg/m²) of all smphipods and of dominant species. All data were log-transformed prior to analysis.

Primary Productivity of Ice Algae and Meiofaunal Communities

The effects of treated and untreated oil on under-ice communities were studied during 14 May-2 June 1982 in Bay 13 (Fig. 1). The treatments were crude oil (Venezuela Lagomedio), solidified oil (BP treatment), oil dispersed with three different chemical dispersants (**Corexit** 9527, BP1100 WD and BP **CTD**), and no oil (control). Each of these treatments was applied to the under-ice surface within large buoyant plexiglass enclosures 1.2 m in diameter and 30 cm in depth. There were two enclosures for each of the six treatments; one set of six enclosures was established at Location 1 and the other set of six was nearby at Location 2.

Oil and dispersants (10:1 ratio) were mixed with seawater in 9 L air-pressurized hand-held fire extinguishers. Dispersed oil, untreated oil, and water (control and solidified oil treatments) were introduced from the extinguishers into the enclosures. In this way, any disturbance of the

under-ice surface that resulted from the use of fire extinguishers was similar for all treatments. Oil was solidified under ambient (surface) conditions, transferred to a polyethylene bag and passively introduced into the enclosure. The bottom of each enclosure was covered by polyethylene sheeting during the application of treatments. Dispersed oil was contained within the enclosures for a period of 4-5 h and then the bottom sheet was removed; control, oil and solidified oil enclosures remained covered during the release of the dispersed oil. Untreated oil and solidified oil remained in localized areas within the enclosures throughout the study. Just after the treatments were applied, water samples from each enclosure were collected in 50 mL polypropylene syringes and frozen. Oil concentrations were measured with a Turner-Designs **Fluorometer** by Seakem Oceanography Ltd. The nominal concentration within each dispersed oil enclosure was 100 ppm; actual concentrations in the enclosures (average ppm in two samples) were as follows:

	Treatment					
	Control	Oil	Solidified Oil	BP CTD +Oil	BP 1100WD +Oil	Corexit 9527 +Oil
Location 1	0.24	0.19	0.15	5.80	15.50	14.50
Location 2	0.28	0.22	0.15	6.70	26.50	36.50

Sampling was carried out within the enclosures during five periods, each consisting of two days: 18-19, 21-22, 26-27, 28-29 May and 1-2 June. Treatments were applied on 23-24 May. In each of these periods, Locations 1 and 2 were sampled (or treated) on the first and second day, respectively.

Productivity of under-ice algae was determined by a modification of the standard ^{14}C light and dark bottle technique (Strickland and Parsons 1972). The 'bottles' in this case were cylindrical plexiglass chambers with an area of 78.6 cm² and a length of 15.3 cm (volume = 1202 cc). Chambers were inserted about 1-2 cm into the soft bottom layer of ice, and ^{14}C -sodium bicarbonate (New England Nuclear Corp.) with a specific activity of 53 $\mu\text{Ci/mol}$ was injected to yield a final concentration of 75.9 $\mu\text{Ci/L}$. Incubations began between 1100 and 1200 h (local apparent) and were allowed to proceed for a period of 2-2.5 hours. At the end of the incubation periods, ice cores were severed, the chambers were capped and 1 mL of concentrated formalin was injected into each.

During each sampling period, three replicate light chambers and one dark chamber were used to incubate ice (+ water) samples in each enclosure. Because each treatment was applied to two enclosures, there was a total of six light and two dark chambers per treatment and sampling period. In order to determine the contribution of algae in the water to the above results, water samples were also collected immediately beneath the ice within the enclosures. One light and one dark chamber were incubated for each treatment in each period. Separate samples of ice (+ water) were collected in the same way and returned immediately to the field laboratory for the determination of salinity, alkalinity, and ambient inorganic nutrient concentrations.

Carbonate alkalinity was calculated according to the methods of Strickland and Parsons (1972). A Fisher Accumet pH meter (model 630, accuracy ± 0.02 pH) was used to measure pH, and salinity was calculated from Knudsen tables using temperature and specific gravity measurements obtained

with a hydrometer (Fisher, 1.000-1.070) . A recording pyranometer (**Kipp** and Zonen, model CM-6) located at the Cape Hatt base camp recorded incoming radiation (W/m^2) during the four weeks that the camp was occupied.

Light was measured with an underwater **irradiometer** (**Kahlsico** model 268 WA310) below the layer of ice algae and above the algal layer (after scraping this layer away) in each enclosure at the beginning and end of each incubation. Simultaneous measurements above the ice were made with a surface cell so that percent transmission through the ice could be calculated.

Incubation chambers were returned to the field laboratory immediately after the incubation period and processed within 8 h. Actual sample volumes varied to a maximum of 1350 mL and were sometimes very low because chambers leaked during transport to the laboratory. Data from chambers where actual volume was <1100 mL (26 of 240 ice samples; 13 of 60 water samples) were not included in the analyses. The nominal chamber volume of 1200 mL was used in calculations for all chambers. **Subsampling** and filtering procedures are shown in Figure 2 and numbers of samples are given in Appendix A. Filtrations were carried out at vacuum pressures of 120 mm Hg (dissolved organic carbon samples) or 200 mm Hg (all other samples).

Nutrient samples were preserved with 1 or 2 drops of chloroform (samples for phosphate and ammonium analyses) or 2 drops of concentrated **sulphuric** acid (samples for nitrate-nitrite analysis) before freezing. Orthophosphate (PO_4) and nitrate (NO_3) concentrations were determined on thawed samples using a **Technicon** Auto-Analyzer II continuous flow system and standard **Technicon** analysis procedures. Ammonia (NH_3) concentrations were determined

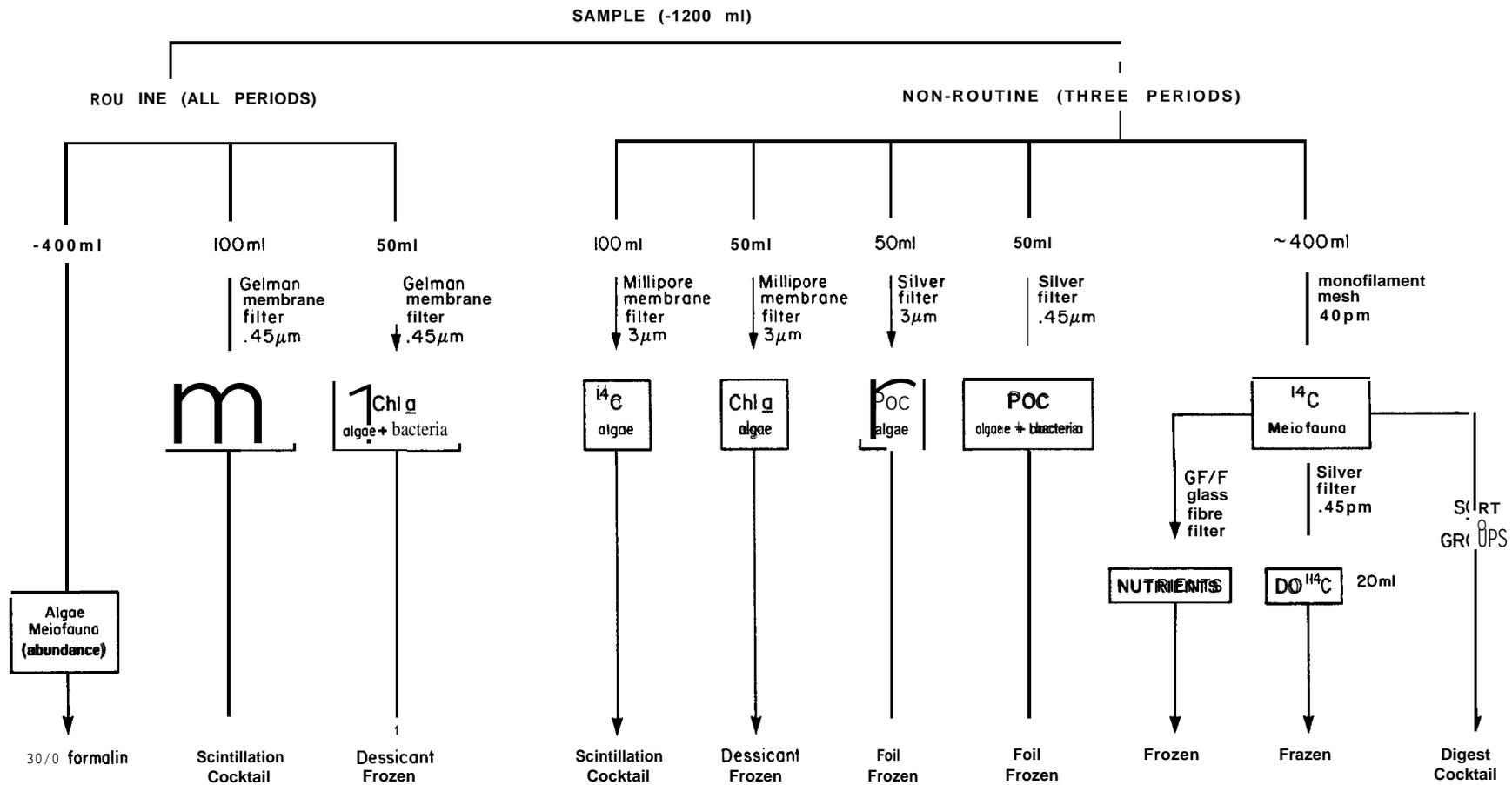


FIGURE 2. Representation of techniques for subsampling, filtration and preservation of ice and water samples.

according to the procedures of Dal Pent et al. (1974). All nutrient concentrations were determined at the Arctic Biological Station, Ste-Anne-de-Bellevue, Quebec.

Chlorophyll a was measured at the Arctic Biological Station by the spectrophotometric procedure described in Strickland and Parsons (1972) using the equation of Jeffrey and Humphrey (1975). Particulate organic carbon concentrations were determined at the Arctic Biological Station by the method described in Bunch et al. (1981).

All radiometric procedures including the preparation of stock solutions were conducted at the Arctic Biological Station. To determine productivity, ^{14}C radioactivity was measured using a Nuclear Chicago **Isocap** 300 scintillation counter. Meiofauna were sorted into major taxa and processed as described in the **NEN-LSC Applications Notes (#1-30)** prior to the measurement of radioactive carbon. Radioactivity in dissolved organic carbon was measured by scintillation counting of the ^{14}C organic residue after acidification to pH 2 and removal of H^{14}CO_3 in a gas stream (N_2 , 30 min.).

Microalgae (subsamples of 5 mL) were identified and enumerated using a modification of the inverted microscope method of **Utermohl** (1958) and magnifications to 625X. Normally, 2.5-10% of the settling chamber was scanned for abundant species and 50% was scanned for others. Numbers of ice algae enumerated were converted to cells/L. Each diatom, **dinoflagellate** and **Dinobryon** cell was counted as an individual, whereas each colony (except for **Dinobryon**) and filament of other groups was counted as one individual. **Microalgae** were identified to species whenever possible. References for

identification included Cupp (1943), **Cleve-Euler** (1951-5) and Hendey (1964) for diatoms, and Paulsen (1908) and Lebour (1925) for dinoflagellates.

Meiofaunal analysis was based on **subsamples** (approximately 500 mL) from each chamber, preserved in 5% **formalin** and filtered through 40 μm mesh netting to reduce the volume. Major **taxonomic** groups (copepods, nematodes and **polychaetes**) in each sample were enumerated using a binocular microscope and plankton counting wheel. Copepods in one half of the total number of samples were identified to species level and counted.

Data on ice algae and meiofauna were analyzed with two- and three-factor analyses of variance, using the SAS general linear models (**GLM**) program (**Helwig** and Council 1979). Variables analyzed included productivity, chlorophyll a, microalgal and **meiofaunal** densities, and ratios between productivity, chlorophyll a, percent transmission and in situ light. Differences between filter types (0.45 μm and 3.0 μm cellulose acetate filters) in productivity, chlorophyll a and particulate organic carbon were analyzed with t-tests for paired comparisons (**Sokal** and **Rohlf** 1969).

RESULTS AND DISCUSSION

Amphipod Distributions and Population Structures

Site Description

Under-ice **amphipods** were sampled over a water depth of 3-4 m in Bays 7, 9, 10 and 11 at Cape Hatt (Fig. 1). Bays 9-11 were sampled in both 1981 and 1982; Bay 7 was sampled only in 1982. Ice depths at the dive holes were 122 to 163 cm in 1981 and 110 to 142 cm in 1982. Snow depths (cm) in each bay in each year were as follows:

Snow depth--mean \pm SD (n)				
	Bay 7	Bay 9	Bay 10	Bay 11
31 May 1981		14.3 \pm 4.2 (39)	14.3 \pm 4.9 (27)	8.9 \pm 5.5 (39)
11,12 May 1982	23.8 \pm 4.1 (17)	18.7 \pm 4.9 (20)	10.6 \pm 2.5 (20)	17.0 \pm 6.2 (20)
3 June 1982	20.8 \pm 3.9 (21)	21.9 \pm 5.0 (20)	8.8 \pm 2.6 (20)	19.0 \pm 9.2 (20)

The bottom of the ice was soft and granular in texture, with small hummocks, depressions and ridges several metres across and up to 20 or 30 cm in relief. In each bay a relatively **light-coloured** algal layer was present on the ice under-surface, and its distribution was patchy on a scale of metres or tens of metres.

Intertidal and shallow sublittoral substrates consisted of fine to coarse sand mixed with pebble and cobble; finer sediments became increasingly predominant with increasing depth. The shoreline was icebound to a depth of 2 or 3 m during May, and very little drifting or grounded ice was present during August and September of either 1981 or 1982.

The under-ice **macrofauna** in the three study bays included arctic cod (*Boreogadus saida*) and mysids (*Mysis_spp.*), but otherwise consisted entirely of gammarid amphipods. Cod were observed only in the large tide cracks just inshore of the entry holes in each of the bays. The edges of these cracks were rounded and about 1/2 m apart at the bottom, and only a few cm wide at a distance of about 1/2 m from the bottom of the ice; most cod moved up into the cracks when disturbed. **Mysids** were present throughout the water column in each bay, and were generally concentrated in the first metre of water just below the ice. Densities of **mysids** were extremely variable both within and among bays; estimates based on amphipod dip net samples were as high as 585 **individuals/m²** or 16 **g/m²**. **These** are underestimates, probably by at least an order of magnitude, because our nets sampled only a part of the water column and because mysids actively avoided the nets. The following results concern only the amphipods collected in this study, and only those amphipods occurring on the under-ice surface are treated in detail.

Species Composition

Thirteen species of **gammarid** amphipods were collected on the under-ice surface at Cape Hatt in 1982 (Table 1). Ten species were collected in 1981 (Cross 1982b), of which eight were also present in 1982. Four of the species collected only in 1982 (Stenothoidae sp., *Pleusymtes* sp., *Monoculodes*

Table 1. Species composition of amphipods in under-ice, intertidal and sublittoral habitats in four bays¹ at Cape Hatt, Baffin Island, during May, August and September 1982².

Taxon	Under-ice (May)			Intertidal (August-September)			Sublittoral (May, August, September)		
	% of numbers	% of biomass	% occurrence	% of numbers	% of biomass	% occurrence	% of numbers	% of biomass	% occurrence
Gamma ridae									
<u>Gamma racanthus loricatus</u>	0.3	5.6	11.7	0.2	0.6	21.3			
<u>Gammarus setosus</u>	1.9	27.4	39.8	43.8	66.1	97.5	<0.1	<0.1	0.8
<u>Gammarus wilkitzkii</u>				<0.1	0.1	6.3			
<u>Melita dentata</u>							<0.1	0.1	0.8
<u>Weyprechtia pinguis</u>	10.7	36.8	84.4				0.4	2.8	11.8
Lysianassidae									
<u>Anonyx nugax</u>	<0.1	0.1	1.6				0.8	31.6	33.6
<u>Anonyx sarsi</u>				<0.1	0.2	3.8	0.2	8.1	14.3
<u>Anonyx juveniles</u>				0.2	0.1	17.5	1.1	1.4	29.4
<u>Boeckosimus edwardsi</u>				<0.1	<0.1	1.3			
<u>Boeckosimus plautus</u>				0.1	0.1	13.8	0.9	1.8	25.2
<u>Boeckosimus sextonae</u>				<0.1	<0.1	1.3			
<u>Onisimus glacialis</u>	1.5	1.4	28.9	20.9	12.2	81.3	<0.1	<0.1	0.8
<u>Onisimus litoralis</u>	0.4	4.4	19.5	21.6	17.4	90.0	0.1	0.2	5.0
<u>Onisimus juveniles</u>	57.7	17.3	92.2	0.1	<0.1	8.8	<0.1	<0.1	1.7
<u>Orchomene minuta</u>				0.4	0.2	32.5	15.9	15.0	58.0
Ischyroceridae									
<u>Ischyrocerus sp.</u>	24.2	6.0	85.2	<0.1	<0.1	1.3	1.4	0.8	14.3
Callionidae									
<u>Apherusa glacialis</u>	0.2	0.1	9.4				0.1	<0.1	1.7
<u>Apherusa egalops</u>				0.1	<0.1	20.0	11.2	2.0	37.8
Stenothoidae									
Unidentified spp.	<0.1	<0.1	0.8	<0.1	<0.1	1.3	7.1	1.1	48.7
Pontogeneiidae									
<u>Pontogeneia inermis</u>	<0.1	<0.1	0.8				0.4	0.4	6.7
Pleustidae									
<u>Pleusyntes sp.</u>	0.1	<0.1	3.9				4.5	0.8	26.1
Oedicerotidae									
<u>Bathymedon longimanus</u>							<0.1	<0.1	0.8
<u>Bathymedon obtusifrons</u>							3.1	0.7	40.3
<u>Monoculodes latimanus</u>	<0.1	<0.1	0.8				5.3	4.4	50.4
<u>Monoculodes packardii</u>				7.5	0.3	51.3			
<u>Monoculodes spp.³</u>							1.5	1.8	31.9
<u>Monoculopsis longicornis</u>				0.3	<0.1	27.5	<0.1	<0.1	3.4
<u>Paroedicerus lynceus</u>							2.1	8.0	41.2
<u>Westwoodilla megalops</u>							0.4	0.1	9.2
Dexaminidae									
<u>Guerneia sp.</u>	<0.1	<0.1	0.8	<0.1	<0.1	1.3	35.8	5.7	90.8
Haustoriidae									
<u>Pontoporeia affinis</u>				<0.1	<0.1	3.8			
<u>Pontoporeia femorata</u>				<0.1	<0.1	2.5	4.3	9.8	56.3
Corophiidae									
<u>Corophium clarencense</u>							0.4	0.1	8.4
<u>Protomedea fasciata</u>							1.1	0.4	16.0
Phoxocephalidae									
<u>Harpina serrata</u>							<0.1	<0.1	0.8
<u>Phoxocephalus holbolli</u>							<0.1	<0.1	1.7
Atylidae									
<u>Atylus carinatus</u>							<0.1	0.1	2.5
Ampeliscaidae									
<u>Ampelisca macrocephala</u>							<0.1	<0.1	0.8
Total %⁴	97.0	99.1		95.2	97.3		98.1	97.2	
Total number, biomass (g) or n	7,117	52.835	128	19,416	260.795	80	9,165	30.429	119
Total nos. /m ² Or g/m ²	14	0.103		971	13.040		509	1.691	

¹ Bay 7 (reference), Bay 9 (dispersed oil release), Bay 10 (dispersed oil contamination), Bay 11 (surface oil release).² Oil was released in late August 1981.³ Includes Monoculodes borealis, M. kroyeri and M. schneideri.⁴ Does not include unidentified, damaged or some juvenile amphipods.

latimanus and Guernea sp.) have not previously been collected on the under-ice surface; none of these species accounted for more than 0.1% of total numbers collected. Nine of the 15 species found at Cape Hatt in the two years have previously been collected in spring on the under-ice surface at various localities in the central and eastern Arctic (Green and Steele 1975; Thomson et al. 1975; Buchanan et al. 1977; Thomson et al. 1978; Cross 1980, 1982a) . Another two species, Weyprechtia pinguis and Pontogeneia inermis, have previously been collected on the under-ice surface only in late February in the western Arctic (Griffiths and Dillinger 1981).

During May 1982, Onisimus juveniles were the dominant amphipods on the under-ice surface in terms of numbers (57.7%). Two species, Weyprechtia pinguis and Ischyrocerus sp., together accounted for most of the remaining numbers (34.9%). Three taxa, Weyprechtia pinguis, Gammarus setosus and Onisimus juveniles, together accounted for 81.5% of total biomass. Percent composition was similar to this in 1981, except that Onisimus juveniles were much less important (only 1.0% of numbers, 0.3% of biomass). Ischyrocerus sp. and Weyprechtia pinguis were dominant in 1981 (together comprising 61.9% of numbers) and the ratio between the two (~2:1) was the same in both years. Weyprechtia pinguis, Gammarus setosus and Onisimus litoralis accounted for most (81.5%) of the biomass in 1981 (Cross 1982b).

Elsewhere, species of Onisimus or Gammarus have most often been reported to be the dominant (or the only) amphipods on the under-ice surface (Green and Steele 1975; Buchanan et al. 1977; Thomson et al. 1978; Grainger and Hsiao 1982). Ischyrocerus sp. was also dominant at some offshore stations in Pond Inlet (Cross 1980, 1982a) , but Weyprechtia pinguis has not been reported to be dominant elsewhere.

Eighteen species of gammarid amphipods were found in the intertidal habitat in August-September 1982 (Table 1). Gammarus setosus was dominant in terms of both numbers (43.8% of total) and biomass (66.1% of total). Onisimus litoralis and Onisimus glacialis, in approximately equal proportions, together comprised most of the remaining numbers and biomass (42.5 and 29.6%, respectively). Gammarus setosus was also dominant in 1981 intertidal samples from Cape Hatt, but many fewer species were collected in 1981; Onisimus glacialis was notable in its absence (Cross 1982b). This is likely a result of sampling at lower tide levels in the second year (see below).

A much higher number of species was found in the shallow (3-4 m) sublittoral habitat in both years: 33 in 1982 (Table 2) and 38 in 1981 (Cross 1982 b). Dominant species were also similar in both years. Guernea sp. , Orchomene minuta and Apherusa megalops together comprised 62.9% of total numbers in 1982 and Guernea sp. , Orchomene minuta and Protomeia fasciata comprised 50.7% of numbers collected in 1981. Anonyx nugax, Anonyx sarsi and Orchomene minuta were dominant in terms of biomass in both years, together accounting for 56.0 and 54.7% of total biomass in 1981 and 1982, respectively.

None of the amphipod species found on the under-ice surface in 1982 was unique to this habitat. Apherusa glacialis was the only species collected only in May (Table 2). It formed a small part of the under-ice community and also was present in shallow sublittoral habitat. It was found in neither intertidal nor sublittoral habitats at any time in 1981 (Cross 1982b; Cross and Thomson 1982). This species is pelagic (Dunbar 1954) and often

Table 2. Percent contribution of under-ice amphipods to numbers collected in under-ice, intertidal and sublittoral habitats in four bays¹ at Cape Hatt, E&fin Island, during May, August and September 1982².

Taxon	Under-ice % of total numbers		Intertidal % of total numbers		Sublittoral % of total numbers		
	Early May	Late May	August	September	May	August	September
<u>Onisimus juveniles</u>	56.3	58.5	0.2	<0.1	<0.1		<0.1
<u>Ischyrocenus sp.</u>	25.9	23.0		<0.1	1.0	0.5	2.9
<u>Weyprechtia pinguis</u>	10.8	10.6				1.2	0.2
<u>Gammarus setosus</u>	1.5	2.2	52.8	37.7	<0.1		
<u>Onisimus glacialis</u>	0.6	2.1	24.3	18.7			<0.1
<u>Onisimus litoralis</u>	0.8	0.2	8.1	30.8	0.1	0.1	0.1
<u>Gammarus juveniles</u>	0.2	0.6	<0.1			0.1	
<u>Gammaracanthus loricatus</u>	0.3	0.3	0.2	0.1	-		
<u>Apherusa glacialis</u>	0.3	0.1			0.3		
<u>Pleusymtes Sp .</u>	0.1	<0.1			1.2	6.1	7.5
<u>Guernea Sp.</u>		<0.1		<0.1	34.1	42.8	31.8
Stenothoidae sp.		<0.1		<0.1	2.3	14.2	7.2
<u>Monoculodes latimanus</u>	<0.1				8.9	2.8	2.5
<u>AnOnyx nugax</u>		<0.1			0.3	0.7	1.5
<u>Pontogeneia inermis</u>		<0.1				0.1	1.1
Total %	9683	97.6 ³	85.6	87.3	48.2	68.6	54.8
Total number collected	2854	4263	7813	11,603	3848	2479	2838
Total area sampled (n?)	256	256	10	10	6	6	6

¹ Bay 7 (reference), Bay 9 (dispersed oil release), Bay 10 (dispersed oil contamination), Bay 11 (surface oil release).

² Oil was released in late August 1981.

³ Does not include unidentified and damaged amphipods.

associates with pan ice in late summer (Stephensen 1942; MacGinitie 1955; Divoky 1978; Thomson et al. 1978).

All of the other species that were common on the under-ice surface were clearly of benthic origin. Gammarus setosus, Onisimus litoralis and Onisimus glacialis almost exclusively inhabited intertidal areas during the ice-free season; this may also be true for Gammaracanthus loricatus, but numbers collected at any time were few. Weyprechtia pinguis and Ischyrocerus sp., on the other hand, were more common in sublittoral than in intertidal habitats during summer. In May, the former was present only on the under-ice surface, whereas Ischyrocerus sp. appeared to show little preference for either habitat. Habitat preferences apparently vary among species, localities and years. The distributions of Weyprechtia pinguis among habitats and months were similar in Cape Hatt in 1981 and 1982. However in 1981, unlike 1982, Ischyrocerus sp. was found in the sublittoral habitat only in May and even then was very rare (1 individual collected; Cross 1982b).

Percy (1975) reported that most Boeckosimus affinis congregate near the ice in winter, but some individuals remain in the sediment; the former animals leave the ice in late May and return to the bottom. Griffiths and Dillinger (1981) reported that Weyprechtia pinguis was collected both on the bottom and on the under-ice surface in Prudhoe Bay in late February.

Six species that were very rare on the under-ice surface in 1982 together comprised a large percentage of the amphipods collected in the sublittoral habitat (46.8 to 66.7%, depending on month). With the possible

exception of Pontogeneia inermis, their occasional presence ON the under-ice surface was likely due to chance.

Abundance and Biomass

Under-ice Habitat

Spatial Effects.--Direct observations by the divers indicated that the distribution of **amphipods** on the under-ice surface in all bays WAS patchy. Larger **amphipod** species (e.g. Gammarus setosus and Gammaracanthus loricatus) were often associated with brine channels and stalactites ON the under-ice surface, or with the tide cracks located just inshore of each dive hole. Smaller **amphipods** were also patchily distributed and were apparently concentrated in areas where concentrations of ice algae were relatively high. The latter type of patchiness was the predominant type in our sampling locations. No systematic sampling was carried out in or near tide cracks, and neither stalactites nor large brine channels were common in the study area. The influence of a freshwater layer caused by melting ice in June and July has also been reported to affect amphipod distributions in Eclipse Sound, both in offshore areas (Cross 1980, 1982a) and at Cape Hatt (N. Snow, pers. comm.). No freshwater layer was observed in the study bays in either year, nor was surface melt apparent at the end of May in either year.

The observed patchiness is also evident in our data. For most species, bays and times, standard deviations greatly exceeded the means (Appendices B and C). Variability among bays is considered significant only if it is even more extreme than the within-bay variability.

Among-bay differences in the densities of dominant **amphipod** species were evident during each year. Three bays were compared in 1981 and four bays in 1982; analyses were carried out only for species and years with relatively high numbers of **amphipods** (Table 3). Densities of amphipods differed significantly among bays in the cases of Weyprechtia pinguis, Ischyrocerus sp. and total amphipods in both years, and Onisimus juveniles in 1982. Weyprechtia pinguis was least abundant in Bay 11 in both years, whereas Ischyrocerus sp. was most abundant in Bays 10 and 11 (Fig. 3). Onisimus juveniles were not common in any bay in 1981; in 1982 they were most abundant in Bay 10 and least abundant in Bays 9 and 11 (Fig. 4). In general, Bay 9 supported the lowest amphipod densities in both years. Highest **amphipod** densities occurred in Bay 11 in 1981, and in Bay 10 in 1982. This shift was primarily a result of decreases in Ischyrocerus sp. and Gammarus setosus densities from 1981 to 1982 in Bay 11, and increases in Onisimus juvenile densities from 1981 to 1982 in Bay 10 (Fig. 4).

Significant interactions between bay and month factors precluded interpretation of among-bay differences in densities of Gammarus setosus (1981 and 1982) and Onisimus litoralis (1981) (Table 3). Inspection of the data, however, shows clear among-bay differences (Fig. 3 and 4). Gammarus setosus was most abundant in Bay 11 and least abundant in Bay 9 during both years, and the opposite was true in the case of Onisimus litoralis in 1981. The latter species was rare in all but Bay 7 in 1982.

Thus there were pronounced among bay differences in abundances of **amphipods** on the under-ice surface. Analyses of variance and inspection of the data showed that each of the dominant species was more abundant in some

Table 3. Seasonal comparisons of the densities of amphipods on the under-ice surface in three or four bays¹ at Cape Hatt, Baffin Island during early and late May 1981 and 1982². F-values are shown with significance levels (ns = P>0.05; * P<0.05; ** P<0.01; *** P<0.001). Significance levels are not shown for the main effects when the interaction term was significant.

Taxon/df	Comparison	Source of Variation		
		Bay ¹	Period ²	Bay x Period
<u>Gammarus setosus</u>	1981	65.35	25.49	6.89 **
	1982	24.84	8.63	14.15 ***
<u>Onisimus litoralis</u>	1981	21.23	13.24	12.37 ***
	1982	53.11 ***	20.06 ***	2.54 ns
<u>Weyprechtia pinguis</u>	1981	5.70 **	14.48 ***	2.17 ns
	1982	23.29 ***	3.03 ns	0.77 ns
<u>Ischyrocerus</u> sp.	1981	23.19 ***	6.91 *	0.24 ns
	1982	86.26 ***	2.43 ns	1.57 ns
Amphipoda (density)	1981	9.38 ***	23,24 ***	1.96 ns
	1982	36.85 ***	22.00 ***	1.69 ns
Amphipoda (biomass)	1981	2.16	14.92	6.73 **
	1982	1.91	7.65	3.75 *
Degrees of freedom	1981	2,74	1,74	2,74
	1982	3,120	1,120	3,120

¹ Bays 9 (dispersed oil release), 10 (dispersed oil contamination) and 11 (surface oil release) in 1981; Bays 7 (reference), 9, 10 and 11 in 1982.

² 17-19 May and 31 May in 1981 (Pre-spill); 8-11 May and 30-31 May in 1982 (Post-spill).

³ Duncan's Multiple Range Test, $\alpha = .05$.

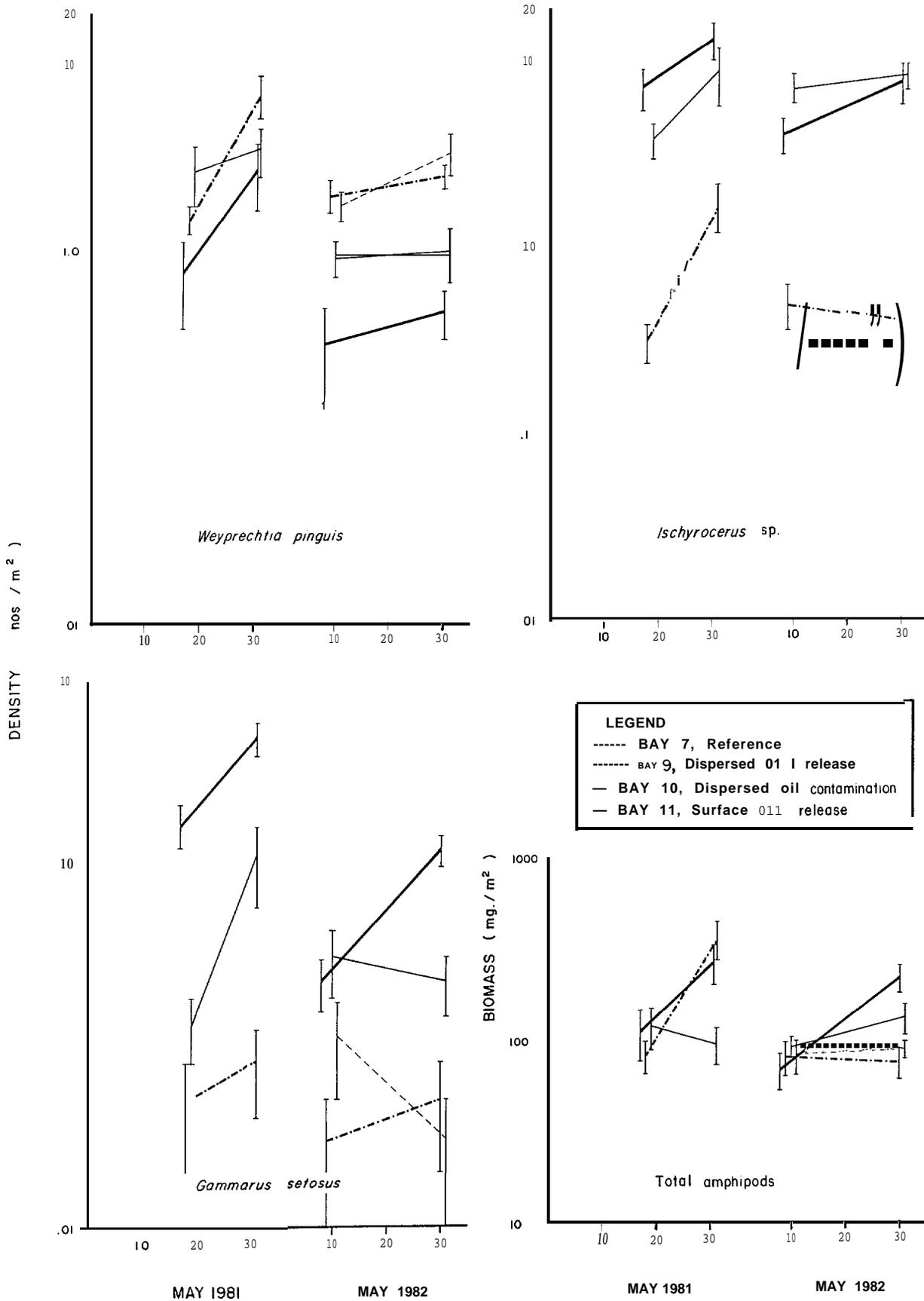


FIGURE 3. Densities of three amphipod species and biomass of total amphipods in the under-ice habitats of four bays at Cape Hatt, Baffin Island, during May 1981 (pre-spill) and May 1982 (post-spill). Data are expressed as the mean of 10-16 replicate 4 m² net samples; vertical lines show standard error.

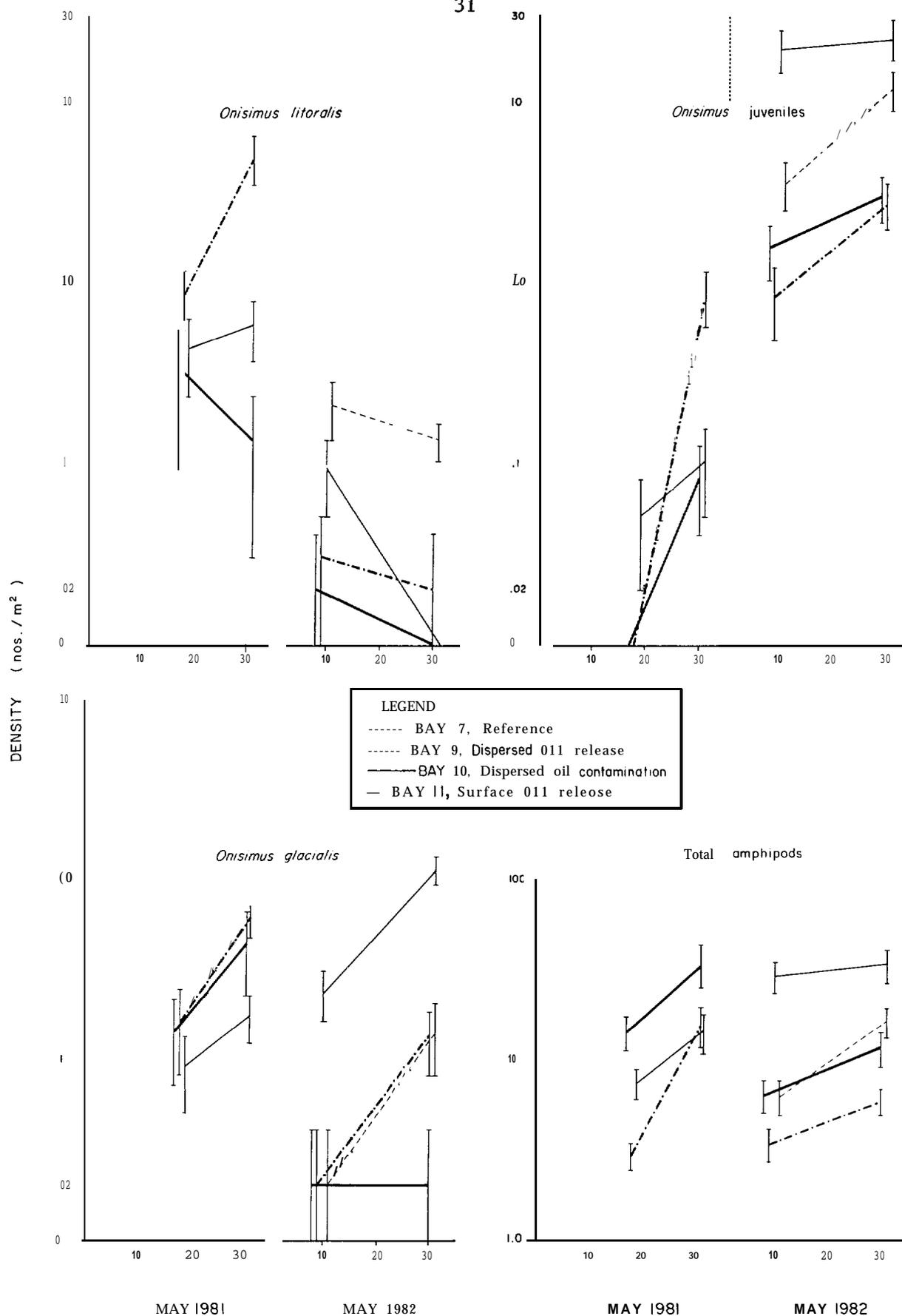


FIGURE 4. Densities of *Onisimus* amphipods in the under-ice habitats of four bays at Cape Hatt, Baffin Island, during May 1981 (pre-spill) and May 1982 (post-spill). Data are expressed as the mean of 10-16 replicate 4 m² net samples; vertical lines show standard error.

bays than others. With the exceptions noted in the previous paragraph, these differences were relatively consistent between the two sampling periods in May of each year.

Temporal effects. --Both year-to-year and seasonal variability were evident in the densities of under-ice amphipods. The predominant seasonal trend was an increase in density from early or mid May to late May (Table 3; Fig. 3 and 4). Seasonal increases in density were apparent in both years and in all bays for Onisimus juveniles, Onisimus glacialis, and all amphipods together. Weyprechtia pinguis and Ischyrocerus sp., on the other hand, showed significant seasonal increases only in 1981; no change occurred between sampling dates in May 1982 (Table 3). Densities of Gammarus setosus also increased during May 1981; the significant bay x date interaction (Table 3) was due to bay-to-bay differences in rates of increase. However, in 1982 densities of Gammarus setosus increased from early to late May in two bays, and decreased in two others. In both years, total amphipod biomass increased during May in some bays and decreased in others, and in 1981 the same was true for densities of Onisimus litoralis. The only case in which there was a consistent seasonal decrease in abundance in all bays was Onisimus litoralis in 1982; however, the significance of this is uncertain due to the low numbers of individuals present.

The observed seasonal increases in many under-ice amphipod species are likely related to the under-ice algal bloom. A distinct seasonal cycle in under-ice algae has often been observed (Homer and Alexander 1972; Clasby et al. 1973; Homer 1976, 1977). Increases in standing stocks and productivity begin sometime in April and generally peak in May or early June, at which

time the dense algal layer sloughs off the bottom of the ice. Under-ice chlorophyll concentrations at Cape Hatt increased significantly during 16-30 May 1981, and there was no indication that the bloom had begun to decline at the end of May.

Year-to-year comparisons are given in Table 4. The only species considered are those whose densities were high in both years. Only the late May sampling period in each year is considered. Year-to-year variation was significant in two of four unambiguous cases (i.e. in 2 of 4 analyses where the year x bay interaction was not significant). Both density and biomass of Weyprechtia pinguis in late May were lower in 1982 than in 1981 (Fig. 3, Appendix C). Neither biomass of Gammarus setosus nor density of Ischyrocerus Sp. varied between the two years (Table 4). In some cases where the interaction term was significant, inspection of the data indicates that the interaction was due to among-bay differences in the rate, and not the direction, of change. In these cases, and for species whose densities were too low to warrant analysis, the predominant annual trend is a decrease in numbers or biomass from 1981 to 1982. This is the case for density of Gammarus setosus, biomass of Ischyrocerus sp. and density and biomass of Onisimus litoralis. Only one group of amphipods shows a consistent increase from 1981 to 1982: Onisimus juveniles.

Annual variability in amphipod densities may also be related to changes in the abundance of ice algae, which in turn may depend on differences in snow cover. Snow cover may affect under-ice chlorophyll concentrations (Grainger 1977; Homer et al. 1974), productivity rates (Welch and Kalff 1975), and the timing of the spring bloom (Cross 1982a). In the study bays

Table 4. Annual comparisons of refer-ice amphipod densities and biomasses in three bays¹ at Cape Hatt, Baf fin Island, during late May 1981 and 1982². F-values are shown with significant levels (ns P>0.05; * P<0.05; ** P<0.01; *** P<0.001). Significance levels are not shown for main effects when the interaction term was significant.

Taxon	Variable	Source of Variation, (df) and Group Means Ranking ³					
		Two-factor Analysis of Variance			One-factor Analysis of Variance (years)		
		Bay (2,74 df)	(1, % %)	Bay x Year (2,74 df)	Bay 9 (1,24 df)	Bay 10 (1,26 df)	Bay 11 (1,24 df)
<u>Onisimus juveniles</u>	Abundance	21.63	113.25	25.04 ***	5.15 * [81<82]	180.07 *** [81<82]	12.32 ** [81<82]
	Biomass	20.54	95.24	23.74 -	2.19 ns	209.36 *** [81<82]	11.74 ** [81<82]
<u>Gammarus setosus</u>	Abundance	59.%	30.89	10.98 ***	0.41 ns	5.06 * [82<81]	32.60 *** [82<81]
	Biomass	139.85 *** [9<10<11]	1.46 ns	0.37 0s			
<u>Ischyrocerus sp.</u>	Abundance	35.01 *** [9<10,11]	1.69 ns	2.46 ns			
	Mamas	31.87	4.49	3.39 *	17.25 *** [82<81]	0.36 ns	1.93 ns
<u>Weyprechtia pinguis</u>	Abundance	12.97 *** [10,11<9]	22.93 *** [82<81]	0.03 ns			
	Biomass	23.47 *** [11<10<9]	5.11 * [82<81]	0.26 ns			
Amphipoda	Abundance	8.47	1.28	14.31 ***	10.61 ** [82<81]	10.57 ** [81<82]	9.05 ** [82<81]
	Biomass	4.78	3.72	9.34 ***	15.22 *** [82<81]	2.31 ns	0.28 ns

¹Bays 9 (dispersed oil release), 10 (dispersed oil contaminat.) and 11 (surface oil release).
²31 May 1981 (Pre-spill) and 30-31 May 1982 (Post-spill); oil was released in late August 1981.
³Duncan's Multiple Range Test, $\alpha = .05$.

at Cape Hatt, snow cover did vary between 1981 and 1982, but the variation was not consistent among bays (see 'Site Description'). Thus the year-to-year variability in **amphipod** abundance cannot be attributed to this factor alone. Nonetheless, snow cover must be taken into account in any interpretation of interactions between bays and years.

Intertidal Habitat

The **amphipods** *Gammarus setosus* and *Onisimus litoralis* are the only two amphipod species previously reported to be abundant in arctic intertidal habitats (Sekerak et al. 1976; Thomson et al. 1978; Thomson et al. 1979; Thomson and Cross 1980; Cross 1982b). Substrates in the intertidal habitats where sampling has been carried out are generally composed of rocks and pebbles with small amounts of sand, although occasionally sand beaches have been included (Thomson et al. 1979; Thomson and Cross 1980). *Gammarus setosus* and *Onisimus litoralis* are both most abundant at low tide; the former shows an apparent preference for rocks >5 cm in diameter, whereas *Onisimus litoralis* occurs primarily in substrates of sand and small pebbles (Thomson et al. 1979).

Thus, factors affecting the abundance of intertidal amphipods include substrate type and tide. In each of the bays at Cape Hatt, rock and cobble were the predominant substrates in the upper and mid intertidal areas, whereas finer sediments (mostly sand) became more common in the low intertidal areas. Substrate type and tide may, therefore, be expected to affect abundance of intertidal amphipods within the study bays.

Intertidal sampling at Cape **Hatt** was carried out at low tide in each year. The range of tide levels sampled was greater in 1981 (26 to 103 cm below mean tide) than in 1982 (66 to 101 cm below mean) because of sampling date. This factor must be taken into account in the interpretation of spatial and temporal distributions.

Spatial Effects.--During 1981, two amphipod species were dominant in the intertidal habitat at Cape Hatt: **Gammarus setosus** and **Onisimus litoralis**. The latter species was found only in Bays 10 and 11, and was relatively abundant only in Bay 11 and only in August (Fig. 5; Appendices D and E). August to September changes in the abundance and biomass of **Gammarus setosus** were not consistent among bays. This interaction (Table 5) necessitated the use of separate one-factor analyses (bay effects) for each month. Numbers and biomass of **Gammarus setosus** differed among bays only in September (Cross 1982b). At this time, density of **Gammarus setosus** was highest in Bay 10 and lowest in Bays 9 and 11; biomass was also highest in Bay 10, but in this case values were lower in Bay 9 than in Bay 11 (Fig. 6).

During 1982, differences among bays were significant for each of the four dominant intertidal amphipod species and also for total **amphipods** (Table 5). Numbers and biomasses of **Gammarus setosus** were lowest in Bay 11 and higher and similar in the other three bays (Fig. 6, Table 5). Numbers and biomasses of both species of **Onisimus** were highest in Bay 11 and lowest in Bay 7 (Table 5); in each species the greatest difference was between Bay 7 and the other three bays, and differences among Bays 9, 10 and 11 were apparently greater in August than in September (Fig. 5). **Monoculodes packardi** was less abundant in Bays 7 and 11 than in Bays 9 and 10, in terms

Table 5. Comparison of densities and biomasses of amphipods in intertidal habitats in three or four bays¹ at Cape Hatt, Baffin Island, during August and September 1981 and 1982². F-values are shown with significance levels (ns = P>0.05; * P<0.05; ** P<0.01; *** P<0.001). Significance levels are not shown for main effects when the interaction term was significant.

Year	Taxon/df	Variable	Source of Variation			Group Means Ranking ³	
			Bay	Month	Bay x Month	Bays	Months
1981	<u>Gammarus setosus</u>	Abundance	1.34	6.90	9.92 ***		
		Biomass	0.20	3.22	6.34 **		
1982	<u>Gammarus setosus</u>	Abundance	9.59 ***	0.00 ns	0.41 ns	11<7,9,10	
		Biomass	12.99 ***	0.14 ns	0.40 ns	11<7,9,10	
	<u>Onisimus litoralis</u>	Abundance	43.99 ***	19.14 ***	2.22 ns	7<9,10<11	
		Biomass	52.31 ***	21.94 ***	1.04 ns	7<9,10<11	
	<u>Onisimus glacialis</u>	Abundance	44.98 ***	5.97 *	0.75 ns	7<9<10<11	
		Biomass	42.68 ***	3.85 ns	0.47 ns	7<9<10<11	
	<u>Monoculodes packardii</u>	Abundance	12.18 ***	1.13 ns	1.41 ns	7,11<9,10	
		Biomass	11.67 ***	2.98 ns	1.88 ns	7,11<9,10	
	Amphipoda	Abundance	7.51 ***	1.19 ns	0.30 ns	7<9,10,11	
		Biomass	3.65 *	3.62 ns	0.45 ns	7,10,11<9	
1981	Degrees of freedom		2,54	1,54	2,54		
1982	Degrees of freedom		3,72	1,72	3,72		

¹ Bays 9 (dispersed oil release), 10 (dispersed oil contamination) and 11 (surface oil release) in 1981; Bays 7 (reference), 9, 10 and 11 in 1982.

² Oil was released in late August 1981.

³ Duncan's Multiple Range Test, $\alpha = .05$.

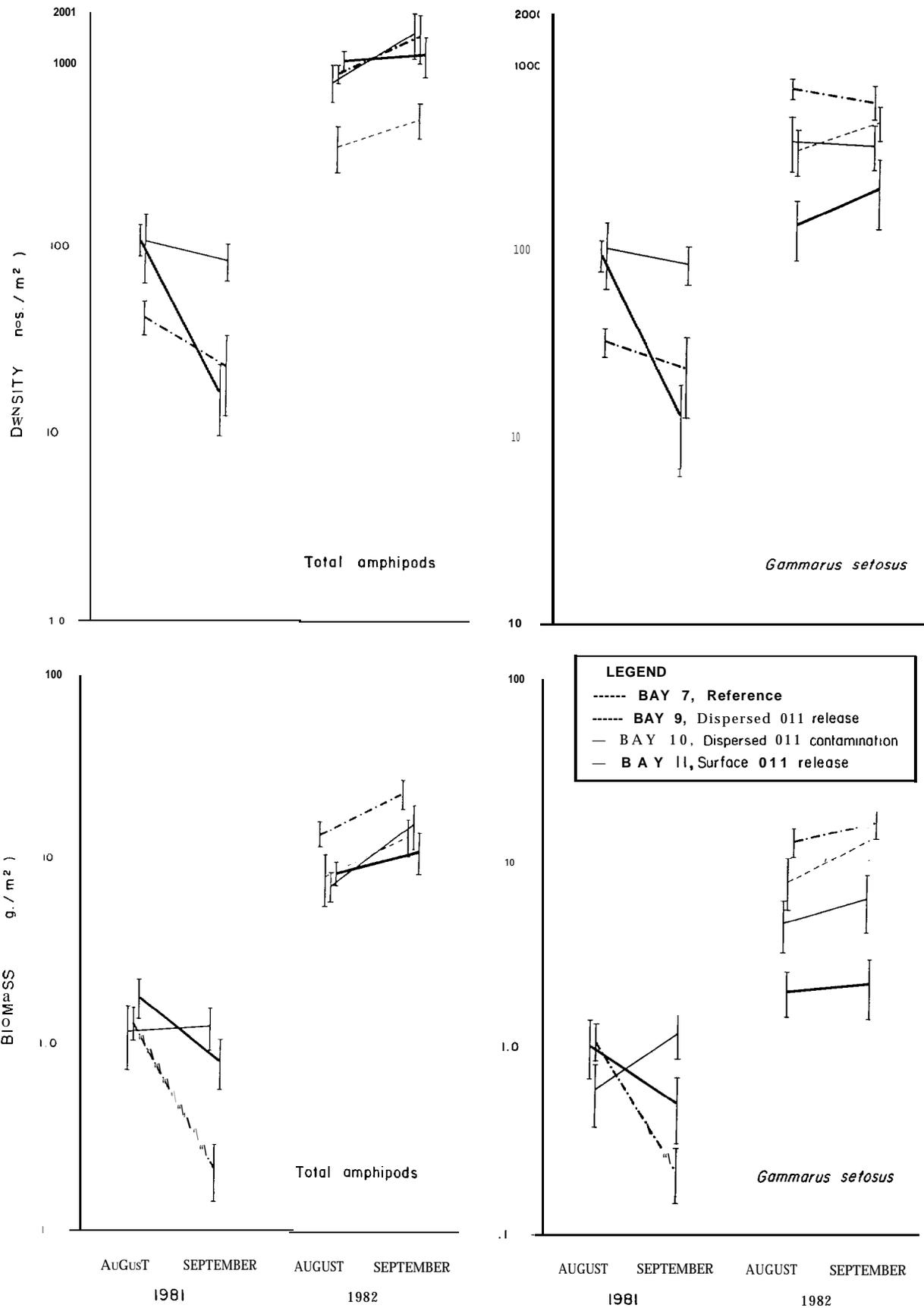


FIGURE 6. Densities and biomasses of *Gammarus setosus* and total amphipods in the intertidal habitats of four bays at Cape Hatt, Baffin Island during August and September 1981 and 1982. Oil was released in late August 1981. Data are expressed as the mean of 10 samples, each covering 0.25 m²; vertical lines show standard error.

of both abundance and biomass. Total **amphipod** abundance and biomass were similar in 3 of 4 bays. Bay 7 supported the lowest total density and Bay 9 supported the highest total biomass of intertidal amphipods (Fig. 6).

In neither year do the observed among-bay differences in **amphipod** distribution appear to be related to tide **level**. In 1981, tide levels at which sampling took place were more similar among bays in September than in August (Appendix D), whereas abundance and biomass of **Gammarus setosus** were more variable in September. In August, tide levels were higher in Bay 11 than in Bay 10, and **Onisimus litoralis** was more abundant in Bay 11; this is not consistent with the observed relationships between substrate type, tide level and density of this species (see above). During 1982, among-bay differences were considerable in all amphipod species examined, whereas tide levels at which sampling took place were relatively constant among bays (Appendix D).

Temporal Effects.--During 1981, differences in abundance and biomass of the dominant intertidal amphipods were not consistent among bays (Fig. 5 and 6). In 1982, differences between August and September were significant only for density and biomass of **Onisimus litoralis** ($P < 0.001$) and for density of **Onisimus glacialis** ($P < 0.05$). **Onisimus litoralis** increased in abundance between August and September, whereas densities of **Onisimus glacialis** were generally lower in September (Table 5); the apparent August to September increase in Bay 9 (Fig. 5) was the result of one sample containing very large numbers of individuals.

In contrast to the apparent lack of seasonal effects, year-to-year differences in the abundance and biomass of intertidal **amphipods** were considerable. This is immediately apparent upon inspection of the data (Fig. 5 and 6; Appendices D and E); differences were so large that analyses were not carried out. Depending on bay and month, mean densities of total **amphipods** in 1982 were 8-68 times greater, and mean **biomasses** were 5-107 times greater than in 1981. Moreover, increases between years included all four of the dominant species collected in the intertidal habitat in 1982. *Gammarus setosus* and *Onisimus litoralis* increased in similar proportions to those given above for total smphipods. *Onisimus glacialis* and *Monoculodes packardi* were absent in 1981, whereas in 1982 densities of these two species were as high as 633.6 and 287.6 **individuals/m²**, respectively (Appendix D).

This difference may represent a real change in **amphipod** distributions from one year to the other. Higher 1982 densities of *Onisimus glacialis*, for example, are likely related to the observed increases in densities of *Onisimus* juveniles under the ice in May (Fig. 4). In turn, this indicates that 1981 was a year of successful breeding, at least in some locations (see below). Year-to-year differences may also be related to **year-to-year** differences in tide levels in combination with substrate differences within bays, or to some other type of sampling bias. Sampling was at lower tide levels in 1982 than in 1981 (66-101 vs. 26-64 cm below mean) in all but one bay/month combination (Appendix D). In this one case differences between years were smaller, but still considerable. Hence it is likely that another factor is involved. In any case, these differences confound the interpretation of oil effects and must be taken into consideration.

Oil Effects

Significant interaction terms **in** analyses of variance have indicated oil effects on dominant **amphipods** in both under-ice and intertidal habitats (Tables 4 and 5). These analyses were based on data collected in three bays (one surface oil release bay and two dispersed oil release bays) during **pre-** and post-spill periods (late May 1981 and 1982; August and September 1981); oil releases took place **in** late August 1981. Interpretation of these apparent oil effects is supplemented with data collected in a fourth (reference) bay and **in** August and September 1982 (one year post-spill).

Dominant **amphipod** taxa in under-ice and intertidal habitats in the study area for which oil effects have been indicated are **Gammarus setosus**, **Ischyrocerus** sp., and **Onisimus** juveniles. The effects of the surface and dispersed oil releases on each of these species will be discussed.

Gammarus setosus

Lagomedio crude oil was released in Bay 11 between the August and September sampling periods in 1981, and a relatively even coating of oil was deposited on the beach (intertidal area) of Bay 11 by the falling tide. Observations following the oil release (Cross and Thomson 1982), inspection of the data (Fig. 6) and significance of the bay x time interaction terms in Table 5 all indicate that oil affected the **amphipods** that occupied the intertidal habitat. The numbers of intertidal **Gammarus setosus** decreased somewhat in Bays 9 and 10 (dispersed oil bays) from August to September 1981, but the corresponding decrease in Bay 11 was much more marked (September

densities were 56.2, 83.2 and 13.4% of August values in Bays 9, 10 and 11, respectively) . Biomass of Gammarus setosus, on the other hand, decreased more in Bay 9 than in Bay 11, and increased in Bay 10 (Fig. 6). Bay 9 was the study bay that received the highest concentrations of dispersed oil (an order of magnitude higher than those in Bay 10). Thus there appear to have been effects on Gammarus setosus related both to the untreated oil and dispersed oil releases.

Differences in the results for density and biomass data suggest that these were size-specific effects, and other data confirm this. Inspection of length-frequency data (Fig. 7) shows that the surface oil affected small Gammarus setosus (0+ year class) to a much greater extent than older individuals. Length-frequency data are not shown for the intertidal habitat in Bay 9, but in that case the converse was true: numbers of small (0+) individuals collected in pre- and post-spill periods (August and September) were similar (42 and 46, respectively), whereas the number of larger individuals collected was much lower in September (13) than in August (65). No size effect was apparent in Bay 10 (Fig. 7).

The persistence of one or both of the observed oil effects (untreated oil , dispersed oil) until May 1982 was indicated by a significant period x year interaction in the analyses of pre- and post-spill densities of Gammarus setosus under the ice in May (Table 4). However, one-factor analyses show bay differences in pre- to post-spill change that are not consistent with those observed in the previous summer or with the type or level of oil contamination. Densities of Gammarus setosus on the under-ice surface decreased from 1981 to 1982 in Bay 11, but also decreased in Bay 10 where no

effect was apparent in the summer of 1981. There was no significant difference between the 1981 and 1982 densities of Gammarus setosus under the ice in Bay 9; densities were low in both years.

Inspection of size-frequency distributions, on the other hand, indicates that effects of the surface oil release in late August 1981 persisted until May 1982. In Bay 11, numbers of newly released juveniles (3 mm in length) and **one-year-olds** (6-10 mm) on the under-ice surface were much lower in May 1982 than in May 1981 (Fig. 7). In the other three bays, both size classes were present (albeit in low numbers) in May 1982. Females brooding young were common in Bay 11 during late May of each year; the release of these young in Bay 11, however, appeared to be delayed in 1982. Differences from 1981 to 1982 in both cohorts can be attributed to the surface oil release in August 1981.

Both of these year classes were present in the intertidal habitat of Bay 11 during August and September 1982 (Fig. 7). Hence the population appears to have at least partially recovered one year following the release of untreated oil. The delayed release of juveniles in the surface release bay in May 1982, however, may have resulted in reduced size of individuals in this year class. The median size of the 0+ year class in Bay 11 was 4 mm in August 1982 as compared with 5 mm in August 1981 (Fig. 7); the latter appears to be the norm in the other bays in both years (Fig. 7 and 8). The implications of this reduced size on survival or fitness are not known.

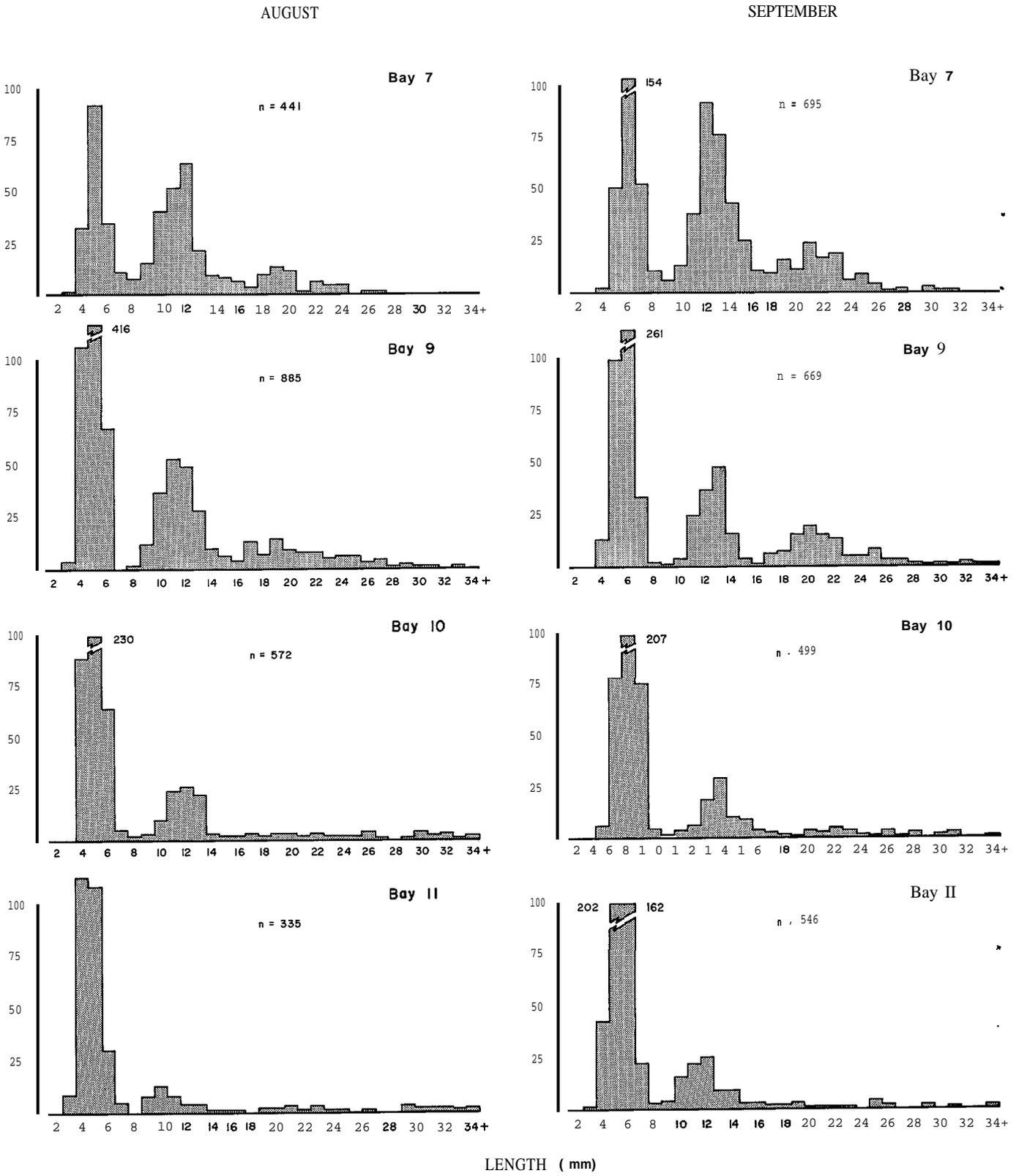


FIGURE 8. Length-frequency histograms for Gammarus setosus in the intertidal habitats of four bays at Cape Hatt, Baffin Island, during August and September 1982.

Among-bay differences in the densities of intertidal Gammarus setosus in 1982 further indicate incomplete recovery from the effects of the surface oil release in 1981. During August and September 1982, densities and **biomasses** were lower in Bay 11 than in the other three bays (Table 5; Fig. 6). In August 1981, on the other hand, densities were highest in Bays 10 and 11, and **biomasses** were similar in all three bays. Effects of the dispersed oil release were not apparent one year following the release. Density and biomass of intertidal Gammarus setosus in 1982 were highest in Bay 9 (Fig. 6), and the population structure in this bay appeared to be normal (Fig. 8).

In summary, there was an unequivocal effect of the surface oil release on Gammarus setosus. Direct oiling of intertidal populations in Bay 11 caused immediate mortality. Densities in this bay were significantly reduced three weeks after the oil release, particularly in the 0+ year class. This cohort was almost absent from the under-ice surface in the following spring but was well represented in the intertidal habitat one year following the oil release. These individuals must have been recruited from adjacent areas. Larvigerous females were present on the under-ice surface in Bay 11 in May of both the **pre-** and the post-spill years, but the release of juveniles was delayed in 1982. This delay apparently resulted in reduced size of the 1982 0+ year class in the intertidal habitat in August and September.

The dispersed oil release, on the other hand, seems to have affected older Gammarus setosus (1 and 2+ year classes). Densities of these individuals were markedly reduced approximately one week following the release, but it is uncertain whether mortality or emigration was the cause of this decrease. Densities on the under-ice surface were low in both the **pre-**

and the post-spill years. No effects were apparent in abundance and population structure data collected in the intertidal habitat one year following the release.

Onisimus juveniles

Numbers of Onisimus juveniles on the under-ice surface increased greatly from May 1981 to May 1982 in all three bays that were sampled in both years. Oil effects on Onisimus juveniles were indicated by significant bay x year interaction terms (Table 4). Increases in density and biomass of juvenile Onisimus from 1981 to 1982 were much more pronounced in Bay 10 than in Bays 9 or 11 (Fig. 4; Appendix C). These differences, together with the observed high densities of these juveniles in Bay 7 (reference bay) during May 1982, suggest that a natural population increase from 1981 to 1982 may have been partly inhibited in bays that received high levels of dispersed oil (Bay 9) or surface oil (Bay 11).

Ischyrocerus sp.

Ischyrocerus sp. was sufficiently abundant to warrant analysis only in the under-ice habitat. Biomass of this species on the under-ice surface decreased significantly from late May 1981 to late May 1982 in Bay 9 but not in Bays 10 or 11 (Table 4). This suggests that biomass was reduced by the dispersed oil released in Bay 9 between the two sampling dates. When density data were considered, the interaction term was not significant, nor was there any significant difference in densities between the late May sampling periods of the two years. Differences in the results for density and biomass suggest

that there were size-specific effects. Numbers of Ischyrocerus sp. in Bay 9 were too few, however, to warrant any analysis of size effects (only 25 individuals collected in May 1982).

Ischyrocerus sp. was sparsely distributed (0.7 individuals/m²) in the sublittoral habitat of Bay 9 at the time of the dispersed oil release (Cross 1982b). The occurrence of Ischyrocerus anguipes on the under-ice surface in offshore locations (Cross 1980, 1982a), together with its overall low abundance in the sublittoral habitat at Cape Hatt in 1981 (Cross 1982b), suggest that under-ice populations of this species may be recruited, at least in part, from the water column. In this case the size effect suggested above probably was not related to the release of dispersed oil at Cape Hatt. Stephensen (1935), on the other hand, reported an association between Ischyrocerus anguipes and shallow water macroalgae. In each of five sampling periods in 1980-1982, Bays 10 and 11 supported higher biomasses of macroalgae at 3 m depth than did Bays 7 or 9 (Cross et al. 1983). In May 1981 and 1982, Ischyrocerus sp. was also more abundant in Bays 10 and 11 than in Bays 7 and 9 (Fig. 9). Population structures of Ischyrocerus sp. on the under-ice surface differed between Bays 10 and 11, and mean size was smaller in Bay 11 during all four spring sampling periods (Fig. 9). These observations indicate that under-ice populations of this species at Cape Hatt are of benthic rather than pelagic origin, and furthermore, that these populations are relatively immobile on a large (bay) scale.

Therefore, we must conclude that there was an effect of dispersed oil on Ischyrocerus sp., and that this effect may have been size-specific. Additional spring sampling in subsequent years would be required to determine if populations of this species in the dispersed oil bay will recover.

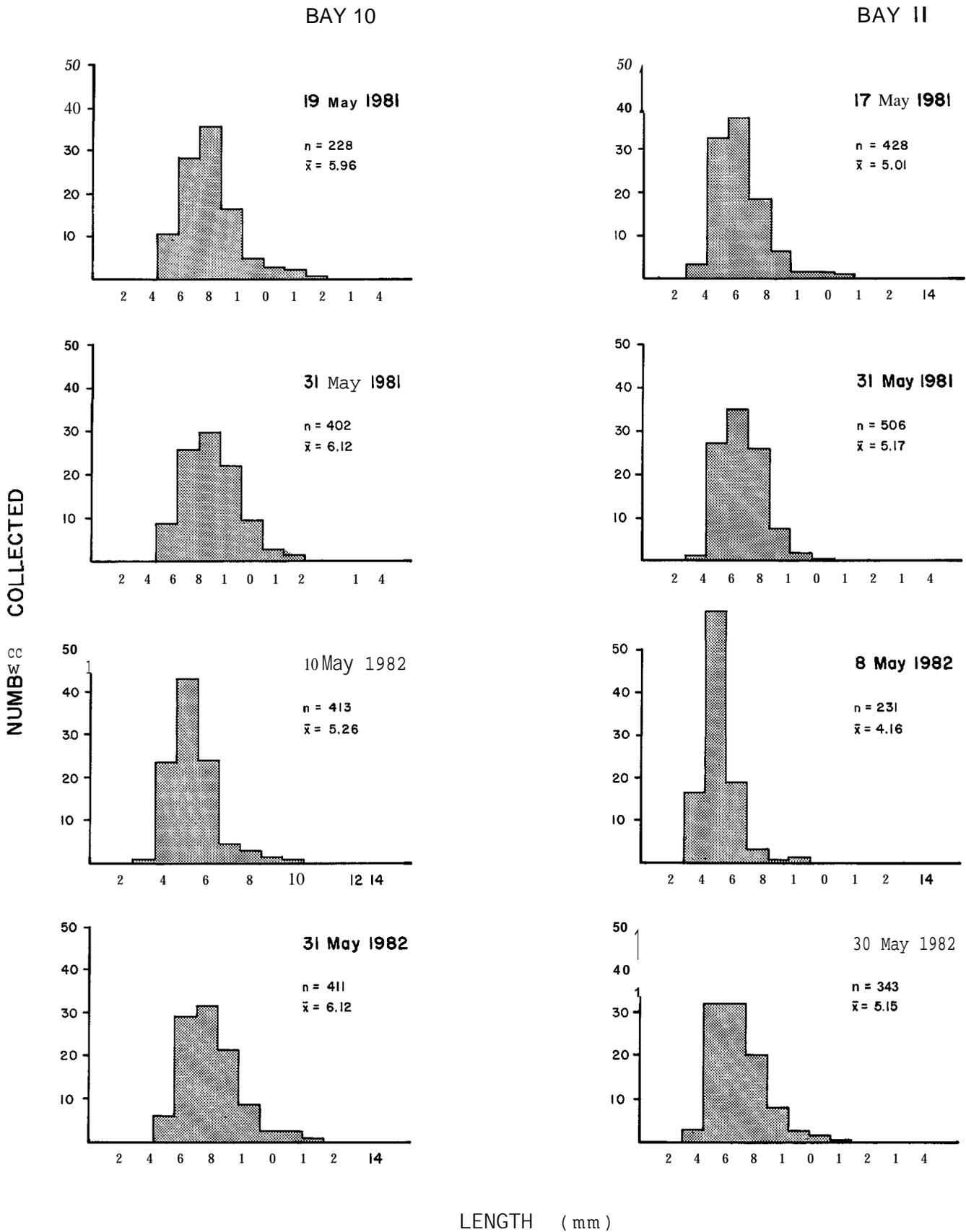


FIGURE 9. Length-frequency histograms for Ischyrocerus sp. in the under-ice habitats of two bays at Cape Hatt, Baffin Island, during May 1981 (pre-spill) and May 1982 (post-spill).

Productivity and Biomass of Under-Ice Algae

Site Description

The under-ice surface in the study areas was smooth and relatively flat, **with** shallow hummocks and ridges. Ice depth was 135 cm at the entry hole. Snow depths over the study areas (locations) on 3 June 1982 were 9.8 ± 1.7 cm ($n = 14$) and 18.2 ± 7.4 cm ($n = 30$) in Locations 1 and 2, respectively. The site was selected within Bay 13 on 7 May, with low even snow depth (**~ 10 cm**) and 10 m water depth as the criteria. Differences in snow cover between locations were the result of high winds, snow fall and drifting snow on 12 and 13 May; snow cover was higher and more variable over Location 2, which was in the lee of two tents during the period of high winds. The amount of light penetrating the snow and ice varied both spatially (primarily because of variable snow cover) and temporally; temporal variation, within and among days, resulted from changes in cloud conditions and in solar elevation. Total in situ radiation varied among enclosures and periods by almost an order of magnitude.

Salinity of ice (+ water) samples ranged from 30.1-32.4 ‰; no consistent differences were apparent among days on which determinations were made (18 May-1 June). Snow melt was beginning near the end of May, but no obvious effects were observed under the ice.

Ambient (**pre-incubation**) nutrient samples were collected in duplicate on 18, 19, 27 and 28 May and 1 June. Phosphate concentrations were from 1.25 to 1.90 $\mu\text{mol/L}$, nitrate concentrations were from 3.04 to 10.23 $\mu\text{mol/L}$, and

ammonia concentrations were from 0.65 to 2.47 $\mu\text{mol/L}$. These nutrient concentrations fall within ranges previously reported (e.g., Alexander et al. 1974; Cross 1980, 1982a; Grainger and Hsiao 1982), and are sufficient to support the growth of ice **microalgae** (Hsiao 1980).

Phytoplankton Biomass and Productivity

Biomass (as estimated by chlorophyll a concentration), and productivity were very low in the water immediately beneath the ice at Cape Hatt in 1981 and 1982. Concentration of chlorophyll a in control water samples were $1.19 \pm \text{SD } 0.47 \text{ mg/mg}^3$ ($n = 8$) and $1.93 \pm 3.14 \text{ mg/m}^3$ ($n = 24$) in 1981 and 1982, respectively. The concentration of algal cells in near-ice water was $1.3 \pm 0.7 \times 10^4 \text{ cells/L}$ ($n = 17$) during 18 May to 2 June 1982, and dominance was shared by pennate diatoms (48%) and **microflagellates** (45%). Biomass and standing stocks at Cape Hatt were similar to those reported in other locations (Alexander et al. 1974; Cross 1980, 1982a; Grainger and Hsiao 1982). After correction for dilution (sampled ice depth = 1 to 2 cm; chamber depth = 15 cm), algal concentrations per unit volume were lower in the water than in the ice by 2 to 3 orders of magnitude.

Productivity in the near-ice water was also low during 1981 and 1982; indeed, after dark ^{14}C uptake was subtracted from light ^{14}C fixation, productivity values for most samples were slightly negative. Mean uptake rates of radiocarbon in dark chambers were $0.28 \pm 0.09 \text{ mgC/m}^3 \cdot \text{h}$ ($n = 4$) and $0.29 \pm 0.26 \text{ mgC/m}^3 \cdot \text{h}$ ($n = 11$) in 1981 and 1982, respectively. Net productivity rates, calculated by subtracting dark values from values measured in light chambers, were -0.033 ± 0.23 ($n = 4$) and $-0.0002 \pm 0.2885 \text{ mgC/m}^3 \cdot \text{h}$ ($n = 13$) in the two years of study. There was no significant

difference ($P > 0.5$) between light and dark radiocarbon uptake in 1982 (paired t-test on scintillation counts for nine pairs of chambers; $t = 0.20$, $P > 0.5$). Alexander et al. (1974) also reported low productivity estimates for phytoplankton in May at Barrow, Alaska: averages of 0.30 and 0.23 mg C/m³ for 1972 and 1973, respectively.

Ice Algal Composition and Distribution

Major groups of microalgae were enumerated in a total of 174 ice samples collected in 1982 (including 83 controls), and species were identified and counted in 72 of these samples (32 controls). In contrast with samples of near-ice water, samples containing the bottom 1-2 cm layer of ice were overwhelmingly dominated by pennate diatoms (89% of algal cells in 83 control samples). A total of 59 species or varieties of microalgae were identified, and at least another 17 distinct but unidentified species were found in 72 samples. Sixty-one of the 76 species were pennate diatoms (Table 6).

Nitzschia grunowii was the dominant species in 68 of 72 samples; it comprised an average of 54.8% of total algal numbers in 32 control samples. Nitzschia frigida was dominant in 3 samples and ranked second in most of the remainder of the 72 samples. It comprised an average of 15.2% of total cells in 32 control samples. A similar dominance of these two species in Pond Inlet was reported by Cross (1982a).

Microalgae were relatively evenly distributed on a small scale (i.e. within the 1.2 m² enclosures); the standard deviation was usually much less than the mean (Table 7). Spatial variation on a larger scale (among

Table 6. Genera and species of microalgae found in diver-collected ice cores¹ from Cape Hatt, Baffin Island, during 18 May-2 June 1982².

Bacillariophyceae	<i>N. spicula</i> (Hickie) Cleve
Centrales ³	<i>N. transitans</i> Cleve
Chaetoceros ³	<i>N. transitans</i> var. <i>incudiformis</i> (Grunow in Cleve) Cleve
<i>C. compressus</i> Lauder	<i>N. trigonocephala</i> Cleve
<i>C. karianus</i> Grunow in Cleve et Grunow	<i>N. valida</i> Cleve and Grunow
<i>C. septentrionalis</i> Östrup	<i>N. valida</i> var. <i>minuta</i> Cleve
<i>C. simplex</i> Ostensfeld	<i>Nitzschia</i> ³
Coscinodiscus ³	<i>N. angularis</i> Wm. Smith
Melosira ³	<i>N. brebissoni</i> var. <i>borealis</i> Grunow in Cleve et Möller
<i>M. arctica</i> (Ehrenberg) Dickie in Pritchard	<i>N. cylindrus</i> Hasle
Thalassiosira ³	<i>N. delicatissima</i> Cleve
<i>T. nordenskiöldii</i> Cleve	<i>N. dissipata</i> (Kützing) Grunow
Pennales ³	<i>N. distans</i> Gregory
Achnanthes	<i>N. frigida</i> Grunow
<i>A. taeniata</i> Grunow	<i>N. grunowii</i> Hasle
Amphiprora ³	<i>N. hybrida</i> Grunow in Cleve et Grunow
<i>A. concilians</i> Cleve	<i>N. laevissima</i> Grunow in Cleve et Möller
<i>A. gigantea</i> var. <i>septentrionalis</i> (Grunow in Cleve et Grunow) Cleve	<i>N. lecontei</i> Van Heurck
<i>A. kjellmani</i> Cleve	<i>N. linearis</i> (Agardh) Wm. Smith
<i>A. pallidosa</i> Wm. Smith	<i>N. longissima</i> (Brebisson in Kützing) Grunow
Amphora ³	<i>N. seriata</i> Cleve
<i>A. laevis</i> var. <i>laevissima</i> (Gregory) Cleve	<i>N. sigma</i> (Kützing) Wm. Smith
<i>A. proteus</i> Gregory	<i>Pinnularia</i> ³
Cylindrotheca	<i>P. ambigua</i> Cleve
<i>C. closterium</i> (Ehrenberg) Reimann et Lewin	<i>P. quadratarea</i> (Schmidt) Cleve
Diploneis	<i>P. quadratarea</i> var. <i>bicontracta</i> (Östrup) Heiden in Schmidt et al.
<i>D. litoralis</i> Cleve	<i>P. quadratarea</i> var. <i>constricta</i> (Östrup) Heiden in Schmidt et al.
<i>D. litoralis</i> var. <i>arctica</i> Cleve	<i>Pleurosigma</i> ³
<i>D. litoralis</i> var. <i>clathrata</i> (Östrup) Cleve	<i>P. angulatum</i> (Quekett) Wm. Smith
Gomphonema ³	<i>P. elongatum</i> Wm. Smith
<i>G. exiguum</i> Kützing	<i>Stenoneis</i>
Licmophora ³	<i>S. inconspicua</i> var. <i>baculus</i> (Cleve in Cleve et Möller) Cleve
Navicula ³	Chlorophyceae
<i>N. algida</i> Grunow	<i>Carteria</i> ³
<i>N. cancellata</i> Donkin	Chrysophyceae
<i>N. crassirostris</i> Grunow in Cleve et Grunow	<i>Dinobryon</i>
<i>N. digitoradiata</i> (Gregory) Ralfs	<i>D. balticum</i> (Schuett) Lemmermann
<i>N. directs</i> (Wm. Smith) Ralfs	Dinophyceae ³
<i>N. gastrum</i> (Ehrenberg) Kützing	<i>Gymnodinium</i> ³
<i>N. gelida</i> Grunow	<i>Peridinium</i> ³
<i>N. membranacea</i> Cleve	<i>Prorocentrum</i> ³
<i>N. novadiciapiens</i> Hustedt	Euglenophyceae ³
<i>N. pelagica</i> Cleve	<i>Euglena</i> ³
<i>N. rhycocephala</i> Kützing	Craspedophyceae ³
<i>N. salinarum</i> Grunow	

¹ 72 cores 10 cm in diameter and 2-3 cm in depth.

² Includes both pre- and post-spill sampling periods.

³ Taxa for which unidentified cells or colonies were found.

enclosures separated by ~ 1 to 20 m) and temporal variation (among 5 sampling periods within the period 18 May to 2 June 1982) were considerable: Total **microalgal** densities in control samples ranged from 1.7 to 384.7×10^7 **cells/m²** (Table 7). In general, cell densities increased throughout the study period. Mean cell densities (all enclosures considered) increased progressively from $90.9 \pm 65.7 \times 10^7$ **cells/m²** (n = 43) on 18-19 May to $210.8 \pm 86.2 \times 10^7$ **cells/m²** (n = 42) on 1-2 June. A similar trend was evident in control data (i.e. all enclosures in two **pre-spill** periods; control enclosures only in three post-spill periods), except that mean density was highest (375.0 ± 50.0 ; n = 4) on 28-29 May.

Mean ice algal densities in most locations at Cape Hatt in spring 1982 were typical of those reported for other arctic and subarctic locations. The maximum (single sample) density found at Cape Hatt (466.7×10^7 **cells/m²**) is similar to single sample maxima in Frobisher Bay (399.3×10^7 **cells/m²**; Grainger and Hsiao 1982) and Pond Inlet (441.4×10^7 **cells/m²**; Cross 1982a). A higher maximum level (3420×10^7 **cells/m²**) was reported by Hsiao (1980); however, this value was integrated for the entire ice column. Cell densities in some locations at Cape Hatt (those $\ll 10^9$ **cells/m²**) are low relative to typical densities in spring.

Evaluation of Filtration Techniques

In the present study we used **labelled** inorganic carbon and a differential filtration technique (see Derenbach and Williams 1974) to estimate, during 2-3 h incubations, (1) carbon fixation by ice microalgae, (2) release of dissolved organic carbon (**DOC**) by algae, and (3) subsequent

Table 7. Under-ice productivity, chlorophyll a, microalgal density and in situ light data measured in all sampling periods at Cape Hatt, Ruffin Island, during 18 May-2 June 1982. Data are expressed as mean \pm SD; sample sizes are given in Appendix A.

Variable	Period ¹	Location	Treatment						
			Control	Oil ²	Solidified Oil ²	BP CTD +Oil ²	8P HLOOVD +Oil ²	Corexit 9527 +Oil ²	
Productivity ³ (mgC/m ² /h)	Pre-spill 1	1	1.50 \pm 0.18	0.05	0.21 \pm 0.05	2.14 \pm 0.60	1.08* 0.19	0.30 \pm 0.04	
		2	1.50 \pm 0.86	0.82 \pm 0.23	0.33 \pm 0.09	0.16 \pm 0.10	0.11 \pm 0.07	1.89 \pm 0.34	
	Pre-spill 2	1	1.92 \pm 0.54	-0.08 \pm 0.05	0.16 \pm 0.20	1.82* 0.26	1.47 \pm 0.24	0.49 \pm 0.08	
		2	2.95 \pm 1.61	0.95 \pm 0.52	0.70 \pm 0.29	0.88* 0.25	-0.05 \pm 0.03	1.38 \pm 0.31	
	Post-spill 1	1	1.78 \pm 0.77	0.19 \pm 0.03	1.29* 0.53	1.16 \pm 0.44	1.20 \pm 0.29	1.11 \pm 0.49	
		2	2.11 \pm 0.53	1.90 \pm 0.28	1.52 \pm 0.46	1.28* 0.39	0.09 \pm 0.07	0.94 \pm 0.37	
	Post-spill 2	1	2.58 \pm 0.50	0.30 \pm 0.03	1.46 \pm 0.48	2.10* 0.11	1.57 \pm 0.36	2.21 \pm 0.15	
		2	2.33 \pm 0.07	2.18 \pm 0.48	1.64 \pm 0.55	1.53* 0.45	-0.10 \pm 0.04	1.98 \pm 0.28	
	Post-spill 3	1	2.09* 0.00	0.38* 0.06	1.55* 0.48	1.85* 0.38	1.38* 0.25	1.39* 0.16	
		2	2.16 \pm 0.51	1.79 \pm 0.03	1.12* 0.24	1.31 \pm 0.29	0.07 \pm 0.03	2.11 \pm 0.42	
	Chlorophyll a ³ (mg/m ²)	Pre-spill 1	1	10.83 \pm 1.65	3.35* 0.58	6.04 \pm 0.70	11.66 \pm 2.74	10.15* 1.34	7.65* 2.57
			2	12.80 \pm 2.41	11.31 \pm 0.86	10.85 \pm 4.61	6.82 \pm 4.14	5.78 \pm 0.43	11.66 \pm 1.55
Pre-spill 2		1	11.66 \pm 2.72	6.23* 5.32	6.95 \pm 2.45	10.24 \pm 0.28	10.85 \pm 0.50	11.44* 5.31	
		2	13.36* 1.94	10.93 \pm 1.29	9.73* 2.08	10.50 \pm 0.61	3.91 \pm 2.74	13.98 \pm 2.14	
Post-spill 1		1	15.64* 1.7a	6.47 \pm 1.20	14.98 \pm 4.02	13.76 \pm 1.47	15.26 \pm 1.41	12.10 \pm 2.27	
		2	12.04 \pm 2.36	14.18 \pm 1.55	14.49* 1.36	10.77* 0.96	5.32 \pm 2.50	12.79 \pm 1.96	
Rx-spill 2		1	14.60 \pm 2.56	10.93 \pm 2.38	16.29 \pm 3.30	11.64* 1.35	13.47 \pm 3.20	12.19 \pm 1.68	
		2	13.31 \pm 0.13	13.67 \pm 2.37	13.95 \pm 1.63	9.70 \pm 1.32	4.25 \pm 1.81	10.68 \pm 1.46	
post-spill 3		1	16.67 \pm 1.92	10.67 \pm 1.42	20.18* 2.39	11.98 \pm 0.39	13.07 \pm 2.82	11.81 \pm 4.65	
		2	14.99 \pm 3.76	13.01* 1.75	15.10* 4.71	9.09 \pm 1.78	5.98* 3.09	10.72 \pm 2.25	
Microalgae (cells/mh0 ³)		Pre-spill 1	1	157.47* 54.39	9.21 \pm 5.20	44.31* 20.14	167.35 \pm 70.13	100.76 \pm 63.47	57.89 \pm 31.41
			2	103.96 \pm 29.16	105.85* 32.24	77.00 \pm 37.00	47.15 \pm 36.17	21.29 \pm 7.18	176.55 \pm 68.9%
	Pre-spill 2	1	270.56 \pm 130.33	1.65* 0.68	20.31	246.02	317.91* 97.06	56.64 \pm 56.41	
		2	332.78 \pm 68.84	121.69 \pm 12.24	72.50* 16.42	126.88	11.76* 13.75	240.52 \pm 68.55	
	Post-spill 1	1	249.68* 130.8	15.94 \pm 2.32	215.87 \pm 83.41	245.13 \pm 71.14	205.30* 55.65	156.49 \pm 42.90	
		2	237.11* 64.51	268.51 \pm 79.21	171.21 \pm 26.98	146.30 \pm 30.31	21.79 \pm 12.68	169.18 \pm 34.9%	
	Post-spill 2	1	365.27 \pm 9.37	113.44 \pm 76.33	261.60 \pm 18.01	267.40	228.00 \pm 26.06	175.96 \pm 59.04	
		2	384.71 \pm 83.81	255.49 \pm 10.23	205.19 \pm 2.16	111.60 \pm 30.82	20.55 \pm 11.42	238.18 \pm 56.31	
	Post-spill 3	1	254.37 \pm 15.07	169.8 \pm 35.17	359.8 \pm 78.67	246.17* 47.04	236.99 \pm 82.82	229.30* 5.18	
		2	280.22 \pm 13.65	205.11 \pm 34.07	322.80 \pm 116.94	167.82 \pm 51.76	51.34 \pm 41.42	185.78 \pm 36.85	
	Light (Watt-h/m ²)	Pre-spill 1	1						
			2						
Pre-spill 2		1	86.10	21.53	34.28	75.41	59.26	36.49	
		2	117.59	86.10	47.29	73.32	17.31	64.03	
Post-spill 1		1	108.41	24.40	23.01	82.15	8.82	84.13	
		2	106.67	79.25	49.39	71.81	14.29	67.63	
Post-spill 2		1	82.85	22.69	36.95	96.45	51.71	62.75	
		2	103.30	65.3*3	57.29	61.01	12.20	77.16	
Post-spill 3		1	80.53	20.45	34.74	72.97	38.81	53.57	
		2	121.66	72.39	56.47	61.59	16.97	90.40	

¹Oil treatments were applied on 23 and 24 May 1982.

²Unweathered Lagomedio crude oil.
30.45 μ m filter.

assimilation of DOC by bacteria. Dissolved organic carbon was separated using 0.45 μm silver filters and thus includes any particles $<0.45 \mu\text{m}$ (e.g. bacteria); details of DOC techniques and results are discussed in a later section. We attempted to separate carbon uptake by algae and bacteria by filtering separate 100 mL subsamples through 3.0 μm and 0.45 μm cellulose acetate filters. Particulate radiocarbon taken up by algae was estimated as radioactivity retained on 3.0 μm filters, and radiocarbon in bacteria was estimated as the difference between radioactivity retained on 0.45 μm and 3.0 μm filters (i.e. $^{14}\text{C}_{.45} - ^{14}\text{C}_{3.0}$). A correction factor for small microalgae ($<3.0 \mu\text{m}$) was obtained by repeating the differential filtration procedure with 50 mL subsamples and measuring chlorophyll a and particulate organic carbon (POC).

The results of paired comparisons for all control incubations of ice algae where both filter types were used (Periods 1, 3 and 5) are as follows:

	Productivity	Chlorophyll <u>a</u>	Poc
subsampling volume	100 mL	50 mL	50 mL
filter difference	0.45 < 3.0	0.45 = 3.0	0.45 = 3.0
P	P<0.01	P>0.5	P>0.1
t	3.098	0.269	1.616
df	41	54	17

Ice algal biomass (chlorophyll a and POC) did not differ significantly between the two filter types in spite of the difference in pore size. This may indicate that microalgae and bacteria $<3.0 \mu\text{m}$ were not abundant in the under-ice community. It is also possible that filters became clogged because of the high algal concentrations, resulting in no effective difference in pore size between the two types of filter.

The difference in productivity data between filter types (average of 21% more radioactive carbon on 3.0 μm filters than on 0.45 μm filters) is less easy to interpret. It is possible that this difference resulted from the higher volume of sample filtered for ^{14}C determinations (100 mL) than for biomass determinations (50 mL); it has previously been reported that damage to algal cells and loss of cell contents through filters increases with sample volume (Arthur and Rigler 1967; Carpenter and Lively 1980; Mague et al. 1980). It is not clear, however, why loss of cell contents would be greater for the filters with smaller pore size. All data reported in the following sections are based on samples from the smaller (0.45 μm) filters, which are in more common use, but it should be pointed out that the reported values for particulate carbon fixation by ice algae may underestimate actual under-ice productivity.

Ice Algal Biomass

The distribution of chlorophyll a in the bottom layer of ice, like cell densities, was relatively even on a small scale (Table 7). Variation among locations and periods was also relatively low, unlike data on cell densities. Mean chlorophyll a concentrations in control samples varied from 3.4 to 16.7 mg/m^2 ; single sample minimum and maximum values were 0.64 and 23.20 mg/m^2 , respectively. Mean chlorophyll concentrations increased progressively throughout the 1982 study period, from $9.1 \pm 3.3 \text{ mg}/\text{m}^2$ (n = 42) on 18-19 May to $15.7 \pm 3.0 \text{ mg}/\text{m}^2$ (n = 7 control samples) or $12.8 \pm 4.5 \text{ mg}/\text{m}^2$ (n = 42; all treatments) on 1-2 June. Concentrations were very similar at Cape Hatt in 1981: chlorophyll concentrations in the bottom layer of ice increased from $6.6 \pm 2.0 \text{ mg}/\text{m}^2$ (n = 14) on 16 May to $10.9 \pm 0.6 \text{ mg}/\text{m}^2$ (n = 4) on 30 May.

Ice algal biomass (as estimated by chlorophyll concentration) at Cape Hatt during spring 1981 and 1982 was comparable to biomasses reported for May and June in a number of other arctic locations: Jones Sound (3.0-23.0 mg/m^2 ; Apollonio 1965); Barrow, Alaska (3.0-30.5 mg/m^2 ; Clasby et al. 1973); and Robeson Channel and Barrow Strait (0.6-12.5 mg/m^2 ; Dunbar and Acreman 1980). Considerably higher concentrations were found at fast ice stations in Pond Inlet (17.6-182.6 mg/m^2 ; Cross 1980, 1982a). Differences in chlorophyll concentrations are likely a result of differences in the timing of the spring bloom or differences in snow cover. The lowest mean biomass reported for Pond Inlet was at the station with the highest mean snow depth (15.8 cm), and a significant negative correlation between snow depth and biomass was found at some stations (Cross 1982a). An inverse relationship between ice chlorophyll and snow depth has also been observed by Alexander et al. (1974).

Carbon to chlorophyll a ratios in control samples ranged from 12.6 to 40.8 (overall mean of $21.1 \pm \text{SD } 8.8$; $n = 22$). The ratio increased during the study period, from 16.0 ± 2.3 ($n = 14$) during 15-18 May to 30.0 ± 9.1 ($n = 8$) during 26 May-2 June. Carbon to chlorophyll ratios for ice algae at Cape Hatt are near the lower end of the range of 20 to 200 suggested for mixed phytoplankton populations (see Raymont 1980, p. 90). There are no previous data of this kind on arctic ice algae, but our results are similar to those of Bunt and Lee (1970), who reported a range of 24 to 59 in carbon to chlorophyll ratios in antarctic ice algae.

Ice Algal Productivity

Ice algal productivity rates reported herein are based on differences between light and dark incubation chambers in the amount of radiocarbon retained on 0.45 μ m cellulose triacetate filters. All incubations were carried out around noon for 2-3 h periods. Sky conditions varied during incubation periods and from day to day, and the resultant daily values of surface light during incubations ranged from approximately 13,000 to 20,000 watt-h/m^2 . Variation in the amount of light reaching the bottom of the ice included not only a temporal component resulting from changes in surface light, but also a spatial component: percent transmission through the ice and snow, measured within each enclosure, varied from 0.11-0.77%. Spatial variability was likely the result of variable snow cover. Snow depths, measured at the surface in the estimated locations of the under-ice enclosures, were from 8.5 to 30.6 cm. The estimated amount of light reaching each enclosure during each incubation is given in Table 7. These values varied over an order of magnitude, from 12.2 to 121.7 watt-h/m^2 .

Ice algal productivity increased with increasing light over the range of conditions encountered (Fig. 10). There was no evidence of photosynthetic inhibition at the highest light levels (approximately 120 watt-h/m^2 in a 2-3 h period). Productivity rates were near zero at the lowest light levels (approximately 20 watt-h/m^2 ; Fig. 10).

Productivity of ice algae varied considerably among locations (enclosures) and periods: mean productivity rates in controls were from near zero to 2.95 $\text{mgC/m}^2\cdot\text{h}$ (Table 7). The lowest productivity rates were

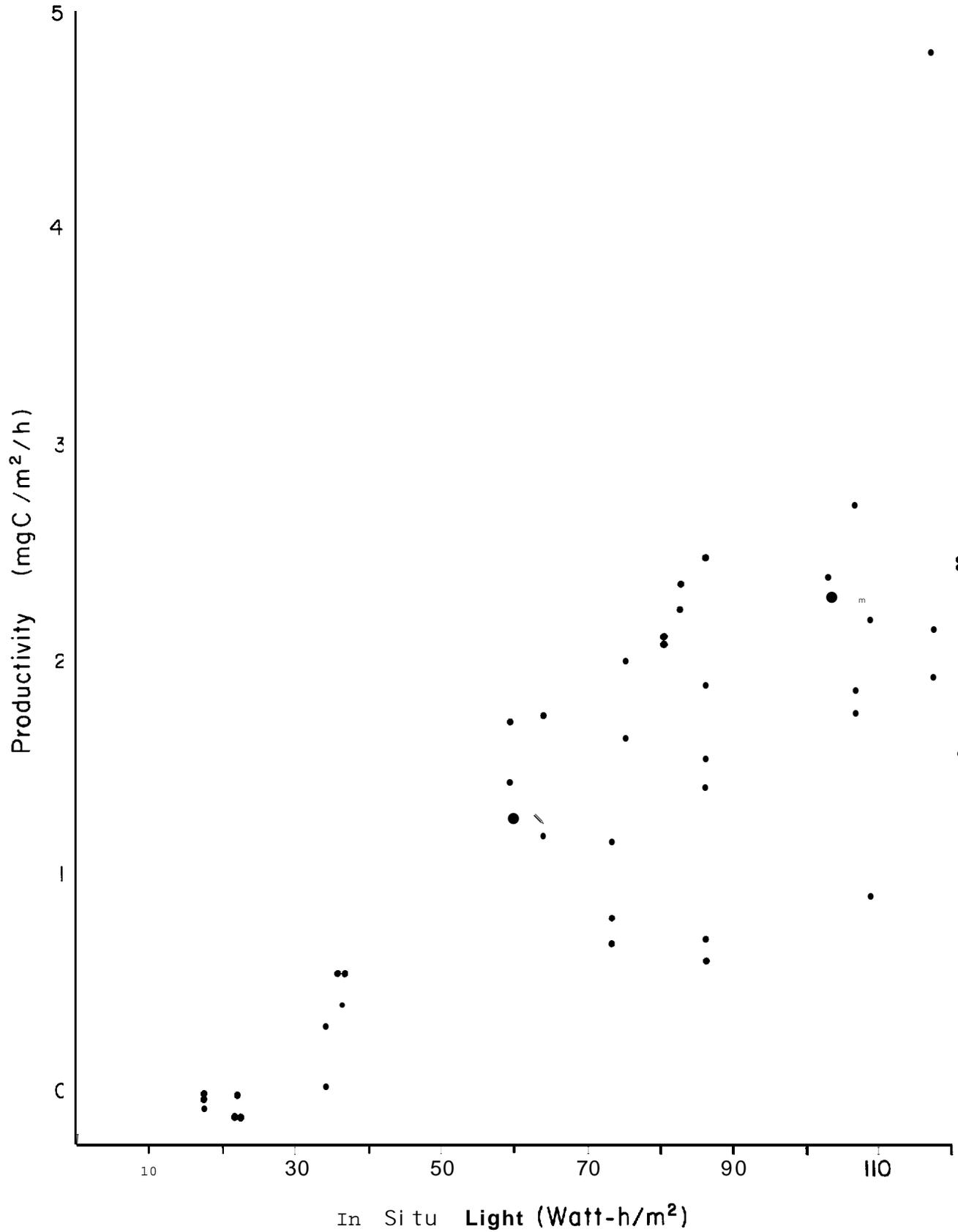


Figure 10. Ice algal productivity ($\text{mgC}/\text{m}^2 \cdot \text{h}$) vs. In situ light ($\text{watt-h}/\text{m}^2$) at Cape Hatt, northern Baffin Island, during 18 May-2 June 1982. Each point is the productivity rate calculated for one control incubation; one light measurement was made for each set of 2 or 3 productivity rates,

obtained from enclosures with the lowest recorded light values, e.g., the 'oil' enclosure at Location 1 and the 'BP 1100 WD + oil' enclosure at Location 2 (Table 7). Productivity in control samples increased progressively from 18-19 May ($0.85 \pm 0.75 \text{ mg C/m}^2 \cdot \text{h}$; $n = 31$) to 28-29 May ($2.48 \pm 0.38 \text{ mg C/m}^2 \cdot \text{h}$; $n = 5$), and decreased slightly by 1-2 June to $2.13 \pm 0.36 \text{ mgC/m}^2 \cdot \text{h}$ ($n = 5$). Increased productivity was likely related to increased chlorophyll a concentrations; however, productivity per unit chlorophyll in control samples also increased progressively from 18-19 May to 28-29 May (0.08 to 0.19 mg C/mg Chl a·h), and decreased by 1-2 June (0.14 mg C/mg Chl a·h).

Productivity rates at Cape Hatt were similar in 1981 and 1982. Mean productivity in 1981 varied from 0.26 ± 0.07 to $3.34 \pm 1.96 \text{ mgC/m}^2 \cdot \text{h}$ ($n = 5$ in each case), but there was no apparent increase or decrease over the study period (Cross 1982b). Data from Cape Hatt are also comparable to those of Clasby et al. (1973) at Barrow, Alaska, who reported mean productivity values between 4 and $4.5 \text{ mgC/m}^2 \cdot \text{h}$ on 6 and 21 May, and values between 1 and $1.5 \text{ mgC/m}^2 \cdot \text{h}$ between 25 May and 5 June. It appears that the under-ice algal bloom, and concomitant high productivity, had begun to decline earlier at Barrow in 1972 and possibly at Cape Hatt in 1982, than at Cape Hatt in 1981.

Dissolved Organic Carbon

Productivity rates of dissolved organic carbon (DOC) reported herein are based on the same samples (incubation chambers) and methods of calculation used to estimate particulate radiocarbon productivity. Data presented below include only control samples: all enclosures on 18-19 May, and control

enclosures only on 26-27 May and 1-2 June. Radioactivity in DOC was measured in filtrates of **subsamples** filtered through 0.45 μm silver filters, and purged of inorganic radiocarbon by acidification and aeration. Cell rupture during filtration was avoided by the use of small (20 mL) sample volumes and low (<120 mm Hg) vacuum pressures (see **Mague** et al. 1980). Other sources of error in DO^{14}C determinations were discussed by Sharp (1977): organic contamination of the **innoculum** and incomplete removal of inorganic radiocarbon from filtrates. The low levels of DO^{14}C observed in 'controls' (e.g., dark incubations; see below) in the present study, however, and the subtraction of dark values from light values in productivity calculations, eliminates uncertainty associated with these sources of error.

Following 2-3 h incubations at Cape Hatt in 1982, levels of dissolved organic radiocarbon were similar in dark incubation chambers containing ice (+ water), in dark chambers containing water, and in light chambers containing water. DOC productivity rates in dark chambers containing ice (+ water) and water, respectively, were $0.201 \pm \text{SD } 0.093 \text{ mgC/m}^2\cdot\text{h}$ ($n = 15$) and $0.181 \pm 0.095 \text{ mgC/m}^2\cdot\text{h}$ ($= 1.185 \text{ mgC/m}^3\cdot\text{h}$; $n = 6$). After correction for dark values, DOC productivity in light chambers containing near-ice water was very low: $0.025 \pm 0.709 \text{ mgC/m}^3\cdot\text{h}$ ($n = 7$). In contrast, mean DOC productivity in light chambers containing ice was very high: $3.25 \pm 2.86 \text{ mgC/m}^2\cdot\text{h}$ ($n = 41$). DOC productivity by ice algae, like particulate carbon productivity, varied considerably among enclosures (0.13 to $9.33 \text{ mgC/m}^2\cdot\text{h}$). Dissolved and particulate carbon productivity rates were highly correlated ($r = 0.926$; $P < 0.0001$; $n = 41$). On average, DOC accounted for 70.5% of total (dissolved + particulate) production. This percentage is near the upper end of the range of values previously reported

in coastal and oceanic waters (see Sharp 1977 for a review; Smith et al. 1977; Lancelot 1979; Larsson and **Hagström** 1979, 1982; **Mague** et al. 1980; **Sellner** 1981; Welter 1982; Jensen 1983). To our knowledge, DOC production by ice algae has not previously been reported.

There are several possible sources of the dissolved organic carbon. Inorganic radiocarbon fixed by algae can be released into the medium in dissolved or colloidal form in several ways: active release of photosynthetic products by healthy algae (**Fogg** 1977), **lysis** of plant cells through various means (see Cole et al. 1982), degradation of non-living **plankton** (Sharp 1977), losses associated with mechanical breakage of cells during grazing (**Lampert** 1978), and excretion by grazers that have consumed labeled algae. The release of significant amounts of **DOC** by healthy algae has been disputed (Sharp 1977) , but evidence to the contrary is still convincing (**Fogg** 1977; **Sellner** 1981; Larsson and **Hagström** 1982; Welter 1982; Jensen 1983).

Regardless of the mechanism of **DOC** release, however, dissolved organic radiocarbon present in the medium was originally fixed by algae and must be included in our estimates of productivity. Thus mean ice algal productivity (particulate + dissolved) was $4.39 \pm 3.69 \text{ mgC/m}^2 \cdot \text{h}$ (n = 41) over the range of light levels studied at Cape Hatt in May 1982. The highest productivity rate measured (single sample) was $12.7 \text{ mgC/m}^2 \cdot \text{h}$. If high DOC production is characteristic of the ice algal community, previous reports on particulate carbon fixation (e.g. , **Clasby** et al. 1973; **Cross** 1982b) may have underestimated ice algae productivity to a significant extent. Even higher productivity rates would be expected in areas where, unlike the present study area, ice algal biomass was very high (e.g., Pond Inlet in 1979; **Cross** 1980, 1982a).

The fate of dissolved organic carbon produced by ice algae, and in particular its contribution towards the transfer of energy to higher trophic levels, is not known. Bacteria may be important in the sea ice community as consumers of DOC released by algae and as a particulate food source for protozoans and metazoans. Bacteria are common and often abundant in sea ice (Homer 1976), and extremely high bacterial activity was found in the under-ice community at Cape Hatt in May 1981 (J. Bunch, unpubl. data). At Barrow, Alaska, uptake of labeled dissolved organic substances by the sea ice community was almost exclusively by bacteria (Homer and Alexander 1972b). In other marine habitats, bacterial uptake of photosynthetically produced DOC can be as high as 90% (e.g., Welter 1982; Jensen 1983). Attempts to measure bacterial uptake in the present study were not successful (see 'Evaluation of Filtration Techniques' section), but any radiocarbon present in bacteria <0.45 μm in size would be included in our estimates of dissolved organic carbon productivity.

Oil Effects

Impingement of unweathered oil and dispersed oil onto the under-ice surface would probably cause some immediate mortality of under-ice algae. Inhibition of photosynthesis in ice algae was observed at the highest levels of oil and dispersed oil tested in 1981 (Cross 1982b). There may also be some subsequent recovery of the ice algae as the oil moves into the ice or as the dispersed oil is removed by currents and dilution. The extent and rate of this mortality and subsequent recovery are as yet unknown.

In the present study, standing stocks and productivity of under-ice algae were measured before and after treatment with crude oil (Venezuela Lagomedio) , solidified oil (BP treatment), oil mixed with each of three dispersants (Corexit 9527, BP 1100 WD and BP CTD), and no oil (control). Dispersed oil, in concentrations between 5.8 and 36.5 ppm, was contained within enclosures beneath the ice for approximately five hours. Oil and solidified oil remained in the enclosures on the under-ice surface during post-treatment sampling periods, and sampling was carried out within the enclosures but not directly in the oiled areas. Oil concentrations in the water within enclosures containing oil and solidified oil, measured 5 h after treatment, were similar to control values (see 'Methods').

During the first year of studies at Cape Hatt, analysis of **covariance** with in situ light intensity as the **covariate** proved **useful** in taking variability due to light into account before testing for differences among periods or treatment levels (Cross 1982b). The larger number of replicates and treatments used in the present study, however, together with other changes in the study design, resulted in the measurement of light for each enclosure (i.e. for each treatment and location) but not for each replicate. Hence, analysis of **covariance** was not used. Analysis of variance was applied to data on standing stocks and productivity, and to ratios calculated to standardize for light effects: standing stocks/percent transmission, and productivity/in situ light during incubations. Productivity per unit of chlorophyll and productivity per unit chlorophyll per unit light were also subjected to analysis of variance.

Three factor analysis of variance (period, treatment and location) were carried out, but significant three way interactions necessitated the use of two factor ANOVAs (period, treatment) for each of the two locations. The results of these analyses for eight variables are given in Table 8. Most interactions between period and treatment factors were significant (13 of 16 cases). In these cases, the significant interaction terms means that **period-to-period** variation was not consistent among treatments, indicating the possibility of an oil effect. However, other factors besides the treatment could also lead to significant interaction terms.

To determine whether the significant interactions were attributable to the two enclosures with very low levels of light and productivity, these enclosures (treatments) were excluded from the analyses. Results were very similar to those shown in Table 8. The significance of the period x treatment interaction in the new analyses differed from that in Table 8 in only two cases: when low-light treatments were excluded, the interaction was non-significant for productivity per unit chlorophyll per unit light only in Location 2, and was marginally significant ($P = 0.028$) for chlorophyll concentration over percent transmission only in Location 2. Hence, the significance of period x treatment interactions (Table 8) was not attributable to effects of low-light conditions.

It was necessary to examine the nature of the period-to-period variability among treatments to determine whether it was consistent with expected oil effects. Expected oil effects would include (1) marked deleterious effects of oil relative to controls, (2) immediate effects in dispersed oil treatments, followed by recovery, (3) delayed effects in oil or

Table 8. Results of analysis of variance for standing stocks and productivity of under-ice algae at Cape Hatt, northern Baffin Island, during 18 May-2 June 1982. F-values are shown with significance levels (ns = P>0.05; * P<0.05; ** P<0.01; *** P<0.001).

Variable	Location	Source of variation			Degrees of Freedom ¹
		Period	Treatment	Period x Treatment	
Productivity (P)	1	16.46 ***	45.75 ***	3.25 ***	4, 5, 20/53
	2	7.01 ***	33*68 ***	2.38 **	4, 5, 20/54
Chlorophyll. <u>a</u> (B)	1	17.98 -	11.78 ***	2.56 **	4, 5, 20/76
	2	2.69 *	33.58 ***	1.47 ns	4, 5, 20/75
Algal density (D)	1	19.72 ***	17.77 ***	2.39 **	4, 5, 20/56
	2	19.42 ***	35.90 ***	4.26 ***	4, 5, 20/58
P/B	1	8.49 ***	34.24 -	3.19 ***	4, 5, 20/52
	2	8.43 ***	38.75 ***	3.01 ***	4, 5, 20/52
P/Light ²	1	23.60 ***	15.55 ***	5.77 ***	3, 5, 15/44
	2	8.71 ***	22.34 ***	1.45 ns	3, 5, 15/44
P/B/Light ²	1	14.02 -	9.80 ***	6.07 ***	3, 5, 15/43
	2	14.15 ***	20.40 ***	3.01 **	3, 5, 15/43
B/Percent transmission ²	1	1.13 ns	14.35 ***	2.48 **	3, 5, 15/61
	2	4.81 **	26.05 ***	1.07 ns	3, 5, 15/60
D/Percent transmission ²	1	8.11 -	13.27 ***	4.11 ***	3, 5, 15/41
	2	2.65 ns	9.52 ***	2.95 **	3, 5, 15/42

¹Degrees of freedom shown are numerator df for period, treatment and period x treatment interaction, followed by denominator df.

²All analyses including light or percent transmission exclude data from Period 1, where percent transmission data were not recorded.

solidified oil treatments, and (4) effects in dispersed oil treatments that were consistent with measured oil levels (see 'Methods'), i.e. least in BP CTD; more pronounced in Location 2 than Location 1 for **Corexit** 9527 and BP 1100 WD. Inspection of the data (Fig. 11) showed little evidence for any of these expected oil effects.

There were no marked deleterious effects of any oil treatment on any of the variables. Decreases in some or all variables from the immediate **pre-spill** to immediate post-spill periods were evident in some enclosures, (e.g., **Corexit** + oil, Location 2), but these generally corresponded with decreases in light, and were also evident in the control.

There were no marked immediate effects of dispersed oil treatments, nor was there any evidence of recovery in later post-spill **periods**. Differences among dispersants or between locations were not consistent with measured oil concentrations.

Inspection of the data for oil and solidified oil treatments indicated the possibility of a stimulation effect of these treatments on the biomass and productivity of under-ice algae. Progressive (period-to-period) increases in biological variables were not common in any treatment except the solidified oil and, to a lesser extent, untreated oil treatments. This progressive increase is not clearly related to increases in light, particularly in the case of the solidified oil treatment. In some cases, however, increases in biological variables at these locations were also apparent between the two **pre-spill** periods. Increases in biomass and productivity are typical of under-ice algae during the spring before the peak

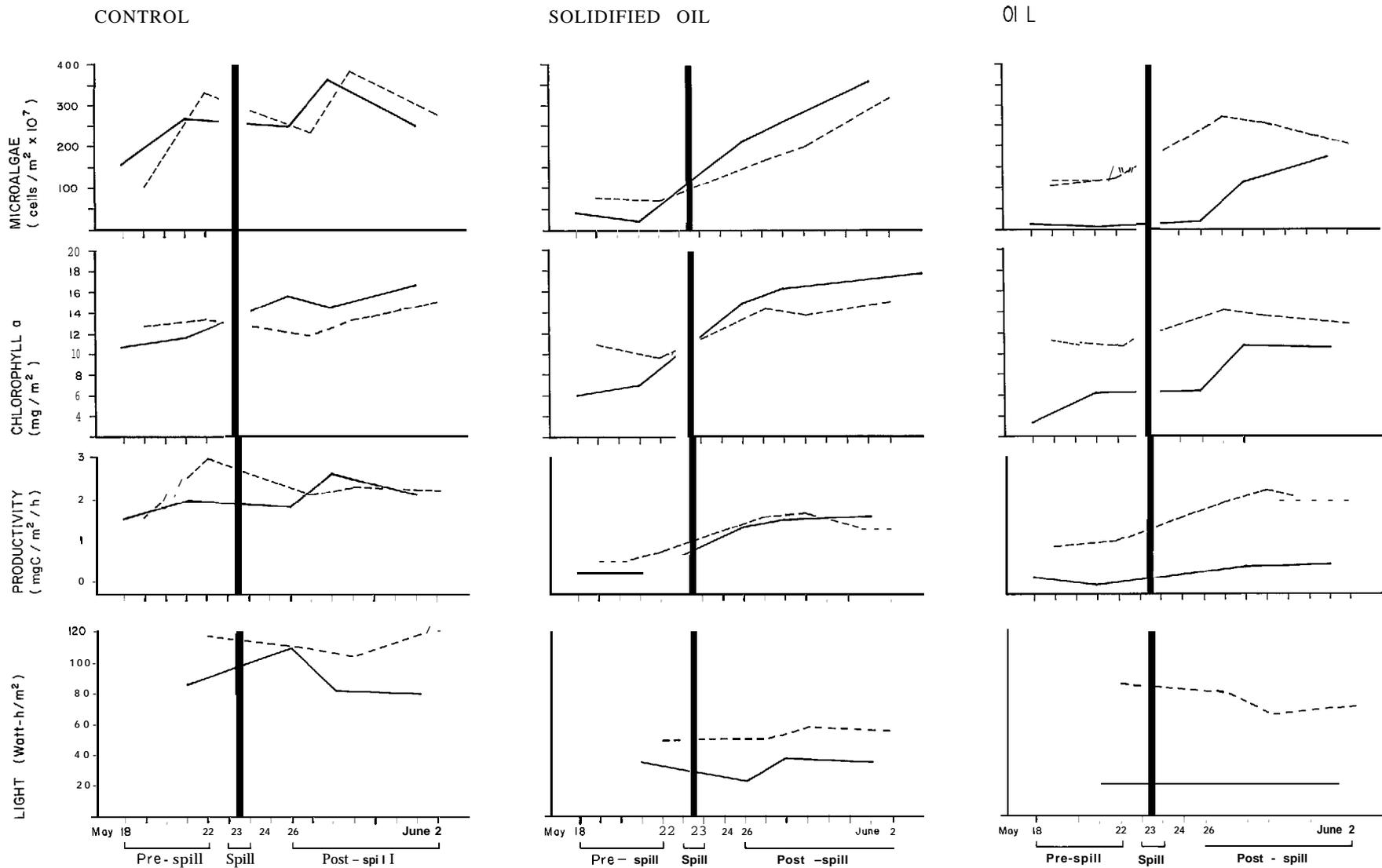


FIGURE 11. Under-ice productivity, chlorophyll a, microalgal density and in situ light data in two locations at Cape Hatt, Baffin Island, during 18 May-2 June 1982. Location 1 is represented by a uniform line; Location 2 is represented by a broken line. Values for each date are means of 3-4 replicate ice core samples (10 cm diameter).

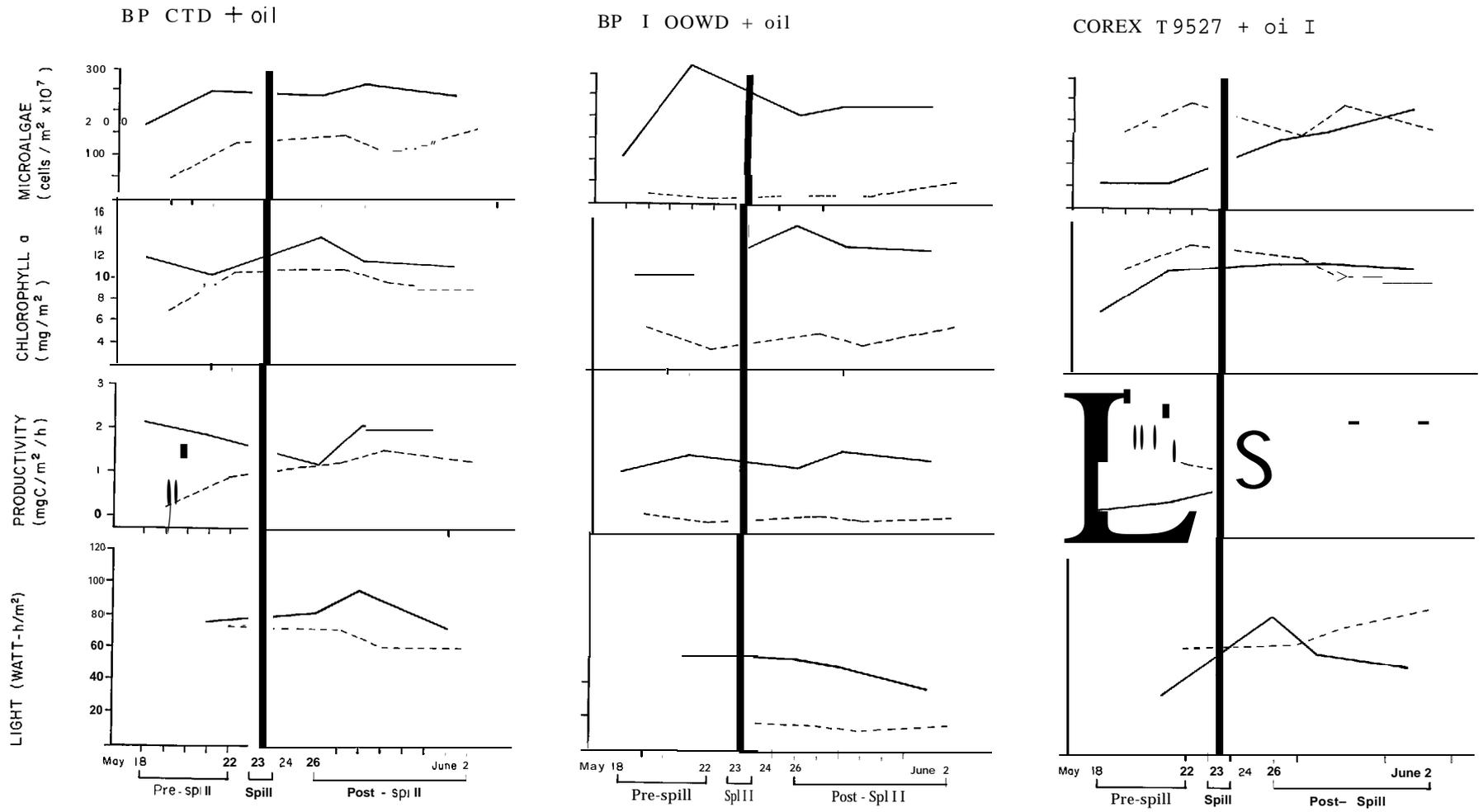


FIGURE 11. continued.

of the bloom (Homer and Alexander 1972; **Clasby** et al. 1973) and were also evident in Cape Hatt during May 1981 (Cross 1982 b). Overall, productivity and standing stocks in control samples increased during the 1982 study period (see above). Differences among enclosures (treatments) in the nature of the increases may also be related to snow conditions, and in particular, changes in snow depth that occurred immediately before the study period.

Inhibition of photosynthesis of ice algae was observed at the highest levels of oil and dispersed oil tested at Cape Hatt in 1981 (10,000 ppm; Cross **1982b**). At this level, dispersed oil apparently had a larger effect (**total** suppression of productivity) than did undispersed oil, but even in the latter case productivity was much reduced from control levels.

Hsiao et al. (1978) reported oil effects on productivity of arctic marine **phytoplankton** in oil-seawater dispersions at concentrations as low as 10 ppm; at concentrations between 43 and 147 ppm **values** were 20 to 40% of control productivity, depending on type of oil. Similar results on diatom growth were obtained when **oil** was added directly to algal cultures to give nominal concentrations between 10 and 10,000 ppm (**Hsiao** 1978). After 10 day's exposure, diatom growth was reduced at all concentrations for **all** oils tested, but the highest concentration was lethal only to some combination of species and **oils**.

In the present study, we attempted to create realistic scenarios for the impingement of oil onto the under-ice surface: low concentrations of dispersed oil contacting the ice for a short period of time, and untreated oil and solidified oil remaining in place on the under-ice surface. Analyses

and inspection of the data showed considerable spatial and temporal variability in productivity and standing stocks of under-ice algae, but there was little evidence for any of the expected oil effects.

Under-ice Meiofaunal Communities

In this section we examine the effects of in situ applications of oil and chemically treated oil on the distribution of major **meiofaunal** groups. Meiofauna are defined as those invertebrates falling within the size range 40 μm to 1 mm, after **Elmgren** (1976). A description of abundance, species composition and spatial and temporal variability in the **meiofaunal** community is based on control samples collected in both **pre-spill** and post-spill periods at the productivity study site (Bay 13) at Cape **Hatt**. The distribution of under-ice meiofauna in the four BIOS study bays (Bays 7, 9, 10 and 11) at two times in May 1982 is also described.

Species Composition

The under-ice meiofauna collected at Cape Hatt during 18 May-2 June 1982 included copepods, nematodes, **polychaete** larvae, rotifers and gastropod **veligers**. Copepods, the numerically dominant taxon, comprised 92.3% of total numbers collected during the study. Nematodes and **polychaetes** made up 4.0% and 3.2% of total numbers, respectively. Rotifers and gastropod **veligers** were also present in very small numbers. Thomson et al. (1978) also reported that copepods were predominant (79.0% of total **meiofaunal**) in the under-ice surface in Brentford Bay, Boothia Peninsula. Elsewhere, nematodes are usually the most abundant group of under-ice meiofauna (Carey and Montagna 1982; Cross 1982a; **Grainger** and **Hsiao** 1982; Kern and Carey 1983).

During 18 May-2 June 1982, **cyclopoid** and **harpacticoid copepods** comprised 83.2% and 16.3%, respectively, of the ice copepod fauna (Table 9). **Calanoid** copepods were only represented by **nauplii**, and accounted for the remainder of total numbers. A total of six species of **cyclopoid** and **harpacticoid** copepods were collected in systematic samples from the under-ice surface. **Cyclopina schneideri** and **cyclopoid** copepodites (mostly **Cyclopina** sp.) were present in most samples, and together comprised over 80% of total **copepods** identified. The **harpacticoid** copepod **Tisbe furcata** occurred in all control ice samples, and represented an average of 12.2% of total **copepod** numbers. Other **cyclopoids** (**Oithona similis** and **Oncaea minuta**) and **harpacticoids** (**Microsetella** sp. and **Dactylopodia vulgaris**) were rare, both in terms of abundance and occurrence; each contributed less than 1% to total copepod numbers during the study. One solitary individual of the species **Harpacticus superflexus** was present in a non-quantitative sample.

Low species diversity of copepods is apparently characteristic of the soft bottom layer of the ice. The genera **Cyclopina, Harpacticus, Oithona, Oncaea** and **Tisbe** have been consistently found in under-ice habitats of arctic and antarctic regions (Andriashev 1968; Thomson et al. 1978; Cross 1982a; Grainger and Hsiao 1982; Kern and Carey 1983).

Abundance

Total **meiofaunal** densities at the productivity site in Bay 13 (control samples only) averaged approximately 54,000 individuals/m²; copepods alone contributed about 50,000 **ind./m²** (Table 10). Water samples taken just below the ice-water interface included all major ice-associated taxa,

Table 9. Species composition of under-ice copepods in the productivity study site at Cape Hatt, Baffin Island, during 18 May-2 June 1982¹. Data are based on 10 cm diameter ice cores.

Taxon	Period →	Pm-spill 1		Pre-spill 2		Post-spill 1		post-spill 2		Post-spill 3	
	Date → n →	18-19 May 21		21-22 May 21		26-27 May 4		28-29 May 3		1-2 June 4	
		% of numbers	% occurrence								
Copepoda											
Cyclopoida (total) ²		(83.3)		(85.5)		(73.5)		(77.3)		(72.7)	
<u>Cyclopina schneideri</u>		12.5	86	24.3	100	44.6	100	49.8	100	51.4	100
<u>Oithona similis</u>		0.2	14	<0.1	5			0.2	67		
<u>Oithona copepodite</u>				0.1	19						
<u>Oncaea minuta</u>		0.1	10	<0.1	10			0.1	33		
<u>Oncaea copepodite</u>		0.1	10	0.1	29	0.6	75	0.5	67	0.2	25
Unidentified copepodite ³		67.4	100	58.0	100	26.1	100	24.8	100	19.1	100
Naupl ii		2.7	81	2.3	100	1.1	100	1.1	67	1.0	50
Harpacticoida (total)											
<u>Tisbe furcata</u>		13.2	100	10.5	100	18.0	100	15.6	100	19.1	100
<u>Tisbe copepodite</u>		2.0	76	1.4	86	2.5	100	1.6	100	3.9	100
<u>Microsetella sp.</u>				0.1	19	0.3	25				
<u>Microsetella copepodite</u>				-				0.3	67	0.4	50
<u>Dactylopodia vulgaris</u>		0.1	5	0.1	14	0.1	25	0.2	33	0.4	50
Unidentified copepodite				0.1	10	0.5	25				
Naupl ii		0.9	48	2.0	91	4.5	100	4.2	100	3.3	75
Calanoida											
Nauplii		0.5	38	0.4	81	0.6	75	0.8	100	0.2	25
Total number identified		2,521		8,546		799		1,165		508	

¹ Data from only pre-spill periods and control treatments in post-spill periods are included.

² 'fetal % includes unidentified adults.

³ Majority identified as Cyclopina sp.

Table 10. Density (nos./m²x10³) of major meiofaunal groups on the under-ice surface in the productivity study site at Cape Hatt, Baffin Island, during 18 May-2 June 1982¹. Data are expressed as mean ± SD and are based on 10 cm diameter ice cores.

Taxon	Date → n ² →	Period				
		Pre-spill 1 18-19 May 21 [43]	Pre-spill 2 21-22 May 21 [40]	Post-spill 1 26-27 May 4[8]	Post-spill 2 28-29 May 3[6]	Post-spill 3 1-2 June 4[7]
Copepoda (total)		(43.55 ± 24.92)	(54.67 ± 27.77)	(62.72 ± 16.38)	(52.36 ± 17.57)	(48.62 ± 13.65)
Cyclopoida (total)		(38.23 ± 19.17)	(51.64 ± 21.77)	(49.57 ± 13.92)	(44.85 ± 16.47)	(34.03 ± 13.16)
Adult		6.05 * 3.89	15.10 ± 8.01	30.80 ± 11.29	29.56 ± 15.61	24.54 * 11.08
Copepodite		30:96 ± 16.25	35.16 * 16.05	18.01 ± 4.16	14.65 * 2.76	8.99 ± 1.96
Nauplii		1.22 ± 0.90	1.38 ± 0.75	0.77 ± 0.47	0.64 ± 0.65	0.50 ± 0.81
Harpacticoida (total)		(7.45 * 5.43)	(8.50 * 6.93)	(17.41 ± 4.02)	(12.74 * 3.90)	(12.06 * 4.03)
Adult		6.10 ± 5.13	6.38 ± 6.04	12.36 * 3.21	9.19 * 3.87	8.90 ± 2.89
Copepodite		0.93 ± 1.23	0.89 ± 1.05	2.09 ± 0.88	1.14 * 0.42	1.82 ± 1.41
Nauplii		0.42 * 0.66	1.22 * 0.95	3.03 * 1.15	2.41 * 1.43	1.34 * 1.64
Calanoida						
Nauplii		0.24 ± 0.35	0.25 ± 0.17	0.43 ± 0.35	0.45 ± 0.27	0.08 ± 0.15
Nematoda		1.11 ± 1.17	1.55 ± 1.32	3.44 ± 1.08	4.40 ± 2.89	4.92 ± 2.26
Polychaeta		1.15 ± 1.14	1.87 ± 1.05	2.26 ± 1.53	2.11 ± 0.97	1.70 ± 0.63
Total nos./m ² x10 ³		45.81	58.09	68.42	58.87	55.24

¹ Data from only pre-spill periods and control treatments in post-spill periods are included.

² Numbers of samples are shown for copepod sub-group followed by major groups [in parentheses].

but their abundance was much lower than in the ice above: about 13,000 individuals/m³ or 2,000 ind./m², based on 184 individuals in 24 control samples. Most of the meiofauna in ice (+ water) samples, therefore, occurred in the bottom layer of ice.

Under-ice **copepod** densities were higher, and nematode densities generally lower, than those previously reported in arctic and sub-arctic waters during May:

Location	Sample size	Mean ¹ densities (no./m ²)			Source
		total	copepod	nematode	
Cape Hatt	104	2500-54,000	2000-50,000	20-1930	Present study
Brenford Bay	16	17,003	13,003	2900	Thomson et al. (1978)
Pond Inlet	29	300-53,030	100-20,500	0-31,900	Cross (1982a)
Stefansson Sound	9	4,500	800	3500	Carey and Montagna (1982)
Stefansson Sound	33	19,000	6500	8500	Kern and Carey (1983)
Frobisher Bay	-	46,000-326,000	603-15,000	20,700-293,000	Grainger and Hsiao (1982)

¹ Ranges are for stations within locations, or for data for which means could not be calculate.

Spatial Effects

Meiofauna were relatively evenly distributed on a small scale (i.e. within the 1.2 m² enclosures) at the productivity site in Bay 13. The standard deviation was usually much less than the mean for each of the major meiofaunal groups (Appendix F). Variation on a larger scale (among enclosures in Bay 13--Fig. 12; among bays--Table 11) was considerable, and was evident for all **meiofaunal** groups. Nematodes were the one group for which interactions did not confound the results; differences among enclosures were highly significant (P<0.001; Table 12).

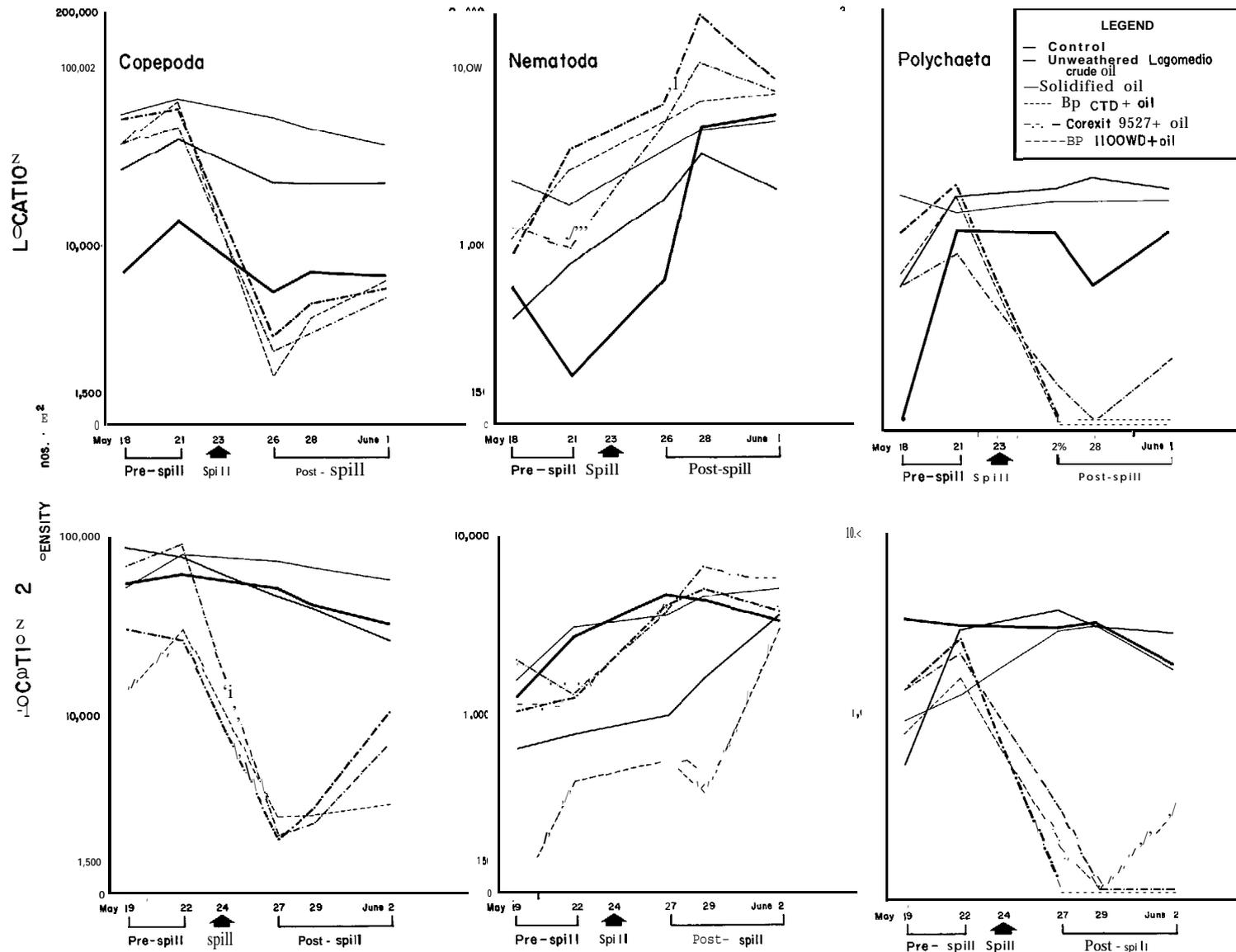


FIGURE 12. Densities of major meiofaunal groups exposed to oil and chemically treated oil on the under-ice surface in two locations at Cape Hatt, Baffin Island, during 18 May-2 June 1982. Values for each date are means of 3-4 replicate ice core samples (10 cm diameter).

Table 11. Density (nos./m²) of under-ice amphipods, meiofauna and microalgae and snow depth (cm) in four bays¹ at Cape Hatt, Baffin Island, during May 1982. Meiofaunal and microalgal data are based on 5 replicates and amphipod data are based on 16 replicates³ in each bay and sampling period.

Taxon		Bay 7	Bay 9	Bay 10	Bay 11
		mean ± SD	mean ± SD	mean ± SD	mean ± SD
Microalgae (x10 ⁷)	Early May	196 ± 89	164 ± 99	298 ± 71	84 ± 51
	Late May	361 ± 158	362 ± 69	300 ± 91	121 * 126
Copepoda	Early May	14,510 ± 6,511	9,333 ± 7,605	11,705 * 11,807	4,565 * 4,324
	Late May	9,547 ± 5,914	2,068 ± 560	50,122 ± 18,307	4,115 ± 1,369
Nematoda	Early May	204 ± 264	230 ± 293	490 ± 411	26 ± 57
	Late May	392 ± 428	311 ± 422	289 * 200	49 ± 67
Polychaeta	Early May	383 ± 239	459 ± 306	1,346 ± 705	2,933 * 1,265
	Late May	220 ± 305	70 * 105	265 ± 325	4,446 * 2,142
Amphipoda	Early May	6 ± 5	3 ± 3	29 ± 24	6 ± 5
	Late May	16 ± 12	6 ± 4	33 * 26	12 ± 10
Snow depth ⁴ (cm)	Early May	23.8 ± 4.1	18.7 ± 4.9	10.6 ± 2.5	17.0 ± 6.2
	Early June	20.8 * 3.9	21.9 * 5.0	8.8 ± 2.6	19.0 * 9.2

¹ Bay 7 (reference), Bay 9 (dispersed oil release), Bay 10 (dispersed oil contamination), Bay 11 (surface oil release); oil was released in August 1981.

² Core samples; 2.5 cm diameter for microalgae, 10 cm diameter for meiofauna.

³ Net samples covering 4 m².

⁴ Data are based on 17-21 replicates.

Table 12. Comparison of densities of meiofauna exposed to **oil**¹ and chemically treated **oil**¹ on the under-ice surface in the productivity study site at Cape Hatt, **Baffin** Island, during 18 May-2 June 1982². F-values are shown with significance levels (ns = $P > 0.05$; * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$). Significance levels are not shown for main effects when the interaction term was significant.

Taxon	Location	Source of Variation (df)		
		Period (4,77)	Treatment (5,77)	Period x Treatment (20,77)
Copepoda	1	42.31	35.14	5.10 ***
	2	28.12	45.99	5.34 ***
Nematoda	1	36.91 ***	11.58 ***	1.60 ns
	2	11.55 ***	12.34 ***	0.87 ns
Polychaeta	1	5.73	15.55	2.91 ***
	2	8.24	20.93	3.32 ***

¹Unweathered **Lagomedio** crude oil.

²Oil treatments were applied on 23 and 24 May 1982.

Densities of meiofauna in the BIOS study bays are shown in Table 11 together with corresponding data on snow depths and densities of **microalgae** and amphipods. No consistent relationships are apparent between any of these variables. In some cases, this may be related to differences in sample types and locations within the bays; meiofauna samples were randomly located, whereas amphipod samples were systematically located and covered much larger areas. The lack of any consistent relationship among groups of meiofauna, however, indicates that a number of different factors are involved and whose effects on **meiofaunal** distribution differ among the groups.

There are several possible sources of this large scale variability, including snow depth, light and concentrations of **microalgae**. In all Bay 13 control enclosures taken together ($n = 104$), light was positively correlated with densities of nematodes ($r = 0.58$; $P < 0.001$), copepods ($r = 0.52$; $P < 0.001$) and, to a lesser extent, polychaetes ($r = 0.27$; $P < 0.01$). Similar correlations were evident between chlorophyll a concentrations and the densities of each of these groups. Light and chlorophyll concentrations were also positively correlated ($r = 0.68$; $P < 0.001$). From a correlation analysis of this type it is not possible to identify causal relationships.

Cross (1982a) reported that copepod abundance, but not nematode abundance, was significantly greater in brown ice than in clear ice at one station in Pond Inlet. At another station both nematode and copepod numbers were significantly greater in a dense, loose algal layer under clear ice than in brown ice. Over 92% of the nematodes found by Thomson et al. (1978) in 16 core samples collected in Brentford Bay were in three samples taken under an area of ice that had previously been cleared of snow. At the same time there

was no corresponding increase in copepod density or in apparent algal growth. Thus, it is possible that nematode densities are more strongly influenced by light, and copepod densities by algal concentrations.

Other factors may also influence the distribution of meiofauna. Carey and Montagna (1982) suggest that ice meiofauna may be recruited from **benthic** or pelagic habitats by means of vertical migration or advective forces. Hence, their distribution and abundance may also be influenced by water depth and prevailing currents. Differences among groups would be expected for swimming (copepods and some **polychaetes**) and non-swimming (nematodes and other **polychaetes**) forms.

Warwick (1981b) points out that meiobenthic nematodes are rarely or never found in stomach contents of **benthic** predators, whereas **meiobenthic** copepods are known to form a significant item in their diets. Small copepods of the antarctic ice fauna were found in fingerlings of Trematomus borchgrevinki by Andriashev (1968), and ice copepods dominated the diet of arctic cod near the Pond Inlet ice edge (Bradstreet and Cross 1982); in each case nematodes were not mentioned. Predation may, therefore, affect ice copepod densities, but this would not appear to be the case for nematodes.

Temporal Effects

Results of two-factor analyses of variance (treatments and periods) for densities of **meiofaunal** groups in Bay 13 were unambiguous only in the case of nematodes (Table 12). In both locations, nematode densities showed a highly significant ($P < 0.001$) period effect; mean density in control samples

increased from 1100 **individuals/m²** on 18 May to 4900 **ind./m²** on 2 June 1982 (Fig. 12). Nematode densities also increased over the same time period in three of the four BIOS study bays. Similar increases in nematode densities during the spring bloom have been reported in Frobisher Bay during 1981 (20,700 to 293,000 **ind./m²**; Grainger and Hsiao 1982) and in the Beaufort Sea in 1980 (350 to 25,000 **ind./m²**; Kern and Carey 1983).

Copepod and **polychaete** abundances in control samples from Bay 13 were relatively constant over the study period (Fig. 12). However, this was not true for all particular types of copepods. **Cyclopoid** copepodites in Bay 13 decreased from 30,900 **individuals/m²** on 18-19 May to 9000 **ind./m²** on 1-2 June. At the same time, **cyclopoid** adults increased from 6000 to 24,500 **ind./m²** (Table 10). In contrast, harpacticoid copepods showed no obvious temporal variation related to stages of development. In the other four bays, the trends in **numbers** from early to late May were not consistent among bays or groups (Table 11).

Kern and Carey (1983) reported significant temporal variation in **copepod** and **polychaete** densities in the Beaufort Sea during May 1980, but no progressive change was evident in either group. Numbers of both groups decreased substantially between early and late May in Frobisher Bay (Grainger and Hsiao 1982).

Oil Effects

The study design of this component involves five oil treatments plus a control in each of two locations, and two **pre-spill** and three post-spill sampling periods. Three-factor analyses of variance (locations, treatments,

periods) were carried out, but significant interactions involving location precluded unambiguous interpretation of period x treatment interactions and main effects. Therefore, separate two-factor analyses of variance (treatments and periods) were carried out in each of the two locations for each of the three variables: densities of copepods, nematodes and **polychaetes**. Treatment x period interactions were highly significant ($P < 0.001$) for two of these groups, copepods and **polychaetes**, in each of the locations (Table 12).

Copepod and **polychaete** densities decreased dramatically between **pre-spill** and post-spill periods in each of the three dispersed oil treatments in each location; densities in the other three treatments (control, solidified oil and oil) remained relatively constant (**Fig. 12**). Nematodes were completely unaffected by any of the oil treatments; densities increased throughout the study period in each treatment and in each location (**Fig. 12**). The observed response in copepods and **polychaetes** was similar for the three types of **dispersants** and the two locations, irrespective of the differences in oil concentrations measured within the enclosures (6-37 ppm).

Densities of **polychaetes** and **copepods** in dispersed oil treatments increased slightly between post-spill Periods 1 and 3. This increase was more apparent for copepods than for **polychaetes**, probably indicating a faster recovery rate (**Fig. 12**). It is not known whether the copepods or **polychaetes** were killed outright or merely displaced from the ice undersurface. **Gyllenberg and Lundqvist** (1976) found that 2 pelagic species of **copepods** exposed to dispersed oil first performed escape movements (period of high activity) and then entered a state of narcosis and sank to the bottom. Ice-associated **meiofauna** that left the ice would likely be susceptible to **benthic**

predators. In deep water, even if complete recovery occurred in the water column, possibilities for returning to the ice seem remote.

Conflicting evidence has been reported on the effects of oil on meiofauna. Dana Venezia and Fossato (1977) found that the copepod Tisbe bulbisetosa was quite tolerant to a suspension composed of Kuwait oil and Corexit. Boucher (1980) observed that some harpacticoid copepods were unaffected by oil, and some were even attracted to it. Kontogiannis and Barnett (1973), on the other hand, found that oil was toxic to a tide pool copepod, and suggested that resistance to crude oil may change from species to species and from habitat to habitat.

The differences in our results for copepods and nematodes is consistent with a current theory that the ratio of nematodes to copepods is a potentially useful tool in monitoring organic pollution, including oil pollution (Raffaelli and Mason 1981; Warwick 1981a). Coull et al. (1981) argue, however, that the use of this ratio is an oversimplification. Again, conflicting evidence has been reported. McLachlan and Harty (1982) found that dispersed oil was more toxic than fresh oil to all taxa, but that nematodes generally were the least sensitive and oligochaetes the most sensitive. Boucher (1980), on the other hand, found a general decrease in abundance of nematodes in the intertidal zone impacted by the Amoco Cadiz Oil spill.

The higher nematode to copepod ratios in areas of the under-ice surface exposed to dispersed oil treatments (Table 13) concur with the postulation of Raffaelli and Mason (1981) and Warwick (1981a). At Cape Hatt, nematode to

Table 13. Nematode to copepod ratios in two locations exposed to oil¹ and chemically treated oil¹ on the wrier-ice surface in the productivity study site at Cape Hatt, Baffin Island, during 18 May-2 June 1982². Data are based on 4 replicate ice cores (10 cm diameter) for each treatment, location and sampling period.

Period	Location	Treatment					
		Control	Oil ¹	Solidified Oil ¹	BP CID +Oil ¹	BP 1100WD +Oil ¹	Corexit 9527 +Oil ¹
Pre-spill 1	1	0.042	0.081	0.014	0.017	0.029	0.034
	2	0.029	0.023	0.007	0.035	0.007	0.029
Pre-spill 2	1	0.025	0.013	0.020	0.058	0.042	0.021
	2	0.038	0.044	0.010	0.046	0.014	0.014
Post-spill 1	1	0.064	0.115	0.079	1.933	2.582	1.838
	2	0.049	0.088	0.021	1.964	0.203	1.781
Post-spill 2	1	0.096	0.638	0.147	3.957	1.606	3.179
	2	0.067	0.102	0.040	1.644	0.127	2.667
Post-spill 3	1	0.135	0.782	0.092	1.507	1.102	1.442
	2	0.085	0.100	0.133	0.361	0.954	0.782

¹Unweathered Lagomedio crude oil.

²Oil treatments were applied on 23 and 24 May 1982,

copepod ratios were low in all study bays in May 1982 (Tables 11 and 13) . If this ratio does prove to be a useful indicator of pollution in under-ice communities , the conclusion would follow that the Cape Hatt/Ragged Channel area is a non-polluted environment in spite of the experimental releases of oil carried out in 1981.

In view of the contradictory and limited data available on the effects of oil on meiofauna, however, we must be cautious in using such a simple ratio as a pollution indicator (see Coull et al. 1981). In addition, too few data are available concerning the composition of the under-ice meiofaunal community under pristine conditions, and on natural factors affecting the distributions of copepods and nematodes.

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Appendix A. Numbers of samples of variables for productivity component of the under-ice study, at Cape Hatt, Baffin Island, during 18 May-2 June 1982. Ice samples¹, followed by near-ice water samples² (in parentheses) are shown.

Variable	Date ->	Pre-spill Periods		Post-spill Periods			Total	
		1 18-19 May	2 21-22 May	1 26-27 May	2 28-29 May	3 1-2 June	Ice	Water
Inorganic nutrients - post incubation		24 (6)		24 (6)		24 (6)	72	18
- pre incubation		13		2		2	17	
Chlorophyll <u>a</u> , phaeopigments	>.45 μ m	48 (12)	48 (12)	48 (12)	48 (12)	48 (12)	240	60
	>3 μ m	48 (12)		48 (12)		48 (12)	144	36
Particulate carbon	>.45 μ m	24 (6)		24 (6)		24 (6)	72	18
	>3 μ m	24 (6)		24 (6)		24 (6)	72	18
Microalgae - numbers		24 (6)	24 (6)	24 (6)	24 (6)	24 (6)	120	30
- species		24 (6)		24 (6)		24 (6)	72	18
Meiofauna - numbers, groups		24 (6)	24 (6)	24 (6)	24 (6)	24 (6)	120	30
- species		24 (6)	24 (6)	24 (6)	24 (6)	24 (6)	120	30
¹⁴ C activity - 'Algae'	>3 μ m	48 (12)		48 (12)		48 (12)	144	36
Algae + Bacteria	>.45 μ m	48 (12)	48 (12)	48 (12)	48 (12)	48 (12)	240	60
Dissolved organic		48 (12)		48 (12)		48 (12)	144	36
Meiofauna (groups)		48 (12)		48 (12)		48 (12)	144	36

¹ Sample numbers are evenly distributed among treatments and locations (6 x 2 per period); in a few cases the number of samples per period/treatment/location (usually 3 or 4 depending on variable) was reduced by 1 or 2.

² 1 or 2 replicates in each treatment and period: BP CTD -toil, oil, solidified oil (Location 1) and Corexit 9527 +oil, BP 1100WD toil, control (Location 2).

Appendix C. Biomass (mg/m²) of dominant amphipods on the under-ice surface in four bays¹ at Cape Hatt, Baffin Island, during May 1981 and 1982². Data are based on 10-16 samples, each revering 4 n?, in each bay and sampling period.

Taxon	Year	Bay 7		Bay 9		Bay 10		Bay 11	
		Early May - * s o	Late May mean ± SD	Early May mean ± SD	Late May mean ± SD	Early May mean ± SD	Late May - * S D	Early May mean ± SD	Late May - * S D
<u>Weyprechtia pinguis</u>	1981			46.4 ± 41.7	103.0 ± 73.9	88.5 ± 124.6	29.5 ± 27.8	14.2 ± 26.0	7.7 ± 13.7
	1982	58.2 ± 58.1	45.1 ± 35.8	74.5 ± 66.0	64.5 ± 55.4	21.6 ± 20.5	24.2 ± 41.1	11.0 ± 27.9	5.0 ± 10.5
<u>Onisimus litoralis</u>	1981			31.1 ± 45.9	219.7 ± 222.5	13.3 ± 26.4	25.4 ± 32.9	14.1 ± 43.8	3.9 ± 9.6
	1982	14.4 ± 22.8	8.9 ± 10.0	2.7 ± 7.4	1.6 * 6.4	6.8 * 11.9	0	1.4 ± 5.6	0
<u>Onisimus glacialis</u>	1981			1.9 * 3.6	8.2 ± 5.0	1.1 * 2.2	3.0 ± 3.2	1.2 * 2.4	4.2 ± 7.0
	1982	0.2 ± 0.6	1.1 * 1.9	0.2 ± 0.8	1.0 ± 1.6	2.5 ± 3.6	6.2 ± 5.9	0.1 ± 0.4	0.2 ± 0.8
<u>Onisimus juveniles</u>	1981			0	3.3 * 3.8	0.1 * 0.3	0.6 * 0.9	0	0.3 * 0.6
	1982	6.2 * 7.6	26.4 * 25.5	1.5 ± 2.5	6.0 * 6.9	36.2 * 37.6	58.3 + 8.8	2.5 * 3.0	5.7 * 6.3
<u>Gammarus setosus</u>	1981			13.3 ± 0.6	0.8 * 1.6	0.6 * 1.1	5.9 * 8.5	66.7 ± 69.7	206.6 ± 168.9
	1982	1.8 ± 4.6	0.8 ± 2.9	0.1 ± 0.3	0.3 * 13.7	1.9 * 3.3	3.8 ± 7.6	33.0 ± 42.6	184.8 * 146.2
<u>Ischyrocerus sp.</u>	1981			13.6 * 0.8	5.1 * 4.2	9.8 ± 7.7	27.5 * 36.7	10.2 * 12.6	22.0 * 18.6
	1982	0.4 * 0.5	0.6 ± 0.6	0.8 ± 0.7	0.7 ± 0.6	11.9 ± 8.8	20.0 ± 14.7	3.6 ± 3.5	11.8 ± 14.6
Amphipoda	1981			82.3 * 69.0	353.5 * 265.3	117.6 ± 125.8	93.5 + 73.8	111.4 ± 133.9	264.3 ± 211.2
	1982	81.8 ± 70.7	86.9 ± 37.6	83.0 * 68.3	74.3 * 55.9	90.0 ± 53.6	129.5 * 97.5	68.3 ± 62.3	215.7 * 150.9

¹ Bay 7 (reference), Bay 9 (dispersed oil release), Bay 10 (dispersed oil contamination), Bay 11 (surface oil release).

² Pre-spill (August 1981) and Post-spill (September 1981, August 1982, September 1982).

Appendix D. Density (nos./m²) of dominant amphipods and tide levels (cm below mean) in the intertidal habitats of four bays¹ at Cape Hatt, Baffin Island, during August and September 1981 and 1982. Data are based on 10 samples, each covering 0.25 m², in each bay and sampling period.

Taxon	Year	Bay 7		Bay 9		Bay 10		Bay 11	
		August mean ± SD	September - * s o	August mean ± SD	September mean ± SD	August mean ± SD	September mean ± SD	August mean ± SD	September mean ± SD
<u>Gammarus setosus</u>	1981		0	42.0 * 21.6	23.6 ± 34.1	102.4 * 129.4	85.2 * 61.4	95.2 * 58.9	12.8 ± 20.6
	1982	355.2 * 310.2	501.6 * 342.5	758.8 ± 316.1	649.2 * 430.2	398.4 * 399.0	376.0 * 322.7	138.8 * 157.1	222.4 * 278.6
<u>Onisimus litoralis</u>	1981		0	0	0	0.8 ± 1.7	0.4 * 1.3	12.8 * 7.3	0.8 * 1.7
	1982	2.8 * 3.3	5.2 * 5.0	34.0 * 19.3	376.4 * 745.8	78.4 * 103.3	572.4 ± 952.8	216.0 ± 136.6	473.2 ± 501.3
<u>Onisimus glacialis</u>	1981		0	0	0	0	0	0	0
	1982	2.8 ± 3.8	2.4 ± 3.4	63.6 * 60.3	228.0 ± 637.8	236.4 ± 224.3	237.6 ± 377.3	633.6 ± 245.0	398.0 ± 476.1
<u>Monoculodes packardii</u>	1981		0	0	0	0	0	0	0
	1982	0.8 ± 1.7	0	31.2 * 25.5	165.6 ± 277.0	81.6 ± 159.5	287.6 ± 414.9	10.4 ± 22.4	2.0 ± 3.9
<u>Amphipoda</u>	1981		0	43.2 ± 29.0	23.6 ± 34.1	108.0 ± 135.0	86.4 ± 60.6	111.6 ± 67.5	16.8 ± 21.7
	1982	362.4 ± 315.7	511.2 * 346.3	892.8 ± 310.2	1,468.8 ± 1,375.7	835.2 * 541.7	1,514.8 * 1,345.8	1,065.6 * 399.5	1,146.4 * 892.2
Tide levels (cm below mean)	1981		28-31	36-49	33-34	101-103	33-34	57-64	26-31
	1982	66-75	68-78	74-W	68-87	68-95	68-93	89-101	71-94

¹ Bay 7 (reference), Bay 9 (dispersed oil release), Bay 10 (dispersed oil contamination), Bay 11 (surface oil release).
 Pre-spill (August 1981) and Post-spill (September 1981, August 1982, September 1982).

Appendix E. Biomass(mg/m²) of dominant amphipods in the intertidal habitats of four bays¹ at Cape Hatt, Baffin Island, during August and September 1981 and 1982². Data are based on 10 samples, each covering 0.25 m², in each bay and sampling period.

Taxon	Year	Bay 7		Bay 9		fray 10		Bay 11	
		August mean ± SD	September - * S D	August mean ± SD	September mean ± SD	August mean ± SD	September mean ± SD	August mean ± SD	September mean ± SD
<u>Gammarus setosus</u>	1981		0	1,132*799	223 ± 242	621 ± 718	1,246 ± 1,072	1,070 ± 1,171	521 ± 635
	1982	8,325 ± 8,198	13,891 ± 9,692	13,522 * 7,343	17,175 * 9,417	4,993 ± 4,845	6,672 ± 7,073	2,103 * 1,739	2,320 ± 2,582
<u>Onisimus litoralis</u>	1981		0	0	0	52 * 123	32 ± 100	770 * 440	60 ± 126
	1982	22 ± 26	52*50	304 ± 168	4,335 ± 8,809	676 ± 837	6,423 ± 10,541	1,793 ± 1,243	5,313 ± 6,009
<u>Onisimus glacialis</u>	1981		0	0	0	0	0	0	0
	1982	22 ± 31	23*33	454 ± 424	1,993 * 5,538	1,664 * 1,651	2,331 * 3,778	4,271 * 1,803	3,304 * 4,193
<u>Monoculodes packardi</u>	1981		0	0	0	0	0	0	0
	1982	1 ± 2	0	12 ± 9	93 ● 153	27 ± 50	144 ● 209	3*5	1 ± 2
Amphipoda	1981		0	1,353 * 846	223 ± 242	1,202 * 1,400	1,292 + 1,056	1,859 * 1,423	842 ± 796
	1982	8,371 * 8,230	13,973 ± 9,757	14,312 ± 7,215	23,837 ± 13,311	7,471 * 4,257	16,064 * 13,786	8,740 * 3,999	11,551 * 9,301

¹ Bay 7 (reference), Bay 9 (dispersed oil release), Bay 10 (dispersed oil contamination), Bay 11 (surface oil release).

² Pre-spill (August 1981) and Pmt.-spill (September 1981, August 1982, September 1982).

Appendix F. Density (nos./m² × 10³) of major meiofaunal groups exposed to oil¹ and chemically treated oil¹ in two locations on the under-ice surface at Cape Hatt, Baffin Island, during 18 May–2 June 1982. Data are expressed as mean ± SD and based on 4 replicate ice cores (10 cm diameter) for each treatment, location and sampling period.

Taxon	Period ²	Location	Treatment					Corexit 9527 +Oil ¹		
			control	Oil ¹	Solidified Oil ¹	BP CID +Oil ¹	8P 1100WD +Oil ¹			
Copepoda	Pre-spill 1	1	54.51 ± 12.90	7.08 ± 6.22	26.97 ± 10.14	51.64 ± 13.58	36.15 ± 27.67	36.72 ± 25.75		
		2	52.40 ± 13.69	54.89 ± 11.64	%.19 ± 11.53	33.41 ± 5.35	13.39 ± 10.39	68.95 ± 19.81		
	Pre-spill 2	1	65.63 ± 21.37	13.85 ± 12.42	39.82 ± 14.24	58.90 ± 39.34	62.98 ± 20.51	45.76 ± *	16.57	
		2	79.69 ± 20.43	60.80 ± 11.73	76.35 ± 6.32	26.78 ± 14.22	30.90 ± 22.36	90.28 ± 13.03		
	Past-spill 1	1	52.14 ± 13.20	5.41 ± 2.75	22.33 ± 7.60	3.10 ± 1.53	1.87 ± 1.48	2.55 ± 1.55		
		2	73.31 ± 12.37	51.53 ± 7.69	46.41 ± 13.69	2.01 ± 2.55	2.69 ± 1.52	2.08 ± 1.65		
	Post-spill 2	1	45.15 ± 13.89	7.05 ± 2.89	21.81 ± 7.77	4.70 ± 3.06	3.92 ± 1.37	3.26 ± 2.08		
		2	66.77 ± 18.48	41.61 ± 12.23	39.55 ± 7.54	3.01 ± 0.87	2.75 ± 1.78	2.49 ± 1.47		
	Post-spill 3	1	36.80 ± 6.97	6.69 ± 2.31	22.14 ± 4.47	5.69 ± 1.62	6.26 ± 3.92	5.00 ± 1.33		
		2	57.48 ± 9.80	32.81 ± 8.30	26.46 ± 5.00	10.31 ± 0.84	3.10 ± 2.86	6.87 ± 2.51		
	Nematoda	Pm-spill 1	1	2.30 ± 1.93	0.57 ± 0.81	0.38 ± 0.54	0.89 ± 0.80	1.05 ± 0.0%	1.24 ± 0.85	
			2	1.53 ± 1.33	1.24 ± 1.01	0.64 ± 0.44	1.05 ± 0.0%	0.10 ± 0.19	2.01 ± 1.96	
Pre-spill 2		1	1.67 ± 1.14	0.18 ± 0.77	0.78 ± 0.18	3.43 ± 1.55	2.63 ± 0.87	0.97 ± 0.23		
		2	3.05 ± 1.83	2.66 ± 1.35	0.76 ± 0.33	1.23 ± 0.39	0.42 ± 0.43	1.26 ± 0.70		
Past-spill 1		1	3.33 ± 1.19	0.62 ± 0.20	1.77 ± 1.40	5.99 ± 1.73	4.82 ± 2.71	4.68 ± 2.00		
		2	3.55 ± 1.13	4.54 ± 1.65	0.8 ± 0.19	3.95 ± 2.25	0.55 ± 0.49	3.71 ± 1.40		
Post-spill 2		1	4.35 ± 3.55	4.53 ± 1.82	3.20 ± 0.76	18.60 ± 12.22	6.30 ± 3.26	10.35 ± 5.31		
		2	4.48 ± 2.01	4.25 ± 4.04	1.57 ± 1.72	4.95 ± 2.88	0.35 ± 0.32	6.64 ± 6.10		
Past-spill 3		1	4.9b ± 2.33	5.24 ± 2.0%	2.04 ± 0.51	8.57 ± 3.11	6.90 ± 3.35	7.21 ± 2.38		
		2	4.90 ± 2.57	3.27 ± 1.47	3.52 ± 2.41	3.72 ± 1.60	2.96 ± 1.02	5.37 ± 1.30		
Polychaeta		Pre-spill 1	1	2.30 ± 1.93	0*0	0.57 ± 0.49	1.15 ± 1.38	0.67 ± 0.65	0.57 ± 0.49	
			2	0.89 ± 0.44	3.35 ± 1.18	0.51 ± 0.44	1.34 ± 0.73	0.77 ± 0.0%	1.34 ± 1.19	
	Pre-spill 2	1	1.48 ± 1.99	1.18 ± 0.63	1.82 ± 0.19	2.13 ± 1.73	1.84 ± 1.37	0.86 ± 0.43		
		2	1.25 ± 0.54	3.10 ± 0.51	2.87 ± 0.77	2.54 ± 0.66	1.55 ± 0.74	2.11 ± 0.97		
	Post-spill 1	1	1.68 ± 1.51	1.13 ± 1.14	1.98 ± 1.52	0 ± 0	0 ± 0	0.16 ± 0.19		
		2	2.83 ± 1.51	2.95 ± 1.11	3.61 ± 0.53	0.13 ± 0.22	0.17 ± 0.24	0.29 ± 0.37		
	Post-spill 2	1	1.68 ± 0.89	0.57 ± 0.27	2.28 ± 0.66	0.10 ± 0.17	0.14 ± 0.20	0 ± 0		
		2	2.98 ± 0.70	4.25 ± 4.04	2.99 ± 2.78	0.10 ± 0.09	0.08 ± 0.09	0.11 ± 0.0(M)		
	Post-spill 3	1	1.68 ± 0.98	1.13 ± 1.07	1.99 ± 0.59	0.15 ± 0.2b	0 ± 0	0.22 ± 0.44		
		2	1.72 ± 0.39	1.80 ± 0.56	2.71 ± 0.41	0 ± 0	0.26 ± 0.24	0.13 ± 0.26		

¹ Unweathered Lagomedio crude oil.

² Oil treatments were applied on 23 and 24 May 1982.

Appendix G. Numbers of dominant¹ copepod groups or species collected on the under-ice surface in the productivity study site at Cape Hatt, Baffin Island, during 18 May-2 June 1982². Data are total numbers in subsamples of 4 replicate ice cores (10 cm diameter) for each treatment and sampling period.

Taxon	Period ²	Treatment					
		Control	Oil ³	Soldified Oil ³	BPCID +Oil ³	BP 11OCMD +Oil ³	Corexit 9527 +Oil ³
<u>Cyclopina schneideri</u>	Pre-spill 1	62	37	50	35	52	78
	Pre-spill 2	460	220	288	292	290	525
	Post-spill 1	356	106	122	1	4	5
	Post-spill 2	580	238	269	22	34	27
	Post-spill 3	261	66	58	40	37	35
Cyclopoid copepodite ⁴	Pre-spill 1	359	218	293	176	292	360
	Pre-spill 2	695	696	1,019	564	884	1,099
	Post-spill 1	208	111	88	1	2	7
	Post-spill 2	289	257	326	10	27	23
	Post-spill 3	97	60	94	18	15	17
<u>Tisbe furcata</u>	Pre-spill 1	86	56	18	48	25	100
	Pre-spill 2	206	146	56	89	114	288
	Post-spill 1	144	83	35	5	2	4
	Post-spill 2	182	148	109	11	9	25
	Post-spill 3	97	41	78	11	17	11
<u>Tisbe</u> copepodite	Pre-spill 1	19	1	2	14	8	7
	Pre-spill 2	19	12	15	32	7	32
	Post-spill 1	20	6	10	6	0	2
	Post-spill 2	19	8	43	22	2	3
	Post-spill 3	20	2	14	3	0	1
Nauplii (Cyclopoid and Harpacticoid)	Pre-spill 1	15	14	8	18	21	14
	Pre-spill 2	67	67	48	67	43	80
	Post-spill 1	45	30	24	15	9	5
	Post-spill 2	62	71	109	6	14	16
	Post-spill 3	22	17	20	4	2	3

¹ 96.6% of total copepod numbers.

² Oil treatments were applied on 23 and 24 May 1982.

³ Unweathered Lagomedio crude oil.

⁴ Majority identified is Cyclopina sp.

Appendix H. Water-ice productivity and biomass data for variables measured in only three sampling periods at Cape Hatt, Baffin Island, during 18 May-2 June 1982¹. Sample sizes are given in Appendix A.

Variable	Period ¹	Location	Treatment					
			Control	Oil ²	Solidified Oil ²	BP CTD +Oil ²	BP 1100WD +Oil ²	Corexit 9527 +Oil ²
Productivity ³ (mgC/m ² /h)	Pre-spill 1	1	1.49 * 0.13	0.03	0.19 * 0.01	2.97 * 0.45	1.12 ± 0.22	0.34 * 0.07
		2	1.66 * 1.03	0.96 * 0.31	0.40 ± 0.19	0.11 * 0.03	0.11 * 0.08	3.61 * 1.25
	Wet-spill 1	1	1.92 * 0.75	0.12 * 0.03	1.33 * 0.60	1.15 * 0.43	1.25 ± 0.14	1.12 ± 0.46
		2	2.45 * 0.49	1.99 * 0.27	1.62 * 0.44	1.26 * 0.28	0.09 * 0.08	1.07 * 0.31
	Post-spill 3	1	2.273 * 0.05	0.41 * 0.05	1.57 * 0.40	2.02 * 13.35	1.43 * 0.22	1.40 ± 0.16
		2	2.51 * 0.58	1.89 * 0.07	1.14 * 0.20	1.41 * 0.32	0.07 * 0.03	2.05 ± 0.36
Chlorophyll a ³ (mg/m ²)	Wet-spill 1	1	10.61 * 1.66	3.32 * 0.50	6.30 ± 0.65	11.77 * 2.40	10.79 * 1.19	8.02 * 2.76
		2	12.18 ± 2.02	10.88 * 0.81	10.50 * 2.69	6.49 ± 3.50	5.12 * 0.57	13.05 * 2.88
	Post-spill 1	1	14.52 ± 1.09	5.68 * 1.18	14.85 * 3.18	13.17 * 1.56	13.72 * 1.02	11.12 * 1.89
		2	13.08 ± 1.33	13.07 * 1.82	12.42 ± 1.06	9.27 ± 1.09	4.13 ± 3.12	11.92 ± 1.08
	Post-spill 3	1	15.20 ± 1.69	9.98 * 1.17	19.84 * 3.54	10.82 * 0.80	12.25 ± 2.81	11.55 * 2.59
		2	14.70 ± 2.93	13.89 ± 1.46	15.06 ± 3.73	9.57 ± 2.02	6.57 ± 2.73	12.24 ± 3.73
Particulate Carbon ⁴ (mg/m ²)	Pre-spill 1	1	197.45 ± 1.85	36.87	120.72 ± 26.61	217.72	166.31 ± 6.71	146.12 ± 44.36
		2						
	Post-spill 1	1	290.55 ± 34.19	115.74 ± 27.59	214.43 ± 48.36	226.75 ± 26.61	314.11 ± 111.00	208.69 ± 51.06
		2	485.78 ± 26.83	354.81 ± 14.71	356.95 ± 62.32		177.71 ± 87.7%	264.00 ± 16.34
	Post-spill 3	1	418.53 ± 19.37	225.98 ± 11.04	371.33 ± 46.30	357.87 ± 54.09	298.73 ± 47.28	328.57 ± 30.40
		2	599.99 ± 7.25	355.42	392.67 * 167.15	255.43 * 69.35	123.47 * 2.16	367.35 * 22.29
Particulate Carbon ³ (mg/m ²)	Pre-spill 1	1	426.11 * 18.25	65.57	159.12 * 56.69	284.27	363.15 ± 115.87	191.17 * 59.61
		2						
	Post-spill 1	1	324.21 ± 49.55	113.45 * 15.90	262.40 ± 41.11	260.18 ± 17.42	278.08 ± 4.00	200.43 ± 25.53
		2	466.19 ± 236.35	353.3% ± 41.44	337.75 ± 10.49	230.72 * 27.91	134.56 ± 95.10	405.68 ± 57.23
	Post-spill 3	1	437.27 ± 35.27	182.84 ± 8.66	289.25 ± 20.45	336.92 ± 15.80	246.25 ± 3.79	229.96 ± 28.99
		2	441.41 ± 62.10	313.34 ± 9.95	261.32 ± 64.70	204.33 ± 30.40	84.61 ± 17.7%	297.81 ± 7.25
Dissolved Organic Carbon ⁴ (mgC/m ² /h)	Pre-spill 1	1	8.88 ± 0.55	0.20	0.70 ± 0.24	7.68 ± 1.59	4.02 * 1.72	1.62 ± 0.13
		2	4.41 * 1.89	2.15 * 0.77	0.61 ± 0.13	0.35 ± 0.09	0.50 ± 0.33	6.17 ± 1.45
	Post-spill 1	1	9.87 ± 4.39	0.51 * 0.23	3.57 ± 2.47	4.74 ± 1.14	5.60 ± 0.23	5.03 ± 1.50
		2	11.64 ± 3.36	8.42 ± 1.45	5.84 ± 1.67	3.77 * 1.01	0.22 * 0.37	4.46 * 2.14
	Post-spill 3	1	9.24 ± 0.73	1.86 ± 0.81	6.79 ± 0.78	7.09 * 1.35	6.54 * 1.69	5.71 ± 1.06
		2	10.60 ± 1.94			4.40	-0.04 * 0.23	5.94 ± 0.47

¹ Oil treatments were applied on 23 and 24 May 1982.

² Unweathered Legation crude oil.

³ 3.0 µm filter.

⁴ 0.45µ filter.

Appendix I. ^{14}C activity in under-ice copepods exposed to oil¹ and chemically treated oil¹ on the under-ice surface in the productivity study site at Cape Hatt, Baffin Island, during 18 May-2 June 1982². Sample sizes are given in Appendix A.

Variable	Period	Location	Treatment					
			control	oil ¹	Solidified Oil ¹	BP CTD +Oil ¹	BP 1100WD +Oil ¹	Corexit 9527 +Oil ¹
^{14}C activity per copepod (mgC/cop/h x 10 ⁻⁷)	Pre-spill 1	1	2.9 ± 0.8	0.2	0.6 ± 0.2	3.9 ± 1.3	1.9 ± 0.8	0.8 ± 0.2
		2	1.8 ± 1.2	3.1 ± 0.9	1.9 ± 0.8	0.5 ± 0.3	0.3 ± 0.1	10.1 ± 2.8
	Post-spill 1	1	4.4 ± 2.1	0.2 ± 2.1	4.1 ± 2.4	2.3 ± 0.3	5.9 ± 3.3	6.6
		2	5.0 ± 1.6	5.7 ± 0.1	4.5 ± 0.9	7.5 ± 3.2	0.8 ± 0.6	1.5 ± 0.8
	Post-spill 3	1	6.0 ± 0.6	2.9 ± 2.2	3.4 ± 0.7	6.1 ± 1.8	2.9 ± 0.1	5.4 ± 2.7
		2	4.4	6.0 ± 0.7	3.5 ± 1.1	6.2 ± 1.0	-0.2 ± 0.6	7.0 ± 0.9
Copepod secondary productivity (mgC/m ² /h X 10 ⁻³)	Pre-spill 1	1	13.6 ± 3.0	0.0	1.2 * 0.3	19.0 * 0.9	7.6 * 7.2	2.1 ± 1.6
		2	8.1 * 2.7	18.3 * 7.4	15.2 * 5.4	1.5 * 0.9	0.5 * 0.3	68.3 * 42.0
	Post-spill 1	1	23.5 ± 13.2	0.3 ± 0.9	10.1 ± 8.9	0.5 ± 0.0	1.6 ± 1.8	1.1
		2	39.6 ± 15.8	31.3 * 1.9	21.4 * 9.2	1.1 ± 1.4	0.2 * 0.1	0.3 ± 0.4
	Post-spill 3	1	24.3 ± 5.2	1.8 ± 0.8	7.8 ± 2.8	3.6 ± 1.8	1.5 ± 1.1	2,4* 0.8
		2	27.2	22.3 * 6.7	7.6 ± 1.2	6.4 ± 1.4	0.1 * 0.1	4.2 ± 1.9

¹ Unweathered Lagomedio crude oil.

² Oil treatments were applied on 23 and 24 May 1982.