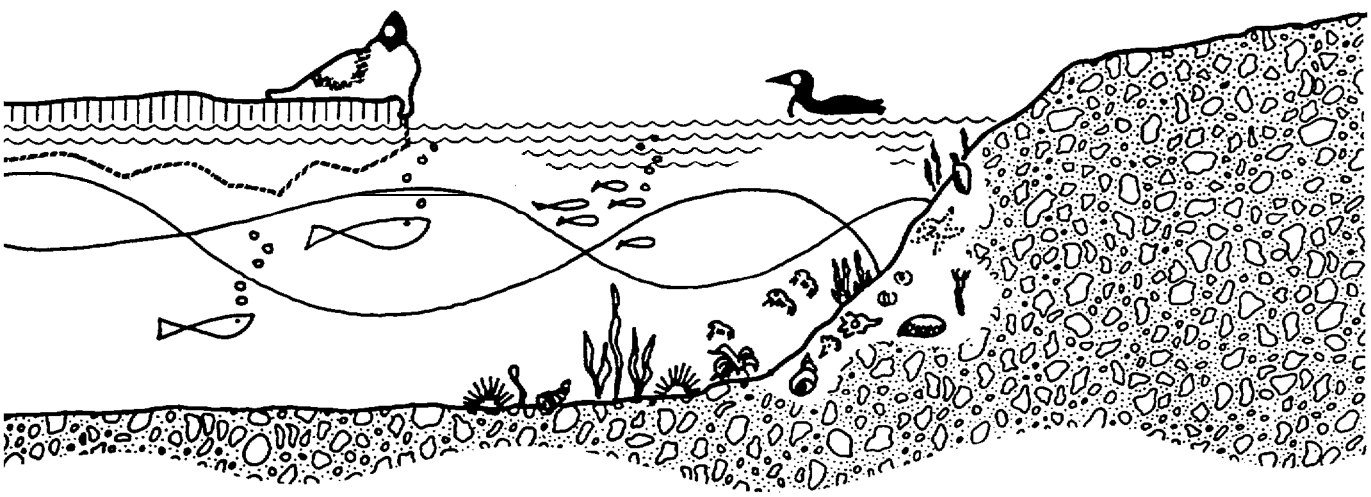
SPECIAL STUDIES



Baffin Island Oil Spill Project

WORKING REPORT SERIES

BIOS CAPE HATT

1982 STUDY RESULTS

FOREWORO

SPECIAL STUDIES 1982

This publication presents the results of selected studies which were associated with the Baffin Island Oil Spill (BIOS) Project or which were carried out at the BIOS Project site of Cape Hatt, Baffin Island. These studies were ancillary to the original design and/or core programs of the Project and, due to financial limitations, the BIOS Project did not directly fund them. Nevertheless, the study results are of relevance to the BIOS Project and are provided in order to both enhance the understanding of BIOS Project findings and to transfer the information to people working in related research. This publication has not undergone rigorous technical review by the BIOS management or technical committees and does not necessarily reflect the view of policies of these groups.

Three reports are contained herein:
The first report presents the second year of a two-year study on the effects of oil on under-ice biota. Portions of the under-ice experiment are related to the interpretation of effects from the original BIOS oil releases.

The second report contains information relevant to the BIOS dispersed oil discharge system design and the understanding of dispersed oil particle behaviour.

The third report describes a spin-off pilot study initiated after observing certain effects caused by the BIOS Project dispersed oil release. This study was expanded and continued with BIOS Project funding in 1983.

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4304 1. Cross, W.E. and C.M. Martin, 1983, In Situ Studies of Effects of Oil and Chemically Treated Oil on Primary Productivity of Ice Algae and on Under-ice Meiofaunal and Macrofaunal Communities. Special Studies - 1982 Study Results. (BIOS) Baffin Island Oil Spill Working Report 82-7.

4305 2. Mackay, O., Hossain, K., Chau, E., Poblete, B. and Nilsson, U., 1983, Behaviour of Subsurface Discharges of Oil, Gas and Dispersants. Special Studies - 1982 Study Results. (BIOS) Baffin Island Oil Spill Working Report 82-7.

4306 3. Engelhardt, R., Mageau, C. and Trucco, R., 1983, Behaviour Responses of Benthic Invertebrates Exposed to Dispersed Crude Oil. Proceedings of the Sixth Arctic Marine Oilspill Program Technical Seminar. pg. 32-51.

BAFFIN ISLAND OIL SPILL PROGRAM

SPECIAL STUDIES

1982 STUDY RESULTS

Part I: *In Situ* Studies of Effects of Oil and Chemically Treated Oil on Primary Productivity of Ice A' gae and on Under-ice Meiofaunal and Macrofaunal Communities

Part II: Behaviour of Subsurface Discharges of Oil, Gas and Dispersants

Part III: Behavioral Responses of Benthic Invertebrates Exposed to Dispersed Crude Oil

December, 1983

4304

In Situ STUDIES OF EFFECTS OF OIL AND CHEMICALLY TREATED OIL ON PRIMARY PRODUCTIVITY OF ICE ALGAE AND ON UNDER-ICE MEIOFAUNAL AND MACROFAUNAL COMMUNITIES

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EXECUTIVE SUMMARY

Effects of in situ applications of oil and chemically treated oil on the under-ice algae, meiofauna and amphipods were studied at Cape Hatt, northern Baffin Island. Immediate effects of oil on ice algae and meiofauna were studied by adding oil, solidified oil and oil treated with three different dispersants (Corexit 9527, BP 11OOWD, BP CTD) into large enclosures on the under-ice surface. The abundance and productivity of ice algae and the abundance of meiofauna were studied. In addition, distribution and life history data were collected for amphipods occupying under-ice, intertidal and shallow sublittoral habitats. The latter component of the study utilized the large-scale experimental spills carried out at the BIOS (Baffin Island Oil Spill) site in August 1981; we obtained pre-spill (May and August 1981) and post-spill (September 1981 and August and September 1982) data.

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. 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 four small bays at a depth of 3-5 m, or on the ice undersurface at the same locations; intertidal sampling was carried out 150 m of beach within each of the BIOS study bays. Experimental

studies on ice algae and meiofaunal communities were conducted on the under-ice surface in another bay over a water depth of 10 m.

Quantitative samples of amphipods were collected in the under-ice habitat at two times in May 1981 and 1982; in the shallow (3-5 m) sublittoral habitat in May, August and September 1981 and 1982; and in the intertidal habitat in August and September 1981 and 1982. Amphipods were identified, counted, weighed and measured. Spatial, seasonal and habitat variability in species composition, distribution and population structures, together with the effects of experimental oil releases in August 1981, were examined using ANOVA techniques.

The effects of treated and untreated oil on under-ice communities were studied during 14 May-2 June 1982. Productivity of under-ice algae was determined by a modification of the standard ^{14}C light and dark bottle technique (Strickland and Parsons 1972); ice and water samples were incubated *in situ* for 2 h periods. We attempted to trace carbon pathways in arctic under-ice communities by utilizing labelling and differential filtration to separate dissolved organic carbon and the particulate organic carbon contained in bacteria, algae and their meiofaunal consumers. We also compared these results with production estimates based on repeated measures of photosynthetic pigments, particulate organic carbon, and numbers and species or group composition of microalgae and meiofauna. Ratios between the various measures of standing stock were employed to obtain estimates of the physiological condition of the microalgae. The effects of oil, dispersed oil and solidified oil on production and productivity were determined relative to temporal and spatial controls.

Macrofauna.--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. Mysids were present throughout the water column in each bay, and were generally concentrated in the first metre of water just below the ice; mysid densities were extremely high and variable both within and among bays.

Ten and thirteen species of gammarid amphipods were collected on the under-ice surface at Cape Hatt in 1981 and 1982, respectively. Two species, Ischyrocerus sp. and Weyprechtia pinguis, were dominant in terms of numbers in both years, and Onisimus juveniles were abundant only in 1982. Weyprechtia pinguis and Gammarus setosus were dominant in terms of biomass in both years. Four and eighteen amphipod species were collected in the intertidal habitat in 1981 and 1982, respectively. Gammarus setosus was dominant in terms of both numbers and biomass in both years; Onisimus litoralis and Onisimus glacialis were abundant only in 1982. In the shallow (3-4 m) sublittoral habitat, 38 and 33 species were collected in 1981 and 1982, respectively. In both years, Orchomene minuta and Guernea sp. were dominant in terms of numbers, and Orchomene minuta, Anonyx nugax and Anonyx sarsi were dominant in terms of biomass.

Aside from Apherusa glacialis, all of the other species that were common on the under-ice surface were clearly of benthic origin. Apherusa glacialis was present only in May (under-ice and sublittoral habitats), and is commonly associated with pan ice in the open water season. Gammarus setosus, Onisimus litoralis and Onisimus glacialis almost exclusively inhabited intertidal areas during the ice-free season. *Weyprechtia pinguis* and *Ischyrocerus* sp., on the other hand, were more common in sublittoral than in intertidal habitats during summer. Species that were very rare on the under-ice surface together comprised a large percentage of the amphipods collected in the sublittoral habitat. Their occasional presence on the under-ice surface was likely due to chance.

Amphipod distribution on the under-ice surface was patchy, and was apparently related to the distribution of under-ice algae. In general, there were pronounced among bay differences in amphipod abundances. Analyses of variance and inspection of the data showed that each of the dominant species was more abundant in some bays than others. 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 to late May, and the predominant annual trend was a decrease in numbers or biomass from 1981 to 1982. *Onisimus* juveniles were the one exception: numbers increased markedly in all bays from 1981 to 1982.

Differences among bays in the densities and biomass of intertidal amphipods were considerable in both 1981 and 1982. During 1981, differences between August and September in abundance and biomass of the dominant intertidal amphipods were not consistent among bays. In 1982, differences between August and September were significant only for *Onisimus litoralis* and *Onisimus glacialis*: the former increased in abundance between August and September, whereas densities of *Onisimus glacialis* were generally lower in September. Year-to-year differences in the abundance and biomass of intertidal amphipods were considerable.

These differences 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. In turn, this indicates that 1981 was a year of successful breeding, at least in some locations. 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.

Significant interaction terms in analyses of variance have indicated oil effects on dominant amphipods in both under-ice and intertidal habitats. There was an unequivocal effect of the surface oil release in Bay 11 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 O+ 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 O+ 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.

Increases in density and biomass of juvenile Onisimus from 1981 to 1982 were much more pronounced in Bay 10 (some dispersed oil contamination) than in Bays 9 (dispersed oil release) or 11 (surface oil release). 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. was sparsely distributed in the sublittoral habitat of Bay 9 at the time of the dispersed oil release. Population structures of Ischyrocerus sp. on the under-ice surface indicated 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. Biomass of Ischyrocerus sp. 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. This suggests that biomass was reduced by the dispersed oil released in Bay 9 between the two sampling dates. Differences in the results for density and biomass suggest that there were size-specific effects. Additional spring sampling in subsequent years would be required to determine if populations of this species in the dispersed oil bay will recover.

Microalgae.--Phytoplankton in the water immediately below the ice at Cape Hatt during May 1982 occurred at low concentrations (<10^4 cells/L), and consisted primarily of pennate diatoms (48% of cell numbers) and microflagellates (45%). Biomass (chlorophyll *a* concentration) and productivity were also very low in sub-ice water during May 1981 and 1982-- 2 to 3 orders of magnitude below those in the bottom layer of ice. In both years, chlorophyll *a* concentrations were <2 mg/m^3, and net productivity rates (calculated by subtracting dark values from values measured in light chambers) were slightly negative.

The ice algal community in the bottom layer of ice during May 1982 was dominated by pennate diatoms (89% of algal cells in 83 control samples). Sixty-one of the total of 76 species or varieties of microalgae identified were pennate diatoms. *Nitzschia grunowii* and *N. frigida* were the most common species collected, comprising 54.8% and 15.2%, respectively, of total cell numbers in control samples. Total densities ranged from 1.7 to 384.7 x 10^7 $cells/m^2$, and mean densities increased progressively throughout the study period. Cell densities in most locations at Cape Hatt were typical of those reported for other arctic locations.

Differential filtration procedures were used to attempt to separate algae (>3 µm) from bacteria (<3 µm, >0.45 µm). Results of comparisons between filter types, however, indicated the possibility that the high concentrations of algae present in samples resulted in clogging of filters, rupture of algal cells and loss of cell contents through the filters. Thus, reported values of particulate organic carbon productivity (i.e. ^{14}C retained on filters) may underestimate actual carbon fixation by ice microalgae. Different techniques were used to estimate dissolved organic carbon (DOC) productivity (smaller sample volumes, lower filtration pressure), and the reported values for DOC are considered to be more realistic estimates. For comparative purposes, all data reported herein are based on the filter type in most common use (0.45 µm pore size).

Chlorophyll _a_ concentrations in control ice samples varied from 0.6 to 23.2 mg/m^2; mean chlorophyll concentration increased from 9.1 mg/m^2 on 18-19 May to 15.7 mg/m^2 on 1-2 June 1982. Carbon to chlorophyll ratios for the ice algal community increased from 16 to 30 over the study period. A similar increase in chlorophyll concentration (6.6 to 10.9 mg/m^2) occurred at Cape Hatt during 16-30 May 1981, and these values are typical of ice algal biomass reported in a number of other arctic locations. Considerably higher concentrations of chlorophyll under the ice have been reported (e.g., in Pond Inlet during 1979; Cross 1982a), and differences are likely a result of differences in snow cover.

The amount of light reaching the under-ice surface at Cape Hatt in 1982 varied over an order magnitude because of variability in snow cover and sky condition. Particulate carbon productivity of ice algae increased with increasing light, from near zero at the lowest light levels to a maximum of 2.95 $mgC/m^2.h$. Productivity and productivity per unit chlorophyll increased over the study period. Our data on particulate carbon productivity from 1982 are similar to those from Cape Hatt in May 1981 (Cross 1982b) and from Barrow, Alaska in May-June 1972 (Clasby et al. 1973).

Productivity rates of dissolved organic carbon (DOC) have not previously been measured for under-ice algae. At Cape Hatt in 1982 DOC productivity was considerably higher than particulate carbon productivity: from 0.1 to 9.3 $mgC/m^2.h$ (overall mean of 3.3 $mgC/m^2.h$). Regardless of the source of the observed radioactive DOC, this material was originally fixed by ice algae, and must be included in estimates of total productivity. On average, DOC accounted for 70% of total (particulate + dissolved) carbon production. If such high DOC productivity is characteristic of the ice algae community, previous reports on particulate carbon fixation may have underestimated ice algal productivity to a significant extent.

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.

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. Most interactions between period and treatment factors were significant (13 of 16 cases). In these cases, the significant interaction terms meant 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. It was, therefore, necessary to examine the nature of the period-to-period variability among treatments to determine whether it was consistent with expected oil effects.

Inspection of the data showed little evidence for any of the 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, 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 was 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 of the bloom and were also evident in control samples at Cape Hatt during May 1981 and 1982. 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.

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.

Meiofauna.--The under-ice meiofauna (invertebrates in the size range 40 µm to 1 mm) 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 89.3% of total numbers collected during the study. Nematodes and polychaetes made up 6.3% and 3.5% of total numbers , respectively. Rotifers and gastropod veligers were also present in very small numbers. Cyclopoid and harpacticoid copepods comprised 82.3% and 17.2%, respectively, of the ice copepod fauna. 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.

Total meiofaunal densities at the productivity site in Bay 13 (control samples only) averaged approximately 54,000 individuals/m^2; copepods alone contributed about 50,000 ind./m^2. Under-ice copepod densities were higher, and nematode densities generally lower, than those previously reported in arctic and sub-arctic waters. Meiofauna were relatively evenly distributed on a small scale (i.e.. within the 1.2 m^2 enclosures), whereas variation on a larger scale (among enclosures in Bay 13 and among bays) was considerable, and was evident for all meiofaunal groups.

There are several possible sources of this large scale variability, including snow depth, light intensity and concentrations of microalgae. Light level was positively correlated with densities of nematodes, copepods and, to a lesser extent, polychaetes. Similar correlations were evident between chlorophyll a concentrations and the densities of each of these groups.

Nematode densities in unoiled control samples increased significantly over the study period, whereas copepod and polychaete abundances in control samples from Bay 13 were relatively constant over the study period. However, this was not true for all particular types of copepods. Densities of cyclopoid copepodites decreased from 18 May-2 June; at the same time, densities of cyclopoid adults increased. In contrast, harpacticoid copepods showed no obvious temporal variation related to stages of development.

Analysis of variance showed significant treatment x period interactions (oil effects) for two of the meiofaunal groups, copepods and polychaetes. 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. Nematodes were unaffected by any of the oil treatments; densities increased throughout the study period in each treatment and in each location. The observed reductions in copepod and polychaete densities were 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 during the post-spill period. This increase was more apparent for copepods than for polychaetes, probably indicating a faster recovery rate. It is not known whether the copepods or polychaetes were killed outright or merely displaced from the ice undersurface.

Copepod densities decreased in response to dispersed oil, whereas nematode densities did not. The differences in our results for copepods and nematodes are 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 1981; cf. Coull et al. 1981). In the four BIOS study bays at Cape Hatt, nematode to copepod ratios were low in May 1982. If this type of 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. 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.