June 1980
FRI-UW-8011

PRUDHOE BAY DRILLING FLUID DISPOSAL STUDY, ENVIRONMENTAL EVALUATION: PERIPHYTON AND SETTLING BLOCK COMMUNITY ANALYSIS

by

Ronald M. Thom

and

Roy E. Nakatani

Final Report to
Northern Technical Services (NORTEC)

June 1980

June 1980
FRI-UW-8011

FISHERIES RESEARCH INSTITUTE
College of Fisheries
University of Washington
Seattle, Washington 98195

PRUDHOE BAY DRILLING FLUID DISPOSAL STUDY, ENVIRONMENTAL EVALUATION: PERIPHYTON AND SETTLING BLOCK COMMUNITY ANALYSIS

by

Ronald M. Thom and Roy E. Nakatani

Final Report to

Northern Technical Services (NORTEC)

June 1980

Approved:

Submitted: June 20, 1980

Robert L. Burgner
Director

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

This report summarizes the analysis of benthic communities associated with submerged artificial substrata placed near a drilling fluid disposal site and a control site in the Beaufort Sea near Prudhoe Bay, Alaska. The artificial substrata consisted of plexiglass plates and cement blocks. A diatom assemblage formed on the plates during one season, and an assemblage of small infauna colonized the sediment occurring on the tops of the blocks during all seasons. The qualitative and quantitative aspects of the communities at these two sites were compared to assess and evaluate the effects of drilling fluid disposal on the benthic biota. The analysis is carried out on collections made during summer (August 1979), winter (January 1980) and spring (April 1980). Additional data are presented on the trace metal content of specimens of selected species from both sites.

Two progress reports (November 1979, March 1980) preceded this this final report. The preliminary results contained within the progress reports are presented in final form herein along with previously unreported data from the last study period (spring 1980).

The biological material that attached to the plexiglass plates at the sites is generally referred to as periphyton. In most instances, periphytic communities are dominated by small algae and animal species that are able to persist on the smooth surface of the plates. The periphytic community can be relatively delicate and sensitive to variations in the environment. For these reasons, there is a long history ($\sim$ 70 years) of the use of periphytic communities as indicators of environmental quality (Patrick 1973). These past studies have been largely concentrated in freshwater habitats. However, studies in the marine environment (i.e. Hohn 1959, Archibald 1972, Harger and Nassichuk 1974, Sullivan 1976, Thom 1978) indicate that periphyton communities respond to pollution in a manner similar to those in freshwater. Two quantifiable parameters of the diatom component of this community are affected by pollution. In general, the number of species (i.e. species richness), and species diversity (i.e. the number of species and their abundances) are modified by pollution. Changes in species abundances (the species and their abundances) depend upon physiological and anatomical tolerances of the species in the vicinity of the test substrata to the chemical and physical environment. These species abundance changes generally result in the exclusion of certain intolerant species and the increased dominance of tolerant species. In turn, the parameters of species richness and diversity are also modified. An assemblage dominated by one or a few tolerant species usually has a correspondingly low species richness and diversity. In the present study, we examine the diatom assemblage on the plexiglass plates for modifications in the above two parameters. We have not been able to locate in the literature previous investigations on the impact of drilling fluid on the structure of marine benthic diatom assemblages.

Water-borne sediments settled on the upper surface of the cement blocks placed at the two sites. Several taxa of invertebrate infauna and a few non-motile invertebrate taxa colonized this sediment in appreciable abundances. We examined the differences between sites in the abundances of the colonizing taxa. Like diatom assemblages, benthic invertebrate assemblages have been shown to be sensitive indicators of environmental modifications. Furthermore, changes in the parameters of benthic invertebrate assemblages are qualitatively the same as those seen in benthic diatom assemblages.

Tagatz and Tobia (1978) investigated the impact of various concentrations of barite ($BaSO_4$) (the primary component of oil drilling muds) on taxa abundances of infaunal assemblages. The assemblages were developed from planktonic larvae in aquaria containing sand and flowing estuarine water. They found that significantly fewer individuals and species colonized aquaria sand covered by barite than in control aquaria or aquaria containing a one part barite to 10 parts sand mixture. Annelids were particularly affected and mollusc populations were somewhat less impacted. Tagatz and Tobia concluded that sediment containing large quantities of this compound could adversely affect the colonization of benthic organisms.

Certain organisms that were associated with the experimental apparatus used in the present study were analyzed for concentrations of several trace metals. Drilling fluid contains several trace metals of which barium is in highest concentration. In order for benthic organisms to respond to pollutional disturbance, there must either be some form of contact between the pollutant and the sensitive portion of the organism or there must be some disruption of mechanisms involved in the normal functioning of the organism (e.g. turbidity reducing photosynthesis). Organisms can take up trace metals from the environment and may concentrate these metals in their tissues. As an initial investigation of the concentration of certain trace metal components of drilling fluids in benthic biota, we analyzed the tissues of specimens from both sites.

MATERIALS AND METHODS

Study Sites

The two study sties were located in the Beaufort Sea near Prudhoe Bay, Alaska. TP4 (70°27′22"N, 148°16′01"W) was the experimental above ice disposal site, and was located approximately 13 km north of Heald Point. Heald Point forms the eastern tip of Prudhoe Bay (Fig. 1). Drilling fluid was discharged into diked areas positioned over TP4 in April 1979. To assure that the fluid reached the sea floor, several holes were drilled through the ice shortly before the discharge. TP3

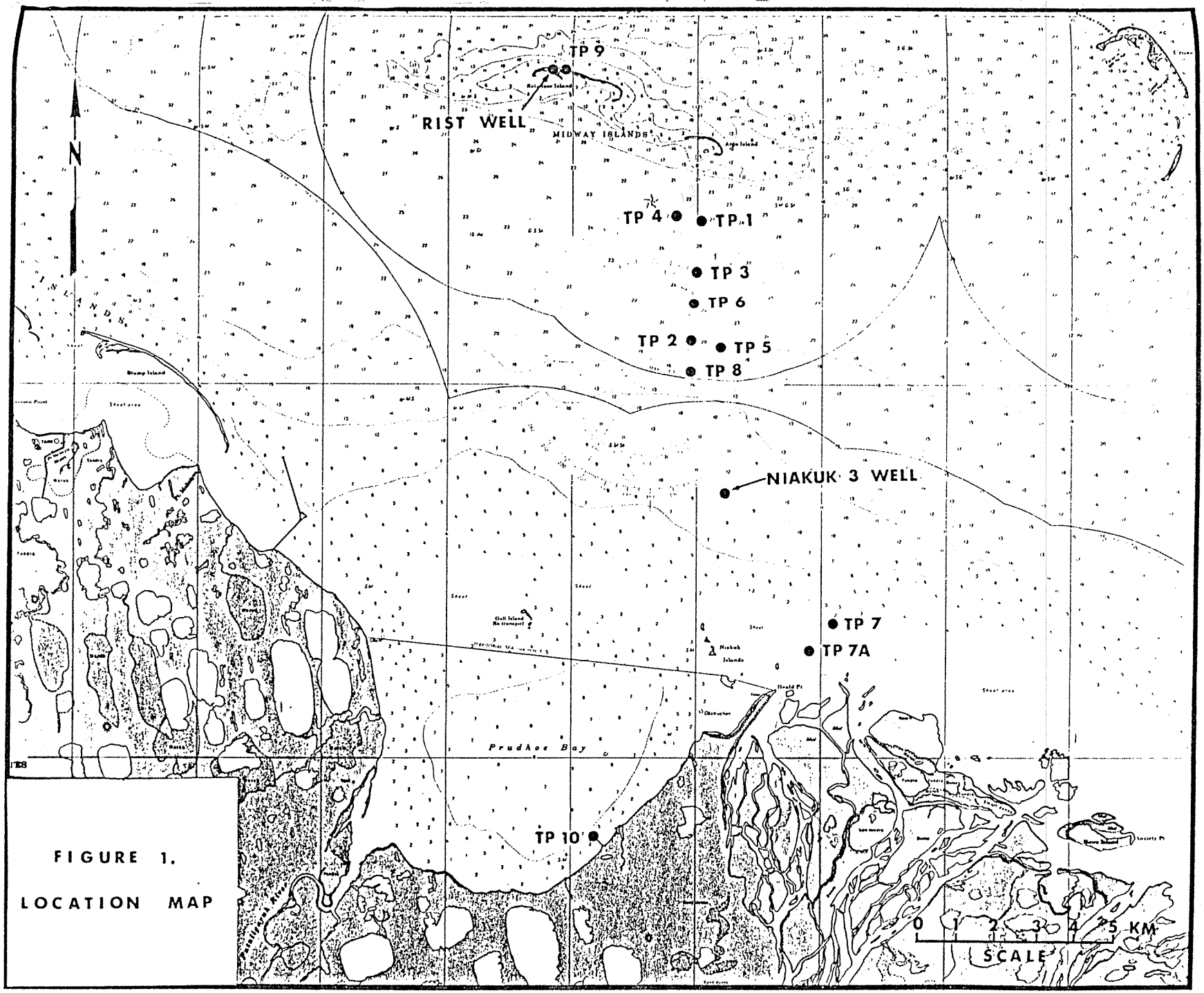

FIGURE 1.

LOCATION MAP

(70°26′34"N, 148°15′22"W) was the control site for our study and was located about 11 km north of Heald Point (Fig. 1).

Experimental Apparatus

The apparatus used consisted of an eight sided cement patio block attached by rope to a $0.1m^2$ plexiglass plate (Fig. 2). The patio block formed the anchor for the apparatus and rested horizontally on the bottom. The surface area of the top of the block in this position was approximately $0.12m^2$. The plate was vertically oriented, suspended 1 m above the block, and was tied to a float. The depths at the sites were similar (approximately 6 m). Several sets of the apparatus were set out at each site prior to the experimental drilling fluid disposal in April.

Sampling

Sampling was conducted on 2-3 August 1979, 7 and 9 January and 1-5 May 1980. Divers using SCUBA recovered the plates and blocks. The material attached to the plates was removed by vigorous brushing with a denture brush. This material was placed in small vials and preserved in a 5% solution of formalin. The sediment on the top of the block was scooped carefully into plastic whirlpak bags and preserved in 10% formalin. Large organisms (e.g. starfish, macroalgae) associated with the ropes and blocks were placed in plastic bags and frozen. This latter material was analyzed for trace metal content. One to five of the plate and block set ups were recovered from each site during each sampling trip. The number varied due to the loss of several of the set ups from TP4 between samplings.

Sample Processing

A preliminary microscopic examination of material brushed from the plates collected in August revealed that diatoms dominated all samples. Very few other organisms were noted. Most of the diatom cells (i.e. >90%) were alive when preserved as indicated by the presence of chloroplasts in the specimens examined.

The identification of species of diatoms using classical methods requires cleaned diatom frustules. To accomplish this, 5 ml of material from the bottom of the sample vials (the vials were undisturbed for at least 48 hr prior to extraction of the subsample) was placed into a centrifuge tube and centrifuged for 3 min at high speed. The liquid was gently decanted and 5-7 ml of tap water was added to the tube. The tube was shaken vigorously, centrifuged and decanted. This washing process was repeated four more times to remove formalin and salt from the material. Concentrated nitric acid was then added to the

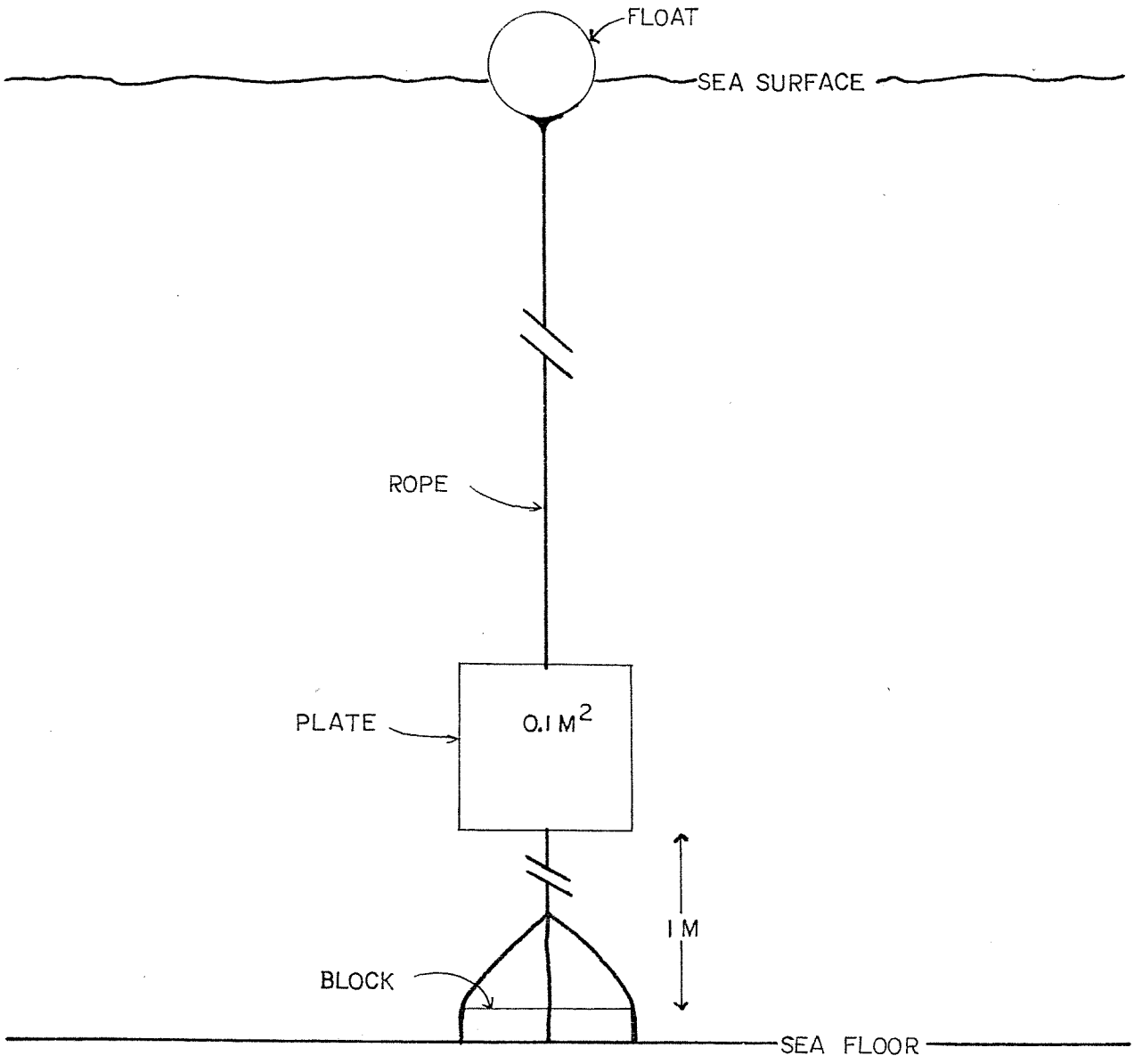

Figure 2. The experimental apparatus.

tube and the contents were boiled for 30 min under a fume hood. After cooling, the cleared frustules were washed with water four times as above. The material was then shaken and a small subsample was withdrawn from the middle of the solution with a pipette. This material was mounted in Hyrax mounting media on a standard microscope slide. The first 500 diatom frustules encountered at random at a magnification of 1250X under a compound microscope were identified and enumerated. A species-area curve constructed for a sample from TP3 revealed that very few new species were encountered above a sample size of 350 frustules. The taxonomic literature consulted was the standard references suggested by Dr. Charles Reimer, curator of diatoms at the Philadelphia Academy of Sciences, and Dr. C. David McIntire of Oregon State University. Dr. McIntire kindly allowed us to use his literature on diatom taxonomy and checked the identifications of some of our specimens. All species encountered on the slides were photographed, sketched and measured. Several species were not located in the literature, and these were assigned a number.

The sediment from the top of the blocks was carefully rinsed through a 125 μm mesh screen. All specimens retained on the screend were identified to the lowest taxon possible and enumerated. Mr. Jeff Cordell, a specialist in harpacticoid copepod taxonomy, identified all of the specimens within this group.

Analysis for trace metal content of selected species was carried out by Mr. Sam Felton of the Fisheries Research Institute. Species were selected for analysis if they were represented in collections from both sites during a sampling period and if there was sufficient material obtained for the chemical analyses.

RESULTS AND DISCUSSION

Miscellaneous Observations

Physical-chemical data (from NORTEC) showed that water temperatures near the sites varied from -1.98 to -1.32° C between April and August 1979. Current speeds varied daily with a maximum range of approximately 1-11 cm/sec. The salinity at TP6 (see Fig. 1) on 17 April 1979 was 32.80 ppt. Ice breakup near the sites in 1979 occurred in late June and early July. All ice had disappeared from the area by 12 July. Divers reported that turbidity was high at both sites in August.

Sampling was conducted from a boat in August and from land vehicles during the other sampling times. Divers (NORTEC personnel) were responsible for removing the plates and blocks and their observations are pertinent to the present results. In August, the divers noted that several of the set ups had become entangled and certain portions of

some of the plates showed evidence of scraping due to this entanglement. We, therefore, confined comparisons to relative abundance estimates and did not attempt to analyze the samples for chlorophyll content or biomass. Since the scrapes were density independent and confined to small areas of the plates, comparisons based on relative abundances were appropriate.

Sediment associated with the blocks was also disturbed during collection. A certain amount of the uppermost sediment was lost, and we assumed that this loss was approximately the same between the sites. The presence of large numbers of epibenthic taxa such as harpacticoid copepods suggested that losses were not substantial.

Diatom Assemblages

Periphyton was found on the plates only from August samples. A thick ice covering probably inhibited the development of periphyton during the other seasons.

Data on species-area relationships averaged over five August samples revealed that a subsample of 500 cells was adequate to assess species richness (Table 1). The number of new species encountered in sample sizes above approximately 300 cells were few in comparison to increases below this count.

The average number of diatom species was not significantly different between TP3 and TP4 (Table 2). This result was also true for species diversity as measured by Shannon's Index (H') (Table 2). Evenness, a component of species diversity that reflects the distribution of abundances among species in a sample, was also very similar between sites (Table 2). Noteworthy is the fact that these subtidal assemblages are diverse as compared to diatom assemblages from other marine and estuarine areas (McIntire and Overton 1971). Diversity has been shown to be low in the Arctic in other groups of organisms (i.e. polychaetes, Bilyard and Carey 1980) and is attributed to the geologically relatively new habitat. However, a rapidly reproducing assemblage in a new environment where disturbance is high may exhibit a relatively high species diversity (Levin and Paine 1974). The diversity of arctic subtidal marine diatom assemblages has not been reported previously.

Eighty-three diatom taxa were distinguished in the samples (Table 3). A large proportion (i.e. 42%) of these entities could not be identified to species, and approximately one-third of the remaining taxa varied enough from published descriptions that we felt it necessary to distinguish these with a question mark (Table 3). Notable is the fact that several of the taxa (e.g. Cymbella) are reported only from freshwater habitats. This may indicate that there is a substantial freshwater influence at the sites. The large number of unnamed

Table 1. Species-area relationship based on five diatom samples from August 1979. $\bar{X}$ = mean; SD = standard deviation.

Sample size no. cells	Total no. species $\bar{X}$	SD	Gain in no. species $\bar{X}$	SD
0-50	14.8	2.63	14.8	2.63
51-100	22.4	2.70	7.5	1.00
101-150	27.0	2.55	4.6	1.67
151-200	31.4	2.30	4.4	1.95
201-250	34.2	3.11	2.8	1.48
251-300	36.4	1.94	2.2	1.30
301-350	39.2	3.27	2.8	1.92
351-400	40.6	3.58	1.4	1.14
401-450	42.4	4.39	1.8	1.30
451-500	43.8	4.87	1.4	0.89

Table 2. Number of species (S), species diversity (H'), and evenness (E) of diatom assemblages at the two sites in August 1979. $\bar{X}$ = mean; SD = standard deviation.

Plate no.	Sites: TP3 0	TP3 A	TP3 5	TP3 $\bar{X}$	TP3 SD	TP4 23	TP4 24	TP4 26	TP4 $\bar{X}$	TP4 SD	t-test
S	37	46	47	43.3	5.51	43	37	36	38.7	3.79	Not sig.(P=0.05)
H'	2.13	2.53	2.55	2.40	0.237	2.27	2.36	2.44	2.36	0.085	Not sig.(P=0.05)
E	0.59	0.66	0.66	--	--	0.60	0.65	0.68	--	--	

Where:

S = no. of species

$H' = -\Sigma\left(\frac{Ni}{N}\right) \log \left(\frac{Ni}{N}\right)$, N_i = no. of individuals in species i

N = total no. of individuals

$E = \frac{H'}{\log S}$ S = no. of species

Table 3. Mean ($\bar{X}$) and standard deviation (SD) of diatom species abundances at the two sites in August 1979 (N = 3). Counts are from a sample of 500 cells. A question mark next to a name indicates that the specimen differs slightly from published descriptions.

Species	TP3		TP4	
	$\bar{X}$	SD	$\bar{X}$	SD
Achnanthes lanceolata var. 1	0.3	0.58	0	-
A. longipes	0.7	1.15	0	-
A. minuitissima var. cryptocephala	12.3	4.16	9.3	4.04
A. 9	14.3	7.09	20.0	4.00
Amphora coffeaeformis	0.3	0.58	0.7	0.58
A. exigua	0.3	0.58	2.0	2.00
A. laevis	1.7	1.53	5.0	2.65
A. proteus	3.0	1.00	2.7	2.52
A. 4	0.3	0.58	0	-
Cocconeis costata	0.7	0.58	1.3	0.58
C. placentula var. 1	0.3	0.58	0	-
C. scutellum var. stauroneiformis	1.0	1.00	1.0	1.00
C. 2	0	-	0.3	0.58
Cymbella 1	5.3	6.11	62.0	52.83
Diploneis 1	0.3	0.58	0	-
Fragilaria cylindrus	1.7	1.53	2.3	1.53
F. pinnata	0	-	0.3	0.58
Gomphonema acuminatum	4.7	2.52	1.0	0.00
G. lanceolatum?	0.3	0.58	0	-
G. 1	5.3	1.53	6.0	1.73
Gyrosigma acuminatum?	1.0	1.73	0	-
G. attenuatum?	1.0	1.00	0.3	0.58
G. fasciola	0.3	0.58	0	-
G. 1	1.7	2.89	0	-
Navicula agnita?	195.3	31.56	169.3	48.35
N. crucigera	0.7	0.58	0.7	1.15
N. cryptolyra?	5.3	2.08	1.7	1.15
N. directa?	88.0	14.80	67.3	26.16
N. dissipata?	12.0	7.55	3.0	1.00
N. dithmarsica?	1.3	1.15	1.0	1.00
N. gysingensis	0.3	0.58	1.0	1.73
N. hungarica f. linearis	2.3	2.08	1.3	1.53
N. litoricola	0.3	0.58	0	-
N. lucens?	1.0	1.00	0.3	0.58
N. luzonensis	2.3	0.58	7.0	6.08
N. peregrina?	0.3	0.58	0	-
N. salinarum f. minima?	0	-	0.3	0.58
N. Utermöhlii?	0.3	0.58	0.7	1.15
N. 1	0.3	0.58	0	-
N. 2	0.3	0.58	1.7	1.53
N. 4	6.7	1.53	4.0	1.00
N. 5	0.3	0.58	0	-
N. 6	1.3	1.15	0.7	1.15

Table 3. Mean ($\bar{X}$) and standard deviation (SD) of diatom species abundances at the two sites in August 1979 (N = 3). Counts are from a sample of 500 cells. A question mark next to a name indicates that the specimen differs slightly from published descriptions - continued.

Species	TP3		TP4	
	$\bar{X}$	SD	$\bar{X}$	SD
N. 7	20.7	29.94	57.3	27.74
N. 8	1.7	2.08	0	-
N. 9	0.3	0.58	0	-
N. 10	0.7	0.58	1.3	1.53
N. 16	0	-	1.0	1.73
N. 21	0	-	0.3	0.58
N. 22	0.7	1.15	0.3	0.58
N. 24	0.3	0.58	0	-
N. 25	0.7	0.58	0	-
N. 26	0.7	1.15	0.3	0.58
N. 30	0	-	0.3	0.58
N. 31	0	-	0.7	1.15
N. 32	0	-	1.0	1.73
N. 33	0	-	0.3	0.58
N. 35	3.0	2.65	6.7	6.35
N. 36	1.0	1.73	0.7	1.15
N. 37	0.3	0.58	0	-
Nitzschia acuminata	0.3	0.58	0	-
N. angularis	2.0	1.00	2.3	0.58
N. closterium	0	-	0.7	1.15
N. frustulum	1.0	1.00	0.3	0.58
N. lanceolata?	5.7	9.81	2.3	1.53
N. socialis var. kariana	0	-	0.3	0.58
N. subtilis?	0	-	2.3	1.53
N. thermalis?	10.7	11.02	7.7	8.62
N. vermicularis	1.3	1.53	0	-
N. vitrea?	11.7	9.61	9.3	6.81
N. 1	8.3	9.71	0.3	0.58
N. 4	6.0	5.57	11.7	5.13
N. 6	6.3	6.03	1.0	1.73
Pinnularia quadratarea	4.3	1.15	0.3	0.58
P. 3	0.7	1.15	0	-
P. 4	0	-	0.3	0.58
Stauroneis anceps var. javanica	14.3	5.77	9.3	5.86
Surirella ovalis	0.7	0.58	0	-
Synedra investiens	0	-	1.0	1.00
S. puchella var. lacerata	1.7	1.53	2.3	2.31
S. ulna	1.0	1.00	2.0	2.65
S. 3	14.0	18.25	1.0	1.00
Thallasiosira balthica	9.7	3.21	7.3	2.08

entities can be explained by the fact that no comprehensive list of arctic subtidal benthic diatoms exists. Furthermore, the unique and isolated nature of the Arctic Ocean may account for this unique flora.

The majority (57%) of the taxa were found at both sites (Table 3). Spearman's rank correlation coefficient (R) computed using ranks of average cell counts was very high (R = .91) between sites. This suggests that there was little overall difference in the species abundances between the sites. At least two of the ten most abundant taxa (i.e. Cymbella 1, Navicula 7) showed substantial between-site differences, however (Table 3).

Infaunal Assemblages

The samples from August were dominated by harpacticoid copepods and newly settled polychaetes. In this stage of development, most polychaetes are extremely difficult to identify to a taxon lower than family. For the practical purposes of this investigation we felt it appropriate to identify all polychaete specimens to family, thus avoiding some misinterpretations of between site and among season comparisons of taxa abundances. The most abundant group encountered were harpacticoid copepods. The majority of specimens collected were mature and were identified to species when the size and condition of the specimen allowed this.

There were large differences in the abundances of infaunal assemblages between the two sites in the August collections (Tables 4 and 5). Polychaetes and harpacticoid copepods were in far greater abundance in the samples from TP3. Although between site differences were evident within other groups, the count values were highly variable.

Our results agree with those of Tagatz and Tobia (1978) with regard to the adverse affect of drilling fluids on the colonization of sediments by annelids. However, they could detect no significant effect of barite on colonization levels of arthropods. They used a larger mesh screen (1 mm) to seive their samples than we did (125 μm). Harpacticoid copepods are generally very small (< 1 mm in length) and are not effectively sampled with a 1 mm mesh seive. The distribution and abundance of harpacticoid copepods are largely determined by sediment grain size and quality. Although we did not analyze our samples for these parameters, a difference in grain size associated with drilling fluid disposal could explain the observed differences. Important is the fact that harpacticoids form a major component of the diet of many bottom feeding fish.

All but two of the experimental set ups at TP4 were lost between August and January. Large differences in the infaunal assemblages existed between the sites again in January. Differences appeared to be less pronounced in the samples from May (Tables 4 and 5). This latter

Table 4. The average of several replicates within a season, or the total count if only one sample was collected, of numbers of individuals within invertebrate phyla. Ectoprocta and Foraminifera are excluded from these counts. Sample size in parentheses.

	August		January		May	
Phyla	TP3(3)	TP4(3)	TP3(4)	TP4(1)	TP3(5)	TP4(1)
Annelida	61	0	27	0	43	19
Arthropoda	575	0	18	0	53	12
Mollusca	1	0.3	2	1	5	3
Nematoda	0	0	5	1	15	5
Others	1	0.3	0.4	0	3	3

Table 5. Summary of data on taxa associated with patio blocks. Blank = absent; $\bar{X}$ = mean of counts, (No./0.12m^2); SD = standard deviation; P = present on at least one block; T = total.

TAXA	August				January			May		
	TP3(N=3)		TP4(N=3)		TP3(N=4)		TP4(N=1)	TP3(N=5)		TP4(N=1)
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	T	$\bar{X}$	SD	T
Algae:										
Antithamnionella sp.					P					
Odonthalia sp.					P					
Phycodrys sp.					P			P		P
Annelida:										
ampharetidae					6.8	10.31		5.2	11.08	6
capitellidae					3.0	2.00		2.6	3.71	3
cirratulidae					1.2	1.89		1.8	2.95	
dorvilleidae	12.3	10.26			0.2	0.50		0.4	0.89	
flabelligeridae	0.7	1.15			0.8	1.50		0.8	1.30	
hesionidae	8.7	10.79			2.5	3.79		0.2	0.45	1
lumbrineridae					0.2	0.50		0.6	1.34	
maldanidae					1.2	2.50		0.8	1.79	
nereidae					0.8	0.96		1.2	1.30	2
orbiniidae								0.2	0.45	
polynoidae					0.8	0.50		2.5	0.71	1
sigalonidae								0.2	0.45	
spionidae	4.0	3.0			1.7	1.37				
syllidae					7.5	10.47		26.6	40.33	5
terebellidae	1.3	1.15			0.5	0.58				1
unidentified juveniles	35.0	43.71						0.2	0.45	

Table 5. Summary of data on taxa associated with patio blocks. Blank = absent; $\bar{X}$ = mean of counts, (No./0.12m^2); SD = standard deviation; P = present on at least one block; T = total (continued).

TAXA	August				January			May		
	TP3(N=3)		TP4(N=3)		TP3(N=4)		TP4(N=1)	TP3(N=5)		TP4(N=1)
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	T	$\bar{X}$	SD	T
Arthropoda:										
Acarina										
Halacaridae					0.2	0.50		0.6	1.34	
Calanoida										
copepodite	0.3	0.58			0.2	0.50				
nauplius	0.3	0.58								
Cladocera	0.3	0.58								
Cumacea										
Brachydiastylis resima					0.2	0.50		3.2	1.92	
Diastylis sp.								0.2	0.45	
Lecon fulvus					0.2	0.50				
L. sp.								0.3	1.34	
Cyclopoida										
Euryte longicauda					0.2	0.50				
Gammaridea										
Aceroides latipes					0.5	0.58				
Apherusa sp. (juv.)	1.0	1.73								
Bathymedon sp.					0.2	0.50		0.8	1.30	
Gammarus loricatus	0.3	0.58								
Halirages sp.								0.6	0.89	
Ischyrocerus sp.					0.2	0.50				
Lysianassidae								0.2	0.45	
Melita sp.					0.2	0.50				
Pleustidae								0.4	0.55	
Stenothoidae								0.2	0.45	
Unidentifiable								0.2	0.45	

Table 5. Summary of data on taxa associated with patio blocks. Blank = absent; $\bar{X}$ = mean of counts, (No./0.12m^2); SD = standard deviation; P = present on at least one block; T = total (continued).

TAXA	August				January			May		
	TP3(N=3)		TP4(N=3)		TP3(N=4)		TP4(N=1)	TP3(N=5)		TP4(N=1)
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	T	$\bar{X}$	SD	T
Harpacticoida										
Ameira sp.					0.2	0.50		3.4	5.64	
Ameiridae (juv.)	0.7	1.15			0.2	0.50				1
Cleotididae (copepodite)	1.0	1.73								
Cleotididae (juv.)					0.2	0.50				
copepodites (unidentified)	154.7	122.65						19.0	42.49	1
Dactylopodia sp.										1
Danielssenia typica	101.5	34.65			0.2	0.50		2.8	6.26	
D. sp.	6.7	9.87								
Diosaccidae (juv.)					0.2	0.50				
Ectinosomatidae	212.0	94.06			5.2	4.42		10.2	19.56	3
Ehydrosoma sp.								0.8	1.79	
Eurycletodes major	1.3	1.53								
Haloschizopera sp.	1.3	2.31								
Harpacticus sp.					0.5	0.58				
nauplii	12.4	16.07			1.2	2.50		2.8	4.76	
Paradactylopodia brevicornis	0.7	1.15								
Paralaophonte perplexa										1
Paramphiascella sp.					0.2	0.50		0.6	0.89	
Proameira sp.	12.3	9.45			1.0	2.00		1.4	3.13	2
Rhizothrix curvata								1.2	1.64	
R. sp.					0.2	0.50				
Stenhalia nuwukensis	1.3	0.58			0.5	1.00		0.2	0.45	1
S. sp.	5.0	3.46			0.8	0.96		1.8	2.49	1
Tachidiidae (unid. sp.)	0.3	0.58								
Tegastes sp.					0.2	0.50				

Table 5. Summary of data on taxa associated with patio blocks. Blank = absent; $\bar{X}$ = mean of counts, (No./0.12m^2); SD = standard deviation; P = present on at least one block; T = total (continued).

TAXA	August				January			May		
	TP3(N=3)		TP4(N=3)		TP3(N=4)		TP4(N=1)	TP3(N=5)		TP4(N=1)
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	T	$\bar{X}$	SD	T
Thalestridae (copepodite)								0.4	0.89	
Tisbe sp.								0.8	1.79	1
Typhlamphiascus sp.								0.4	0.89	
Isopoda										
Munna sp.								0.2	0.45	
Ostracoda					2.5	2.38		0.4	0.55	1
Tanaidacea										
Leptognathia sp.	0.7	0.58			0.2	0.50		1.8	3.49	
Typhlotanais sp.					0.5	0.58				
Cnidaria:										
Actinaria					0.2	0.50		0.6	0.89	
Echinodermata:										
Holothuroidea					0.2	0.50				
Ectoprocta:										
Cheilostomata					P		P			
Cyclostomata					P		P	P		
Foraminifera:	P		P		P		P	P		P

Table 5. Summary of data on taxa associated with patio blocks. Blank = absent; $\bar{X}$ = mean of counts, (No./0.12m^2); SD = standard deviation; P = present on at least one block; T = total (continued).

TAXA	August				January			May		
	TP3(N=3)		TP4(N=3)		TP3(N=4)		TP4(N=1)	TP3(N=5)		TP4(N=1)
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	T	$\bar{X}$	SD	T
Mollusca:										
Bivalvia										
Astarte sp.							1	3.4	7.06	
Macoma sp.					0.2	0.50		0.2	0.45	1
Nucula sp.								0.8	0.84	1
Portlandia sp.					0.2	0.50				
Yoldia sp.								0.2	0.45	
Unidentified (crushed)	1.3	2.31			1.2	2.50				
Gastropoda										
Neptunea sp.								0.4	0.89	1
Nudibranchia			0.3	0.58						
Nematoda:					4.8	2.06	1	14.6	15.32	5
Nemertea:	0.3	0.58						1.4	1.67	1
Sipuncula:	0.7	1.15						1.2	1.64	2

result may indicate recovery of the benthic area in the vicinity of TP4.

Trace Metals

Most trace metal concentrations were higher in specimens from TP3 as compared to those from TP4 in January (Table 6). An exception was the concentrations of Cu and Zn in the red alga Phycodrys. In May, the concentrations of most metals were again highest in specimens from TP3. Barium concentrations were highest in specimens from TP3 except for sea raspberries (May) and worm tubes (January).

SUMMARY AND CONCLUSIONS

We assume that at least some of the drilling fluid deposited on the ice fell in the area of the blocks and plates at TP4. There appeared to be no demonstrable effect of the above ice disposal of the material on the structure of benthic diatom assemblages that developed during the summer. It is known that drilling fluid is not highly toxic and, due to its weight, the material tends to sink rapidly out of the water column. However, our samples were taken in August approximately 3 weeks after the area was ice free. We, therefore, cannot speculate on the immediate effects of leakage of the fluids into the water column. Our results indicate that, if the periphyton community is impacted during this time, the impact is short-termed.

The number and types of infauna colonizing sediments on blocks at the experimental dump site were appreciably less than at the control site. Polychaete worms and harpacticoid copepod populations showed the largest differences. Although only one sample was available from the dump site during the final sampling, it appeared that some recovery had taken place by that time (approximately one year after the experiment began). The numbers of individuals of polychaetes and copepods were similar at the two sites at this time. The recovery may be due to turnover and mixing of sediments by physical and biological mechanisms during the time between the January and May samplings.

Noteworthy is the diversity and unique nature of the diatom assemblage from this region. The number of taxa that were not located in the classical taxonomic literature is related to the fact that few studies on benthic diatoms have been conducted in the arctic.

Finally, there was no evidence of increased concentrations of trace metals in the specimens from the dump site. Most metals were in higher concentrations in specimens collected from the control site.

Table 6. Trace metal analysis results. Values are ppm (mg/kg dry wt.) except Hg which is ppb (µg/kg dry wt.) ND = not determined.

Month	Site	Organism	Metal							
			Cu	Cr	Pb	Zn	Cd	Ba	Fe	Hg
January	TP3	snail eggs	6.5	1.21	ND	82	0.56	1.10	ND	ND
	TP3	snail eggs	10.6	1.40	ND	84	1.58	1.90	ND	ND
	TP4	worm tubes	7.2	4.14	6.96	21	ND	25.9	ND	ND
	TP3	worm tubes	24.4	6.85	7.41	73	ND	10.6	ND	ND
	TP4	red alga[1]	44.3	5.77	ND	71	ND	11.6	ND	ND
	TP3	red alga[1]	24.6	ND	ND	50	ND	17.8	ND	ND
May	TP4	sea raspberry	8.5	3.86	0.73	134	2.44	42.1	312	ND
	TP3	sea raspberry	10.7	1.54	0.35	224	3.51	29.3	488	0.014
	TP4	polychaete	39.6	1.01	1.11	255	3.37	18.2	497	ND
	TP3	polychaete	33.7	1.85	1.78	270	6.12	34.0	1550	ND
	TP4	sea star	7.0	2.69	0.11	41	0.78	47.7	196	ND
	TP3	sea star	14.3	2.24	0.12	58	4.61	55.0	194	ND

[1] Phycodrys

LITERATURE CITED

Archibald, R. E. M. 1972. Diversity in some south African diatom associations and its relation to water quality. Water Res. 6:1220-1238

Bilyard, G. R. and A. G. Carey. 1980. Zoogeography of western Beafort Sea polychaeta (Annelida). Sarsia 65:19-26.

Harger, J. R. E. and M. D. Nassichuk. 1974. Marine intertidal community responses to Kraft pulp mill effluent. Water, Air Soil Pollut. 3:107-122.

Hohn, M. H. 1959. The use of diatom populations as a measure of water quality in selected areas of Galveston and Chocolate Bay, Texas. Publ. Inst. Mar. Sci. Univ. Texas 6:206-212.

Levin, S. and R. Paine. 1974. Disturbance, patch formation, and community structure. Proc. Natn. Acad. Sci. U.S.A. 71:2744-2747.

McIntire, C. D. and W. S. Overton. 1971. Distributional patterns in assemblages of attached diatoms from Yaquina estuary, Oregon. Ecology 52:758-777.

Patrick, R. 1973. The use of algae especially diatoms, in the assessment of water quality. Pages 76-95 in J. Cairns Jr. and K. L. Dickson, eds., Biological methods for the assessment of water quality. American Society Test. Mater. Spec. Tech. Publication No. 528.

Sullivan, M. J. 1976. Long-term effects of manipulating light and nutrient enrichment on the structure of a salt marsh diatom community. J. Phycol. 12:205-210.

Tagatz, M. E. and M. Tobia. 1978. Effect of barite ($BaSO_4$) on development of estuarine communities. Estuarine Coastal Marine Sci. 7:401-407.

Thom, R. M. 1978. The composition, growth, seasonal periodicity and habitats of benthic algae on the eastern shore of central Puget Sound, with special reference to sewage pollution. Ph.D. Dissertation, Univ. Washington, Seattle. 237 pp.