ECOLOGY OF THE PLANKTON OF PRUDHOE BAY, ALASKA

Rita A. Horner, Kenneth O. Coyle, and Douglas R. Redburn

IMS Report No. R74-2
Sea Grant Report No. 73-15
August 1974

D. W. Hood, Director
Institute of Marine Science

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The North Slope of Alaska has received increasing attention since the discovery of oil at Prudhoe Bay in 1968. The development of these gas and oil reserves will not proceed without some degree of impact on the natural environment. Prudhoe Bay and the surrounding coastal zone are especially important, not only because this is the northern terminus of the Trans-Alaska pipeline, but also because of increased marine traffic in the form of shipping and the possibility of offshore drilling. A knowledge of the present local oceanographic regime is essential for establishing some basis for monitoring and documenting for regulatory purposes the impact of the expected resource development on the marine ecosystem.

The original purpose of this project was to obtain basic quantitative information on the phytoplankton of the Prudhoe Bay area. The phytoplankton community was selected for study because phytoplankton are the primary energy source upon which the marine food web is based and any major changes in the phytoplankton composition might affect the entire ecosystem. The objectives of this study were fourfold:

1) to describe the phytoplankton community in terms of species composition and relative numbers of individuals present;

2) to determine the primary productivity;

3) to estimate the contribution of the ice algae to the primary production;

4) to determine the major environmental parameters influencing primary productivity, such as temperature, salinity, nutrient concentrations, and water transparency.

The zooplankton section of the study was added in 1972 as a logical extension of the original proposal because zooplankton are generally the primary consumers in a food web. The objectives of this section were:

1) to describe the spatial variability in community composition and determine the relative abundances of the species present;

2) to examine the relationship of any observed variability to the hydrographic conditions existing at the station locations.

Financial support for this project was provided by NOAA-Sea Grant through Grant No. 04-3-1581-41. Logistic support, including use of the M/V *Natchik* and aircraft, was provided by the Naval Arctic Research Laboratory, Barrow, Alaska, under Office of Naval Research Grant No. N00014-67-A-0317-003.

We thank Dr. Max C. Brewer and Mr. John F. Schindler, former Directors of the Naval Arctic Research Laboratory, for their advice and support during the course of this project. Other members of the NARL staff, especially pilots and boat operators, were extremely helpful. Field collections were made by Dr. Rita Horner, Mr. Grant E. M. Matheke, Mr. Sherwood Maynard, Mr. Kenneth O. Coyle, and Mr. Douglas R. Redburn: automated nutrient analyses were done by Dr. D. M. Schell; nitrate and ammonia uptake experiments were analyzed by Dr. Vera Alexander; Dr. R. T. Cooney supervised the zooplankton work. The results of the phytoplankton study have been presented to the Institute of Marine Science, University of Alaska, by Mr. Kenneth O. Coyle in partial fulfillment of the requirements for the Master of Science degree.

Literature Review

Collections of biological samples have been made in Arctic areas since the early 1800's with the first reference to diatoms being that of Ehrenberg in 1841. The reports were primarily lists of the species collected by the early expeditions. G. O. Sars' (1900) work on the marine crustaceans collected by the Norwegian North Polar Expedition established the systematic foundation for future arctic zooplankton studies, while Cleve and Grunow (1880) and Gran (1904) provided much of the impetus for phytoplankton work.

The first collections of a biological nature from the Alaskan coast were made during the Canadian Arctic Expedition, 1913-1918. Major groups of zooplankton reported from this expedition included the ctenophores and hydromedusae (Bigelow 1920), amphipods (Shoemaker 1920), copepods (Willey 1920), and schizopod crustaceans (Schmitt 1919). The results from these surveys indicated that the primary constituents of the zooplankton were crustaceans, most particularly copepods.

Mann (1925) reported on the marine diatoms collected by this expedition. Only 4 samples were taken from the Beaufort Sea coast, and of these, only the Harrison Bay sample was from a net tow. Most of the diatoms thus described are benthic forms.

Soviet and other investigators collected phytoplankton in the Russian and northern European arctic seas in the early 1900's. Most of the samples were taken with plankton nets, but some water samples were concentrated for standing stock analyses. Usachev (1947) has summarized the Soviet data (see also the English review in Zenkevitch 1963).

Plankton research in arctic regions expanded in the 1930's and later with icebreaker surveys in the Bering Sea, central Arctic Basin, and Chukchi and Beaufort seas. The first extensive, systematic studies of the calanoid copepod fauna in the Bering and Chukchi seas were initiated by the Soviet

State Hydrological Institute in 1932. The *Sadko* expedition and the drift of the icebound vessel *Sedov* further extended Soviet research on plankton into the Eurasian basin of the high arctic. The analysis of the *Sedov* collections by Bogorov (1946) corroborated Sars' earlier conclusion that many copepod species found in the central arctic were Atlantic in origin.

The Soviets were also pioneering with the use of aircraft-supported, drifting ice stations (the North Pole series) as scientific platforms. These stations permitted the first long term, deep water collection of arctic zooplankton. Vertical tows provided the material for the description of 19 copepod species not previously recorded and it was concluded from this material that most of these species were endemic to the deeper waters of the basin (Brodskii and Nikitin 1955).

The first major American effort toward the collection and study of marine zooplankton in the Bering and Chukchi seas came with the cruise of the U. S. Coast Guard Cutter *Chelan* in 1934 (Johnson 1934). The results of this, and other studies by Johnson (1953) and Stepanova (1937) demonstrated the existence of a northward transport of endemic Bering Sea plankton into the Chukchi Sea. Johnson (1956) reported on the zooplankton collected by the U. S. S. *Burton Island* in the Beaufort and Chukchi seas in the summers of 1950 and 1951, while Hand and Kan (1961) described the hydromedusae, their breeding ranges and the influence of hydrography on species distribution.

The establishment of Station Bravo on Fletcher's Ice Island (T-3) in 1952, expanded the oceanographic investigations into the central arctic, but plankton studies did not commence until the International Geophysical

Year, 1957-58, when biological programs were initiated on both T-3 and drifting floe station Alpha. The results of these investigations, concerned mainly with seasonal variation in biomass, plankton associations with water masses, and seasonal vertical distributions of organisms are reported by Johnson 1963, Grainger 1965, Mohr and Geiger 1968, Hughes 1968, Hopkins 1969, and Scott 1969.

With regard to phytoplankton, Usachev (1946, 1961) has reviewed the work of Soviet investigators working from the North Pole series of drifting stations and from the icebreaker *Sedov*. English (1961) reported low primary productivity from drift station Alpha during the IGY and suggested that low light levels limited production. Kawamura (1967) discussed the phytoplankton collected from ARLIS II (Arctic Research Laboratory Ice Station) in 1964 in terms of species present and seasonal and vertical distribution.

Knowledge of annual cycles, biomass, population dynamics, and production in both phytoplankton and zooplankton communities in neritic areas of the arctic comes from the Canadian eastern arctic (Grainger 1959, 1962, 1964; Bursa 1961a, 1961b); east Greenland (Digby 1953, 1954); and the Barents Sea (Zenkevitch 1963). Extensive studies along the Alaskan coast have been primarily at Point Barrow (MacGinitie 1955; Johnson 1958; Bursa 1963; Horner 1969, 1972, 1973; Redburn 1973).

MacGinitie's (1955) study was concerned with the benthic invertebrates and included a limited discussion of both phyto- and zooplankton, based on reproductive periods and relative abundances. He reported the highest phytoplankton concentrations in September, with a small spring bloom in June. Johnson (1958) described the qualitative and quantitative composition of the inshore zooplankton community for a one month period during the summer of 1957.

Bursa (1963) studied the taxonomy and abundance of phytoplankton from several habitats near Barrow. In the brackish water of Elson Lagoon, he found large populations of *Chaetoceros socialis* Lauder, *Ch. wighami* Brightwell, and *Gonyaulax catenata* (Levander) Kofoid along with a large number of unidentified flagellates. The nearshore marine community was reported to contain coccolithophorids and many unidentified flagellates, while the offshore waters contained more oceanic forms such as *Chaetoceros concavicornis* Mangin, *Leptocylindrus danicus* Cleve, other diatoms, and the flagellate *Dinobryon balticum* (Schütt) Lemmermann.

At Point Barrow, the annual phytoplankton cycle is bimodal with a spring maximum in June and early July before ice breakup and a fall maximum in August-September (Horner 1969, 1972). The spring bloom is dominated by *Phaeocystis pouchetii* (Har.) Lagerh., *Fragilariopsis oceanica* Cl. (=*Nitzschia grunowii* Hasle), and *Porosira glacialis* (Gun.) Jørg. with *Thalassiosira gravida* Cleve and *T. nordenskioeldii* Cleve occurring toward the end of the bloom. In the fall, several species of the genus *Chaetoceros*, including *Ch. gracilis* Schütt, *Ch. socialis*, and *Ch. wighami*, *Leptocylindrus danicus*, and *Dinobryon balticum* are common. Dinoflagellates may occur in larger numbers in the fall also, but they are present all year. August and September is also the time when species usually associated with more central arctic water masses or with water from the Bering Sea may appear at Barrow.

Redburn (1973) described the zooplankton community at Barrow in terms of species abundance and composition, life cycles, and relationship to the local hydrographic regime. He found that copepods were the major constituents of the community with hydromedusae, chaetognaths, and barnacle larvae as additional summer constituents. The intrusion of Bering Sea water into the Barrow area was evidenced by the presence of several expatriate copepod species along with the occurrence of several populations of copepods and hydromedusae that breed from the Bering Sea to Barrow. Large numbers of meroplanktonic larvae were present in the community, possibly accounting for the high community biomass, which was an order of magnitude higher than that reported for a similar period in the central arctic. The summer plankton community at Barrow exists in an unbalanced state, such that the periods of high zooplankton standing stock lag one to two weeks behind the phytoplankton peaks, a situation also reported by MacGinitie (1955).

Biological investigations in the Beaufort Sea since the Canadian Arctic Expedition are few; the zooplankton studies of Johnson (1956) and Hand and Kan (1961) in the offshore area have been mentioned. Wing and Quast (unpublished) have collected zooplankton and fishes in the offshore Beaufort Sea as part of the Western Beaufort Sea Ecological Cruises (WEBSEC) sponsored by the U. S. Coast Guard, but these data are not yet available.

As part of a continuing survey to determine the areal extent of the ice algal community along the Arctic coast, single stations were taken in

Harrison Bay, Smith Bay, and Dease Inlet in early June 1971 (Horner 1972). Primary productivity and chlorophyll *a* measurements were made for water and ice samples. The high values of 22.05 mg chl *a* m^{-3} and 4.76 mg C m^{-3} hr^{-1} for the water in Harrison Bay are probably not very realistic because the water samples were collected through a 7.5 cm hole in the ice and were contaminated by organisms from the ice.

The Institute of Marine Science Colville River group has studied phytoplankton standing stock and primary productivity, epibenthic invertebrates, fishes, and zooplankton in the Simpson Lagoon - Harrison Bay area (Kinney et al. 1971, 1972; Schell et al. in prep., Alexander 1974).

In the invertebrate community, Cooney and Crane (Kinney et al. 1972) found some 38 species with the large isopod *Mesidotea entomon* and the mysid, *Mysis oculata*, usually numerically dominant. They concluded that the fauna in the lagoon areas was similar in composition to that of offshore areas outside the barrier islands, the major difference being absolute abundance. Crane (1974) has discussed the distribution patterns and biology of *Mesidotea entomon* and *Mysis oculata*.

Alexander (1974) reported primary productivity, chlorophyll *a*, and biomass data for the phytoplankton community. In 1970, the highest chlorophyll occurred below the surface near shore where the salinity was relatively low. In 1971, the highest chlorophyll again occurred below the surface near shore, but the highest primary productivity was found in surface water away from shore. Mean primary productivity data for surface water in July and August 1971 was 1.3 mg C m^{-3} hr^{-1} for Simpson Lagoon and a Thetis Island transect, 0.6 mg C m^{-3} hr^{-1} for Harrison Bay, and

0.4 mg C m^{-3} hr^{-1} for Beaufort Sea stations located outside the barrier islands. This indicates an enhancement of productivity in the lagoon area for surface samples. Depth profiles in Simpson Lagoon and the Beaufort Sea station indicate that maximum productivity takes place in early August. The total productivity is about the same amount in the two areas, but the Beaufort Sea productivity occurs over a greater depth. Annual seawater productivity is estimated to be in excess of 10-15 g C m^{-2}. The species composition of the phytoplankton community varied with depth, season and between seasons, with many of the organisms being small. Fresh and brackish water flagellates were more common in 1971, while marine diatoms were abundant in 1972.

Materials and Methods

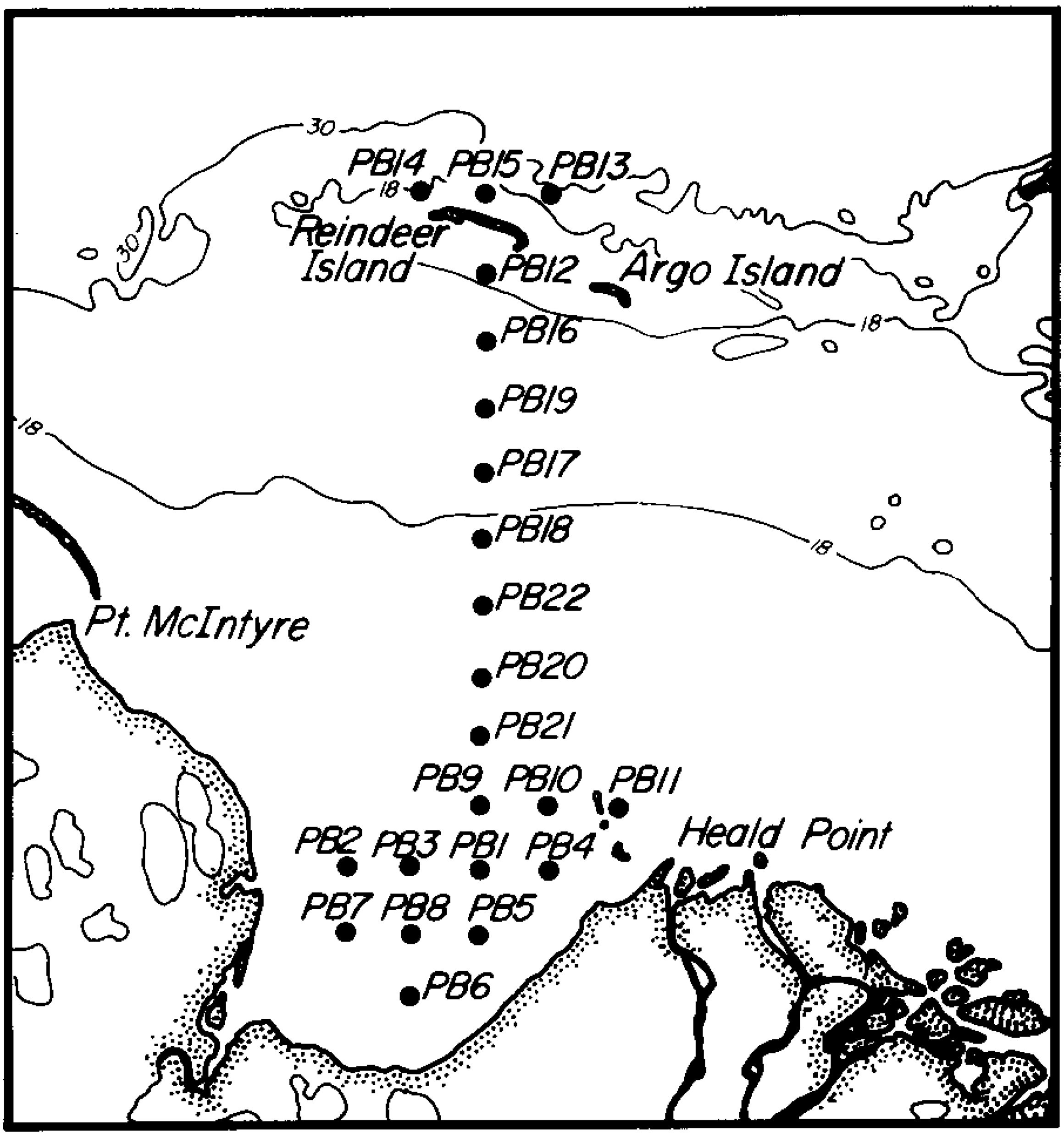
1. Sampling

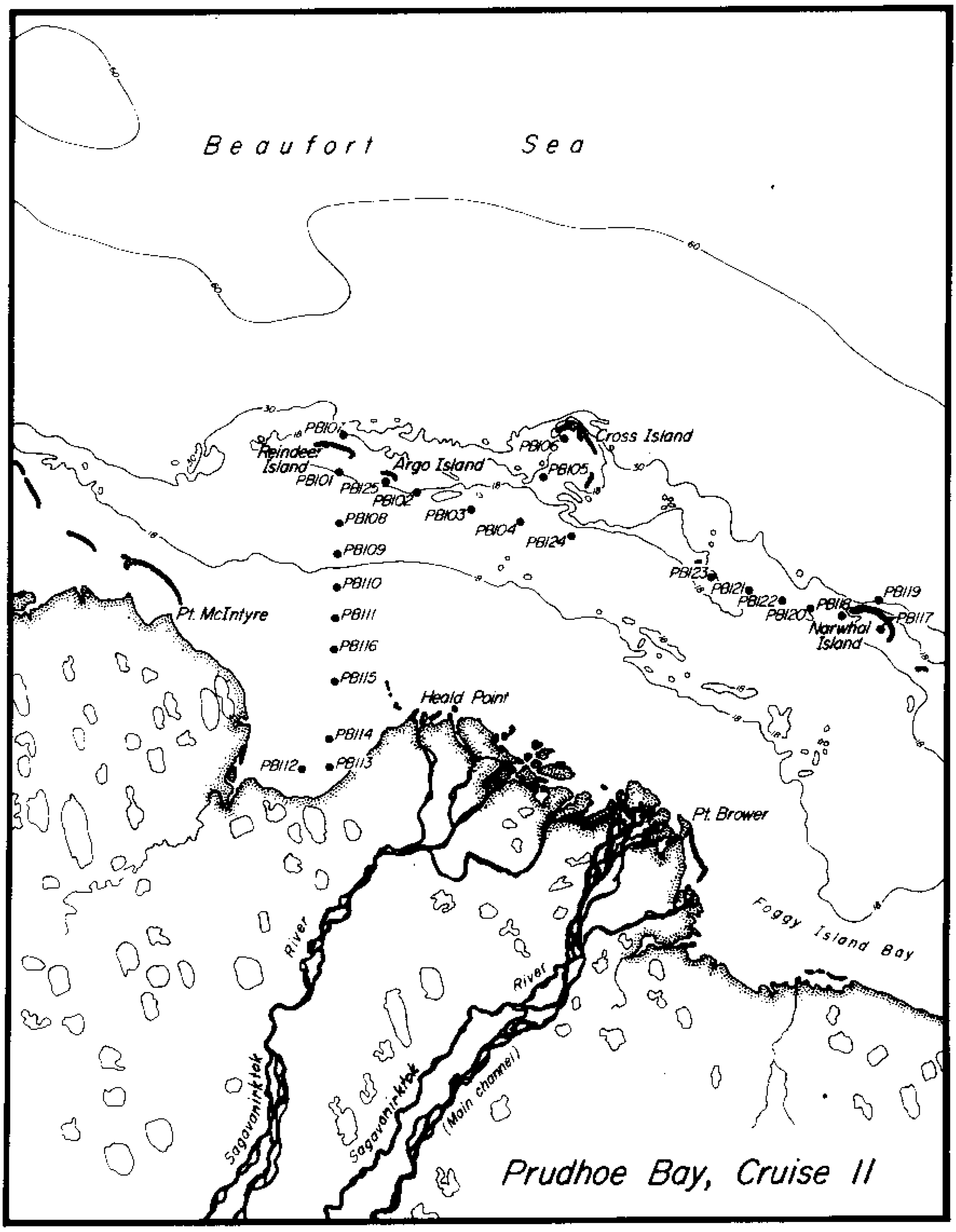
Station locations are shown in Figs. 1-3. Different sampling techniques were needed during the winter-spring and summer periods because of the presence of ice during winter-spring.

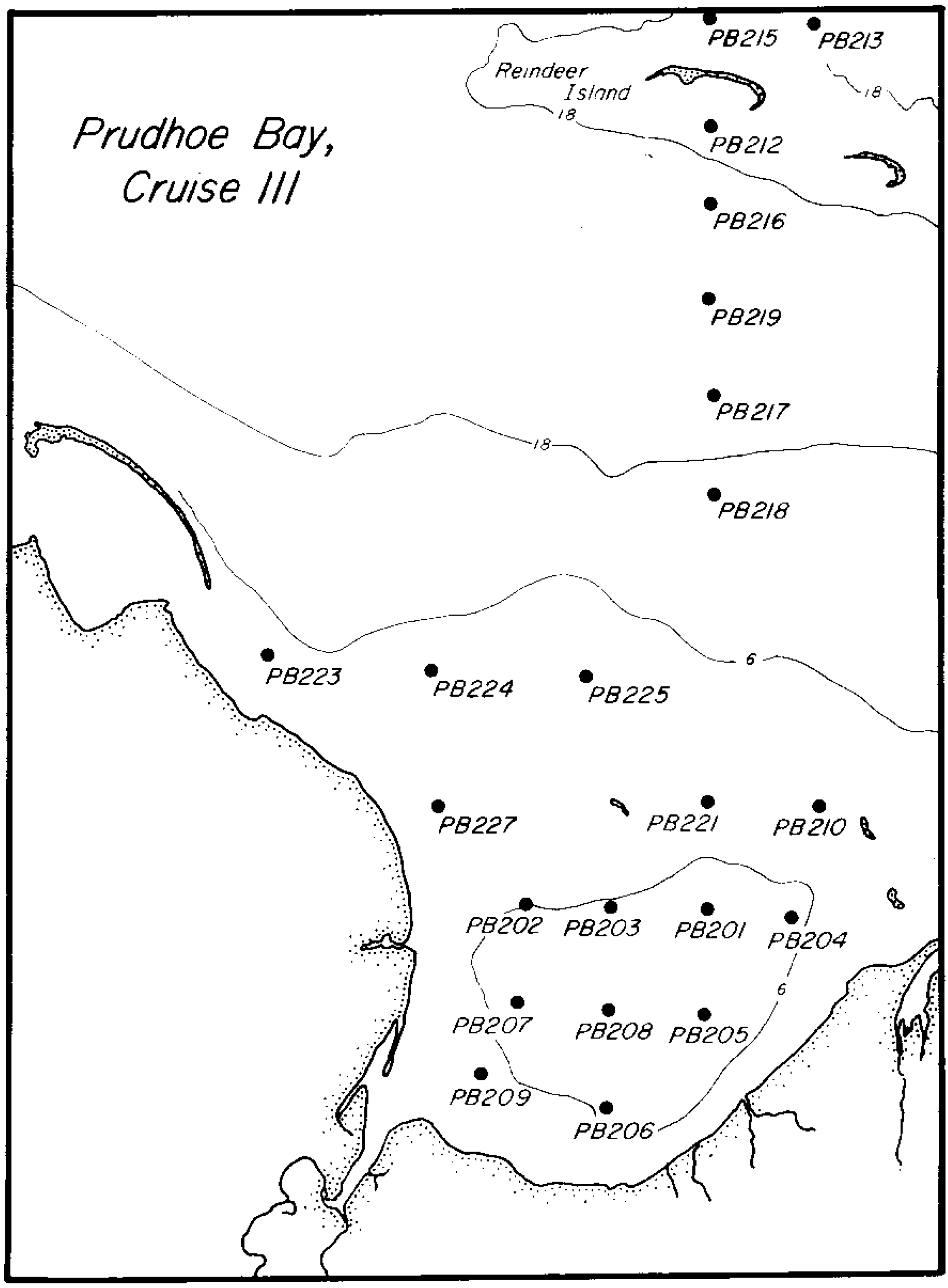
a. Winter-spring

Two areas were chosen, primarily because they were sufficiently separated to provide comparative information. One site, located approximately in the center of Prudhoe Bay and corresponding to station 8 (Fig. 1), was in the deepest part of the bay where 0.3-0.6 m of water remained unfrozen in winter. The second site, about 1 km north of Reindeer Island, station 15 in Fig. 1, was an area of relatively deep water with 6-7 m of water being present under the ice. These sites were reached via Cessna 180 aircraft on wheel-skis.

Figures 1-3. Station locations for the three summer cruises.


30
30
18
PB14
PB15
PB13
Reindeer Island
PB12
Argo Island
PB16
PB19
PB17
PB18
PB22
PB20
PB21
Pt. McIntyre
PB9
PB10
PB11
Heald Point
PB2
PB3
PB1
PB4
PB7
PB8
PB5
PB6


Beaufort Sea
Reindeer Island
Argo Island
Cross Island
PB101
PB107
PB125
PB102
PB103
PB104
PB105
PB106
PB108
PB109
PB110
PB111
PB116
PB115
PB114
PB113
PB112
PB124
PB123
PB121
PB122
PB120
PB118
PB119
PB117
Narwhal Island
Pt. McIntyre
Heald Point
Pt. Brower
Foggy Island Bay
Sagavanirktok River
Sagavanirktok River
(Main channel)
Prudhoe Bay, Cruise II


Prudhoe Bay,
Cruise III
Reindeer
Island
18
6
PB215
PB213
PB212
PB216
PB219
PB217
PB218
PB223
PB224
PB225
PB227
PB221
PB210
PB202
PB203
PB201
PB204
PB207
PB208
PB205
PB209
PB206

An ice corer (Testlab, Oak Grove Village, Ill.) was used to cut cores 7.5 cm in diameter. The length of each core was measured and 10-15 cm sections cut from the top, middle, and bottom. The sections were placed in clean plastic containers and returned to the Naval Arctic Research Laboratory at Barrow for processing; all ice samples were allowed to thaw at room temperature. Water samples were obtained by dipping water from the core holes using a 500 ml polyethylene bottle. Two 4-ℓ polyethylene bottles were filled with water and slush at each core hole. Chlorophyll *a* and other determinations were done with water from the second of the two bottles to minimize errors due to contamination of the water by pieces of the bottom section of ice. Water and air temperatures were taken with a mercury thermometer.

Winter-spring samples were collected on 27 March and 10 May 1971 and 2 February and 18 and 25 May 1972.

b. Summer

Summer stations were chosen to provide as wide coverage as possible of the bay and surrounding lagoon areas. The winter stations were used as permanent sites and were repeated on each cruise. Station location was somewhat determined by local weather conditions and water depth. All summer sampling was done from the M/V *Natchik* belonging to the Naval Arctic Research Laboratory.

Summer cruises took place 24-29 July and 15-19 August 1971 and 11-15 August 1972.

Water samples were collected with a 6-ℓ polyvinylchloride bottle. Surface water samples were taken at all stations during cruises I and II and at deep stations during cruise III. At stations where the water depth was more than 2.5 m, a second sample was collected from near the bottom during cruises I and II. A Beckman RS5-3 salinity probe was used during cruise III to determine stratification of the water column and a second sample was collected from the water below the salinity discontinuity layer. At shallow water stations where no salinity discontinuity layer occurred, one sample was collected from the middle of the water column. Measurements made on the water and ice samples included chlorophyll *a*, primary productivity, phytoplankton standing stock, salinity, temperature, turbidity (Secchi disc), nutrient concentrations (nitrate, nitrite, ammonia, silicate, and phosphate), particulate nitrogen, and ammonia and nitrate uptake rates. Not all measurements were done on all stations (Tables 1-3).

Net tows for phytoplankton were made at most stations using a conical net made of 0.046 mm mesh Nitex with a 0.25 m diameter mouth. A 125-ml glass bottle was used as the collecting bucket. The samples were transferred to 250-ml jars and preserved with 20 ml of 4% formalin buffered with sodium acetate.

Zooplankton tows were made at 7 of 20 stations during cruise III (Fig. 3) in three major areas: Prudhoe Bay proper, between Point McIntyre and the Midway Islands, and seaward of the Midway Islands. Conical nets approximately 3 m long with a 0.75 m diameter mouth were used. A removable polyvinylchloride cup was attached to the cod end of the net. The netting was high-capacity monofilament nylon (Nitex) with an aperture size of 0.308 mm.

Towing procedures for the net were consistently followed. A 0.65 cm diameter polypropylene line was attached to the center of the ring crossbar and the net placed in the water while the vessel was underway. Towing

Tables 1-3. Summary of samples taken and measurements made during the three cruises.

Table 1. Summary of the samples taken at each station and the measurements made on each sample during cruise I. All depths are in meters.

Station Number	Station Depth	Sample Depth	Measurements Made[1]
PB 1	2.3	0	C, P, N
PB 1		2	C, P, N
PB 2	2.0	1.5	C
PB 3	1.5	0.8	C
PB 4	2.0	1.0	C
PB 5	2.5	0	C, P
PB 5		1.5	N
PB 5		2.0	C, P
PB 6	2.0	1.5	C, P, N, Ph
PB 7	2.0	1.5	C, Ph
PB 8	2.5	1.5	C, P, N, Ph
PB 9	1.8	1.5	C, Ph
PB 10	1.0	0	C, N, P, Ph
PB 11	0.5	0	C, Ph
PB 12	4.0	0	C, P, Ph
PB 12		2.0	N
PB 12		3.5	C, P, Ph
PB 13	4.0	0	C, Ph
PB 13		3.5	C, Ph
PB 14	4.5	0	C, Ph
PB 14		4.0	C
PB 15	5.3	0	C, P
PB 15		2.5	N
PB 15		4.5	C, P
PB 16	7.0	0	C
PB 16		6.0	C, Ph
PB 17	6.5	0	C
PB 17		6.0	C, Ph
PB 18	5.0	0	C
PB 18		4.5	C
PB 19	6.0	0	C, Ph
PB 19		2.5	N
PB 19		5.5	C, Ph
PB 20	2.3	1.5	C, N, Ph
PB 21	1.5	1.0	C, Ph
PB 22	2.3	1.5	C, P, N, Ph

[1]C = Chlorophyll *a*, nutrient and salinity measurements.
Ph = phytoplankton standing stock sample.
P = primary productivity measurement.
N = nitrate and ammonia uptake and particulate nitrogen concentration.

Table 2. Summary of the samples taken at each station and the measurements made on each sample during cruise II. All depths are in meters.

Station Number	Station Depth	Sample Depth	Measurements Made[1]
PB 101	5.0	0	C, P, Ph
PB 101		2.5	N
PB 101		4.5	C, P, Ph
PB 102	5.0	0	C
PB 102		4.5	C, Ph
PB 103	4.5	0	C
PB 103		4.0	C, Ph
PB 104	5.5	0	C, P
PB 104		3.0	N, Ph
PB 104		5.0	C, P
PB 105	6.0	0	C, Ph
PB 105		4.5	C
PB 106	6.0	0	C, Ph
PB 106		5.5	C
PB 107	10.0	0	C, P
PB 107		5	N, Ph
PB 107		9.5	C, P
PB 108	7.0	0	C, P
PB 108		3.5	N, Ph
PB 108		6.5	C, P
PB 109	6.0	0	C, Ph
PB 109		5.5	C
PB 110	5.0	0	C, Ph
PB 110		4.5	C, Ph
PB 111	2.8	1.5	C
PB 112	2.5	1.0	C, P, N, Ph
PB 113	2.5	1.0	C, Ph
PB 114	2.5	1.0	C, Ph
PB 115	1.3	0	C
PB 116	1.3	0	C
PB 117	4.0	0	C, P
PB 117		2.0	N, Ph
PB 117		3.5	C, P
PB 118	6.0	0	C, Ph
PB 118		5.5	C, Ph
PB 119	9.5	0	C, P
PB 119		5.0	N, Ph
PB 119		9.0	C, P
PB 120	8.5	0	C, Ph
PB 120		8.0	C, Ph
PB 121	7.5	0	C, Ph
PB 121		7.0	C, Ph
PB 122	8.0	0	C, P
PB 122		4.0	N, Ph
PB 122		7.5	C, P
PB 123	5.0	0	C, P
PB 123		4.5	C, P, N, Ph
PB 124	7.0	0	C
PB 124		6.5	C
PB 125	3.0	1.5	C

[1]Symbols same as in Table 1.

Table 3. Summary of the samples taken at each station and the measurements made on each sample during cruise III. All depths are in meters.

Station Number	Station Depth	Sample Depth	Measurements Made[1]
PB 201	2.8	1.0	C
PB 202	2.5	1.0	C
PB 203	2.5	1.3	C, P, Ph
PB 204	2.3	1.0	C
PB 205a	2.5	1.0	C
PB 205b	2.5	1.0	C, P, Ph
PB 206	2.0	1.0	C, P, Ph
PB 207	2.5	1.0	C
PB 208	3.0	1.0	C, P, Ph
PB 209	2.1	1.0	C, Ph
PB 210	1.0	0	C, P, Ph
PB 212	4.5	0	C, P, Ph
PB 212		4.0	C, P, Ph
PB 213	10.0	0	C, P, Ph
PB 213		8.0	C, P, Ph
PB 215	11.0	0	C, Ph
PB 215		8.0	C, Ph
PB 216	6.5	0	C, Ph
PB 216		5.0	C, Ph
PB 217	6.5	0	C, P, Ph
PB 217		5.0	C, P , Ph
PB 218	4.0	0	C, Ph
PB 218		4.0	C
PB 219	7.0	0	C, Ph
PB 219		5.0	C, Ph
PB 221	1.3	0	C
PB 223	1.2	1.0	C, P, Ph
PB 224	1.5	0	C
PB 225	1.8	0	C
PB 227	1.3	0	C

[1]Symbols same as in Table 1. No particulate nitrogen or ammonia and nitrate uptake measurements were made during Cruise III. Salinity measurements were not made at stations PB 201, 202, 204, and 207.

proceded horizontally at the surface for approximately 2.5 minutes at approximately 4-5 knots. Duplicate hauls were taken at all stations except for one vertical tow of 20 m collected at station 213 on 15 August. Although the towing speed exceeded that ideally suitable for netting of 0.308 mm, such speeds were unavoidable because of the preset gearing of the vessel. After retrieval, the nets were rinsed twice and the sample placed in 500-ml wide-mouth jars and preserved immediately in 10% formalin buffered with sodium acetate.

2. Chemical analyses

Chlorophyll *a* measurements were done using the Unesco-Score (1966) method. During cruise III replicate samples were taken and the Lorenzen (1967) method was also used to determine chlorophyll *a* and phaeopigments.

Primary productivity was measured using the technique described by Steemann Nielsen (1952). Incubations were done in plastic buckets on the boat deck during cruises I and II. Carbon-14 uptake was determined using a Nuclear Chicago D-47 gas-flow proportional counter. During cruise III incubations were done in clear plastic tubes or in tubes covered with metal screening to simulate 1% or 10% of the incoming radiation. Carbon-14 uptake was determined using a Nuclear Chicago 6848 liquid scintillation system; efficiency was determined by the channels ratio method. Primary productivity in mg C m^{-3} hr^{-1} was calculated according to the equations given by Strickland and Parsons (1968). Total alkalinity was determined according to the method of Strickland and Parsons (1968).

Nitrate and ammonia uptake rates were determined according to the technique described by Dugdale and Goering (1967). The particulate nitrogen concentration was determined using a Coleman nitrogen analyzer after the water sample had been filtered through a glass fiber filter (Gelman Type A).

Samples for salinity and nutrient analyses were water or melted ice which had been filtered to remove the phytoplankton. Water for nutrient analyses was either frozen immediately after filtration or poisoned with two drops of 0.5% mercuric chloride and frozen later.

Nitrate, nitrite, silicate, and phosphate determinations were done on an autoanalyzer following techniques described by Strickland and Parsons (1968). Ammonia was determined according to Solórzano's (1969) technique for cruises I and II; for cruise III, the Solórzano technique was modified for the autoanalyzer (Schell unpublished).

Salinity determinations were usually done using a Beckman RS7-B induction salinometer. During cruise III, a Beckman RS5-3 salinity probe was used. Temperature measurements were made with a mercury thermometer or the salinity probe.

3. Water transparency and depth

Water transparency was determined with a 26 cm diameter white Secchi disc. Extinction coefficients were calculated using the equation

$$K = 1.7/D$$

where D is the depth at which the Secchi disc is no longer visible (Poole and Atkins 1929).

Water depth was determined by using the Secchi disc as a lead line.

4. Biological analyses

a. Phytoplankton standing stock and community composition

Subsamples for standing stock determinations were taken from all water samples. About 200-ml of water were poured into 250-ml glass jars and preserved with 5-10 ml of 4% formalin buffered with sodium acetate.

Standing stock determinations were made using a technique originally described by Utermöhl (1931) and modified by Horner (1969) for Arctic samples. Carl Zeiss counting chambers, holding 5 and 50 ml of sample, and a Zeiss phase-contrast inverted microscope were used to enumerate the samples.

Usually, cells in one-half or one-third of a 5-ml chamber were counted by examining the appropriate number of transects. If the number of cells was extremely high as in some of the samples or there was much sediment present as in some of the Prudhoe Bay samples, counts were made by examining a series of fields across the center of the chamber or a single transect across the center of the chamber. The cell concentration in each sample was calculated by multiplying the number of cells counted by a factor determined from the fraction of the chamber bottom counted. Magnification used for the counts was 400 or 500 X.

The entire bottom of the 50-ml chamber was counted using 100 or 125 X magnification, but only cells larger than 40 μm were counted. Unusual or rare organisms smaller than this were counted if they could be recognized at the magnification used. This volume of sample is examined to determine large or relatively rare organisms, while the 5-ml volume determines the smaller and more common organisms. Summary sheets of the cell counts are in Coyle (1974).

Net tows were examined microscopically to provide species lists which could then be used to aid enumeration as it is usually easier to identify an organism on a microscope slide than in a counting chamber. Small portions of a net tow sample were placed on a microscope slide and examined using a Zeiss WL phase-contrast compound microscope. Magnifications used varied from 125 to 1250 X.

Major references used to identify the phytoplankton were:

Butcher 1959	Hustedt 1930, 1959-1962
Cupp 1943	Lemmermann 1908
Gemeinhardt 1930	Meunier 1910
Gran 1908	Paulsen 1908
Hendey 1964	Schiller 1933-1937

b. Zooplankton standing stock and community composition

Zooplankton collections were examined for identification of organisms, sizing, and determination of abundance. Systematic classifications were completed using the following references:

Naumov 1969	Hydrozoa
Pettibone 1954	Polychaeta
Barnard 1969 Tencati 1970	Amphipoda
Sars 1900 Brodskii 1967 Vidal 1971	Copepoda
Leung 1970	Euphausiacea
Dawson 1971	Chaetognatha
Wimpenny 1966	Larvacea

Each zooplankton sample was sorted to remove large and rare organisms prior to subsampling. These organisms were identified, measured and set aside. The remaining, homogeneous sample was placed in a calibrated 1000-ml wide-mouth beaker and diluted to 400 ml. The contents were suspended by rapid stirring and subsamples randomly extracted with Hensen-Stempel pipets equipped with interchangeable sampling spools of 1, 2, 5, and 10 ml. The size of the subsample was adjusted accordingly to provide a minimum of 100 specimens.

Subsamples were then placed into 60 x 15 or 100 x 15 mm Pyrex petri dishes and the most abundant species was counted and used as the standard against which the less prevalent species were compared. The percentage of the total counts in the subsample was determined for each species. Size measurements were made on all individuals in an effort to establish developmental stages. Specimens were measured to the nearest 0.1 mm under the stereomicroscope with a transparent, millimeter-ruler.

Results

1. Chemistry

a. Chlorophyll *a*

Chlorophyll *a* concentrations for winter-spring ice and water are shown in Table 4. The highest chlorophyll *a* concentration occurred in the bottom ice in spring, with the maximum being 97.9 mg m^{-3} at Reindeer Island on 10 May 1971. The highest concentration in the bottom ice inside Prudhoe Bay was 19.0 mg m^{-3} on 25 May 1972. The chlorophyll *a* concentration in the top and middle layers of ice is variable with higher concentrations usually occurring earlier in the year. The concentration in the upper layers of ice is usually considerably lower than that in the bottom layer.

Table 4. Chlorophyll *a* concentration in mg m^{-3} for winter-spring ice and water samples.

	1971		1972		
	27 Mar	10 May	2 Feb	18 May	25 May
Prudhoe Bay					
Ice					
Top	3.6	3.0	1.6	0.6	0.8
Middle	1.1	1.2	1.1	0.5	0.8
Bottom	5.7	1.7	2.1	1.5	19.0
Water	1.4	0.6	1.4	1.1	2.8
Reindeer Island					
Ice					
Top	7.0	0.7	0.8	0.3	0.8
Middle	1.5	0.9	2.2	0.3	0.7
Bottom	5.0	97.9	2.1	7.2	4.5
Water	0.9	3.9	0.4	1.7	2.6

The highest chlorophyll *a* concentration in the seawater under the ice occurred at Reindeer Island on 10 May 1971 also. Microscopic examination of this sample indicated that most of the organisms in the water were present in the ice. Other spring water samples also contained ice organisms.

Chlorophyll *a* concentrations for the summer cruise water samples are given in Tables 5-7; major trends are shown in Fig. 4. The highest chlorophyll *a* concentration during the summer cruises occurred at 3.5 m at station 12 during cruise I. In general, the chlorophyll *a* concentration was higher in deeper, more saline water than in the brackish surface water. Chlorophyll *a* concentrations averaged slightly higher for cruise I than for subsequent cruises, while cruise II was considerably lower.

b. Primary productivity

Primary productivity, chlorophyll *a* and light data are tabulated in Tables 8-10. The highest primary productivity, 21.2 mg C m^{-3} hr^{-1}, occurred at 3.5 m at station 12 where the highest chlorophyll *a* concentration also occurred. Primary productivity inside Prudhoe Bay was higher during cruise I than during cruises II and III. Most of the primary productivity measurements during cruise II were done on shallow water from the lagoon area and rates were low, ranging from 0.1-1.0 mg C m^{-3} hr^{-1}. During cruise III, primary productivity rates were consistently low being generally below 1.0 mg C m^{-3} hr^{-1}. The highest productivity rate, 2.4 mg C m^{-3} hr^{-1}, occurred at 8 m at station 213 located on the north side of Reindeer Island.

c. Nitrate and ammonia uptake rates

Nitrate and ammonia uptake rates are listed in Table 11. The concentration of ammonia in the seawater during cruises I and II was estimated to be 1 μg-atom $liter^{-1}$ in order to calculate the uptake of the

Table 5. Chlorophyll *a* and salinity concentrations for cruise I samples.

Station Number	Sample Depth (m)	Chl *a* ($mg\ m^{-3}$)	Salinity (°/₀₀)
1	0	1.3	21.55
	2.0	1.0	21.83
2	1.5	1.0	19.56
3	0.8	1.0	20.06
4	1.0	0.8	17.58
5	0	0.8	19.16
	2.0	1.3	21.07
6	1.5	2.9	19.68
7	1.5	1.7	18.40
8	1.5	3.6	13.02
9	1.5	1.6	6.86
10	0	1.5	5.46
11	0	1.6	11.46
12	0	0.1	24.33
	3.5	7.4	31.17
13	0	0.5	18.07
	3.5	0.4	24.37
14	0	0.5	18.26
	4.0	0.7	25.33
15	0	0.5	21.03
	4.5	1.2	31.67
16	0	0.4	19.74
	6.0	6.6	31.61
17	0	0.2	21.74
	6.0	1.2	29.53
18	0	0.4	26.61
	4.5	0.4	25.03
19	0	0.3	22.15
	5.5	0.8	28.65
20	1.5	0.6	25.67
21	1.0	1.4	25.68
22	1.5	0.5	24.45

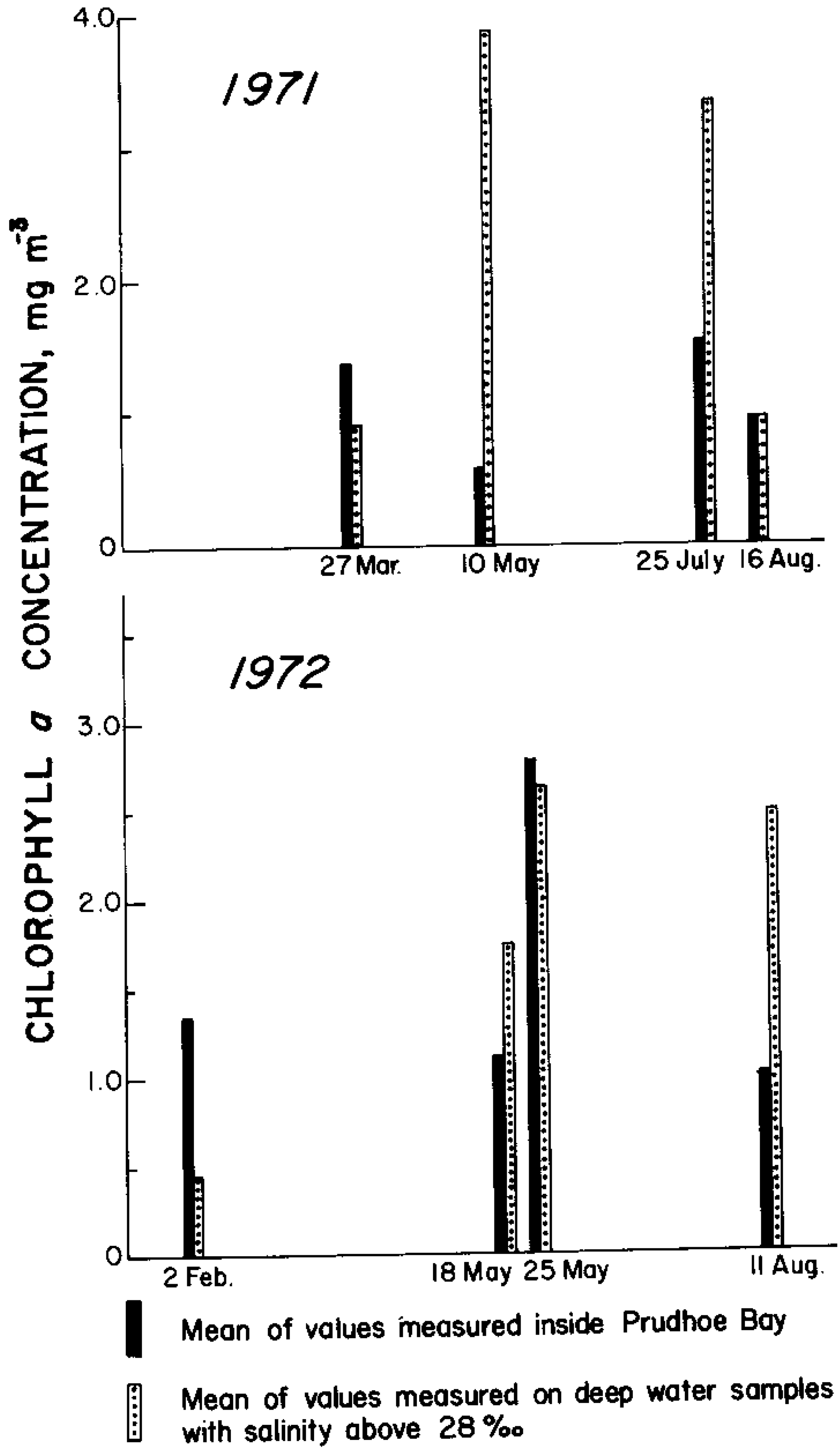
Table 6. Chlorophyll *a* and salinity concentrations for cruise II samples.

Station Number	Sample Depth (m)	Chl *a* ($mg\ m^{-3}$)	Salinity (°/₀₀)
101	0	0.4	17.73
	4.5	0.6	17.86
102	0	0.7	18.40
	4.5	0.4	18.45
103	0	0.5	18.46
	4.0	0.5	18.50
104	0	0.3	18.35
	5.0	0.9	25.85
105	0	0.4	18.35
	4.5	0.7	19.23
106	0	0.6	19.01
	5.5	0.7	19.39
107	0	0.5	17.90
	9.5	0.7	30.42
108	0	0.5	16.92
	6.5	0.7	30.12
109	0	0.6	17.27
	5.5		24.45
110	0	0.7	16.13
	4.5	0.7	18.34
111	1.5	0.6	16.10
112	1.0	1.0	13.90
113	1.0	1.2	14.59
114	1.0	0.9	13.52
115	0	1.3	14.57
116	0	0.9	15.79
117	0	0.3	19.13
	3.5	0.5	20.30
118	0	0.6	18.61
	5.5		22.40
119	0	0.5	18.76
	9.0	1.3	30.09
120	0	0.5	18.78
	8.0	0.9	30.32
121	0	0.6	18.89
	7.0		25.91
122	0	0.6	20.35
	7.5		26.83
123	0	0.4	18.99
	4.5		24.83
124	0	0.5	18.28
	6.5		24.61
125	1.5	1.5	18.76

Table 7. Chlorophyll *a* and salinity concentrations for cruise III samples.

Station Number	Sample Depth (m)	Chl *a* (mg m^{-3})	Salinity (°/₀₀)
201	1.0	0.7	
202	1.0	1.0	
203	1.3	1.1	20.15
204	1.0	2.6	
205a	1.0	2.1	19.10
205b	1.0	1.3	16.76
206	1.0	0.6	19.30
207	1.0	0.7	
208	1.0	0.7	19.30
209	1.0	0.4	19.28
210	0	0.9	19.30
212	0	0.9	20.73
	4.0	0.3	21.11
213	0	0.6	21.26
	8.0	2.4	30.42
215	0	0.7	20.88
	8.0	3.8	30.52
216	0	0.6	20.49
	5.0	1.3	20.54
217	0	1.1	20.30
	5.0	1.4	25.75
218	0	1.4	19.90
	4.0	1.3	19.90
219	0	1.5	20.29
	5.0	0.9	20.62
221	0	1.0	19.55
223	1.0	1.6	19.01
224	0	1.0	19.68
225	0	0.9	19.71
227	0	1.8	18.80

Fig. 4. Mean chlorophyll *a* concentrations for 1971 and 1972. The values for 25 July, 16 August 1971, and 11 August 1972 are means of the chlorophyll *a* concentrations from the three cruises. The values for the other dates are the results of single determinations. All measurements were made on water samples.



1971
1972
CHLOROPHYLL a CONCENTRATION, mg m^{-3}
4.0
2.0
0
27 Mar.
10 May
25 July
16 Aug.
3.0
2.0
1.0
0
2 Feb.
18 May
25 May
11 Aug.
Mean of values measured inside Prudhoe Bay
Mean of values measured on deep water samples with salinity above 28 ‰

Table 8. Sample depth, primary productivity, chlorophyll *a* concentration, and approximate percentage of incident solar radiation at the sample depth for cruise I.

Station Number	Sample Depth (m)	Primary Productivity (mg C m^{-3} hr^{-1})	Chl *a* (mg m^{-3})	Approximate % Light
1	0	1.4	1.2	100
	2.0	2.3	1.0	1
5	0	1.3	0.8	100
	2.0	8.0	1.3	1
6	1.5	12.3	2.9	<1
8	1.5	6.5	3.6	<1
10	0	3.9	1.5	100
12	0	0.4	0.2	100
	3.5	21.22	7.4	10
15	0	0.0	0.5	100
	4.5	1.8	1.2	25
22	1.5	0.2	0.5	25

Table 9. Sample depth, primary productivity, chlorophyll *a* concentration, and approximate percentage of incident solar radiation at the sample depth for cruise II.

Station Number	Sample Depth (m)	Primary Productivity (mg C m^{-3} hr^{-1})	Chl *a* (mg m^{-3})	Approximate % Light
101	0	1.0	0.4	100
	4.5	0.6	0.6	10
104	0	0.3	0.3	100
	5.0	0.7	0.9	15
107	0	0.6	0.5	100
	9.5	1.3	0.7	<1
112	1.0	1.4	1.0	25
117	0	0.2	0.3	100
	3.5	0.3	0.5	25
119	0	0.1	0.5	100
	9.0	0.7	1.3	8
122	0	0.4	0.6	100
	7.5	0.4	0.5	8
123	0	0.4	0.4	100
	4.5	0.4	0.3	25

Table 10. Sample depth, primary productivity, chlorophyll *a* concentration, and approximate percentage of incident solar radiation at the sample depth for cruise III.

Station Number	Sample Depth (m)	Primary Productivity (mg C m^{-3} hr^{-1})	Chl *a* (mg m^{-3})	Approximate % Light
203	1.3	0.9	1.1	10
205b	1.0	0.9	1.3	10
206	1.0	0.4	0.6	20
208	1.0	0.4	0.7	11
210	0	1.0	0.9	100
212	0	0.5	0.9	100
	4.0	0.4	0.3	2
213	0	0.8	0.6	100
	8.0	2.4	3.3	1
217	0	1.0	1.1	100
	5.0	2.1	1.4	1
223	1.0	0.6	1.6	<1

Table 11. Nitrate and ammonia uptake rates during cruises I and II.

Station Number	Sample Depth (m)	NO_3 Light	NO_3 Dark	NH_3 Light	NH_3 Dark
			(μg $liter^{-1}$ hr^{-1})		
1	0	0.093	0.045	0.369	0.151
	2.0	0.120	0.040	0.235	0.189
5	1.5	0.077	0.050	0.171	0.186
6	1.5	0.349	0.108	0.896	0.556
8	1.5	0.259	0.127	1.076	0.728
10	0	0.210	0.068	0.204	0.105
12	2.0	1.432	1.172	0.747	0.212
15	2.5	0.040	0.038	0.084	0.051
19	2.5	0.030	0.021	0.073	0.063
22	1.5	0.036	0.021	0.060	0.033
101	2.5	0.010	0.013	0.036	0.045
104	3.0	0.007	0.043	0.036	0.030
107	5.0	0.009	0.002	0.027	0.018
108	3.5	0.017	0.003	0.046	0.040
112	1.0	0.086	0.021	0.196	0.128
117	2.0	0.012	trace	0.054	0.034
119	5.0	0.028	0.014	0.067	0.042
122	4.0	0.022	none	0.062	0.073
123	4.5	0.008	0.004	0.036	0.025

^{15}N-labelled nitrate and ammonia. The uptake of both ^{15}N ammonia and nitrate was greater during cruise I than during cruise II which corresponds to the greater primary productivity during cruise I. Ammonia uptake was higher than nitrate uptake except at station 12 where uptake was determined only for the deeper, more saline water.

d. Nutrient concentrations

Nutrient concentrations in the ice were extremely variable; this variability also occurs at Barrow (Alexander and Horner unpublished) where many more samples have been analyzed over a longer period of time. Generally the bottom section of the ice has the highest nutrient concentration except during the time of the algal bloom in the bottom layer of the ice when the nutrient concentrations may be low.

The nutrient cycle in the seawater is similar to that at Barrow. Highest concentrations of nitrate, ammonia, phosphate and silicate occur under the ice in late winter and spring (Tables 12-14) decreasing to a summer low following ice breakup and the spring phytoplankton bloom.

High nitrate concentration occurred in Prudhoe Bay and off Reindeer Island in winter and spring, ranging from near 10 μg-atoms liter^{-1} to about 1 μg-atom liter^{-1}, except at stations 9-11 which were near the mouth of the Sagavanirktok River and may have received runoff high in nitrate from the river. Ammonia concentrations were generally low, ranging from 2.5 - 1 μg-atom liter^{-1}.

The phosphate concentration was never high, always being below 1.6 μg-atoms liter^{-1}. The summer phosphate concentration was lower inside Prudhoe Bay than in the deeper water of the lagoon.

Table 12. Nutrient concentrations from cruise I.

Station Number	Sample Depth (m)	PO_4-P	NO_3-N	NO_2-N	NH_3-N	$Si(OH)_4$-Si
		(μg-atoms $liter^{-1}$)				
1	0	0.4	0.4	0.1	2.7	
	2.0	0.4	0.4	0.1	1.4	12.0
2	1.5	0.4	0.3	0.1	1.4	13.5
3	0.8	0.4	0.4	0.1	1.7	15.0
4	1.0	0.2	0.8	0.1	1.6	17.3
5	0	0.2	0.4	0.1	1.4	13.6
	2.0	0.2	0.2	0.1	1.6	8.5
6	1.5	0.3	0.4	0.1	1.6	13.0
7	1.5	0.3	0.3	0.1	1.5	14.7
8	1.5	0.3	0.3	0.1	1.8	14.7
9	1.5	0.1	2.7	0.1		27.0
10	0	0.2	2.7	0.1		28.3
11	0	0.1	2.2	0.1		25.8
12	0	0.5	0.0	0.1		6.1
	3.5	0.8	0.1	0.1		6.8
13	0	0.4	0.1	0.1		5.8
	3.5	0.6	0.0	0.1		6.2
14	0	0.5	0.1	0.1		6.2
	4.0	0.7	0.0	0.1		7.1
15	0	0.3	0.2	0.1		6.2
	4.5	0.7	0.0	0.1		7.0
16	0	0.8	0.3	0.1		5.7
	6.0	0.9	0.1	0.1		6.5
17	0	0.5	0.2	0.0		5.0
	6.0	0.9	0.1	0.1		5.4
18	0	0.6	0.1	0.1		6.3
	4.5	0.7	0.1	0.1		6.1
19	0	0.5	0.1	0.1		6.0
	5.5	0.7	0.0	0.1		5.4
20	1.5	0.7	0.1	0.1		7.0
21	1.0	0.5	0.1	0.1		7.4
22	1.5	0.7	0.1	0.1		6.2

Table 13. Nutrient concentrations from cruise II.

Station Number	Sample Depth (m)	PO_4-P	NO_3-N	NO_2-N	NH_3-N	$Si(OH)_4$-Si
		(μg-atoms liter^{-1})				
101	0	0.3	0.1	0.1		7.1
	4.5	0.3	0.1	0.1		5.8
102	0	0.4	0.1	0.1		7.5
	4.5	0.3	0.1	0.1		7.5
103	0	0.3	0.1	0.1		7.4
	4.0	0.3	0.1	0.1		7.7
104	0	0.4	0.1	0.1		7.5
	5.0	0.6	0.1	0.1		8.2
105	0	0.3	0.0	0.1		6.0
	4.5	0.4	0.1	0.1		7.6
106	0	0.3	0.2	0.0		6.2
	5.5	0.4	0.1	0.1		7.1
107	0	0.3	0.1	0.1		6.1
	9.5	0.8	0.2	0.1		7.5
108	0	0.2	0.1	0.1		7.1
	6.5	0.7	0.1	0.1		6.5
109	0	0.3	0.1	0.1		8.6
110	0	0.3	0.1	0.1		9.3
	4.5	0.2	0.1	0.1		4.8
111	1.5	0.2	0.2	0.1		1.0
112	1.0	0.1	0.2	0.1		16.4
113	1.0	0.1	0.2	0.1		11.4
114	1.0	0.1	0.2	0.1		16.3
115	0	0.2	0.2	0.1		12.8
116	0	0.3	0.2	0.1		10.2
117	0	0.3	0.2	0.1		5.0
	3.5	0.5	0.1	0.1		5.5
118	0	0.4	0.2	0.1		4.6
119	0	0.4	0.2	0.1		0.5
	9.0	0.8	0.2	0.1		4.5
120	0	0.4	0.2	0.1		5.9
	8.0	0.8	0.2	0.1		5.7
121	0	0.4	0.2	0.1		6.5
122	0	0.4	0.1	0.1		5.5
123	0	0.3	0.0	0.1		6.8
124	0	0.3	0.1	0.1		7.6
125	1.5	0.4	0.0	0.1		7.1

Table 14. Nutrient concentrations from cruise III.

Station Number	Sample Depth (m)	PO_4-P	NO_3-N + NO_2-N	NH_3-N	$Si(OH)_4$-Si
		(μg-atoms liter^{-1})			
201	1.0	0.4	0.3	0.6	9.0
202	1.0	0.4	0.1	0.3	7.7
203	1.3	0.4	0.3	0.3	8.8
204	1.0	0.3	0.3	0.9	9.5
205a	1.0	0.5	0.4	1.5	11.0
205b	1.0	0.3	0.8	0.9	16.9
206	1.0	0.3	0.3	1.7	10.1
207	1.0	0.4	0.1	0.2	7.7
208	1.0	0.5	0.4	0.6	9.3
209	1.0	0.6	0.3	0.7	9.6
210	0	0.4	0.5	1.3	10.3
212	0	0.5	0.6	4.1	7.8
	4.0	0.4	0.3	0.4	6.8
213	0	0.5	0.3	0.0	7.0
	8.0	0.5	0.3	0.0	7.0
215	0	0.5	0.3	0.7	7.1
	8.0	0.5	0.3	0.7	7.1
216	0	0.5	0.5	1.1	9.3
	5.0	0.6	0.3	0.7	9.0
217	0	0.5	0.3	0.7	8.7
	5.0	0.6	0.4	0.8	6.4
218	0	0.4	0.4	0.6	9.5
	4.0	0.4	0.3	0.7	9.7
219	0	0.6	0.2	0.7	9.0
	5.0	0.5	0.3	0.6	8.1
221	0	0.4	0.4	0.9	9.6
223	1.0	0.2	0.6	0.5	11.0
224	0	0.3	0.2	0.2	9.2
225	0	0.4	0.5	1.2	8.5
227	0	0.3	0.4	0.5	10.6

The highest silica concentrations, ranging from 10 μg-atoms $liter^{-1}$ in August 1972 to 35 μg-atoms $liter^{-1}$ in March 1971, occurred inside Prudhoe Bay. Off Reindeer Island the silica concentration ranged from 9.3 - 17.0 μg-atoms $liter^{-1}$.

e. Salinity and temperature

Salinity (Tables 5-7) in Prudhoe Bay is high in winter and spring because of the depth of the bay and the freezing process. Only in the relatively deep, 2.7 m, middle of the bay is there any water under the approximately 2 m thick ice. This water is highly saline with a salinity near 70°/₀₀ in May. North of Reindeer Island the winter-spring salinity ranged from 28-35.5°/₀₀.

During the summer, no significant stratification occurs within Prudhoe Bay primarily because of wind mixing. The bay receives water from the Sagavanirktok River in the spring and summer and consequently has lower salinities and warmer temperatures than the lagoon and offshore areas. Salinity inside the bay varied from 13-22°/₀₀ during the summer cruises. In the transects across the lagoon area from the bay to Reindeer Island, surface salinity ranged from 14.57°/₀₀ near Gull Island during cruise II to 26.61°/₀₀ at station 18 midway along the transect during cruise I. Salinities of 15-31°/₀₀ occurred in water below 3.5 m. In the Narwhal Island area, the salinity varied from 18.61°/₀₀ in surface water at station 118 off the west end of Narwhal Island to 24.83°/₀₀ at 4.5 m at station 123 located near Dinkum Sands. The salinity at stations between Dinkum Sands and Reindeer Island was generally about 18-19°/₀₀ with the exception of the 5 m sample at station 104 where the salinity was 25.85°/₀₀.

Water temperatures under the ice were below 0°C with the lowest value being -4.0°C on 25 May 1972 in Prudhoe Bay when the salinity was 66.27°/₀₀. Summer surface temperatures ranged from 2-9°C.

2. Water transparency

Inside the bay, detritus is extensive and Secchi disc depths were often less than 1 m. Outside the bay in the lagoon area, transparency increased and average Secchi disc depths of 2 m were recorded. North of Reindeer Island Secchi disc depths of 2-5.3 m were recorded. Secchi disc depths are listed in the station summary sheets in Appendix 1.

3. Biology

a. Phytoplankton

Summary sheets containing the phytoplankton standing stock data for each sample are compiled in Coyle (1974).

Pennate diatoms were the dominant algae in the bottom ice and in the water just below the ice during the spring. The highest cell concentration occurred in the bottom ice off Reindeer Island on 10 May 1971 when 83 million cells per liter were present. Of these, 97% were pennate diatoms with *Fragilariopsis* spp. accounting for 79% and *Nitzschia frigida* Grunow another 10% of the total number of cells. Also present were *Cylindrotheca closterium* (Ehrb.) Reimann and Lewin, *Navicula directa* W. Smith, *N. valida* Cleve and Grunow, *Gomphonema exiguum* Kützing, and *Gyro-Pleurosigma* spp. Many of the pennate diatoms could not be identified and are included in the summary sheets by size class based on the length of the apical axis. The water sample from under the ice had the same general species composition but contained only 7.9 million cells per liter.

In May 1972, off Reindeer Island, there were nearly three times as many cells in the seawater as in the ice and the species composition was considerably different from that found in 1971. *Fragilariopsis* spp. and *Nitzschia frigida* were rare or not seen: *Chaetoceros septentrionalis* Østrup, *Navicula directa, N. debilissima* Grunow, *N. pediculus* Cleve, *N. gelida* Grunow, *N. sibirica* Grunow, and *Gyro-Pleurosigma* spp. were present, but not numerous. Small, unidentified flagellates made up 17.5% of the total number of cells found in the ice and 30% of the cells found in the water.

In Prudhoe Bay in spring 1972, *Nitzschia frigida* and *Fragilariopsis* spp. were abundant in the ice and *Diploneis* sp., *Navicula debilissima, N. gelida, N. transitans* Cleve, and *Cylindrotheca closterium* were also present along with unidentified pennate diatoms and small flagellates. The same species were present in the seawater under the ice.

The similarity between the ice and water communities is caused by the sampling technique which results in contamination of the water sample by pieces of ice.

Three major phytoplankton communities were found during the summer cruises. Inside Prudhoe Bay, an assemblage of pennate diatoms is common, often comprising 50-70% of the total number of cells. Many of these pennate diatoms were not identified, but *Gomphonema exiguum, Navicula transitans, N. pediculus, N. debilissima,* and *Amphora* sp. were usually present. A euglenoid, similar to *Eutreptiella braarudi* Throndsen, accounted for nearly 32% of the cells at station 6, but generally, flagellates were rare and accounted for less than 10% of the total number of cells.

A second phytoplankton community occurred in the deeper, more saline water in the lagoon and north of Reindeer Island. Centric diatoms, including *Chaetoceros socialis*, *Ch. atlanticus* Cleve, *Ch. wighami*, *Ch. septentrionalis*, *Ch. compressus* Lauder, *Porosira glacialis*, *Thalassiosira gravida*, and *T. nordenskioeldii* were common. The presence of *Eucampia zoodiacus* Ehrenberg at stations 213 and 215 probably indicates the presence of more oceanic water either as an intrusion from the Bering Sea or from oceanic regions of the Beaufort Sea. The pennate diatoms *Nitzschia delicatissima* Cleve and *Cylindrotheca closterium* were also abundant in the deeper water community.

The third community was dominated by microflagellates. This community occurred in low salinity surface water in the lagoon areas. The most abundant species included *Monosiga marina* Grøntved, *Dinobryon balticum*, *Calycomonas vangoorii* (Conrad) Lund, and a species of *Platymonas*. Other flagellates present were *Diaphanoeca grandis* Ellis, *Calycomonas ovalis* Wulff, and *Ebria tripartita* (Schumann) Lemmermann. Flagellates that could not be identified were present at all brackish water stations and sometimes accounted for more than 40% of the cells.

Dinoflagellates were not a major component of the phytoplankton communities, rarely being more than 4% of the total number of cells at any station. Species present included *Peridinium pallidum* Ostenfeld, *P. minusculum* Pavillard, *P. brevipes* Paulsen, *P. trochoideum* (Stein) Lemmermann, *Gonyaulax catenata* (Levander) Kofoid, *Dinophysis arctica* Mereschkowsky, and *Gymnodinium lohmanni* Paulsen.

b. Zooplankton

Thirty categories of zooplankton, including 9 phyla, were described from the 13 samples taken in the Prudhoe Bay vicinity during August 1972

(Table 15). Major taxa are presented in systematic order with zooplankton categories listed alphabetically within these taxa.

Phylum Coelenterata

Five species of Hydrozoa were identified from the collections. *Perigonimus yoldia-arctica* Pallas was the most prevalent, occurring at all stations and in greatest abundance inside Prudhoe Bay. Bell heights ranged from 5-25 mm, indicative of both a juvenile and adult population. The holoplanktonic *Aeginopsis laurentii* Brant was taken at 5 of 7 stations, but rarely in the region from Point McIntyre to Reindeer Island; specimens were all immature. *Aglantha digitale* (Muller) var. *camtschatica* (Brandt), also a common arctic holoplanktonic medusa, was usually found outside Prudhoe Bay proper, always as immature individuals in low numbers. Both *Obelia longissema* (Pallas) and an unidentified species with 8 radia and 4 tentacles were collected in waters with a strong oceanic influence, but only rarely inside the Midway Islands.

Phylum Annelida

Larval and postlarval polychaetes were found at four stations and occurred in highest numbers outside Reindeer Island. Specimens in the families Phyllodocidae and Syllidae comprised the largest fraction of total individuals.

Phylum Arthropoda

Amphipoda

Gammarid amphipods were present in modest abundance in the waters sampled outside Prudhoe Bay; only one specimen was taken inside the bay.

Table 15. The zooplankton community composition and relative abundance at zooplankton stations occupied in the Prudhoe Bay vicinity, August 1972.

TAXON	Prudhoe Bay 208	Prudhoe Bay 201	Lagoon to Midway Isl. 219	Lagoon to Midway Isl. 218	Lagoon to Midway Isl. 224	Outside Reindeer Isl. 213a	Outside Reindeer Isl. 213b
COELENTERATA							
Hydrozoa							
Aeginopsis laurentii	+	+	+			+	+
Aglantha digitale		+	+	+		+	+
Obelia longissema					+		+
Perigonimus yoldia-arctica	o	o	+	+	+	+	+
Unidentified species			+				+
ANNELIDA							
Polychaeta							
Pelagic larvae	+		+			o	o
ARTHROPODA							
Amphipoda							
Gammaridae	+		+	+	o	o	+
Hyperiidae							+
Cirripedia							
Balanus nauplii			+	+		+	o
Balanus cyprids			+	+		+	o
Copepoda							
Acartia spp.	●●	●●●●	o	o	●●●	+	
Calanus cristatus			+				
Calanus glacialis	+	+	●●	●	o	o	o
Calanus hyperboreus	o	+	+	+	+	+	+
Chiridius obtusifrons	+	+	+	+	+	o	●
Euchaeta sp.	+		+	+		+	
Metridia longa		+	+	+	+	+	
Microcalanus pygmaeus			+			●	o
Oithona similis			o	+		o	
Pseudocalanus minutus	o	o	●	●●	●	●●	●●
Copepod nauplii			+	+		o	+
Decapoda							
Crab zoea larvae	+		+	o	+	+	o
Shrimp juveniles						+	+
Euphausiacea							
Thysanoëssa raschii						+	+
Mysidacea	+			+	o	+	o

ECHINODERMATA							
Pelagic larvae							+
CHAETOGNATHA							
Sagitta elegans arctica			+	+		o	+
UROCHORDATA							
Oikopleura sp.							o
VERTEBRATA							
Pisces	+		+	+		+	+

- ● category represents 20% of individuals at the station
- o category represents 2-10% of individuals at the station
- \+ category present, but rare (1% of the total individuals)
- a horizontal tows
- b vertical composite tow

Individuals of the genus *Pseudalibrotus* were numerically dominant and were encountered at all remaining stations except 201. All *Pseudalibrotus* were immature and ranged from 3-12 mm in length (an average of 7 mm). A gammarid species with long, brown speckled pereiopods and a brown pigmentation of the thorax was collected at station 224. An additional species with a hooked rostrum was also found in the material gathered outside Reindeer Island.

Hyperiid amphipods were rarely observed; the only specimen (probably the genus *Hyperia*) was sampled seaward of the Midway Islands.

Cirripedia

Barnacle larvae, the genus *Balanus*, were nonexistent at stations south of Point McIntyre; in waters south and adjacent to Reindeer Island, nauplii and cyprid larvae were infrequently noted. Surface tows outside Reindeer Island contained somewhat larger numbers, but larvae occurred in significant quantities only on the single occasion when the oceanic Beaufort Sea water underlying the dilute surface layer was sampled by a vertical tow at station 213.

Copepoda

Copepods were the most diverse (10 species) and abundant group of zooplankters in Prudhoe Bay and surrounding waters; *Acartia* spp. and *Pseudocalanus minutus* were the most numerous.

Acartia spp. is clearly the numerically dominant member of the zooplankton community within Prudhoe Bay and northward to Point McIntyre. This genus was represented by two species, *A. clausi* Giesbrecht, a classic neritic warm water copepod, and *A. longiremis* Lilljeborg, a species of both offshore and inshore regions. *Acartia* was taken at all stations and contributed no fewer than 40% and up to 80% of the individuals in samples collected from the inside waters (stations 208, 201, 224). This genus was not dominant in collections taken north of Reindeer Island. The majority of specimens encountered at all sites were in the later stages of development, usually adults and stage V copepodids. Scattered individuals of stages II, III, and IV were found at stations 218 and 224.

The microcalanoid, *Pseudocalanus minutus* (Krøyer), was second in overall abundance, comprising at least 20% of the catch at all stations (with the exception of 201). *Pseudocalanus* contributed the largest fraction of the total catch in waters outside the Midway Islands (40%), although the species was also common just south of the islands. Inside Prudhoe Bay, *P. minutus* was markedly subordinate in number to *Acartia*. Copepodids IV and V were the dominant developmental stages at all stations, with adults and stage II and III copepodids present in fewer numbers. Ovigerous females were reported only from the vertical collections made north of Reindeer Island.

Three species of the genus *Calanus* were identified. *Calanus glacialis* Jaschnov was the most common of the trio, its presence reported from all 7 stations. This species also represented the greatest percentage of the community at locations 218 and 219. Specimens in all stages of development existed simultaneously, with stages II and IV generally prevailing throughout the entire area. Copepodids I and II were abundant at stations 218 and 219. Adults appeared north of the offshore islands but rarely in the inside waters.

Calanus hyperboreus Krøyer was also of ubiquitous distribution, but was present in smaller numbers relative to *C. glacialis*. Copepodid III was the most common stage at all stations; stages IV and V were secondarily important members. A few adults were collected at station 213.

One individual of *Calanus cristatus* Krøyer, a common species in the surface waters of the Bering Sea during summer, was reported from station 219.

Two characteristically offshore arctic copepods, *Euchaeta norvegica* Boeck and *Metridia longa* (Lubbock), were rare but consistent members of the communities found in the three major hydrographic regions in the Prudhoe Bay vicinity. *Metridia longa* appeared exclusively as copepodids II and III. *Euchaeta* persisted in a number of developmental states, from stages II to V (station 213) and as stage IV at station 219.

Chiridius obtusifrons Sars, *Microcalanus pygmaeus* (Sars) and *Oithona similis* Claus occurred in varying numbers. *Chiridius* was taken at all stations, but was not often collected south of Reindeer Island. All individuals of this species were immature stage II and III copepodids. *Microcalanus* exhibited a restricted distribution and was collected almost exclusively as stage IV and V copepodids outside the offshore islands where it represented a rather sizable fraction of the community. *Oithona similis*, a cyclopoid copepod, was numerically important at station 213, as were both *C. obtusifrons* and *M. pygmaeus*. *Oithona* was not present in the dilute waters of Prudhoe Bay.

Copepod nauplii were notably absent from the plankton out to Point McIntyre and were not very abundant at any of the remaining locations.

Decapoda

The Decapoda were represented by crab zoea and juvenile shrimp. Larvae of both anomuran and brachyuran varieties were present, the largest contributing families being the Lithodidae and Inachidae, respectively. Zoea occurred in the samples from all areas under investigation, being in greatest density at stations 218 and 213. No megalops larvae were taken in collections at any station.

Euphausiacea

The euphausiids were poorly represented in the plankton. Immature *Thysanoëssa raschii* (M. Sars) up to 15 mm long were occasionally sampled north of Reindeer Island. No euphausiid nauplii or calyptopid stages were encountered in the collections.

Mysidacea

Mysids were collected at 5 of 7 stations. The relatively high number of individuals found at stations 224 and 213 (vertical tow) may reflect a disturbance of the bottom during towing procedures. *Mysis oculata* (Fabricius) was identified and ranged in length from 8 mm to a fully mature 25 mm specimen taken outside Reindeer Island. The majority of individuals were approximately 16 mm in total length.

Phylum Echinodermata

Larval echinoderms were encountered only outside the Midway Islands, and in very sparse numbers. Echinoplutei larvae appeared to be distributed exclusively below the pycnocline in the oceanic water underlying the surface layer, since they were absent in surface tows at the same locations.

Phylum Chaetognatha

Sagitta elegans arctica Aurivillius was the only species of Chaetognatha present in the collections. Specimens were not observed at all from the Prudhoe Bay samples and only rarely out to the Midway Islands. *Sagitta* experienced its greatest relative abundance at station 213, where it comprised 10% of the catch. The population was wholly juvenile with the majority of individuals measuring 15-18 mm in length although isolated specimens of 5 and 25 mm were also recorded.

Phylum Urochordata

The pelagic tunicate, *Oikopleura*, cf. *O. vanhöffeni* Lohmann, was collected only in the more saline waters north of Reindeer Island in a vertical tow to a depth of 10 meters. Individuals were present in modest abundance in this zone.

Pisces

Larval fishes were widely distributed but infrequent (at least in samples) members of the plankton communities at most locations. Specimens averaged 8 mm in length. No juvenile fishes were identified. Fish eggs were encountered outside the Midway Islands.

Discussion and Conclusions

Recent discussions of chlorophyll *a* concentrations and primary production in sea ice (Apollonio 1965; Meguro, Ito, and Fukushima 1966, 1967; Horner 1972, 1973; Horner and Alexander 1972; Clasby et al. 1973; Alexander 1974) indicate that the ice algae may provide a significant contribution to the annual productivity of the Arctic nearshore area, although the timing of the algal bloom in the ice may be more important than the absolute values. The chlorophyll *a* concentration in the bottom ice is variable (Apollonio 1965; Horner 1972) reflecting the patchy distribution of the ice organisms and the difficulty in collecting quantitative samples using surface coring techniques. The recorded chlorophyll concentrations should therefore be considered minimum values.

The spring bloom of ice organisms probably started later in Prudhoe Bay than at Reindeer Island; reasons for this are unclear, but may be related to differences in snow cover, and thus light penetration. Snow cover in Prudhoe Bay is often more than 15 cm thick and blown into hard drifts; near Reindeer Island, at least at the spring sampling area, the snow cover was usually less than 10 cm and not blown into drifts. Light has been suggested as the major factor in triggering the spring bloom in the ice (Clasby et al. 1973) because active photosynthesis does not occur until the light intensity is near 66 lux.

The bloom in the ice disappears at Barrow in early June when increased solar radiation causes melting to occur in the ice. Some of the melting is probably caused by the organisms themselves as they trap solar energy within the ice. At the same time, brine drainage occurs and some cells are washed out of the ice by this mechanism. The bottom few centimeters of ice have always been softer and more friable than the rest of the ice and are thus easily destroyed. Water currents under the ice hasten the destruction.

The time when the ice algae disappeared from the ice at Prudhoe Bay is not known because ice conditions toward the end of May and in early June make it impossible to land on the ice to sample. It is likely that it occurs about the same time as at Barrow, at least at Reindeer Island. Inside the bay conditions are somewhat different because of overflow water from the Sagavanirktok River.

Meguro et al. (1967) have reported that the release of diatoms from the ice produces the spring phytoplankton bloom in the water column. This is probably not so, although the data presented here suggest that many ice organisms are found in the seawater under the ice. This is because of the spring sampling technique. The spring phytoplankton bloom in the water column is primarily composed of centric diatoms including *Porosira glacialis*, and several species of *Thalassiosira*; the flagellate *Phaeocystis pouchetii* may also be common. *Nitzschia grunowii* Hasle is the major pennate diatom found in both ice and water so it is difficult to tell where it originated. Some pennate diatoms from the ice do occur in the water column for short periods, but more taxonomic studies are needed before we can determine the absolute role of the ice organisms in the spring bloom of the water column. Questions which remain unanswered with regard to the ice organisms include where they originate and what happens to them when they leave the ice.

Nutrient concentrations within the ice, while sometimes low, are probably not limiting for the ice algae. The method of measurement, melting the ice before nutrient determinations, gives minimal values for the nutrients. Recent data from the Barrow area (Clasby et al. 1973, in prep.) indicate that interstitial water removed from sections of ice by vacuum filtration contains 2-22 times higher nutrient concentrations and salinity. If it is assumed that the organisms are actually living in the interstitial water, then nutrient concentrations are not limiting and the salinity would be 2-3 times the figures reported here. One caution with regard to the environment in which the ice organisms live: many of the organisms, at least at Barrow, are organisms reported primarily from brackish water. Many of these same organisms, both diatoms and flagellates, that have been grown in culture thrive only at low salinities. Cells isolated from the ice grow well at 3-5 °/₀₀ salinity, but do not grow well at 28-30 °/₀₀, an average seawater salinity for the Barrow area, and 4-10 ‰ less than the winter seawater salinity or the ice interstitial water salinity.

Early papers on the ice community were lists of the organisms found, primarily pennate diatoms. Recently, Horner and Alexander (1972) have described the ice community in more detail, reporting not only pennate diatoms, but dinoflagellates, flagellates from several algal phyla, ciliated Protozoans, harpacticoid copepods, turbellarians, and nematodes.

The ice community at Reindeer Island and Prudhoe Bay is similar to that at Barrow. Common pennate diatoms included *Nitzschia frigida, Fragilariopsis* spp. (renamed as *Nitzschia* species by Hasle 1972), *Gomphonema exiguum, Cylindrotheca closterium* (as *Nitzschia closterium* W. Smith in previous reports), *Gyro-Pleurosigma* spp., and *Navicula* spp. Coyle (1974) lists the centric diatom *Chaetoceros septentrionalis* as relatively abundant in the ice, especially at Reindeer Island in 1971. This diatom has been found rarely in fresh ice samples from Barrow, but always occurs in abundance in cultures started from pieces of sea ice, indicating that cells are present in the ice, but conditions are not optimal for growth. Coyle (1974) shows dinoflagellates, cryptomonads, and the green flagellate *Platymonas* as common in the ice in the Prudhoe Bay area: these are also common at Barrow. Although Coyle (1974) has not listed ciliates they are probably present and have been included in his "unknown" category. He does not mention small Metazoa. With the exception of nematodes, the occurrence of these at Barrow is sporadic and this is probably also true here. Harpacticoid copepods have been found in an ice sample collected near Narwhal Island (Horner unpublished); they were obviously grazing on the ice algae as evidenced by full digestive tracts.

Nutrient concentrations in the water below the ice with the exception of phosphate, are considerably higher than after ice breakup. There are two possible reasons for this: utilization by the phytoplankton during the spring bloom and dilution of the seawater by melting sea ice and run-off during river breakup.

Phosphate concentrations ranged from 0.1-0.9 μg-atoms $liter^{-1}$, averaging 0.42 μg-atoms $liter^{-1}$, during the three cruises with the highest concentrations occurring during cruise I. The phosphate concentration in North Slope rivers is low according to Schell (Kinney et al. 1972) and this probably affects the seawater concentration.

The nitrate plus nitrite concentration in the water column during the cruises never exceeded 0.9 μg-atoms $liter^{-1}$ except at stations 9-11. The ammonia concentration was also low, averaging 1.7 μg-atoms $liter^{-1}$ during cruise I and 0.8 μg-atoms $liter^{-1}$ during cruise III.

Half-saturation constants for nitrate and ammonia uptake have been measured for several species of marine phytoplankton and found to vary from 1.4-144 μg-atoms NO_3-N $liter^{-1}$ and 1.4-130 μg-atoms NH_3-N $liter^{-1}$ (Eppley et al. 1969). Eppley and Thomas (1969) concluded that half-saturation constants for nitrate limited growth and nitrate limited uptake were similar, therefore the half-saturation constants for nitrate uptake indicate the concentration at which nitrate becomes limiting, thus suggesting that nitrogen was probably limiting for the phytoplankton population in the Prudhoe Bay area.

Schell (Kinney et al. 1972) has discussed the probability that marine phytoplankton in the Simpson Lagoon-Harrison Bay area are nitrate limited, partially basing his reasoning on the low nitrogen:phosphorus ratio. The usual N:P ratio quoted in the literature is about 15:1; in Simpson Lagoon in winter, the ratio is closer to 5:1. In the Prudhoe Bay area the same argument seems to hold with the N:P ratio about 3:1.

The limited information from the nitrate and ammonia uptake experiments also tends to confirm the idea that nitrogen is limiting phytoplankton production in the area. With the exception of station 12, ammonia uptake rates were higher than nitrate uptake rates. Dugdale and Goering (1967) have shown that ammonia is a regenerated nitrogen source and can maintain a phytoplankton population for a short time, but a new source of nitrogen, i.e. nitrate, is necessary for growth to occur.

Silicate concentrations were variable, but were probably always sufficient to provide enough silicon for diatom growth. The half-stauration constant for silicon uptake, measured in natural marine phytoplankton populations is about 3 μg-atoms liter^{-1} (Goering et al. 1973) and ranged from 0.80-3.37 μg-atoms liter^{-1} for several marine diatom species grown in culture (Paasche 1973). With the exception of station 110 located about half way between Prudhoe Bay and Reindeer Island, the silica concentration was always above 4 μg-atoms liter^{-1}.

The silicate concentration was higher inside Prudhoe Bay and in surface, low salinity water than in the deeper, more saline water, partly because greater diatom populations were supported in the deeper water. Schell (Kinney et al. 1972) has shown that the silica concentration is high in North Slope rivers. Stations 9-11, apparently influenced by run-off from the Sagavanirktok River as evidenced from the low salinities, had the highest silicate concentrations.

While we suggest that nitrogen is a limiting nutrient for phytoplankton growth in the area studied, it must be pointed out that recent research indicates that for some nutrients it is not the nutrient concentration in the medium that is important for growth, but the concentration in some metabolically active nutrient pool inside the cell (see Guillard et al. 1973 and references cited therein for discussion). In addition, we have no information on trace metal or vitamin concentrations which also affect the growth of marine phytoplankton.

Chlorophyll *a* concentrations and primary productivity were generally higher in the deeper more saline water during the summer. This is probably because of the relatively greater number of photosynthetic organisms in the deeper water and the greater amounts of chlorophyll present in the diatoms of this community as compared with the microflagellate community of shallower water, as well as the higher nutrient concentrations. The average chlorophyll *a* concentration for all samples collected during cruise I was slightly higher than that for the other cruises, while the primary productivity during cruise I was 3-4 times that of the other two cruises.

There are several possible reasons for this. Cruise I took place during the third week in July, not too long after ice breakup. At Barrow, the main spring phytoplankton bloom occurs under the ice just before breakup. It is possible that we sampled the end of the spring bloom during this cruise. Diatom species present such as *Porosira glacialis*, *Thalassiosira nordenskioeldii*, and *T. gravida* which are primarily spring forms support this possibility. It has been reported that the time of ice breakup is an extremely productive time in terms of numbers of sea birds and mammals (J. Burns, C. P. McRoy personal communication), but until recently no studies had been done to determine the reasons behind these observations. It has also been suggested that the melting ice releases nutrients or certain unknown factors into the water which tend to enhance phytoplankton production. English (1961) has pointed out the problem of relative concentrations such that only a small amount of ice melts annually when compared with the volume of water already present in the Arctic Ocean.

The three stations, 9-11, where the salinity was the lowest during cruise I, contained 50-60% pennate diatoms and the chlorophyll *a* concentrations were 1.5-1.6 mg m^{-3}. At station 12, the surface chlorophyll *a* concentration was 0.1 mg m^{-3}, but the species composition consisted of 54% flagellates and only 7% diatoms. *Dinobryon balticum* comprised 29% of the flagellates in the surface water. The 3.5 m sample, with a chlorophyll *a* concentration of 7.4 mg m^{-3}, contained about 4 times as many cells as the surface sample with 84% of the cells being diatoms and only 5% being flagellates. Of the diatoms, 39% were *Thalassiosira nordenskioeldii* cells.

Cruise II in mid-August extended biological coverage of the area eastward to Narwhal Island (147° 29' W). While nutrient concentrations and salinity were not appreciably lower, primary productivity and chlorophyll *a* concentrations averaged only 50% of those of the other cruises. The reason for this seems to be the presence of high numbers of flagellates, many of which are probably non-photosynthetic. For all standing stock stations, flagellates averaged 68.4% and diatoms only 2.9% of the total number of cells. This same situation is also true at Barrow where the diatom population drops drastically following breakup because of the low salinity. Small flagellates become dominant during the summer.

During cruise III, also in August, the highest productivity occurred at 8 and 5 m at stations 213 and 217. The diatoms at these two stations averaged 98.5%, while flagellates averaged only 0.5% of the total number of cells. At all other stations productivity was lower, the flagellates averaged 76.2% and the diatoms 13%. It is difficult to determine whether the populations occurring at this time are spring-summer groups or fall species. The presence of *Thalassiosira nordenskioeldii* and *Fragilariopsis* spp. in the 8 m sample at station 213 indicate a spring-summer community, but the presence of over one million cells of *Chaetoceros socialis* and *Ch. wighami* suggest a summer-fall species assemblage. Usachev (1961) found that during August the diatom community was dominated by *Ch. socialis* and considered other summer forms to be *Ch. atlanticus, Ch. compressus, Ch. convolutus*, and *Eucampia zoodiacus*. Other spring forms which were abundant in the deep water near Prudhoe Bay during cruises I and III were *Nitzschia delicatissima* and *Ch. furcellatus*. *Nitzschia delicatissima* was not reported by either Horner (1969) or Bursa (1961b), possibly because it is difficult to recognize, but it was one of the most abundant species off Reindeer Island during cruise III. Usachev (1961) considered it to be a spring form which is arctic-boreal and neritic. Near Barrow, *Ch. furcellatus* with spores was most abundant in the spring near the edge of the ice (Horner 1969). She thought it was also present later, but was not recognized because it lacked resting spores. Spores were common in the deeper water off Reindeer Island during cruise III.

The deep water diatom community near Prudhoe Bay was dominated by arctic and arctic-boreal forms which are neritic and common in the spring and early summer. *Distephanus speculum* (Ehrenberg) Haeckel, which is common in the central Arctic Ocean (Usachev 1961, Tibbs 1967, Horner unpublished) and in temperate neritic waters, but not at Barrow (Horner 1969) was seen only once near Prudhoe Bay. *Ebria tripartita*, which is usually considered to be a silicoflagel_ate, was common in the brackish water samples from Prudhoe Bay.

It has been reported from the White Sea and southern regions of the Kara and Laptev seas (Usachev 1946) and from more temperate regions (Gemeinhardt 1930).

The pennate diatom community found inside Prudhoe Bay during cruise I was very productive (Table 8). Since this community was limited to the shallow water inside the bay, and because the standing stock samples contained a large amount of sediment, most of the diatoms were probably benthic forms that were suspended in the water column by turbulence, although some of the cells may have been ice algae. The pennate community was not found during cruises II and III and possibly occurs only in late spring and early summer.

The flagellate community of the surface water layer was present during all three cruises, but was never very productive. A large percentage of this community was non-photosynthetic, composed of *Monosiga marina*, *Calycomonas vangoorii*, and *Ebria tripartita*. Although *Platymonas* sp. and *Dinobryon balticum* were abundant during cruises II and III, they were not as productive as the diatoms. Centric diatoms were occasionally seen in the brackish layer, but were never abundant and usually appeared to be in poor condition.

Alexander (1974) found large numbers of fresh water flagellates in Simpson Lagoon and Harrison Bay, in particular *Chromulina* sp. and *Rhodomonas minuta* Skuja, and suggested that their occurrence was related to salinity stratification. The pycnocline appears to have restricted the diatoms to the deeper water near Prudhoe Bay, but this was not observed in the samples from Harrison Bay and Simpson Lagoon where dinoflagellates and silicoflagellates increased with depth. The highest primary productivity rates occurred in early August and increased with depth in the Beaufort Sea off Simpson Lagoon. This is similar to the pattern observed near Prudhoe Bay.

Because it was not possible to obtain a coherent series of measurements during the productive season at Prudhoe Bay, the primary productivity data are difficult to interpret. The average mid-summer productivity in the deeper water during the three cruises was 1-3 mg C m^{-3} hr^{-1}, if the results from station 12 are excluded. Assuming the depth of the deep layer in the lagoons to average 3 m and a day length of 20 hours, the primary productivity in the deep water for July and August (62 days) probably exceeds 10 g C m^{-2}. Because the most productive periods in the nearshore arctic environment occur in June and late August, the contribution of the deep layer to the total annual primary productivity may be more than twice this amount. The average primary productivity in the shallow lagoon water during the three cruises was 0.45 mg C m^{-3} hr^{-1}. The depth of the shallow layer averaged 5 m and, assuming a day length of 20 hours, the primary productivity of the shallow layer during July and August is probably about 3 g C m^{-2}. The annual primary productivity of the water column in the lagoons therefore may range between 13 and 23 g C m^{-2}.

From the Barrow data, Alexander (1974) has estimated the annual primary productivity of the ice algae to be about 5 g C m^{-2}, probably the most reliable figure which could presently be applied to the lagoon and Beaufort Sea ice communities. Matheke (1973) measured the primary productivity of the benthic microalgae near Barrow and recorded an average value for July and August of 26.7 mg C m^{-2} hr^{-1}. Assuming the productive season extends from the beginning of July through September, with a day length of 20 hours, the benthic microalgae may produce about 50 g C m^{-2} yr^{-1}. Unfortunately no data are available on the occurence or productivity of the benthic microalgae in the lagoons near Prudhoe Bay, but using Matheke's data for the benthic microalgae, the total annual productivity of the offshore lagoons near Prudhoe Bay may be near 70–80 g C m^{-2}, of which 6% is produced by the ice algae, 62% by the benthic microalgae, and 31% by the phytoplankton.

Although a spring ice algal bloom does occur in Prudhoe Bay, the rapid drop in nitrate concentration during the bloom suggests that, contrary to offshore conditions, nutrients may limit the ice algal productivity. In addition, the low chlorophyll *a* concentration and the late occurrence of the bloom indicate that the total annual primary productivity of the ice algal community inside Prudhoe Bay is much lower than outside the bay, and may be as low as 1 g C m^{-2} yr^{-1}. The high spring salinity and rapid change from hypersaline to hyposaline conditions during breakup probably suppresses the spring plankton bloom in the bay. Nevertheless, a relatively productive pennate diatom community does develop in July, with an average productivity of 5 mg C m^{-3} hr^{-1}. Assuming the average depth of the bay to be 1.5–2 m and a day length of 20 hours, the primary productivity for July may be about 5–6 g C m^{-2}. The average productivity for August was 1 mg C m^{-3} hr^{-1}. Applying the same day length and water depth assumptions as above, the total primary productivity inside Prudhoe Bay for August and September may be near 2–2.5 g C m^{-2}. Although a benthic microalgal community may develop during July, it may be washed out by high waves during August and September and therefore does not contribute to the total annual primary productivity during those months. The total annual primary productivity inside Prudhoe Bay therefore, probably does not exceed 10 g C m^{-2}, 10% of which may come from the ice organisms.

Alexander (1974) estimated the annual productivity of the water column in Harrison Bay and Simpson Lagoon to exceed 10–15 g C m^{-2} and compared this with north temperate values (55.91 g C m^{-2} yr^{-1} in the mid-Pacific, 90-240 g C m^{-2} yr^{-1} in the Gulf of Alaska and the Washington-Oregon coast). McRoy et al. (1972) measured maximum primary productivity rates of 4.1 g C m^{-2} day^{-1} in Bering Strait during June and data from Frobisher Bay (Grainger 1971) suggest an annual productivity in excess of 40 g C m^{-2}. The data from Barrow (Horner 1972) suggest that the nearshore primary productivity of the water column may be about 10 g C m^{-2} yr^{-1}, and English's figures (1961) indicate that the total annual primary productivity of the central Arctic Ocean is probably less than 1 g C m^{-2}. The annual primary productivity of Prudhoe Bay and the nearshore lagoons therefore exceeds the value expected in the central Arctic Ocean, but is less than that of more temperate regions, perhaps due to low nutrient levels and shortness of the growing season.

Grainger (1965) has clearly demonstrated the existence of a well-defined relationship between temperature, salinity, and the observed distributional patterns of major arctic zooplankton species. Three groups are described, each with differing affinities to the type of hydrographic regime preferred. The geographic distribution of the zooplankton in the Prudhoe Bay vicinity, on a somewhat smaller scale, also gives evidence of a variable community structure as a result of differing hydrographic properties. The implications of the observed distributions become evident when analyses of the collections indicate that only 6 of 30 categories of zooplankton are ubiquitously distributed throughout the entire area sampled. Three areas can be biologically differentiated from one another on the basis of varying community structure and the relative abundance of the species comprising the community: waters inside Prudhoe Bay, those seaward of the Midway Islands, and a transitional zone existing between Point McIntyre and the Midway Islands exhibiting physical and biological properties somewhat intermediate between those of the other areas.

The Prudhoe Bay community proved to be the least diverse of the three, with only 14 categories of zooplankton described. Two copepods, *Acartia* and *Pseudocalanus*, made up the overwhelming majority of individuals collected within this area; *Acartia clausi* was the dominant species in the community. This species is typical of freshened, nearshore regimes along the Southern Beaufort Sea (Grainger 1965) and also exists as a northeastern extension of a subarctic Pacific population into the southern Chukchi Sea near Point Barrow (Johnson 1956; Redburn 1973). *Acartia clausi* is described as a classically neritic form, thriving best in a warm water, low salinity environment such as occurs seasonally in Prudhoe Bay.

The presence of the copepods *Pseudocalanus minutus*, *Calanus hyperboreus*, *C. glacialis*, and *Metridia longa*, and the mysid *Mysis oculata* were to be expected as the temperature-salinity regime at Prudhoe Bay is within the range of reported tolerance for these members (Granger 1965). However, the presence of *Aeginopsis laurentii* and *Aglantha digitale*, both arctic species generally found in more saline waters, is unexpected although possibly explained by horizontal mixing of waters outside the Midway Islands with those inside the bay. *Microcalanus pygmaeus*, a copepod infrequently found in highly neritic waters, was absent from the Prudhoe Bay community.

The zooplankton community inside Prudhoe Bay was clearly holoplanktonic in nature. With the exception of a very small number of polychaete larvae and crab zoea, the meroplanktonic contribution was nonexistent. It is possible that the height of the spawning period had passed before August, which would give the impression that the benthic population is sparse in the area. On the other hand, the paucity of meroplanktonic larvae could indicate that very few benthic species producing pelagic larvae exist inside Prudhoe Bay. This would appear to be the case, at least for the barnacles, as the muddy bottom of the bay offers little in the way of potential substratum sites necessary for the successful attachment of settling cyprid stages. In addition the severe physical and biological stresses imposed on this shallow estuary during the winter, such as ice scouring and increased biological oxygen demand, would seem to render the environment highly unstable and unfavorable for the permanent establishment of any but the most hardy benthic species. Available data on the benthic communities in the similar estuarine environments of Harrison Bay and Simpson Lagoon (Crane 1974) corroborate this contention, indicating low diversity and a numerical dominance by *Mysis oculata* and the isopod, *Mesidotea entomon*, neither of which liberate planktonic larvae.

Concerning the production of the holoplanktonic members, with specific reference to the Copepoda, all indications were that the peak recruitment period in Prudhoe Bay had occurred some time before August as no nauplii were encountered at any stations inside the bay. No ripe females of any species of copepod were reported. Primary productivity and chlorophyll *a* content in the bay at this time were also low.

The zooplankton community between Prudhoe Bay and the Midway Islands was more diverse than in Prudhoe Bay, with 24 categories identified from the composite collections at three stations (218, 219, and 224). This environment, as is Prudhoe Bay, is apparently unsuitable for the chaetognath, *Sagitta elegans arctica*. The few individuals recorded were probably the result of mixing with the outside, oceanic waters. Mixing processes would appear to be responsible for the overall increase in community diversity over Prudhoe Bay, although the relative abundances of the copepods *Calanus glacialis* and *Oithona similis*, rare to nonexistent in Prudhoe Bay, seem to indicate that they are indigenous to the area. The *Acartia* community of the bay is replaced by one with *Calanus glacialis* and *Pseudocalanus minutus* sharing the dominant role. *Balanus* nauplii and cyprid larvae were reported in small numbers and crab zoea occurred in modest abundance south and adjacent to Reindeer Island, perhaps suggesting some local as well as advective recruitment.

An interesting find in this region was the occurrence of a single specimen of *Calanus cristatus*. This species is a visitor from the Bering Sea and the only explanation for its presence is the intrusion of north Pacific water along the coast of Alaska as far east as Prudhoe Bay. Such a flow is well documented (Coachman and Barnes 1961; Hufford 1973, 1974; Hufford et al. in press) and further substantiated by the observation of several characteristically southern copepod species along the northern coast of Alaska and Canada (Johnson 1956). In fact, Johnson (1956) has reported the occurrence of *C. cristatus* as far east as 140° 59' W.

It was only outside the Midway Islands that the composition of the zooplankton community began to take on an oceanic character. This was especially true of samples taken below the pycnocline. Here, the number of zooplankton categories increased to 28, including 4 categories not present in the other areas. Juvenile shrimp and euphausiids were encountered for the first time, and *Oikopleura* sp. and echinopluteii larvae were taken from the vertical composite tow at station 213. In the more oceanic water a new dominance structure was observed in the community with *Microcalanus, Pseudocalanus* and *Chiridius obtusifrons*, a species rarely taken in other areas, assuming the greatest numerical importance. Copepod nauplii were present in some abundance and egg-carrying females of *Pseudocalanus minutus* were also recorded suggesting some copepod reproduction was still taking place at that time.

In contrast to the nearly exclusive holoplanktonic communities found inside the offshore islands, the meroplankton played a more significant role in the community at station 213. The spawn of decapods, polychaetes, and barnacles increased in number, although the copepods remained the numerically dominant group of zooplankton.

The community structure in the estuarine environment of Prudhoe Bay and adjacent waters is radically different from that found in the neritic region of the Chukchi Sea near Point Barrow. Notable absences from the Beaufort community included the Ctenophora, Pteropoda, and Ostracoda, all common at Barrow (MacGinitie 1955; Johnson 1958; Redburn 1973). Contrastingly, *Microcalanus pygmaeus, Chiridius obtusifrons*, and *Perigonimus yoldia-arctica* were not found in the inshore community of the Chukchi Sea. The major difference between the two seas lies not so much in the presence or absence of these few groups, but in the presence or absence of holo- or meroplankton. In the nearshore Beaufort Sea, the holoplankton was the most important part of the zooplankton while planktonic larvae of benthic invertebrates were sparse. The opposite situation prevails in the neritic Chukchi Sea, where the meroplankton, most importantly barnacle larvae, crab zoea, and hydromedusae, occur in sufficiently high numbers during the summer as to overshadow the holoplankton (Johnson 1958; Redburn 1973). Five species of meroplanktonic hydromedusae have been reported from the inshore community of Point Barrow: one species, *Obelia longissema*, was reported from the present collections in Prudhoe Bay.

Consistent with the findings of this study, Johnson (1956) found that the entire continental shelf of the Beaufort Sea was less productive than the shelf areas of the Chukchi Sea. He surmised that this was due to the composite effects of a narrower shelf and a less favorable temperature regime in the Beaufort Sea, with a correspondingly smaller meroplanktonic contribution to the community. In the specific area of Prudhoe Bay, the paucity of meroplankton is probably due to the extremely dilute environment, a seasonally harsh climate, and a sea bed unfavorable for the settlement and success of barnacle larvae.

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Appendix. Station summary sheets.

Spring Sampling

27 March and 10 May 1971

1. 27 March 1971.

Reindeer Island

	S°/oo	Nutrients (μg-atoms liter^{-1})					Chl. *a*
		PO_4-P	NO_3-N	NO_2-N	NH_3-N	SiO_4-Si	mg m^{-3}
Top ice	8.58	0.2	1.0	0.1	1.5	4.0	7.0
Middle ice	4.57	0.4	0.9	0.1	5.0	2.0	1.5
Bottom ice	4.75	0.3	0.8	0.1	1.0	3.0	5.0
Water	30.47	1.3	3.7	0.1	3.2	17.0	0.9

Prudhoe Bay

	S°/oo	Nutrients (μg-atoms liter^{-1})					Chl. *a*
		PO_4-P	NO_3-N	NO_2-N	NH_3-N	SiO_4-Si	mg m^{-3}
Top ice	4.24	0.1	0.3	0.1	1.0	1.0	3.6
Middle ice	4.83	0.1	0.7	0.0	1.2	2.0	1.1
Bottom ice	20.23	0.7	2.2	0.1	2.3	31.0	5.7
Water	57.43	0.8	9.4	0.1	7.9	35.0	1.4

2. 10 May 1971. Weather: clear, sunny, no wind.

Reindeer Island

Air temp.	-4.5°C					Snow depth:	8 cm
Water temp.	-2.0°C					Core length:	152 cm
	S°/°°	Nutrients (μg-atoms liter^{-1})					Chl. *a*
		PO_4-P	NO_3-N	NO_2-N	NH_3-N	SiO_4-Si	mg m^{-3}
Top ice	8.43	0.2	0.5	0.1		2.9	3.9
Middle ice	6.91	0.2	0.4	0.0		2.1	0.7
Bottom ice	22.35	1.3	2.4	0.1		5.2	97.9
Water	32.08	0.1	3.9	0.1		15.0	3.9

Prudhoe Bay

Air temp.	-5.0°C					Snow depth:	18 cm
Water temp.	-4.2°C					Core length:	185 cm
	S°/°°	Nutrients (μg-atoms liter^{-1})					Chl. *a*
		PO_4-P	NO_3-N	NO_2-N	NH_3-N	SiO_4-Si	mg m^{-3}
Top ice	5.06	0.1	0.4	0.1		1.8	3.0
Middle	5.87	0.1	0.7	0.0		2.8	1.3
Bottom ice	18.37	0.3	2.7	0.1		11.8	1.7
Water	72.08	1.2	10.2	0.3		20.2	0.6

Cruise I

24 - 29 July 1971

1. 24 July 1971. Weather: cloudy, foggy, wet, strong wind from N.E.

Station Number	Station Depth	Secchi Depth	Temp. °C Air	Temp. °C H_2O	Sample Depth	S°/°°	Nutrients (µg-atoms $liter^{-1}$) PO_4-P	NO_3-N	NO_2-N	NH_3-N	SiO_4-Si	Chl. *a* mg m^{-3}	Total CO_2	Prim. Prod. mg C m^{-3} hr^{-1}
PB 1	2.3	0.8	5	6	0	21.55	0.4	0.4	0.1	2.7		1.3	2.04	1.4
PB 1					2.0	21.83	0.4	0.4	0.1	12.0	1.0	2.04	2.3	
PB 2	2.0	0.8	5	6	1.5	19.56	0.4	0.3	0.1	1.4	13.5	1.0		
PB 3	1.5	0.8	5	7	0.8	20.06	0.4	0.4	0.1	1.7	15.0	1.0		
PB 4	2.0	0.5	4	7	1.0	17.58	0.2	0.8	0.1	1.6	17.3	1.2		
PB 5	2.5	0.8	4	8	0	19.12	0.2	0.4	0.1	1.4	13.6	0.8	2.04	1.3
PB 5					2.0	21.07	0.2	0.2	0.1	1.6	8.5	1.3	2.05	8.0

2. 25 July 1971. Weather: cloudy, foggy, strong wind from N.E.

Station Number	Station Depth	Secchi Depth	Temp. °C Air	Temp. °C H_2O	Sample Depth	S°/°°	Nutrients (µg-atoms $liter^{-1}$) PO_4-P	NO_3-N	NO_2-N	NH_3-N	SiO_4-Si	Chl. *a* mg m^{-3}	Total CO_2	Prim. Prod. mg C m^{-3} hr^{-1}
PB 6	2.0	0.5	6	8	1.5	19.76	0.3	0.4	0.1	1.6	13.8	2.9	2.09	12.3
PB 7	2.0	0.5	6	8	1.5	18.40	0.3	0.3	0.1	1.5	14.7	1.7		

3. 26 July 1971. Weather: foggy but clearing to partly cloudy, slight wind to E.N.E.

Station Number	Station Depth	Secchi Depth	Temp. °C Air	Temp. °C H_2O	Sample Depth	S°/°°	Nutrients (µg-atoms $liter^{-1}$) PO_4-P	NO_3-N	NO_2-N	NH_3-N	SiO_4-Si	Chl. *a* mg m^{-3}	Total CO_2	Prim. Prod. mg C m^{-3} hr^{-1}
PB 8	2.5	0.3	5	8	1.5	13.02	0.3	0.3	0.1	1.8	14.8	3.6	2.12	6.5
PB 9	1.8	0.3	7	8	1.5	6.86	0.1	2.7	0.1		27.0	1.6		
PB 10	1.0	0.3	6	8	0	5.46	0.2	2.7	0.1		28.3	1.5	2.02	3.9
PB 11	0.5	0.3	7	8	0	11.46	0.1	2.2	0.1		25.8	1.6		

4. 28 July 1971. Weather: cloudy, occasional rain, light wind from N.

Station Number	Station Depth	Secchi Depth	Temp. °C Air	H_2O	Sample Depth	S°/₀₀	Nutrients (µg-atoms $liter^{-1}$) PO_4-P	NO_3-N	NO_2-N	NH_3-N	SiO_4-Si	Chl. *a* mg m^{-3}	Total CO_2	Prim. Prod. mg C m^{-3} hr^{-1}
PB 12	4.0	3.5	6	5	0	24.33	0.5	0.0	0.1		6.1	0.1	1.87	0.4
PB 12					3.5	31.17	0.8	0.1	0.1		6.8	7.4	2.22	21.2
PB 13	4.0	4.0	4	2	0	18.07	0.4	0.1	0.1		5.8	0.5		
PB 13					3.5	24.37	0.6	0.0	0.1		6.2	0.4		
PB 14	4.5	4.5	5	3	0	18.26	0.5	0.1	0.1		6.2	0.5		
PB 14					4.0	25.33	0.7	0.0	0.1		7.1	0.7		
PB 15	5.3	5.3	6	3	0	21.03	0.3	0.2	0.1		6.2	0.5	1.36	0.0
PB 15					4.5	31.67	0.7	0.0	0.1		0.7	1.2	2.09	1.8
PB 16	7.0	5.3	9	4	0	19.74	0.8	0.3	0.1		5.7	0.4		
PB 16					6.0	31.16	0.9	0.1	0.1		6.5	6.6		
PB 17	6.5	4.0		5	0	21.74	0.5	0.2	0.0		5.0	0.2		
PB 17					6.0	29.53	0.9	0.1	0.1		5.4	1.2		
PB 18	5.0	2.5	8	7	0	26.61	0.6	0.1	0.1		6.3	0.4		
PB 18					4.5	25.03	0.7	0.1	0.1		6.1	0.4		

5. 29 July 1971. Weather: partly cloudy, occasional rain, moderate wind from N.

Station Number	Station Depth	Secchi Depth	Temp. °C Air	H_2O	Sample Depth	S°/₀₀	Nutrients (µg-atoms $liter^{-1}$) PO_4-P	NO_3-N	NO_2-N	NH_3-N	SiO_4-Si	Chl. *a* mg m^{-3}	Total CO_2	Prim. Prod. mg C m^{-3} hr^{-1}
PB 19	6.0	4.0	12	4	0	22.15	0.5	0.1	0.1		6.0	0.3		
PB 19					5.5	28.65	0.7	0.0	0.1		5.4	0.8		
PB 20	2.3	2.0	11	6	1.5	25.68	0.7	0.1	0.1		7.0	0.6		
PB 21	1.5	0.5	8	7	1.0	25.70	0.5	0.1	0.1		7.4	1.4		
PB 22	2.3	1.5	5	7	1.5	24.46	0.7	0.1	0.1		6.2	0.5	1.87	0.2

Cruise II

15 - 19 August 1971

1. 15 August 1971. Weather: clear and sunny, moderate wind from E.N.E.

Station Number	Station Depth	Secchi Depth	Temp. °C Air	Temp. °C H_2O	Sample Depth	S°/°°	Nutrients (µg-atoms liter^{-1}) PO_4-P	NO_3-N	NO_2-N	NH_3-N	SiO_4-Si	Chl. *a* mg m^{-3}	Total CO_2	Prim. Prod. mg C m^{-3} hr^{-1}
PB 101	5.0	3.5	7	5	0	17.73	0.3	0.1	0.1		7.1	0.4	1.54	1.0
PB 101					4.5	17.86	0.3	0.1	0.1		5.8	0.6	1.52	0.6
PB 102	5.0	4.0	5	4	0	18.40	0.4	0.1	0.1		7.5	0.7		
PB 102					4.5	18.45	0.3	0.1	0.1		7.5	0.4		
PB 103	4.5	5.5	5	5	0	18.46	0.3	0.1	0.1		7.4	0.5		
PB 103					4.0	18.50	0.3	0.1	0.1		7.7	0.5		
PB 104	5.5	4.0	7	5	0	18.35	0.4	0.1	0.1		7.5	0.3	1.55	0.3
PB 104					5.0	25.85	0.6	0.1	0.1		8.2	0.9	1.95	0.7
PB 105	6.0	3.5	8	5	0	18.35	0.3	0.0	0.1		6.0	0.4		
PB 105					4.5	19.23	0.4	0.1	0.1		7.6	0.7		
PB 106	6.0	5.0	5	4	0	19.01	0.3	0.2	0.0		6.2	0.6		
PB 106					5.5	19.39	0.4	0.1	0.1		7.1	0.7		

2. 16 August 1971. Weather: warm, sunny, calm.

Station Number	Station Depth	Secchi Depth	Temp. °C Air	Temp. °C H_2O	Sample Depth	S°/°°	Nutrients (µg-atoms liter^{-1}) PO_4-P	NO_3-N	NO_2-N	NH_3-N	SiO_4-Si	Chl. *a* mg m^{-3}	Total CO_2	Prim. Prod. mg C m^{-3} hr^{-1}
PB 107	10.0	2.5	6	5	0	17.90	0.3	0.1	0.1		6.1	0.5	1.57	0.6
PB 107					9.5	30.42	0.8	0.2	0.1		7.5	0.7	2.16	1.3
PB 108	7.0	3.0	11	6	0	16.92	0.2	0.1	0.1		7.1	0.5		
PB 108					6.5	30.12	0.7	0.1	0.1		6.5	0.7		
PB 109	6.0	3.5	14	6	0	17.27	0.3	0.1	0.1		8.6	0.6		
PB 109					5.5	24.45	0.6	0.2	0.1		7.0	0.4		
PB 110	5.0	2.0	14	6	0	16.13	0.3	0.1	0.1		9.3	0.7		
PB 110					4.5	18.34	0.2	0.1	0.1		4.8	0.7		
PB 111	2.8	1.5	18	6	1.5	16.10	0.2	0.2	0.1		1.0	0.6		

3. 17 August 1971. Weather: partly cloudy, calm breeze from E.

Station Number	Station Depth	Secchi Depth	Temp. °C Air	Temp. °C H_2O	Sample Depth	S°/°°	Nutrients (µg-atoms $liter^{-1}$) PO_4-P	NO_3-N	NO_2-N	NH_3-N	SiO_4-Si	Chl. *a* mg m^{-3}	Total CO_2	Prim. Prod. mg C m^{-3} hr^{-1}
PB 112	2.5	1.0	14	9	1.0	13.90	0.1	0.2	0.1		16.3	1.0	1.89	1.4
PB 113	2.5	1.0	14	8	1.0	14.59	0.1	0.2	0.1		11.4	1.2		
PB 114	2.5	1.0	14	8	1.0	13.52	0.1	0.2	0.1		16.3	0.9		
PB 115	1.3	0.5		9	0	14.57	0.3	0.2	0.1		12.8	1.3		
PB 116	1.3	0.8	13	7	0	15.79	0.3	0.2	0.1		10.2	0.9		

4. 18 August 1971. Weather: partly sunny, slight breeze from W.S.W. changing to E.N.E.

Station Number	Station Depth	Secchi Depth	Temp. °C Air	Temp. °C H_2O	Sample Depth	S°/°°	Nutrients (µg-atoms $liter^{-1}$) PO_4-P	NO_3-N	NO_2-N	NH_3-N	SiO_4-Si	Chl. *a* mg m^{-3}	Total CO_2	Prim. Prod. mg C m^{-3} hr^{-1}
PB 117	4.0	4.0	7	4	0	19.13	0.3	0.2	0.1		5.0	0.3	1.45	0.2
PB 117					3.5	20.30	0.5	0.1	0.1		5.5	0.5	1.59	0.3
PB 118	6.0	5.5	8	4	0	18.61	0.4	0.2	0.1		4.6	6.0		
PB 118					5.5	22.40	0.6	0.2	0.1		5.4	0.5		
PB 119	9.5	5.5	7	5	0	18.76	0.4	0.2	0.1		0.5	0.5	1.46	0.1
PB 119					9.0	30.09	0.8	0.2	0.1		4.5	1.3	2.15	0.7
PB 120	8.5	6.5	5	4	0	18.78	0.4	0.2	0.6		5.9	0.5		
PB 120					8.0	30.32	0.8	0.2	0.1		5.7	0.9		
PB 121	7.5	7.5	4	5	0	18.89	0.4	0.2	0.1		6.5	0.6		
PB 121					7.0	25.91	0.6	0.2	0.1		3.4	0.4		

5. 19 August 1971. Weather: partly cloudy, cold, light wind, fog.

Station Number	Station Depth	Secchi Depth	Temp. °C Air	Temp. °C H_2O	Sample Depth	S°/°°	Nutrients (µg-atoms $liter^{-1}$) PO_4-P	NO_3-N	NO_2-N	NH_3-N	SiO_4-Si	Chl. *a* mg m^{-3}	Total CO_2	Prim. Prod. mg C m^{-3} hr^{-1}
PB 122	8.0	5.0	8	3	0	20.35	0.4	0.1	0.1		5.5	0.6	1.57	0.4
PB 122					7.5	26.83	0.7	0.2	0.1		4.2	0.5	1.95	0.4
PB 123	5.0	5.0	5	5	0	18.99	0.3	0.0	0.1		6.8	0.4	1.5	0.4
PB 123					4.5	24.83	0.6	0.1	0.1		4.8	0.3	1.84	0.4
PB 124	7.0	4.0	5	5	0	18.23	0.3	0.1	0.1		7.6	0.5		
PB 124					6.5	24.61	0.6	0.1	0.1		5.5	1.0		
PB 125	3.0	3.0	5	4	1.5	18.76	0.4	0.0	0.1		7.1	0.5		

Spring Sampling

2 February, 18 May and 25 May, 1972

1. 2 February 1972. Weather: clear cold.

Reindeer Island

Air temp. -30°C | Snow depth: 4 cm
Water temp. -1.8°C | Core length: 85 cm

	S°/oo	Nutrients (μg-atoms liter^{-1})					Chl. *a*
		PO_4-P	NO_3-N	NO_2-N	NH_3-N	SiO_4-Si	mg m^{-3}
Top ice	6.04	0.2	1.4	0.1	2.9	3.0	0.8
Middle ice	7.06	0.2	1.3	0.1	6.0	3.0	2.2
Bottom ice	5.45	0.2	1.1	0.1	3.4	2.0	2.1
Water	35.48	1.4	6.9	0.1	2.5	15.1	0.4

Prudhoe Bay

Air temp. -31°C | Snow depth: 15 cm
Water temp. -3.0°C | Core length: 110 cm

	S°/oo	Nutrients (μg-atoms liter^{-1})					Chl. *a*
		PO_4-P	NO_3-N	NO_2-N	NH_3-N	SiO_4-Si	mg m^{-3}
Top ice	5.23	0.2	0.4	0.0	3.3	1.0	1.6
Middle ice	5.13	0.2	0.5	0.1	4.2	0.9	1.1
Bottom ice	5.95	0.1	2.5	0.1	4.7	2.1	2.1
Water	45.03	1.6	7.5	0.3	2.3	23.3	1.4

2. 18 May 1972. Weather: overcast, high wind from N.E.

Reindeer Island

Air temp. −10.5°C Snow depth: 20 cm Core length: 187 cm

	S°/oo	Nutrients (μg-atoms $liter^{-1}$)					Chl. *a*
		PO_4-P	NO_3-N	NO_2-N	NH_3-N	SiO_4-Si	mg m^{-3}
Top ice	5.14	4.0	0.1	0.0	1.3	1.6	0.3
Middle ice	5.42	2.0	0.4	0.0	1.3	2.1	0.3
Bottom ice	5.71	0.2	0.3	0.0	1.6	1.1	7.2
Water	30.58	0.8	0.8	0.1	1.5	7.5	1.7

Prudhoe Bay

Air temp. −9.0°C Snow depth: 30 cm Core length: 184 cm

	S°/oo	Nutrients (μg-atoms $liter^{-1}$)					Chl. *a*
		PO_4-P	NO_3-N	NO_2-N	NH_3-N	SiO_4-Si	mg m^{-3}
Top ice	3.99	1.1	0.1	0.0	1.7	0.5	0.6
Middle ice	5.83	0.2	0.0	0.2	1.3	0.5	0.5
Bottom ice	11.74	0.2	1.2	0.6	2.2	5.5	1.5
Water	66.11	0.8	5.1	0.2	1.5	28.6	1.1

3. 25 May 1972. Weather: clear, 20 kt wind from N.E.

Reindeer Island

Air temp.	-6.0°C					Snow depth:	24 cm
Water temp.	-2.0°C					Core length:	172 cm
	S°/oo	Nutrients (µg-atoms liter^{-1})					Chl. *a*
		PO_4-P	NO_3-N	NO_2-N	NH_3-N	SiO_4-Si	mg m^{-3}
Top ice	6.52	5.0	1.9	1.7	1.4	3.7	0.8
Middle ice	5.29	2.1	0.4	1.0	1.4	1.5	0.7
Bottom ice	5.66	0.1	0.3	0.0	1.6	1.2	4.5
Water	28.80	0.9	1.0	0.1	1.1	9.3	2.6

Prudhoe Bay

Air temp.	-5.0°C					Snow depth:	25 cm
Water temp.	-4.0°C					Core length:	189 cm
	S°/oo	Nutrients (µg-atoms liter^{-1})					Chl. *a*
		PO_4-P	NO_3-N	NO_2-N	NH_3-N	SiO_4-Si	mg m^{-3}
Top ice	4.20	0.9	0.7	2.0	1.3	2.5	0.8
Middle ice	8.14	2.1	1.1	2.2	1.4	2.9	0.8
Bottom ice	13.40	0.4	1.2	0.0	2.0	6.3	19.0
Water	66.27	0.8	2.0	1.1	1.1	24.3	2.8

Cruise III

11 - 15 August 1972

The chlorophyll results are from the UNESCO determinations.

1. 11 August 1972. Weather: moderate wind, cloudy, rainy.

Station Number	Station Depth	Secchi Depth	Sample Depth	Temp. °C H_2O	S°/°°	Nutrients (µg-atoms $liter^{-1}$) PO_4-P	$NO_3 + NO_2$-N	NH_3-N	SiO_4-Si	Chl. *a* mg m^{-3}	Total CO_2	Prim. Prod. mg C m^{-3} hr^{-1}
PB 201	2.8	1.0	1.0			0.4	0.3	0.6	9.0	0.7 1.1		
PB 202	2.5	1.0	1.0			0.4	0.1	0.3	7.7	1.0 1.1		
PB 203	2.5	1.0	0.3	7.4	20.15	0.4	0.3	0.3	8.8	1.1 0.9	1.88	0.9
PB 204	2.3	0.7	1.0			0.3	0.3	0.9	9.4	2.6 1.6		
PB 205a	2.5	0.8	1.0	8.3	19.10	0.5	0.4	1.5	11.0	2.1 1.4		
PB 207	2.5	1.0	1.0			0.4	0.1	0.2	7.7	0.7 0.9		
PB 208	3.0	1.0	1.0	7.6	19.30	0.5	0.4	0.6	9.3	0.7 0.7	1.86	0.4
PB 209	2.1	1.3	1.0	7.4	19.29	0.6	0.3	0.7	9.6	0.4 0.4		

2. 12 August 1972. Weather: partly sunny, high waves, patchy fog, wind from N.E.

Station Number	Station Depth	Secchi Depth	Sample Depth	Temp. °C H_2O	S°/°°	Nutrients (µg-atoms $liter^{-1}$) PO_4-P	$NO_3 + NO_2$-N	NH_3-N	SiO_4-Si	Chl. *a* mg m^{-3}	Total CO_2	Prim. Prod. mg C m^{-3} hr^{-1}
PB 206	2.0	1.5	1.0	7.8	18.80	0.3	0.3	1.7	10.1	0.6 0.4	1.82	0.4
PB 210	1.0	-	0	7.2	19.30	0.4	0.5	1.3	10.3	0.9 1.0	1.79	1.0
PB 221	1.3	-	0	7.2	19.55	0.4	0.4	0.9	9.6	1.0 1.2		
PB 223	1.2	1.0	1.0	8.2	19.01	0.2	0.6	0.5	11.0	1.6 1.7	1.90	0.6
PB 224	1.5	-	0	6.4	19.68	0.3	0.2	0.2	9.2	1.0 0.9		
PB 225	1.8	-	0	5.5	19.71	0.4	0.5	1.2	8.5	0.9 0.8		
PB 227	1.3	-	0	7.3	18.80	0.3	0.4	0.5	10.6	1.8 1.5		

3. 13 August 1972. Weather: cloudy, foggy, rain, wind from N.E.

Station Number	Station Depth	Secchi Depth	Sample Depth	Temp. °C H_2O	S°/°°	Nutrients (µg-atoms liter^{-1}) PO_4-P	NO_3 + NO_2-N	NH_3-N	SiO_4-Si	Chl. *a* mg m^{-3}	Total CO_2	Prim. Prod. mg C m^{-3} hr^{-1}
PB 205b	2.5	1.0	1.0	6.7	16.76	0.3	0.8	0.9	16.9	1.3	1.86	0.9

4. 14 August 1972. Weather: cloudy, patchy fog, wind from N.

Station Number	Station Depth	Secchi Depth	Sample Depth	Temp. °C H_2O	S°/°°	Nutrients (µg-atoms liter^{-1}) PO_4-P	NO_3 + NO_2-N	NH_3-N	SiO_4-Si	Chl. *a* mg m^{-3}	Total CO_2	Prim. Prod. mg C m^{-3} hr^{-1}
PB 216	6.5	2.5	0		20.49	0.5	0.5	1.1	9.3	0.6		
PB 216			5.0		20.54	0.6	0.3	7.2	9.0	1.3		
PB 219	7.0	1.5	0		20.29	0.6	0.2	0.7	9.0	1.5		
PB 219			5.0		20.62	0.5	0.3	0.6	8.1	0.9		

5. 15 August 1972. Weather: Foggy in morning, sunny later, light variable wind.

Station Number	Station Depth	Secchi Depth	Sample Depth	Temp. °C H_2O	S°/°°	Nutrients (µg-atoms liter^{-1}) PO_4-P	NO_3 + NO_2-N	NH_3-N	SiO_4-Si	Chl. *a* mg m^{-3}	Total CO_2	Prim. Prod. mg C m^{-3} hr^{-1}
PB 212	4.5	2.0	0	3.4	20.73	0.5	0.6	4.1	7.8	0.9	1.74	0.5
PB 212			4.0	2.8	21.11	0.4	0.3	0.4	6.8	0.3	1.73	0.4
PB 213	10.0	3.5	0	2.8	21.26	0.5	0.3	0.0	7.0	0.6	1.78	0.8
PB 213			8.0	sub 0	30.42	0.9	0.4	1.0	5.8	3.3	1.79	2.4
PB 215	11.0	3.5	0	2.8	20.88	0.5	0.3	0.7	7.1	0.7		
PB 215			8.0	sub 0	30.52	0.8	0.4	0.4	5.9	3.8		
PB 217	6.5	2.0	0	4.4	20.30	0.5	0.3	0.7	8.7	1.1	1.70	1.0
PB 217			5.0	0.6	25.75	0.6	0.4	0.8	6.4	1.4	1.90	2.1
PB 218	4.0	1.5	0	4.4	19.90	0.4	0.4	0.6	9.5	1.4		
PB 218			4.0	4.4	19.90	0.4	0.3	0.7	9.7	1.3		