CRDI

Environmental Assessment of the Alaskan Continental Shelf

Annual Reports of Principal Investigators for the year ending March 1978

Volume VI. Receptors — Microbiology

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration

U.S. DEPARTMENT OF INTERIOR
Bureau of Land Management

VOLUME I	RECEPTORS -- MAMMALS BIRDS
VOLUME II	RECEPTORS -- BIRDS
VOLUME III	RECEPTORS -- BIRDS
VOLUME IV	RECEPTORS -- FISH, LITTORAL, BENTHOS
VOLUME V	RECEPTORS -- FISH, LITTORAL, BENTHOS
VOLUME VI	RECEPTORS -- MICROBIOLOGY
VOLUME VII	EFFECTS
VOLUME VIII	CONTAMINANT BASELINES
VOLUME IX	TRANSPORT
VOLUME X	TRANSPORT
VOLUME XI	HAZARDS
VOLUME XII	HAZARDS
VOLUME XIII	DATA MANAGEMENT

Environmental Assessment of the Alaskan Continental Shelf

Annual Reports of Principal Investigators for the year ending March 1978

Volume VI. Receptors — Microbiology

Outer Continental Shelf Environmental Assessment Program
Boulder, Colorado

October 1978

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration

U.S. DEPARTMENT OF INTERIOR
Bureau of Land Management

DISCLAIMER

The National Oceanic and Atmospheric Administration (NOAA) does not approve, recommend, or endorse any proprietary product or proprietary material mentioned in this publication. No reference shall be made to NOAA or to this publication furnished by NOAA in any advertising or sales promotion which would indicate or imply that NOAA approves, recommends, or endorses any proprietary product or proprietary material mentioned herein, or which has as its purpose an intent to cause directly or indirectly the advertised product to be used or purchased because of this publication.

ACKNOWLEDGMENT

These annual reports were submitted as part of contracts with the Outer Continental Shelf Environmental Assessment Program under major funding from the Bureau of Land Management.

RECEPTORS -- MICROBIOLOGY

Contents

ANNUAL REPORT

Assessment of Potential Interactions of Microorganisms and Pollutants Resulting from Petroleum Development on the Outer Continental Shelf of Alaska

RU #29

Contract #03-5-022-85

April 1, 1978

Submitted by:
Ronald M. Atlas, Ph.D.
Principal Investigator
Department of Biology
University of Louisville
Louisville, Kentucky 40208

Prepared for:
Outer Continental Shelf Energy Assessment Program
National Oceanic and Atmospheric Administration

CONTRIBUTING PERSONNEL

Principal Investigator:	Ronald M. Atlas
Research Associates:	Tatsuo Kaneko Amikam Horowitz John Haines
Research Assistant:	George Roubal
Research Technicians:	Teiko Kaneko Anne Bronner Craig Short Ramneek Mohan Michael Busdosh
Consultants:	Micah Krichevsky Elaine Krichevsky

I. Objectives - Summary

The main objectives of this study were to characterize microbial populations in Lower Cook Inlet, to determine microbial hydrocarbon biodegradation potentials in Lower Cook Inlet, to study degradation of petroleum under ice in the Beaufort Sea and to study degradation of petroleum in sediment in the Beaufort Sea. In situ experiments were begun and sampled in Elson Lagoon to determine the fate of oil trapped under ice or in sediment. A new Most Probable Number Procedure was developed for enumeration of hydrocarbon utilizing microorganisms. Hydrocarbon utilizers in Cook Inlet were found in higher numbers in Kachemak Bay, near Kennedy entrance and near Upper Cook Inlet than elsewhere in this area. Hydrocarbon biodegradation potentials in Cook Inlet were lower in November than in April. Hexadecane and naphthalene were utilized to a greater extent than pristane and benzanthracene, indicating the resistance of highly branched and condensed aromatic hydrocarbons to biodegradation. The numbers of viable heterotrophs enumerated in Cook Inlet were very low compared to Beaufort Sea and lower forty-eight coastal waters. The diversities of heterotrophic bacterial communities in Cook Inlet were high, indicative of a pristine area. The numerical taxonomic studies showed that exposure to oil enriched for hydrocarbon utilizers and that mixtures of hydrocarbons were more readily utilized than individual hydrocarbons. Our studies indicate that both simple aliphatic and aromatic compounds are degraded by microorganisms indigenous to areas of the Beaufort Sea, Gulf of Alaska and Cook Inlet.

II. Introduction - Scope of Work

This study is a continuation of an effort to characterize microbial populations and the ability of microorganisms to biodegrade petroleum hydrocarbons in proposed Alaskan OCS oil and gas lease areas. The approach has been to determine the distribution and population levels of several microbiological groups, *e.g.* hydrocarbon degraders within a geographic area, to extensively characterize selected microorganisms and using numerical taxonomy to determine the diversity of the microbial community and an inventory of the dominant microbial taxa within the geographic area. During this year microbial populations were characterized within Cook Inlet. We also have analysed further taxonomic data on microorganisms from the Beaufort Sea.

As part of this study intensive surveys have been conducted to determine the biodegradation potentials of indigenous microbial populations for petroleum hydrocarbons. During the past year hydrocarbon biodegradation potentials were estimated within Cook Inlet. Comparisons are contained in this report between hydrocarbon biodegradation potentials within Cook Inlet and previously studied Beaufort Sea and Gulf of Alaska regions. In addition to surveys to determine hydrocarbon biodegradation potentials, intensive studies have been initiated in the Beaufort Sea to follow the chemical changes in crude oil as it undergoes biotic (biodegradation) and abiotic (physical and chemical) weathering in sediment and under ice.

III. Current State of Knowledge

The state of knowledge concerning microbial populations and hydrocarbon biodegradation in Alaskan OCS areas has been summarized in previous annual reports. New information developed from this project is described below.

IV. Study Area

The sampling sites used during this study are shown in Figure 1. Recent sampling has been restricted to Lower Cook Inlet (Figure 2) and Elson Lagoon in the Beaufort Sea region. Times of sample collection and mean temperatures and salinities of the samples are shown in Table 1.

V. Methods and Rationale of Data Collection

Enumeration

The rationale of data collection for characterization of microbial populations was to sample surface water and sediment at a series of stations within a geographic area at 2 times of year. Microbial populations were enumerated from each sample using direct count and viable plate count procedures. These procedures have been described in previous reports.

Because of problems associated with viable plate counts for enumerating hydrocarbon utilizing microorganisms, a new Most Probable Number (MPN) method was developed and used in the recent Lower Cook Inlet

Figure 1. Sampling sites

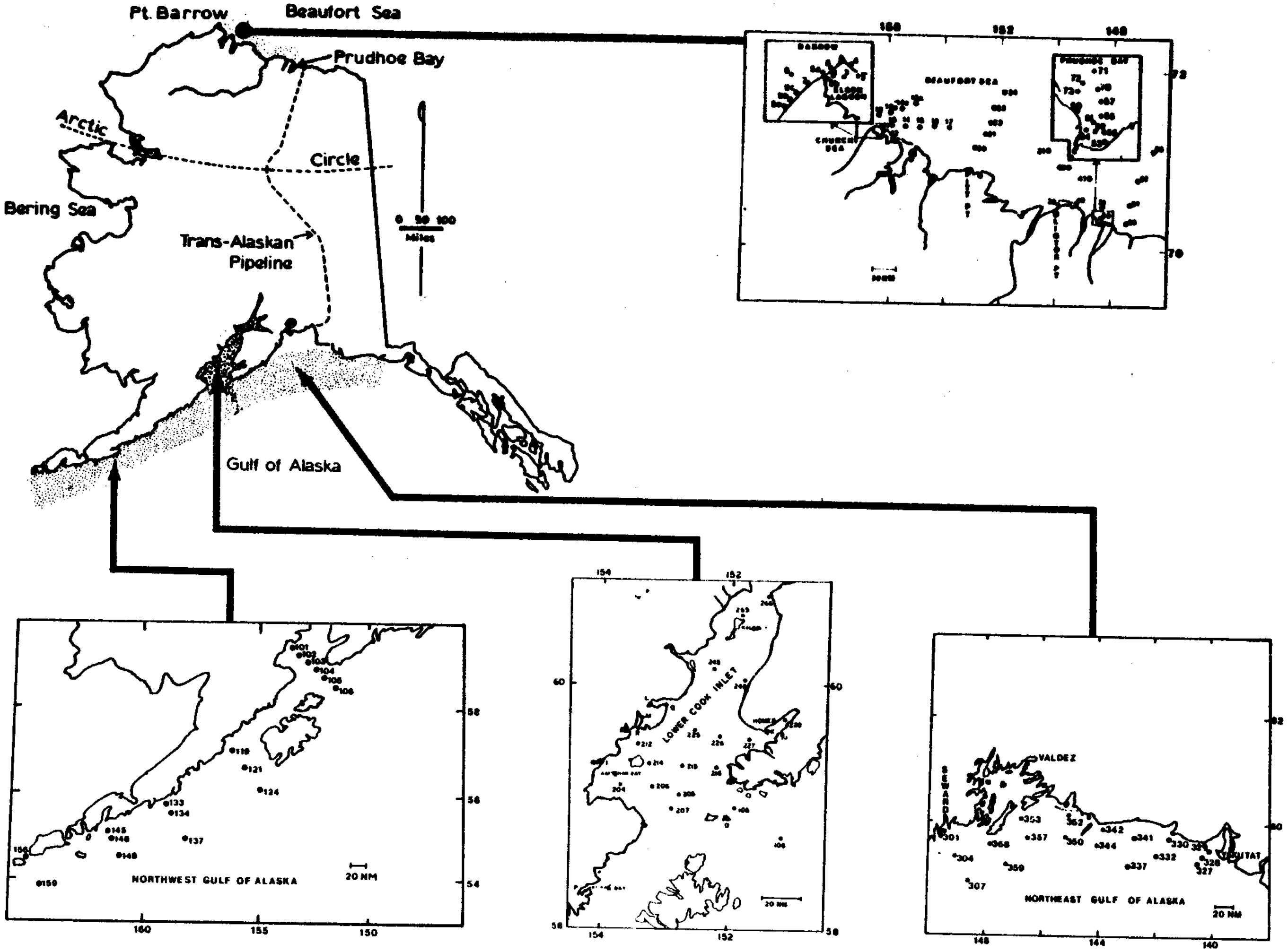


Figure 2.

COOK INLET SAMPLE SITES

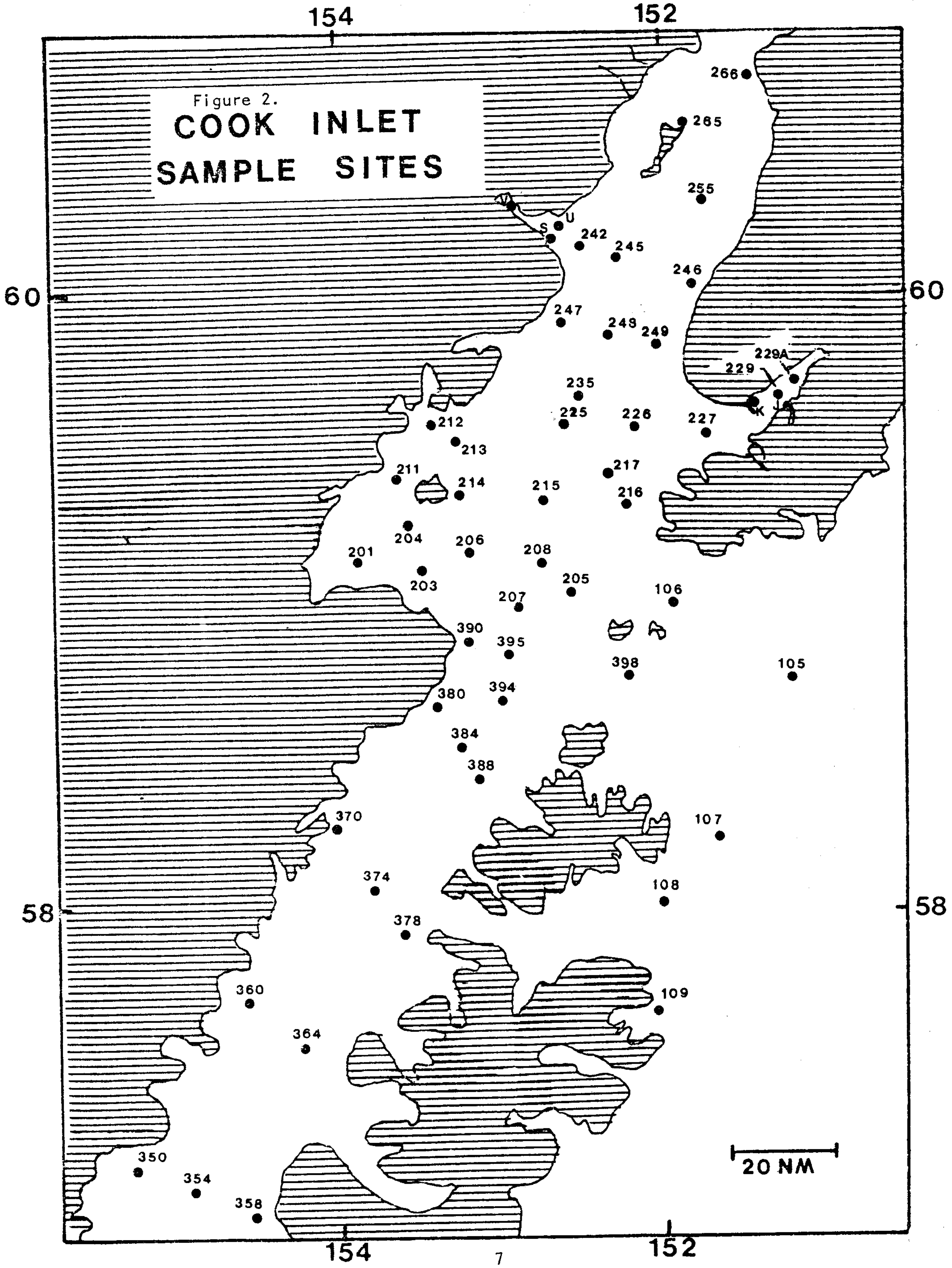


Table 1. Temperatures and salinities of samples

Source		Temperature (°C)		Salinity (o/oo)	
		Mean	Range	Mean	Range
Beaufort Sea					
Aug.-Sept. 1975	water	+1.1	-1.2 - +3.2	17.4	11.1 - 27.0
Aug.-Sept. 1975	sediment	+1.0	-0.8 - +3.2	19.8	17.0 - 22.8
April 1976	ice	-2.0	-2.2 - -1.5	6.7	1.0 - 11.0
April 1976	water	-1.9	-2.0 - -1.5	24.3	17.0 - 31.0
April 1976	sediment	-1.8	-2.0 - -1.5	-	-
Aug. —Sept. 1976	water	+0.5	-1.3 - +2.7	16.5	5.1 - 29.5
Aug. —Sept. 1976	sediment	+0.1	-1.6 - +2.1	31.0	24.5 - 39.2
Northwest Gulf of Alaska					
Oct. 1975	water	+8.5	+7.3 - +9.4	31.0	29.5 - 32.0
Oct. 1975	sediment	+7.0	+4.7 - +9.3	32.1	30.8 - 32.5
Northeast Gulf of Alaska					
March 1976	water	+3.8	+2.0 - +5.0	31.7	30.7 - 32.3
March 1976	sediment	+4.7	+2.1 - +5.8	32.8	31.9 - 34.6
Cook Inlet					
Oct. 1976	water	+9.1	+6.0 - +12.0	24.2	17.0 - 27.5
Oct. 1976	sediment	+8.7	+6.0 - +10.0	26.5	23.2 - 28.0
April 1977	water	+3.8	+1.0 - +5.3	28.1	21.0 - 31.7
April 1977	sediment	+4.5	+2.3 - +7.5	31.5	30.2 - 32.6
Nov. 1977	water	+6.2	+2.2 - +7.8	30.5	23.0 - 32.2
Nov. 1977	sediment	+5.5	+2.0 - +7.3	31.2	29.0 - 33.4

studies. Most Probable Number estimates of hydrocarbon utilizers were performed as follows: Dilutions of samples were added to 60 ml stoppered serum vials containing 10 ml autoclaved Bushnell Haas broth (Difco) with 3% added NaCl, and 50 µl filter sterilized (0.2 µm Millipore filter) Cook Inlet crude oil spiked with 1-^{14}C n hexadecane (s.p. act. = 0.9 µCi/ml oil). Sterility of the oil was checked by plating portions of the oil onto marine agar 2216 (Difco) and observing for colony formation and by measuring $^{14}CO_2$ production from uninoculated vials. Poisoned controls were prepared by adding 0.2 ml concentrated hydrochloric acid to the vials. A 3 tube MPN procedure was used. One set per sample was used. Following incubation at 5 C for 6 weeks, the solutions were acidified with 0.2 ml concentrated hydrochloric acid. After the solutions were allowed to cool, the $^{14}CO_2$ was recovered by purging the vials with air and trapping the $^{14}CO_2$ in 1 ml hyamine hydroxide in percolation tubes, 0.5 cm x 10 cm, containing glass beads. The hyamine hydroxide was washed from the tubes into scintillation vials with 3 one ml portions of methanol. The counting solution was 10 ml Omnifluor + toluene (New England Nuclear). Counting was with a Beckman liquid scintillation counter. Counts greater than or equal to 2 times control were considered as positive; counts less than 2 times control were considered as negative. The most probable number of hydrocarbon degrading microorganisms was determined from the appropriate MPN Tables and recorded as most probable number per ml for water samples or most probable number per g dry wt. for sediment samples.

Taxonomic Characterization

Microorganisms selected at random from marine agar 2216 enumeration plates were considered as representative heterotrophic microorganisms. These organisms were extensively characterized. Approximately 300 phenotypic characteristics were determined for each strain. Characterization included morphological, physiological, biochemical and nutritional testing. A comprehensive list of tests was supplied in a previous annual report.

In addition to characterizing heterotrophic microorganisms, presumed hydrocarbon utilizing microorganisms were selected at random from oil-agar enumeration plates and MPN enumeration tubes. Approximately 100 phenotypic characteristics were determined for each strain of presumed hydrocarbon utilizing microorganism. These tests included extensive testing for the ability to utilize paraffinic and aromatic hydrocarbons. Table 2 shows a list of tests used for presumed hydrocarbon utilizers.

Following testing of heterotrophic and presumed hydrocarbon utilizing microorganisms, the data was analysed by cluster analysis.

Table 2.
FEATURES UTILIZED IN HYDROCARBON DATASETS

Gram positive.
Gram negative.
Cells are acid fast by Ziehl-Neelsen method.
Cells motile.
Cells are rod-shaped.
Cells are spherical.
Pleomorphic cells are characteristic.
Cells occur singly.
Cells occur in pairs.
Cells arranged in angular fashion after division (snapping).
Cells occur in chains.
Cells arranged in irregular aggregates.
Cells arranged in two-dimensional tetrads.
Organisms filamentous, greater than 10 micrometers, if lticellular the organism has little or no indentation at each ptum (For branched filaments also see Section 8).
Colonies are pure (paper) white on solid medium.
Colonies are gray on solid medium.
Diffusible (water-soluble) pigments are produced.
Non-diffusible red pigments are produced.
Non-diffusible brown pigments are produced.
Non-diffusible violet (purple) pigments are produced.
Non-diffusible golden (yellow) pigments are produced.
Non-diffusible orange pigments are produced.
Non-diffusible black pigments are produced.
Fluorescent pigment observable with short velength ultraviolet light (ca. 260 nm.).
Non-diffusible pink pigments are produced.
Agar macro-colonies are translucent.
Agar macro-colonies are transparent.
Agar macro-colonies are opaque.
Agar macro-colony margin is entire.
Colony surface is glistening.
Colony surface is dull (matte).
Sensitive to nitrofurantoin concentration (disc) 100 ugm.
Sensitive to penicillin G concentration (disc) 2 units.
Sensitive to streptomycin concentration (disc) 2.0 ugm.
Sensitive to novobiocin (albamycin) concentration (disc) 5 ugm.
Sensitive to sulfisoxazole (gantrisin) concentration isc) 5 ugm.
Growth takes place at an initial pH of 4.0.
Growth takes place at an initial pH of 5.0.
Growth takes place at an initial pH of 6.0.
Growth takes place at an initial pH of 7.0.
Growth takes place at an initial pH of 8.0.
Growth takes place at an initial pH of 9.0.
Growth takes place at an initial pH of 10.0.
Growth at 5 C.
Growth at 10 C.
Growth at 15 C.
Growth at 20 C.
Growth at 25 C.
Growth at 37 C.
Growth at 43 C.
Added NaCl is required for growth.
Growth in the presence of 0.5% NaCl.
Growth in the presence of 3% NaCl.
Growth in the presence of 7.5% NaCl.

Table 2. con't

Growth in the presence of 10% NaCl.
Gelatin is hydrolyzed (liquefied).
Starch is hydrolyzed.
Tween 20 is hydrolyzed.
Tween 80 is hydrolyzed.
Hydrogen peroxide is decomposed.
Kovacs' oxidase test positive (smear from colony turns dark rple with tetramethylparaphenylenediamine dihydrochloride).
Methyl red test is positive.
Nitrate is reduced.
Nitrite is reduced.
D-Glucose catabolized aerobically.
D-Glucose catabolized anaerobically.
Acid produced from D-Fructose.
Acid produced from Lactose.
Acid produced from Maltose.
Acid produced from Sucrose.
Acid is produced from 1,2,3-Propanetriol (Glycerol).
Acid is produced from D-Mannitol.
Acid produced from D-Galactose.
D-Galactose is utilized.
D-Glucose is utilized (also see Section 24).
Lactose is utilized.
Sucrose is utilized.
Ethanol is utilized.
1,2,3-Propanetriol (Glycerol) is utilized.
D-Mannitol is utilized.
Cyclohexanol is utilized.
Meso-Inositol is utilized.
Phenol is utilized.
Acetic acid is utilized.
Palmitic acid is utilized.
Succinic acid is utilized.
10-Octadecynoic acid is utilized.
Oleic acid is utilized.
Citric acid is utilized.
Benzoic acid is utilized.
Cyclohexane carboxylic acid is utilized.
L-Asparagine is utilized.
L-Aspartic Acid is utilized.
L-Glutamic Acid is utilized.
L-Methionine is utilized.
L-Tryptophan is utilized.
L-Valine is utilized.
Ethanolamine can be used as the sole source of nitrogen.
Cyclohexanone can be used as the sole source of carbon.
N-Decane is utilized.
N-Hexadecane is utilized.
N-Nonane is utilized.
N-Octadecane is utilized.
N-Pentadecane is utilized.
1-Methylnaphthalene is utilized.
Omega-Phenyldecane is utilized.
Toluene is utilized.
Pristane (2,6,10,14-Tetra-methylpentadecane) is utilized.
Pentadecylcyclohexane is utilized.
2,2,4,4,6,8,8-Heptamethylnonane is utilized.
Ethylcyclohexane is utilized.
Dicyclohexyl is utilized.
Diphenylmethane is utilized.

Table 2. con't

Acenaphthalene is utilized.
9-Methylanthracene is utilized.
Napthanol is utilized.
Prudhoe crude oil is utilized.
JP5 is utilized.
Gasoline (unleaded) is utilized.
Mineral oil is utilized.
API Reference Oil #1 IS utilized.
API Reference Oil #2 IS utilized.
API Reference Oil #3 IS utilized.
API Reference Oil #4 IS utilized.
Tolerant to mercury.
Tolerant to lead.
Urease (3.5.1.5) is produced.

Cluster analyses were performed using Jaccard coefficients and unweighted average linkage sorting. Taxonomic groupings or clusters were recognized at greater than 70% similarity. The diversity of bacterial populations was estimated using the Shannon diversity index. The formula $\bar{H} = C/N\ (N \log_{10} N - \Sigma n_i \log_{10} n_i)$ was used where $C = 3.3219$, N = total number of individuals and n_i = total number of individuals in the i^{th} taxonomic grouping.

Hydrocarbon Biodegradation Activity

Natural Biodegradation Potential

Ten ml of water samples or 10 ml of a 1:100 dilution of sediment samples were added to 60 ml stoppered serum vials containing 10 ml autoclaved Rila marine salts solution and 50 μl filter sterilized Cook Inlet crude oil spiked with ^{14}C radiolabelled hydrocarbon. Poisoned controls were prepared by adding 0.2 ml concentrated hydrochloric acid. The hydrocarbons used in these studies were: 1-^{14}C n-hexadecane (Amersham Corp.), 1-^{14}C pristane (Cal Atomics), 1-^{14}C naphthalene (Amersham Corp.) and 1-^{14}C benzanthracene (Amersham Corp.). The compounds were all 99+% purity analyzed hydrocarbons. The concentrations were adjusted to 0.9 μCi ^{14}C hydrocarbon/ml crude oil. After incubation at 5 C for 6 weeks, the $^{14}CO_2$ produced was recovered and counted as described above for the MPN procedure. Duplicate determinations were made for each. Counts from the controls were subtracted from the non-poisoned counts and recorded as arbitrary units (CPM $^{14}CO_2$ produced) of hydrocarbon biodegradation potential. Since there were approximately 100,000 CPM in the spiked oil, every 1,000 units of $^{14}CO_2$ produced is equivalent to 1% conversion of hydrocarbon to CO_2.

There was sufficient oxygen in the head space of the vials to support complete oxidation of the added hydrocarbon to CO_2. We also have compared the $^{14}CO_2$ produced from vials flushed weekly with $^{14}CO_2$ produced during 6 weeks incubation and found no significant difference. We interpret this as indicating no oxygen limitation and no appreciable loss of $^{14}CO_2$ through the stoppers during our studies. The time course studies also showed that long incubation times were needed for assessing biodegradation potentials.

Non-nutrient Limited Biodegradation Potential

Non-nutrient limited hydrocarbon biodegradation potentials were determined in an identical manner to the natural hydrocarbon biodegradation potentials, except that 10 ml Bushnell Haas broth with 3% NaCl was added to each vial to remove inorganic nutrient limitations, replacing the 10 ml Rila marine salts solution.

In situ Biodegradation

Intensive *in situ* hydrocarbon biodegradation studies were initiated in the Beaufort Sea. A site was selected in Elson Lagoon. The site was chosen because of its accessability for diving operations, and because it is representative of the nearshore ecosystems likely to be the initial sites for oil development in the Beaufort Sea.

During January 1978, 7.5 cm diameter x 3 m length stainless steel cylinders were implanted into the ice. The ice depth at that time was approximately 1 meter. One ml Prudhoe Bay crude oil was injected into each cylinder by scuba divers. The oil appears to cover about 50% of the available ice surface. The cylinder does not cause the oil to pile up. Replicate cylinders were recovered after a few hours, and after 10 days' exposure to measure the initial weathering losses from the oil. Other cylinders were left in the ice and an attempt to recover them will be made in April to measure degradation of the oil exposed under ice for 4 months. The ice in the recovered cylinders was thawed and the oil recovered by repeated solvent extraction. The recovered oil will be analysed by gas liquid chromatography and mass spectrometry. The recovered oils have not yet been analysed and are being maintained at -20° C.

Oil was also exposed *in situ* in sediment. Two hundred ml Prudhoe Bay crude oil was placed in 0.25 m^2 Plexiglas trays. Freshly collected sediment was added to the trays to a depth of 5 cm. The trays were replaced *in situ*. Replicate trays were collected after 2 days' exposure. Additional trays will be collected in April after 4 months' exposure. An earlier *in situ* oil in sediment experiment had been begun in May 1977, supported by the Office of Naval Research. Samples were collected for up to 8 months. This long term experiment was unfortunately disrupted when a NOAA-OCSEAP sampling vessel used the buoy marking the site of the experiment for navigational purposes. The propeller thrust overturned the trays, terminating the experiment.

Oil has been recovered from the sediment using sequential solvent extraction with diethyl ether, benzene and methylene chloride. The oil residues will be analysed by gas liquid chromatography and mass spectrometry.

VI. Results

Enumeration

A summary of all total direct count and viable heterotroph count data, accumulated for all areas that we have so far studied, is shown in Table 3. Enumerations of total and viable heterotrophic microorganisms at specific stations have been reported in previous quarterly reports. The data clearly shows that numbers of microorganisms in surface water are very low in Cook Inlet. Especially low are populations enumerated as viable heterotrophs.

The Most Probable Number enumeration method appears to be superior to previous methods for estimating numbers of hydrocarbon utilizing microorganisms. Figures 3 and 4 show the Most Probable Numbers of hydrocarbon utilizers enumerated in Cook Inlet during April 1977 and November 1977 respectively. The distribution pattern shows that hydrocarbon utilizers are in higher numbers in Kachemak Bay, near the forelands (Upper Cook Inlet) and at Kennedy entrance to the Inlet than elsewhere within the Inlet. The distribution within Cook Inlet is consistent with areas of reported occurrence of hydrocarbons in the sediment (R. Feely, Lower Cook Inlet Synthesis Meeting). The results are also consistent with a distribution pattern showing water flow up the eastern part of the Inlet, without extensive mixing with water from Kachemak Bay, and down the Inlet close to the western shore. We have no direct information on whether high concentrations of hydrocarbons

Table 3. Summary of enumeration data.

Sample	Number of Observations	Mean	Standard Deviation	Range
Direct Count				
Water (#/ml)				
N.W. Gulf of Alaska, October 1975	14	$3.0x10^5$	$1.3x10^5$	$1.0x10^5-5.0x10^5$
N.E. Gulf of Alaska, March 1976	23	$1.4x10^5$	$8.7x10^4$	$3.1x10^4-3.3x10^5$
Cook Inlet, October 1976	21	$8.8x10^5$	$2.5x10^6$	$6.6x10^4-1.2x10^7$
Cook Inlet, April 1977	23	$2.5x10^4$	$8.8x10^3$	$1.4x10^4-5.6x10^4$
Cook Inlet, November 1977	44	$5.8x10^4$	$2.4x10^4$	$2.5x10^4-1.3x10^5$
Beaufort Sea, August 1975	33	$8.4x10^5$	$7.2x10^5$	$2.1x10^5-4.1x10^6$
Beaufort Sea, April 1976	20	$1.8x10^5$	$1.3x10^5$	$6.2x10^4-6.4x10^5$
Beaufort Sea, August 1976	20	$5.2x10^5$	$3.9x10^5$	$2.6x10^5-2.1x10^6$
Sediment (#/g dry wt.)				
N.W. Gulf of Alaska, October 1975	0	-	-	-
N.E. Gulf of Alaska, March 1976	19	$2.7x10^9$	$1.7x10^9$	$1.1x10^6-6.2x10^9$
Cook Inlet, October 1976	12	$1.6x10^9$	$1.9x10^9$	$2.7x10^8-7.1x10^9$
Cook Inlet, April 1977	13	$7.7x10^7$	$3.6x10^7$	$4.3x10^7-1.6x10^8$
Cook Inlet, November 1977	19	$5.9x10^8$	$2.1x10^8$	$2.5x10^8-1.1x10^9$
Beaufort Sea, August 1975	23	$6.2x10^7$	$1.1x10^8$	$2.3x10^6-4.8x10^8$
Beaufort Sea, April 1976	15	$2.7x10^9$	$4.2x10^9$	$3.2x10^7-1.4x10^{10}$
Beaufort Sea, August 1976	13	$2.1x10^9$	$1.6x10^9$	$7.6x10^8-6.9x10^9$
Marine Agar 4°C				
Water (#/ml)				
N.W. Gulf of Alaska, October 1976	14	$1.0x10^2$	$6.9x10^1$	$2.0x10^1-2.5x10^2$
N.E. Gulf of Alaska, March 1976	22	$1.1x10^3$	$4.6x10^3$	$6.0x10^0-2.2x10^4$
Cook Inlet, October 1976	21	$8.0x10^3$	$2.4x10^4$	$5.0x10^0-1.1x10^5$
Cook Inlet, April 1977	26	$3.9x10^2$	$4.8x10^2$	$2.8x10^1-1.9x10^3$
Cook Inlet, November 1977	35	$5.2x10^2$	$9.9x10^2$	$1.0x10^1-5.1x10^3$
Beaufort Sea, August 1975	43	$7.3x10^3$	$7.3x10^3$	$2.0x10^1-2.8x10^4$
Beaufort Sea, April 1976	20	$2.7x10^3$	$7.6x10^3$	$1.0x10^1-3.2x10^4$
Beaufort Sea, August 1976	20	$4.4x10^6$	$1.9x10^7$	$4.4x10^2-8.8x10^7$
Sediment (#/g dry wt.)				
N.W. Gulf of Alaska, October 1975	5	$6.3x10^5$	$5.6x10^5$	$1.0x10^4-1.4x10^6$
N.E. Gulf of Alaska, March 1976	20	$9.9x10^5$	$2.1x10^6$	$1.5x10^3-9.0x10^6$
Cook Inlet, October 1976	13	$4.6x10^6$	$6.6x10^6$	$1.0x10^4-2.1x10^7$
Cook Inlet, April 1977	15	$1.1x10^7$	$2.7x10^7$	$5.1x10^4-1.1x10^8$
Cook Inlet, November 1977	17	$1.4x10^4$	$2.0x10^7$	$9.1x10^4-6.7x10^7$

Table 3. Continued.

Sample		Number of Observations	Mean	Standard Deviation	Range
			Marine Agar 4°C		
	Sediment (#/g dry wt.)				
Beaufort Sea,	August 1975	33	$3.1\text{x}10^5$	$4.0\text{x}10^5$	$2.9\text{x}10^3$-$1.5\text{x}10^6$
Beaufort Sea,	April 1976	15	$6.9\text{x}10^4$	$9.6\text{x}10^4$	$2.4\text{x}10^2$-$3.7\text{x}10^5$
Beaufort Sea,	August 1976	14	$1.1\text{x}10^7$	$2.8\text{x}10^7$	$1.5\text{x}10^5$-$1.1\text{x}10^8$
			Marine Agar 20°C		
	Water (#/ml)				
N.W. Gulf of Alaska,	October 1975	7	$5.3\text{x}10^2$	$6.4\text{x}10^2$	$4.3\text{x}10^1$-$2.0\text{x}10^3$
N.E. Gulf of Alaska,	March 1976	22	$1.1\text{x}10^4$	$4.2\text{x}10^3$	$6.7\text{x}10^0$-$2.0\text{x}10^4$
Cook Inlet,	October 1976	21	$1.0\text{x}10^4$	$2.4\text{x}10^4$	$3.3\text{x}10^1$-$9.7\text{x}10^4$
Cook Inlet,	April 1977	12	$1.6\text{x}10^3$	$1.7\text{x}10^3$	$2.3\text{x}10^1$-$5.1\text{x}10^3$
Cook inlet,	November 1977	36	$2.5\text{x}10^2$	$4.2\text{x}10^2$	$3.0\text{x}10^0$-$2.2\text{x}10^3$
Beaufort Sea,	August 1975	43	$9.9\text{x}10^3$	$9.0\text{x}10^3$	$7.0\text{x}10^1$-$2.9\text{x}10^4$
Beaufort Sea,	April 1976	20	$1.8\text{x}10^5$	$1.3\text{x}10^5$	$6.2\text{x}10^4$-$6.4\text{x}10^4$
Beaufort Sea,	August 1976	20	$5.0\text{x}10^4$	$4.8\text{x}10^4$	$1.9\text{x}10^3$-$1.8\text{x}10^5$
	Sediment (#/g dry wt.)				
N.W. Gulf of Alaska,	October 1975	3	$8.0\text{x}10^5$	$3.5\text{x}10^5$	$3.5\text{x}10^5$-$1.2\text{x}10^6$
N.E. Gulf of Alaska,	March 1976	20	$2.9\text{x}10^6$	$7.7\text{x}10^6$	$3.3\text{x}10^3$-$3.2\text{x}10^7$
Cook Inlet,	October 1976	13	$7.8\text{x}10^6$	$1.0\text{x}10^7$	$4.0\text{x}10^3$-$3.2\text{x}10^7$
Cook Inlet,	April 1977	6	$3.2\text{x}10^7$	$4.5\text{x}10^7$	$2.2\text{x}10^5$-$1.3\text{x}10^8$
Cook Inlet,	November 1977	36	$2.6\text{x}10^2$	$4.2\text{x}10^2$	$3.0\text{x}10^0$-$2.2\text{x}10^3$
Beaufort Sea,	August 1975	32	$2.1\text{x}10^5$	$3.2\text{x}10^5$	$6.5\text{x}10^3$-$1.8\text{x}10^6$
Beaufort Sea,	April 1976	15	$2.5\text{x}10^5$	$4.7\text{x}10^5$	$1.8\text{x}10^3$-$1.9\text{x}10^6$
Beaufort Sea,	August 1976	13	$8.6\text{x}10^6$	$1.2\text{x}10^7$	$3.5\text{x}10^4$-$4.5\text{x}10^7$

Figure 3. Most Probable Numbers of hydrocarbon utilizers in Cook Inlet - April 1977 samples.
Solid bars= water Open bars=sediment

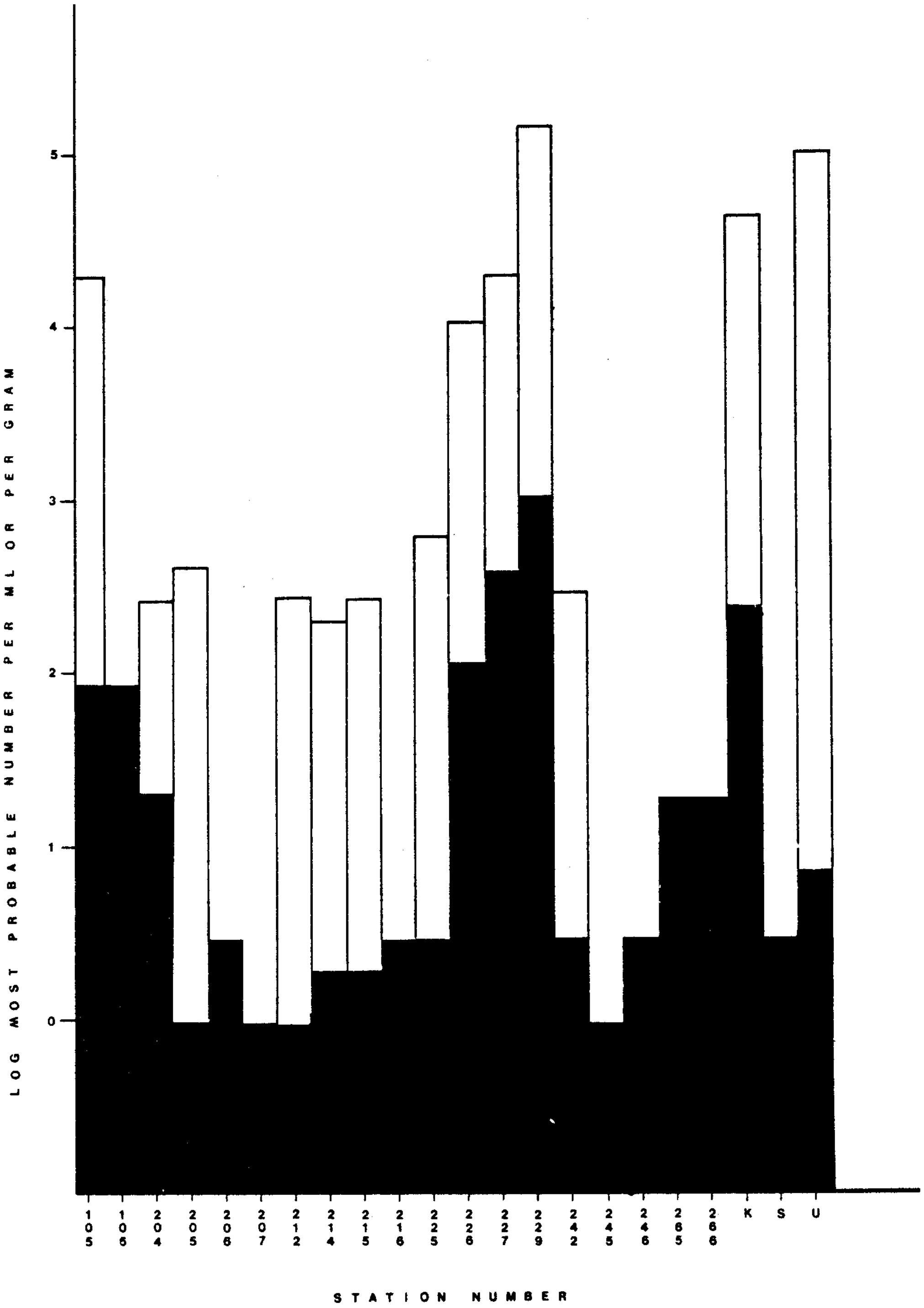
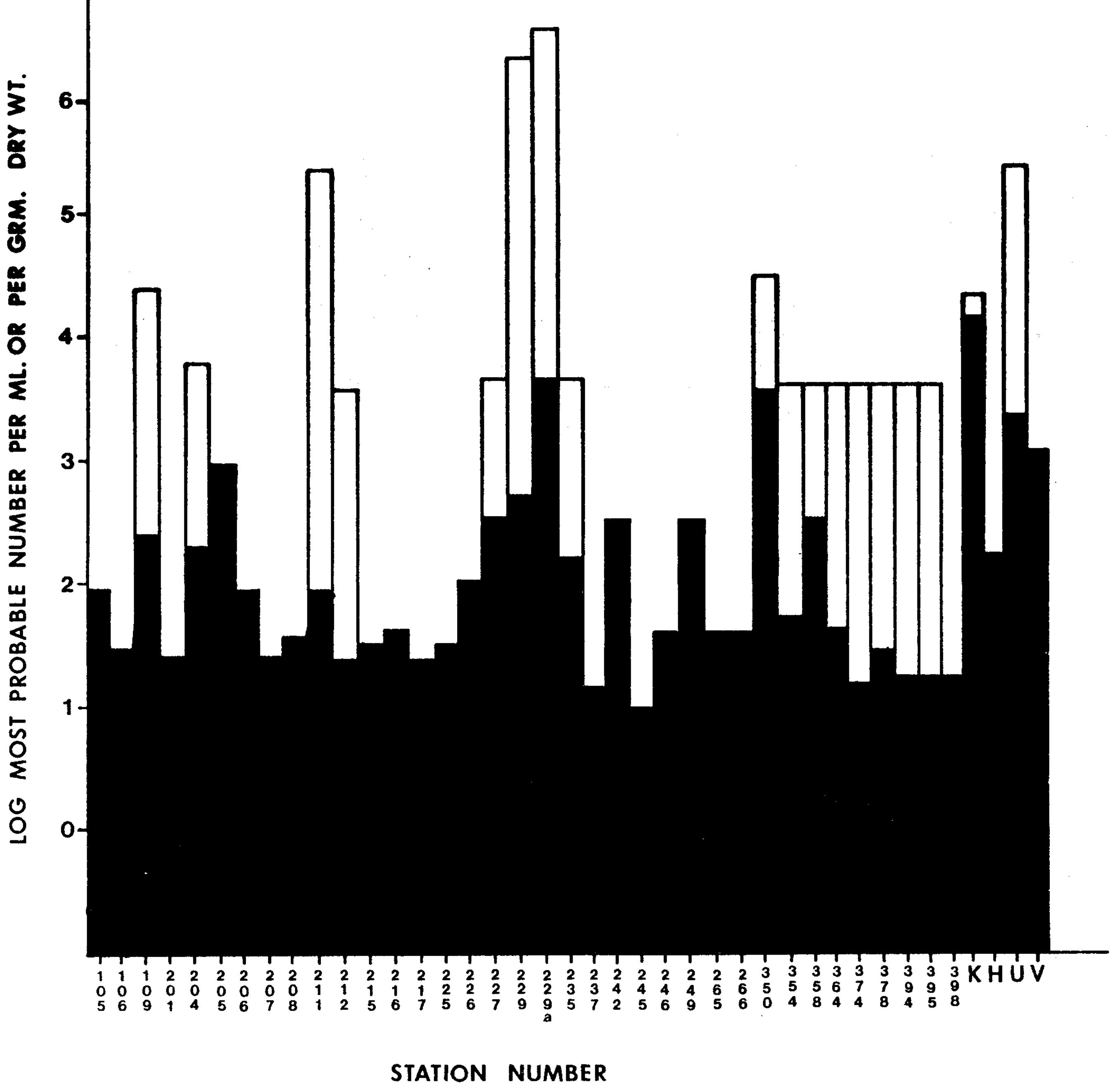


Figure 4. Most Probalbe Numbers of hydrocarbon utilizers in Cook Inlet November 1977 samples. Solid bars=water Open bars=sediment



occur near the Kennedy entrance to the Inlet where high MPN estimates of hydrocarbon utilizers were found. It appears that the distribution of hydrocarbon utilizing microorganisms in Cook Inlet can be used as an indicator of areas of occurrence of hydrocarbons. We therefore predict that a source of hydrocarbons in the environment will be found near the Kennedy entrance to Cook Inlet.

Taxonomic Characterization

The results of cluster and feature frequency analyses on viable heterotrophic bacterial populations in the Beaufort Sea that were sampled during summer 1975 have been condensed to show the major characteristics of the dominant phenotypic clusters (Table 4). We have concluded that the bacterial populations in the Beaufort Sea are taxonomically distinct from bacterial populations in temperate marine ecosystems. Flavobacterium, Vibrio and Microcyclus have been tentatively identified as the dominant genera in Beaufort Sea water and sediment samples.

Cluster analyses have been performed for viable heterotrophic microbial populations in Cook Inlet isolated from November 1976 and April 1977. The results of the cluster analyses are shown as dendrograms (Figs. 5 and 6). Typically, clusters contained few organisms.

The Shannon diversity indices were calculated for the bacterial populations at each sampling station (Table 5). Diversity of populations

Table 4. Prominent features of major clusters of bacteria from the Beaufort Sea

Cluster L-1: 21 strains- Estimated 7.5% of population

Morphological characteristics

Gram negative, non-motile, highly pleomorphic rods. Some cells were horseshoe shaped, length 3-4 microns. Other cells were very large, often 10 microns length. Colonies small, non-pigmented, glistening, translucent, convex, with entire edge.

Physiological characteristics

Growth range 5-25°C, pH 6-8, 0.5-5% NaCl. Optimal pH 7-8, optimal NaCl concentration 3%.

Biochemical Characteristics

Generally no acid from carbohydrates. Starch, gelatin, Tween 20 and Tween 80 not hydrolyzed. Alkaline phosphatase positive. Catalase positive.

Antibiotic sensitivity

Sensitive to 11 of 12 antibiotics.

Nutritional characteristics

Require vitamins as growth factors. Utilize glucose, acetate, propionate, caprylate, fumarate, beta-hydroxybutyrate, citrate, alpha-ketoglutarate, pyruvate, glutarate, glycerol, p-hydroxybenzoate, alanine, serine, threonine, glutamate, gamma-aminobutyrate.

Distribution

Wide geographic distribution in both water and sediment.

Identification

Unidentified.

Cluster L-2: 9 strains- Estimated 3.2% of population

Morphological characteristics

Gram negative, pleomorphic, non-motile rods occurring singly, or in chains. Length varies but typically about 2 microns. Colonies small, non-pigmented, glistening, smooth, convex, with entire edge.

Physiological characteristics

Growth range 5-25°C, pH 6-9, 0.5-5% NaCl.

Biochemical characteristics

No acid produced from carbohydrates. No hydrolysis of polymers. Alkaline phosphatase positive, catalase weakly positive, oxidase negative.

Antibiotic sensitivity

Sensitive to 9 of 12 antibiotics.

Nutritional characteristics

Require vitamins as growth factors. Utilize xylose, glucose, cellobiose, acetate, caprylate, malonate, beta-hydroxybutyrate, alpha-ketoglutarate, pyruvate, glutarate, glycerol, p-hydroxybutyrate, glutamate, aminobutyrate.

Table 4. (continued)

Cluster L-2: 9 strains

Distribution

Water samples from stations 55 and 70.

Identification

Unidentified.

Cluster L-4: 60 strains - Estimated 21.6% of population

Morphological characteristics

Gram negative non-motile highly pleomorphic rods, 1.2-1.5 microns length, some elongated, greater than 20 microns. Cells occur singly and in chains. Round body (or spherical body) formation very common, especially in old cultures. Colony orange pigmented, translucent, glistening, smooth, convex.

Physiological characteristics

Growth range 5-20°C, pH 5-9, 0.5-5% NaCl.

Biochemical characteristics

Some produced acid from sucrose. Gelatin hydrolyzed by some. No amylase nor lipase produced. Alkaline phosphatase positive, catalase positive, oxidase negative, typically arginine decarboxylase positive. No nitrate reduction.

Antibiotic sensitivity

Sensitive to 6 of 12 antibiotics.

Nutritional characteristics

Require vitamins as growth factors. Utilize galactose, glucose, mannose, maltose, glutamate.

Distribution

Found at all stations. Incidence much higher in water than sediments.

Identification

Tentatively identified as *Flavobacterium* spp.

Cluster L-5: 4 strains - Estimated 1.4% of population

Morphological characteristics

Gram negative, non-motile, horseshoe shaped, curved rods, ca 3-4 microns length. Round bodies common. Cells occur singly. Colonies small (0.1 mm in a diameter), yellow pigmented, transluscent, convex, entire, glistening, smooth.

Physiological characteristics

Growth range: 5-15°C, pH 6-9, 3-5% NaCl.

Biochemical characteristics

Acids not produced from carbohydrates. No hydrolysis of polymers. Alkaline phosphatase positive, catalase weakly positive, oxidase negative.

Antibiotic sensitivity

Sensitive to 6 of 12 antibiotics.

Nutritional characteristics

Fastidious. Require complex growth factors. Substrates not utilized without added amino acids and vitamins.

Table 4 . (continued)

Cluster L-5: 4 strains

Distribution

Mainly sediment at Station 2.

Identification

Tentatively identified as *Microcyclus* spp.

28 strains

Morphological characteristics

Morphologically similar to Cluster L-4, but smaller rods, length 0.8 micron. Orange pigments produced. Non-motile.

Physiological characteristics

Growth range 5-20°C, pH 6-8, 0.5-3% NaCl.

Biochemical characteristics

Some produced acid from D-glucose aerobically. No hydrolysis of polymers. Catalase positive, oxidase negative.

Antibiotic sensitivity

Sensitive to 8 of 13 antibiotics.

Nutritional characteristics

Require complex growth factors. Substrates not utilized without added amino acids and vitamins.

Distribution

Widely distributed. High incidence in water at Prudhoe Bay.

Identification

Tentatively identified as *Flavobacterium* spp.

Cluster L-7: 7 strains- Estimated 2.5% of population

Morphological characteristics

Gram negative, non-motile, straight or curved rods, two types were seen, the first type was broader, size ca 2-2.5 micron long and 1.0 micron wide, the second type was more slender, 0.6-0.8 micron wide and 2.5-3.0 micron long. Irregular pleomorphic shapes often developed. Cells occur singly. Colonies white-gray, opaque, entire, glistening, smooth and convex.

Physiological characteristics

Growth range 5-10°C, pH 5-9, 3-5% NaCl.

Biochemical characteristics

Acid from D-glucose anaerobically. Starch, gelatin, Tween 20 and Tween 80 hydrolyzed, alkaline phosphatase positive, NO_3 to NO_2 positive, oxidase variable, catalase variable.

Antibiotic sensitivity

Sensitive to 8 of 12 antibiotics.

Nutritional characteristics

Require amino acids as growth factors.

Distribution

Sediment from Sts. 10 and 71.

Identification

Tentatively identified *Vibrio* spp.

Table 4. (continued)

Cluster L-9: 4 strains - Estimated 1.4% of population

Morphological characteristics

Gram negative, typically large 4-5 micron length, straight rods. Cells occur singly and in chains. Motility positive in three of four strains. Colonies non-pigmented, translucent, convex, entire glistening and smooth.

Physiological characteristics

Growth range 5-15°C, pH 5-9, 3-5% NaCl.

Biochemical caracteristics

Acid from D-glucose, both aerobically and anaerobically. Gelatin, Tween 20 and Tween 80 hydrolyzed, alkaline phosphatase positive. Catalase positive. Oxidase negative. Ammonia produced from peptones NO_3 reduced to NO_2.

Antibiotic sensitivity

Sensitive to 5 of 12 antibiotics.

Nutritional characteristics

Require vitamins for growth. Only pyruvate utilized on media B. Fructose, glucose, succinate, fumarate, lactate utilized on media E.

Distribution

Only found in Station 10 sediment.

Identification

Tentatively identified as *Vibrio* or *Beneckea* spp.

Cluster L-10: 10 strains - Estimated 3.6% of population

Morphological characteristics

Gram negative, non-motile rods, 1-2.5 micron length, often slightly curved. Generally capsulated. Colonies small non-pigmented translucent, convex, entire, glistening and smooth.

Physiological characteristics

Growth range 5-25°C, pH 5-9, 0-5% NaCl.

Biochemical characteristics

No acid from carbohydrates. Starch and gelatin not hydrolyzed. Tween 20 hydrolyzed, Catalase positive. NO_3 reduced to NO_2.

Antibiotic sensitivity

Sensitive to 10 of 12 antibiotics.

Nutritional characteristics

Do not require growth factors. Utilize caprylate, pyruvate, alanine, aspartate, gamma-aminobutyrate. Carbohydrates not utilized.

Distribution

Found in sediment, at several stations.

Identification

Unidentified.

Table 4. (continued)

Cluster L-11: 6 strains - Estimated 2.1% of population

Morphological characteristics

Gram negative motile rods, curved axis, 2-3 micron length. Cells occur singly. Colonies white translucent, convex glistening, smooth and entire.

Physiological characteristics

Growth range 5-15°C, pH 5-10, 3-5% NaCl.

Biochemical characteristics

Acid from D-fructose and D-glucose aerobically and anaerobically. No hydrolysis of starch, gelatin, Tween 20 and Tween 80. Alkaline phosphatase positive. Catalase positive. Oxidase negative. Ammonia produced from peptone. NO_3 reduced to NO_2. Arginine decarboxylase positive.

Antibiotic sensitivity

Sensitive to 5 of 12 antibiotics.

Nutritional characteristics

Do not require growth factors. Utilized ribose, fructose, glucose, maltose, fumarate, citrate, alpha-ketoglutarate. pyruvate, glutarate, glycerol, L-arginine, N-acetyclucosamine.

Distribution

Sediment at stations 10 and 71.

Identification

Tentatively identified as Vibrio spp.

Cluster H-2: 13 strains.- Estimated 4.7% of population

Morphological characteristics

Gram negative, motile, straight and curved, rods, 2-4 micron length. Cells occur singly. Colonies gray, opaque, convex, entire, glistening and smooth.

Physiological characteristics

Growth range 5-15°C, pH 5-10, 3-5% NaCl.

Biochemical characteristics

Acids from fructose and glucose both aerobically and anaerobically. Catalase positive. Oxidase negative. NO_3 reduced to NO_2.

Antibiotic sensitivity

Sensitive to 5 of 12 antibiotics.

Nutritional characteristics

Require vitamins as growth factors. Utilized ribose, fructose, galactose, glucose, mannose, salicin, maltose, fumerate, glycerate, citrate, glutarate, glycerol, aspartate and N-acetylglucosamine.

Distribution

Sediment at stations 2 and 10.

Identification

Tentatively identified as Vibrio spp.

Table 4. (continued)

Cluster H-3: 7 strains - Estimated 2.5% of population

Morphological characteristics

Gram negative non-motile rods, 0.6-1.0 microns length. Cells occur singly. Colonies yellow, opaque, convex, entire, glistening, smooth.

Physiological characteristics

Growth range 5-20°C, pH 6-8, 3.0% NaCl.

Biochemical characteristics

Acid not produced. Starch hydrolyzed. Gelatin and Tween not hydrolyzed. Catalase positive, alkaline phosphatase negative, oxidase negative, NO_3 reduced to NO_2.

Antibiotic sensitivity

Sensitive to 8 of 11 antibiotics.

Nutritional characteristics

No substrates utilized on defined media. Require unknown growth factors.

Distribution

Sediment from stations 2 and 10.

Identification

Tentatively identified as _Flavobacterium_ spp.

Cluster H-4: 36 strains Estimated 12.9% of population

Morphological characteristics

Gram negative rods, straight or curved,often comma-shaped. Highly pleomorphic with very large cells as well as round bodies often seen. Typical cells 2.5-3.5 microns long x 0.8-1.0 microns wide. Cells occur singly. Colonies orange, translucent or transparent, convex, entire, glistening and smooth.

Physiological characteristics

Growth range 5-25°C, pH 5-8, 0.5-3% NaCl.

Biochemical characteristics

Some produced acid from glucose and sucrose both aerobically and anaerobically. Starch and Tween 80 hydrolyzed. Most hydrolyzed gelatin. Alkaline phosphatase positive, most catalase positive. Ammonia produced from peptone.

Antibiotic sensitivity

Sensitive to 9 of 11 antibiotics.

Nutritional characteristics

Require amino acids or more complex growth factors.

Distribution

Distributed at all stations except station 10.

Identification

Tentatively identified as _Flavobacterium_ spp.

Table 4. (continued)

Cluster H-5: 9 strains - Estimated 3.2% of population

Morphological characteristics

Gram negative, non-motile rods, ca 0.8-1.2 micron length. Colonies small, 0.5-0.8 mm in diameter, yellow, trnaslucent, convex, entire glistening and smooth.

Physiological characteristics

Growth range 5-25°C, pH 5-8, 0-10% NaCl.

Biochemical characteristics

No acid from carbohydrates. Lipase positive. Alkaline phosphatase positive. Catalase negative. Oxidase negative. Ammonia produced from peptones.

Antibiotic sensitivity

Sensitive to 7 of 14 antibiotics.

Nutritional characteristics

Do not require growth factors. Utilized glucose, propionate, butyrate, valerate, isovalerate, caprylate, fumarate, beta-hydroxybutyrate, itaconate, 1-butanol, isoleucine.

Distribution

Stations 10, 30, 55 and 71.

Identification

Tentatively identified as <u>Flavobacterium</u> spp.

Cluster H-6: 7 strains - Estimated 7.5% of population

Morphological characteristics

Gram negative, non-motile, curved rods, 2-5 micron length. Cells occur singly. Some cells horseshoe shaped, some form rings. Colonies gray, entire, convex, glistening and smooth.

Physiological characteristics

Growth range 5-25°C, pH 5-9, 0-3% NaCl.

Biochemical characteristics

No acid from carbohydrates. Tween 20 hydrolyzed. No hydrolysis of starch, gelatin or Tween 80. Alkaline phosphatase positive, catalase positive. Ammonia produced from peptones. NO_3 reduced to NO_2.

Antibiotic sensitivity

Sensitive to 10 of 11 antibiotics.

Nutritional characteristics

Require vitamins as growth factors. Utilize fumarate, pyruvate, alanine, aspartate, glutarate, gamma-aminobutyrate.

Distribution

Sediment samples collected from Stations 30, 70 and 71.

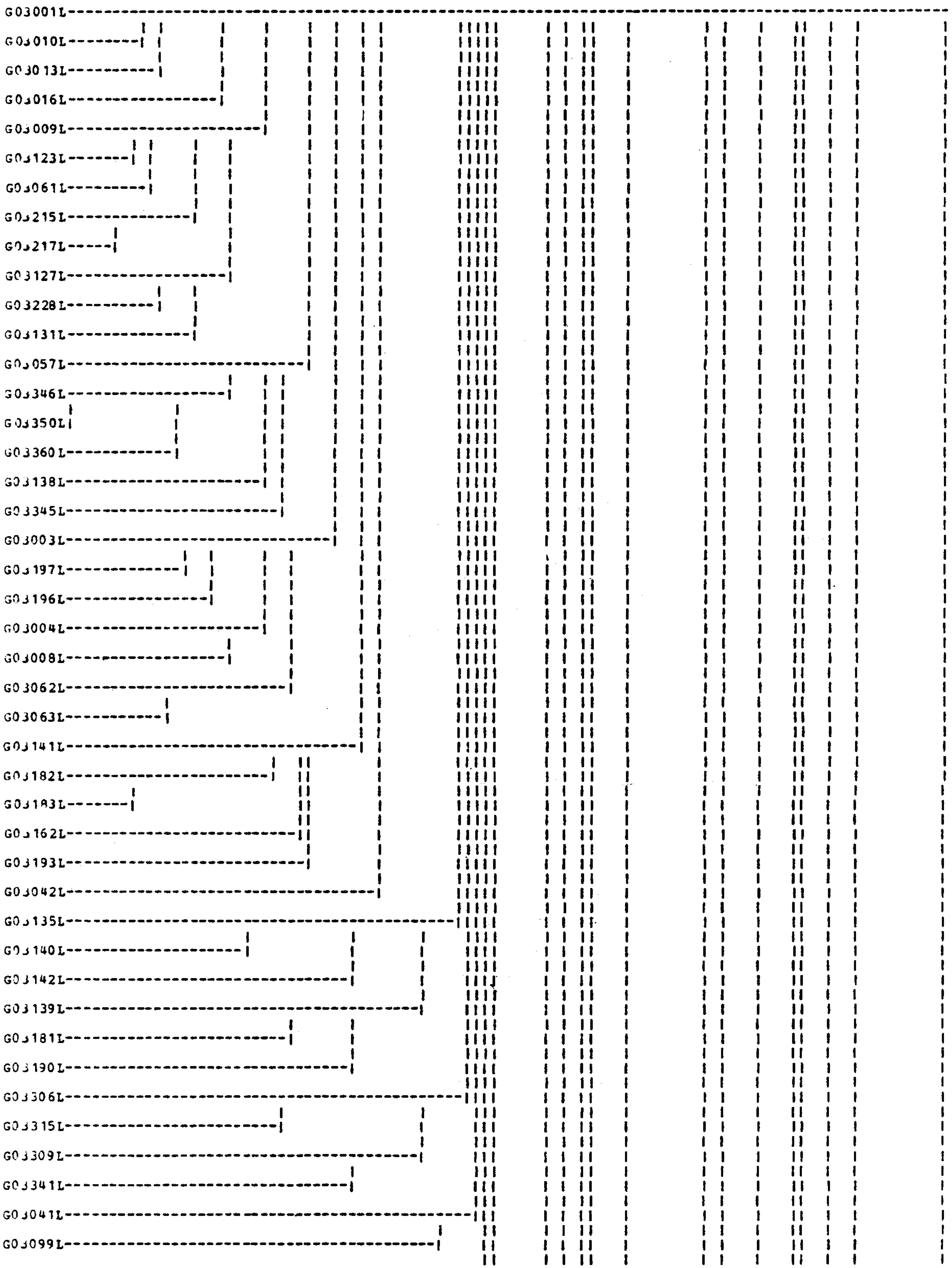
Identification

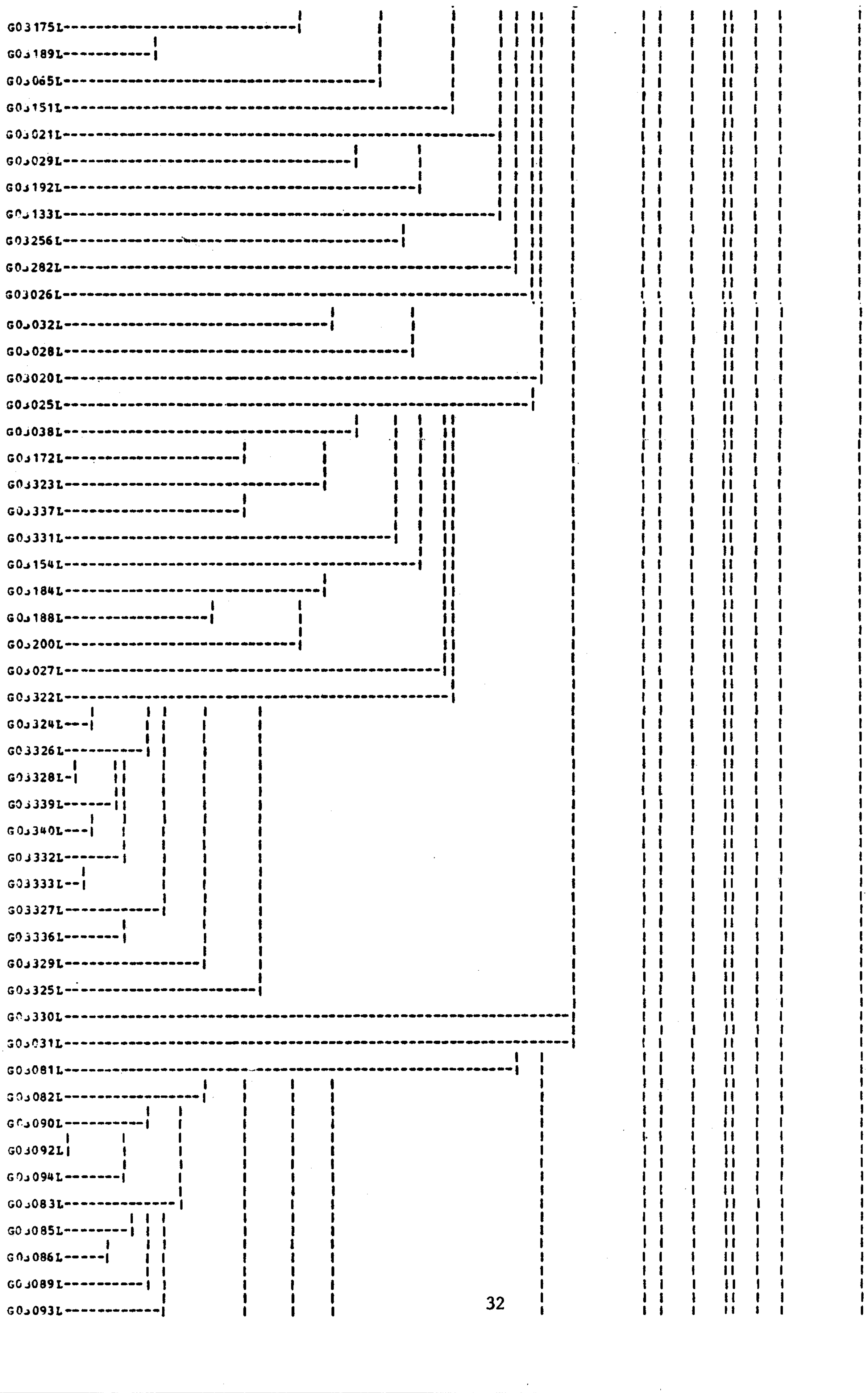
Tentatively identified as <u>Microcyclus</u> spp.

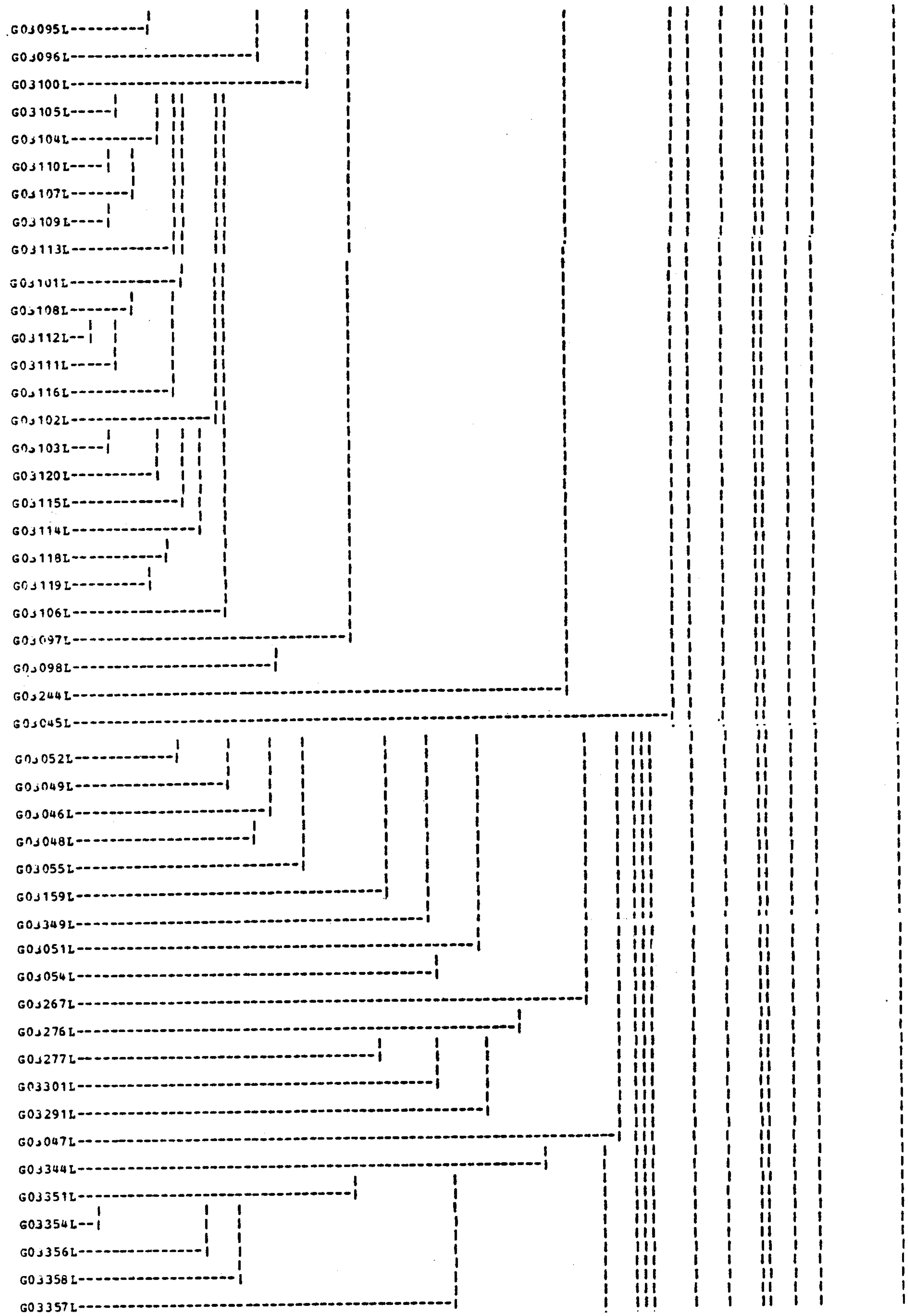
Figure 5. Dendrogram of Cook Inlet isolates from November 1976.

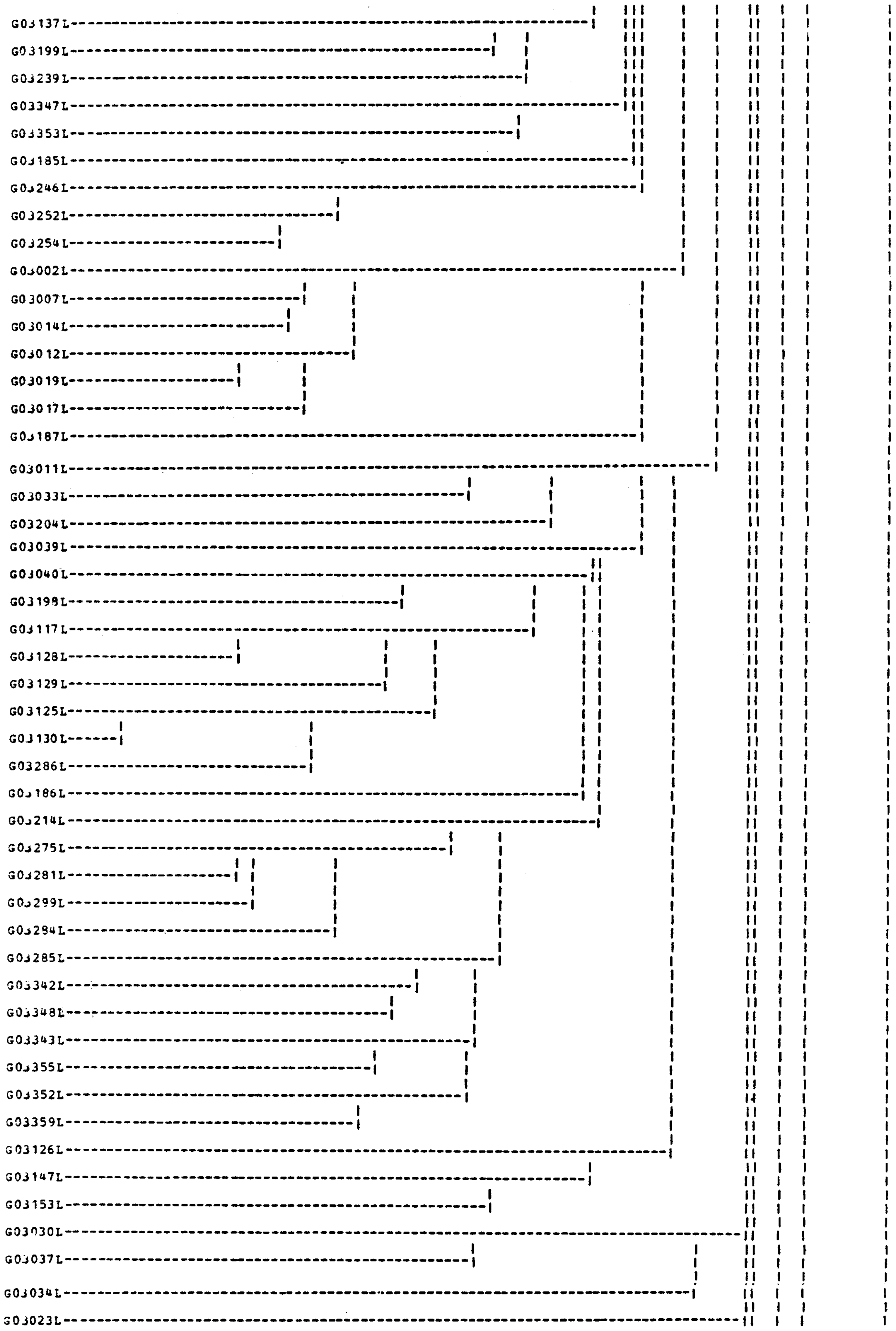
COEFFICIENT: S (J)
SIMILARITY AT TIP (LEFT) = .9545

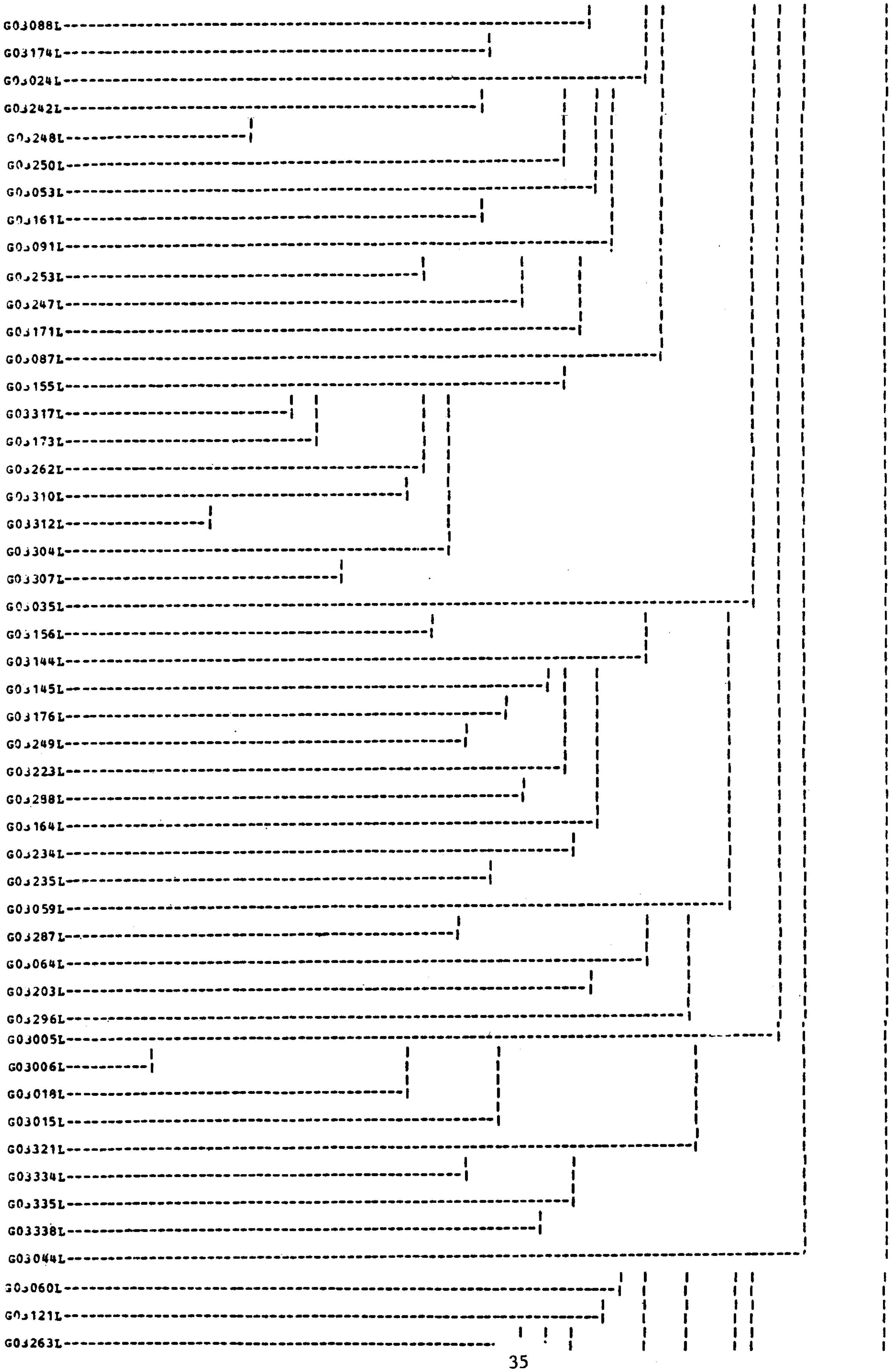
SIMILARITY AT BASE (RIGHT) = .2605

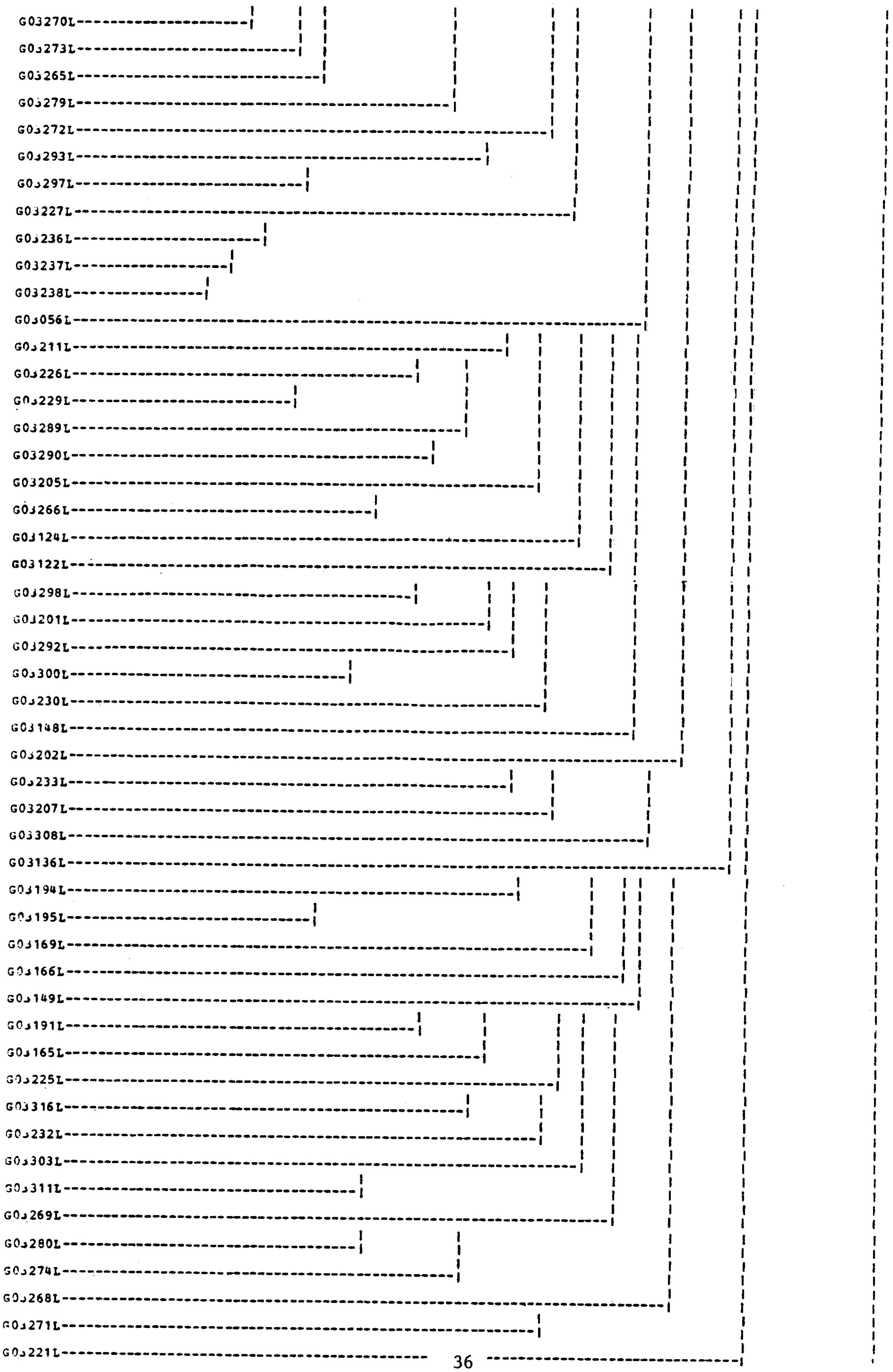



G03175L
G03189L
G03065L
G03151L
G03021L
G03029L
G03192L
G03133L
G03256L
G03282L
G03026L
G03032L
G03028L
G03020L
G03025L
G03038L
G03172L
G03323L
G03337L
G03331L
G03154L
G03184L
G03188L
G03200L
G03027L
G03322L
G03324L
G03326L
G03328L
G03339L
G03340L
G03332L
G03333L
G03327L
G03336L
G03329L
G03325L
G03330L
G03031L
G03081L
G03082L
G03090L
G03092L
G03094L
G03083L
G03085L
G03086L
G03089L
G03093L


G03095L
G03096L
G03100L
G03105L
G03104L
G03110L
G03107L
G03109L
G03113L
G03101L
G03108L
G03112L
G03111L
G03116L
G03102L
G03103L
G03120L
G03115L
G03114L
G03118L
G03119L
G03106L
G03097L
G03098L
G03244L
G03045L
G03052L
G03049L
G03046L
G03048L
G03055L
G03159L
G03349L
G03051L
G03054L
G03267L
G03276L
G03277L
G03301L
G03291L
G03047L
G03344L
G03351L
G03354L
G03356L
G03358L
G03357L


G03137L
G03199L
G03239L
G03347L
G03353L
G03185L
G03246L
G03252L
G03254L
G03002L
G03007L
G03014L
G03012L
G03019L
G03017L
G03187L
G03011L
G03033L
G03204L
G03039L
G03040L
G03198L
G03117L
G03128L
G03129L
G03125L
G03130L
G03286L
G03186L
G03214L
G03275L
G03281L
G03299L
G03294L
G03285L
G03342L
G03348L
G03343L
G03355L
G03352L
G03359L
G03126L
G03147L
G03153L
G03030L
G03037L
G03034L
G03023L


G03088L
G03174L
G03024L
G03242L
G03248L
G03250L
G03053L
G03161L
G03091L
G03253L
G03247L
G03171L
G03087L
G03155L
G03317L
G03173L
G03262L
G03310L
G03312L
G03304L
G03307L
G03035L
G03156L
G03144L
G03145L
G03176L
G03249L
G03223L
G03298L
G03164L
G03234L
G03235L
G03059L
G03287L
G03064L
G03203L
G03296L
G03005L
G03006L
G03018L
G03015L
G03321L
G03334L
G03335L
G03338L
G03044L
G03060L
G03121L
G03263L


G03270L
G03273L
G03265L
G03279L
G03272L
G03293L
G03297L
G03227L
G03236L
G03237L
G03238L
G03056L
G03211L
G03226L
G03229L
G03289L
G03290L
G03205L
G03266L
G03124L
G03122L
G03298L
G03201L
G03292L
G03300L
G03230L
G03148L
G03202L
G03233L
G03207L
G03308L
G03136L
G03194L
G03195L
G03169L
G03166L
G03149L
G03191L
G03165L
G03225L
G03316L
G03232L
G03303L
G03311L
G03269L
G03280L
G03274L
G03268L
G03271L
G03221L

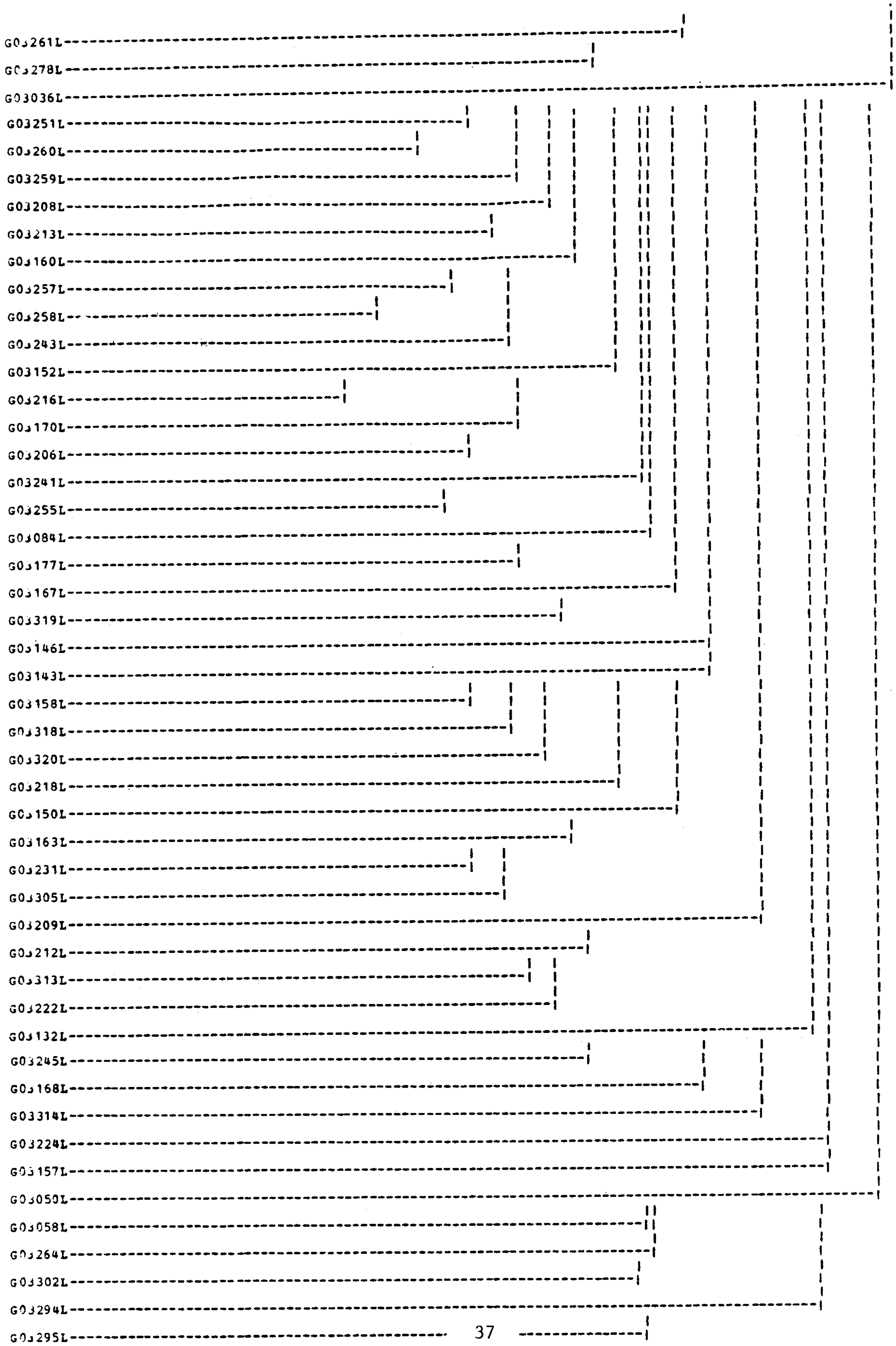
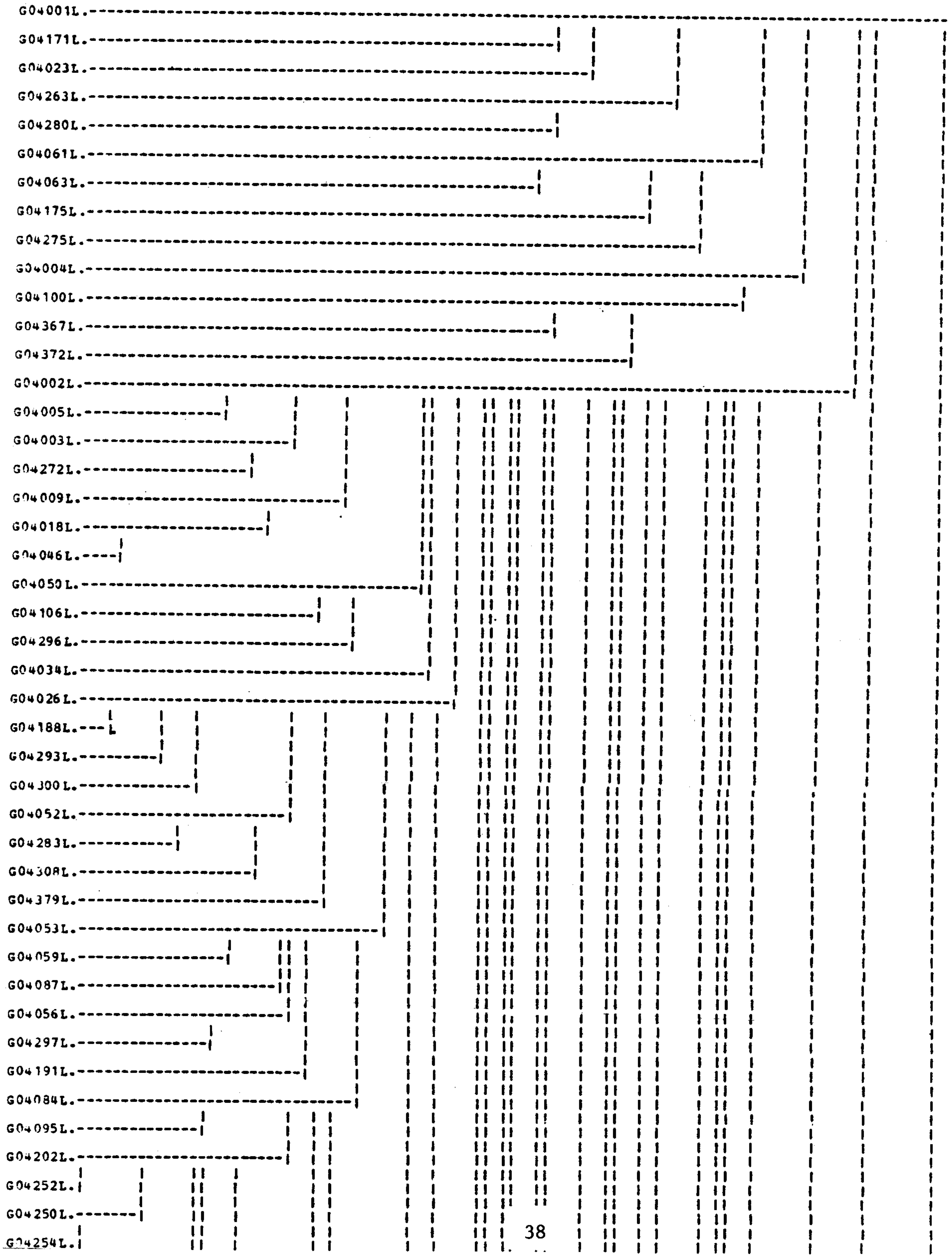
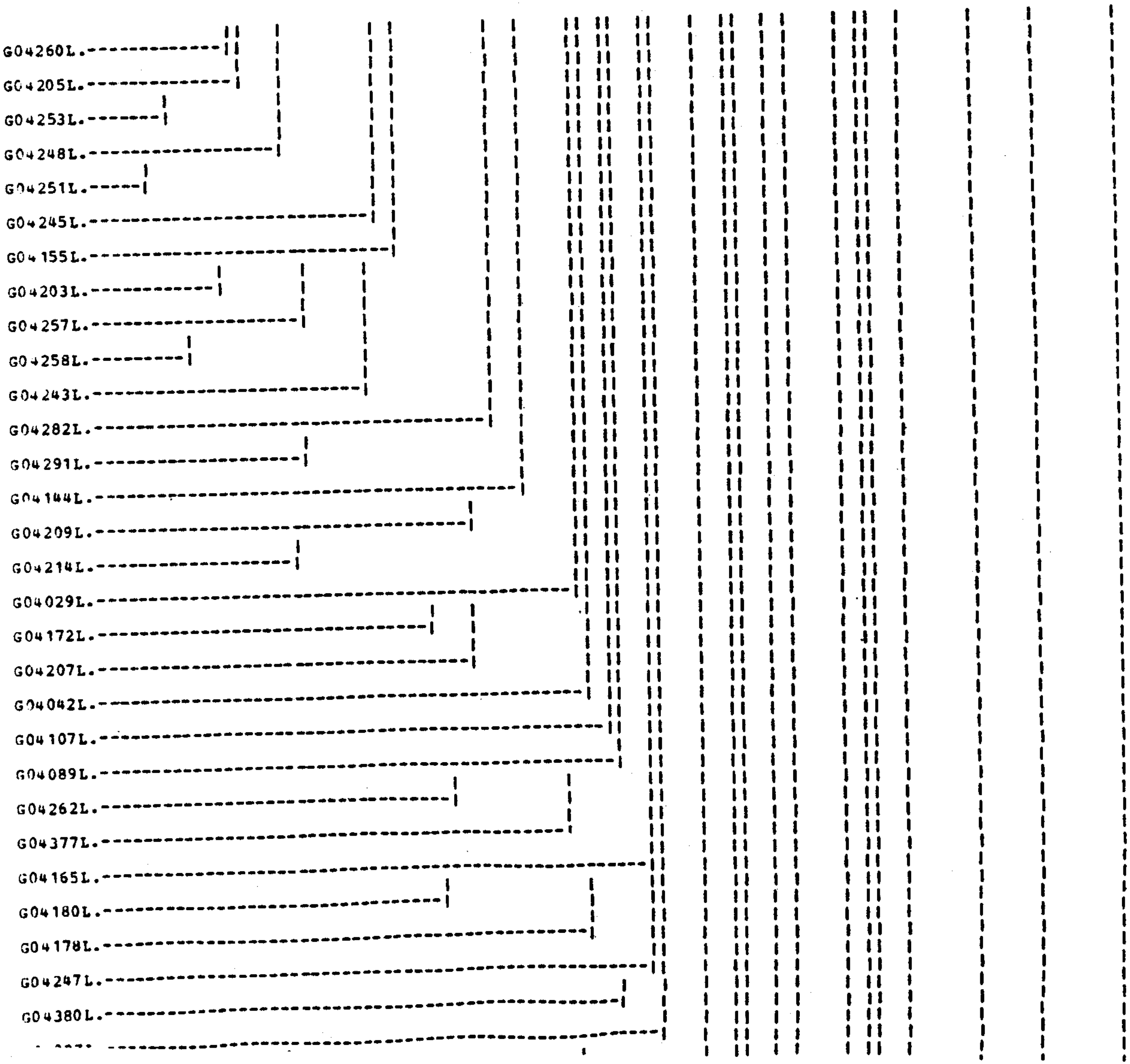
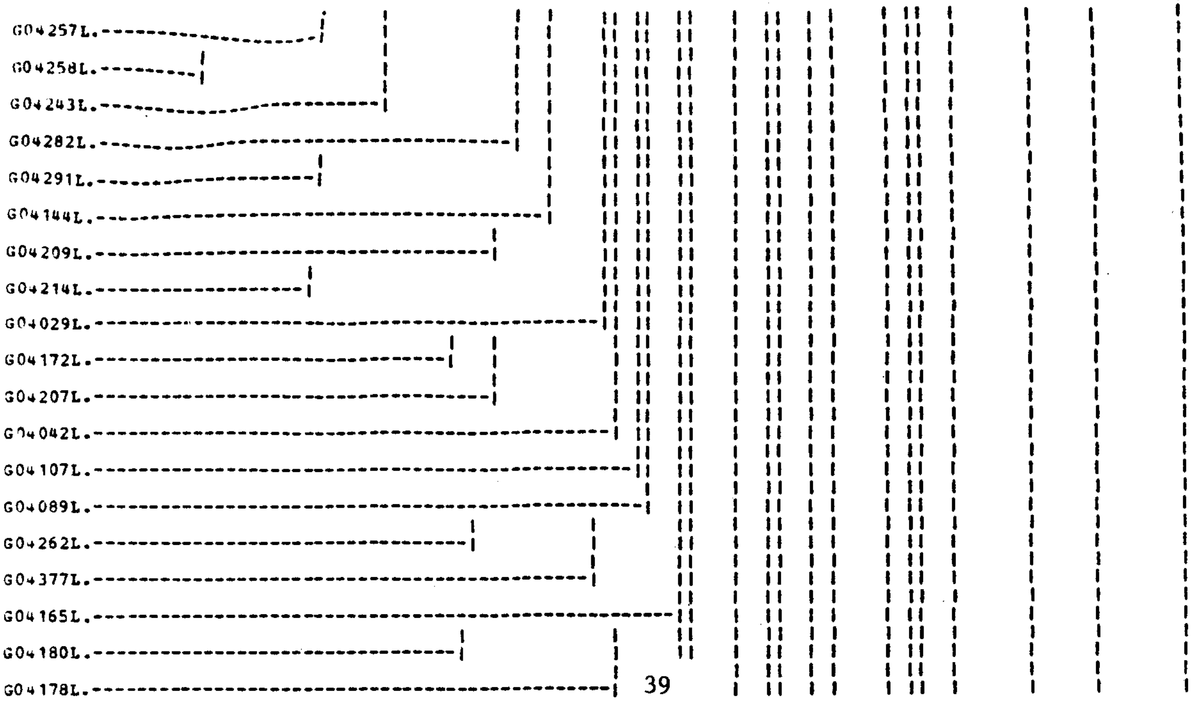

G03261L
G03278L
G03036L
G03251L
G03260L
G03259L
G03208L
G03213L
G03160L
G03257L
G03258L
G03243L
G03152L
G03216L
G03170L
G03206L
G03241L
G03255L
G03084L
G03177L
G03167L
G03319L
G03146L
G03143L
G03158L
G03318L
G03320L
G03218L
G03150L
G03163L
G03231L
G03305L
G03209L
G03212L
G03313L
G03222L
G03132L
G03245L
G03168L
G03314L
G03224L
G03157L
G03050L
G03058L
G03264L
G03302L
G03294L
G03295L

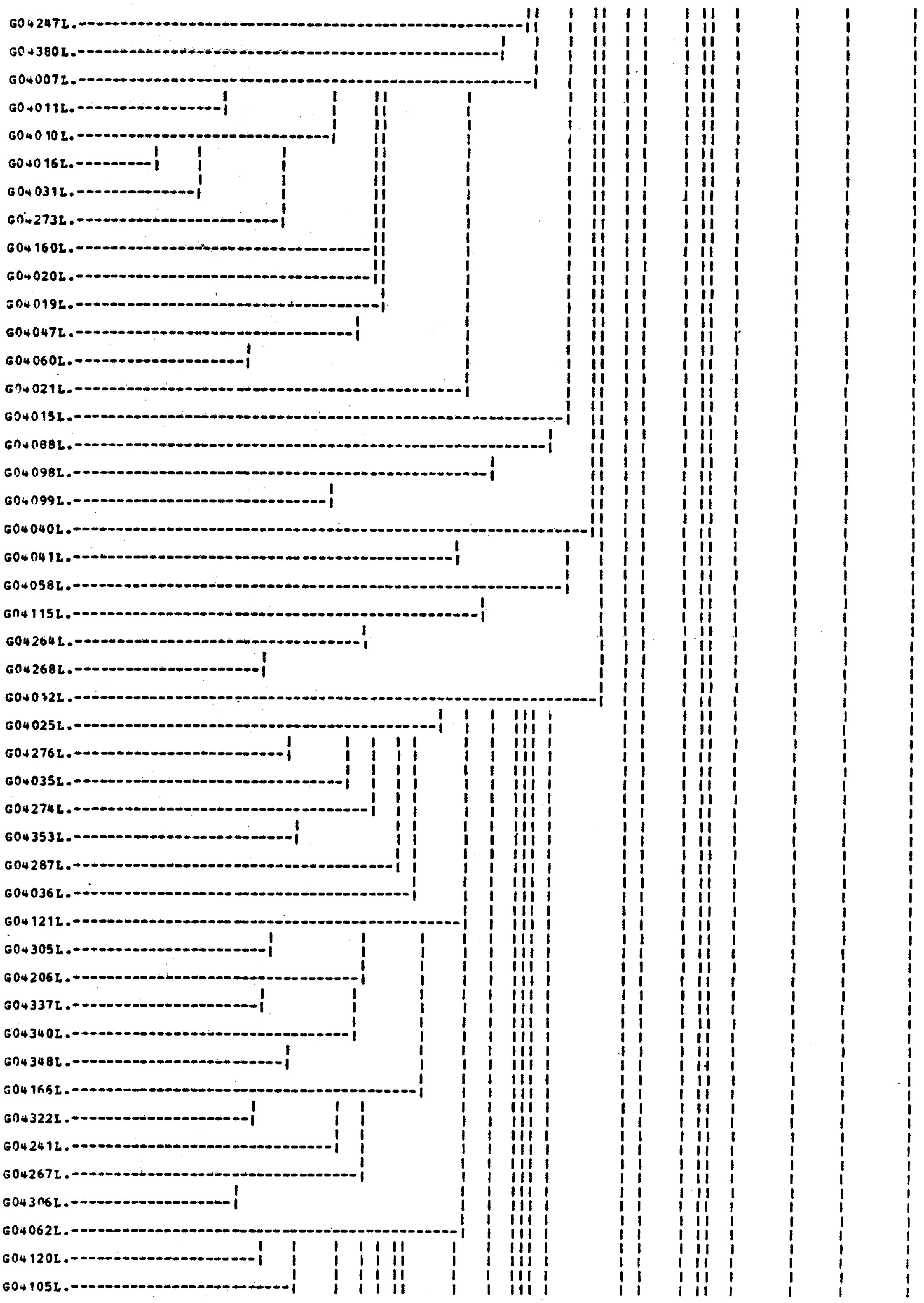
Figure 6. Dendrogram of Cook Inlet isolates from April 1977.

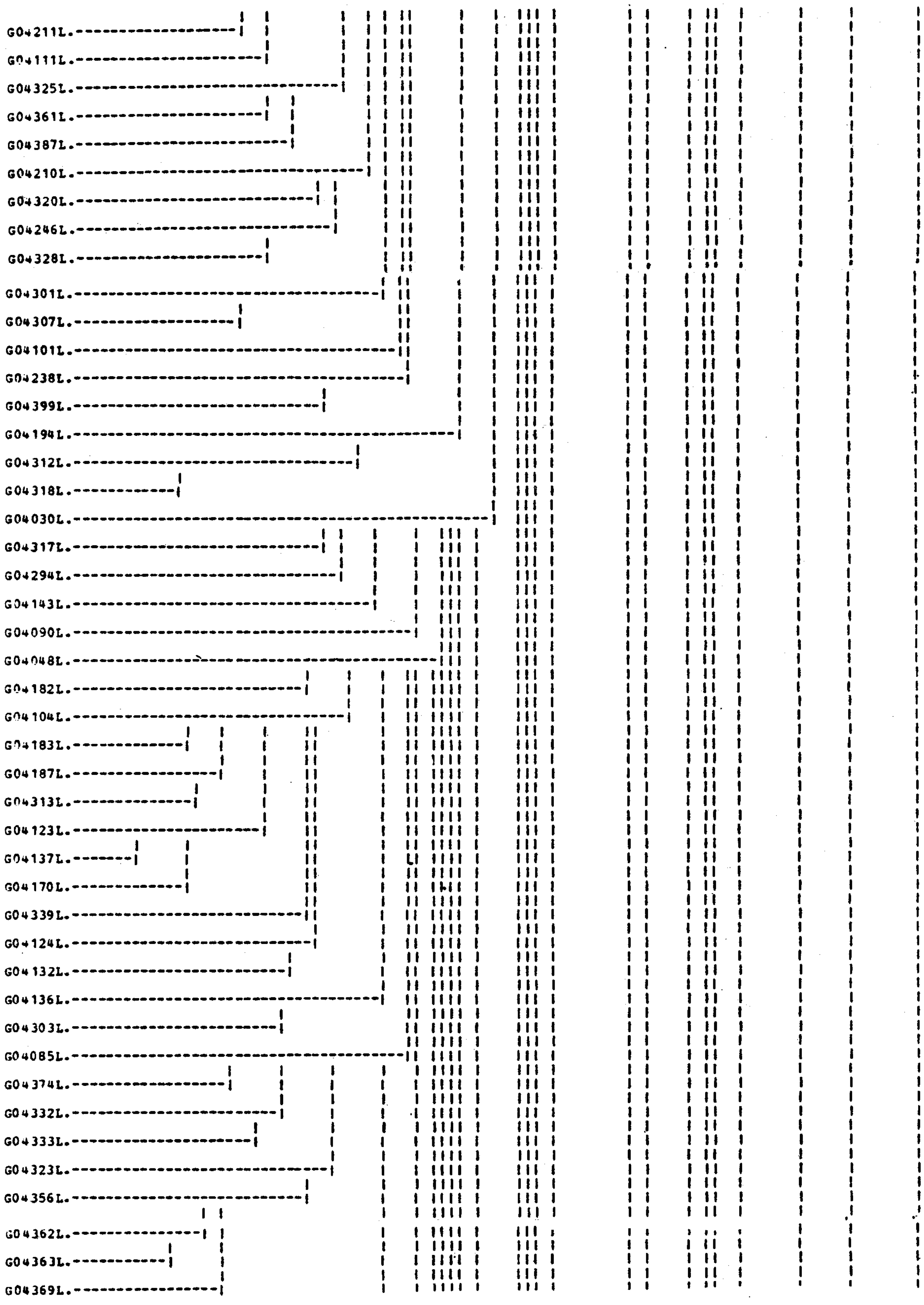
```
                    NT 100256

COEFFICIENT: S(J)
SIMILARITY AT TIP (LEFT) = .9390

SIMILARITY AT BASE (RIGHT) = .3569
```

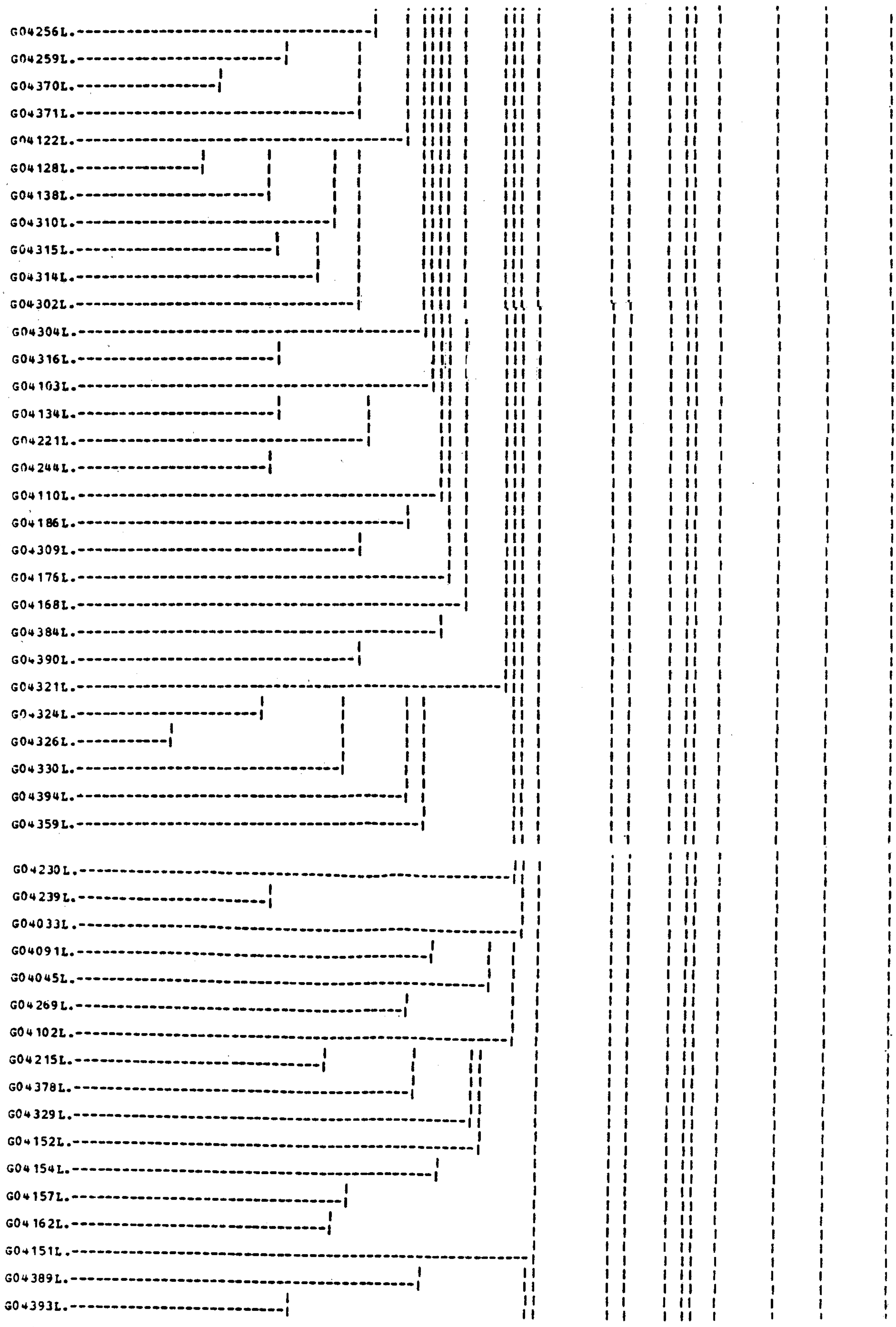


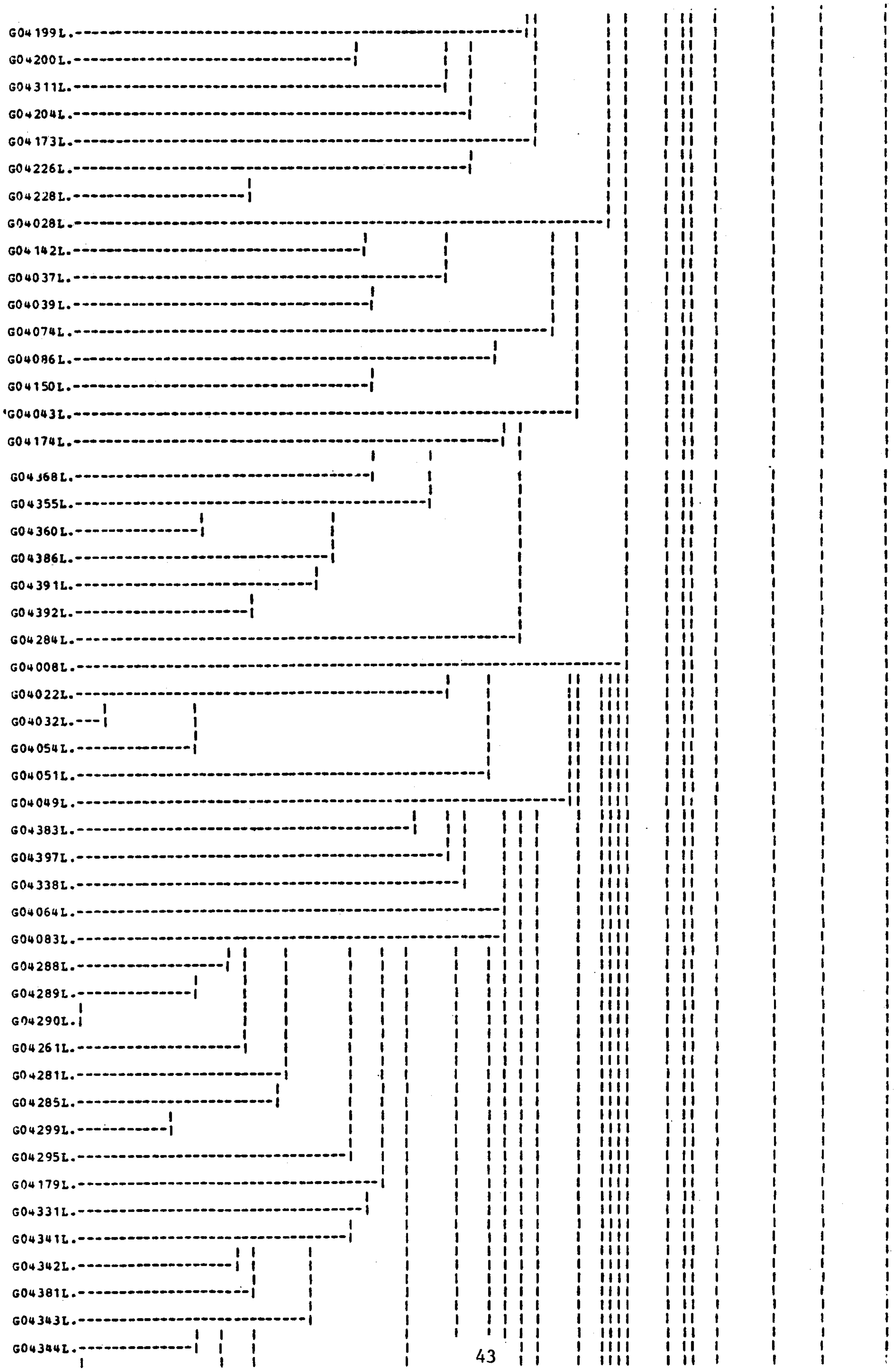

G04260L.
G04205L.
G04253L.
G04248L.
G04251L.
G04245L.
G04155L.
G04203L.
G04257L.
G04258L.
G04243L.
G04282L.
G04291L.
G04144L.
G04209L.
G04214L.
G04029L.
G04172L.
G04207L.
G04042L.
G04107L.
G04089L.
G04262L.
G04377L.
G04165L.
G04180L.
G04178L.
G04247L.
G04380L.

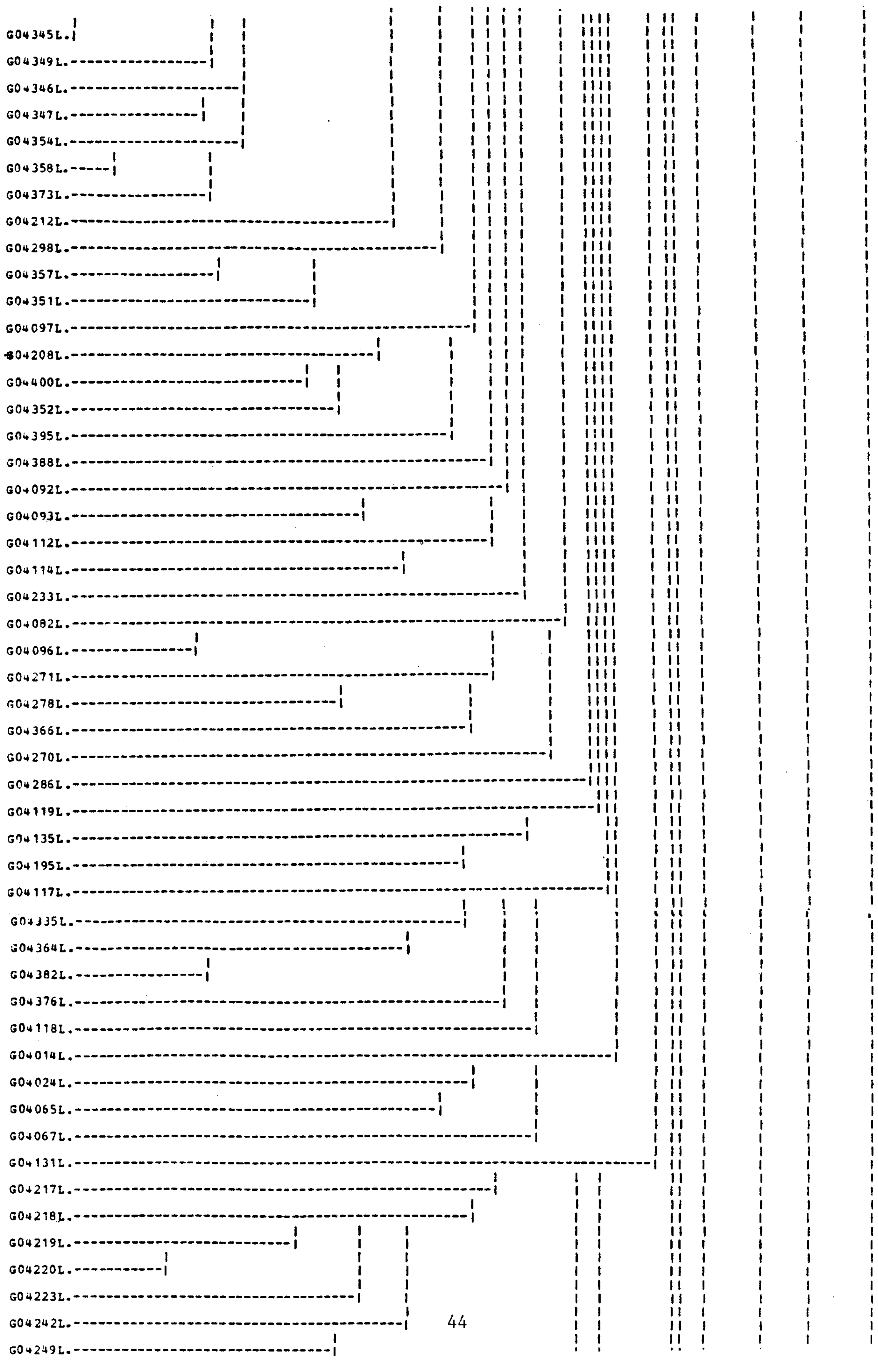

G04257L.
G04258L.
G04243L.
G04282L.
G04291L.
G04144L.
G04209L.
G04214L.
G04029L.
G04172L.
G04207L.
G04042L.
G04107L.
G04089L.
G04262L.
G04377L.
G04165L.
G04180L.
G04178L.

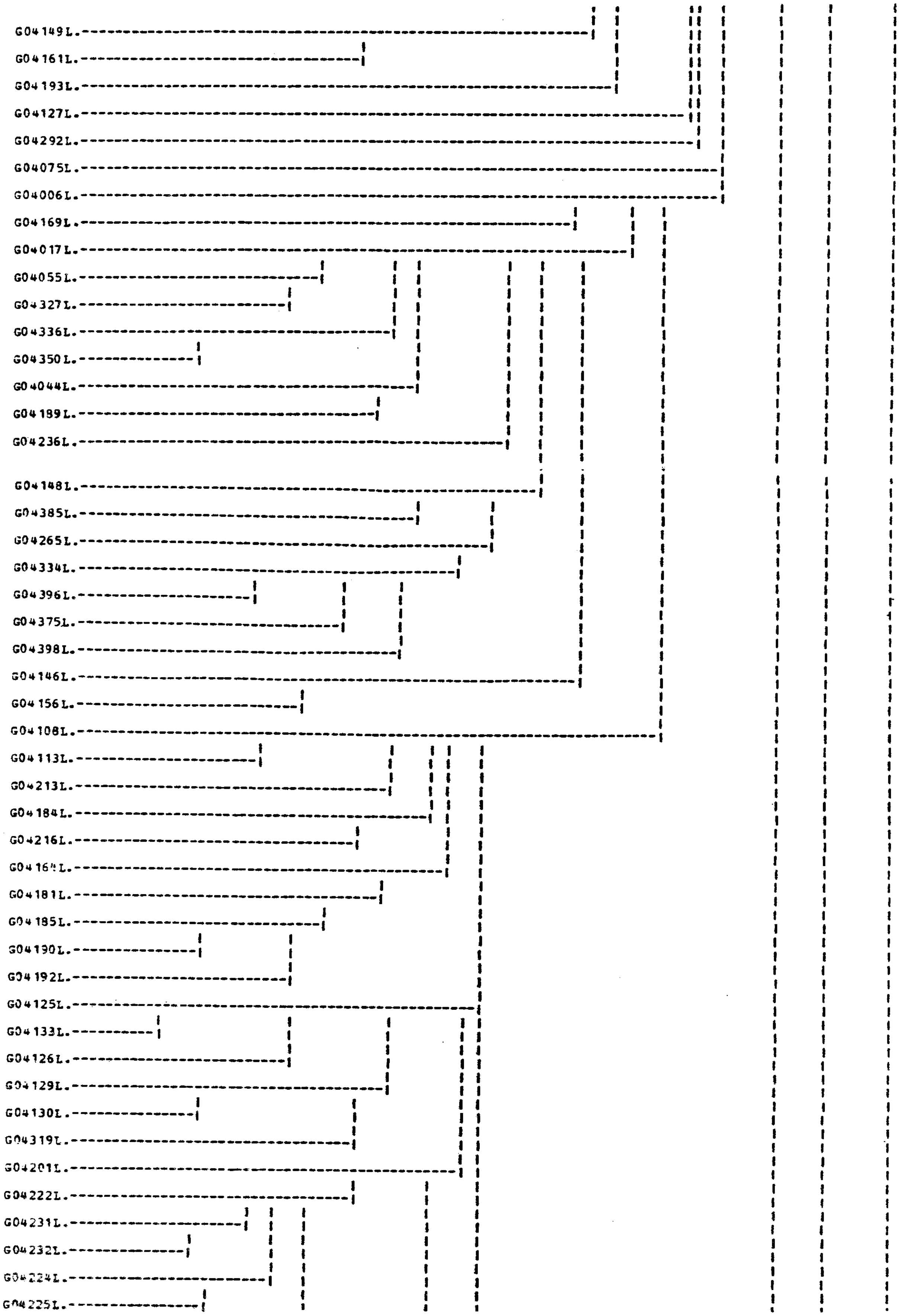

G04247L.
G04380L.
G04007L.
G04011L.
G04010L.
G04016L.
G04031L.
G04273L.
G04160L.
G04020L.
G04019L.
G04047L.
G04060L.
G04021L.
G04015L.
G04088L.
G04098L.
G04099L.
G04040L.
G04041L.
G04058L.
G04115L.
G04264L.
G04268L.
G04032L.
G04025L.
G04276L.
G04035L.
G04274L.
G04353L.
G04287L.
G04036L.
G04121L.
G04305L.
G04206L.
G04337L.
G04340L.
G04348L.
G04166L.
G04322L.
G04241L.
G04267L.
G04306L.
G04062L.
G04120L.
G04105L.


G04211L.
G04111L.
G04325L.
G04361L.
G04387L.
G04210L.
G04320L.
G04246L.
G04328L.
G04301L.
G04307L.
G04101L.
G04238L.
G04399L.
G04194L.
G04312L.
G04318L.
G04030L.
G04317L.
G04294L.
G04143L.
G04090L.
G04048L.
G04182L.
G04104L.
G04183L.
G04187L.
G04313L.
G04123L.
G04137L.
G04170L.
G04339L.
G04124L.
G04132L.
G04136L.
G04303L.
G04085L.
G04374L.
G04332L.
G04333L.
G04323L.
G04356L.
G04362L.
G04363L.
G04369L.


G04256L.
G04259L.
G04370L.
G04371L.
G04122L.
G04128L.
G04138L.
G04310L.
G04315L.
G04314L.
G04302L.
G04304L.
G04316L.
G04103L.
G04134L.
G04221L.
G04244L.
G04110L.
G04186L.
G04309L.
G04176L.
G04168L.
G04384L.
G04390L.
G04321L.
G04324L.
G04326L.
G04330L.
G04394L.
G04359L.
G04230L.
G04239L.
G04033L.
G04091L.
G04045L.
G04269L.
G04102L.
G04215L.
G04378L.
G04329L.
G04152L.
G04154L.
G04157L.
G04162L.
G04151L.
G04389L.
G04393L.


G04199L.
G04200L.
G04311L.
G04204L.
G04173L.
G04226L.
G04228L.
G04028L.
G04142L.
G04037L.
G04039L.
G04074L.
G04086L.
G04150L.
G04043L.
G04174L.
G04368L.
G04355L.
G04360L.
G04386L.
G04391L.
G04392L.
G04284L.
G04008L.
G04022L.
G04032L.
G04054L.
G04051L.
G04049L.
G04383L.
G04397L.
G04338L.
G04064L.
G04083L.
G04288L.
G04289L.
G04290L.
G04261L.
G04281L.
G04285L.
G04299L.
G04295L.
G04179L.
G04331L.
G04341L.
G04342L.
G04381L.
G04343L.
G04344L.


G04345L.
G04349L.
G04346L.
G04347L.
G04354L.
G04358L.
G04373L.
G04212L.
G04298L.
G04357L.
G04351L.
G04097L.
G04208L.
G04400L.
G04352L.
G04395L.
G04388L.
G04092L.
G04093L.
G04112L.
G04114L.
G04233L.
G04082L.
G04096L.
G04271L.
G04278L.
G04366L.
G04270L.
G04286L.
G04119L.
G04135L.
G04195L.
G04117L.
G04335L.
G04364L.
G04382L.
G04376L.
G04118L.
G04014L.
G04024L.
G04065L.
G04067L.
G04131L.
G04217L.
G04218L.
G04219L.
G04220L.
G04223L.
G04242L.
G04249L.


G04149L.
G04161L.
G04193L.
G04127L.
G04292L.
G04075L.
G04006L.
G04169L.
G04017L.
G04055L.
G04327L.
G04336L.
G04350L.
G04044L.
G04189L.
G04236L.
G04148L.
G04385L.
G04265L.
G04334L.
G04396L.
G04375L.
G04398L.
G04146L.
G04156L.
G04108L.
G04113L.
G04213L.
G04184L.
G04216L.
G04164L.
G04181L.
G04185L.
G04190L.
G04192L.
G04125L.
G04133L.
G04126L.
G04129L.
G04130L.
G04319L.
G04201L.
G04222L.
G04231L.
G04232L.
G04224L.
G04225L.

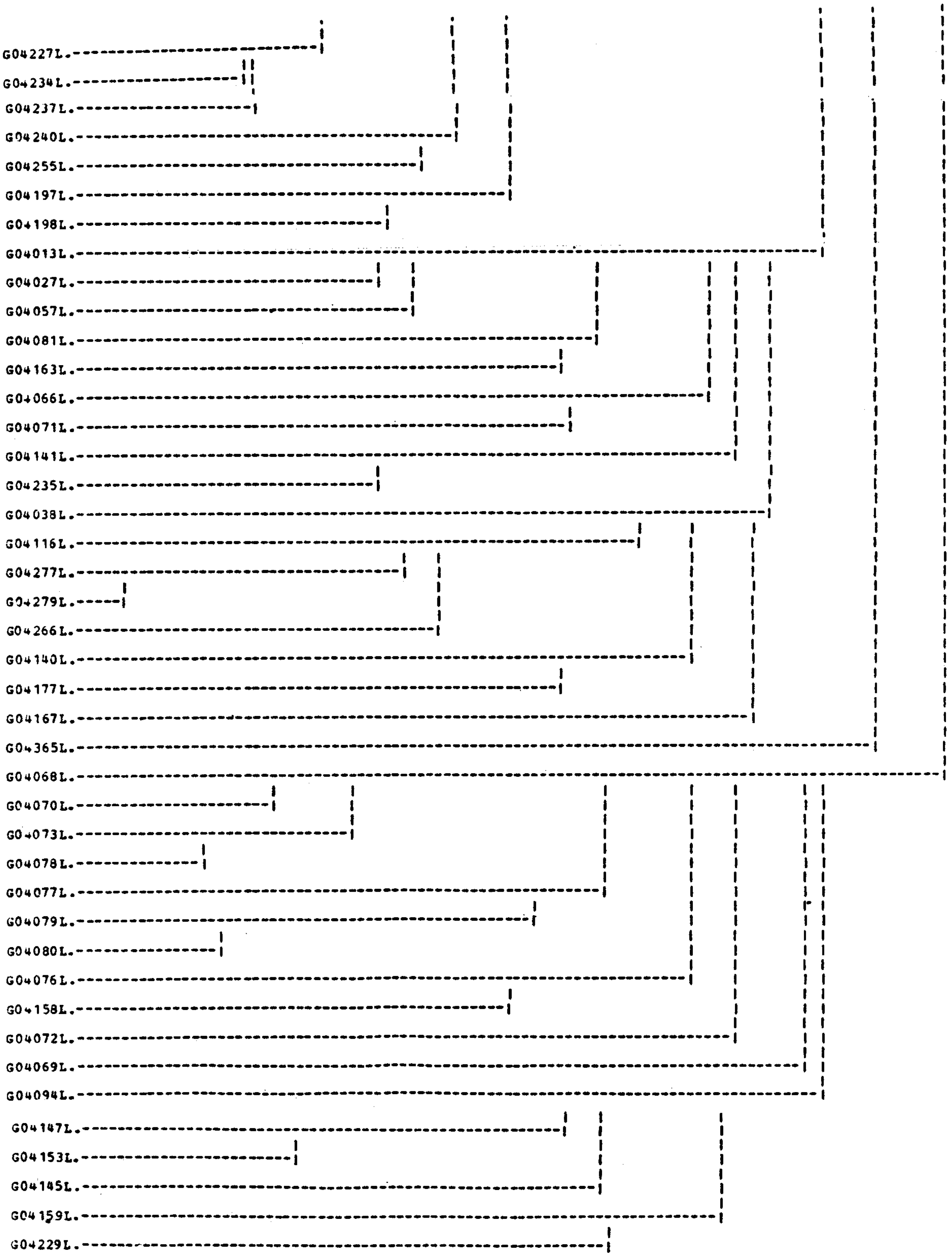

G04227L.
G04234L.
G04237L.
G04240L.
G04255L.
G04197L.
G04198L.
G04013L.
G04027L.
G04057L.
G04081L.
G04163L.
G04066L.
G04071L.
G04141L.
G04235L.
G04038L.
G04116L.
G04277L.
G04279L.
G04266L.
G04140L.
G04177L.
G04167L.
G04365L.
G04068L.
G04070L.
G04073L.
G04078L.
G04077L.
G04079L.
G04080L.
G04076L.
G04158L.
G04072L.
G04069L.
G04094L.
G04147L.
G04153L.
G04145L.
G04159L.
G04229L.

Table 5. Diversity indices ($\bar{H}$) for heterotrophic bacterial populations isolated at 4°C from Cook Inlet.

Station No.	November	April
	Water	
105	4.22	2.26
204	2.74	4.02
205	-	3.17
212	-	4.22
215	3.31	2.75
225	0.72	2.92
226	-	3.56
229	1.39	3.78
245	2.94	3.62
265	4.01	3.89
266	4.08	3.24
395	-	2.50
K	0.30	-
L	2.78	-
M	2.56	-
U	-	3.49
	Sediment	
105	2.85	-
204	3.72	-
205	-	3.69
212	-	3.32
215	3.72	3.92
225	3.78	3.38
226	-	3.49
229	3.40	3.34
L	1.39	-
M	3.88	-
U	-	4.12

from water were lower in November than April at a number of comparable stations. Notable exceptions were stations near Kennedy entrance and Upper Cook Inlet. No significant differences in diversity indices were seen between populations from November and April sediment samples.

The dendrograms from the cluster analyses of presumed hydrocarbon utilizing microorganisms are shown in Fig. 7 for organisms selected from enumeration plates and in Fig. 8 for organisms selected from Most Probable Number enrichments. The clustering patterns showed that closely related organisms had been isolated from Gulf of Alaska, Cook Inlet and Beaufort Sea water and sediment samples for presumed ability to utilize hydrocarbons. The cluster analyses also showed that many taxonomic groups were represented, *i.e.* many different microbial species and genera are able to grow on media with petroleum hydrocarbons added.

Examination of the feature frequency analyses showed that only 20% of the organisms used in the cluster analyses from the oil-agar enumeration plates had been scored positive for any of the hydrocarbons tested. The remaining 80% of the organisms were petroleum tolerant bacteria, able to grow in the presence of petroleum, and probably were low nutrient requiring bacteria able to grow on trace organic compounds in the control media. This fact emphasizes why we subtract control plate counts from oil-agar counts in the enumeration of hydrocarbon utilizing bacteria procedure and why plate count enumeration procedures

Figure 7. Simplified Dendrogram of presumed hydrocarbon utilizers from enumeration plates.

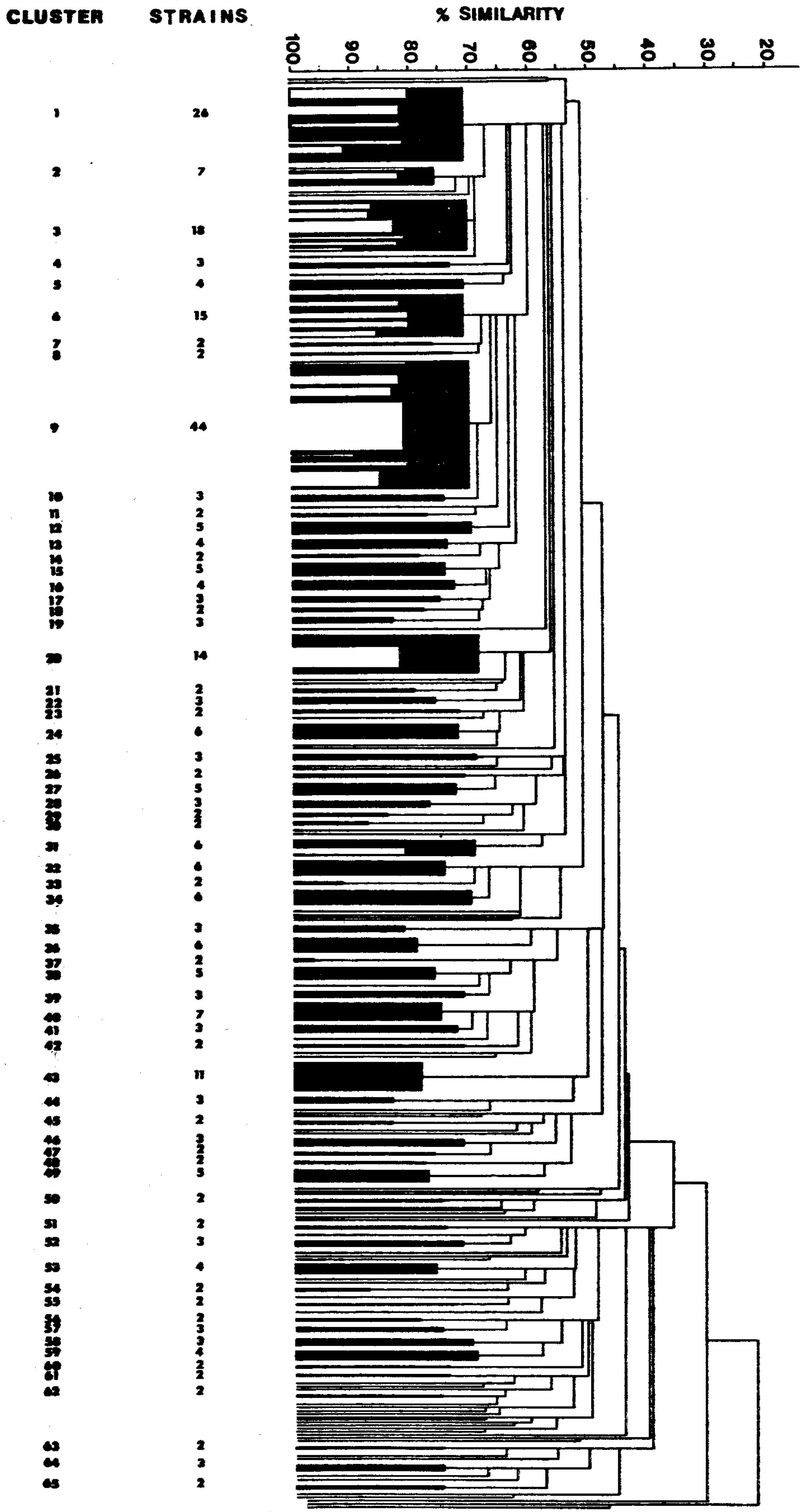


Figure 8. Simplified Dendrogram of presumed hydrocarbon utilizers from MPN enumerations.

CLUSTER	NO. OF STRAINS
1	2
2	14
3	4
4	29
5	2
6	15
7	3
8	5
9	15
10	14
11	2
12	4
13	3
14	2
15	3
16	2
17	3
18	2
19	2
20	10
21	2
22	8
23	2
24	9
25	2

should be replaced by Most Probable Number determinations for hydrocarbon utilizers. Several of the major clusters contained members that utilized hydrocarbons (Table 6). The organisms that utilized hydrocarbons typically formed subclusters within the major clusters representing 20-25% of the organisms in several major clusters. This indicates that some hydrocarbon utilizing bacterial species are very closely related to the non hydrocarbon utilizing species and may even be strains of the same species.

The feature frequencies showed that 75%, a much higher percentage, of the strains in the cluster analyses from the MPN enrichment were able to utilize hydrocarbons. In fact, all of the organisms in the major clusters were capable of hydrocarbon utilization (Table 6). Exposure to crude oil obviously selects and enriches for hydrocarbon utilizers. Further analyses of the hydrocarbon utilizers showed that a higher percentage of the strains could use mixtures of hydrocarbons, *e.g.* a crude oil, than could use pure hydrocarbons (Table 7). Both aliphatic and aromatic compounds could be utilized by some organisms.

Hydrocarbon Biodegradation Activity

In Cook Inlet natural hydrocarbon biodegradation potentials (no nutrients added) followed the order: naphthalene $\geq$ hexadecane > pristane $\geq$ benzanthracene in both water and sediment samples

Table 6. Percent of strains in clusters scored positive for ability to utilize any hydrocarbon or hydrocarbon mixture.

From Enumeration Plates

*Cluster No.	Percent Positive for hydrocarbon utilization
1	23
6	7
9	20
20	78
31	70
32	17
34	85
36	100
38	20
39	68
43	100
49	100
58	100
59	100

From MPN Enrichments

*Cluster No.	Percent Positive for hydrocarbon utilization
2	14
4	100
6	100
8	80
9	90
10	100
12	100
20	100
22	100
24	100

*Cluster No. refers to dendrogram

Table 7. Percent utilization of hydrocarbons by strains in major clusters from MPN enrichment cluster analyses.

Hydrocarbon Utilized	Cluster No.									
	2	4	6	8	9	10	12	20	22	24
N-Decane	7	0	0	0	0	0	0	100	0	79
N-Hexadecane	0	14	0	0	20	57	0	90	100	44
N-Nonane	0	0	0	0	0	0	0	90	100	79
N-Octadecane	0	0	0	0	0	0	0	100	100	67
N-Pentadecane	0	0	0	0	0	0	0	90	100	89
1-Methylnaphthalene	14	0	0	0	0	0	0	100	100	100
Omega-Phenyldecane	7	0	0	40	0	0	0	100	100	67
Toluene	7	0	0	0	13	0	0	90	100	89
Pristane	0	0	0	0	0	0	0	100	100	0
Pentadecylcyclohexane	0	0	0	0	0	21	0	100	100	0
Ethylcyclohecane	0	0	0	0	13	0	0	100	100	100
Dicyclohexyl	0	0	0	0	0	0	0	100	100	0
Diphenylmethane	0	0	0	0	0	0	0	90	100	67
Acenaphthalene	0	0	0	0	0	7	0	100	100	100
9-Methylanthracene	0	0	0	0	0	0	0	100	100	56
Napthanol	0	0	0	0	0	0	0	0	0	0
Prudhoe crude oil	0	100	100	20	80	100	100	100	100	78
JP 5	0	0	0	0	0	0	0	100	100	100
Gasoline (unleaded)	0	0	0	0	0	0	0	100	100	56
Mineral oil	0	45	100	80	87	0	100	100	100	100
API reference oil #1	0	0	0	0	7	0	0	100	100	56
API reference oil #2	0	0	0	0	0	0	0	100	75	56
API reference oil #3	0	0	0	0	0	0	0	100	100	22
API reference oil #4	0	0	0	0	0	0	0	90	100	22

collected during both April and November 1977 (Figs. 9-17). Natural biodegradation potentials for pristane and benzanthracene were often zero (not shown in Figures). The natural hydrocarbon biodegradation potentials were higher in April than in November for water samples. Natural hydrocarbon biodegradation potentials in sediment were similar for comparable station samples in April and November.

The non-nutrient limited biodegradation potentials followed the order: hexadecane > naphthalene >>> pristane > benzanthracene (Figs. 17-32). In almost all cases the removal of nutrient limitation resulted in higher biodegradation potentials for hexadecane and naphthalene but not for pristane and benzanthracene. The lack of stimulated degradation for pristane and benzanthracene when nutrient limitations were removed probably indicates that these compounds are resistant to mineralization by the available enzymatic systems. Pristane and benzanthracene could have been partially degraded without production of $^{14}CO_2$. The non-nutrient limited biodegradation potentials were much higher in April than November samples for all substrates. It is possible that some additional growth factor was required by microorganisms in the November samples. The large difference between the biodegradation potentials of November and April samples probably indicates that the fate of spilled oil in Cook Inlet will be highly dependent on the time of year that contamination occurs. The hydrocarbon

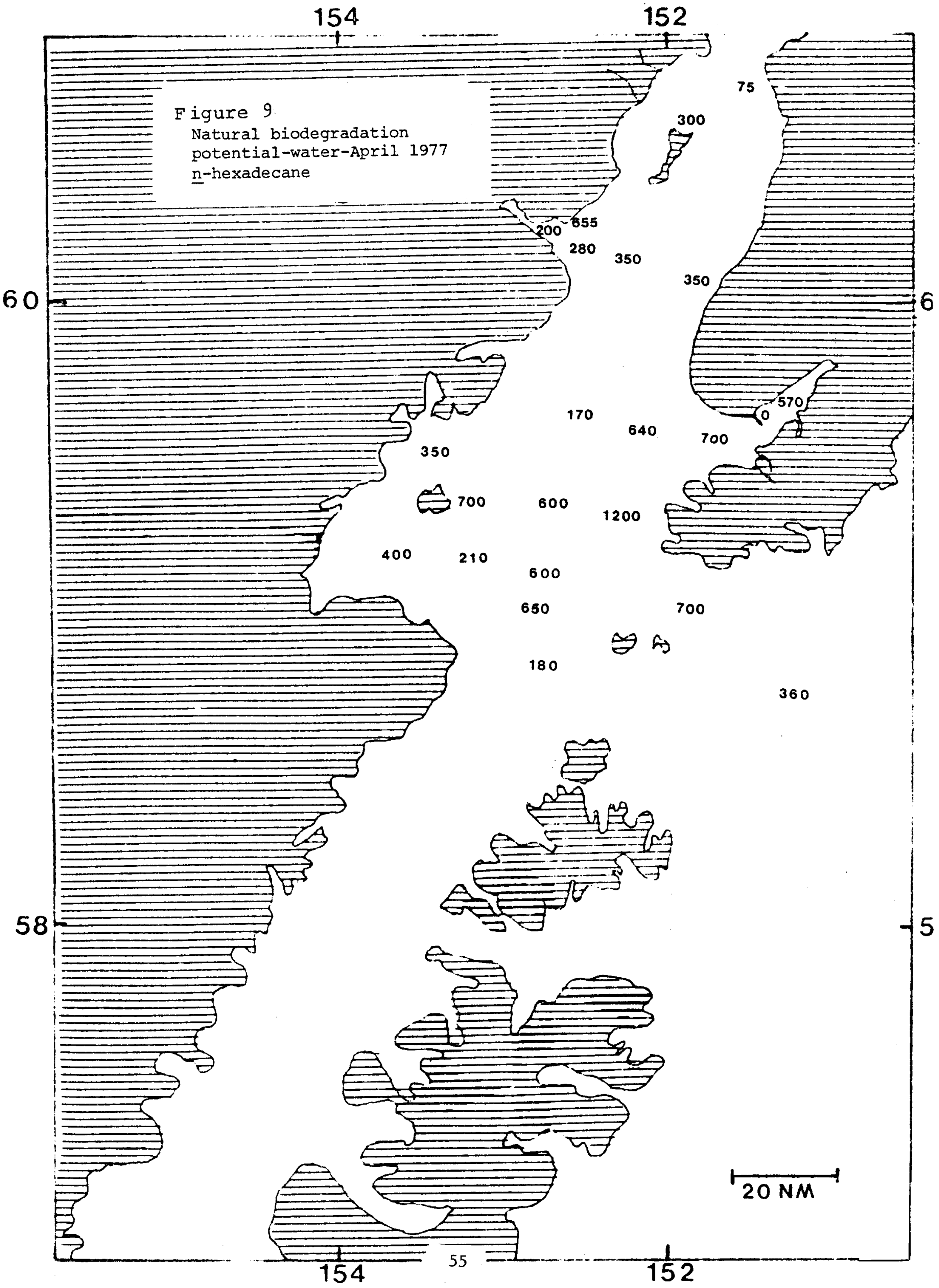
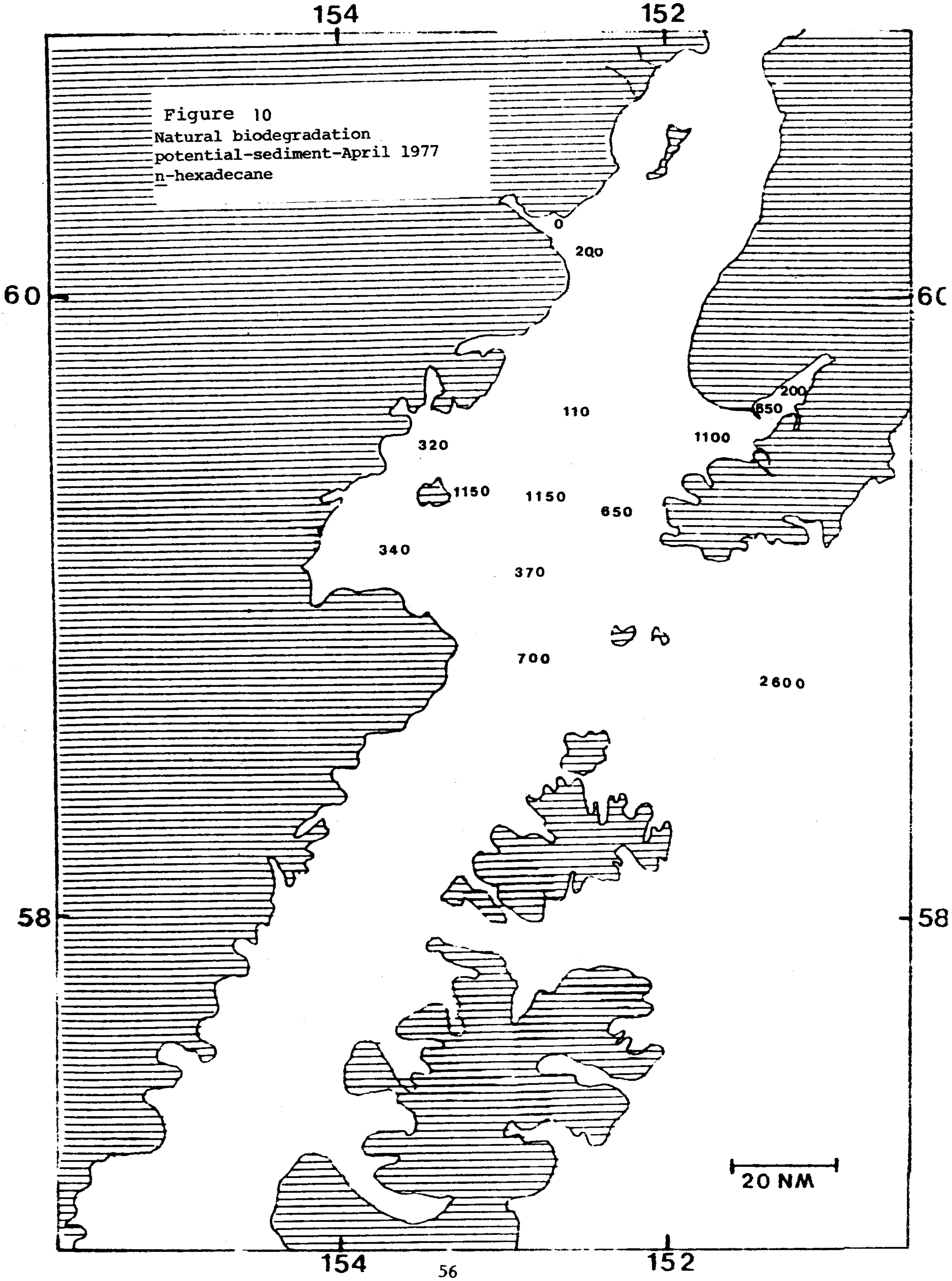


Figure 9
Natural biodegradation potential-water-April 1977 n-hexadecane



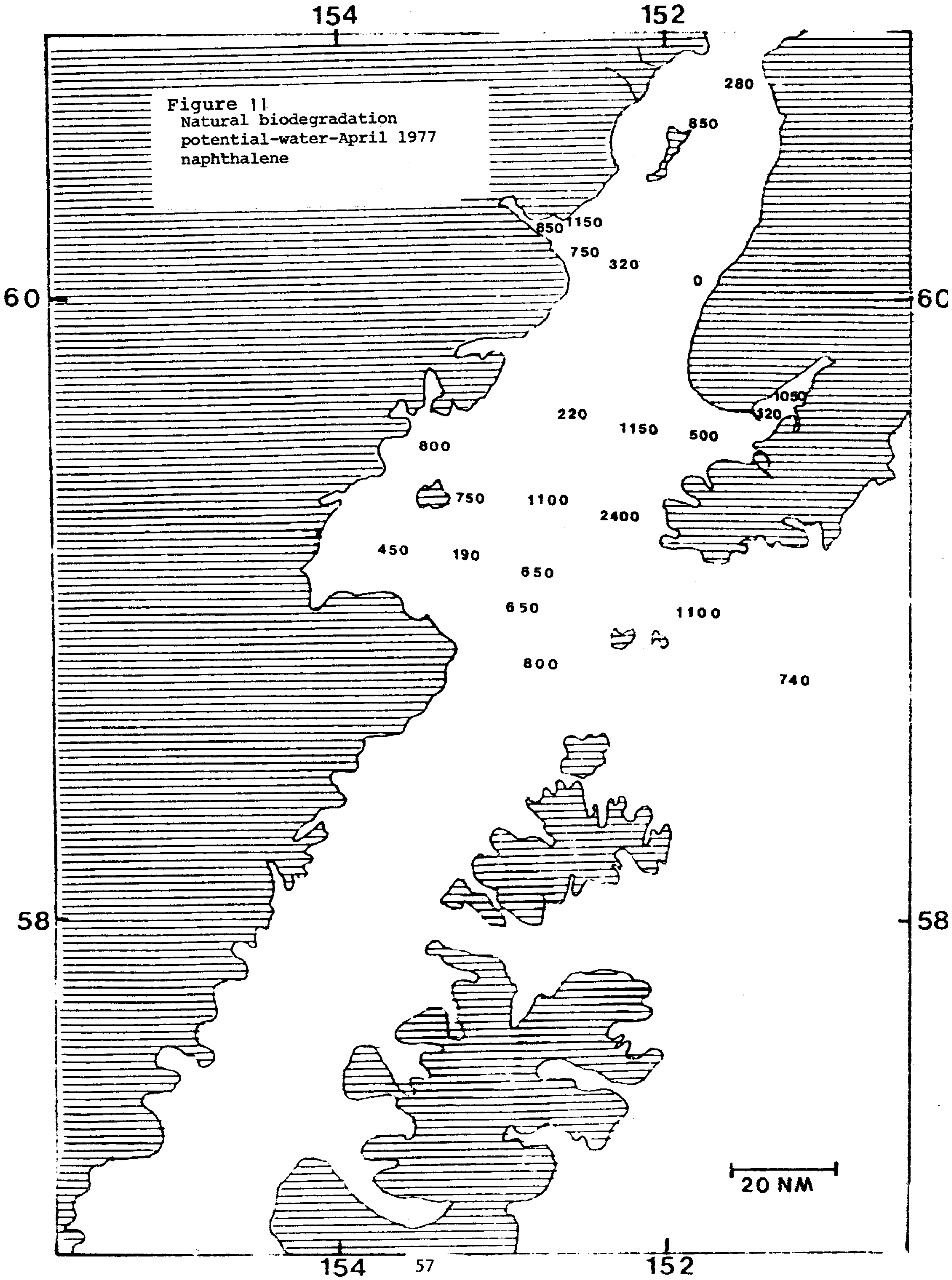


Figure 11
Natural biodegradation potential-water-April 1977 naphthalene

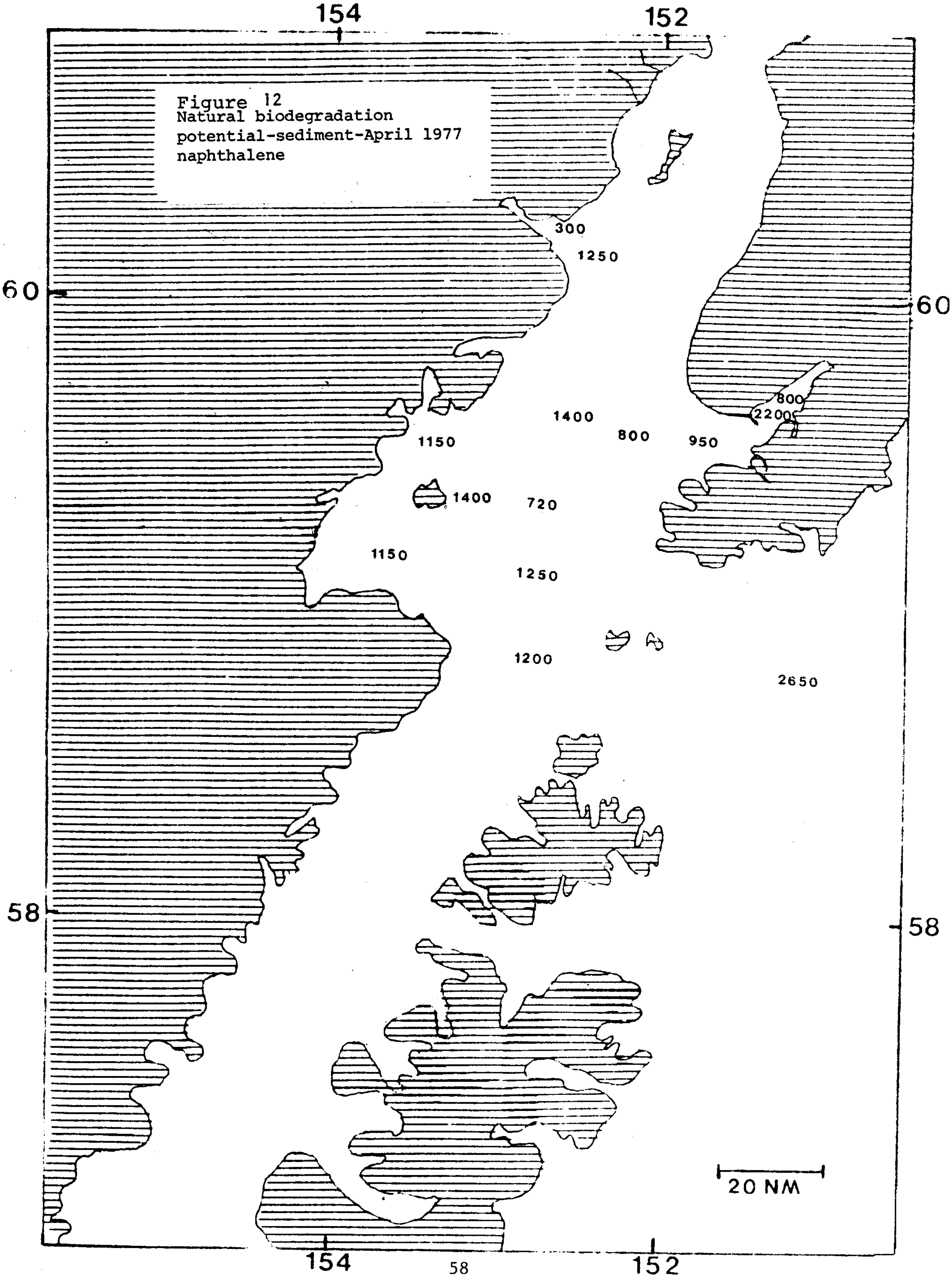


Figure 12
Natural biodegradation potential-sediment-April 1977 naphthalene

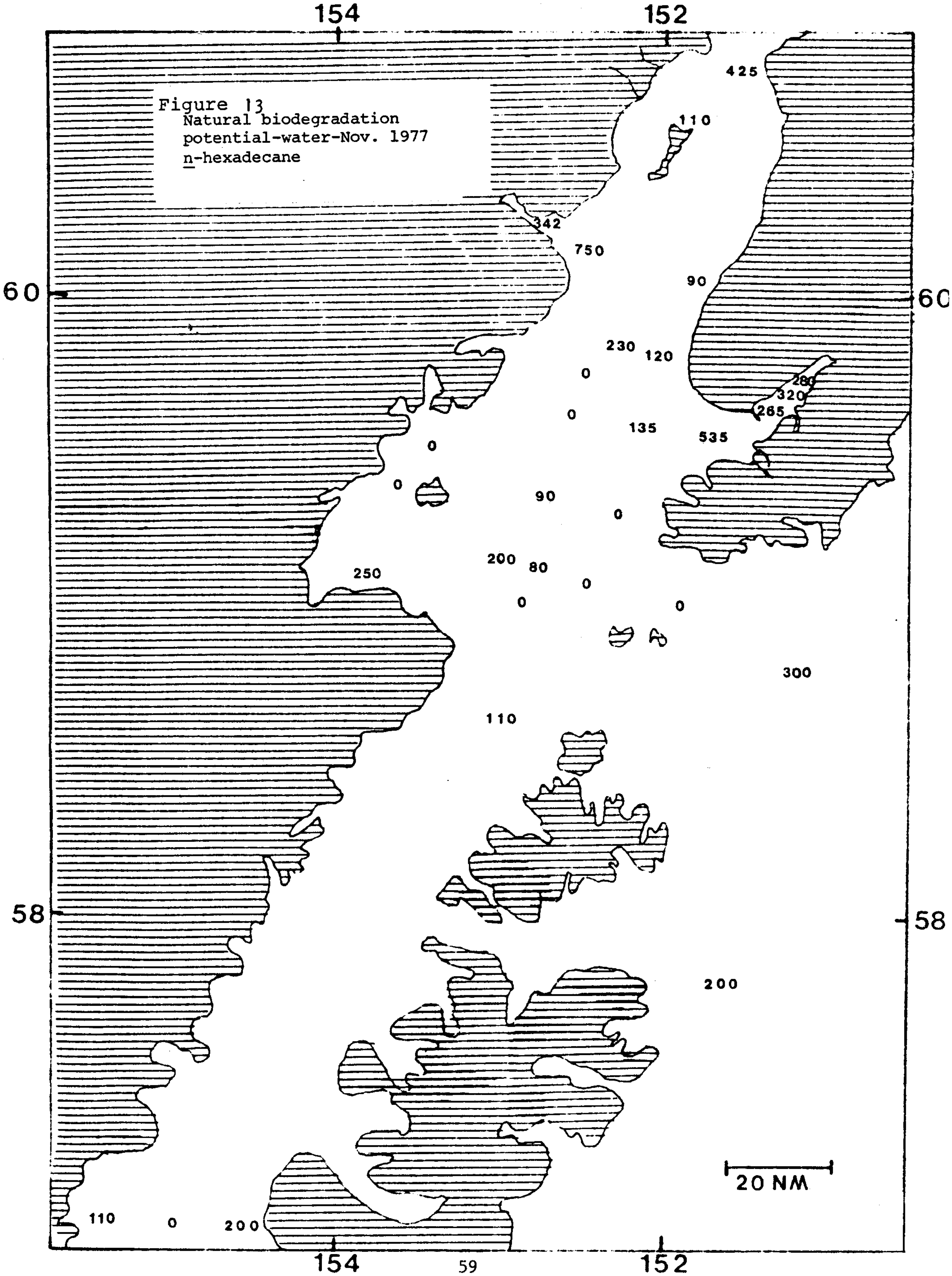


Figure 13
Natural biodegradation potential-water-Nov. 1977 *n*-hexadecane

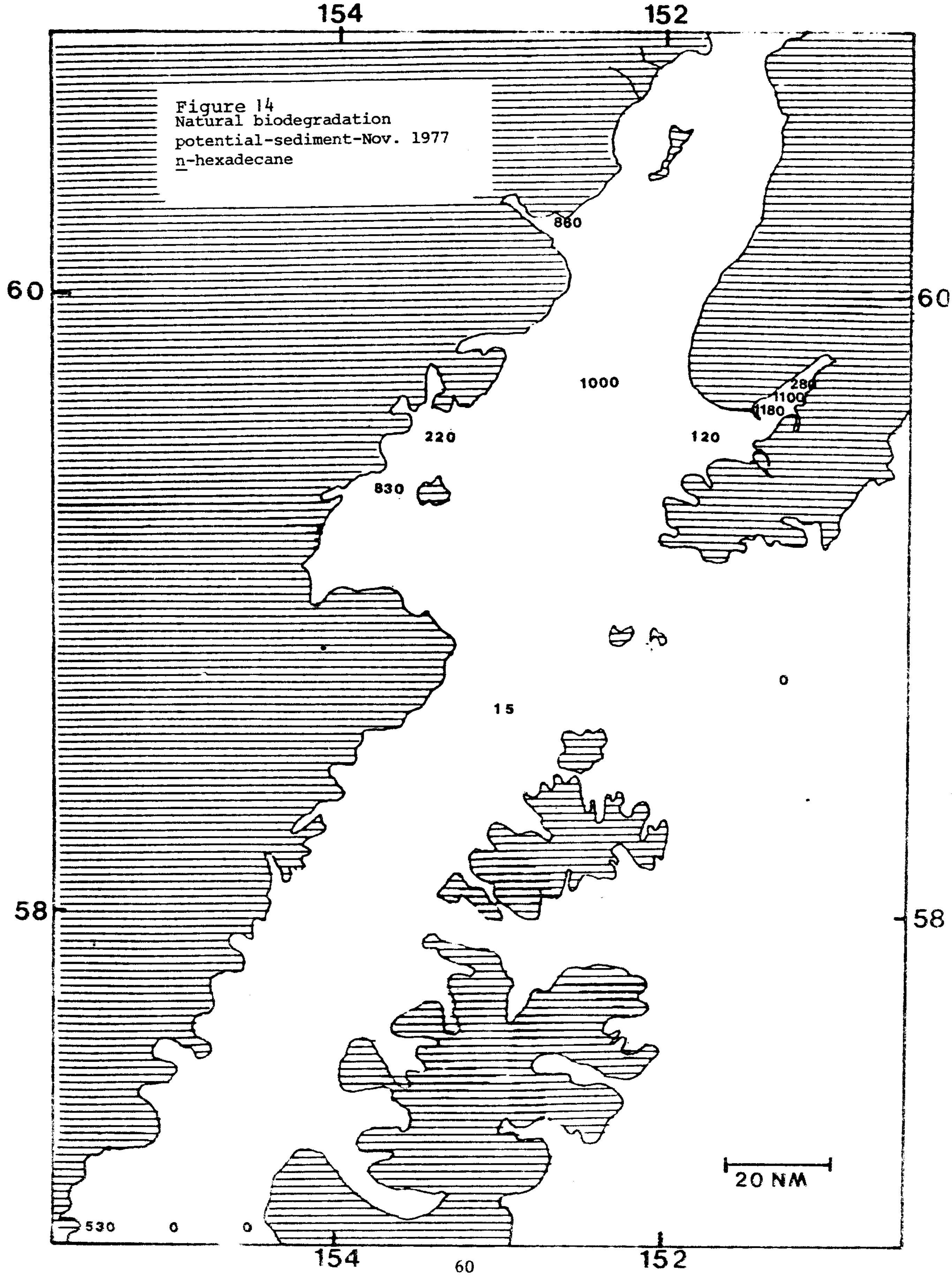


Figure 14
Natural biodegradation
potential-sediment-Nov. 1977
n-hexadecane

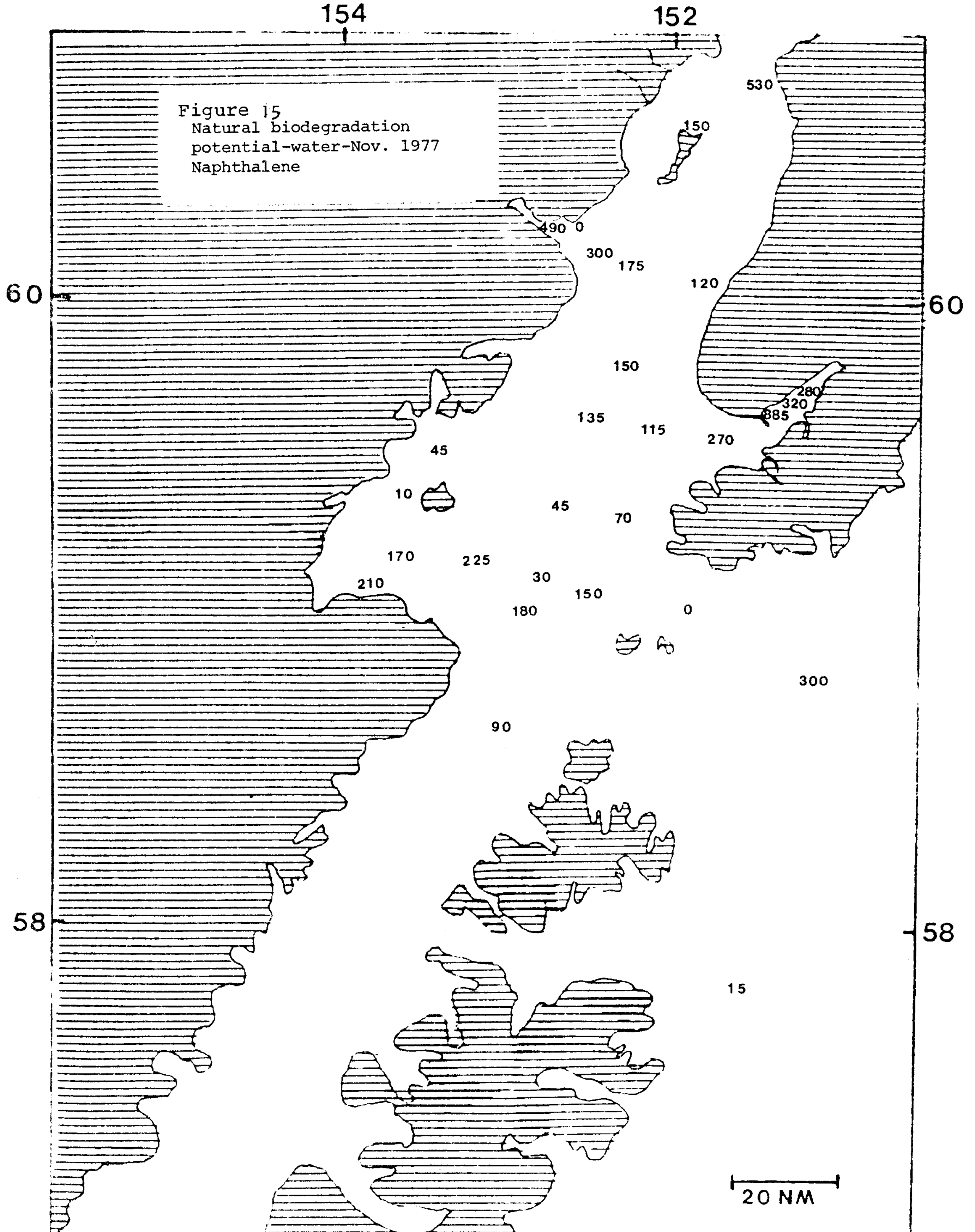


Figure 15
Natural biodegradation
potential-water-Nov. 1977
Naphthalene

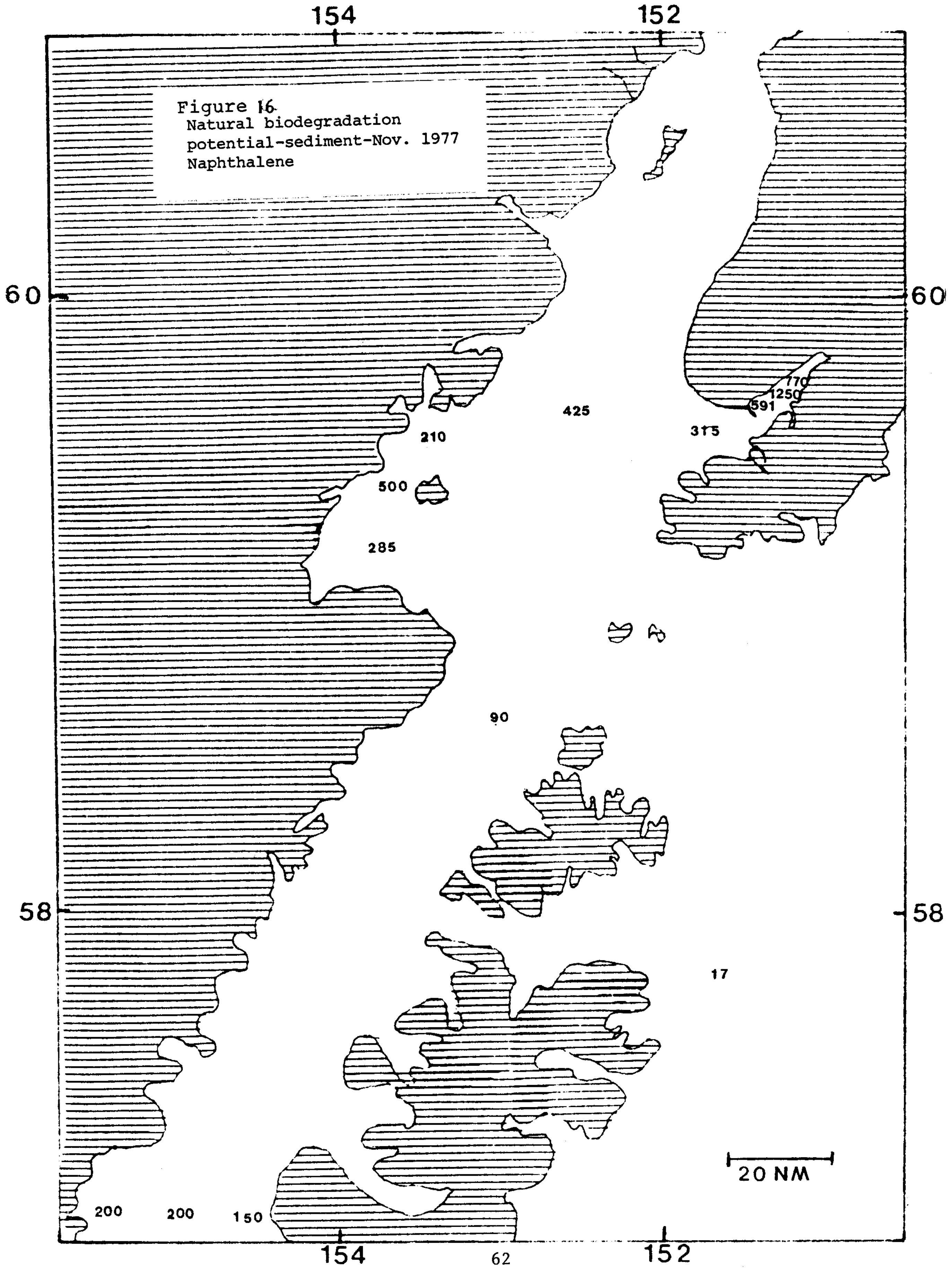


Figure 16
Natural biodegradation potential-sediment-Nov. 1977
Naphthalene

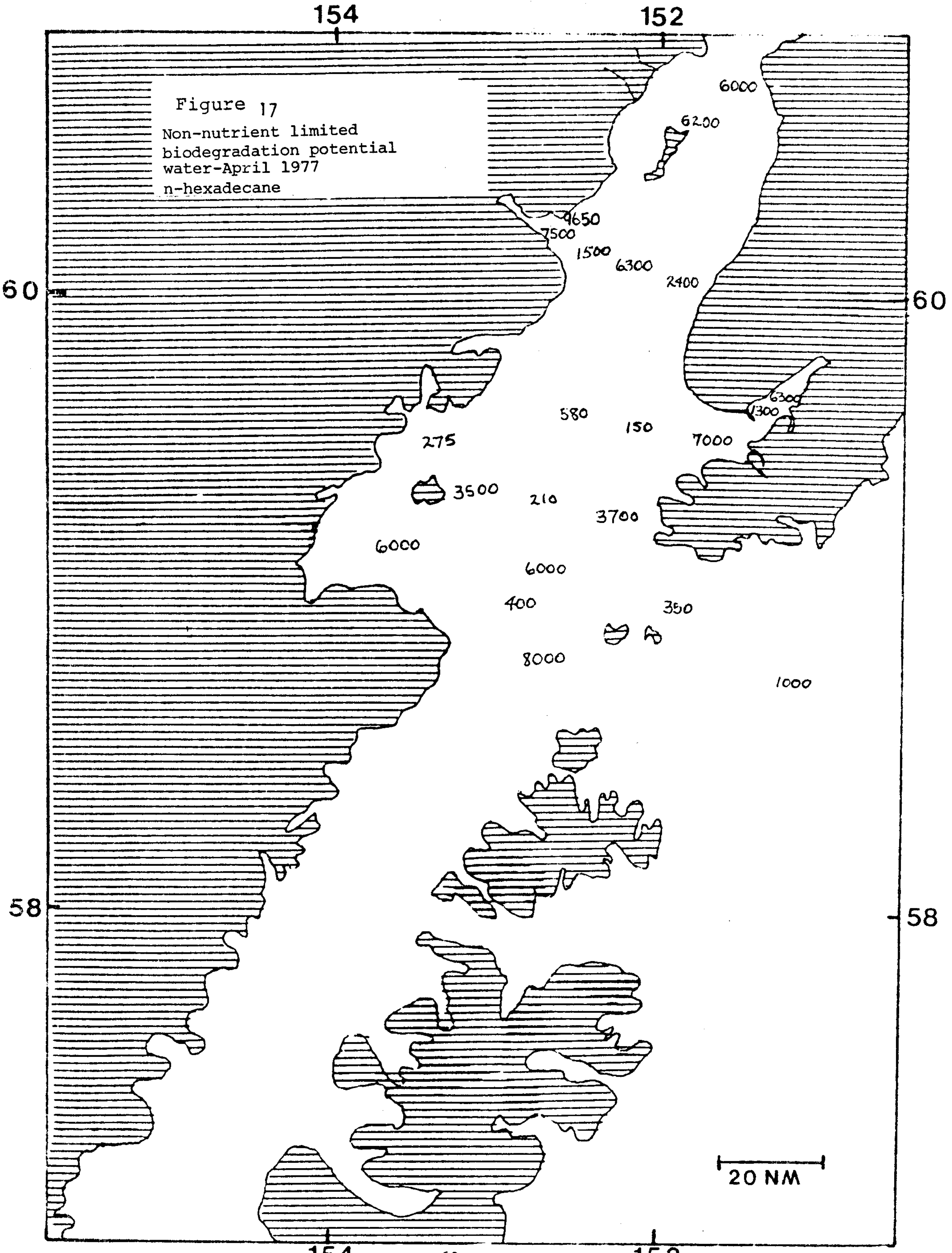


Figure 17
Non-nutrient limited
biodegradation potential
water-April 1977
n-hexadecane

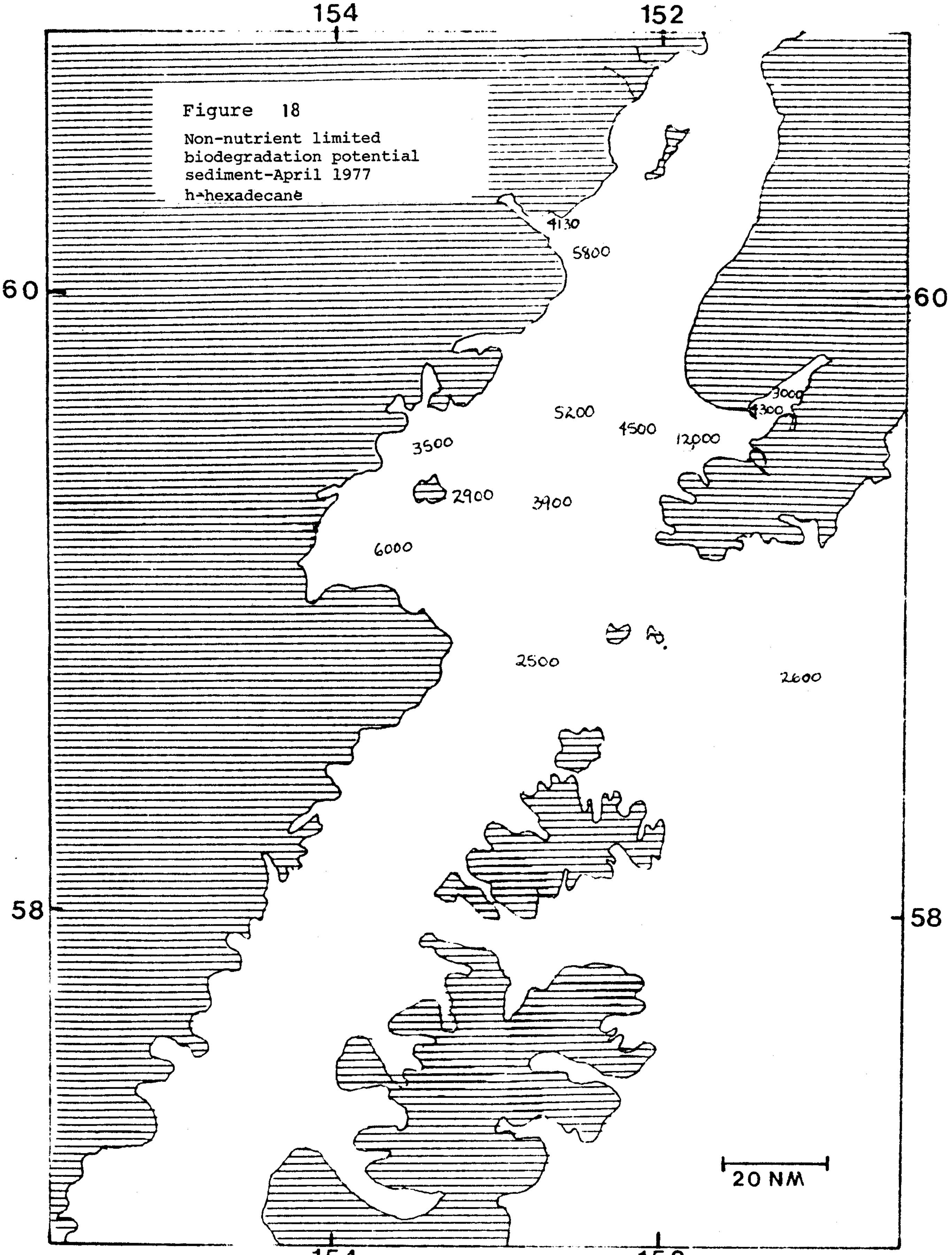


Figure 18

Non-nutrient limited biodegradation potential sediment-April 1977 h-hexadecane

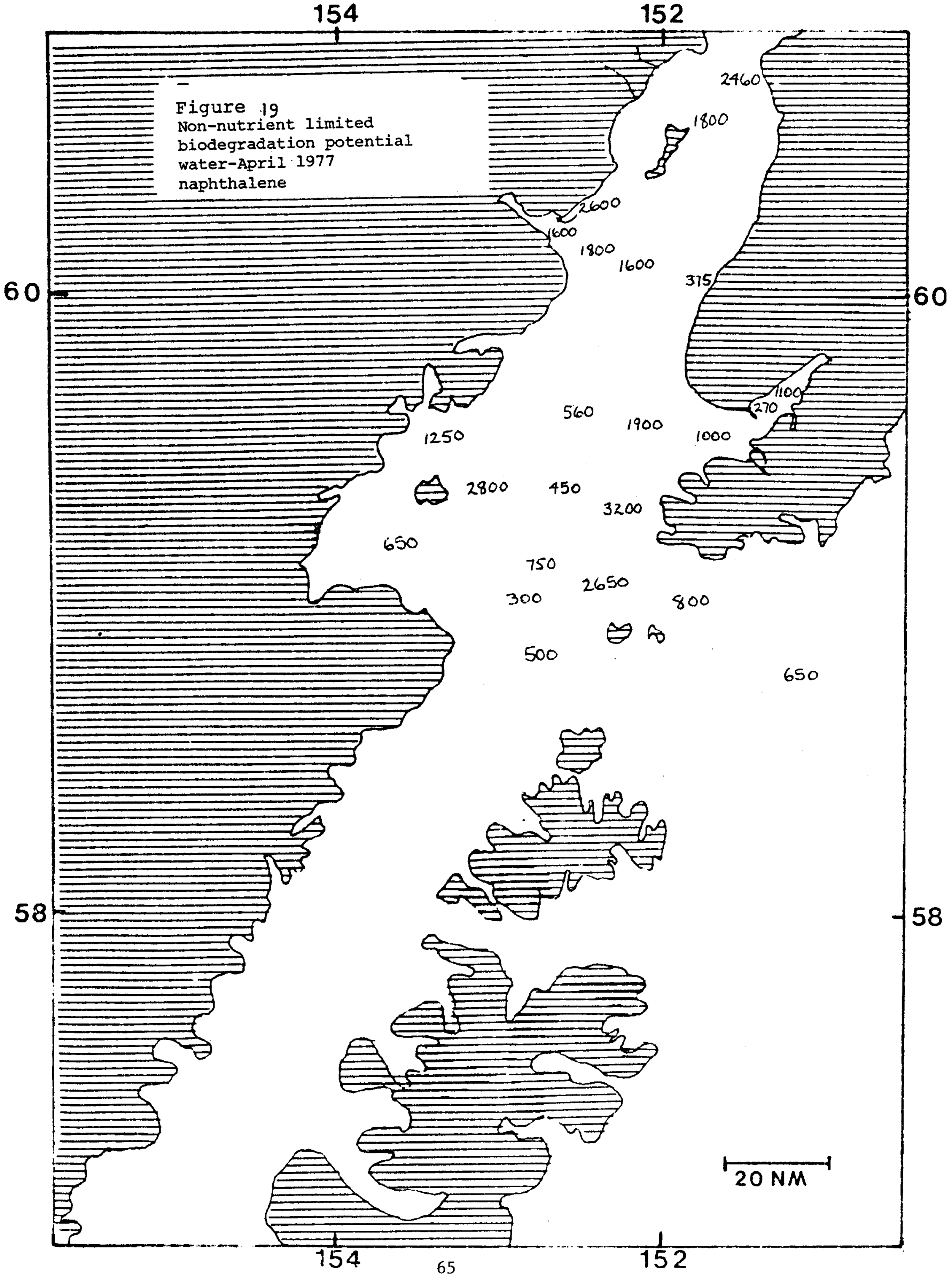


Figure 19
Non-nutrient limited
biodegradation potential
water-April 1977
naphthalene

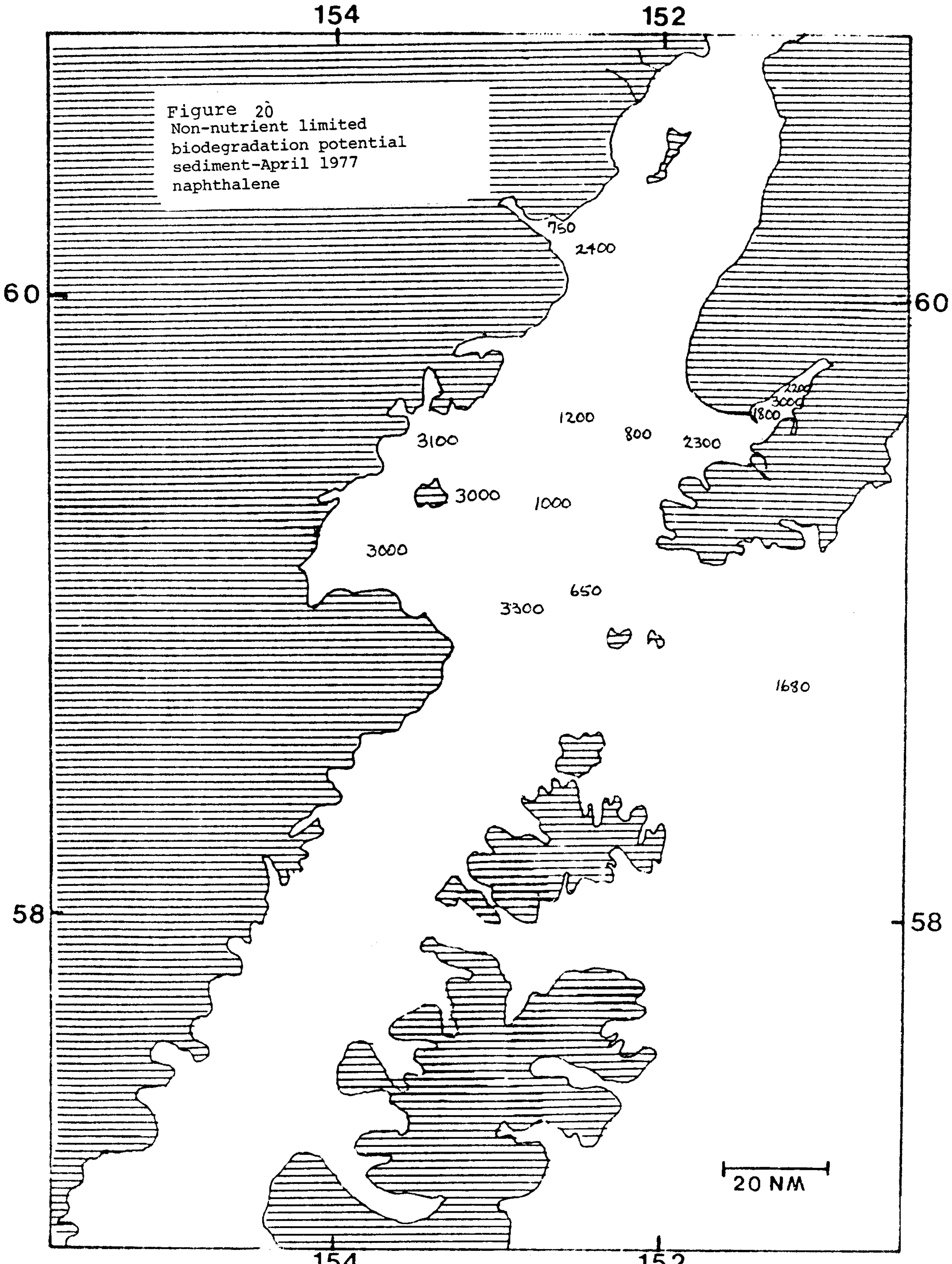


Figure 20
Non-nutrient limited
biodegradation potential
sediment-April 1977
naphthalene

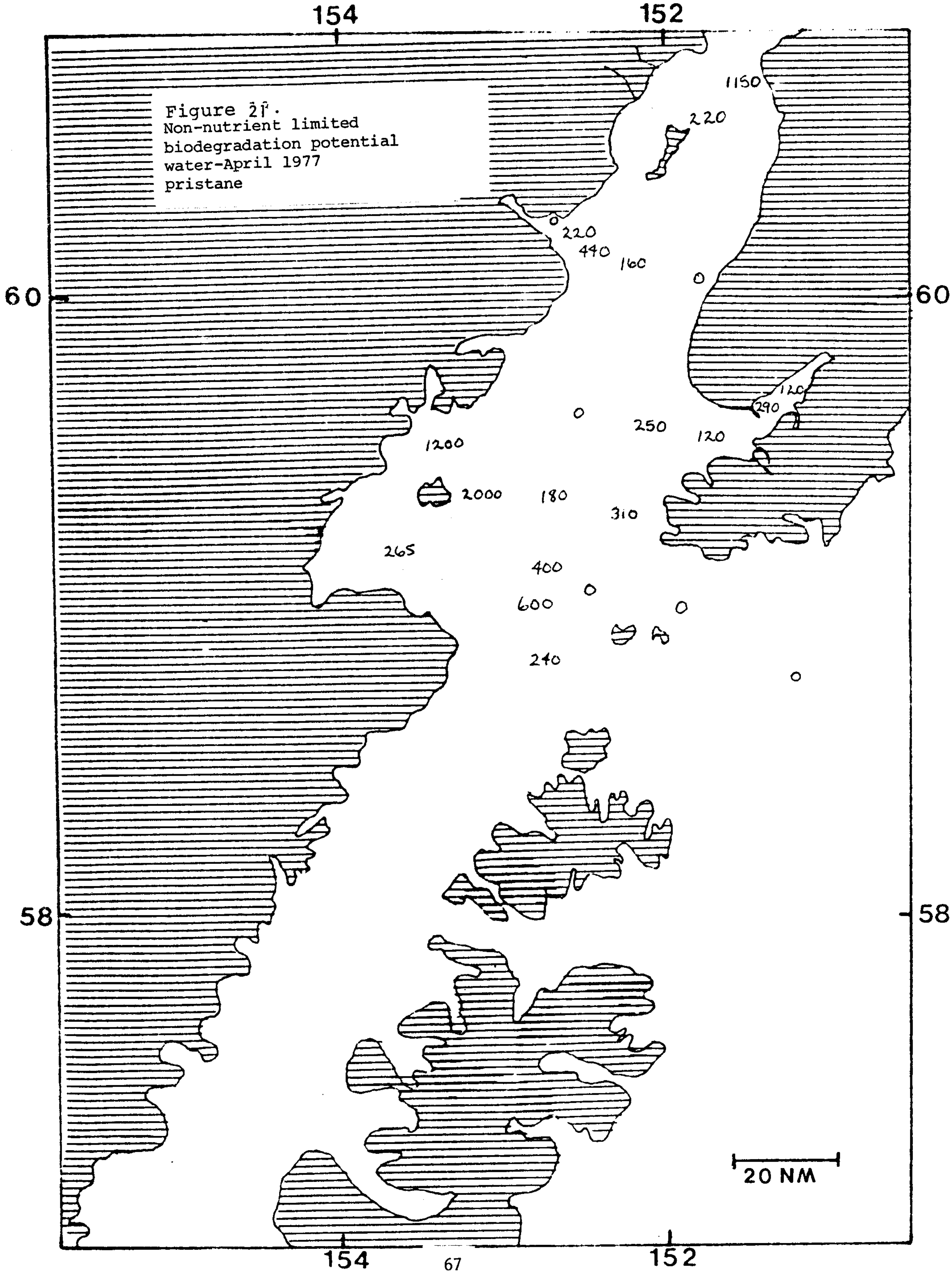


Figure 21.
Non-nutrient limited
biodegradation potential
water-April 1977
pristane

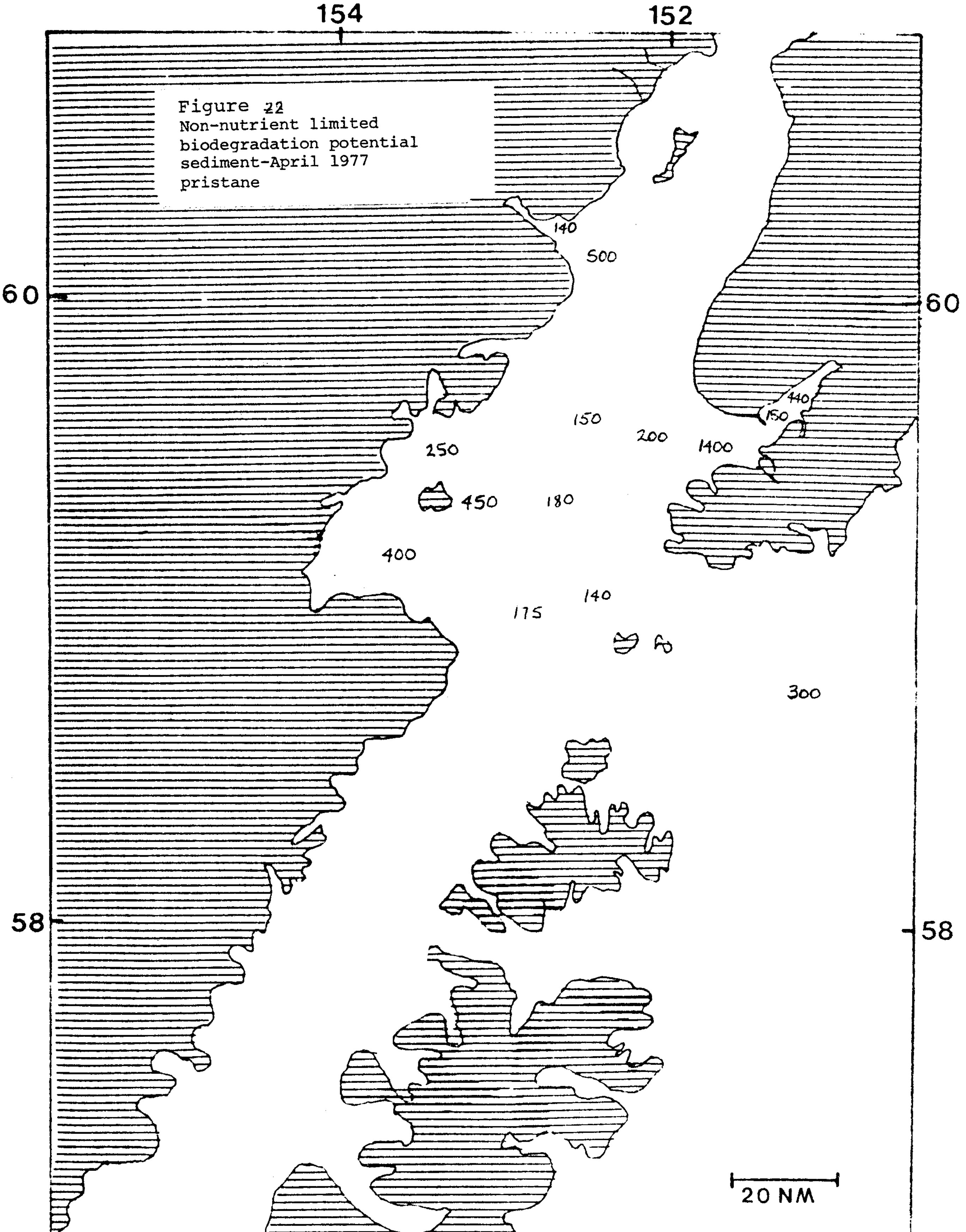


Figure 22
Non-nutrient limited
biodegradation potential
sediment-April 1977
pristane

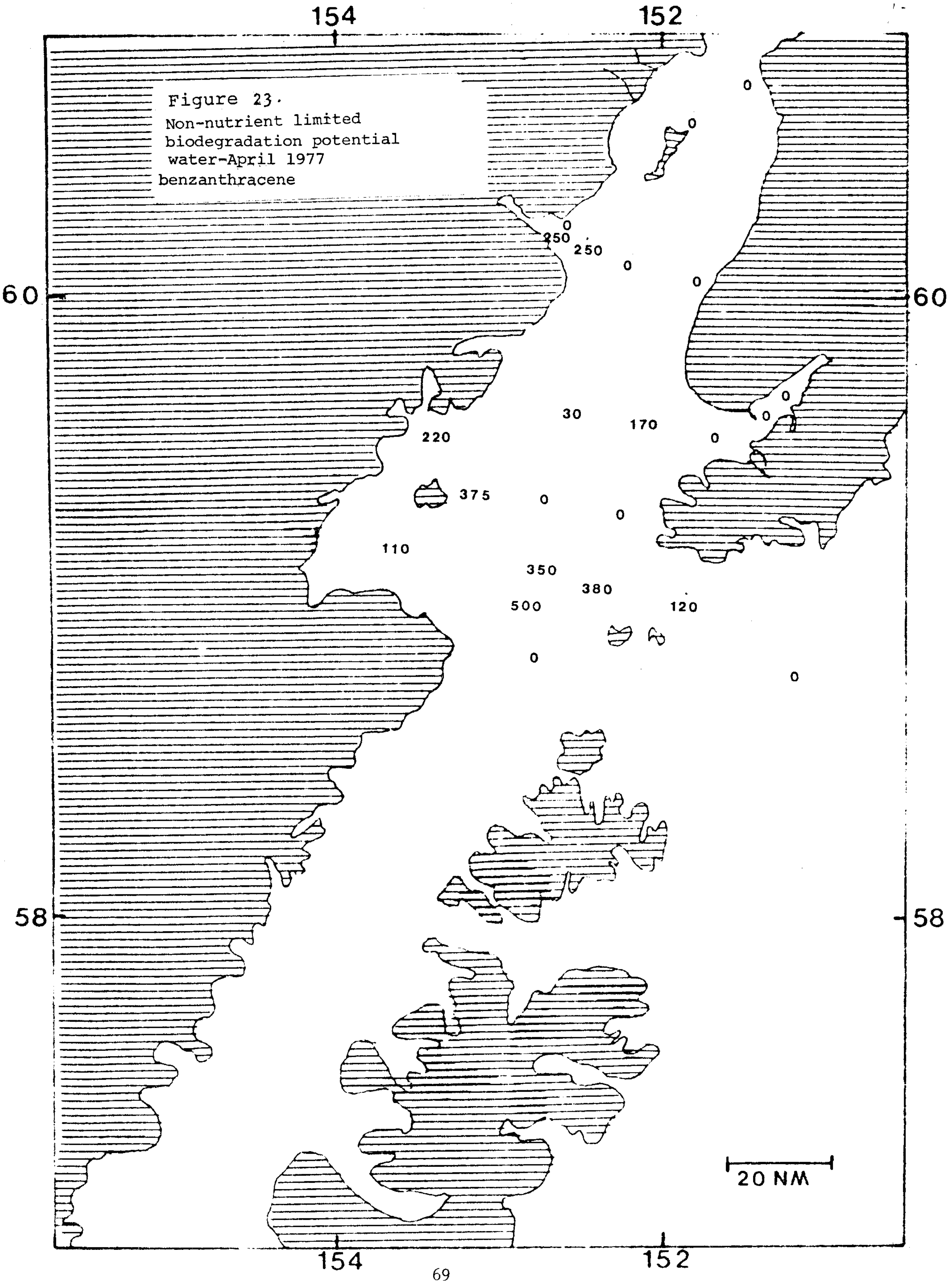


Figure 23. Non-nutrient limited biodegradation potential water-April 1977 benzanthracene

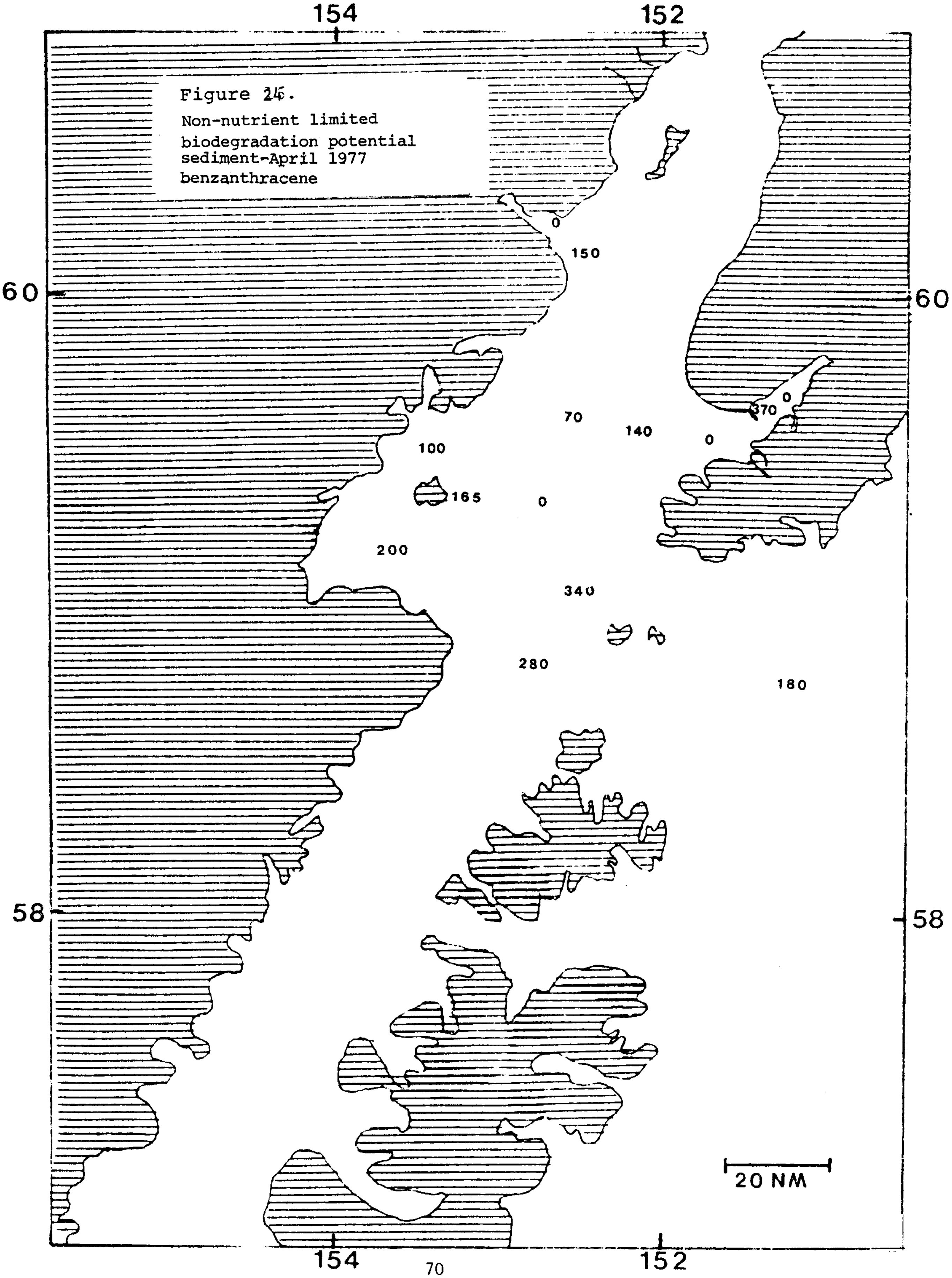


Figure 26.
Non-nutrient limited
biodegradation potential
sediment-April 1977
benzanthracene

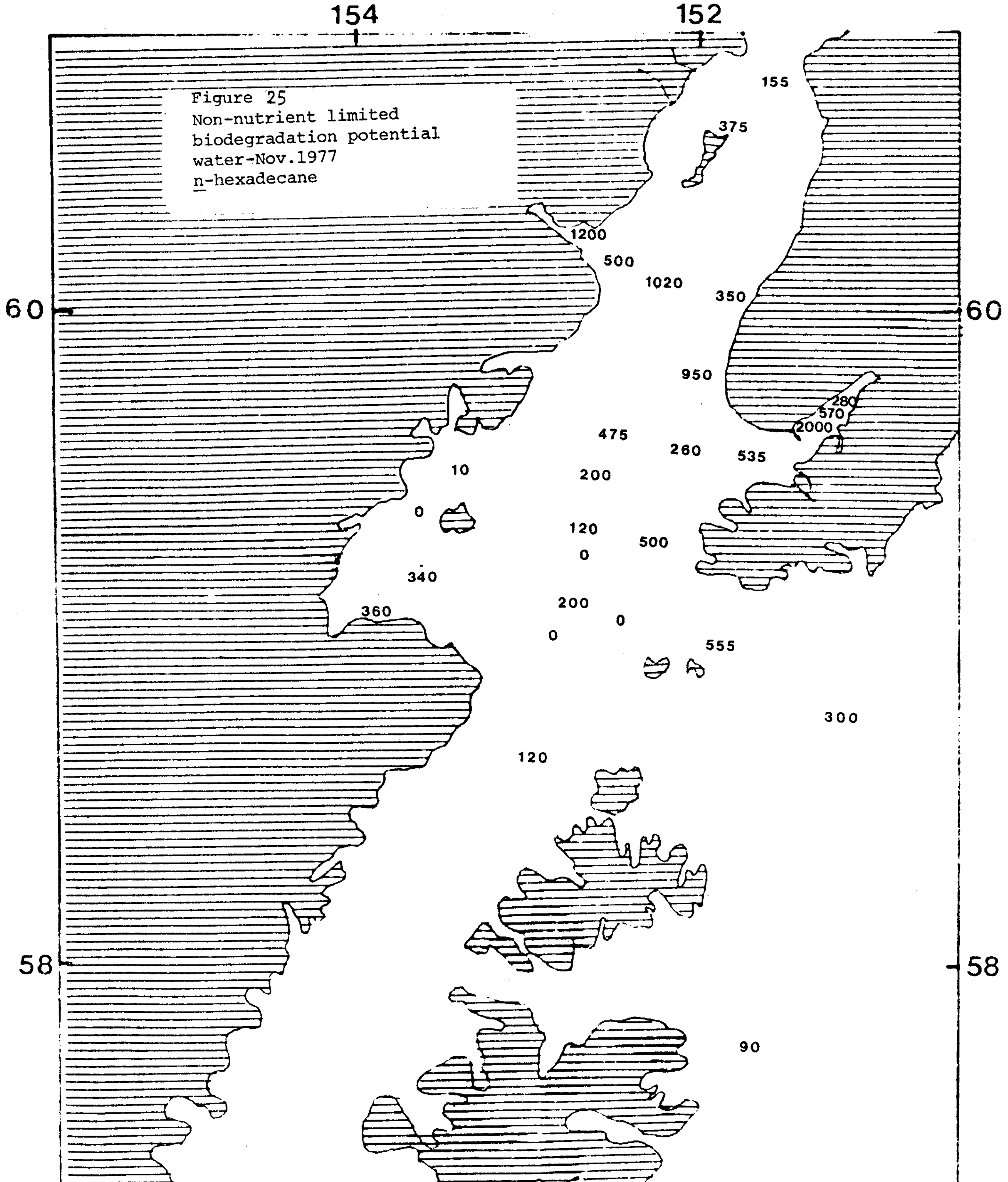


Figure 25
Non-nutrient limited
biodegradation potential
water-Nov.1977
n-hexadecane

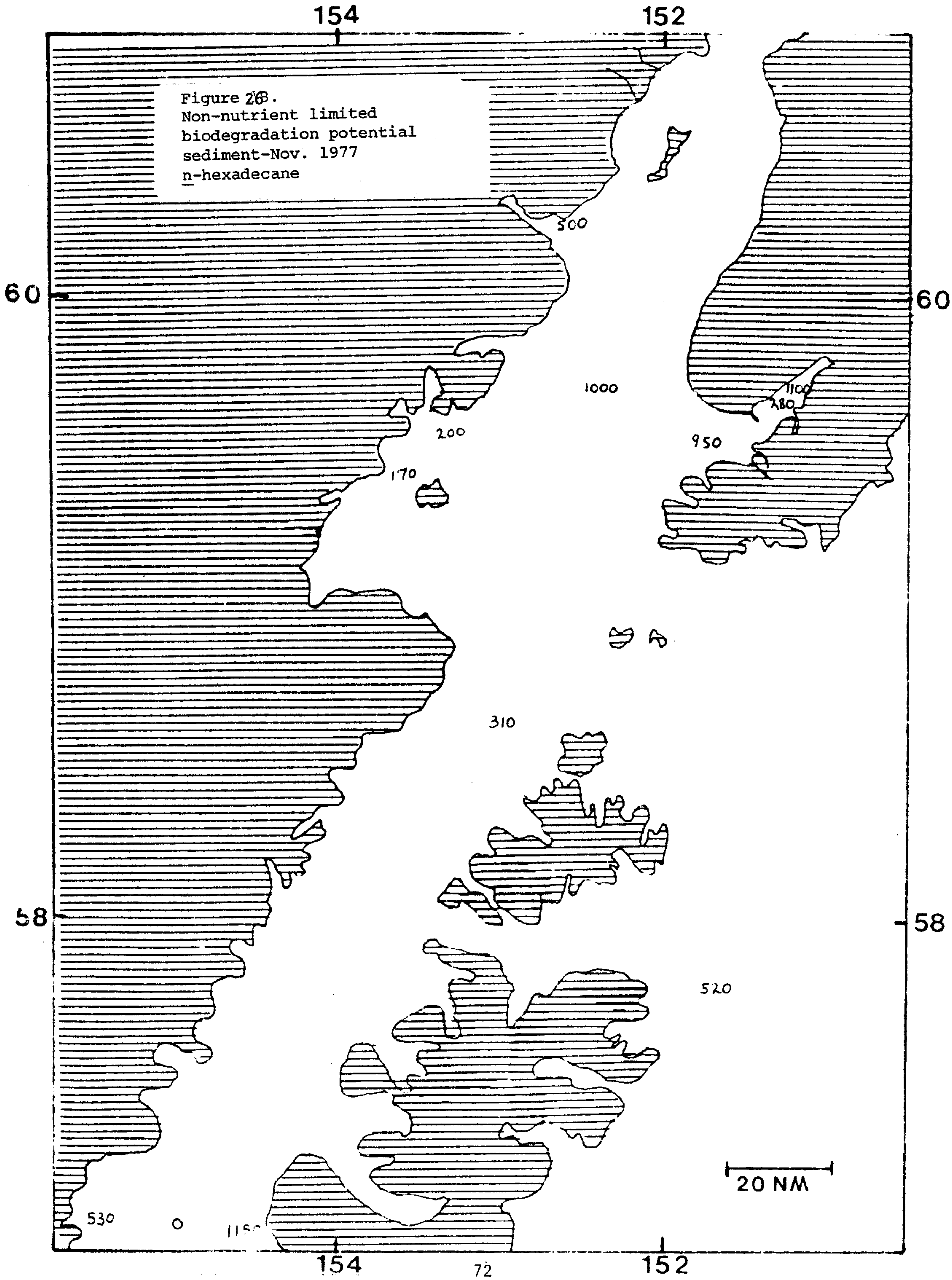


Figure 26.
Non-nutrient limited
biodegradation potential
sediment-Nov. 1977
n-hexadecane

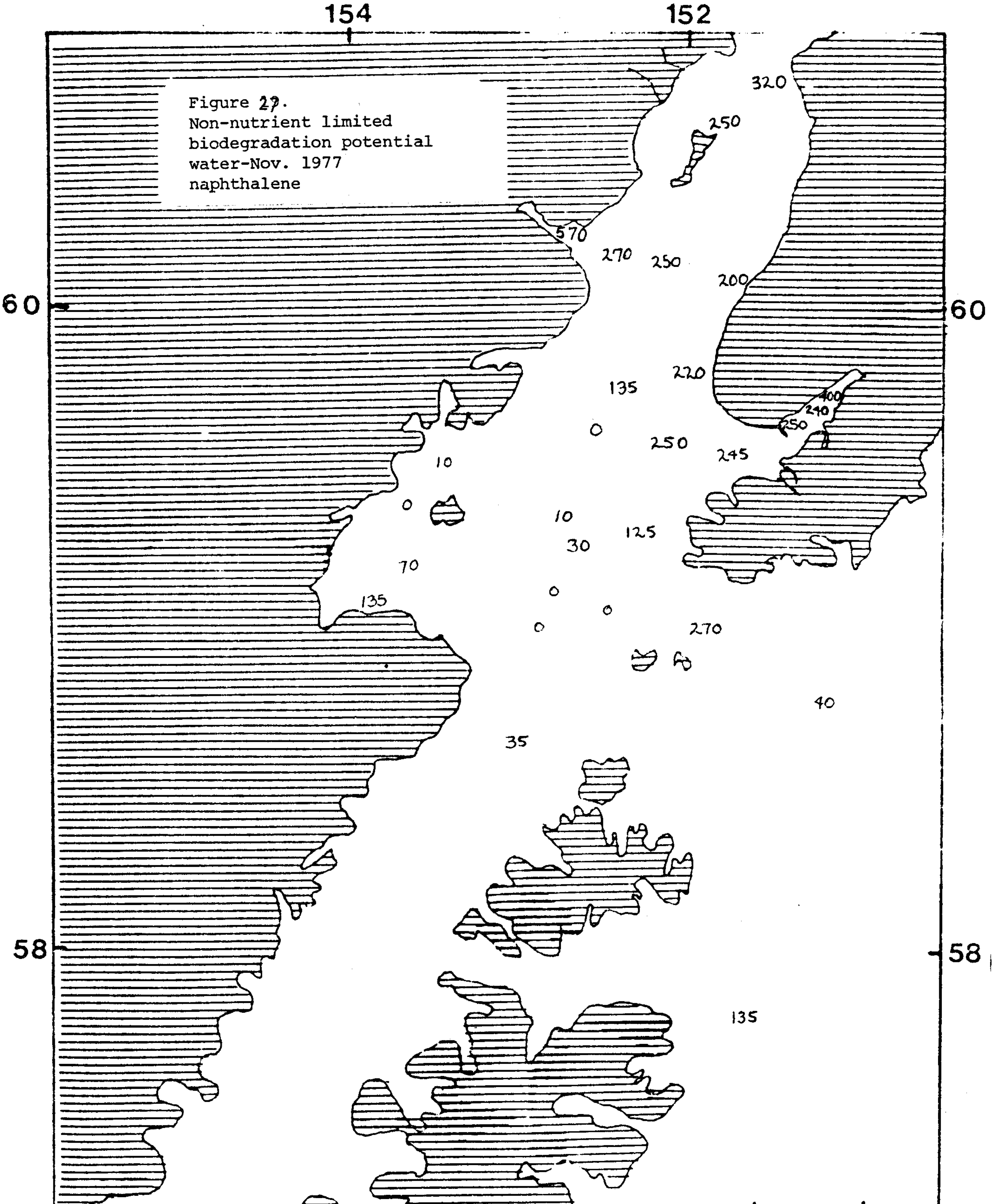


Figure 27.
Non-nutrient limited
biodegradation potential
water-Nov. 1977
naphthalene

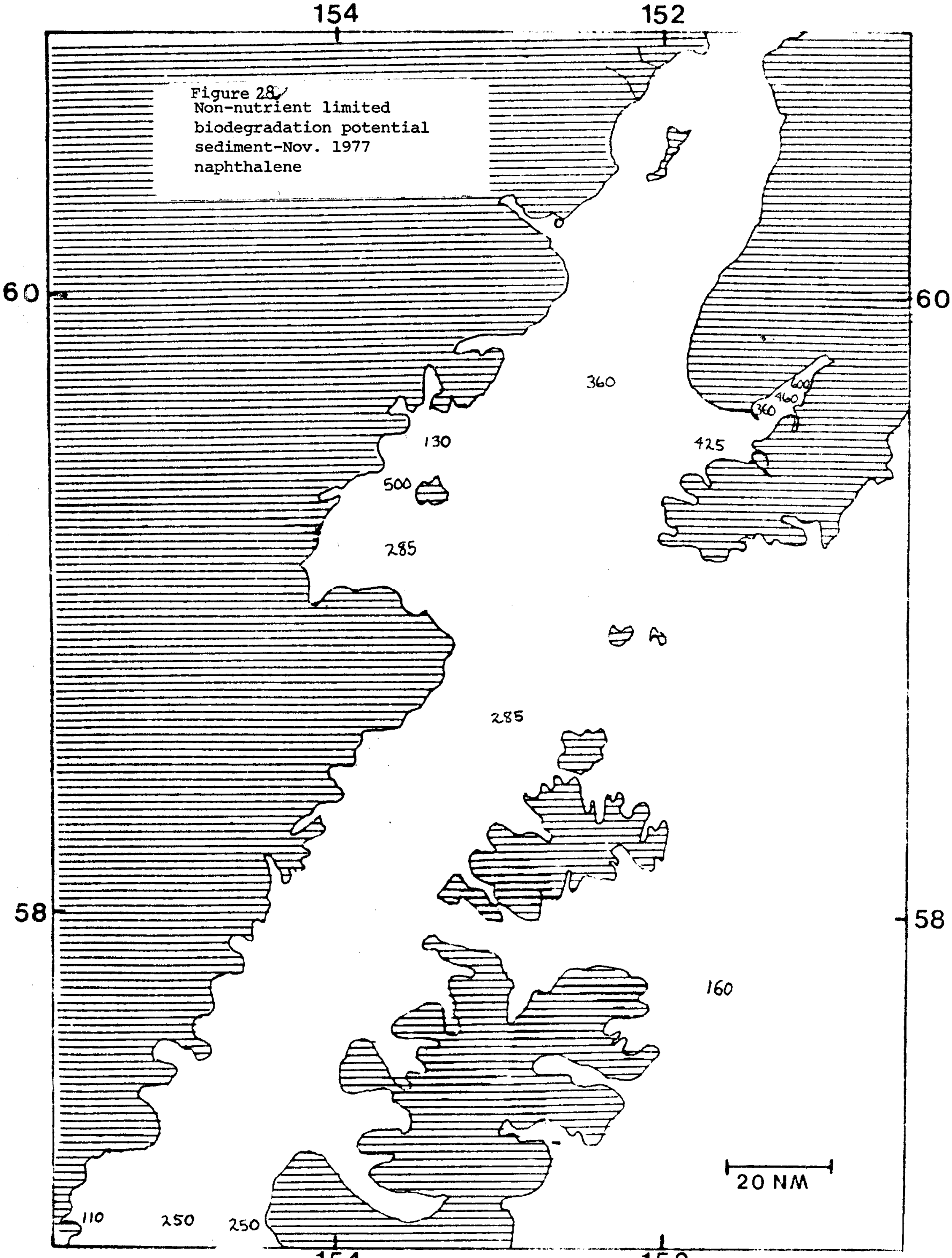


Figure 28
Non-nutrient limited
biodegradation potential
sediment-Nov. 1977
naphthalene

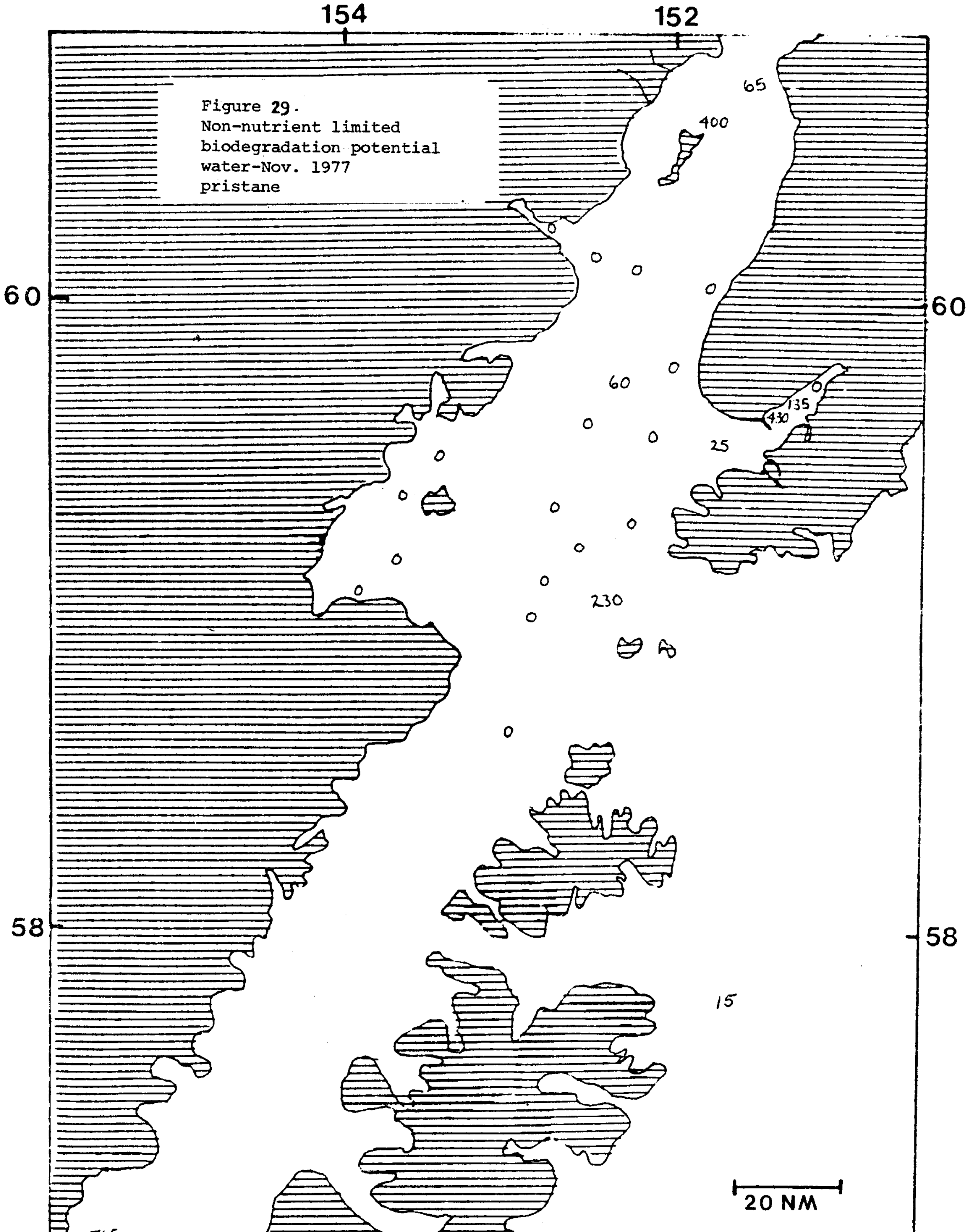


Figure 29.
Non-nutrient limited
biodegradation potential
water-Nov. 1977
pristane

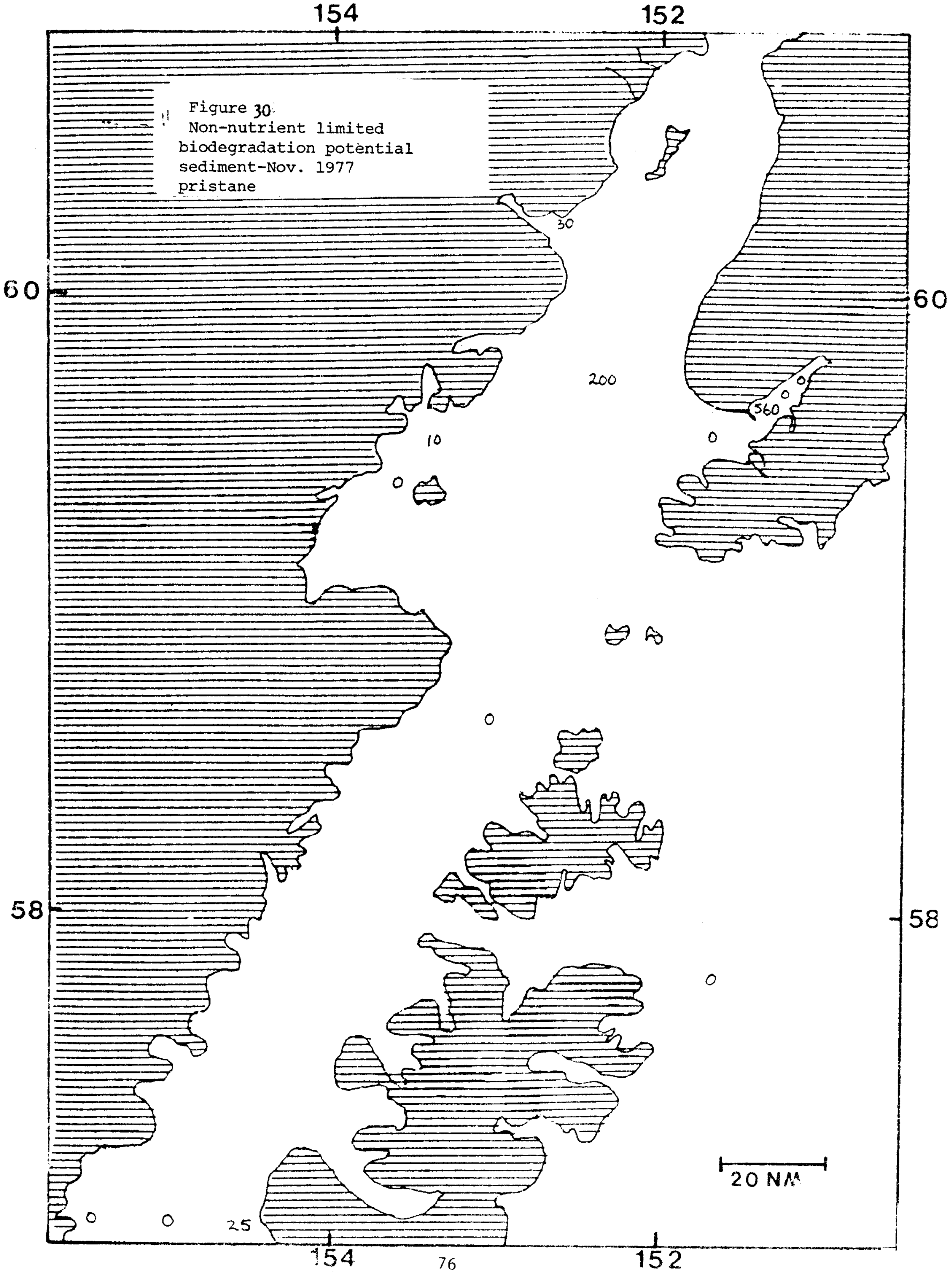


Figure 30 Non-nutrient limited biodegradation potential sediment-Nov. 1977 pristane

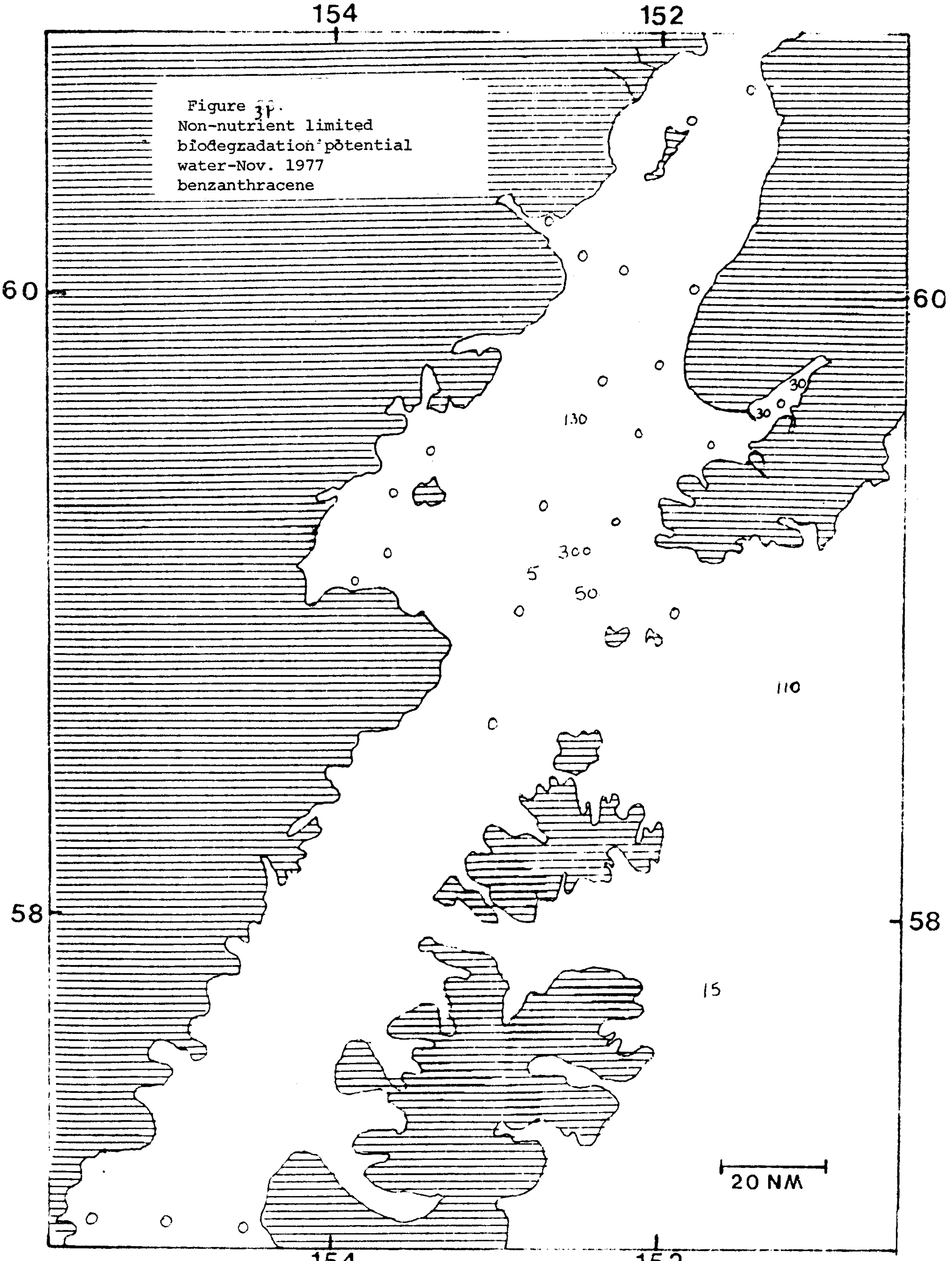


Figure 31.
Non-nutrient limited
biodegradation potential
water-Nov. 1977
benzanthracene

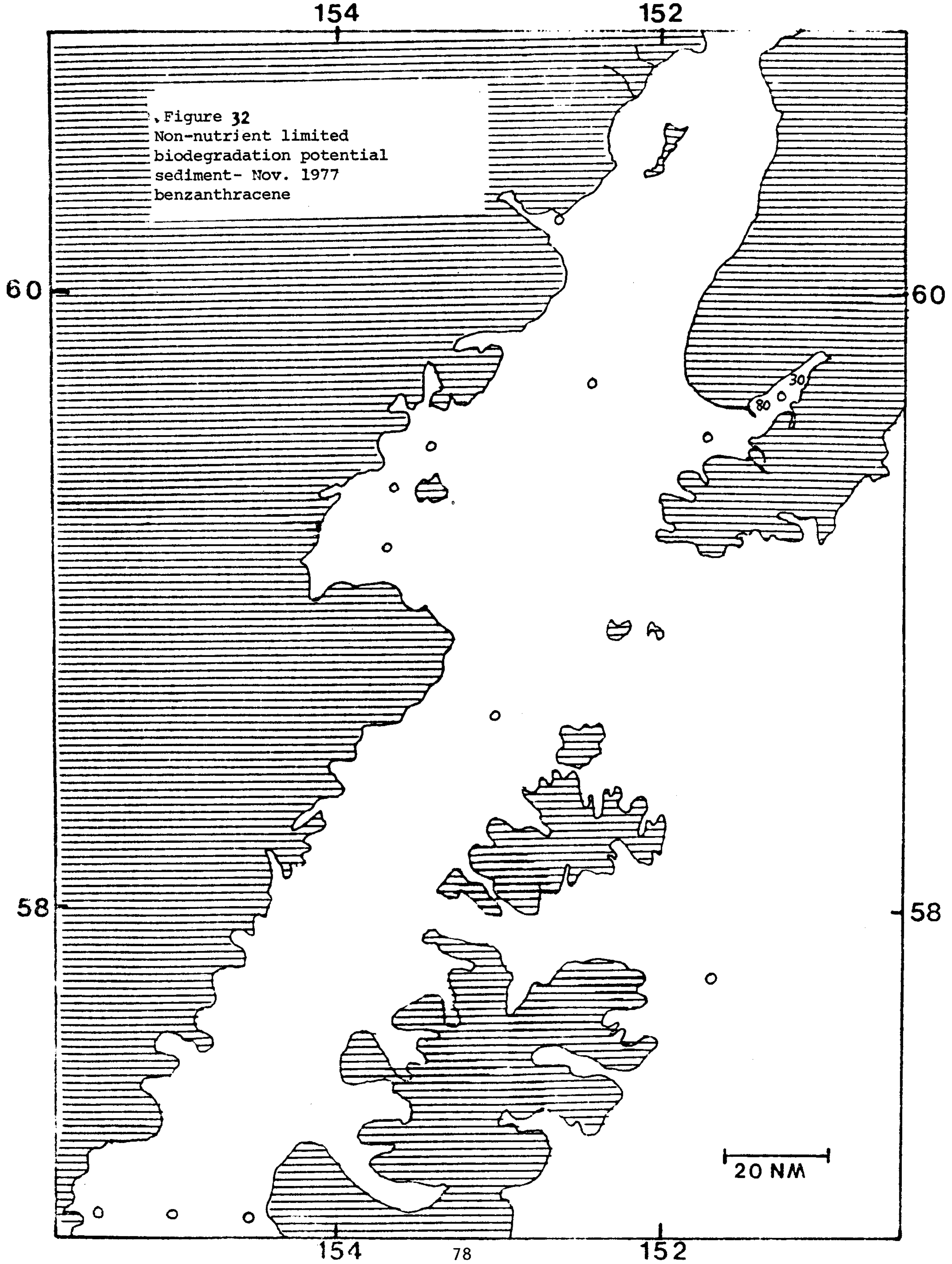


Figure 32
Non-nutrient limited biodegradation potential sediment- Nov. 1977 benzanthracene

biodegradation potentials were generally higher in Kachemak Bay and near Upper Cook Inlet than in the central areas of Lower Cook Inlet. This pattern is consistent with the distribution pattern of hydrocarbon utilizing microorganisms enumerated by the MPN method.

The use of crude oil, as a carrier in the biodegradation activity measurements allows for sparing or cooxidation that would occur in actual oil contamination incidents. The four ^{14}C hydrocarbons used are representative of major classes of hydrocarbons found in petroleum, *i.e.* straight chain paraffins, branched paraffins, simple aromatics and polynuclear aromatics. Branching and multiple condensed aromatic rings appear to greatly reduce biodegradability.

The "real biodegradation rates" that would occur in oil contamination incidents, probably lie somewhere between the natural and non-nutrient limited biodegradation potentials. Whether the "real" rates approach the non-nutrient limited biodegradation potentials will depend on the degree of mixing in a given area allowing for nutrient replenishment. In areas of Cook Inlet, where there is high mixing energy, the real degradation rates should approach the non-nutrient limited biodegradation potential rates. The biodegradation potentials measured in our study are potentials for complete biodegradation to CO_2 and H_2O, *i.e.,* mineralization. Degradation of hydrocarbons to products such as alcohols or acids, which are intermediary degradation products, would not be measured in our biodegradation potentials. The degradation rates that were measured in this study show total biodegradation of hydrocarbons are, thus, conservative in the estimate of hydrocarbons removed.

VII. Discussion and Conclusions

The numbers of viable microorganisms in Gulf of Alaska and Cook Inlet are clearly lower than in the Beaufort Sea. The reason for the low numbers of viable microorganisms in this area is still unknown. The taxonomic analyses show that Beaufort Sea microorganisms are distinctly adapted to the Arctic marine ecosystem. The taxonomic studies of hydrocarbon utilizers indicate that microorganisms respond to the presence of petroleum with an enrichment in the population of hydrocarbon utilizers. The diversities of heterotrophs in Cook Inlet were generally high,indicating that this area is generally not now under severe natural or man made stress.

The Most Probable Number enumerations of hydrocarbon utilizers and biodegradation potentials in Cook Inlet showed that Kachemak Bay, Kennedy entrance and Upper Cook Inlet had higher numbers of hydrocarbon utilizers, suggesting previous exposure to hydrocarbons, i.e. a source of hydrocarbons in these areas. The biodegradation potentials indicated that branched paraffins and condensed aromatic hydrocarbons would be degraded much more slowly in an oil than simple aromatics and unsubstituted paraffins. The biodegradation potentials also indicated that there are seasonal differences in rates of petroleum hydrocarbon biodegradation in Cook Inlet; rates in November being lower than rates in April.

VIII. Study Needs

There are several ongoing areas of research for this project which have not yet been completed. Our major ongoing reseach for the Beaufort Sea area is the in situ ice and sediment studies of petroleum biodegradation described earlier in this report. We need to analyse the hydrocarbons in the residual petroleum already recovered in this study. We further need to continue recovering samples from this study site on a long term basis to examine the persistence of petroleum hydrocarbons in Arctic marine sediment. A similar in situ study is needed in a southern Alaskan area, eg. within Cook Inlet near Homer. Larger scale multidisciplinary oil spill experiments in nearshore Arctic and subarctic ecosystems are needed, but environmental protection requirements may preclude such experiments.

There remains a large portion of the Alaskan OCS area in which we know little or nothing about the microbial communities. If ice conditions permit, an area in the Beaufort Sea between Prudhoe Bay and the Canadian border will be examined this summer. This will still leave the Kodiak lease area, all of the Bering Sea and the Chukchi Sea, including Bristol Bay and Norton Sound areas without microbiological OCSEAP studies. It is necessary to examine microbial populations in these potential lease areas. Some of these areas are rich shellfishing areas which could be adversely affected by changes in microbial populations. Our studies have shown that there are several orders of magnitude difference in viable microorganisms between the Gulf of Alaska and the Beaufort Sea. We do not know if there is a gradual rise in population levels moving northward or an abrupt change somewhere north of the Aleutian Islands. Hydrocarbon biodegradation potentials should be known for these areas before petroleum development. Also, there should be a taxonomic inventory or characterization of the microbial communities in these areas as will have been accomplished in Cook Inlet and the Beaufort Sea.

Studies are needed on the effects of petroleum hydrocarbons on microorganisms indigenous to OCS lease areas. We intend to examine some of the changes in microbial community structure in our in situ Beaufort Sea oil in sediment studies. We also intend to carry out some pilot studies to examine denitrification rates in sediment in Cook Inlet and the effects of oil on denitrification rates. We also plan to develop a new medium to determine what proportion of the indigenous heterotrophs in an area can tolerate the presence of petroleum hydrocarbons. These effects studies should be expanded to determine what levels of chronic hydrocarbon inputs can be tolerated by the microbial populations.

Many of these study needs have been outlined in previous reports and at meetings with NOAA OCSEAP staff. Adequate funding, program continuity and program coordination are essential for fulfilling microbiological information gaps.

IX. Summary of 4th Quarter Activities

The in situ oil under ice and oil in sediment experiments described earlier in this report, were established in Elson Lagoon in January. This was the only field work accomplished during this time period. Other activities included participation in the Lower Cook Inlet and and Beaufort Sea synthesis meetings with subsequent report writing.

In the laboratory modifications were made in a gas chromatograph and a mass spectometer installed to analyse the residual oil from the _in situ_ oil experiments. Taxonomic testing was completed on microorganisms isolated from the November, 1977 sampling cruise in Cook Inlet. Determinations of hydrocarbon biodegradation potentials for these samples were also completed during the past three months.

Third Annual Report

Task Numbers A-27; B-9
Contract # 03-5-022-68
Reserach Unit #190
Report Period 1 April, 1977 to
31 March, 1978

Number of pages: 94

Study of Microbial Activity and Crude Oil-Microbial Interactions in the Waters and Sediments of Cook Inlet and the Beaufort Sea

SUBMITTED BY:

Robert P. Griffiths
Co-Principal Investigator
Assistant Professor
Department of Microbiology
Oregon State University
Corvallis, OR 97331

Richard Y. Morita
Co-Principal Investigator
Professor of Microbiology
and Oceanography
Department of Microbiology
Oregon State University
Corvallis, OR 97331

Date submitted

March 29, 1978

TABLE OF CONTENTS

Page Number

TABLE OF CONTENTS CONTINUED

TABLE OF CONTENTS CONTINUED

Page numbe

1. Summary of objectives, conclusions, and implications with respect to OCS oil and gas development.

A. Objectives

In general terms, our main objectives during the last year were to obtain information about marine microbial function in the Beaufort Sea and Cook Inlet, Alaska and to obtain information about the effects of crude oil on specific processes. The microbial functions that we were primarily concerned with were, relative microbial activity and respiration in surface waters and sediments and rates of nitrogen fixation in the sediments. By both field and laboratory observations, we were to estimate the effects of crude oil on these processes.

B. Conclusions and Implications

1. One of the most important findings of the last year concerned the potential incorporation of crude oil into the sediments of Cook Inlet and the Shelikof Strait via surface oil spills in the Upper Cook Inlet. This conclusion can be reached by integrating the results of several studies; namely the results of Drs. Feely and Cline (RU#154), Miller and Allen (RU #436) and ourselves. It was previously assumed that since most of the suspended matter in these waters consists of glacial flour, there would be little absorption of crude oil onto these particles. It was also assumed, prior to our studies, that there was very little microbial activity to be found in these waters because of the shallow photic zone. Both assumptions appear to be incorrect.

Drs. Feely and Cline (1977) reported that preliminary data taken in the Upper Cook Inlet indicate that crude oil can be absorbed onto the suspended matter found in the waters of the Upper Cook Inlet. We found that the northern waters of the Cook Inlet showed very high levels of microbial activity (the highest values observed anywhere in the Cook Inlet and the Shelikof Strait) and that the level of activity was correlated with the turbidity of the water. Microscopic observation of the water samples revealed that most of the bacteria present were associated with these particles. The presence of these bacteria on these particles may explain why the glacial flour in the waters of Cook Inlet can absorb components of crude oil where as glacial flour itself might not have these properties. It is quite likely that the bacteria render the surface of these particles more hydrophobic, thus making it more likely that hydrocarbons will absorb onto the surface. If crude oil did become associated with the particles on the water column in this region, it would be important to determine where these particles would settle and what effect this might have. We have enough information at this time to partially answer these questions.

The study of surface water circulation patterns by Miller and Allen (1976) indicate that the net flow of this water mass is to the south along the western edge of the inlet and then down through the Shelikof Strait. The studies of Feely and Cline (1977) have also shown that the suspended matter settles out of the water column as this water mass moves south. They felt that most of the particles settle out into the sediments of the Shelikof Strait. Figure 3 (page 795) of their report which illustrates the distribution of total suspended matter in surface waters bears a striking resemblance to the patterns of relative microbial activity and respiration percentages that we have observed in the surface waters of Cook Inlet and Shelikof Strait (Figs. 10,12,and 13). Our data as well as that reported by Feely and Cline indicate that as the northern water mass moves south, it is mixed with the open ocean water that is consistently moving to the northwest from the southeast entrances of the inlet. Our studies on relative microbial activity in the sediments indicate that these particles probably settle out of the water column in both the lower Kamishak Bay area as well as the Shelikof Strait. The information collected thus far indicates that there is a strong possibility that crude oil spilled on the surface in the upper Cook Inlet will end up in the sediments of Kamishak Bay and the Shelikof Strait.

Both our studies on the effects of crude oil on nutrient uptake and respiration in marine microbial populations and a recent study by Hodson et al. (1977) have shown that marine microbial populations are inhibited in the presence of crude oil. Dr. Atlas (RU #30) has observed that bacterial populations in Beaufort Sea water show an increase in numbers after extended exposure to crude oil; however, the species diversity markedly decreases. These data suggest that crude oil suppresses the growth of certain bacteria whereas it acts as an energy source for other bacteria thus altering the natural balance within the population. Data collectecd in our aquarium studies and Dr. Atlas's Beaufort Sea chemostat studies (not funded by OCSEAP), have shown that presence of crude oil does not adversely effect the ability of the microbial population to utilize certain soluble organic nutrients after extended exposure. This is only one of hundreds of roles bacteria perform in the marine environment.

Another function performed by marine bacteria is nitrogen fixation. We have studied the effects of crude oil on nitrogen fixation (acetylene reduction) in sediment samples taken from both the Cook Inlet and the Beaufort Sea. Studies made on samples in the field have shown little or no effect of crude oil on this process. In another series of experiments conducted on sediments transported to our laboratory at Oregon State have shown that crude oil might effect this process over extended exposure. In this series, the samples were amended with sucrose which usually enhances acetylene reduction. We felt that by speeding up the process, effects of crude oil on the growth of nitrogen fixing bacteria might be determined. The results of these experiments show that crude oil does not consistently inhibit acetylene reduction. This determination is relatively crude and extrapolations of these observations back to nature should be taken with caution. Further study should give a more precise picture of what crude oil effects might have in the environment. The results of our sediment work in Cook Inlet have shown that nigrogen fixation is probably quite important to the detrital food chain in Kachemak Bay and in other areas in and around Cook Inlet.

Other possible effects of crude oil which have yet to be tested are the effect on bacterial colonization of detritus particles and the effect on the grazing of bacteria by protozoa and higher animals. Any detrimental effect in these functions would soon alter the biological productivity on all trophic levels (including all species of commercial importance).

In summary, it can no longer be assumed that crude oil spills in Cook Inlet would primarily impact only shoreline communities. There is a very real possibility that this oil could be absorbed onto the suspended particulate matter in the water column and carried to the sediments on the west side of the inlet and into the sediments of the Shelikof Strait. The possible long range effects of this on the biological productivity of Cook Inlet is yet to be determined.

2. The correlation between relative microbial activity and crude oil Biodegradation potentials.

Up to this time, we have assumed that areas which showed the highest relative microbial activity would be the ones which also would show the highest rates of crude oil degradation. The results of two studies conducted on marine sediments indicates that this might not be the case. We correlated the relative microbial activity with the release of $^{14}CO_2$ from sediments which were exposed to crude oil which contained labeled hexadecane and pristane under conditions where neither nitrogen nor phosphorous was limiting. A study on the Beaufort Sea sediments gave a correlation coefficient of -0.42 and a similar study in the Cook Inlet gave a correlation of 0.09. At least under these conditions, this assumption was not shown to be true. It must be kept in mind that the method used to determine crude oil biodegradation potentials was a highly artificial system and these measurements may not reflect relative degradation rates _in situ_. Dr. Atlas has observed that areas which show the highest concentrations of hydrocarbon utilizing bacteria in Cook Inlet are also the areas where we have observed the highest levels of relative microbial activity. Further study will be required before the best method of estimating _in situ_ crude oil degradation potentials is identified.

3. Crude oil degradation potentials in various geographical locations

We measured the crude oil biodegradation potentials in the sediment samples that were sent to us by Dr. Carey (RU #6) from the summer, 1977 Beaufort Sea cruise. The highest rates were observed in the sediments taken to the east of Prudhoe Bay. Theoretically, the highest rates should be associated with sediments that have been chronically exposed to hydrocarbons. If this is the case, these sediments have been exposed to elevated levels of either natural or polluting hydrocarbons.

Studies of crude oil degradation potential in Cook Inlet using the ^{14}C labeled crude oil mentioned above, has not produced consistant geographical trends.

4. The presence of Desulfovibrio sp. in Cook Inlet sediments

Of potential interest to those planning to construct metal structures that come into contact with sediments is the presence of a group of anaerobic bacteria known as Desulfovibrio. The growth of these organisms may produce considerable corrosion of most metals. These organisms are also known to grow in drilling muds with the resulting release of H_2S. During the April, 1977 Cook Inlet cruise, the presence of these organisms was measured in a number of sediment samples. Except for the sediment analyzed from station 214, all samples tested showed significant concentrations of this organism in Cook Inlet sediments (10^3 to 10^6 bacteria per ml sediment). In most dilution tubes, growth was visible within four weeks incubation at 8 C.

II. Introduction

A. General nature and scope of the study

Our main objective has been to study the natural levels of relative microbial heterotrophic activity, respiration percentages and nitrogen fixation rates in natural microbial populations found in the Beaufort Sea and Cook Inlet under contrasting seasonal conditions. Our other objectives have been to evaluate the effects of crude oil on microbial activity and nitrogen fixation rates. These studies have been interpreted in light of other data that has also been collected on the same samples. These data include inorganic nutrient data, sample temperature, salinity and location; direct count, plate count and crude oil degradation potential data collected by both ourselves and Dr. Atlas, and microbial population characterizations made by Dr. Atlas.

B. Specific Objectives

1. Cook Inlet

a. To continue studies of relative microbial activity and respiration (mineralization) of natural microbial populations found in water and sediment samples. The samples were to be taken in such a way as to characterize these measurements both geographically and temporally. These studies were to fill some of the data gaps which still exist from past studies in this region. These data may also be used in the future to estimate the degree of perturbation caused by chronic crude oil input.

Characterization of water masses using microbial measurements which might be used to follow the movement of water masses within the Inlet.

b. To evaluate the extent of nitrogen fixation in the sediments and gut contents of animals found in this region and to determine what, if any, effect crude oil might have on this process. Significant impact on function of any process in the nitrogen cycle could have a profound effect on all trophic levels in the Cook Inlet.

c. To evaluate techniques which might be used to determine crude oil degradation in sediments.

d. To provide nutrient data on all water and sediment samples taken by both microbiological groups. These data are important in evaluating other data collected by us, especially data on N_2 fixation and denitrification.

2. Beaufort Sea

a. To obtain information concerning the effects of added crude oil on the natural microflora of the sediments. These studies were to include crude oil effects on microbial function as measured by uptake and respiration characteristics using several labeled compounds. These studies were also to include the study of nitrogen fixation and the effects of crude oil on this process. These studies are designed to simulate the introduction of crude oil into the sediments by buried pipeline breaks similar to those discussed during the February, 1977 synthesis meeting held in Barrow, AK.

b. To continue collecting data on relative microbial activity and respiration percentages in this region during the August-September, 1978 Glacier cruise in this region. Nitrogen fixation rates will also be estimated on sediment samples collected at the same time.

c. To provide nutrient data on all water and sediment samples collected by both Dr. Atlas and ourselves.

d. To estimate the effects of crude oil on natural microbial populations which undergo osmotic stress during freezing and thawing.

3. General

a. To coordinate our sampling efforts and experimentation with that of Dr. Atlas and his associates at the University of Louisville. This will minimize duplication of effort and maximize the usefulness of the resulting data.

b. To continue our laboratory studies at Oregon State University on the effects of crude oil on nitrogen fixation in marine sediments. We also plan to study crude oil degradation by bacteria isolated from the Beaufort Sea and the Cook Inlet.

II. Field and Laboratory Activities.

C. Relevance to problems of petroleum development

Our major area of concern is the interaction between the crude oil that might be accidently spilled during the course of petroleum production in potential lease areas and the microorganisms present that might be perturbed by such a spill. Our studies will produce information about microbial function in these areas before extensive perturbation has occurred.

We are also determining what effect crude oil has on specific microbial function. These data will provide information about what types of microbial function are most likely to be impacted by a crude oil spill. In addition, field studies on the effects of crude oil on microbial function will provide information about what geographical areas are most likely to be impacted. These data along with data provided by other investigators can be used to locate areas which are particularly sensitive to crude oil perturbation. These data, in turn, can be used by planners and managers in both government and industry to better assess the potential risks involved and better estimate what measures must be taken to minimize risks to the environment.

Another study is being made on the degradation of crude oil by microorganisms. It is important to determine the rate of crude oil degradation under a variety of environmental conditions so that under a given set of circumstances, a prediction of crude oil residence time can be estimated. This is a very complex problem because so many variables effect this process. This information must be obtained if estimates of potential impact are to be made. We have conducted some studies in this area but the majority of this work is being conducted by Dr. Atlas and his associates.

III. Current state of knowledge

Most of the information that is known about the distribution and relative activity in the sediments and waters of the Beaufort Sea and the Cook Inlet has been generated by both Dr. Atlas (RU #29 and 30) and ourselves. This information is available in our past reports to NOAA under this project. Information about the effects of crude oil on microbial activity and nitrogen fixation in these two regions can also be found in our past reports. To our knowledge, there have been no other papers published on the effects of crude oil on nitrogen fixation in marine sediments; however, there has been a recent study published on the effects of crude oil on the uptake and respiration of labeled glucose by micrganisms in seawater near Vancouver Island, B.C. (Hodson et al., 1977).

There is a great deal of information that has accumulated concerning crude oil biodegradation processes; however, there have been relatively few field studies on this process in Alaska waters. Besides Dr. Atlas's and our work, the other studies that have been published are Kinney et al. (1969); Arhelger et al. (1977); and Robertson et al. (1973).

IV. Study areas

During the past year we have conducted three field studies; one in the Cook Inlet in April, 1977, another in November 1977 and a third in the Beaufort Sea in January, 1978. The latter study was conducted as a part of the crude oil degradation study in Elson Lagoon near Barrow, AK. In September, 1977, we received a set of 20 sediment samples that were taken by Dr. Carey's group during the Glacier Beaufort Sea cruise. The stations that were sampled during these operations are illustrated in Figs. 1 to 4. The exact locations of the sampling sites are given in Tables 2 to 4.

V. Methods

A. Sampling procedures

1. Cook Inlet Cruises

The water samples were taken in sterile Niskin plastic water sample bags fitted in Niskin "butterfly" water samplers. With the exception of the depth profile studies made during the November cruise, all water samples were taken within two meters of the surface and were processed within two hours after they were collected.

All sediment samples except those taken at the beach stations were obtained by a Van Veen grab. Approximately 150 grams of surface sediment were taken from the top two to four cm. Portions of these samples were used to determine percent respiration, relative microbial activity and nitrogen fixation rates within four hours of their collection.

2. Beaufort Sea (Glacier cruise)

Sediment samples were taken using a Smith-McIntyre grab. The subsamples were taken as described above.

3. Beaufort Sea (Elson Lagoon, Jan., 1978).

Water samples were taken through hole drilled through the ice using a Niskin "butterfly" water sampler. The samples were kept at in situ temperature while they were transported back to the Naval Arctic Research Laboratory (NARL). The samples were processed within 5 hours after they were collected. Sediment samples were taken directly from the bottom by divers.

B. Relative microbial activity and percent respiration determinations

The procedure used in these studies involved adding a U-^{14}C compound to identical subsamples which were contained in 50 ml serum bottles.

After addition of subsample, the 50 ml serum bottles that were used for reaction vessels were sealed with rubber serum bottle caps fitted with plastic rod and cup assemblies (Kontes Glass Co., Vineland, N.J.:K-882320) containing 25 x 50 mm strips of fluted Whatman #1 chromatography paper. The samples were incubated in the dark within 0.5 C of the *in situ* temperature. After the incubation period, the bottles were injected through the septum with 0.2 ml of 5N H_2SO_4 in order to stop the reaction and release the $^{14}CO_2$. After the addition of the acid, 0.15 ml of the CO_2 absorbent, β-phenethylamine, was injected onto the filter paper. The bottles were then shaken on a rotary shaker at 200 rpm for at least 45 minutes at room temperature to facilitate the absorption of CO_2. The filter papers containing the $^{14}CO_2$ were removed from the cup assemblies and added to scintillation vials containing 10 ml of toluene based scintillation fluor (Omiflour, New England Nuclear).

The subsamples were filtered through a 0.45 μm membrane filter (Millipore). The trapped cells on the filter were washed with three 10 ml portions of seawater at 0-3 C. The filters were dried and then added to scintillation vials containing 10 ml of the above mentioned fluor. The vials were counted in a Beckman model LS-100 C liquid scintillation counter located in our laboratory at Oregon State University.

In the sediment samples, a 1.0 ml subsample was diluted 1,000 times (v/v) with a 32 o/oo (w/v) solution of sterile artificial seawater. Ten ml subsamples of the sediment slurry were dried and weighed to determine the dry weights. These dry weights were used to calculate the observed uptake rates in terms of grams dry weight of sediment.

U-^{14}C L-glutamic acid with a specific activity of 237 mCi/mmole (Amersham-Searle) was used in all water samples giving a final concentration of 5.4 ug/liter. Glutamic acid with a lower specific activity (10 mCi/mmole) was used in all sediment samples except those collected at Elson Lagoon in January, 1978. In these sediments, the higher specific activity glutamic acid was used. U-^{14}C D-glucose with a specific acitvity of 328 mCi/mmole (Amersham-Searle) was used in all water and sediment samples. The final concentration used was 3.8 ug/liter. The ^{14}C sodium acetate used in the April Cook Inlet sediment samples had a specific activity of 54 mCi/mmole and a final concentration of 6.9 μg/liter.

Triplicate subsamples were analyzed for each sample and the results reported here are the means of the observed values. The channels ratio method for determining counting efficiencies was used. The observed CPM was converted to DPM before the mean value was calculated. The percent respiration was calculated by dividing the amount of labeled carbon associated with the CO_2 fraction by the total amount of labeled carbon taken up by the cells (both cell and CO_2 radioactivity) and multiplying this ratio by 100. All samples were incubated in the dark at a temperature within 0.5 C of the *in situ* temperature.

C. Direct Cell Counts

Ten ml of seawater was fixed in the field laboratory by adding it to 0.6 ml of membrane (0.45 μm) filtered formaldehyde (37%). The vials containing the fixed water samples were sealed and stored until they could be counted in our laboratory at Oregon State University. In the sediment studies, the final dilution of the sediments in the heterotrophic potential studies was used and treated the same as the seawater samples.

From 5 to 17 ml of sample were filtered through a 0.2 μm Nuclepore filter. When a relatively high number of organisms was present, the samples were diluted with membrane filtered artificial seawater. The number of organisms per field was kept within acceptable limits and the volume filtered was kept above 5 ml. Controls were run using filtered artificial seawater and all of the reagents used in the staining and mounting procedure. These counts were no more than 5% of those found in the samples and were considered insignificant.

The staining procedure used was that of Zimmerman and Meyer-Reil (1974). This procedure involves staining the cells trapped on the membrane filter with acridine organe and then destaining with isopropyl alcohol. The membranes were dried and mounted on microscopic slides. Immersion oil was used as the mounting medium.

The bacterial cells were counted using a Zeiss IV Fl epi-fluorescence condenser microscope fitted with filters KP 500, IP 490, FT 510, and LP 520. The eyepiece used was Kpt W 12.5 x and the objective was plan 100 x. Approximately 50 restriction fields were counted per sample. Representative fields were counted from the center of the membrane filter to the outside edge of the filtration circle.

Only bodies with distinct fluorescence (either orange or green), clear outline and recognizable bacterial shape were counted as being bacterial cells.

D. Desulfovibrio concentrations in sediments

Subsamples of a 10^{-3} dilution were added to screw top test tubes so that no air would be introduced to the semisolid anaerobic medium. Serial dilutions were made in the range of 10^{-5} to 10^{-6} in most cases. The medium used was a modification of marine desulfovibrio medium PM 10 E (ZoBell and Morita, Deep Sea Research 3:66-73, 1955). This medium contained the following ingredients: Na formaldehyde sulfoxylate, 0.1 g; K_2HPO_4, 0.5 g; NH_4Cl, 1 g; Na_2SO_4, 1 g; $CaCl_2 \cdot 2H_2O$, 0.1 g; $MgSO_4 \cdot 7H_2O$, 1 g; agar, 3 g; H_2O, 1 liter. The medium was adjusted to a pH of 7.5 and sterilized by autoclaving at 30 psi for 15 min. Prior to use, the medium was steamed for one hour to drive off gases within the medium.

The test tubes were kept at 4 C or below during transport to our laboratory at Oregon State University. These tubes were incubated at 8 C for four weeks before they were checked for growth. The incubation temperature was then increased to 25 C and checked again for growth after an additional two weeks incubation.

E. Crude oil degradation potential in sediments

These experiments were conducted on sediment samples that were brought back to the laboratory at Oregon State. The samples were kept at or below 4 C between the time they were collected and the start of the experiment. Subsamples of the sediment were diluted 1:10 in seawater salts supplemented with Nitrogen and Phosphorus. Ten ml of this dilution were placed into 50 ml serum bottles. To this was added 0.1 ml of Cook Inlet Crude oil which contained 7.5×10^{-3} µCi pristane and 7.5×10^{-3} µCi hexadecane. The bottles were sealed with rubber stoppers fitted with a plastic bucket containing fluted filter paper. Duplicate subsamples and one acidified control were used to determine crude oil mineralization in each of the sediments analyzed. The samples were incubated at 8 C for 31 days. At the end of the incubation period, the evolved $^{14}CO_2$ was collected and assayed for radioactivity.

F. Nitrogen fixation and nitrogen fixing bacterial concentrations in sediments

Nitrogen fixation in the sediments was determined in the field by using the acetylene reduction method (Stewart et al, 1967, Proc. N.A.S.-U.S. 58:2071 - 2078). Ten ml subsamples of sediment were added to respective 50 ml serum bottles: one control and two duplicate samples were used for each analysis. After the bottles were sealed with a rubber stopper, the samples were gassed for one min with He at a flow rate of 10 cc/sec. Ten ml of acetylene was then added to each bottle and the bottles were allowed to incubate for 24 hr before incubation was terminated with one ml of 50% trichloracetic acid (TCA). The controls were treated in the same way before incubation and were used to determine the amount of ethylene that was released abiotically. After the incubation was terminated, the tops of the rubber stoppers were sealed with silicone cement. The bottles were kept at or below 4 C until they could be assayed for ethylene in our laboratory at Oregon State University. The analysis for ethylene was made on a Hewlett Packard model 5830A gas chromatograph. The column used was 1.9 meter of 1/8" stainless steel tubing packed with Porapak R 80-100 mesh and the oven temperature was 40 C. The carrier gas was nitrogen flowing at a rate of 29 cc/min. The resulting levels of ethylene were normalized using incubation times and gram dry weight conversions.

During the November, 1977 Cook Inlet cruise, we collected a number of benthic organisms to determine if any nitrogen fixation activity was associated with them. As soon as the animals were collected, they were placed on ice until they could be processed. Either whole animals or just the gut (in larger animals) were blended in a blender fitted with a microcup. Ten ml of the blended tissue was added to a 50 ml serum bottle and assayed for nitrogen fixation rates as described above. These samples were fixed with two ml of saturated $HgCl_2$ solution at the end of the 24 hr incubation period. The samples were incubated at temperature within 0.5C of that found in situ. After the samples were fixed, they were returned to the laboratory for gas analyses and dry weight determinations.

The studies on the effects of crude oil on nitrogen fixation in sediments which had been exposed to sucrose to stimulate this process were conducted in our laboratory at Oregon State. The sediment samples used in these experiments were kept at or below 4C during transport and storage. Most of these determinations were made within four weeks after the samples were collected. Sucrose at a final concentration of 10^{-3}M was used to stimulate nitrogen fixation because it has been found to be one of the most effective energy sources for that purpose by both ourselves and other investigators (Keirn-Brezonik, 1971).

Unless otherwise indicated, the incubation temperature used was 5C. The incubation times varied from 4 to 7 days. All rates were calculated in terms of pmoles nitrogen fixed per gram dry weight of sediment per hour. A conversion factor of 0.33 was used to calculate the amount of nitrogen fixed from the amount of ethylene produced.

G. Crude oil effects on uptake and respiration of labeled organic compounds

These studies included both field and laboratory observations. Field observations of crude oil effects were made on sediment samples collected during the recent Elson Lagoon study and on water samples collected during the November Cook Inlet cruise. The observations made on sediments collected during the Glacier cruise in the Beaufort Sea and the sediments collected during the November Cook Inlet cruise were made in our laboratory at Oregon State. The method used to handle these sediments has been described above.

During these studies, we analyzed the effects of crude oil (both Prudhoe Bay and Cook Inlet crude), "weathered" crude oil and aqueous extracts of crude oil. The "weathered" crude oil was prepared by evaporating off the lower boiling point hydrocarbons under a stream of air. This produced a crude oil that was reduced in weight by 27% and one that had lost virtually all of the lower boiling point hydrocarbons as determined by gas chromatography. The crude oil aqueous extract was prepared by adding 5 ml of crude oil to 1 liter of sterile artificial seawater solution and gently stirring this mixture at 5°C for 24 hours. The aqueous phase was decanted and dispensed into sterile dilution bottles.

H. Enumeration of bacteria using various agar media

During the course of these studies, a number of different media were used to determine the relative concentrations of various types of bacteria. Two media were used to determine "total" numbers of bacteria present in sediment samples. These were marine agar 2216 (Difco) and Lib X agar. Lib X agar is made up of 1.2 g Bacto-yeast extract, 2.3 g Trypticase (BBL), 0.3 g sodium citrate, 0.3 g L-glutamic acid, 0.05 g sodium nitrate, 0.005 g ferrous sulfate, 33 g Rila marine salts disolved in 1 liter of distilled water, and 12 g agar. The pH is adjusted to 7.5 and autoclaved. In the studies designed to determine the effects of crude oil on bacterial growth, 5 ml of crude oil was added to autoclaved Lib X agar and then mixed in a blender. Uninoculated control plates were always used to insure that no contamination had occurred during this process.

The concentration of *Vibrio* sp. was determined on TCBS agar (Difco) plates. The concentration of anaerobic bacteria was determined on Glucose agar plates which were made up of a 1:10 dilution of Lib X medium with 0.5% glucose. The Tween 80 medium was Sierra Agar with marine salts and Tween 80. The concentration of lipase producing organisms was determined by counting only those colonies which showed a positive lipase reaction on these agar plates. The concentration of obligate anaerobic bacteria was calculated by substracting the total *Vibrio* count from the Glucose agar count. The percent of obligate anaerobic bacteria, the percent lipolytic bacteria and the percent fermentative bacteria were all calculated relative to the Lib X counts.

I. Statistical analysis

The correlation coefficients used in this report were computed using the following equation:

$$r = \frac{N\Sigma XY-(\Sigma X)\ (\Sigma Y)}{[N\Sigma X^2-(\Sigma X)^2]-[(N\Sigma Y^2-(\Sigma Y)^2]}$$

The significance of differences between mean values were made using Student's "t" test. A critical value of 0.05 was used in these determinations. Whenever it is stated that there was a "significant" difference between two mean values, the difference fulfills the above condition.

VI. Results

A. Experiments designed to expose potential problems in methodology

Many of the studies reported here involve the use of relatively new techniques or new applications to standard techniques. As a result, a great deal of testing was required to insure that the observations that we were making were not prejudiced by faulty assumptions or techniques. The following is a description of these studies.

1. Problems in sampling error and sample handling.

a. It has been reported that sterile plastic sample bags that we employ in obtaining water samples may alter microbial function in the collected sample. We checked to see if these samplers affected glucose and glutamic acid uptake and respiration by comparison to similar samples taken by other means. We observed no alteration in function.

b. In some cases, we have had to store sediment samples so that further analyses could be conducted after the termination of the field period. We have attempted to keep these samples at or below the *in situ* temperature until they can be processed. Comparisons between field laboratory data have shown that in general, nitrogen fixation rates decrease and glucose and glutamic acid uptake rates increase with increased incubation time. These observations reconfirm the validity of our usual practice of conducting as many observations as possible in the field on samples as soon as they are collected.

c. Since were are not able to carry our gas chromatograph into the field, we had to devise some method of storing and transporting gas samples from our nitrogen fixation studies. After trying a number of different techniques we found that if the reaction was run in a 50 ml serum bottle, the reaction could be terminated by injecting 1 ml of saturated $HgCl_2$ solution through the septum. If the septum was then sealed with a silicone cement, the sample could be stored at normal refrigerator temperatures for several weeks without significant gas loss. We found that trichloroacetic acid (TCA) could also be used to terminate the reaction successfully but in sediments with large amounts of carbonate, CO_2 was released causing a positive pressure within the reaction vessel.

2. Problems in assaying radioactivity

a. The beta rays which emit from ^{14}C labeled compounds are very easily blocked. For this reason, we wanted to make sure that radioactivity measurements we were making in the cell fraction within sediments were not significantly affected by the presence of the sediment particles themselves. This was done in two ways; by running a dilution series and looking for changes in radioactivity and by combusting all of the cellular material to CO_2 and assaying this fraction without interference from the sediment particles. In the first experiment, a sediment with a ^{14}C labeled natural microbial population was diluted by a factor of 100,500,1,000, 5,000, and 10,000. The DPM observed at each of these dilutions were corrected for the respective dilution factor and compared. The first two dilutions did show significant quenching but there was no significant quenching observed above the 500 : 1 dilution. Since a 1,000 dilution was routinely used in these studies, it was felt that this was not a serious problem.

It occurred to us that the above test would still not exclude the possibility that sediment particles might still be interfering with the method used to assay radioactivity. A better but much more difficult test would involve combusting the sediment samples containing labeled microorganisms. In whis way all of the radioactivity associated with the cells would be oxidized to CO_2 which could be trapped and assayed separately from the sediment itself. Such a series of tests have been initiated on sediment samples we have collected from both the Beaufort Sea and the Cook Inlet. Although not all of the tests have been completed as of this date, preliminary results indicate that as much as 38% of the radioacitivty in our sediment cell fractions might be absorbed by sediment particles so that they are not counted by liquid scintillation. Although the data we have reported on relative levels of microbial activity in the sediments are still valid, actual rates would undoubtedly be higher than those we have reported and the respiration percentages would be lower if further tests confirm our original observations. These changes would if anything further exaggerate comparisons we have made between levels of activity and respiration differences in water and sediment microbial populations and does not substantially effect the conclusions we have drawn from these data. We are currently exploring different methods to separate the cells from the sediment either by solubilizing the cellular components or oxidizing the samples to CO_2 prior to assay.

b. In the experiments concerning the effect of crude oil on glucose and glutamic acid respiration, we felt that there might be some problem recovering all of the CO_2 from the aqueous phase because of the film of crude oil on the water surface. A series of 12 identical subsamples containing labeled carbonate disolved in artificial seawater was used. One tenth of a ml of crude oil was added to one half of the samples. The CO_2 was collected in the usual manner and the resulting radioactivity in the two sets was compared. No differences were observed therefore we concluded that the presence of crude oil in this system did not materially effect the recovery process.

c. It is known that crude oil can act as a significant quenching agent in the scintillation cocktails that we use to assay radioactivity. We originally thought that any crude oil that remained on the filters (used to retain the cell fraction) would disolve into the toluene fluor. Once in the fluor, the quench caused by the crude oil should be reflected in a depressed channels ratio which would then be translated into a corrected count. The results of our earlier experiments indicated that this might not be the case. We checked this by adding crude oil to radioactive cells and assaying-for the radioactivity on the membrane filters after filtration. The activity was lower in these samples than in the controls indicating that enough crude oil remained in contact with the cells to reduce counting efficiency without altering the channels ratio enough to account for all quenching. We have since modified our technique so that no crude oil is associated with the cell fraction when it is filtered and thus no crude oil is present in the scintillation fluor during the counting process.

The work that we conducted on the summer Beaufort Sea sediments was done using the original technique therefore, the effects of crude oil on the uptake of glucose and glutamic acid may be in error as they are reported in our last quarterly report. The effects that we observed in crude oil aqueous samples would not be effected by crude oil quenching; however, the depression in radioactivity observed in the cells that had been exposed to either raw or weathered crude oil are probably lower than the actual levels. All data reported in this communication have been interpreted in terms of these new findings.

3. Determination of the most effective method for determining relative microbial activity.

a. There are several different approaches one can use to obtain information about the relative levels of microbial activity in marine samples. When we initiated our studies in this program, we chose to assay both the uptake and respiration of glutamic acid at several substrate concentrations. This technique enabled us to measure the kinetics of glutamic acid utilization. It is a rather cumbersome technique since it involves a large number of subsamples to make a single determination. Since time and manpower restraints are particularly acute in the field, more samples could be analyzed if only one substrate concentration were used in these studies. We made a comparison between these two methods and found that the corrlation coefficients were generally above 0.90 (Table 1 and Griffiths et al., 1977). Since the correlations were so high, we started using the single concentration method exclusively for routine field microbial activity determinations. This has resulted in the much higher resolution found in our most recent field studies.

b. During the course of our studies, we have utilized a number of labeled compounds. These include ^{14}C labeled glucose, glutamic acid, acetate, and algal protein hydrolysate. Of these, we have found that the first two provided the most useful information therefore we use both of these compounds routinely to characterize various microbial populations.

B. Abiotic variables observed in field studies

1. Cook Inlet

During the last year, we participated in two Cook Inlet cruises; one on board the Discoverer in April, 1977 and the other on board the Surveyor in November, 1977. During the first cruise, 44 water and 15 sediment samples were collected from 7 beach and 29 offshore stations. During the second cruise, 60 water and 20 sediment samples were collected from 3 beach and 56 offshore stations. The location of these stations and their respective station numbers are illustrated in Figs. 1-3. The exact position of these stations and a summary of abiotic variables are listed in Tables 2 and 3. During the April cruise, the surface waters were generally colder and more saline than they were during the November cruise.

Distinct patterns of surface water salinity were observed during both of the Cook Inlet cruises (Figs. 5 and 6). During both the cruises, the lowest salinities were observed in the northern section of Cook Inlet and the highest values were observed to the southeast. The higher resolution study in November gives the most comprehensive picture of surface water salinity patterns. The salinities to the west are lower than those found in the eastern half of the inlet. Salinities in the region of Kalgin Island and Tuxedni Bay were below 30 o/oo. The area to the south and west including Kamishak Bay and the western half of the Shelikof Straight had surface water salinities below 31 o/oo. With the exception of Kachemak Bay, all other areas studied had salinities above 31 o/oo.

2. Beaufort Sea

During the Glacier cruise in August-September, 1977, 20 sediment samples were taken from 20 offshore stations. The locations and station numbers for these stations are illustrated in Fig. 4. The exact position and depth information for these stations are given in Table 4. These samples were collected for us by Dr. Carey's associates and were analyzed in our laboratory at Oregon State after the cruise. The salinity temperature data collected during this cruise will be reported by Drs. English and Horner.

During the winter Elson Lagoon study, 4 water, 1 ice, and 9 sediment samples were collected near our Beaufort Sea station #3. These samples were collected as a part of the *in situ* crude oil degradation studies which we are conducting with Dr. Atlas' group (RU #30).

C. Relative microbial activity and respiration percentages in water samples

1. Cook Inlet

Patterns of relative microbial activity in offshore surface waters have been found to be similar in all three Cook Inlet cruises in which we have participated (Figs. 7-10, Tables 5 and 6). This was true if microbial activity was measured using either glucose or glutamic acid as the labeled substrate (Figs. 7 and 8). In all cases. the relative microbial activity in the northern waters was the highest, the lowest values were observed to the south and east of the inlet and in open ocean waters. Intermediate values were observed in samples collected along the western side of the inlet. A comparison of microbial activity levels during all three sampling periods have shown differences in mean values when comparing one cruise to another. There have also been local differences observed between values; however, these differences are not statistically significant. As has been the case in the past, relative microbial activity in water samples taken near the beach are higher than those taken further offshore (Table 7).

Consistant respiration percentage patterns were also seen when the results of the data collected on these three cruises are compared (Figs. 11-13). The values in the area near Kalgin Island and Tuxedni Bay are very low ranging from 31 to 40%. Contours of increasing values run in lines which run diagonally from the northeast to the southwest. Intermediate values are found along these contours in the center of the inlet and the highest values are found in the southeastern portion of the inlet and in the open seawater. Again, differences were seen between values observed in one location from cruise to cruise but the differences between mean values are not statistically significant.

2. Beaufort Sea

During this period, the only observations that were made on seawater samples taken from the Beaufort Sea were conducted in Elson Lagoon. Four water samples and one ice sample were analyzed for glucose and glutamic acid uptake and respiration (Table 8). The levels of relative microbial activity were essentially the same as that observed in the same location in April, 1976 (almost two years earlier). These levels are approximately one order of magnitude lower than that normally found in the summer in Elson Lagoon. The percent respiration was also about the same as that observed during the April, 1976 study.

D. Relative microbial activity and respiration percentages in sediment samples

1. Cook Inlet

In general, the highest levels of microbial activity were observed in Tuxedni Bay, Kachemak Bay and in the southern portion of Kamishak Bay (Figs. 14 and 15, Tables 9 and 10). During the April cruise, extremely high values were observed in the two samples taken in the Shelikof Strait; however, these high values were not observed during the November cruise when a much more comprehensive study was conducted. It must be concluded at this time that there are very large seasonal changes in the microbial activity in the Shelikof Strait sediments or that the extremely high values observed during the April cruise was caused by some experimental error. During the November cruise, the levels of microbial activity were lower in the Shelikof Strait than they were in the Cook Inlet.

The levels of microbial activity were lower in sediments analyzed during the October, 1976 and November, 1977 cruises than they were in the April cruise but these differences are not statistically significant using Student's "t" test.

The percent respiration values observed in the sediment samples taken from the Shelikof Strait in November were higher than those observed in Cook Inlet sediments. As we have observed in the past, the percent respiration values in sediment samples were lower than those observed in water samples.

2. Beaufort Sea

The sediment samples analyzed from the summer Glacier cruise indicated that the highest levels of microbial activity were found in the area near Point Barrow and the lowest activities were seen near Prudhoe Bay at stations 74a and 80a and near the Canadian border at station 110 (Figs. 16 and 17 and Table 11). This was true when either glucose or glutamic acid was used in the determinations. Since the samples were stored for up to four weeks before they could be analyzed, it is impossible to make a valid comparison between these data and that observed in the field during the 1976 Glacier cruise where only fresh samples were analyzed. The average percent respiration observed in sediments while using glutamic acid as the substrate was 38%. This is higher than the value of 28% observed during the previous cruise, however, this difference may be due to the condition of the samples at the time of assay.

During the January Elson Lagoon study, 9 sediment samples were analyzed for relative microbial activity and percent respiration (Table 8). The rate of glutamic acid uptake and percent respiration in the undisturbed samples (samples BB402-406) was essentially the same as that observed in the same location in April, 1976. There was no significant difference between the uptake and respiration found in the control tray sediment and sediment found in a sample taken a few meters from the crude oil degradation study site. There were also no differences seen between these controls and the sediments that had been taken from the trays and treated with crude oil at the begining of the experiment (July, 1977). Differences were seen however, between these sediments and the sediment that was used to initiate a new series of experiments on crude oil degradation. The first sediments were representative of the top 4 cm of the sediment. The sediment used in the degradation study preparation was taken from deeper sediments and were not as active (sample BB407). After the sediment had set under the ice for 24 hours, the observed activity doubled (samples BB408 and BB409). After the sediments sat for another 24 hours, the activity levels were equal to that observed in the undisturbed sediment (sample BB410).

E. Nitrogen fixation rates observed in the Beaufort Sea and Cook Inlet

In the sediments analyzed from the April cruise, the highest rates of nitrogen fixation observed were seen in Kachemak Bay and in the Shelikof Strait (Fig. 18 and Table 12). The average rate of nitrogen fixation observed was 0.28 ng nitrogen fixed per gram dry weight of sediment per hour. During the November cruise a more comprehensive study was made of nitrogen fixation rates in sediments (Figs. 19 and 20). The average rate observed at that time in Cook Inlet was 0.82 ng per g dry wt. per h (1.16 ng per g per h if all stations from the Shelikof Strait are included). Although the average rate was higher in the samples analyzed from the November cruise, the difference was not significant at the 95% confidence level when compared to the April results. As was the case in the April cruise, sediments taken from Kachemak Bay and the Shelikof Straight showed the highest activities. There were 7 stations which were sampled during both cruises. If the rates observed at these two times are compared, the resulting correlation coefficient is 0.88 indicating that relative levels of nitrogen fixation in Cook Inlet are probably consistent geographically (Table 13). Further comparison of this kind will be made during the next scheduled Cook Inlet cruise. These data will be required to substantiate this conclusion.

Nitrogen fixation rates were also measured in the sediment samples that we received from the Beaufort Sea (Fig. 21 and Table 14). The highest levels were observed in the samples taken near Point Barrow. The average rate of nitrogen fixation observed in these sediments was 0.06 ng per g dry weight per hour. This is significantly lower than the average values observed in the Cook Inlet; however, this comparison should be taken with caution since it is quite likely that the actual rates were higher than those reported here due to the storage time involved.

Nitrogen fixation rates were observed in a number of water samples taken from the Cook Inlet during both cruises. In all cases, the fixation rates were too low to measure. The rates of nigrogen fixation observed in the benthic organism preparations were also very low. These observations will be repeated during the next Cook Inlet cruise using a refinement on the method employed in this study.

F. Crude oil biodegradation potential studies

Crude oil degradation potentials were measured in diluted sediment samples using crude oil containing ^{14}C labeled pristane and hexadecane. The levels of radioactivity observed in those samples collected during the April and October Cook Inlet cruises are illustrated in Figs. 22-24. During the April cruise, the highest rates of degradation were observed in samples collected in Tuxedni and Kachemak Bays. The more comprehensive study conducted in November; however, shows no distince pattern of hydrocarbon biodegradation potential.

A similar study was conducted on the sediments collected during the summer, 1977 Glacier cruise. Most of the highest values measured were observed in sediments taken to the east of Prudhoe Bay (Fig. 25).

G. Enumeration of bacteria

During all of our past studies, we have made bacterial concentration measurements using epifluorescent microscopy. The bacterial concentrations observed in both water and sediment samples collected during the April cruise are given in Table 15. Average values that we observed in both types of samples were essentially the same as we observed in samples taken during the October, 1976 cruise in the same area. No direct count data were made on samples that had been collected since then because we have judged that this information was of only limited use and it was essentially a duplication of similar observations being made by Dr. Atlas's group on the same samples.

During the April cruise we measured the presence of *Desulfovibrio* sp. bacteria in the sediment of Cook Inlet. This study was conducted because under the right conditions the organisms can greatly accelerate metal corrosion; a possible concern to those planning the construction of drilling platforms in Cook Inlet. The relative levels of these organisms in sediments are illustrated in Fig. 26.

Since Dr. Atlas and his associates did not have access to sediment samples that we received from the Beaufort Sea, we made our own measurements of bacterial concentrations using different agar media. (This is a type of measurement that they routinely make on the samples that we take together). The results of this study are given in Table 16. In this study we compared the total counts obtained on two general purpose marine agar media; Lib X and Marine agar 2216. The counts obtained on Lib X were on the average twice those obtained on 2216. The average concentration of organisms reported here are close to the values that Dr. Atlas obtained in the Glacier cruise the summer before.

We calculated a series of correlation coefficients on bacterial concentrations as determined by counts on various media and the rates of glucose and glutamic acid uptake in the same samples (Table 18). The correlation coefficients were higher between the uptake rates and Lib X medium counts than with 2216 counts. A similar comparison was made on sediment samples collected during the April, 1977 Cook Inlet cruise (Table 19). In both of these studies, the correlation between bacterial concentration (as determined by plate counts) and substrate uptake was higher when glucose was used than when glutamic acid was used to measure activity.

During the April cruise, we also estimated the concentration of presumptive nitrogen fixing bacteria found in the sediment samples collected (Table 20). These values did not correlate well with the rates of nitrogen fixation that were observed in the same samples.

H. Effects of crude oil on microbial function

We measured the effects of crude oil on the growth of bacteria plated on a agar medium. The inocula that we used were subsamples of the sediment samples that were collected during the November Cook Inlet cruise. Both Lib X plates with and without crude oil were used. There was an average reduction of 33% in the number of colonies that formed on the crude oil supplemented agar. The same inhibitory effect was not observed, however, in sediment samples collected in Elson Lagoon (Table 17).

We have also conducted studies on the effect of crude oil on nitrogen fixation rates using the acetylene reduction method. The effect of crude oil acetylene reduction was measured in 10 sediment samples during the November 1977 Cook Inlet cruise. No significant difference was seen between samples that had been treated with Cook Inlet crude oil and those that were not (Table 12). A series of related studies has been conducted on sediment samples collected from several sources (Table 21).

These included 12 sediment samples collected during the November, 1977 Cook Inlet cruise, 4 from the April cruise, 9 samples from the summer Beaufort Sea cruise, and 5 Yaquina Bay, Oregon samples. All of these studies were conducted on samples that had been returned to our laboratory at Oregon State. In these studies, the effect of crude oil on acetylene reduction was measured using both untreated samples and samples to which sucrose had been added to stimulate acetylene reduction. In the case where no sucrose had been added, we observed little or no effect. In the samples which were supplemented with sucrose, both decreases and increases were observed. If there is an effect, it is not consistantly negative.

The effect of crude oil on the uptake and respiration of glucose and glutamic acid by microbial populations in sediment and water samples has been studied. Two sets of data were collected from samples in the field and one set was taken from samples processed in our laboratory at Oregon State. After conducting these studies, it was discovered that cell fractions which were coated with crude oil at the time of assay produced erroneously low counts because of reduction in the counting efficiency caused by the crude oil. We have since modified our techniques so that this will no longer be a problem. The data presented here has been interpreted in light of this finding.

The effects of crude oil on the rate of glucose oxidation was measured in 21 water samples collected during the November Cook Inlet cruise (Table 22). The average percent reduction in the samples exposed to crude oil was 41. The other field study was conducted on 8 Beaufort Sea samples during the January, 1978 field trip. The average reduction in glucose oxidation rates in the presence of crude oil was measured at 45% (Table 22).

The effects of crude oil on glucose respiration was measured in 20 summer Beaufort Sea sediment samples as soon as they were received. The average reduction in respiration rate was 35% (Table 23). When the same experiment was conducted two weeks later, a reduction of 20% was observed. During the same studies, crude oil effects on glutamic acid respiration were also measured. The average reduction in respiration observed in these studies was 33% and 15% respectively. These data suggest that the apparent effect of crude oil on the microbial populations in sediments decreases with increased storage time.

A comparison of the effects of crude oil, crude oil extract, and "weathered" crude oil on glucose and glutamic acid respiration by microbial populations was made on the 20 Beaufort Sea sediments. The average percent reduction was essentially the same in all of these preparations when glucose was used. When the effect on glutamate respiration was measured, both crude oil and weathered crude oil had the same effect, the effect of the aqueous extract was less pronounced.

A pilot study was conducted to determine what effect crude oil has on the kinetics of respiration (Table 24). This study was conducted on sediment samples from the Beaufort Sea that had been stored for 2 months before they were used in these experiments, therefore, these results should be interpreted with caution. The calculated values for V_{max} were about the same in both sets of samples. In all cases, however, the T_t and the $K_t + S_n$ values increased in the samples that had been exposed to crude oil. This is the type of response one would expect if there was some component of the crude oil that the cells were utilizing as glucose. It is also the response one would expect from uncompetitive inhibition in classical enzyme kinetics. Further studies with fresh samples will be made during the next cruise to substantiate these observations.

VII. Discussion

A. Glucose and glutamic acid uptake and respiration in water and sediment samples

1. Cook Inlet

At this point, data have been collected during three cruises in the Cook Inlet; October, 1976, April, 1977 and November, 1977. Each successive study has produced higher resolution data which have shown consistent trends. The resulting patterns when interpreted in light of what is known about the hydrography and chemistry of the region, produces an overall picture of the dynamics of the system which will assist those in government and industry in making a more accurate assessment of the potential problems related to crude oil production in Cook Inlet.

A discussion of the conclusions drawn from these data as well as the facts and assumptions on which these were based have already been mentioned at length in section I.B.1. of this report. The following is an amplification of the data presented in that section.

There are two distinct water masses present in Cook Inlet; one to the north that is very turbid and of relatively low salinity and one to the south and southeast which is more typical of open ocean water. We have found that both of these water masses have characteristic patterns of microbial activity and respiration. Glutamic acid uptake studies in surface waters have shown that the relative microbial activity is very high and the respiration percentages are very low in the northern water mass. The reverse pattern is seen in the water mass to the south. Intermediate values were observed in regions where these two water masses meet in the area to the north and east of Augustine Island. This is the same region in which a gyre has been observed by other investigators. In general, the patterns of surface water microbial activity and respiration reflect the net surface circulation patterns reported by Miller and Allen (1976).

As far as we know, this is the first study made in which patterns of microbial activity in marine waters have been used to characterize more than one distinct water mass and to indicate regions of interaction between those water masses. The two water masses in question are clearly shown by the surface water salinity data illustrated in Figs. 5 and 6. This is a similar pattern to that observed by Kinney et al. (1969). This is also the same type of pattern that one would expect from the current data presented by Miller and Allen. Since these observations were taken at various times, it would appear that this is a relatively consistent feature in Cook Inlet. These same patterns are clearly shown in the relative levels of microbial activity and respiration percentages observed in the same region (Figs. 7-13) during all three Cook Inlet cruises.

At this point it is important to reflect on what these observations mean in terms of what is occurring in these water masses. The water mass to the southeast is coastal water which is being pushed into the inlet by inshore currents moving to the west. These waters probably contain very low levels of available organic nutrients. As a result, the level of microbial activity is low and the percent respiration is high. It has already been established by a number of investigators (Wright and Hobbie, 1966; Vaccaro and Jannasch, 1966; Crawford et al., 1974; and Carney and Colwell, 1976) that the uptake rate of simple labeled amino acids and sugars by natural microbial populations usually reflect the levels of nutrients present in the surrounding water. The significance of the percent respiration data is less clear. A relatively high percent respiration value indicates that the population is using proportionately more of the nutrient as an energy source and less of it to produce cellular material. There are at least two conditions in which this might occur. If the cells are starved, the cells will utilize most of added nutrient for energy requirements before biosynthesis is initiated. A more likely explaination is that growth factors are not present in sufficient concentration to allow biosynthesis to occur even though nutrients are available to the cells during the course of the experiment.

The high levels of relative microbial activity and low respiration rates found in the northern waters, indicate that these waters contain nutrients that are qualitatively and/or quantitatively different than those found in the southern waters. The regions where these two water masses mix show intermediate values between these two extremes. These intermediate values could be caused by at least two factors. As the northern water mass moves south along the western edge of the inlet, the nutrients present are being consumed by the microorganisms present. At the same time, low nutrient waters from the south are being mixed with other water thus diluting the nutrients.

Drs. Cline and Feely have shown in their studies that the water mass at any given point in Cook Inlet is well mixed vertically. We conducted relative microbial activity at three locations and at various depths during the November cruise. We found no significant microbial activity stratification with depth. It would thus appear that the observations made in the surface waters should hold true for the entire water column in a given location.

We have also observed that the relative levels of microbial activity are directly related to the levels of suspended matter in the surface waters. When relative microbial activity as measured using glutamic acid is compared with turbidity in the same samples, correlation coefficients of 0.87 and 0.89 were observed for all water samples collected during the April and November cruises respectively. This correlation is also substantiated by the suspended matter patterns reported by Feely and Cline (1977). There is a stricking similarity between these patterns and the patterns of microbial activity and respiration percentages reported here. During our determinations of bacterial concentrations using epifluorescent microscopy, we have observed that 70-80% of the bacteria present in water samples are associated with the particulate matter.

Feely and Cline also reported that much of the suspended matter found in the northern waters probably makes its way into the sediments of the Shelikof Strait. Our studies of relative microbial activity in the Cook Inlet and Shelikof Strait sediments during the April cruise tend to support this hypothesis; however, a somewhat different pattern was observed during the November cruise. During both cruises, relatively high rates of microbial activity were observed in the sediments of Tuxeni Bay, Kachemak Bay and the southern portion of Kamishak Bay. The high rates of activity seen in Kachemak Bay are probably due to the trapping of nutrients within the bay. It has been observed by other investigators that the net flow of water through this bay is very low. The extremely high rate observed in the sediments of the Homer boat basin is undoubtedly due to organic pollutants introduced from man's activities there. The extent to which this nutrient input affects the microbial activity in the rest of the bay is unknown.

The high levels of microbial activity observed in Tuxedni Bay sediments are probably due to the sedimentation of the microbiologically active suspended matter in the water column in this area. Assuming that the bacterial populations associated with these particles remain active even after they have settled into the sediments, then measurements of microbial activity in the sediments can be used as a tracer to determine the sedimentation patterns of the suspended matter found in the northern water mass. If we make this assumption, it would appear that at least some of this matter settles into the sediments in the southern Kamishak Bay area (Figs. 14 and 15). If the values observed for the two Shelikof Strait sediment samples analyzed during the April cruise are accurate, then it would appear that significant quantities of this material also settle out in the Shelikof Strait under certain conditions.

2. Beaufort Sea

During the Glacier cruise (summer, 1976), we did not see any significant trends in microbial activity in the sediment relative to geographical location. A similar study made on sediments collected during the summer, 1977 cruise did show a geographical trend. The levels of microbial activity were highest in the stations closest to Point Barrow. The difference in these two sets of observations could be due to yearly variations but is most likely related to the way in which the samples were taken. During the previous summer, the sediment samples were taken with a Van Veen grab. During the 1977 cruise, the sediment samples were taken with a Smith-McIntyre grab. The latter sampler, gives a much less disturbed sample thus the subsamples taken from it are more representative of the original. For this reason, we are recommending that either a Smith-McIntyre grab or box corer be used in all future microbiological work. The importance of working with relatively undisturbed sediments was graphically shown during our more recent Beaufort Sea study. Samples taken from the surface of the sediment by divers were very similar in their microbial characteristics to sediment samples taken from control and oiled sediment trays in the oil degradation study in Elson Lagoon. Another sample taken by divers a few days later which included sediments from a much greater depth had very low activity. When the same sample had been placed in a tray and left for 24 hours, the activity was the same as that found in undisturbed surface sediments. The observed increase was undoubtedly caused by a silting in by surrounding sediments.

Both water and sediment samples taken during the same time, gave relative microbial activity levels and respiration percentages which were essentially the same as those observed at the same location in April, 1976. These observations further support our earlier observation that the levels of microbial activity are approximately one order of magnitude lower in the winter than they are in the summer. The respiration percentages are, on the other hand, higher in the winter than they are in the summer (see our last annual report for details).

B. Nitrogen fixation studies

Under most conditions, nitrogen is usually not limiting to bacterial growth in seawater; however, the same may not be true in sediments. Inshore sediments often contain detritus particles which have very high carbon to nitrogen ratios. Studies of detrital food chains have shown that nitrogen fixation in sediments may be a very important factor in the effective utilization of detritus food particles by higher trophic levels (Mann, 1972; Fenchel and Jørgensen, 1977). This is particularly important when one realizes that the majority of organic nutrients available to support all of the animal population in the inlet probably come from detritus particles. In order for this to become available as a food source for animals from the level of the protozoa on up, the detritus particles must become colonized by bacteria. In order for bacteria to grow, they need fixed nitrogen.

Although nitrogen fixation rates in the seawater samples that we have analyzed have been too low to measure, most of the sediments analyzed showed detectable levels of nitrogen fixation. The sediments in some areas, notably Kachemak Bay and the Shelikof Straight, showed relatively high rates. During both cruises, we have measured levels of nitrogen fixation in Kachemak Bay sediments at about 1 ng nitrogen fixed per g dry wt. per h. If this is indeed representative of average nitrogen fixation rates over the normal year, and if nitrogen is limiting to bacteria growth in these sediments, then this level of nitrogen fixation could account for a yearly production of bacterial biomass in Kachemak Bay of 400 tons.

The studies of Dr. Feder and his associates (1977) have shown that the food chain can be very short from bacterial biomass to commercially valuable species. In the case of the King crab, one of the major pathways runs from bacteria in detritus to detrital feeding clam to crab. Anything that might affect bacterial production will be directly reflected in changes at higher trophic levels. We have conducted a series of experiments designed to measure the effects of crude oil on rates of nitrogen fixation. In untreated sediment samples, we found that crude oil did not significantly alter nitrogen fixation rates. These data suggested that the immediate effects of crude oil on this process is probably not an important factor; however, it is still not known what the longer term effects might be. It is quite likely that crude oil might not affect existing enzyme systems but it might affect enzyme induction, enzyme synthesis or cell growth. One approach that we have taken to evaluate the possible long term effects was to stimulate nitrogen fixation rates in sediment samples by adding sucrose. When this was done, the samples containing crude oil sometimes inhibited and sometimes stimulated rates of nitrogen fixation in the presence of sucrose. We are planning a series of experiments with pure cultures of nitrogen fixing bacteria to obtain more specific information on what effect crude oil has on this process.

Another approach to this problem is also being conducted in the Elson Lagoon studies that have already been mentioned. During this series of experiments, we will be comparing nitrogen fixation rates in sediment samples that have been exposed to crude oil over an extended period of time. This type of study should produce the most definitive answers to the long term effects problem.

There have been very few reports in the literature concerning the rates of nitrogen fixation in marine sediments. Of these, the study that most closely approximates ours was that of Herbert (1975). This was an *in situ* study of nitrogen fixation in sediment cores taken at a location on the northeast coast of Scotland. Herbert observed a maximum nitrogen fixation rate of 1.84 ng nitrogen fixed per g dry wt. per h. This rate is the *average* rate of nitrogen fixation observed by us in all sediment samples analyzed during the November Cook Inlet cruise. The maximum rate that we observed was 6.3 ng/g/h. In another study, Brooks et al. (1971) reported a range of nitrogen fixation in 8 sediments taken from a Florida estuary of from 0.64 to 6.0 ng N/g/h. The highest value that they observed was very close to the highest value that we observed in November (Homer boat basin). Marsho et al. (1975) reported an average annual nitrogen fixation rate of 2.9 ng N/g/h in sediments taken from 7 stations in the Rhode River close to Chesapeake Bay. These data suggest that the rates of nitrogen fixation that we observed in Cook Inlet and the Shelikof Strait are close to that observed in other marine sediments and relatively high when compared to sediments that were most similar (the Herbert study). Again this substantiates the potential importance of nitrogen fixation in Cook Inlet.

C. Effects of crude oil on nutrient uptake and mineralization rates by microbial populations

Our effects of crude oil studies on nutrient uptake and mineralization have shown that both of these processes are inhibited by the presence of crude oil. This was true when either glucose or glutamic acid was the nutrient source. This effect was seen in sediment samples when glucose was the substrate and when the microorganisms were exposed to either crude oil, an aqeous extract of crude oil or "weathered" crude oil.

In a recent report by Hodson et al. (1977), the effects of four oils on glucose uptake and mineralization were observed in seawater samples collected from the CEPEX seawater enclosure bags located in Saanich Inlet, British Columbia. They observed an inhibition effect similar to that observed by us in Cook Inlet waters. Our aquarium studies and the results of studies conducted by Atlas et al. (1976) on the long term effects of crude oil on microbial populations in Prudhoe Bay waters have shown that the presence of crude oil does not inhibit heterotrophic activity in marine microbial populations after extended exposure. In fact, heterotrophic activity may actually increase as the crude oil is degraded. What our short term exposure experiments do suggest is that components of crude oil may act as an environmental stress which effectively eliminates certain forms and encourages the growth of hydrocarbon utilizing bacteria. Dr. Atlas and his associates have been conducting chemostat studies at Barrow, Alaska under another program. These studies were designated to measure the fate and effects of oil on marine microorganisms in seawater under simulated *in situ* conditions. They observed that the species diversity index dropped with exposure time to crude oil. (R. M. Atlas, personnel cummunication). They have thus observed what we would have predicted from our acute effects studies.

If the presence of crude oil decreases the diversity of the species composition of a natural microbial population, it must affect the number of functions that that population is capable of performing. We are in the process of determining the microbial functions that are critical to the Arctic and Subarctic marine ecosystems and to assess what effect crude oil has on these processes

VIII. Conclusions

1. Evidence is accumulating which suggests that crude oil which is spilled in the turbid waters of the Upper Cook Inlet may become associated with the suspended matter found in these waters. If this occurs, then crude oil components would become associated with the sediment when these particles settle out of the water solumn. Our studies and the studies of Drs. Feely and Cline suggest that these particles probably settle out into the sediments of the southern Kamishak Bay and/or the sediments of the Shelikof Strait.

2. Measurements of relative microbial activity and respiration percentages can be used to characterize specific water masses and give some information about the organic nutrients found in these waters. The above measurements should be made in both the water column and sediments in new lease areas where this information is not available. These data should provide information about potential transport mechanisms as well as data about biological productivity potential.

3. Nitrogen fixation in the sediments of Cook Inlet and the Shelikof Strait may be an important contributing factor to the overall productivity of the detritus based food chain in that area.

4. Our studies on the effects of crude oil on nitrogen fixation in natural sediment samples showed that the presence of crude oil had little or no short term adverse effect on this process. The method used to determine longer term effects produced inconclusive evidence as to what effect may be produced in actual sediment samples in nature.

5. Crude oil did have an inhibitory effect on glucose respiration in natural marine microbial populations. This effect was noted when either crude oil, crude oil aqueous extract or weathered crude oil was used. This effect probably reflects an environmental stress which could cause a reduction in species diversity such as that already observed in Arctic marine waters exposed to crude oil over extended periods.

6. Observations made in Beaufort Sea sediment samples show that the highest rates of nitrogen fixation and relative levels of microbial activity were highest in the area near Point Barrow with the highest rates of crude oil biodegradation found to the east of Prudhoe Bay.

7. Other observations in the Beaufort Sea confirm earlier findings which indicated that the relative levels of microbial activity in the winter are about one order of magnitude lower than that found in the summer. Both the level of microbial activity and respiration in the water and sediment at one station in Elson Lagoon was the same in January, 1978 as it was in April, 1976.

8. The patterns of microbial activity and respiration percentages in the Cook Inlet surface waters are relatively constant. High levels of microbial activity and low respiration percentages were found in the northern water mass and the reverse pattern was seen in the waters to the south and southeast. These differences probably reflect qualitative and/or quantitative differences in organic nutrients present in these two water masses.

IX. Needs for future research

A. Detrital food webb studies

With the increasing emphasis on food webb studies in the Cook Inlet and the area around Kodiak Island, it is imparative that an analysis of microbiological variables be included in these studies. As more is known about the dynamics of the detrital food webb, it is becoming increasingly obvious that bacteria play a critical role in the energy transfer within this system (Fenchel and Jorgensen, 1977; Mann, 1972). It has been estimated that the majority of primary productivity in inshore communities is carried out by macrophytes rather than by phytoplankton (Mann, 1972). It has also been estimated that only about 10% of macrophytic biomass is utilized directly by grazers. Since this material has such high carbon to nitrogen ratios, it by itself is a very poor food source for marine animals. Observations to date suggest that this material must be colonized by bacteria before it can become a valuable food source for other organisms. The bacteria utilize the carbon from the plant material and absorb nitrogen and phosphate from the water to form a food source with relatively low carbon to nitrogen and carbon to phosphate ratios. When the plant material is ingested by marine animals, the bacteria are digested and the rest of the material is defecated. The resulting fecal pellets are recolonized by bacteria and reinjested etc., etc. The role of protozoa and meiofauna in the efficiency of energy transfer mediated by the bacterial population is poorly understood but it is known that both of these groups graze on bacteria and are thus increasing the efficiency of the bacterial degradation of detritus particles by some unknown mechanism. Of the inorganic nutrients required for this bacterial process, fixed nitrogen is most likely to be limiting, thus the importance of nitrogen fixation in sediments. Of the above mentioned processes, only one, to our knowledge, has been studied in terms of crude oil effects. This is our study of the effects of crude oil on nitrogen fixation in sediments which has been described above. It seems quite likely that there might be some critical step in energy transfer system that is susceptable to the presence of petroleum hydrocarbons.

Since relatively little is known about this critical process in the inshore food webb, it is imparative that a study be initiated which would include microbiologists and benthic ecologists with specific areas of expertise. Before the effects of crude oil on this process can be initated, basic observations must be made on the rate of energy flow through the major elements of the benthic community. As far as the microbiological studies are concerned, these would include measurements of bacterial biomass, growth rates, metabolic activity rates, as well as grazing rates by protozoa, protozoa growth rates, and biomass determinations. Once the methods have been established to make these observations, and some basic information has been established, then the effects of crude oil on these processes can be determined.

B. In situ studies of the fate and effects of crude oil in marine sediments

We recommend that the fate and effects studies which have been initiated in Elson Lagoon near Barrow, AK be continued. Both Dr. Atlas and ourselves have been involved in this study using oiled sediment samples in plastic trays. Dr. Atlas has been primarily studying the fate aspects of the project and we have concentrated on the effects aspects. This is a project which should be continued for an extended period of time so that the long range effects of crude oil as well as the long range fate can be determined under actual field conditions.

We also recommend that a similar study be initiated in the Cook Inlet since the conditions found in these two regions are so radically different. A similar approach should also be used to study the fate and effects of crude oil in the water column - a more challenging technological problem.

C. Background information on the microbiology of new lease areas

Our study of microbiological activity and respiration in the Cook Inlet and Shelikof Strait have given us a great deal of information about the dynamics of the system and have helped pinpoint potential problem areas within Cook Inlet. There is still a need to collect similar data in such areas as Bristol Bay and Norton Sound where currently none of this information is available.

X. Summary of last quarter operations

A. Field studies

During this quarter we conducted a field trip in January, 1978 to the Naval Arctic Research Laboratory in Barrow. We worked for about 10 days collecting sediment trays inoculated with crude oil which had been placed there last summer. The divers that had collected the first set of trays also established a new experiment by placing a new set of trays at the same location. These trays will be sampled again in April and September of this year. We measured relative rates of microbial activity and respiration percentages in sediment, ice and water samples. We also conducted crude oil effects studies on the same samples. Subsamples of sediments were returned to our laboratory at Oregon State for further analysis.

B. Laboratory studies

Much of our effort during this time has been devoted to analyzing samples that were returned from both the November Cook Inlet cruise and the January NARL field trip. We have also been analyzing the data that was collected during these two field trips. In addition, we have continued our crude oil degradation studies and have started analyzing degraded crude oil samples using our new GC - calculator interface. Studies have also been initiated to improve our current methodology and to gain expertise in conducting energy charge measurements in sediment microbial populations.

XI. Projected activities for next quarter

A. Field studies

In April we will be participating in the Cook Inlet chemistry cruise. During this cruise, we will be collecting sediment and water samples from both the Shelikof Strait and the Cook Inlet. The effects of crude oil on microbial activity and respiration and on nitrogen fixation in sediments will be studied. We will be coordinating our studies with those conducted by both the chemists and the benthic ecologist involved in the cruise.

We will also participate in a field trip to NARL to continue our study of the long term effects of crude oil on the microbial community in the Elson Lagoon sediments.

B. Laboratory studies

We will be continuing the studies that we have outlined under the previous section. In addition, we will be analyzing the nutrient chemistry information generated from the last few field trips as well as the data generated by the field trips being conducted during this quarter.

C. Problems encountered

An analysis of our sediment data indicates that the Van Veen grab samplers that have been available for our use in the past are not adequate for our work. In future field work we will require a sediment sampler that will produce a more representative sample.

We have also encountered problems with methodology that have been mentioned in this report. Studies are being conducted to eliminate problem areas.

XII. Acknowledgements

We would like to thank the crews of the NOAA ships Surveyor and Discoverer for their excellent assistance in our Cook Inlet studies and the employees of the Naval Arctic Research Laboratory at Barrow, AK for their excellent logistical support during our Beaufort Sea studies.

We would also like to thank Dr. Eugene Ruff with Dr. Andrew Carey's group (RU#7) for collecting sediment samples for us during the August,

1977 Beaufort Sea cruise. In addition, we would like to thank Dr. Rita Horner (RU#359) for transporting these samples from the field to our laboratory at Oregon State University.

We would also like to thank Dr. John Baross of our laboratory (not funded by NOAA) for his analysis of total bacterial concentrations, concentrations of nitrogen fixing bacteria, anaerobic bacterial concentrations and Vibrio sp. concentrations in sediment samples returned to our laboratory from field trips.

XIII. Literature cited

Atlas, R. M., E. A. Schofield, F. A. Morelli, and R. E. Cameron. 1976. Effects of petroleum pollutants on Arctic microbial populations. Environ. Pollut. 10: 36-43.

Arhelger, S. D., B. R. Robertson, ad D. K. Button. 1977. Arctic hydrocarbon biodegradation in Alaskan waters. In: Fate and Effects of Petroleum Hydrocarbon in Marine Ecosystems and Organisms. pp. 270-275. Pergamon Press. N.Y.

Brooks, R. H., Jr., P. L. Brezonik, H. D. Putnam, and M. A. Keirn. 1971. Nitrogen fixation in an estaurine environment: the Wacasassa on the Florida Gulf Coast. Limn. Oceanogr. 16: 701-710.

Carney, J. F. and R. R. Colwell. 1976. Heterotrophic utilization of glucose and glutamate in an estuary: Effect of season and nutrient load. Appl. Environ. Microbiol. 31: 227-233.

Feder, H. M. 1977. The distribution, abundance, diversity and biology of benthic organisms in the Gulf of Alaska and the Bering Sea. In: Environmental Assessment of the Alaskan Continental Shelf. Year ending March, 1977. 8: 367-710.

Feely, R. A., and J. D. Cline. 1977. The distribution, composition, transport, and hydrocarbon adsorption characteristics of suspended matter in the Gulf of Alaska. Lower Cook Inlet and Shelikof Strait. In: Environmental Assessment of the Alaskan Continental Shelf. April-June. 1: 787-800.

Fenchel, T. M., and B. B. Jørgensen. 1977. Detritus food chains of aquatic ecosystems: The role of bacteria. In: Advances in Microbial Ecology. 1: 1-58.

Griffiths, R. P., S. S. Hayasaka, T. M. McNamara, and R. Y. Morita. 1977. Comparison between two methods of assaying relative microbial activity in marine environments. Appl. Environ. Microbiol. 34: 801-805.

Griffiths, R. P., S. S. Haysaka, T. M. McNamara, and R. Y. Morita. 1978. Relative microbial activity and bacterial concentrations in water and sediment samples taken in the Beaufort Sea. Can. J. Microbiol. (in press).

Herbert, R. A. 1975. Heterotrophic nitrogen fixation in shallow estuarine sediments. J. Exp. Mar. Biol. Ecol. 18: 215-225.

Hodson, R. E., R. Azam, and R. F. Lee. 1977. Effects of four oils on marine bacterial populations: Controlled ecosystem pollution experiment. Bull. Mar. Sci. 27: 119-126.

Keirn, M. A. and P. L. Brezonik. 1971. Nitrogen fixation by bacteria in Lake Mize, Florida, and in some lacustrine sediments. Limn. Oceanogr. 16: 720-731.

Kinney, P. J., D. K. Button, and D. M. Schell. 1969. Kinetics of dissipation and biodegradation of crude oil in Alaska's Cook Inlet. In: Prevention and Control of Oil Spills. API-EPA Proceedings. pp. 333-340.

Mann, K. H. 1972. Macrophyte production and detritus food chains in coastal waters. Proc. IBP-UNESCO Symp. Detritus and Its Ecological Role In: Aquatic Ecosystems. Pallanza. It. pp. 353-383.

Marsho, T. V., R. P. Burchard, and R. Fleming. 1975. Nitrogen fixation in the Rhode River estuary of Chesapeake Bay. Can. J. Microbiol. 21: 1348-1356.

Miller, R. C. and A. A. Allen. 1976. Oil spill trajectory analysis: Lower Cook Inlet, Alaska. In: Environmental Assessment of the Alaskan Continental Shelf. Oct.-Dec., 1976. pp. 765-824.

Morita, R. Y. and C. E. ZoBell. 1955. Occurrence of bacteria in pelagic sediments collected during the Mid-Pacific Expedition. Deep-Sea Res. 3: 66-73.

Robertson, B., S. Arhelger, P. J. Kinney, and D. K. Button. 1973. Hydrocarbon biodegradation in Alaskan waters. In: The Microbial Degradation of Oil Pollutants. pp. 171-184.

Stewart, W. D. P., G. P. Fitzgerald, and R. H. Burns. 1967. *In situ* studies on N_2 fixation using the acetylene reduction technique. Proc. N.A.S. (US) 58: 2071-2078.

Vaccaro, R. F. and H. W. Jannasch. 1966. Studies on heterotrophic activity in seawater based on glucose assimilation. Limn. Oceanogr. 11: 596-607.

Wright, R. T., and J. E. Hobbie. 1966. Use of glucose and acetate by bacteria and algae in aquatic ecosystems. Ecology. 47: 447-464.

Zimmerman, R. and L.-A. Meyer-Reil. 1974. A new method for fluorescence staining of bacterial populations on membrane filters. Kieler Meeresforschungen 30: 24-27.

Table 1. Correlation coefficients calculated from the comparison between the maximum potential uptake rate of glutamic acid (V_{max}) and the uptake rate of glutamic acid at the concentration listed in the table.

Location of the study	Number of samples analyzed	Substrate concentration μg/liter	Correlation coefficient
	WATER SAMPLES		
Antarctic, February, 1972	83	7.9	0.92
Beaufort Sea, August, 1975	47	2.3	0.88
Beaufort Sea, April, 1976	25	3.5	0.90
Beaufort Sea, August, 1976	16	2.7	0.77
Gulf of Alaska, March, 1976	26	3.5	0.95
Lower Cook Inlet, October, 1976	35	2.7	0.95
Total samples	232		
	SEDIMENT SAMPLES		
Beaufort Sea, August, 1975	23	13.0	0.90
Beaufort Sea, April, 1976	13	3.5	0.94
Beaufort Sea, August, 1976	11	72.7	0.98
Gulf of Alaska, March, 1976	20	80.9	0.98
Lower Cook Inlet, October, 1976	12	72.7	0.97
Total Samples	79		

Table 2. Summary of water depth, temperature, and salinity data and positions of stations sampled during the April, 1977 Cook Inlet cruise. Sediment samples having the same number as the listed water samples were taken at the same locations. (*) those stations at which temperature and salinity were determined using a portable field salinometer of relatively low accuracy. (a) those beach samples taken 10 meters offshore. (b) those beach samples taken in the surf line.

Station number	Water Sample number	Depth of water column (meters)	Temperature		Salinity 0/00		Lat. North	Long. West
			Surface	Bottom	Surface	Bottom		
D *	GW401 (b)	shore	6.5	--	16.5	--	57 39.0	152 31.0
266 *	GW402	36	1.0	--	21.0	--	60 41.2	151 25.0
265 *	GW403	39	0.44	0.38	27.38	27.41	60 34.3	151 51.4
244	GW404	56	2.21	2.36	30.08	30.21	60 09.6	152 15.0
245 *	GW405	46	2.9	--	26.0	--	60 06.8	152 14.0
S *	GW406 (a)	shore	2.8	--	24.5	--	60 10.7	152 36.0
S *	GW407 (b)	shore	4.5	--	24.0	--	"	"
T *	GW408 (a)	shore	2.8	--	25.0	--	60 09.3	152 38.0
T *	GW409 (b)	shore	4.0	--	25.0	--	"	"
242	GW410	39	2.35	2.33	30.19	30.19	60 09.5	152 25.0
U *	GW411 (a)	shore	6.0	--	15.0	--	60 12.7	152 36.5
V *	GW412 (a)	shore	4.0	--	22.0	--	60 13.7	152 46.8
V *	GW413 (b)	shore	2.0	--	23.0	--	"	"
242	GW415	33	2.29	2.31	30.11	30.10	60 09.5	152 25.0
242	GW416	33	2.28	2.29	30.08	30.08	"	"
246 *	GW417	15	2.5	--	25.5	--	60 03.0	151 46.2
235	GW418	40	2.81	2.83	30.60	30.64	59 40.8	152 38.6
236	GW419	48	4.06	3.96	31.41	31.37	59 40.9	151 14.1
227	GW420	90	4.46	4.36	31.41	31.49	59 33.5	151 36.4
K *	GW421 (a)	shore	2.5	--	25.5	--	59 36.1	151 25.0
K *	GW422 (b)	shore	5.0	--	26.0	--	"	"
J *	GW423 (a)	shore	4.6	--	26.8	--	59 35.3	151 10.7
J *	GW424 (b)	shore	5.0	--	25.0	--	"	"
229	GW425	66	4.16	4.11	31.25	31.33	59 37.6	151 18.0
216	GW426	86	4.95	4.97	31.46	31.46	59 18.2	152 14.1
217	GW427	74	4.64	4.47	31.47	31.51	59 27.0	152 23.2
226	GW428	60	4.66	4.66	31.46	31.47	59 33.5	152 18.7
225	GW429	39	3.68	4.44	31.25	31.48	59 31.4	152 41.5
213	GW430	33	3.13	3.13	30.98	30.98	59 30.0	153 13.2
214	GW431	49	3.28	3.27	31.10	31.09	59 18.2	153 14.3
204	GW432	36	2.72	2.95	30.79	30.91	59 14.2	153 39.7
206	GW433	39	4.89	4.95	31.51	31.53	59 09.8	153 08.2
212	GW434	27	2.30	2.48	30.59	30.66	59 32.4	153 21.8
215	GW435	76	3.41	4.62	31.16	31.51	59 21.9	152 48.7
212	GW436	22	2.38	2.39	30.68	30.70	59 33.4	153 24.5
208	GW437	104	4.92	5.39	31.62	31.92	59 14.7	152 45.5
205	GW438	148	5.00	5.42	31.64	32.14	59 06.3	152 43.1
207	GW439	148	4.82	5.28	31.67	31.92	58 59.9	152 52.0
395	GW440	170	--	--	--	--	58 53.0	152 54.0
106	GW441	202	4.75	5.56	31.49	32.08	59 00.4	152 00.6
105	GW442	118	4.74	7.49	31.29	32.63	58 50.0	151 20.7
398	GW443	122	4.69	5.32	31.74	32.11	58 48.8	152 11.9
388	GW444	169	--	--	--	--	58 28.6	153 10.9
378	GW445	95	4.22	4.98	31.72	31.95	58 02.0	153 29.5

Table 3. Summary of water depth, temperature, and salinity data and positions of stations sampled during the November, 1977 Cook Inlet cruise.

Station number	Sample number	Depth in meters	Temperature Surface	Temperature Bottom	Salinity 0/00 Surface	Salinity 0/00 Bottom	Lat. North	Long. West
429	GW501	88	7.11	7.14	31.668	32.218	57 58.0	151 58.8
418	GW502	168	6.43	5.96	32.020	32.872	58 04.8	151 42.0
407	GW503	75	6.16	5.50	32.224	33.162	58 19.0	151 25.7
398	GW504	124	6.96	5.64	31.996	33.084	58 48.9	152 11.6
J*	GW505	surf.	7.5		29		59 35.5	151 10.5
K*	GW506	surf.	3.5		29		59 36.5	151 25.5
380	GW507	75	4.78	7.39	29.856	31.380	58 39.5	153 23.5
370	GW508	125	5.20	7.27	30.207	32.272	58 17.2	154 02.3
360	GW509	225	6.99	5.44	30.658	33.139	57 57.0	154 41.3
350	GW510	265	6.68	5.85	30.538	32.909	57 31.4	155 32.8
354	GW511	251	6.09	4.96	31.836	33.502	57 27.5	155 14.5
358	GW512	186	6.25	5.38	31.750	33.068	57 18.4	154 57.0
364	GW513	214	6.06	5.04	31.900	33.423	57 50.1	154 25.0
378	GW514	91	6.38	6.91	31.242	32.278	58 01.6	153 29.0
374	GW515	193	6.98	5.46	31.342	33.097	58 10.8	153 45.0
388	GW516	214	7.34	5.81	31.249	32.939	58 27.0	152 57.5
384	GW517	178	7.31	6.40	30.884	32.684	58 33.4	153 14.3
394	GW518	126	7.43	6.62	31.035	32.486	58 42.4	152 59.7
390	GW519	163	5.08	6.68	30.202	32.600	58 53.3	153 11.5
395	GW520	168	7.11	6.11	31.903	32.784	58 53.3	152 54.0
205	GW521	141	7.82	6.50	31.040	32.652	59 06.2	152 41.3
206	GW522	87	6.61	8.04	30.309	31.984	59 09.4	153 07.1
212	GW523	27	5.71	5.71	30.096	30.099	59 32.5	153 21.2
211	GW524	19	5.60	5.63	30.252	30.265	59 26.1	153 37.3
213	GW525	37	5.97	5.99	29.895	29.902	59 29.4	153 12.7
214	GW526	50	6.24	6.59	29.977	30.483	59 17.8	153 14.0
203	GW527	44	5.05	5.47	30.302	30.469	59 06.2	153 29.1
201	GW528	18					59 12.8	153 52.4
204	GW529	33					59 14.3	153 38.5
215	GW530	81	6.47	8.14	30.632	31.931	59 21.1	152 48.8
208	GW531	106	7.00	7.89	31.032	32.062	59 15.0	152 44.9
207	GW532	167	7.03	6.36	31.402	32.703	58 59.8	152 52.9
216	GW533	75	7.81	7.92	31.413	31.544	59 18.0	152 15.0
217	GW534	71	7.56	7.59	31.494	31.531	59 27.7	152 22.9
225	GW535	64	7.13	7.12	31.306	31.318	59 31.5	152 41.9
226	GW536	49	7.18	7.21	31.336	31.268	59 33.3	152 18.6
228	GW537	46					59 32.9	151 53.4
227	GW538	88	7.23	7.38	30.991	31.144	59 33.5	151 36.1
249	GW539	44	6.29	6.29	30.802	30.811	59 51.3	152 02.1
246	GW540	20			30.714		60 02.5	151 47.5
266	GW541	40	4.4		23.031		60 41.2	151 25.6
265	GW542	23					60 33.6	151 51.6
255	GW543	50	5.35	5.35	28.810	28.991	60 19.9	151 45.9
248	GW544	51	5.87	6.05	29.760	29.962	59 50.5	152 21.4
235	GW545	36	6.08	6.09	30.046	30.067	59 42.1	152 38.0
234	GW546	43	6.33	6.35	30.356	30.360	59 37.6	152 55.8
245	GW547	44	5.29	5.70	29.358	29.616	60 06.7	152 14.5
241	GW548	31					60 06.8	152 36.0
U*	GW549	surf.	2.0		27		60 12.8	152 36.1
V*	GW550	surf.	2.0		28		60 13.7	152 45.7
241	GW551	31					60 06.8	152 36.0
242	GW552	35	5.05	5.39	29.343	29.442	60 09.0	152 25.5
247	GW553	34					59 56.0	152 37.1
233	GW554	26					59 50.4	152 56.5
213	GW555	35	5.56	5.56	30.280	30.287	59 29.4	153 12.7
236	GW556	47	6.95	6.95	31.390	31.383	59 41.3	152 14.1
229A	GW557	24	5.48	5.58	30.729	30.811	59 40.4	151 14.3
229	GW558	75	6.15	6.98	30.902	31.111	59 37.5	151 17.8
106	GW559	209	6.90	6.62	31.540	32.386	59 00.6	152 01.0
105	GW560	126	6.45	6.77	31.174	32.605	58 49.8	151 19.2

(*) Shore stations. Temperature and salinity measurements were made using a portable salinometer.

Table 4. Description of sample position, water column depth, grab numbers (OSU), sample numbers, station numbers and sampling date for all sediment samples collected during the summer, 1977 Glacier Cruise.

Sample number	Grab number	Station number	Sample depth (meters)	Date	Position Lat	Long.
BB301	1523	14b	123	8/7	71° 46'	155° 35'
" 302	1529	18	384	8/9	71 57.5	154 34
" 303	1536	19	51	8/10	71 34.2	153 39.5
" 304	1544	24b	55	8/11	71 19.2	152 54
" 305	1555	25a	40	8/11	71 13.8	152 57.9
" 306	1568	25	24	8/11	71 0.6	153 01
" 307	1569	24	79	8/12	71 21.2	152 35
" 308	1580	24a	102	8/12	71 23.0	152 41
" 309	1586	31a	42	8/15	71 07.2	149 56.7
" 310	1588	74a	21	8/16	70 39.0	148 28.5
" 311	1595	80a	30	8/18	70 31.4	147 30.5
" 312	1598	91	31	8/18	70 23.2	146 33.3
" 313	1600	99	3841	8/20	72 53.8	146 27
" 314	1621	115	659	8/25	70 42.8	141 39.5
" 315	1628	110	26	8/26	69 49.5	141 28.5
" 316	1642	113	50	8/26	70 10.0	141 17.7
" 317	1648	114	106	8/27	70 33	142 27.5
" 318	1654	103	146	8/27	70 37.5	143 57
" 319	1660	95	521	8/29	71 01.5	145 26
" 320	1662	93	42	8/30	70 40.5	146 31

For tempt salinity data see Dr. Horner's annual report.

Table 5. Relative levels of microbial activity and percent respiration of glutamic acid and glucose observed in all water samples collected during the April cruise.

Station number	Sample number	*Substrate Uptake		Percent Respiration	
		Glucose	Glutamic Acid	Glucose	Glutamic Acid
D	GW401	6.7	38.8	51	76
266	GW402	8.5	52.4	15	36
265	GW403	2.7	24.7	17	34
244	GW404	1.6	14.6	15	31
245	GW405	1.6	11.7	27	35
S	GW406	2.6	15.2	19	38
S	GW407	3.3	25.7	20	44
T	GW408	2.4	13.5	15	34
T	GW409	1.1	8.3	17	34
242	GW410	1.9	15.5	16	32
U	GW411	7.9	67.7	23	58
V	GW412	39.7	129	15	50
V	GW413	18.0	78.9	16	39
242	GW415	1.8	9.3	5	27
242	GW416	--	17.9	--	33
246	GW417	11.5	66.5	14	34
235	GW418	2.0	6.8	16	34
236	GW419	0.3	0.9	34	52
227	GW420	0.4	0.9	26	61
K	GW421	3.7	8.0	47	53
K	GW422	6.7	28.1	22	54
J	GW423	0.5	1.8	41	49
J	GW424	1.0	4.8	25	58
229	GW425	0.9	0.9	36	67
216	GW426	0.3	2.0	47	61
217	GW427	0.3	1.0	39	64
226	GW428	0.3	0.7	42	61
225	GW429	0.6	1.5	36	55
213	GW430	0.3	1.8	40	41
214	GW431	0.3	0.5	35	42
204	GW432	0.8	3.0	34	48
206	GW433	0.4	0.6	31	56
212	GW434	1.1	3.8	32	54
215	GW435	0.5	1.5	37	62
212	GW436	0.6	2.0	26	40
208	GW437	0.2	0.8	36	61
205	GW438	1.0	2.7	36	64

Table 5. (con't)

Station number	Sample number	*Substrate Uptake Glucose	 Glutamic Acid	Percent Respiration Glucose	 Glutamic Acid
207	GW439	1.0	2.0	39	67
395	GW440	0.2	0.7	45	68
106	GW441	0.2	0.5	39	45
105	GW442	0.4	2.0	45	72
398	GW443	0.7	2.9	49	70
388	GW444	2.0	2.6	16	70
378	GW445	0.8	2.2	30	62

(*) The uptake rates are reported as ng substrate/liter/h.

Table 6. Relative levels of microbial activity and percent respiration of glutamic acid and glucose observed in all water samples collected during the November cruise.

Station number	Sample number	*Substrate Uptake Glucose	Glutamic Acid	Percent Respiration Glucose	Glutamic Acid
429	GW501	<0.2	1.1	L	60
418	GW502	0.4	0.9	67	59
407	GW503	0.3	1.4	41	68
398	GW504	<0.2	0.4	L	71
J	GW505	<0.2	1.1	L	63
K	GW506	11.3	18.0	25	61
380	GW507	<0.2	1.0	L	61
370	GW508	<0.2	1.0	L	63
360	GW509	<0.2	0.6	L	59
350	GW510	<0.2	1.0	L	67
354	GW511	<0.2	1.1	L	62
358	GW512	<0.2	0.9	L	56
364	GW513	<0.2	0.8	L	61
378	GW514	<0.2	1.2	L	68
374	GW515	<0.2	<0.4	L	L
388	GW516	<0.2	<0.4	L	L
384	GW517	<0.2	0.8	L	76
394	GW518	<0.2	<0.4	L	L
390	GW519	<0.2	0.4	L	79
395	GW520	<0.2	0.7	L	76
205	GW521	<0.2	<0.4	L	L
206	GW522	<0.2	0.9	L	62
212	GW523	<0.2	0.5	L	67
211	GW524	<0.2	1.3	L	67
213	GW525	0.4	2.0	39	57
214	GW526	<0.2	0.8	L	69
203	GW527	0.4	2.8	35	63
201	GW528	0.9	3.8	44	65
204	GW529	0.8	3.2	21	61
215	GW530	0.2	0.5	47	64
208	GW531	0.2	1.3	31	79
207	GW532	<0.2	0.4	L	90
216	GW533	<0.2	0.6	L	82
217	GW534	<0.2	0.5	L	81
225	GW535	0.3	2.0	60	60

Table 6 (con't)

		*Substrate Uptake		Percent Respiration	
Station number	Sample number	Glucose	Glutamic Acid	Glucose	Glutamic Acid
226	GW536	<0.2	1.1	L	63
228	GW537	0.2	0.5	89	64
227	GW538	<0.2	2.0	L	76
249	GW539	1.0	7.5	36	51
246	GW540	2.0	8.5	19	44
266	GW541	6.6	61.0	12	32
265	GW542	1.8	16.5	14	35
255	GW543	2.0	4.1	16	47
248	GW544	<0.2	1.3	L	31
235	GW545	<0.2	2.8	L	45
234	GW546	0.3	3.3	15	36
245	GW547	0.3	4.3	29	48
241	GW548	4.4	30.3	13	35
U	GW549	4.3	19.0	14	31
V	GW550	6.1	44.4	13	39
241	GW551	2.4	11.9	17	37
242	GW552	0.4	2.5	22	39
247	GW553	3.3	21.0	14	34
233	GW554	0.6	2.6	27	56
213	GW555	0.5	3.3	33	58
236	GW556	0.2	1.6	36	66
229A	GW557	0.4	2.5	32	54
229	GW558	0.4	2.6	43	65
106	GW559	<0.2	1.0	L	65
105	GW560	<0.2	0.6	L	70

(*) The uptake rates are reported as ng substrate/liter/h.

(L) Those values which were too low to obtain an accurate rate.

Table 7. A comparison of glutamic acid uptake in water samples taken in the surf zone and 10 meters offshore during the April Cook Inlet cruise.

Glutamic acid uptake (ng/1/h)	
Surfline	Offshore
14	4.9
26	5.8
39	21
8.3	0.9
256	236
51	50
3.5	2.1
7.3	0.4
3.3	2.6
2.4	1.1
40	18
6.7	3.7
1.0	0.5

Table 8. Relative levels of microbial activity and percent respiration of glucose and glutamic acid observed in samples collected at Elson Lagoon, Barrow, AK in January, 1978

Sample number	*Substrate Uptake		Percent Respiration	
	Glucose	Glutamic acid	Glucose	Glutamic Acid
		WATER SAMPLES		
BW401	0.4	4.8	51	69
¢BI401	0.5	4.5	37	69
BW402	0.3	3.8	46	64
BW403	0.3	3.4	34	68
BW408	0.3	2.4	32	61
		SEDIMENT SAMPLES		
BB402	3.4	22.6	25	44
BB403	7.8	27.6	20	41
BB404	5.7	44.3	20	45
BB405	2.9	14.5	27	49
BB406	2.0	14.9	27	48
BB407	0.2	2.8	42	55
BB408	1.2	6.0	23	51
BB409	1.1	6.1	24	50
BB410	3.4	19.9	23	48

¢ Melted ice water

* Substrate uptake reported as ng substrate taken up/unit/h. The unit for water samples was liters and the unit for sediment samples was g. gry wt.

Table 9. Relative levels of microbial activity and respiration percentages observed using glucose, glutamic acid and acetate in all sediment samples collected during the April cruise.

		*Substrate Uptake			Percent Respiration		
Station number	Samples number	Glucose	Acetate	Glutamic acid	Glucose	Acetate	Glutamic acid
D	GB401	0.6	1.8	0.01	36	73	48
U	" 411	24.0	19.2	0.89	16	75	45
V	" 412	18.0	7.5	0.66	14	70	37
227	" 420	18.4	5.7	0.36	16	54	49
K	" 421	44.8	13.3	1.57	22	32	54
229	" 425	12.8	6.0	0.30	19	60	45
213	" 430	3.7	6.7	0.14	36	49	41
214	" 431	2.0	4.9	0.08	19	63	40
204	" 432	13.2	7.3	0.37	22	55	46
212	" 434	6.4	4.6	0.16	32	57	41
212	" 436	5.1	13.3	0.17	26	62	45
395	" 440	11.6	9.3	0.27	16	62	45
105	" 442	1.4	6.3	0.11	23	61	42
388	" 444	618	72.4	9.22	65	84	57
378	" 445	211	22.1	10.50	35	44	60

*Uptake rates reported as ng/g dry wt/h.

Table 10. Relative levels of micobial activity and percent respiration of glutamic acid and glucose observed in all sediment samples collected during the November cruise.

		*Substrate Uptake		Percent Respiration	
Station number	Sample number	Glucose	Glutamic Acid	Glucose	Glutamic Acid
429	GB501	0.9	75	27	58
418	GB502	3.2	61	24	55
K	GB506	32.6	787	19	47
380	GB507	1.5	20	16	L
370	GB508	1.9	20	33	L
360	GB509	2.6	22	22	46
350	GB510	0.7	20	29	L
354	GB511	1.5	20	39	53
358	GB512	<0.4	20	L	L
364	GB513	1.2	33	35	42
378	GB514	0.9	31	40	61
374	GB515	1.4	20	51	L
388	GB516	<0.4	20	L	L
384	GB517	<o.4	16	L	75
394	GB518	<0.4	20	L	L
390	GB519	2.2	20	36	70
395	GB520	0.7	20	40	L
212	GB523	2.6	41	26	57
211	GB524	5.4	73	23	51
213	GB525	3.1	38	34	43
214	GB526	3.4	61	13	48
203	GB527	14.5	204	17	47
204	GB529	7.1	106	21	45
207	GB532	1.4	76	32	55
227	GB538	6.7	129	19	55
U	GB549	23.3	572	13	45
233	GB554	3.9	87	20	46
229A	GB557	21.5	252	18	48
229	GB558	6.4	231	19	47

*Uptake rates reported on ng/g dry wt/hr.

Table 11. Relative rates of microbial activity and respiration percentages observed in sediment samples collected during the summer, 1977 Glacier cruise in the Beaufort Sea.

	Substrate Uptake		Percent Respiration	
Sample number	*Glucose	**Glutamic acid	Glucose	Glutamic acid
BB301	56.5	0.95	22	53
BB302	25.6	0.27	24	49
BB303	15.3	0.62	15	28
BB304	4.8	0.49	22	38
BB305	6.0	0.46	18	35
BB306	26.4	1.06	34	40
BB307	7.3	0.34	16	37
BB308	20.3	0.43	17	38
BB309	7.2	0.49	24	38
BB310	0.8	0.03	28	50
BB311	1.1	0.04	25	39
BB312	6.3	0.50	23	37
BB313	0.9	0.06	42	38
BB314	2.0	0.41	38	40
BB315	1.1	0.04	20	35
BB316	5.5	0.43	28	38
BB317	6.6	0.38	18	33
BB318	4.1	0.49	24	27
BB319	2.3	0.42	29	32
BB320	3.8	0.42	24	44
Average	10.2	0.42	25	38

* Substrate uptake reported as ng/g dry wt/h.

** Substrate uptake reported as μg/g dry wt/h.

Table 12. Rates of nitrogen fixation observed in sediments collected during the April cruise.

Station number	Sample number	Nitrogen fixation rates ng/g dry wt./hr Field	Laboratory
D	GB401	0.06	
U	GB411	0.09	0.16
V	GB412	0.02	
227	GB420	0.52	0.65
K	GB421	1.36	
J	GB424	0.11	
229	GB425	0.90	0.90
204	GB432	0.05	
212	GB434	0.02	
215	GB435	0.00	
212	GB436	0.03	
208	GB437	0.01	
395	GB440	0.43	0.39
105	GB442	0.00	
388	GB444	0.33	0.50
Average		0.28 ng/g hr	
Correlation coefficient lab vs. field on four samples		0.96	
Average rate observed in five sediments taken from Yaquina Bay, Oregon		1.07 ng/g/hr	

Table 13. Rates of nitrogen fixation in sediments collected during the November cruise.

		*Nitrogen Fixation Rates			
		Field Observations		Laboratory Observations	
Station number	Sample number	No oil	Oil added	No Oil	¢April rates
429	GB501	0.3			
418	GB502	0.9			
K	GB506	6.3	3.6	1.4	1.4
380	GB507	0.3	0.7	0.1	
370	GB508	0.5			
360	GB509	1.3		0.1	
350	GB510	1.2		0.2	
354	GB511	4.4	4.1	0.4	
358	GB512	2.5		0.1	
364	GB513	2.3		0.4	
378	GB514	0.8		0.1	
374	GB515	2.5	2.2	0.5	
388	GB516	0.8			
384	GB517	0.5	0.3		
394	GB518	0.3	0.2		
390	GB519	0.3			
395	GB520	0.5			0.4
212	GB523	0.05			0.03
211	GB524	0.15			
213	GB525	0.08			
214	GB526	0.07			
203	GB527	0.3			
204	GB529	0.15	0.2		0.05
207	GB532	0.8		0.1	
227	GB538	1.7	1.4	0.3	0.5
U	GB549	0.2			0.09
233	GB554	0.2			
229A	GB557	0.5	0.6		
229	GB558	1.0	1.0	0.5	0.9
Average		1.1 @1.8 @@2.1	1.4	0.4	

* Rates of nitrogen fixation reported as ng nitrogen fixed per g dry wt. per h.

¢ Nitrogen fixation rates observed in sediments collected at the same stations during the April, 1977 cruise.

@ Mean value for sediments which had been analyzed for crude oil effects.

@@ Mean value for sediments which had also been analyzed in our laboratory several weeks after the field observations.

Table 14. Nitrogen fixation rates observed in Beaufort Sea sediment samples as calculated using the acetylene reduction method.

Sample number	*Nitrogen fixation rate
301	0.21
302	0.20
303	0.18
304	0
305	0
306	0.12
307	0
308	0.09
309	0.03
311	0.05
312	0
313	0
314	0.02
315	0.01
316	0.07
317	0.003
318	0
319	0.09
320	0
Average	0.06

*Values reported as ng nitrogen fixed per gram dry weight of sediment per h.

Table 15. Concentrations of bacteria in water and sediment samples collected during the April cruise as determined by epiflourescent microscopy.

WATER

Sample number	10^5 Cells/ml	Sample number	10^5 Cells/ml
GW401	2.4	GW423	1.1
GW402	17.4	GW424	1.0
GW403	23.3	GW425	1.4
GW404	10.9	GW426	2.2
GW405	17.4	GW427	1.4
GW406	19.6	GW428	1.3
GW407	32.7	GW429	0.9
GW408	14.1	GW430	1.0
GW409	12.4	GW431	1.7
GW410	12.4	GW432	1.8
GW411	17.0	GW433	1.7
GW412	96.4	GW434	1.1
GW413	138	GW435	0.8
GW415	1.0	GW436	5.7
GW416	1.1	GW437	0.9
GW417	121	GW438	0.8
GW418	6.5	GW439	1.0
GW419	1.2	GW440	0.8
GW420	1.0	GW441	5.3
GW421	1.2	GW442	2.0
GW422	1.3	GW443	0.7
Average	3.0×10^6	GW444	1.4
		GW445	2.0

SEDIMENTS

	10^9 Cells/ml
GB401	0.4
GB411	4.8
GB412	7.1
GB420	3.6
GB421	3.1
GB425	4.8
GB430	5.9
GB431	7.3
GB432	9.2
GB434	7.2
GB436	8.9
GB440	5.8
GB442	3.3
GB444	2.1
GB445	3.1
Average	2.5×10^9

Table 16. Concentrations of various types of bacteria found in the Beaufort Sea sediment samples. All numbers are in number of cells per g dry wt. sediment.

Sample Number	Total Counts Lib-X	2216	Anaerobic count	Total vibrios	Percent fermentative	Percent lipase+
BB301	3.0E7		7.7E6	7.7E5	26	6
BB302	1.2E7	5.4E6	3.5E6	7.9E4	29	5
BB303	1.0E7	7.0E6	1.4E6	8.7E5	14	10
BB304	8.8E6		1.3E6	9.5E5	15	12
BB305	4.5E6	2.4E6	7.5E5	4.0E5	17	2
BB306	1.6E7	4.3E6	2.6E6	7.4E5	16	9
BB307	1.9E7	1.0E7	4.5E6	2.0E6	24	10
BB308	1.9E7	8.6E6	4.8E6	1.1E6	25	10
BB309	7.1E6		2.0E6	8.0E6	29	20
BB310	1.5E6	4.5E5	3.1E5	1.3E5	20	9
BB311	8.4E5	5.1E5	4.5E4	2.6E4	5	23
BB312	5.8E6		4.3E5	2.3E5	7	11
BB313	1.5E6	5.0E5	2.3E4	1.1E4	1.6	18
BB314	9.4E5		2.1E4	2.2E4	2	19
BB315	9.4E5		9.8E4	3.2E4	10	12
BB316	9.3E6	3.6E6	8.1E5	4.3E5	9	15
BB317	2.7E7	3.8E6	9.8E6	1.5E5	36	8
BB318	3.9E6	1.1E6	2.7E5	1.8E5	7	5
BB319	3.5E6	6.9E5	3.0E5	7.9E4	8.5	17
BB320	6.8E6		8.2E5	1.4E5	12	12
Average	9.4E6	3.7E6	2.1E6	4.6E5	16	12

Percent fermentative and percent lipase positive based on Lib-X total counts as 100%.
All count data based on plates that had been incubated at 0.5C for 14 days.

Table 17. Concentrations of various types of bacteria found in Beaufort Sea Sediment samples collected during the January Elson Lagoon study.

	Total # Bacteria			
Sample number	Lib X	Marine Agar 2216	Lib X + 1% Crude oil	Percent Lipolytic Bacteria
BB402	1.9E6	1.6E6	1.2E6	15
BB403	2.3E6	2.1E6	8.2E5	15
BB404	3.6E6	2.7E6	2.0E6	3
BB405	2.9E6	1.4E6	1.0E6	10
BB406	3.2E6	7.8E6	3.9E6	8
BB407	2.9E5	2.2E5	1.0E6	12
BB408	2.4E5	3.1E5	3.7E5	6
BB409	7.6E6	9.3E6	6.5E6	88
BB410	8.8E5	8.5E5	1.4E6	11

Table 18. Correlation coefficients calculated from various measurements made on Beaufort Sea sediments.

	Glutamic acid	Glucose uptake	Lib "X" plate counts	2216 plate counts	Tween 80 plate counts	Anaerobes	Total vibrios	Total sucrose utilizers	% fermentative bacteria	% lipase producers
Glucose uptake	0.68									
Lib "X" plate counts	0.57	0.73								
2216 plate counts	0.35	0.60	0.73							
Tween 80 plate counts	0.49	0.79	0.90	0.92						
Anaerobes	0.37	0.61	0.95	0.55	0.84					
Total vibrios	0.39	0.32	0.53	0.87	0.60	0.38				
Total sucrose utilizers	0.52	0.67	0.62	0.60	0.70	0.47	0.49			
% fermentative bacteria	0.12	0.12	0.25	-0.01	0.22	0.30	0.07	0.03		
% lipase producers	-0.35	-0.44	-0.45	-0.31	-0.43	-0.40	-0.19	-0.29	-0.03	

Table 19. Correlation coefficients observed between measurements made in 16 sediment samples collected during the April cruise.

	*Total plate counts	Total fermentative organisms	Total *Vibrio* counts	Total sucrose + *Vibrio* counts	Glutamic acid uptake rates	Glucose uptake rates
Total fermentative organisms	0.98					
Total *vibrio* counts	0.96	0.99				
Total sucrose + *Vibrio* counts	0.97	0.97	0.97			
Glutamic acid uptake rates	0.61	0.65	0.61	0.59		
Glucose uptake rates	0.92	0.92	0.87	0.86	0.84	
Acetate uptake rates	0.94	0.92	0.87	0.86	0.77	0.97

*Plate count determinations made on Lib X agar plates.

Table 20. Concentration of presumptive nitrogen fixing bacteria in sediments collected during the April, 1977 Lower Cook Inlet cruise.

Sample number	Station number	Counts x 10^3 per g dry wt.
GB401	D	4.0
GB410	242	<0.1
GB411	U	2.4
GB412	V	1.2
GB420	227	340
GB421	K	22
GB424	J	1.3
GB425	229	800
GB430	213	0.02
GB431	214	<0.01
GB432	204	40
GB434	212	--
GB435	215	0.8
GB436	212	0.2
GB437	208	14
GB440	395	56
GB442	105	0.7
GB444	388	<0.01
GB445	378	0.2

Table 21. The effects of crude oil on nitrogen fixation in sediment samples which had not been treated and those which had been treated with sucrose.

All values reported as ng nitrogen fixed per g. dry wt./h.

A. Yaquina Bay, OR	No Sucrose		Sucrose	
Sample number	No oil	Oil	No Oil	Oil
A.	0.28	0.22	16.1	17.2
B.	0.5	0.5	0.6	0.6
C.	0.86	0.75	8.5	3.8
D.	0.36	0.28	3.3	
E.	1.55	0.22	9.7	7.1
B. Cook Inlet, April, 1977				
411	0.08	0.11	9.0	3.4
420	0.42	0.33		0.6
425	0.48	0.44	4.5	8.5
440	0.22	0.14	0.67	0.67
444	0.26	0.26	0.57	0.49
C. Beaufort Sea, September, 1977				
301	0.21	0.23	0.32	0.23
302	0.20	0.20	0.31	0.31
303	0.19	0.16	0.25	0.21
306	0.04	0.05	1.25	0.51
308	0.13	0.12	0.15	0.17
314	0.02	0.02	0.67	0.84
315	0.02	0.02	0.07	0.04
317	0.01	0.01	0.29	0.12
319	0.09	0.10	1.57	1.24
D. Cook Inlet, November, 1977				
506	1.43	1.38	1.77	1.43
507	0.07	0.09	0.13	0.18
509	0.07	0.17	0.17	0.26
510	0.18	0.18	0.22	0.26
511	0.43	0.35	1.06	0.79
512	0.10	0.08	0.40	0.33
513	0.36	0.33	0.55	0.44
514	0.09	0.05	0.30	0.28
515	0.48	0.35	0.61	0.52

Table 21.

	No Sucrose		Sucrose	
Sample number	No oil	Oil	No Oil	Oil
D. Cook Inlet, November, 1977 (con't)				
532	0.11	0.09	0.21	0.17
538	0.33	0.23	0.36	0.33
558	0.51	0.45	0.57	0.54
E. Beaufort Sea, January, 1978				
402	0.15	0.16	0.50	0.32
403	0.15	0.15	0.51	0.25
404	0.09	0.10	0.63	0.41
405	0.08	0.08	0.22	0.20
406	0.05	0.04	0.18	0.18
407	0.10	0.08	0.13	0.12
408	0.11	0.10	0.14	0.14
409	0.11	0.10	0.27	0.23
410	0.08	0.07	0.15	0.16

Table 22. Effects of crude oil on glucose respiration rates observed in the field.

A. Water samples collected during the November Cook Inlet cruise.

	*DPM		Percent Reduction
Sample number	No oil	Oil	
505	246	156	37
506	3866	1553	60
511	226	201	11
513	171	L	
514	260	L	
517	204	93	54
528	722	199	72
530	155	123	21
533	165	78	53
534	122	105	14
535	404	189	53
536	221	87	61
538	516	133	74
539	1265	388	69
540	1235	411	67
541	6491	5806	11
542	2054	844	54
543	704	951	0
546	396	345	13
551	1651	1584	4
552	314	194	38
557	457	185	60
558	570	404	29
Average			41%

B. Sediment samples collected during the January Beaufort Sea field trip.

Sample number	No oil	Oil	Oil Extract	Percent Reduction
402	259		108	58
403	447		50	89
404	435	345		21
405	307	202		34
406	236	152		36
408	110	47		58
409	124	98		21
410	347	205		41
Average				45%

(*) Disintegrations per min. - a measurement of radioactivity which is directly proportional to the amount of glucose respired.

(L) Too low to be detected.

Table 23. Percent reduction in respiration rates observed in sediment samples exposed to crude oil, crude oil aqueous extract or weathered crude oil.

A. First study on summer Beaufort Sea samples exposued to crude oil.

	Percent Reduction	
Sample #	Glucose	Glutamic acid
301	30	55
302	49	17
303	40	37
304	25	45
305	46	56
306	58	37
307	42	19
308	41	0
309	46	38
310	0	50
311	22	23
312	39	32
313	14	24
314	42	48
315	8	19
316	65	48
317	55	50
318	42	5
319	12	0
320	19	50
Average	35	33

Table 23. (con't)

B. Second study on the above samples conducted two weeks later.

Sample #	Glucose			Glutamic Acid		
	Oil	Extract	Weathered	Oil	Extract	Weathered
301	16	39	21	6	3	0
302	59	9	49	36	0	35
303	8	22	0	9	0	7
304	30	52	23	16	12	13
305	26	60	0	6	0	13
306	21	60	12	0	0	0
307	65	20	63	43	0	40
308	7	40	16	0	0	0
309	59	21	66	46	23	67
310	0	0	0	13	0	6
311	0	0	0	0	0	0
312	23	43	27	13	2	9
313	0	0	0	0	0	0
314	32	3	15	29	0	44
315	2	15	12	8	12	21
316	21	0	30	8	12	21
317	21	66	39	0	0	0
318	9	16	0	29	0	24
319	40	38	7	10	0	0
320	12	0	22	7	26	7
Average	20	23	21	15	8	19

Table 24. Kinetic experiments on the effects of crude oil on glucose uptake in sediment samples collected in Elson Lagoon in January, 1978.

	No Oil			Crude Oil Extract		
Sample number	V_{max}	T_t	$K_t + S_n$	V_{max}	T_t	$K_t + S_n$
BB402	0.14	188	26	0.15	469	73
BB403	0.25	178	45	0.25	205	50
BB405	0.10	368	35	0.08	928	75
BB408	0.09	395	37	0.06	1438	80
BB410	0.09	401	35	0.12	350	41

V_{max} is the maximum potential rate of goucose uptake.

T_t is the time in hours required for the natural microbial population to utilize all of the naturally occurring glucose in the sample.

$K_t + S_n$ is the transport constant plus the natural substrate concentration.

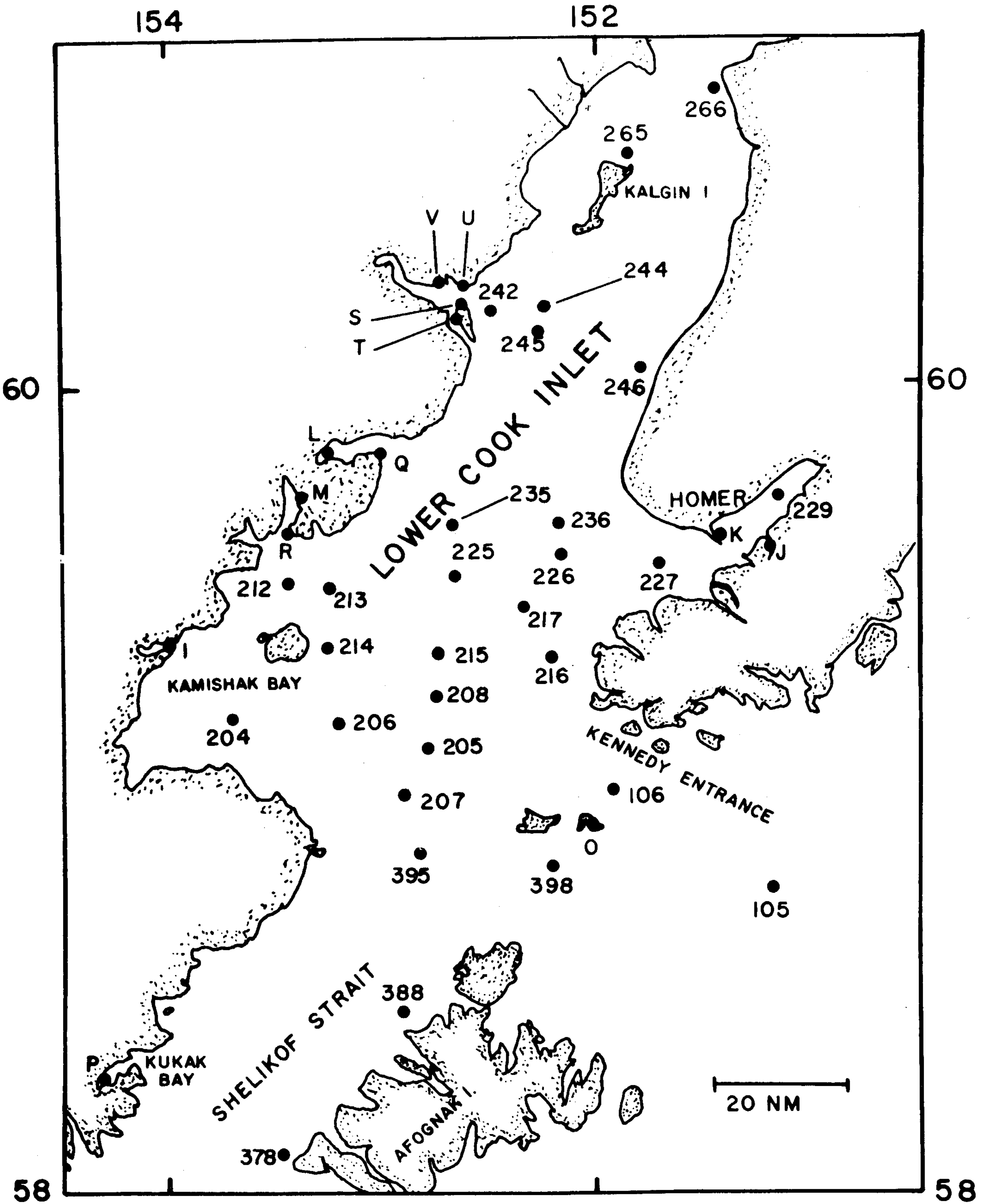


Figure 1. Station locations and numbers for stations occupied in the Cook Inlet area during the April cruise.

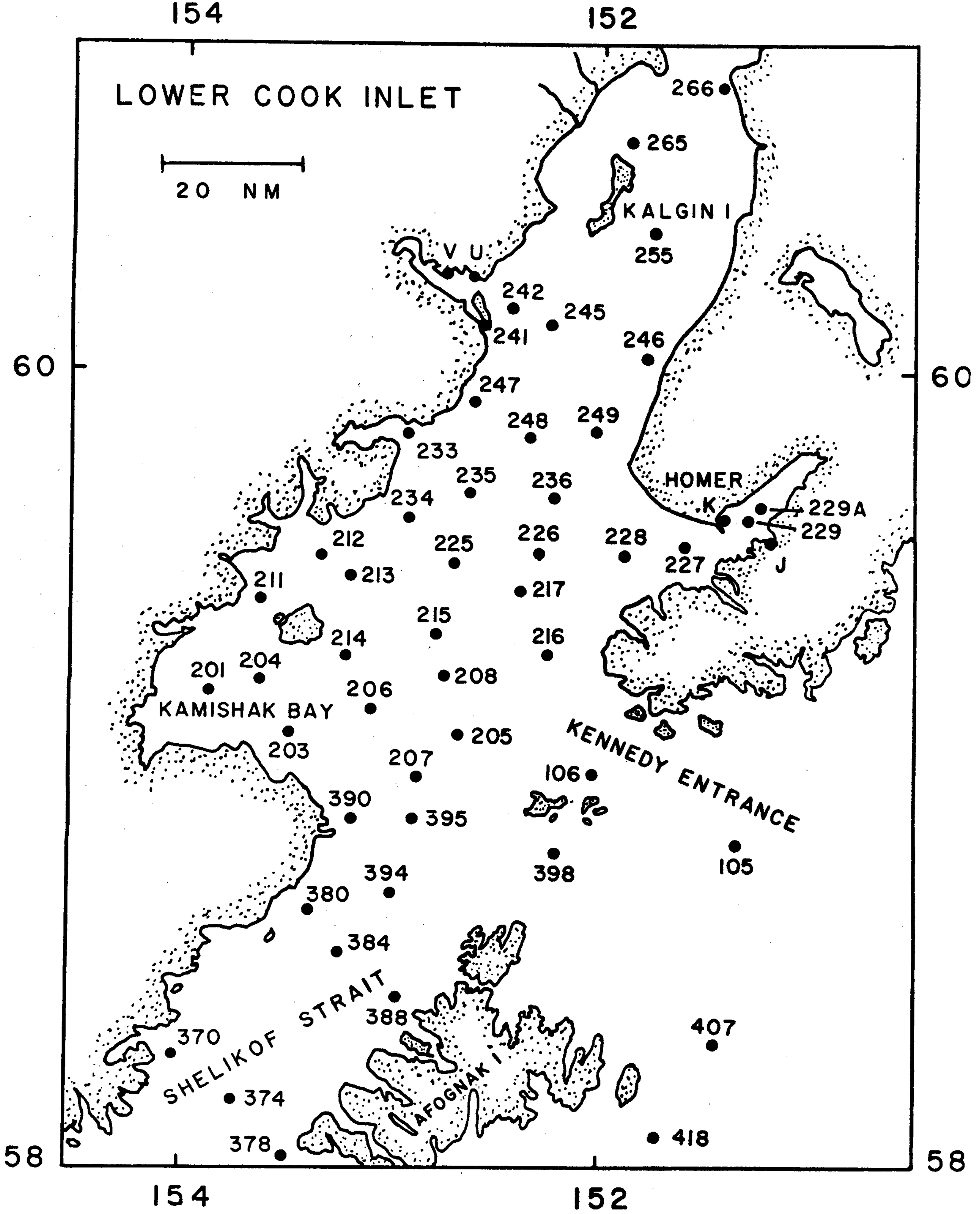


Figure 2. Station locations and numbers for stations occupied in the Cook Inlet during the November cruise.

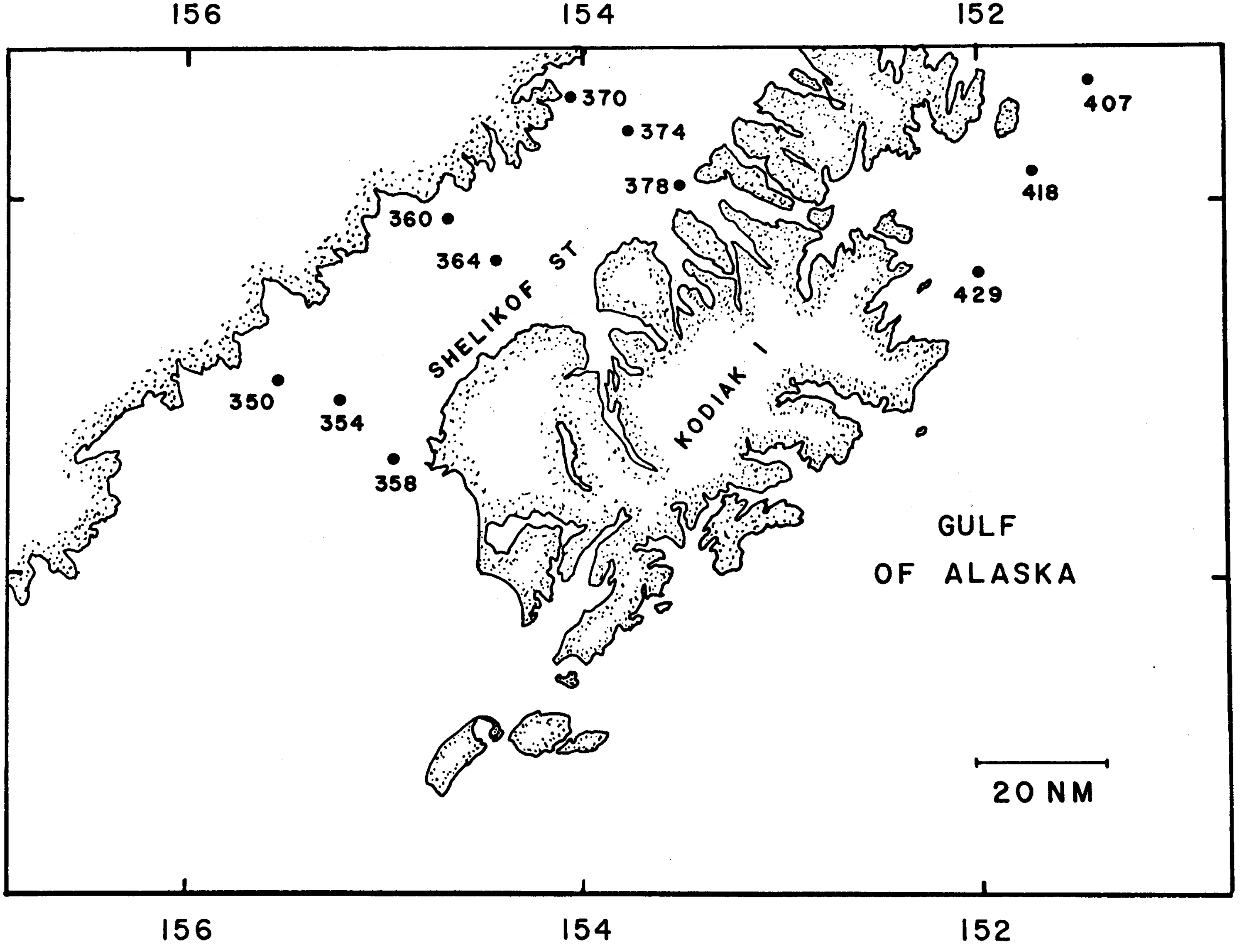


Figure 3. Station locations and numbers for stations occupied in the Cook Inlet during the November cruise.

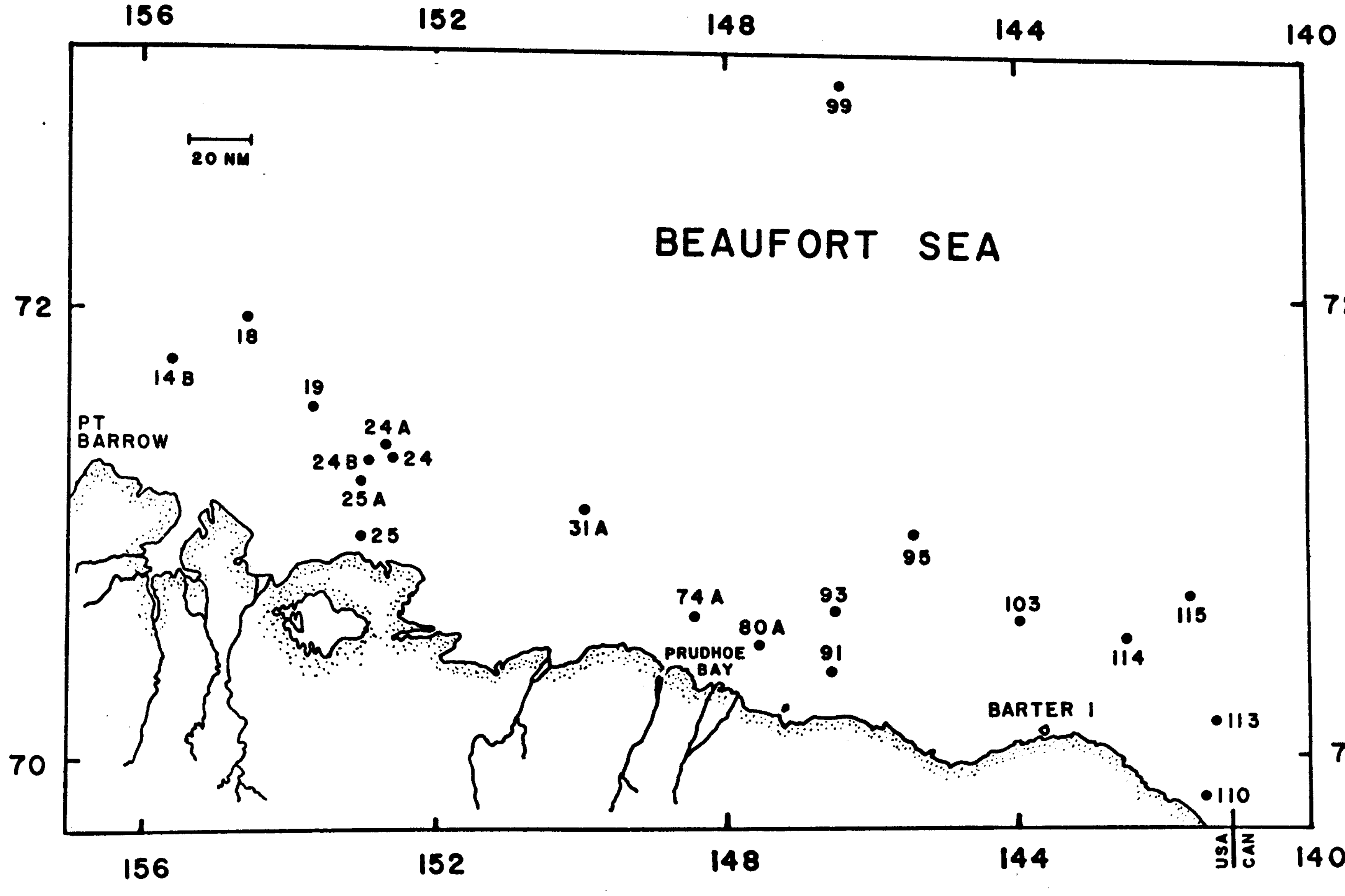


Figure 4. Station locations and numbers for stations occupied in the Beaufort Sea during the September cruise.

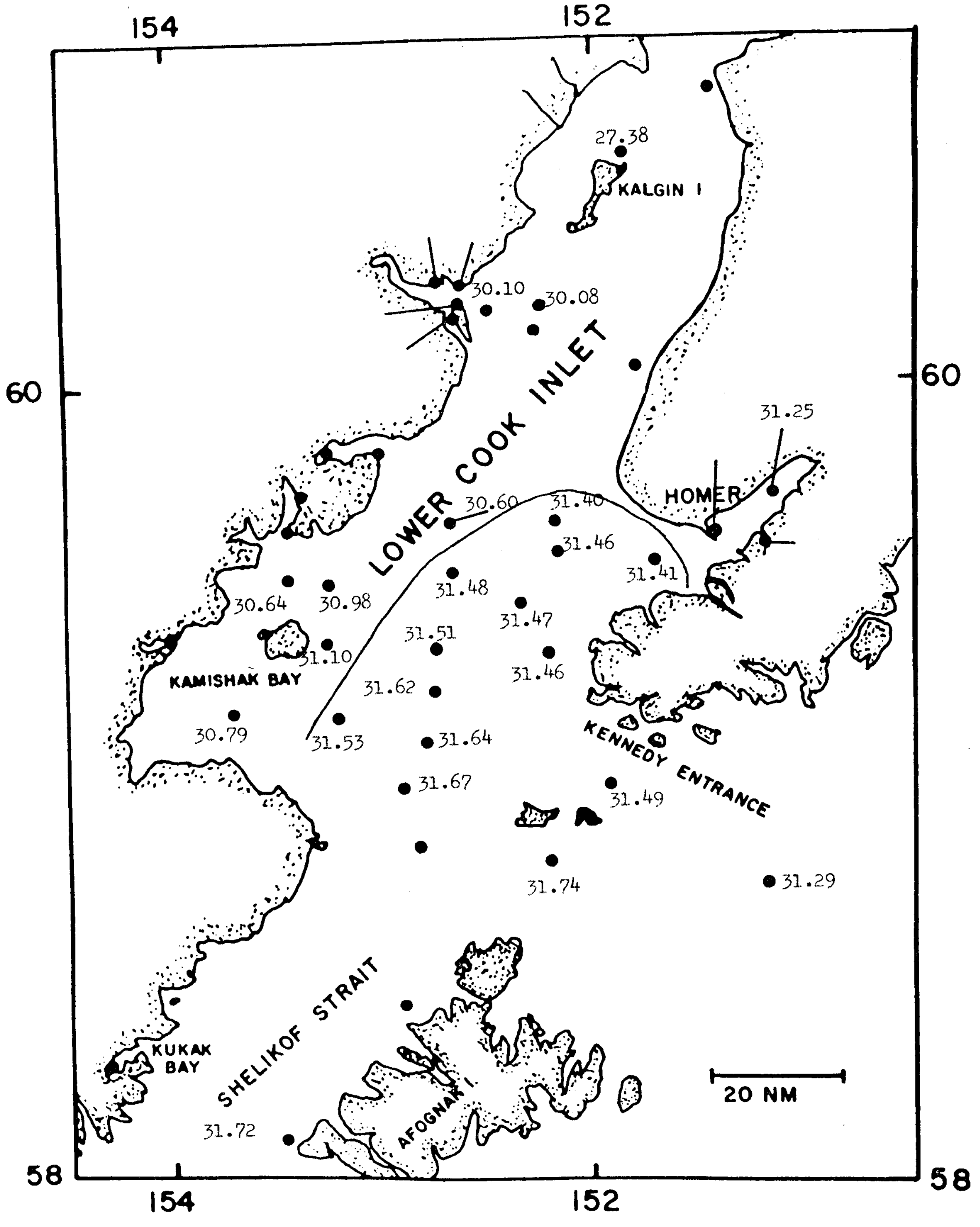


Figure 5 . Salinity measurements made in surface water samples analyzed during the April cruise. The unit used is parts per thousand.

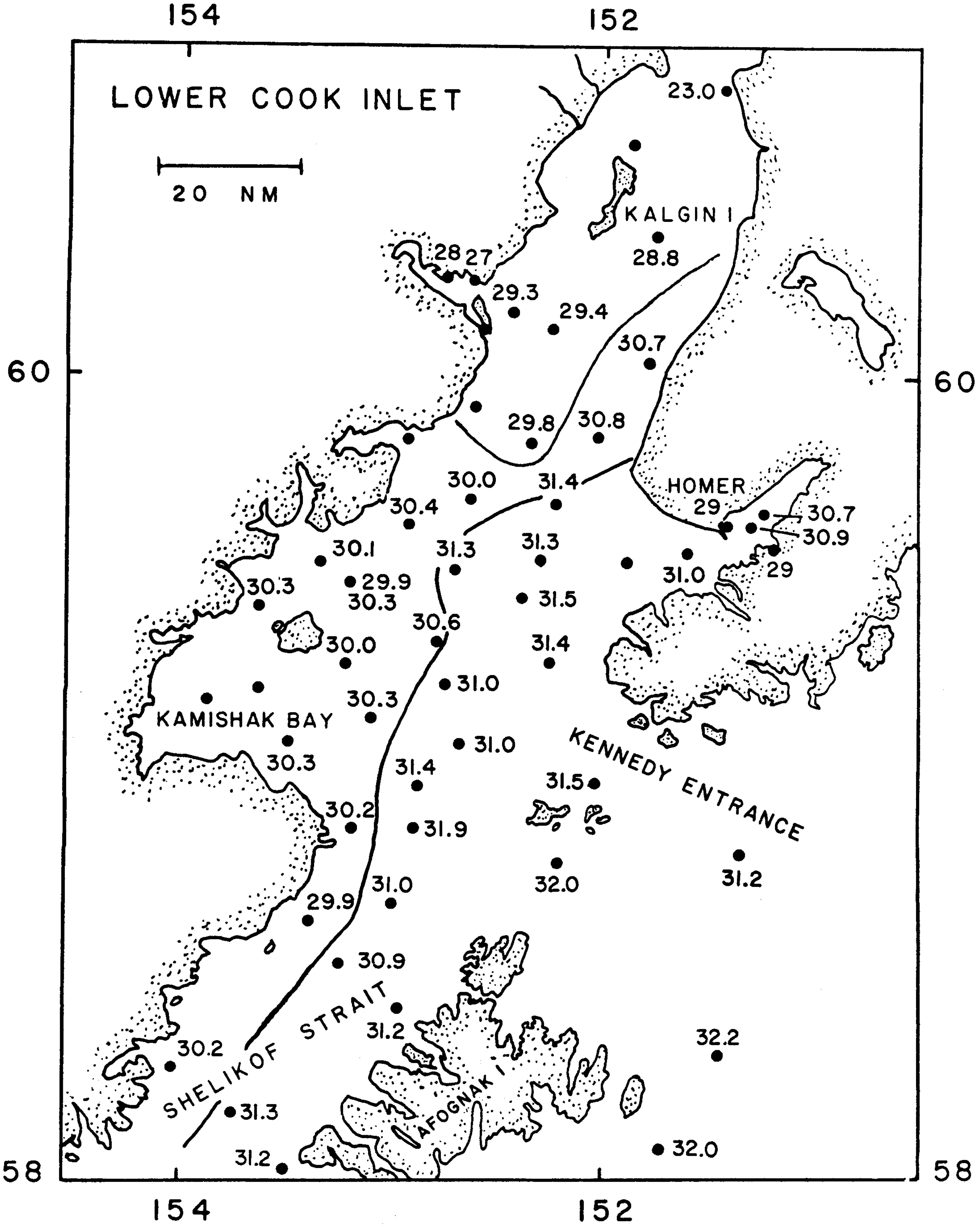


Figure 6. Salinity measurements made in surface water samples analyzed during the November cruise. The unit used is parts per thousand.

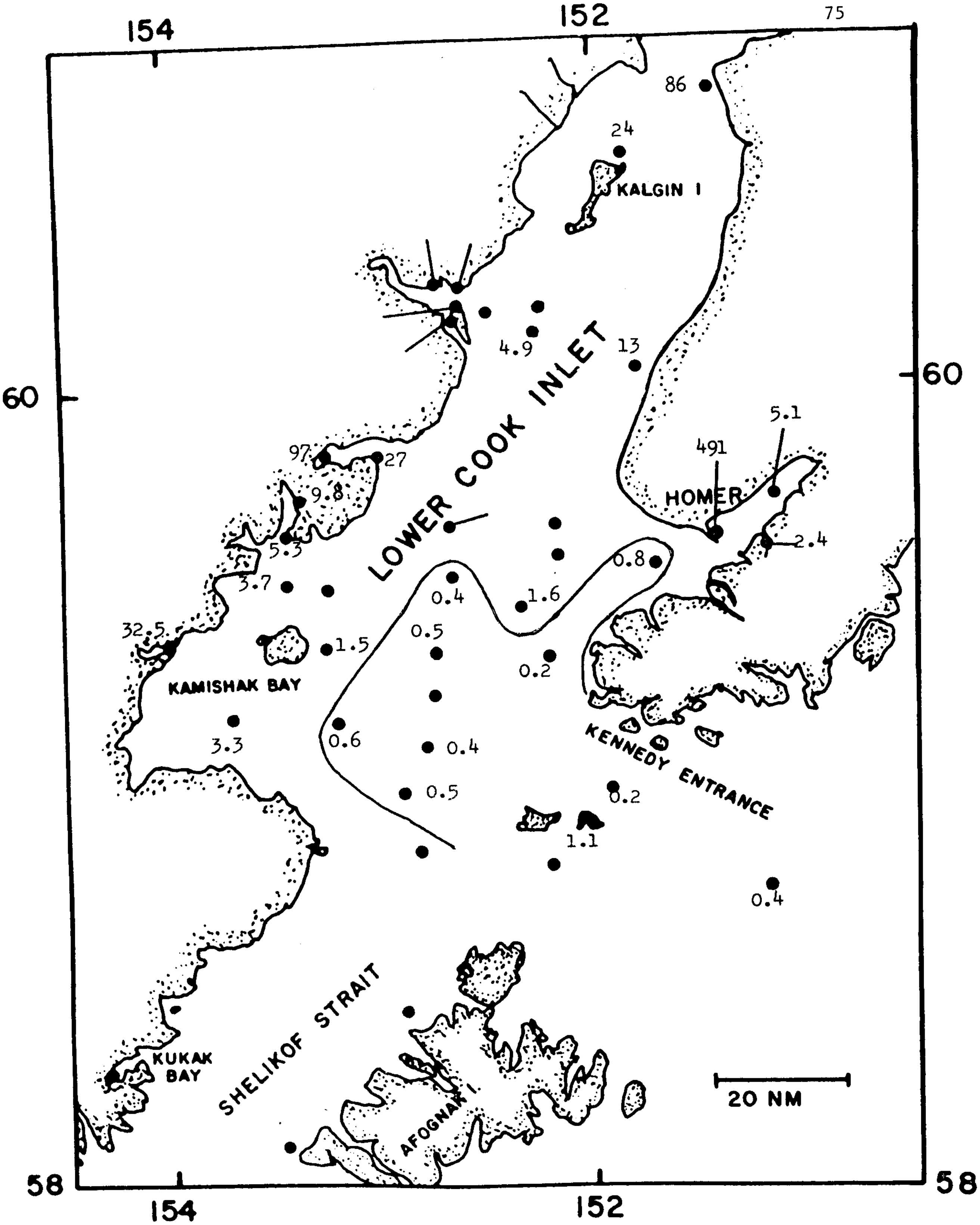


Figure 7. Relative microbial activity in water samples as measured using glutamic acid during the October cruise. The units are reported as ng/liter/h.

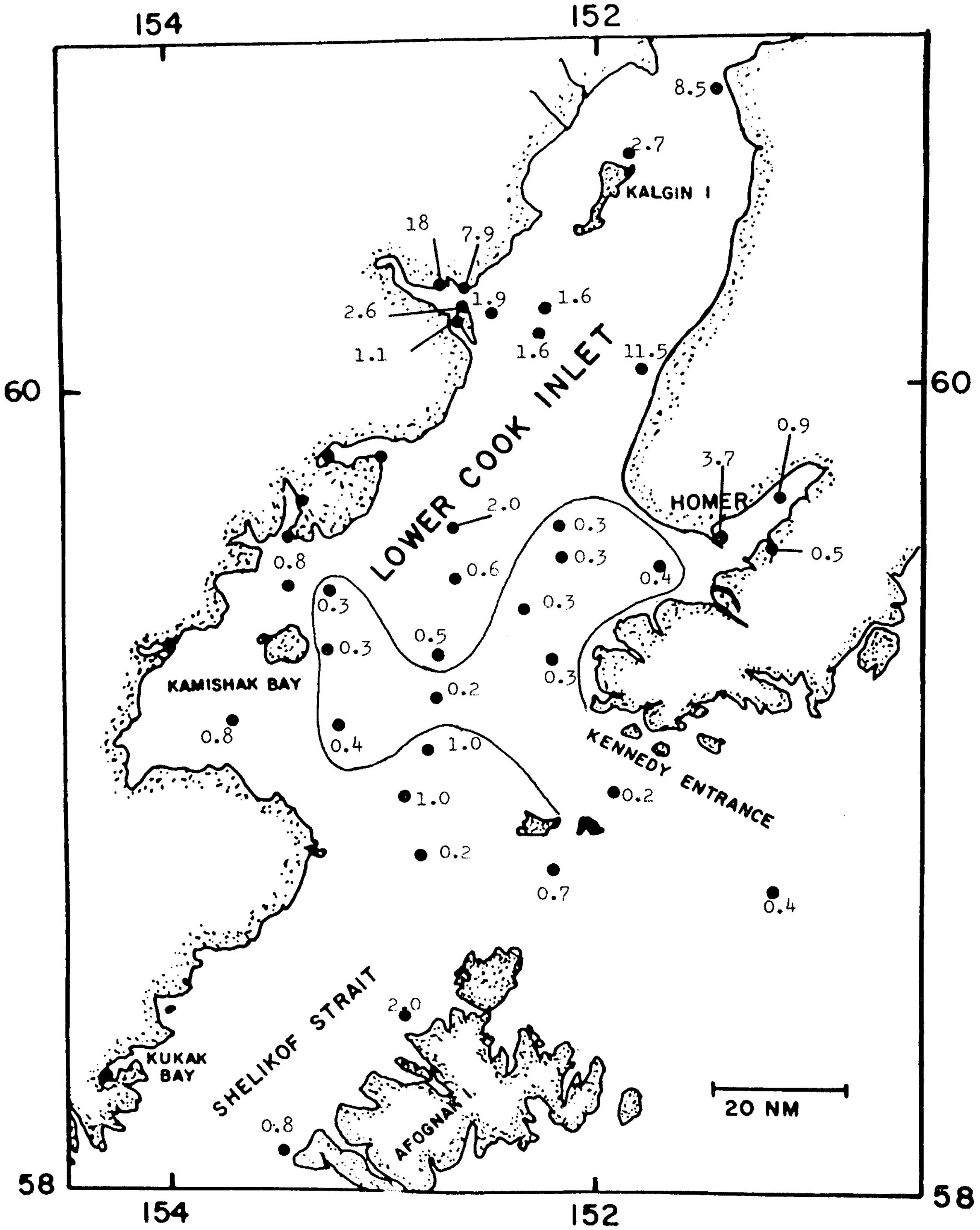


Figure 8. Relative microbial activity in water samples as measured using glucose during the April cruise. The units are reported as ng/liter/h.

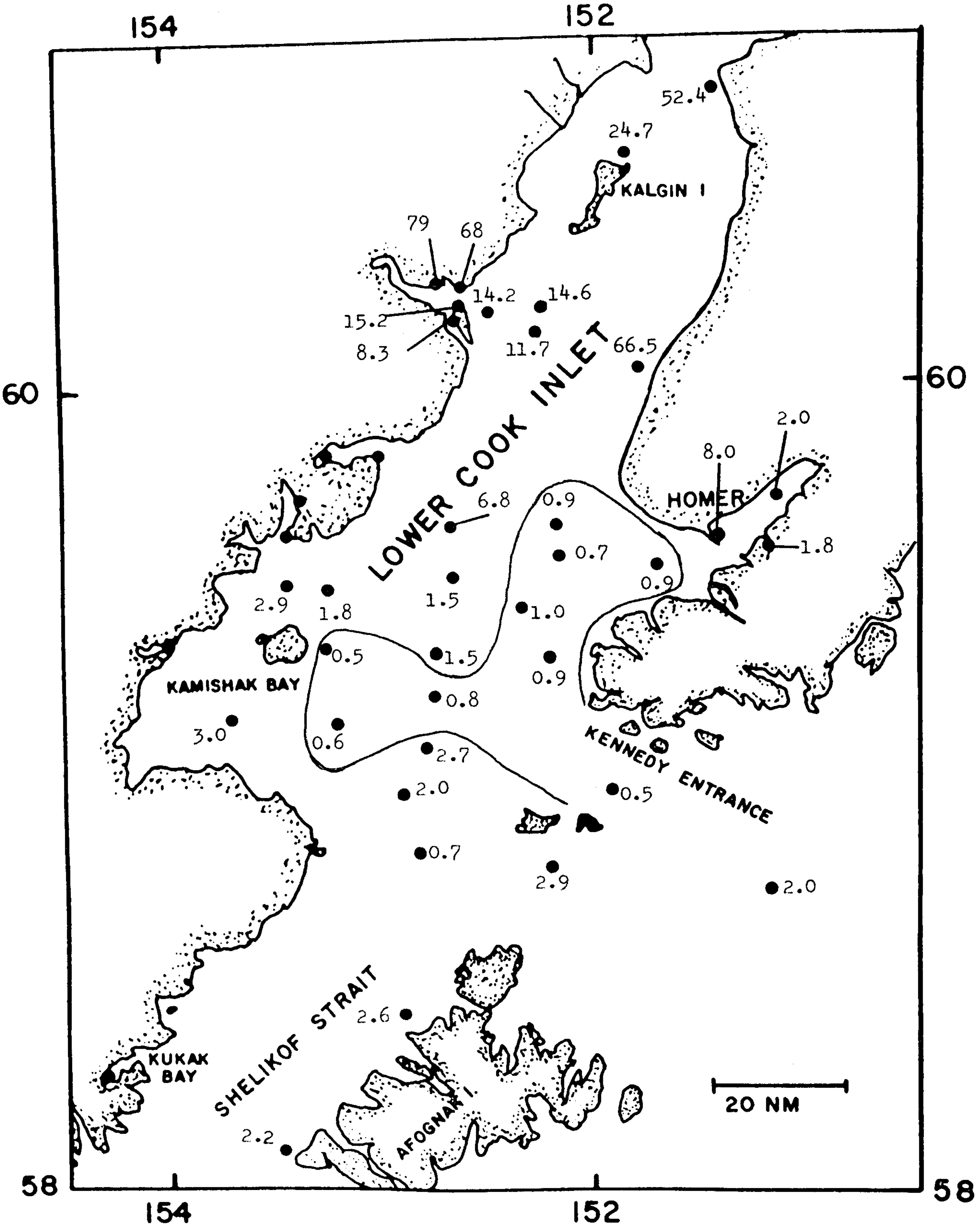


Figure 9. Relative microbial activity in water samples as measured using glutamic acid during the April cruise. The units are reported as ng/liter/h.

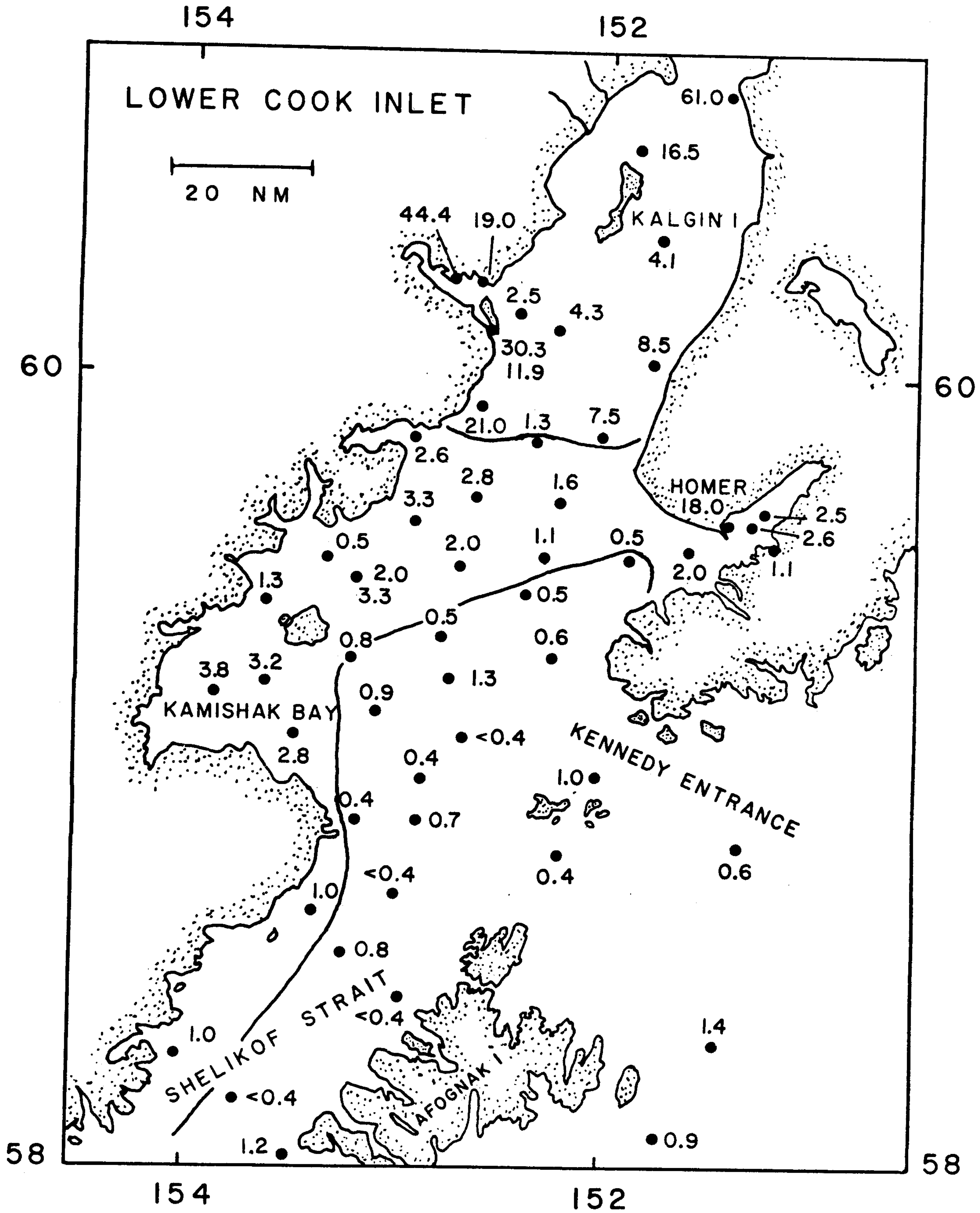


Figure 10. Relative microbial activity in water samples as measured using glutamic acid during the November cruise. The units are reported as ng/liter/h.

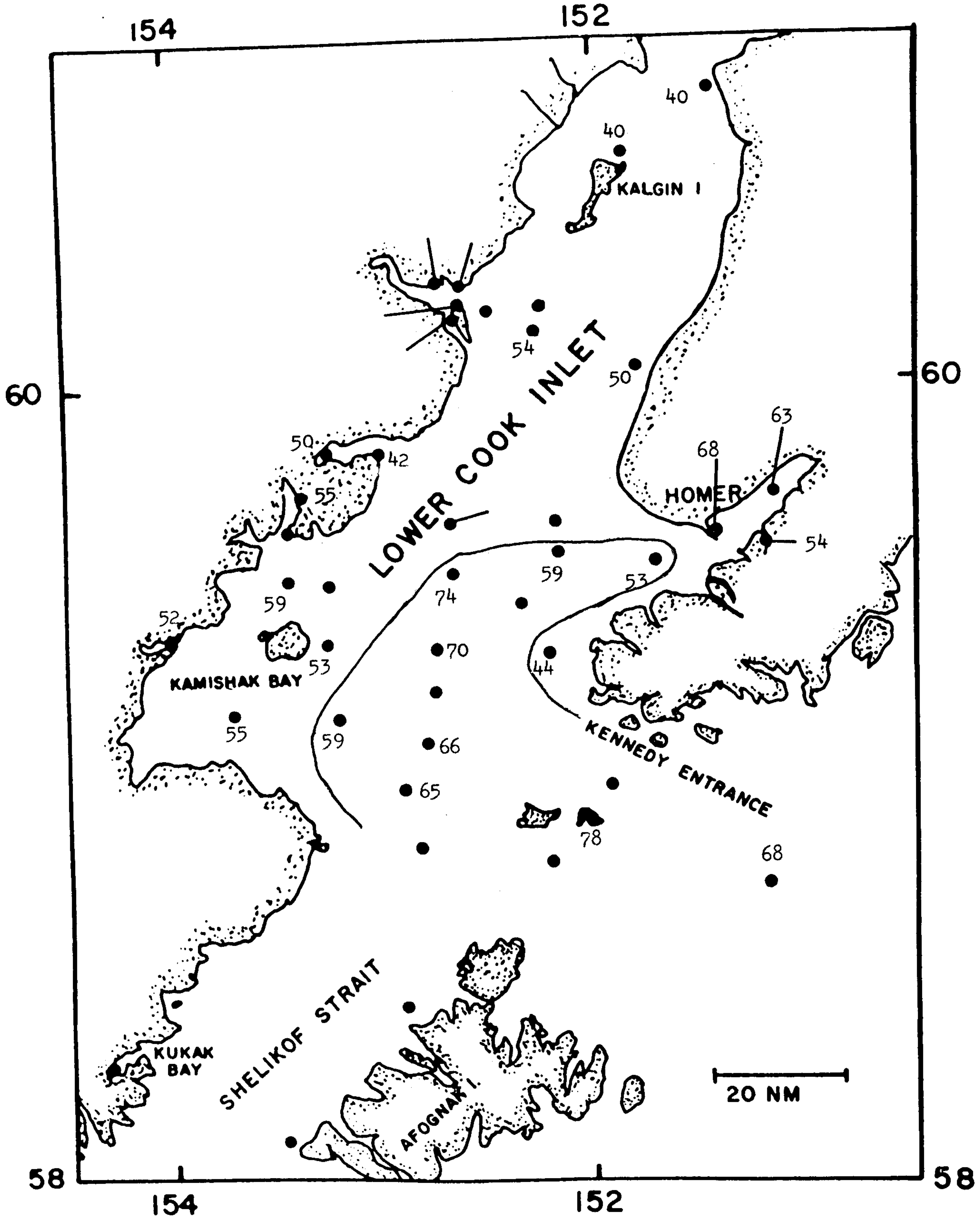


Figure 11. Respiration percentages observed in water samples as measured using glutamic acid during the October cruise.

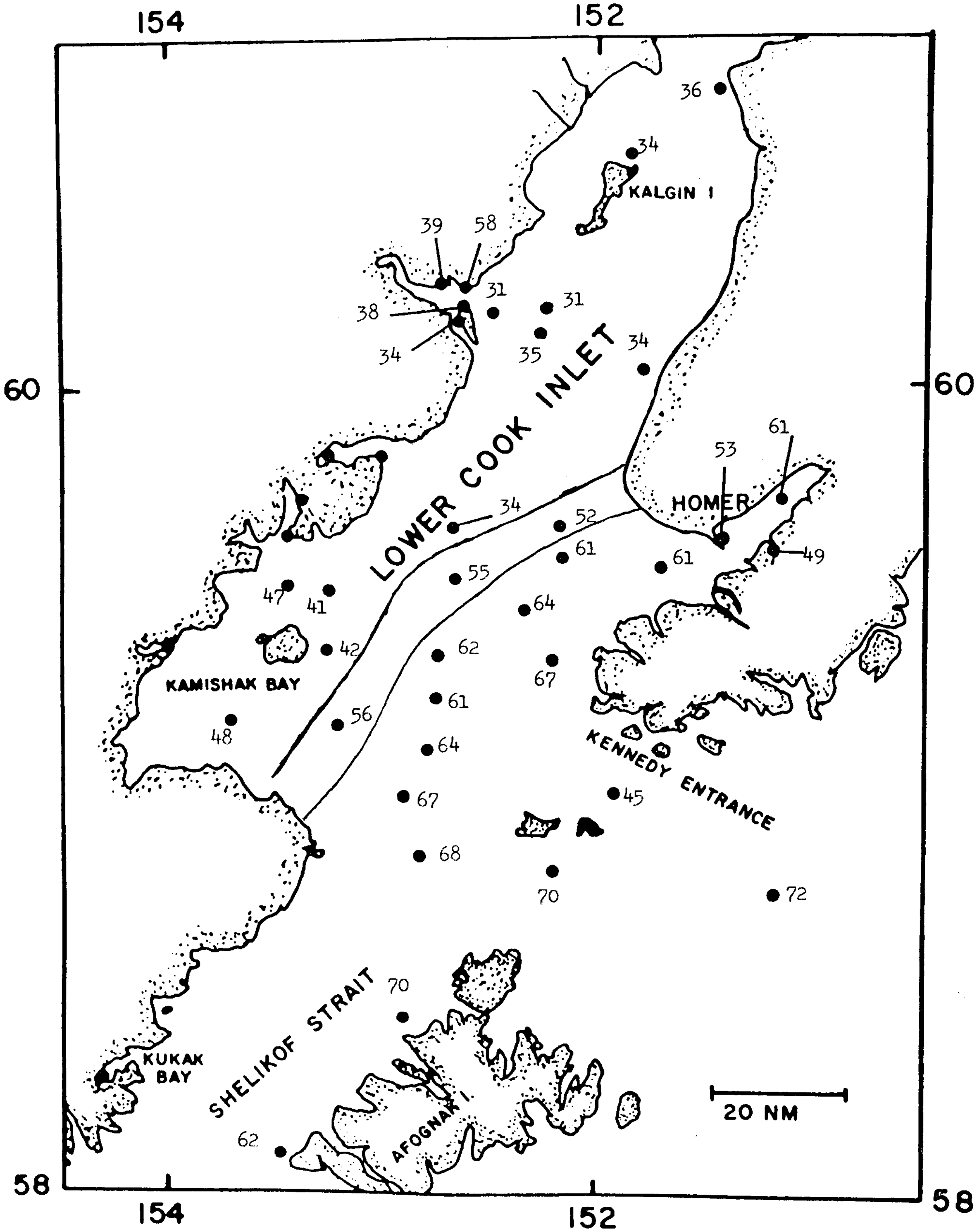


Figure 12. Respiration percentages observed in water samples as measured using glutamic acid during the April cruise.

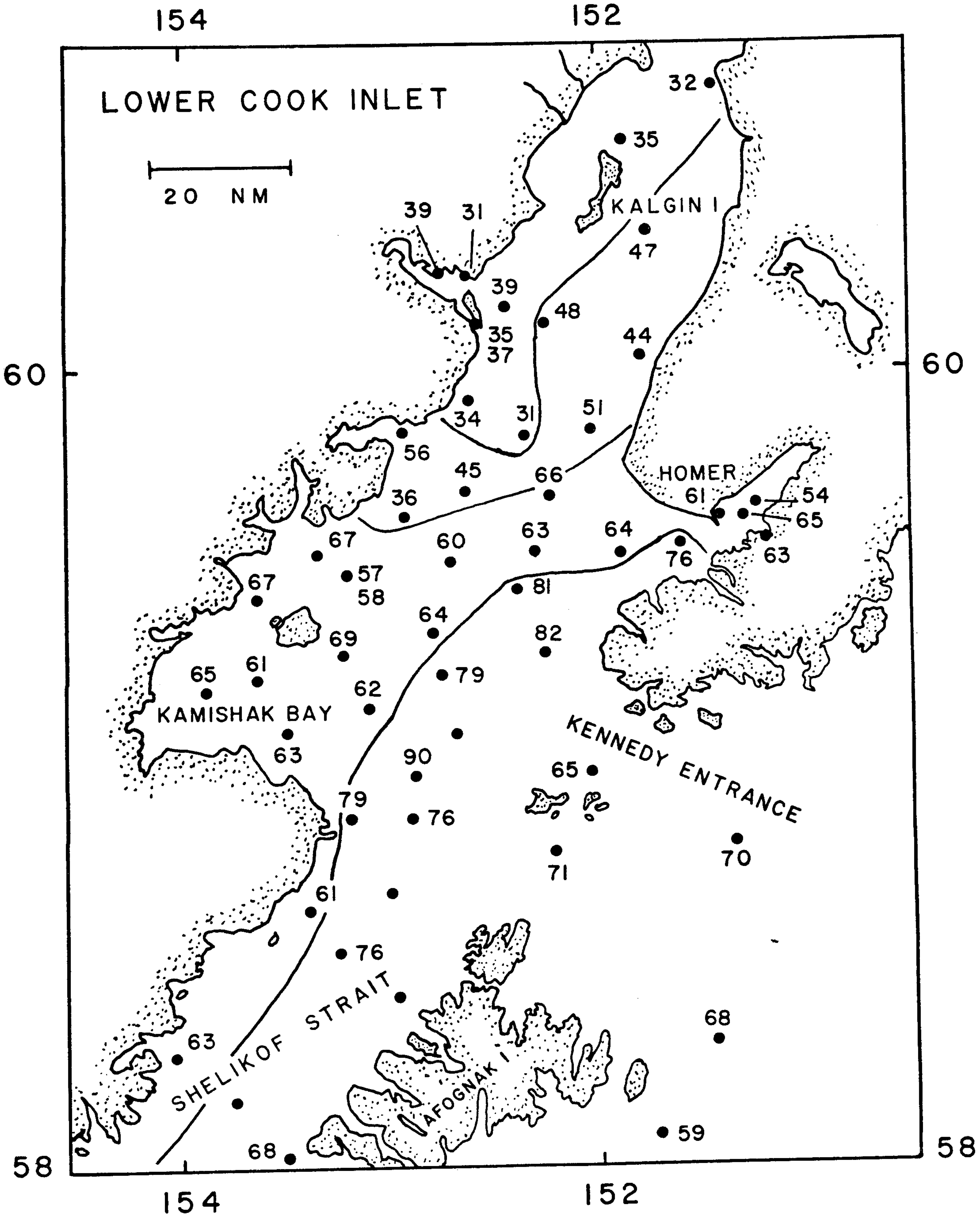


Figure 13. Respiration percentages observed in water samples as measured using glutamic acid during the November cruise.

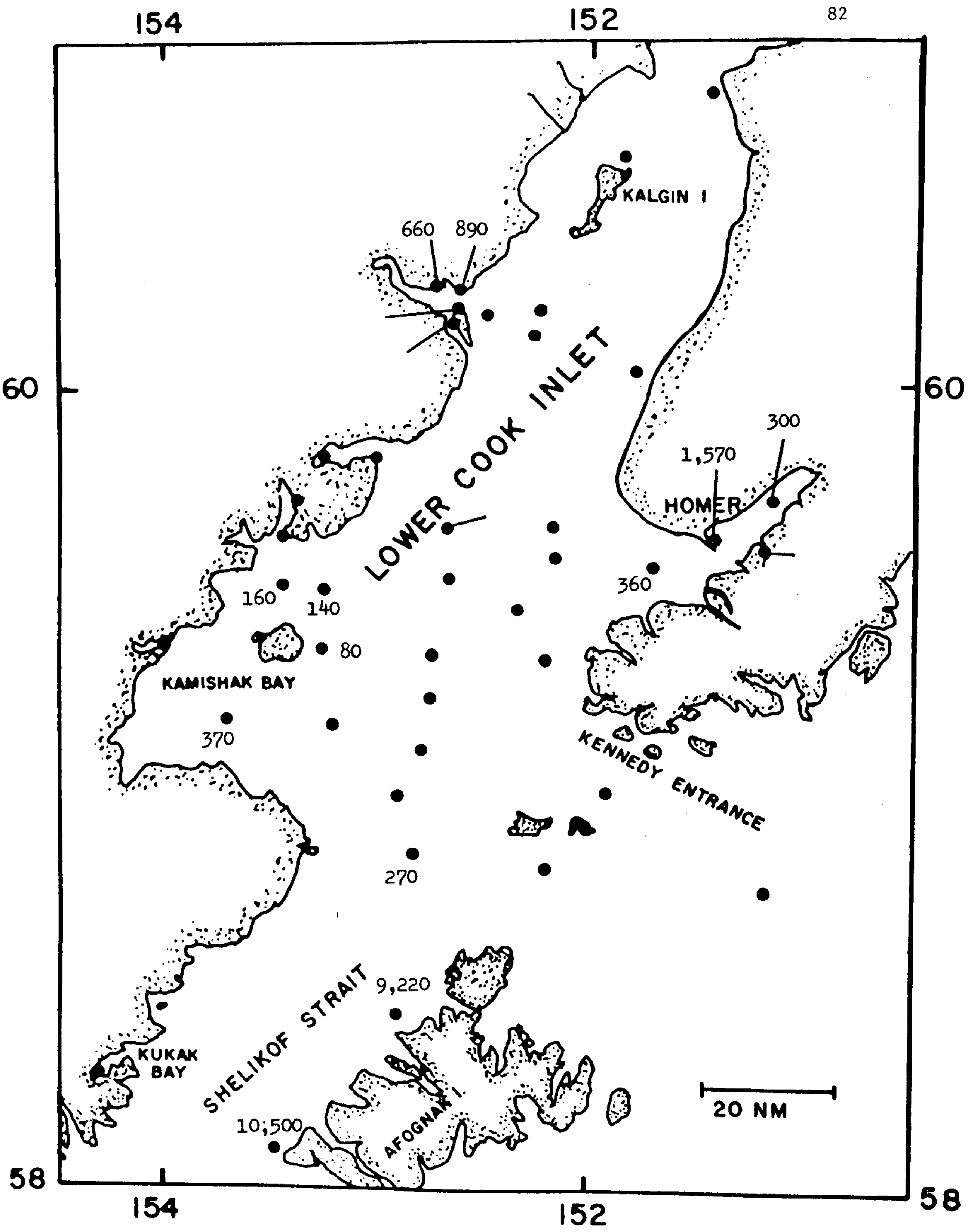


Figure 14. Relative microbial activity in sediment samples as measured using glutamic acid during the April cruise. The units are reported as ng/g. dry wt./h.

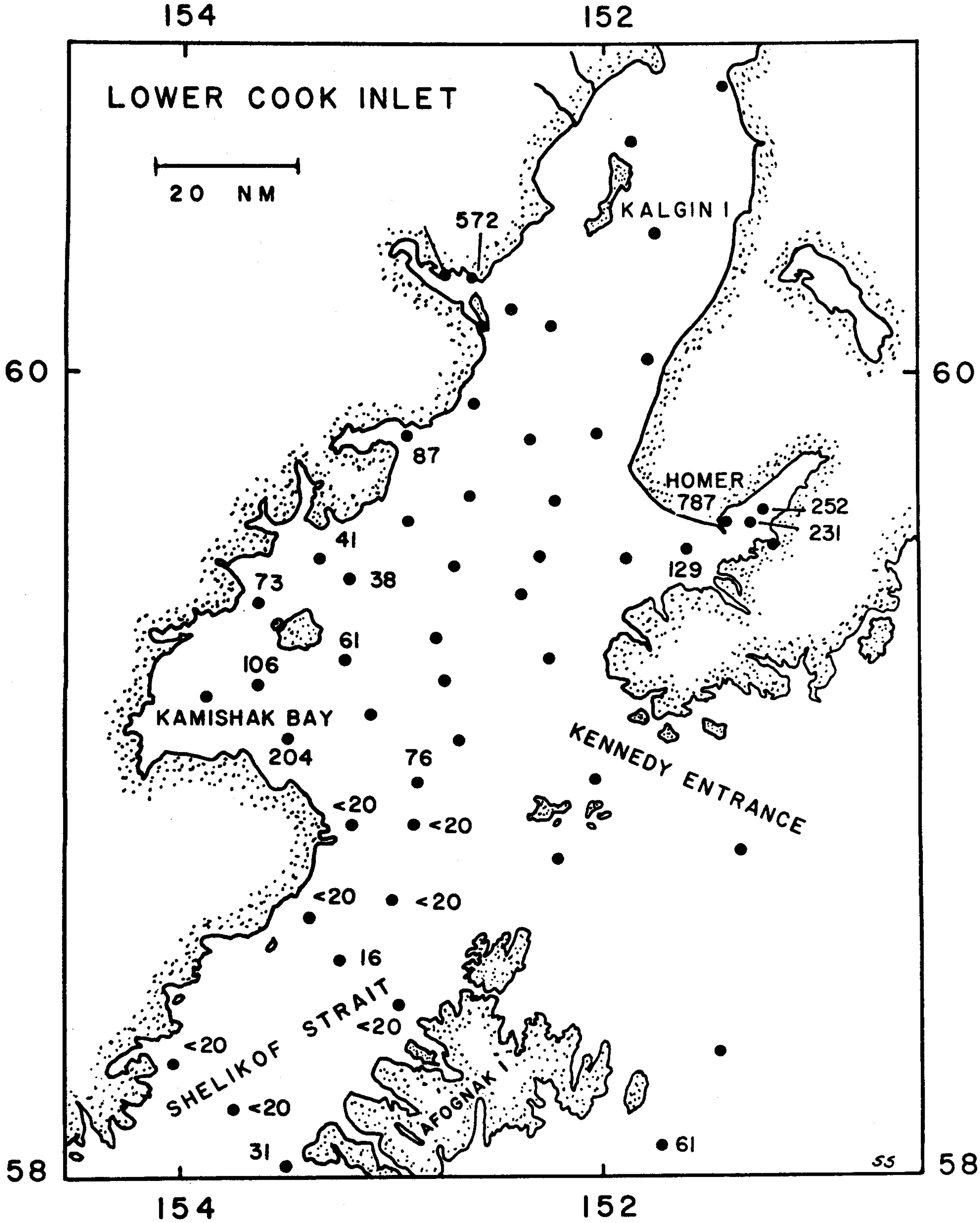


Figure 15. Relative microbial activity in sediment samples as measured using glutamic acid during the November cruise. The units are reported as ng/g. dry wt./h.

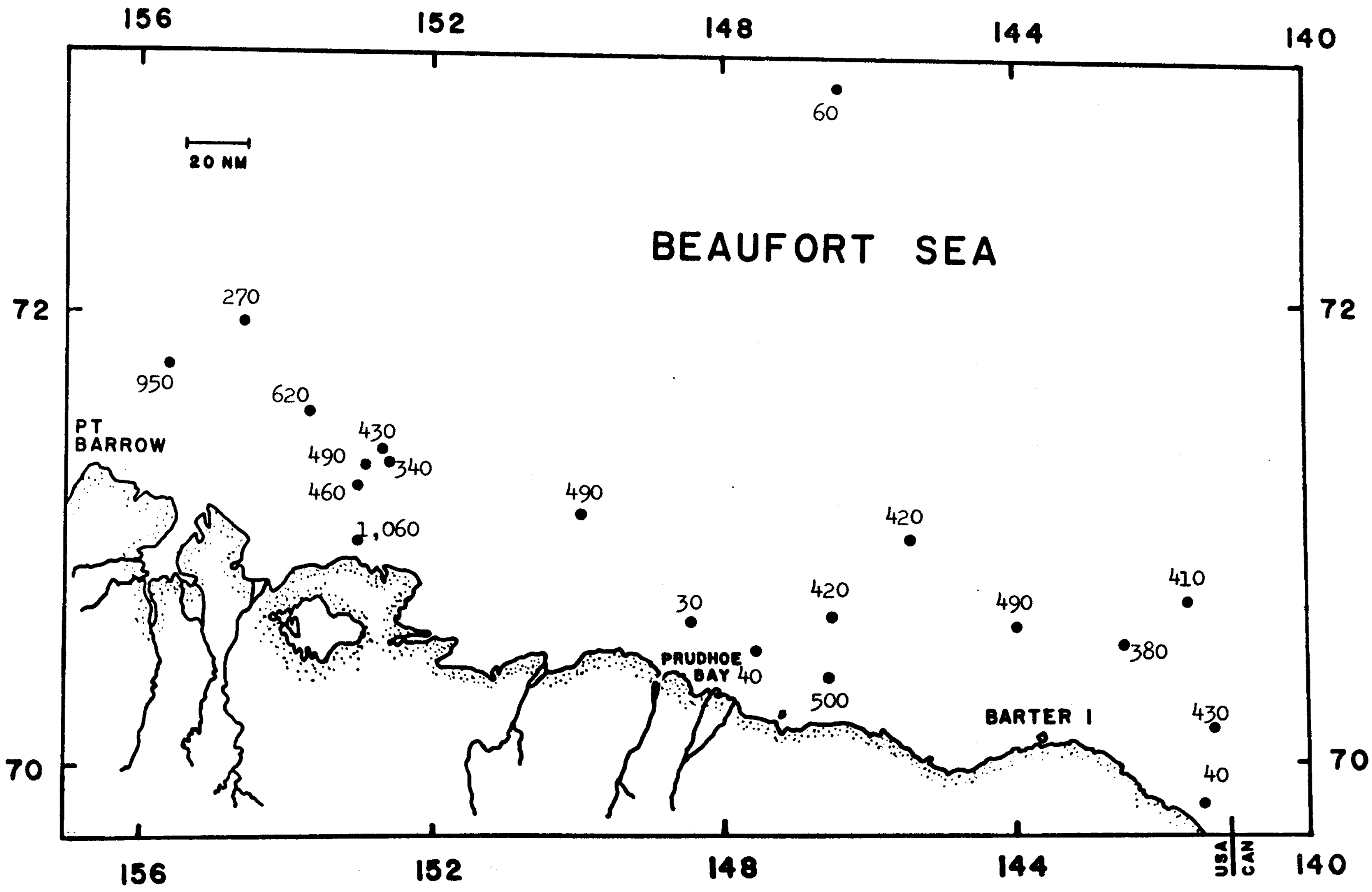


Figure 16. Relative microbial activity in sediment samples as measured using glutamic acid during the September Beaufort Sea cruise. The units are reported as ng/g. dry wt./h.

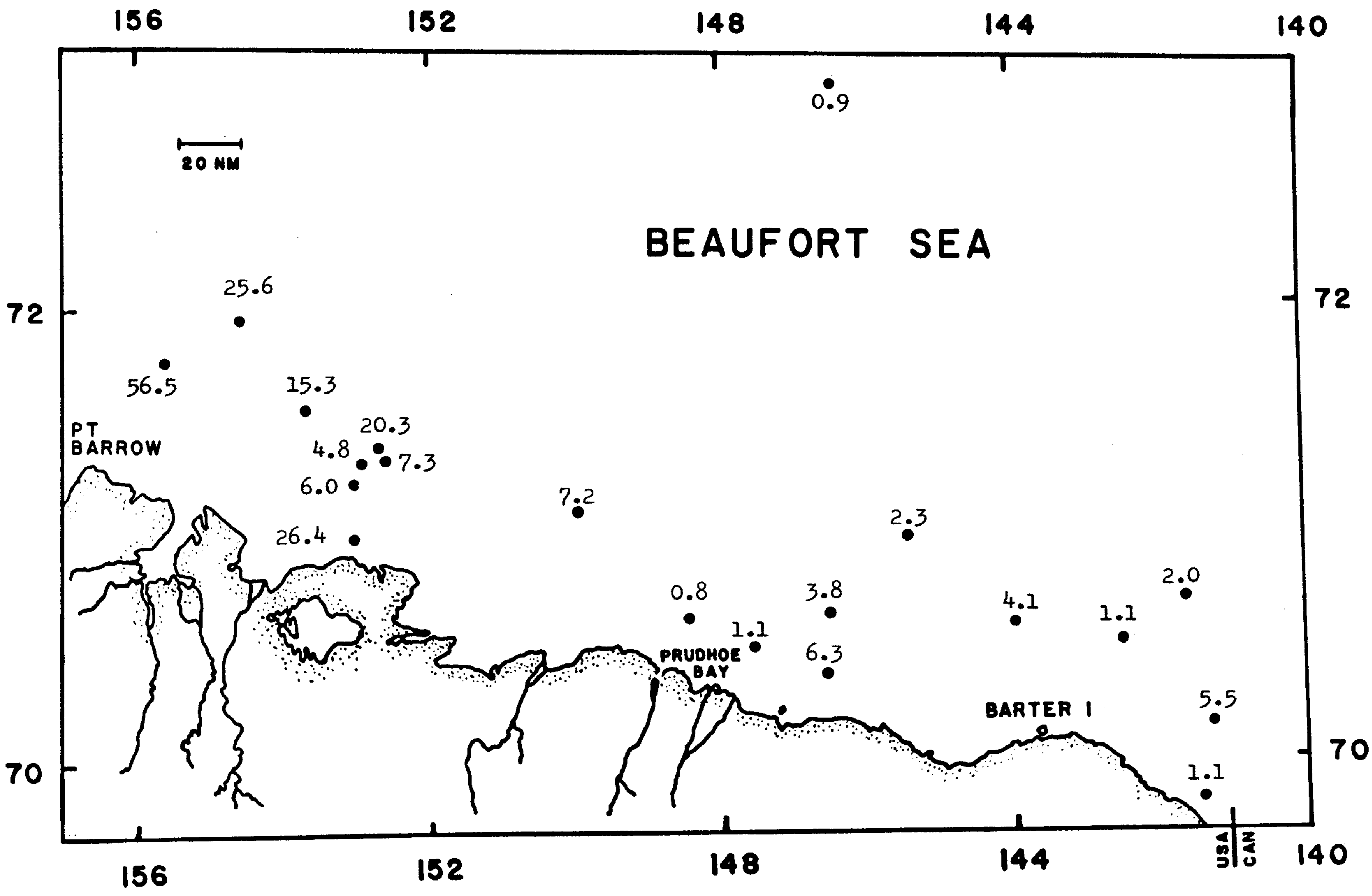


Figure 17. Relative microbial activity in sediment samples as measured using glucose during the September Beaufort Sea cruise. The units are reported as ng/g.dry wt./h.

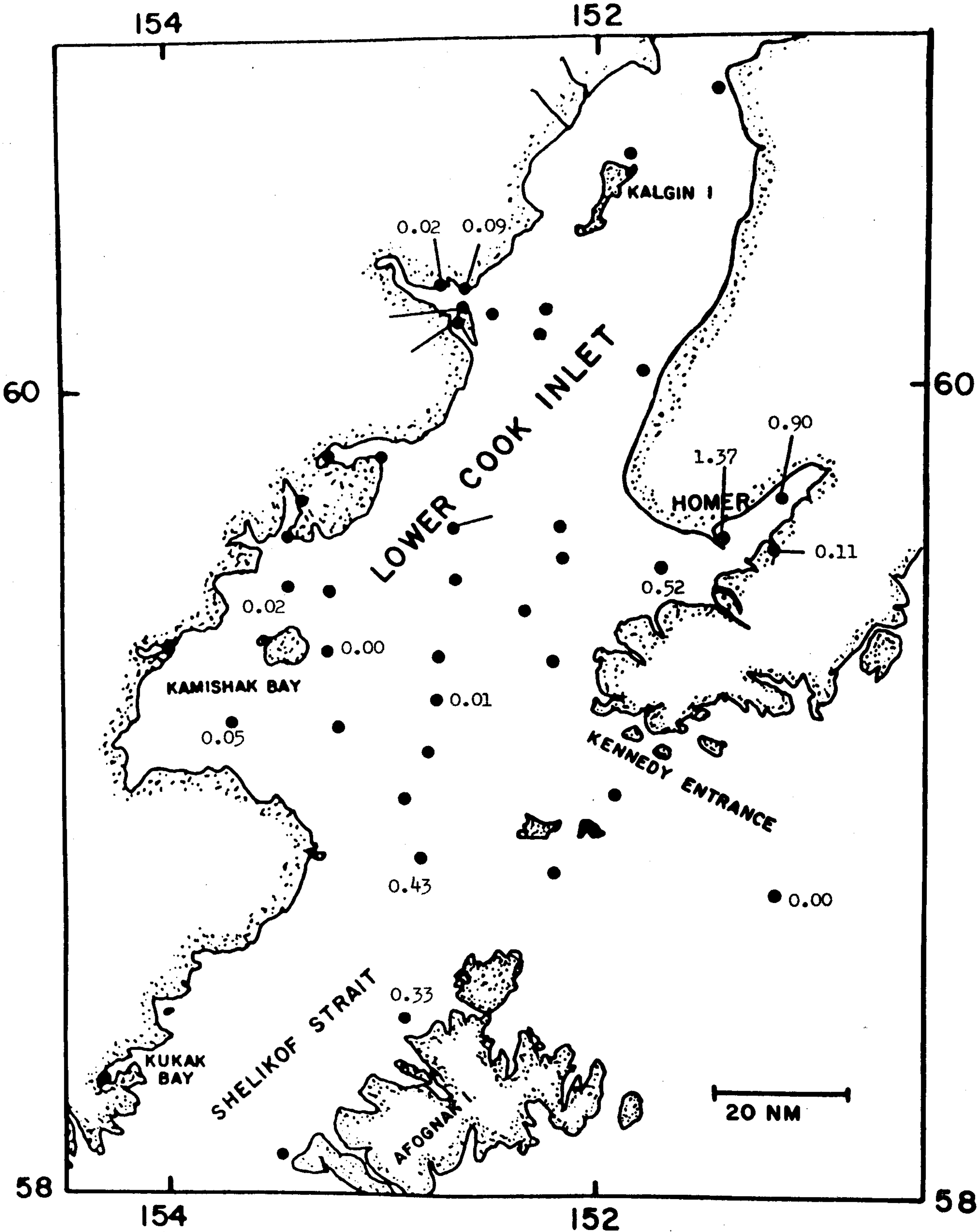


Figure 18. Observed rates of nitrogen fixation in sediment samples collected during the April cruise. The unit of measurement used was ng nitrogen fixed/gram dry weight of sediment/h.

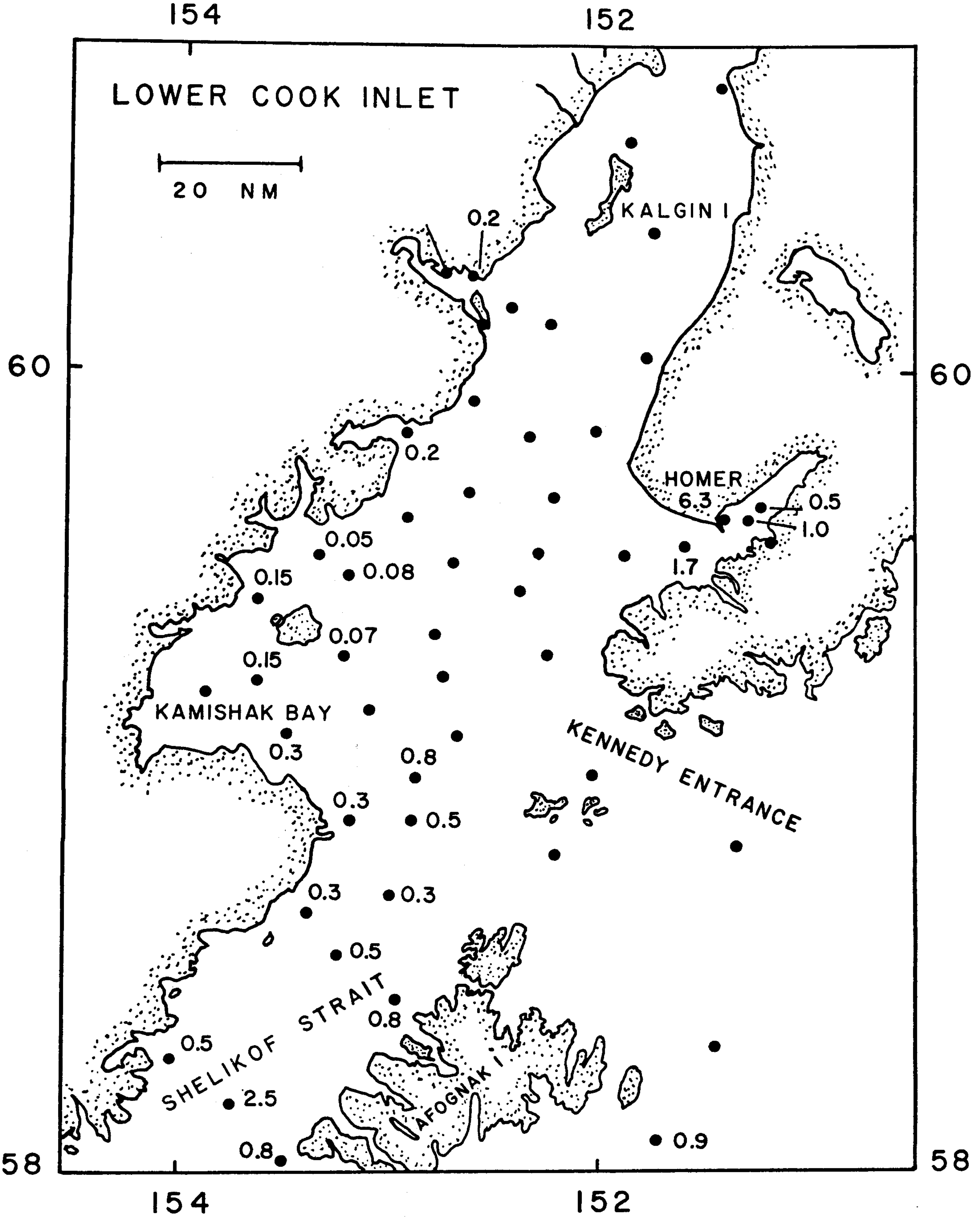


Figure 19. Nitrogen fixation rates in sediment samples collected during the November cruise. The unit of measurement used was ng nitrogen fixed /g. dry wt./h.

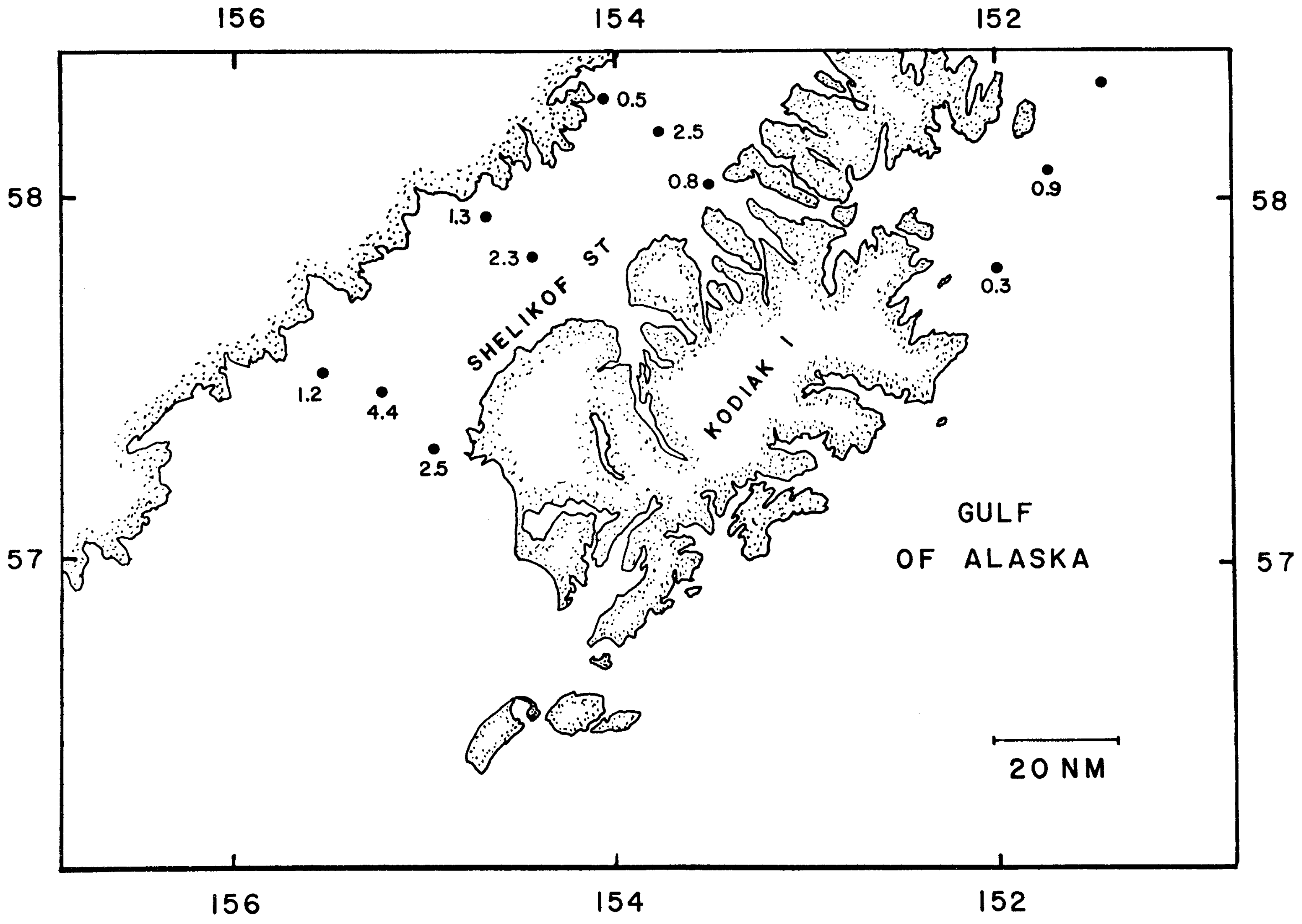


Figure 20. Nitrogen fixation rates in sediment samples collected during the November cruise. The unit of measurement used was ng nitrogen fixed/g. dry wt./h.

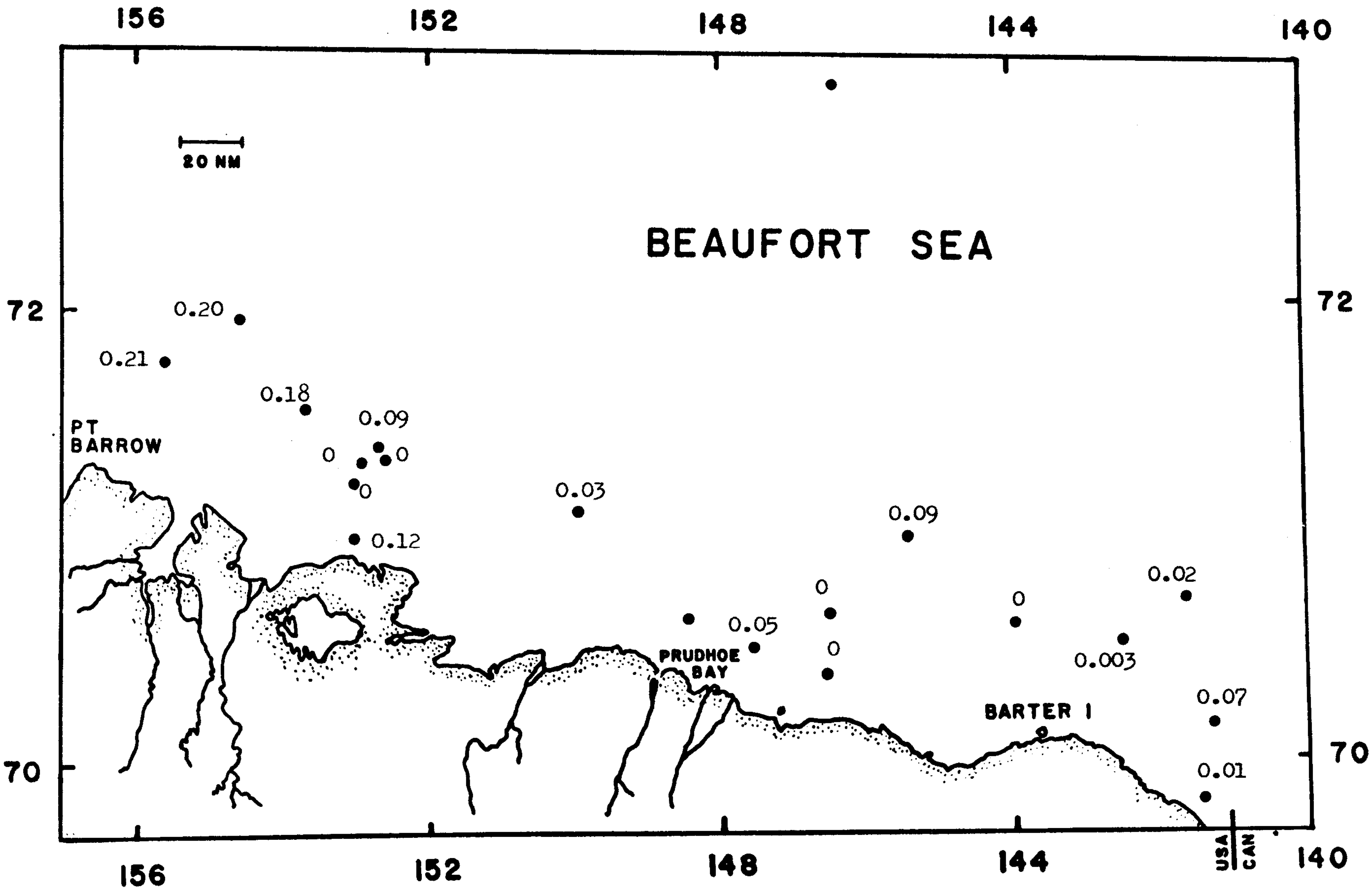


Figure 21. Nitrogen fixation rates in sediment samples collected during the September Beaufort Sea cruise. The unit of measurement used was ng nitrogen fixed /g. dry wt./h.

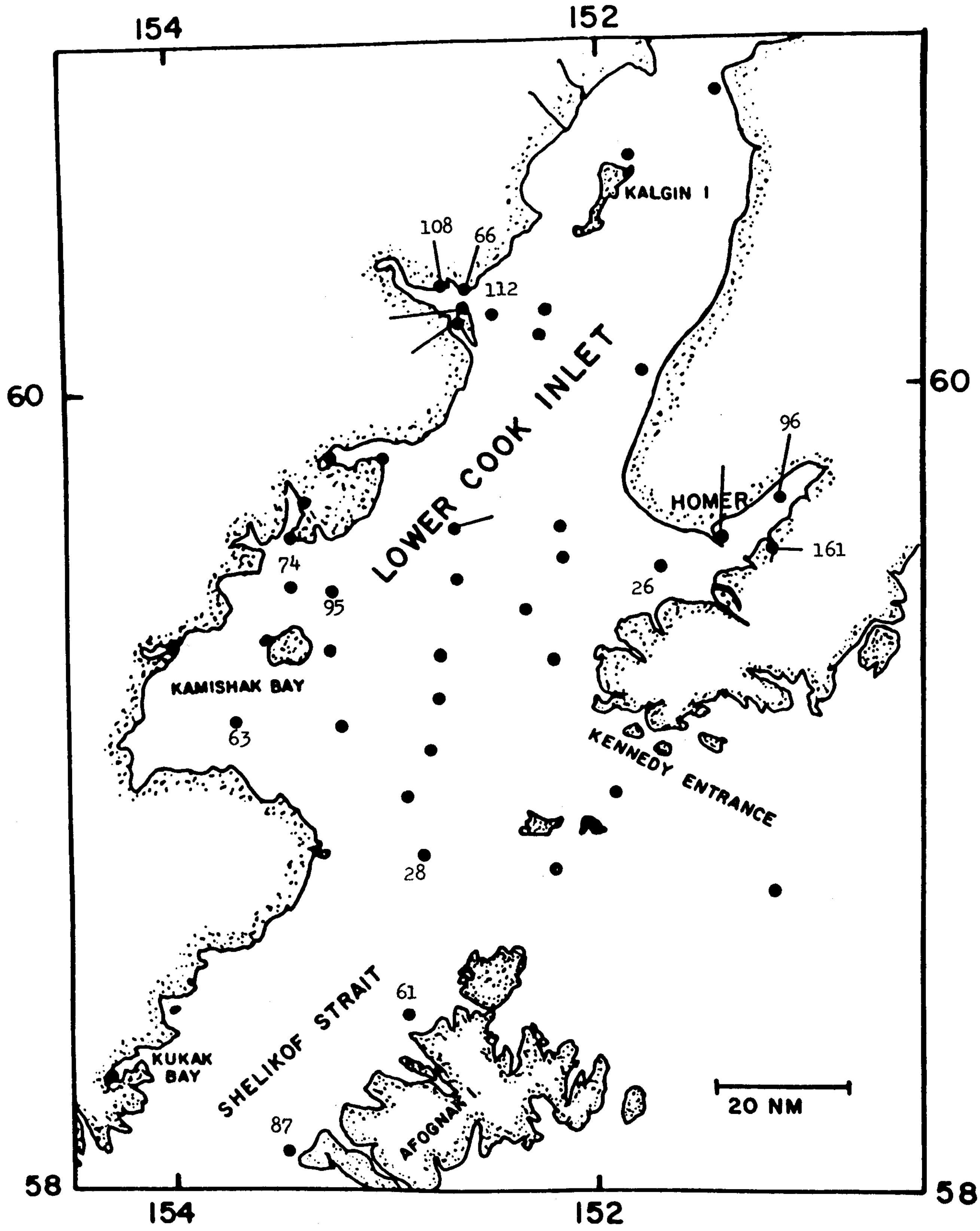


Figure 22. Crude oil degradation potential measurements in sediments collected during the April cruise. Units reported as DPM/ gr. dry weight.

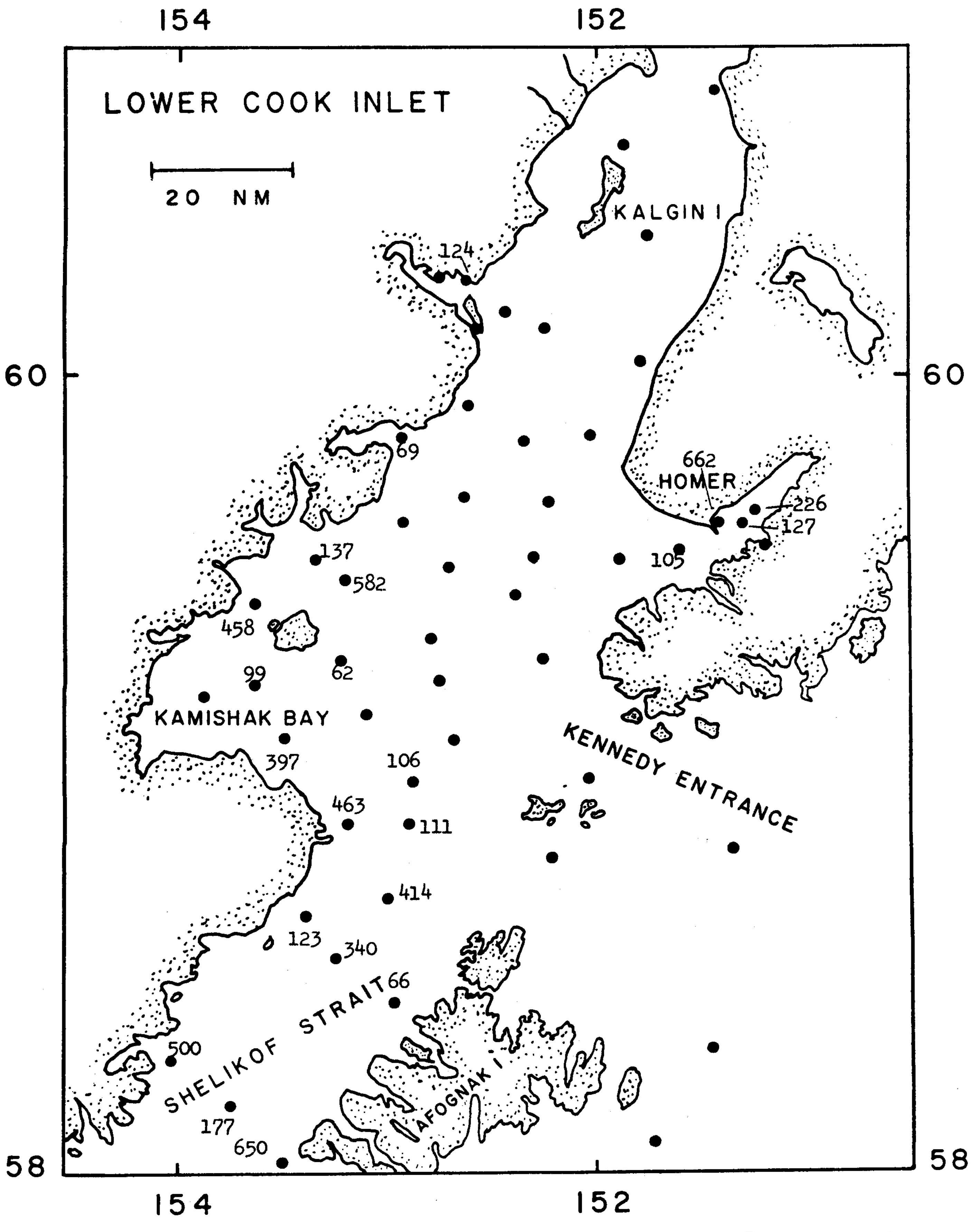


Figure 23. Crude oil degradation potentials observed in Cook Inlet sediment samples collected during the November cruise. The unit of measurement used was DPM/g. dry wt.

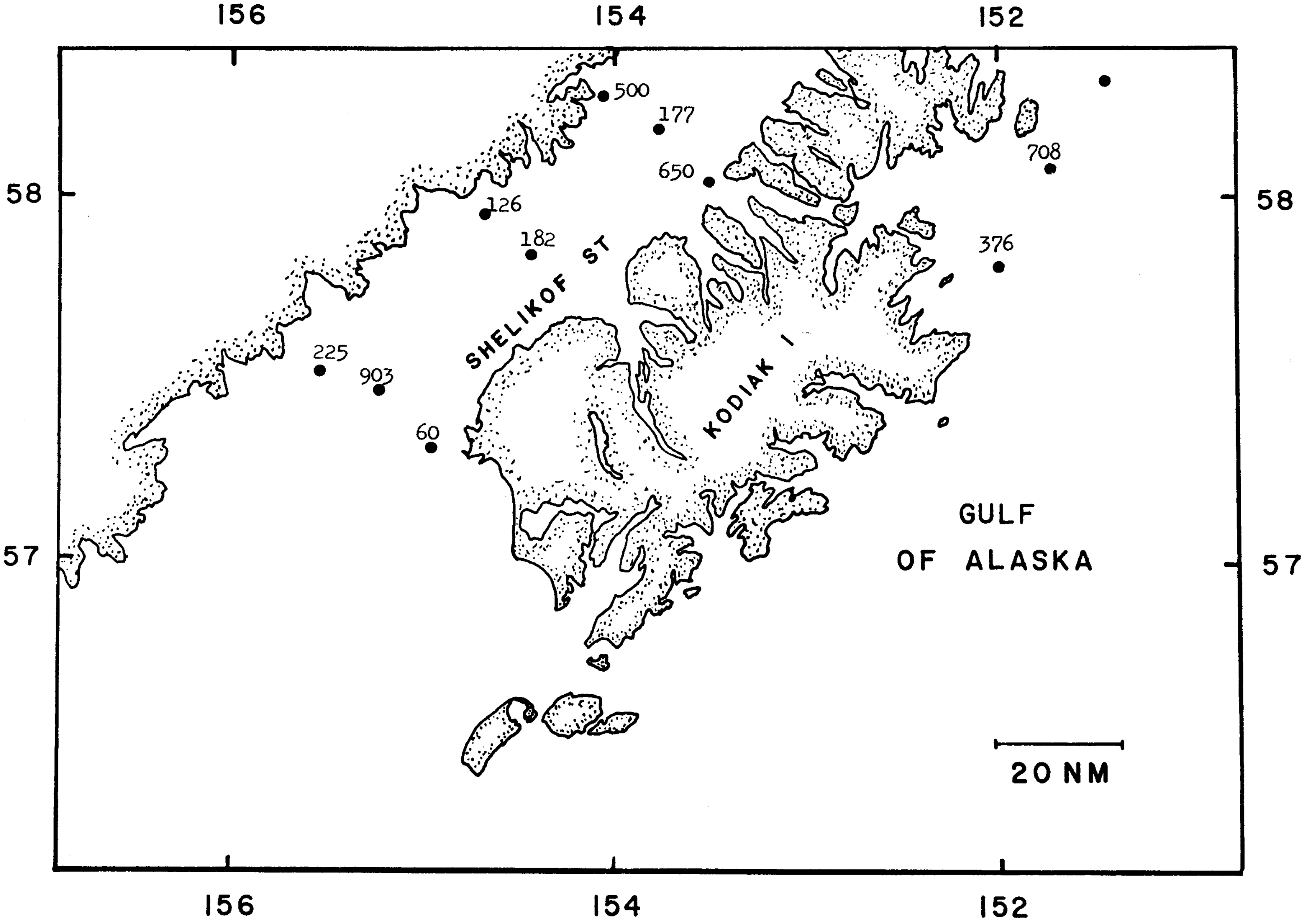


Figure 24. Crude oil degradation potentials observed in Cook Inlet sediment samples collected during the November cruise. The unit of measurement used was DPM/g. dry wt.

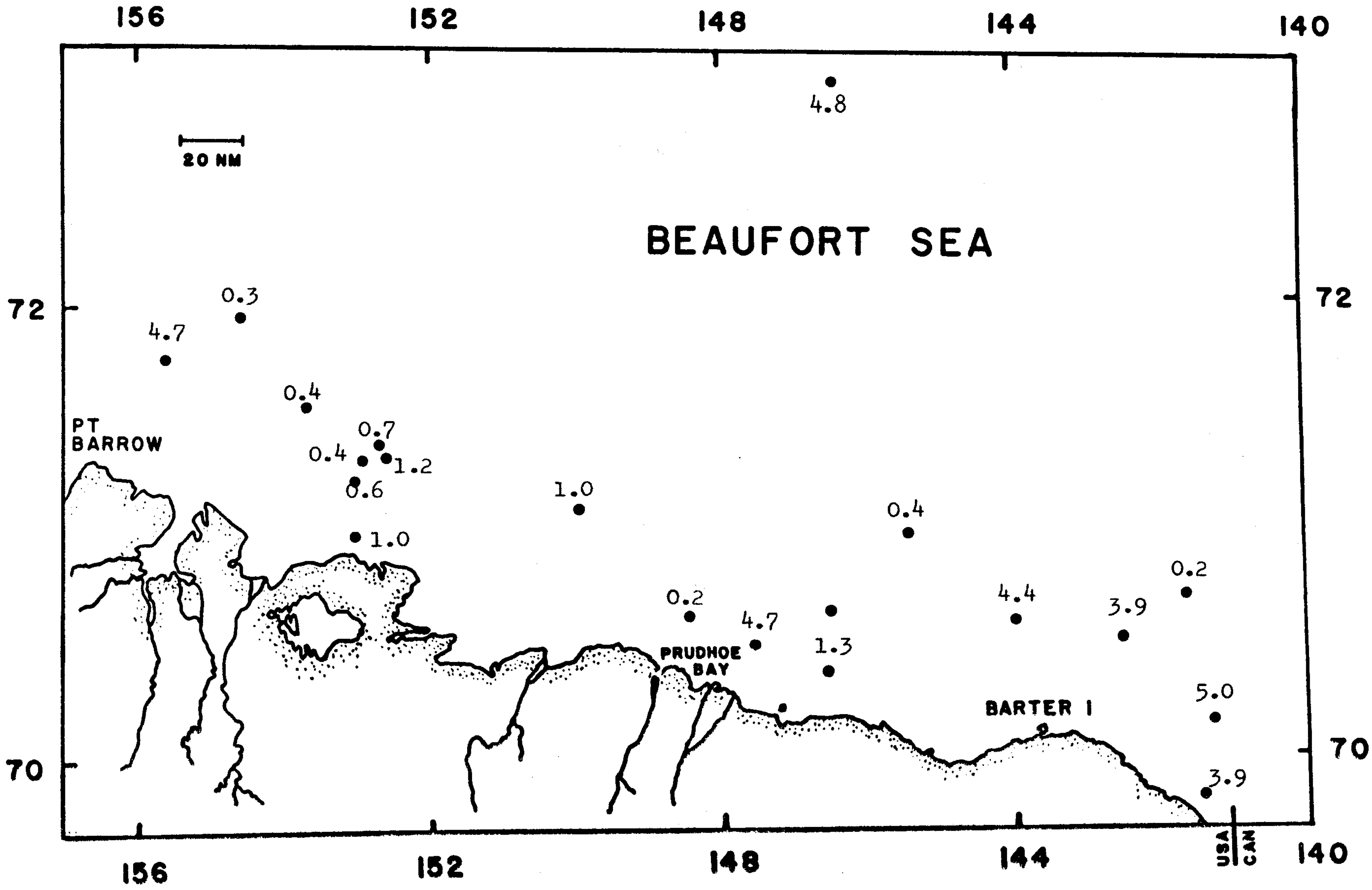


Figure 25. Crude oil biodegradation potentials observed in the Beaufort Sea sediments collected during the September cruise. The unit of measurement used was DPM in thousands/g. dry wt.

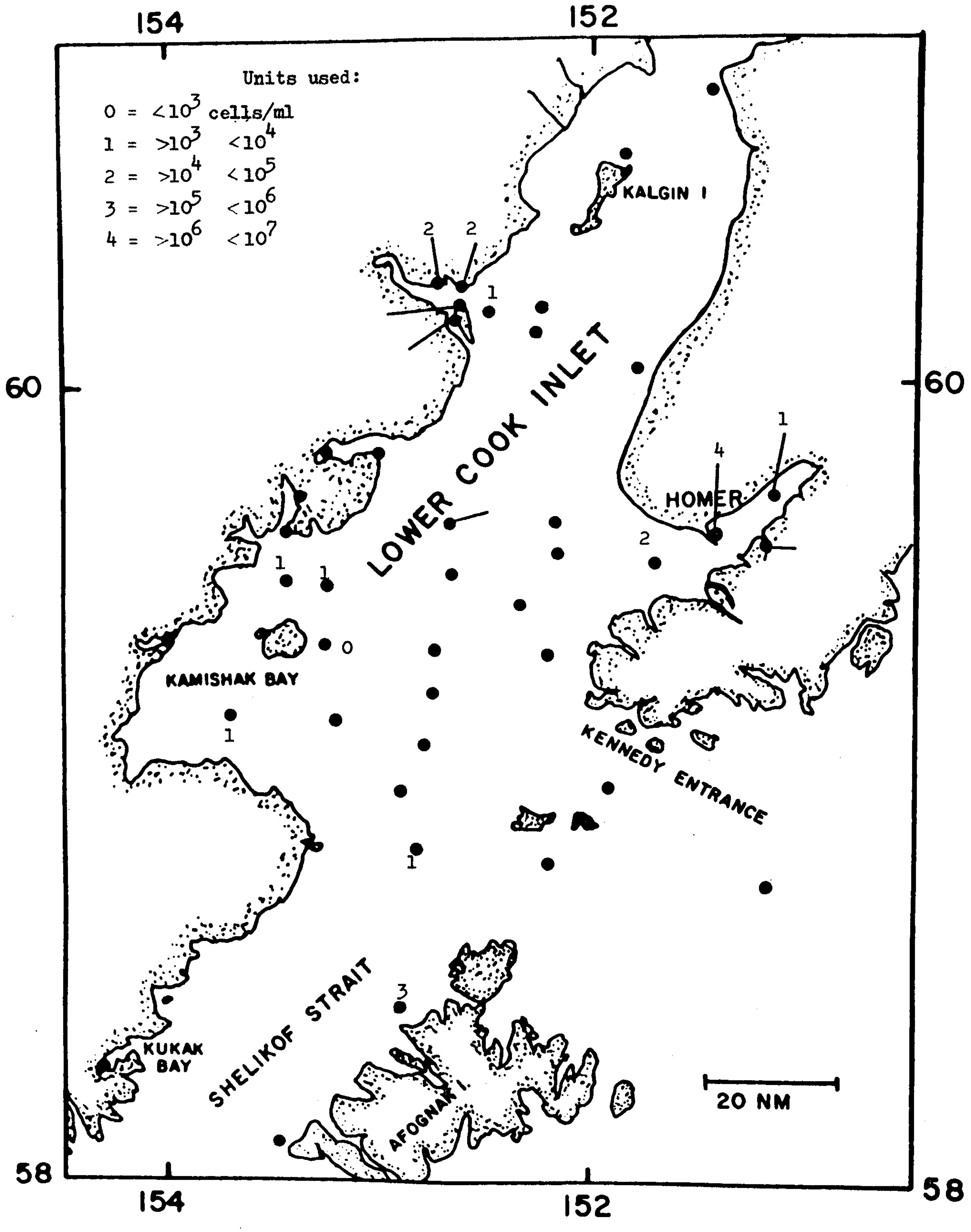


Figure 26. Relative concentrations of Desulfovibrio sp. present in sediments analyzed during the April cruise.

DETERMINE THE FREQUENCY AND PATHOLOGY OF MARINE FISH DISEASES IN THE BERING SEA, GULF OF ALASKA, AND BEAUFORT SEA

by

Bruce B. McCain*
Harold O. Hodgins*
Albert K. Sparks*
William D. Gronlund*

Submitted as an Annual Report
for Contract #R7120817
Research Unit #332
OUTER CONTINENTAL SHELF ENERGY ASSESSMENT PROGRAM
Sponsored by
U.S. Department of the Interior
Bureau of Land Management

April, 1978

* Principal Investigators, Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 2725 Montlake Boulevard East, Seattle, Washington, 98112

Annual Report for Research Unit #332

I. Summary of objectives, conclusions, implications with respect to Outer Continental Shelf oil and gas development.

A. Summary of Objectives

The overall objectives are to determine the frequency and pathology of marine animal diseases in the Bering Sea and Gulf of Alaska (GOA). Special emphasis was placed on the northern GOA during the present reporting period.

B. Summary of Conclusions

Four major pathological conditions were found in 6 species of marine fish from the GOA in 1977. The species involved, the type of condition, and the average prevalence and the range of frequencies at the sampling stations of each condition were as follows: Pacific cod (*Gadus macrocephalus*), pseudobranchial tumors, 2.5% (1.0 to 50%); pollock (*Theragra chalcogramma*), pseudobranchial tumors, 0.7% (0.3 to 14.3%); rock sole (*Lepidopsetta bilineata*), epidermal papillomas, 0.2% (0.0 to 0.5%); flathead sole (*Hippoglossoides elassodon*), epidermal papillomas, 0.4% (1.7 to 16.7%); Pacific ocean perch (*Sebastes alutus*), epitheliod tumors, 0.6% (0.2 to 21.0%); and Pacific cod, skin ulcers, 0.9% (0.6 to 46.2%). The geographical distributions of all these conditions, except the tumors of Pacific ocean perch, were concentrated in the northwestern GOA, east and northeast of Kodiak Island. All of the tumors had in common the presence of tumor-specific cells known as X-cells which suggests a common etiology. Possible causes of these tumors include a virus(es), natural or man-made toxic chemical(s), or a single-celled parasite.

C. Implications with Respect to Outer Continental Shelf Oil and Gas Development

These field studies have increased our knowledge of the health status of demersal fishes in the GOA. Although the overall prevalence of the observed pathological conditions were relatively low, sampling stations with frequencies of over 14% were found for all the conditions except one. Therefore, in the aftermath of possible incidents of crude oil contamination of the GOA, the finding of high frequencies of diseased fish alone will not be sufficient to show the harmful effects of oil.

In addition, information has been gained concerning which species are particularly susceptible to diseases and which diseases seem closely correlated or not correlated with man's activities.

II. Introduction

A. General nature and scope of study.

The purpose of this investigation is to obtain baseline data on the prevalence, distribution, and pathology of diseases presently existing in fish and invertebrates in the Bering, Beaufort, and Chukchi Seas, Norton Sound, and Gulf of Alaska (GOA). This effort requires both field and laboratory activities. Field activities are performed in cooperation with the Resource Assessment and Conservation Engineering Division (RACE), NWAFC, Seattle, WA., (OCSEAP R.U. #175). Animals captured by R.U. #175 are divided into subsamples, and most or all of the individuals in each are examined for externally visible pathological conditions. The biological and pathological characteristics of each affected animal are determined.

B. Specific objectives.

The specific objectives of this investigation include the following: (1) determine the frequency of each major type of pathological condition in demersal fishes and invertebrates in the northern GOA; (2) establish the geographical distribution of each disease; (3) define the histopathological features of each disease by examining tissues from lesions and associated major internal organs and blood, using light and/or electron microscopy; (4) isolate disease-associated microorganisms from lesions and internal tissues, use taxonomic tests to identify them, and determine if any microorganisms is disease specific; and (5) compare the size, weight, age, and sex frequencies of diseased animals with those of normal-appearing animals of the same species.

C. Relevance to problems of petroleum development.

The principal contributions of these studies are the demonstration that significant frequencies of disease exist in the demersal fish populations associated with Alaska's Outer Continental Shelf. In addition, these studies provide information concerning the species free of detectable diseases and those species affected by specific diseases, the geographical distribution of affected fish, and the possible causes of some of the diseases. Therefore, in the aftermath of possible incidents of crude oil contamination of Alaskan marine waters, the simple existence of diseased fish will not be sufficient to show the harmful effects of oil. If, however, certain aspects of pathological conditions deviate significantly from the parameters established during these baseline studies, then oil contamination could be a possible cause.

III. Current state of knowledge.

Six major pathological conditions have been reported by us in fish from Alaskan marine waters. They include epidermal papillomas of rock sole (Lepidopsetta bilineata) and flathead sole (Hippoglossoides elassodon), pseudobranchial tumors of cod (Gadus macrocephalus) and pollock (Theragra chalcogramma), gill-associated tumors of Pacific ocean perch (Sebastes alutus), lymphocystis of yellowfin sole (Limanda aspera), skin lesions in cod, and larval trematode infestations characterized by black spots in the skin of Pacific herring (Clupea harengus pallasi), toothed smelt (Osmerus mordax dentex), and saffron cod (Eleginas gracilis) (McCain et al 1978, Wellings et al 1977, Alpers et al 1977a and 1977b, Myers et al, manuscript in preparation). Two important pathological conditions found in epibenthic invertebrates were infestation of sea stars (Leptasterias sp.) by parasitic gastropods, and extensive attachment of leech eggs to the appendages of shrimp (Sclerocrangon boreas) (Katherine King, manuscript in preparation). Tumor bearing cod, pollock, and rock sole, and cod with skin lesions were found in both the Bering Sea and GOA. Lymphocystis of yellowfin sole was observed only in the Bering Sea; tumor-bearing Pacific ocean perch and flathead sole were found only in the GOA; and the trematode infestations of toothed smelt, Pacific herring, and saffron cod were detected only in the Norton Sound/Chukchi Sea.

The causes of all but possibly two of their pathological conditions are not known. The exceptions are lymphocystis of yellowfin sole, which is caused by a virus, and the apparently bacterially-caused skin ulcers of cod. Cod and pollock pseudobranchial tumors (probably carcinomas),gill-associated tumors of Pacific ocean perch and epidermal papillomas of sole, are neoplasms of unknown cause(s).

IV. Study Area

During the last year, the area of the northern GOA investigated had the approximate boundaries of:

54.5° to 58° N. Lat.
133° to 152° W. Long.

V. Sources, Methods, and Rationale of Data Collection

Research efforts were of two general types, field and laboratory activities. Field activities were performed aboard the NOAA Ship *Miller Freeman* and the Polish research ship *Professor Siedlecki*. Gear characteristics, trawling methods, and sampling procedures were similar to those used by Kaimmer et al. (1976). Each catch was sorted according to species by our personnel and by members of OCSEAP R.U. #175, and a randomly-selected subsample of each species (200 to 400 fish) was used to estimate size, age composition, and sex ratios. The samples were examined for externally-visible pathological conditions and, when feasible, for readily recognizable internal disorders.

The types and frequencies of each abnormality found during these examinations were recorded on an individual data sheet. The species, sex, length, weight, and age of each affected fish were determined; and the type, location, and size of the pathological condition(s) was recorded. Either the diseased tissue alone, or the affected tissue in combination with the major internal organs, was preserved in 10% formalin with phosphate-buffered saline and returned to the laboratory and examined histologically. Isolates of bacteria, fungi, and virus were obtained by standard microbiological procedures.

Field data were recorded on 4 different types of data sheets corresponding to 4 data management record types. These record types included, File Header (describing the cruise and investigators), Station Header (describing the haul related data), Species Catch (describing the fish caught and the frequency of pathological conditions), and the above mentioned Individual Data.

The information on the Data Sheets was key-punched onto computer cards by the Fisheries Analysis Center, University of Washington, Seattle. Duplicate computer cards are made out and sent to OCSEAP, and the original cards will be used for transferring the data to magnetic tape.

Laboratory activities involved processing tissue specimens and data obtained in the field. Specimens to be examined by light microscopy were embedded in paraffin, sectioned, and stained with hemotoxylin and eosin, May-Grunwald-Giemsa, or Massons trichrome (Preece 1972).

Specimens of tissue for examination by electron microscopy were fixed in a solution containing glutaraldehyde, formalin, and acrolein (Hawkes 1974) in the field, returned to the laboratory, and post-fixed in osmium tetroxide, dehydrated, embedded in plastic, and sectioned for both light and electron microscopy. Richardson's stain was used for sections cut for light microscopy. Thin sections were triple stained with lead citrate, uranyl acetate, and again with lead citrate, and examined with a transmission electron microscope.

VI. Results

During 1977, research efforts emphasized the health status of demersal fishes in the GOA. During 2 separate cruises, one on the NOAA Ship *Miller Freeman* and the other on the Polish R/V Professor Siedlecki, 5 major pathological conditions were found in 4 species of fish (Table 1). Thirty-nine other species of demersal fish were examined and found to be free of detectable diseases (Table 2). The remainder of this section will be concerned with the distribution, frequency, pathology, and biology of fish with these conditions.

A. Pseudobranchial Tumors of Pollock

The geographical distribution of this condition was generally confined to the western portions of the GOA near Kodiak and the Kenai Peninsula (Figure 1). Only one trawl in the central region of the Gulf produced tumor-bearing pollock, and none were found in the eastern region. The prevalence of this condition in individual hauls ranged from 0.3% to 14.3% with an average frequency of 0.7% (Table 1). The disease was not depth related. The sex ratio was 2.8:1, males to females. The significance of this ratio is not yet known, since data for the normal pollock population has not yet been completed by the RACE division of NWAFC (R.U. #175). The sex data may simply reflect unequal proportions of male and female pollock captured. Of those tumor-bearing pollock aged, most were age 2 (34 out of 38), with the ages ranging up to 10 years (Figure 2). The relationship of this condition to age, growth rate, and population density is unknown, pending completion of compilation of normal pollock data.

The appearance and size of the pollock tumors were very similar to that previously reported for pseudobranchial tumors of pollock in the Bering Sea (Annual Report, April, 1977, OCSEAP R.U. 332). Four of the 38 tumor-bearing pollock had unilateral tumors.

The microscopic anatomy of these tumors was very much like that described for the same condition in Pacific cod, (Alpers et al 1977a) with the following exceptions: (1) granulomas common to Pacific cod tumors were not seen in pollock tumors; (2) the fibrous stoma of the pollock tumors was populated with numerous melanophores, while melanophores were seldom observed in the stroma of Pacific cod tumors; and (3) the pollock tumors had a marked infiltration of macrophages and lymphocytes, this was not the case in the Pacific cod tumors.

B. Pseudobranchial Tumors of Pacific Cod

The overall prevalence of pseudobranchial tumors of Pacific cod in the GOA was 2.5% (range 1.0 to 50.0%)(Table 1). The condition did not appear to be related to sex, as was shown by the male: female ratio of 1.3:1. The age of tumor-bearing fish was from 1 to 4 years, and 69% of them were 2 or 3 years (Figure 2). Pacific cod with tumors were distributed in a broad geographical area of the western GOA near Kodiak Island the Kenai Peninsula (Figure 3). An index of this broad distribution is that 41% of the hauls in which Pacific cod were captured had tumor-bearing cod. The geographical distribution of this condition does not seem to be depth related.

The gross appearance and histopathology of the pseudobranchial tumors have been previously reported (McCain et al 1978, Alpers et al 1977a).

C. Skin Ulcers of Pacific Cod

Pacific cod with skin ulcers were found in only 5 of 61 (8%) hauls in which cod were captured, and these hauls tended to be in the north-central portion of the GOA (Figure 4). The overall prevalence was 0.9% (Table 1). The male to female ratio of 0.8:1 suggests that this condition is not sex-related. The age of diseased Pacific cod ranged from 1 to 5, with 61% being 2 or 3 years of age (Figure 2).

Although two types of lesions were observed on Pacific cod in the Bering Sea, a "ring-shaped" lesion and an ulcer, only the skin ulcer was found in the GOA. The ulcers ranged in diameter from 5 to 20 mm, and distributed over the exposed body surface in a random manner, with several fish having more than 40 ulcers.

The histopathological properties of the ulcers and the etiology of the ulcers have been previously reported (Annual Report, April, 1977, OCSEAP, R. U. #332) and will be described only briefly here. A typical ulcer showed either a focally or completely exfoliated epidermis, exposing the underlying dermal components. The dermis exhibited a chronic inflammatory response consisting of increased vasculorization, perivascular hemorrhage, hyperemia, and infiltration with a mixed population of lymphocytes, macrophages, and melanophore-containing cells. The underlying musculature is usually not involved, but occasionally well encapsulated fibrogranulomatous centers are observed beneath the hypodermis.

Preliminary evidence suggests that these ulcers are caused by a pseudomonas-like bacteria. In previous work in the Bering Sea, taxonomically identical bacteria were isolated, sometimes in pure culture from the ulcers of 5 different Pacific cod.

D. Epidermal Papillomas of Rock Sole

Only 1 haul yielded rock sole with epidermal papillomas. This haul was taken near Afognak Island (Figure 5) at a depth of 63 m. Since the mean depth of all the hauls in which rock sole were captured was 138.5 m, the depth-related nature of this condition was again demonstrated. Of the 3 tumor-bearing fish captured in that haul, representing an individual haul frequency of 0.5% (3/615 and an overall prevalence of 0.2% (Table 1), 2 were age 8 and 1 was 7 years.

The gross appearance and histopathology of the rock sole tumors are very similar to epidermal papillomas reported for other flatfish (Wellings et al 1976) and have been previously described (McCain et al 1978, Wellings et al 1977).

E. Epidermal Papillomas of Flathead Sole

Although hauls containing tumor-bearing flathead sole were limited to a small geographical area east of Kodiak Island (Figure 6), this condition does appear to be more widespread in the GOA than the similar condition in rock sole; 6 of 49 hauls in which flathead sole were captured had tumor-bearing flathead sole. The overall prevalence was 0.4% (10/2439) with a frequency range for individual hauls of 1.7 to 16.7% (Table 1). The ages of tumor-bearing fish were evenly distributed between 4 and 11 years (Figure 2).

The gross appearance of the flathead tumors differed slightly from that of the rock sole tumors. Three basic types of flathead sole tumors were observed: (a) the typical epidermal papilloma, 7 fish had this type; (b) a tumor type identified as an angioepithelial nodule (AEN) (Wellings et al 1976) which is known to be the progenitor of the epidermal papilloma, these tumors were on 3 fish; and (c) an unclassified form of an epidermal papilloma that has not been previously described. This latter tumor was similar in texture and appearance to an epidermal papilloma, except that this tumor was black rather than brown and more loosely attached to the underlying dermis. The appearance and histopathological characteristics (see above) of this tumor suggest that it is an epidermal papilloma in the process of regression.

The microscopic anatomy of the epidermal papillomas and AENs was similar to that previously reported by Wellings et al (1976) for similar tumors found in other pleuronectids. The unclassified tumor differed from the above tumors by having signs of a pronounced inflammatory host response. The stroma of the tumor contained numerous pleomorphic melanophores, macrophages, lymphocytes, and eosinophilic granular cells. A high percentage of tumor-specific cells, known as X-cells (Wellings et al 1976), near the surface of the tumors were degenerated; the X-cells in typical epidermal papillomas are very seldom necrotic.

F. Epithelioid Tumors of Pacific Ocean Perch

Epithelioid tumors of Pacific ocean perch (POP) were located on membranes associated with gills, and on body surfaces. Tumor-bearing POP were in

7 of 36 POP-containing hauls which were taken along the northwestern to northeastern periphery of the GOA (Figure 7). The prevalence ranged from 0.2 to 21.0%, with an overall average of 0.6% (Table 1). No relationship between the depth of a haul and the frequency of tumor-bearing POP was observed. Also, males and females had similar tumor frequencies, as was suggested by the ratio of tumor-bearing males to females of 0.9:1.0. Only POP 8 years or older had detectable tumors, the maximum age was 17 years (Figure 2).

The epithelial tumors appeared as multiple raised nodules and/or flat, spreading growths of dull red to pink. A variety of anatomical structures were found with these tumors, including: (1) the translucent membrane on the body surface between the cleithrum and the posterior holobranch of the gills (Figure 8); (2) the membrane on the underside of the opercula (Figure 9); (3) the gill rakers, rays, and filaments (Figure 8); (4) the body surface sometimes associated with the pectoral, pelvic, caudal and anal fins, and (5) several structures (anterior isophagus, various epithelial membranes) of the buccal cavity as a result of spreading from the above-mentioned primary tumor sites (Figure 10a and 10b). Fish with the most severe and widespread tumors were also the oldest (ages 14 to 17 years).

Although the histological characteristic of the POP tumors have many similarities to the previously mentioned X-cell tumors (pseudobranchial tumors of Pacific cod and pollock, and skin tumors of rock sole and flathead sole), there are several important differences; the most dramatic of which was the commonly observed invasiveness of the POP tumors. Several tumors contained areas on their periphery in which X-cells had spread into connective and/or epithelial tissues (Figure 11). In addition secondary tumors or metastases with no connection with primary tumors were found.

Another characteristic of POP tumors seldom observed in the other X-cell tumors was a mononuclear infiltrate composed mainly of lymphocytes which was present to a variable degree in most tumors. Normally the infiltrate was diffuse and mild, but dense foci were occasionally noted.

POP tumors were generally more vascular. The stroma surrounding the nests of tumor cells was collagenous and contained numerous capillaries, venules, and arterioles (Figure 12).

Electron microscopic examination of several different types of POP epithelioid tumors has demonstrated that these tumors are composed of X-cells morphologically very similar to X-cells found in the epidermal papillomas of pleuronectids (Brooks et al. 1969) and the pseudobranchial tumors of Pacific cod (Alpers et al. 1977a) (Figures 13 and 14).

VII. Discussion

Several aspects of the geographical distribution, prevalence, age, sex, and pathology of the diseased fish from the GOA warrant further discussion. However, such discussion at this time will be somewhat restricted because data on the above mentioned subjects for normal fish captured in the same hauls containing diseased fish are not yet available to us.

Fish with 5 of the 6 pathological conditions (POP tumors were the exception) were largely captured in the northwestern periphery of the GOA. The following reasons may independently or collectively account for this observation: (1) disease frequency may be related to fish density, and more areas with high fish densities may be in the northwestern GOA; (2) since 4 of the 5 conditions were founc in even higher prevalences in the Bering Sea, some diseased fish may have migrated into the GOA from the north; (3) the bottom types in the northwestern GOA may contribute to disease induction, and (4) infectious agents and/or disease-related chemicals may be in higher concentrations in the northwestern GOA.

The overall average frequency of diseases in the GOA was relatively low, with only pseudobranchial tumors of Pacific cod having a frequency of over 1.0%. In the Bering Sea, for example, average disease frequencies ranged from 1.3 to to 8.7%, as compared to 0.2 to 2.5% in the GOA. Nevertheless, in the GOA, each of the fish diseases, with the exception of the rock sole skin tumors, had frequencies of between 14 and 50% in certain hauls. Thus, unexplained disease "hot spots" do exist in the GOA.

Three diseases, pseudobranchial tumors of Pacific cod and pollock and the skin ulcers of Pacific cod, appear to largely affect fish less than 5 years of age. On the other hand, mainly older (over 8 years) POP had tumors. The reasons for this apparent age specificity are not clear. One likely explaination is that sampling bias caused by sampling techniques and/or the life histories of the affected fish permit only certain age groups to be captured. For example, POP can be captured with an age range of 8 to 21 years or 2 to 15 years depending upon the mesh size of the trawls and the sampling location (Major and Shippen 1970).

Epidermal or epithelioid tumors represent 5 of the 6 diseases found in the GOA. All of these tumors have in common the presence of the tumor-specific X-cell. The existing histochemical and ultrastructural evidence strongly suggests the X-cells from each tumor type are very similar. Therefore, it is possible that the epidermal papillomas, the pseudobranchial tumors, and the epithelioid tumors have a common etiology. The nature of this etiology is not known. Possible causes include a tumorigenic virus, a single cell parasite, or chemical carcinogens.

With the possible exception of the epidermal papillomas of pleuronectids, the X-cell-containing tumors are invasive. The POP tumors appear to be the most invasive.

VIII. Conclusions

Three of the 4 major pathological conditions involving 6 species of fish were tumors with a possibly common etiology. The 3 types of tumors, epidermal papillomas of pleuronectids, pseudobranchial tumors of gadids, and epithelioid tumors of Sebastes sp., all contained morphologically identical, tumor-specific cells known as X-cells. The origin of X-cells is not known; although they could be virally or chemically transformed host cells, or single-cell parasites.

For reasons not yet understood, all but one of the pathological conditions occurred most often and in highest frequencies in the northwestern GOA, east and northeast of Kodiak Island. The one exception, epithelioid tumors of Sebastes sp., was geographically distributed along the northeastern and eastern periphery of the GOA.

Thus, the GOA contains at least four demersal fish diseases which are endemic in certain areas. The overall prevalence of the conditions was relatively low, ranging from 0.2 to 2.5%, although some sampling stations had epizootic levels of disease frequency ranging from 14.3 to 50% for 5 of the 6 fish species affected.

IX. Needs for Further Study

Investigations of the health status of demersal fishes in Alaskan marine waters are very complementary to resource assessment studies. Marine animals captured and examined for population studies can also be examined for pathological conditions with only a small increase in time and personnel. Thus, as long as OCSEAP-supported resource assessment programs are carried out in Alaskan waters, it would seem to be in OCSEAP's best interest to continue marine animal disease studies.

X. Summary of Fourth Quarter Activities

A. Ship and Laboratory Activities

1. Ship or Field Trip Activities

None

2. Scientific Party

Bruce B. McCain, Ph.D.
NMFS, NOAA, NWAFC

Role: Principal investigator, coordinates field and laboratory activities, participates in histopathological and microbiological analyses, and writes progress reports and manuscripts.

Harold O. Hodgins, Ph.D.
NMFS, NOAA, NWAFC

Role: Principal investigator, supervises NMFS investigations and reviews all reports and manuscripts.

Albert K. Sparks, Ph.D.
NMFS, NOAA, NWAFC

Role: Principal investigator, supervises the collection and histological analyses of invertebrates.

William D. Gronlund, M.S.
NMFS, NOAA, NWAFC

Role: Principal investigator, participates in field activities, data processing, and analyses of biological data.

Mark S. Myers
NMFS, NOAA, NWAFC

Role: Performs histopathological analyses of tissue specimens and participates in field activities and data processing.

Kenneth V. Pierce, M.S.
NMFS, NOAA, NWAFC

Role: Histopathologist.

Rod Ramos
NMFS, NOAA, NWAFC

Role: Histology technician.

3. Methods

Two main research activities were performed during the last quarter. Arrangements were made for our participation in the nearshore study of demersal fishes in the northern GOA coordinated by Dr. Murray Hayes of the Race Division of the NWAFC. The other activity concerned further analyses of biological data and tissue specimens taken in 1977 from the northern GOA.

The biological data was recently provided by the RACE Division and involved the length/weight/age data of the normal fish captured in the northern GOA by the Polish R.V. <u>Professor Fiedlecki</u>. This data is presently being tabulated and compared with similar data for diseased fish taken on the same cruise. In addition, a variety of histochemical techniques (Mowry's colloidal iron stain, Fontana-Masson Silver Method, Mayer's Mucicarmine Method, methyl green, and Gomorri's Aniline Blue Stain) were employed to further characterize tissue specimens from tumor-bearing fish from the northern GOA (Preece 1972, Armed Forces Institute of Pathology 1968). Of special interest were tumor-specific X-cells and mononuclear cells which were observed infiltrating certain tumors.

4. Sample Collection Localities

None were obtained

5. Data Collected or Analyzed

a. Number and types of samples

No. of fish from which tissue specimens were taken	46
No. of tissue specimens processed histologically	276

b. Number and types of analyses

No. of histological slides examined microscopically and interpreted. – 590

XI. Auxiliary Material

A. References Used

Alpers, C.E., B.B. McCain, M.S. Myers, S.R. Wellings, M. Poore, J. Bagshaw, and C.J. Dawe.

1977. Pathological anatomy of pseudobranch tumors in Pacific cod. *Gadus macrocephalus*. J. Natl. Cancer Inst. 54:377-98.

Alpers, C.E., B.B. McCain, M.S. Myers, and S.R. Wellings.

1977. Lymphocystis disease in yellowfin sole (*Limanda aspera*) in the Bering Sea. J. Fish Res. Board Can. 34:611-6.

Armed Forces Institute of Pathology .

1968. Manual of histological staining methods. L.C. Luna, Ed. McGraw Hill Book Co., New York 258 p.

Brooks, R.E., G.E. McArn, and S.R. Wellings.

1969. Ultrastructural observations on an unidentified cell type found in epidermal tumors of flounders. J. Natl. Cancer Inst. 43:97-100.

Hawkes, J.W.

1974. The structure of fish skin. I. General organization. Cell Tissue Res. 149:147-58.

Major, R.L. and H.H. Shippen.

1970. Synopsis of biological data on Pacific ocean perch, *Sebastodes alutus*. FAO Species Synopsis No. 79. NOAA, NMFS, Washington D.C. 38 pp.

McCain, B.B., S.R. Wellings, C.E. Alpers, M.S. Myers, and W.D. Gronlund.
1978b. The frequency, distribution, and pathology of three diseases of demersal fishes in the Bering Sea. J. Fish. Biol. 12 (In press).

Preece, A.
1972. Manual for histological technicians. Little, Brown, and Xo., Boston, Mass., 428 p.

Wellings, S.R., B.B. McCain, and B.S. Miller.
1976. Epidermal papillomas in Pleuronectidae of Puget Sound, Washington. Prog. Exp. Tumor Res. 20:55-74.

Wellings, S.R., C.E. Alpers, B.B. McCain, and M.S. Myers.
1977. Fish diseases of the Bering Sea. Annals N.Y. Acad. Sci. 298:290-304.

B. Papers in preparation or in print

McArn, G.E., B.B. McCain, and S.R. Wellings.
1978. Skin lesions and associated virus in Pacific cod (*Gadus macrocephalus*) in the Bering Sea. Fed. Am. Soc. Exp. Biol. (Abst., In press).

McCain, B.B., S.R. Wellings, C.E. Alpers, M.S. Myers, and W.D. Gronlund.
1978. The frequency, distribution, and pathology of three diseases of demersal fishes in the Bering Sea. J. Fish. Biol. 11 (In press).

McCain, B.B., W.D. Gronlund, M.S. Myers, and S.R. Wellings.

1978. Tumors and microbial diseases of marine fishes in Alaskan waters. J. Fish Diseases (Submitted).

McArn, G.E., B.B. McCain, S.R. Wellings.

1978. Skin hypertrophic cell disease and associated virus in Pacific cod (Gadis macrocephalus) J. Fish. Res. Board of Canada (Submitted)

McCain, B.B.

1978. The effects of Alaskan crude oil on flatfish, and the prevalence of fish pathology in Alaskan marine waters. In: (D. Wolfe, Ed.) Sublethal Effects of Petroleum Hydrocarbons and Trace Metals Including Biotransformations, as Reflected by Morphological, Physiological, Pathological, and Behavioral Indices. NOAA Tech. Memo. (In press).

C. Oral Presentations

McCain, B.B.

The Effects of Alaskan Crude Oil on Flatfish, and the Prevalence of Fish Pathology in Alaskan Marine Waters. OCSEAP Program Review, Nov. 29-Dec. 2, 1977, Seattle, Washington.

PROBLEMS ENCOUNTERED -- None

ESTIMATE OF FUNDS EXPENDED

Total spent: $19.2K

TABLE 1

Data Describing the Prevalence of the Six Major Diseases Found in the GOA During 1977.

Species and Disease	No. of Fish Affected	No. of Fish Examined	Average Disease Frequency (%)	Average Disease Ranged (%)	No. of Hauls With Diseased Fish	Total No. of Hauls Examined
Pollock:						
Pseudobranchial tumors	38	5541	0.7	(0.3-14.3)	9	64
Pacific Cod:						
Pseudobranchial tumors	51	2079	2.5	(1.0-50.0)	25	61
Skin ulcers	18	2079	0.9	(0.6-46.2)	5	61
Rock Sole:						
Epidermal papilloma	3	1945	0.2	(0.0-0.5)	1	23
Flathead Sole:						
Epidermal papilloma	10	2439	0.4	(1.7-16.7)	6	49
Pacific Ocean Perch:						
Epithelioid tumors	15	2466	0.6	(0.2-21.0)	7	36

TABLE 2

FISH SPECIES CAPTURED IN THE GOA DURING 1977 IN WHICH NO DETECTABLE PATHOLOGICAL CONDITIONS WERE IDENTIFIED. ONLY THOSE SPECIES OF WHICH 50 OR MORE WERE EXAMINED ARE LISTED.

Species	Total Number Examined
Black cod *Anaplopoma fimbria*	646
Arrowtooth flounder *Atheresthes stomias*	4612
Spinyhead sculpin *Dasycottus setiger*	56
Rex sole *Glyptocephalus zachirus*	2024
Arrowhead sculpin *Gymnocanthus galeatus*	50
Yellow Irish lord *Hemilepidotus jordani*	271
Pacific halibut *Hippoglossus stenolepsis*	401
Dover sole *Microstomus pacificus*	665
Great sculpin *Myoxocephalus polyacanthocephalus*	100
Rougheye rockfish *Sebastes aleutianus*	616
Silvergrey rockfish *S. brevispinus*	72
Dusky rockfish *S. ciliatus*	111
Yellowtail rockfish *S. flavidus*	211
Northern rockfish *S. polyspinus*	55
Harlequin rockfish *S. variegatus*	288
Shortspine thornyhead *Sebastobolus alascanus*	603
22 species of which less than 50 were examined	212
Total: 39 species	10,992

List of Figures

Figure 1. Geographical distribution of pseudobranchial tumors of pollock in the GOA. Hauls in which this species were captured were designated O for the R/V *P. Siedlecki* and□ for the NOAA Ship *Miller Freeman*; hauls which had diseased fish were designated ● and , respectively. The numbers beside the closed symbols indicate the disease frequency in those hauls.

Figure 3. Geographical distribution of pseudobranchial tumors of Pacific cod in the GOA. See Figure 1 for a definition of the symbols and numbers.

Figure 4. Geographical distribution of skin ulcers in Pacific cod in the GOA. See Figure 1 for a definition of the symbols and numbers.

Figure 5. Geographical distribution of epidermal papillomas of rock sole in the GOA. See Figure 1 for a definition of the symbols and numbers.

Figure 6. Geographical distribution of epidermal papillomas of flathead sole in the GOA. See Figure 1 for a definition of the symbols and numbers.

Figure 7. Geographical distribution of epithelioid tumors of POP in the GOA. See Figure 1 for a definition of the symbols and numbers. * Designates that the tumor-bearing fish captured in this haul was a *Sebaste zacentrus*.

Figure 8. The ventral view of the gill cavity of a POP with extensive epithelioid tumors of the membrane between the posterior holobranch and clerthrum (m) and of the arch (A) and filaments (f) of the posterior holobranch.

Figure 9. Epithelioid tumors (t) on the membrane on the underside of the operculum of a POP.

Figure 10. a. The anterior esophagus of a normal POP. b. The same view of a POP which had an extensive epithelioid tumor that had apparently spread from the primary tumor located on the membrane adjacent to the posterior holobranch (see arrows).

Figure 11. Light micrograph of a section of an epithelioid tumor of the skin of a POP. X-cells (x) in a variety of stages are arranged in nests surrounded by a basement membrane (bm). The nests are surrounded by a collagenous vascular stroma (s) which is continuous with the str atum spongiosum of the dermis. Two cells appearing to be X-cells are present in the stroma (arrows). Also, note the numerous capillaries (c) in the stroma. Richardson's Stain, X780.

Figure 12. Light micrograph of a epithelioid tumor from the opercular membrane of a POP. X-cells (x) have a variably granular cytoplasm and some are in a state of degeneration. Basement membranes (bm) of X-cell nests are separated by a thin stroma containing capillaries (c). Richardson's Stain, X780.

Figure 13. Electron micrograph of portions of 6 X-cells and 3 envelope cells (E) from a gill-associated epithelioid tumor of a POP. The X-cell nucleus contains a large, centeral nucleolus (N) with a characteristic hollow area, and numerous nuclear pores (arrows). The X-cell cytoplasm contains a variety of vacuoles and swollen mitochondria (M) with sparce, disintegrating cristae. X22,000. (Courtesy Dr. Joyce Hawkes)

Figure 14. Electron micrograph of a section of an epithelioid tumor of the skin of a POP. Portions of 5 X-cells (X) are bounded by a typical basal lamina (bl). Collagenous and vascular elements of the dermis (D) are evident below the basal lamina. X 7,000 (Courtesy Dr. Joyce Hawkes)

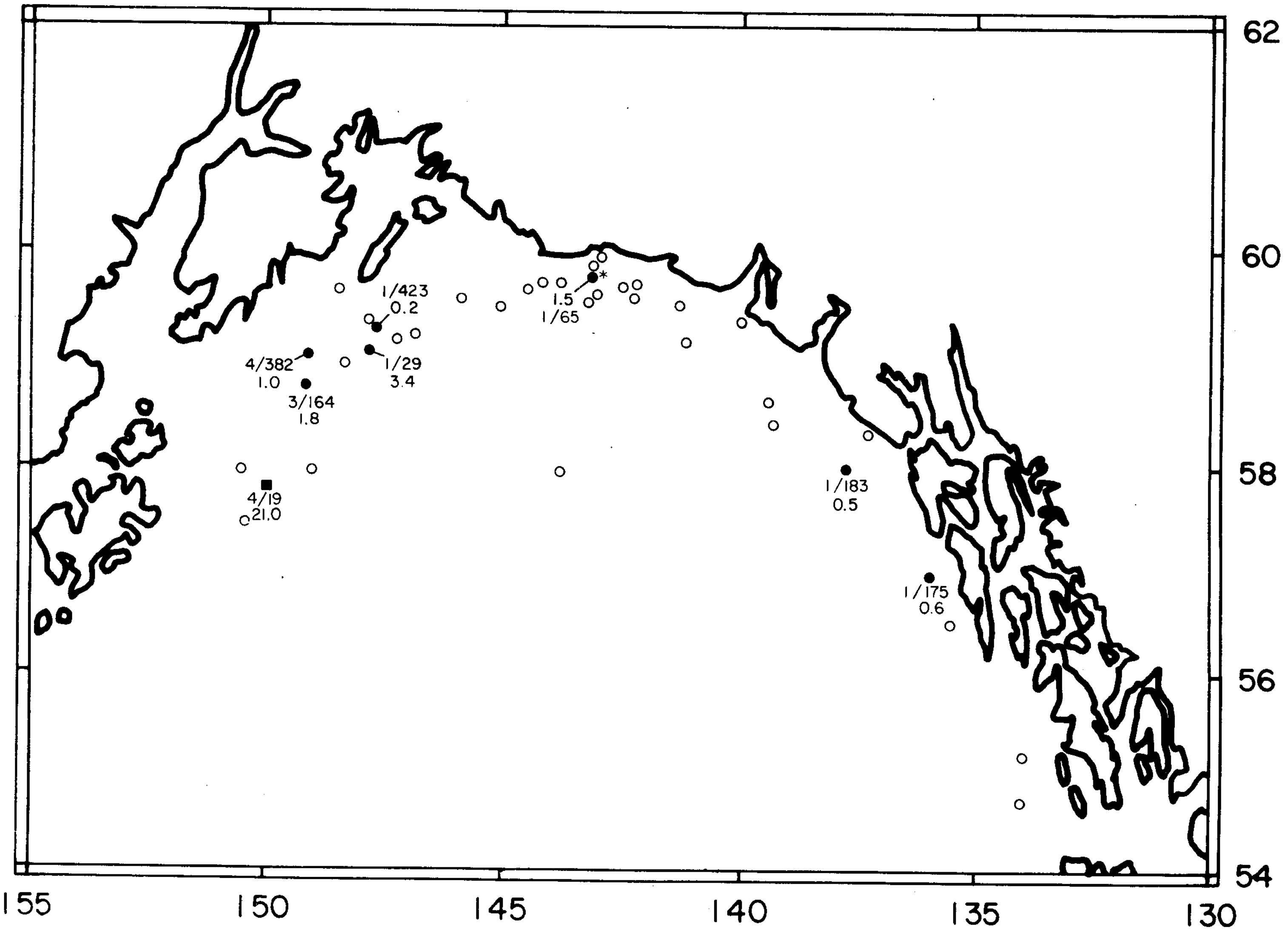

62
60
58
56
54
155
150
145
140
135
130
1/423
0.2
*
1.5
1/65
4/382
1.0
1/29
3.4
3/164
1.8
4/19
21.0
1/183
0.5
1/175
0.6

Figure 1.

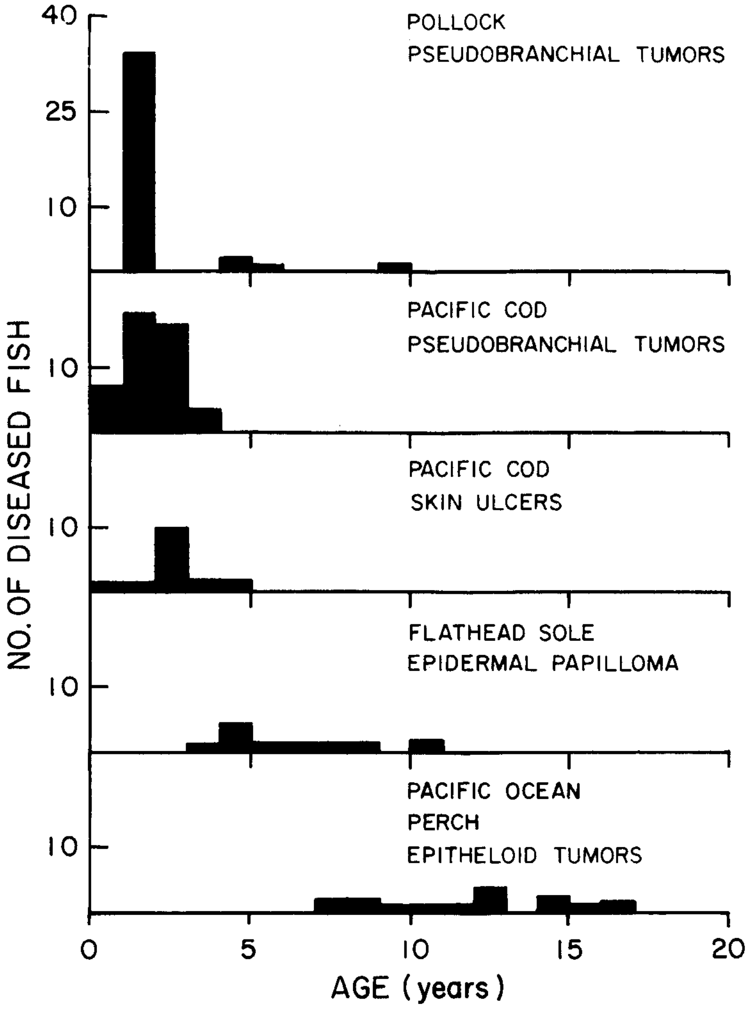


Figure 2.

Figure 2. Age frequencies for 5 different pathological conditions.

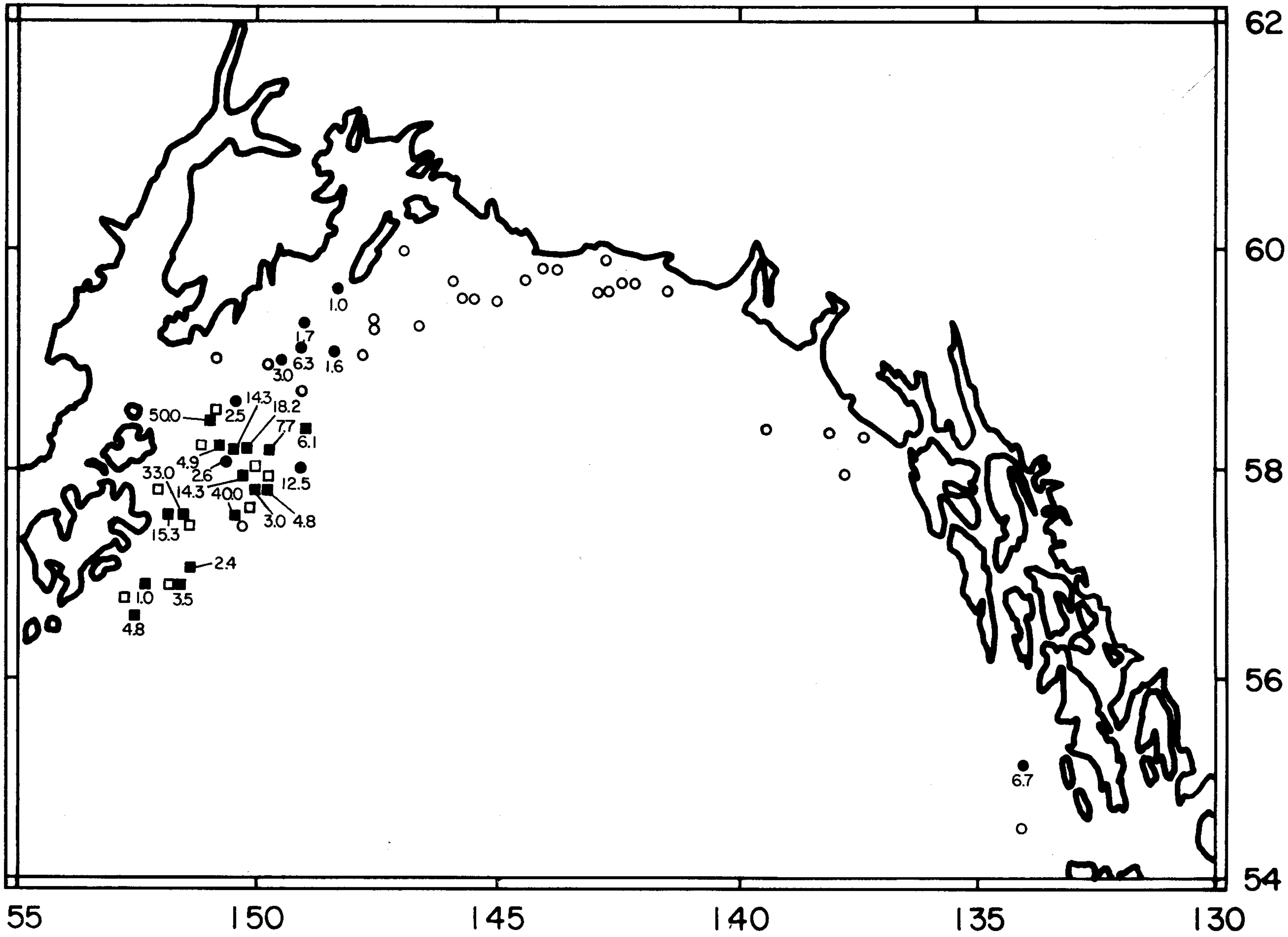

62
60
58
56
54
155
150
145
140
135
130
1.0
1.7
6.3
3.0
1.6
50.0
2.5
14.3
18.2
7.7
6.1
4.9
2.6
33.0
14.3
40.0
12.5
3.0
4.8
15.3
2.4
1.0
3.5
4.8
6.7

Figure 3.

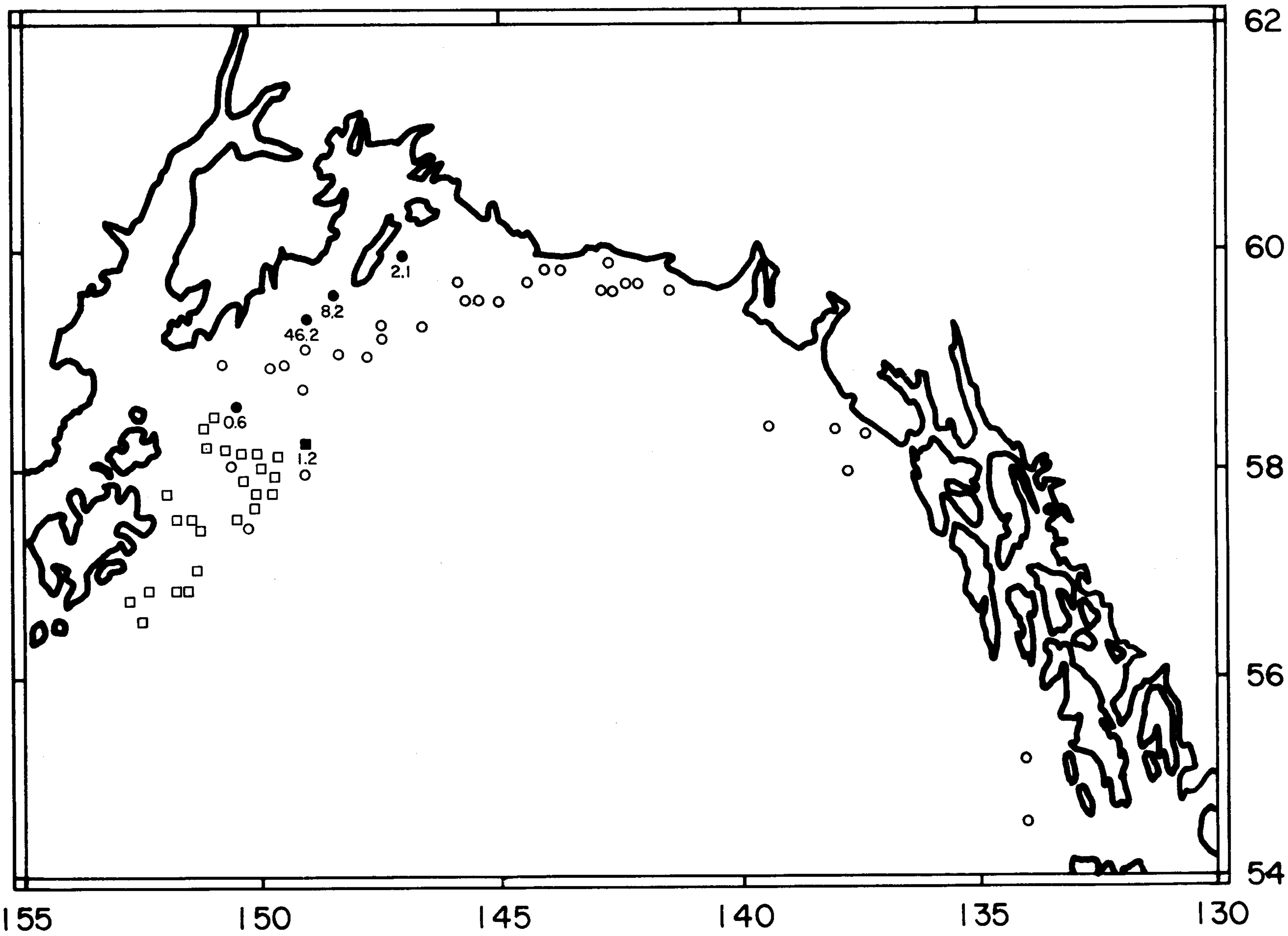


Figure 4.

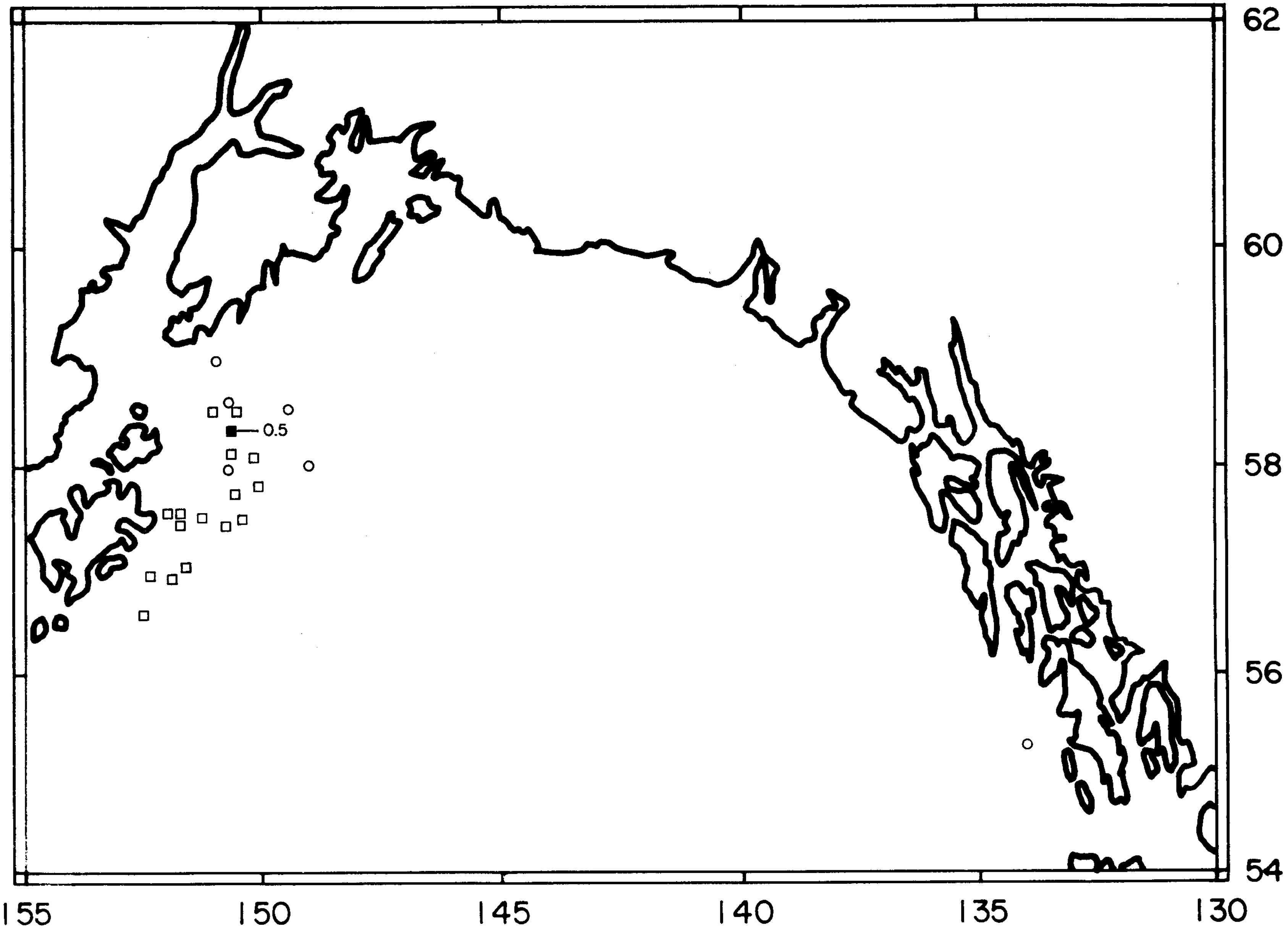


Figure 5.

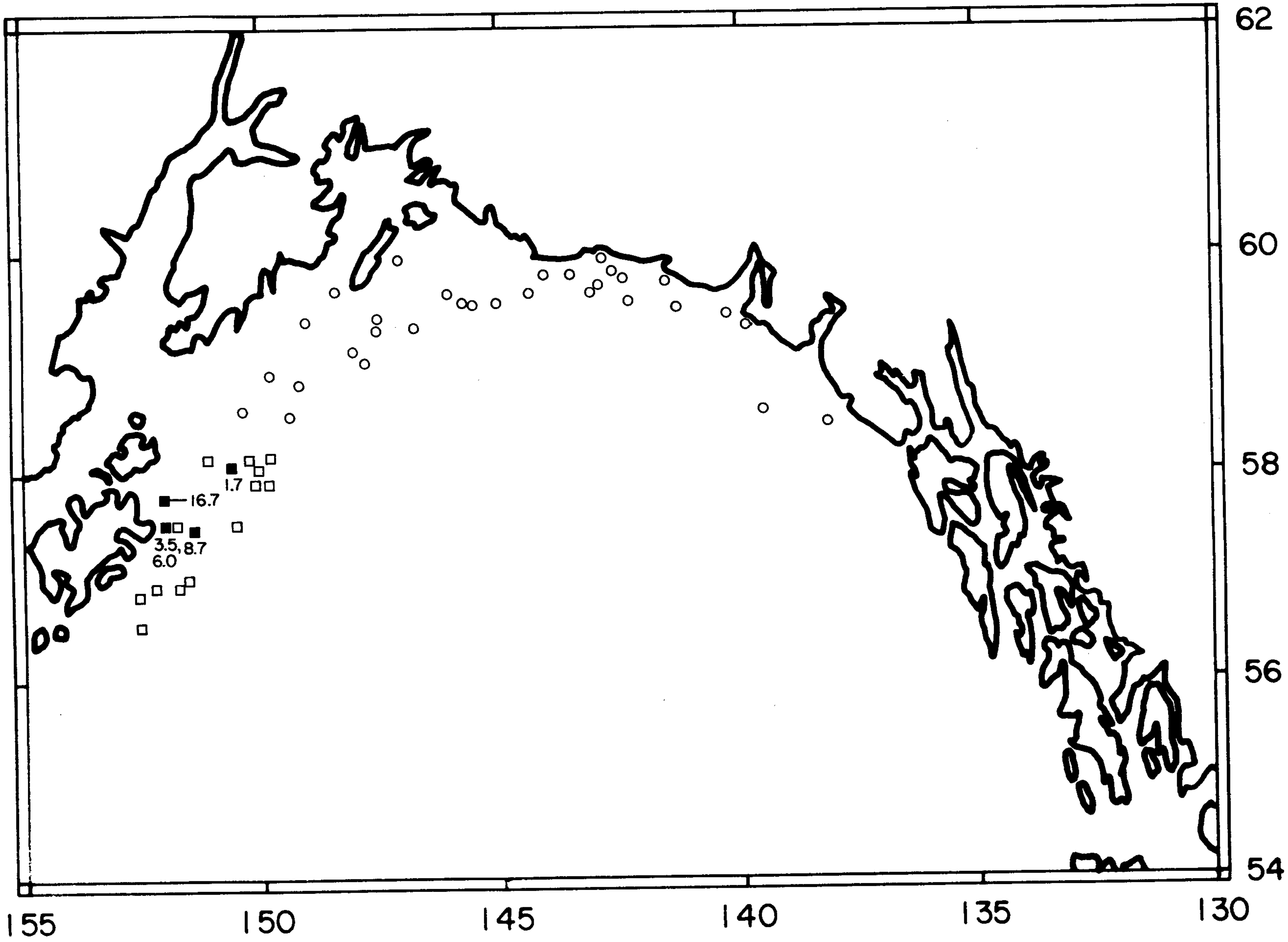


Figure 6.

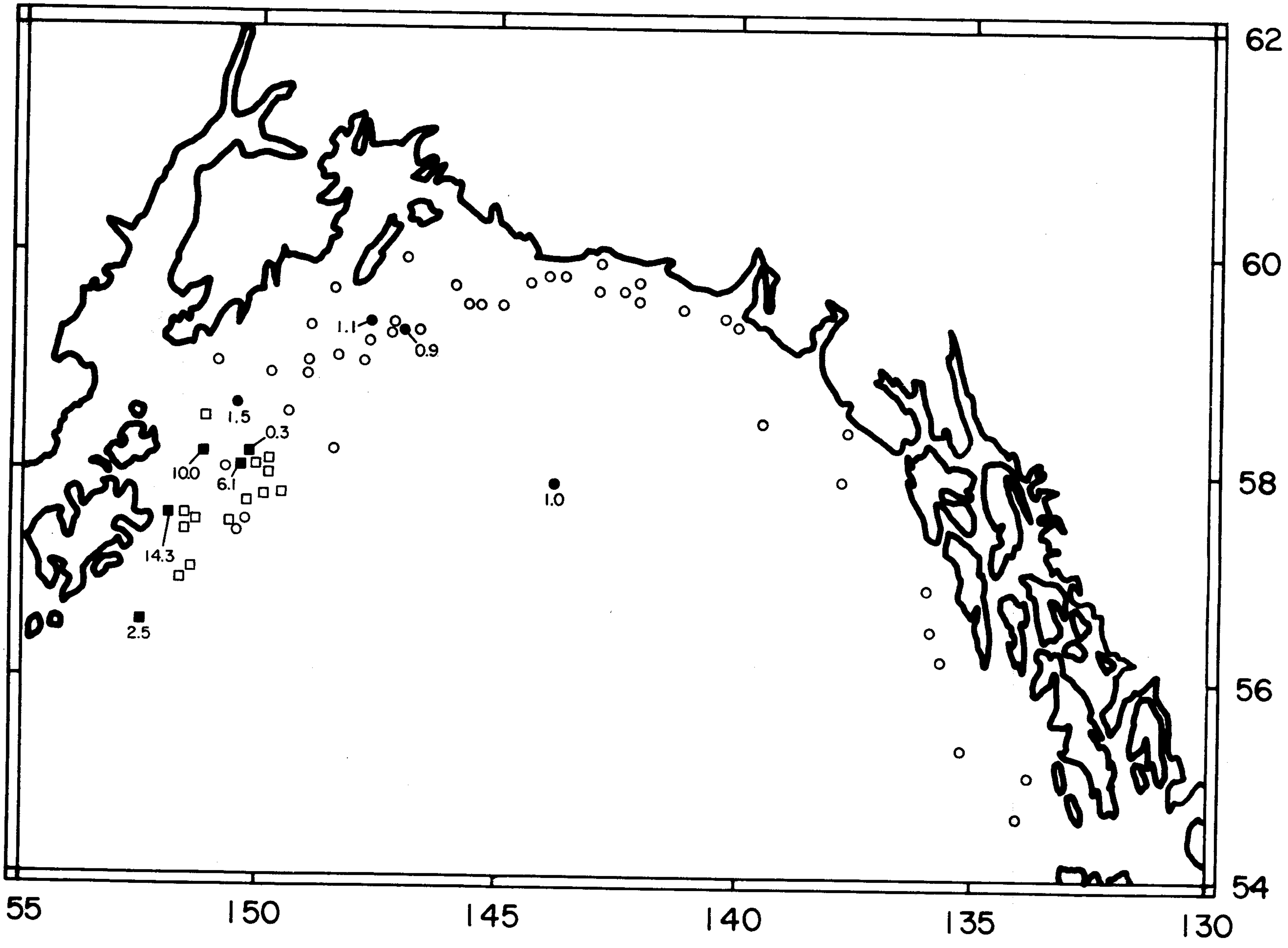


Figure 7.

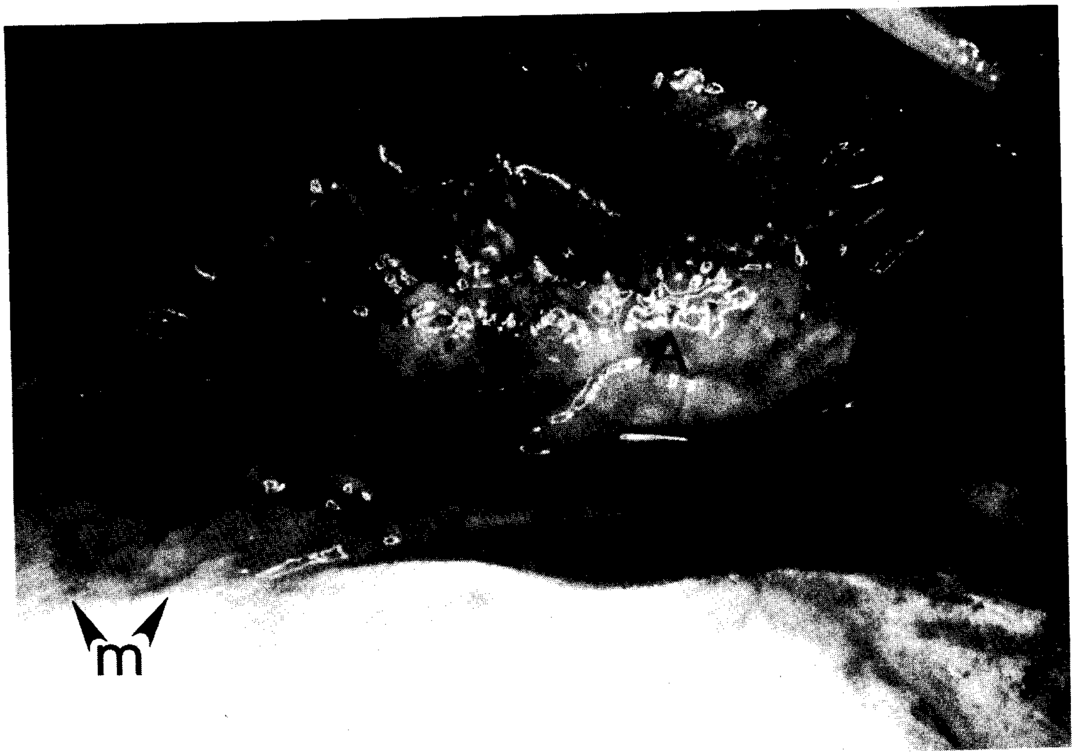


Figure 8.

Figure 9.

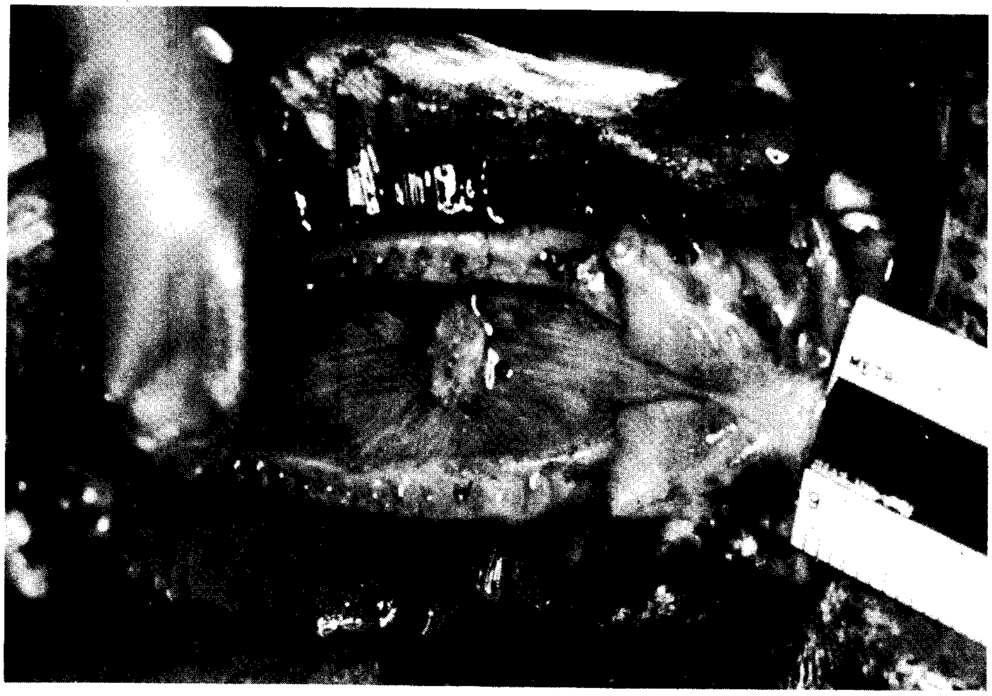


Figure 10a.

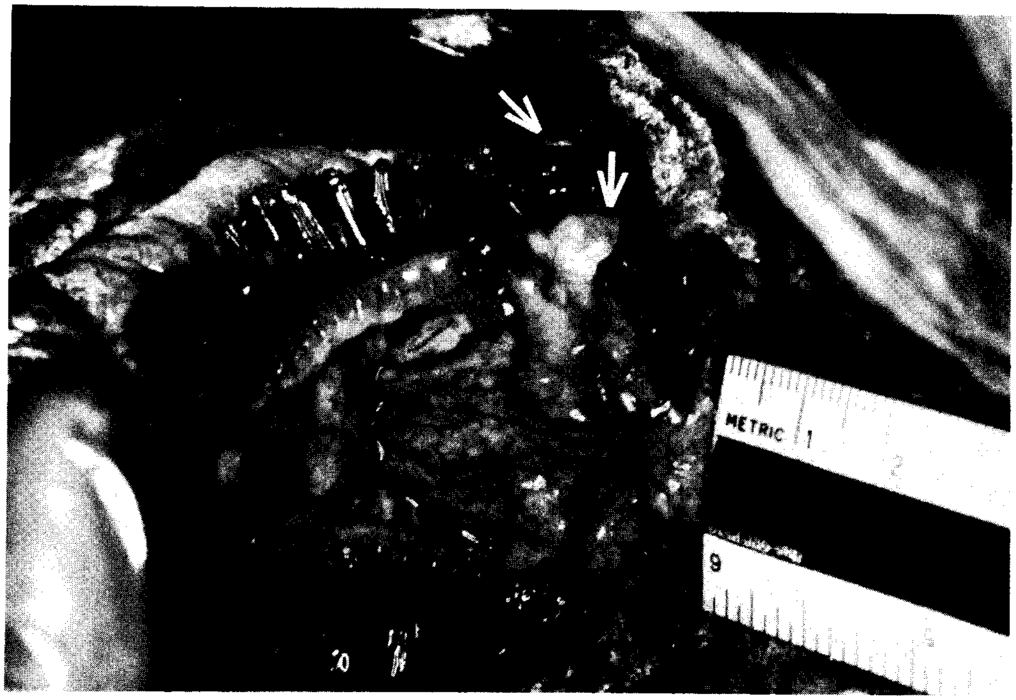


Figure 10b.

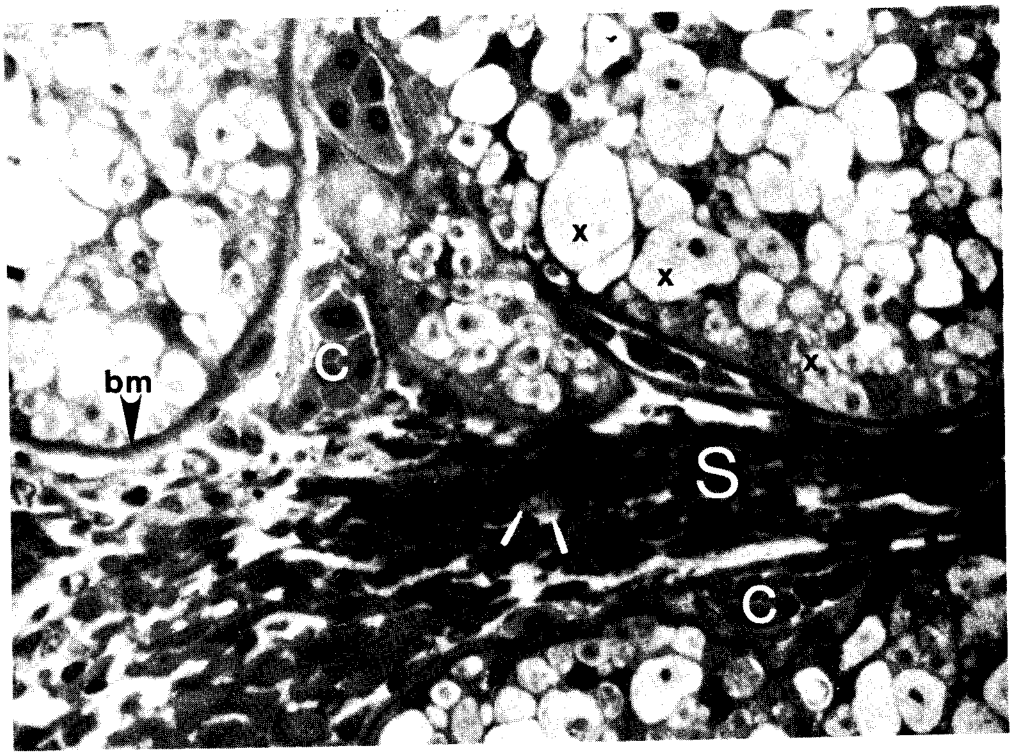


Figure 11.

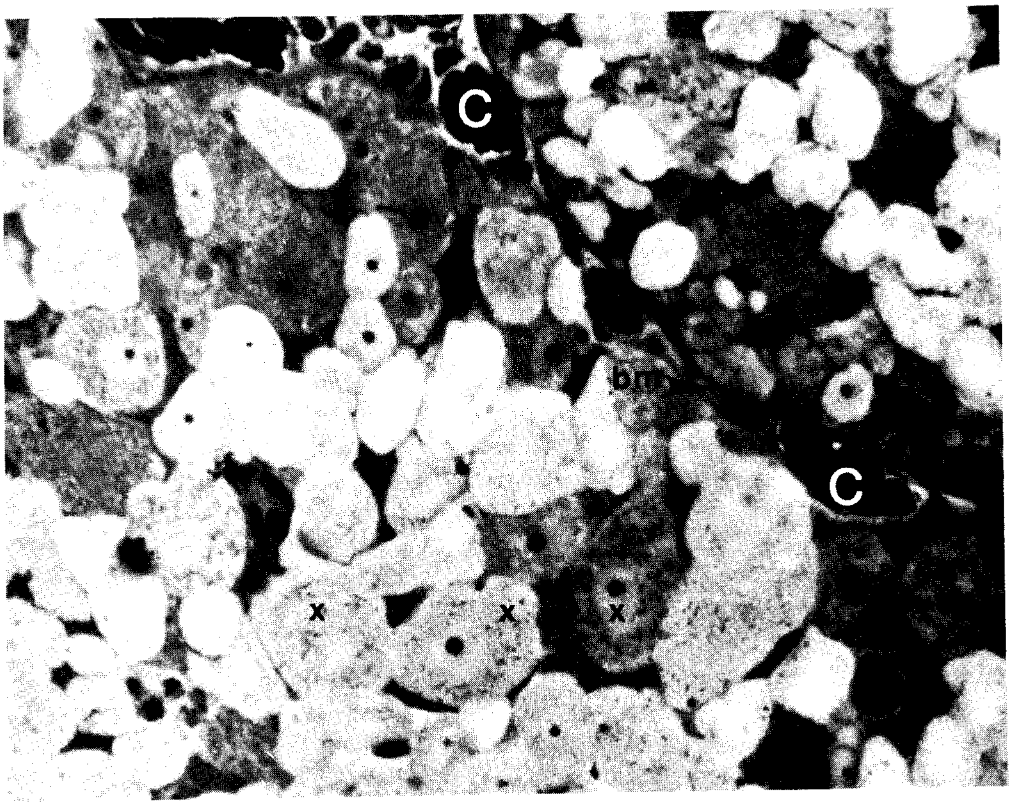


Figure 12.

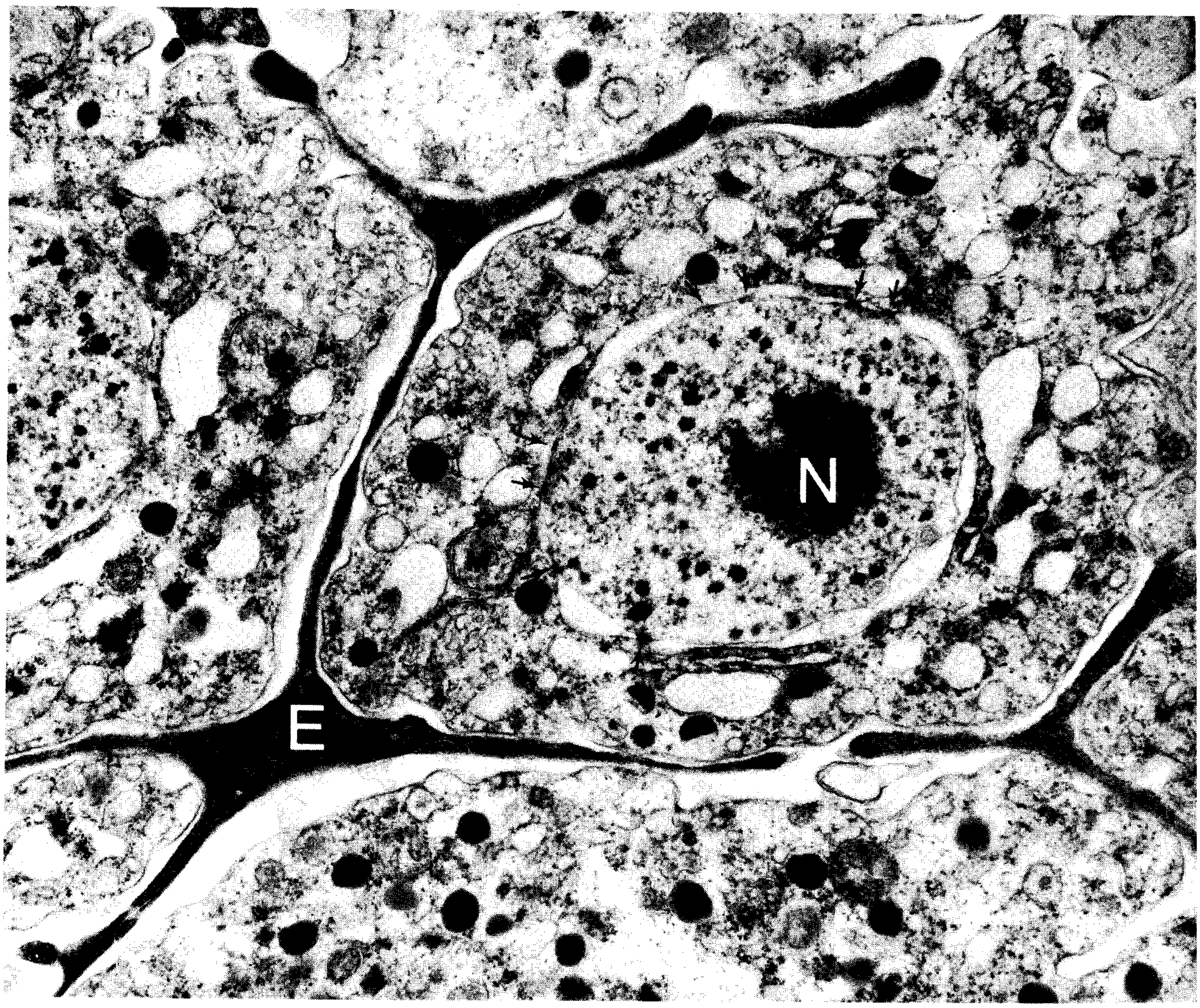


Figure 13.

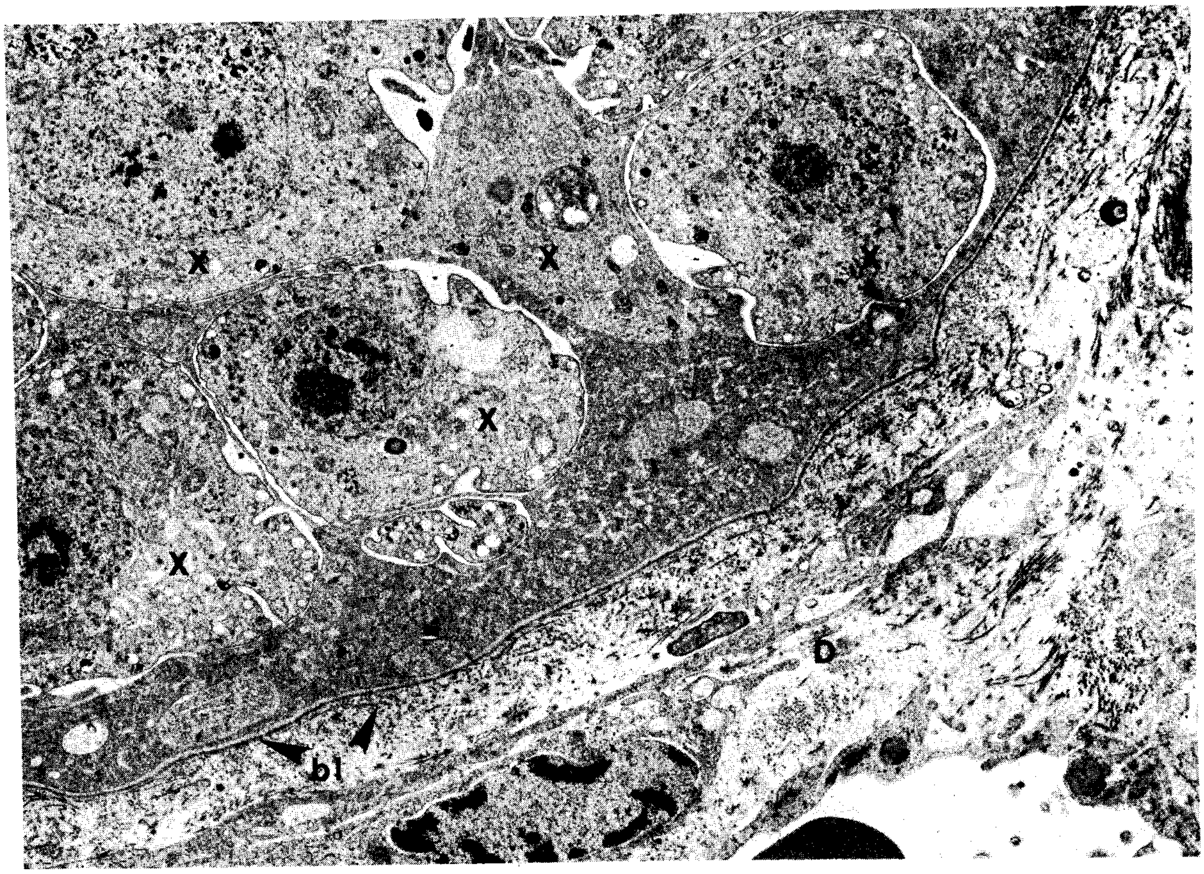


Figure 14.

ANNUAL REPORT

Contract: #03-5-022-56
Research Unit: #427
Task Order: #1
Reporting period: 3/1/77-3/31/78
Number of pages: 246

ENVIRONMENTAL-ASSESSMENT OF THE ALASKAN CONTINENTAL SHELF

Bering Sea Ice Edge Ecosystem Study: Nutrient Cycling and Organic Matter Transfer

Dr. V. Alexander

with

Dr. R. Ted Cooney

Institute of Marine Science
University of Alaska
Fairbanks, Alaska 99701

March 1978

TABLE OF CONTENTS

SECTION I

TABLE OF CONTENTS (CONTINUED)

SECTION II

LIST OF TABLES

APPENDIX I - TABLES

LIST OF TABLES (CONTINUED)

APPENDIX I - TABLES (CONTINUED)

Appendix I - A.

LIST OF FIGURES

APPENDIX I - FIGURES

LIST OF FIGURES (CONTINUED)

APPENDIX I - FIGURES (CONTINUED)

SECTION I

I. SUMMARY OF OBJECTIVES, CONCLUSIONS AND IMPLICATION WITH RESPECT TO OCS OIL AND GAS DEVELOPMENT

The objectives of this study were to determine the seasonal and spatial dynamics of the Bering Sea phytoplankton production in areas subject to future OCS development, with emphasis on the ice-edge community. The compression of annual primary production into a short spring period over much of the Bering Sea shelf implies that hazards associated with development could be particularly critical during short periods of the year. The ice-edge is associated with an intense bloom each spring. This area is also critical to higher trophic levels, and large numbers of birds and mammals are found along the receeding seasonal ice. The nature of the transfer of the spring production to the zooplankton population is not clear, and the possibility exists that much of the annual feeding involves detritus from the products of the spring bloom or even previous years. This project (then) was closely coordinated with Dr. Cooney's zooplankton work in order to make preliminary estimates of zooplankton grazing in conjunction with the phytoplankton production work in order to estimate the proportion of production used immediately during the spring period.

We have concluded that the spring bloom results from stabilization of the water column, not so much as a result of salinity gradients or marked temperature gradients, but caused by the presence of ice and its surpressing effect of the extent of mixing. High nutrient conditions and the increased availability of light in the spring, both as a result of ice breakup and increased insolation, result in a short-lived and intense bloom. This bloom follows the ice edge, albeit this is not a clear line across the shelf, and extends approximately 30 to 50 miles away. Phytoplankton populations within this zone are distinct. The underice production also contributes (epontic algae), but probably to a lesser extent. The extreme seasonal nature of this major production peak and the tendency of the surface layer with its algae to sink below the warmer water away from the ice could result in a downward transport to the benthic regions of oil-contaminated seawater, as well as oil-contaminated plankton, in the event of a major spill, and this may affect the hydrocarbon content of benthic invertebrate populations. We now have a reasonably good estimate of Bering Sea primary productivity and believe that we understand the shelf system sufficiently to make preliminary predictions with respect to possible impacts of OCS development on planktonic populations.

II. INTRODUCTION

A. The Bering Sea has been recognized (from the earliest western explorations) as a productive area of the world sufficient to be of international interest (as early as the Russian American explorations). The initial resource wealth was harvested in furs, then whales and most recently as a major international fishery. The feeding populations of pelagic birds are among the largest in the world and the marine mammal population currently exceeds millions. The success and abundance of these higher trophic level organisms is naturally dependent on the photosynthetic ability of the phytoplankton community to fix the carbon necessary to support these populations. The phytoplankton population together with a small but significant contribution from the coastal *Zostera* beds and other sources of detritus are responsible for the total annual production of the Bering Sea.

While it is obvious that the organic production of the Bering Sea shelf area is high it is remarkable too that this production occurs during a limited portion of the year since the usual winter ice cover and low light levels existent during almost half of the year effectively curtail any net production during the fall and winter months.

Our aim was to study and describe the phytoplankton dynamics of the Bering Sea throughout the year, with particular emphasis on the receeding ice edge over the shelf, in order to delineate and describe the basis for the overall Bering Sea ecosystem productivity. In this report, only work through 1976 is included. The 1977 results will be reported later.

B. Specific Objectives

In order to define the phytoplankton dynamics of the relatively vast and unstudied Bering Sea, it is necessary to thoroughly investigate all the factors affecting (limiting or enhancing) phytoplankton growth at different times throughout the year. Our specific objectives are:

1. to study the seasonal variations in primary productivity throughout the Bering Sea together with all associated factors affecting these rates including nutrient concentration, vertical stability of the water column and ice cover effects,

2. to identify, catalogue and quantitatively determine the biomass of the phytoplankton species found in the area of study,

3. to review the literature discussing the phytoplankton of the eastern Bering Sea and to integrate any unpublished data from the study area as might be available,

4. to initiate cooperative studies with the zooplankton program to follow the transfer of organic matter between primary producers and zooplankton and to conduct other experiments to resolve hypothetical questions which may arise during the investigation,

5. to develop a model of the dynamics of the ice edge plankton population,

6. to determine critical areas and times during which disturbance due to development activities could result in serious impact.

C. Relevance to petroleum development

The tremendous primary productivity of the Bering Sea is confined to a relatively short productive period of ice free conditions prior to the onset of low light conditions of fall and winter. Our studies have shown that under certain conditions the bloom is very intense for an extremely short period of time during which the water column is stripped of nutrients, and at least over the major area of the shelf, most of the production occurs during a 3-4 week period. Another feature of this ice edge production zone is that the initial bloom occurs in a very defined layer 5-10 m thick, probably the result of surface ice (chunks) stabilizing the water column. This layer is observed first at the surface and moves deeper away from the ice edge. The surface nature and intensity of this bloom phenomena, given that it represents perhaps most of the annual production for the area, make it particularly vulnerable to an untimely oil spill. The potential for long lasting effects, possibly seriously affecting the entire annual production for the year, exists to a far greater degree in the vicinity of the receeding ice edge.

Secondly, while little production occurs at low light levels in the water column beneath the solid ice pack, production can be very high within areas of loose ice chunks. In fact, fields of broken ice seem to provide the mechanism for the intense surface bloom mentioned earlier. Post-winter high nutrient conditions are capable of supporting a bloom, but less than 1% of the surface radiation penetrates the ice. Following the breakup of the large ice plates into ice chunks (with open spaces between) allowing light penetration, the primed water column becomes productive. Our observations indicate that partial ice coverage, with coincident prevention of wind mixing in the water, is more conducive to an intense burst of phytoplankton activity than is a completely ice free surface.

Additionally, during this period of ice breakup the ice chunk edges which are exposed to light (exposed edges of the ice chunks with their regular exposure to light) allow ice associated phytoplankton to flourish. As these ice edges grate together during storms the slush ice sloughed from the edges, together with associated phytoplankton cells, float on the surface. Such slush fields may cover extensive areas. The plant cells are buoyed up in the well lighted surface area by the ice and are yet exposed to the necessary nutrients. We have observed an area of such slush formed during a night storm to become visibly tinged with the ochre color of diatoms in a single day. Color photos taken from a helicopter clearly show the surface color and the chlorophyll concentration of this slush was very high.

These conditions present another threatening situation. First, if some sort of oil spill or slick were to occur in this area of fragmented ice, clean-up or containment would be virtually impossible because of the ice itself. Furthermore, the action of the ice would tend to emulsify the floating oil and could possibly result in much higher hydrocarbon concentrations in the water than would otherwise be found. Not only would this have adverse effects on the near surface phytoplankton community, but perhaps more importantly, we have observed this richly productive surface water formed at the ice front to sink beneath the warmer ocean water approaching from the south. This sinking of the surface water would effectively transport dissolved hydrocarbons into the deeper waters perhaps all the way to the bottom where it could affect migrating zooplankton and benthic populations. It appears that while this sinking tongue of cold water remains discrete, not mixing easily with other waters, transport and containment of high hydrocarbon concentrations at depth could result.

III. CURRENT STATE OF KNOWLEDGE

Major studies of primary productivity in the Bering Sea have been carried out over the past few years by McRoy and his colleagues (McRoy *et al*, 1972; McRoy and Goering, 1974). Several cruises by Japanese ships, specifically the *Hakuho Maru*, have added valuable data on a transect basis. In addition, the principal investigator of this project has carried out primary productivity studies during June-July, 1974 on the R/V *Alpha Helix*.

Summer measurements have shown that activity over much of the Bering Sea shelf is extremely low. The earliest measurements were those of Holmes (1958) who measured rates of 11 mg $C/m^2 \cdot day$ near the Aleutian Islands. Koblentz-Mishke estimated somewhat higher amounts (Koblentz-

Mishke, 1965), whereas Taniguchi estimated rates of 160 to 630 mg $C/m^2 \cdot$ day for the eastern Bering Sea. McRoy and his coworkers have estimated 18-867 mg $C/m^2 \cdot$ day as the range, with an average based on more than 20 stations of 243 mg $C/m^2 \cdot$ day. Previous winter work detected the under-ice algal component and the ice-edge component of the early season primary productivity, attributing substantial rates to the ice-algae (44 to 95 mg $C/m^3 \cdot$ day; McRoy and Goering, 1975). The estimates are based on work done at a much lower level of resolution and intensity than the present OCS work. We feel that the annual estimate suggested by previous workers is low, and some attention needs to be devoted to updating the total estimates based on the new data available from the present program. We expect to accomplish this during the final phases of the project.

Inadequate information exists relative to the role of detritus in the Bering Sea food chain, and its major sources and fate. McRoy (1970) has made estimates of input from sea grass beds, but we have little information on input from rivers on the Alaskan coast, or on the recycling of phytoplankton carbon from the spring production in the form of detritus.

IV. STUDY AREA

In most cases the study area was determined by the location of the ice edge which was emphasized most because of the dynamic phytoplankton activity associated with it. At times when no ice edge was present, stations were distributed throughout the southeastern Bering Sea with an attempt to relocate stations in areas formerly sampled.

Consequently, the data presented in this report covers three ice edge cruises: *Discoverer* Leg I, 1975, where major sampling efforts were conducted northeast of the Pribilofs; *Surveyor* Leg I, 1976, with emphasis southeast of the Pribilofs along the shelf break; and *Surveyor* Leg II, with emphasis west of the Pribilofs and again far to the east in the region of southern Bristol Bay. *Discoverer* Leg II, 1975, was done in conjunction with the benthic sampling program and stations were widely scattered. During the November 1975 *Miller Freeman* cruise, the weather was so marginal that no predetermined cruise track was possible. We sampled when and where weather permitted with a jaunt northward in search of a forming ice front.

Figures 1-4 show the sampling stations for each cruise.

V. SOURCES, METHODS AND RATIONALE OF DATA COLLECTION

All sampling was conducted from the NOAA ships *Discoverer, Miller Freeman* and *Surveyor* for a total of six cruises from May 1975 until May 1976. Specific cruise dates were:

1. *Discoverer*, Leg I - May 15-May 30, 1975
2. *Discoverer*, Leg II - June 2-June 19, 1975
3. *Discoverer*, Leg I - August 9-August 28, 1975
4. *Miller Freeman*, Leg II - November 10-November 26, 1975
5. *Surveyor*, Leg I - March 14-April 2, 1976
6. *Surveyor*, Leg II - April 12-April 30, 1976

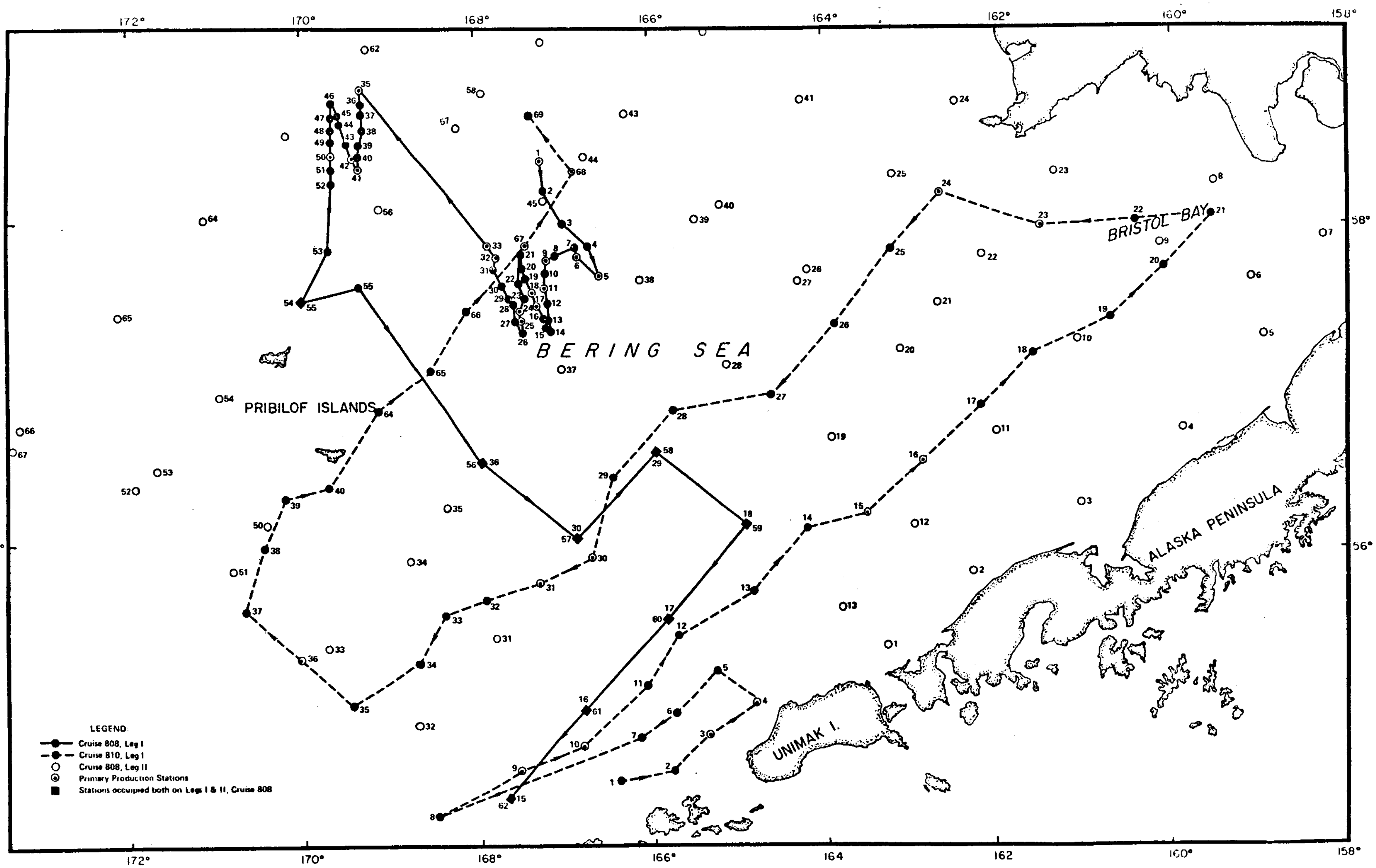


Figure 1. Cruise track for 1975 *Discoverer* cruises.

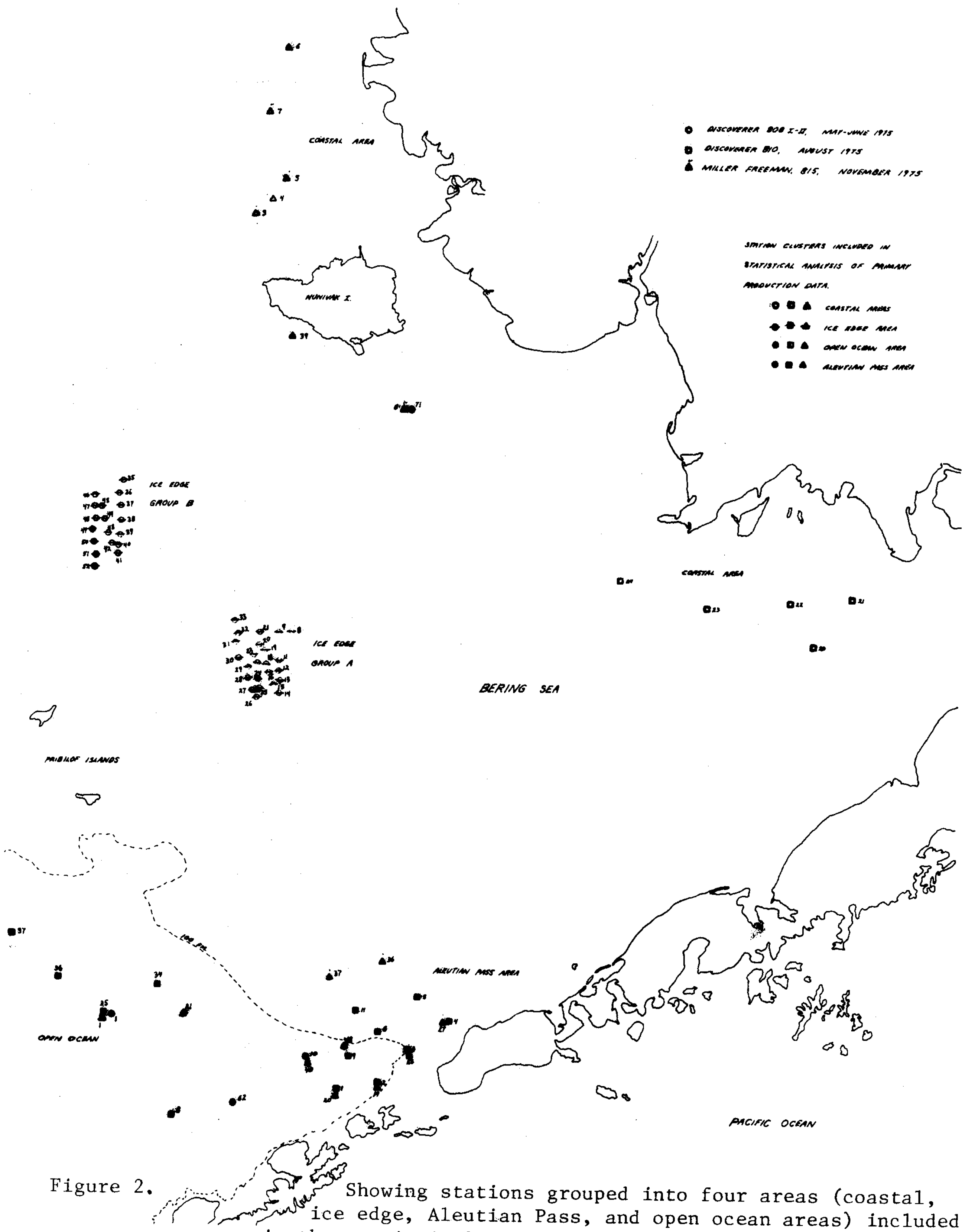


Figure 2. Showing stations grouped into four areas (coastal, ice edge, Aleutian Pass, and open ocean areas) included in the statistical analysis of primary production data, presented in Tables I through VII. Areas include stations occupied during spring, summer, and fall seasons of 1975. Table IX presents data from some of these stations re-occupied at various seasons.

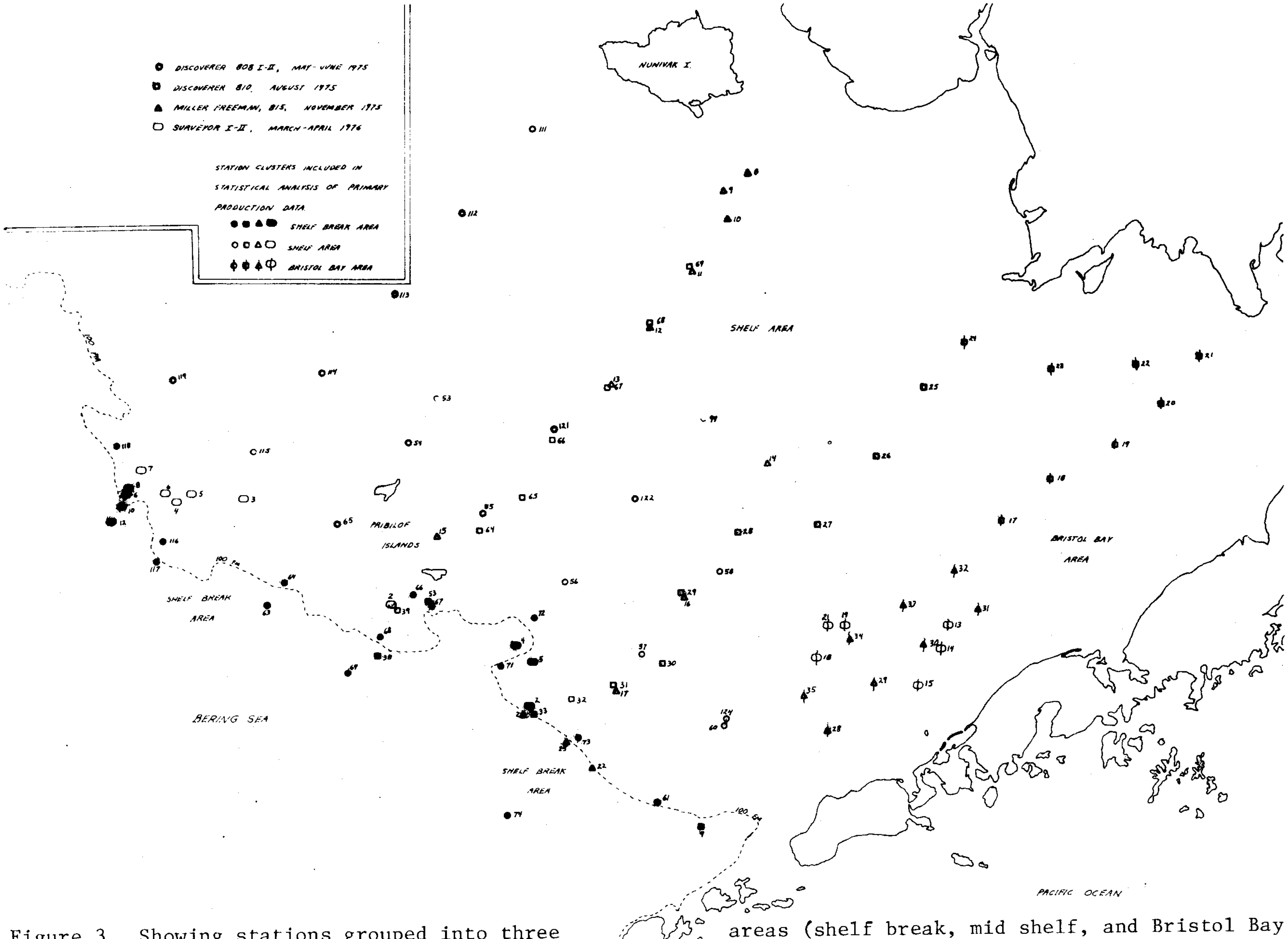


Figure 3. Showing stations grouped into three areas (shelf break, mid shelf, and Bristol Bay areas) included in the statistical analysis of primary production data, presented in Tables I - VII. Areas include stations occupied during spring, summer, and fall of 1975; and spring of 1976. Table IX presents data from some of these stations re-occupied at various seasons.

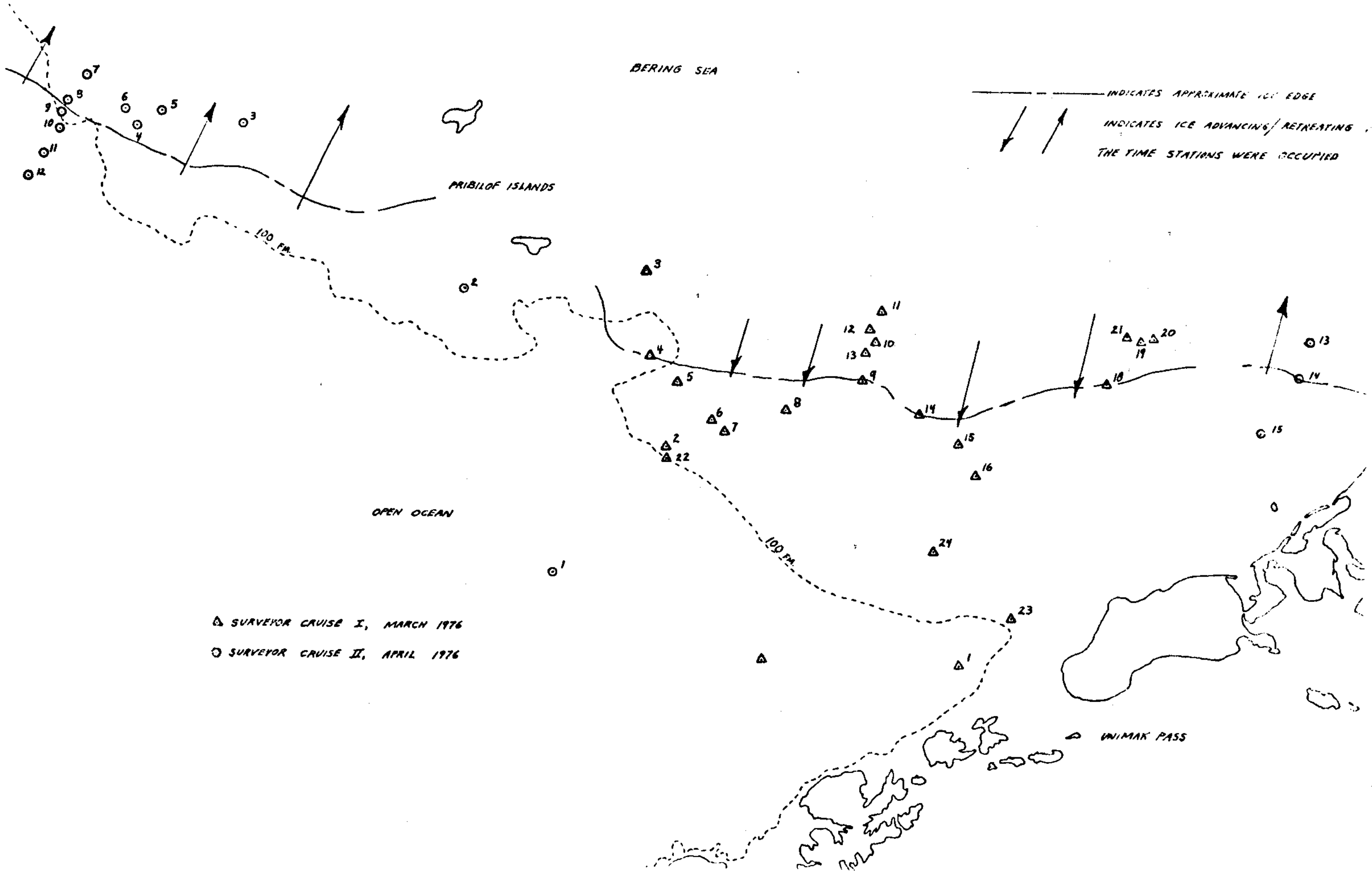


Figure 4. Showing stations occupied during March and April of 1976, in relation to the ice edge, presented in conjunction with Table VIII listing values for chlor (*a*) and carbon uptake per square meter surface area.

All sampling for phytoplankton studies was done with the CTD/Rosette Niskin sampler aboard ship, with the exception of ice samples which were obtained either with a SIPRE corer or with the aid of divers.

The scope of the initial task to describe the phytoplankton dynamics of the Bering Sea with particular emphasis on the ice edge phenomena was great. For although various investigators had made productivity measurements in certain areas at certain times, there had been no seasonal approach designed to follow and describe the entire seasonal dynamics. McRoy and Goering (1974) were able to recognize and describe the ice edge production as significant to the annual production of the Bering Sea, but until the initiation of this study no intensive investigation of the ice edge had been attempted.

The rationale of our data collection involved repeated sampling throughout the year of transects from Unimak Pass toward the ice edge over the shelf break and onto the shelf. At those times when no ice was present, i.e., August 1975 *Discoverer* cruise and November 1975 *Miller Freeman* cruise, those areas which had been sampled during ice edge cruises were emphasized.

In attempting to describe the phytoplankton dynamics of the Bering Sea, it was necessary to distinguish the various productivity regimes for different areas namely: deep water, shelf break and shelf areas in addition to investigating the role of the ice edge.

Micronutrient concentrations were measured throughout the year to depths well below the euphotic zone. Phytoplankton standing crop was estimated by chlorophyll concentration. Specific c[illegible] counts and identification of phytoplankton was done and carbon fixation was measured by the ^{14}C technique. The CTD parameters profiled during the hydrocasts were correlated with the phytoplankton structure.

Methodology

Standard methods were used for data collection with some minor changes to make better use of ship time and to accommodate some peculiarities inherent in high latitude research to make the data more consistent throughout the year. Additionally, as we acquired more sophisticated instrumentation, some of the more laborious techniques were abandoned in favor of more modern technology, although cross calibration of methods was done. Methods are described together with changes below.

Chlorophyll

Initially, 1 ℓ of water from the Niskin bottle was filtered through 47 mm Gelman type A-E glass fibre filters. Under refrigeration the filters were then extracted with 10 ml of 90% spectral grade acetone for 24 hr in the dark. After centrifuging, the absorbance of the acetone-chlorophyll extract was measured with a Beckman DU-2 Spectrophotometer at wavelengths of 630, 645, 665, 750 nm. Chlorophyll *a* concentration was calculated from the equation of Parsons and Strickland.

For the August 1975 *Discoverer* cruise and the November 1975 *Miller Freeman* cruise when the spectrophotometer on board was non-functional, the filters were frozen immediately and absorbance measured following filter grinding and extraction for 24 hr in 90% acetone on a Perkin-Elmer 202 Ultra-Vis recording spectrophotometer at the previously mentioned wavelengths.

For the *Surveyor* cruises of 1976, 1 ℓ of water collected from the Niskin bottle was filtered and extracted as before. After centrifugation the fluorescence of the chlorophyll extract was measured with a Turner

Model III Fluorometer. At representative stations and depths a duplicate sample of 1 ℓ was filtered and frozen. These filters were returned to the laboratory for spectrophotometric analysis as before with the Perkin-Elmer Model 202. Chlorophyll *a* concentrations were calculated from the Parsons-Strickland equation and the results were used to calibrate the fluorometer.

Nutrients

Water samples for nutrient analysis were filtered through Gelman Type A-E glass fibre filters into aged polyethylene bottles (125 ml) and immediately frozen. Analyses for nitrate, nitrite, ammonia, silicate and phosphate were performed using automated methods on a Technicon Auto-Analyzer II.

Phytoplankton populations

Aliquots from the Niskin bottles were poured into glass jars and preserved with a modified acetic acid Lugol's solution. The Utermöhl inverted microscope technique using a Zeiss phase-contrast inverted microscope and Zeiss counting chambers was used for identifying and counting phytoplankton. To clear diatoms of protoplasmic contents for morphological study of the frustule, samples were placed in a muffle furnace at 560°C for 15-20 minutes. In addition, line drawing of un-identified species were made and photographs taken using an American Optical Differential Contrast Microscope. All phytoplankton samples have been archived for future reference.

Primary productivity

Samples from five depths were placed into glass bottles, dark and light, and to each was added 5 μCi ^{14}C as HCO_3^-. Incubations were done on deck at approximately *in situ* light conditions using neutral density light screens representing 100%, 50%, 25%, 10% and 1% incident light intensities. Surface seawater circulated through the incubator continuously to maintain sea temperature. Following 6 hr incubations, the samples were filtered through a 25 mm HA Millipore filter, rinsed with filtered seawater, the filter dried, and frozen. Upon return to the laboratory the filters were counted on a Picker low background β counter.

For the November *Miller Freeman* cruise the incubations were done somewhat differently. Due to the rigorous weather conditions and the very short daylight hours primary productivities were incubated in a temperature controlled incubation room. Deck light intensities were measured with a light meter and the incubation room light was adjusted to be approximately 80% of the noon radiation on a typically cloudy Bering Sea day. This procedural change enabled us to select stations of interest rather than restricting us to stations where time of arrival permitted daylight incubation.

Furthermore, as attempts were made to integrate marine mammal research with the oceanographic sampling program, it became increasingly difficult to be on station in early morning. Also the great distances transected during the day and/or night left many areas unsampled. It is most certainly unjustified to compare an early morning first light 6 hr incubation with an afternoon or evening incubation. Additionally, the late spring and summer light conditions make it very difficult to decide on uniform incubation times. For these reasons, we feel that

24 hr incubation times are the only solution to provide comparative data and to effectively utilize ship time. Consequently, all primary productivity incubations beginning with the *Surveyor* cruises of 1976 were incubated for 24 hr. During the 1977 field season we set up several comparative 6 hr and 24 hr incubations together with nutrient depletion studies. These data will be reported in the Annual Report for the 1977 field season.

pH and alkalinity were measured to determine the inorganic carbon available. pH was measured by a Coleman portable pH meter, Model 37A. Alkalinity was measured by adding a standard equivalent of HCl and back titrating with standardized NaOH.

Ice sampling

SIPRE cores of the ice were collected from the ice pack in the vicinity of the ship with the aid of small boats and on the *Surveyor* at greater distance from the ship by helicopter. On one cruise ship's divers collected algal samples from beneath and around the edges of floating ice chunks using a 50 ml syringe to collect algae from pockets and depressions with the under ice surface.

Grazing experiments

On *Surveyor* Leg II, experiments were performed to determine the effects of grazing, addition of copper, and addition of oil on the growth rate of the endemic phytoplankton population of the surface waters (0-5 m) at various stations. On site sea water was filtered through 216 μ Nitex netting to remove zooplankters and enriched with a nutrient stock solution to yield a final enrichment of 0.3 μg-at PO_4-P/ℓ and 4.5 μg-at

NO_3-N/ℓ. An initial subsample was preserved with modified Lugol's solution for later identification of the organisms. Initial particle counts were obtained using a Model B Coulter Counter with a 200 μ orifice allowing counts of particles from 4-80 μ diameter. The initial sample system water was subdivided into 1 ℓ poly bottles. To each was added one of the following variables:

1. Grazers (female copepods, *Calanus marshallae*)
2. Copper ($CuSO_4$) concentrations of 2, 4 or 8 μg Cu^{++}/ℓ
3. Oil concentrations of 10 or 30 ppm (μl/ℓ) Prudhoe Crude

These experimental systems were incubated in a deck incubator exposed to surface radiation with a continuous flow of surface seawater to maintain ambient sea temperature. Samples were removed from the bottles at regular intervals for particle counting.

At the termination of some of the experiments, subsamples were again preserved with modified Lugol's solution for phytoplankton identification and counting to be compared with the initial population, and 24 hr primary productivity using $H^{14}CO_3^-$ were run.

One set of experiments (Station 13B, Event #240) used ice algae collected from the bottom of an ice core. A quantity of ice core containing plant material was gently melted and diluted 50:1 with filtered seawater.

Particle counts were done from samples collected at 0, 20 and 50 m at Station 14 (Event #257).

The zooplankters were preserved in formation, later dried and weighed according to the method of Lovegrove (1966). Particle concentrations were converted to mg wet weight by multiplying their volume by 1.02 g/ml which is taken to be their average density.

Filtering rates of the grazers was calculated according to Rigler (1971):

$$(1) \qquad F = \frac{V \ln (C_o/C_t)}{tN}$$

where F = filtering rate (ml/hr/individual)

V = volume ml

C_o = initial particle concentration (mg/ℓ for particles 10-80 μ diameter)

C_t = particle concentration after time t

t = time interval in hr

N = number of grazers

and sssuming that the detrital fraction is insignificant.

Growth rates were calculated from:

$$(2) \qquad C_t = C_o\ e^{rt}$$

If the controls exhibited growth or mortality, corrected filtering rates were calculated from:

$$F' = \frac{V \ln (C_o/C_t \ell^{-rt})}{t \cdot N}$$

This correction implies that growth or mortality occurred immediately prior to the counting.

VI. RESULTS

Field Measurements

This report incorporates some preliminary integration of the results of the various cruises. Stations were divided in groups representing shelf area, shelf break, Bristol Bay area, coastal areas, open ocean station, Aleutian pass area and ice edge station. Tables I through VII compresses data from these areas respectively by depth (where $\bar{X}$ represents the mean

TABLE I

SHELF AREA

A. Cruise 808-I, May 1975

Chlorophyll *a*	$\bar{X}$	n	σ	90% C.I.
0	6.92	7	4.67	±2.54
10	7.61	7	4.77	±2.59
20	8.15	7	4.86	±2.64
30	7.88	7	4.55	±2.47
40	6.82	6	4.84	±2.92
Nitrate				
0	1.17	7	2.03	±1.10
10	1.64	7	1.87	±1.02
20	2.76	7	1.74	±0.95
30	4.34	7	2.67	±1.45
40	5.13	7	4.16	±2.26
60	11.49	7	2.72	±1.48
Ammonia				
0	0.13	7	0.11	±0.06
10	0.13	7	0.11	±0.06
20	0.13	7	0.08	±0.04
30	0.24	7	0.21	±0.12
40	0.27	7	0.24	±0.13
60	0.44	7	0.22	±0.12
Silicate				
0	8.14	7	6.47	±3.51
10	8.00	7	5.92	±3.21
20	11.71	7	6.99	±3.80
30	15.86	7	11.45	±6.22
40	17.14	7	7.71	±4.19
60	27.81	7	11.28	±6.13

TABLE I. Continued

B. Cruise 808-II, June 1975, post-bloom period

Chlorophyll *a*	$\bar{X}$	n	σ	90% C.I.
0	0.58	10	0.55	±0.25
10	1.02	10	1.26	±0.59
20	1.61	10	2.17	±0.95
30	2.09	10	2.29	±1.00
50	2.80	10	3.11	±1.36
Carbon				
0	3.00	2	2.26	±4.94
10	2.30	2	0.71	±1.54
20	2.40	2	0.57	±1.24
30	2.20	2	0	0
50	0		0	0
Nitrate				
0	0.48	4	0.15	±0.12
10	0.50	4	0.14	±0.11
20	2.73	4	4.58	±3.76
30	5.53	4	4.34	±3.56
50	13.73	4	3.67	±3.97
Ammonia				
0	0.70	10	0.54	±0.44
10	0.95	10	0.45	±0.37
20	0.78	10	0.43	±0.36
30	1.43	10	1.07	±0.88
50	0.98	10	0.62	±0.51
Silicate				
0	3.80	5	6.83	±4.67
10	3.80	5	6.83	±4.67
20	6.40	5	10.11	±6.91
30	11.20	5	10.11	±6.91
50	22.00	4	7.26	±5.95

TABLE I. Continued

C. Cruise 810, August 1975

Chlorophyll *a*	$\bar{X}$	n	σ	90% C.I.
0	0.78	15	0.73	±0.25
10	0.93	15	1.02	±0.36
20	1.33	15	1.03	±0.36
30	1.14	15	1.08	±0.38
50	0.50	11	0.46	±0.19
Carbon				
0	1.73	4	1.23	±0.94
10	1.58	4	1.28	±0.98
20	1.77	3	1.01	±1.09
30	1.03	3	0.67	±0.73
50	0.10	4	0.12	±0.10
Nitrate				
0	1.64	14	1.10	±0.40
10	1.37	14	0.76	±0.27
20	2.52	13	1.54	±0.58
30	3.85	12	2.03	±0.80
50	4.65	11	2.98	±1.23
Ammonia				
0	0.71	14	0.37	±0.13
10	0.69	14	0.32	±0.12
20	1.39	12	0.96	±0.38
30	1.76	12	1.00	±0.38
50	1.73	10	0.61	±0.44
Silicate				
0	9.46	13	3.18	±1.20
10	10.23	13	3.44	±1.30
20	10.83	12	2.37	±0.89
30	14.27	11	5.12	±2.11
50	16.27	11	8.31	±3.43

TABLE I. Continued

D. Cruise 815, November 1975

Chlorophyll *a*	$\bar{X}$	n	σ	90% C.I.
0	0.93	8	0.67	±0.33
5	1.05	5	0.69	±0.47
10	0.96	8	0.59	±0.29
15	1.66	4	1.07	±0.88
20	0.90	8	0.90	±0.45
30	0.82	5	0.62	±0.42
50	0.47	4	0.36	±0.29
Carbon (1 station)				
0	1.1			
5	1.2			
10	0.5			
15	0.5			
Nitrate				
0	0.34	8	0.11	±0.05
10	0.94	9	1.66	±0.77
20	0.30	8	0.12	±0.06
30	0.95	6	1.69	±1.02
50	1.57	3	2.19	±2.40
Ammonia				
0	0.36	9	0.23	±0.11
10	0.81	9	0.95	±0.44
20	0.24	8	0.21	±0.11
30	0.60	6	0.99	±0.60
50	0.20	3	0.17	±0.19
Silicate				
0	11.78	9	10.91	± 5.09
10	11.33	9	11.82	± 5.52
20	12.13	8	11.29	± 5.67
30	17.00	6	12.36	± 7.72
50	19.10	3	16.47	±18.00

TABLE II

SHELF BREAK

Shelf Break includes stations over shelf break area and within 10 mi of 100 fm contour.

A. Cruise 808-II, June 1975, post-bloom period

Chlorophyll *a*	$\bar{X}$	n	σ	90% C.I.
0	7.82	12	5.08	±2.00
10	7.72	12	4.86	±1.82
20	9.34	12	4.98	±1.88
30	9.73	12	5.10	±1.92
50	3.45	12	2.63	±0.99
Carbon				
0	8.18	4	3.35	±2.74
10	7.58	4	4.28	±3.51
20	7.90	4	3.67	±3.01
30	6.95	4	4.17	±3.42
50	0.48	4	0.46	±0.38
Nitrate				
0	6.23	12	3.13	±1.23
10	6.02	12	4.43	±1.67
20	5.90	12	3.21	±1.26
30	8.42	12	4.35	±1.64
50	13.84	12	7.03	±2.65
Ammonia				
0	0.48	12	0.33	±0.13
10	0.53	12	0.52	±0.21
20	0.46	12	0.34	±0.14
30	0.80	12	0.64	±0.25
50	0.65	12	0.42	±0.17
Silicate				
0	16.38	13	10.74	±4.05
10	13.92	13	9.05	±3.41
20	16.33	12	9.35	±3.67
30	19.08	13	9.19	±3.46
50	35.92	13	16.40	±6.18

TABLE II. Continued

B. Cruise 810, August 1975

Chlorophyll *a*	$\bar{X}$	n	σ	90% C.I.
0	2.78	4	1.89	±1.60
10	2.72	4	1.71	±1.44
20	2.45	4	1.45	±1.22
30	0.44	3	0.14	±0.16
Carbon (1 station)				
0	3.0			
10	1.9			
20	0.5			
30	0.3			
50	0.1			
Nitrate				
0	1.20	3	0.26	±0.29
10	7.10	4	9.70	±8.20
20	9.40	4	10.25	±8.66
30	11.88	4	9.98	±8.43
Ammonia				
0	0.78	4	0.15	±0.13
10	0.88	4	0.31	±0.26
20	1.05	4	0.38	±0.32
30	1.05	4	0.35	±0.30
50	0.93	4	0.13	±0.11
Silicate				
0	6.75	4	1.71	± 1.44
10	15.25	4	11.95	±10.10
20	31.50	4	39.10	±33.04
30	35.75	4	36.90	±31.18
50	42.00	3	41.62	±39.33

TABLE II. Continued

C. Cruise 815, November 1975

Chlorophyll *a*	$\bar{X}$	n	σ	90% C.I.
0	0.2	3	0	0
10	0.2	3	0	0
20	0.2	3	0	0
30	0.2	3	0	0
50	0.2	3	0	0
Carbon (1 station)				
0	0			
10	0.3			
20	0.3			
30	0.2			
50	0			
Nitrate				
0	13.53	3	5.25	±5.74
10	13.93	3	4.92	±5.38
20	14.40	3	3.80	±4.15
30	13.67	3	1.53	±1.67
50	12.60	3	5.29	±5.78
Ammonia				
0	0.53	3	0.32	±0.35
10	0.63	3	0.49	±0.54
20	0.93	3	0.61	±0.67
30	2.03	3	2.48	±2.71
50	0.73	3	0.50	±0.55
Silicate				
0	23.00	3	11.14	±12.17
10	25.33	3	12.22	±13.35
20	25.67	3	10.26	±11.21
30	21.67	3	1.15	± 1.26
50	22.67	3	11.55	±12.61

TABLE III

BRISTOL BAY

A. Cruise 810, August 1975

Chlorophyll *a*	$\bar{X}$	n	σ	90% C.I.
0	1.13	8	1.18	±0.59
10	1.03	8	0.69	±0.34
20	1.39	8	1.13	±0.57
30	0.66	8	0.34	±0.17
50	0.74	7	0.74	±0.38
Carbon				
0	0.70	2	0.14	±0.31
10	0.90	2	0.28	±0.61
20	1.35	2	0.64	±1.39
30	0.25	2	0.07	±0.15
50	0.05	2	0.07	±0.15
Nitrate				
0	2.32	6	2.02	±1.22
10	1.72	6	1.26	±0.76
20	3.42	6	2.86	±1.73
30	5.08	6	2.22	±1.34
50	4.80	6	3.36	±2.03
Ammonia				
0	1.18	8	0.80	±0.40
10	3.03	8	2.83	±1.42
20	2.86	8	2.57	±1.29
30	3.49	8	3.58	±1.79
50	4.20	6	2.18	±2.54
Silicate				
0	8.75	8	4.23	± 4.39
10	6.50	8	0.93	± 0.46
20	10.00	8	4.87	± 2.44
30	12.50	8	7.11	± 3.57
50	29.17	6	30.92	±15.52

TABLE III. Continued

B. Cruise 815, November 1975

Chlorophyll *a*	$\bar{X}$	n	σ	90% C.I.
0	0.48	8	0.70	±0.35
10	0.23	7	0.06	±0.04
20	0.21	8	0.09	±0.05
30	0.24	7	0.12	±0.07
50	0.21	7	0.10	±0.06
Nitrate				
0	5.71	8	2.05	±1.03
10	8.50	8	3.13	±1.59
20	8.59	8	3.57	±1.79
30	6.98	8	4.22	±2.15
50	6.75	8	2.16	±1.10
Ammonia				
0	1.06	8	0.91	±0.46
10	1.38	8	2.49	±1.25
20	1.29	7	1.34	±0.73
30	1.53	8	1.68	±0.84
50	1.25	8	1.35	±0.68
Silicate				
0	14.25	8	7.32	±3.68
10	18.13	8	5.62	±2.82
20	18.50	8	7.71	±3.87
30	14.00	8	6.57	±3.30
50	15.25	8	6.73	±3.38

TABLE IV

COASTAL AREAS

A. Cruise 810, August 1975

Chlorophyll *a*	$\bar{X}$	n	σ	90% C.I.
0	1.53	5	1.05	±0.72
10	2.78	5	3.25	±2.22
20	3.93	5	3.68	±2.51
30	4.06	5	3.84	±2.62
Carbon				
0	2.9	2	1.41	±3.09
10	2.7	2	1.34	±2.93
20	2.6	2	1.48	±3.24
30	1.5	2	0.85	±1.85
Nitrate				
0	4.16	5	0.05	±0.04
10	4.20	5	0.17	±0.12
20	4.22	5	0.13	±0.09
30	4.28	5	0.25	±0.17
Ammonia				
0	0.84	5	0.66	±0.45
10	0.80	5	0.57	±0.39
20	0.98	5	0.65	±0.45
30	0.70	5	0.31	±0.21
Silicate				
0	6.0	5	0	0
10	6.8	5	0.84	±0.57
20	7.8	4	1.71	±1.40
30	7.6	5	1.67	±1.14

TABLE IV. Continued

B. Cruise 815, November 1975

Chlorophyll *a*	$\bar{X}$	n	σ	90% C.I.
0	0.33	6	0.13	±0.08
5	0.40	6	0.16	±0.10
10	0.35	6	0.13	±0.08
15	0.66	6	0.45	±0.27
20	1.31	5	0.47	±0.29
Nitrate				
0	1.98	5	0.69	±0.47
5	1.78	5	0.45	±0.31
10	1.58	5	0.50	±0.34
15	1.68	5	0.82	±0.56
20	1.62	5	1.08	±0.73
Ammonia				
0	1.92	5	0.81	±0.56
5	2.08	5	1.02	±0.70
10	1.84	5	0.78	±0.53
15	2.24	5	1.38	±0.94
20	1.40	5	0.73	±0.50
Silicate				
0	16.0	5	2.45	±1.67
5	16.6	5	4.77	±3.26
10	15.2	5	4.76	±3.25
15	14.8	5	3.83	±2.62
20	14.0	5	4.36	±2.98

TABLE V

OPEN OCEAN

<u>Cruise 810, August 1975</u>

Chlorophyll *a*	$\bar{X}$	n	σ	90% C.I.
0	3.79	5	2.97	±2.03
10	4.02	4	3.63	±2.98
20	1.38	5	0.46	±0.31
30	0.96	5	0.72	±0.49
50	0.27	3	0.23	±0.19
Carbon (1 station)				
0	5.5			
10	7.1			
20	0.9			
30	0.4			
50	0			
Nitrate				
0	1.27	3	0.38	±0.41
10	3.08	5	2.84	±1.94
20	7.44	5	3.00	±2.05
30	19.20	5	9.98	±6.82
50	12.60	3	5.82	±6.36
100	25.10	4	5.40	±4.43
Ammonia				
0	1.35	4	0.30	±0.25
10	1.68	5	0.69	±0.47
20	1.60	5	0.39	±0.26
30	2.05	4	0.77	±0.63
50	1.90	4	1.01	±0.83
100	1.80	5	1.17	±0.80
Silicate				
0	5.67	3	0.58	± 0.63
10	8.20	5	6.06	± 4.14
20	15.4	5	5.73	± 3.91
30	53.00	5	36.61	±25.01
50	21.25	4	7.37	± 6.04

TABLE VI

ALEUTIAN PASS AREA

A. <u>Cruise 810, August 1975</u>

Chlorophyll *a*	$\bar{X}$	n	σ	[illegible] C.I.
0	4.17	9	3.18	±1.48
10	7.19	9	6.09	±2.84
20	4.05	9	3.20	±1.49
30	3.00	9	2.46	±1.15
50	1.68	8	2.14	±1.08
Carbon				
0	0.70	2	0.42	±0.93
10	2.93	3	3.14	±3.43
20	0.70	3	0.52	±0.57
30	0.47	3	0.29	±0.32
50	0.10	3	0.10	±0.11
Nitrate				
0	4.64	9	6.42	±3.00
10	5.81	9	4.36	±2.04
20	11.39	9	8.77	±4.09
30	10.83	9	8.04	±3.75
50	14.17	9	6.35	±2.96
Ammonia				
0	0.89	7	0.70	±0.38
10	1.45	6	0.95	±0.57
20	2.63	7	1.45	±0.79
30	2.33	7	0.69	±0.37
50	2.39	7	0.78	±0.42
Silicate				
0	6.17	9	3.62	± 1.69
10	13.44	9	10.90	± 5.09
20	17.67	9	8.63	± 4.03
30	13.88	8	13.28	± 6.66
50	32.63	8	25.11	±12.60

TABLE VI. Continued

B. Cruise 815, November 1975

Chlorophyll *a*	$\bar{X}$	n	σ	90% C.I.
0	0.30	8	0.19	±0.10
10	0.23	8	0.11	±0.06
20	0.25	8	0.16	±0.08
30	0.26	8	0.15	±0.08
50	0.23	8	0.11	±0.10
Nitrate				
0	10.69	8	6.27	±3.14
10	8.34	8	6.19	±3.11
20	7.90	8	5.58	±2.80
30	9.34	8	6.28	±3.15
50	11.29	8	6.79	±3.41
Ammonia				
0	1.04	8	1.12	±0.56
10	0.94	8	2.58	±1.29
20	0.69	8	0.96	±0.48
30	0.89	8	0.91	±0.46
50	1.14	8	1.30	±0.65
Silicate				
0	23.38	8	10.23	±5.13
10	19.75	8	11.07	±5.55
20	21.00	8	11.71	±5.88
30	22.88	8	12.55	±6.30
50	23.50	8	13.41	±6.73

TABLE VII

ICE EDGE

A. Cruise 808-I, May 1975, Group A

Chlorophyll *a*	$\bar{X}$	n	σ	90% C.I.
0	19.53	(23)	9.62	±2.65
5	18.26	(21)	8.67	±2.52
10	19.18	(24)	7.53	±2.03
15	12.41	(24)	7.57	±2.04
20	11.69	(24)	8.34	±2.25
30	6.18	(23)	3.30	±0.91
40	5.20	(23)	2.72	±0.75
60	4.81	(19)	2.37	±0.72
Carbon				
0	24.0	8	13.01	±6.5
5	17.8	7	5.65	±3.1
10	20.0	8	7.52	±3.8
15	14.7	8	11.16	±5.6
20	2.0	8	1.67	±0.8
Nitrate				
0	0.24	9	0.31	±0.14
10	0.93	9	1.31	±0.61
20	9.24	9	5.86	±2.73
30	13.25	8	3.41	±1.71
40	14.21	9	2.44	±1.14
60	13.08	8	3.60	±1.81
Ammonia				
0	0.38	9	0.20	±0.09
10	0.44	9	0.25	±0.12
20	0.46	9	0.29	±0.13
30	1.11	8	1.01	±0.51
40	0.92	9	0.83	±0.39
60	0.66	9	0.72	±0.34
Silicate				
0	3.67	9	3.54	±1.65
10	4.69	9	6.15	±2.87
20	26.89	9	19.17	±9.20
30	38.01	8	13.91	±6.86
40	41.78	9	11.82	±5.52
60	39.63	8	10.97	±5.50

TABLE VII. Continued

B. <u>Cruise 808-I, May 1975, Group B</u>

Chlorophyll *a*	$\bar{X}$	n	σ	90% C.I.
0	19.13	18	5.56	±1.74
5	21.01	17	9.63	±3.13
10	20.22	17	6.27	±2.04
15	18.51	18	7.85	±2.46
20	13.81	18	6.93	±2.17
30	5.90	18	7.05	±2.21
40	3.68	18	1.39	±0.44
60	3.50	18	1.31	±0.41
Carbon				
0	13.75	4	6.57	±5.39
5	19.63	4	11.55	±9.47
10	19.09	4	3.48	±2.85
15	13.08	4	8.04	±6.59
20	0.60	4	0.34	±0.28
Nitrate				
0	0.52	6	0.83	±0.50
10	0.33	6	0.35	±0.21
20	4.72	6	2.39	±1.44
30	8.98	5	5.91	±4.04
40	10.53	6	6.15	±3.71
60	11.56	5	4.95	±3.38
Ammonia				
0	0.38	6	0.27	±0.16
10	0.38	6	0.24	±0.14
20	0.62	6	0.20	±0.12
30	1.10	5	0.85	±0.56
40	0.92	6	0.62	±0.25
60	0.72	5	0.15	±0.10
Silicate				
0	3.67	6	2.34	±1.41
10	4.50	6	2.35	±1.42
20	16.50	6	5.89	±3.56
30	27.40	5	15.06	±9.40
40	35.80	6	8.61	±5.20
60	38.80	5	4.55	±2.75

value for all stations within a group at a depth). From data presented in this way, the intensity of production at this ice edge station can be seen (Table VII), for example, for further elaboration, see the Discussion below.

Table VIII analyzes the spring bloom and ice edge production regime in greater detail. This presents results for primary productivity and carbon integrated with depth. The high activity well into the ice is evident in March, but this intensifies during the major bloom to extremely high values.

Several stations, or stations in approximately similar location, were occupied more than once. These may be used for seasonal comparison and are shown in Table IX.

A preliminary list of phytoplankton species found in the Bering Sea, with accompanying notes, is found in Table X. Table XI examines the total of all numbers for the 1976 *Surveyor* cruise with respect to distance from the ice.

In order to look more closely at the major groups of phytoplankton in the ice population, a sample from each of the two *Surveyor* cruises is shown in great detail in Table XII.

Table XIII analyzes phytoplankton as percentages by major groups at the various stations of the surface samples.

During cruise 802 (May-June 1977), the phytoplankton population at the ice edge was extremely diverse and showed very high densities. Major species included a large number of diatoms of genera *Thalassiosira, Nitzschia* (Fragilariopsis) and *Chaetoceros*.

The August 1975 *Discoverer* cruise showed some areas of high diversity and abundance (to 10^6 cells/liter), but with most areas one or two orders of magnitude lower (10^4 or 10^5) and with lower diversity.

TABLE VIII

INTEGRATED CHLOROPHYLL *a* AND CARBON UPTAKE VALUES FOR *SURVEYOR* I AND II CRUISES ALONG THE ICE EDGE DURING MARCH AND APRIL 1976

Refer to Figure III for Station Plot and Ice Edge Location

Surveyor I Sta. #	Chlor *a* $mg \cdot m^{-2}$	Carbon $mg \cdot m^{-2} \cdot hr^{-1}$	Sta. relation to ice edge	*Surveyor* II Sta. #	Chlor *a* $mg \cdot m^{-2}$	Carbon $mg \cdot m^{-2} \cdot hr^{-1}$	Sta. relation to ice edge
1	21.0		Unimak Pass	1	24.4	88.8	Open ocean
2	17.6		50 mi from ice	2	23.5		50 mi from ice
3	24.3		10 mi into ice	3	523.5	480.8	20 mi into ice
4	11.8	11.5	ice edge	4	468.6	302.2	ice edge
5	15.1		5 mi from ice	5	614.4	604.4	20 mi into ice
6	19.1		10 mi from ice	6	429.6	520.1	10 mi into ice
7	13.6		20 mi from ice	7	831.1	725.2	30 mi into ice
8	12.7		10 mi from ice	8	628.1		ice edge
9	12.4		ice edge	9	695.0		ice edge
10	16.4	13.7	10 mi into ice	10	271.6	222.5	10 mi from ice
11	22.0	34.7	30 mi into ice	11	131.5		20 mi from ice
12	31.3	46.7	20 mi into ice	12	50.1		30 mi from ice
13	23.0		5 mi into ice	13	178.2	426.0	20 mi into ice
14	17.9		ice edge	14	73.4	102.7	ice edge
15	17.7		10 mi from ice	15	35.3	56.3	30 mi from ice
16	15.7		20 mi from ice				
17	14.1		10 mi from ice				
18	17.3	22.2	ice edge				
19	22.9	22.9	10 mi into ice				
20	16.9	28.6	10 mi into ice				
21	17.6		10 mi into ice				
22	20.0	33.3	10 mi from ice				
23	11.8		100 mi from ice				
24	18.7	46.0	50 mi from ice				

Note: All Chlor *a* and Carbon values are integrated from 50 m to the surface from discrete sample values at 0 m, 10 m, 20 m. 30 m and 50 m.

TABLE IX

SEASONAL COMPARISON OF PRIMARY PRODUCTION DATA FROM STATIONS OF CLOSE PROXIMITY SAMPLED AT VARIOUS TIMES

A. Pre- and post-ice edge

Cruise:		808-II	808-I	808-II
Sta. #:		113	46	35
Time:		pre-ice	post-ice	post-ice
Chlor *a* μg/ℓ	0 m	0.17	21.2	12.4
	10 m	0.20	20.1	22.9
	20 m	0.26	11.5	5.2
	30 m	0.95	2.2	4.0
	50 m	0.72	2.5	3.5
NO_3/SiO_3 μg-at/ℓ	0 m	0.4/1	0.8/6	0/0
	10 m	0.5/1	0.9/6	0/1
	20 m	0.4/1	4.9/18	6/20
	30 m	8.1/19	10.8/35	6/19
	50 m	10.3/38	10.0/32	3/9

B. Shelf area

Cruise:		808-I	810	815
Sta. #:		20	67	13
Time:		March, ice	August	November
Chlor *a* μg/ℓ	0 m	27.7	0.25	0.62
	10 m	22.7	0.48	0.70
	20 m	3.1	0.70	0.58
	30 m	2.3	0.50	0.69
	50 m	1.8	1.35	
NO_3/SiO_3 μg-at/ℓ	0 m	0.8/8	2.2/11	0.2/11
	10 m	0.8/8	2.2/11	5.3/9
	20 m	15.2/50	5.0/13	0.3/11
	30 m	15.4/51	-	4.4/8
	50 m	15.8/53	5.7/14	-

TABLE IX. Continued

C. Mid-shelf area

Comparative transects of Cruise 810, August, and 815, November.

Cruise:		810/815	810/815	810/815	810/815
Sta. #:		67/13	68/12	69/11	70/10
Chlor *a* μg/ℓ	0 m	0.25/0.6	1.75	1.85/1.35	0.68/2.0
	10 m	0.48/0.7	1.60/0.9	3.20/0.8	1.80/1.7
	20 m	0.70/0.6	1.15/0.8	1.50/0.4	2.20/2.4
	30 m	0.50/0.7	1.10/0.8	2.20/1.8	- / -
	50 m	1.35/ -	1.45/1.09	- / -	- / -
NO_3 μg-at/ℓ	0 m	2.20/.2	2.20/0.2	2.20/0.3	2.20/0.4
	10 m	2.20/5.3	2.20/1.1	2.20/0.2	2.20/0.3
	20 m	5.00/0.3	2.20/0.2	2.20/0.3	2.20/0.1
	30 m	- /4.4	2.20/0.3	- /0.1	- / -
	50 m	5.70/ -	2.20/ -	- / -	- / -
SiO_3 μg-at/ℓ	0 m	11/12	11/17	12/3	11/2
	10 m	11/9	11/9	13/3	11/2
	20 m	13/11	11/12	13/3	11/1
	30 m	-/8	11/14	-/3	-/-
	50 m	14/-	13/-	-/-	-/-

D. Open ocean area

Cruise:		810	815	SU-II
Sta. #:		35	1	1
Time:		August	November	April
Chlor *a* μg/ℓ	0 m	1.40	0.29	0.60
	10 m	1.28	0.30	0.54
	20 m	1.65	0.14	0.44
	30 m	1.08	0.20	0.48
	50 m	0.03	0.25	0.44
NH_4 μg-at/ℓ	0 m	1.5	0.7	4.7
	10 m	2.7	-	3.5
	20 m	2.1	0.4	3.2
	30 m	2.5	0.3	0.6
	50 m	3.1	0.3	0.5
NO_3 μg-at/ℓ	0 m	1.7	31.8	27.2
	10 m	1.6	-	20.7
	20 m	7.7	10.6	26.9
	30 m	24.9	18.6	26.7
	40 m	18.1	16.0	26.9

TABLE IX. Continued

D. Open ocean area (cont'd)

Cruise:		810	815	SU-II
Sta. #:		35	1	1
Time:		August	November	April
PO_4	0 m	5.8	9.1	1.6
µg-at/ℓ	10 m	2.2	-	1.7
	20 m	0.8	2.9	2.0
	30 m	0.8	9.1	1.9
	50 m	0.9	9.4	2.1
SiO_3	0 m	6.0	44.0	53.0
µg-at/ℓ	10 m	5.0	-	40.0
	20 m	18.0	20.0	53.0
	30 m	81.0	31.0	52.0
	50 m	30.0	25.0	53.0

TABLE X

1975 - 1976 PHYTOPLANKTON SPECIES IN THE BERING SEA

CHRYSOPHYTA

Bacillariophyceae (diatoms)

Achnanthes sp. Bory
Actinocyclus roperii (de Bréb.) Grun. ex Van Heurck
Actinoptychus splendens (Shad.) Ralfs ex Pritch.
Amphiprora sp. Ehrenberg
Asterionella glacialis Castr. (*Asterionella japonica* Cleve & Möller)
A. kariana Grun.
Bacteriosira fragilis Gran
Biddulphia aurita (Lyng.) Bréb. & God.
B. longicuris Grev. cf.
Chaetoceros affinis Laud.
C. atlanticus C.
C. borealis Bail.
C. cinctus Gran
C. compressus Laud.
C. concavicornis Mang.
C. convolutus Castr.
C. curvisetus Cl. cf.
C. danicus Cl. (spore)
C. debilis Cl.
C. decipiens Cl.
C. furcellatus Bail.
C. fragilis Meun. cf.
C. gracilis Schütt cf.
C. holsaticus Schütt
C. laciniosus Schütt
C. lorenzianus Grun.
C. radicans Schütt
C. seiracanthas Gran
C. septentrionalis Oestrup
C. similis Cl.
C. socialis Cl.
C. subsecundus (Grun.) Husted
C. wighami Brighw.
C. spp.
Cocconeis sp. Ehr.
Corethron criphilum Castr. (Corethron hystrix Hensen)
Coscinodiscus centralis Ehr.
C. concinnus Ehr.
C. excentricus Ehr.
C. lineatus Ehr.
C. marginatus Ehr.
C. oculus iridis Ehr.
C. radiatus Ehr.
C. spp.

TABLE X. Continued

CHRYSOPHYTA
Bacillariophyceae (diatoms)

Cylindrotheca closterium (Ehr.) Reiman & Lewin (*Nitzschia closterium* Ehr.)
C. gracilis (de Bréb.) Grun.
Dactyliosolen mediterraneus H. Pér.
Denticula seminae Simonsen et Kanaya
Detonula confervacea (Cleve) Gran
Ditylum brightwellii (West) Grun.
Eucampia zoodiacus Ehr.
Gyrosigma or *Pleurosigma* sp I
Gyrosigma or *Pleurosigma* sp II
cf. *Hemiaulus* sp. Ehr.
cf. *Hyalodiscus* sp. Ehr.
Leptocylindrus danicus Cl.
Licmophora sp. Ag.
Melosira sulcata (Ehr.) Kütz.
M. sp. Ag.
Navicula pelagica (Cleve) (*Stauropsis pelagica* (Cleve) Meun.)
N. transitans Cleve
N. vanhöffeni Gran (*Stauropsis vanhöffeni* (Gran) Meun.)
N. spp.
Nitzachia delicatissima Cl. cf
N. frigida Grun.
N. longissima (Bréb.) Ralfs cf.
N. paradoxa (Gmel.) Grun. cf.
N. seriata Cl.
N. subpacifica Hasle
Pleurosigma sp. W. Smith
Porosira glacialis (Gran) Jörg. (*Podosira glacialis* Cleve, *Lauderia glacialis* (Grun.) Cl.
Rhizosolenia alata Brightw.
R. delicatula Cl.
R. fragilissima Berg.
R. hebetata f. *semispina* (Hen.) Gran
R. hebetata f. hiemalis Gran
R. setigera Brightw.
R. stolterfothii H. Per.
R. styliformis Brightw.
cf. *Rhabdonema* sp. Kützing
cf. *Schroderella delicatula* (H. Pér.) Pav.
Skeletonema costatum (Grev.) Cl.
Stephanopyxis nipponica Gran & Yendo
Thalassionema nitzschioides Grun.
Thalassiosira aestivalis (Grun.) Jorg.
T. gravida Cl.
T. hylina (Grun.) Gran

TABLE X. Continued

CHRYSOPHYTA
  Bacillariophyceae (diatoms)

- *Thalassiosira nordenskioldii* Cl.
- *T. polychorda* (Gran) Jørg.
- *T. rotula* Meun.
- *T.* spp.
- *Thalassiothrix frauenfeldii* Grun. cf.
- *Tropidoneis lepidoptera* (Greg.) Cl. cf.
- unidentified centric diatoms
- unidentified pennate diatoms

  Chrysophyceae
- *Dictyocha fibula* Ehr.

DINOPHYTA (dinoflagellates)

- *Ceratium lineatum* (Ehr.) Cleve
- *C. tripos* (O.F. Müller) Nitzsch.
- *Dinophysis norvegica* Clap. et. Lachm.
- cf. *Gymnodinium* sp. Stein
- *Oxytoxum* sp. Stein
- *Protoperidinium minisculum* (*Peridinium minisculum*)
- *P. pallidum* (Ostenf.) Balech
- *P.* spp.
- unidentified dinoflagellates

PRASINOPHYTA (microflagellates)

HAPTOPHYTA
  Haptophyceae
  Coccolithaceae
  Phaeocystaceae
   Phaeocystis sp.

CYANOPHYTA
   unidentified bluegreens

EUGLENOPHYTA
   unidentified euglenoids

Microflagellates of uncertain taxonomic position

CRASPEDOPHYTA

NOTES CONCERNING TAXONOMY SEE SPECIES LIST

CRASPEDOPHYTA (choanoflagellates) were reported in 1975, but recent literature and studies by Leadbeater, B.S.C. and Manton (1974) suggest these organisms should be grouped with the animal kingdom. Parke and Dixon (1976) Checklist of British Marine Algae - Third Revision do not report them. I did not include them in the 1976 counts for those reasons.

The genus *Fragilariopsis* has been synonymized under *Nitzshia* spp. In 1975 it was reported as *Fragilariopsis* but in 1976 and now is reported as *Nitzschia* sp. (Hasle 1972).

The name *Melosira moniliformis* reported in 1975 is incorrect. It may be a *Detonula* but the identification of this diatom is still uncertain.

Thalassiosua hylina known to occur in the Bering Sea has not been separated in 1975 and 1976 data, but noted as *Thalassiosira* spp.

The diatom *Denticula seminae* has been lumped with *Nitzschia* sp. (Fragilariopsis) in 1975 and 1976 data. This specie is an important component of the Bering Sea phytoplankton especially during bloom conditions.

TABLE XI

PHYTOPLANKTON (CELLS/LITER) AT VARYING DISTANCES FROM ICE

A. LEG 1 SURVEYOR 1976

LOCATION	IN ICE PACK		OUTSIDE ICE EDGE		AWAY FROM ICE EDGE	
	Station	Cells/Liter	Station	Cells/Liter	Station	Cells/Liter
	4	1.6×10^4	7	7.8×10^4	25	2.6×10^4
DEPTH 0m	11	7.96×10^4	15	1.32×10^4		
	12	1.0×10^5	16	-		
	10	3.2×10^4	18	8.24×10^4		
	13	5.0×10^4				
	4	-	7	-	25	3.0×10^4
10m	11	1.06×10^5	15	-		
	12	1.12×10^5	16	2.48×10^4		
	10	2.12×10^4	18	2.72×10^4		
	13	9.4×10^4				
	4	1.52×10^4	7	-	25	-
20m	11	4.8×10^4	15	-		
	12	5.4×10^4	16	1.28×10^4		
	10	-	18	-		
	13	-				

TABLE XI. Continued

B. LEG II SURVEYOR 1976

LOCATION		IN ICE PACK		PARALLEL TO ICE EDGE		JUST OUTSIDE ICE EDGE		AWAY FROM ICE	
		Station	Cells/Liter	Station	Cells/Liter	Station	Cells/Liter	Station	Cells/Liter
		7	$6.2x10^5$	4	$2.7x10^5$	10	$1.09x10^5$	1	$8.56x10^4$
DEPTH	0m	8	$7.3x10^5$	5	$2.8x10^5$	11	$9.52x10^4$	2	$1.2x10^4$
		9	$5.42x10^5$	6	$4.04x10^5$	12	$9.9x10^4$		
		13	$4.8x10^5$						
	20m	7	-	4	$1.85x10^5$	10	$8.56x10^4$	1	$3.8x10^4$
		8	$5.42x10^5$	5	$3.06x10^5$	11	$1.23x10^5$	2	-
		9	-	6	$4.5x10^5$	12	$8.2x10^4$		
		13	-						
		7	-	4	$2.12x10^5$	10	$9.3x10^4$	1	-
	30m	8	-	5	$3.16x10^5$	11	$8.6x10^4$	2	$1.17x10^5$
		9	-	6	$3.2x10^5$	12	$4.8x10^4$		
		13	-						
		7	-	4	$2.0x10^5$	10	$1.1x10^5$	1	-
	40m	8	-	5	-	11	-	2	-
		9	-	6	-	12	-		
		13	-						
		7	-	4	$7.68x10^4$	10	$4.2x10^4$	1	-
	50m	8	-	5	$2.0x10^4$	11	$1.26x10^5$	2	$1.48x10^4$
		9	-	6	-	12	$6.8x10^3$		
		13	-						

TABLE XII

SURVEYOR LEG I

20 March 76 Ice Pack Sample Station 4 0m Total Cells/Liter 1.6×10^4

	Cells/Liter
Chrysophyta	
Bacillariophyceae (diatoms)	
Cylindrotheca closterium	3200
Nitzschia sp.	400
Rhizosolenia alata	1200
Thalassiosira spp	800
Dinophyta (dinoflagellates)	
cf. *Gymnodinium* sp	400
unidentified dinoflagellates	800
Microflagellates	
0-4 µ	6000
5-10 µ	1600
Prasinophyta	1600
TOTAL	16000

TABLE XII. Continued

SURVEYOR LEG II

21 April 76 Ice Pack Sample Station 7 0m Total Cells/Liter 6.2×10^5

	Cells/Liter
Bacillariophyceae (diatoms)	
Bacteriosira fragilis	11200
Chaetoceros compressus	8800
C. debilis	7200
C. gracilis cf.	800
C. socialis	7200
C. wighami cf.	8000
C. sp.	3200
Cylindrotheca closterium	5600
Eucampia zoodiacus	1600
Licmophora sp.	800
Nitzschia sp. (*Fragilariopsis*)	188000
N. sp. (*Fragilariopsis*)	62400
N. sp. (*Fragilariopsis oceanica* f *circularis*)	8000
Nitzschia sp.	800
Navicula vanhoffeni	6400
Navicula sp.	3200
Porosira glacialis	1600
Thalassiosira decipiens	45600
T. gravida	84000
T. nordenskioldii	12000
T. rotula	3200
T. sp.	4000
T. sp.	2400
T. spp.	80800
unidentified pennates	10400
unidentified cells	6400
Dinophyta (dinoflagellates)	
cf. *Gymnodinium* sp.	9600
cf. *Oxytoxum*	800
Microflagellates	
0-4 µ	24000
5-10 µ	2400
Prasinophyta	5600

TABLE XIII

COMPOSITION OF THE PHYTOPLANKTON BY MAJOR GROUPS AT 0m LEG I AND LEG II SURVEYOR MARCH-APRIL 1976

(% of total cells/liter)

LOCATION	LEG I IN ICE PACK Station	% of Total	PARALLEL TO ICE EDGE Station	% of Total	JUST OUTSIDE EDGE Station	% of Total	AWAY FROM ICE Station	% of Total
Phytoplankton Groups ↓	4				7		25	
Diatoms		35		-		24		11
Dinoflagellates		8		-		41		14
Microflagellates		57		-		34		72
Unknown		0		-		0		3

LOCATION	LEG II IN ICE PACK Station	% of Total	PARALLEL TO ICE EDGE Station	% of Total	JUST OUTSIDE EDGE Station	% of Total	AWAY FROM EDGE Station	% of Total
Phytoplankton Groups ↓	2		4		10		1	
Diatoms		92		96		81		41
Dinoflagellates		2		0		5		2
Microflagellates		5		4		14		52
Unknown		1		0		1		5
	8		5		11		2	
Diatoms		94		92		74		11
Dinoflagellates		1		1		4		6
Microflagellates		5		7		22		83
Unknown		0		0		0		0

By the November *Miller Freeman* cruise diversity was low with microflagellates making up a large part of the phytoplankton population. Dinoflagellates of the genera *Ceratium*, *Dinophysis* and *Peridinium* occurred. Leg I of the *Surveyor* (March 1976) cruise illustrated pre-bloom conditions. Table XII shows that microflagellates and dinoflagellates constitute a large precentage of the phytoplankton population during pre-bloom conditions. Diatoms occur in small numbers and low diversity with members of the genera *Thalassiosira*, *Chaetoceros* and *Cylindrotheca* the most common.

By Leg II (April 1976) of the *Surveyor* cruise phytoplankton had increased in numbers and diversity dramatically from Leg I. (see Table XII). There was an order of magnitude difference in cells/liter reported. Diatoms predominated with *Nitzschia* (Fragilariopsis), *Thalassiosira*, and *Chaetoceros* occurring in largest numbers.

Modeling

Both the process of modeling and results from models contribute to research in the marine environment. At the conceptual level, a model provides structure for study planning and data collection. It also provides a framework for organizing literature information. When field data is available, a model is a powerful analysis tool, relating a variety of data points in a biologically meaningful way.

A conceptual model is a description of the structure and internal dynamics of a particular ecosystem, including food chains and nutrient pathways. We have developed a conceptual model for the Bering Sea Shelf with carbon, nitrogen, and silicon units. Pelagic, benthic, and sea ice communities are incorporated. Compartments were selected to emphasize major material flows, important biological control mechanisms, and commercially fished species. Arranging compartments in a matrix format shows exchanges of N, C, and Si between compartments. For each compartment, inputs are elements in its row of the matrix, and losses are elements in its column. Empty cells indicate potential flow pathways which are known or assumed not to occur.

Constructing a conceptual model as part of developing a study plan has two advantages. First, it insures that the data needed for the model are recognized so that they will be collected. Second, it requires that the model be designed to use information which is measurable. Development of the conceptual model interfaces the expertise of all investigators.

After listing the data needed to model the whole Bering Sea shelf ecosystem as described in the conceptual model, it became apparent that available information was insufficient, and that collection of all the required data was an impossible task within the limits of the present study. Therefore it was decided to concentrate modeling efforts on the sea ice and plankton communities, which can be done well. A revised conceptual model increasing resolution on the plankton by dividing phytoplankton, zooplankton, and micronekton into species groups will assist in planning future field experiments.

Both the conceptual and mathematical levels of a model are statements of a complex hypothesis about ecosystem dynamics. Assumptions which go into a model are made explicit, so that they can be recognized and evaluated objectively. Assumptions will place known limitations on interpretation of final model results. We expect some conceptual difficulties with modeling the ice edge as it traverses various water masses. However, through use of a model our hypotheses can be tested by comparing field data with model predictions.

In the mathematical model for the ice edge ecosystem, the terms which express flows between compartments will express assumptions on the nature of and the factors controlling material flows. Assumptions, hypotheses, and knowledge of the biology of the system are incorporated into the mathematics.

Computer simulation and sensitivity analysis of the system have not yet been done. Results, when available, will aid in evaluating the effects of perturbations related to OCS development on the marine ecosystem.

Plant Submodel

Field data on phytoplankton in the Bering Sea shelf region show that primary production is greatest near the ice edge in the spring. Production rates averaged 6.6 $gC/m^2/day$ at ice edge stations in early May, and 4 $gC/m^2/day$ in open waters later in the month. In contrast, production rates averaged only 1.5 $gC/m^2/day$ in June, 0.76 $gC/m^2/day$ in August, and 0.06 $gC/m^2/day$ in November. (These values may deviate from values in Table VIII because of different assumptions but are in fact quite comparable). Nutrient concentrations in the water column were severely depleted during the spring bloom, particularly at ice edge stations.

The mechanism for simulating production rates in the plant submodel is calculation of a maximum potential photosynthetic rate as a function of available light and chlorophyll concentration, which is decreased as a function of nutrient concentration. Threshold minimum nutrient concentrations cut off production at low nutrient levels. Light and ice movement are the driving variables in the model. Light available to sea ice algae is modified by snow cover and ice thickness, and light available to phytoplankton is further reduced by the density of the ice algae. The model time step will be 10 days for most of the year, but shortened to a daily time step during the spring bloom to increase resolution.

Input to the plant compartments is photosynthesis. Losses are respiration, sinking, and grazing. Grazing, or the transfer of carbon to zooplankton trophic levels, will be emphasized in plankton model formulation and field studies.

In the plankton model, phytoplankton and zooplankton will be divided into species groups, including those associated with the sea ice. The model will incorporate factors determining primary production and grazing rates.

Grazing Experiments

Of the first five grazing experiments (stations 1, 4, 6, 8 and 13) only one (station 13) resulted in positive filtering rates. An experiment was conducted which consisted of a check of the amount of particulate matter carried over with the zooplankters during transfer into the experimental containers and/or excretion products of the zooplankters. Nineteen *C. marshallae* were transferred directly into 1 ℓ of glass fiber filtered sea water. Counts were obtained after 1 and 5 hrs. After 1 hr there existed 0.21 mg/ℓ total particulate matter with a peak at 58 μm. After 5 hrs the peak had disappeared and the total amount of particulate matter had been reduced to 0.11 mg/ℓ. The amount of particulate matter between 4 and 9 μm had increased. This indicated that large particulate matter was carried over with the zooplankters and ingested and that fecal matter probably contributed to an increase in small particulate matter.

Grazing results are shown in Table XIV. The mean filtering rate ranged from 5.9 to 7.3 ml/hr/mg dry wt. The filtering rate at station 15 is somewhat higher than the mean for station 13 - 7.3 compared to 6.5. This may be due to the higher concentration of phytoplankton at station 13. The size ranges filtered corresponded to the upper and lower size limits of the blooms.

Figure 5 shows the results for station 13 after 26 hrs of incubation. The phytoplankton size at peak concentration did not change under grazing pressure.

At the conclusion of the grazing experiment at station 15, a 24-hr primary productivity experiment yielded 11.51×10^3 CPM/mg of particles for the control and 8.65×10^3 CPM/mg of particles for the water previously grazed by 6 copepods.

The copepods did not appear to feed on suspended ice algae.

Copper Toxicity

The results of the copper toxicity experiments are shown in Table XV and Figures 6 and 7. A concentration of 2 μg/ℓ had no observable effect on large phytoplankton (10-80 μm) in ice-free and ice-flow areas. Above 2 μg/ℓ growth rate was inhibited. No differences were noted in the tolerances of algae from ice-free and ice-flow areas since the curves in Figure 6 parallel each other.

Mean carbon uptake rates per unit biomass for total phytoplankton from ice-flow areas do not appear to be influenced by copper concentrations. This suggests that enzyme and/or transport systems other than the

TABLE XIV

MEAN FILTERING RATE, SIZE AND SIZE RANGE FILTERED AT FIVE STATIONS IN THE BERING SEA FOR *CALANUS MARSHALLAE*

Station	Number of copepods	Mean length (μm)	Mean dry wgt. (mg/copepod)	Size range filtered (μm)	mls/hr·Individual^{-1}		mls/hr·mg dry wgt.$^{-1}$	
					Uncorrected	Corrected	Uncorrected	Corrected
13	6	-	0.56	18-90	2.0	3.9$^{(1)}$	3.6	7.0$^{(1)}$
13	20	4.4	0.59	18-90	2.9	3.5$^{(1)}$	4.9	5.9$^{(1)}$
13B	20	4.4	0.56	-	0.24	-	0.43	-
15	6	4.5	0.60	23-90	7.3	4.4$^{(2)}$	12.2	7.3$^{(2)}$

(1) Corrected fpr particle growth rate of .012 hr^{-1}

(2) Corrected for particle mortality rate of .018 hr^{-1}

n.b. Stations 13 and 13B used unwashed copepods

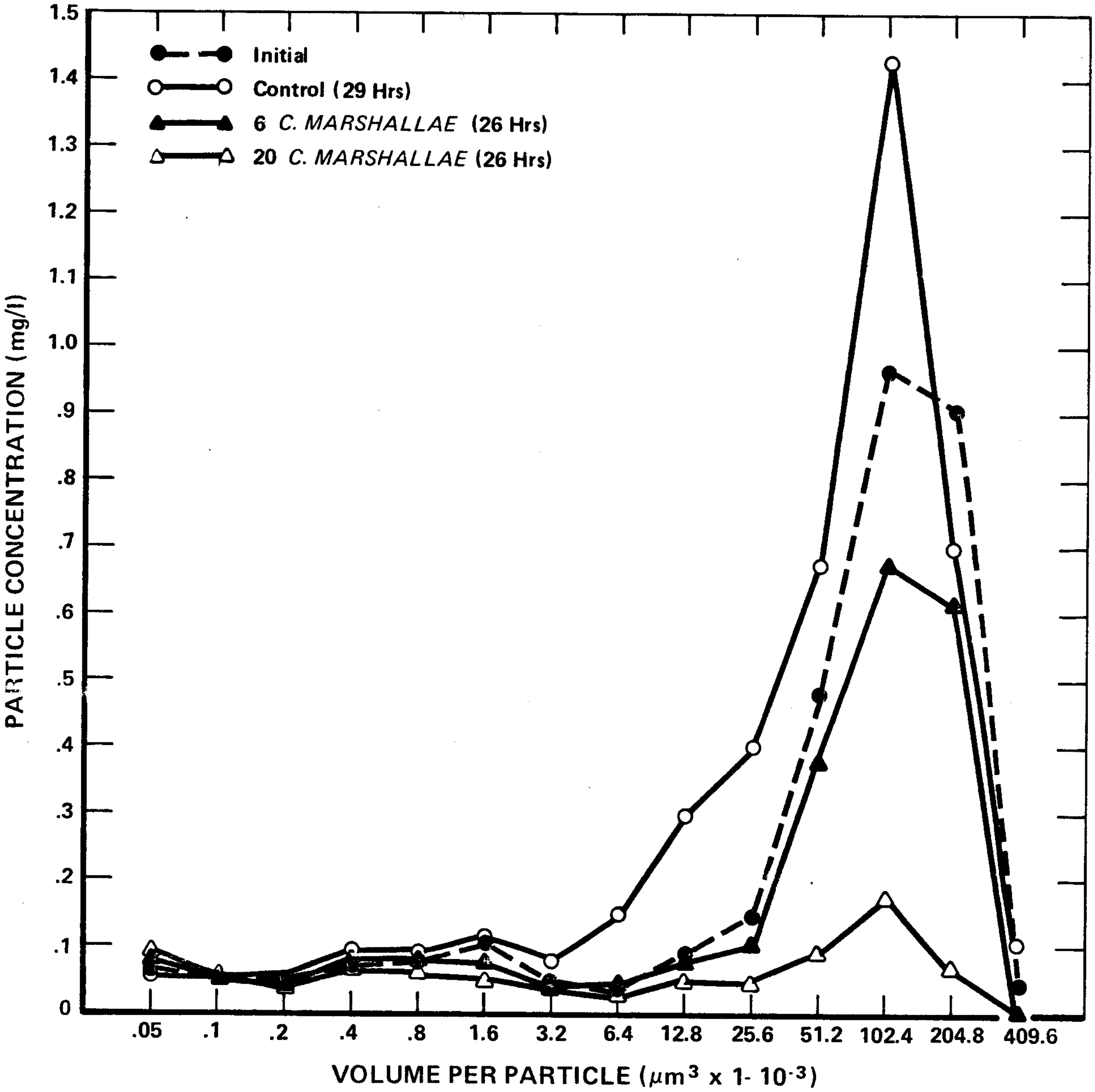


Figure 5. Particle concentration vs. particle size for station 13 grazing experiment.

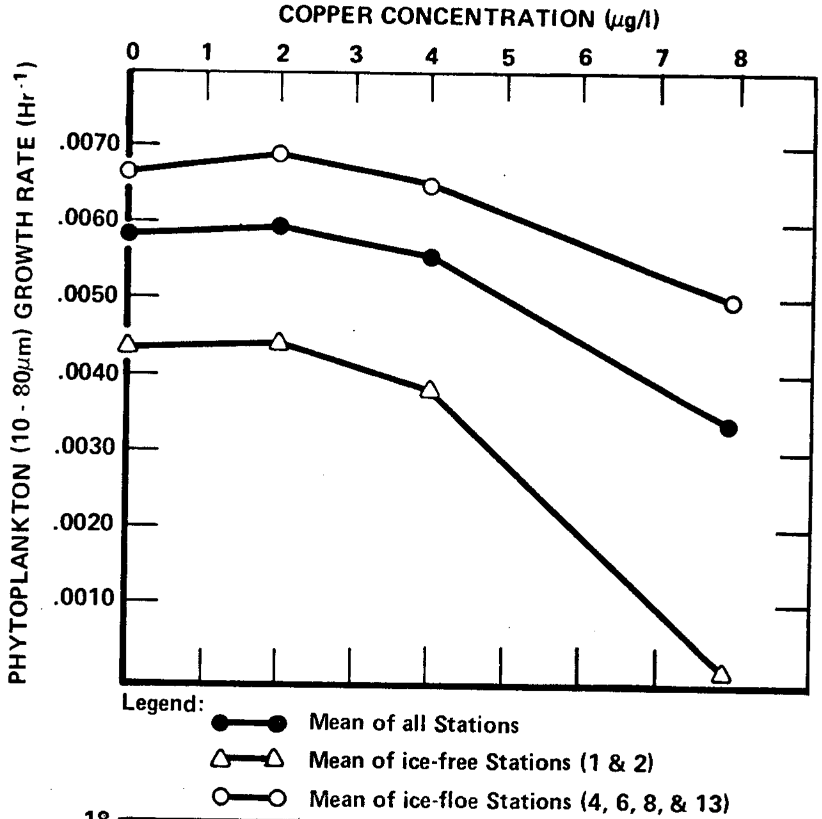
TABLE XV

PLYTOPLANKTON GROWTH RATES (hr^{-1}) AT FOUR COPPER CONCENTRATIONS FOR SIX STATIONS IN THE BERING SEA[1]

Station	Copper concentration (μg/ℓ) 0	2	4	8	Length of Expt (hrs)
1	.0069	-.0021	.0037	-.0025	105
2	.0018	.0108	.0037	.0026	151
4	.0071	.0078	.0061	.0013	126.5
6	.0057	.0059	.0058	.0055	130.5
8	.0052	.0048	.0060	.0059	132
13	.0086	.0089	.0082	.0073	105.5
Mean 1+2 (ice free)	.0044	.0044	.0037	.0001	-
Mean 4, 6, (ice flow)	.0067	.0069	.0065	.0050	-
Mean all stations	.0059	.0060	.0056	.0034	-

---

(1) Phytoplankton were 10-80 μm in diameter.



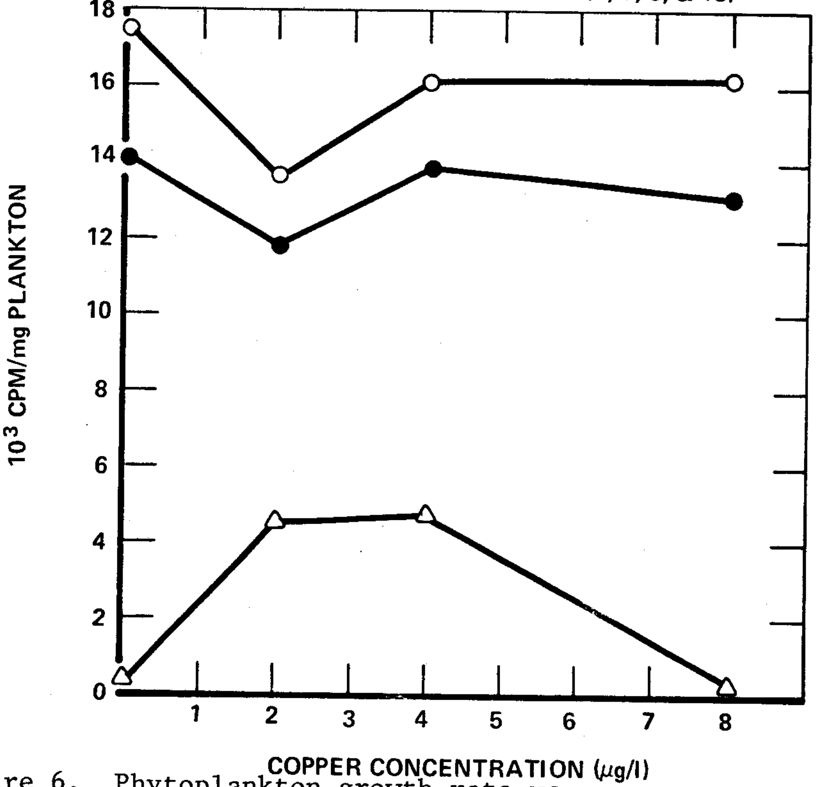


Figure 6. Phytoplankton growth rate vs. copper concentration for phytoplankton 10-80 μ diameter.

Figure 7. Twenty-four hour primary productivity for total phytoplankton at four concentrations of copper. The planktons were first subjected to copper for periods ranging from 105-151 hours.

photosynthetic system are influenced by copper resulting in a decrease in growth rate. Carbon uptake by phytoplankton from an ice-free station was stimulated at low copper concentrations.

A typical set of experimental data is shown in Figure 8. Particle size at peak concentration does not decrease with increasing copper concentration.

Oil Toxicity

Results of the oil toxicity experiments are shown in Table XVI and Figures 9 and 10. Concentrations of 10 and 30 ppm oil inhibited the growth rates of large phytoplankton (10-80 μm) from ice-flow areas. In contrast, the mean growth rate for phytoplankton in ice-free areas increased at 10 ppm but was inhibited at 30 ppm.

A typical set of experimental data is shown in Figure 11. Particle size at peak concentration decreased with increasing oil concentration.

Figure 9 also shows the growth rate of suspended ice algae at 0, 10 and 30 ppm of Prudhoe crude oil. Growth rate decreased with increasing oil concentration.

The results of grazing experiments carried out in 1977 on the *Discoverer* are presented separately as Appendix I.

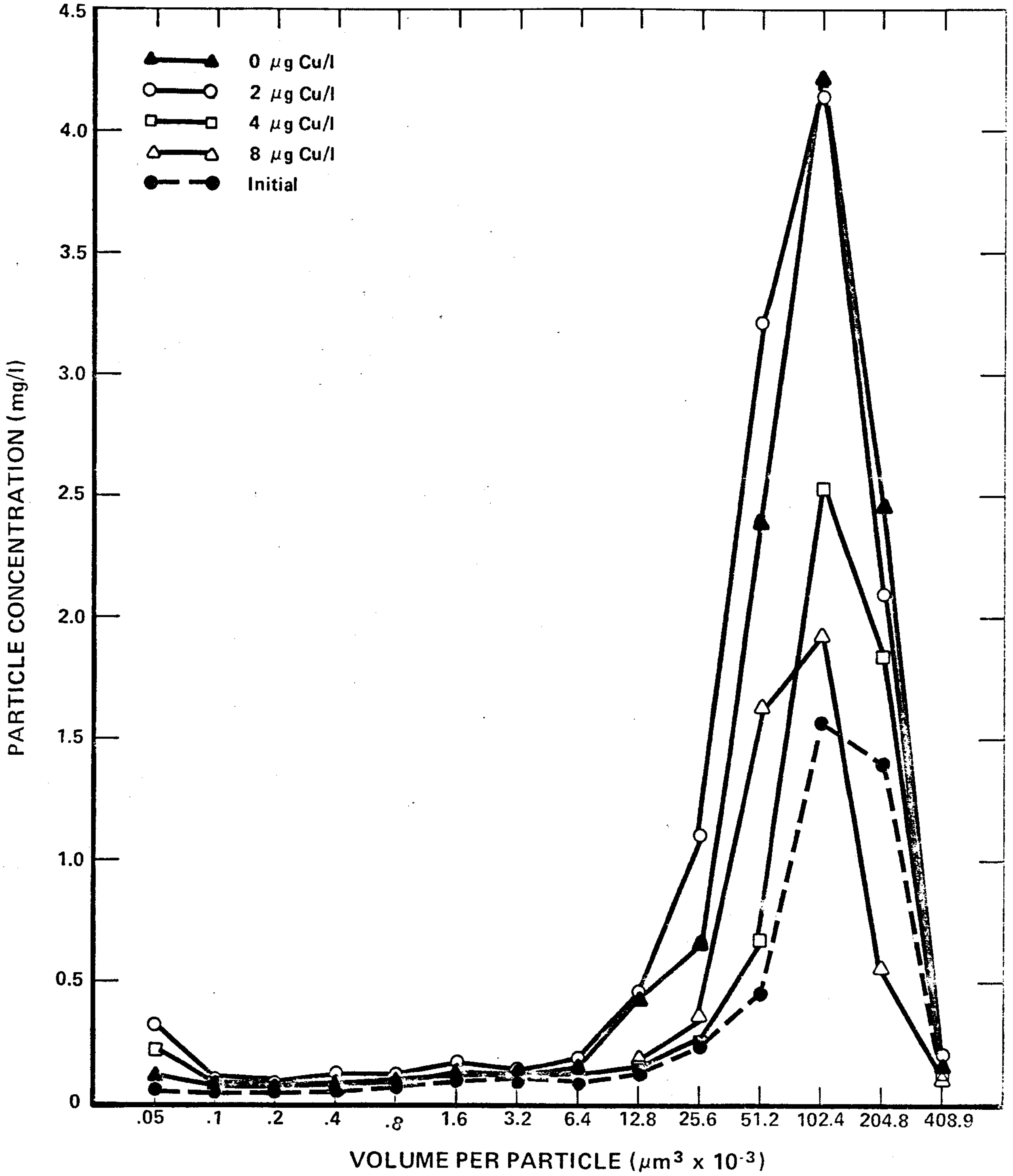


Figure 8. Particle concentration vs. particle size at Station 4 at four copper concentrations after 126.5 hours.

TABLE XVI

PHYTOPLANKTON GROWTH RATES (hr^{-1}) AT THREE CONCENTRATIONS OF CRUDE OIL FOR SIX STATIONS IN THE BERING SEA(1)

Station	Oil concentration (ppm)			Length of Expt (hrs)
	0	10	30	
1	.0069	.0115	-.0019	105
2	.0018	0	.0002	151
4	.0071	-.0045	-.0087	126.5
6	.0057	.0052	-.0046	130.5
8	.0052	.0043	.0004	132
13	.0086	.0004	-.0060	105.5
Mean 1+2 (ice free)	.0044	.0058	-.0009	-
Mean 4, 6, 8, 13 (ice flow)	.0067	.0014	-.0047	-
Mean all stations	.0059	.0028	-.0034	-

---

(1) Phytoplankton were 10-80 μm in diameter.

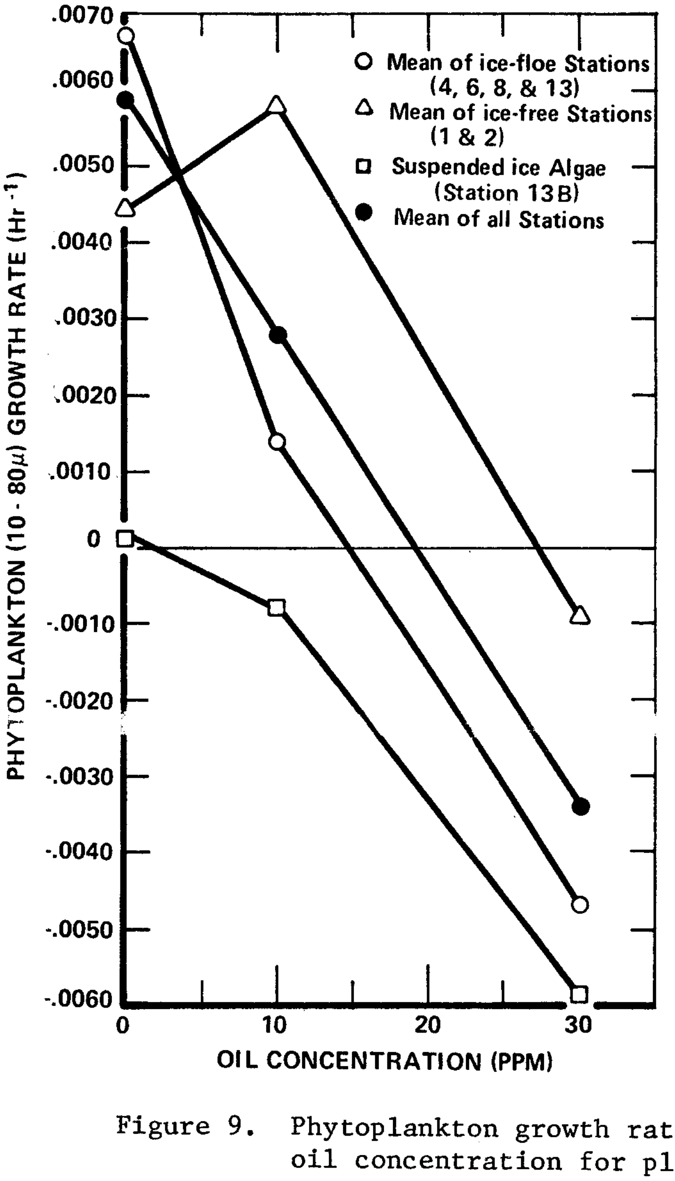


Figure 9. Phytoplankton growth rate vs. oil concentration for plankton 10-80 μm diameter.

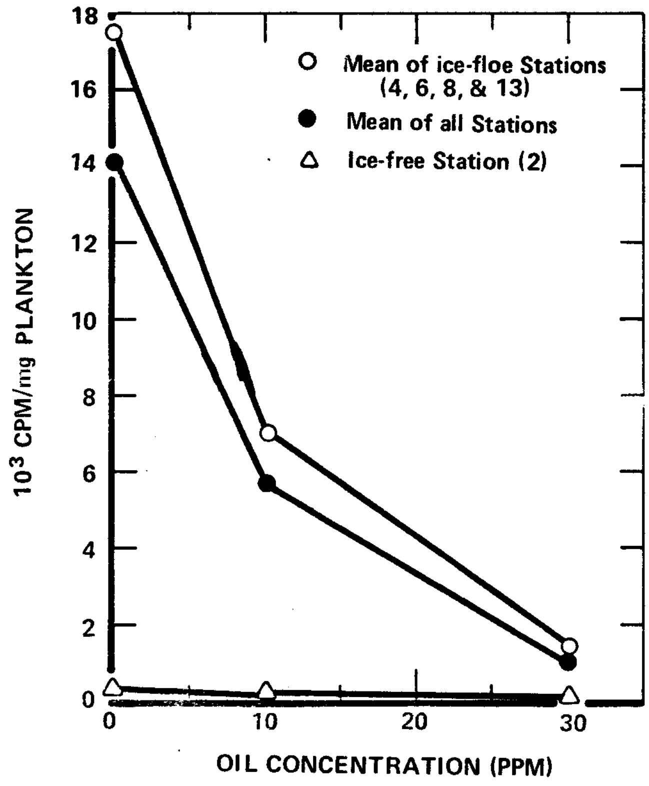


Figure 10. Twenty-four hour primary productivity for total phytoplankton at three concentrations of Prudhoe crude oil. The plankton populations were first subjected to oil for periods ranging from 150-151 hours.

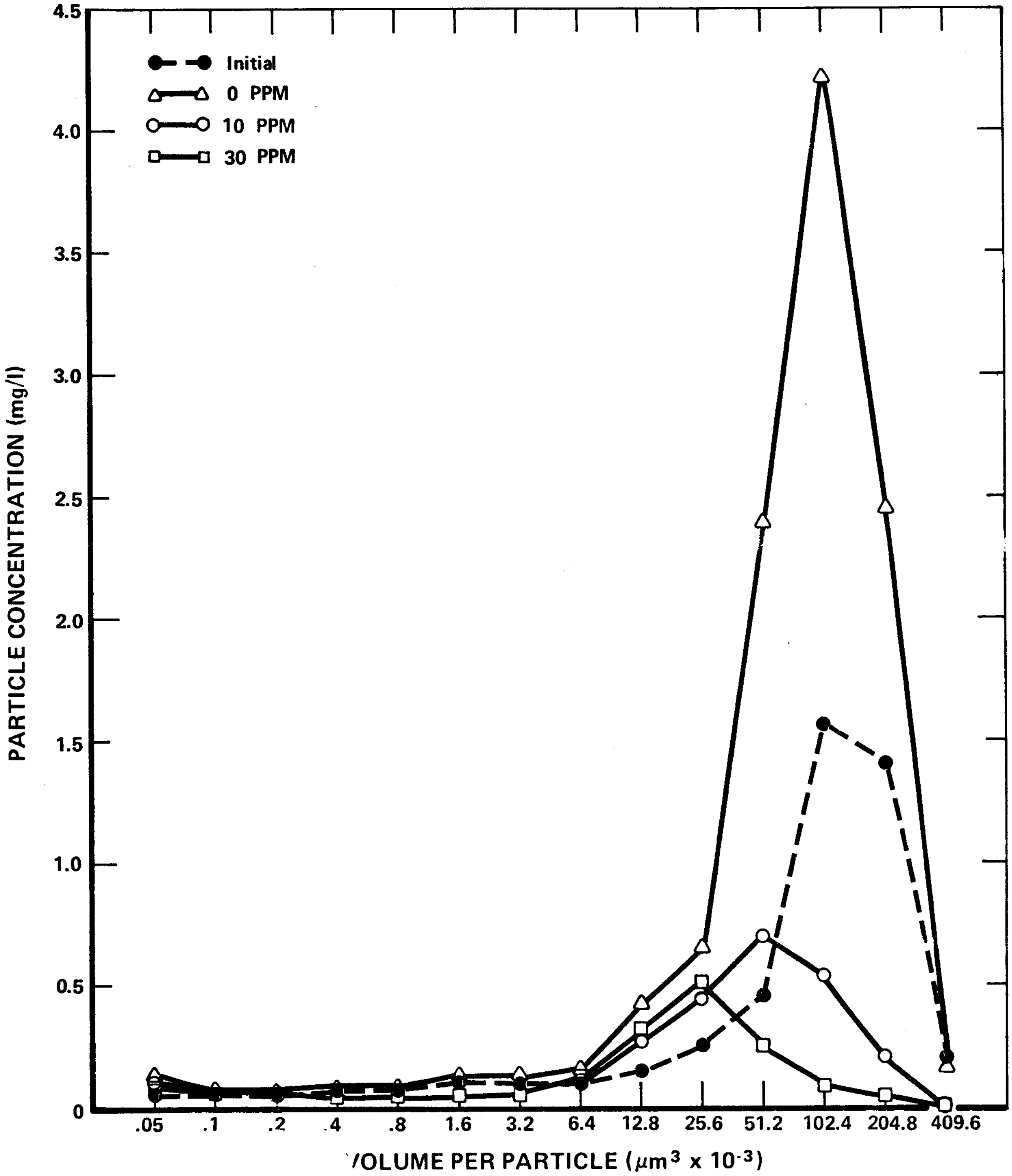


Figure 11. Particle concentration vs. particle size at Station 4 for three concentrations of crude oil after 126.5 hours.

VII. DISCUSSION

The ice edge bloom

The initial sampling of the ice edge zone revealed an extremely high standing crop of phytoplankton and high rates of carbon fixation. Surface chlorophyll values frequently exceeded 20 mg/m^3 and productivity frequently exceeded 25 mg $C/m^3 \cdot hr$. These are extremely high values and such rates of production must be limited to short periods of time. Resampling of the area where these results were obtained on Leg I of the *Discoverer* cruise showed that surface chlorophyll values had declined to an average of less than 1 mg/m^3 in less than three weeks. Nutrient levels observed during the bloom and again three weeks later were very low with nitrate concentrations - less than 1 μg-at/ℓ at both times and silicate concentrations dropping from 6 μg-at/ℓ to 1 μg-at/ℓ during the period. Obviously, the system is nutrient-limited soon after the initiation of the bloom. Low concentrations of ammonia were observed indicating that *in situ* regeneration of available nitrogen is not occurring significantly or at least that utilization equals regeneration. Diatoms comprise the greatest percentage of the phytoplankton population at the ice edge during a bloom. These diatoms at the ice front are considerably smaller then those found in the warmer open water due probably to the rapid rate of reproduction and perhaps to adaptations to the extreme cold water. This small organism size would greatly accelerate the sinking rate of the cells as the water warmed. Another perhaps major phenomena to carry cells downward out of the euphotic zone, thus reducing the possibility of any nutrient regeneration, will be discussed later. Apparently, the ice edge bloom begins when sufficient light becomes available and progresses rapidly until nutrients are depleted.

The initial supply of available nutrients over the shelf when the ice begins to receed would appear to determine the gross production at the ice front. Since the initial cruise occurred well into the bloom we did not obtain any pre-bloom nutrient concentrations until the following spring when the *Surveyor* Leg I cruise arrived at the ice edge prior to the initiation of the bloom. At that time nutrient concentrations were observed to be very uniform throughout the water column except near the bottom and also uniform over the entire shelf area. At that time the water column over the shelf had nitrate concentrations of approximately 17.5 μg-at/ℓ in contrast to the waters beyond the shelf break where nutrient concentrations were considerably higher. Since we observed near total depletion of nutrients following the bloom we can assume that potential production within the euphotic zone is a function of the initial nutrient supply, i.e., 17.5 μg-at NO_3 and 34 μg at SiO_3 assuming that there is no immediate *in situ* regeneration.

Rapidly dividing algal cells - like diatoms during a spring bloom situation - have relatively low C:N ratios, 6.5:1, indicating high protein content (Russel-Hunter). Since the bloom conditions we observed showed extremely rapid growth rates we can assume that high protein cells are being produced - a situation highly favorable to the higher trophic levels and perhaps a factor in the overall high production of the Bering Sea.

The initial supply of 17.5 μg-at/ℓ NO_3-N would then permit a potential fixation of approximately 1.6 g of C/m^3. With an average observed rate of C fixation of 25 mg/m^3/hr and assuming a productive day length of 12 hr we arrive at the conclusion that under ideal conditions the ice edge bloom might be complete within 5-6 days. For a variety of reasons the bloom time is probably a little longer than this estimate, but it can be of extremely short duration. We know from our own work and from Goering and McRoy (1972) that very little production occurs under the solid ice pack, one reason alone being that less than 1% of the sub-surface light penetrates the ice cover. Yet we have also observed nearly complete nitrogen depletion very shortly after the ice pack has broken up sufficiently to allow light penetration but still represents 30-50% coverage indicating that the bloom does occur rapidly with great intensity.

The Ice

The normal limit of ice cover in the Bering Sea is the shelf break with the shelf area itself being ice covered by seasonal ice. Although significant cell concentrations are found within the ice they are restricted to a relatively narrow band and while these epontic algal growths may act to seed the water column they are probably not major contributors to the annual production when compared to the potential of the water column.

Microscopic observation of ice core samples shows the cells to exist in distinct channels within the ice structure. Melting of the ice causes the cells to be flushed from the channels. During the late stages of ice disintegration cells are not found within the ice.

These populations are difficult to study *in vivo* because of the susceptibility to lysis when the ice melts. Maintaining incubation temperatures such that the ice does not melt and alter the salinity is beyond the scope of a survey approach. Attempts to incubate samples *in situ* were unsuccessful. Therefore, we have no reliable estimates of the actual production rates within the ice. Recently we have observed that less than 1% of the subsurface light is available beneath the ice, and suspect the production is low. When the ice and snow cover becomes sufficiently thin to allow more light to penetrate, the cells have already been flushed from the ice during the melt.

Yet, the ice edge does exhibit abnormally high primary production under certain circumstances. We believe that the major effect of the receeding ice edge on the productivity regime results from a stabilization of the water column by dampening the effects of wind mixing.

The Bering Sea is an area of frequent storms and the sea state is usually active. Considering the low angle of the sun it is probable that wind mixing effects do inhibit production by transporting the cells out of the euphotic zone. As already mentioned total ice cover severely reduces the light available to the water column. With the advent of milder temperatures, so that refreezing does not occur, the ice edge gradually breaks up into smaller flows from sea and swell action. But these ice flows do not melt rapidly and a system of ice flows with openings develops and characterizes the receeding ice front throughout its retreat. It is this physical system which so enhances productivity. The partial ice cover effectively prevents wind mixing while the open spaces between the ice allow sufficient light penetration to initiate a bloom. It is this stabilized system that promotes the development of the strongly stratified bloom in the surface waters of the ice front. The surface bloom is at times sufficiently intense in the upper waters to severely light limit the deep waters.

The extent and nature of the ice cover may strongly influence the nature of the productivity regime. The ice edge system is too complex and variable for us to define all of its aspects from the two seasons we observed it. The most recent cruises, spring 1977, provided the opportunity to observe the shelf situation when less than normal ice coverage existed due to the mild winter. Those areas over the shelf which had not been ice covered and therefore exposed to the available light but also to wind mixing showed a less intense bloom of a more "normal" distribution throughout a greater depth of the water column. Thus, it appears that an ice edge effect is to induce a very intense stratified bloom which causes rapid nutrient depletion of the water, while the non-ice covered areas demonstrate a slower rate of production perhaps over a longer period of time. Not enough data is yet available to estimate which of the two regimes is ultimately the most productive on an annual basis. If the protein content of these rapidly growing ice edge diatoms is significantly greater than in a slow growth regime as Russel-Hunter (1970) suggests, then we may assume that the energy transfer to higher trophic levels is more efficient for the ice edge algae than the open water system.

VIII. CONCLUSIONS

Our studies of primary productivity related to the edge of the seasonal ice pack in the Bering Sea enable us to draw the following tenative conclusions:

1. The major effects of the ice field appear to be in limiting light energy to the water column and reducing windmixing at the surface. This means that water column plant production is probably negligible until the pack begins to break up. While loose ice is present at the sea surface (in the retreating edge zone) it tends to stabilize the wind mixed layer and hence, greatly inhances the opportunity for rapid plant production. With reduced mixing, ample light, and nutrients, an exceedingly intense bloom of short duration often occurs. This band of production follows the ice northward in the late spring.

2. The very cold ice-related water tends to sink away from the surface as warming progresses. We present evidence that algal populations also sink with the water mass. The ramifications of oil contamination are obvious, particulary since a surface spill could become incorporated and carried to depth with the sinking algal cells to enter benthic food webs on the sea bed.

IX. NEEDS FOR FURTHER STUDY

With respect to our current work, we still have some mop-up work to do on the phytoplankton taxonomy. Certain diatom species cannot be properly identified without clearing them (oxidizing them of protoplasmic contents) because taxonomy is based on the morphology of the frustule and cell contents obscure the frustule markings. We have been using a muffle furnace set at 560°C for 15-20 minutes to clear diatoms for taxonomic study (Zoto *et al.*, 1973). In addition, line drawings are made of unidentified species and photographs have been taken using an American Optical Differential Contrast Microscope.

For further analysis of the phytoplankton data we plan to use cluster analysis techniques to delineate changes in community structure between station, depths and seasons. Changes in community structure may correlate with changes in other parameters such as light intensity, nutrient concentration, etc. In addition, we may look at the diversity of communities and how they change spatially and seasonally. Differences between the ice communities and phytoplankton in open water will be studied. Our preliminary completion runs show promise.

With respect to the *in situ* dynamics of phytoplankton, the fate of the cells from the spring bloom, the transfer to grazers of the ice algae and the ice edge cells, and the role of detritus in the Bering Sea food chain, all remain to be clarified.

X. SUMMARY OF JANUARY - MARCH QUARTER

A. Laboratory Activities

1. Data synthesis from all 1977 cruises has been completed.
2. Report preparation and computer interpretation of station data.
3. Drafting of station plots.
4. Cluster analysis work on phytoplankton population initiated with preliminary successful runs of the program.

Personnel involved: T. Chapman, G. Mimken, L. Schandelmeier, L. Molot, V. Alexander.

REFERENCES

Hasle, G. 1972. *Fragilariopsis* Husted as a section of the genus *Nitzschia* Hassall in R. Simonsen (ed.). First symposium on recent and fossil diatoms. Proceedings. *In* Nova-Hedwiga, Weinheim, Germany. pp. 111-119.

Holmes, R. W. 1958. Surface chlorophyll *a*, surface primary production and zooplankton volumes in the Eastern Pacific Ocean. Rapp. Reun. Cons. Perm. Int. Explor. Mer. 144:109-116.

Koblentz-Mishke, O. J. 1965. Primary production in the Pacific. *Okeanol.* 5:325-337 (in Russian, English translation, IPST, 614 pp., 1969).

Leadbeater, B. S. C. and I. Manton. 1974. Preliminary observations on the chemistry and biology of the lorica in a collared flagellate (*Stephanoeca diplocosta* Ellis). *J. Mar. Biol. Assoc. U.K.* 54:269-276.

Lovegrove, T. 1966. The determination of the dry weight of plankton and the effect of various factors on the values obtained, *In* Some Contemporary Studies in Marine Science. H. Barnes (ed.), Hafner Publishing Co., New York.

McRoy, V. P. 1970. On the biology of eelgrass in Alaska, Ph. D dissertation, University of Alaska, Fairbanks. 156 pp.

McRoy, C. P. and J. J. Goering. 1974. The influence of ice on the primary productivity of the Bering Sea. *In* Oceanography of the Bering Sea, D. W. Hood, (ed.) Occasional Publication No. 2, Institute of Marine Science, University of Alaska, Fairbanks.

McRoy, C. P. and J. J. Goering. 1975. Primary production budget for the Bering Sea. *In* Bering Sea Oceanography: an Update. Results of a seminar and workshop on Bering Sea Oceanography under Auspices of the U.S. - Japan Program. Office of International Programs, National Science Foundation.

McRoy, C. P., J. J. Goering and W. E. Shields. 1972. Studies of primary production in the eastern Bering Sea. pp. 199-216 *In* Biological Oceanography of the Northern North Pacific Ocean, A. Y. Takenouti (ed.) Idemitsu Shoten, Tokyo.

Parke and Dixon. 1976. Checklist of British Marine Algae. Third Revision *J. Mar. Biol. Ass. U.K.* 56:527-594.

Rigler, F. H. 1971. Feeding rates. *In* A manual on methods for assessment of secondary productivity in fresh waters. IBP Handbook No. 17, W. T. Edmondson and G. G. Winberg (eds.), F. A. Davis Co., Philadelphia.

Russell-Hunter, W. D. 1970. *Aquatic Productivity*, MacMillan Co., New York. 306 pp.

Zoto, G. A., D. O. Dillion and H. E. Schlichting Jr. 1973. A rapid method for taxonomic and ecological studies. Phycologia 12(1/2).

SECTION I - APPENDIX I

REPORT ON ZOOPLANKTON COMMUNITY GRAZING EXPERIMENTS CONDUCTED ON BOARD THE NOAA SHIP, *DISCOVERER*, IN THE BERING SEA, MAY-JUNE 1977

Lewis Molot

REPORT ON ZOOPLANKTON COMMUNITY GRAZING EXPERIMENTS CONDUCTED ON BOARD THE NOAA SHIP, *DISCOVERER*, IN THE BERING SEA, MAY-JUNE 1977

METHODS

Two types of grazing experiments were performed during a cruise to the Bering Sea outer continental shelf in May and June 1977, one monospecific, using various herbivorous species, and the other using natural assemblages.

Single Species Grazing

Surface sea water was filtered through 211 μm Nitex netting and subdivided into one litre poly bottles. Animals were gathered from a vertical net tow, transferred to a beaker of filtered sea water and left in the dark at 4°C for 12 hours. The animals were then added to the poly bottles in various concentrations. Initial particle counts in the range 4-80 μm were obtained using a Model B Coulter Counter (Coulter Electronics, Inc.) with a 200 μm orifice tube before incubation at 4°C under a dim incandescent bulb. The bottles were removed at regular intervals for particle counting. Initial and final samples of some experiments were preserved with lugol for phytoplankton species identification. Primary productivities (24 hr) were incubated under the same conditions at the conclusion of some experiments. Dry weights were measured on a Cahn Electrobalance after the animals had been rinsed in distilled water for a few seconds, dried in a vacuum oven at 60°C for 18 3/4 hrs, and cooled in a vacuum dessicator for 1 1/2 hours.

Community Grazing

Each set of experiments consisted of three 20-litre cubetainers filled with surface layer sea water. One cubetainer had been filtered through

211 μm Nitex netting and was used as a control, another cubetainer contained unfiltered surface layer water and the third contained a salted community of zooplankton, which had been obtained by towing a 1-m vertical net slowly through the water column, closing it before it entered the euphotic zone, and transferring the animals to the cubetainer. The cubetainers were incubated at 4°C under a dim incandescent bulb. Samples were taken regularly for particle counts. At the end of each experiment, the zooplankton were preserved in 10% formalin for identification. Twenty-four hour primary productivities were run at the conclusion of some experiments.

Filtering rates were calculated using (Coughlan 1969) -

$$F = \frac{\ln\,(C_o/C_t\;\ell^{-Rt})}{t} \qquad (1)$$

where F = filtering rate (mls/hr/litre of community) of particles 10-80 μm,

t = time intervals (hrs)

C_o = initial particle concentration (mg wet wgt/ℓ) of particles 10-80 μm,

C_t = final particle concentration (mg wet wgt/ℓ) of particles 10-80 μm,

R = instantaneous growth rate (hr^{-1}) as measured from the growth of particles 10-80 μm in the control.

Ingestion rates were calculated directly from volume counts by,

$$I = (C_o - C_t)/t \qquad (2)$$

This assumes that R = o.

Particle concentrations were converted to mg wet weight by assuming a mean density of 1g/ml.

Results

The data are presented in Tables I-II and in Figures 1-9. The algal blooms at stations 9, 10, 26 and 27 occurred within the broken ice of the receding ice edge. The blooms were primarily diatoms with peak diameters in the window 51-64 μm. The bloom at station 39, which occurred much farther south in the open water near Unimak Pass, was primarily Haptophyta (*Phaeocystis* sp.) with a peak diameter in the window 5-6.3 μm. Grazing rates of particles 4-10 μm at station 39 could not be calculated due to high background counts induced by line voltage surges.

Single Species Grazing

Single species grazing rates are presented in Table II. Maximum rates occurred during the first counting interval, probably because of the prior starvation period in filtered seawater. Calculated filtering rates for the first interval in ml/hr•mg dry weight were 26.2 for *Metridia lucens*, 32.4 for *Pseudocalanus* sp. and 5.2 for *Calanus glacialis*. The latter agrees well with the data obtained for *Calanus marshallae* in the ice edge (range 5.9-7.3) in April 1976.

Primary productivity data are given in Table VIII for *M. lucens*. There is little difference in CPM/mg wet weight between ungrazed and grazed algal populations, suggesting that growth rates are unaffected by grazing during the course of the experiment.

Mean dry weights per animal are given in Table III for the three grazing species used.

TABLE I

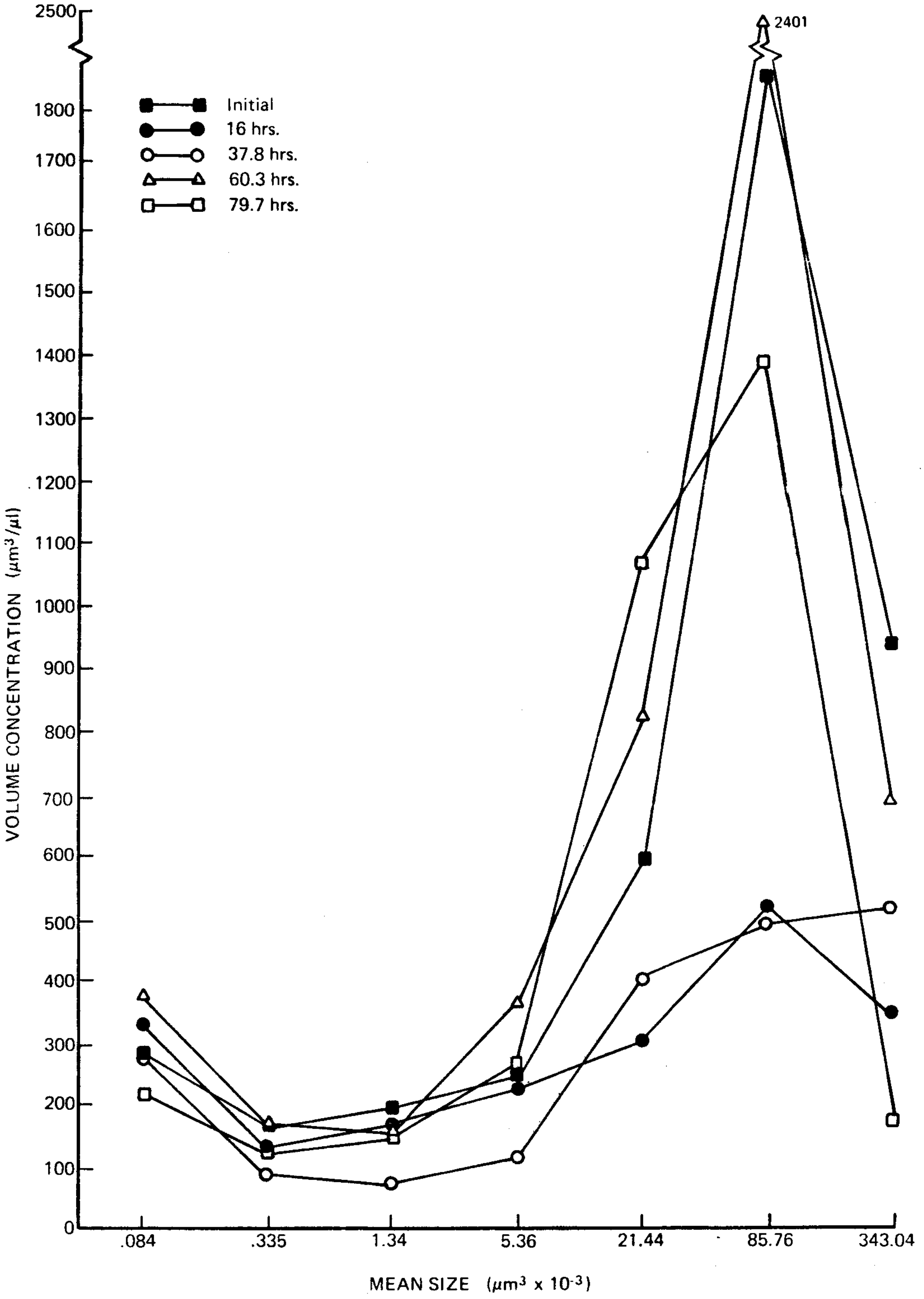
STATION LOCATION, ICE CONDITION AND DATE

Station	Ice Condition	Latitude	Longitude	Date
9	ice	60°37.0'	174°30.3'	May 26/77
10	ice	60°39.0'	174°33.8'	May 27/77
26	ice	60°57.5'	170°51.8'	June 4/77
27	ice	60°40.5'	169°32.3'	June 6/77
39	ice free	55°08.1'	166°05.1'	June 9/77

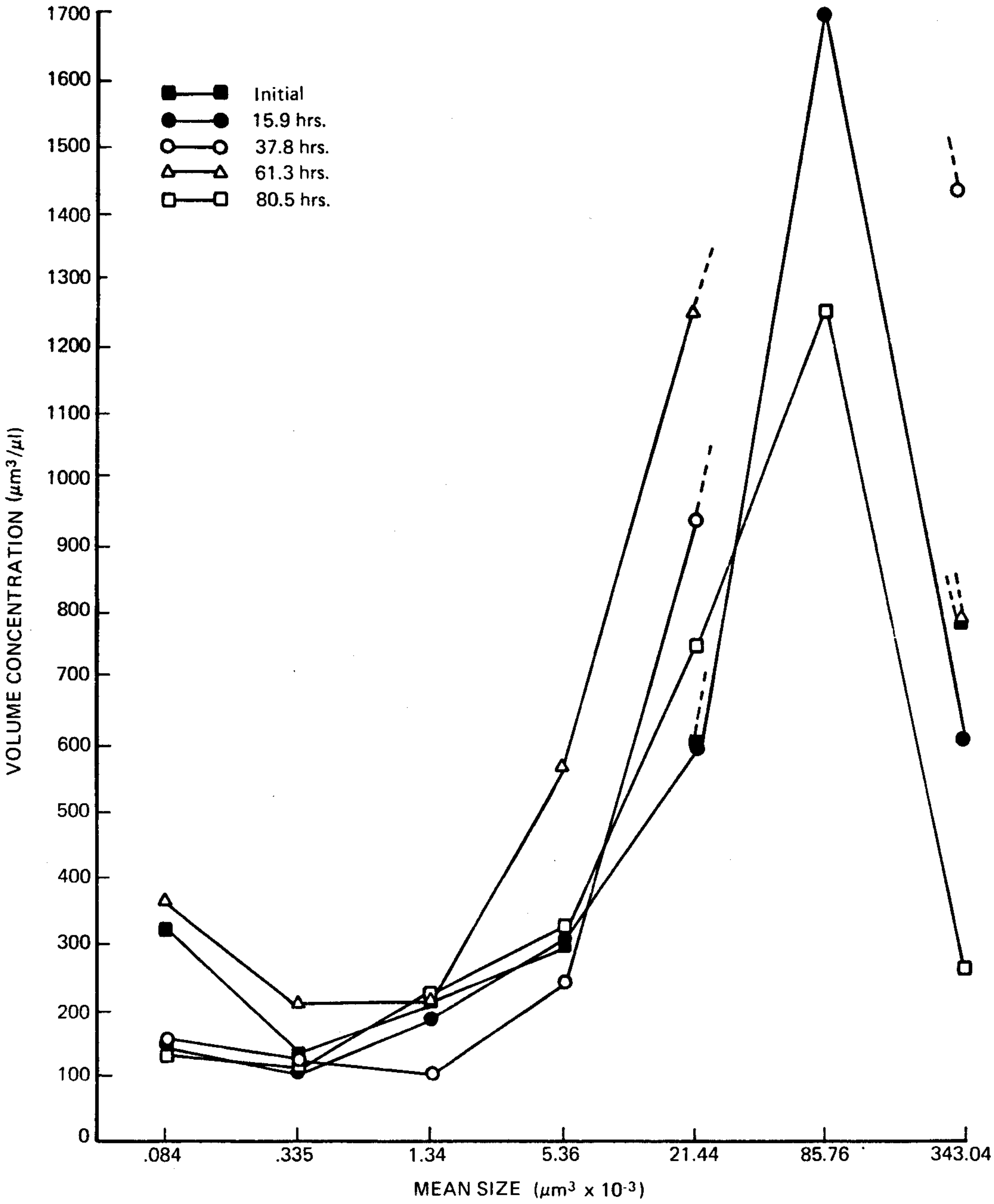
TABLE II

SINGLE SPECIES' FILTERING RATES (ml/hr•mg DRY WGT)

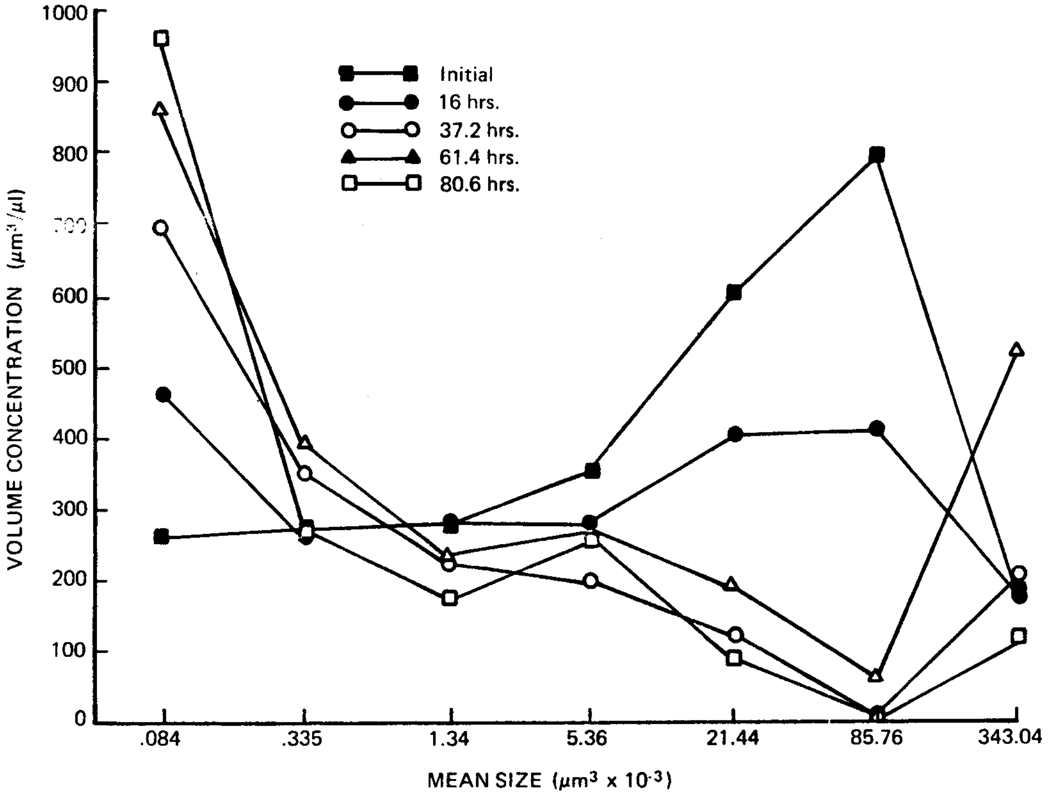
Station	Interval	Length of Interval (hrs)	Number of animals per bottle				
			5	6	10	19	Mean
9 (*Metridia lucens*)	1	13.6	60.7	17.1	21.0	11.1	27.5
	2	10.1	0	0	0	0	0
	ave	23.7	4.6	0	7.1	5.1	4.2
			4	11	18		Mean
10 (*M. lucens*)	1	15.3	27.1	18.8	28.4		24.8
	2	19.3	0	7.7	0		2.6
	ave	37.4	4.5	12.5	11.8		9.6
			11	22			Mean
26 (*Calanus glacialis*)	1	24.4	4.8	5.5			5.2
			55				
27 (*Pseudocalanus* sp.)	1	23.0	32.4				
	2	25.6	16.7				
	ave	48.6	25.2				



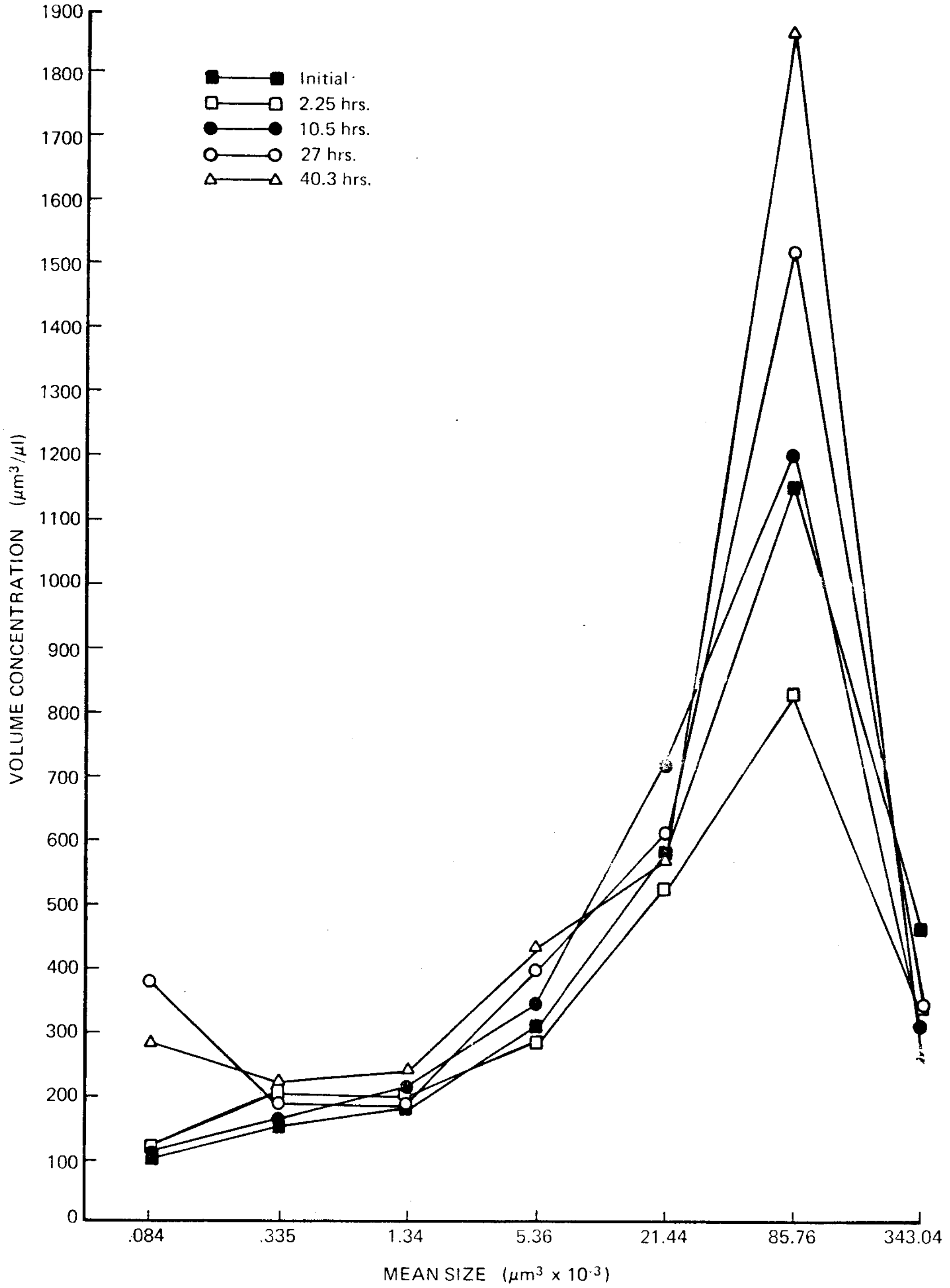
Appendix I - Figure 1. Community grazing Station 9A, control.



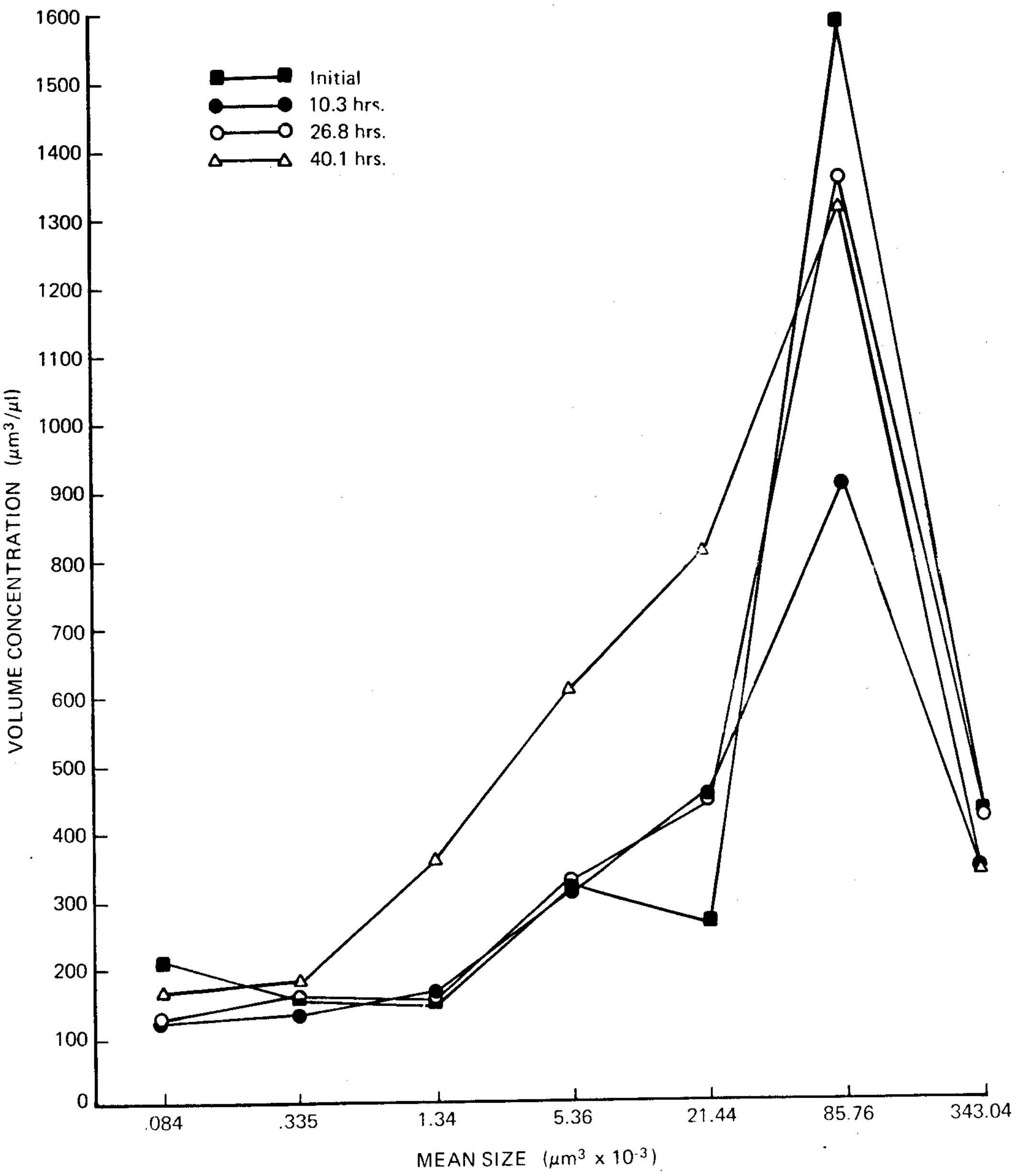
Appendix I - Figure 2. Community grazing experiment Station 9A unsalted.



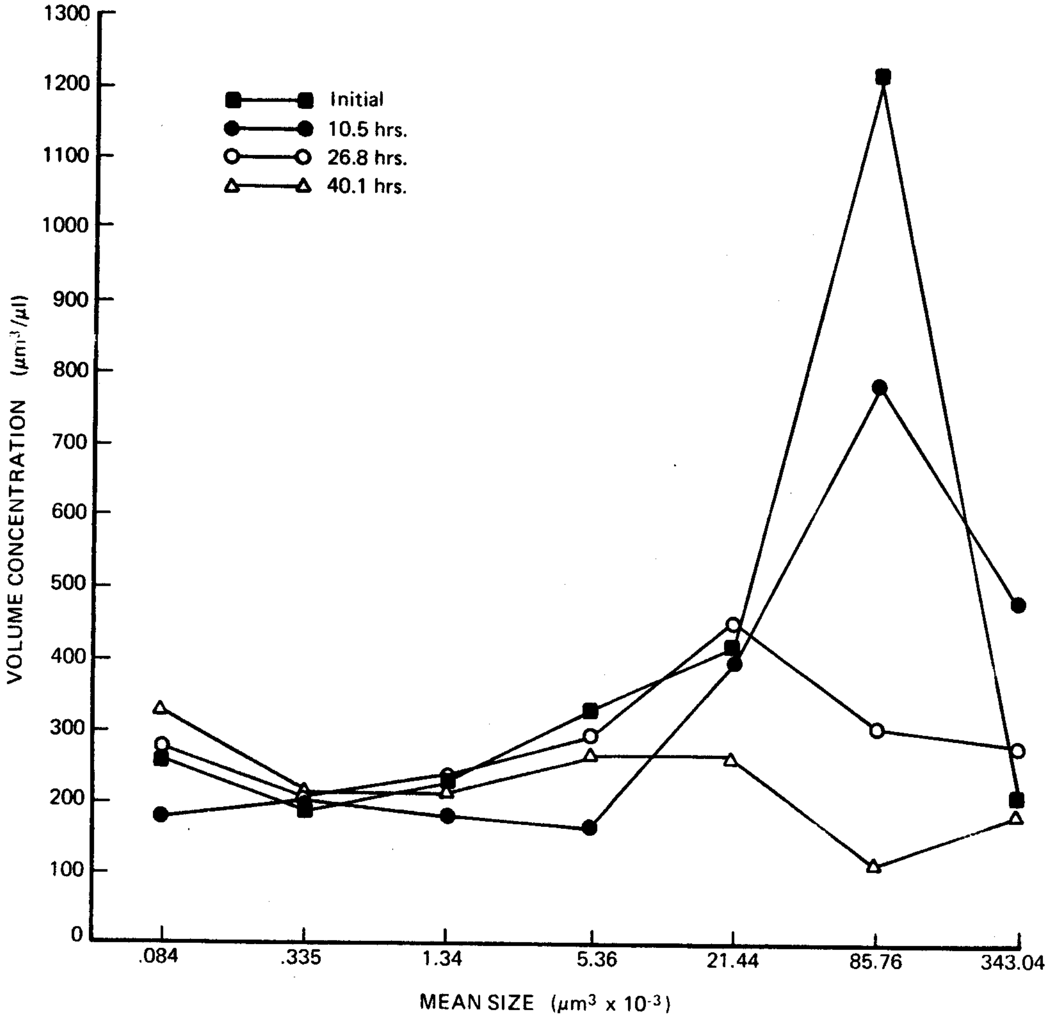
Appendix I - Figure 3. Community grazing Station 9A salted.



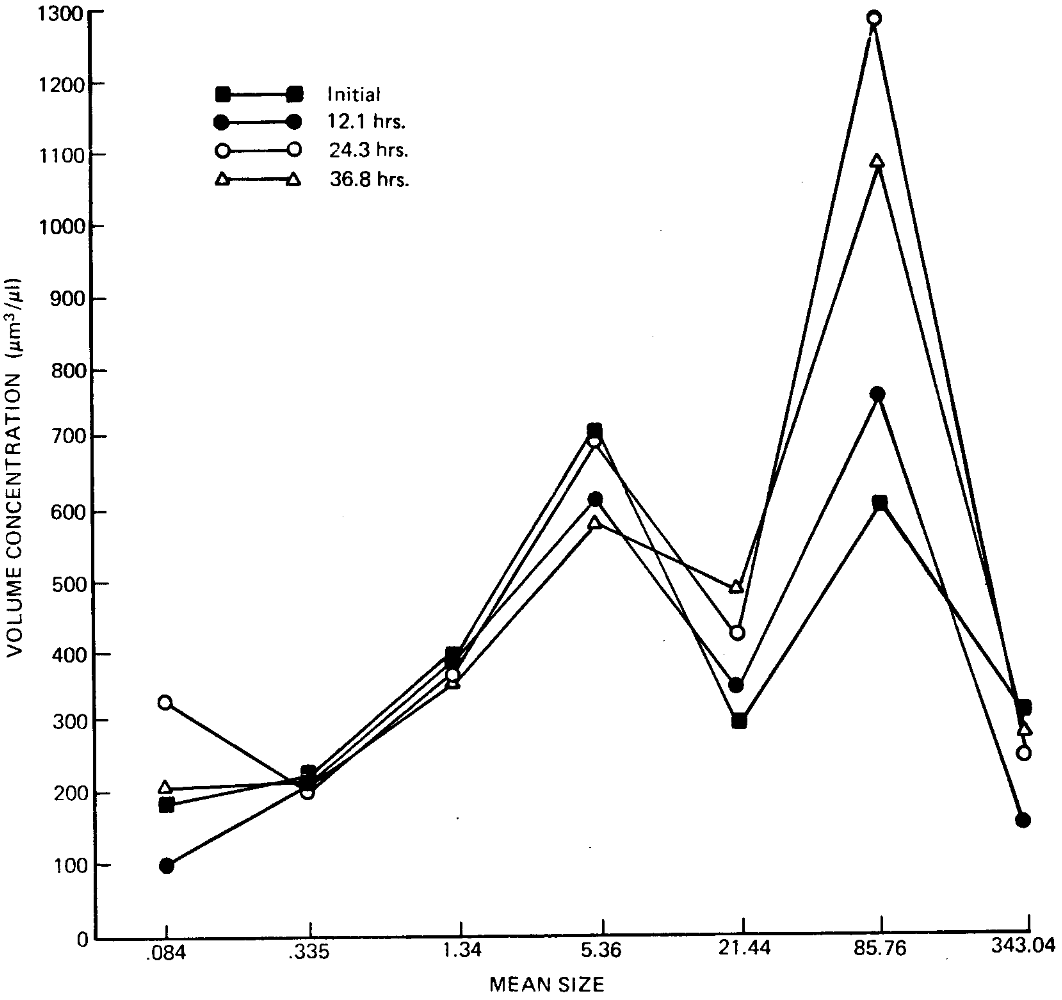
Appendix I - Figure 4. Community grazing Station 26, control.



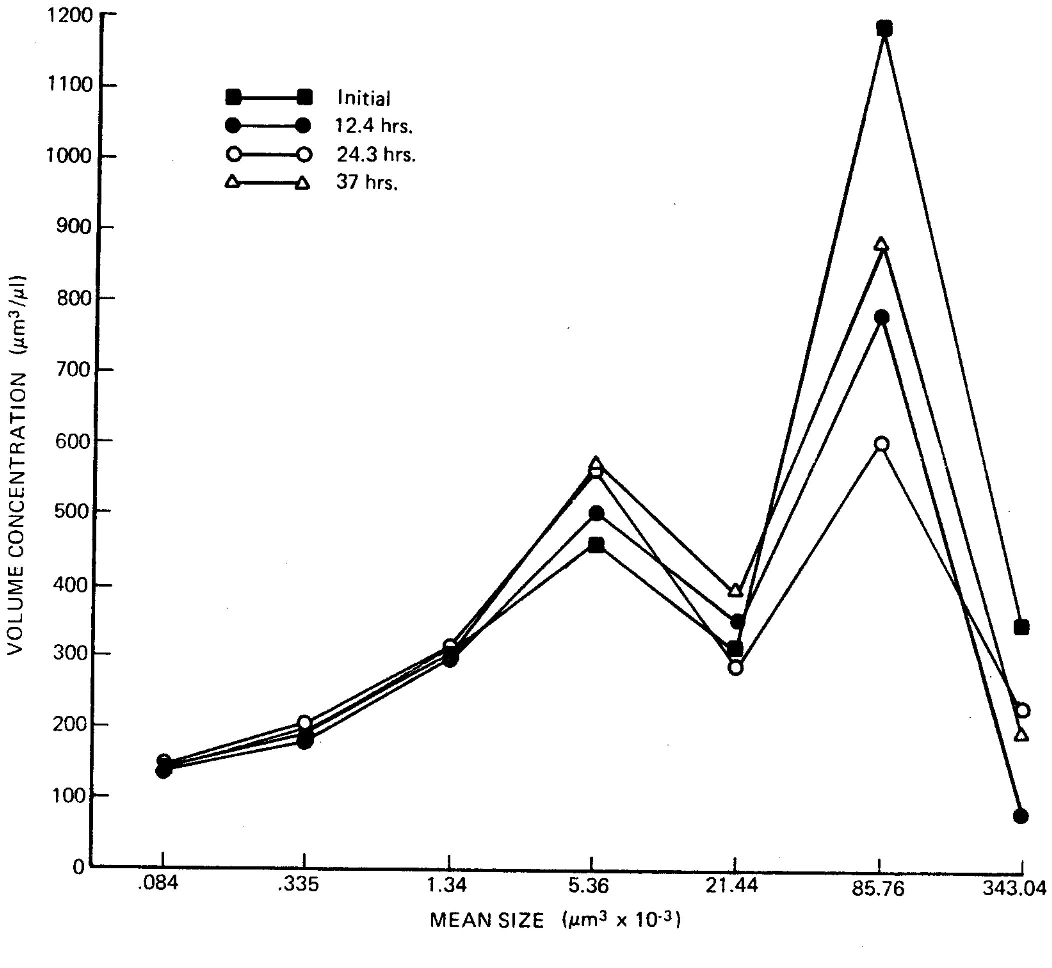
Appendix I - Figure 5. Community grazing Station 26, unsalted.



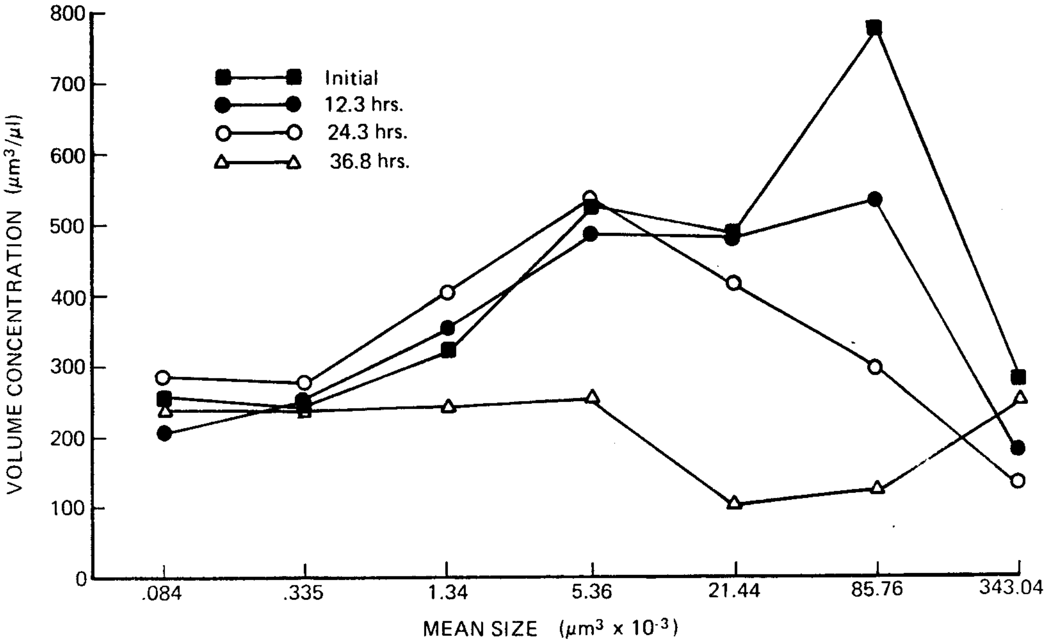
Appendix I - Figure 6. Community grazing Station 26, salted.



Appendix I - Figure 7. Community grazing Station 27, control.



Appendix I - Figure 8. Community grazing size distribution for Station 27, unsalted.



Appendix I - Figure 9. Community grazing Station 27, salted.

TABLE III

SPECIES DRY WEIGHTS (mg/ANIMAL)

Species	Range	Mean
Metridia lucens	.094 - .139	.121
Calanus glacialis	.420 - .436	.428
Pseudocalanus sp.	-	.011

Community Grazing

Sampling depth, time of day and tow volume are presented in Table IV. Sampling was done as close as possible to midnight in order to maximize the number of animals in the unsalted experiment.

Community filtering rates of particles 10-80 μm diameter are given in Table V. After 37-40 hours, the unsalted communities of stations 9A, 26 and 27 showed little or no grazing (0, 0, .008 ℓ/hr•ℓ respectively, corrected for growth of algae) while the salted community had filtering rates of .006, .027 and .031 ℓ/hr•ℓ respectively. Note that filtering rates are equivalent to hourly turnover rates. Results from station 39 are ignored because line voltage problems prevented counting of the bloom windows.

The species composition of the zooplankton can be used to calculate filtering rates based on single-species experiments. The results are presented in Table VI. One would expect the single-species derived results to be lower than the community-derived rates since the presence of raptors would decrease the number of grazers in the cubetainer and only the final zooplankton composition is available. However, the reverse is true as single-species derived rates are 5-40 times higher than community-derived rates.

Algal size distributions for the experiments are shown in Figures 1-9. The blooms in the salted cubetainers were grazed down to baseline levels within 40 hours. This is verified by primary productivity measurements (Table VIII) which showed no C-14 uptake by the salted community phytoplankton.

Community ingestion rates are shown in Table VII. The salted rates for stations 9A, 26 and 27 after 37-40 hours were 1.96, 1.70 and 2.00 μg C/hr•ℓ. Assuming a 10 hour feeding period, this amounts to only 20 μg C/day•ℓ.

TABLE IV

SAMPLING DEPTH, TIME, AND TOW DISTANCE OF COMMUNITY GRAZING EXPERIMENTS

Station	Water Sample Depth (m)	Depth of Main Chlorophyll *a* Peak (m)	Time of Collection	Vertical Tow Distance (m)	Tow Volume (m^3)
9	12	12	∿0500	-	-
9A	10	12	2130	90-48	33.0
26	5	5	∿midnight	50-12	29.8
27	12	0	∿midnight	40-12	22.0
39	8	8	0600	75-30	35.3

TABLE V

COMMUNITY FILTERING RATES (ℓ/hr·ℓ COMMUNITY)

Station	Interval	Length of interval (hrs)	Filtering Rate*	
			Unsalted	Salted
9	1	14.5	.001(0)	-
9A	1	16.0	0(.014)	0(.022)
	2	21.5	0(0)	.036(.035)
	3	23.9	.039(0)	.024(0)
	4	19.2	.018(.037)	.014(.026)
	ave	80.5	.015(.005)	.001(.015)
	ave (1+2)	37.5	0(0)	.006(.029)
26	1	10.5	.026(.022)	.021(.017)
	2	16.4	0(0)	.019(.017)
	3	13.3	0(0)	.041(.030)
	ave	40.2	0(0)	.027(.021)
27	1	12.4	.020(.021)	.013(.013)
	2	11.9	.025(.006)	.040(.016)
	3	12.6	0(0)	.041(.048)
	ave	37.0	.008(.003)	.031(.026)
39	1	13.8	.005(.010)	0(.002)
	2	12.2	0(.005)	0(.026)
	ave	25.9	0(.007)	0(.013)

* Filtering rates without control growth rate correction are in parentheses.

TABLE VI

ZOOPLANKTON SPECIES COMPOSITION AND COMMUNITY FILTERING RATES BASED ON SINGLE SPECIES EXPERIMENTS

	Station 9A		Station 26		Station 27	
	No/20ℓ	Filtering Rate (ℓ/hr•ℓ)	No/20ℓ	Filtering Rate (ℓ/hr•ℓ)	No/20ℓ	Filtering Rate (ℓ/hr•ℓ)
Grazers						
Pseudocalanus sp.	6520	0.116	15360	0.273	3440	0.061
Acartia longiremis	80	0.001	280	0.005	120	0.002
Calanus glacialis	160	0.018	240	0.027	920	0.102
Metridia lucens	2080	0.330	-	-	-	-
Total		0.465		0.305		0.165
Major Raptors						
Sagitta elegans	2640		3360		1960	
Bathymedon sp.	760		320		-	
Thysanoessa raschii	-		440		-	

Ratio of *Sagitta/Pseudocalanus/Acartia/Calanus/Metridia* numbers

9A: 33/81.5/1/2/26
26: 14/64/1.2/1/0
27: 16.3/28.7/1/7.7/0

TABLE VII

COMMUNITY INGESTION RATES*

		Unsalted ingestion rate		Salted ingestion rate	
Station	Interval	mg wet wgt/hr·ℓ	µg C-12/hr·ℓ**	mg wet wgt/hr·ℓ	µg C-12/hr·ℓ**
9	1	0	0	-	-
9A	1	.051	2.55	.041	2.05
	2	0	0	.038	1.90
	3	0	0	0	0
	4	.149	7.45	.031	1.55
	ave (80.5 hrs)	.017	0.85	.019	0.95
	ave (1+2)	0	0	.039	1.96
26	1	.053	2.65	.038	1.90
	2	0	0	.029	1.45
	3	0	0	.037	1.85
	ave (40.2 hrs)	0	0	.034	1.70
27	1	.049	2.45	.030	1.50
	2	.001	0.05	.029	1.45
	3	0	0	.060	3.00
	ave (37.0 hrs)	.007	0.35	.040	2.00
39	1	.007	0.35	.003	0.15
	2	.004	0.20	.033	1.65
	ave (25.9 hrs)	.006	0.30	.017	0.85

---

* $I = (C_o - C_t)/t$, assuming no growth of algae

** Assuming 5% of wet weight is carbon

TABLE VIII

FINAL C-14 UPTAKE (CPM/mg WET WGT)

	Number of animals					
Experiment	0	5	6	10	19	Mean (5, 6, 10, 19)
9 - *M. lucens*	2447	4436	1459	1615	1496	2252
	0	4	11	18		Mean (4, 11, 18)
10 - *M. lucens*	1305	1813	1718	1618		1716
	0			Unsalted		Salted
26	3744			3852		0
27	2445			2427		0

Carbon-12 uptake measurements for the ice edge stations ranged from 0 to 1400 μg C/day•ℓ. Hence the salted communities were ingesting only 2% of the daily net primary productivity. Unsalted community ingestion was barely measurable.

Discussion

The salted community grazing rates were lower than the potential rates derived from single species data. This can probably be attributed to extreme concentrations of grazers and their main predator, *Sagitta elegans*. Perhaps the grazers were resource limited and/or they spent a great deal of time avoiding predators since the cubetainers were incubated under constant light. Although grazing was lower than expected, it exceeded productivity and the phytoplankton concentrations were reduced to virtually nothing after about forty hours.

The zooplankton composition of a vertical tow was used to derive a mean hourly filtering rate of 0.61 ml/hr•ℓ for the euphotic zone to a depth of 12 meters (Table IX). The zooplankton concentrations were very low and probably were not resource limited, nor seriously inhibited by predators in contrast to salted population since most of their feeding would occur in the dark (assuming that *Sagitta* is visually oriented). Using a mean algal concentration of 1.38 mg wet weight/ℓ in the 12 meter water column, a 10 hour feeding period, and a carbon conversion factor of .05, the mean daily grazing amounts to only 0.42 μg C/day•ℓ. This is insignificant in comparison to daily primary productivity which ranged from 0-1400 μg C/day•ℓ.

Grazing rates of unsalted communities may be measurable during non-bloom conditions since the change in initial particle concentration may be significant. During an intense bloom at low grazing rate, $C_o/C_t = 1$. During

TABLE IX

MEAN COMPOSITION OF ZOOPLANKTON IN TWO ONE-METER VERTICAL TOWS SAMPLED FROM 0-12 M AT 0220, JUNE 6/77 AND CALCULATED FILTERING RATES

	Total mean number	Mean number/ℓ	Filtering rate ml/hr•ℓ
Grazers			
Pseudocalanus sp.	6340	0.673	0.239
Acartia longiremus	5800	0.616	0.219
Calanus glacialis	640	0.068	0.151
		Total	0.61 ml/hr•ℓ
Major Predators			
Sagitta elegans	9190	0.976	-

non-bloom conditions however, it may be that $C_o/C_t >> 1.$ and filtering and ingestion rates would be measurable.

Recommendations

1) We must verify that single-species derived rates are valid before we can come to conclusions regarding crowding and energy transfer to the zooplankton community. If a number of salted community experiments were conducted using various degrees of salting, then an optimum concentration or tow length would be indicated by that salted community having a grazing rate equal to or greater than the corresponding single-species derived rate. Any concentration less than the optimum would probably not be sufficient to allow measurement and any concentration greater would probably include significant crowding effects. I suspect that the tow distance may only be one or two meters. The ingestion rate may then be divided by the zooplankton salting factor to arrive at an unsalted ingestion rate. It may only be necessary, however, to apply single species rates to natural zooplankton concentrations to arrive at valid ingestion rates.

2) Daily ingestion rates for the water column are complicated by the vertical migration of the zooplankton. It will be necessary to know the residence time of the grazers in the euphotic zone. Perhaps a series of experiments can be conducted in which grazing is measured at several depths in the water column over a 24 hour period. *In situ* light intensities at the time of sampling would need to be simulated.

3) A shaking device will be necessary to prevent algae from settling to the bottom of the cubetainers. This suggests the use of smaller cubetainers, say 10 ℓ, (which will affect the tow distance) for ease of handling.

REFERENCES

Coughlan, J. 1969. The estimation of filtering rate from the clearance of suspensions. *Mar. Biol.* 3:356-358.

APPENDIX A

PARTICLE SIZE DISTRIBUTIONS FOR 23 STATIONS IN THE BERING SEA, MAY-JUNE 1977

APPENDIX TABLE I

PARTICLE SIZE DISTRIBUTIONS AT 0 METERS IN THE BERING SEA, MAY-JUNE 1977

Station	Ice condition	Peak size (μm)	Abundance of 10-100 μm (mg wet wgt/ℓ)
1	ice free	40-64*	3.87
2	ice free	40-64*	4.18
3	ice free	25-40*	2.37
4	ice free	40-64*	1.82
6	ice free	40-64*	2.67
8	ice	40-64*	1.74
9	ice	40-64*	3.27
10	ice	51-64	2.72
11	ice edge	51-64	3.25
13	ice edge	40-51	2.22
16	ice free	51-64	0.88
17	ice free	40-51	0.80
18	ice free	51-64	2.38
20	ice free	32-40	1.35
22	ice free	32-40	0.43
23	ice	51-64	1.13
26	ice	51-64	2.48
27	ice	51-64	2.16
28	ice	51-64	1.48
32	ice free	40-51	1.13
34	ice free	51-64	0.67
39	ice free	5-6.3	0.75 (0.45 in the 4-10 μm)
40	ice free	40-64	0.69

* Counted with 7 window resolution. Stations 10-40 counted with 13 window resolution.

APPENDIX TABLE II

PARTICLE SIZE DISTRIBUTIONS AT DEPTH OF MAXIMUM CHLOROPHYLL *a* IN THE BERING SEA, MAY-JUNE 1977

Station	Ice condition	Depth of max CHL *a*	Depth of count (m)	Peak size (μm)	Abundance of 10-100 μm (mg wet wgt/ℓ)
1	ice free	5	10	40-64*	3.49
2	ice free	5	10	40-64*	4.11
3	ice free	-	10	40-64*	2.48
4	ice free	0	0	40-64*	1.83
6	ice free	0-42	20	40-64*	4.31
8	ice	0-10	0	40-64*	1.74
9	ice	12	10	40-64*	3.78
10	ice	-	10	51-64	4.83
11	ice edge	20	20	40-51	3.34
13	ice edge	20	20	40-51	3.07
16	ice free	42	40	51-64	1.58
17	ice free	35	40	51-64	1.73
18	ice free	50	50	32-40	2.22
20	ice free	45	30	25-32	1.90
22	ice free	57	50	32-40	1.47
23	ice	5	5	32-64	0.88
26	ice	5	5	51-64	2.79
27	ice	0	0	51-64	2.16
28	ice	0, 12	0, 10	51-64, 51-64	1.48, 2.10
32	ice free	10	10	51-64	1.50
34	ice free	30	30	40-51	1.15
39	ice free	8	10	5.0-6.3	0.56 (0.86 in 4-10 μm)
40	ice free	10, 30	10, 30	32-40, 4-5	0,63, 0.33 (0.2 in 4-10 μm at 30 m)

* Counted with 7 window resolution. Station 10-40 counted with 13 window resolution.

SECTION II

I. SUMMARY

This report describes progress made towards stated program goals and presents a bibliography (Section II, Appendix I) in fulfillment of task A-22 as applied to the Bering Sea: "to summarize the existing literature and unpublished data on the transfer of synthesized organic matter to zooplankton, micronekton, and ichthyoplankton." The finished product goes beyond the original task description with the inclusion of references on the following subjects: uptake of organic and inorganic nutrients by primary producers; primary production; trophic interactions, distribution, and population dynamics of marine mammals and sea birds; trophic interactions, population dynamics, and distribution of benthic invertebrates and fishes; the taxonomy and ecology of parasites, of invertebrates and vertebrates; microbial decomposition of marine organic matter.

II. INTRODUCTION

In 1977 studies by Alexander and Cooney of the ice edge ecosystem were merged into a single research unit, No. 427. This work was directed toward a quantitative understanding of the processes of primary productivity, nutrient cycling, and organic matter transfer at the edge of the seasonal ice pack in the Bering Sea. We proposed to model the lower trophic levels of this system in an attempt to better understand the partitioning of organic matter utilized on the underice, in the water column, and on the seabed. It was my purpose to describe the grazing community adjacent to and under the edge zone of the seasonal pack, and to then conduct the experiments necessary to estimate grazing losses in the water column. The preliminary observations of distribution and abundance were accomplished during this funding period; proposed measures of particle ingestion by the grazing community were planned for FY 78.

III. CURRENT STATE OF KNOWLEDGE

Cooney (1976, 1977, 1978) reviewed the literature pertaining to zooplankton and micronekton in the southeastern Bering Sea. While not exhaustive, these reviews and final report represent an overview of the animal plankton and micronekton assemblages, their composition and the distribution and abundance of dominant species. Some preliminary notions concerning the effect of the ice pack were presented.

IV. STUDY AREA

Samples were obtained in the edge zone of the seasonal ice pack March 15-April 4 and April 14-May 3, 1977 aboard the NOAA vessel *Surveyor*. Additional collections were made between June 20 and July 11 in the Norton Sound and southern Chukchi Sea from the *Discoverer*.

V. SOURCES, MATERIALS, METHODS

The bibliography prepared as this report was compiled from library searches accomplished at the University of Alaska (Fairbanks), the University of Washington (Seattle), and Oregon State University (Corvallis) by Mr. Al Adams.

Field data were collected as per Task Order No. 1.

VI. RESULTS

Over 1500 references have been accumulated addressing Task Order A-22 as pertaining to the southeastern Bering Sea and north Pacific Ocean (see Section II, Appendix I).

The results of zooplankton data collected in the field will appear as the Final Report of this project, September, 1978. Funding delays have prevented the final processing and assessment of collections made in the spring and summer of last year.

VII. SUMMARY OF FOURTH QUARTER OPERATIONS

The final processing of samples obtained aboard the *Discoverer* (June-July, 1977) were begun, together with statistical studies of data processed for the spring cruise. This material address both the question of the nearshore zones along the northern shelf, and details of the distribution of dominant species adjacent to and under the ice pack in the southern shelf area. The synthesis of this information will form the content of the Final Report of the project.

REFERENCES

Cooney, R. T. 1976. Environmental assessment of the Alaskan Continental Shelf: zooplankton and micronekton studies in the Bering/Chukchi/Beaufort Seas. Annual Report, Institute of Marine Science, Fairbanks. 53 p.

Cooney, R. T. 1977. Environmental assessment of the Alaskan Continental Shelf: zooplankton and micronekton studies in the Bering/Chukchi/Beaufort Seas. Annual Report, Institute of Marine Science, Fairbanks. 83 p.

Cooney, R. T. 1978. Environmental assessment of the Alaskan Continental Shelf; zooplankton and micronekton studies in the southeastern Bering Sea. Final Report, Institute of Marine Science, Fairbanks.

SECTION II - APPENDIX I

A bibliography of references pertaining to the following subjects as applying to natural phenomena occurring in the north Pacific Ocean: uptake of organic nutrients by primary producers, primary production; trophic interactions, distributions, and population dynamics of marine mammals and sea birds; trophic interactions; population dynamics, and distribution of benthic invertebrates and fishes; the taxonomy and ecology of parasites of invertebrates and vertebrates; and microbial decomposition of organic matter.

In general, most of the references apply primarily to the Bering Sea, Chukchi Sea, and northern north Pacific Ocean (with the Kurile-Kamchatka Trench as a southern boundary in the west and the Gulf of Alaska as a southern boundary in the east). Some species with particularly widespread distributions have been studied in northern waters of the north Atlantic Ocean, Canadian and Siberian Arctic Ocean, and the Barents Sea. Because this literature represents a significant contribution to an understanding of the ecology of marine organisms (which are found in the Bering Sea) it has been included in the bibliography.

Some omissions were unavoidable due to time constraints upon the total number of citations that could be examined. This is especially true of literature concerning commercial harvests and taxonomy of marine mammals and fish, taxonomy and productivity of sea birds, and taxonomy of benthic invertebrates. Popular reading materials (such as newspapers and non-scientific magazines) were not searched.

The bibliography is arranged alphabetically by author. Most titles are in English, however, a number of Russian titles have only been transliterated. Some references which were cited in the literature were not available for examination and could not be varified. In these cases the inclusive page numbers are generally missing; however, such articles have been retained in the bibliography due to their pertinence.

Abakumov, V. A. 1964. On the oceanic period in the life cycle of the lamprey *Entosphenus tridentatus* (Richardson). *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 49:268-270.

Abbot, D. P. 1961. The ascidians of Point Barrow, Alaska, Part I. Suborder Phlebobranchia (Enterogona). *Pac. Sci.* 15(1):137-143.

Abbott, R. T. 1954. *American Seashells.* Van Nostrand, New York. 541 pp.

Abrams, J. P., H. T. Kemp, and J. B. Kirkwood. 1968. Commercial fisheries related to Amchitka Island. Amchitka Bioenvironmental Progr., Battelle Mem. Inst. 171-109:1-70.

Adachi, R. 1972. Surface nannoplankton collected from the northwestern North Pacific Ocean in summer 1967. *In* A. Y. Takenouti (ed.), *Biological Oceanography of the Northern North Pacific Ocean.* Idemitsu Shoten, Tokyo, Japan. pp. 139-144.

Afanas'ev, V. P. 1941. Parasitofauna of the commercial mammals of the Commander Islands. Leningrad Gosudar. Univ., *Uchenye Zapiski, Seriya Biol. Nauk.* 74(18):93-117.

Aikawa, H. 1933. On the planktology of the Okhotsk Sea in autumn. *Bull. Jap. Soc. Sci. Fish.* 2(4):175-182. (In Japanese, with Engl. Synopsis).

Aikawa, H. 1932. On the summer plankton in the waters of the western Aleutian Islands in 1928. *Bull. Jap. Soc. Sci. Fish.* 1(2):70-74.

Aikawa, H. 1935. On the quantitative analysis of the plankton associations in adjacent seas of Japan III. *J. Imp. Fish. Expl. Stn.* 6:131-172. (In Japanese, with Engl. Summ.).

Aikawa, H. 1936a. The planktological properties of the principal sea areas surrounding Japan. *Bull. Jap. Soc. Sci. Fish.* 5:33-41. (In Japanese, with Engl. summ.).

Aikawa, H. 1936b. On the diatom communities in the waters surrounding Japan. *Rec. Oceanogr. Wks. Japan* 8:1-159.

Aikawa, H. 1938. On the quantitative analysis of the plankton associations in the adjacent seas of Japan. *J. Imp. Fish. Expl. Stn.* 9:67-86. (In Japanese, with Engl. summary).

Aikawa, H. 1940. On the plankton associations in the Bering Sea and the Okhotsk Sea. *Kaiyo-Gyogyo.* 5(1):20-31. (In Japanese).

Akimushkin, I. I. 1957. Cephalopod fauna of the Far Eastern Seas of the U.S.S.R. *Issled. Dal'nevost. Morei SSSR.* No. 4:127-148.

Akimushkin, I. I. 1963. Golovonogie mollyuski morei SSSR (*Cephalopods of the Seas of the U.S.S.R.*). Izd. Akad. nauk SSSR.

Akhmerov, A. Kh. 1951. Nekotorye dannye o parazitakh mintaya. (Some data on parasites of pollack). *Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.* Vol. 34:99-104.

Alexander, A. B. 1892. Data (on the food of fur seals) collected by A. B. Alexander on the Corwin, 1892 (Gulf of Alaska). (Three longhand record sheets from the library of the International Fisheries Commission, Seattle). Cited by: Scheffer (1950).

Alexander, V. 1971. An investigation of heterotrophy in arctic sea ice populations. *Proc. Alaska Sci. Conf.* 22:127. (Abstract).

Alexander, V. 1975. Phytoplankton studies in the Bering Sea. *In: Environmental Assessment of the Alaskan Continental Shelf; Principal Investigators' Reports July-September* 1975 *Volume I.* Environmental Research Laboratory, Boulder, Colorado. pp. 625-627.

Allan, C. H. 1959. Movement of salmon in the North Pacific Ocean and Bering Sea as determined by tagging (1956-1958). Fish. Res. Inst., College of Fish., Univ. Wash. Circular No. 106.

Allen, E. W. 1944. North Pacific Fisheries *Trans. North Amer. Wildlife Conf.* 9:220-223.

Allen, G. H. and W. Arno. 1958. Food of salmonid fishes of the western North Pacific Ocean. *U.S. Fish Wildl. Serv., Spec. Sci. Rept. - Fish.* No. 237:1-11.

Allen, J. A. 1870. The eared seals (Otariadae), with detailed descriptions of the North Pacific species...together with an account of the habits of the northern fur seal (*Callorhinus ursinus*), by Charles Bryant. *Bull. Mus. Comp. Zool. Harv.* 2:1-108.

Allen, M. B. 1970. Metabolic activities of phytoplankton associated with arctic sea ice. Univ. Alaska, Inst. Mar. Sci. Rept. R70-1. pp 1-17.

Allen, M. B. 1971. Winter growth of the cryobiota of arctic sea ice. *Proc. Alaska Sci. Conf.* 22:123.

Allen, W. E. 1927. Surface catches of marine diatoms and dinoflagellates made by U.S.S. *Pioneer* in Alaskan waters in 1923. *Bull. Scripps Inst. Oceanogr., Tech. Ser.* 1:39-48.

Allen, W. E. 1929. Surface catches of marine diatoms and dinoflagellates made by U.S.S. *Pioneer* in Alaskan waters in 1924. *Bull. Scripps Inst. Oceanogr., Tech. Ser.* 2:139-153.

Allen, W. E. 1930. Quantitative studies of surface catches of marine diatoms and dinoflagellates taken in Alaskan waters by the International Fisheries Commission in the fall and winter of 1927-1928 and 1929. *Bull. Scripps Inst. Oceanogr., Tech. Ser.* 2:389-399.

Allen, W. E. 1941. Depth relationships of plankton diatoms in sea water. *J. Mar. Res.* 4(2):107-111.

Allen, W. E. 1943. Summary of results of twenty years of researches on marine phytoplankton. *Pacif. Sci. Congr.* 6:577-583.

Alvariño, A. 1962. Two new Pacific chaetognaths, their distribution and relationship to allied species. *Bull. Scripps Inst. Oceanogr.* 8(1):1-50.

Alvariño, A. 1964. Bathymetric distribution of chaetognaths. *Pacif. Sci.* 18:64-82.

Alverson, D. L. 1960. The Japanese and Russian trawl fishery in the Bering Sea. *West. Fish.* April, 12-14; 30-31.

Alverson, D. L. and W. T. Pereyra. 1969. Demersal fish explorations in the northeastern Pacific Ocean - an evaluation of exploratory fishing methods and analytical approaches to stock size and yield forecasts. *J. Fish. Res. Bd. Can.* 26(8):1985-2001.

Alverson, D. L. and L. J. Westrheim. 1959. A review of the taxonomy and biology of the Pacific Ocean perch. *Intern. Comm. Northwest Atlan. Fish.* Ser. 679, Contrib. A-3.

Alverson, D. L. and N. J. Wilimovsky. 1966. Fishery investigations of the southeastern Chukchi Sea. *In*: H. J. Wilimovsky (ed.), *Environment of the Cape Thompson Region, Alaska.* Atomic Energy Comm. pp. 843-860.

Ambroz, A. I. 1930. Problem of resources of Pacific herring in Far Eastern Seas. *Rybn. Khoz. Dal'nego Vostoka*, No. 2.

Amos, M. H. 1966. Commercial clams of the North American Pacific coast. U.S. Dept. Interior, Bur. Comm. Fish. Circular No. 237.

Anderson, A. W. and C. B. Carlson. 1945. A preliminary report on the fisheries possibilities of the Nome area. U.S. Fish and Wildl. Serv., Washington.

Anderson, G. C. and R. E. Munson. 1972. Primary productivity studies using merchant vessels in the North Pacific Ocean. *In* A. Y. Takenouti (ed.), *Biological Oceanography of the Northern North Pacific Ocean.* Idemitsu Shoten, Tokyo, Japan. pp. 245-251.

Anderson, G. J. 1962. Distribution patterns of recent Foraminifera of the Bering Sea. Dept. Biol., Univ. S. Calif., 1-8.

Anderson G. J. 1963. Distribution patterns of recent foraminifera of the Bering Sea. *Micropaleontol.* 9(3):305-317.

Andrews, R. C. 1914. Monographs of the Pacific Cetacea. I. The California gray whale (*Rachianectes glaucus Cope*). *Mem. Am. Mus. Nat. Hist.,* M.S. 1:227-287.

Andreyev, V. L. 1968. Procedure for determination of the age and growth of the walleye pollack. *Izv. Tikhookean. Nauchno-issled. Inst. Rybn. Khoz. Okeanogr.* 65:253-256.

Andrievskaya, L. D. 1957. The food of Pacific salmon in the northwestern Pacific Ocean. Moscow, *Materialy po Biol. Morsk. Perioda Zhizni Dal'nevost. Lososei.* pp. 64-75.

Andrievskaya, L. D. 1957. Letnie migratsii tikhookeanskikh lososei i ikh pitanie v morskoi period zhizni (Summer migrations of Pacific salmon and feeding during the marine period of life). *Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.* Vol. 44:75-96.

Andrievskaya, L. D. 1968. The food and feeding of young Pacific salmon in the sea. *Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.* Vol. 64:73-80.

Andriyashev, A. P. 1935a. Geographical distribution of commercial fishes in the Bering Sea and the problems associated with it. *Issled. Morei SSSR.* 22:135-145.

Andriyashev, A. P. 1935b. New data on deep-sea fishes of the Bering Sea. Akad. nauk SSSR, (Doklady). Vol. 4(1-2):113-116.

Andriyashev, A. P. 1937. K poznaniy ikhtiofauny Beringova i Chukotskogo morei (The fishes from the Bering and Chukchi Seas). Gosudar. Gidrolog. Inst., Gidrometerol. Izdatel., Leningrad - Moscow, *Issled. Morei SSSR.* Vol. 25: 292-355.

Andriyashev, A. P. 1937. On the ichthyofauna of the Bering and Chukchi Seas. Gidrometeo., Leningrad, *Issled. Morei SSSR.* 25:292-355.

Andriyashev, A. P. 1939. Ocherk zoogeografii i poriskhozhdeniya fauny ryb Beringova morya i sopredel'nykh vod. (*Outline of Zoogeography and Origin of Fish Fauna of the Bering Sea and Adjacent Waters*). Izdatel'stvo Leningrad Gosudar. Univ.

Andriyashev, A. P. 1952a. Fishes of the Chukchi Sea and the Bering Strait. Sbornik: *Krainii Severo-Vostok SSSR.* Vol. 2.

Andriyashev, A. P. 1952b. New deep-sea fish of the Zoarcidae from the Bering Sea. Akad. Nauk SSSR, *Trudy Zool. Inst.* Vol. 12:415-417.

Andriyashev, A. P. 1952c. O nakhozhdelii dvukh vidov ryb roda *Lampanyctus* Bonap. u beregov Kamchatki. Izd. Akad. Nauk SSSR, Moscow, *Issled. Dal'nevost. Morei SSSR.* Vol. 3:99-102.

Andriyashev, A. P. 1953a. Ancient abyssal and bathyal fish forms and their significance in zoogeographical analysis. *Ocherki po Obsh. Vopr. ikhtiol.,* Izd. Akad. Nauk SSSR.

Andriyashev, A. P. 1953b. Discovery of the Pacific sturgeon in the Bering Sea. *Zool. Zhur.* 32(5).

Andriyashev, A. P. 1954. Ryby severnykh morei SSSR (Fishes of the Northern Seas of the U.S.S.R.). Moscow-Leningrad. Izd. Akad. Nauk SSSR.

Andriyashev, A. P. 1955a. A contribution to the knowledge of the fishes of the Bering and Chukchi Seas. *Spec. Sci. Rept. U.S. Fish. Wildl. Serv. Fisheries.* 145:1-81.

Andriyashev, A. P. 1955b. Obzop ugrevidnykh likodov (*Lycenchelys* Gill (Pisces, Zoarcidae); blizkie formy) morei SSSR i sopredel'nykh vod. Akad. nauk SSSR, *Trudy Zool. Inst.* Vol. 18:349-384.

Andriyashev, A. P. 1961. Survey of the hookear sculpins of the genus *Artediellus* Jordan (Pisces, Cottidae) of the Bering Sea. *Vopr. Ikhtiol.* 1(2):231-241.

Andriyashev, A. P. 1970. Cryopelagic fishes of the Arctic and Antarctic and their significance in polar ecosystems. *In*: M. W. Holdgate (ed.) *Antarctic Ecology, Vol. I.* Academic Press, London. pp. 297-304.

Annenkova, N. P. 1952. Mnogoshchetinkovye chervi Chukotskogo morya i Beringova proliva (Polychaetes of the Chukchi Sea and Bering Strait). *In* Sbornik: *Krainii Severo-Vostok SSSR,* Vol. 2.

Anisimov, I. S. and R. N. Pozdnov. 1960. "Mercury Experiment" in the study of the herring of the Bering Sea. *Rybn. Promysh. Dal'nego Vostoka,* No. 2.

Anonymous. 1942. Report of the Alaska Crab Investigation. U.S. Fish Wildl. Serv., Fish Market News 4(5a), Supplement. 107 pp.

Anonymous. 1948. Canned crab industry of Japan. *U.S. Fish and Wildl. Serv., Fishery Leaflet* 314.

Anonymous. 1954. "King crab." Alaska Dept. Fish., Annual Report for 1954.

Anonymous. 1955. *Atlas Bespozvonochnykh Dal'nevostochnykh Morei SSSR.* Akad. Nauk SSSR, Moscow-Leningrad, Izd. Akad. Nauk SSSR. 243 pp.

Anonymous. 1955. Atlas kart okeanograficheskikh dannykh promyslovykh raionov Beringova i Okhotskogo morei. (Atlas of Charts of Oceanographic Data for Fishing Grounds in the Bering and the Okhotsk Seas.) IOAN-TINRO.

Anonymous. 1965. Bering Sea shrimp fishery trends. *Comm. Fish. Rev.* 27(9):68.

Anonymous. 1969. C. Investigations by the United States for the International North Pacific Fisheries Commission - 1967. *Int. N. Pacif. Fish. Comm. Annu. Rept.* 1967:78-107.

Anonymous. 1970. Report on the biological research of groundfish in the Bering Sea and the northeastern Pacific by Tanshu Maru in 1969. Fishery Agency of Japan.

Anonymous. 1972. Measuring mortality of fur seal pups is important to management of herds. *Comm. Fish. Rev.* 34(3-4):29-31.

Anonymous. 1972. Report on the biological research of groundfish in the Bering Sea and Northeastern Pacific by Tanshu Maru in 1971. Fishery Agency of Japan.

Anonymous. 1974. Report on the eighth meeting of U.S. and Soviet scientists on questions concerning the condition of the stocks of fish and crustaceans in the northeastern Pacific Ocean and on the coordination of fisheries research. Seattle, Washington. Natl. Mar. Fish. Serv., unpublished. 27 pp.

Anonymous. 1976. *Invertebrate Fisheries Syllabus FW466*. Dept. Fisheries Wildlife, Oregon State University, Corvallis, Oregon.

Anraku, M. 1952. Plankton copepods collected by R. S. *Yushio Maru* in Pacific waters to the east of northern Japan during her cruise in November 1948. *Bull. Fac. Fish.* Hokkaido Univ. 3:31-39. (In Japanese).

Anraku, M. 1954. Gymnoplea copepoda collected in Aleutian waters in 1953. *Bull. Fac. Fish.* Hokkaido Univ. 5(2):123-136.

Anraku, M. 1963. Feeding habits of planktonic copepods (Review). *Inf. Bull. Planktol. Japan.* No. 9:10-35. (In Japanese).

Anraku, M. and M. Omori. 1963. Preliminary survey of the relationship between the feeding habit and the structure of the mouth-parts of marine copepods. *Limnol. Oceanogr.* 8(1):116-126.

Anufriev, V. M. 1961. A new shrimp fishing ground. *Rybn. Promysh. Dal'nego Vostoka,* No. 3.

Apollonio, S. 1961. The chlorophyll content of arctic sea ice. *Arctic.* 14:197-199.

Arai, M. N. and J. Fulton. 1973. Diel migration and breeding cycle of *Aglantha digitale* from two locations in the northeastern Pacific. *J. Fish. Res. Bd. Can.* 30(4):551-553.

Arashkevich, E. G. 1969a. The food and feeding of copepods in the northwestern Pacific. *Okeanol.* 9(5):857-873; also: *Oceanol.* 9(5):695-709 (English translation).

Arashkevich, E. G. 1969b. The trophic relation of the copepods from different depths in boreal and tropical regions of the Pacific Ocean. Ph.D. Thesis, Inst. Oceanol., Moscow. 105 pp. (In Russian).

Arashkevich, E. G. 1972. Vertical distribution of trophic groups of copepods in the boreal and tropical regions of the Pacific Ocean. *Okeanol.* 12(2):315-325; also: *Oceanol.* 12(2):265-274 (English translation).

Arashkevich, E. G. 1975. Duration of digestion of food in marine copepods. *In*: Ecosystems in the pelagic regions of the Pacific Ocean. Akad. nauk SSSR, Leningrad. *Trudy Inst. Okeanol.* Vol. 104.

Aristova, L. B. 1963. Composition and distributions of amphipods in the eastern part of the Bering Sea. *In*: P. A. Moiseev (ed.), *Soviet Fisheries Investigations in the Northeast Pacific. Part I.* Moscow. pp. 231-234.

Arnold, L. W. 1948. Observations on populations of North Pacific pelagic birds. *Auk.* 65:553-558.

Aron, W. 1959. Midwater trawling studies in the North Pacific. *Limnol. Oceanogr.* 4(4):409-418.

Aron, W. 1962. The distribution of animals in the eastern North Pacific and its relationship to physical and chemical conditions. *J. Fish. Res. Bd. Can.* 19(2):271-314.

Arsen'ev, V. A. 1940. Pitanie polosatogo tyulenya (Diet of the ribbon seal). *Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.* Vol. 20:121-127.

Arsen'ev, V. A. 1961. Distribution of whales in the Bering Sea and the possibilities for expansion of the whaling industry. Akad. nauk SSSR, *Trudy Sovesch. Ikhtiol. Komissii.* Vol. 12:112-124.

Arsen'ev, V. A. and K. I. Panin (eds.). 1968. Pinnipeds of the North Pacific. *Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. i Okean., Trudy.* Vol. 68. 274 pp.

Arsen'ev, V. K. 1927. *Tikhookeanskii morzh (The Pacific Walrus).* Khabarovsk-Vladivostok.

Arsen'yev, V. S. and V. I. Voytov. 1968. Relative transparency and color of Bering Sea water. *Oceanol.* 8(1):41-43.

Aruga, Y., Y. Yokohama and M. Nakanishi. 1968. Primary production studies in February-March in the northwestern Pacific off Japan. *J. Oceanogr. Soc. Japan.* 24:275-280.

Ass, M. Ya. 1932. K poznaniy ektoparazitov morskikh mvekopitaushikh *Anoplura* morzhei. (A study on the ectoparasites of marine mammals, *Anoplura* on walruses). Vses. Arkt. Inst., Leningrad, *Trudy Arkt. Inst.* Vol. 9:89-105.

Austin, O. L., Jr. and N. Kuroda. 1953. The birds of Japan, their status and distribution. *Bull. Mus. Comp. Zool.* 109:280-637.

Ayushin, B. N. 1963. Abundance dynamics of herring populations in the seas of the Far East, and reasons for the introduction of fishery regulations. *Rapp. P. V. Cons. Perm. Inst. Explor. Mer.* 154:262-269.

Azova, N. V. 1964. Primary production of the Pribilof-Bristol Bay area of the Bering Sea. *Izv. Tikhookean. Nauchno-Issled. Inst. Ryb. Khoz. Okeanogr.* Vol. 52:149-154. (English translation in *Soviet Fishery Investigations in the Northeast Pacific, Part III.* pp. 137-143.

Babcock, J. P., W. A. Found, M. Freeman, and H. O'Malley. 1930. Investigations of the International Fisheries Commission to December 1930, and Their Bearing on Regulation of the Pacific Halibut Fishery. Rept. IFC, 7.

Bailey, A. M. 1952. Laysan and black-footed albatrosses. *Museum Pictorial.* No. 6:1-78.

Bailey, J. W. 1856. Notice of microscopic forms found in the soundings of the sea of Kamtschatka. *Amer. J. Sci., Ser. II.* Vol. 22:1-6.

Bakkala, R. G. 1971. Distribution, abundance and migrations of immature sockeye salmon (*Oncorhynchus nerka*) in offshore waters investigated by the Bureau of Commercial Fisheries. *Bull. Int. N. Pacific Fish. Comm.* 27:1-70.

Bakzevich, E. D. 1963. Weight and chemical composition of the sablefish. *Rybn. Khoz.* No. 2:77-78.

Banner, A. H. 1948. A taxonomic study of the Mysidacea and Euphausiacea (Cruseacea) of the northeastern Pacific: I. Mysidacea, from family Lophogastridae through Tribe Erythropini. *Trans. Royal Can. Inst.* 26:345-397.

Banner, A. H. 1949a. A taxonomic study of the Mysidacea and Euphausiacea (Crustacea) of the northeastern Pacific: II. Euphausiacea. *Trans. Roy. Can. Inst.* 28:2-63.

Banner, A. H. 1949b. A taxonomic study of the Mysidacea and Euphausiacea (Crustacea) of the northeastern Pacific (Part III). *Trans. Roy. Can. Inst.* 28(58):1-56.

Banner, A. H. 1954a. A supplement to W. M. Tattershall's review of the Mysidacea of the United States National Museum. *Proc. U.S. Natl. Mus.* 103(3334):575-583.

Banner, A. H. 1954b. New records of Mysidacea and Euphausiacea from the northeastern Pacific and adjacent areas. *Pacif. Sci.* 8(2):125-139.

Banse, K. 1962. Net zooplankton and total zooplankton. *Rapp. P.V. Rêun. Perm. Int. Explor. Mer.* 153:211-215. Also: Dept. Oceanogr., Univ. Wash., Contrib. 254:211-215.

Banse, K. 1964. On the vertical distribution of zooplankton in the sea. *In*: M. Sears (ed.), *Progress in Oceanography. Vol. 2.* The MacMillan Co., New York. pp. 55-125.

Barabash-Nikiforov, I. I. 1933. Kalan ili morskaya vydra (morskoi bobr) (Sea Otter). Biol. ocherk. Moscow. Izd. Sovet. Aziya.

Barabash-Nikiforov, I. I. 1936. Lastonogie Komandorskikh ostrovov (Pinnipeds of the Commander Islands). *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 3:223-237.

Baranenkova, A. S. and N. S. Khokhlina. 1970. The distribution and length of capelin (*Mallotus villosus*) larvae and fingerlings in the Barents Sea. *Mater. Ryb. Khoz. Issled. Severnogo Basseyna.* No. 16, Pt. 1:118-131.

Baranenkova, A. S. 1934. Report on studies of the biology of young salmon. *Byul. Kamchatsk. Otd. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.* No. 2.

Baranova, Z. I. 1955. Novye vidy i podvidy iglokozhikh iz Beringova morya (New species and subspecies of echinoderms of the Bering Sea). Akad. Nauk SSSR. *Trudy Zool. Inst.* Vol. 18:334-342.

Baranova, Z. I. 1957. Iglokozhie Beringova Morya (Bering Sea echinodermata). *Issled. Dalvnevo-stochnych Moreii SSSR.* Vol. 4:149-266.

Barnaby, J. T. 1952. Offshore fishing in Bristol Bay and the Bering Sea. *U.S. Fish Wildl. Serv., Spec. Sci. Rept. - Fish.* No. 89. 30 pp.

Barnes, C. A., T. G. Thompson, and F. A. Zeusler. 1935. Summary of the oceanographic investigations of Bering Sea and Bering Strait. *Trans. Am. Geophys. Union,* 16th Annual Meeting. pp. 258-264.

Barr, Lewis. 1970. Alaska's Fishery Resources - The Shrimps. *Fishery Leaflet* 631, U.S. Dept. Interior, Washington, D.C.

Barsdate, R. J. 1970. Biologically mediated trace metal cycles. *In* Barsdate *et al.* (eds.) Oceanography of the Bering Sea - Phase I. Turbulent Upwelling and Biological Productivity Mechanisms in the Southeastern Bering Sea and Aleutian Islands. Inst. Mar. Sci. Rept. R70-8, Univ. Alaska, Fairbanks. 6 pp.

Barsukov, V. V. 1964a. Intraspecific variability in the Pacific rockfish (*Sebastodesalutus* Gilbert). *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 49:241-267.

Barsukov, V. V. 1964b. Key to the fishes of the family Scorpaenidae common in trawl catches on the continental slope of the Bering Sea and in the Gulf of Alaska. *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 53:226-262.

Barsukov, V. V. 1970. Species composition of genus *Sebastes* in the North Pacific and description of a new species. Akad. Nuak SSSR, Leningrad. *Doklady.* 195(4):994-997.

Bartholomew, G. A. and F. Wilke. 1956. Body temperature in the northern fur seal, *Callorhinus ursinus. J. Mamm.* 37(3):327-337.

Bartonek, J. C., R. Elsner, and R. H. Fay. 1974. Mammals and birds. *In* PROBES, a Prospectus on Processes and Resources of the Bering Sea Shelf, 1975-1985. Deliberations of a workshop in promotion of the U.S. program for Bering Sea oceanography 24-30 November 1973. Public Inform. Bull. 74-1, Inst. Mar. Sci, Univ. Alaska, Fairbanks. pp.29-33.

Barua, R. K., and R. A. Morton. 1949. Studies in vitamin A. 12. Whale-liver oil anlaysis: preparation of ketol esters. *Biochem. J.* 45(3):308-317.

Barysheva, K. P. 1964. Characterization of the cumacean fauna of the eastern part of the Bering Sea. *In*: P. A. Moiseev (ed.), *Soviet Fisheries Investigations in the Northeast Pacific.* Part III. Moscow. pp.197-207.

Barysheva, K. P. 1965. Cumacean fauna of the Gulf of Alaska. *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 58:70-75.

Battle, H. I. 1935. Digestion and digestive enzymes in the herring (*Clupea harengus* L.). *J. Biol. Bd. Can.* 1:145-147.

Baylis, H. A. 1932. A list of worms parasitic in Cetacea. *Discovery Repts.* 7:393-418.

Baylis, H. A. 1947. A redescription of *Uncinaria lucasi* Stiles, a hookworm of seals. *Parasitology.* 25:308-316.

Bean, T. H. 1880. On the occurrence of *Hippoglossus vulgaris* Flem. at Unalaska and St. Michael's, Alaska. *Proc. U.S. Nat. Mus.,* Washington, D.C. Vol. 2:63-67.

Bean, T. H. 1881. A contribution to the biography of the commercial cod of Alaska. *Trans. Amer. Fish - Cultural Assoc.* Vol. 10:3-34.

Bean, T. H. 1882. A preliminary catalog of the fishes of Alaskan and adjacent waters. *Proc. U.S. Nat. Mus.*, Washington, D.C. Vol. 4:239-272.

Bean, T. H. 1887. The fishery resources and fishing grounds of Alaska. *In*: George Brown Goode (ed.), *Fisheries and Fishery Industries of the United States,* Sec. 3. Washington, Govt. Print. Off. pp. 81-113.

Bean, T. H. 1887. The cod fishery of Alaska. *In*: George Brown Goode (ed.), *Fisheries and the Fishery Industries of the United States,* Sec. 5, Vol. 1. Washington, D.C., Govt. Print. Off. pp. 198-224.

Bédard, J. 1967. Ecological segregation among plankton-feeding Alcidae (*Aethia* and *Cyclorrhynchus*). Ph.D. Thesis, Univ. British Columbia. 177 pp.

Bédard, J. 1969a. Feeding of the least, crested, and parakeet auklets around St. Lawrence Island, Alaska. *Can. J. Zool.* 47(5):1025-1050.

Bédard, J. 1969b. The nesting of the crested, least, and parakeet anklets on St. Lawrence Island, Alaska. *Condor.* 71(4):386-398.

Beers, J. R. and G. L. Stewart. 1969. The vertical distribution of microzooplankton and some ecological considerations. *J. Cons. Int. Explor. Mer.* 33(1):30-44.

Begak, A. and N. Smirnov. 1908. Route of zoological studies of Commander Bering in 1907 in the Sea of Okhotsk and the Bering Sea. *Ezhegodnik Zoologischeskogo Muzeya Akad. Nauk.* 13(4).

Behrisch, H. W. 1969. Temperature and the regulation of enzyme activity in Poikilotherms. Fructose diphophatase from migrating salmon. *Biochem J.* 115:687-696.

Behrisch, H. W. 1971. Temperature and the regulation of enzyme activity in poikilotherms. Regulatory properties of fructose diphosphatase from muscle of the Alaskan king crab. *Biochem. J.* 121:399-409.

Behrisch, H. W. 1972. Molecular mechanisms of adaptation to low temperature in marine poikilotherms. Some regulatory properties of dehydrogenases from two Arctic species. *Mar. Biol.* 13(4):267-275.

Beklemishev, C. W. 1953. O bzaimootnosheniyach morskogo zooplantona i phitoplanktona. Ph.D. Disser., Inst. Okeanol., Moscow.

Beklemishev, C. W. 1954. Pitanie nekotorykh plankticheskikh kopepod v dal'nevostochnykh moryakh (Feeding habits of some widespread planktonic Copepoda in Far Eastern Seas). *Zool. Zhur.* Vol. 33(6):1210-1230. (In Russian).

Beklemishev, C. W. 1957a. Spatial relationships of marine zooplankton and phytoplankton. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 20:253-278.

Beklemishev, C. W. 1957b. Superfluous feeding of the zooplankton and the problem of sources of food for bottom animals. *Tr. Vses. Giilrobiol. Obsch.* 8:354-358.

Beklemishev, C. W. 1959. Anatomy of copepod chewing apparatus. Second communication: Chewing edge of mandible in some Calanidae and Eucalanidae. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 30:148-155.

Beklemishev, C. W. 1960. Biotope and community in marine plankton. *Int. Rev. Ges. Hydrobiol.* Bd. 45, H.2:297-301.

Beklemishev, C. W. 1961a. O prostranstvennoi strukture planktonnykh soobshchestv v zavisimosti ot tipa okeanicheskoi tsirkulyatsii (On the spatial structure of the plankton communities in relation to the type of oceanic circulation). *Okeanol.* 1(6):1059-1072.

Beklemishev, C. W. 1961b. On the transformation of plankton in the North Pacific Current and adjacent waters. Tenth Pacif. Sci. Congress, Honolulu.

Beklemishev, C. W. 1962a. Zooplankton severo-vostochnoi chasti Tikhogo okeana zimoi 1958-1959 gg. (Zooplankton in the northeastern Pacific in the winter of 1958-1959). Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 45:142-171.

Beklemishev, C. W. 1962b. Superfluous feeding of marine herbivorous zooplankton. *Rapp. Proc. Verb. Rêun. Cons. Perm. Int. Explor. Mer.* 153:108-113.

Beklemishev, C. W. 1969. *Ecology and Biogeography of the Open Ocean.* Izd. Nauka, Moscow. 291 pp. (In Russian).

Beklemishev, C. W., and V. A. Burkov. 1958. The connection between plankton distribution and the distribution of water masses in the frontal zone of the northeastern part of the Pacific Ocean. Akad. Nauk SSSR, Leningrad, *Tr. Inst. Okeanol.* 27:55-65.

Beklemishev, C. W., and H. A. Lubny-Gerzik. 1959. The distribution of the zooplankton in the eastern North Pacific in winter 1958-1959. Akad. Nauk SSSR, Moscow, *Doklady.* 128(6):1271-1273.

Beklemishev, C. W., and A. P. Nakonechnaya. 1972. Plankton of the North Pacific current. *In*: A. Y. Takenouti (ed.), *Biological Oceanography of the Northern North Pacific Ocean.* Idemitsu Shoten, Tokyo, Japan. pp. 367-371.

Beklemishev, C. W., and N. V. Parin. 1960. Biogeographical boundaries in the pelagic realm of the Northern Pacific Ocean in the winter of 1958-1959. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 41:257-265.

Belkin, A. N. 1966. Present population of sea otters on the Kurile Islands. *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 58: 3-13.

Belkovich, V. M. 1961. On the physical thermoregulation in belucha. Akad. Nauk SSSR, *Trudy Sovesch. Ikhtiol. Komissii.* Vol. 12:50-59.

Bell, F. H. and J. T. Gharrett. 1945. The Pacific coast blackcod, *Anoplopoma fimbria. Copeia.* No. 2:94-103.

Belopol'skii, L. O. 1939. Migrations and the ecology of reproduction of the Pacific Ocean walrus. *Zool. Zhur.* 18(5):762-77.

Belyayeva, A. I. 1955. Giperiidae (Amphipoda-Hyperiidea) severo-zapadnoie chasti Tikhogo Okeana. Akad. Nauk SSSR, Moscow. *Doklady.* 102(5):1047-1050.

Belyaeva, N. V. 1960. Distribution of foraminifera in the western part of the Bering Sea. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 32:158-170.

Belyaeva, T. V. 1961. Diatoms in the surface layer of the sediments of the northwestern Pacific Ocean. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 46: 231-246.

Belyayev, G. M. 1960. Quantitative distribution of bottom fauna in the northwestern part of the Bering Sea. Akad. Nauk SSSR, *Tr. Inst. Okeanol.* 34(8):85-103.

Berg, L. S. 1918. O prichinakh skodstva fauny severnykh chastei Atlanticheskogo i Tikhogo okeanov (Causes of the similarity between the ichthyofauna of the northern parts of the Atlantic and Pacific Oceans). *Izv. Rossiiskoi Akad. Nauk.* 6(16).

Berg, L. S., A. S. Bogdanov, N. I. Kozhin, and T. S. Rass (eds.). 1949. Promyslovye ryby SSSR. Atlas. (Commercial Fishes of the U.S.S.R. Atlas.) Moscow, Pishchepromizdat.

Berkeley, E. and C. Berkeley. 1957. On some pelagic polychaeta from the northeast Pacific north of latitude 40°N and east of longitude 175°W. *Can. J. Zool.* 35(4):573-578.

Berkeley, E. and C. Berkeley. 1960. Some further records of pelagic polychaeta from the northeast Pacific north of latitude 40°N and east of longitude 175°W together with records of Siphonophora, Mollusca, and Tunicata from the same region. *Can. J. Zool.* 38:737-749.

Berzin, A. A. 1959. Feeding of the sperm whale in the Bering Sea. *Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.* Vol. 47.

Berzin, A. A. 1964a. Determination of age composition of the sperm whale stock of the Bering Sea and adjacent parts of the Pacific. *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 53:263-266.

Berzin, A. A. 1964b. Growth of sperm whales in the North Pacific. *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 53:267-271.

Berzin, A. A. and A. A. Rovnin. 1966. Distribution and migration of whales in the Northeast Pacific in the Bering and Chukchi Seas. Vladivostok, *Izv. Tikhookean. Nauchno-Issled. Inst. Ryb. Khoz. Okeanogr.* Vol. 58: 179-207.

Betesheva, E. I. 1954. Data on the feeding of baleen whales in the Kurile Islands region. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* 11:238-245.

Bethesheva, E. I. 1955. Food of whalebone whales in the Kurile Islands region. Akad Nauk SSSR, *Trudy Inst. Okeanol.* 18:78-85.

Betesheva, E. I. and I. I. Akimushkin. 1955. Food of the sperm whale (*Physeter catodon*) in the Kurile Islands region. Akad. Nauk SSSR, Leningrad, *Trudy. Inst. Okeanol.* Vol. 18:86-94.

Bieri, R. 1959. The distribution of the planktonic Chaetognatha in the Pacific and their relationship to the water masses. *Limnol. and Oceanogr.* 4(1):1-28.

Bilton, H. T. and S. A. M. Ludwig. 1966. Times of annulus formation on scales of sockeye, pink, and chum salmon in the Gulf of Alaska. *J. Fish Res. Bd. Can.* 23:1403-1410.

Birman, I. B. 1958. Distribution of certain pelagic fish in the North Pacific. *Zool. Zhur.* 37(7):1058-1062.

Birman, I. B. 1960. Times of formation of annuli on the scales of Pacific salmon and the rate of growth of pink salmon. *Dokl. Akad. Nauk SSSR.* 132(5):1187-1190. (English translation by Fish. Res. Bd. Can., Biol. Sta., Nanaimo, B.C., Transl. Ser. 327.)

Birman, I. B. 1969. Distribution and growth of young Pacific salmon of the genus *Oncorhynchus* in the sea. *Problems of Ichthyology.* 9(5):651-665.

Birshtein, Ya. A. 1951. Leptostraca of the Bering Sea and the Sea of Okhotsk. Akad. Nauk SSSR, Moscow-Leningrad, *Doklady.* 78(6):1251-1254.

Birshtein, Ya. A. 1960. The Family Ischnomesidae (Crustacea, Isopoda, Asellota) in the northwestern Pacific Ocean and the problem of amphiboreal and bipolar distribution of deepwater fauna. *Zool. Zhur.* 39(1):3-28.

Birshtein, Ya. A. 1963. *Deepwater Isopods of the Northwestern Pacific Ocean.* Moscow, Izd. Akad. Nauk SSSR.

Birshtein, Ya. A. and Yu. G. Chindonova. 1958. Deep-water Mysids of the Northwestern Pacific Ocean. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 27: 258-355.

Birshtein, Ya. A. and M. E. Vinogradov. 1953. Novye donnye po faune desyatinogikh rakoobraznykh Beringova morya. (New data on the Bering Sea decapods). *Zool. Zhur.* 32(2):215-228.

Birshtein, Ya. A. and M. E. Vinogradov. 1954. Amphipoda of the Kurile-Kamchatka basin. *Priroda.* No. 9:119-120.

Birshtein, Ya. A. and M. E. Vinogradov. 1955a. Notes on the feeding of deepwater fishes of the Kurile-Kamchatka Basin. *Zool. Zhur.* 34(4):842-849.

Birshtein, Ya. A. and M. E. Vinogradov. 1955b. The pelagic gammarids of the Kurile-Kamchatka Trench. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 12: 210-287.

Birshtein, Ya. A. and M. E. Vinogradov. 1958. Pelagic Gammarids of the northwestern Pacific Ocean. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 27: 219-257.

Birshtein, Ya. A., M. E. Vinogradov and Yu. G. Chindonova. 1954. Vertical zonation of plankton of the Kurile-Kamchatka Basin. Akad. Nauk SSSR, Moscow, *Doklady.* 95(2):389-392.

Bishop, J. W. 1968. A comparative study of feeding rates of tentaculate ctenophores. *Ecol.* 49(5):996-997.

Boden, B. P. 1950. The post-naupliar larval stages of the crustacean *Euphausia pacifica. Trans. Amer. Microbial Soc.*, No. 69.

Boden, B. P., M. W. Johnson, and E. Brinton. 1955. The Euphausiacea (Crustacea) of the North Pacific. *Bull. Scripps Inst. Oceanogr.*, Univ. Calif. 6(8): 287-400.

Bogdanov, Yu. A. 1966. Vzveshennoe organicheskoe veshchestko v vodakh Tikhogo okeana (Suspended matter in the Pacific). *Vtoroi Mezhdunarodnyi okeanograficheskii kongress, 30 maya - 9 iyunya. Synopses of Reports.* Moscow, Izdatel'stvo "Nauka".

Bogolepova-Dobrokhotova, I. I. 1960. Dicyemids of the Far Eastern Seas. Part I. New species of the genus *Dicyema. Zool. Zhur.* 39(9):1293-1302.

Bogorov, B. G. 1932. Materials on the biology of the copepods of the Barents and the White Seas. *Gosudarstucnnyi Okeanogr. Inst., Byull.* 4:1-16. (In Russian, English summary).

Bogorov, B. G. 1935. Plankton. *Technika molodezhi.* No. 12.

Bogorov, B. G. 1938. Biological seasons of the Arctic Sea. Akad. Nauk SSSR, *Comptes Rendus,* (Doklady). 19:641-648.

Bogorov, B. G. 1939. The particularities of seasonal phenomena in the plankton of Arctic Seas and their significance for ice forecastings. *Zool. Zhur.* 18(5):735-747.

Bogorov, B. G. 1941. Biological seasons in the plankton of different seas. Akad. Nauk SSSR, *Comptes Rendus,* (Doklady). 31(4):404-407.

Bogorov, B. G. 1955. Regularities of plankton distribution in the northwest Pacific. *Proc. U.N.E.S.C.O. Symp. Phys. Oceanogr. Tokyo.* 1955:260-276.

Bogorov, B. G. 1958a. Biogeographic regions of the plankton of the northwestern Pacific Ocean and their influence on the deep sea. *Deep Sea Res.* 5(2): 149-161.

Bogorov, B. G. 1958b. Estimates of primary production in biogeographical regionization of the Ocean. *Rapp. P.V. Rêun. Cons. Perm. Int. Explor. Mer.* 144:117-121.

Bogorov, B. G. 1958c. Perspectives in the study of seasonal changes of plankton and of the number of generations at different latitudes. *In*: A. A. Buzzati-Traverso (ed.), *Perspectives in Marine Biology.* Univ. Calif. Press. pp. 145-158.

Bogorov, B. G. 1958d. Produktsia planktona i kharakteristika biogeograficheskikh oblastei okeana. (The production of plankton as a characteristic of differenct biogeographic provinces of the ocean). Akad. Nauk SSSR, Leningrad, *Doklady.* 118(5):917-919.

Bogorov, B. G. 1960a. Foraging grounds of fishes and whales in the northwestern Pacific Ocean. *Trudy Sovesh. biol. osnov. Okean, Ryb.*

Bogorov, B. G. 1960b. Geographic changes in the fat content of oceanic plankton. Akad. Nauk SSSR, *Doklady.* 134(6):1441-1442.

Bogorov, B. G. 1965. Quantitative appraisal of animal and plant populations of the ocean. Akad. Nauk SSSR, Leningrad, *Doklady.* 162(5):1181-1183.

Bogorov, B. G. 1966. Productivity of the ocean. Primary production and its nutritional value. *Vtoroi Mezhdunarodnyi okeanograficheskii kongress, 30 maya - 9 iyunya 1966g. Synopses of Reports.* Moscow, Izdatel'stvo "Nauka".

Bogorov, B. G. 1967. Biological transformation and exchanges of energy and substances in the ocean. *Okeanol.* 7(5):839-859.

Bogorov, B. G. 1969. Plankton in the metabolism of the ocean. *Oceanol.* 9(1):121-126.

Bogorov, B. G. and C. W. Beklemishev. 1955. O produktsii fitoplankton v severo-zapadnoi chasti Tikhogo okeana (Phytoplankton yield in the northwest Pacific Ocean). Akad. Nauk SSSR, Leningrad, *Doklady.* 104(1):141-143.

Bogorov, B. G., C. W. Beklemishev, and M. E. Vinogradov. 1961. The distribution of plankton in the Pacific Ocean and its relation to geographical zonation. 10th Pacific Sci. Congr., Contrib. Papers on Plank. and Mar. Prod.

Bogorov, B. G., and M. E. Vinogradov. 1956. Some essential features of zooplankton distribution in the northwestern Pacific. Akad. Nauk. SSSR, *Trudy Inst. Okeanol.* Vol. 18:113-123. (In Russian).

Bogorov, B. G. and M. E. Vinogradov. 1958. Distribution of zooplankton in the northwestern Pacific Ocean. Akad. Nauk SSSR, *Trudy Okeanogr. Komissii.* Vol. 3:100-101.

Bogorov, B. G. and M. E. Vinogradov. 1955. Zooplankton of the northwestern Pacific Ocean. Akad. Nauk SSSR, *Doklady.* 102(4):835-838.

Bogorov, B. G. and M. E. Vinogradov. 1955. Some essential features of zooplankton distribution in the northwestern Pacific Ocean. Akad. Nauk SSSR, Leningrad, *Trudy Inst. Okeanol.* Vol. 18:113-123.

Bogorov, B. G. and M. E. Vinogradov. 1960. The distribution of the zooplankton in the Kurile-Kamchatka region of the Pacific. Akad. Nauk SSSR, Moscow, *Trudy Inst. Okeanol.* Vol. 34:60-84.

Bogorov, B. G., M. E. Vinogradov, N. W. Voronina, I. P. Kanaeva and I. A. Suetova. 1968. Distribution of the zooplanktonic biomass in the surface layer of the oceans. Akad. Nauk SSSR, *Doklady.* 182(5):1205-1207.

Bogorov, B. G., and L. A. Zenkevich. 1966. Biological structure of the ocean. *In* Sbornik: *Ekologiya zodnykh organizmov.* Moscow, Izdatel'stvo "Nauka".

Bogorov, B. M. 1972. Weight and ecological features of the macroplankton organisms of the Barents Sea. Newfoundland, Memorial Univ., St. Johns Library, *Library Bull.* 6(2):21-28.

Bolin, R. L. 1936. New cottid fishes from Japan and Bering Sea. *Proc. U.S. Nat. Mus.* Vol. 84(3000):25-38.

Bolin, R. L. 1939. A review of the Myctophid fishes of the Pacific coast of the United States and of lower California. *Stanford Ichthyol. Bull.* 1(4):90-156.

Bordovskii, O. K. 1957. Sustav organicheskogo veshchestva savremennykh osadkov Beringova morya (Organic content of recent sediments of the Bering Sea). Akad. Nauk SSSR, Moscow, *Doklady.* 116(3):443-446.

Bordovskii, O. K. 1960. Organicheskoe veshchestvo sovremennykh osadkov Beringova morya (Organic matter of recent sediments of the Bering Sea). Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 42:89-106.

Bordovskii, O. K. 1974. Basic features of the chemical composition of organic matter in sediments of marine and oceanic basins. *Okeanol.* 14(3):448-456.

Bowman, T. E. 1960. The pelagic amphipod *Parathemisto* (Hyperiidea:Hyperiidae) in the North Pacific and adjacent Arctic Ocean. *Proc. U.S. Natl. Mus.* 112(3439):343-392.

Bowman, T. E., and J. C. McCain. 1967. Variation and distribution of the pelagic amphipod *Cyphocaris challengeri* in the Northeast Pacific (Gammaridea, Lysianassidae). *Proc. U.S. Natl. Mus.*, Smithsonian Inst. 122(3588):1-14.

Boyer, C. S. 1926. Synopsis of North American Diatomaceae, Part I. *Proc. Acad. Natur. Sci., Philad.* Vol. 78:1-228.

Boyer, C. S. 1927. Synopsis of North American Diatomaceae. Part II. *Proc. Acad. Natur. Sci., Philad.* Vol. 79:229-583.

Bradshaw, J. S. 1959. Ecology of living planktonic Foraminifera in the North and Equatorial Pacific Ocean. *Cont. Cushman Found. Foramin. Res.* 10:25-64.

Brandes, Carl-Heinz. 1941. Uber den Oelgehalt der Kopepoden (The oil content of copepods). *Zeitschr. Fisch. u. Hilfsw.* 39(1):59-78.

Brett, J. R. 1962. Some considerations in the study of respiratory metabolism in fish, particularly salmon. *J. Fish. Res. Bd. Can.* 19(6):1025-1038.

Brett, J. R. 1963. The energy required for swimming by young sockeye salmon with a comparison of the drag force on a dead fish. *Trans. Royal Soc. Can.,* Ser. IV, 1:441-457.

Brett, J. R. 1964. The respiratory metabolism and swimming performance of young sockeye salmon. *J. Fish. Res. Bd. Can.* 21(5):1183-1226.

Brett, J. R. 1965. The relation of size to rate of oxygen consumption and sustained swimming speed of sockeye salmon. *J. Fish. Res. Bd. Can.* 22(6):1491-1501.

Brett, J. R., and N. R. Glass. 1973. Metabolic rates and critical swimming speeds of sockeye salmon (*Oncorhynchus nerka*) in relation to size and temperature. *J. Fish. Res. Bd. Can.* 30(3):379-387.

Brinton, E. 1959. Geographical isolation in the pelagic environment. A discussion of the distribution of euphausiid crustaceans in the Pacific. Scripps Inst. Oceanogr. (mimeographed).

Brinton, E. 1962a. The distribution of Pacific Euphausiids. *Bull. Scripps Inst. Oceanogr.* 8:51-270.

Brinton, E. 1962b. Variable factors affecting the apparent range and estimated concentration of euphausiids in the North Pacific. *Pacif. Sci.* 16(4):374-408.

Brodskii, K. A. 1938. Contribution to the ecology and morphology of *Calanus tonsus* Brady (syn: *C. plumchrus* Marukawa) of far-eastern seas. Akad. Nauk SSSR, *Comptes Rendus (Doklady).* 19(1/2):123-126.

Brodskii, K. A. 1948. O zoogeographii glubin severo-zapadnoiechasti Tikhogo Okeana. Akad. Nauk SSSR, Leningrad, *Doklady.* 60(6):1053-1056.

Brodskii, K. A. 1949. Vertical distribution of the Copepoda and the connection of the Arctic Ocean with the Pacific and Atlantic. Akad. Nauk SSSR, Leningrad, *Doklady.* 65(3):365-368.

Brodskii, K. A. 1950. *Calanoida of the Far Eastern Seas and Polar Basin of the U.S.S.R. Keys to the Fauna of the U.S.S.R.* Akad. Nauk SSSR, Leningrad, Zool. Inst. 442 pp.

Brodskii, K. A. 1952a. Deep-sea copepods of the northwestern Pacific Ocean. *Issled. Dal'nevost. Morei SSSR.* No. 3:37-87.

Brodskii, K. A. 1952b. O vertikal'nom raspredelenii veslonogikh rachkov v severo-zapadnoi chasti Tikhogo Okeana. Izd. Akad. Nauk SSSR, Moscow, *Issled. Dal'nevost. Morei SSSR.* No. 3:88-94.

Brodskii, K. A. 1955a. The Calanoida of the Kurile-Kamchatka trench. Akad. Nauk SSSR, Leningrad, *Trans. Inst. Okeanol.* Vol. 12:184-209. (In Russian).

Brodskii, K. A. 1955b. New deep-sea Copepod species in the Northern Pacific Ocean. Akad. Nauk SSSR, *Trudy Zool. Inst.* Vol. 21:186-189.

Brodskii, K. A. 1955c. Oceanic zoogeographical boundary in the Far Eastern Seas and northwestern Pacific Ocean. Akad. Nauk SSSR, *Doklady.* 102(3): 649-652.

Brodskii, K. A. 1955d. Plankton distribution in the northwest Pacific. Akad. Nauk SSSR, Moscow, *Doklady.* 101(5):961-964.

Brodskii, K. A. 1955e. Plankton of the northwestern part of the Kuroshio and the waters of the Pacific Ocean adjacent to the Kurile Islands. Akad. Nauk SSSR, Moscow, *Okeanol.* Vol. 18:124-133.

Brodskii, K. A. 1955f. Vertical distribution of plankton in the World Ocean and the typology of sea basins. Akad. Nauk SSSR, Leningrad, *Doklady.* 103(5): 917-920.

Brodskii, K. A. 1956. Zonal distribution (by latitude) of copepods in the northern Pacific Ocean and adjacent waters. Akad. Nauk SSSR, Moscow, *Doklady.* 106(6):1103-1106.

Brodskii, K. A. 1957. Fauna veslonogikh rachkov i zoogeograficheskoe raionirovanie severnoi chasti Tikhogo okeana (The Copepod Fauna and Zoogeographical Zonation of the North Pacific). Izd. Akad. Nauk SSSR, Moscow.

Brodskii, K. A. 1959a. On phylogenetic relations of some *Calanus* (Copepoda) species of northern and southern hemisphere. *Zool. Zhur.* 38(10):1537-1553. (In Russian).

Brodskii, K. A. 1959b. Zooplankton of sea waters of south Sakhalin and south Kurile Islands. Akad. Nauk SSSR, *Issled. Dal'nevost. Morei.* 6:5-46.

Brodskii, K. A. 1962. The species and distribution of Clanaoida in northwestern Pacific surface waters. *Issled. Dal'nevost. Morei SSSR.* No. 8:91-166.

Brodskii, K. A. 1965. The taxonomy of marine plankton organisms and oceanography. *Okeanol.* 5(4):577-591; also *Oceanol.* 5(4):1-12. (English translation).

Brokh, Kh. 1933. O nekotorykh interesnykh i geographicheskom otnoshenii nakhodkakh al'vionarii i gidrokorallov v severnoi chasti Tikhogo okeana. Gosudar. Gidrolog. Inst., Leningrad, *Issled. Morei SSSR.* No. 17:81-82.

Brooks, J. W. 1954. A contribution to the life history and ecology of the Pacific walrus. *Alaska Cooperative Wildlife Research Unit, Spec. Rept. 1.*

Brown, A. H. 1948. The carbohydrate constituents of *Scenedesmus* in relation to the assimilation of carbon by photoreduction. *Plant Physiol.* 23(3): 331-337.

Bui Thi Lang. 1965. Taxonomic Review and Geographical Survey of the Copepod Genera *Eucalanus* and *Rhincalanus* in the Pacific Ocean. Ph.D. Thesis, Univ. Calif., San Diego. 284 pp.

Bukhaenvich, I. B. 1963. Certain data on the growth of the larvae of rockfish during the first days of their life. *Tezisy Dokladov na Soveshchanii Molodykh Uchenykh. Moscow.*

Bulycheva, A. I. 1955. Hyperiids of the northwestern Pacific Ocean. Akad. Nauk SSSR, Moscow, *Doklady.* 102(5):1047-1050.

Burns, J. J. 1965. The walrus in Alaska: its ecology and management. Alaska Dept. Fish. Game, Juneau. Fed. Aid Wildl. Rest. Proj. Rept., Proj. W-6-R-5. 48 pp.

Burns, J. J. 1970. Remarks on the distribution and natural history of pagophilic pinnipeds in the Bering and Chukchi Seas. *J. Mammalogy.* 51:445-454.

Burns, J. J. 1971. Biology of the ribbon seal, *Histriophoca fasciata*, in the Bering Sea. Proc. Alaska Sci. Conf. 22:135.

Butler, T. N. 1967. Shrimp exploration and fishing in the Gulf of Alaska and Bering Sea. *Fish Res. Bd. Can., Tech. Rept.* No. 18:1-49.

Cade, T. 1952. Notes on the birds of Sledge Island, Bering Sea, Alaska. *Condor.* 54:51-54.

Calman, W. T. 1912. The Crustacea of the Order Cumacea in the collection of the United States National Museum. Proc. U.S. Nat. Mus. 41(1876):603-676.

Campbell, M. H. 1934. The life-history and post-embryonic development of the copepods *Calanus tonsus* Brady and *Euchaeta japonica* Marukawa. *J. Biol. Bd. Can.* 1:1-65.

Carey, A. G., Sr. 1975. Biology and ecology of the Bering Sea benthos. *In*: D. W. Hood and Y. Takenouti (convenors), Bering Sea Oceanography: An Update, Results of US-Japan Seminar/Workshop on Bering Sea Oceanography R75-2, Inst. Mar. Sci., Univ. Alaska, Fairbanks (Abst.). pp. 131-138.

Carey, A. G. 1977. The distribution, abundance, diversity and productivity of the western Beaufort Sea benthos. *In: Environmental Assessment of the Alaskan Continental Shelf, Vol. 2.* Environmental Res. Lab., Boulder, Colorado. pp. 6-31.

Chamberlain, F. M. 1906. Some observations on salmon and trout in Alaska. *U.S. Bureau Fish., Annual Rept.* Doc. No. 627. 109 pp.

Chamberlain, R. V. 1919. The Annelida Polychaeta. *Mus. Comp. Zool. Harvard Mems.* 48.

Chang, S. 1974. An evaluation of eastern Bering Sea fisheries for Alaska pollock (*Theragra Chaleogramma*, Pallas): population dynamics. Ph.D. Dissertation, Univ. Washington, Seattle. 313 pp.

Chapman, D. G. 1964. A critical study of Pribilof fur seal population estimates. U.S. Fish Wildlife Serv. *Fish. Bull.* 63(3):657-669.

Chapman, V. J. 1946. Marine algal ecology. *Biol. Rev.* 12(10):628-674.

Chapman, W. M. 1940. Oceanic fishes from the northeast Pacific Ocean. *Occas. Pap. Brit. Col. Prov. Mus.* Vol. 2:1-44.

Chebanov, S. M. 1965a. Biology of the king crab, *Paralithodes camtschatica* Tilesius, in Bristol Bay. *In*: P. A. Moiseev (ed.), *Soviet Fisheries Investigations in the Northeast Pacific.* Part IV. Moscow, 1970. pp. 82-84.

Chebanov, S. M. 1965b. Distribution of hyperiids in the surface layer of the southern Bering Sea and adjacent parts of the Pacific. *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 58:76-81.

Chekovskaya, M. P. 1973. Distribution of benthic foraminifers in the northeastern Bering Sea. *Okeanol.* 13(4):691-696; also: *Oceanol.* 13(4): 571-575 (English translation).

Chen, L. C. 1971. Systematics, variation, distribution and biology of rockfishes of the subgenus *Sebastomus* Pisces, Scorpaenidae, Sebastes). *Bull. Scripps Inst. Oceanogr.* 18:1-107.

Chernykh, Z. V. 1940. Pitanie sel'di Kronotskogo Zaliva i raspredelenie ee kormovykh ob'ektov v letnii period 1938-1939 gg. (Feeding of herring in Kronotskii Gulf and the distribution of its food items during the summer of 1938 and 1939). *Fondy Kamchat. Otdel. Tikhookean. Nauchno-Issled. Inst. Ryb. Khoz. Okeanogr.*

Chislenko, L. L. 1975. Specificity of some statistical characteristics for taxa of superspecies range in marine Calanoida of the USSR (body size taken as an example). *Zool. Zhur.* 54(3):355-363.

Chlebovitsch, V. V. 1962. Pelagic sexual stages of Polychaeta, caught at light, in the region of the Kurile Islands. Izd. Akad. Nauk SSSR, Moscow, *Issled. Dal'nevost. Morei SSSR.* No. 8:167-180.

Clark, A. H. 1940. A new genus of starfishes from the Aleutian Islands. *Proc. U.S. Nat. Mus.* 86(3061):497-500.

Clark, C. V. 1876. Report of the hydroids collected on the coast of Alaska and the Aleutian Islands by W. H. Dall. *Proc. Acad. Natrl. Sci.,* Philad. pp. 209-247.

Clark, H. L. 1911. North Pacific ophiurans in the collection of the United States National Museum. *Bull. U.S. Nat. Mus.* 75:302 pp.

Clasby, R. C., R. Horner, and V. Alexander. 1973. Arctic sea ice algae: an *in situ* primary productivity method. *J. Fish. Res. Bd. Can.* 30:835-838.

Cleaver, F. C. 1963. Bering Sea crab (*Paralithodes camtschatica*) tagging experiments. *N. Atl. Fish. Symp., Special Publ. No. 4.*

Cleaver, F. C. 1964. Origins of high seas sockeye salmon. U.S. Fish Wildl. Serv. *Fish. Bull.* 63:445-476.

Clemens, W. and G. V. Wilby. 1946. Fishes of the Pacific coast of Canada. *Fish. Res. Bd. Can. Bull.* 68.

Cleve, P. T. 1873. On diatoms from the Arctic Sea. *Bih. Kongl. Svensk. Vet.-Akad. Handl.* 1(11):1-13.

Cobb, J. N. 1906. The commercial fisheries of Alaska in 1905. *U.S. Bur. Fish., Annual Rept.* Document No. 603.

Cobb, J. N. 1927. Pacific cod fisheries. *Rept. U.S. Fish. Bur.* 1926: 383-497.

Cohen, D. M. 1956. The synonymy and distribution of *Leuroglossus stilbius* Gilbert, a North Pacific bathypelagic fish. *Stanford Ichthyol. Bull.* 7(2):19-23.

Collard, S. B. 1970. Forage of some eastern Pacific midwater fishes. *Copeia.* 1970:348-354.

Collin, G., J. C. Drummond, T. P. Hilditch and E. R. Gunther. 1934. Observations on the fatty constituents of marine plankton. II. General character of the plankton oils. *J. Exp. Biol.* 11:198-202.

Conover, R. J. 1968. Zooplankton - life in a nutritionally dilute environment. *Am. Zool.* 8:107-118.

Cooney, R. T. 1972. A review of the biological oceanography of the northeast Pacific Ocean. *In*: D. H. Rosenberg (ed.), A Review of Oceanography and Renewable Resources of the Northern Gulf of Alaska. Inst. Mar. Sci. Rept. No. R72-23; Sea Grant Rept. No. 73-3. 689 pp.

Cooney, R. T. and J. Van Hyning. 1974. Associations of juvenile walleye pollock, *Theragra chalcogramma* with the jellyfish, *Cyanea*. *Copeia.* 3:791.

Cooney, R. T. 1975. Environmental assessment of the northeast Gulf of Alaska: Zooplankton and micronekton. Final Rept. to N.O.A.A., Inst. Mar. Sci. 159 pp.

Cooney, R. T. 1975. Secondary productivity. *In*: D. W. Hood and Y. Takenouti (convenors), Bering Sea Oceanography: An Update, Results of US-Japan Seminar/Workshop on Bering Sea Oceanography R75-2, Inst. Mar. Sci., Univ. Alaska, Fairbanks. pp. 117-121.

Cooney, R. T. 1975. The animal plankton community of the northern Gulf of Alaska. Symposium on Science, Resources and Technology in the Gulf of Alaska. AINA (Abstract).

Cooper, L. H. N. 1939. Phosphorous, nitrogen, iron and manganese in marine zooplankton. *J. Mar. Biol. Assn.* Vol. XXIII(2):387-390.

Cooper, S. C. 1964. Benthonic foraminifera of the Chukchi Sea. Contrib. Cushman Found. Foram, Res. 15(3):79-104.

Cornwall, I. E. 1927. Some North Pacific whale barnacles. *Contrib. Can. Biol. Fish.* 3:503-520.

Coyle, K. O. 1974. The ecology of the phytoplankton of Prudhoe Bay, Alaska, and the surrounding waters. M. S. Thesis. Univ. of Alaska, Fairbanks. 106 pp.

Crane, J. J. and R. T. Cooney. 1975. The nearshore benthos. *In*: Environmental Studies of an Arctic Estuarine System - Final Report EPA-660/3-75-026, Corvallis, Oregon. 536 pp.

Cundell, A. M. and R. W. Traxler. 1973. Microbial degradation of petroleum at low temperature. *Mar. Pollut. Bull.* 4(8):125-127.

Cupp, E. E. 1937. Seasonal distribution and occurrence of marine diatoms and dinoflagellates at Scotch Cap, Alaska. *Bull. Scripps Inst. Oceanogr. Tech. Ser.* 4:71-100.

Cupp, E. E. 1943. Marine plankton diatoms of the west coast of North America. *Bull. Scripps Inst. Oceanogr.* 5(1):1-238.

Cushing, D. H. 1958. The effect of grazing in reducing the primary production: a review. *Rapp. P.V. Rêun. Cons. Perm. Int. Explor. Mer.* 144:149-154.

Cushing, D. H. 1976. Biology of fishes in the pelagic community. *In*: D. H. Cushing and J. J. Walsh (eds.), *Ecology of the Seas*. Blackwell, Oxford. pp. 317-340.

Cushman, J. A. 1914. A monograph of the Foraminifera of the North Pacific Ocean. Part IV. Chilostomellidae, Globigerinidae, Nummulitidae. Smithsonian Inst. *Bull. U.S. Nat. Mus.* 71:1-43.

Dales, R. P. 1957. Pelagic polychaetes of the Pacific Ocean. *Bull. Scripps Inst. Oceanogr.* 7(2):99-168.

Dales, R. P. and G. Peter. 1972. A synopsis of the pelagic Polychaeta. *J. Natur. Hist.* 6(1):55-92.

Dall, W. H. 1872. Descriptions of sixty new species of mollusks from the west coast of North America and the North Pacific Ocean, with notes on others already described. *Amer. J. Conch.* 7(2):93-160.

Dall, W. H. 1873. Aleutian cephalopods. *Amer. Nat.* Vol. 7:484-485.

Dall, W. H. 1874. Catalogue of shells from Bering Strait and the adjacent portions of the Arctic Ocean, with descriptions of three new species. *Proc. Calif. Acad. Sci.* Vol. 5:246-253.

Dall, W. H. 1876. On the marine faunal regions of the North Pacific. *Proc. Acad. Natrl. Sci., Philad.* pp. 205-208.

Dall, W. H. 1884. Contributions to the history of the Commander Islands. No. 3. Report on the Mollusca of the Commander Islands, Bering Sea collected by Leonhard Stejneger in 1882 and 1883. *Proc. U.S. Nat. Mus.* Vol. 7: 340-349.

Dall, W. H. 1885. New or specially interesting shells of the Point Barrow Expedition. *Proc. U.S. Nat. Mus.* Vol. 7:523-526.

Dall, W. H. 1886. Supplementary notes on some species of mollusks of the Bering Sea and vicinity. *Proc. U.S. Nat. Mus.* Vol. 9:297-309.

Dall, W. H. 1899. The mollusk fauna of the Pribilof Islands. *In*: D. S. Jordan (ed.), *The Fur Seals and Fur Seal Islands of the North Pacific Ocean, Pt. III.* U.S. Govt. Print. Off., Washington, D.C. pp. 539-546.

Dall, W. H. 1907. Descriptions of new species of shells chiefly Buccinidae, from the dredgings of the U.S.S. *Albatross* during 1906 in the northwestern Pacific, Bering, Okhotsk and Japan Seas. *Smith. Misc. Coll.* Vol. 50: 139-173.

Dall, W. H. 1919. Descriptions of new species of Mollusca from the North Pacific Ocean in the collection of the United States National Museum. *Proc. U.S. Nat. Mus.* Vol. 56(2295):293-371.

Dall, W. H. 1921. Summary of the marine shell-bearing Mollusks of the northwest coast of America from San Diego, California, to Polar Sea. *Bull. U.S. Nat. Mus.* No. 112. 217 pp.

Dark, T. A., K. N. Thorson, and G. K. Tanonaka. 1969. Ocean growth and mortality. *Int. N. Pac. Fish. Comm. Annu. Rept.* 1967:107-109.

Davidson, F. A. and E. Vaughan. 1941. Relation of population size to marine growth and time of spawning migration in the pink salmon (*Oncorhynchus gorbuscha*) of southeastern Alaska. *J. Marine Res.* 4(3):231-246.

Davis, C. C. 1949. The Pelagic Copepoda of the Northeastern Pacific Ocean. *Univ. Washington Publ. Biol.* Vol. 14:1-118.

Dawson, E. Y. 1946. A guide to the literature and distribution of the marine algae of the Pacific coast of North America. *Mem. S. Claif. Acad. Sci.* 3(1):1-134; also: *Pacif. Sci.* 15(3):370-461.

Dawson, J. K. 1971. Taxonomic guides to Arctic zooplankton (III), species of the Arctic Ocean chaetognaths. *Univ. S. Calif. Tech. Rept.* (4):3-21.

Dawson, W. A. 1965. Phytoplankton data from the Chukchi Sea, 1959-1962. *Univ. Wash. Dept. Oceanogr. Tech. Rept.* No. 117. 99 pp.

Day, D. and C. R. Forrester. 1971. A preliminary bibliography on the trawl fishery and groundfish of the Pacific coast of North America. *Fish. Res. Bd. Can. Tech. Rept.* (246):1-91.

Dekhnik, T. V. 1959. Data on the reproduction and development of certain Far Eastern flatfish. *Issled. Dal'nevost Morei SSSR.* No. 6:109-131.

Delyamure, S. L. 1952. Zoogeographical characteristics of the helminthofauna of pinnipeds and cetaceans. Akad. Nauk SSSR, *Trudy Gel'mintol. Lab.* 6:235-250.

Delyamure, S. L. 1968. *Helminthofauna of Marine Mammals (Ecology and Phylogeny)* Academy of Sciences of the U.S.S.R. Laboratory of Helminthology Translated by Israel Program for Scientific Translations.

Deryugin, K. M. 1933. Issledovaniya dal'nevostochnykh morei (Investigation of the Far Eastern Seas). *Priroda.* No. 10.

Deryugin, K. M. 1937. Mollyski severnykh i dal'nevostochnykh morei (Mollusks of the northern and far eastern seas). *In: Zhivotnyi Mir SSSR.* Vol. 1.

Deryugin, K. M. 1939. The Far Eastern Seas and their resources. *Nauki i Zhizn'.* No. 2.

Deryugin, K. M. and A. V. Ivanov. 1937. Preliminary review of work on benthos of the Bering and Chukchi Seas. Gidrometeo., Leningrad, *Issled Morei SSSR.* No. 25:246-259.

Derzhavin, A. N. 1926. Cumacea of the 1908-1909 Kamchatka Expedition. *Gidrobiol. Zhur. SSSR.* 5(7-9).

Derzhavin, A. N. 1927a. Gammaridae of the 1908-1909 Kamchatka Expedition. *Gidrobiol. Zhur. SSSR.* 6(1-2).

Derzhavin, A. N. 1927b. Hyperiidae and Caprellidae of the 1908-1909 Kamchatka Expedition. *Gidrobiol. Zhur. SSSR.* 6(1-2).

DeVries, A. L. 1976. Study of effects of acute and chronic exposure to hydrocarbons on shallow water Bering Sea fishes. *In: Environmental Assessment of the Alaskan Continental Shelf, Volume 2,* Principal Investigators Reports, April-June 1976. Environmental Research Laboratories, Boulder, Colorado.

Dickinson, W. R. 1973. Japanese fishing vessels off Alaska. *Mar. Fish. Rev.* 35(1-2):6-18.

Dodimead, A. J., F. Favorite, and T. Hirano. 1963. Salmon of the North Pacific Ocean - Part II - Review of oceanography of the Subarctic Pacific Region. *Bull. Int. N. Pacif. Fish. Comm.*, 13. 195 pp.

Dodimead, A. J. and H. J. Hollister. 1958. Physical, chemical and plankton data record North Pacific and Bering Sea July to August 1958. Fish Res. Bd. Can., Manuscript Report Series (Ocean. and Liminol.). No. 28.

Dogel', V. A. 1955. General character of the parasitofauna of animals in the Far Eastern Seas. Akad. Nauk SSSR, *Trudy Zool. Inst.* Vol. 21: 53-61.

Dogel', V. A. and V. V. Reshetnyak. 1952. Data on the Radiolaria of the Northwest Pacific Ocean. *Issled. Dal'nevost. Morei SSSR.* No. 3:5-36.

Dogel', V. A. and V. V. Reshetnyak. 1956. Radiolarian fauna of the Far Eastern Seas. Akad. Nauk SSSR, *Trudy Zool. Inst.* Vol. 6.

Dolbish, G. A. 1961. Bering Sea fish as a source of vitamin A. *Rybn. Promysh. Dal'nego Vostoka.* No. 10.

Dorofeev, S. V. 1961. Soviet investigations of fur seals in the northern Pacific Ocean. Akad. Nauk SSSR, *Trudy Sovesh. Ikntiol. Komissii.* No. 12:164-169.

Dorofeev, S. V. 1964. Severnye morskie kotiki (The northern fur seals). *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 51:23-50.

Dougherty, E. C. 1944. The lungworms (Nematoda:Pseudaliidae) of the Odontoceti. Part I. *Parasitology.* 36(1-2):80-94.

Dubrovskii, A. 1938. Perspektivy lova paltusa v Kamchatskikh vodakh (Prospects for halibut fishing in Kamchatka waters). *Ryb. Khoz.* No. 7.

Dudnik, Yu. I. and E. A. Usol'tsev. 1964. The herrings of the eastern part of the Bering Sea. *Tr. Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okean.* Vol. 49:236-240.

Dugdale, R. C. 1967. Nutrient limitation in the sea: dynamics, identification and significance. *Limnol. Oceanogr.* 12:685-695.

Dugdale, R. C. and J. J. Goering. 1967. Uptake of new and regenerated forms of nitrogen in primary productivity. *Limnol. Oceanogr.* 12:196-206.

Dunbar, M. J. 1940. On the size distribution and breeding cycles of four marine planktonic animals from the Arctic. *J. Animal Ecol.* 9(2): 215-226.

Dunbar, M. J. 1941. The breeding cycle in *Sagitta elegans arctica* Aurivillius. *Can. J. Res.* D. 19:258-266.

Dunbar, M. J. 1953. Arctic and subarctic marine ecology, immediate problems. *Arctic* 6:75-90.

Dunbar, M. J. 1957. The determinants of production in northern seas: a study of the biology of *Themisto libellula* Mandt. *Can. J. Zool.* 35:797-819.

Dunbar, M. J. 1960. The evolution of stability in marine environments. Natural selection at the level of the ecosystem. *Amer. Nat.* 94(875): 129-136.

Dunbar, M. J. 1962. The life cycle of *Sagitta elegans* in Arctic and Subarctic seas, and the modifying effects of hydrographic differences in the environment. *J. Mar. Res.* 20(1):76-91.

Dunbar, M. J. 1968. *Ecological Development in Polar Regions. A Study in Evolution.* Prentice Hall, Inc. Englewood Cliffs, N.J. 119 pp.

Dunlop, H. A. 1957. Management of the halibut fishery of the northeastern Pacific Ocean and Bering Sea. *Rept. Inter. Techn. Conf. Conserv. Living Resources of the Sea.*

D'yakonov, A. M. 1923. Fauna Rossii i sopredel'nykh stran'. Iglokozhya (Morske ezhi). [*Fauna of Russia and Adjacent Countries. Echinodermata. Echinoidea*]. Petrograd, 265 pp.

D'yakonov, A. M. 1938a. Monograph on sea stars of the genus *Leptasterias* in the northwestern Pacific. Akad. Nauk SSSR, *Trudy Zoolog. Inst.* 6(5).

D'yakonov, A. M. 1938b. Monographic essay on sea stars of the northwestern Pacific Ocean. Communication 1. Akad. Nauk SSSR, *Trudy Zool. Inst.* 4(5).

D'yakonov, A. M. 1945. Interrelationship between the Arctic and the Pacific marine faunas in the instance of zoogeographic analysis of echinodermata. Moscow, *Zhur. Obshch. Biol.* 6(2).

D'yakonov, A. M. 1949. Opredelitel' iglokozhikh dal'nevostochnykh morei [Key to Echinodermata of the Far Eastern Seas]. *Izv. Tikkookean. Vses. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.* Vol. 30:3-130.

D'yakonov, A. M. 1950. Monograph on sea stars of the northwestern Pacific - Echinodermata, Asteroidea, II-IV. *Issled. Dal'nevost. Morei* SSSR, No. 2: 58-139.

D'yakonov, A. M. 1950. Morskie zvezdy morei SSSR [*Sea stars of the USSR seas*]. Leningrad, Izd. Akad. Nauk SSSR.

D'yakonov, A. M. 1952. Description of new species and subspecies of sea stars from the Far Eastern Seas. Akad. Nauk SSSR, *Trudy Zool. Inst.*, Vol. 12:408-414.

D'yakonov, A. M. 1952. Iglokozhie Chukotskogo morya i Beringova proliva [Echinoderms of the Chukchi Sea and the Bering Strait] *in* Sbornik: *Krainii Severo-Vostok SSSR*, Vol. 2.

D'yakonov, A. M. 1954. Ophiury (zmeekhvostki) morei SSSR. [*Ophiuroids of the USSR Seas*]. Moscow-Leningrad, Izd. Akad. Nauk SSSR, 135 pp.

D'yakanov, A. M. 1958. Echinodermata, excluding Holothuroidea, collected by the Kuril-Sakhalin expedition in 1947-1949. Izd. Akad. Nauk SSSR, Moscow, *Issled. Dal'nevost. Morei* No. 5:271-357.

D'yakonov, A. M. 1961. Obzop vindov morskikh svesd roda Henricia Gray iz severo-zapadnykh chastei Tikhogo Okeana. [Review of the species of starfish (the genus *Henricia* Gray) from the northwestern part of the Pacific Ocean]. Izd. Akad. Nauk SSSR, Moscow, *Issled. Dal'nevost. Morei* SSSR, No. 7:5-46.

D'yakonov, A. M., Z. I. Baranova and T. S. Savelyaeva. 1958. Note about Holothuroidea of the South Sakhalin and the South Kurile Islands region. Izd. Akad. Nauk SSSR, Moscow, *Issled. Dal'nevost. Morei* No. 5:358-380.

Efremenko, V. N. and L. A. Lisovenko. 1970. Morphological features of intraovarian and pelagic larvae of some *Sebastodes* species inhabiting the Gulf of Alaska. *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol 70:267-286.

Ekman, Sver. 1953. *Zoogeography of the Sea.* Sidgwick and Jackson, London. 417 pp.

Elliott, H. W. 1884. Report on the seal islands of Alaska. *In*: Dept. of Int., Census Office, Tenth Census of the United States, Vol. 8. Special Reports on News-papers and Periodicals, Alaska, Fur-Seal Islands, and Shipbuilding, 188 pp.

Ellson, J. G., B. Knake and J. Dassow. 1949. Report of Alaskan exploratory fishing expedition, fall of 1948, to northern Bering Sea. *U.S. Fish Wildl. Serv., Fish. Leaflet* 369, 56 pp.

Ellson, J. G., D. E. Powell and H. H. Hildebrand. 1950. Exploratory fishing expedition to the northern Bering Sea in June and July, 1949. *U.S. Fish Wildlife Serv., Fish. Leaflet* (369):1-56.

English, T. S. 1977. Alaska marine ichthyoplankton key. *In: Environmental Assessment of the Alaskan Continental Shelf, Vol. 2.* Environmental Res. Lab., Boulder, Colorado. pp. 351-585.

Epshtein, V. M. 1962. A survey of fish leeches (Hirudinea, Piscicolidae) from the Bering and Okhotsk Seas and from the Sea of Japan. Akad. Nauk SSSR, *Doklady* 144(5):1181-1184.

Evermann, B. W. and E. L. Goldsborough. 1907. The fishes of Alaska. *Bull. U.S. Bur. Fish.* Vol. 26:1-376.

Faculty of Fisheries, Hokkaido University. 1957a. 1953 cruise of the "Oshoro Maru" to Aleutian waters. *Data Rec. Oceanogr. Obsns. Explor. Fish.* No. 1:1-26.

Faculty of Fisheries, Hokkaido University. 1957b. 1954 cruise to the Bering Sea. *Data Rec. Oceanogr. Obsns. Explor. Fish.* No. 1:27-50.

Faculty of Fisheries, Hokkaido University. 1957c. 1955 cruise of the 'Oshoro Maru' to the Bering Sea and northern North Pacific (Norpac project). IV. *Data Rec. Oceanogr. Expl. Fish.* No. 1:67-132.

Faculty of Fisheries, Hokkaido University. 1957d. 1956 cruise to the Bering Sea. *Data Rec. Oceanogr. Obsns. Explor. Fish.* No. 1:133-243.

Faculty of Fisheries, Hokkaido University. 1958. 1957 cruise of the 'Oshoro Maru' to the Aleutian waters. *Data Rec. Oceanogr. Obsns. Explor. Fish.* No. 2:1-124.

Faculty of Fisheries, Hokkaido University. 1960. The 'Oshoro Maru' Cruise 44 to the Bering Sea in June-July 1959. *Data Rec. Oceanogr. Obsns. Explor. Fish.* No. 4:1-112.

Faculty of Fisheries, Hokkaido University. 1961. The 'Oshoro Maru' Cruise 46 to the Bering Sea and North Pacific in June-August 1960. *Data Rec. Oceanogr. Obsns. Explor. Fish.* No. 5:51-261.

Faculty of Fisheries, Hokkaido University. 1962. The 'Oshoro Maru' Cruise 48 to the Bering Sea and northwestern North Pacific in June-July 1961. *Data Rec. Oceanogr. Obsns. Explor. Fish.* No. 6:21-149.

Faculty of Fisheries, Hokkaido University. 1963. II. The 'Oshoro Maru' cruise 50 to the Bering Sea and northwestern North Pacific in May-July 1962. *Data Rec. Oceanogr. Obsns. Explor. Fish.* No. 7:41-140.

Faculty of Fisheries, Hokkaido University. 1964. The "Oshoro Maru" cruise 4 to the Bering Sea and northwestern North Pacific in May-July 1963. *Data Rec. Oceanogr. Obsns. Explor. Fish.* No. 8:199-303.

Faculty of Fisheries, Hokkaido University. 1965. The "Oshoro Maru" cruise 9 to the northern North Pacific, Bering and Chukchi Sea in October 1963-January 1964. *Data Rec. Oceanogr. Obsns. Explor. Fish.* No. 9:219-314.

Faculty of Fisheries, Hokkaido University. 1966. The "Oshoro Maru" cruise 14 to the northern North Pacific and Bering Sea in May-August 1965. *Data Rec. Oceanogr. Obsns. Explor. Fish.* No. 10:249-354.

Faculty of Fisheries, Hokkaido University. 1967. The 'Oshoro Maru' cruise 19 to the northern North Pacific and Bering Sea, June-August 1966. *Data Rec. Oceanogr. Obsns. Explor. Fish.* No. 11:165-261.

Faculty of Fisheries, Hokkaido University. 1968. The 'Oshoro Maru' cruise 24 to the northern North Pacific and Bering Sea in June-August 1967. *Data Rec. Oceanogr. Obsns. Explor. Fish.* No. 12:241-420.

Faculty of Fisheries, Hokkaido University. 1969. The 'Oshoro Maru' cruise 28 to the northern North Pacific, Bering Sea and the Gulf of Alaska. *Data Rec. Oceanogr. obsns. Explor. Fish.* No. 13:1-135.

Faculty of Fisheries, Hokkaido University. 1970. The "Oshoro Maru" cruise 32 to the northern North Pacific, Bering Sea and Bristol Bay in June-August 1969. *Data Rec. Oceanogr. Obsns. Explor. Fish.* No. 14:1-123.

Faculty of Fisheries, Hokkaido University. 1972. The "Oshoro Maru" cruise 37 to the northern North Pacific, Bering Sea and Gulf of Alaska in June-August 1970. *Data Rec. Oceanogr. Obsns. Explor. Fish.* No. 15:1-95.

Faculty of Fisheries, Hokkaido University. 1973. Data record of oceanographic observations and exploratory fishing. *Data Rec. Oceanogr. Obsns. Explor. Fish.* 16, 1973:1-341.

Faculty of Fisheries, Hokkaido University. 1974. The Oshoro Maru cruise 45 to the north Pacific, Bering Sea, Bristol Bay and Chukchi Sea in June-August 1972. *Data Rec. Oceanogr. Obsns. Expl. Fish.*, No. 17:1-129.

Faculty of Fisheries, Hokkaido University. 1975. The "Oshoro Maru" cruise 49 to the Bering Sea and the Bristol Bay in June-August 1973. *Data Rec. Oceanogr. Obsns. Explor. Fish.* No. 18:1-224.

Faculty of Fisheries, Hokkaido University. 1976. The "Oshoro Maru" cruise 53 to the Bering Sea and the Bristol Bay in June-July 1974. *Data Rec. Oceanogr. Obsns. Explor. Fish.* No. 19:1-151.

Fadeev, N. S. 1961. Biological features of flatfish. *Priroda* No. 3, p. 113.

Fadeev, N. S. 1963. Yellowfin sole of the Eastern Bering Sea. *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 48:281-291.

Fadeev, N. S. 1965. Comparative outline of the biology of flatfishes in the southeastern part of the Bering Sea and condition of their resources. *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 58: 112-128.

Fadeev, N. S. 1968a. *Flounders from the Southeastern Bering Sea.* Yuzhno-Sakhalinsk. 47 pp.

Fadeev, N. S. 1968. O migratsiyakh tikhookeanskogo morskogo okunya. [The migrations of rockfish]. *Izv. Tikhook. Nauchno-Issled. Inst. Ryb. Khoz. Okeanol.* Vol. 65:170-177.

Fadeev, N. S. 1970. Fishery and biological characteristics of yellowfin sole in the eastern part of the Bering Sea. *Trudy Vses. Nauchno-Issled. Inst. Morsk. Ryb. Khoz. Okeanogr.* Vol. 70:327-390. [in Russian]

Fager, E. W. and J. A. McGowan. 1963. Zooplankton species in the North Pacific. *Science* 140(3566):453-460.

Favorite, F. 1969a. Fishery oceanography - III. Ocean temperature and distribution of Pacific salmon. *Comm. Fish. Rev.* 31(10):34-40.

Favorite, F. 1969b. Fishery oceanography - IV. Ocean salinity and distribution of Pacific salmon. *Comm. Fish. Rev.* 31(11):29-32.

Favorite, F. 1969c. Fishery oceanography - V. Oceanic circulation and distribution of sockeye salmon. *Comm. Fish. Rev.* 31(12):35-39.

Favorite, F. 1969d. A summary of BCF investigations of the physical-chemical environment of Pacific salmon, 1955-1968. Bureau of Commercial Fisheries, Biological Laboratory, Seattle, Washington. *Inst. N. Pacific Fish. Comm. Document 1216.* 38 pp.

Favorite, F. 1970. Fishery oceanography - VI. Ocean food of sockeye salmon. *Comm. Fish. Rev.* 32(1):45-49.

Favorite, F. 1975. Physical oceanography in relation to fisheries. *In* D. W. Hood and Y. Takenouti (convenors). Bering Sea Oceanography: An Update, Results of US-Japan Seminar/Workshop on Bering Sea Oceanography Report R75-2, Inst. Mar. Scil, Univ. Alaska, Fairbanks. pp. 157-179.

Favorite, F. and M. G. Hanavan. 1963. Oceanographic conditions and salmon distribution south of the Alaska peninsula and Aleutian Islands, 1956. *Bull. Int. N. Pacif. Fish. Commm.* 11:57-72.

Favorite, F. and W. J. Ingraham, Jr. 1972. Influence of Bowers Ridge on circulation in Bering Sea and influence of Amchitka branch, Alaskan Stream, on migration paths of sockeye salmon. *In* A. Y. Takenouti (ed.) *Biological Oceanography of the Northern North Pacific Ocean.* Idemitsu Shoten, Tokyo, Japan. pp. 13-29.

Favorite, F. and G. Pedersen. 1959. North Pacific and Bering Sea oceanography, 1958. *U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish.* 312:1-230.

Fay, F. H. 1955. The Pacific walrus (*Odobenus rosmarus divergens*): spatial ecology, life history and population. Ph.D. Thesis, Univ. Brit. Col., Vancouver, 171 pp.

Fay, F. H. 1975. Mammals and birds. *In* D. W. Hood and Y. Takenouti (convenors), Bering Sea Oceanography: An Update, Results of US-Japan Seminar/Workshop on Bering Sea Oceanography, Report R75-2, Inst. Mar. Sci., Univ. Alaska, Fairbanks. pp. 133-138.

Fay, F. H. 1977. Morbidity and mortality of marine mammals (Bering Sea). *In: Environmental Assessment of the Alaskan Continental Shelf, Vol. 1.* Environmental Res. Lab., Boulder, Colorado. pp. 276-284.

Fay, F. H. and T. J. Cade. 1959. An ecological analysis of the avifauna of St. Lawrence Island, Alaska. *Univ. Calif. Publ. Zool.* 63:73-150.

Fay, F. H. and C. Ray. 1968. Influence of climate on the distribution of walruses, *Odobenus rosmarus* (Linnaeus). I. Evidence from thermoregulatory behavior. *Zoologica* 53:1-14.

Federov, V. V. 1967a. Description of *Notosudis adleri* sp. n. (Pisces, Notosudidae) a new species from the Bering Sea. *Vopr. Ikhtiol.* 7(6): 967-978.

Federov, V. V. 1967b. On the occurrence of the deepwater flatfish *Embassichthys bathybius* (Gilbert, 1891) (Pleuronectidae, Pisces) in the Bering Sea. *Vopr. Ikhtiol.* 7(3):566-570.

Federov, V. V. and M. Yu Kulikov. 1964. *Lampanyctus jordani* Gilbert caught in the southeastern Bering Sea. Akad Nauk SSSR, Moscow, *Doklady* 157(5): 1243-1244.

Fedoseev, G. A. 1965. Pitanie kol'chatoi nerpy (*Pusa hispida* Schr.) [Diet of the ringed seal (*Pusa hispida* Schr.)]. *Inv. Tikhookean, Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.* Vol. 59:216-223.

Fedosov, M. V. 1965. Conditions of formation of the primary food resources in the ocean. *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 57:145-160.

Fedosov, M. V. and I. A. Ermachenko. 1961. Formation and decomposition rates for organic matter in northern seas. Pervichnaya produktsiya morei i vnutrennikh vod, Izd. Ministerstva vysshego, srednego spetsial'nogo i professional'nogo obrazovaniya Belo. Sovet. Sotsial. Respub.

Filatova, Z. A. 1938. Kolichestvennyi uchet donnoi fauna yugo-zapadnoi chasti Beringova morya [Quantitative assessment of benthic fauna in the southwestern part of the Bering Sea]. *Trudy Polyarn. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 2.

Filatova, Z. A. 1957a. Certain new representatives of the Family Astartidae (Bivalvia) of the Far Eastern Seas. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 23:297-302.

Filatova, Z. A. 1957b. Obshchii obzor dvustvorchatykh molluskov severnykh morei SSSR (General review of bivalves of the northern seas of the USSR) Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 20:3-59.

Filatova, Z. A. 1958. Certain new species of bivalves of the northwestern Pacific Ocean. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 27:208-218.

Filatova, Z. A. and N. G. Barsanova. 1964. Communities of benthic fauna in the western Bering Sea. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 69:6-97 (Engl. transl. by U.S. Naval Oceanogr. Off., Trans. No. 459).

Filatova, Z. A. 1960. Kolichestvennoe raspredelenie dvustvorchatnykh mollyuskov v dal'nevostochnykh moryakh SSSR i severo-zapadnoi chasti Tikhogo okeana (Quantitative distribution of bivalves in the Far Eastern Seas of the USSR and in the northwestern Pacific) Akad. Nauk SSSR, *Trudy Inst. Okeanol.* 41:132-145.

Filatova, Z. A. and R. J. Levenstein. 1961. The quantitative distribution of the deep-sea bottom fauna in the northeastern Pacific. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 45:191-213.

Filatova, Z. A. and A. A. Neiman. 1963. Benthic biocoenoses of the Bering Sea. *Okeanol.* 3(6):1079-1084.

Filatova, Z. A. and L. A. Zenkevich. 1966. Quantitative distribution of deep-sea benthic fauna in the Pacific Ocean, *Vtoroi Mezhdunarodnyi okeanograficheskii kongress, 30 maya-9 iyunya 1966 g. Synopses of Reports*. Moscow, Izdatel'stvo "Nauka".

Filip'ev, I. N. 1916-1917. Free-living nematodes in the collections of the Zoological Museum of the Imperial Academy of Sciences (Bering Sea). *Ezhegodnik Zool. Mueya Akad. Nauk* Vol. 21.

Fiscus, C. H. and H. W. Braham. 1976. Baseline characterization of marine mammals in the Bering Sea. *In: Environmental Assessment of the Alaskan Continental Shelf, Volume 1*; Principal Investigators. Reports July-September 1976. Environmental Research Laboratories, Boulder, Colorado. pp. 3-29.

Fiscus, C. H., H. Braham, and R. Mercer. 1977. Seasonal distribution and relative abundance of off-shore marine mammals in the western Gulf of Alaska Kodiak Island to Umnak Island. *In: Environmental Assessment of the Alaskan Continental Shelf, Vol. 1*. Environmental Res. Lab., Boulder, Colorado. pp. 265-271.

Fiscus, C. H., H. W. Braham, R. W. Mercer *et al.* 1977. Seasonal distribution and relative abundance of marine mammals in the Gulf of Alaska. *In: Environmental Assessment of the Alaskan Continental Shelf, Vol. 1.* Environmental Res. Lab., Boulder, Colorado. pp. 19-264.

Fiscus, C. H., H. Braham, and D. Rugh. 1977. Baseline characterization of marine mammals in the Bering Sea. *In: Environmental Assessment of the Alaskan Continental Shelf, Vol. 1*. Environmental Res. Lab., Boulder, Colorado. pp. 3-18.

Fisher, J. 1952. *The Fulmar*. Collins, London. 496 pp.

Fisher, L. R. 1962. The total lipid material in some species of marine zooplankton. *Rapp. P. V. Rêun. Cons. Perm. Int. Explor. Mer* 153: 129-136.

Fisher, W. K. 1911. Asteroidea of the North Pacific and adjacent waters (*Phanerozonia* and *Spinulosa*). *Smiths. Inst. U.S. Nat. Mus. Bull.* Vol. 76, pt. 1:1-407.

Fisher, W. K. 1930. Asteroidea of the North Pacific and adjacent waters. Smithsonian Inst., *Bull. U.S. Nat. Mus. 76*. pp. 1-3.

Fisher, W. K. 1946. Echiuroid worms of the North Pacific Ocean. *Proc. U.S. Natl. Mus.* 96(3198):215-292.

Fisher, W. K. 1948. A review of the Bonelliidae (Echiuroidea). *Ann. Mag. Nat. Hist.* 14(115).

Fisheries Agency of Japan. 1966. Report on research by Japan for International North Pacific Fisheries Commission during the year 1964. *Int. N. Pacif. Fish. Comm. Annu. Rep.* 1964:48-79.

Fisheries Agency of Japan. 1967. Report on research by Japan for International North Pacific Fisheries Commission during the year 1966. *Int. N. Pacif. Fish. Comm. Annu. Rep.* 1966:51-71.

Fisheries Agency of Japan. 1967. B. Report on research by Japan for the International North Pacific Fisheries Commission during the Year 1967. *Int. N. Pacif. Fish. Comm. Annu. Rept.* 1967:56-77.

Fleming, R. H. 1955. Review of the oceanography of the northern Pacific. *Bull. Int. N. Pacif. Fish. Comm.* 2:1-42.

Foerster, R. C. 1934. The importance of Copepods in the natural diet of sockeye salmon. *Proc. 5th Pacif. Sci. Congr. (Canada)* 1933,3:2009-2016.

Foerster, R. E. 1968. The sockeye salmon (*Oncorhynchus nerka*). *Bull. Fish. Res. Bd. Can.* No. 162, 422 pp.

Foerster, R. E. and A. L. Pritchard. 1941. Observations on the relation of egg content to total length and weight in the sockeye salmon (*O. nerka*) and the pink salmon (*O. gorbuscha*). *Trans. Roy. Soc. Canada*, Sec. 5, 35: 51-60.

Fontaine, M. 1955. The planktonic copepods (Calanoida, Cyclopoida, Monstrilloida) of Ungava Bay, with special reference to the biology of *Pseudocalanus minutus* and *Calanus finmarchicus*. *J. Fish. Res. Bd. Can.* 12(6):858-898.

Fraser, J. H. 1962. The role of ctenophores and salps in zooplankton production and standing crop. *Rapp. P. V. Réun. Cons. Perm. Int. Explor. Mer* 153:121-123.

Fredin, R. A. and D. D. Worlund. 1974. Catches of sockeye salmon of Bristol Bay, Alaska, U.S.A origin by the Japanese mother ship salmon fishery 1956-1970. *Bull. Int. N. Pacif. Fish. Comm.* (30)1974:1-80.

Freiman, S. Yu. 1936. Distribution of pinnipeds in the Far Eastern Seas. *Trudy Vses. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.* Vol. 3:184-203.

Freiman, S. Yu. 1941. Data on the biology of the Chukchi Sea walrus. *Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.* Vol. 20:3-20.

French, R. R. 1966. Salmon distribution and abundance studies. *Int. N. Pacif. Fish. Commn. Annu. Rep.* 1964:91-101.

French, R. R., R. C. Bakkala, M. Osako and J. Ito. 1971. Distribution of salmon and related oceanographic features in the North Pacific Ocean, spring 1968. Dept. Commer., *Spec. Sci. Rept. Fish.* (625):1-22.

French, R. R., D. Craddock, R. Bakkala, J. Dunn and D. Sutherland. 1970. Ocean distribution, abundance, and migration of salmon. *Int. N. Pacif. Fish. Comm. Annu. Rep.* 1968:79-90.

French, R. R. and J. E. Mason. 1964. Salmon distribution and abundance on the high-sea winter season 1962 and 1963. *Int. N. Pacific. Fish. Comm. Ann. Rept.* 1963:131-141.

French, R. R. and W. B. McAlister. 1970. Winter distribution of salmon in relation to currents and water masses in the Northeastern Pacific Ocean and migrations of sockeye salmon. *Trans. Amer. Fish. Soc.* 99(4):649-663.

Frisch, J. and J. Krog. 1968. Temperature loss through the skin of Arctic marine mammals. *IN: R/V Alpha Helix Bering Sea Exped.*, p. 147.

Frost, B. W. 1972(Nov). Effects of size and concentration of food particles on the feeding behavior of the marine planktonic copepod *Calanus pacificus*. *Limnol. Oceanogr.* 17(6):805-815.

Fuji, T. 1975. On the relation between the homing migration of the western Alaskan sockeye salmon *Oncorhynchus nerka* (Walbaum) and oceanic conditions in the eastern Bering Sea. *Mem. Fac. Fish., Hokkaido Univ.* 2(2):99-191.

Fujii, T., K. Masuda, T. Nishiyama, T. Kobayashi and G. Anma. 1974. A consideration on the relation between oceanographic conditions and distribution of Bristol Bay sockeye salmon *Oncorhynchus nerka* (Walbaum) in the eastern Bering Sea, with special reference to its poor return in 1973. *Bull. Fac. Fish. Hokkaido Univ.* 25(3):214-229.

Fujita, H., K. Takeshita and S. Kawasaki. 1973. Seasonal movement of adult male king crab in the eastern Bering Sea revealed by tagging experiment. *Bull. Far Seas Fish. Res. Lab.* (9):89-107. [In Japanese with English res.].

Fukuchi, M. T. Nishiyama and T. Tsujita. 1974. Vertical stratification of zooplankton and ichthyoneuston in the northern north and central Pacific Ocean. Symposium on mechanism of biological production system in the North Pacific Ocean, October, Tokyo. (Abstract, in Japanese).

Fukuchi, M. and T. Tsujita. 1973. Oxygen consumption and caloric equivalence of body in larval walleye pollock, *Theragra chalcogramma* (Palla). Lecture at the annual meeting of Jap. Soc. Sci. Fish., April, 1973. Tokyo.

Fukuchi, M. and T. Tsujita. 1974. Changes of caloric values and chemical composition of body parts in larval walleye pollock, *Theragra chalcogramma* (Pallas). Lecture at the annual meeting of Jap. Soc. Sci. Fish., April, 1974. Tokyo.

Fukuda, Y. 1969. Area review on living resources of the World's ocean: Northwest Pacific. *FAO Fish. Circ. 109.* 14, FAO, Rome, 35 pp.

Fukuhara, F. M. 1953. Japanese 1952 North Pacific salmon-fishing expedition. U.S. Dept. Int., Fish Wildl. Serv., *Comm. Fish. Rev.* 15(2):1-17.

Gabrielson, I. N. and F. C. Lincoln. 1959. *Birds of Alaska.* Wildl. Mgmt. Inst., Washington, D.C., 922 pp.

Gaevskaya, N. S. 1949. O pishevoi elektivnosti u zhivotnykh-fil'tratorov [On selectivity in filter-feeders]. *Tr. Vses. Hidrobiol. Obshchestva*, Vol. 1.

Gaffron, H. 1944. Photosynthesis, photoreduction and dark reduction of carbon dioxide in certain algae. *Cambridge Philos. Soc. Biol. Rev.* 19:1-20.

Gail, G. I. 1935. Plant resources of the Far Eastern Seas. *Na Rubezhe* No. 2.

Gail, G. I. 1936. Laminaria algae of the Far Eastern Seas. Akad. Nauk SSSR, *Vestnik Dal'nevost. Filiala* No. 19:31-65.

Galkin, A. S. and S. M. Kovalev. 1975. Fecundity of the capelin, *Mallotus villosus villosus* of the Barents Sea. *J. Ichthyol.* 15(4):579-583.

Galkin, Yu. I. 1955. *Trochidae (Gastropoda) of the Far Eastern and the Northern Seas of the USSR.* Moscow-Leningrad, Izd. Akad. Nauk SSSR.

Galkina, L. A. 1957. Effect of salinity on the sperm, eggs and larvae of the Okhotsk herring. *Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.* Vol. 45:37-50.

Galkina, L. A. 1960. Reproduction and development of Okhotsk herring. *Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.* Vol. 46: 3-40.

Galkina, L. A. 1961. Reproduction and early developmental stages of herring in the northern area of the Sea of Ilhotsk. *Problemy Severa* No. 4.

Galkina, L. A. 1968. Survival of eggs and larvae of herring during the period of mass approach. *Vopr. Ikhtiol.* 8(4):679-688.

Galzow, P. 1909. Chaetognathen der Pacifisch - Borealen Subregion. *Zool. Jahrb. Syst.* 28:1-22.

Gardner, N. L. 1922. The genus *Fucus* on the Pacific coast of North America. *Univ. Calif. Publ. Bot.* 10:1-180.

Gaskin, D. E. 1976. The evolution, zoogeography and ecology of cetacea. *In* H. Barnes (ed.), *Oceanography and Marine Biology, An Annual Review.* Allen and Unwin Ltd., London. pp. 247-346.

Gauld, D. T. 1951. The grazing rate of planktonic copepods. *J. Mar. Biol. Assoc. U.K.* 29:695-706.

Gauld, D. T. 1966. The swimming and feeding of planktonic copepods. *In* H. Barnes (ed.), *Some Contemporary Studies in Marine Science*. Allen and Unwin Ltd., London. pp. 313-334.

Gauld, D. T. and J. E. G. Raymont. 1953. The respiration of some planktonic copepods. II. The effect of temperature. *J. Mar. Biol. Ass. U.K.* 31:447-460.

Geraci, J. R. and T. G. Smith. 1976. Direct and indirect effects of oil on ringed seals (*Phoca hispida*) of the Beaufort Sea. *J. Fish. Res. Bd. Can.* 33(9):1976-1984.

Gershanovich, D. E. 1964. New data on organic accumulation in recent sediments of the far north of the Pacific Ocean. Izd. Akad. Nauk SSSR, Moscow, *Morskaya Geol.* (Doklady Sovet. Geol. 22 sessii Meshdunarodnyi Geol. Kong.)

Gessner, F. 1959. *Hydrobotanik.* Ver Deutsher Verlag der Wissenschaftern, Berlin. 701 pp.

Gilbert, C. H. and C. V. Burke. 1910. Fishes from Bering Sea and Kamchatka. *Bull. U.S. Bur. Fish.* Vol. 30:31-96.

Gilbert, C. H. and D. S. Jordan. 1899. *Fishes of the Bering Sea*. Washington, D.C.

Gilfillan, E. S. 1970. The effects of changes in temperature, salinity and undefined properties of sea-water on the respiration of *Euphausia pacifica* Hansen (crustacea) in relation to the species' ecology. Ph.D Thesis, Univ. Brit. Col., Vancouver, 126 pp.

Gilfillan, E. S. 1972. Seasonal and latitudinal effects on the responses of *Euphausia pacifica* Hansen (Crustacea) to experimental changes of temperature and salinity. *In* A. Y. Takenouti (ed.), *Biological Oceanography of the Northern North Pacific Ocean.* Idmitsu Shoten, Tokyo, Japan. pp. 443-463.

Gill, T. and C. Townsend. 1897. Diagnoses of new species of fishes found in the Bering Sea. *Proc. Biol. Soc. Wash.* Vol. 11.

Gilmore, R. M. 1960. The California gray whale, his abundance and migration. *Norsk hvalfangsttidende* No. 9.

Given, R. A. 1965. Five collections of Cumacea from the Alaskan Arctic. *Arctic* 18(4):213-229.

Godfrey, H. 1969. Salmon of the North Pacific Ocean - Part IX. Coho, chinook and masu salmon in offshore waters. 1. Coho salmon in offshore waters. *Bull. Int. N. Pacif. Fish. Commn.* 16:16-39.

Goering, J. J. 1970. Biological oceanography. *In* R. J. Barsdate *et al.* (eds.), Oceanography of the Bering Sea - Phase I. Turbulent Upwelling and Biological Productivity Mechanisms in the Southeastern Bering Sea and Aleutian Islands. Report R70-8, Inst. Mar. Sci., Univ. Alaska, Fairbanks. 6 pp.

Goering, J. J., C. P. McRoy and W. E. Shiels. 1971. Biological Oceanography of the Bering Sea. *In* D. W. Hood *et al.* (eds.), Oceanography of the Bering Sea - Phase I. Turbulent Upwelling and Biological Productivity Mechanics in the Southeastern Bering Sea and Aleutian Islands. Report R71-9, Inst. Mar. Sci., Univ. Alaska, Fairbanks. pp. 175-188.

Golikov, A. N. 1963. Bryukhonogie mollyuski roda *Neptunea* bolten [*Gastropods of the Genus Neptunea Bolten*]. Akad. Nauk SSSR, Moscow-Leningrad, Izd. Zool. Inst.

Golovkin, A. N. and E. A. Zelickman. 1965. Development of *Calanus* in the region of nesting colonies of sea birds on the Murmansk coast. *Okeanol.* 5(1):117-127. Also *Oceanol.* 5(1):88-98 [Engl. transl.]

Gonor, J. J. 1965. Pogonophores off the northern coast of Alaska. Univ. Alaska, *Inst. Mar. Sci. Rept.* (R-65-5):1-10.

Goodman, J. R., J. H. Lincoln, T. G. Thompson and F. A. Zeusler. Physical and chemical investigations: Bering Sea, Bering Strait, Chukchi Sea during the summers of 1937 and 1938. *Univ. Washington Publ. Oceanography* 3(4):105-169, 1942.

Gorbunov, G. P. 1952. Dvustvorchatye mollyuski Chukotskogo morya i Beringova proliva. Krainii Severo-Vostok Soyuza SSR [Bivalve mollusks of the Chukchi Sea and the Bering Strait. Extreme northeast of the USSR]. *Izd. Akad. Nauk SSSR* Vol. 2.

Gorbunova, N. N. 1954. Razmnozhenie i razvitie mintaya [Reproduction and development of Alaska pollock]. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 11:132-195.

Gorbunova, N. N. 1962. Spawning and development of Hexagrammidae (Pisces). Akad. Nauk SSSR, Leningrad, *Trudy Inst. Okeanol.* Vol. 59:118-182.

Gorbunova, N. N. 1964. Reproduction and development of hemilepidotine sculpins (Cottidae, Pisces). Akad. Nauk SSSR, Leningrad, *Trudy Inst. Okeanol.* Vol. 73:235-251.

Gordeev, V. D. 1949. Sostoyanie i perspektivy tralovogo promysla na Dal'nem Vostoke. [State and prospects of trawling in the Far East]. *Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okean.* Vol. 29:3-33.

Gordeev, V. D. 1954. Rezul'taty rabot Beringovomorskoi tralovi ekspeditsii 1950-1952 gg. [The results of the Bering Sea Trawling Expedition in 1950-1952]. *Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.* Vol. 41:253-267.

Gordeeva, K. T. 1952. O pitanii treski severnoi chasti Beringova morya. [The diet of codfish of the northwestern Bering Sea]. *Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.* Vol. 37:145-162.

Gordeeva, K. T. 1954a. Pitanie paltusov v Beringovom more. [The diet of halibut in the Bering Sea]. *Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.* Vol. 39:111-134.

Gordeeva, K. T. 1954b. Materialy po pitaniyu treski Beringova morya. [Data on the diet of cod of the Bering Sea]. *Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.* Vol. 42:191-207.

Gordon, C. P. 1950. What do whales eat. *Canadian Fisherman* 37(9):11.

Gordon, L. I., E. A. Seifert, L. I. Barstow and P. K. Park. 1975. Organic carbon in the Bering Sea. *In* D. W. Hood and Y. Takenouti (convenors), Bering Sea Oceanography: An Update, Results of US-Japan Seminar/ Workshop on Bering Sea Oceanogrpahy, Report R75-2, Inst. Mar. Sci., Univ. Alaska, Fairbanks. pp. 239-244.

Grachev, L. E. 1968. Some data on the fertility of the Pacific salmon. *Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.* Vol. 64: 43-51.

Grachev, L. YE. 1971. Alteration in the number of oocytes in the pink salmon [*Oncorhynchus gorbuscha* (Walbaum)] in the marine period of life. *J. Ikhthyol.* 11(2):199-206; also: *J. Ichthyol.* 11(6):897-906 (English translation).

Graham, H. W. 1934. The distribution of the plankton of the Pacific as related to some physical and chemical conditions of the water. *Proc. 5th Pacif. Sci. Congress* 3:2035-2043.

Graham, H. W. and R. L. Edwards. 1962. The world biomass of marine fishes. *In* Eirik Heen (ed.) *Fish in Nutrition.* Fishing News, London. pp. 3-8.

Grainger, E. H. 1959. The annual oceanographic cycle at Igloolik in the Canadian Arctic. I. The zooplankton and physical and chemical observations. *J. Fish. Res. Bd. Can.* 16(4):453-501.

Grainger, E. H. 1961. The copepods *Calanus glacialis* Jaschnov and *Calanus finmarchicus* (Gunnerus) in Canadian Arctic-Subarctic waters. *J. Fish. Res. Bd. Can.* 18(5):663-678.

Grainger, E. H. 1965. Zooplankton from the Arctic Ocean and adjacent Canadian waters. *J. Fish. Res. Bd. Can.* 22(2):543-564.

Gran, H. H. 1904. Diatomaceae from the ice-floes and plankton of the Arctic Ocean. *Sci. Res. Norw. North Polar Exped. 1893-1896* 4(11).

Gray, J. 1948. Aspects of the locomotion of whales. *Nature (London)* 161(4084):199-200.

Grebnitskii, N. 1897. Spisok ryb, vodyashchikhsya u ostrovov komandorskikh i poluostrova kamchatka. [A list of fishes of the Commander Islands and the Kamchatka Peninsula]. *Vestnik Rybopromyshlennosti* Vol. 12.

Grey, M. 1956. The distribution of fishes found below a depth of 2000 meters. *Fieldiana Zool.* 36(2).

Grey, M. 1960. A preliminary review of the family Gonostomatidae, with a key to the genera and description of a new species from the tropical Pacific. *Bull. Mus. Comp. Zool. Harvard Coll.* 122(2):55-125.

Gribanov, V. I. 1949. Kizhuch - *Onchorhynchus kisutch* (Walbaum). Nerka - *Oncorhyncus nerka* (Walbaum). [Coho salmon (*Oncorhynchus kisutch* (Walbaum) and sockeye salmon (*Oncorhynchus nerka* (Walbaum)]. Promysl. Ryby SSSR. Pishchepromizdat.

Grier, M. C. 1941. Oceanography of the North Pacific Ocean, Bering Sea and Bering Strait: A contribution toward a bibliography. Seattle, *Univ. Washington Publ.* Vol. 2. 290 pp.

Grill, E. V. and F. A. Richards. 1964. Nutrient regeneration from phytoplankton decomposing in seawater. *J. Mar. Res.* 22:51-69.

Grimm, O. A. 1891. K voprosu o svobodnom promysle v Beringovom more. [Problem of unrestricted fishing in the Bering Sea]. *Vestnik Rybopromyshlennosti* No. 1.

Grinols, R. B. 1965. Check-list of the offshore marine fishes occurring in the northeastern Pacific Ocean, principally off the coasts of British Columbia, Washington and Oregon. MS Thesis, Univ. of Washington, Seattle. 217 pp.

Gritsenko, O. N. 1963. Vozrast i temp rosta tikhookeanskogo morskogo okunya Beringova morya. [Age and growth rate of Pacific rockfish of the Bering Sea]. *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 48:328-331.

Gudkov, V. M. 1959. Lethee rasprostranenie morskikh ptish v Beringovom More v 1955 gody. Izd. Morsk. Inst., *Tezisy 11 Vses. Ornitol. Konf.* Vol. 3:82-84.

Gudkov, V. M. 1962. On the relationships between the distribution of zooplankton, sea birds, and whalebone whales. Akad. Nauk SSSR, Leningrad, *Trudy Inst. Okeanol.* Vol. 58:298-313.

Gulland, J. A. 1969a. Area reviews on living resources of the World's ocean: Oceanic resources. *FAO Fish. Circ. 109* 17, FAO, Rome, 21 pp.

Gulland, J. A. 1969b. Area reviews on living resources of the World's ocean: Northeast Pacific. *FAO Fish. Circ. 109* 12, FAO, Rome, 20 pp.

Gun, K. E. 1959. Ecology of some Arctic foraminifera. *In* V. Bushnell (ed.) Scientific Studies at Hetcher's Ice Island, T-3, 1952-1955, Geophys. Res. Papers No. 63, AFCRC-TR-59-232(1). ASTIA Doc. No. AD 216813. pp. 59-81.

Gunther, E. R. 1934. Observations on the fatty constituents of marine plankton. I. Biology of the plankton. *J. Exp. Biol.* Vol. XI(2): 173-197.

Gur'yanova, E. 1933. K faune ravnonogikh rakov (Isopoda) Tikhogo okeana. 1. Novye vidy *Valvifera* i *Flabellifera.* Gosudar. Gidrolog. Inst., Leningrad, *Issled. Morei SSSR* No. 17:87-106.

Gur'yanova, E. F. 1936. Ravnonogie raki dal'nevostochnykh morei. [*Isopoda of the Far Eastern Seas*]. Moscow-Leningrad, Izd. Akad. Nauk SSSR.

Gur'yanova, E. F. 1951. Bokoplavy morei SSSR. [*Amphipods of the Seas of the USSR*]. Moscow, Izd. Akad. Nauk SSSR.

Gur'yanova, E. F. 1952a. Higher crustaceans of the Chukchi Sea and the Bering Strait. *In* Sbornik: *Krainii Severo-Vostok SSSR* Vol. 2.

Gur'yanova, E. F. 1952b. K faune vysshik rakoobraznykh (Crustacea-Malacostraca) severnoi chasti Tikhogo Okeana. Izd. Akad. Nauk SSSR, Moscow, *Issled. Dal'nevost. Morei* SSSR, No. 3:113-115.

Gur'yanova, E. F. 1952c. New amphipod species of the Far Eastern Seas. Akad. Nauk SSSR, *Trudy Zool. Inst.* Vol. 12:171-194.

Gur'yanova, E. F. 1955. Novye vidy bokoplavov (Amphipoda, Gammaridea) iz severnoi chasti Tikhogo Okeana. Akad. Nauk SSSR, *Trudy Zool. Inst.* Vol. 18:166-218.

Gur'yanova, E. F. 1962. Bokoplavy severnoi chasti Tikhogo okeana (*Amphipoda of the Northern Pacific Ocean), Part I.* Moscow-Leningrad, Izd. Akad. Nauk SSSR.

Hada, Y. 1972. Studies on plankton organisms in Akkeshi Bay, eastern district of Hokkaido, Japan. *In* A. Y. Takenouti (ed.), *Biological Oceanography of the Northern North Pacific Ocean.* Idemitsu Shoten, Tokyo, Japan. pp. 173-188.

Haffner, R. E. 1952. Zoogeography of the bathypelagic fish, *Chauliodus. System. Zool.* 1(3).

Hammel, H. T., J. Maggert and P. F. Scholander. 1968. Freezing in tissue of arctic fish. *In: R/V Alpha Helix Bering Sea Exped.* 23-26.

Hanamura, N. 1966. Salmon of the North Pacific Ocean - Part III. A review of the life history of North Pacific salmon. 1. Sockeye salmon in the Far East. *Bull. Int. N. Pacif. Fish. Commn.* 18:1-27.

Hanavan, M. G. 1960. Distribution and racial sampling of salmon on the high seas. *Int. N. Pacif. Fish. Comm., Annu. Rept.* 1959:79-85.

Hanavan, M. G. and G. K. Tanonaka. 1959. Experimental fishing to determine distribution of salmon in the North Pacific Ocean and Bering Sea, 1956. *U.S. Fish Wildl. Serv., Spec. Sci. Rept.-Fish.* No. 302, 22 pp.

Hand, C. and L. B. Kan. 1961. The medusae of the Chukchi and Beaufort Seas of the Arctic Ocean including the description of a new species of *Eucodonium* (Hydrozoa, anthomedusae). Arctic Inst. N. Amer., Tech. Paper 6:1-23.

Handa, N. and K. Yanagi. 1969. Studies on water-extractable carbohydrates of the particulate matter from the northwest Pacific Ocean. *Mar. Biol.* 4(3):197-207.

Hanna, G. D. 1924. Temperature records of Alaska fur seals. *Amer. J. Physiol.* 68:52-53.

Hansen, H. J. 1915. The Crustaceå Euphausiacea of the United States National Museum. *Proc. U.S. Natn'l Mus.* Vol. 48:59-114.

Hansen, W., E. Bulleid and M. J. Dunbar. 1971. Scattering layers, oxygen distribution and the copepod plankton in the upper 300 meters of the Beaufort Sea. Mar. Sci. Center, McGill Univ., Manuscript Rept. No. 20. 84 pp.

Haq, S. M. 1967. Nutritional physiology of *Metridia lucens* and *M. longa* from the Gulf of Maine. *Limnol. Oceanogr.* 12:40-51.

Harding, G. C. H. 1966. Zooplankton distribution in the Arctic Ocean with notes on life cycles. MS Thesis, McGill Univ., Montreal. 134 pp.

Hargrave, B. T. and G. H. Geen. 1970. Effects of copepod grazing on two natural phytoplankton population. *J. Fish. Res. Bd. Can.* 27(8):1395-1403.

Harman, O. 1948. The Polychaeta Annelids of Alaska. *Pacif. Sci.*, Vol. 11

Harrison, R. W. 1942. Report of the Alaskan crab investigation. *Fishery Market News* 4(59):94.

Harry, G. Y., Jr. 1964. The shrimp fishery of Alaska. *Proc. Gulf Carib. Fish. Inst., 16th Annu. Sess.*:64-70.

Harry, R. R. 1953. Studies on the bathypelagic fishes of the family Paralepididae. 1. Survey of the genera. *Pacif. Sci.* 7(2):219-249.

Harry, R. R. 1953. Studies on the bathypelagic fishes of the family Paralepididae. 2. A review of the North Pacific species. *Proc. Acad. Natur. Sci. Philad.* Vol. 105.

Hart, I. 1939. Cumacea and Decapoda of the Western Canadian Arctic Region. *Can. J. Res.* 17D:62-67.

Hart, J. L. 1973. Pacific Fishes of Canada. *Fish. Res. Bd. Can. Bull.* (180):1-740.

Hart, J. S. and L. Irving. 1959. The energetics of harbor seals in air and in water with special consideration of seasonal changes. *Can. J. Zool.* 37:447-457.

Hartman, O. 1948. The polychaetous annelids of Alaska. *Pacif. Sci.* 2(1): 3-58.

Hartman, W. L. 1971. Alaska's fishery resources, the sockeye salmon. *U.S. Dept. Commer., Fish. Leaflet* (636), 1-8.

Hartt, A. C. 1962a. Movement of salmon in the North Pacific Ocean and Bering Sea as determined by tagging, 1956-1958. *Bull. Int. N. Pacif. Fish. Comm.* No. 6. 157 pp.

Hartt, A. C. 1962b. Observations on pink salmon in the Aleutian Island area 1956-1960. *In: Symposium on Pink Salmon.* H. R. MacMillan Lectures in Fisheries, Inst. Fish., Univ. Brit. Col., Vancouver, B.C. pp. 123-133.

Hartt, A. C. 1966. Migrations of salmon in the North Pacific Ocean and Bering Sea as determined by seining and tagging, 1959-1960. *Bull. Int. N. Pacif. Fish. Commn.* 19, 141 p.

Haryu, T., T. Nishiyama and T. Tsujita. 1975. Geographical and seasonal distribution of walleye pollock (*Theragra chalcogramma*) larvae in the Bering Sea in summer, 1964-1974. Ann. Meeting Jap. Soc. Sci. Fish., April, Tokyo. (Abstract, in Japanese).

Hattori, A. and E. Wada. 1972. Assimilation of inorganic nitrogen in the euphotic layer of the North Pacific Ocean. *In* A. Y. Takenouti (ed.), *Biological Oceanography of the Northern North Pacific Ocean.* Idemitsu Shoten, Tokyo, Japan. pp. 279-287.

Hattori, A. and E. Wada. 1974. Assimilation and oxidation-reduction of inorganic nitrogen in the North Pacific Ocean. *In* D. W. Hood and E. J. Kelley (eds.), Oceanography of the Bering Sea. Inst. Mar. Sci., Univ. Alaska, Fairbanks. Occas. Publ. No. 2, pp. 149-162.

Haxo, F. and P. Healey. 1968. Photosynthesis and respiration in Arctic algae. *In: R/V Alpha Helix Bering Sea Exped.* pp. 69-71.

Hayes, F. R. and D. Pelluet. 1945. The effect of temperature on the growth and efficiency of yolk conversion in the salmon embryo. *Canadian J. Res. Sect. D. Zool. Sci.* 23(2):7-15.

Haynes, E. B. 1974. Distribution and relative abundance of larvae of king crab, *Paralithodes camtschatica*, in the southeastern Bering Sea, 1969-70. *U.S. Dept. Commer., Fish. Bull.* 72(3):804-812.

Haynes, E., J. F. Karinen, J. Watson and D. J. Hopson. 1976. Relation of number of eggs and egg length to carapace width in the brachyuran crabs *Chionoecetes bairdi* and *C. opilio* from the southeastern Bering Sea and *C. opilio* from the Gulf of St. Lawrence. *J. Fish. Res. Bd. Can.* 33(11): 2592-2595.

Haynes, E. B. and G. C. Powell. 1968. A preliminary report on the Alaska sea-scallop fishery exploration, biology and commercial processing. *U.S. Dept. Fish and Game Info. Leaflet 125.*

Healey, F. P. 1972. Photosynthesis and respiration of some Arctic seaweeds. *Phycologia* 11(3-4):267-271.

Healy, M., J. J. Kelley, P. K. Park and W. S. Reeburgh. 1974. Chemical oceanography. *In* PROBES, a Prospectus on Processes and Resources of the Bering Sea Shelf 1975-1985. Deliberations of a workshop in promotion of the U.S. program for Bering Sea oceanography 24-30 November 1973. *Inst. Mar. Sci. Public Inform. Bull.* 74-1, Univ. Alaska, Fairbanks.

Hebard, I. F. 1959. Currents in the southeastern Bering Sea and possible effects upon king crab larvae. *U.S. Fish. Wildl. Serv., Spec. Sci. Rept. Fish.* No. 293.

Heinrich, A. K. 1955. Sezonnae ya'leniya v zooplanktone Beringova Morya. [Seasonal phenomena in the zooplankton of the Bering Sea]. MS Thesis, Inst. Okeanol., Moscow.

Heinrich, A. K. 1956a. On the production of copepods in the Bering Sea. Akad. Nauk SSSR, *Comptes Rendues, Doklady* 111:199-201.

Heinrich, A. K. 1956b. On seasonal races of *Calanus tonsus* in the Bering Sea. Akad. Nauk SSSR, Leningrad, *Doklady* 109(2):403-406.

Heinrich, A. K. 1956c. Size composition of Chaetognatha and their reproduction rates in the western regions of the Bering Sea. Akad. Nauk SSSR, *Doklady* 110(6):1105-1108.

Heinrich, A. K. 1957a. Multiplication and development of massive copepods in the Bering Sea. *Tr. Vses. Gidrobiol. Obsh.* 8:

Heinrich, A. K. 1957b. The propagation and development of the common copepods in the Bering Sea. *Trudy Vses. Gidrobiol. Obshch.* 8:143-162.

Heinrich, A. K. 1957c. Sutochnye Vertikal'nye migratsii zooplanktona v pribrekhnykh raionakh Beringova morya. *Izv. Tikhookean. Nauchno-Issled. Inst. Tybn. Khoz. Okeanogr.* Vol. 44:67-73.

Heinrich, A. K. 1959. Biological seasons in the plankton of the Bering Sea and horizontal distribution of zooplankton biomass. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* 30:107-114. [In Russian].

Heinrich, A. K. 1961a. A comparison of the seasonal changes of plankton in different regions of the World Ocean. I. Seasonal phenomena in the plankton of high and temperate latitudes. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* 51:57-81.

Heinrich, A. K. 1961b. The peculiarities of the main plankton communities in the Pacific. 10th Pacif. Sci. Congr., Honolulu. Abstr. of paper.

Heinrich, A. K. 1961c. Seasonal phenomenon in plankton of the World Ocean. I. Seasonal phenomenon in the plankton of high and temperate latitudes. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* 51:57-81.

Heinrich, A. K. 1962a. The life histories of plankton animals and seasonal cycles of plankton communities in the oceans. *J. Cons. Int. Explor. Mer* 27:15-24.

Heinrich, A. K. 1962b. On the production of copepods in the Bering Sea. *Int. Rev. Ges. Hydrobiol. Hydrog.* 47:465-469.

Heinrich, A. K. 1962c. Peculiarities of the main plankton communities in the Pacific. Akad. Nauk SSSR, Leningrad, *Trudy Inst. Okeanol.* Vol. 58: 114-134.

Heinrich, A. K. 1963. The filtering capacity of copepods in the boreal and tropical regions of the Pacific. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 61.

Heinrich, A. K. 1969. The ranges of neuston copepods in the Pacific Ocean. *Zool. Zhur.* 48(10):1456-1466.

Heinrich, A. K. 1972. Seasonal phenomena in the plankton of the northeast Pacific Ocean. *Okeanol.* 8(2):287-296; also *Oceanol.* 8(2):231-239. (English transl.).

Hennick, D. P. 1970. Reproductive cycle, size at maturity, and sexual composition of commercially harvested weathervane scallops (*Patinopecten caurinus*) in Alaska. *J. Fish. Res. Bd. Can.* 27(11):2112-2119.

Henry, D. P. 1942. Studies on the sessile cirripedia of the Pacific coast of North America. *Univ. Wash. Publ. Oceanogr.* 4(3):95-134.

Heron, G. A. 1964. Seven species of *Eurytemora* (Copepoda) from northwestern North America. *Crustaceana* 7(3):199-211.

Hida, T. S. 1957. Chaetognaths and pteropods as biological indicators in the North Pacific. *U.S. Fish Wildl. Serv., Spec. Sci. Rept. Fisheries* 215:1-13.

Hirano, Y. 1953. Migrating course of salmonoid fish in northwest areas of North Pacific as presumed by tag-experiments during the years 1917-1942. I. Dog salmon (*Oncorhynchus keta*) and humpback-salmon (*O. gorbuscha*). *Bull. Jap. Soc. Sci. Fish.* 18(10):544-557.

Hirano, Y. and H. Kondo. Unpublished. Salmon-tagging experiments in high seas of the North Pacific. Working paper of the Japanese Fisheries Agency, Tokyo, Japan dated September 1959. [Cited by Hartt, 1966].

Hirota, J. 1972. Laboratory culture and metabolism of the planktonic ctenophore, *Pleurobrachia bachei* A. Agassiz. *In* A. Y. Takenouti (ed.) *Biological Oceanography of the Northern North Pacific Ocean.* Idemitsu Shoten, Tokyo, Japan. pp. 465-484.

Hitz, C. R. 1965. Field identification of the northeastern Pacific rockfish (*Sebastodes*). U.S. Dept. Int., *Fish Wildl. Serv., Bur. Comm. Fish., Circ. No. 203.* 58 pp.

Hochachka, P. W. 1968. Regulation of blood glucose in the king crab. *In: R/V Alpha Helix Bering Sea Exped.* pp. 188-189.

Hochachka, P. W. and D. E. Schneider. 1968. Organization and control of metabolism in the king crab gill. *In: R/V Alpha Helix Bering Sea Exped.* pp. 195-205.

Hochachka, P. W. and D. E. Schneider. 1968. Temperature effects on the metabolism of juvenile king crabs. *In: R/V Alpha Helix Bering Sea Exped.* pp. 206-207.

Holmes, R. W. 1958. Surface chlorophyll a, surface primary production and zooplankton volumes in the eastern Pacific Ocean. *Rapp. Réun. Cons. Perm. Int. Explor. Mer* 144:109-116.

Holmquist, C. 1963. Some notes on *Mysis relicta* and its relatives in northern Alaska. *Arctic* 16:109-128.

Honjo, T. and T. Hanaoka. 1969. Diurnal fluctuations of photosynthetic rate and pigment contents in marine phytoplankton. *J. Oceanogr. Soc. Japan* 25(4):182-190.

Hood, D. W. (Principal Investigator). 1976. PROBES, Processes and Resources of the Bering Sea Shelf. Vol. II: PROBES Research Projects, Phase I. Submitted to Office of Polar Progr., NSF, Washington, D.C., Proposal No. P76-12.

Hood, D. W. and E. J. Kelley. 1974. *Oceanography of the Bering Sea with Emphasis on Renewable Resources.* Occ. Publ. No. 2, Inst. Mar. Sci., Univ. Alaska, Fairbanks. 623 pp.

Hood, D. W. and Y. Takenouti (convenors). 1975. Bering Sea Oceanography: An Update. Results of US-Japan Seminar/Workshop on Bering Sea Oceanography, Report R75-2, Inst. Mar. Sci., Univ. Alaska, Fairbanks, 292 pp.

Hoopes, D. T. and J. F. Karinen. 1971. Note on the longevity and growth of tagged king crabs in the eastern Bering Sea. *Proc. Alaska Sci. Conf.* 22:107.

Hoopes, D. T. and J. F. Karinen. 1972. Longevity and growth of tagged king crabs in the eastern Bering Sea. U.S. Natl. Mar. Fish. Serv., *Fish Bull.* 70(1):225-226.

Hoopes, D. T. J. F. Karinen, J. W. Greenough and M. J. Pelto. 1971. King and tanner crab research. *Int. N. Pacif. Fish. Comm., Annu. Rept. 1969*: 125-133.

Hopkins, T. L. 1969. Zooplankton standing crop in the Arctic Basin. *Limnol. Oceanogr.* 14(1):80-85.

Horikoshi, M. 1975. Benthological studies in the Bering Sea. *In* D. W. Hood and Y. Takenouti (convenors), Bering Sea Oceanography: An Update, Results of the US-Japan Seminar/Workshop on Bering Sea Oceanography, Report R75-2, Inst. Mar. Sci., Univ. Alaska, Fairbanks. pp. 123-129.

Horner, R. A. 1971. Ecology of arctic sea ice organisms. *Proc. Alaska Sci. Conf.* 22:124. An abstract.

Horner, R. and V. Alexander. 1972. Algal populations in Arctic sea ice, an investigation of heterotrophy. *Limnol. Oceanogr.* 17(3):454-458.

Horner, R., K. O. Coyle and D. R. Redburn. 1974. Ecology of the Plankton of Prudhoe Bay, Alaska. Rept. No. R-74-2, Inst. Mar. Sci., Univ. Alaska, Fairbanks. 78 pp.

Howell, A. B. and L. M. Huey. 1930. Food of the California gray and other whales. *J. Mammal.* 11(3):321-322.

Howell, B. J. 1968. Acid-base characteristics in normal and stressed king crabs. *In: R/V Alpha Helix Bering Sea Exped.* pp. 208-212.

Hsü, H. F. 1933. A new Nematoda *Anisakis alata* from the Walrus. *Peking Nat. Hist. Bull.* Vol. 8:59-62.

Hunt, G. L., Jr., M. W. Hunt, S. D. L. Causey, D. B. Schwartz and L. E. Holmgren. 1975. The reproductive ecology, foods, and foraging areas of seabirds nesting on St. Paul Island, Pribilof Islands. *In: Environmental Assessment of the Alaskan Continental Shelf; Principal Investigators. Reports July-September 1975, Volume 1.* Environmental Research Laboratories, Boulder, Colorado, 1975. pp. 127-242.

Hurley, D. E. ad J. L. Mohr. 1957. On whale lice (Amphipoda: Cyamidae) from the California gray whale, *Eschrichtius glaucus*. *J. Parasitol.* 43:352-357.

Ichihara, T. 1958. Gray whale observed in the Bering Sea. *Sci. Repts. Whales Res. Inst*, Tokyo 13:201-205.

Ichikawa, T. 1971. Particulate Organic Carbon and Nitrogen in the Eastern Pacific Ocean. MS thesis, Hokkaido University. 36 pp.

Ichimura, S., Y. Saiio and Y. Aruga. 1962. Photosynthetic characteristics of marine phytoplankton and their ecological meaning in the chlorophyll method. *Botanical Mag. Tokyo* 75:212-220.

Ievleva, M. Ya. 1951. Morphology and rate of embryonic development of Pacific salmon. *Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.* Vol. 34:123-130.

Ievleva, M. Ya. 1952. Morphology of the Kamchatka herring larvae at different developmental stages. *Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.* Vol. 37:249-258.

Iizuka, A. and M. Tamura. 1958. Planktological environment in the Bering Sea, northern North Pacific and Okhotsk Sea in the summer of 1957. *Bull. Hokkaido Regl. Fish. Res. Lab.* 19:25-32.

Ikeda, T. 1970. Relationship between respiration rate and body size in marine plankton animals as a function of the temperature of the habitat. *Bull. Fac. Fish., Hokkaido University* 21(2):91-112.

Ikeda, T. 1971a. Changes in respiration rate and in composition of organic matter in *Calanus cristatus* (Crustacea, Copepoda) under starvation. *Bull. Fac. Fish., Hokkaido University* 21(4):280-298.

Ikeda, T. 1971b. Preliminary shipboard culture experiments on the feeding and respiration of an oceanic copepod, *Calanus cristatus*, in the Bering Sea. *Bull. Plankton Soc. Japan* 18(1):5-14.

Ikeda, T. 1972. Chemical composition and nutrition of zooplankton in the Bering Sea. *In* A. Y. Takenouti (ed.), *Biological Oceanography of the Northern North Pacific Ocean.* Idemitsu, Shoten, Tokyo. pp. 433-442.

Ikeda, T. 1974. Nutritional ecology of marine zooplankton. *Mem. Fac. Fish. Hokkaido University* 22(1):1-97.

Institute of Marine Science. 1975. PROBES, Processes and Resources of the Bering Sea Shelf. Vol. I PROBES: An Integrated Research Plan for a Study of Processes and Resources in the Bering Sea Shelf. Univ. Alaska, Fairbanks.

International Fisheries Commission. 1953. Regulation and investigation of the Pacific halibut fishery in 1952. *Rept. Int. Fish. Comm.*, No. 20.

International Pacific Halibut Commission. 1957-1960. Regulation and Investigation of the Pacific halibut fishery in 1956-1960. *Rept. Intern. Pacif. Halibut Comm.*, Nos. 25, 27, 29, 30.

International North Pacific Fisheries Commission. 1962. Report concerning halibut stocks jointly managed by Canada and the United States in the Bering Sea, with particular references to catches and research. *Bull. Int. N. Pacif. Fish. Comm.*, No. 7.

Irving, L. and J. Krog. 1954. Body temperature of arctic and subarctic birds and mammals. *J. Appl. Physiol.* 6(11):667-680.

Irving, L., C. P. McRoy and J. J. Burns. 1970. Birds observed during a cruise in the ice-covered Bering Sea in March 1968. *Condor* 72:110-112.

Irving, L., L. J. Peyton, C. H. Bahn and R. S. Peterson. 1962. Regulation of temperature in fur seals. *Physiol. Zool.* 35(4):275-284.

Isaichikov, I. M. 1922. The sixth Russian Helminthological Expedition organized in 1921 in the Arctic Ocean. *Veterinarnogo Delo* 2/3:36-49.

Isaichikov, I. M. 1928. K. poznaniy paraziticheskikh chervei nekotorykh grupp pozvonochnykh Russkoi Arktiki (A study of the parasitic worms of some groups of vertebrates of the Russian Arctic). A. Trematodes, Moscow. *Trudy Morskoi Nauch Inst.* 3(2):81 pp.

Ishida, T. 1967. Age and growth of Alaska pollock in the East Bering Sea. *Bull. Hokkaido Fish. Res. Lab.* 32:1-7.

Isigaki, T. 1960. Where do pollock go after spawning? *Hokusiushi Geppo* 17(9).

Ito, J. 1964. Food and feeding habits of Pacific salmon (genus *Oncorhynchus*) in their oceanic life. *Bull. Hokkaido Reg. Fish. Res. Lab.* 29:85-97.

Ito, J. 1968. Distribution of Pacific salmon on the central subarctic and neighboring waters in April and May 1967. *Bull. Jap. Soc. Fish. Oceanogr.* 13:56-62. (English transl. in Int. N. Pacif. Fish. Comm., Doc. 1110.)

Ito, K. 1970. A consideration of feeding habits of planktonic copepods in relation to the structure of their oral parts. *Bull. Plankton Soc. Japan* 17(1):1-10.

Ito, K. and S. Kurahashi. 1955. On the egg distribution of Alaska pollock (*Theragra chalcogramma*) observed in Funka (Uchiura) Bay, 1955. III. Hokkaido Fish. Hatch., Sapporo, *Sci. Repts. Hokkaido Fish. Hatchery* 10(1)145-159.

Ivanenkov, V. N. 1961. Primary production of the Bering Sea. Akad. Nauk. SSSR, *Trudy Inst. Okeanol.* Vol. 55:36-56.

Ivankov, V. N. 1966. Biological Features of the Humpback Salmon in the Southern Kurile Islands. Candidate dissertation, Far East University, Vladivostok.

Ivankov, V. N. and V. L. Andreyev. 1969. Fecundity of Pacific salmon (genus *Oncorhynchus* spp.). *J. Ichthyol.* 9(1):59-66.

Ivanov, A. V. 1952. New Pogonophora of the Far Eastern Seas. *Zool. Zhur.* 31(3):372-391.

Ivanov, A. V. 1960. Data on the ecology and geographical distribution of Pogonophores. Akad. Nauk SSSR, Moscow. *Trudy Inst. Okeanol.* Vol. 34:3-20.

Ivanov, A. V. and A. A. Strelkov. 1949. Commercial Invertebrates of the Far Eastern Seas. Description of Structure and Atlas of Anatomy. Vladivostok.

Ivanov, B. G. 1962. Skopleniya krevetok v zapadnoi chasti Alyaskinskogo zaliva (Shrimp concentrations in the western part of the Gulf of Alaska). *Ryb. Khoz.* 1:14-17.

Ivanov, B. G. 1963. Some data on the biology of shrimp in the western part of the Gulf of Alaska. *Tr. Vses. Nauchno-Issled. Morsk. Inst. Rybn. Khoz. Okeanogr.* Vol. 48:218-230.

Ivanov, B. G. 1964a. Biology and distribution of shrimps during winter in the Gulf of Alaska and the Bering Sea. *In* P. A. Moiseev (ed.) *Soviet Fisheries Investigations in the Northeast Pacific. Part III.* Moscow. *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 53:176-190.

Ivanov, B. G. 1964b. Quantitative distribution of echinodermata on the shelf of the eastern Bering Sea. *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 49:126-146.

Ivanov, B. G. 1964c. Predvaritel'nye itogi izucheniya biologii i raspredeleniya krevetok v Pribylovskom raione Beringova morya (Results in the study of biology and distribution of shrimp in the Pribilof area of the Bering Sea). *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 49:115-125.

Ivanov, B. G. 1967. Patterns in the distribution of the norhtern shrimp *Pandalus borealis* Kr. in the Bering Sea and Gulf of Alaska. *Okeanol.* 7(5):920-926.

Ivanov, B. G. 1970. Distribution of the deep-sea prawn (*Pandalus borealis* Kr.) in the Bering Sea and Gulf of Alaska. *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 70:125-142.

Ivanova, E. I. 1955. 1. The smelts *Hypomesus* sp. 2. The smelt *Osmerus eperlanus* Steindachner. Geographic distribution of fishes and other commercial items of the Sea of Okhotsk and Bering Sea. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 14:35-41.

Ivashin, M. V. 1960. Znachenie razlichnykh ob'ektov v pitanie gorbatogo kita (The importance of various food items in the diet of the humpback wale). *Informatsionnyi Sbornik Vses. Nauchno-Issled. Inst. Morsk. Rybn. Knoz. Okeanogr.*, No. 8.

Iversen, J. A. and J. Krog. 1972a. Body temperature and resting metabolic rate in small petrels. *Norw. J. Zool.* 20(2):141-144.

Iversen, J. A. and J. Krog. 1972b. Body temperatures in active and resting Charadriform birds (Murres, Puffins and Auklets) at different ambient temperatures. *Norw. J. Zool.* 20(2):145-146.

Iversen, J. A. and J. Krog. 1973. Heat production and body surface area in seals and sea otters. *Norw. J. Zool.* 21:51-54.

Ivlev, V. S. 1955. Experimental Ecology and Nutrition of Fishes. Pishchepromizdat Moscow. (Transl. D. Scott, Yale Univ. Press, New Haven, 1961.) 302 pp.

Iwata, M. 1974. Population identification of Walleye Pollock, *Theragra chalcogramma* (Pallas), in the vicinity of Japan. Ph.D. Thesis, Hokkaido Univ., Hakodate. 133 pp.

Iwata, M. 1975. Population identification of walleye pollock, *Theragra chalcogramma* (Pallas), in the vicinity of Japan. *Mem. Fac. Fish., Hokkaido University* 22(2):193-258.

Izuka, A., T. Kurohagi, K. Ikuta and T. Imai. 1954. Composition of the food of Alaska pollack (*Theragra chalcogramma*) in Hokkaido with special reference to its local difference. *Bull. Hokkaido Reg. Fish. Lab.* 11:7-20.

Jackson, P. B. 1971. U.S.A. king and tanner crab fishery in the eastern Bering Sea. *Int. North Pacif. Fish. Comm., Ann. Rept.* 1971:122-128.

Jessee, W. F. 1968. Atherosclerosis in pinnipeds. *In: R/V Alpha Helix Bering Sea Exped.* pp. 78-80.

Johnson, H. C. 1959. King crab, shrimp and bottom fish explorations from Shumagin Islands to Unalaska, Alaska - summer and fall, 1957. U.S. Fish Wildl. Serv., *Comm. Fish. Rev.* 21(3):7-19.

Johnson, M. W. 1934. The life history of the copepod *Tortanus discaudatus* (Thompson and Scott). *Biol. Bull.* 67(1):182-200.

Johnson, M. W. 1936a. *Pachyptilus pacificus* and *Centraugaptilus porcellus* two new copepods from the North Pacific. Bull Scripps Inst. Oceanogr., Tech. Ser. 4(2):65-70.

Johnson, M. W. 1936b. The production and distribution of zooplankton in the surface waters of the Bering Sea and Bering Strait, Part II (B). Rept. Oceanogr. Cruise U.S. Coast Guard *Cutter Chelan* 1934. (Mimeo. Rept.)

Johnson, M. W. 1937. The developmental stages of the copepod *Eucalanus elongatus* var. *bungii* Giesbrecht. *Trans. Amer. Micr. Soc.* 54(1):79-98.

Johnson, M. W. 1938. Concerning the copepod *Eucalanus elongatus* Dana, and its varieties in the northeast Pacific. *Bull. Scripps Inst. Oceanogr., Tech. Ser.* 4(6):165-180.

Johnson, M. W. 1940. The study of species formation in certain *Eucalanus* copepods in the North Pacific. Sixth Pacif. Sci. Congr., Vol. III. Berkeley and Los Angeles.

Johnson, M. W. 1953. Studies on plankton of the Bering and Chukchi Seas and adjacent areas. *Proc. Seventh Pac. Sci. Cong.* 4:480-500.

Johnson, M. W. 1956. The plankton of the Beaufort and Chukchi Sea areas of the Arctic and its relation to the hydrography. *Arctic Inst. N. Amer. Tech. Paper* 1:1-32.

Johnson, M. W. 1958. Observations on inshore plankton collected during summer 1957 at Point Barrow, Alaska. *J. Mar. Res.* 17:272-281.

Johnson, M. W. 1961 (July). Zooplankton of some Arctic coastal lagoons of northwestern Alaska with description of a new species of *Eurytemora*. *Pacif. Sci.* 15:311-323.

Johnson, M. W. 1963. Zooplankton collections from the high polar basin with special reference to the Copepoda. *Limnol. Oceanogr.* 8:89-102.

Johnson, M. W. 1966. The nauplius larvae of *Eurytemora herdmani* Thompson and Scott, 1897 (Copepoda, Calanoida). *Crustaceana* 11(3):307-313.

Johnson, M. W. and E. Brinton. 1963. Biological species, water-masses and currents. *In* M. N. Hill (ed.), *The Sea, Ideas and Observations on Progress in the Study of the Seas.*, Vol. 2. Intersci. Publ., New York-London-Sydney. pp. 381-414.

Jordan, D. S. and G. A. Clark. 1898. The history, condition and needs of the herd of fur seals resorting to the Pribiloff Islands. Part I, *In: The Fur Seals and Fur Seal Islands of the North Pacific Ocean.* U.S. Govt. Print. Off. Washington, D.C. pp. 1-247.

Jordan, D. S. and C. H. Gilbert. 1899. The fishes of the Bering Sea. *In* D. S. Jordan (ed.), *The Fur Seals and Fur Seal Islands of the North Pacific Ocean*, Part III. U.S. Govt. Print. Off., Washington, D.C. pp. 433-510.

Jorgensen, C. B. 1955. Quantitative aspects of filter feeding in invertebrates. *Cambridge Philos. Soc. Biol. Rev.* 30(4):391-454.

Jorgensen, C. B. 1966. Biology of Suspension Feeding. Pergamon Press, Oxford, London, New York, Paris. 357 pp.

Jørgensen, E. G. 1966. Photosynthetic activity during the life cycle of synchronous *Skeletonema* cells. *Physiol. Plantarum* 19:789-799.

Kaganovskaya, S. M. 1949. Certain data on the distribution and biology of walleye pollock. *Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okean.* Vol. 29:179-181.

Kaganovskaya, S. M. 1950. Contribution to the knowledge of the pollock. *Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Knoz. Okeanogr.* Vol. 32: 103-119.

Kaganovskaya, S. M. 1958. Prospects for the development of Alaska pollock fisheries in the seas of the Far East. *In: Proceedings of a Conference on the Biological Principles of Ocean Fishing.* Akad. Nauk SSSR.

Kaganovskii, A. G. 1939. Discovery of shad herring in the western Bering Sea. Akad. Nauk SSSR, *Vestnik Dal'nevost. Filiala* No. 33(1).

Kaganovskii, A. G. 1949. Some aspects of the biology and population dynamics of the pink salmon. *Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.* Vol. 31:3-57.

Kaganovskii, A. G. 1955a. Char from the Bering Sea Basin. *Vopr. Ishtiol.* 3:54-56.

Kaganovskii, A. G. 1955b. 1. Herring - *Clupea harengus pallasi* (Walb.). 2. Chum salmon - *Oncorhynchus keta* (Walb.). 3. Humpback salmon - *Oncorhynchus gorbuscha* (Walb.). Geographic distribution of fishes and other commercial items of the Sea of Okhotsk and Bering Sea. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* 14:14-26.

Kaganovskii, A. G. 1955c. Main features of the behavior of pelagic fish and methods of detecting and forecasting their entry into the Far Eastern Seas. *Trudy Sovesk. po Voprosam Razvedki Povde. Ryb.* (1953g).

Kagei, N., T. Oshima and A. Takemura. 1967. Survey of *Aniskais* spp. (Anisakinae: Nematoda) in marine mammals on the coast of Japan. *Jap. J. Parasitol.* 16:427-435.

Kamba, M. 1974. Food and feeding habit of walleye pollock, *Theragra chalcogramma* (Pallas), in larval and juvenile stage in Funka Bay. MS Thesis, Hokkaido University, Hakodate. 35 pp.

Kamshilov, M. M. 1955. Feeding of *Beroe cucumis* Fabr. Akad. Nauk SSSR, *Doklady* 102(2):399-402.

Kamshilov, M. M. 1960a. Biology of ctenophores off Murman. Cons. Int. Explor. Mer., Committee Meeting 1960, Document No. 157 (Mimeo). 5 pp.

Kamshilov, M. M. 1960b. Feeding of the ctenophore *Beroe cucumis* Fabr. Akad. Nauk SSSR, Leningrad, *Doklady* 130(5):1138-1140.

Kanno, Y., and J. Hamai. 1971. Food of salmonid fish in the Bering Sea in summer of 1966. *Bull. Fac. Fish. Hokkaido University* 22(2):107-128.

Karohji, K. 1958. Report from the Oshoro Maru on oceanographic and biological investigations in the Bering Sea and northern North Pacific in the summer of 1955. IV. Diatom standing crops and the major constituents of the populations as observed by net sampling. *Bull. Fac. Fish. Hokkaido University* 8(4):243-252.

Karohji, K. 1959. Report from the Oshoro Maru on oceanographic and biological investigations in the Bering Sea and northern North Pacific in the summer of 1955. VI. Diatom associations as observed by underway samplings. *Bull. Fac. Fish. Hokkaido University* 9(4): 259-267.

Karohji, K. 1972. Regional distribution of phytoplankton in the Bering Sea and western and northern subarctic regions of the north Pacific Ocean in summer. *In* A. Y. Takenouti (ed.), *Oceanography of the Northern North Pacific Ocean.* Idemitsu Shoten, Tokyo. pp. 99-115.

Kashkina, A. A. 1965a. Reproduction of yellowfin sole (*Limanda aspera* [Pallas]) and changes in its spawning stocks in the eastern Bering Sea. *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* 59:182-190.

Kashkina, A. A. 1965b. The winter fish plankton in the area of the Commander Islands. Soviet fisheries research in the northwestern Pacific. *Tr. Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* 58:170-181.

Kawaguchi, K. 1969. Diurnal vertical migration of micronektonic fish in the western North Pacific. *Bull. Plankt. Soc. Japan* 16(1):63-66.

Kawamura, A. 1970a. Does whale vomit stomach contents? *Geiken-tsushin* 225:1-6.

Kawamura, A. 1970b. On *Sergestes similis* Hansen, a newly found food staff of baleen whales in the North Pacific pelagic whaling in 1969 and 1970 seasons. *Geiken-tsushin* 231:1-7. [In Japanese].

Kawamura, T. 1963. Preliminary survey of primary production in the northern North Pacific and Bering Sea, June-August 1960. *Inf. Bull. Planktol. Japan* 10:25-35. [In Japanese, with Engl. Summ.].

Kawarada, Y. 1957. A contribution of microplankton observations to the hydrography of the northern North Pacific and adjacent seas. II. Plankton diatoms in the Bering Sea in the summer of 1955. *J. Oceanogr. Soc. Japan* 13(4):151-155.

Kawarada, Y. and M. Ohwada. 1957. A contribution of microplankton observations to the hydrography of the northern North Pacific and adjacent seas. I. Observations in the western North Pacific and Aleutian waters during the period from April to July 1954. *Oceanogr. Mag.* 9:149-158.

Kawarada, Y. and A. Sano. 1969. Distribution of chlorophyll and phaeophytin in the western North Pacific. *Oceanogr. Mag.* 21(2):137-146.

Kawarada, Y. and A. Sano. 1972. Distributions of chlorophyll a and phaeopigments in the northwestern North Pacific in relation to the hydrographic conditions. *In* A. Y. Takenouti (ed.), *Biological Oceanography of the Northern North Pacific Ocean.* Idemitsu Shoten, Tokyo, Japan. pp. 125-138.

Kelley, E. J. and D. W. Hood (eds.). 1974. PROBES: A Prospectus on Processes and Resources of the Bering Sea Shelf. Inst. Mar. Sci., Univ. Alaska, Fairbanks Public. Information Bull. 74-1. 71 pp.

Kellogg, R. 1929 What is known of the migration of some of the whalebone whales. *Smithsonian Report* No. 2997.

Kellogg, R. 1940. Whales, giants of the sea. *Nat. Geogr. Mag.* 77:35-90.

Kenyon, K. W. 1949. Distribution of the Pacific kittiwake in November and December of 1948. *Condor* 51(4):188.

Kenyon, K. W. 1956. Food of fur seals taken on St. Paul Island, Alaska, 1954. *J. Wildl. Mgmt.* 20(2):214-215.

Kenyon, K. W. 1961. Cuvier beaked whales stranded in the Aleutian Islands. *J. Mammal.* 42(1):71-76.

Kenyon, K. W. 1965. Food of harbor seals of Amchitka Island, Alaska. *J. Mammal.* 46(1):103-104.

Kenyon, K. W. and J. W. Brooks. 1960. Birds of Little Diomede Island, Alaska. *Condor* 62(6):457-463.

Kenyon, K. W. and D. W. Rice. 1961. Abundance and distribution of the Stellar sea lion. *J. Mammal.* 42(2):223-234.

Ketchen, K. S. 1956. Climatic trends and fluctuations in yield of marine fisheries of the northeast Pacific. *J. Fish. Res. Bd. Can.* 13(3):357-374.

Ketchen, K. S. 1961. Observations on the ecology of the Pacific cod (*Gadus macrocephalus*) in Canadian waters. *J. Fish. Res. Bd. Can.* 18(4):513-558.

Khak, S. M. 1966. Comparative study of the physiology of feeding of copepods *Metridia longa* and *M. lucens* in the Men Bay. 2nd Intern. Oceanogr. Congr. Summaries of papers, Moscow.

Kihara, K. and M. Uda. 1969. Studies on the formation of demersal fishing grounds. 1. Analytical studies on the mechanism concerning the formation of demersal fishing grounds in relation to the bottom water masses in the eastern Bering Sea. *J. Tokyo Univ. Fish.* 55(2):83-90.

Kim, K. C. 1972. Ecology and morphology of the sucking lice (Anoplura, Echinophthiruidae) on the northern fur seal. *Rapp. P. V. Réun. Cons. Int. Explor. Mer.* 169:504-515.

King, J. E. 1949. Experimental fishing trip to Bering Sea. *Comm. Fish. Rev.* 11(1):1-13, and *U.S. Fish. Wildl. Serv., Fish. Leaflet* #330, 13 pp.

Kiselev, I. A. 1937. Zusammensetzung und Verteilung des phytoplanktons im nordlichen Teil des Beringmeeres und im sublichen Teil des Tschuktschenemeeres. *Issled. Morei, SSSR* Vol. 25:217-245.

Kiselev, I. A. 1947. Phytoplankton of the Far Eastern Seas as an indicator of some characteristics of the hydrological regime. *Trudy Gosudar. Okeanogr. Inst.* No. 1(13).

Kiselev, I. A. 1950. *Marine and freshwater dinoflagellates of the U.S.S.R.* Moscow-Leningrad, Izd. Akad. Nauk SSSR.

Kitano, K. 1958. Oceanographic structure of the Bering Sea and the Aleutian waters. Pts. 1 and 2. *Bull. Hokkaido Regl. Fish. Res. Lab.*, No. 19.

Kitou, M. 1958. Distribution of plankton copepods at the ocean weather station "X", May 1950 to April 1951. *Oceanogr. Mag.* 10(2):193-199.

Kjellman, F. 1889. Om Beringhafvets Algflora. *Sv. Vet. Akad. Handl.* 23(8).

Klatter, R. I. 1966. Microdistribution and schooling behavior of pelagic mysids, *Vtoroi Mezhdunarodnyi okeanograficheskii kongress, 30 maya - 9 iyunya 1966 g. Synopses of Reports.* Moscow, Izdatel'stvo, "Nauka".

Kleie, E. F. 1959. Tekhnokhimicheskaya kharakteristika nekotorykh ryb Beringova morya (Technological and chemical characteristics of several Bering Sea fishes). *Rybn. Khoz.* 8:56-59.

Klekovski, R. Z., I. V. Kukina and N. I. Tumantseva. 1975. Rate of plankton metabolism. Akad. Nauk SSSR, Leningrad. *Trudy Inst. Okeanol.*, Vol. 104.

Klumov, S. K. 1937. Saika (*Boreogadus saida*) i ee znachenie diya nekotorykh protsessov Arktiki [The pollock (*Boreogadus saida*) and its role in some of the processes of Arctic life]. *Izv. Akad. Nauk SSSR, Ser. Biol.* 1:175-188.

Klumov, S. K. 1949. Arctic cod - *Boreogadus saida* (Lepechin). Promysl. Ryby SSSR. Pistchepromizdat.

Klumov, S. K. 1955. Location of whale schools. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 18:7-27.

Klumov, S. K. 1956. Some results of an expedition to the Bering Sea and the Kurile Islands. Akad. Nauk SSSR, *Vestnik*, No. 5.

Klumov, S. K. 1958. Relationships of plankton biomass and the baleen whale catch in the northwestern Pacific Ocean. *Rybn. Khoz.* No. 11:16-20.

Klumov, S. K. 1959. Osonovnye rezul-taty raboty ekspeditsii Instituta okeanologii AN SSSR i TINRO po izucheniyu dal'nevastochnykh kitoobraznykh v 1951-1956 gg (General results of the research of the expedition of the Oceanology Institute of the Academy of Sciences of the U.S.S.R. and TINRO on the investigation of Far Eastern Cetacea in 1951-1956). Akad Nauk SSSR, *Fondy Inst. Okeanol*, part 2.

Klumov, S. K. 1961. Plankton and the feeding of the whalebone whales (Mystacoceti). Akad. Nauk SSSR, Leningrad. *Trudy Inst. Okeanol.* Vol. 51:142-156.

Klumov, S. C. 1962. The right whales in the Pacific Ocean. Akad. Nauk SSSR, Leningrad. *Trudy Inst. Okeanol.* Vol. 58:202-297.

Klumov, S. K. 1963. Feeding and helminth fauna of baleen whales in the main fishery regions of the world's oceans. Akad. Nauk SSSR, Leningrad. *Trudy Inst. Okeanol.* Vol. 71:94-194.

Klyashtorin, L. B. 1962. Diatom incrustation of whales of the Far Eastern Seas. Akad. Nauk SSSR. *Trudy Inst. Okeanol.* Vol. 58:314-321.

Klyashtorin, L. B. and A. A. Yarzhombek. 1973. Energy consumption in active movements of planktonic organisms. *Okeanol.* 13(4):697-703; also *Oceanol.* 13(4):575-580. (English translation).

Klyuge, G. A. 1952. Bryozoa of the Chukchi Sea and the Bering Strait. Sbornik: *Krainii Severo Vostok SSSR*, Vol. 2.

Klyuge, G. A. 1961. List of Bryozoan Species of the U.S.S.R. Far Eastern Seas. *Issled. Dal'nevost. Morei SSSR* 7:118-143.

Kobayashi, H. A. 1974. Growth cycle and related vertical distribution of the thecosomatous pteropod *Spiratella (Limacina) helicina* in the Central Arctic Ocean. *Mar. Biol.* 26:295-301.

Kobayashi, K. 1957. 1956 cruise of the *Oshoro Maru* to the Bering Sea. Fac. Fish. Hokkaido Univ. *Data Rec. Oceanogr. Observ. Explor. Fish.*, No. 1.

Kobahashi, K. 1957. Cruise of the *Oshoro Maru* to the Bering Sea and Northern Pacific. Fac. Fish. Hokkaido Univ. *Data Rec. Oceanogr. Observ. Explor. Fish.*

Kobayashi, K. 1957. Larvae and young of sablefish *Anaplopoma fimbria* (Pallas) from the sea near the Aleutian Islands. *Bull. Jap. Soc. Sci. Fish.* 33(7&8):376-382.

Kobayashi, K. 1958. Cruise of the *Oshoro Maru* to Aleutian waters. *Data Rec. Oceanogr. Observ. Explor. Fish.*, No. 2.

Kobayashi, K. 1959. *Oshoro Maru* cruise 42 to the Bering Sea. Fac. Fish. Hokkaido Univ. *Data. Rec. Oceanogr. Observ. Expl. Fishing*, No. 3.

Kobayashi, K. 1960. The *Oshoro Maru* cruise 44 to the Bering Sea in June-July. Fac. Fish. Hokkaido Univ. *Data. Rec. Oceanogr. Observ. Expl. Fishing*, No. 4.

Kobayashi, K. 1961a. Larvae and young of the sand lance, *Ammodytes hexapterus* Pallas from the North Pacific. *Bull. Fac. Fish. Hokkaido University* 12(2):111-120.

Kobayashi, K. 1961b. The *Oshoro maru* cruise 46 to the Bering Sea and North Pacific in June-August 1960. Fac. Fish. Hokkaido University. *Data Rec. Oceanogr. Observ. Expl. Fishing*, No. 5.

Kobayashi, K. 1962a. The *Hokusei Maru* cruise 10 (1-3) to the north-western Pacific in June-August. Fac. Fish. Hokkaido Univ. *Data Rec. Oceanogr. Observ. Explor. Fish.*, No. 6.

Kobayashi, K. 1962b. The *Oshoro Maru* cruise 48 to the Bering Sea and Northwestern Pacific in June-July 1961. Fac. Fish. Hokkaido Univ. *Data Rec. Oceanogr. Observ. Explor. Fish.*, No. 6.

Kobayashi, K. 1964a. Larvae and young of the whiting, *Theragra chalcogramma* (Pallas) from the North Pacific. *Bull. Fac. Fish. Hokkaido University* 14(2):55-63.

Kobayashi, K. 1964b. The *Oshoro Maru* cruise 4 to the Bering Sea and North Pacific. Fac. Fish. Hokkaido Univ. *Data Rec. Oceanogr. Observ. Explor. Fish.*, No. 8.

Koblentz-Mishke, O. J. 1957. O produktsii fitoplanktona v severo-zapadnoi chasti Tikhogo okeana vesnoi 1955g (On phytoplankton production in the northwestern Pacific Ocean in spring 1955). Akad. Nauk SSSR, *Doklady* 116(6):1029-1032.

Koblentz-Mishke, O. J. 1960. On the study of primary production in the sea by Soviet scientists. *Int. Rev. Ges Hydrobiol.* 45(3):319-326.

Koblentz-Mishke, O. J. 1960. Vidovoi sostav fitoplanktona i pervichnaya produktsiya v severo-vostochnoi chasti Tikhogo okeana (Specific composition of phytoplankton and primary production in the northeastern Pacific). Akad. Nauk SSSR, *Trudy Inst. Okeanol.* 45:172-189.

Koblentz-Mishke, O. J. 1961. The geographic aspect of primary production in the sea. *In: Primary Production of Seas and Inland Waters.* Minsk.

Koblentz-Mishke, O. J. 1963. Summary of data on primary production measurements for the North Pacific. *Okeanol. Issled.*, No. 8.

Koblentz-Mishke, O. J. 1965a. Primary production in the Pacific. *Okeanol.* 5(2):325-327; also *Oceanol.* 5(2):104-116. (Engl. translation).

Koblentz-Mishke, O. J. 1965b. Primary production. *In* Tikhiy okean. VII. *Biologiya tikhogo okeana, Kn. I. Plankton* (Pacific Ocean. VII. *Biology of the Pacific Ocean Vol. I Plankton*). Akad. Nauk SSSR, Trudy. Inst. Okeanol., Izd. Nauka.

Koblentz-Mishke, O. J. 1967. Primary production. *In* B. G. Bogorov (ed.), *The Pacific Ocean*, Vol. 1. Izd "Nauka", Moscow. pp. 86-97.

Koblentz-Mishke, O. J., O. D. Bekasova, V. I. Vedernikov, B. V. Konovalov, V. W. Sapozhnikov and V. A. Terskisk. 1972. Photosynthesis, pigments and underwater irradiation in the area of the Kurile-Kamchatka Trench during the summer of 1966. *In: Biological Oceanography of the Northern North Pacific Ocean* (A. Y Takenouti, ed.) Idemitsu Shoten, Tokyo, Japan. pp. 263-274.

Koblentz-Mishke, O. J., A. K. Karelin and V. A. Rutkovskaya. 1966. [The Unusual Form of Curves Showing the Effect of Depth on the Amount of Photosynthesis by Homogenous Phytoplankton in the Sea] II. Synopses of Reports. Moscow, Izdatel'stvo "Nauka".

Koblentz-Mishke, O. J. and M. V. Kozlyaninov. 1966. Vertical distribution of phytoplankton and transparency in the North Pacific. Akad. Nauk SSSR, *Doklady* 166(2):459-461.

Koblentz-Mishke, O. J., O. D. Bekasova, V. I. Vedernikov, B. V. Konovalov, V. W. Sapozhnikov and V. A. Terskikh. 1970. Primary production and pigments in the area of the Kurile-Kamchatka Trench in the summer of 1966. Akad. Nauk SSSR, Leningrad, *Tr. Inst. Okeanol.* Vol. 86:77-98.

Koblentz-Mishke, O. J., V. V. Volkoninskii, and Yu. G. Kabanova. 1968. Distribution and magnitude of the primary production of the oceans. *Sbornik Nauchno-Technicheskoi Informatsii VNIRO* No. 5.

Kodolov, L. S. 1968. Some peculiarities in the reproduction of black cod [*Anaplopoma fimbria* (Pall.)]. *Vopr. Ikhtiol.* 8(4):662-668.

Kodolov, L. S. 1970. Squids of the Bering Sea. *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 70:157-160.

Kokubo, S. 1932. Quantitative studies on microplankton in Aomori Bay during 1929-1930. *Rec. Oceanogr. Works in Japan* 4:171-244.

Koltun, V. M. 1955. New genera and species of sponges from the Sea of Okhotsk and the Bering Sea. Akad. Nauk SSSR, *Trudy Zool. Inst.* Vol. 18: 13-25.

Komaki, Y. 1960. On euphausiids collected on the second cruise of the Japanese expedition of deep sea (JEDS-2). *J. Oceanogr. Soc. Jpn.* 16(4):29-41.

Komaki, Y. 1967. On the surface swarming of euphausiid crustaceans. *Pacif. Sci.* 21(4):433-448.

Kon, S. K. and S. Y. Thompson. 1949. Preformed vitamin A in northern krill. *Biochem. J.* 45(5):xxxi.

Kondakov, N. N. 1941. Cephalopoda of the USSR Far Eastern Seas. *Issled. Dal'nevost. Morei SSSR* No. 1.

Kondo, H., Y. Hirano, N. Nakayama and M. Miyake. 1965. Offshore distribution and migration of Pacific salmon (genus *Oncorhyncus*) based on tagging studies (1958-1961). *Int. N. Pacif. Fish. Commn. Bull.* 17, 213 pp.

Konovalov, S. M. 1963. Possible use of certain parasites as indicators of local schools of sockeye in the sea. *Tezisy Dokladov na Soveshchanii molodykh uchenykh*, Moscow.

Konovalov, S. M. 1967. Some data on the distribution of local stocks of *Oncorhynchus nerka* (Walbaum) in the northern Pacific Ocean. *Vopr. Ikhtiol.* 7(6):1086-1099.

Konovalov, S. M. 1967. The use of parasitological data to discriminate local populations of Far Eastern salmon. *Parazitolog. Sb. Zool. Inst. Akad. Nauk. SSSR* 23:236-249.

Konzhukova, E. D. 1957. Plechenogie (Brachiopoda) dal'nevostochnykh morei SSSR [Brachiopoda of the Far Eastern Seas of the U.S.S.R]. Izd. Akad. Nauk SSSR, Moscow, *Issled. Dal'nevost. Morei* No. 4:5-84.

Koo, T. S. Y. 1955. *Biology of the Red Salmon, Oncorhynchus nerka (Walbaum) of Bristol Bay, Alaska as revealed by a Study of Their Scales.* Ph.D. Thesis, University of Washington. 164 pp.

Koo, T. S. Y. (ed.). 1962. *Studies of Alaska Red Salmon.* University of Washington Press, Seattle.

Kooyman, G. L., R. L. Gentry and W. B. McAlister. 1977. Physiological impact of oil on pinnipeds. *In: Environmental Assessment of the Alaskan Continental Shelf, Vol. 3.* Environmental Res. Lab., Boulder, Colorado. pp. 3-26.

Korolev, N. G. 1964. Biology and fishing of the king crab *Paralithodes camtschatica* (Tilesius) in the southeastern part of the Bering Sea. *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 49: 102-108.

Korotkevich, V. S. 1955. *Pelagic Nemertea of the Far Eastern Seas of the U.S.S.R.* Moscow-Leningrad, Izd. Akad. Nauk SSSR.

Korotkevich, V. S. 1958. Pelagic nemertines of the Far Eastern Seas of the U.S.S.R reviewed by N. A. Livanov. *Zool. Zhur.* 37(7):1106-1107.

Kort, V. G. (ed.). 1967. *Biology of the Pacific Ocean. Book I Plankton.* Akad. Nauk SSSR, Moscow, Izd. "Nauk", 268 pp.

Kort, V. G. (ed.). 1967. *Biology of the Pacific Ocean. Book III Fishes of the Open Waters.* Akad. Nauk SSSR, Moscow, Izd. "Nauk".

Kort, V. G. (ed.). 1969. *Biology of the Pacific Ocean. Book II The Deep-Sea Bottom Fauna, Pleuston.* Akad. Nauk SSSR, Moscow, Izd. "Nauk", 268 pp.

Koslow, J. A. 1975. Anatomy of a modern fishery: the Bering Sea pollock fishery. *J. Mar. Tech. Soc.* 10(1):28-34.

Kostarev, V. L. 1965. The fecundity of the Okhotsk pink salmon. *Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Oceanogr.* Vol. 59:145-155.

Kosygin, G. M. 1966a. Distribution and biology of seals in the Bering Sea (Spring and Summer 1963). *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 58:117-124.

Kosygin, G. M. 1966b. Nekotorye materialy po pitaniyu lakhtaka v Beringovom more v vesenne-letnii period [Some data on the diet of the bearded seal in the Bering Sea in spring and summer]. *Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.* Vol. 58:153-157.

Koto, H. and T. Fujii. 1958. Structure of the waters in the Bering Sea and the Aleutian region. *Bull. Hokkaido Reg. Fish. Res. Lab.* 19:10-24.

Kotori, M. 1969. Vertical distribution of chaetognaths in the northern North Pacific and Bering Sea. *Bull. Plankton Soc. Japan* 16(1):52-57.

Kotori, M. 1972. Vertical distribution of chaetognaths in the northern North Pacific Ocean and Bering Sea. *In* A. Y. Takenouti (ed.), *Biological Oceanography of the Northern North Pacific Ocean.* Idemitsu Shoten, Tokyo, pp. 291-308.

Kotori, M. 1974. Ecological Studies of Chaetognaths in the Bering Sea and Northern Pacific Ocean. Ph.D. Thesis, Hokkaido Univ., 81 pp. [In Japanese].

Kotori, M. 1975. Newly hatched larvae of *Sagitta elegans*. *Bull. Plankton Soc. Japan* 21(2):113-114.

Koyama, T., A. Kobayashi, M. Kumada, Y. Komiya, T. Oshima, N. Kagei, T. Ishii and M. Machida. 1969. Morphological and taxonomical studies on Anisakidae larvae found in marine fishes and squids. *Jap. J. Parasitol.* 18:466-487. [In Japanese with Engl. abstract].

Krashkina, A. A. 1970. Summer ichthyoplankton of the Bering Sea. *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 70:225-247.

Krause, A. 1885. Ein Beitrag zur kenntnis der Mollusken-fauna des Beringsmeeres. I. Brachiopoda et Lamellibranchiata. *Archiv für Naturgeschichte* 51(1):14-40.

Krishnaswamy, S. 1959. *Metabolic Studies on Marine Parasitic Copepods and on Certain Zooplankton Species.* Ph.D. Thesis, Univ. Southampton.

Kriss, A. E. 1952. Microbial Population of the Chukchi Sea and the Bering Strait. *In* Sbornik: *Krainii Severo-Vostok SSSR* Vol. 2.

Kriss, A. E. and V. I. Birjuzova. 1955. Vertical distribution of microorganisms in the Kurile-Kamchatka Trench of the Pacific Ocean. Akad. Nauk SSSR, *Doklady* 100(6):1175-1178.

Krivobok, M. N. and O. I. Tarkovskaya. 1964. Chemical characteristics of yellowfin sole, cod and Alaska pollock in the southeastern part of the Bering Sea. *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 49:271-287.

Krogius, V. F. and Ye. M. Krokhin. 1956. The results of research on the biology of the sockeye, the state of its commercial stocks and fluctuations in its abundance in Kamchatkan waters. *Vopr. Ikhtiol.* No. 7:3-20.

Krylov, V. I. 1962. Distribution rate of the Pacific walrus. *Zool. Zhur.* 41(1):116-120.

Krylov, V. I. 1968. Present condition of the Pacific walrus stocks and prospects of their rational exploitation. *In* V.A. Arsen'ev and K. I. Panin (eds.), Pinnipeds of the North Pacific. *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 68:185-200.

Kubo, T., Y. Hirano, S. Sano, K. Taguchi and H. Kasahara. 1955. On the salmon in waters adjacent to Japan - a biological review. *Bull. Int. N. Pacif. Fish. Comm.* No. 1:57-92.

Kulikov, M. Yu. 1965. Vertical distribution of sablefish [*Anoplopoma fimbria* (Pallas)] on the Bering Sea continental slope. *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 58:157-161.

Kulikova, E. B. 1957. Growth of deep-sea fishes. Akad. Nauk SSSR, Moscow, *Trudy Inst. Okeanol.* Vol. 20:347-355.

Kun, M. S. and L. V. Mikulich. 1954. Diet of commercial Far Eastern crabs in summer. *Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.* Vol. 41:319-332.

Kurata, H. 1959. Studies on the larva and post-larva of *Paralithodes camtschatica*. I. Rearing of the larvae, with special reference to the food of the zoea. *Bull. Hokkaido Reg. Fish. Res. Lab.* 20:76-83.

Kurata, H. 1960. Last stage zoea of *Paralithodes camtschatica* with intermediate forms between normal last stage zoea and glaucothoe. *Bull. Hokkaido Reg. Fish. Res. Lab.* 22:49-56.

Kurata, H. 1960. Studies on the larva and post-larva of *Paralithodes camtschatica*. II. Feeding habits of the zoea. *Bull. Hokkaido Reg. Fish. Res. Lab.* No. 21:1-8.

Kurata, H. 1960. Studies on the larvae and post-larvae of *Paralithodes camtschatica*. III. The influence of temperature and salinity on the survival and growth of the larva. *Bull. Hokkaido Reg. Fish. Res. Lab.* 21:9-14.

Kurata, H. 1963. Larvae of decapoda Crustacea of Hokkaido. II. Majidae. *Bull. Hokkaido Reg. Fish. Res. Lab.* 27:25-31.

Kurata, H. 1964a. Larvae of decapoda Crustacea of Hokkaido. III. Pandalidae. *Bull. Hokkaido Reg. Fish. Res. Lab.* 28:23-34.

Kurata, H. 1964b. Larvae of decapoda Crustacea of Hokkaido. IV. Crangonidae and Gliphocrangonidae. *Bull. Hokkaido Reg. Fish. Res. Lab.* 28:35-50.

Kurochkin, E. N. 1963. Raspredelenie nekotorykh vidov morskikh ptits v severnoi chasti Tikhogo okeana [Distribution of certain sea bird species in the North Pacific Ocean]. *Zool. Zhur.* 42(8):1223-1231.

Kuroda, N. 1955. Observation on pelagic birds of the Northwest Pacific. *Condor* 57(5):290-300.

Kuroda, N. 1960. Analysis of seabird distribution in the northwest Pacific Ocean. *Pacif. Sci.* 14(1):55-67.

Kusakin, O. G. 1962. Fauna of Munnidae (Isopoda, Asellota) of the Far Eastern Seas of the U.S.S.R. Akad. Nauk SSSR, *Trudy Zool. Inst.* Vol. 30.

Kuz'mina, A. I. 1959. Some data on spring-summer phytoplankton of the northern Kurile area. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 36: 215-229.

Kuznetsov, A. P. 1957. Polya pitaniya donnykh promyslovykh ryb i kanchatskovo kraba v raione severnykh kuril'skikh ostrovov [Feeding grounds of commercial benthic fishes and king crab in the northern Kurile Islands area]. *Rybn. Khoz.* No. 10:44-46.

Kuznetsov, A. P. 1961. On the ecology of some common benthic organisms from Eastern Kamchatka and the northern Kuril Islands. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 46:85-97.

Kuznetsov, A. P. 1963. *Fauna of Benthic Invertebrates in Kamchatka Waters of the Pacific Ocean and the Northern Kurile Islands.* Moscow, Izd. Akad. Nauk SSSR.

Kuznetsov, A. P. 1964. Distribution of benthic fauna in the western Bering Sea by trophic zones and some general problems of trophic zonation. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 69:98-177 (Engl. transl. by U.S. Naval Oceanogr. Off., Transl. No. 400).

Kuznetsov, A. P. and M. N. Sokolova. 1961. O kharaktere pitaniya raspredeleniya *Ophiopholis aculeata* [Feeding and distribution of *Ophiopholis aculeata*]. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 46: 98-102.

Kuznetsov, I. I. 1928. Some observations on the reproduction of the Amur and Kamchatka salmon. *Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.* 2(3):1-195.

Laevastu, T., J. Dunn and F. Favorite. 1976. Consumption of copepods and euphausids in the eastern Bering Sea. *Cons. Inst. Explor. Mer, Plankton Committee, C.M. 1976/L:34*, 10 pp.

Laevastu, T. and F. Favorite. 1977. Evaluation of standing stocks of marine resources in the Eastern Bering Sea. *In: Environmental Assessment of the Alaskan Continental Shelf, Vol. 3.* Environmental Res. Lab., Boulder, Colorado. pp. 91-148.

LaLanne, J. J. 1971. Marine growth of chum salmon. *Int. N. Pacif. Fish. Comm. Bull.* 27:71-91.

Lander, R. H. and G. K. Tanonaka. 1964. Marine growth of western Alaskan sockeye salmon (*Oncorhynchus nerka* Walbaum). *Int. N. Pacif. Fish. Comm. Bull.* 14:1-31.

Landrum, B. J. and T. A. Dark. 1968. The distribution of mature western Alaskan and Kamchatkan sockeye salmon (*O. nerka*) in the North Pacific Ocean and Bering Sea. *Int. N. Pacif. Fish. Comm. Bull.* 24, 110 pp.

Lapin, Yu. E. 1963. The age and population dynamics of Pacific pink salmon, *Oncorhynchus gorbuscha* Walb. *Vopr. Ikhtiol.* 3(2):243-255.

Lapin, Yu. E. 1964. Peculiarites in abundance dynamics of Pacific Ocean pink salmon, *Oncorhynchus gorbuscha* (Walbaum). *Vopr. Ikhtiol.* 4(2): 233-242.

Larrance, J. D. 1971. Primary productivity in the mid-Subarctic Pacific Ocean region, 1966-1968. *Fish. Wildl. Serv., Fish. Bull.* 69:595-613.

Lasker, R. 1960. Utilization of organic carbon by a marine crustacean: analysis with carbon-14. *Science* 131(3406):1098-1100.

Lasker, R. 1966. Feeding, growth, respiration and carbon utilization of a euphausiid Crustacean. *J. Fish. Res. Bd. Can.* 23(9):1291-1317.

Lea, H. E. 1955. The chaetognaths of western Canadian coastal waters. *J. Fish. Res. Bd. Can.* 12(4):593-617.

Lebour, M. V. 1922. The food of plankton organisms. *J. Mar. Biol. Assoc. U.K.* 12(4):644-677.

LeBrasseur, R. J. 1959. *Sagitta scripsae*, a biological indicator species in the subarctic waters of the eastern Pacific Ocean. *J. Fish. Res. Bd. Can.* 16(6):795-805.

LeBrasseur, R. J. 1964. A preliminary checklist of some marine plankton from the northeastern Pacific Ocean. *Fish. Res. Bd. Can., M.S. Rept. Series* 174:1-14.

LeBrasseur, R. J. 1965a. Biomass atlas of net zooplankton in the northeastern Pacific Ocean, 1956-1964. *Fish. Res. Bd. Can., M.S. Rep. Ser. (Oceanogr. Limnol.)* 201: 14 pp.

LeBrasseur, R. J. 1965b. Seasonal and annual variations of net zooplankton at Ocean Station P 1956-1964. *Fish. Res. Bd. Can., M.S. Rep. Ser. No. 202*, 163 pp.

LeBrasseur, R. J. 1965c. Stomach contents of salmonids caught in the northeastern Pacific Ocean, 1958. *Fish. Res. Bd. Can. Circ. (Statistical Ser.)* 1(15):1-39.

LeBrasseur, R. J. 1966. Stomach contents of salmon and steelhead trout in the northeastern Pacific Ocean. *J. Fish. Res. Bd. Can.* 23(1):85-100.

LeBrasseur, R. J. 1972. Utilization of herbivore zooplankton by maturing salmon. *In* A. Y. Takenouti (ed.), *Biological Oceanography of the Northern North Pacific Ocean.* Idemitsu Shoten, Tokyo, Japan. pp. 581-588.

LeBrasseur, R. J. and D. A. Doidge. 1966. Stomach contents of salmonids caught in the northeastern Pacific Ocean, 1956, 1957, 1959, 1960, 1962, 1963 and 1964. *Fish. Res. Bd. Can., Circ. (Statistical Ser.)* Nos. 20: 1-80; 21:1-67; 22:1-80; 23:1-80.

LeBrasseur, R. J. and O. D. Kennedy. 1972. Microzooplankton in coastal and oceanic areas of the Pacific subarctic water mass: a preliminary report. *In* A. Y. Takenouti (ed.), *Biological Oceanography of the Northern North Pacific Ocean*, Idemitsu Shoten, Tokyo, Japan. pp. 355-365.

LeBrasseur, R. J. and R. R. Parker. 1964. Growth rate of central British Columbia pink salmon (*Oncorhynchus gorbuscha*) and chum salmon (*O. keta*). *J. Fish. Res. Bd. Can.* 21(5):1101-1128.

Lee, R. F. and J. Hirota. 1973. Wax esters in tropical zooplankton and nekton and the geographical distribution of wax esters in marine copepods. *Limnol. Oceanogr.* 18(2):227-239.

Lehninger, A. L. 1965. *Bioenergetics.* W. A. Benjamin, Inc., New York. 285 pp.

Leith, D. and J. Brain. 1968. Respiration mechanics of diving mammals. *In: R/V Alpha Helix Bering Sea Exped.* pp. 163-164.

Lenfant, C. and K. Johansen. 1968. Respiratory properties of the blood of some pinnipeds. *In: R/V Alpha Helix Bering Sea Exped.* p. 166.

Lenfant, C. and K. Johansen. 1968. Respiratory response to oxygen and/or carbon dioxide in the phocidae. *In: R/V Alpha Helix Bering Sea Exped.* p. 165.

Lensink, C. J. and C. S. Harrison. 1977. Seasonal distribution and abundance of marine birds: Part II. Aerial surveys. *In: Environmental Assessment of the Alaskan Continental Shelf, Vol. 1.* Environmental Res. Lab., Boulder, Colorado. pp. 624-635.

Lestev, A. V. 1960. Rezervy Morskoi okun' [Reserves of rockfish]. *Rybn. Promysh. Dal'nego Vostoka* No. 2.

Lestev, A. V. 1961a. Ob osobennostyakh tralovogo lova okunya v Beringovom more [Characteristic aspects of rockfish trawling in the Bering Sea]. *Ryb. Khoz.* 37(9).

Lestev, A. V. 1961b. Ulovistost'i povrezhdaemost'tralov pri love okunya v Beringovom more [Fishing efficiency and damagability of trawls in fishing for rockfish in the Bering Sea]. *Ryb. Khoz.* 37(4):53-58.

Lestev, A. V. 1964. Techniques of fish trawling at depths of 300-700 m in the Bering Sea. *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 53:286-318.

Lestev, A. V. 1964. Technique of rockfish trawling in the Bering Sea. *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 53:319-336.

Leung, Y. 1971. Taxonomic guides to Arctic zooplankton (III), Pteropods of the central Arctic. *Univ. S. Calif. Tech. Rept.* (4):22-28.

Leung, Y., A. Havens and W. Rork. 1971. Taxonomic guides to Arctic zooplankton (III), Decapods of the central Arctic. *Univ. S. Calif. Tech. Rept.* (4):29-45.

Levenstein, R. Ya. 1957. New and rare deep-sea species of polychaete worms in the Bering Sea. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 23:286-290.

Levenstein, R. Ya. 1958. Polychaeta of the abyssal parts of the Bering Sea. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 34:147-178.

Levenstein, R. Ya. 1960. The quantitative distribution of the Polychaeta in the northwestern Bering Sea. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 34:104-122.

Levenstein, R. Ya. 1961. Polychaete worms of the abyssal region of the Bering Sea. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 46:147-178.

Levenstein, R. Ya. 1961. Quantitative distribution of Polychaeta in the northern Pacific. Akad. Nauk SSSR, *Tr. Inst. Okeanol.* 45:214-222.

Lewis, A. G. 1967. An enrichment solution for culturing the early developmental stages of the planktonic marine copepod *Euchaeta japonica* Marukawa. *Limnol. Oceanogr.* 12(1):147-148.

Lewis, A. G. and A. Ramnarine. 1969. Some chemical factors affecting the early development of *Euchaeta japonica* (Crustacea:Copepoda:Calanoidea). *J. Fish. Res. Bd. Can.* 26(5):1347-1362.

Lewis, A. G. 1972. Hydrographic conditions and the seasonal effect of an enrichment medium on the early developmental stages of *Euchaeta japonica* (Crustacea, Copepoda, Calanoida). *In* A. Y. Takenouti (ed.), *Biological Oceanography of the Northern North Pacific Ocean.* Idemitsu Shoten, Tokyo, Japan. pp. 395-401.

Lewis, R. W. 1969. The fatty acid composition of Arctic marine phytoplankton and zooplankton with special reference to minor acids. *Limnol. Oceanogr.* 14(1):35-40.

Lindberg, G. U. 1927. Promyslovye ryby Dal'nego Vostoka i ikh ispol'zovanie [Commercial fishes of the Far East and their utilization]. *Proizvoditel'nye sily Dal'nego Vostoka* No. 4 Section "Zhivotnyi mir".

Lindberg, G. U. 1937. The classification and distribution of sand-lances, genus *Ammodytes* (Pisces). Akad. Nauk SSSR, *Vestnik Dal'nevost. Filiala* No. 27:85-93.

Lindberg, G. U. 1949. 1. Pond smelt - *Hyponesus olidus* (Pallas). 2. Pacific navaga - *Eleginus gracilis* (Tilesius) Promyl. Ryby SSSR. Pishchepromizdat.

Lindberg, G. U. and A. P. Andriyashev. 1950. Review of the genus *Sarritor* Cramer (Pisces, Agonidae) of the Far Eastern Seas. Izd. Akad. Nauk SSSR, Moscow, *Issled. Dal'nevost. Morei* No.2:293-303.

Linford, E. 1965. Biochemical studies on marine zooplankton. II. Variations in the lipid content of some Mysidacea. *J. Cons. Perm. Int. Explor. Mer* 30(1):16-27.

Linko, A. K. 1908. Izopody russkikh severnykh morei [Isopoda of Russian northern seas]. *Byull. Imperatorskoi Akad. Nauk* No. 1.

Lipanov, V. G. and P. I. Shestopalov. 1961a. Beringovomorskaya sel'd'i perspektivy ee promysla [The Bering Sea herring and prospects for its fishing]. *Ryb. Khoz.* No. 11:45-47.

Lipanov, V. G. and P. I. Shestopalov. 1961b. First results in exploiting the fish resources of the Bering Sea. *Rybn. Promysh. Dal'nego Vostoka* No. 6.

Lisitsyn, A. P. 1955a. Raspredelenie aytigennogo kremnezema b donnych otlozheniyach zapadnoi chasti Beringova Morya. Akad. Nauk SSSR, Moscow, *Doklady* 103(3):479-482.

Lisitsyn, A. P. 1955b. Raspredelenie ogranicheskogo ugleroda v osadkakh zapadnoi chasti Beringove morya [Distribution of organic carbon in the sediments of the western part of the Bering Sea]. Akad. Nauk. SSSR, Leningrad, *Doklady* 103(2):299-302.

Lisovenko, L. A. 1964. Distribution of the larvae of rockfish (*Sebastodes alutus* Gilbert) in the Gulf of Alaska. *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 53:217-225.

Lisovenko, L. A. 1965. Fecundity of *Sebastodes alutus* Gilbert in the Gulf of Alaska. *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 58:162-169.

Liston, J., J. Peters and J. A. Stern. 1961. Parasites in summer-caught Pacific rockfishes. *U.S. Fish. Wildl. Serv., Spec. Sci. Rept., Fish.* No. 352, 10 pp.

Loder, T. C. III. 1971. Distribution of dissolved and particulate organic carbon in Alaskan Polar, sub-polar and estuarine waters. Univ. Alaska, Ph.D. Dissertation 1971, 1-236. Univ. Alaska. Inst. Mar. Sci. Rep. (R71-15), 1-236.

Lomakina, N. B. 1952a. Novye vidy kumovykh rakov iz dal'nevostochnykh more [New species of cumacean crustaceans from the Far Eastern Seas]. Akad. Nauk SSSR, *Trudy Zool. Inst.* Vol. 12:155-170.

Lomakina, N. B. 1952b. Novye interesnye v zoogeograficheskom otnoshenii nakhodki kumovykh rakov v dal'nevostochnykh moryakh [New and zoogeographically important findings of cumaceans in the Far Eastern Seas]. *Zool. Zhur.* 31(2):244-248.

Lomakina, N. B. 1955a. Kumovye raki (Cumacea) dal'nevostochnykh morei [Cumacea of the Far Eastern Seas]. Akad. Nauk SSSR, *Trudy Zool. Inst.* Vol. 18:112-165.

Lomakina, N. B. 1955b. Otryad kumovye raki-Cumacea [The Order Cumacea]. *In: Atlas Bespozvonochnykh dal'nevostochnyk morei SSSR.* Moscow, Izd. Akad. Nauk SSSR, pp. 125-127.

Lomakina, N. B. 1956. Kumovye raki (Cumacea) dal'nevostochnykh morei [Cumacea of the Far Eastern Seas]. Zool. Inst. Akad. Nauk SSSR, *Trudy Problem. Temat. Sovesh.* No. 6.

Lomakina, N. B. 1958a. Kumovye raki (Cumacea) raiona rabot Kurilo-Sakhalinskoi ekspeditsii [Cumacea of the areas surveyed by the Kurilo-Sakhalin Expedition]. *Issled. Dal'nevost. morei SSSR* Vol. 5:205-216.

Lomakina, N. B. 1958b. Kumovye raki (Cumacea) morei SSSR [Cumacea of the Soviet seas]. Moscow, Izd. Akad. Nauk SSSR.

Lomakina, N. B. 1962. Cumacea severno-zapadnoi chasti Tikhogo okeana [Cumacea of the Northwestern Pacific]. *Tezisy doklady na konferentsii po sovmestnomu issdovaniyu fauny i flory.*

Low, L. L. 1974a. Atlas of Japanese far seas fisheries in the Bering Sea, November 1970 to October 1972: Three-dimentional graphs of monthly catch statistics. U.S. Dept. of Commer., N.M.F.S. processed report. 93 pp.

Low, L. L. 1974b. A study of four major groundfish fisheries of the Bering Sea. Ph.D. Thesis, Univ. Washington, Seattle, 240 pp.

Low, L. L. 1975. Available fisheries statistics for the Bering Sea. *In* D. W. Hood and Y. Takenouti (convenors), Bering Sea Oceanography: An Update, Results of US-Japan Seminar/Workshop on Bering Sea Oceanography, Report R75-2, Inst. Mar. Sci., Univ. Alaska, Fairbanks. pp. 139-151.

Lowry, L. F. and J. J. Burns. 1976. Trophic relationships among ice inhabiting phocid seals. *In: Environmental Assessment of the Alaskan Continental Shelf, Vol. 1*; Principal Investigators' Reports July-September 1976. Environmental Research Laboratories, Boulder, Colorado. pp. 127-144.

Lowry, L. F., K. J. Frost and J. J. Burns. 1977. Trophic relationships among ice inhabiting phocid seals. *In: Environmental Assessment of the Alaskan Continental Shelf, Vol. 1.* Environmental Res. Lab., Boulder, Colorado. pp. 359-375.

Lozina-Lozinskii, L. K. 1933. Pantopoda vostochnykh morei SSSR [Pantopoda of the eastern seas of the U.S.S.R]. Gosudar. Gidrolog. Inst., Leningrad, *Issled. Morei SSSR* No. 17:43-80.

Lozina-Lozinskii, L. K. 1961. Mnogokolenchatye (Pantopoda) dal'nevostochnykh morei SSSR [Pantapoda of the Far Eastern Seas of the U.S.S.R.]. Izd. Akad. Nauk SSSR, Moscow, *Issled. Dal'nevost. Morei SSSR* No. 7:47-117.

Lozina-Lozinskii, L. K. and E. P. Turpaeva. 1958. The genus *Colossendeis* (Pantopoda) in the northern Pacific Ocean. *Byull. Moskov. Obshch. Ispytat. Prirody* Vol. 63(1).

Lubny-Gertsyk, E. A. 1953. Vesovaya Kharakteristika osnovnykh predslavitelei zooplanktona Okhotskogo i Beringova morei [Weight caracterization of the principal representatives of the zooplankton of the Okhotsk and Bering Seas]. Akad. Nauk SSSR, *Doklady* 91(4):949-952.

Lubny-Gertsyk, E. A. 1955. Some data on plankton distribution in the surface layer of Pacific Kurile waters. Akad. Nauk SSSR, *Doklady* 101(3):561-564.

Lubny-Gertsyk, E. A. 1962. Problems of the relationship between the feeding of *Theragra chalcogramma* and the distribution of plankton. Akad. Nauk SSSR, Leningrad, *Trudy Inst. Okeanol.* Vol. 58:157-162.

Lucas, F. A. 1899. Food of the northern fur seals. *In* D. S. Jordan (ed.) *The Fur Seals and Fur Seal Islands of the North Pacific Ocean, Pt. III.* U.S. Govt. Print. Off., Washington, D.C. pp. 59-68.

Ludwig, H. 1886. Echinodermen des Beringsmeeres. *Zool. Jahrb., Abt. f. Syst.* Bd. 1:275-296.

Lukin, A. V. 1947. O roli temperaturnogo faktora v protsesse prisprosobleniya razmnozheniya ryb k usloviyam sredy [Effect of temperature on the adaptation of fish reproduction to environmental conditions]. Akad. Nauk SSSR, Moscow-Leningrad, *Doklady* 58(4):717-718.

Lukina, O. V. 1973. Respiratory rate of the North Okhotsk chum salmon [*Oncorhynchus keta* (Walb.)]. *J. Ichthyol.* 13(3):425-430.

Luss, V. Ya. 1970. Quantitative distribution of benthos on the continental slope of the eastern part of the Bering Sea. *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 70:116-124.

Luss, V. J. and A. P. Kuznetsov. 1961. Data on the quantitative distribution of the bottom fauna in the Korpho-Karaginsky region of the Bering Sea. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 46:124-139.

Lyaiman, E. M. 1937. Parasitic worms of the Amur salmon (*Onchorhynchus gorbuscha*). *Raboty po Gel'mintologic-Sbornik posvyashchennyi akademiku K.I. Shryabinu.* pp. 359-362.

Lyubimova, T. G. 1961. O morskom okune zaliva Alyaska [Rockfish of the Gulf of Alaska]. *Rybn. Khoz.* No. 9:27-30.

Lyubimova, T. G. 1963a. Basic aspects of the biology and distribution of Pacific rockfish (*Sebastodes alutus* Gilbert) in the Gulf of Alaska. *Trudy Vses. Nauchno-Issled. Morsk. Inst. Rybn. Khoz. Okeanogr.* Vol. 48:308-318.

Lyubimova, T. G. 1963b. Biological prerequisites for the formation of commercial concentrations of rockfish in the Gulf of Alaska. *Tezisy Dokladov na Soveschanni molodykh uchenykh.* Moscow.

Lyubimova, T. G. 1964. Biological characteristics of the school of Pacific rockfish (*Sebastodes alutus* G.) in the Gulf of Alaska. *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 53:208-216.

MacDonald, R. 1928. The life history of *Thysanoessa raschii*. *J. Mar. Biol. Assoc.* 15(1):55-66.

MacGinitie, G. E. 1955. Distribution and ecology of the marine invertebrates of Point Barrow, Alaska. *Smithsn. Misc. Collns.* 128(9):1-201.

MacGinitie, G. E. 1960. Marine mollusca of Point Barrow, Alaska. Smithsonian Inst., Washington, D.C. *Proc. U.S. Nat. Mus.* 109(3412):59-208.

Machida, M. 1970. Gastric nematodes of the northern fur seals on the Commander Islands. *Jap. J. Parasitol.* 19:407. [In Japanese].

Machidori, S. 1966. Vertical distribution of salmon (genus *Oncorhynchus*) in the northwestern Pacific. I. *Bull. Hokkaido Reg. Fish. Res. Lab.* No. 31:11-17.

MacIsaac, J. J. and R. C. Dugdale. 1969. The kinetics of nitrate and ammonia uptake by natural populations of marine phytoplankton. *Deep-Sea Res.* 16(1):45-57.

Mackintosh, N. A. 1946. The natural history of whale-bone whales. *Biol. Rev. Cambridge Phil. Soc.* 21(2):60-74.

Mackay, W. and C. L. Prosser. 1968. Osmotic and ionic properties of crustaceans. *In: R/V Alpha Helix Bering Sea Exped.*:217-224.

Maeda, T. 1959. Study on the salmon fishing grounds in the North Pacific Ocean. *Bull. Fish., Hokkaido Univ.* 9(4):268-282.

Maeda, T. 1972a. Fishing grounds of Alaska pollock. *Bull. Jap. Soc. Sci. Fish.* 38(4):362-371.

Maeda, T. 1972b. On the fishing conditions of Alaska pollock in the eastern Bering Sea in 1969 and 1970. *Bull. Jap. Soc. Sci. Fish.* 38(7):685-692. [In Japanese].

Maeda, T. 1973. Environments for Alaska pollock. Mimeographed report of seminar on Alaska pollock, in 1973. pp. 89-95. [In Japanese].

Maeda, T. 1974. Environments for Alaska pollock. (Unpublished report cited in D. W. Hood and Y. Takenouti, 1975).

Maeda, T., T. Fujii and K. Masuda. 1967. Studies on the trawl fishing grounds of the eastern Bering Sea. I. On the oceanographical condition and the distribution of fish shoals in 1963. *Bull. Jap. Soc. Sci. Fish.* 33(8):713-720. [In Japanese with English abstract].

Maeda, T. and H. Hirakawa. 1977. Spawning grounds and distribution pattern of the Alaskan pollock in the Eastern Bering Sea. *Bull. Jap. Soc. Sci. Fish.* 43(1):39-46.

Maguro, H., I. Kuniyuki and H. Fukushima. 1966. Diatoms and the ecological conditions of their growth in sea ice in the Arctic Ocean. *Science* 152(3725):1089-1090.

Maher, W. J. 1960. Recent records of the California gray whale (*Eschrichtius glaucus*) along the north coast of Alaska. *Arctic* 13(4):257-265.

Makarov, R. R. 1966. *The Larvae of Shrimps, Hermit Crabs and Crabs on the West Kamchatka Shelf and Their Distribution.* Moscow. Izd. "Nauka".

Makarov, V. V. 1937a. Materialy po kolichestvennomu uchetu donnoi fauny severnoi chasti Beringova i yuzhnoi chasti Chukotskogo morei [Data on the quantitative assessment of bottom fauna of the northern Bering Sea and southern Chukchi Sea]. *Issled. Morei SSSR* No. 25:260-291.

Makarov, V. V. 1937b. Hermit crab fauna of the Far Eastern Seas. *Issled. Morei SSSR* No. 23.

Makarov, V. V. 1938. Fauna SSSR. Rakoobraznye [*Fauna of the U.S.S.R. Crustacea*]. Moscow-Leningrad. Izd. Akad. Nauk SSSR, 298 pp.

Makarov, V. V. 1941. Fauna Decapoda Beringova i Chukotskogo morei [Decapod Fauna of the Bering and Chukchi Seas]. *Issled. Dal'nevost. Morei.* No. 1.

Makarov, V. V. 1950. Sipunculoidea, Echiuroida, and Priapulida Fauna of the Far Eastern Seas. Izd. Akad. Nauk SSSR, Moscow, *Issled. Dal'nevost. Morei SSSR* No. 2:239-24 .

Makushina, V. 1932. Fish reserves of Alaska and their utilization. *Sovetskii Sever* No. 1-2.

Malins, D. C., E. H. Gruger, Jr., H. O. Hodgins and D. D. Weber. 1977. Sublethal effects as reflected by morphological, chemical, physiological, behavioral, and pathological indices. *In: Environmental Assessement of the Alaskan Continental Shelf, Vol. 3.* Environmental Res. Lab., Boulder, Colorado. pp. 46-86.

Malins, D. C. and H. O. Hodgins. 1976. Sublethal effects as reflected by morphological, chemical, physiological, and behavioral indices. *In: Environmental Assessment of the Alaskan Continental Shelf, Volume 2*; Principal Investigators' Reports, April-June 1976. Environmental Research Laboratories, Boulder, Colorado. pp. 27-40.

Malins, D. C., W. L. Reichert and W. T. Roubal. 1976. Identification of major processes in bio-transformations of petroleum hydrocarbons and trace metals. *In: Environmental Assessment of the Alaskan Continental Shelf, Volume 2*; Principal Investigators' Reports, April-June 1976. Environmental Research Laboratories, Boulder, Colorado. pp. 41-59.

Manzer, J. I. 1958. Salmon distribution and abundance in the northeast Pacific, 1956 and 1957, with some comparisons with other regions of the North Pacific and the Bering Sea. *Fish. Res. Bd. Can., Manuscr. Rept. Ser. (Biol.)* No. 656, 38 pp.

Manzer, J. I. 1964. Preliminary observations on the vertical distribution of Pacific salmon (genus *Oncorhyncus*) in the Gulf of Alaska. *J. Fish. Res. Bd. Can.* 21:891-903.

Manzer, J. I., T. Ishida, A. E. Peterson and M. G. Hanavan. 1965. Salmon of the North Pacific Ocean - Part V. Offshore distribution of salmon. *Bull. Int. N. Pacif. Fish. Comm.* No. 15, 452 pp.

Margolis, L. 1954. List of the parasites recorded from sea mammals caught off the west coast of North America. *J. Fish. Res. Bd. Can.* 11(3):267-283.

Margolis, L. 1956. Parasitic helminths and arthropods from Pinnipedia of the Canadian Pacific coast. *J. Fish. Res. Bd. Can.* 13(4):489-505.

Margolis, L. 1959. Records of *Cyamus balaenopterae* Barnard and *Neocyamus physeteris* (Pouchet), two species of whale-lice (Amphipoda), from the northeast Pacific. *Can. J. Zool.* 37:895-897.

Margolis, L. and T. H. Butler. 1954. An unusual and heavy infection of a prawn *Pandalus borealis* Kröyer by a nematode *Contracaecum* sp. *J. Parasitol.* 40(6):649-653.

Margolis, L., F. C. Cleaver, Y. Fukuda and H. Godfrey. 1966. Salmon of the North Pacific Ocean. Part VI. Sockeye salmon in offshore waters. *Bull. Inst. N. Pacif. Fish. Comm.* 20. 70 pp.

Mar. Mammal Biol. Lab. 1969. Fur seal investigations, 1966. *U.S. Fish Wildlife Serv., Spec. Sci. Rept. Fish.* (584):1-123.

Mar. Mammal Biol. Lab. 1970. Fur seal investigations, 1967. *U.S. Fish Wildlife Serv., Spec. Sci. Rept. Fish.* (597):1-104.

Marr, J. C. (ed.). 1970. *The Kuroshio, A Symposium on the Japan Current.* East-West Center Press. Honolulu. 613 pp.

Martinsen, G. V. 1969. Problems of the world sea fisheries. *Oceanol.* 9(6):842-848.

Marukawa, H. 1933. Biological and fishery research on Japanese king crab *Paralithodes camtschatica* (Tilesius). *J. Imp. Fish. Exp. Sta.* 4(37): 1-152.

Marumo, R. 1955. Analysis of water masses by distribution of the microplankton. *J. Oceanogr. Soc. Japan* 11(3):133-137.

Marumo, R. 1956. Diatom communities in the Bering Sea and its neighboring waters in the summer of 1954. *Oceanogr. Mag.* 8(1):69-74.

Marumo, R. 1957. Plankton as the indicator of water masses and ocean currents. *Oceanogr. Mag.* 9:55-63.

Marumo, R. 1966. *Sagitta elegans* in the Oyashio Undercurrent. *J. Oceanogr. Soc. Japan* 22(4):129-137.

Marumo, R. 1967. General features of diatom communities in the North Pacific Ocean in summer. *Inf. Bull. Planktol. Japan, Commem. Number Dr. Y. Matsue* 1967:115-122.

Marumo, R., M. Kitou and O. Asaoka. 1960. Plankton in the north-western Pacific Ocean in summer of 1958. *Oceanogr. Mag.* 12(1):17-47.

Marumo, R. and T. Minoda. 1975. Phytoplankton in the subarctic and tropical waters in the Pacific: Phytoplankton in the subarctic water and the Bering Sea. *In* D. W. Hood and Y. Takenouti (eds.), Bering Sea Oceanography: An Update, Results of US-Japan Seminar/Workshop on Bering Sea Oceanography, Report R75-2, Inst. Mar. Sci., Univ. Alaska, Fairbanks. pp. 109-116.

Mason, J. E. 1965. Salmon of the North Pacific Ocean - Part IX. Coho, chinook, and masu salmon in offshore waters. 2. Chinook salmon in offshore waters. *Bull. Int. N. Pacif. Fish. Comm.* 16:41-73.

Matheke, G. E. M. and R. Horner. 1974. Primary productivity of the benthic microalgae in the Chukchi Sea near Barrow, Alaska. *J. Fish. Res. Bd. Can.* 31(11):1779-1786.

Mathisen, O. A. 1959. Studies on the stellar sea lion (*Eumetopias jubatus*) in Alaska. Reprinted from Transactions of the Twenty-fourth Amer. Wildl. Conf.

Mathisen, O. A. 1962. Comparative characteristics of age and growth of the sockeye salmon in Kurile Lake, Kamchatka, and the Bristol Bay of Alaska. *Vopr. Ikhtiol.* 2(1):42-54.

Mathisen, O. A. 1963. Biological investigations of the sockeye salmon in Bristol Bay. *Vopr. Ikhtiol.* 3(1):51-83.

Matsubara, K. 1955. Shinkaigyo "Onihadaka" *Cyclothone microdon* (Günther) nitsuite. *Umi to Sora* 31(5-6) [Cited by Mukacheva, 1964].

Matsudaira, Y. 1932. Planktons included in the sea-ice. *J. Ocean.* (Kobe, Japan) 4:269-273. [In Japanese].

Mattson, C. R. 1962. Chum salmon resources of Alaska from Bristol Bay to Point Hope. *U.S. Fish Wildlife Serv., Spec. Sci. Rept. Fish. 425*: 1-22.

Mauchline, J. 1966. The biology of *Thysanoessa raschii* (M. Sars), with a comparison of its diet with that of *Meganyctiphanes norvegica*. *In* H. Barnes (ed.), *Some Contemporary Studies in Marine Science.* George Allen and Unwin Ltd., London. pp. 493-510.

Mauchline, J. 1967a. Feeding appendages of the Euphausiacea (Crustacea). *J. Zool. Soc. London* 153:1-43.

Mauchline, J. 1967b. Volume and weight characteristics of species of Euphausiacea. *Crustaceana* 13(3):241-248.

Mauchline, J. and L. R. Fisher. 1969. The biology of euphausiids. *In* F. Russell and M. Yonge (eds.), *Advances in Marine Biology, Vol. 7.* Academic Press. pp. 1-454.

May, F. H. 1937. The food of the fur seal. *J. Mammal.* 18(1):99-100.

McAlister, W. B., C. Mahnken, R. C. Clark, Jr., W. J. Ingraham, Jr., J. Larrance and D. Day. 1968. Final report: Oceanography and marine ecology in the vicinity of Amchitka Island. *Battelle Mem. Inst., Columbus Lab., Columbus, Ohio, BMI-172-112.* 146 pp.

McAllister, C. D. 1961. Zooplankton studies at Ocean Weather Station "P" in the Northeast Pacific Ocean. *J. Fish. Res. Bd. Can.* 18(1):1-29.

McAllister, C. D. 1962a. Photosynthesis and chlorophyll measurements at Ocean Weather Station "P", July 1959 to Nov. 1961. *Fish. Res. Bd. Can., MS Rept. Ser.* No. 126.

McAllister, C. D. 1962b. Further productivity experiments at Ocean Station "P". *Fish. Res. Bd. Can. MS Rept. Ser.* No. 136, 1-7.

McAllister, C. D. 1962c. Measurements of primary production at Ocean Station "P". *Fish. Res. Bd. Can. MS Rept. (Ocngr. Limnol.)* No. 137, 7 p.

McAllister, C. D. 1963. Measurements of diurnal variation in productivity at Ocean Station "P". *Limnol. Oceanogr.* 8(2):289-292.

McAllister, C. D. 1969. Aspects of estimating zooplankton production from phytoplankton production. *J. Fish. Res. Bd. Can.* 26(2):199-220.

McAllister, C. D. 1970. Zooplankton rations, phytoplankton mortality and the estimation of marine production. *In* J. H. Steele (ed.), *Marine Food Chains*. Oliver and Boyd, Edinburgh. pp. 419-457.

McAllister, C. D. 1971. Some aspects of nocturnal and continuous grazing by planktonic herbivores in relation to production studies. *Fish. Res. Bd. Can., Tech. Rept. No. 248*, 281 pp.

McAllister, C. D. 1972. Estimates of the transfer of primary production to secondary production at Ocean Station "P". *In* A. Y. Takenouti (ed.), *Biological Oceanography of the Northern North Pacific Ocean*. Idemitsu Shoten, Tokyo, Japan. pp. 575-579.

McAllister, C. D., T. R. Parsons and J. D. H. Strickland. 1960. Primary productivity and fertility at Station "P" in the northeast Pacific Ocean. *J. Cons. Perm. Int. Explor. Mer* 25(3):240-259.

McCain, B. B., H. O. Hodgins and W. D. Gronlund. 1977. Determine the frequency and pathology of marine animal diseases in the Bering Sea, Gulf of Alaska and Beaufort Sea. *In: Environmental Assessment of the Alaskan Continental Shelf, Vol. 1.* Environmental Res. Lab., Boulder, Colorado. pp. 789-827.

McCain, B. B., S. R. Wellings, H. O. Hodgins, W. D. Gronlund and D. D. Weber. 1976. Determine the frequency and pathology of marine fish and invertebrates in the Bering, Beaufort, Chukchi Seas, Gulf of Alaska, and Norton Sound. *In: Environmental Assessment of the Alaskan Continental Shelf, Volume 2*; Principal Investigators' Reports, April-June, 1976. Environmental Research Laboratories, Boulder, Colorado. pp. 72-98.

McCauley, J. E. 1964. Gastropod larvae from the brood pouch of an Arctic shrimp. *Trans. Amer. Microsc. Soc.* 83(3):290-293.

McGary, J. W. and J. J. Graham. 1960. Biological and oceanographic observations in the central North Pacific July-September 1958. *U.S. Fish Wildl. Serv., Spec. Sci. Rept.-Fish.* 358:1-107.

McGowan, J. A. 1960. The relationship of the distribution of the planktonic worm, *Poeobius meseres* Heath, to the water masses of the North Pacific. *Deep-Sea Res.* 6(2):125-139.

McGowan, J. A. 1963. Geographical variation in *Limacina helicina* in the North Pacific. *In* J. P. Harding and N. Tebble (eds.), *Speciation in the Sea*. The Systematics Assoc., London. pp. 109-128.

McLaren, I. A. 1963. Effects of temperature on growth of zooplankton, and the adaptive value of vertical migration. *J. Fish. Res. Bd. Can.* 20(3): 685-727.

McLaren, I. A. 1965. Some relationships between temperature and egg size, body size, development rate, and fecundity of the copepod *Pseudocalanus*. *Limnol. Oceanogr.* 10(4):528-538.

McLaren, I. A. 1966. Adapttive significance of large size and long life of the chaetognath *Sagitta elegans* in the arctic. *Ecology* 47:852-855.

McLaren, I. A., C. J. Corkett and E. J. Zillioux. 1969. Temperature adaptations of copepod eggs from the arctic to the tropics. *Biol. Bull.* 137: 486-493.

McLaughlin, P. A. 1963. Survey of the benthic invertebrate fauna of the eastern Bering Sea. *U.S. Fish. Wildlife Serv., Spec. Sci. Rept. Fish.* 401:1-41.

McMullen, J. C. and H. T. Yoshihara. 1970. The king and tanner crab fishery of the Alaska peninsula - Aleutian Islands Management Area; 1969-1970. *State of Alaska, Dept. Fish and Game. Info. Leaflet 148*:1-29.

McMynn, R. G. 1951. The effects of some constant and changing conditions of salinity on the development and mortality of the eggs and larvae of the Pacific herring, *Clupea pallasi* Cuvier. M.A. Thesis. University of British Columbia.

McMynn, R. G. and W. S. Hoar. 1953. Effects of salinity on the development of the Pacific herring. *Can. J. Zool.* 31(4):417-432.

McRoy, C. P. 1966. The standing stock and ecology of eelgrass (*Zostera marina* L.) in Izembek Lagoon, Alaska. M.S. Thesis, Univ. Wash., Seattle, Wash. 138 pp.

McRoy, C. P. 1968a. Biological oceanographic observations in the ice covered Bering Sea, 6-29 March, 1968. *In: R/V Alpha Helix Bering Sea Exped.* 83-105.

McRoy, C. P. 1968b. The distribution and biogeography of *Zostera marina* (eelgrass) in Alaska. *Pacif. Sci.* 22:504-513.

McRoy, C. P. 1969. Eelgrass under Arctic winter ice. *Nature* 224(5221): 818-819.

McRoy, C. P. 1970a. Eelgrass under Arctic winter ice. Rept. R-70-1, Inst. Mar. Sci., Univ. Alaska, Fairbanks. pp. 118-130.

McRoy, C. P. 1970b. Environment, temperature and eelgrass ecology in Izembek Lagoon, Alaska. Rept. R-70-1, Inst. Mar. Sci., Univ. Alaska, Fairbanks. pp. 53-73.

McRoy, C. P. 1970c. *On the Biology of Eelgrass in Alaska.* Ph.D. Dissertation, Univ. Alaska, Fairbanks, 156 pp.

McRoy, C. P. 1970d. R/V *Alpha Helix* Bering Sea Expedition, 1968. Biological Oceanographic observations in the ice-covered Bering Sea, 6 to 29 March, 1968. Rept. R-70-1, Inst. Mar. Sci., Univ. Alaska, Fairbanks. pp. 74-97.

McRoy, C. P. 1970e. Standing stocks and other features of eelgrass (*Zostera marina*) populations on the coast of Alaska. *J. Fish. Res. Bd. Can.* 27(10):1811-1821.

McRoy, C. P. 1971. Winter studies of primary productivity in the eastern Bering Sea. *Proc. Alaska Sci. Conf.* 22:125.

McRoy, C. P. 1972. On the biology of eelgrass in Alaska. Report R72-1, Inst. Mar. Sci., Univ. Alaska, Fairbanks. 156 pp.

McRoy, C. P. and R. J. Barsdate. 1970. Phosphate absorption in eelgrass. *Limnol. Oceanogr.* 15(1):6-13.

McRoy, C. P., R. J. Barsdate and M. Nebert. 1972. Phosphorous cycling in an eelgrass (*Zostera marina*) ecosystem. *Limnol. Oceanogr.* 17(11):58-67.

McRoy, C. P. and J. J. Goering. 1967. The ecology of eelgrass. Rept. R-68-3, Inst. Mar. Sci., Univ. Alaska, Fairbanks. pp. 1-4.

McRoy, C. P. and J. J. Goering. 1973. Nutrient transfer between the seagrass *Zostera marina* and its epiphytes. *Nature* 248:173-174.

McRoy, C. P. and J. J. Goering. 1974a. The influence of ice on the primary productivity of the Bering Sea. *In* D. W. Hood and E. J. Kelley (eds.), *Oceanography of the Bering Sea.* pp. 403-421.

McRoy, C. P. and J. J. Goering. 1974b. Sea ice and under ice plankton. *In* H. T. Odum, B. J. Copeland and E. A. McMahan (eds.), *Coastal Ecological Systems of the United States.* The Conservation Foundation, Washington, D.C. 3:55-70.

McRoy, C. P. and J. J. Goering. 1975. Primary production budget for the Bering Sea. *In* D. W. Hood and Y. Takenouti (eds.), Bering Sea Oceanography: An Update, Results of the US-Japan Seminar/Workshop on Bering Sea Oceanography, Rept. R75-2, Inst. Mar. Sci., Univ. Alaska, Fairbanks. pp. 97-107.

McRoy, C. P., J. J. Goering and W. E. Shiels. 1971. Studies of primary production in the eastern Bering Sea. Rept. R71-9, Inst. Mar. Sci., Univ. Alaska, Fairbanks. pp. 189-216.

McRoy, C. P., J. J. Goering and W. S. Shiels. 1972. Studies of primary productivity in the eastern Bering Sea. *In* A. Y. Takenouti *et al.* (eds.), *Biological Oceanography of the Northern North Pacific Ocean (Motoda commemorative volume).* Idemitsu Shoten, Tokyo, Japan. pp. 199-216.

Mechnikov, I. I. 1869. O lichinochnykh stadiyakh *Euphausia* [On the larval stages of *Euphausia*]. *Zeitshrift fur wissensch.-Zoology* Vol. XXI, No. 4 [In German].

Mechnikov, I. I. 1871. O nauplial'noi stadii *Euphausia* [On the nauplius stage of *Euphausia*]. *Zeitschrift fur wissensch.-Zoology* Vol. XXI.

Mednikov, B. M. 1955. O planktone i sel'di severo-zapadnoi chasti Beringova Morya. *Rykopisv. Moskovskii Gosudar. Univ.*

Mednikov, B. M. 1957. O planktone i sel'di Olyutorsko-Navarinskogo raiona [On the plankton and herring of the Olyutorskii-Navarin Region]. *Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.* Vol 44:57-65.

Mednikov, B. M. 1961. On sex ratio in deep-water Calanoida. *Crustaceana* 3(2):105-109.

Mednikov, B. M. and V. G. Prokhorov. 1956. New species of *Cyclopteropsis* (Pisces, Cyclopterinae) in the Bering Sea. Akad. Nauk SSSR, *Doklady* 111(3):717-719.

Meguro, H., K. Ito and H. Fukushima. 1966. Diatoms and the ecological conditions of their growth in sea ice in the Arctic Ocean. *Science* 152: 1089-1090.

Meguro, H., K. Ito and H. Fukushima. 1967. Ice flora (bottom type): a mechanism of primary production in polar seas and the growth of diatoms in sea ice. *Arctic* 20(2):114-133.

Merrell, T. R., Jr. 1970. Alaska's fishery resources, the chum salmon. *U.S. Fish Wildl. Serv., Fish. Leafl.* (632):1-7.

Merrell, T. R., Jr. 1971. Marine fishery resources in the vicinity of Amchitka Island, Alaska. *Bioscience* 21(12):610-614.

Merritt, L. B. and C. P. McRoy. 1972. Simulation of the annual ecological cycle of shallow marine plants-eelgrass of Izembeck Lagoon, Alaska. Int. Symp. Math. Model. Tech. Water Res. Systems, Ottawa.

Meshcheryakova, I. M. 1964. Kolichestvennoe raspredelenie planktona yugo-vostochnoi chasti Beringova morya [Quantitative distribution of plankton in the southeastern part of the Bering Sea]. *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 49:147-158.

Meshcheryakova, I. M. 1970a. Plankton of the eastern Bering Sea in Spring and Autumn. *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 70:92-108.

Meshcheryakova, I. M. 1970b. Winter and Spring plankton in the southeastern part of the Bering Sea. *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 70:109-115.

Micklukhina, A. P. 1969. Distribution and specific composition of plankton in the zone of the Pacific drift. *Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.* Vol. 68:116-124.

Mikulich, L. V. 1954. O pitanii mintaya v severnoi chasti Beringova morya [On the feeding of the Alaska pollock in the north of the Bering Sea]. *Izv. Tikhookean. Inst. Rybn. Khoz. Okeanogr.* Vol. 42:177-189.

Mikulich, L. V. 1957. Pitanie nagul'noi sel'di v severnoi chasti Okhotskogo morya [Diet of foraging herring in the north of the Sea of Okhotsk]. *Uchenye Zapiski Dal'nevost. Gosudar. Inst.* No. 1.

Mileikovsky, S. A. 1969. Vertical distribution, breeding and abundance of pelagic polychaetes in the northwestern Pacific. *Okeanol.* 9(4):676-685.

Mileikovsky, S. A. 1970. The distribution of pelagic larvae of bottom invertebrates in the Kurile-Kamchatka Region. Akad. Nauk SSSR, Leningrad, *Trudy Inst. Okeanol.* Vol. 86:117-133.

Mileikovsky, S. A. 1970. Larvae of the pelagic polychaete *Pelagobia longicirrata* Greeff in the plankton of the Kurile-Kamchatka Region. Akad. Nauk SSSR, Leningrad, *Trudy Inst. Okeanol.* Vol. 86:249-251.

Miller, L. K. M. Rosenmann, P. R. Morrison and L. Irving. 1973. Metabolism and temperature regulation in newborn and developing harbor seals. *Federation Proc.* 32:391.

Milne, D. S. 1968. *Sergestes similis* Hansen and *S. consobrinus* n. sp. (Decapoda) from the northeastern Pacific. *Crustaceana* 14(1):21-34.

Milovidova-Dubrovskaya, N. V. 1932. Dal'nevostochnaya navaga [Pacific Navaga]. Vladivostok.

Milovidova-Dubrovskaya, N. V. 1938. K biologii molodi vostochnoi navagi [Biology of the Pacific navaga fry]. Akad. Nauk SSSR, *Vestnik Dal'nevost. Filiala* No. 28:140-144.

Mineva, T. A. 1955. Some data on the biology of sandfish (*Trichodon trichodon*). *Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.* Vol. 43:195-198.

Mineva, T. A. 1964. On the biology of some flatfishes in the eastern Bering Sea. *Trudy. Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 49:227-235.

Minoda, T. 1958. Report from the 'Oshoru Maru' on oceanographic and biological investigations in the Bering Sea and northern North Pacific in the summer of 1955. V. Observations on copepod community. *Bull. Fac. Fish., Hokkaido Univ.* 8(4):253-263.

Minoda, T. 1967. Seasonal distribution of Copepoda in the Arctic Ocean from June to December, 1964. *Rec. Oceanogr. Works Japan* 9(1):161-168.

Minoda, T. 1971. Studies on pelagic copepoda in the Bering Sea and the northwestern North Pacific with a special reference of their vertical distribution. *Mem. Fac. Fish., Hokkaido Univ.* 18:1-74.

Minoda, T. 1972. Characteristics of the vertical distribution of copepods in the Bering Sea and south of the Aleutian Chain, May-June, 1962. *In* A. Y. Takenouti, *Biological Oceanography of the Northern North Pacific Ocean*. Idemitsu Shoten, Tokyo. pp. 323-332.

Minoda, T. and R. Marumo. 1975. Regional characteristics of distribution of phyto- and zooplankton in the eastern Bering Sea and Chukchi Sea in June-July, 1972. *In* D. W. Hood and Y. Takenouti (eds.), Bering Sea Oceanography: An Update, Results of US-Japan Seminar/Workshop on Bering Sea Oceanography. Rept. R75-2, Inst. Mar. Sci., Univ. Alaska, Fairbanks. pp. 83-95.

Minoda, T., T. Nishiyama and M. Fukuchi. 1975. Peculiarity of zooplankton biomass distribution in the Bering Sea in fall season. (Abstract, in Japanese). Ann. Meeting Oceanogr. Soc. Japan, April, Tokyo.

Mirinova, N. V. 1958. The contribution of the coastal zone to the Barents Sea fisheries. *In: Patterns of the Concentration and Migration of Food Fishes in the Murmansk Coastal Zone in Relation to Biological, Hydrological and Hydrochemical Processes.* Moscow, Leningrad, USSR Acad. Sci. Press, 1958.

Mitchell, E. 1968. Northeast Pacific standing distribution and seasonality of Cuvier's beaked whale *Ziphius cavirostris*. *Can. J. Zool.* 46:265-279.

Mito, K. 1974. *Food Relation in Demersal Fishing Community in the Bering Sea - Walleye Pollock Fishing Ground in October and November 1972.* M.S. Thesis, Hokkaido Univ., Hakodate, 86 pp.

Mizue, K. 1951. Food of whales. *Sci. Rept. Whales Res. Inst. Tokyo* No. 5: 81-91.

Moberg, E. G. 1926. Chemical composition of marine plankton. *Third Pan-Pacific Sci. Congr., Tokyo*:233-236.

Mohr, J. L. and J. Libbs. 1963. Ecology of ice substrates. *In: Proc. Arctic Basin Symp., Oct. 1962.* The Arctic Inst. of N. Amer., Washington, D.C. pp. 245-249.

Moiseev, P. A. 1934. K voprosu o termicheskom rezhime beringovomorskoi treski [On the thermal regime of Bering Sea cod]. *Ryb. Khoz. Dal'nego Vostoka* Nos. 1-2.

Moiseev, P. A. 1935. To the knowledge of fishes belonging to the Scorpaenidae fauna of the Far Eastern Sea. *Explorations des Mers URSS* 23:113-138. [Cited in Chen, 1971].

Moiseev, P. A. 1936. K poznaniuy semeistva Scorpaenidae dal'nevostochnykh morei [Concerning the Family Scorpaenidae of Far Eastern Seas]. *Issled. Morei SSSR* No. 23.

Moiseev, P. A. 1946. *Commercial Flatfish of the Far East.* Vladivostok.

Moiseev, P. A. 1949. More attention to the fishery for benthic fish in the Far East. *Rybn. Khoz.* No. 5.

Moiseev, P. A. 1952. Nekotorye spetsificheskie cherty raspredeleniya donnykh i pridonnykh ryb v dal'nevostochnykh moryakh [Certain specific features of the distribution of benthic and demersal fish in the Far Eastern seas]. *Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.* Vol. 37:129-137.

Moiseev, P. A. 1953a. Characteristics of the way of life and distribution of bottom and demersal fishes in the Far Eastern Sea. *Vopr. Ikhtiol.* 1:24-36.

Moiseev, P. A. 1953b. Cod and flounder of the Far Eastern Seas. *Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.* Vol. 40:1-288.

Moiseev, P. A. 1954. Biologiya donnykh ryb dal'nevostochnykh morei i metody ikh razvedki [The biology of bottom fish of Far Eastern Seas and methods for their exploration]. Izd. Akad. Nauk SSSR, *Trudy Sovesch. po Razvedki Ryb.*

Moiseev, P. A. 1955a. Belokoryi paltus [The Halibut]. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 14:56-70.

Moiseev, P. A. 1955b. Novye dannye o rasprostranenii belokorogo paltusa [New data on the distribution of the halibut]. Akad. Nauk SSSR, *Doklady* 105(2):374-375.

Moiseev, P. A. 1956a. Population dynamics of commercial fauna in the northwestern Pacific and its causes. *Zool. Zhur.* 35(11).

Moiseev, P. A. 1956b. Salmon fishing in the open sea in the North Pacific. *Rybn. Khoz.* No. 4:54-59.

Moiseev, P. A. 1958. Some distribution patterns of benthic fish in the Far Eastern Seas. Synopses of reports. Akad. Nauk SSSR, *Trudy Okeanogr. Komissii* Vol. 3:122-123.

Moiseev, P. A. 1960a. Fishery research in the Pacific Ocean. Akad. Nauk SSSR, *Vestnik* No. 6:109-111.

Moiseev, P. A. 1960b. On the behavior of Pacific cod in different zoogeographical zones. *Zool. Zhur.* 39(4):558-562.

Moiseev, P. A. 1961a. Some features of the commercial fauna of the North Pacific Basin. *Rybn. Promysh. Dal'nego Vostoka* No. 2.

Moiseev, P. A. 1961b. Some patterns in the population dynamics of commercial fish of the Northwestern Pacific Ocean. Synopses of reports. *Trudy Sovesh. po Dinamike Chislennosti Ryb.*

Moiseev, P. A. 1963a. The scientific background of the organization of the Bering Sea Expedition. *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 48:1-8.

Moiseev, P. A. (ed.). 1963b. *Soviet Fisheries Investigations in the Northeast Pacific. Part I. Trudy. Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 48; also *Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.* Vol. 50, 316 pp. [Engl. Transl. by Israel Prog. Sci. Transl. TT67-51203, 1968].

Moiseev, P. A. 1963c. The world's oceans and their resources, *Rybnaya Promyshlennost' Dal'nego Vostoka* 2:

Moiseev, P. A. 1964a. Some data on the development and state of world fisheries. *Vopr. Ikhtiol.* 4(2):211-225.

Moiseev, P. A. 1964b. Some results of the work of the Bering Sea Expedition. *In* P. A. Moiseev (ed.), *Soviet Fisheries Investigations in the Northeast Pacific. Part III.* Izd. "Pishch. Promysh.", Moscow. pp. 1-21.

Moiseev, P. A. (ed.). 1964c. *Soviet Fisheries Investigations in the Northeast Pacific. Part II. Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 49; also *Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.* Vol. 5, 272 pp. [Engl. Transl. by Israel Program Sci. Transl. TT67-51204, 1968].

Moiseev, P. A. (ed.). 1964d. *Soviet Fisheries Investigations in the Northeast Pacific. Part III. Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 53; also *Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.* Vol. 52, 341 pp. [Engl Transl. by Israel Program Sci., Transl. TT67-51205, 1968].

Moiseev, P. A. (ed.). 1965. *Soviet Fisheries Investigations in the Northeast Pacific. Part IV. Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 58; also *Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.* Vol. 53, 345 pp. [Engl. Transl. by Israel Program Sci. Transl. TT67-51206, 1968].

Moiseev, P. A. 1969. *The Living Resources of the World Ocean.* Izdatel'stvo "Pishchevaya Promyshlennost", Moscow.

Moiseev, P. A. (ed.). 1970. *Soviet Fisheries Investigations in the Northeast Pacific. Part V.* Moscow, 1970. *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 70; also *Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.* Vol. 72, 454 pp. [Engl. Transl. by Israel Progr. Sci. Trans. TT71-50127, 1972].

Moiseev, P. A. and I. A. Paraketsev. 1961. Some ecological data on rockfishes (Family Scorpaenidae) in the North Pacific. *Vopr. Ikhtiol.* 1(1): 39-45.

Mokiyevskaya, V. V. 1956. Some data on the chemistry of biogenic components of the Bering Sea. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 17.

Moore, J. P. 1903. Polychaeta from the coastal slope of Japan and from Kamchatka and the Bering Sea. *Proc. Acad. Natur. Sci. Philad.* Vol. 55.

Mori, T. 1937. *The Pelagic Copepoda from the Neighboring Waters of Japan.* Yokendo Co., Tokyo. 150 pp.

Morioka, Y. 1969. Species characteristics of vertical distribution of Calanoida (Copepoda) in the northern and southwestern parts of the North Pacific Ocean. *Bull. Plankton Soc. Japan* 16(1):58-59.

Morioka, Y. 1972. The vertical distribution of calanoid copepods off the southeast coast of Hokkaido. *In* A. Y. Takenouti (ed.), *Biological Oceanography of the Northern North Pacific Ocean.* Idemitsu Shoten, Tokyo, Japan. pp. 309-321.

Morita, R. V. and R. P. Griffiths. 1977. Study of microbial activity in the lower Cook Inlet and analysis of hydrocarbon degradation by psychrophilic microorganisms. *In: Environmental Assessment of the Alaskan Continental Shelf, Vol. 1.* Environmental Res. Lab., Boulder, Colorado. pp. 761-788.

Morrison, P., M. Rosenmann and J. A. Estes. 1974. Metabolism and thermoregulation in the sea otter. *Physiol. Zool.* 47(4):218-229.

Mosentsova, T. N. 1957. Massovoe razvitie gammarid v zapadnoi chasti Beringova morya [Mass development of gammarids in the western part of the Bering Sea]. *Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.* Vol. 44:255.

Moser, J. F. 1899. The salmon and salmon fisheries of Alaska. Report of the operations of the U.S.F.C.S. "Albatross" for the year ending June 30, 1898. *Bull. U.S. Fish. Comm.*, Wash. 178 pp.

Motoda, S. 1943. Seasons of occurrence of *Calanus plumchrus* (Copepoda) in Aomori Bay and Oshoro Bay. *Prog. Rep. Hokkaido Fish. Sci. Inst. No. 282*: 207.

Motoda, S. 1971. Vertical structure of ecosystems. [Abstract]. *Proc. Joint Oceanogr. Assembly*, Tokyo, September 1970. pp. 266-267.

Motoda, S. and M. Anraku. 1955. The variability of catches in vertical plankton hauls. *Bull. Fac. Fish., Hokkaido Univ.* 6(2):152-175.

Motoda, S. and T. Fujii. 1956. Report from the 'Oshoro Maru' on oceanographic and biological investigations in the Bering Sea and northern North Pacific in the summer of 1955. I. Program of investigations and records of eye observations of sea-birds and marine mammals. *Bull. Fac. Fish., Hokkaido Univ.* 6:280-297.

Motoda, S., A. Iizuka and T. Kurohagi. 1950. Ecological investigations on the young sand-eel around the coast of Hokkaido. I. Water temperature at fishing season; plankton at fishing ground; burrowing behavior; body-length composition; and growth rate. *Sci. Papers Hokkaido Fish. Sci. Inst.* No. 7:46-55.

Motoda, S. and T. Kawanura. 1963. Light assimilation curves of surface phytoplankton in the North Pacific, 42°N-61°N. *In* C. H. Oppenheimer (ed.), *Symposium on Marine Microbiology*. Chicago. pp. 251-259.

Motoda, S., T. Kawanura and S. Nishizawa. 1970. Biological structure of the sea at long. 142°E in the North Pacific with particular reference to the interrelation between living and non-living organic matter. *The Kuroshio, A Symposium on the Japan Current, Honolulu, April-May 1968*. pp. 241-248.

Motoda, S. and Y. Kawarada. 1955. Diatom communities in western Aleutian waters on the basis of net samples collected in May-June 1953. *Bull. Fac. Fish., Hokkaido Univ.* 6:191-200.

Motoda, S. and S. Kokubo. 1933. On the morphology and ecology of *Calanus cristatus* Kröyer. *Plankton Jiho (Bull. of Planktology)* No. 6.

Motoda, S. and T. Minoda. 1970. Herbivorous zooplankton-phytoplankton relationship in the western North Pacific (142°E). *2nd CSK Symp. Abstracts*, 28 Sept.-1 Oct. 1970. Japanese National Commission for UNESCO:30.

Motoda, S. and T. Minoda. 1974. Plankton of the Bering Sea. *In* D. W. Hood and Y. Takenouti (eds.), *Oceanography of the Bering Sea with Emphasis on Renewable Resources*. Occ. Publ. No. 2, Inst. Mar. Sci., Univ. Alaska, Fairbanks. 623 pp.

Motoda, S. and T. Minoda. 1972. Plankton of the Bering Sea largely based on the material obtained during the cruises of the 'Oshoro Maru', 1954-1970. *Proc. Symp. Bering Sea Study, Hakodate, Jan.-Feb. 1972.*

Motoda, S. and S. Sato. 1949. A brief observation on the diurnal migration of marine plankton off Shiretoko, Hokkaido. *Sci. Papers Hokkaido Fish. Sci. Inst.* No. 2:72-77.

Motoda, S. adn I. Takeuchi. 1949. The food of spring herring in Hokkaido in 1948. *Sci. Papers Hokkaido Fish. Sci. Inst.* (Yoichi, Japan):No. 1: 32-44.

Motoda, S. and I. Takeuchi. 1950. A bibliography of herring. *Sci. Papers Hokkaido Fish. Sci. Inst.* No. 6 (Suppl.):1-72.

Motoda, S. and Y. Tanaka. 1950. Ecological investigations on the young sand-eels around the coast of Hokkaido. II.. Feeding habit. *Sci. Papers Hokkaido Fish. Sci. Inst.* No. 7:56-62.

Motoda, S. A. Taniguchi and T. Ikeda. 1972. Plankton ecology in the western North Pacific Ocean: primary and secondary productivities. *I.P.F.C. Symposium on Coastal and High Sea Pelagic Resources*, Wellington, October 1972.

Motoh, H. 1973. Laboratory-reared zoea and megalops of zuwai crab from the Sea of Japan. *Bull. Jap. Soc. Sci. Fish.* 39:1223-1230.

Mozgovoi, A. A. 1949. The study of anisakids of cetaceans. Akad. Nauk SSSR, *Trudy Gel'mintol. Lab.* 2:26-40.

Mukacheva, V. A. 1954. *Cyclothone microdon* Günther (Pisches, Gonostomidae) - the most numerous Far Eastern deep-sea fish. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 11:206-220.

Mukacheva, V. A. 1957. Development of the Pacific navaga - *Eleginus gracilis* (Tilesius). Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 20: 356-370.

Mukhacheva, V. A. 1959. Spawning stocks of commercial fish in the area of the northern Kurile Islands and southern Kamchatka. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 36:259-

Mukhacheva, V. A. 1964. On the genus *Cyclothone* (Gonostomatidae, Pisces) of the Pacific Ocean. Akad. Nauk SSSR, Leningrad, *Trudy Inst. Okeanol.* Vol. 73:93-138.

Mukhacheva, V. A. 1968. The *Cyclothone* (Family Gonostomatidae). *In* V. G. Kort (ed.), *Tikhiy okean* [Pacific Ocean], *7. Biologiya Tikhogo okeana* [The biology of the Pacific Ocean], *Part 3*. Moscow, Nauka Press. pp. 182-199.

Mukhacheva, V. A. and O. A. Zvyagina. 1960. Razvitie tikhookeanskoi treski *Gadus morrhua macrocephalus* Tilesius [Development of the Pacific cod, *Gadus morrhua macrocephalus* Tilesius]. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 31:145-165.

Mullin, M. M. 1963. Some factors affecting the feeding of marine copepods of the genus *Calanus*. *Limnol. Oceanogr.* 8(2):239-250.

Mullin, M. M. 1969. Production of zooplankton in the ocean: The present status and problems. *In* H. Barnes (ed.), *Oceanography and Marine Biology; An Annual Review. Vol. 7.* George Allen and Unwin Ltd., London. pp. 293-313.

Mullin, M. M., P. R. Sloan and R. W. Eppley. 1966. Relationship between carbon content, cell volume and area in phytoplankton. *Limnol. Oceanogr.* 11(2):307-311.

Munk, W. H. and G. Riley. 1952. Absorption of nutirents by aquatic plants. *J. Mar. Res.* 11(2):215-240.

Murdoch, J. 1885a. Description of seven new species of Crustacea and one worm from Arctic Alaska. *Proc. U.S. Nat. Mus.* Vol. 7:518-522.

Murdoch, J. 1885b. Natural History. V. Marine Invertebrates. *Report of the International Polar Expedition to Point Barrow, Alaska, Part V.* pp. 136-176, pls 1-2. Washington, U.S. Printing Office.

Murie, O. J. 1940. Notes on the sea otter. *J. Mammal.* 21(2):119-131.

Murina, V. V. 1957. Deepwater Sipunculoidea of the genus *Phascolion* Theel of the northwestern Pacific Ocean collected by the "Vityaz" in 1950-1955. *Zool. Zhur.* 36(12).

Musienko, L. N. 1954. Molod'kambal (Pleuronectidae) dal'nevostochnykh morei SSSR [Juvenile flounders (Pleuronectidae) of the Far Eastern Seas of the USSR]. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 11:62-131.

Musienko, L. N. 1955. 1. Coho salmon - *Oncorhyncus kisutch* (Walb.). 2. Chinook salmon - *Oncorhyncus tschawytscha* (Walb.). 3. Dolly Varden char - *Salvelinus malma* (Walb.). 4. Siberian char - *Salvelinus leucomaenis* (Pallas). Geographic distribution of fishes and other commercial items of the Sea of Okhotsk and Bering Sea. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 14:28-35.

Musienko, L. N. 1957. Young flat-fishes of the Far-Eastern seas. Akad. Nauk SSSR, Moscow, *Trudy Inst. Okeanol.* Vol. 20:312-346.

Musienko, L. N. 1961. Distinguishing features of the Far Eastern cod fry (family Gadidae). Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 43:270-281.

Musienko, L. N. 1963. Ikhtioplankton Beringova morya po materialam Beringovomorskoi ekspeditsii TINRO-VINRO 1958-1959 gg. [Ichthyoplankton of the Bering Sea from data of the Bering Sea Expedition of 1958-1959]. Moscow, *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 48(1): 251-286.

Musienko, L. N. 1970. Reproduction and development of Bering Sea fishes. *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 70: 161-224.

Nagai, T. 1974. Studies on the marine snail resources in the eastern Bering Sea. I. Species composition, sex ratio and shell length composition of snails in the commercial catch by snail basket-gear in the adjacent waters of Pribilof Islands, 1973. *Bull. Far Seas Fish. Res. Lab.* (10): 141-156.

Nakai, Z. 1942. The chemical composition, volume, weight and size of the important marine plankton, *J. Oceanogr. Soc. Japan* 1:45-55. [In Japanese].

Nakai, Z. 1952. On quantitative distribution of plankton reproduced in the Northern Pacific. *Tokai Regl. Fish. Res. Lab., Spec. Publ.* No. 2, 6 pp.

Nakai, Z. 1955. The chemical composition, volume, weight and size of the important marine plankton. *Tokai Reg. Fish. Res. Lab., Spec. Publ.* No. 5: 12-24.

Nakai, Z. and K. Honjo. 1954a. A preliminary report on surveys of plankton and salmon stomach contents from the North Pacific, 1952. *Tokai Reg. Fish. Res. Lab.* (Tokyo), *Spec. Publ.* No. 3:6-12.

Nakai, Z. and K. Honjo. 1954b. [Stomach content of whales caught by the "Baikal-maru" fleet in the North Pacific, May-September 1953 (Preliminary Rept.)]. Tokyo, Japan Whaling Assoc. [Mimeograph in Japanese].

Nakajima, K. 1969. Suspended particulate matter in the waters on both sides of the Aleutian Ridge. *J. Oceanogr. Soc. Japan* 25:239-248.

Nakajima, K. 1971. *Suspended Particulate Matter in the Western North Pacific Ocean.* Ph.D. Thesis, Hokkaido Univ., 179 pp.

Nakajima, K. and S. Nishizawa. 1972. Exponential decrease in particulate carbon concentration in a limited depth interval in the surface layer of the Bering Sea. *In* A. Y. Takenouti (ed.), *Biological Oceanography of the Northern North Pacific Ocean*, Idemitsu Shoten, Tokyo, Japan. pp. 495-505.

Nakamura, T. 1963. Distribution of the black-footed albatrosses (*Diomedea nigripes*) in the North Pacific Ocean. *Yamashina's Inst. Ornithol. Zool. Misc. Rep.* 3:239-246.

Nasu, K. 1957. Oceanographic conditions of the whaling grounds in the waters adjacent to the Aleutian Islands and the Bering Sea in summer of 1955. *Sci. Rept. Whales Res. Inst.* No. 12:91-102.

Nasu, K. 1963. Oceanography and whaling ground in the subarctic region of the Pacific Ocean. *Sci. Rept. Whales Res. Inst.* 17:105-155.

Natorov, V. V. 1963. O vodnykh massakh i techenyakh Beringova morya. *Sov. Rybkhoz. Issled. v Sev.-Vost. Chasti Tikhogo okeana* Vol. 1.

Natarov, V. V. and N. P. Novikov. 1970. Oceanographic conditions in the southeast Bering Sea and some distributional characteristics of the halibut. *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 70:288-299.

Naumov, S. P. and N. A. Smirnov. 1936. Materialy po sistematike i geographicheskomu rasproctraneniy *Phocidae* severnoi chasti Tikhogo Okeana. *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 3:161-184.

Navozov-Lavrov, N. 1927. Kratkie svedeniya o treske i paltuse v vodakh Dal'nevostochnyi Voennyi Okrug [Brief data on cod and halibut of Far Eastern waters]. *Byull. Rybn. Khoz.* Nos. 11/12:32-33.

Neave, F. 1948. Fecundity and mortality in Pacific salmon. *Trans. Roy. Soc. Canada* Sec. V, 42:97-105.

Neave, F. 1961. Pacific salmon: Ocean stocks and fishery developments. *Proc. 9th Pacif. Sci. Congr.* 10:59-62.

Neave, F. 1964. Ocean migrations of Pacific salmon. *J. Fish. Res. Bd. Can.* 21(5):1227-1244.

Neave, F. and M. G. Hanavan. 1960. Seasonal distribution of some epipelagic fishes in the Gulf of Alaska region. *J. Fish. Res. Bd. Can.* 17(2):221-233.

Neave, F., T. Ishida and S. Murai. 1967. Salmon of the North Pacific Ocean - Part VII. Pink salmon in offshore waters. *Bull. Int. N. Fish. Pacif. Comm.* 22:1-39.

Neiman, A. A. 1960a. Kormovaya baza kambal v vostochnoi chasti Beringova morya [Forage resources for flatfishes in the eastern part of the Bering Sea]. *Rybn. Khoz.* No. 10.

Neiman, A. 1960b. Quantitative distribution of benthos in the eastern part of the Bering Sea. *Zool. Zhur.* 39(9):1281-1292. [In Russian with Engl. summary].

Neiman, A. A. 1961a. Nekotorye zakonomernosti kolichestvennogo raspredeleniya bentosa v Beringovom more [Certain regularities of the quantitative distribution of benthos in the Bering Sea]. *Okeanol.* 1(2).

Neiman, A. A. 1961b. The vertical distribution of zoogeographical complexes of the bottom fauna in the shelf and the upper horizons of the slope in the eastern part of the Bering Sea. *Okeanol.* 1(6):1073-1078.

Neiman, A. A. 1962. Certain patterns of the distribution of the benthos on the Bering Sea shelf. *Vopr. ekologii* Vol. 5:145-147.

Neiman, A. A. 1963a. Kolichestvennoe raspredelenie bentosa i kormovaya baza donnykh ryb v vostochnoi chasti Beringova morya [Quantitative distribution of the benthos and forage resources for benthic fishes in the eastern part of the Bering Sea]. *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 48(1):143-217.

Neiman, A. A. 1963b. Patterns of the composition of marine benthic biocoenoses. *Zool. Zhur.* 42(4):618-621.

Neimann, A. A. 1964. The age of bivalve mollusks and utilization of benthos by flatfishes in the southeastern area of the Bering Sea. *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 53:199-204.

Nelson, M. O. 1975. Review and evaluation of historical data base on non-salmonid pelagic fishery resources of the Gulf of Alaska shelf and slope. *In: Environmental Assessment of the Alaskan Continental Shelf; Principal Investigators' Reports July-September 1975 Volume 1.* Environmental Research Laboratories, Boulder, Colorado, 1975. pp. 499-509.

Nemoto, T. 1956. On the diatoms of the skin film of whales in the Northern Pacific. *Sci. Rept. Whales Res. Inst.* No. 11:99-132.

Nemoto, T. 1957. Foods of baleen whales in the Northern Pacific. *Sci. Rept. Whales Res. Inst.* No. 12:33-90.

Nemoto, T. 1959. Food of baleen whales with reference to whale movements. *Sci. Rept. Whales Res. Inst.* No. 14:149-290.

Nemoto, T. 1962a. Distribution of five main euphausiids in the Bering Sea and the northern part of the North Pacific. *J. Oceanogr. Soc. Jpn.* 20th Anniv. Vol. pp. 615-627. [In Japanese with Engl. abst.].

Nemoto, T. 1962b. Food of baleen whales. *Geiken-sosho* 4:1-136. [In Japanese].

Nemoto, T. 1963. Some aspects of the distribution of *Calanus cristatus* and *C. plumchrus* in the Bering Sea and its neighboring waters with reference to the feeding of baleen whales. *Sci. Rept. Whales. Res. Inst.* Tokyo No. 17:157-170.

Nemoto, T. 1966. *Thysanoessa* euphausiids, comparative morphology, allomorphosis and ecology. *Sci. Rept. Whales Res. Inst.* No. 20:109-155.

Nemoto, T. 1967. Feeding pattern of euphausiids and differentiations in their body characters. *Inf. Bull. Planktonol. Japan Commem. No. of Dr. Y. Matsue*:157-174.

Nemoto, T. 1968. Chlorophyll pigments in the stomachs of euphausiids. *J. Oceanogr. Soc. Japan* 24:253-260.

Nemoto, T. 1970. Chlorophyll pigments in digestive guts of zooplankton. *Bull. Plankton Soc. Japan* 17(1):50-55.

Nemoto, T. 1970. Feeding pattern of baleen whales in the ocean. *In* J. H. Steele (ed.), *Marine Food Chains.* Oliver and Boyd, Edinburgh. pp. 241-252.

Nemoto, T. 1972. Chlorophyll pigments in the stomach and gut of some macrozooplankton species. *In* A. Y. Takenouti (ed.), *Biological Oceanography of the Northern North Pacific Ocean.* Idemitsu Shotan, Tokyo, Japan. pp. 411-418.

Nemoto, T. 1974. Regional and vertical distribution of *Thysanoessa* (Euphausiacea) in the northeastern Bering Sea and Chukchi Sea. Hokkaido Univ., Manuscr. Rept. Fac. Fish. Lab., 24 pp.

Nemoto, T. and T. Kasuya. 1965. Foods of baleen whales in the Gulf of Alaska of the North Pacific. *Sci. Rept. Whales Res. Inst.*, Tokyo. No. 19:45-51.

Nemoto, T. and K. Nasu. 1962. Stones and other aliens in the stomachs of sperm whales in the Bering Sea. *Sci. Rept. Whales Res. Inst.* Tokyo. No. 17:83-91.

Nemoto, T. and Y. Saijo. 1968. Trace of chlorophyll pigments in stomachs of deep sea zooplankton. *J. Oceanogr. Soc. Japan* 24:310-312.

Nesis, K. N. 1965. Aspects of the food structure of a marine biocoenosis. *Okeanol.* 5(4):701-714; also *Oceanol.* 5(4):96-107.

Nikolotova, L. A. 1954. Feeding of the Pacific navaga. *Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.* Vol. 42:286-293.

Nikulin, P. G. 1941. Chukotskii morzh [Chukchi walrus]. *Izv. Tikhookean Nauchno-Issled. Rybn. Khoz. Okeanogr.* Vol. 20:21-59.

Nikulin, P. G. 1946. Distribution of cetaceans in seas adjoining the Chukchi Peninsula. *Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.* Vol. 22:255-257.

Nishimoto, S., M. Tozawa and T. Kawakami. 1952. Food of Sei Whales caught in the Bonin Island Waters. *Sci. Rept. Whales Res. Inst.*, Tokyo. No. 7:79-86.

Nishiyama, T. 1970. Tentative estimation of daily ration of sockeye salmon, *Oncorhynchus nerka* in Bristol Bay prior to ascending migration. Hokkaido University, Hakodate. *Bull. Fac. Fish. Hokkaido University* Vol. 20(4):265-276.

Nishiyama, T. 1972. Growth and food of salmon, with special reference to red salmon in Bristol Bay. *Bull. Jap. Soc. Fish. Oceanogr.* 21:123-126.

Nishiyama, T. 1974a. Energy requirement of Bristol Bay sockeye salmon in the central Bering Sea and Bristol Bay. *In* D. W. Hood and E. J. Kelley (eds.), *Oceanography of the Bering Sea.* Inst. Mar. Sci., Univ. Alaska Fairbanks. pp. 321-343.

Nishiyama, T. 1974b. Population structure of Bristol Bay sockeye salmon population. [Abstract, in Japanese]. Ann. Meeting Jap. Soc. Sci. Fish., April, Tokyo.

Nishiyama, T. 1974c. Role of function of water temperature upon growth of Bristol Bay sockeye salmon. [Abstract, in Japanese]. Eleventh Meeting Salmon Res. Invest., December, Ohzuchi.

Nishiyama, T. 1975a. Ecological approach to fisheries. *In* D. W. Hood and Y. Takenouti (convenors), Bering Sea Oceanography: An Update, Results of US-Japan Seminar/Workshop on Bering Sea Oceanography. Rept. R75-2, Inst. Mar. Sci., Univ. Alaska, Fairbanks. pp. 153-156.

Nishiyama, T. 1975b. Studies on food requirement of Bristol Bay sockeye salmon *Oncorhynchus nerka* (Walbaum) at the last stage of marine life. Ph. D. thesis, Hokkaido University, 211 pp.

Nishiyama, T., T. Fujii, H. Ogi, S. Yamamoto and K. Masuda. 1973. Age, sex and maturity of Bristol Bay sockeye salmon population. [Abstract, in Japanese]. Tenth Meeting Salmon Res. Invest., December, Kumamoto.

Nishiyama, T., T. Fujii, H. Ogi, S. Yamamoto and K. Masuda. 1975. Distribution and population structure of mature Bristol Bay sockeye salmon on the Bering Sea. *Sci. Rept. Salmon Res. Invest.* No. 4.

Nishiyama, T., M. Fukuchi and T. Tsujita. 1974. Zooplankton community and caloric values of representative species in the northern and central Pacific Ocean. [Abstract, in Japanese]. Symposium on mechanism of biological production system in the North Pacific Ocean, October, Tokyo.

Nishiyama, T. and S. Mishima. 1966. Food habit and diurnal rhythm of feeding of pink and chum salmon in the northern North Pacific Ocean. [Abstract, in Japanese]. The Third Meeting Salmon Res. Invest., January, Morioka.

Nishiyama, T., M. Narita, H. Ogi and T. Tsujita. 1975. Summer distribution and population structure of walleye pollock (*Theragra chalcogramma*) in the Bering Sea basin area, 1973-1975. (In preparation).

Nishizawa, S. 1965. *Seawater Turbidity and Suspended Particulate Materials.* Ph.D. Thesis, Hokkaido University, 242 pp.

Nishizawa, S. 1966. Suspended material in the sea: from detritus to symbiotic microcosmos. *Inf. Bull. Planktol. Japan* No. 13:1-33.

Nishizawa, S. and K. Nakajima. 1971. Concentration of particulate organic material in the sea surface layers. *Bull. Plankton Soc. Japan* 18(2): 12-19.

Norman, J. R. 1934. *A Systematic Monograph of the Flatfishes (Heterostomata).* Trustees of the British Museum, London. 459 pp.

Novikov, N. P. 1960. Paltusy Beringova morya [Halibut of the Bering Sea]. *Rybn. Khoz.* No. 1:12-15.

Novikov, N. P. 1961. Novye dannye o raspredelenii paltusov i nekotorykh drugikh promyslovykh ryb v Beringovom more [New data on the distribution of halibut and certain other commercial fish in the Bering Sea]. *Zool. Zhur.* 40(10):1510-1515.

Novikov, N. P. 1962a. Kratkoe nastav'lenie po razvedke paltusov v Beringovom more [*Brief Instructions for Halibut Surveys in the Bering Sea*). Vladivostok, Promizdat.

Novikov, N. P. 1962b. On the probability of gynogenesis in the American arrow-toothed halibut in the Bering Sea. Akad. Nauk SSSR, *Doklady* 147(1):215-216.

Novikov, N. P. 1963a. Attacks by the Pacific lamprey on halibut and other fishes of the Bering Sea. *Vopr. Ikhtiol.* 3(3):567-569.

Novikov, N. P. 1963b. O chislennosti belokorogo paltusa v Beringovom more [Numbers of Pacific halibut in the Bering Sea]. *Zool. Zhur.* 42(8):1183-1186.

Novikov, N. P. 1964. Basic elements of the biology of the Pacific halibut (*Hippoglossus hippoglossus stenolepsis* Schmidt) in the Bering Sea. *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 49: 175-219.

Novikov, N. P. 1965. Resources of the continental slope of the North Pacific and prospects of their development. *Rybn. Khoz.* No. 8:11-16.

Novikov, N. P. 1968. Tagging of black cod (*Anoplopoma fimbria* Pall). *Vopr. Ikhtiol.* 8(5):955-957.

Novikov, N. P. 1970. Biology of *Chalinura pectoralis* in the North Pacific. *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 70: 304-331.

Ochiai, A. and T. Yoshimitsu. 1964. On the population and migration of adult red salmon in the western parts of the North Pacific and Bering Sea, as estimated by age composition. *Bull. Jap. Soc. Sci. Fish.* 30(4): 734-741.

Ogata, T. 1956. Optimal water temperature, vertical distribution and other characteristics of the walleye pollock. *Hokkaido Fish. Exp. Sta., Monthly J.* 27(9).

Ogi, H. 1973. Ecological studies on the juvenile *Oncorhynchus nerka* in Bristol Bay with special reference to its distribution and population. *Bull. Fac. Fish., Hokkaido Univ.* 24(1):14-41.

Ogi, H. and T. Tsujita. 1973. Preliminary examination of stomach contents of murres, *Uria* spp., from the eastern Bering Sea and Bristol Bay, Alaska, U.S.A. June-August 1970 and 1971. *Jap. J. Ecol.* 23(5):201-209.

Ogura, N. 1970. The relation between dissolved organic carbon and apparent oxygen utilization in the western North Pacific. *Deep-Sea Res.* 17(2): 221-231.

Ogura, N. 1972. Decomposition of dissolved organic matter derived from dead phytoplankton. *In* A. Y. Takenouti (ed.), *Biological Oceanography of the Northern North Pacific Ocean.* Idemitsu Shoten, Tokyo, Japan. pp. 507-515.

Ohtani, K. 1973. Oceanographic structure in the Bering Sea. Hokkaido Univ., *Mem. Fac. Fish.* 21:65-106.

Ohigashi, S. and K. Ito. 1955. On the Alaska pollock juvenile (*Theragra chalcogramma*) taken from the Funka Bay. Hokkaido Fish Hatch., Sapporo, *Sci. Rept. Hokkaido Fish Hatch.* 10(1):161-168.

Ohshima, H. 1933. Echinoids and Holothurians from the North Kuriles. *Bull. Biogeogr. Soc. Japan* Vol. 4:228-235.

Ohtani, K. 1966. The Alaskan Stream and the sockeye salmon fishing ground. *Bull. Fac. Fish., Hokkaido Univ.* 16(4):209-240.

Ohwada, M. 1972. Vertical distribution of diatoms in the Sea of Japan. *In* A. Y. Takenouti (ed.), *Biological Oceanography of the northern North Pacific Ocean.* Idemitsu Shoten, Tokyo, Japan. pp. 145-163.

Ohwada, M. and H. Kon. 1963. A microplankton survey as a contribution to the hydrography of the North Pacific and adjacent seas. II. Distribution of the microplankton and their relation to the character of water masses in Bering Sea and northern North Pacific Ocean in the summer of 1960. *Oceanogr. Mag.* 14:87-99.

Oishi, K., S. Oka and M. Hiroaki. 1972. Food hygenic studies on Anisakis larva - II. Free and combined amino acid composition of Anisakis larvae (the 3rd stage) from Alaska pollock. *Bull. Jap. Soc. Sci. Fish.* 38(1):69-72.

Okada, H. and S. Honjo. 1973. The distribution of oceanoc coccolithophorids in the Pacific. *Deep-Sea Res.* 20(4):355-374.

Okada, S. and K. Kobayashi. 1968. *Colored Illustrations of Pelagic and Bottom Fishes in the Bering Sea*: Hokuyu-Gyorui-zusetsu. 180 pp. [In Japanese].

Okamura, K. 1932. The distribution of marine algae in Pacific waters. *Rec. Oceanogr. Works Japan* Vol. 4:30-47.

Okamura, K. 1933. On the algae from Alaska collected by Y. Kobayashi. *Rec. Oceanogr. Works Japan* 5(1):85-97.

Okhryamkin, D. I. 1931. Morskie ryby Dal'nego Vostoka [Marine Fishes of the Far East]. Moscow-Khabarovsk, 50 pp.

Okutani, T. and T. Nemoto. 1964. Squids as the food of sperm whales in the Bering Sea and Alaskan Gulf. *Sci. Rept. Whales Res. Inst.*, Tokyo. No. 18:111-123.

Olsen, O. W. 1958. Hookworms, *Uncinaria lucasi* Stiles, 1901, in fur seals, *Callorhinus ursinus* (Linn.), on the Pribilof Islands. *Trans. N. Amer. Wildl. Conf.* 23:152-175.

Olsen, O. W. 1959. Investigations on the biology and ecology of hookworms (*Uncinaria lucasi* Stiles) in fur seals on the Pribilof Islands, Alaska. VI. Hatching of hookworm eggs on the rookeries. U.S. Dept. Int., Fish and Wildl. Serv., Washington, D.C. 13 pp. Hectograph.

Olsen, O. W. and E. T. Lyons. 1962. Life cycle of the hookworm, *Uncinaria lucasi* Stiles, of northern fur seals, *Callorhinus ursinus*, on the Pribilof Islands in the Bering Sea. *J. Parasit.* 48(Suppl.):42-43.

Olsen, O. W. and E. T. Lyons. 1965. Life cycle of *Uncinaria lucasi* Stiles, 1901 (Nematoda, Acylostomatidae) of fur seals, *Callorhinus ursinus* Linn., on the Pribilof Islands, Alaska. *J. Parasit.* 51(5):689-700.

Omori, M. 1965. The distribution of zooplankton in the Bering Sea and northern North Pacific, as observed. High-speed sampling of the surface water, with special reference to the copepods. *J. Oceanogr. Soc. Japan* 21(1):18-27.

Omori, M. 1967. *Calanus cristatus* and submergence of the Oyashio water. *Deep-Sea Res.* 14(5):525-532.

Omori, M. 1969. Weight and chemical composition of some important oceanic zooplankton in the North Pacific Ocean. *Mar. Biol.* 3:4-10.

Omori, M. 1970. Variations of length, weight, respiratory rate, and chemical composition of *Calanus cristatus* in relation to its food and feeding. *In* J. H. Steele (ed.), *Marine Food Chains.* Oliver & Boyd, Edinburgh. pp. 113-126.

Omori, M., A. Kawamura and Y. Aizawa. 1972. *Sergestes similis* Hansen, its distribution and importance as food of fin and sei whales in the North Pacific Ocean. *In* A. Y. Takenouti (ed.), *Biological Oceanography of the Northern North Pacific Ocean.* Idemitsu Shoten, Tokyo, Japan. pp. 373-391.

Omori, M. and O. Tanaka. 1967. Distribution of some cold-water species of copepods in the Pacific water off east-central Honshu, Japan. *J. Oceanogr. Soc. Japan* 23(2):63-73.

Omura, H. 1955. Whales in the northern part of the North Pacific. *Norsk Hvalfangst-Tid.* No. 6:323-345.

Omura, H. 1958. North Pacific right whales. *Sci. Rept. Whales Res. Inst.* No. 13:1-52.

Ortmann, A. E. 1906. Schizopod crustaceans in the United States National Museum - The families Lophogastridae and Eucopiidae. *Proc. U.S. Nat. Mus.* Vol. 31:23-54.

Ortmann, A. E. 1908. Schizopod Crustaceans in the U.S. National Museum: Schizopods from Alaska. *Proc. U.S. Nat. Mus.* Vol. 34:1-10, pl. 1.

Orton, J. H. 1920. Sea temperature, breeding and distribution in marine animals. *J. Mar. Biol. Assoc. U.K.* 12:339-366.

Oshima, T., A. Kobayashi, M. Kumada, T. Koyama, N. Kagei and T. Nemoto. 1968. Experimental infection with second stage larvae of *Anisakis* sp. on *Euphausia similis* and *Euphausia pacifica*. *Jap. J. Parasitol.* 17(supplement):585. [In Japanese].

Oshima, T., T. Shimazu, H. Koyama and H. Akahane. 1969. On the larvae of the genus *Anisakis* (Nematoda: Anisakinae) from the euphausiids. *Jap. J. Parasitol.* 18:241-248.

Otsuki, A. 1968. Biogeochemical studies on the production of the dissolved organic matter in relation to food chain of hydrosphere. Ph.D. Thesis, Tokyo Metropolitan Univ., Tokyo, 79 pp.

Paine, R. T. 1964. Ash and caloric determinations of sponge and opisthobranch tissues. *Ecol.* 45(2):384-387.

Paine, R. T. and R. L. Vadas. 1969. Calorific values of benthic marine algae and their postulated relation to invertebrate food preference. *Mar. Biol.* 4(2):79-86.

Palenichko, Z. G. 1941. Distribution and biology of the shrimp in the Barents Sea. *Zool. Zh.* 20(3):398-414.

Panin, K. I. 1950. [Material on the biology of herring of northeastern Kamchatka]. *Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.* Vol. 32:3-36.

Panin, K. I. and G. K. Panin. 1968. *In* V. A. Arsen'ev and K. I. Panin (eds.), Pinnipeds of the North Pacific. *Tr. Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okean.* Vol. 68:66-76.

Panina, G. K. 1966. Food of stellar sea lions and seals on the Kurile Islands. *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 58:235-236.

Paraketsov, I. A. 1963. O biologii *Sebastodes alutus* G. Beringova morya [Biology of *Sebastodes alutus* G. in the Bering Sea]. *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Oceanogr.* Vol. 48:319-327.

Paranjape, M. A. 1967. Moulting and respiration of euphausiids. *J. Fish. Res. Bd. Can.* 24(6):1229-1240.

Parin, N. V. 1961. Distribution of deep-sea fishes in the upper bathypelagic layer of subarctic waters in the northern Pacific. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 45:259-278.

Parin, N. V. 1966. Oceanic epipelagic ichthyofauna and basic features of its distribution. *Vtoroi Mezhdunarodnyi Okeanograficheskii Kongress, 30 maya-9 iyunya 1966 g. Synopses of Reports*. Moscow, Izdatel'stvo "Nauka".

Parin, N. V. 1968. Ikhtiofauna Okeanskoi Epipelagiali [*Ichthyofauna of the Epipelagic Zone*]. Moscow, Izdatel'stvo "Nauka".

Parin, N. V., V. E. Becker, O. D. Borodulina and V. M. Chuvassov. 1973. Bathypelagic fishes of the south-eastern Pacific and adjacent waters. Akad. Nauk SSSR, Leningrad. *Trudy. Inst. Okeanol.* Vol. 94:71-172.

Park, T. S. 1968. Calanoid copepods from the central North Pacific Ocean. *U.S. Fish. Wildl. Serv., Fish. Bull.* 66(3):527-572.

Parker, R. R. and L. Margolis. 1964. A new species of parasitic copepods, *Caligus clemensi* sp. nov. (Caligoida, Caligida) from pelagic fishes in the coastal waters of British Columbia. *J. Fish. Res. Bd. Can.* 21(5): 873-889.

Parry, D. A. 1949. The structure of whale blubber, and discussion of its thermal properties. *Quat. J. Microsc. Sci.* 90(1):13-25.

Parsons, T. R. 1969. The use of particle size spectra in determining the structure of a plankton community. *J. Oceanogr. Soc. Japan* 25:172-181.

Parsons, T. R. 1972. Size fractionation of primary producers in the subarctic Pacific Ocean. *In* A. Y. Takenouti (ed.), *Biological Oceanography of the Northern North Pacific Ocean*. Idemitsu Shoten, Tokyo, Japan. pp. 275-278.

Parsons, T. R. and G. C. Anderson. 1970. Large-scale studies of primary production in the North Pacific Ocean. *Deep-Sea Res.* 17:765-776.

Parsons, T. R., L. F. Giovando and R. J. LeBrasseur. 1966. The advent of the spring bloom in the eastern subarctic Pacific Ocean. *J. Fish. Res. Bd. Can.* 23:539-546.

Parsons, T. R. and R. J. LeBrasseur. 1968. A discussion of some critical indices of primary and secondary production for largescale ocean surveys. *Rept. Calif. Coop. Oceanic Fish. Invest.* 12:54-63.

Parsons, T. R. and R. J. LeBrasseur. 1970. The availability of food to different trophic levels in the marine food chain. *In* J. H. Steele (ed.), *Marine Food Chains*. Oliver and Boyd, Edinburgh. pp. 325-346.

Parsons, T. R., R. J. LeBrasseur and J. D. Fulton. 1967. Some observations on the dependence of zooplankton grazing on the cell size and concentration of phytoplankton blooms. *J. Oceanogr. Soc. Japan* 23:10-17.

Parsons, T. R., K. Stephens and J. D. H. Strickland. 1961. On the chemical composition of eleven species of marine phytoplankters. *J. Fish. Res. Bd. Can.* 18(6):1001-1016.

Parsons, T. R. and J. D. H. Strickland. 1962. On the production of particulate organic carbon by heterotrophic processes in sea water. *Deep-Sea Res.* 8(3/4):211-222.

Parsons, T. and M. Takahashi. 1974. *Biological Oceanographic Processes.* Pergamon Press, New York.

Pasternak, F. A. 1960. The deep-sea Pennatularia from the Bering Sea and Kurile-Kamschatka trench. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* 34:329-335.

Pasternak, F. A. 1961. New data on the specific composition and distribution of the deep-sea pennatularian genus *Kophobelemnon.* Akad. Nauk SSSR, *Trudy Inst. Okeanol.* 45:240-258.

Patten, B. C. 1968. Mathematical models of plankton production. *Int. Revie Ges. Hydrobiol.* 53(3):357-408.

Patterson, J. and T. R. Parsons. 1963. Distribution of chlorophyll and degradation products in various marine materials. *Limnol. Oceanogr.* 8(3):355-356.

Paulson, A. C. and R. L. Smith. 1974. Occurrence of Pacific staghorn sculpin (*Leptocottus armatus*) in the southern Bering Sea. *J. Fish. Res. Bd. Canada* 31(7):1262.

Pavlenko, M. 1914. *Investigations on the Pacific Herring (Clupea harengus L.).* Publ. by Dept. of Agriculture, Petrograd. [In Russian].

Pedersen, T. and J. T. Rudd. 1946. A bibliography of whales and whaling. *Norske Vidensk.-Akad. Oslo Hvalrådets Skrift-Sci. Results Marine Biol. Res.* 30:1-32.

Pennell, D. A., C. D. Becker, and N. R. Scofield. 1973. Helminths of sockeye salmon, *Oncorhynchus nerka*, from the Kvichak River system, Bristol Bay, Alaska, U.S.A. *U.S. Natl. Mar. Fish. Serv., Fish. Bull.* 71(1):267-277.

Percy, J. A. 1975. Ecological physiology of Arctic marine invertebrates. Temperature and salinity relationships of the amphipod *Onismus affinis* H. J. Hansen. *J. Exp. Mar. Biol. Ecol.* 20(1):99-117.

Pergament, T. S. 1961. K faune Echiurida dal'nevostochnykh morei SSSR. Izd. Akad. Nauk SSSR, Moscow, *Issled. Dal'nevost. Morei* 7:144-150.

Perlov, A. S. 1968. Fur seal distribution in the region of the Commander Islands in spring and summer. *In* V. A. Arsen'ev and K. I. Panin (eds.), *Pinnipeds of the North Pacific. Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okean.* Vol. 68:77-82.

Pertseva-Ostroumova, T. A. 1954. Data on the development of the far Eastern flatfish. Communication 1. Development of the yellowfin sole. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 11:221-232.

Pertseva-Ostroumova, T. A. 1955. Opredelitel'nye tablitsy pelagicheskoi ikry ryb zal. Letra Belikogo. *Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.* Vol. 43:43-68.

Pertseva-Ostroumova, T. A. 1960. Reproduction and development of the arrow-toothed halibuts of the genus *Atheresthes* J. et G., *Zool. Zhur.* 39(11):1659-1669.

Pertseva-Ostroumova, T. A. 1961. Breeding and Development of Far Eastern Flatfishes. Moscow, Izd. Akad. Nauk SSSR.

Peruyeva, Ye. G. 1971. Some quantitative regularities in the feeding of the copepod *Calanus*. *Okeanol.* 11(2):283-292; also *Oceanol.* 11(2): 232-239 [English translation].

Pettibone, M. 1954. Marine polychaeta worms from Point Barrow, Alaska with additional records from the North Atlantic and North Pacific. *Proc. U.S. Nat. Mus.* 103(3324):203-356.

Phifer, L. D. 1934. The occurrence and distribution of plankton diatoms in Bering Sea and Bering Strait, 26 July to 24 August, 1934. University of Washington Oceanographic Laboratories, Part II. Rept. Oceanogr. Cruise U.S. Coast Guard Cutter *Chelan* 1934.

Phifer, L. D. 1940. Phytoplankton of the northeastern Pacific and eastern Bering Sea. (An abstract of a paper presented before the Pacific Section of the Botanical Society of America, Seattle, Washington, June 17-22, 1940.) *Amer. J. Bot.* 27(8):709.

Pieper, R. E. 1967. Mesopelagic faunal discontinuities in the eastern North Pacific. Tech. Rept. No. 67-19, General Motors Corporation, Defense Research Laboratories, Santa Barbara, California.

Pike, G. C. 1950. Stomach contents of whales caught off the coast of British Columbia. Prog. Rept. Pacific Coast Sta. 83:27-28.

Pike, G. C. 1962. Migration and feeding of the gray whale (*Eschrichtius gibbosus*). *J. Fish. Res. Bd. Canada* 19(5):815-838.

Pilsbry, H. A. 1911. Barnacles of Japan and Bering Sea. *Bull. U.S. Bur. Fish.*, 1909 29:59-84.

Pilsbry, H. A. 1916. The sessile barnacles (Cirripedia) contained in the collections of the U.S. National Museum; including a monograph of the American species. *Bull. U.S. Natl. Mus.* No. 93. 366 pp.

Piskunov, I. A. 1955. Materials on the biology of young coho during the marine period of existence. *Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.* Vol. 43:3-10.

Piskunov, I. A. 1959. The biology of young chum during the marine period of their existence. *Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.* Vol. 47.

Pitcher, K. and D. Calkins. 1977. Biology of the harbor seal, *Phoca vitulina richardi*, in the Gulf of Alaska. *In: Environmental Assessment of the Alaskan Continental Shelf, Vol. I.* Environmental Res. Lab., Boulder, Colorado. pp. 325-357.

Polutov, I. A. and E. I. Pashkeev. 1967. Migration of flatfishes in coastal waters of Kamchatka. *Vopr. Ikhtiol.* 7(3):529-539.

Polutov, I. A. and V. I. Tikhonov. 1959. Commercial fishes of the Bering Sea. *Kanuch. Sovnarkhoz. Tekhn. Ekonom. Byull.* No. 5-6:16-22.

Polutov, I. A. and V. N. Tripol'skaya. 1954. Pelagicheskie lichinki i ikra morskikh ryb u beregov kamchatki [Pelagic larvae and eggs of marine fishes off the coasts of Kamchatka]. *Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.* Vol. 41:295-308.

Ponomareva, L. A. 1949. O pitanii planktonoyodniaech kitov Beringova morya [On the zooplankton diet of baleen whales in the Bering Sea]. Akad. Nauk SSSR, *Doklady* 68(2):401-403.

Ponomareva, L. A. 1951. O vzaimootnosheniyakh sel'dei roda *Clupea* [Interrelationships of herring of the genus *Clupea*]. *Uchenye Zapiski Gor'kovskogo Gosudarstvennogo Universiteta*, No. 19.

Ponomareva, L. A. 1954a. Euphausiids of the Sea of Japan feeding on the copepoda. Akad. Nauk SSSR, *Doklady* 98(1):153-154.

Ponomareva, L. A. 1954b. Importance of particular species of Euphausisiacea as fish and whale food. Akad. Nauk SSSR, Leningrad, *Trudy Inst. Okeanol.* Vol. 8:200-205.

Ponomareva, L. A. 1955. The euphausiids of the Kurile-Kamchatka Trench. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 12:288-297.

Ponomareva, L. A. 1957. Distribution of euphausiids in the Far Eastern Seas. Akad. Nauk SSSR, *Doklady* 114(6):1214-1216.

Ponomareva, L. A. 1959a. The euphausiid crustacean plankton of the Far Eastern Seas and the Northwest Pacific. Int. Oceanogr. Congr. Rept. pp. 170-172.

Ponomareva, L. A. 1959b. On euphausiids of the Okhotsk and Bering Seas. *Trudy Inst. Okeanol.* Vol. 30:115-147.

Ponomareva, L. A. 1959c. Reproduction of euphausiids of the Sea of Japan and development of their early larval stages. *Zool. Zhur.* 38(11):1649-1662.

Ponomareva, L. A. 1960. Euphausiid plankton of the Far Eastern Seas and Northwest Pacific. *Int. Rev. Ges. Hydrobiol.* 45(2):303-307.

Ponomareva, L. A. 1962. Euphausiids of the North Pacific. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* 58:135-155.

Ponomareva, L. A. 1963. *Euphausiids of the North Pacific. Their Distribution and Ecology.* Akad. Nauk SSSR, Inst. Okeanol., Moscow 1966. 154 pp.

Ponomareva, L. A. 1966. Quantitative distribution of euphausiids in the Pacific Ocean. *Okeanol.* 6(4):690-692.

Popov, A. M. 1931a. A new genus of fish *Davidijordana* (Zoarcidae, Pisces) in the Pacific Ocean. Akad. Nauk SSSR, *Doklady* 1(8):210-215.

Popov, A. M. 1931b. The Wolf-eel; its systematic position and distribution, with notes on wolf-fish of the U.S.S.R. Akad. Nauk SSSR, *Doklady* Seriya A, No. 14:380-386.

Poppe, S. A. 1884. Free-living copepoda from the north Pacific Ocean and the Bering Sea. *Arch. Naturg.* 50:281-304.

Potapov, V. F. 1961. Longline fishing of halibut in the Bering Sea. Petropavlovsk-Kamchatskii.

Potapova, G. A. 1965. Bibliography on fishery investigations (in Russian) in the northeast Pacific Ocean. *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 58:297-373.

Powell, D. E. and A. E. Peterson. 1957. Experimental fishing to determine distribution of salmon in the North Pacific Ocean, 1955. *U.S. Fish. Wildl. Serv., Spec. Sci. Rept. Fish.* No. 205. 30 pp.

Pozdnyakov, Yu. F. 1957. On the fecundity of the capelin of the Barents Sea. Akad. Nauk SSSR, Leningrad, *Doklady* 112(4):777-778.

Pravdin, I. F. 1940. A review of research on Far Eastern salmon. *Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.* Vol. 18.

Pravdin, I. F. 1949. 1. Chum salmon - *Oncorhynchus keta* (Walbaum). 2. Chinook salmon - *Oncorhynchus tschawytscha* (Walbaum). 3. Dolly Varden char - *Salvelinus malma* (Walbaum). Promyl. Ryby. SSSR. Pishchepromizdat.

Preble, E. A. and W. L. McAtee. 1923. Biological survey of the Pribilof Islands, Alaska. Part I. Birds and Mammals. *U.S. Fish Wildl. Serv. N. Amer. Fauna* 46:1-128.

Prokhorov, V. G. 1968. On the winter period of life of herring in the Bering Sea. *Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.* Vol. 64:329-337.

Prosser, C. L. 1958. *Physiological Adaptation.* Ronald Press, New York. 185 pp.

Provasoli, L. 1963. Organic regulation of phytoplankton fertility. *In* M. N. Hill (ed.), *The Sea, Vol. 2.* Interscience, New York. pp. 165-219.

Pruter, A. T. 1973. The development and present status of bottom fish resources in the Bering Sea. *J. Fish. Res. Bd. Canada* 30(12, pt 2): 2373-2385.

Pruter, A. and D. L. Alverson. 1962. Abundance, distribution and growth of flounders in the southeastern Chukchi Sea. *J. du Conseil.* 27(1):81-99.

Pushkareva, N. F. 1951. Pitanie gorbushi v kontse morskogo etapa migratsionnogo puti [Feeding of the humpback salmon at the end of the marine stage of the migration route]. *Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.* Vol. 35:33-39.

Pyatakov, M. 1930. Promysel chilimov na Alyaske [*Pandalus* catch in Alaska]. *Rybn. Khoz. Dal'nego. Vostoka.* No. 3-4.

Quast, J. C. 1974. Density distribution of juvenile arctic cod, *Boreogadus saida*, in the eastern Chukchi Sea in the fall of 1970. *U.S. Natl. Mar. Fish. Serv. Fish. Bull.* 72(4):1094-1105.

Quast, J. C. and E. L. Hall. 1972. List of fishes of Alaska and adjacent waters with a guide to some of their literature. U.S. Dept. Commer., Tech. Rept. NMFS, SSRF-658. pp. 1-47.

Rao, K. P. and T. H. Bullock. 1954. Q_{10} as a function of size and habitat temperature in poikilotherms. *Amer. Natl.* 88(843):33-44.

Rass, T. S. 1933. Nerest moivy (*Mallotus villosus Müll*) Barentsova morya [Spawning of the capelin (*Mallotus villosus Müll*) in the Barents Sea]. Izd. Gosudar. Okeanogr. Inst., Moscow, *Trudy Gosudar. Okeanogr. Inst.* 4(1):3-34.

Rass, T. S. 1935. Nekotorye zakonomernosti v stroenii ikrinoki lichinok ryb v severnykh vadakh [Some characteristic features of the structure of fish eggs and larvae in northern waters]. Akad. Nauk SSSR, Compte Rendus, *Doklady* 7:597-600.

Rass, T. S. 1945. Ikhtioplankton iz Vostochno-Sibirskogo i Chukotskogo morei [Ichthyoplankton from the Eastern Siberian and Chukchi Seas]. *Problemy Arktiki* No. 1.

Rass, T. S. 1948. Mirovoi promysel vodnykh zhivotnykh [World Catch of Marine Animals]. Moscow, Izd. *"Sovets. Nauka"*.

Rass, T. S. 1949. 1. Siberian char - *Salvelinus leucomaenis* (Pallas) 2. Alaskan Greenling - *Hexagrammus octogrammus* (Pallas). Promyl. Ryby. SSSR, Pishchepromizdat.

Rass, T. S. 1950. Geographic complexes in the world catch of marine animals. *Izv. Vses. Geograf. Olishch.* 82(3):

Rass, T. S. 1953a. Deep-sea fishes at the Far Eastern Seas. *Priroda* 1953, 2:107-109.

Rass, T. S. 1953b. Importance of research on the reproduction of fishes for evaluation of possible catches. *Rybn. Khoz.* No. 2.

Rass, T. S. 1954. Deep-sea fishes of the Far Eastern Seas of the USSR. *Zool. Zhur.* 33(6):1312-1324.

Rass, T. S. 1955a. Deep-sea fishes of the Kurile-Kamchatka Trench. Akad. Nauk SSSR, Leningrad. *Trudy Inst. Okeanol.* Vol. 12:328-339.

Rass, T. S. 1955b. New fishing areas and new commercial species in the sea of the Far East. *Vopr. Ikhtiol.* 4:

Rass, T. S. 1956. Prospects for considerable increases in fish catches in the Far East. *Rybn. Khoz.* No. 9:57-60.

Rass, T. S. 1958a. Deep-sea fishes of the Northern Pacific and Far Eastern Seas. *Intl. Congr. Zool. Proc., Sect. III* 34:229-231.

Rass, T. S. 1958b. Ichthyological investigations of the Institute of Oceanology of the Academy of Science of the USSR in the Far Eastern Seas. Akad. Nauk SSSR, *Trudy Okeanogr. Komissii.* Vol. 3:118-121.

Rass, T. S. 1959. Glubokovodnye ryby [Deep-sea fishes]. Izd. Akad. Nauk SSSR, *Dostizheniya Nauki*, No. 1.

Rass, T. S. 1960a. Oceanic fisheries of the world, their current state and trends. Izd. Akad. Nauk SSSR, Moscow. *Trudy Soveshch. Biologich. Osnovam. Okeanich. Rybol.* (1958).

Rass, T. S. 1960b. Some patterns in the geographical distribution of deep-sea fishes. Izd. Akad. Nauk SSSR, Mezhdunarodnom okeanograficheskom kongresse.

Rass, T. S. 1963. Possibility of using the fish resources of the world ocean. *Okeanol.* 3(3):495-499.

Rass, T. S., A. G. Kaganovskii and S. K. Klumov. 1955. Geograficheskoe rasprostranenie ryb i drugikh promyslovykh zhivotnykh Okhotskogo i Beringova morei [Geographic distribution of fish and other commercial animals of the Sea of Okhotsk and the Bering Sea]. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 14:1-120.

Rass, T. S. and A. A. Kashkina. 1967. Bathylagid fishes of the Northern Pacific (Pisces, Bathylagidae). Akad. Nauk SSSR, Leningrad. *Trudy Inst. Okeanol.* Vol. 84:209-221.

Rass, T. S., T. A. Pertseva-Ostroumova, N. N. Gorbunova and E. B. Kulikova. 1956. Spawning grounds of certain spring-spawning fish of the Far Eastern Seas. Akad. Nauk SSSR. *Trudy Problemnykh i Tematicheskikh Soveshchanii Zoolog. Inst.* Vol. 6.

Rathbun, M. J. 1899. List of the Crustacea known to occur on or near the Pribilof Islands. *The Fur Seals and Fur Seal Islands in the North Pacific Ocean, Part 3.* Washington.

Rathbun, M. J. 1904. Decapod crustaceans of the northwest coast of North America. *Harriman Alaska Expedition*, Vol. 10, Crustacea.

Rathjen, W. F. and J. B. Rivers. 1964. Gulf of Alaska scallop explorations, 1963. *Comm. Fish. Rev.* 26(3):1-7.

Rausch, R. L. 1953. Studies on the helminth fauna of Alaska. XIII. Disease in the sea otter, with special reference to helminth parasites. *Ecology* 34(3):584-604.

Raymont, J. E. G. 1963. *Plankton and Productivity in the Ocean.* Pergamon Press, New York. 660 pp.

Raymont, J. E., R. T. Srinivasagam and J. K. Raymont. 1969. Biochemical studies on marine zooplankton. VII. Observations on certain deep-sea zooplankton. *Int. Rev. Ges. Hydrobiol.* 54(3):357-365.

Redburn, D. R. 1973. The ecology of the inshore marine zooplankton of the Chukchi Sea near Point Barrow, Alaska. M.S. Thesis, Univ. Alaska, Fairbanks. 172 pp.

Redfield, A. C., B. H. Ketchum and F. A. Richards. 1963. The influence of organisms on the composition of sea water. *In* M. N. Hill (ed.), *The Sea, Ideas and Observations on Progress in the Study of the Seas*, Vol. 3. Interscience Publishers, New York and London. pp. 26-77.

Redikortsev, V. V. 1941. Ascidiae of the Far Eastern Seas of the U.S.S.R. *Issled Dal'nevost. Morei SSSR*, No. 1.

Red'ko, B. A. 1926. Rybnyi promysel na Komandorakh [The fishery at the Commander Islands]. *Byull. Ryb. Khoz.* No. 2.

Reeve, M. R. 1964. Feeding of zooplankton, with special reference to some experiments with *Sagitta*. London. *Nature* 201:211-213.

Reeve, M. R. 1970. Complete cycle of development of a pelagic chaetognath in culture. London. *Nature* 227:381.

Regan, L. R. 1968. *Euphausia pacifica* and other euphausiids in coastal waters of British Columbia: Relationship to temperature, salinity and other properties in the field and laboratory. Ph.D. Thesis, Univ. British Columbia, Vancouver, 1968. 274 pp.

Reid, J. L., Jr. 1962. On circulation, phosphate phosphorous content, and zooplankton volumes in the upper part of the Pacific Ocean. *Limnol. Oceanogr.* 7:287-306.

Reish, D. J. 1965. Benthic polychaetous annelids from Bering, Chukchi and Beaufort Seas. *Proc. U.S. Nat. Mus.*, Smithsonian Inst. 117(3511): 131-158.

Renfro, W. C. and W. G. Pearcy. 1966. Food and feeding appartus of two pelagic shrimps. *J. Fish. Res. Bd. Canada* 23(12):1971-1975.

Renshaw, R. W. 1965. Distribution and morphology of the medusa, *Calycopsis nematophora*, from the North Pacific Ocean. *J. Fish. Res. Bd. Canada* 22(3):841-847.

Reshetnyak, V. V. 1955. New species of giant Radiolaria of the genus *Cytocladus* Schr. from the Bering Sea. Akad. Nauk SSSR. *Trudy Zool. Inst.* Vol. 18:10-12.

Rice, S. D. and J. F. Karinen. 1976. Acute and chronic toxicity, uptake, and depuration and sublethal metabolic response of Alaskan marine organisms to petroleum hydrocarbons. *In: Environmental Assessment of the Alaskan Continental Shelf, Volume 2.* Principal Investigator's Reports, April-June 1976. Environmental Research Laboratories, Boulder, Colorado. pp. 12-26.

Rich, W. H. and E. M. Ball. 1928. Statistical review of the Alaska salmon fisheries. Part 1. Bristol Bay and Alaska Peninsula. *Bull. U.S. Bur. Fish.* 44 (Doc. 1014):41-95.

Richardson, H. 1904. Isopod crustaceans of the northwest coast of North America. *Harriman Alaska Series, Smith. Inst.* 10:211-230.

Richardson, H. 1909. Isopods collected in the northwest Pacific by the U.S. Bureau of Fisheries Steamer *Albatross* in 1906. *Proc. U.S. Nat. Mus.* 37:75-129.

Ricker, W. E. 1964. Ocean growth and mortality of pink and chum salmon. *J. Fish. Res. Bd. Canada* 21:905-931.

Ricker, W. E. 1969. Food from the Sea. *In: Resources and Man, A Study and Recommendations*. Comm. Res. and Man, Natl. Acad. Sci., Natl. Res. Comm., W. H. Freeman and Co., San Francisco. pp. 87-108.

Riley, G. A. 1963. Theory of food-chain relations in the ocean. *In* M. N. Hill (ed.), *The Sea, Vol. 2*. Interscience, New York. pp. 438-463.

Riley, G. A. 1965. A mathematical model of regional variations in plankton. *Limnol. Oceanogr.* 10(Suppl.):R202-215.

Riley, G. A. 1970. Particulate organic matter in sea water. *In* F. S. Russell and M. Yonge (eds.), *Advances in Marine Biology*, Vol. 8. Academic Press, London-New York. pp. 1-118.

Robbins, L. L., F. K. Oldham and E. M. K. Geiling. 1937. The stomach contents of sperm whales caught off the west coast of British Columbia. *Rept. British Columbia Mus.* 1937:10-20.

Rodin, V. E. 1970. An estimation of the state of the king crab (*Paralithodes camtschatica* Tilesius) stock in the southeastern Bering Sea. *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 70:149-156.

Rodin, V. E. 1970. Some data on the distribution of king crab (*Paralithodes camtschatica* Tilesius) in the southeastern Bering Sea. *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 70:143-148.

Romanov, N. S. 1959. Index of Literature on Fisheries in the Far East for 1923-1956. Moscow, Akad. Nauk SSSR. 292 pp.

Roncholt, L. L. 1963. Distribution and relative abundance of commercially important pandalid shrimps in the northeastern Pacific Ocean. *U.S. Fish. Wildl. Serv., Spec. Sci. Rept.-Fish.* No. 449. 28 pp.

Roppel, A. Y., A. M. Johnson, R. E. Anas, D. G. Chapman. 1965. Fur seal investigations, Pribilof Islands, Alaska, 1964. *U.S. Fish. Wildl. Serv., Spec. Sci. Rept. Fish.* 502:1-46.

Rosenthal, H. and G. Hempel. 1970. Experimental studies in feeding and food requirements of herring larvae. *In* J. H. Steele (ed.), *Marine Food Chains*. Oliver and Boyd, Edinburgh. pp. 344-364.

Round, F. E. 1971. Benthic marine diatoms. *In* H. Barnes (ed.), *Oceanography and Marine Biology, An Annual Review*. Allen and Unwin Ltd., London. pp. 83-139.

Rounsefell, G. A. 1929. Contribution to the biology of the Pacific herring, *Clupea harengus pallasi*, and the conditions of the fishery in Alaska. U.S. Dept. Commerce Bull., Bureau of Fish., Document No. 1880. pp. 227-320.

Rounsefell, G. A. 1957. Fecundity of North American Salmonidae. *U.S. Fish. Wildl. Serv., Fish. Bull.* 57(122):449-468.

Rozenberg, L. A. 1954. Bacterial count in the bottom sediment of the Bering Sea; Methodical investigation based on quantitative record of bacteria. Akad. Nauk SSSR., *Trudy Inst. Okeanol.* Vol. 11:264-270.

Rozenberg, L. A. 1958. Zonation of bacteria in waters of the Far Eastern Seas and the Northwestern Pacific Ocean. Akad. Nauk SSSR, *Doklady* 122(3):378-380.

Rudjakov, J. A. 1962. Ostracoda Mycodocopa of the family Halocypridae from the north-western Pacific. Akad. Nauk SSSR, Leningrad. *Trudy Inst. Okeanol.* Vol. 58:172-201.

Rumyantsev, A. I. 1955. Capelin - *Mallotus villosus socialis* (Pallas). Geographic distribution of fishes and other commercial items of the Sea of Okhotsk and the Bering Sea. Akad. Nauk SSSR. *Trudy Inst. Okeanol.* Vol. 14:41-43.

Rumyantsev, A. I., and M. A. Darda. 1970. Summer herring in the eastern Bering Sea. *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 70:402-432.

Runnstrom, S. 1928. Amphipoda, Isopoda and Pycnogonida from the Siberian Arctic Ocean. Norwegian North Polar Expedition with the "Mand" 1918-1925. *Sci. Res.* Vol.8:1-18.

Russell, F. S. 1932. On the biology of *Sagitta*. The breeding and growth of *Sagitta elegans* Verrill in the Plymouth area, 1930-1931. *J. Mar. Biol. Ass. U.K.* 18:131-145.

Russell, F. S. 1932. On the biology of *Sagitta*. The breeding and growth of *Sagitta elegans* Verrill and *Sagitta setosa* J. Müller in the Plymouth area. *J. Mar. Biol. Assoc. U.K.* 18:559-574.

Rutenberg, E. 1932. Two forms of *Pleurogrammus monopterygius* (Pallas) and variability of lateral lines in this species (Pisces, Hexagrammidae). Akad. Nauk SSSR, *Trudy Zool. Inst.* 1(1).

Rutenberg, E. P. 1962. Obzor ryb semeistva terpugovykh (Hexagrammidae) [A review of the greenling fish (Family Hexagrammidae)]. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 59:3-100.

Ryabinina, N. V. 1952. Carditacea of the Chukchi Sea and the Bering Strait. Sbornik: *Krainii Severo-Vostok SSSR*, Vol. 2.

Ryther, J. H. 1963. Geographic variations in productivity. *In* M. N. Hill (ed.), *The Sea. Ideas and Observations on Progress in the Study of the Seas* Vol. 2, Intersci.-John Wiley, New York and London. pp. 347-380.

Ryther, J. H. 1969. Photosynthesis and fish production in the sea. *Science* 166(6901):72-76.

Ryther, J. H. and C. S. Yentsch. 1957. The estimation of phytoplankton production in the ocean from chlorophyll and light data. *Limnol. Oceanogr.* 2(3):281-286.

Saidova, Kh. M. 1959. Distribution of Foraminifera in the bottom deposits and paleogeography of the northwestern Pacific Ocean. Akad. Nauk SSSR, Moscow, *Doklady* 129(6):1401-1404.

Saidova, Kh. M. 1961a. Ekologiya foraminifer i paleogeographiya dal'nevostochnykh morei SSSR i severo-zapadnoi chasti tikhogo okeana [*Ecology of Foraminifera and Paleogeography of the Far Eastern Seas of the U.S.S.R. and Northwestern Pacific Ocean*]. Akad. Nauk SSSR, Moscow, Izd. Akad. Nauk SSSR, 264 pp.

Saidova, Kh. M. 1961b. Quantitative distribution of bottom Foraminifera of North-eastern Pacific. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 45: 62-71.

Saidova, Kh. M. 1964. Raspredelenie donnykh foraminifer i stratigrafiya osadkov v severo-vostochnoi chasti Tikhogo okeana [Distribution of benthic Foraminifera and stratigraphy of sediments in the northeastern Pacific Ocean.]. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 68:84-119.

Saijo, Y. and S. Ichimura. 1960. Primary production in the northwestern Pacific Ocean. *J. Oceanogr. Soc. Japan* 16(3):139-145.

Saiki, M. and T. Mori. 1956. Studies on the whale oil. XII. On the lipid from *Calanus cristatus* (part 1). Fatty acids composition of oil from *Calanus cristatus* collected in the stomach of fin whale caught at the northern Pacific Ocean. *Bull. Jap. Soc. Sci. Fish.* 21:1041-1044.

Saito, K. 1974. *Regional Distribution of Phytoplankton in the Chukchi Sea and Northern Part of the Bering Sea in Summer 1972.* M.S. dissertation, Hokkaido Univ., 32 pp.

Saito, K. and N. Kitahara. 1972. Nutriment and coloring matter of pollock egg. *Dept. Agr. and Forest Special Sci. Prog. Rept. in Walleye Pollock* No. 1:56-61.

Sakai, K. 1957. More fish and bigger pack in spite of restriction. *Pacif. Fish.* 55(2):167-172.

Sakai, K. 1958. World-girdling fleets find rich 1957 fishing in Bering and Atlantic. *Pacif. Fish.* 56(1):161-166.

Sakai, K. 1960. Japan. *Pacif. Fish.* 58(2):115-118.

Sakai, K. 1961. Japan. *Pacif. Fish.* 59(2):81-85.

Sanger, G. A. 1972a. Fishery potentials and estimated biological productivity of the subartic Pacific region. *In* A. Y. Takenouti (ed.), *Biological Oceanography of the Northern North Pacific Ocean.* Idemitsu Shoten, Tokyo, Japan. pp. 561-574.

Sanger, G. A. 1972b. Preliminary standing stock and biomass estimates of seabirds in the subarctic Pacific region. *In* A. Y. Takenouti (ed.), *Biological Oceanography of the Northern North Pacific Ocean.* Idemitsu Shoten, Tokyo, Japan. pp. 589-611.

Sano, S. 1966. Salmon of the North Pacific Ocean - Part III. A review of the life history of North Pacific salmon. 3. Chum salmon in the Far East. *Bull. Int. N. Pacif. Fish. Comm.* 18:41-57.

Sano, S. and T. Kobayashi. 1953. An ecological study on the salmon fry, *Oncorhynchus keta.* (2) The migration and growth of the fry in the marking experiment. *Sci. Rept. Hokkaido Fish Hatch.* 8(1,2):71-79. [Engl. Transl., Bur. Commer. Fish., Biol. Lab., Seattle, Wash.].

Sato, C. 1913. Pelagic copepods. *J. Hokkaido Fish. Exper. Sta.* 1:1-79. [In Japanese].

Sato, S. 1943. Experiments on breeding of zoea of the king crab. *Hokkaido Fish. Exp. Sta., 10-day Report*, part 1, No. 559:1-6; part 2, No. 560: 7-12; part 3, No. 561:13-22.

Sato, S. 1958. Studies on the larval development and fishery biology of the king crab (*Paralithodes camtschatica* Tilesius). *Bull. Hokkaido Reg. Fish. Res. Lab.*

Sato, S. and K. Kobayashi. 1959. "Hokusei Maru" cruise 4 to the North Pacific. *Data Rec. Oceanogr. Observ. Explor. Fish.* No. 3.

Savel'eva, T. S. 1941. Concerning the sea cucumbers of the Far Eastern seas of the U.S.S.R. *Issled. dal'nevost. morei SSSR* Vol. 1.

Scammon, C. M. 1869. On the cetaceans of the western coast of North America. *Proc. Acad. Sci. Phil.* 1869:13-63.

Scammon, C. M. 1874. *The Marine Mammals of the Northwest Coast of North America.* San Francisco. J. H. Carmany.

Schaefer, M. B. 1965. The potential harvest of the sea. *Trans. Amer. Fish. Soc.* 94(2):123-128.

Schaefer, M. B. and D. L. Alverson. 1968. World fish potentials. *In* G. DeWitt (ed.), *The Future of the Fishing Industry of the United States.* Univ. Wash. Publs. Fish., N.S., 4. pp. 81-85.

Schaefers, E. A. and F. M. Fukuhara. 1954. Offshore salmon explorations adjacent to the Aleutian Islands June-July 1953. U.S. Fish Wildl. Serv., *Comm. Fish. Rev.* 16(5):1-20.

Schamel, D., D. Tracy, A. Ionson and P. G. Mickelson. 1977. Avian community ecology at two sites on Espenberg Peninsula in Kotzebue Sound, Alaska. A composite study of: (1) habitat utilization and breeding ecology of waterbirds, (2) habitat utilization and breeding ecology of shorebirds and non-waterbird species and (3) habitat utilization, breeding ecology, and feeding ecology of predators of birds. *In: Environmental Assessment of the Alaskan Continental Shelf, Vol. 1.* Environmental Res. Lab., Boulder, Colorado. pp. 651-718.

Scheffer, V. B. 1939. Organisms collected from whales in the Aleutian Islands. *Murrelet* Seattle, 20(3):67-69.

Scheffer, Victor B. 1942. Sea birds eaten by Alaska cod. *Murrelet* 23(1):17.

Scheffer, Victor B. 1945. Growth and behavior of young sea lions. *J. Mammal.* 26(4):390-392.

Scheffer, V. B. 1950. The food of the Alaska fur seal. *U.S. Fish. and Wildlife Service, Wildl. Leafl.* No. 329. 16 pp.

Scheffer, V. B. 1958. *Seals, Sea Lions and Walruses.* London.

Schmidt, P. Yu. 1902. Geographic distribution of fishes in Eastern Seas. *Russkoe Sudokhodstvo* No. 4.

Schmidt, P. Yu. 1904. Ryby Vostochnykh Morei Rossiiskoi Imperii [*Fishes of the Eastern Seas of the Russian Empire*]. St. Petersburg, Izd. Geogr. Obsch.

Schmidt, P. Yu. 1930. The Pacific halibut. Akad. Nauk SSSR, *Doklady Seriya A*, No. 8:203-208.

Schmidt, P. Yu. 1933a. Scientific investigation of the North Pacific and the tasks of fisheries for the second five-year plan. *In* Sbornik, *Problemy Severa.*

Schmidt, P. Yu. 1933b. O zoogeograficheskom rasprostranenii glavneishikh promyslovykh ryb v zapadnoi chasti Tikhogo okeana [The zoogeographical distribution of the major commercial fish in the western Pacific Ocean]. Akad. Nauk SSSR, *Byull. Tikhookean. Komit.* No. 3.

Schmidt, P. Yu. 1934a. Scientific investigations in the western part of the North Pacific Ocean in 1932. Akad. Nauk SSSR, *Byull. Tikhookean. Komit.* No. 3.

Schmidt, P. Yu. 1934b. Zoogeographic distribution of the most important commercial fishes in the western part of the North Pacific. Akad. Nauk SSSR, *Byull. Tikhookean. Komit.* No. 3.

Schmidt, P. Yu. 1935. Genus *Icelus* Kröyer (Cottidae). *Izv. Akad. Nauk SSSR, Seriya otdeleniya matemat. estes. nauk* No. 3.

Schmidt, P. Yu. 1947. Migratsii Ryb. [*Migrations of Fishes*]. Izd. Akad. Nauk SSSR, Moscow-Leningrad, 362 pp.

Schmidt, P. Yu. 1948. *Fish of the Pacific Ocean. Essay on Modern Theories and Views on Distribution and Development of Fish Fauna of the Pacific Ocean.* Moscow, Pishchepromizdat. 124 pp.

Schmitt, W. L. 1919. Schizopod Crustaceans. *Rept. Can. Arctic Exped.* 1913-1918, Vol. 7:Crustacea, part B:1b-8b.

Schneider, K. 1977. Distribution and abundance of sea otters in southwestern Bristol Bay. *In: Environmental Assessment of the Alaskan Continental Shelf, Vol. 1.* Environmental Res. Lab., Boulder, Colorado. pp. 469-526.

Schneider, D. E. and P. W. Hochachka. 1968. Temperature effects on acetate metabolism in the pink shrimp. *In: R/V Alpha Helix Bering Sea Exped.*:241-244.

Scholander, P. F. 1940. On the respiratory adjustment to prolonged diving in the seal. *Amer. J. Physiol.* 129:456-457.

Scholander, P. F., L. Irving and S. W. Grinnell. 1942. On the temperature and metabolism of the seal during diving. *J. Cell and Comp. Physiol.* 19:67-78.

Scholander, P. F. and J. E. Maggert. 1968. Super-cooling and ice propagation in blood from Arctic fishes. *In: R/V Alpha Helix Bering Sea Exped.*:119-128; also in *Cryobiology* 8(4) 1971:371-374.

Schornikov, E. I. 1970. *Acetabulastoma*, a new genus of ostracods-parasites of Amphipoda. *Zool. Zhur.* 49(8):1132-1143.

Schult, L. P. and A. D. Welander. 1935. A review of the cods of the northeastern Pacific with comparative notes on related species. *Copeia* No. 3:127-139.

Scott, T. 1903. Notes on some Copepoda for the Arctic Seas collected by A. M. Norman. *Ann. Mag. Nat. Hist.* Vol. 11:

Sealy, S. G. 1968. A comparative study of breeding ecology and timing in plankton-feeding alcids (*Cyclorrhynchus* and *Aethia* spp.) on St. Lawrence Island, Alaska. M.S. Thesis, Univ. British Columbia, Vancouver. 193 pp.

Sealy, S. G. 1972. Adaptive difference in breeding biology in the marine bird family Alcidae. Ph.D. Thesis, Univ. Michigan, Ann Arbor. 283 pp.

Sealy, S. G. 1973. Breeding biology of the horned puffin on St. Lawrence Island Bering Sea with zoogeographical notes on the North Pacific puffins. *Pacif. Sci.* 27(2):99-119.

Seki, H. 1969. Decomposition of organic matter in seas and oceans. *Kaiyo Kagaku* 6:38-43.

Seki, H. 1970a. Microbial biomass in the euphotic zone of the North Pacific subarctic water. *Pacif. Sci.* 24:269-274.

Seki, H. 1970b. Microbial biomass on particulate organic matter in seawater in the euphotic zone. *Appl. Microbiol.* 19:960-962.

Seki, H. 1970b. Rôle des micro-organismes dans la chaîne alimentaire de la mer profonde. *La Mer* 8:27-34. [In Japanese with French abstract].

Semenov, V. N. 1964. Quantitative distribution of benthos on the shelf of the southeastern Bering Sea (Bristol Bay, Alaska Peninsula Coast, and Unimak Island). *Trudy Vses. Nauchno-Issled. Inst. Morsk Rybn. Khoz. Okeanogr.* Vol. 53:177-184.

Semenov, V. N. 1965. Quantitative distribution of benthic fauna on the shelf and upper slope in the Gulf of Alaska. *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 58:37-69.

Semina, H. J. 1955a. On the two zonal groups of the phytoplankton (in the example of the Bering Sea). Akad. Nauk SSSR, *Comptes Rendus (Doklady), Novaia Seriia* 101(2):363-366.

Semina, H. J. 1955b. K voprosu o vertikal'nom raspredelenii fitoplanktona v Beringovom morei [Vertical distribution of phytoplankton in the Bering Sea]. Akad. Nauk SSSR, *Comptes Rendus (Doklady), Novaia Seriia* 101(5): 947-949.

Semina, H. J. 1956a. Composition and distribution of phytoplankton in the Northwestern Pacific Ocean in Spring and Autumn 1955. Akad. Nauk SSSR, *Doklady* 110(3):465-468.

Semina, H. J. 1956b. Seasonal changes in the phytoplankton of the western part of the Bering Sea. Botanicheskiye materiales Otd. sporovykh rast. Botan Inst. im. Komarova Akad. Nauk SSSR, 11.

Semina, H. J. 1958. Relation between phytogeographic zones in the pelagial of the northwestern part of the Pacific Ocean with the distribution of water masses in the region. Akad. Nauk SSSR, Leningrad, *Tr. Inst. Okeanol.* Vol. 27:66-76. [In Russian].

Semina, H. J. 1960a. The influence of vertical circulation on the phytoplankton in the Bering Sea. *Int. Rev. Ges. Hydrobiol.* 45(1): 1-10.

Semina, H. J. 1960b. Qualitative composition of the Bering Sea phytoplankton. Communication 1. Chrysophyceae, Peridiniales, Heterococcales. *In* Sbornik, *Botanicheske materialy* Vol. 13.

Semina, H. J. 1965. Patterns governing quantitative distribution of phytoplankton. *Tezisy Dokl. I s'ezda Vses. Gidrobiol. Obsh., Moscow.*

Semina, H. J. 1966. Biotope and quantity of phytoplankton in the oceans. *Uspekhi Sovremennoy Biol.* 62, No. 2(5):289-306.

Semina, H. J. 1969. The size of phytoplankton cells along 174°W long. in the Pacific. *Okeanol.* 9:479-487 [In Russian]; also *Oceanol.* 9(3):391-398 [English translation].

Semina, H. J. and I. Tarkhova. 1972. Ecology of phytoplankton in the North Pacific Ocean. *In* Y. Takenouti (ed.), *Biological Oceanography of the Northern North Pacific Ocean.* Idemitsu Shoten, Tokyo. pp. 117-124.

Semina, H. J. and A. P. Zhuze. 1959. Diatoms in biocenoses and thanatenoses of the Western Bering Sea. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 30:52-67.

Semko, R. S. 1939. The Kamchatka pink salmon. *Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.* Vol. 16.

Semko, R. S. 1949. Humpback Salmon - *Oncorhynchus gorbuscha* (Walbaum). Promysl. Ryby SSSR. Pishchepromizdat.

Semko, R. S. 1953. Causes of population fluctuations of the Pacific salmon and the rational utilization of reserves. *Trudy Konfer. Vopr. Rybn. Khoz.*

Serobaba, I. I. 1965. O zapasakh, biologii i raspredelenii mintaya v vostochnoy chasti Beringova morya [The stocks, bioloby and distribution of the Alaskan pollock in the eastern Bering Sea]. *Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.*

Serobaba, I. I. 1968. The spawning of walleye pollock [*Theragra chalcogramma* (Pallas)] in the northeastern part of the Bering Sea. *Vopr. Ikhtiol.* 8(5):992-1003.

Serobaba, I. I. 1969. Vertical distribution of the walleye pollock in the Bering. *Trudy Vses. Konf. Molodykh Uchenykh.*, Murmansk.

Serobaba, I. I. 1970. Distribution of pollock, *Theragra chalcogramma*, in the eastern Bering Sea and prospects for its commercial use. *Trudy Vses. Nauchno-Issled. Inst. Morsk Rybn. Khoz. Okeanogr.* Vol. 70:433-441.

Serobaba, I. I. 1971. The reproduction of the walleye pollock in the eastern part of the Bering Sea. *Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.* Vol. 75:

Serobaba, I. I. 1974. Spawning ecology of the walleye pollock (*Theragra chalcogramma*) in the Bering Sea. *J. Ichthyol.* 14(4):544-552.

Serventy, D. L. 1967. Aspects of the population ecology of the short-tailed shearwater, *Puffinus tenuirostris*. *Proc., XIV Int. Ornithol. Congr.*:165-190.

Setchell, W. A. 1899. Algae of the Pribilof Islands. *In* D. S. Jordan (ed.), *Fur Seals and Fur Seal Islands of the North Pacific Ocean, Part III.* Govt. Print. Off., Washington, D.C. pp. 589-597.

Setchell, W. A. and N. L. Gardner. 1903. Algae of Northwestern America. *Univ. Calif. Publ. Bot., Vol. I.*

Setchell, W. A. and N. L. Gardner. 1919. The marine algae of the Pacific coast of North America. Part I. Myxophyceae. *Univ. Calif. Publ. Bot.* 8:1-138.

Setchell, W. A. and N. L. Gardner. 1920. The marine algae of the Pacific coast of North America. *Univ. Calif. Publ. Bot.* Vol. VIII, No. 2, Pt. III.

Setchell, W. A. and N. L. Gardner. 1925. The marine algae of the Pacific coast of North America. III. Melanophyceae. *Univ. Calif. Publ. Bot.* Vol. III.

Sewell, R. B. S. 1948. The free swimming planktonic copepoda. Geographical distribution. *John Murray Exped. 1933-1934 Sci. Rep.* 8(3):21-592.

Shaboneev, I. E. 1965. Biology and fishing of herring in the eastern part of the Bering Sea. *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 58:130-146.

Shchapova, T. F. 1948. Geographical distribution of Laminariales in the North Pacific. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 2:89-138.

Shchedrina, Z. G. 1952. Foraminifera of the Chukchi Sea and the Bering Strait. *In* Sbornik, *Krainii Severo-Vostok SSSR,* Vol. 2.

Shchedrina, Z. G. 1958a. Foraminifer fauna of the Kurile-Kamchatka Basin. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 27:180-191.

Shchedrina, Z. G. 1958b. The dependence of the distribution of Foraminifera in the seas of the U.S.S.R. on the environmental factors. *Proc. 15th Int. Congr. Zool.* Sect. III, pp. 218-221.

Sheldon, R. W., T. P. T. Evelyn and T. R. Parsons. 1967. On the occurrence and formation of small particles in seawater. *Limnol. Oceanogr.* 12(3): 367-375.

Shephard, M. P., A. C. Hartt and T. Yonemori. 1968. Salmon of the North Pacific Ocean - Part VIII. Chum salmon in offshore waters. *Bull. Int. N. Pacif. Fish. Comm.* 25, 69 pp.

Shevtsov, V. V. 1964. On the quantitative distribution of benthic fauna in the Gulf of Alaska. *Trudy Vses. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.* Vol. 53:150-166.

Shiga, N. 1976. Maturity stages and relative growth of *Oikopleura labradoriensis* Lohmann (Tunicata, Appendicularia). *Bull. Plankton Soc. Japan* 23(2):81-95.

Shih, C. T., A. J. G. Figueira and E. H. Grainger. 1971. A synopsis of Canadian marine zooplankton. *Bull. Fish. Res. Bd. Can.* (176):1-264.

Shimazu, T. 1969. Oshoru Maru Cruise 23 to the northern North Pacific Ocean, Bering Sea and the Gulf of Alaska. *Data Rec. Oceanogr. Obsns. Explor. Fish., Hokkaido Univ.* No. 13:1-135.

Shimazu, T. 1975a. A description of the adult of *Nybelinia surmenicola* with discussions on its life history (Cestoda, Trypanorhyncha, Tentaculariidae). *Bull. Jap. Soc. Sci. Fish.* 41(8):823-830.

Shimazu, T. 1975b. Some Cestode and Acanthocephalan larvae from euphasiid crustaceans collected in the northern North Pacific Ocean. *Bull. Jap. Soc. Sci. Fish.* 41(8):813-821.

Shimazu, T. and T. Oshima. 1972. Some larval nematodes from euphausiid crustaceans. *In* A. Y. Takenouti (ed.), *Biological oceanography of the Northern North Pacific Ocean.* Idemitsu Shoten, Tokyo, Japan. pp. 403-409.

Shimazu, T., T. Oshima, H. Koyama and H. Akahane. 1970. Further observations on *Anisakis* sp. larvae (Type I) from the eupahusiid crustaceans, and especially on *Euphausia pacifica* as a new intermediate host. *Jap. J. Parasitol.* 19:338. [In Japanese].

Shmidt, V. F. 1933. On the spawning of cod in the Soviet waters of the Bering Sea and the morphology of larval Pacific cod. Akad. Nauk SSSR, *Vest. Dal'nevost. Fil.* Nos. 1-3:79-86.

Shmidt, V. F. 1936. Appearance and settling-in of certain genera of the family Gadidae in the Northern Pacific Ocean. *Zool. Zhur.* 15(1):175-183.

Shmidt, V. F. 1944. O razmnozheniya morskogo okunya *Sebastodes marinus* D. [On the reproduction of the rockfish *Sebastodes marinus* D.]. *Trudy Polyar. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 8.

Shparlinskii, V. M. .1939. The fishing industry of Alaska in 1937. *Rybn. Khoz.* No. 7.

Shubnikov, D. A. 1960. Ugol'naya ryba-novyi ob'ekt sovetskogo promysia v Beringovom more [Sablefish: a new item of commercial exploitation by the Soviet fishing industry in the Bering Sea]. *Rybn. Khoz.* No. 3: 14-18.

Shubnikov, D. A. 1963. Nekotorye dannye po biologii ugol'noi ryby Beringova morya [Data on the biology of sablefish of the Bering Sea]. *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 48:287-296.

Shubnikov, D. A. and L. A. Lisovenko. 1964. Data on the biology of rock sole of the southeastern Bering Sea. *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 49:220-226.

Shults, L. M. and F. H. Fay. 1977. A selected bibliography on mortality and pathology of marine mammals with particular reference to species inhabiting the Alaskan outer continental shelf. *In: Environmental Assessment of the Alaskan Continental Shelf, Vol. 1.* Environmental Res. Lab., Boulder, Colorado. pp. 285-323.

Shuntov, V. P. 1961. Migration and distribution of marine birds in southeastern Bering Sea during Spring-Summer season. *Zool. Zhur.* 40(7): 1058-1069.

Shuntov, V. P. 1963. Distribution of the ichthyofauna in the southeastern Bering Sea. *Zool. Zhur.* 42(5):704-715.

Shuntov, V. P. 1965. Distribution of the Greenland halibut and arrow-toothed halibuts in the North Pacific. *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 58:147-156.

Shuntov, V. P. 1968. Some regularities in the distribution of albatrosses (Tubinares, Diomedeidae) in the northern Pacific. *Zool. Zhur.* 47:1054-1064. [In Russian with Engl. abstract].

Shuntov, V. P. 1970. Seasonal distribution of black and arrow-toothed halibuts in the Bering Sea. *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 70:397-408.

Simmons, H. 1906. Remarks on the ralations of the floras of the North Atlantic, the Polar Sea and the North Pacific. *Beihefte Z.B.CB.* XIX, 2 abt.

Skalkin, V. A. 1963a. Otolity nekotorykh ryb dal'negovostochnykh morei. *Trudy Vses. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.* Vol. 49:159-199.

Skalkin, V. A. 1963b. Pitanie kambal v yugo-vostochnoi chasti Beringova morya [Feeding of flatfishes in the southeastern part of the Bering Sea]. Moscow, *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 48:235-250.

Skalkin, V. A. 1964. Diet of rockfishes in the Bering Sea. Moscow, *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 49:159-174.

Skalkin, V. A. 1970. On the causes of variations in size composition of trawl hauls of Bering Sea rockfish. *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 70:287-291.

Skarlato, O. A. 1960. Dvustvorchatye mollyuski dal'nevostochnykh morei SSSR [*Bivalve Mollusks of the Far Eastern Seas of the U.S.S.R.*]. Akad. Nauk SSSR, Moscow, Izd. Zool. Inst.

Skopintsev, B. A. 1949. Rate of decomposition of organic substances of dead plankton. *Trudy Vses. Gidrobiol. Obsch.* 1:34-43.

Skrjabin, K. I. 1915. *Odhneriella rossica* n.g., n. sp., an agent of worm liver disease in walruses. Petrograd, *Arkhiv Veterinarnykh* 45:1058-1064.

Sleptsov, M. M. 1952. Kitoobraznye dal'nevostochnykh morei [Cetaceans of the Far Eastern Seas]. *Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.* Vol. 38.

Sleptsov, M. M. 1955a. Biology of the Cephalopod mollusks of the Far Eastern Seas and the Northwestern Pacific Ocean. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 18:69-77.

Sleptsov, M. M. 1955b. Biologiya i promysel kitov dal'nevostochnykh morei [*Biology of Whales and the Whaling Industry in the Far Eastern Seas*]. Pishchepromizdat.

Sleptsov, M. M. 1955c. Kitoobraznye dal'nevostochnykh morei [*Cetaceans of the Far Eastern Seas*]. Second edition, Vladivostok, 161 pp.

Sleptsov, M. M. 1961. Environmental conditions of whales in the zones of mixing of the cold (Kurile-Kamchatka) and warm (Kuroshio) currents. *Trudy Inst. Morfol Zhivotnykh* No. 34.

Sliunin, N. 1895. *The Natural Resources of Kamchatka and Sakhalin and the Commander Islands.* St. Petersburg. [In Russian].

Small, L. F. and J. F. Hebard. 1967. Respiration of a vertically migrating marine crustacean *Euphausia pacifica* Hansen. *Limnol. Oceanogr.* 12: 272-280.

Small, L. F., J. F. Hebard, and C. D. McIntire. 1966. Respiration in euphausiids. *Nature* 211(5054):1210-1211.

Smetanin, D. A. 1956. On the evaluation of the organic production in several areas of the Bering and Okhotsk Seas. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 17:192-203.

Smirnov, A. I. 1958. Some characteristics of the reproductive and developmental biology of the salmonid fish, the sockeye [*Oncorhynchus nerka* (Walbaum)]. Akad. Nauk SSSR, Leningrad, *Doklady* 123(2):371-374.

Smirnov, N. A. 1927. Biologicheskie otnosheniya nekotorykh lastonogikh ko l'dam [The biological relationship of certain pinnipeds to ice]. *Sbornik posvyashchennyi k nipovichu.*

Smirnov, N. A. 1935. Morskie zveri arkticheskikh morei (lastonogie i kitoobraznye) [Marine mammals of the Arctic seas (Pinnipeds and Cetaceans)]. *In* G. P. Adlerberg *et al.* (eds.) *Zveri Arktiki.* (Vvedenie v izuchenie kipytnykh, khishchnykh, lastonogikh, kitoobraznykh, nasekomoyadnykh i rukodrylykh). Leningrad, Izd. Glavsevmorputi.

Smirnova, L. I. 1956. Phytoplankton of the northwestern Pacific Ocean. Akad. Nauk SSSR, *Doklady* 109(3):649-652.

Smith, R. L. 1975. Food and feeding relationships in the benthic and demersal fishes of the Gulf of Alaska and Bering Sea. *In: Environmental Assessment of the Alaskan Continental Shelf; Principal Investigators' Reports July-September 1975 Volume 1.* Environmental Research Laboratories, Boulder, Colorado, 1975. pp. 657-659.

Sokolova, M. N. 1956. On the distribution regularities of deep sea benthos. The influence of the macro-relief and distribution of suspension upon the edaphic groups of bottom invertebrates. Akad. Nauk SSSR, Moscow, *Doklady* 110(4):692-695.

Sokolova, M. N. 1957a. Pitanie nekotorykh vidov dal'nevostochnykh Crangonidae [Diet of some species of far eastern Crangonidae]. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 23:269-285.

Sokolova, M. N. 1957b. Feeding of some carnivorous benthic deep-sea invertebrates of the Far-Eastern seas. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 20:279-301.

Sokolova, M. N. 1958. Pitanie neskol'kikh detritoyadnykh bespozvonochnykh glubokovodnogo bentosa dal'nevostochnykh morei [Feeding habits of certain detritophage invertebrates of the deep water benthos in Far Eastern Seas]. Akad. Nauk SSSR, Leningrad. *Trudy Inst. Okeanol.* Vol. 27:123-153.

Sokolova, M. N. 1959. On the distribution of deep-water bottom animals in relation to their feeding habits and the character of sedimentation. *Deep-Sea Res.* 6(1):1-4.

Sokolova, M. N. 1960. Distribution of groupings (biocenoses) of the benthic fauna of the deepwater basins of the Northwestern Pacific Ocean. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 34:21-59.

Sokolova, M. N. 1962. Trophic zonation in the distribution of the benthos of the North Pacific. Sbornik: *Voprosy Ekologii* Vol. 5:201-203.

Sokolova, M. N. and A. P. Kuznetsov. 1960. O kharaktere pitaniya i roli troficheskogo faktora v raspredelenii ploskogo ezha *Echinarachnius parma* [Feeding and the role of the trophic factor in the distribution of the flattened sea urchin *Echinarachnius parma*]. *Zool. Zhur.* Vol. 39(8):1253-1256.

Soldatov, V. K. 1928. Ryby i Rybnyi Promysel [*Fish and Fisheries*]. Moscow, Gosudar. Izd.

Soldatov, V. K. 1938. *Commercial Ichthyology. Part 2. Fishes of Fishing Areas of the U.S.S.R.* Moscow-Leningrad, Pishchepromizdat.

Soldatov, V. K. and G. U. Lindberg. 1930. Obzor ryb dal'nevostochnykh morei [Review of fishes of the seas of the Far East]. *Izd. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.* Vol. 5:3-576.

Somero, G. N. 1968. Enzyme profiles of gill and muscle of the king crab. *In: R/V Alpha Helix Bering Sea Exped.*:245-248.

Southward, E. C. 1963. Pogonophora. *In* H. Barnes (ed.), *Oceanography and Marine Biology, An Annual Review*. Allen and Unwin Ltd., London. pp. 405-428.

Spalding, D. J. 1964. Comparative feeding habits of the fur seal, sea lion, and harbour seal on the British Columbian coast. *Bull. Fish. Res. Bd. Can.* 146:1-52.

Spanovskaya, V. D. and V. A. Grigorash. 1974. Length-weight relationship of some species of the genus *Cyclothone* (Pisces, Gonostomatidae). *J. Ichthyol.* 15(1):146-150.

Sparks, A. K. and W. T. Pereyra. 1966. Benthic invertebrates of the southeastern Chukchi Sea. *In* H. J. Wilimovsky (ed.), *Environment of the Cape Thompson Region, Alaska*. pp. 817-838.

Squires, H. J. 1969. Decapod crustacea of the Beaufort Sea and the Arctic waters eastward to Cambridge Bay, 1960-1965. *J. Fish. Res. Bd. Can.* 26(7):1899-1918.

Starikova, N. D. 1956. Organicheskoe veshchestvo v tolshche osadkov Beringova morya [Organic matter in the sediment layer of the Bering Sea]. Akad. Nauk SSSR, Moscow, *Doklady* 106(3):519-522.

Starodubtsev, E. G. 1970. Seasonal variations in primary production in the southeastern part of the Bering Sea. *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* 70:87-91.

Stebbing, T. R. 1900. Arctic Crustacea: Bruce Collection. *Ann. Mag. Nat. Hist.* Sect. 7, Vol. 5:1-16.

Steele, J. H. 1962. Environmental control of photosynthesis in the sea. *Limnol. Oceanogr.* 7:137-150.

Steele, J. H. (ed.). 1970. *Marine Food Chains.* Oliver and Boyd, Edinburgh. 552 pp.

Steele, J. H. and D. W. Menzel. 1962. Conditions for maximum primary production in the mixed layer. *Deep-Sea Res.* 9(1):39-49.

Steemann-Nielsen, E. 1960. Productivity of the oceans. *Ann. Rev. Plant Physiol.* 11:341-362.

Steemann-Nielsen, E. and V. Kr. Hansen. 1959. Light adaptation in marine phytoplankton and its interrelation with temperature. *Physiol. Pt.* 12:353-370.

Steller, G. W. 1751. De bestis marinis. *Nov. Com. Acad. Sc. Petropol.* II:289-398.

Steller, G. W. 1781. Topographische und physikalische Beschreibung des Beringinsel. [Topographical and physical description of Bering Island]. *Pallas Neue Nordische Beyträge* II:255-309.

Stepanov, A. G., A. V. Lestev and N. P. Novikov. 1962. Exploiting more effectively the resources of the Bering Sea. *Rybn. Promysh. Dal'nego Vostoka*, No. 1.

Stepanov, V. S. 1937. Biologicheskie pokazetelitechenii severnoi chasti Beringova i uzhnoi chasti Chukotskogo morei [Biological indicators of currents in the northern Bering and southern Chukchi Seas]. Gosudar. Gidrolog. Inst., Leningrad. *Issled. Morei SSSR* No. 25:175-216.

Stern, L. J. 1977. Determination and description of knowledge of the distribution, abundance and timing of salmonids in the Gulf of Alaska and Bering Sea. *In: Environmental Assessment of the Alaskan Continental Shelf*, Vol. 2. Environmental Res. Lab., Boulder, Colorado. pp. 586-802.

Stiles, C. W. and A. Hassall. 1899. Internal parasites of the seal. *In* David Jordan *et al.* (eds.), *The Fur Seal and Fur Seal Islands of the North Pacific*, Part 3. Washington. pp. 99-177.

Stoker, S. W. 1971. Winter investigations of benthic fauna in northeast Bering Sea. *Proc. Alaska Sci. Conf.* 22:119.

Straty, R. R. 1973. Ecology and behavior of juvenile sockeye salmon (*Oncorhynchus nerka*) in Bristol Bay and eastern Bering Sea. *In* D. W. Hood and E. J. Kelley (eds.), *Oceanography of the Bering Sea.* Inst. Mar. Sci. Occas. Publ. 2, Univ. Alaska, Fairbanks.

Strelkov, Yu. A. 1960. Endoparasitic worms of marine fish of eastern Kamchatka. Akad. Nauk SSSR. *Trudy Zool. Inst.* No. 8:194-196.

Strickland, J. D. H. 1958. Solar radiation penetrating the ocean. A review of requirements, data and methods of measurement, particular reference to photosynthetic productivity. *J. Fish. Res. Bd. Can.* 15(3):453-493.

Strickland, J. D. H. 1960. Measuring the production of marine phytoplankton. *Bull. Fish. Res. Bd. Can.* 122:1-172.

Strickland, J. D. H. 1965. Production of organic matter in the primary stages of the marine food chain. *In* J. P. Riley and G. Skirrow (eds.), *Chemical Oceanography*, Vol. 1. Academic Press, New York-London. pp. 447-610.

Stunkard, H. W. 1947. On certain Pseudophyllidian cestodes from Alaskan pinnipeds. *J. Parasitol.* Vol. 33 (suppl.). p. 19.

Stunkard, H. W. 1948. Pseudophyllidian cestodes from Alaskan pinnipeds. *J. Parasitol.* 34(3):211-228.

Stunkard, H. W. and H. W. Schoenborn. 1936. Notes on the structure, distribution and synonyms of *Diphyllobothrium lanceolatum.* *Amer. Mus. Novit.* Vol. 880:1-9.

Sund, P. N. 1959. The distribution of chaetognaths in the Gulf of Alaska in 1954 and 1956. *J. Fish. Res. Bd. Can.* 16(3):351-361.

Suschenya, L. M. 1958. Quantitative data on the filtration feeding of plankton crustacea. *Nauchno. Dokl. Vysshei Shkoly, Biol. Nauki.* 1:16-20.

Sushkina, A. P. 1962. Rate of fat expenditure at different temperatures and the life cycle of *C. finmarchicus* (Gunn) and *C. glacialis* (Jashn). *Zool. Zhur.* 41(7):1004-1012.

Suvorov, E. K. 1912. *The Commander Islands and Their Fur-Seal Fisheries.* Publ. by Dept. of Agriculture. St. Petersburg.

Suvorov, E. K. 1946. The biology and organization of the fishery of benthic fishes of the Far East. *Nauch. Byull. Leningr. Gosudar. Univ.*, No. 13.

Suvorov, E. K. 1949. Pacific herring - *Clupea harengus pallasi* Cuvier et Valenciennes. Promysl Ryby SSSR. Pishchepromizdat.

Suvorov, E. K. 1951. Problems of the modern organization of the flatfish fishery in the Far East. *Trudy Karelo-Finskogo Otdel. Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 3.

Surorov, E. K. and L. A. Shchetinina. 1935. Cod Fishery in the Far East. *Rybn. Khoz. Dal'nego Vostoka.* 13(1):57-60.

Surorov, E. K., L. A. Vadova and A. K. Synkova. 1931. The biology of the capelin. *Trudy Leningrad Nauchno-Issled. Ikhtiol. Inst.* No. 11.

Suzuki, T. and J. Ito. 1967. On the DSL in the northwestern area of the North Pacific Ocean. 1. Relationship between vertical migration of DSL, submarine illumination and plankton biomass. *Bull. Jap. Soc. Sci. Fish.* 33(4):325-337.

Sverdrup, H. U. 1953. On conditions for the vernal blooming of phytoplankton. *J. Cons. Explor. Mer.* 18:287-295.

Sverdrup, H. U., M. W. Johnson and R. H. Fleming. 1942. *The Oceans, Their Physics, Chemistry and General Biology.* Prentice-Hall, New York. 1087 pp.

Svetovidov, A. N. 1936. Semeistvo Triglidae [The Triglidae Family]. Moscow-Leningrad, Izd. Akad. Nauk SSSR.

Svetovidov, A. N. 1940. Geographic distribution of cod and other families of the Gadiformes. *Byull. Moskov. Obshch. Ispyt. Prirody, Otdel. Biologii* 49(1).

Svetovidov, A. N. 1948a. Fauna SSSR. Ryby. Trekoo-braznye [Fauna of the USSR Fishes Gadiformes]. Izd. Akad. Nauk SSSR, Moscow-Leningrad. 294 pp.

Svetovidov, A. N. 1948b. Some similarities of the fish fauna of the Caspian and Black Seas and the North Pacific and North Atlantic Oceans. Akad. Nauk SSSR. *Doklady* 62(5):721-724.

Svetovidov, A. N. 1949a. Pacific cod - *Gadus morhua macrocephalus* Tilesius. Promysl. Ryby. SSSR. Pishchepromizdat.

Svetovidov, A. N. 1949b. The possible introduction of new commercial fishes into the Soviet Far Eastern Seas. *Rybn. Khoz.* No. 2.

Svetovidov, A. N. 1952. Fauna SSSR. RYBY. Sel'devye [Fauna of the USSR Fishes. Clupeidae]. Izd. Akad. Nauk SSSR, Moscow-Leningrad. 388 pp.

Svetovidov, A. N. 1953. Similarities and differences in the distribution, ecology and other characteristics of the cod and herring. Sbornik: *Ocherki po obshchim voprosam ikhtiologii.*

Svetovidova, A. A. 1948. O nakhokhdenii tikhookenaskoi minogi [*Entosphenus tridentatus* (Gaird)] v sovetskoi chasti Beringova morya. Akad. Nauk SSSR, *Doklady* 61(1):151-152.

Swarth, H. S. 1934. Birds of Nunivak Island, Alaska. *Pacif. Coast Avif.* 22:1-64.

Synkova, A. I. 1951. Diet of Pacific salmon in Kamchatka waters. *Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.* Vol. 34:105-121.

Taguchi, K. 1948. On the scale and stock of red salmon, *Oncorhynchus nerka*, migrating to Kamchatka. *Bull. Jap. Soc. Sci. Fish.* 13(4):

Taguchi, K. 1957. The seasonal variation of the good fishing area of salmon and the movements of water masses in the waters of western North Pacific. II. The distribution and migration of salmon pouplation in offshore waters. *Bull. Jap. Soc. Sci. Fish.* 22(9):515-521.

Taguchi, K. 1961. On the gorwth rate of catchable salmon in offshore waters. *Bull. Jap. Soc. Sci. Fish.* 27:637-640. [Engl. Transl. *Bur. Commer. Fish., Biol. Lab., Seattle, Wash., Transl. Ser. 34*].

Taguchi, S. 1972. Mathematical analysis of primary production in the Bering Sea in summer. *In* A. Y. Takenouti (ed.), *Biological Oceanography of the Northern North Pacific Ocean.* Idemitsu Shoten, Tokyo, Japan. pp. 253-262.

Taguchi, S. and H. Ishii. 1972. Shipboard experiments on respiration, excretion, and grazing of *Calanus cristatus* and *C. plumchrus* (Copepoda) in the Northern North Pacific. *In* A. Y. Takenouti (ed.), *Biological Oceanography of the Northern North Pacific Ocean.* Idemitsu Shoten, Tokyo, Japan. pp. 419-431.

Takagi, M., A. Iida and S. Oka. 1975. PCB content in several species of zooplankton collected in the North Pacific Ocean. *Bull. Jap. Soc. Sci. Fish.* 41(5):561-565.

Takagi, M., H. Murayama and S. Soma. 1975. PCB content in several species of flatfish collected in the eastern Bering Sea. *Bull. Jap. Soc. Sci. Fish.* 41(6):685-690.

Takahashi, M. and S. Schimura. 1972. Some aspects of primary production in the northwestern Pacific Ocean. *In* A. Y. Takenouti (ed.), *Biological Oceanography of the Northern North Pacific Ocean.* Idemitsu Shoten, Tokyo, Japan. pp. 217-229.

Takahashi, T. and M. Konda. 1974. On the age composition and the hourly changes of the catch of the herring by the trawl net in the northwestern sea area of the Pribilof Islands in the 1971/1972 winter. *Bull. Fac. Fish. Hokkaido Univ.* 25(1):47-54.

Takahashi, Y. and H. Yamaguchi. 1972. Stock of the Alaska pollock in the eastern Bering Sea. *Bull. Jap. Soc. Sci. Fish.* 38(4):389-399.

Takeuchi, I. 1961. The food of young fishes of the family Gadidae in the coast of Hokkaido. *Hokkaido Fish. Expl. Stn., Hokusuishi Geppo.* 18(9):1-8. [In Japanese with Engl. summary].

Takeuchi, I. 1962. Distribution of zoeal larvae of the king crab (*Paralithodes camtschatica*) in the southeastern Bering Sea in 1960. *Bull. Hokkaido Reg. Fish. Res. Lab.* No. 24:163-170.

Takeuchi, I. 1972a. Food animals collected from the stomachs of three salmonid fishes (*Oncorhynchus*) and their distribution in the natural environments in the Northern North Pacific. *Bull. Hokkaido Reg. Fish. Res. Lab.* No. 38:1-119.

Takeuchi, I. 1972b. Some observations of eggs and larvae of the Alaska pollock, *Theragra chalcogramma* (Pallas) off the west coast of Kamchatka. *In* A. Y. Takenouti (ed.), *Biological Oceanography in the Northern North Pacific Ocean.* Idemitsu Shoten, Tokyo, Japan. pp. 613-620.

Takano, H. 1959. Plankton diatoms in western Aleutian waters in the summer, 1953. *Bull. Tokai Regl. Fish. Res. Lab.* 23:1-11.

Takenouti, A. Y. (ed.). *Biological Oceanography of the Northern Pacific Ocean*, Idemitsu Shoten, Tokyo. 626 pp.

Talling, J. F. 1957. The phytoplankton population as a compound photosynthetic system. *New Phytol.* 56:133-149.

Tanaka, O. 1938. Note on *Calanus cristatus* Kröyer. *Jap. J. Zool.* 7(4): 599-601.

Taniguchi, A. 1969a. Mysidacea and Euphausiacea collected in the southeast of Hokkaido, Japan. *Bull. Fac. Fish., Hokkaido Univ.* 20(2):43-59.

Taniguchi, A. 1969b. Regional variations of surface primary productivity in the Bering Sea in summer and the vertical stability of water affecting the production. *Bull. Fac. Fish., Hokkaido Univ.* 20:169-179.

Taniguchi, A. 1970. *Geographical Variation of Primary Production in the Western Pacific Ocean and Adjacent Seas.* Ph.D. Thesis, Hokkaido Univ. 113 pp.

Taniguchi, A. 1976. Phytoplankton communities in the Bering Sea and Adjacent Seas - I. Communities in the early warming season in southern areas. *J. Oceanogr. Soc. Japan* Vol. 32:99-106.

Taniguchi, A., A. Koyama, M. Fukuchi and K. Saito. 1973. Phytoplankton population in the Bering Sea and adjacent sea area (preliminary report). Reprint of: *Ann. Meeting Oceanogr. Soc. Jpn., April 6-11, 1973.* Tokyo, pp. 95-96. [In Japanese].

Tanino, Y., H. Tsujisaki, K. Nakamichi and K. Kyshin. 1959. On the maturity of Alaska pollock. *Bull. Hokkaido Reg. Fish. Res. Lab.* No. 20:145-164.

Tanner, Z. L. 1891. The fishing grounds of the Bristol Bay, Alaska. A preliminary report upon the investigations of the U.S.F.C.S. "Albatross" during the summer of 1890. Washington, *Bull. U.S. Fish. Commiss.* Vol. 9: 279-288.

Tanner, Z. L. 1895. Report on the work of the steamer "Albatross" for the year ending June 30, 1893. *Rept. U.S. Comm. Fish. and Fisheries*, p. 19, Washington.

Tanner, Z. L. 1896. Report upon the operations of the U.S.F.C.S. "Albatross" for the year ending June 30, 1894. *Rept. U.S. Fish. and Fisheries Comm.*, p. 20, Washington.

Taranets, A. Ya. 1933. New data on the ichthyofauna of the Bering Sea. Akad. Nauk SSSR, *Vestnik Dal'nevost. Filiala* No. 1-3:67-78.

Taranets, A. Ya. 1936. A brief survey of the genera of the family Blenniidae related to *Stichaeus* from the Bering Sea, Seas of Okhotsk and Japan. Akad. Nauk SSSR, *Doklady* 1(3):145-148.

Taranets, A. Ya. 1937. Kratkii orpedelitel'ryb Sovetskogo Dal'nego Vostoka i prilezhashchikh vod [Handbook for identification of fishes of the Soviet Far East and adjacent waters]. *Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.* Vol. 11, 200 pp.

Taranets, A. Ya. 1938. Marine and freshwater commercial resources of the Far Eastern Territory. Akad. Nauk SSSR, *Vestnik. Dal'nevost. Filiala* 30, No. 3:143-188.

Tarasevich, M. N. 1963. Data on feeding of sperm whales in the northern area of Kurile waters (aramushir and Onekotan-Shiashkoton regions). Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 71:195-206.

Tarasevich, M. N. 1968. Food connections of sperm whales in the Northern Pacific. *Zool. Zhur.* 47(4):595-602. [In Russian].

Tarasov, N. I. and G. B. Zevina. 1957. Usonogie raki morei SSSR [*Cirripedia of the Seas of the U.S.S.R.*]. Moscow-Leningrad, Izd. Akad. Nauk SSSR.

Tarkhova, I. A. 1968. The distribution of phytoplankton in the eastern North Pacific in the winter of 1958-1959. *In: Plankton of the Pacific Ocean.* Izd. "Nauka" Moscow. pp. 136-146.

Tash, J. C. and K. B. Armitage. 1967. Ecology of zooplankton of the Cape Thompson area, Alaska. *Ecology* 48(1):129-139.

Tattershall, W. M. 1933. Euphausiacea and Mysidacea from Western Canada. *Contrib. Canad. Biol. and Fish.* XVIII(15). [Series A, General, no. 38]: 183-205.

Taylor, F. H. C., M. Fujinoga and F. Wilke. 1955. Distribution and food habits of the fur seals of the North Pacific Ocean. Rept. Co-op. Invest Govern. Canada, Japan, U.S.A., Feb.-July, 1952. Govt. Print. Off., Washington, D.C. 86 pp.

Tchindonova, J. G. 1955. [Chaetognatha of the Kurile-Kamchatka Trench]. *Trudy Inst. Okeanol.* Vol. 12:298-310.

Tchindonova, J. G. 1959. Feeding of some groups of macroplankton in the northwestern Pacific. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 30: 166-189. [In Russian].

Tebble, N. 1962. The distribution of pelagic polychaetes across the North Pacific Ocean. *Bull. Brit. Mus. (Nat. Hist.), Zool.* 7(9):371-492.

Thompson, R. B. 1965. Fecundity of the arctic char, *Salvelinus alpinus* of the Wood River Lakes, Bristol Bay, Alaska. *Copeia* 1959(4):345-346.

Thompson, W. F., Jr. 1941. A note on the spawning of the black cod, *Anoplopoma fimbria. Copeia* 4, p. 270.

Thompson, W. F. and W. Herrington. 1930. History of Pacific halibut fishery. *Rept. Int. Fish. Comm.* No. 5.

Thompson, W. F. and R. Van Cleve. 1936. Life history of the Pacific halibut: (2) Distribution and early life history. *Rept. Int. Fish. Comm. No. 9, 1936*:1-184.

Thorson, G. 1936. The larval development, growth, and metabolism of arctic marine bottom invertebrates compared with those of other seas. *Medd. om Grønl.* Vol. 100(6):155 pp.

Thorson, G. 1956. Marine level-bottom communities of recent seas, their temperature adaptation and their balance between predators and food animals. *Trans. N. Y. Acad. Sci.* Ser. 2, Vol. 28(8):693-700.

Thorson, G. 1957. Bottom communities (Sublittoral or shallow shelf), *Geol. Soc. Amer., Mem. 67*, Vol. 1:461-534.

Thorsteinson, E. D. 1941. New or noteworthy amphipods from the North Pacific coast. *Univ. Wash. Publ. Oceanogr.* 4(2):50-96.

Tikhenko, S. A. 1915a. Rybnye promysly Dal'nego Vostoka v 1913 g [The Far Eastern fisheries in 1913]. *Materialy k Poznaniyu Rosskogo Rubolovstva* 4(7).

Tikhenko, S. A. 1915b. Rybnye promysly Dal'nego Vostoka v 1914 g [The Far Eastern fisheries in 1914]. *Materialy k Poznaniyu Russkogo Rybolovstva* 4(11)

Tikhomirov, E. A. 1964a. Distribution and biology of pinnipeds in the Bering Sea (from materials of the first expedition in 1962). *Trudy Vses. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.* Vol. 53:272-280.

Tikhomirov, E. A. 1964b. Distribution and hunting of the sea lion in the Bering Sea and adjacent parts of the Pacific. *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 53:281-285.

Tikhomirov, E. A. 1964c. On the reproduction of the seals belonging to the family Phocidae in the North Pacific. *Zool. Zhur.* 45(2):275-281.

Tillman, M. F. 1975. Ecosystem dynamics - birds and marine mammals. *In: Environmental Assessment of the Alaskan Continental Shelf; Principal Investigators' Reports July-September 1975 Volume 1,* Environmental Research Laboratories, Boulder, Colorado, 1975. pp. 121-126.

Tomilin, A. G. 1936. Kashalot Kamchatskogo morya [Sperm whales of the Kamchatka Sea]. *Zool. Zhur.* 15(3):483-519.

Tomilin, A. G. 1937a. Kity Dal'nego Vostoka [Whales of the Far East]. Moskovskii Gosudar. Univ., *Uchenye Zapiski, Seriya Zool.* No. 13.

Tomilin, A. G. 1937b. The gray whale in the lagoons of the eastern shoreline of the central Bering Sea. *Priroda* No. 7.

Tomilin, A. G. 1937c. Observations of Far Eastern whales. Akad. Nauk SSSR, *Comptes Rendus (Doklady)* 14(6):399-402.

Tomilin, A. G. 1938. The biology of cetaceans. *Zh. Priroda* No. 7-8.

Tomilin, A. G. 1939. Some notes on the taxonomy, anatomy, biology and migrations of whales. *Tr. Rostovskogo Biol. Obshchestva*, No. 3.

Tomilin, A. G. 1946a. Problems of the Ecology of Cetaceans. Author's Summary. [As cited in Delyamure, 1968].

Tomilin, A. G. 1946b. The lactation and feeding of cetaceans. Akad. Nauk SSSR, *Comptes Rendus (Doklady)* 52(3):277-279.

Tomilin, A. G. 1952. Baird's beaked whale and the so-called far eastern bottlenose. *Byull. Mosk. Obshch. Ispyt. Prirody, Otdel biologii* 57(2)

Tomilin, A. G. 1954. Tipy adaptatsii otryada kitoobraznykh [Types of adaptation in the Order Cetacea]. *Zool. Zhur.* 33(3):677-693.

Topping, M. S. 1966. *A Study of Oxygen Consumption in Calanus plumchrus Marukawa 1921 and Implications on Vertical Migration.* M.S. Thesis, Univ. Brit. Col., Vancouver.

Treschev, V. V. 1966a. A new species of Acanthocephala from a whale of the Chukchi Sea. *Trudy Ukrain. Respub. Nauch. Obsch. Parazit.* 5: 112-115.

Treschev, V. V. 1966b. A new species of the genus *Ogmaster* Jägerskiöld, 1891, (*Ogmaster delamurei* n. sp.). *In: Parazity promezhutochnye koziaeva i perenoschiki.* Akad. Nauk Ukrain. SSSR, Kiev. pp. 22-25.

Treschev, V. V., A. M. Serdiukov and M. V. Yurakhno. 1969. *Orthosplanchnus odobaeni* sp. nov. (Trematoda, Campulidae), a new trematode from the Pacific walrus. *Nauch. Dokl. Vysch. Shkol., Biol. Nauk* 8:7-9.

Tsiban, A. V. 1970. Bacterioplankton and bacterioneuston in the northeastern part of the Pacific Ocean. *Tezisy Dokl. II. S'ezda Vses. Gidrobiol. Obsh., Kishinev.*

Tsiban, A. V. and N. G. Teplinskaya. 1972. Microbial population of the northwestern Pacific waters. *In* A. Y. Takenouti (ed.), *Biological Oceanography of the Northern North Pacific Ocean.* Idemitsu Shoten, Tokyo, Japan. pp. 541-557.

Tsimmer, K. [Zimmer, C.]. 1929. Nekotorye Cumacea iz russkikh morei [Some Cumacea of the Russian seas]. *Issled. Morei SSSR*, Vol. 9:61-69.

Tsimmer, K. [Zimmer, C.]. 1937. Tikhookeanskie Cumacea [Pacific Cumacea]. *Issled. Morei SSSR*, Vol. 23.

Tsunogai, S. 1972. An estimate of the rate of decomposition of organic matter in the deep water of the Pacific Ocean. *In* A. Y. Takenouti (ed.), *Biological Oceanography in the Northern North Pacific Ocean.* Idemitsu Shoten, Tokyo, Japan. pp. 517-532.

Tsuruta, A. 1962. The plankton distribution in the northeast water of the Bering Sea during the early summer in 1961. *J. Shimonoseki Univ. Fish.* 11:577-586. [In Japanese with Engl. summary].

Tsuruta, A. 1963. Distribution of plankton and its characteristics in the oceanic fishing grounds with special reference ot their relation to fishery. *J. Shimonoseki Univ. Fish.* 12(1):13-214.

Tsuruta, A. and T. Chiba. 1954. On the distribution of plankton at the fishing ground of salmons in the North Pacific Ocean, 1952. *J. Shimonoseki Univ. Fish.* 3(3):239-245. [In Japanese with Engl. summ.].

Tuck, L. M. 1960. *The Murres, Their Distribution, Populations and Biology: A Study of the Genus Uria.* Queen's Printer and Controller of Stationery, Ottawa. 260 pp.

Turner, K. 1886. Contributions to the natural history of Alaska. *Arctic Ser. of Publ.* Vol. 2.

Turpaeva, E. P. 1953. Pitanie i pishchevye gruppirovki morskikh donnykh bespozvonochnykh [Feeding and trophic groups of marine benthic invertebrates. *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 7:259-299.

Turpaeva, E. P. 1957. Food relations between dominant species in marine benthic biocoenoses. Akad. Nauk SSSR, Moscow, *Trudy Inst. Okeanol.* Vol. 20:171-185.

Tzvetkova, N. L. 1975. A new species of Pleustidae (Amphipoda), a commensal of sea urchins, from the Commander Islands. *Zool. Zhur.* 54(1):121-123.

Uda, M. 1961. Subarctic oceanography in relation to whaling and salmon fisheries. *Sci. Rept. Whales Res. Inst.* No. 16.

Uda, M. and K. Nasu. 1956. Studies on the whaling grounds in the northern sea region of the Pacific Ocean in relation to the meteorological and oceanographic conditions. (Part 1). *Sci. Rept. Whaling Res. Inst.* No. 11:163-179.

Uno, M. 1936. Age composition of *Theragra chalcogramma*. *Bull. Japn. Soc. Sci. Fish., Tokyo* 5(3):173-174.

Usachev, P. I. 1938. Biological analysis of ice-floes. *Akad. Nauk URSS, Comptes Rendus (Doklady)* 19(8):645-648.

Usachev, P. I. 1958. General features of phytoplankton distribution in the Far Eastern Seas. Akad. Nauk SSSR, *Trudy Okeanogr. Komissii* Vol. 3:75-78.

U.S. Coast Guard. 1936. Report of oceanographic cruise of U.S.C.G. cutter 'Chelan', Bering Sea and Bering Strait 1934 and other related data.

Ushakov, P. V. 1955a. *Fauna of the U.S.S.R.: Polychaeta of the Far Eastern Seas of the U.S.S.R.* Moscow. 448 pp. [In Russian].

Ushakov, P. V. 1955b. Polychaete worms of the family aphroditidae of the Kurile-Kamchatka Basin. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 12: 311-321.

Ushakov, P. V. 1957a. On the polychaete fauna of the Arctic and Antarctic. *Zool. Zhur.* 36:1659-1672.

Ushakov, P. V. 1957b. Pelagic polychaete fauna of the northwestern Pacific Ocean. Izd. Akad. Nauk SSSR, Moscow, *Issled. Dal'nevost. Morei* No. 4: 267-290.

Ushakov, P. V. 1958a. Faunistic investigations of the Zoological Institute of the Academy of Sciences of the USSR in the Far Eastern Seas. Akad. Nauk SSSR, *Trudy Okeanogr. Komissii* Vol. 3:102-108.

Ushakov, P. V. 1958b. Mnogoshchetinkovye chervi dal'nevostchnykh morei [*Polychaeta of the Far Eastern Seas*]. Akad. Nauk SSSR, Moscow, Izd. Zool. Inst.

Ushakov, P. V. 1962. Benthic fauna of the Far Eastern Seas, its composition and distribution patterns. Sbornik dokladov na 2-om plenume Komisii po rybokhozyaistvennym issledovaniyam zapadnoi chasti Tikhogo okeana.

Ussing, H. H. 1938. The biology of some important plankton animals in the fjords of East Greenland. *Medd. Om. Grønland*, Bd. 100(7):1-108.

Uspenskaya, A. V. 1963. Parasitophauna benticheskikh rakoobraznykh barentseva morya [*Parasite Fauna of Benthic Crustaceans from the Barents Sea*]. Akad. Nauk SSSR, Moscow-Leningrad, Izd. Akad. Nauk SSSR, 127 pp.

Uspenskiy, S. M. 1959. Colonially nesting sea birds of the northern and Far Eastern seas of the USSR, their location, numbers and role as consumers of plankton and benthos. *Byull. Moskov. Obshch. Ispyt. Prirody* 44(2).

Vadivasov, M. P. 1946. The whaling of the USSR in the Far East during 1941-1944. *Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.* Vol. 22:239-254.

Van Cleave, H. J. 1927. Ctenophores as the host of the cestode. *Trans. Amer. Micr. Soc.* 46:214-215.

Vasil'yev, I. S. 1959. *An Ecological and Morphological Description of the Summer Chum and the Pink Salmon in the Embrionic and Larval Periods of Their Life.* Author's Abstract of Ph.D. Thesis, Moscow Univ. Press.

Vedenskiy, A. P. 1949. An attempt to locate aggregations of Alaska pollock from floating eggs. *Izv. Tikhookean. Inst. Rybn. Khoz. Okeanogr.* Vol. 29:35-49.

Venrick, E. L. 1969. The distribution and ecology of oceanic diatoms in the North Pacific. Ph.D. Thesis. Univ. Calif. San Diego. 694 pp.

Venrick, E. L. 1971. Recurrent groups of diatom species in the North Pacific. *Ecol.* 52(4):614-625.

Vernidub, M. F. 1936. Material k poznaniyu tikhookeanskogo belokorogo pattusa [Data on pacific halibut]. *Trudy Leningradskogo Obshchestva Estestvoispytatelei* Vol. 15(2). Leningrad.

Vernidub, M. F. 1938. Strelozubye paltusy dal'nevostochnykh morei [Arrow-toothed halibut of Far Eastern Seas]. *Trudy Leningradskogo Obshchestva Estestvoipytatelei* 17(2). Leningrad.

Vernidub, M. F. and K. I. Panin. 1937. Nekotorye dannye o sistematicheskom pdozhenii i biologii tikhookeanskogo predstavitelya *Reinhardtius* Gilb. [Some data on the taxonomic position and biology of the Pacific species of *Reinhardtius* Gilb.]. *Uchennye Zapiski Leningr. Gosudar. Univ.* No. 15.

Verrill, A. 1914. Monograph of the Shallow-water starfishes of the North Pacific coast from the Arctic Ocean to California. Smithsonian Inst., *Harriman Alaska series*, Washington, Vol. 14.

Vidal, J. 1971. Taxonomic guides to Arctic zooplankton (IV), key to the calanoid copepods of the central Arctic Ocean. *Univ. S. Calif. Tech. Rept.* (5):1-128.

Vinogradov, A. P. 1938. Chemical composition of marine plankton. *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 7:97-112.

Vinogradov, A. P. 1953. The elementary chemical composition of marine organisms. *Mem. Sears Found. Mar. Res.* No. 2:647 pp.

Vinogradov, K. A. 1935. On the diet of cod in the eastern coastal waters of Kamchatka. *Rybn. Khoz. Kamchatki* No. 1.

Vinogradov, L. G. 1941. Kamchatskii krab [*The King Crab*], Vladivostok.

Vinogradov, L. G. 1946. Geographic distribution of the king crab. *Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.* Vol. 22:195-232.

Vinogradov, L. G. 1948. O zoologicheskom raionirovanii dal'nevostochnykh morei (predvaritel'noe soobshtenie). [Zoogeographic regionation of the Far Eastern Seas]. *Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.* Vol. 28:162-164.

Vinogradov, L. G. 1963. Marine benthic biocenoses and the application of data on their distribution to fish scouting operations. *In* P. A. Moiseev (ed.), *Soviet Fisheries Investigations in the Northeast Pacific. Part I.* Isdatel'stvo Ryb. Khoz., Moscow. pp. 131-142.

Vinogradov, L. G. and A. A. Neiman. 1965. Distribution of zoogeographical complexes of the bottom fauna in the eastern Bering Sea. *Trudy Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr.* Vol. 58:33-36.

Vinogradov, M. E. 1953. The role of vertical migrations of zooplankton in the feeding of deep-water animals. *Priroda* No. 6:95-96.

Vinogradov, M. E. 1954a. Diurnal vertical migration of zooplankton in the far eastern seas. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 8:164-199. [In Russian].

Vinogradov, M. E. 1954b. Vertikalvnoe raspredelenie biomassy zooplanktona kurilo-kamchatkoi vapadnoi. Akad. Nauk SSSR, Moscow, *Doklady* 96(3): 637-640.

Vinogradov, M. E. 1955a. The nature of the vertical distribution of zooplankton in the waters of the Kurile-Kamchatka Trench. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 12:177-183.

Vinogradov, Mikhail E. 1955b. Vertical distribution and migration of the zooplankton in the Okhotsk and Bering Seas and in the northwestern part of the Pacific. Ph.D. Thesis, Inst. Oceanol. Moscow, 307 pp. [In Russian].

Vinogradov, M. E. 1955c. Vertical migrations of zooplankton and their role in the diets of deep-sea pelagic fauna. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 13:71-76.

Vinogradov, M. E. 1956a. The distribution of the zooplankton in the western area of the Bering Sea. *Tr. Vses. Gidrobiol. Obshch.* 7:173-205. [In Russian].

Vinogradov, M. E. 1956b. Giperiidy (Amphipoda-Hyperiidae) zapadnykh raionov Beringova morya [Hyperrids of the western regions of the Bering Sea]. *Zool. Zhur.* 35(2):

Vinogradov, M. E. 1957. Hyperiids of the northwestern Pacific Ocean. Akad. Nauk SSSR, Moscow, *Trudy. Inst. Okeanol.* Vol. 20:186-227.

Vinogradov, M. E. 1958. On the vertical distribution of deep-sea plankton in the west part of the Pacific Ocean. *Proc. 15th Interml. Congr. Zool.* Sect. III, Paper 31. pp. 223-225.

Vinogradov, M. E. 1959. Vertical subdivision of sea zooplankton. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 30:100-106.

Vinogradov, M. E. 1960a. On the plankton of deep waters in the Sea of Japan. *Zool. Zhur.* 39(4):500-508.

Vinogradov, M. E. 1960b. Quantitative distribution of deep-sea plankton in the western and central Pacific. I. Distribution of the total plankton biomass. Akad. Nauk SSSR, Leningrad, *Trudy Inst. Okean.* Vol. 41:55-84.

Vinogradov, M. E. 1961. Sources of food of the deep-sea fauna (On the rate of decomposition of dead Pteropoda). Akad. Nauk SSSR, *Doklady* 138(6):1439-1442.

Vinogradov, M. E. 1962. Feeding of the deep-sea zooplankton. *Rapp. Proc. Verb. Rêun. Cons. Perm. Intern. Explor. Mer* 153:114-120.

Vinogradov, M. E. 1967. Vertical distribution of zooplankton in the Pacific Ocean. *In* V. G. Kort (ed.), *Tikhiy okean. Biologiya Tikhogo okeana. Kn. I. Plankton.* [*The Pacific Ocean. Biology of the Pacific Ocean. Vol. 7. Book I. Plankton*]. Moscow, Nauka. pp. 179-211.

Vinogradov, M. E. 1968. *Vertical Distribution of the Oceanic Zooplankton.* Izd. Nauka, Moscow, 320 pp. [Engl. Trans. I.P.S.T., 1970].

Vinogradov, M. E. 1970a. Some peculiarities of the change of the ocean's pelagic communities with depth. *In* L. A. Zenkevich (ed.), *Program and Methods of Biogeoceanological Investigation of Surrounding Waters. The Biogeoceanology of the Ocean.* Izd. "Nauka", Moscow. pp. 84-96.

Vinogradov, M. E. 1970b. The vertical distribution of zooplankton in the Kurile-Kamchatka region of the Pacific Ocean (based on the data of the 39th cruise of the R/V "Vityaz"). *Trudy. Inst. Okeanol.* Vol. 86:99-116. [In Russian].

Vinogradov, M. E. 1972. Vertical Stratification of Zooplankton in the Kurile-Kamchatka Trench. *In* A. Y. Takenouti (ed.), *Biological Oceanography of the Northern North Pacific Ocean.* Idemitsu Shoten, Tokyo, Japan. pp. 333-340.

Vinogradov, M. E. and E. G. Arashkevich. 1969. The vertical distribution of interzonal filter-feeding copepods and their importance in the communities of different depths in the northwest Pacific. *Okeanol.* 9(3):488-499; also *Oceanol.* 9(3):399-408. [In Russian].

Vinogradov, M. E., A. K. Brodskii and E. A. Akhmet'yeva. 1970. Biochemistry of ocean plankton and chemical composition of plankton from different depths of the northwestern Pacific. *Okeanol.* 10(5):871-877; also *Oceanol.* 10(5):692-698.

Vinogradov, M. P. 1949. Morskie mlekopitayushchie Artiki [Marine mammals of the Arctic]. Moscow-Leningrad, *Trudy Arkitech. Inst. Glavsevmorputi* 202:1-208.

Vinogradova, N. G. 1954. Materials on the quantitative evaluation of the bottom fauna in some bays of the Okhotsk and Bering Seas. Akad. Nauk SSSR, *Trudy. Inst. Okeanol.* Vol. 9:136-158. [In Russian].

Virketis, M. A. 1952. Zooplankton chukotskogo morya i Beringova proliva [Zooplankton of the Chukchi Sea and the Bering Strait]. Sbornik: *Krainii Severo-Vostok SSSR* Vol. 2.

Vlymen, W. 1970. Energy expenditure of swimming copepods. *Limnol. Oceanogr.* 15(3):348-356.

Volodchenko, N. I. 1941. New species of Nudibranchiata from the Far Eastern Seas of the U.S.S.R. *Issled. Dal'nevost. Morei SSSR* Vol. 1.

Voloshinov, N. A. 1889. Morskie kotiki [*Fur Seals*]. St. Petersburg.

Vorob'ev, A. V. 1926. Present status of the halibut fisheries in the Pacific Ocean. *Byull. Rybn. Khoz.* No. 2.

Vyshkvartzeva, N. V. 1972. The structure of mandibles in Copepoda (the genus *Calanus*) in relation to the latitudinal zonality. Akad. Nauk SSSR, *Issled. fauny morei* Vol. 12:161-171.

Wada, E. and A. Hattori. 1971. Nitrite metabolism in the euphotic layer of the central North Pacific Ocean. *Limnol. Oceanogr.* 16(5):766-772.

Waksman, S. A., C. L. Carey and H. W. Reuszer. 1933. Marine bacteria and their role in the cycle of life in the sea. I. Decomposition of marine plant and animal residues by bacteria. *Biol. Bull.* 65(1):57-79.

Waldron, K. D. and F. Favorite. 1977. Ichthyoplankton of the eastern Bering Sea. *In: Environmental Assessment of the Alaskan Continental Slope, Vol. 2.* Environmental Res. Lab., Boulder, Colorado. pp. 823-831.

Wallace, M. M., C. J. Pertuit and A. R. Rvatum. 1949. Contribution to the biology of the king crab (*Paralithodes camtschatica* Tilesius). *U.S. Fish and Wildl. Serv. Fish. Leafl. No. 40.*

Watanabe, N. 1954. A report on oceanographical investigations in the salmon fishing grounds of the North Pacific, 1952 and 1953. *Tokai Reg. Fish. Res. Lab., special Publication* No. 3:1-5.

Weber, D. D. and T. Miyahara. 1962. Growth of the adult male king crab *Paralithodes camtschatica* (Tilesius). U.S. Fish Wildlife Serv., *Fish. Bull.* 62(200):53-75.

Westrheim, S. J. 1973. Preliminary information on the systematics, distribution and abundance of the dusky rockfish, *Sebastes ciliatus*. *J. Fish. Res. Bd. Can.* 30(8):1230-1234.

Westrheim, S. J. and H. Tsuyuki. 1971. Taxonomy, distribution and biology of the northern rockfish, *Sebastes polyspinis*. *J. Fish. Res. Bd. Can.* 28(10):1621-1627.

Wickett, W. P. 1967. Ekman transport and zooplankton concentration in the north Pacific Ocean. *J. Fish. Res. Bd. Can.* 24(3):581-594.

Wigutoff, N. B. and C. B. Carlson. 1950. S. S. "Pacific Explorer". Part V. 1948 operations in the North Pacific and Bering Sea. *U.S. Fish. Wildl. Serv., Fish. Leafl. No. 361*, 161 pp.

Wilber, C. G. and Z. J. Musacchia. 1950. A comparative study of lipids in Arctic marine mammals. *J. Mammal.* 31(2):162-167.

Wilby, G. V. 1937. The ling cod, *Ophiodon elongatus* Girard. *Bull. Fish. Res. Bd. Can.* No. 54:1-24.

Wilimovsky, N. J. 1956. Ecology of the North Polar pack ice. report AINA Project 137 Natural Histry. Mus., Stanford Univ. IV. 123 pp.

Wilimovsky, N. J. 1964. Inshore fish fauna of the Aleutian Archipelago. *Science in Alaska* 1963:172-190.

Wilimovsky, N. J. 1974. Fishes of the Bering Sea: The state of existing knowledge and requirements for future effective effort. *In* D. W. Hood and E. J. Kelley (eds), *Oceanography of the Bering Sea*. Institute of Mar. Sci., Univ. Alaska, Occas. Publ. No. 2:243-256.

Wilke, F. 1957. Food of sea otters and harbor seals at Amchitka Island. *J. Wildl. Mgmt.* 21(2):241-242.

Wilke, F. and K. W. Kenyon. 1952. Notes on the food of fur seal, sea lion and harbor porpoise. *J. Wildl. Mgmt.* 16(3):396-397.

Wilke, F. and K. W. Kenyon. 1957. The food of fur seals in the Eastern Bering Sea. *J. Wildl. Mgmt.* 21(2):237-238.

Willey, A. 1920. Report on the Marine Copepoda collected during the Canadian Arctic expedition. *Rept. Can. Arctic Exped., 1913-1918*, Vol. 7, part K: Marine Copepoda. pp. 1-46 k.

Williams, C. S. 1938. Notes on food of the sea otter. *J. Mammal.* 19(1): 105-107.

Wilson, C. B. 1908. North American parasitic copepods: a list of those found upon the fishes of the Pacific coast, with descriptions of new genera and species. *Proc. U.S. Nat. Mus.* 35(1652):431-482.

Wilson, C. B. 1950. Copepods gathered by the United States fisheries steamer Albatross from 1887-1909, chiefly in the Pacific Ocean. *Bull. U.S. Nat. Mus.* 100[14](4):141-441.

Wimpenny, R. S. 1937. The distribution, breeding and feeding of some important plankton organisms of the south-west North Sea in 1934: *Calanus finmarchicus* (Gunn), *S. setosa* Müller and *S. elegans* Verrill. *Fish. Invest., Ser. 2, Min. Agric. Fish.* 15(3)(1936):1-53.

Winberg, G. G. 1956. Intensivnost obmena i pishchevye potrebnosti ryb. [*Rate of Metabolism and Food Requirements of Fishes*]. Nauchno Trudy Beloruss. Gosudar. Univ. imeni V. I. Lenina, Minsk. 253 pp.; also Fish. Res. Bd. Can., Transl. Ser. No. 194 [English Translation].

Wingfield, C. A. 1939. The activity and metabolism of poikilothermal animals in different latitudes. IV. *Proc. Zool. Soc. London*, 1939-1940, Ser. A:103-108.

Wirick, C. D. (In prep.). The role of patchiness in pelagic marine food chains. Univ. Washington, Ph.D. Thesis.

Wolotira, R. 1974. Information on the abundance, distribution and history of pollock in the southeastern Bering Sea. *U.S. Dept. Commer., N.M.F.S. Rept.* 35 pp.

Wolotira, R. J. and W. T. Pereyra. 1977. Baseline studies of fish and shellfish resources of Norton Sound and the Southeastern Chukchi Sea. *In: Environmental Assessment of the Alaskan Continental Shelf, Vol. 2.* Environmental Res. Lab., Boulder, Colorado. pp. 271-283.

Wood, E. J. F. 1963. Heterotrophic micro-organisms in the oceans. *In* H. Barnes (ed.), *Oceanography and Marine Biology; An Annual Review, Vol. 1.* George Allen and Unwin Ltd., London. pp. 197-222.

Yakovleva, A. M. 1952. Pantsirnye molluyski morei SSSR [*Amphineura of the U.S.S.R. Seas*]. Moscow-Leningrad, Izd. Akad. Nauk SSSR, 129 pp.

Yamada, M. 1964. The lipid of plankton. *Bull. Jap. Soc. Sci. Fish.* 30: 673-681.

Yamaguchi, H. and Y. Takahashi. 1972. Growth and age estimation of the Pacific pollock *Theragra chalcogramma* in the eastern Bering Sea. *Bull. Far Seas Fish. Res. Lab.* (Shimizu) 7:49-69.

Yamamoto, K. and K. Hamajima. 1947. The form and eggs and larvae of *Eleginus gracilis* and *Theragra chalcogramma* in northern Japan. *Seibutsu* 2:172-177. [In Japanese].

Yanagisawa, T. 1942. Plankton in the vicinity of Kurile Islands. *J. Oceanogr., Kobe Mar. Obs.* 13(3):730-738. [In Japanese].

Yashnov, V. A. 1939. Hydromedusae of the Siberian littoral of the Arctic Ocean (Bering Strait). *Byull. Moskv. Obshch. Ispytat. Prirody* Vol. 48 (Otdel Biologii), No. 2-3.

Yashnov, V. A. 1940. Plankticheskaya producktivnosti severnykh morei SSSR [Planktonic productivity of northern seas of the USSR]. *Izd. Mosk. Obshch. Ispytatelei Prirody*, Moscow:1-86.

Yashnov, V. A. 1952. Kishchnopolostnye iz prikamchatskikh vod Tikhogo Okeana [Coelenterates of the Kamchatkan waters of the Pacific Ocean]. Izd. Akad. Nauk SSSR, Moscow, *Issled. Dal'nevost. Morei* No. 3:95-98.

Yashnov, V. A. 1957. Pacific Ocean species of *Calanus finmarchicus* s. 1. *Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.* Vol. 44: 253-255.

Yashnov, V. A. 1963. Water masses and plankton. 2. *Calanus glacialis* and *Calanus pacificus* as indicators of definite water masses in the Pacific. *Zool. Zhur.* 42(7):1005-1021. [In Russian].

Yingst, D. R. 1972. Pelagic polychaetes of the central Arctic Basin. Taxonomic Guides of Arctic Zooplankton (V). *U.S.C. Dept. Biol. Sci. Tech. Rept.* No.1:1-42.

Yingst, D. R. 1974. The vertical distribution and reproductive biology of *Pelogobia longicirrata* (Annelida) in the central Arctic Ocean. *Biol. Bull.* 147(2):457-465.

Yonge, C. M. 1928. Feeding mechanimsm in the invertebrates. *Proc. Zool. Society London* 3(1):21-71.

Yonge, C. M. 1931 (August). Digestive processes in marine invertebrates and fishes. *J. Cons. Intern. Explor. Mer.* 6(2):175-212.

Yoshida, Y. and M. Kimata. 1972. Effects of zooplankton on the changes in concentration of inorganic nitrogen compounds and phytoplankton number in natural sea water. *In* A. Y. Takenouti (ed.), *Biological Oceanography of the Northern North Pacific Ocean.* Idemitsu Shoten, Tokyo, Japan. pp. 535-540.

Yurakhno, M. V. 1967. *Orthosplanchnus pygmaeus* sp. n. (Trematoda: Campulidae) a parasite of the whale. *Vestnik Zool.* 1967(3):79-82.

Yurakhno, M. V. 1968. A new trematode *Microphallus orientalis* sp. n. (Trematoda: Microphallidae), a parasite of the Pacific walrus and bearded seal. *Zool. Zhur.* Vol. 47:630-631.

Yurakhno, M. V. 1969a. *Pricetrema erignathi* sp. n. (Trematode: Heterophyidae), a parasite of the bearded seal. *Parazitologia* 3:354-356.

Yurakhno, M. V. 1969b. A new trematode, *Orthosplanchnus oculatus* sp. n. (Trematoda, Campulidae), a parasite of the Pacific walrus. *Vestnik Zool.* 1969(4):29-31.

Yurakhno, M. V. 1973. A new species of cestoda - *Diphyllobothrium macroevatum* sp. n (Cestoda, Diphyllobothriidae) - parasite of the gray whale. *Vestnik Zool.* 1973(6):25-30.

Yurakhno, M. V. and A. S. Skrjabin. 1971. *Parafilaroides krascheninnikovi* sp. n. parasite of the lungs of the ringed seal *Pusa hispida kraschenimnikovi* Naumov et Smirnov. *Vestnik Zool.* 1971(1):32-36.

Yusa, T. 1954. On the normal development of the fish, *Theragra chalcogramma* (Pallas), Alaska pollock. *Bull. Hokkaido Reg. Fish. Res. Lab.* No. 10:1-15.

Zahn, M. C. 1970. Japanese tanner crab fishery in eastern Bering Sea. *Comm. Fish. Rev.* 32(2):52-56.

Zaika, V. Ye. and N. A. Ostrovskaya. 1973. Indicators of the availability of food to fish larvae. 2. The percentage of feeding consumers in an unsteady feeding regime. The average time taken to seek out food. *J. Ichthyol.* 13(1):120-128.

Zakrzhevskii, N. I. and M. Yu. Kulikov. 1963. Rezul'taty i perspektivy glubinnykh tralenii v Beringovom more [Results and prospects of deep-water trawling in the Bering Sea]. *Rybn. Khoz.* No. 11.

Zarenkov, N. A. 1960a. Comparative ecology of the Decapod Crustacea of the Far Eastern Seas. *Zool. Zhur.* 39(2):188-199. [In Russian with English summary].

Zarenkov, N. A. 1960b. Note about some Decapod Crustacea of the Okhotsk and the Bering Seas. Akad. Nauk SSSR, Moscow, *Trudy Inst. Okeanol.* Vol. 34:343-350.

Zelickman, E. A. 1958. O sozrevanii gonad i plodovitosti samok massovykh vidov barentsevomorskikh evfauziid [On the ripening of the gonads and the fecundity of females of widespread euphausiid species of the Barents Sea]. Akad. Nauk SSSR, Leningrad, *Doklady* Vol. 118(1):201-204.

Zelickman, E. A. 1959. Some characteristics of the behavior of the Barents Sea Euphausiacea and possible causes of their seasonal vertical migrations. *Int. Oceanogr. Congr.* 1:189-192.

Zelickman, E. A. 1961. The behavior pattern of the Barents Sea Euphausiacea and possible causes of seasonal vertical migrations. *Int. Rev. Ges. Hydrobiol.* 46(2):276-281; also *Tr. Okeanogr. komissii AN SSSR* 10(4): 62-67.

Zelickman, E. A. 1970. Structural features of mass aggregations of jellyfish. *Okeanologiya* 9:688-696 [In Russian with Engl. Summ.]; also *Oceanology* 9(4):558-564 [Engl. Transl.].

Zenkevich, L. A. 1947. *Fauna and Biological Productivity of the Sea*, Vol. 1. Moscow, Izd. Sovetskaya Nauka.

Zenkevich, L. A. 1951a. *Fauna and Biological Productivity of the Sea*, Vol. 2. Moscow, Izd. "Sovets. Nauka". 506 pp.

Zenkevich, L. A. 1951b. Morya SSSR, ikh fauna i flora [*U.S.S.R. Seas, Their Fauna and Flora*] Uchpedgiz. 366 pp.

Zenkevich, L. A. 1953. Deepwater basins of the Pacific Ocean and their fauna. Akad. Nauk SSSR, *Vestnik* No. 12.

Zenkevich, L. A. 1957. A new genus and two new species of deep-sea echiuroids of the Far Eastern Seas and the Northwestern Pacific Ocean. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 23:291-295.

Zenkevich, L. A. 1958a. Deep-sea echiuroids from the Northwestern Pacific Ocean. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 27:192-203.

Zenkevich, L. A. 1958b. Directions of biological investigations of the Institute of Oceanology of the Academy of Sciences of the U.S.S.R. in the Far Eastern Seas: Survey of work done by the Institute of Oceanology on phyto- and zooplankton, phyto- and zoobenthos, ichthyoplankton and fishes of the Far Eastern Seas. Akad. Nauk SSSR, *Trudy Okeanogr. Komissii* Vol. 3:66-74.

Zenkevich, L. A. 1963. *Biology of Seas of the U.S.S.R.* Interscience, N.Y. 955 pp.

Zenkevich, L. A., N. G. Barsanova and G. M. Belyaev. 1960. Quantitative distribution of zoobenthos in the oceanic abyssal. Akad. Nauk SSSR, Leningrad, *Doklady* 130(1):183-186.

Zenkevich, L. A., Ya. A. Birshtein and G. M. Belyaev. 1954. Study of the fauna of the Kurile-Kamchatka Basin from data of the Pacific Ocean Expedition of the Institute of Oceanology of the Academy of Sciences of the U.S.S.R. *Priroda* No. 2:61-74.

Zenkevich, L. A., Ya. A. Birshtein and G. M. Belyaev. 1955. Investigations of the benthic fauna of the Kurile-Kamchatka Basin. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 12:345-381.

Zenkevich, L. A. and Z. A. Filatova. 1958. General brief description of the qualitative composition and the quantitative distribution of benthic fauna of the Far Eastern Seas and the northwestern Pacific. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 27:154-179.

Zenkevich, L. A. and Z. A. Filatova. 1960a. Quantitative-biocentric distribution of benthic fauna of the Far Eastern Seas in the Northwestern Pacific Ocean and its importance as forage in some fishing areas. Synopses of reports - *Trudy Soveshch. po Biol. Osnov. Okean. Rybol.*

Zenkevich, L. A. and Z. A. Filatova. 1960b. Kolichestvennoe raspredelenie glubokovodnoi donnoi fauny v severnoi chasti Tikhogo okeana [Quantitative distribution of deepwater benthic fauna in the northern part of the Pacific]. Akad. Nauk SSSR, Moscow, *Doklady* 133(2):451-453.

Zenkovich, B. A. 1934a. Materials on the study of the large cetaceans of the seas of the Far East. Akad. Nauk SSSR, *Vestnik Dal'nevost. Filiala* No. 10:9-29.

Zenkovich, B. A. 1934b. Some data on whales of the Far East. Akad. Nauk SSSR, *Comptes Rendus (Doklady)* 2(6):388-392.

Zenkovich, B. A. 1934c. Whaling in the Kamchatka and Bering Seas (1933 season). *Rybn. Khoz. Dal'nego Vostoka* No. 2:113-118.

Zenkovich, B. A. 1935. Ectoparasites of certain large cetaceans of the Far East. Akad. Nauk SSSR, *Vestnik Dal'nevost. Filiala* No. 13:117-122.

Zenkovich, B. A. 1937a. Further studies on the grey or California whale (*Rhachianectes glaucus* Cope, 1864). Akad. Nauk SSSR, *Vestnik Dal' nevost. Filiala* No. 23:91-103.

Zenkovich, B. A. 1937b. The humpback or longfinned whale. Akad. Nauk SSSR, *Vestnik Dal'nevost Filiala* No. 27:37-62.

Zenkovich, B. A. 1937c. Migrations of whales in the Northern Pacific Ocean. *Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.* Vol. 10:3-18.

Zenkovich, B. A. 1937d. Observations of whales in the Far Eastern Seas. Akad. Nauk SSSR, *Trudy Dal'nevost. Filiala* Vol. 1.

Zenkovich, B. A. 1937e. Weighing whales. From data on scientific research at the "Aleut" whaling base during 1932-1936. Akad. Nauk SSSR, *Comptes Rendus (Doklady)* 16(3):177-182.

Zenkovich, B. A. 1938a. On the fin whale in the Far Eastern Seas. *Priroda* No. 6.

Zenkovich, B. A. 1938b. Whaling in the Far Eastern Territory (1936 season). *Priroda* No. 6.

Zenkovich, B. A. 1945. A decade of observations on whales. Sbornik: *Rybnaya Promyshlennost'SSSR*, Vol. 3.

Zenkovich, B. A. 1947. The whaling industry of the U.S.S.R. and prospects for its development. *Zhur. Rybn. Khoz.* 10:15-20.

Zenkovich, B. A. 1952. Kity i kitoboinyi promysel [*Whales and Whaling*]. Moscow, Pishchepromizdat.

Zhitlo, Ya. I. 1948. Nekotorye svedeniya o pitanii nagul'noi sel'di Avachinskogo Zaliva v svyazi s sostavom zooplanktona [Some data on the feeding of foraging herring in Avacha Bay in connection with the composition of the zooplankton]. *Fondy Kamchat. Otdel. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr.*

Zhuze, A. P. 1954. Sopostavlenie ruzultatov diatomovogo analiza otlozheni okhotskogo i Beringova moreii. Akad. Nauk SSSR, Leningrad, *Doklady* 98(1):127-130.

Zhuze, A. P. and H. J. Semina. 1955. Obshie zakonomernosti b raspredelenii diatomovych v planktone Beringova Morya i v poverchnostnych donnych osadkach. Akad. Nauk SSSR, Moscow, *Doklady* 100(3):579-582.

Zhuze, A. P. 1957. Diatomovye v donnykh osadkakh Beringova morya [Diatoms in the Bering Sea sediments]. Akad. Nauk SSSR, *Trudy Komissii po Izuch. Chetver. Perioda* Vol. 13.

Zhuze, A. P. 1960. Diatomovye v poverkhnostnom sloe osadkov Beringova morya [Diatoms in the superficial layer of Bering Sea bottom sediments]. Akad. Nauk SSSR, *Trudy Inst. Okeanol.* Vol. 32:171-205.

Zhuze, A. P. and H. J. Semina. 1955. Obshchie zakonomernosti v raspredelenii diatomovykh v planktone Beringova morya i v poverkhnostnykh donnykh osadkakh [General patterns in the distribution of diatoms in the Bering Sea plankton and in the superficial bottom sediments]. Akad. Nauk SSSR, *Doklady* 100(3):

Zimmerman, S. T., T. R. Merrell, Jr., H. S. Sears and N. I. Calvin. 1977. Baseline/reconnaissance characterization littoral biota, Gulf of Alaska and Bering Sea. *In: Environmental assessment of the Alaskan Continental Shelf, Vol. 2.* Environmental Res. Lab., Boulder, Colorado. pp. 59-233.

Zimushko, V. V. and S. A. Lenskaya. 1970. Feeding of the gray whale (*Eschrichtius gibbosus* Erx.) at foraging grounds. *Ecology (Ekologiya)* 1(3):205-212.

Zinova, E. S. 1940. Marine algae of the Commander Islands. Akad. Nauk SSSR, *Trudy Tikhookean. Komiteta* Vol. 5.

Zinova, E. Z. 1952. Vysshie vodorosli Chukotskogo morya i Beringova proliva [Higher algae of the Chukchi Sea and the Bering Strait]. Sbornik: *Krainii Severo-Vostok SSSR* Vol. 2.

Zinova, A. D. 1953. *Key to the Brown Algae of the Northern Seas of the U.S.S.R.* Moscow-Leningrad, Izd. Akad. Nauk SSSR.

Zinova, A. D. 1955. *Key to the Red Algae of the Northern Seas of the U.S.S.R.* Moscow-Leningrad, Izd. Akad. Nauk SSSR.

Zo, Z. 1973. Breeding and growth of the chaetognath *Sagitta elegans* in Bedford Basin. *Limnol. Oceanogr.* 18:750-756.

Zvereva, J. A. 1975. *Valdiviella brodskyi* (Copepoda, Calanoida) from the Pacific Ocean and comparison of genital fields in some species of the genus. *Zool. Zhur.* 54(12):1890-1894.

Zver'kova, L. M. 1969. Spawning of the Alaska pollock [*Theragra chalcogramma* (Pallas)] in the waters of the west coast of Kamchatka. *J. Ichthyol.* 9(2):205-209.

Zver'kova, L. M. 1972. Growth and age of the walleye pollock [*Theragra chalcogramma* (Pall.)] from the northern part of the Sea of Japan. *J. Ichthyol.* 12(5):797-801.

ANNUAL REPORT

Contract: #3-5-022-56
Research Unit: #537
Task Order: #32
Reporting period: 3/1/77-3/31/78
Number of Pages: 25

NUTRIENT DYNAMICS IN NEARSHORE UNDER-ICE WATERS

Dr. Donald M. Schell
Institute of Marine Science
University of Alaska
Fairbanks, Alaska 99701

March 1978

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

I. SUMMARY OF OBJECTIVES, CONCLUSIONS AND IMPLICATIONS WITH RESPECT TO OCS OIL AND GAS DEVELOPMENT

Objectives

The overall objective of RU 537 is to describe the principal processes supplying energy (i.e. fixed carbon) to the biota of the Beaufort Sea coastal zone and to relate the various nutrient chemistry regimes observed to this production of energy. Both terrestrially derived and offshore derived nutrient sources are considered. The information obtained is for integration into the overall structure of the LGL Barrier Island study group, RU 467. Their modelling effort will relate this information to: 1) description of the overall ecosystem, 2) possible OCS direct impacts on the nearshore biota by offshore oil and gas development and 3) possible impacts on the nearshore biota caused by "upstream effects" on land which would change the character of terrestrial input of nutrients and/or carbon to the marine ecosystem via erosional processes or runoff.

Conclusions

The conclusions to date present a picture which is at first startling but upon closer scrutiny is a reasonable, if unusual, pattern for a marine ecosystem. The preliminary estimates of energy input to the nearshore marine biota shows that within approximately 10 km of shore, over 75% of the carbon is derived from the land and that this carbon is composed primarily of peat-like material that has been accumulating on land for up to 12,000 years. Thus the nearshore marine biome is apparently a "fossil fuel" subsidized ecosystem wherein the meager annual primary production by ice algae and phytoplankton is heavily supplemented by organic carbon eroded from coastal peat bluffs and transported by river flow into the coastal zone.

Implications with respect to oil and gas development

The implications of oil and gas development on the primary production and secondary production are mostly indirect but potentially great. Development which would increase or decrease shoreline erosion or significantly alter the rate of riverbank erosion or runoff characteristics could be expected to show corresponding impacts on the nearshore zone. Refinement of our assessments as to the magnitude of these impacts is continuing.

II. INTRODUCTION

General nature and scope of study

This research unit originally proposed to look at a very specific aspect of the nearshore primary production regime, namely, the contribution of ice algae, and the effects of thermohaline convection in supplying nutrients to ice algae populations. Since that time the importance of detritus became more evident and this research unit began to consider the possible magnitude of its significance through the use of data collected previously by the author. These results, summarized in the last quarterly report (October-December 1977), and refined below, show the approximate magnitudes of carbon inputs to the Simpson Lagoon ecosystem and set forth an outline of isotopic techniques that would allow determination of the relative inputs of peat carbon versus modern primary production carbon. Currently, a proposal modification is being presented to NOAA/OCSEAP to provide the support necessary to perform these additional tasks. If approved, RU 537 will expand its coverage from assessing the primary production and nutrient chemistry of the nearshore zone to include the appraisal of all energy sources entering the Beaufort Sea coastal system and will look at the subsequent flow of energy into the higher trophic levels of the Beaufort Sea.

Specific objectives

The specific objectives of this research unit are as follows;

1. Establish mass balance relationships for particulate and dissolved nitrogenous nutrients beneath the winter ice cover in the nearshore Beaufort Sea.
2. Compare standing stocks of epontic algae in relation to under-ice water circulation.
3. Collect data delineating temporal and spatial variability in ice algae blooms in the nearshore Beaufort Sea.

The data requirements of the LGS-Barrier Island study group have identified and necessitated the inclusion of the following objectives relating to the nutrient and energy inputs to the coastal marine ecosystem.

4. Determine the total inputs of energy to the coastal ecosystem including allochthonous carbon and nitrogen entering the system via terrestrial runoff and coastal erosion.
5. Relate the observed patterns in nutrient availability over the annual cycle to the heterotrophic utilization of detrital carbon within the coastal ecosystem.
6. Determine to what extent the detrital carbon is passed up the food chain and the relative significance of the various energy inputs to specific higher organisms in the coastal Beaufort Sea.

Relevance to problems of petroleum development

A detrital based ecosystem such as may be present along large portions of the Beaufort Sea could be readily altered directly or indirectly through OCS related petroleum development. A summary of the specific impacts which might affect the various sources of energy into the ecosystem would include, by type:

Ice algae productivity:

1. Oil spills on or under the spring ice cover would diminish primary production through either phytotoxic effects or by attenuation of light passing through the ice sheet.
2. Alteration of bottom topography by dredging channels or the construction of causeways could alter ice algae production by changing patterns of thermohaline convective flow beneath the ice cover. Prevention of brine drainage by closing off deeper channels would lead to brine accumulation on the bottom which could seriously impact both fauna and flora.

Phytoplankton production: Open water primary production would be most sensitive to such impacts as phytotoxicity resulting from oil spills. The rapid lateral flushing of water along the Beaufort Sea coast may, however, serve to minimize this aspect of potential impact.

Detrital-based production and heterotrophic productivity: Impacts upon the heterotrophic organisms that depend upon eroded and transported peat materials as their energy source would occur primarily through OCS related developments that impinged upon the sources of detritus. Such procedures such as shoreline stabilization could alter the food base by elimination of eroded materials. Causeway construction could change wave energy regimes and thus decrease shoreline erosion. Stabilization or channelizing of streambeds might add to or subtract from the total organic load carried by runoff waters. The present lack of knowledge concerning the role of detrital based production in the overall food web of the Beaufort Sea makes assessment of the potential impacts speculative at this time.

III. CURRENT STATE OF KNOWLEDGE

Primary production

In comparison to the warmer waters along the more southern Alaskan coastlines, the Beaufort Sea supports a relatively sparse biota. No appreciable harvests of renewable marine resources are made with the exception of small commercial fisheries operated principally by native communities in the estuaries along the coast and seasonal harvesting of bowhead whales at Point Barrow. The zone of maximum biological productivity is confined to a relatively narrow strip along the coast wherein the interaction of terrestrial influences ameliorates and somewhat enhances the sparse oceanic regime.

The primary production supporting the pelagic community occurs in two distinct phases in the Beaufort Sea (and other polar waters). The initial algal bloom in the spring occurs well before the >2 m ice cover has begun to melt but after the returning daylight reaches critical intensities sufficient to supply the necessary energy beneath the ice (Appolonio, 1965; Bunt, 1963). Attached, or epontic algal populations grow on the ice-water interface and thrive until the melt begins around the beginning of June. Estimates of the carbon fixed during this period range from about 1 gm/m^2-yr in the shallow Prudhoe Bay area (Horner *et al.*, 1974) to 5 gm/m^2-yr off Point Barrow (Clasby *et al.*, 1976). Little is known of the distribution or spatial variability of ice algae populations along the Beaufort Sea coast.

As the ice cover melts, phytoplankton production assumes the major role in energetic input although the stability of the water column caused by the melting of the nutrient-poor ice cover hinders the advection of deep water nutrients to the photic zone. Only in limited areas near Barter Island has Hufford (1974) identified possible upwelling of deep waters. As a result, primary production by phytoplankton is low and estimates range from <10 g C/m^2-yr in the central arctic Ocean (English, 1961) to about 20 g C/m^2-yr on the coastal zone near Barrow (Alexander *et al.*, 1974).

Input of terrestrial carbon to the nearshore coastal zone

The enhancement of biological activity in the proximity of land has been long recognized and attributed to various factors among which are the provision of suitable habitat for both benthic flora and fauna, substrate for macrophytes and input of terrigenous nitrogen, phosphorus and carbon via runoff from land. The arctic coastline provides very limited habitat for macrophytes or benthic infauna due to the 2 m freeze depth which effectively eliminates the shallow nearshore zone as a year-round environment for marine organisms. Again, in the deeper water, ice scouring creates sufficient habitat disturbance to account for the paucity of observed infauna. Below the 2 m contour in the bays and lagoons, however, large standing stocks of invertebrates - amphipods, mysids and isopods - are common and estimates by the LGL-Barrier Island Study (RU 467) personnel place the biomass at approximately 20 g/m^2 dry weight in Simpson Lagoon. These invertebrates are commonly found in close association with eroded organic material from the shoreline and studies by Broad (RU 356) have shown that certain gammarid amphipods and saduria do ingest and degrade the peat. This ingestion is probably accompanied by the removal and digestion of heterotrophic microflora and microfauna that are attached to the peat particles. Although it is known that the detrital material is ingested and that large numbers of invertebrates are associated with the organic material, as yet no conclusive evidence has been found indicating that the peat carbon is being assimilated either directly or indirectly by invertebrates or is being carried up the food chain to higher organisms such as fish or birds.

By using data obtained by Lewellen (1973) and the author during an earlier study of the Simpson Lagoon shoreline, erosion rates and the resulting quantities of carbon and nitrogen washed into the lagoon were estimated for the shoreline between Oliktok Point and Beechey Point. These estimates have been expanded by Cannon and Rawlinson (RU 530) to include all of Simpson Lagoon and are presented in Section VI. Further estimates on the total input of allochthonous carbon to the Beaufort Sea have been made by the author and S. Rawlinson (RU 530) which show that approximately 75% of the total carbon input is terrestrially derived. The implications of this compartmentalization of the energy input to the marine ecosystem are discussed in Section VI.

IV. STUDY AREA - BEAUFORT SEA - 100%

The study area for this project has been shifted from the originally proposed Elson Lagoon-Dease Inlet area near Pt. Barrow to Simpson Lagoon approximately 60 km west of Prudhoe Bay. This shift in siting was made to allow integration with the tasks being undertaken by the LGL-Barrier Island Study group. The principal data collection effort and detailed analyses on primary production and heterotrophic production will be made in this area. However, in conjunction with RU 530, estimates of terrestrial input of carbon along the entire Beaufort Sea coast via runoff and erosion will be undertaken on a much less detailed program.

V. SOURCES, METHODS AND RATIONALE OF DATA COLLECTION

Primary production by epontic ice algae in Elson Lagoon near Point Barrow

The sampling program for ice algal production and spatial distribution occurs during the spring months and involves sampling the ice-water interface before and after the ice algae bloom. The first sampling period is during early April and yields the water chemistry data representing the maximum nutrient concentrations and salinities of the annual cycle. Ice cores and water samples are taken as logistics and weather allow. Samples are filtered and analyzed for inorganic nutrients and particulate nitrogen to yield a total nitrogen budget for the water column. Sample locations are located to give spatial data yielding densities and distribution of ice algae.

Delays in funding of RU 537 prevented an extensive sampling program in Spring 1977 and very limited data were collected in the Point Barrow area. Extremely poor weather and lack of available helicopter support restricted sampling during the bloom to a single transect of Elson Lagoon. However, the data obtained will serve as a base for the Spring 1978 program near Simpson Lagoon.

Analytical methods employed for nitrate, ammonia and phosphate analyses are similar to those utilized by Alexander *et al.* (1974) for their ice algae studies. Dissolved organic nitrogen was run using the ultraviolet photooxidation technique employed by Schell (1974). Particulate nitrogen analyses were run on glass fiber filters containing aliquots of the melted ice cores or underlying water. The filtered samples were burned and the evolved nitrogen gas measured using a Coleman Nitrogen Analyzer.

By establishing detailed nitrogen budgets for the water column and ice column before and after the epontic algal bloom it is possible to determine two important facets of the nearshore productivity regime. First, the total standing stocks of ice algae (and assimilated nitrogen) can be quantitatively described for the nearshore zone and the validity of extrapolating primary production measurements obtained by Clasby *et al.* (1976) at Point Barrow to include other areas of the Beaufort Sea coast can be determined. Second, by establishing budgets of nitrogen in the dissolved and particulate phase, the importance of thermohaline convective flow as a nutrient input in the nearshore zone can be estimated. This hypothesis states that enhanced primary production by ice algae can be expected in the 2-5 m depth zone in the late Spring and the measurement of total particulate and inorganic nitrogen in the ice/water column offers the most direct test of whether or not this enhancement occurs.

Utilization of detrital carbon and transfer of detrital carbon in the food web

The magnitude of carbon input to the nearshore zone of Simpson Lagoon (Fig. 1) required that the effects of this energy source be evaluated in respect to the inputs of primary production. Detrital input occurs through essentially two sources - coastal erosion and runoff from the tundra. Thus assessment of these inputs becomes a geomorphological problem for the former source and a hydrological problem for the second. Chemical data on the eroded tundra have been previously obtained by Schell (1975) and new

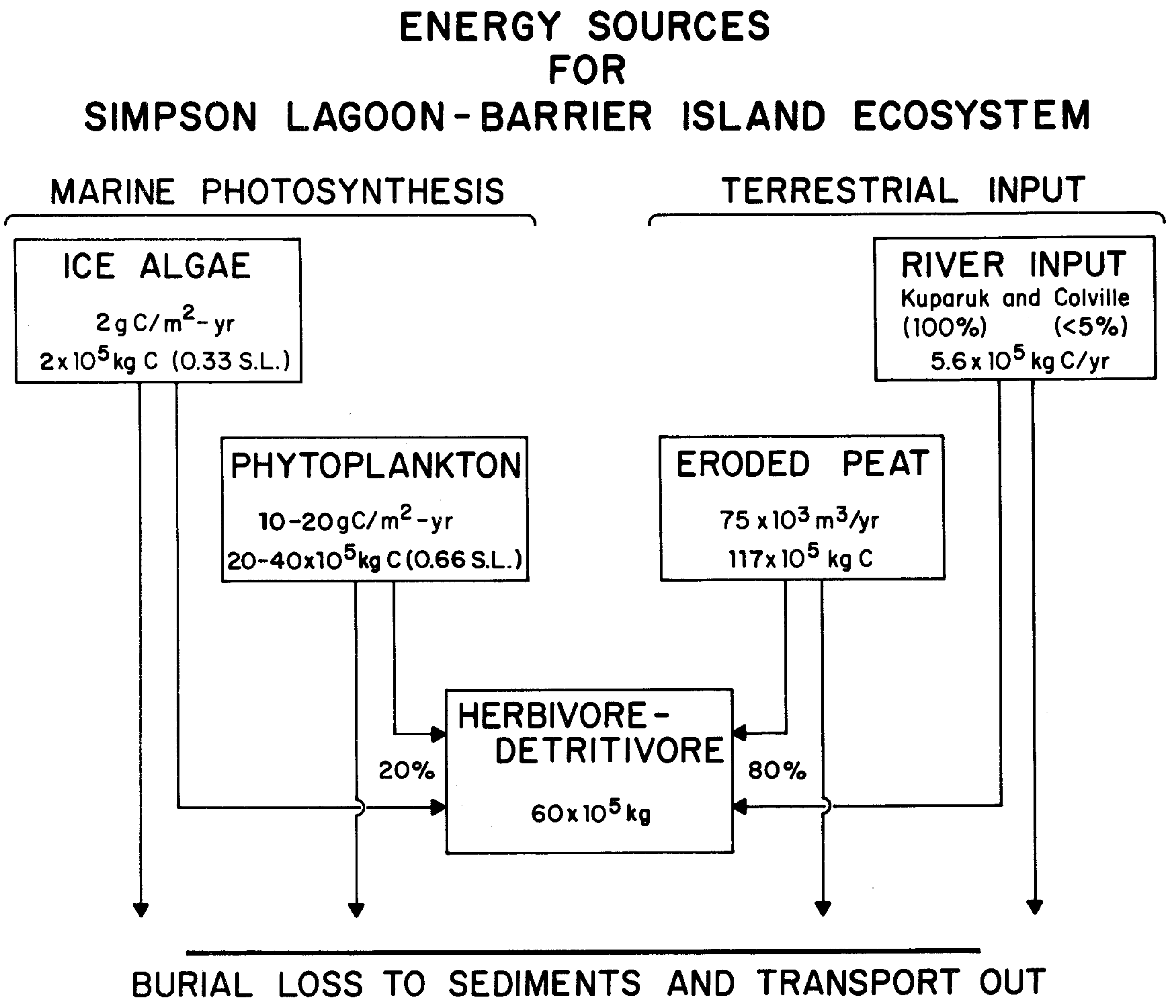


Figure 1. Carbon input to Simpson Lagoon.

erosional data are being determined by Cannon and Rawlinson (RU 530). Total organic carbon data for the Colville River waters have been kindly provided by the US Geological Survey (Charles Sloan, personal communication) and flow data are available from the literature (Arnborg *et al.*, 1967; Walker, 1974). Nitrogen data has been collected by Schell (RU 537) and will be incorporated with the above to yield quantitative inputs of nitrogen and carbon by the Colville River to the nearshore zone.

The utilization of detrital organic carbon by heterotrophs and the further transfer of this carbon into the food web is being investigated through the use of carbon isotope ratios in the various coastal marine living and non-living organic materials. Figure 2A shows the three fractions that would comprise the organic carbon of a detritivore or the predators of detritivores. The proposed analytical techniques to identify these fractions are shown in Figure 2B. If the carbon in the eroded peat materials of the shoreline are incorporated to a significant extent in the food web of heterotrophic microorganisms and these are then consumed and assimilated by benthic invertebrates such as amphipods, isopods and mysid shrimp, the isotopic abundances in the higher organisms should generally reflect the food source. Some species of these benthic invertebrates are known to comprise a large fraction of the diets of higher organisms found in the coastal Beaufort Sea and thus the potential exists for detrital carbon to constitute a large fraction of the energy supply to the ecosystem.

Radiocarbon dating will be used to delineate the fraction of peat carbon in the organisms. Eroded peat in Simpson Lagoon has a mean radiocarbon age of about 4000-5000 years B.P. if the radiocarbon dates given by Lewellen (1973) are representative of the basal peat layer in the Simpson Lagoon area. It is assumed that the peat has been accumulating at

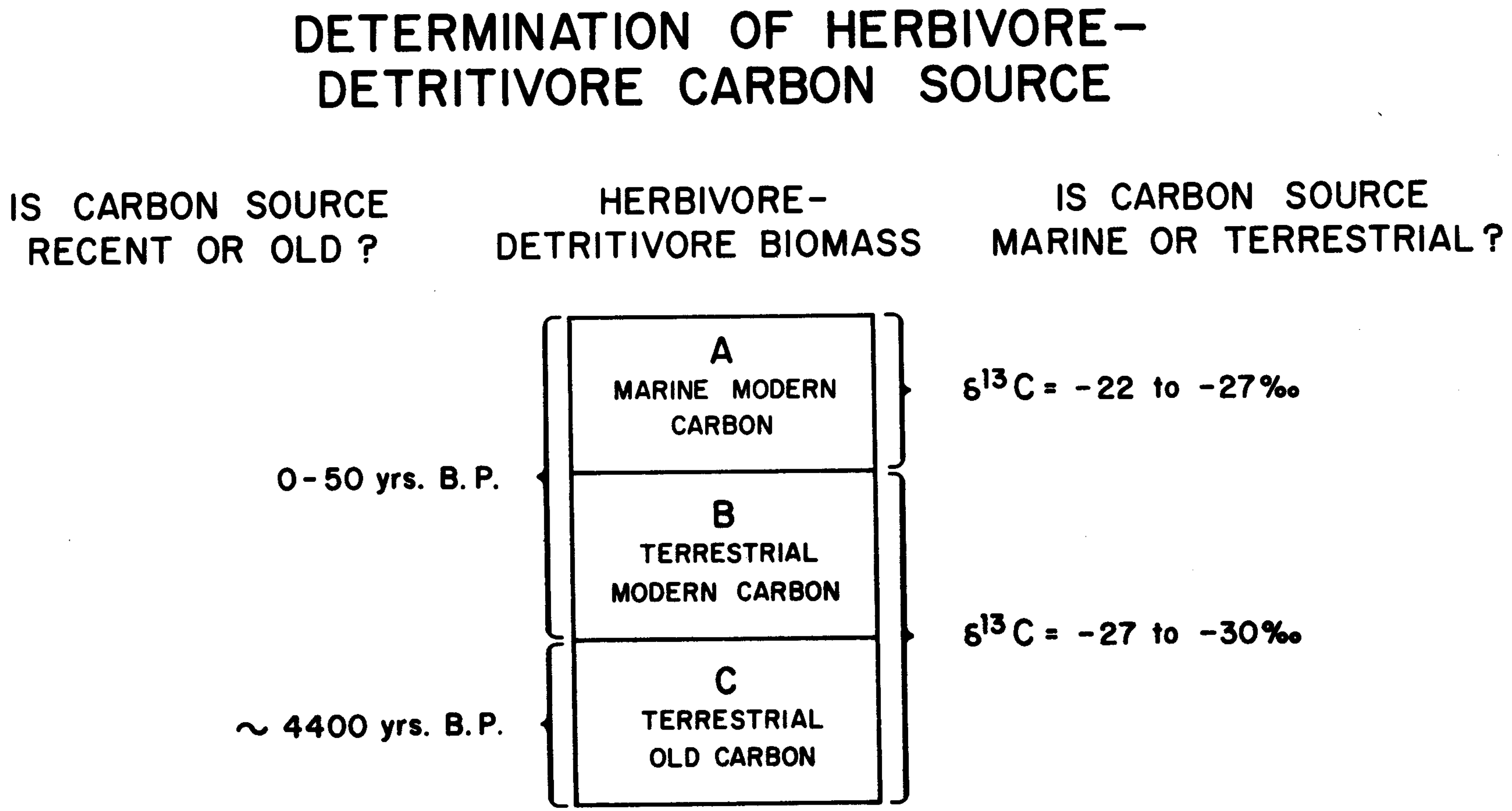


Figure 2A. Fractionation of carbon in nearshore Beaufort Sea fauna and characteristics of carbon isotopes from each source.

RADIOCARBON DATING

$$\%\,C = \left[\frac{\text{Mean peat age} - \text{Sample age}}{\text{Mean peat age}}\right] \times 100$$

$$\%\,A+B = 100 - C$$

= percent modern carbon (marine and terrestrial)

STABLE ISOTOPE RATIOS

$$\%\,A = \frac{{}^{12}C/{}^{13}C(\text{terr.}) - {}^{12}C/{}^{13}C(\text{sample})}{{}^{12}C/{}^{13}C(\text{terr.}) - {}^{12}C/{}^{13}C(\text{marine})} \times 100$$

$$\%\,B = 100 - (A+C)$$

= carbon derived from modern terrestrial sources.

Figure 2B. Techniques for quantitation of carbon input sources shown in Figure 2A.

a constant rate to present. As yet no age has been obtained for carbon transported by the Colville River but the surficial nature of runoff in a permafrost environment such as the North Slope would suggest a modern date somewhat tempered by peat addition via riverbank erosion and collapse.

Stable isotope techniques allow the discrimination of food sources in ecosystems where the source materials (primary producers) have significantly different $^{12}C/^{13}C$ ratios. By comparing $^{12}C/^{13}C$ ratios of organisms at different trophic levels the food sources of the higher organisms can be apportioned. This technique has been used by McConnaughey (1978) to study the detrital input of eelgrass beds in Izembek Lagoon to the fauna of the lagoon and nearshore Bering Sea. Application of this technique is shown in Figure 2B and will be investigated as a method to separate terrestrial and marine contributions to the nearshore fauna. Although the method is acknowledged to be less sensitive than ^{14}C dating, the applicability to modern carbon sources increases its desirability. Analytical cost is low compared to ^{14}C dating.

VI. RESULTS AND DISCUSSION

Primary production by epontic ice algae

Ice algae primary production data for 1977 were obtained for only one transect of Elson Lagoon at Point Barrow due to logistic problems and very poor flying weather which necessitated travel by tracked vehicle. Three stations were selected across the lagoon ranging from relatively deep water near the Eluitkak Pass entrance to the lagoon, another near mid-lagoon and the third approximately one kilometer from the mainland shore. Particulate nitrogen data for these stations are listed in Table I

TABLE I

PARTICULATE NITROGEN CONCENTRATIONS IN ELSON LAGOON AND DEASE INLET ICE AND WATER, SPRING 1977

Dease Inlet 31 March 1977 Station (mgN/m^3)	1 71°13'N 155°28'W	2 71°14'N 155°49'W	3 71°09'N 155°24'W	4 71°02'N 155°25'W	5 70°53'N 155°42'W
Top ice	14	70	67	196	-
Center ice	23	9	49	12	23
Bottom ice	52 (10.6)[1]	39 (7.7)	47 (2.1)	36 (1.7)	28 (8.2)
Under-ice water	27	38	53	18	26

Elson Lagoon 23 May 1977 Station (mgN/m^3)	1 71°21.5'N 156°21.0'W	2 71°21.1'N 156°24.0'W	3 71°20.6'N 156°28.0'W
Top ice	70	-	170
Center ice	83	60	2
Bottom ice	1199 (69.4)	140 (16.3)	340 (35.7)
Under-ice water	48	40	22

[1] Value in parentheses are mgN/m^2 of particulate nitrogen at the water-ice interface.

and compared to data obtained in April 1977 from Dease Inlet. The concentrations are expressed in mg N/liter of the melted core sections and for bottom ice, as mg N/m^2 since the ice algae are present as a discrete layer at the ice-water interface. The much more restricted circulation within Dease Inlet precludes direct comparison of nutrient chemistry in the underlying water column with that of Elson Lagoon and the value of these data in the ice algae study is to give a range of particulate nitrogen values found in the ice column. The high values occasionally present in the top ice were due to bands of detrital material frozen into the ice following storms in the fall. The nutrient data on nitrate, ammonia and phosphate concentrations beneath the ice were useful in assessing heterotrophic activity beneath the ice as discussed in the following section.

The particulate nitrogen values measured in Elson Lagoon are considerably less than those found beneath sea ice on the Chukchi Sea off Point Barrow (V. Alexander, personal communication). Either the nutrient chemistry regime is sufficiently different or the algal bloom had not progressed to the same intensity as when the Chukchi Sea samples were taken. The relatively high ammonia and nitrate concentrations (approximately 5 μg-atoms N/liter) indicate that the latter condition was probably the case. The weather had been cold and overcast for several days prior to sampling and no snow melt had occurred. Typically, ice algae populations reach maximum density just before the ice sheet begins to melt, around 1 June. The 1978 field season and sampling effort will be scheduled to optimize the collection of the maximum ice algae densities.

Carbon input to the nearshore marine zone from terrestrial runoff and coastal erosion

Estimation of erosional input of nitrogen to Simpson Lagoon was first attempted by Schell (1975) using data obtained by Lewellen (1973). Coastal erosion rates were determined through the use of coastline aerial photography made in 1955 and again in 1972. Coastline retreat was utilized with field data on average shoreline relief and soil types to calculate total organic matter and nitrogen being eroded on an annual basis. This technique has been expanded by Rawlinson (RU 530) and the results are shown in Figure 1 which gives the relative carbon inputs to Simpson Lagoon. Approximately 80% of the carbon input to the lagoon system is from terrestrial runoff and 75% is derived from peat eroded from the shorelines. This material, which has an average C:N atom ratio of about 18.8 also represents an input of approximately 730 metric tons of fixed nitrogen to the lagoon system.

When extending these calculations to include the entire Alaskan Beaufort Sea coast, a mean erosional rate of 1.75 m/year and a coastal relief of 1.5 m was assumed, of which 1.0 m was peat materials. From the data available on the Elson Lagoon coastline near Barrow, and the Simpson Lagoon area, the estimates are felt to be about representative. The carbon budget for the nearshore zone as a whole is shown in Figure 3. As in Simpson Lagoon, over 75% of the carbon input is from terrigenous material with 22% derived from marine primary production. Coastline erosion is responsible for approximately half of the total carbon input. Accompanying this approximately 4.5×10^6 tons of carbon is an estimated 2.7×10^4 tons of nitrogen which, after mineralization by heterotrophic oxidation of the carbon, should supply a large fraction of the nitrogen

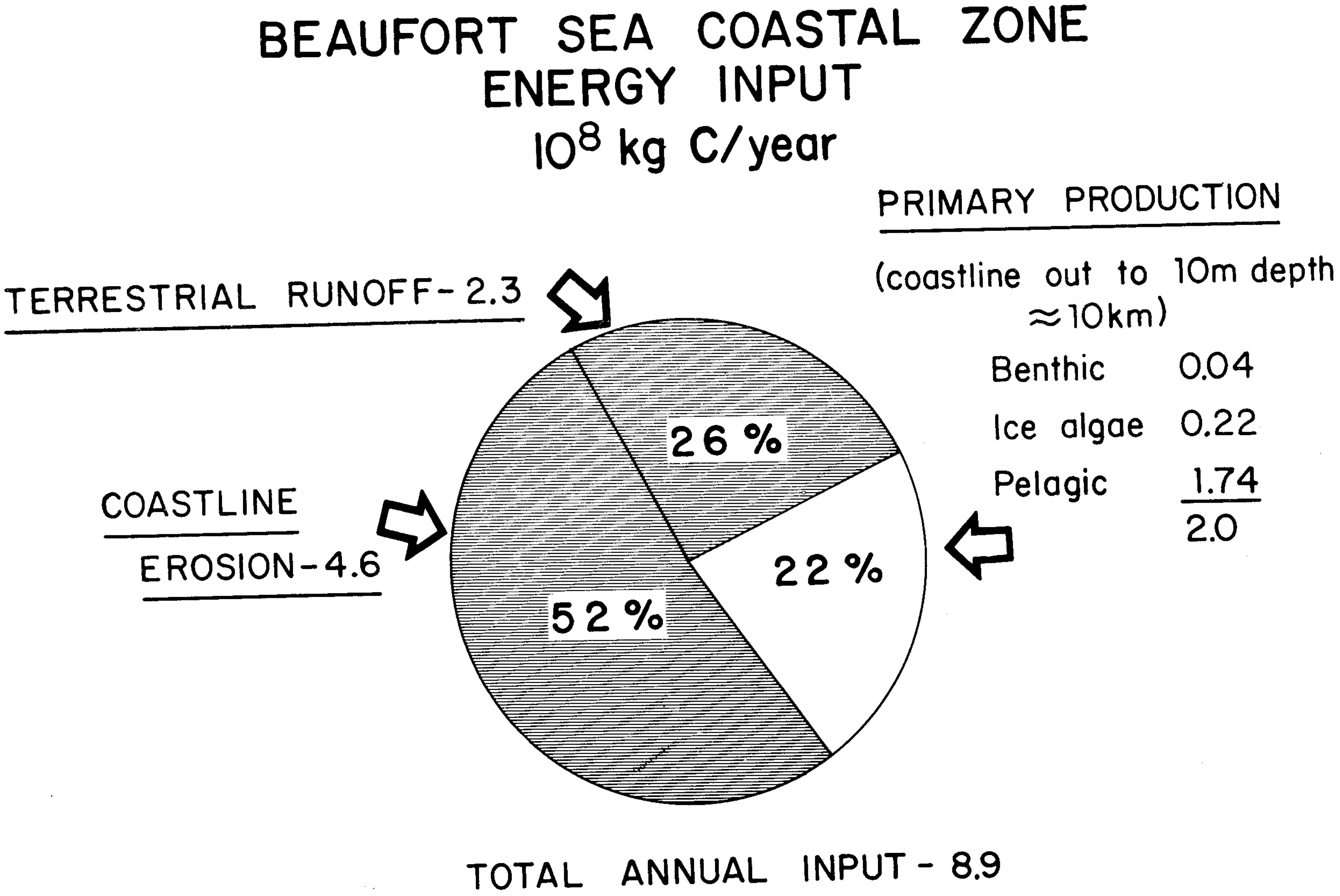


Figure 3. Carbon input to the Alaskan Beaufort Sea coastal zone.

requirements of the nearshore primary producers. The refinement of these estimates of input quantities and nitrogen content will be a major concern during the next year.

Food webs of the coastal Beaufort Sea

The epifauna of the nearshore zone have not been tested using the techniques described above to ascertain the relative amounts of carbon being derived from terrigenous sources versus marine primary production. The predominant species of amphipods that are in close association with the peat (gammarids) have not been found in large percentages in the gut contents of the fish and birds being studied by LGL personnel. To date no data exist which define the role of these nearshore invertebrates in the trophic dynamics of the coastal zone. Only one radiocarbon date has been obtained on a Colville River anadromous fish (*Coregonus autumnalis*) and that specimen was completely modern in radiocarbon age. The dietary information regarding this fish indicates that it feeds upon pelagic invertebrates and thus no conclusions regarding the detrital food web are yet possible. The proposal modification submitted to NOAA by RU 537 will allow a much more detailed compilation of nearshore trophic system data.

Circumstantial evidence for intense heterotrophic activity in the eroded peat is available through re-evaluation of existing Beaufort Sea data. The peat material contains a relatively high nitrogen content but is extremely phosphate deficient. When eroded or transported into the marine waters which contain a high concentration of phosphate, it would be expected that heterotrophic activity would yield measurable changes in the nitrogen-phosphorus ratios in the water through uptake of the limiting nutrient. Figure 4 shows the nitrogen/phosphorus ratios present in the water beneath the ice in Dease Inlet during April, 1973 (Schell, 1975). The water column throughout the inlet and up the delta channels of the Meade River was saline as all freshwater inflow ceases by late fall. A pronounced phosphate depletion is apparent as the stations progress toward the head of the inlet without a corresponding depletion in nitrogen. The author believes that this phosphate consumption is due to intense heterotrophic activity in the detritus and since thermohaline convective processes are active throughout the winter, the eroded terrestrial material must act as sink for phosphorus. The fate of this phosphorus is unknown. If incorporation into the sediments does not occur then at some period of the year, as yet unknown, regeneration and transport outward must be active. The proposed modifications to RU 537 would include study of this problem.

VII. CONCLUSIONS

Much of the work to be accomplished by this research unit has only begun and the conclusions drawn below must be regarded as tentative and undergoing modification as new data is acquired. Specifically, several conclusions regarding the primary production and energetics of the nearshore may be stated:

1. Primary production by ice algae and phytoplankton are a minor fraction of the total carbon input to the nearshore marine ecosystem. No implication as to the significance of marine primary production versus terrestrial input in trophic energetics can be drawn at this time.
2. The offshore waters of the Beaufort Sea are strongly nitrogen limited in respect to phytoplankton nutrition. In the immediate nearshore

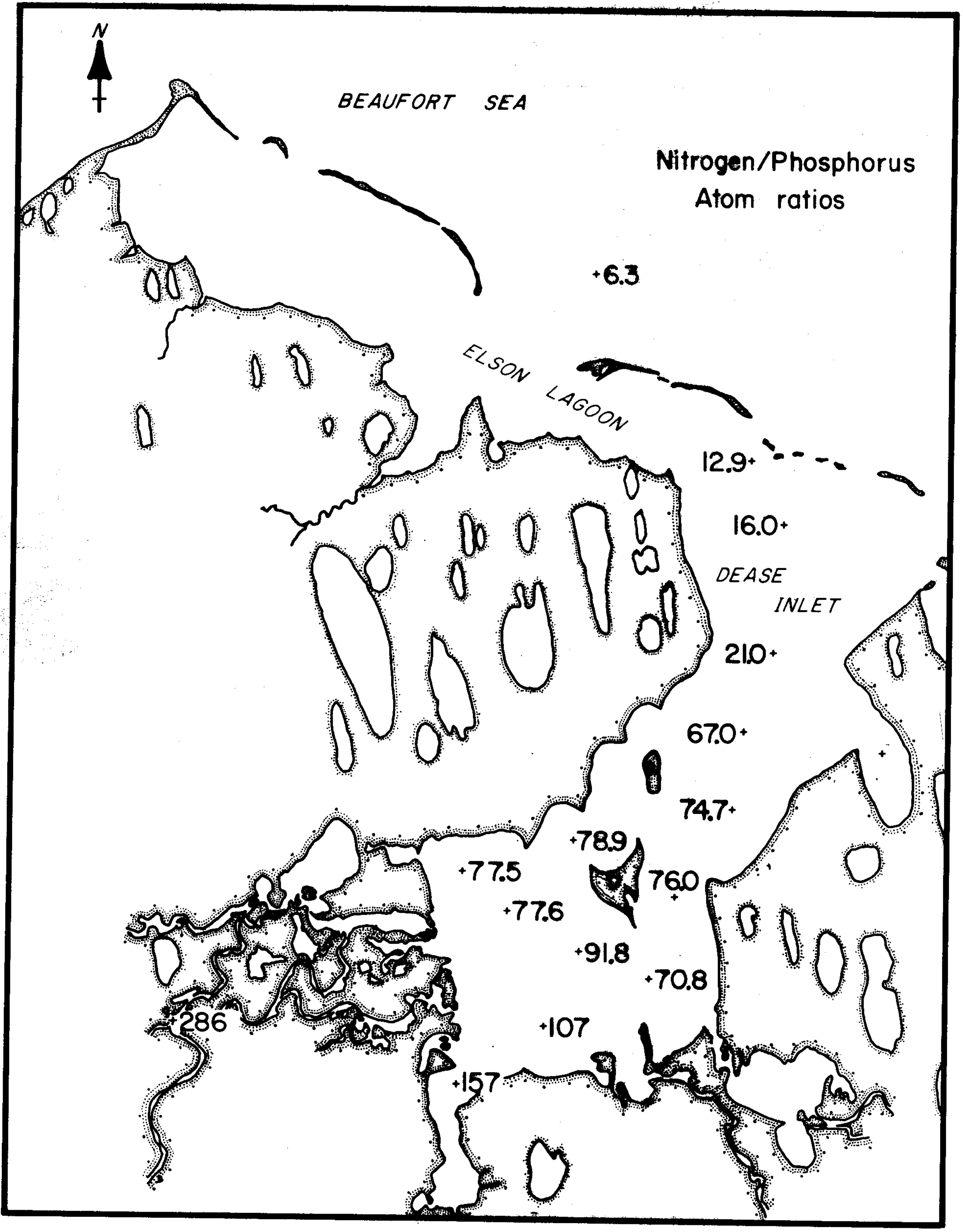


Figure 4. Dease Inlet nitrogen/phosphorus atom ratios in under-ice water, April 1973. Saline waters had intruded to the head of the Meade River delta (lower left) (from Schell, 1975).

zone, however, phosphate appears to be the limiting nutrient.

3. Nutrient regeneration and standing stocks of nutrients in the nearshore water column appear to be controlled by thermohaline convection and heterotrophic utilization during winter months and by primary producers during late spring and summer.
4. Environmental impacts on basic trophic energetics related to OCS development must be assessed with regard to the factors controlling the input of terrestrial organic material as well as factors controlling marine primary production.
5. Important higher organisms (i.e. birds, fish and mammals which utilize the nearshore environment as habitat must be investigated by individual species to determine the relative importance of detrital carbon versus primary production as the ultimate energy source within the nearshore marine ecosystem.

VIII. NEEDS FOR FURTHER STUDY

The various problems delineating the critical areas of study have been described above with the appropriate techniques to obtain the required data.

IX. SUMMARY OF FOURTH QUARTER ACTIVITIES

1. Ship/field trips

   None

2. Scientific party

   Not applicable

3. Methods

   Not applicable

4. Sample localities

   Not applicable

5. Data collected or analyzed

   Particulate nitrogen analyses for all 1977 samples were completed and the data processed.

Meetings

The LGL-Barrier workshop was held in Vancouver on 2-5 December 1977. Techniques for carbon isotope studies were presented as a means of elucidating relative carbon inputs to the food webs of the nearshore Beaufort Sea.

A scientific presentation and review of data obtained to date was given to BLM and NOAA/OCSEAP personnel in Anchorage on 7 March 1978.

REFERENCES

Alexander, V. 1974. Primary productivity regimes of the nearshore Beaufort Sea, with reference to the potential roles of ice biota. *In* J. C. Reed and J. E. Sater (eds.), *The Coast and Shelf of the Beaufort Sea.* Arctic Institute of North America. Arlington, Virginia. pp. 609-636.

Alexander, V., R. Horner and R. C. Clasby. 1974. Metabolism of Arctic sea ice organisms. Inst. Mar. Sci. Rept. R74-4, University of Alaska, Fairbanks. 120 pp.

Appolonio, S. 1965. Chlorophyll in arctic sea ice. *Arctic* 18:118-122.

Arnborg, L., H. J. Walker and J. Peippo. 1967. Suspended load in the Colville River, Alaska, 1962. Geografiska Annaler 49A. pp. 131-144.

Bunt, J. S. 1963. Diatoms of antarctic sea ice as agents of primary production. *Nature* 199:1254-1255.

Clasby, R. C., V. Alexander and R. Horner. 1976. Primary productivity of sea-ice algae. *In* D. W. Hood and D. C. Burrell (eds.), *Assessment of the Arctic Marine Environment: Selected Topics.* Inst. Mar. Sci., Occas. Pub. No. 4, University of Alaska, Fairbanks. pp. 289-304.

English, T. S. 1961. Some biological oceanographic observations in the central North Polar Sea, Drift Station Alpha, 1957-1958. Arctic Inst. of North America Scientific Rept. No. 15. Arlington, Virginia. 79 pp.

Horner, R. A., K. O. Coyle and D. R. Redburn. 1974. Ecology of the plankton of Prudhoe Bay, Alaska. Inst. Mar. Sci. Rept. R74-2, University of Alaska, Fairbanks. 78 pp.

Hufford, G. L. 1974. Dissolved oxygen and nutrients along the north Alaskan shelf. *In* J. C. Reed and J. E. Sater (eds.), *The Coast and Shelf of the Beaufort Sea.* Inst. of North America, Arlington, Virginia. pp. 567-588.

Lewellen, R. I. 1973. Special report (untitled) to University of Alaska, Inst. Mar. Sci., Fairbanks. Arctic Research, Inc., P.O. Box 2435, Littleton, Colorado 80161.

McConnaughey, T. 1978. Ecosystems naturally labeled with carbon-13: Applications to the study of consumer food-webs. Masters Thesis. Inst. Mar. Sci., University of Alaska, Fairbanks.

Schell, D. M. 1974. Regeneration of nitrogenous nutrients in arctic Alaska estuarine waters. *In* J. C. Reed and J. E. Sater (eds.), *The Coast and Shelf of the Beaufort Sea.* Arctic Inst. of North America, Arlington, Virginia. pp. 649-664.

Schell, D. M. 1975. Seasonal variation in the nutrient chemistry and conservative constituents in coastal Alaskan Beaufort Sea waters. *In* Alexander *et al.* (eds.), *Environmental Studies of an Arctic Estuarine System.* Environmental Protection Agency Rept. EPA-660/3-75-026. pp. 233-398.

Walker, H. J. 1974. The Colville River and the Beaufort Sea: Some interactions. *In* J. C. Reed and J. E. Sater (eds.), *The Coast and Shelf of the Beaufort Sea.* Arctic Inst. of North America, Arlington, Virginia. pp. 513-540.