Volume 3

Principal Investigators' Reports
July–September 1976

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

VOLUME 1. MARINE MAMMALS, MARINE BIRDS

VOLUME 2. FISH, PLANKTON, BENTHOS, LITTORAL

VOLUME 3. EFFECTS, CHEMISTRY AND MICROBIOLOGY, PHYSICAL OCEANOGRAPHY

VOLUME 4. GEOLOGY, ICE, DATA MANAGEMENT

Environmental Assessment of the Alaskan Continental Shelf

July - Sept 1976 quarterly reports from Principal Investigators participating in a multi-year program of environmental assessment related to petroleum development on the Alaskan Continental Shelf. The program is directed by the National Oceanic and Atmospheric Administration under the sponsorship of the Bureau of Land Management.

ENVIRONMENTAL RESEARCH LABORATORIES
Boulder, Colorado
November 1976

VOLUME 3

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EFFECTS

EFFECTS

RU# 62

NO REPORT WAS RECEIVED

A final report is expected next quarter

Quarterly Report

Contract No.
Research Unit No. 71
Reporting Period:
7/1/76 to 9/30/76
Number of Pages: 5

Physiological Impact of Oil on Pinnipeds

Co-Principal Investigator Roger Gentry

Co-Principal Investigator Bruce McAlister

Marine Mammal Division
Northwest Fisheries Center
2725 Montlake Boulevard East
Seattle, Washington 98112

September 1976

Quarterly Report

RU 71 -- Physiological Impact of Oil on Pinnipeds

I. Task Objectives

A. To determine the thermal conductance of both normal and oiled fur seal pelts.

B. To measure the effects of oil fouling on the number, depth and frequency of dives made during feeding excursions.

C. To measure the impact of oil fouling on the metabolic rates of fur seals in air and water.

II. Field and Laboratory Activities

A. Ship or Field trip schedule.

1. Laboratory (July, through September, 1976): Scripps Institution of Oceanography, La Jolla, California.

2. Field (July through September, 1976): St. George Island, Alaska.

B. Scientific Party for field research.

Dr. G. L. Kooyman, contract physiologist, Scripps; Mr. Randy Davis, field assistant, Scripps; Mr. Jack Sarno, electronics technician, Scripps; Dr. Roger L. Gentry, Co-Principal Investigator, NMFS; Mr. John Holt, field assistant, NMFS; Mr. Gregory McGlashen, field assistant, NMFS.

C. Methods.

1. Laboratory Analysis: using a special environmental chamber, the contract physiologist conducted 13 metabolic tests of four subadult fur seals, for a total of 130 hours of continuous data. He also measured with a heat flow disc the heat flux across the pelts of 11 pinnipeds (of 8 species) and three sea otters; measurements were made before oiling, after oiling, and after cleaning the pelts with Basic H.

2. Field Procedures: Using the same environmental chamber, the contract physiologist conducted 25 metabolic tests on five subadult fur seals for a total of 220 hours of continuous data. Tests were conducted before oiling, with oil on the pelt, and after cleaning with Shelsol 70 and with Basic H. The tests were made at a variety of water temperatures from 6°C to 25°C. The contract physiologist also applied depth-time recorders, attached by means of a harness, to 6 lactating females (two of which had been oiled prior to release), and to three subadult males.

D. Sample localities. St. George Island, Alaska, and adjacent Bering Sea.

E. Data collected or analyzed.

1. Metabolic Tests: Laboratory*

Water Temperature	Number of Tests
6°C	1
10°C	2
15°C	5
20°C	2
25°C	2
27°C	1

* All tests conducted on unoiled, subadult fur seals, mean duration of each test 10 hours.

2. Metabolic Tests: Field*

Water Temperature	No. Unoiled	No. Oiled	No. Cleaned
6°C	6	5	2
10°C	4	1	1

Metabolic Tests: Field (continued)

Water Temperature	No. Unoiled	No. oiled	No. cleaned
15°C	2	0	0
20°C	1	1	1
25°C	1	0	0

* All tests conducted on subadult male fur seals using same environmental chamber as in laboratory measurements, mean duration of each test 10 hours.

3. Heat Flux measurements*

Species	No. of pelts	No. Oiled Pelts	No. Cleaned Pelts
Enhydra lutris	3**	2	2
Erignathus barbatus	1	1	1
Phoca groenlandica	1	0	0
Lobodon carcinophagus	1	0	0
Hydrurga leptonyx	2	0	0
Leptonychoytes weddelli	2**	1	1
Zalophus californianus	1	1	1
Callorhinus ursinus	2**	2	2
Odobenus rosmarus	1	0	0

* All measurements made with a Beckman-Whitley heat flow disc.

** Includes at least one animal in juvenal pelage (lanugo)

4. Diving Studies. Of the nine depth-time recorders sent out on fur seals in the 1976 field season only three have been recovered by this writing. One seven day record was obtained from a lactating female, one recorder returned flooded

with sea water, and one recorder was taken off after only one day. Recorders on two subadult males are still out but may be recovered. Recorders on four lactating females, two oiled and two unoiled, are presently overdue and their return is now doubtful.

III. Results

Data collection will end in September, 1976. The contract physiologist has been unable to analyze the 360 hours of metabolic tests by this report date. However, analysis is underway, and a final report of results should be available within 90 days. The 1975 diving depths, reported in a previous quarterly report and published separately (Kooyman, and Gentry, 1976. Science 193 (4251):411-412), are presently being reanalyzed for diving effort and sequential patterns in diving behavior. These results will also appear in the final report.

Flux measurements have been conducted on normal and on oiled pelts. To date some of these pelts have not been cleaned and measurements of flux after this cleaning have not been made. However, all such measurements will be completed by the end of September.

IV. Preliminary interpretation of results.

Visual inspection of the metabolic results indicates that a light coating of crude oil (approximately 60cc applied with a brush to the dorsal surface only) causes a significant increase in the metabolic rate of sealsin water, and that this increase lasts a number of days after application. Data analysis will show this trend statistically.

V. Problems encountered/recommended changes.

The main problem encountered in the 1976 field season was the low incidence of recovering the depth-time recorders. In 1975 we recovered three out of three "dummy" packs put on to test the fur seal's ability to carry the recorder, and four out of five functioning recorders. We are therefore unable to explain our recovering only three out of nine recorders sent out in 1976. Unless these recorders are recovered (they will be looked for daily until October 20) we can draw no conclusions about the impact of oil on diving effort.

VI. Estimate of funds expended.

By August, 1976 virtually all funds were spent.

QUARTERLY REPORT

Contract #
Research Units #72, 331, 334
Report Period July 1, 1976 - September 30, 1976
Number of Pages 14

ACUTE AND CHRONIC TOXICITY, UPTAKE AND DEPURATION, AND SUBLETHAL METABOLIC RESPONSE OF ALASKAN MARINE ORGANISMS TO PETROLEUM HYDROCARBONS

Stanley D. Rice

John F. Karinen

Northwest Fisheries Center Auke Bay Fisheries Laboratory
National Marine Fisheries Service, NOAA
P. O. Box 155
Auke Bay, Alaska 99821

September 27, 1976

I. Task Objectives

A. General Tasks

1. Determine the acute and chronic effects of crude oil, its component fractions, and other petroleum-associated chemicals on physiological and behavioral mechanisms of selected arctic and subarctic organisms.
2. Conduct laboratory and field studies to determine recovery rates of selected organisms and ecosystems from perturbations resulting from either contamination or other disturbances associated with petroleum development.

B. Specific Objectives and Studies

1. Determine acute toxicity of previously untested species such as amphipods, mysids, sandlances, and others.
2. Determine acute toxicity at different temperatures with several species such as scallops, pink salmon, and shrimp.
3. Determine the chronic toxicity to shrimp and herring eggs and the effects of oil on newly extruded eggs of crabs.
4. Determine the uptake and depuration of oil components for previously untested species.
5. Determine the effect of temperature on oil component uptake and depuration.
6. Determine the effect of oil on metabolic rate of fish and invertebrates.
7. Determine the effect of oil on scallop growth and behavior.
8. Determine the effect of oil on crab autotomy response.
9. Determine histopathology effects of oil using routine histology, enzyme histochemistry, and electron microscopy.

II. Laboratory Activities

A. General Methods

Standard bioassay techniques, modified by the special requirements of working with hydrocarbons, were used in the majority of our experiments. Animals exposed to oil were monitored for death, sublethal physiological effects, behavioral changes, and metabolism of hydrocarbons.

All bioassays were done at the Auke Bay facility. The majority of organisms for our studies were collected in the vicinity of Auke Bay, Alaska. Exceptions to this are limpets collected at Cape Yakataga.

Cook Inlet oil was obtained from Shell Oil Company in 55-gallon drums. No. 2 fuel was taken from the laboratory heating system fuel tanks. Benzene, toluene, and naphthalene were reagent grade.

1. Mixing

Water-soluble fractions were prepared by gently mixing a 1% oil to water suspension. Depending on the volume needed, the oil-water mixture was prepared in either an 18-liter bottle, a 100-liter glass aquarium, a 55-gallon polyethylene-lined oil barrel, or an 800-liter fiberglass tank. In each case, electric motors with mixing paddles were adjusted to the proper mixing energy to allow the oil vortex to descend one-third of the depth of the container. The mixing continued for 20 hours followed by a 3-hour settling period. The WSF was then siphoned off from beneath the oil slick and diluted for use in exposure.

2. Exposure

Most exposures were static, aerated, and at a tissue-to-volume ratio of 1 gram per liter or less. Oil concentrations were measured analytically at the beginning of the exposures. Organism responses (mortality or some other parameter) were analyzed by computerized probit statistics. For several studies repetitive dosing was used. Periodically the oil concentration was monitored (UVOD) and brought up to the initial concentration by addition of 100% water-soluble fraction. The concentration deviation was minimized by frequent redosing.

3. Analytical Techniques

Our oil-water solutions (WSF's) were routinely analyzed by infrared (IR) and ultraviolet (UV) spectrophotometry, as well as by gas-liquid chromatography (GC).

The IR method is from Gruenfeld (1973), and involves determining the absorbance of light at 3412 nanometer wavelength by the oil-derived hydrocarbons. Aliphatic compounds, which are not very toxic, absorb most strongly at this wavelength. The method does not measure toxic aromatic or polar compounds. We use this method as a general indication of relative differences between successive WSF preparations, and as a means of comparing our work with that of other investigations. Despite its limitations, this method of determining oil in water is far superior to measuring only the volume of oil added to water, since the amount of oil that enters the water column is very dependent on the mixing energy and duration.

A second method that we routinely employ is a modified version of the UV method of Neff and Anderson (1975). This method involves determining the absorbance of oil-derived hydrocarbons at 221 nanometers. Naphthalene and methyl-substituted naphthalenes absorb most strongly at this wavelength, although high concentrations of mononuclear aromatics (such as benzene, toluene, xylene, etc.) can also cause appreciable absorption. The naphthalenes have been implicated in several toxicity studies. We use this method principally as a means of predicting the toxicity of successive WSF preparations. Since the different methyl-substituted naphthalenes have slightly different molar absorptivities at 221 nanometers, we report results by this method as naphthalene equivalents. This is the amount of pure naphthalene that would account for most of the absorbance observed in a given sample of 221 ananometers.

The third method we employ routinely involves gas-liquid chromatography (GLC). We use a column suggested by Supelco, Inc., which is especially suited for separating aromatic hydrocarbons. In this method we extract the WSF with two aliquots of methylene chloride, and then analyze from 1 to 10 microliters of the combined extracts immediately by GLC for mononuclear aromatics. Then we concentrate the extract to 500 microliters, and analyze from 1 to 10 microliters again by GLC for the higher aromatics.

We have established the identity of most of the aromatic peaks by comparing retention times with known standards, by spiking WSF's with known aromatics, and by mass spectroscopic (MS) identification of selected samples. The results from these different methods have always been in agreement. The MS study (conducted at the Northwest Fisheries Center in Seattle) also established that both normal and some branched paraffins elute from our column, and in some cases they elute simultaneously with some of the aromatic compounds. On the basis of this information we are now able to correct for this interference.

4. Bioassay Statistics

When possible, all of our bioassay results are analyzed by a computerized probit analysis by Finney (1971). This statistical technique calculates a maximum likelihood estimation of the oil concentration that would cause 50%

of the exposed animals to respond after exposure to the WSF for some given time.*

Usually the response is death, although we do note certain other behavioral responses as well.

In addition, the probit analysis estimates a 95% fiducial limit about this TLm, and a slope function and 95% fiducial limit about this slope function. The slope function is the rate at which the proportion of animals responding changes with changing oil concentrations in the WSF. From it, one can estimate the most likely proportion of animals that would respond at WSF oil concentrations other than the TLm. It is related to the tolerance distribution of the species being tested.

In some cases our bioassay results are not amenable to probit analysis. Probit analysis requires at least two dose levels of WSF at which the proportion of animals responding is observed to be between zero and one. Occasionally our dose levels will be so distributed that none of the animals respond in some set of lower doses, and all of them respond in the next highest dose and all higher doses. Or, there will be only one dose at which the proportion of animals responding is observed to lie between zero and one. In the former case we estimate the TLm as the antilog of the sum of the log of the highest dose where no animals respond, plus the log of the lowest dose where all of the animals respond, divided by two. In the latter case we estimate the TLm by plotting the dose versus the percent of the animals responding, and noting the dose level that corresponds to 50% response. This is the method of Doudoroff et al. (1951).

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*We call this concentration of oil in the WSF the median tolerance limit, or TLm.

All of our data are being stored on punched computer cards, as well as in record books.

B. Methods for Specific Experiments
(See I-B for objectives)

1. Static Acute Bioassays

a. Bioassays were conducted with several organisms and developmental stages at temperatures ranging from 4-8°C. Water-soluble fractions of crude oils were prepared as described before. Oil exposures were monitored by chemical analyses, i.e. IR, UV, and GC. Mortalities were noted daily and the results were analyzed as described previously (probit statistics with 95% fiducial limits). Sublethal quantifiable behavioral responses were used when possible as an additional indicator of effect.

2. Static Acute Bioassays at Different Temperatures

a. Temperature assays with toluene were run using acute exposures at 4°, 8°, and 12°C with pink salmon, and Eualus shrimp. The three temperatures were run simultaneously with the same initial mix to minimize variability. Animals were temperature-acclimated before testing.

3. No new activities were completed in studies of chronic toxicity to eggs. Samples from earlier experiments are being analysed.

4. An uptake study to document the biological and analytical variability when measuring hydrocarbon accumulation in marine organisms was completed. Fish, shrimp, and scallops were exposed to Cook Inlet WSF for 24 h under static conditions. Replicate samples (whole organisms) were frozen and sent to Scott Warner (Battelle Columbus Laboratory) for gas chromatographic analyses. Warner divided some samples for use in an intercalibration study with Brown of the Northwest Fisheries Center, and Hertz of the National Bureau of Standards.

5. An uptake study to determine effects of temperature on the accumulation of aromatic hydrocarbons in fish, shrimp, and scallops was completed. Cook Inlet WSF spiked with ^{14}C toluene and ^{3}H napthalene was used for a 48 h static exposure with pink salmon, shrimp (Pandalus goniurus), and scallops (Chlamys spp) at 4°, 8°, 12°. Whole organisms were sampled periodically through the exposure period and a subsequent 8 day depuration period. Samples were frozen and will be processed as follows:

a. using a sample oxidizer and scintillation counter to determine the toluene and napthalene content.

b. using the method of Rouble (197) to separate metabolites from parent compounds, then using the sample oxidizer and scintillation counter to document the percent metabolism of toluene and napthalene.

c. sending samples to Battelle Columbus Laboratory for gas chromatographic analyses to quantitate certain aromatic and aliphati oil components.

6. The effect of oil on the metabolic rate of pink salmon at different temperatures has been determined. The method of Thomas and Rice (1975) which used opercular rate as a measurement of metabolic activity was employed to document the effect of toluene napthalene and CIWSF on pink salmon at 4-12°.

For each test, two groups were acclimated at 4° and 12°C respectively. Identical sublethal concentrations of toxicant were prepared and brought to proper exposure temperature before the flow-through test was begun. The concentration of the stock tanks was measured and spiked frequently to prevent the toxicant concentration from declining. The ventilation movements were recorded from free swimming fish (no surgery or anesthetizer) in special confining chambers before and during exposure for up to 15 hours of exposure. Previous experiments have shown that increases and decreases in oxygen consumption measurements parallel ventilation recordings.

In an additional test the metabolic response of pink salmon to toluene and napthalene, as measured by opercular rate, was compared to direct oxygen consumption measurements. Flow-through tunnel respirometers were used with precise temperature control (6 replicates).

7. Effects of oil on the long term survival and behavior of scallops in the field is being determined. Marked scallops (350) were exposed to 5 doses of Cook Inlet WSF for 24 h. A sixth group served as controls. All scallops were placed in a 10- by 10- by 5-foot high net lined enclosure with no bottom or top. Mortality and predation will be noted periodically by divers.

8. No new activities were initiated in autotomy studies. Some data remains to be analyzed.

9. A study was completed to determine effects of oil on pink salmon tissues and correlate results with the respiration measurements of Thomas and Rice (see #6.)

Pink salmon fry (Oncorhynchus gorbuscha) were exposed to approximately 25% and 75% of the TLm dose of a WSF of Cook Inlet crude oil. Total exposure was for 96 hours, with a depuration period of 16 days. The crude oil and seawater were mixed in a barrel by ABFL's standard procedure, allowed to set for three hours, sparged and siphoned into tanks.

Gill and liver samples were taken at 3, 10, 24, 48, and 96 hours from each dose during exposure; then samples were taken from depurating fish at 1, 4, 6, 10, and 16 days. Control samples were also taken.

Tissues were fixed in buffered 5% formalin. Six fish were sampled at each period from each dose. Controls were taken 3 times for a total of approximately 200 tissue samples. One half of these have been washed, dehydrated and embedded in paraffin. Processing (including staining) is continuing and the slides will be evaluated in the next few months.

III. Results

1. Acute Bioassays

Results of recent assays completed at Auke Bay were presented at the American Institute of Biological Sciences meeting August 1976, Washington, D.C. (copy enclosed.) Bioassays completed this quarter include:

Species	Common Name	Cook Inlet WSF	Fuel Oil WSF
Crangon franciscorum	shrimp	X	X
Myoxycephalus polyacanthocephalus	sculpin	X	X
Aulorhynchus flavidus	tubesnout fish	X	X
Snail (unidentified)	snail	X	X
Hemigrapsus nudus	shore crab	X	X
Clupea pallasi	herring	X	X
Nucella lima	high intertidal whelk	X	X
Littorina sitkana	high intertidal snail	X	
Balanus glandula	barnacle	X	
Margaretes pupallus	low tidal snail	X	X
Tonicella lineata	chiton	X	X
Katharina tunicata	chiton	X	X
Eupentacta quinquesemita	sea cucumber		X
Mytilus edulus	mussel	X	X
Mopalia ciliata	chiton	X	

2. Temperature bioassays at different temperatures

The original temperature effects study was modified to use toluene instead of benzene and eliminate scallops in an effort to clarify results.

Pink salmon and Eualis spp shrimp were tested with toluene at 4, 8, and 12°. The manuscript "Effects of temperature on the acute toxicity of

Cook Inlet water soluble fraction, toluene, and napthalene to pink salmon and shrimp" will be presented and published at the NOAA Symposium November 1976, Seattle, Washington.

The study of temperature effects on the stability of water soluble fractions was completed and data analyzed. Manuscript "Effects of temperature, volatility, and biodegradation on the persistence of aromatic hydrocarbons in seawater" by Cheatham et al. will be presented at the NOAA November, 1976 Symposium, Seattle, Washington.

3. The manuscript "Effects of Cook Inlet crude oil water soluble fraction on survival and molting of king crab and coonstripe shrimp larvae" was presented at the 27th annual Alaska Science Conference and is being rewritten and modified for presentation and publication at the NOAA Symposium November 1976 (abstract enclosed).

All samples have been collected from the tanner crab egg study (see last quarter's report) and are being processed.

4. Analyses of samples from the uptake studies is proceeding with results expected by November 1976.

5. The samples from the temperature uptake study will be processed in October 1976 when the sample oxidizer arrives at this facility. We expect a completed manuscript by February 1977.

6. The manuscript "Effects of Cook Inlet crude oil, benzene, and napthalene on heart rates of the Alaskan King Crab" was presented at the 27th annual Alaska Science (July 1976) Conference and is being rewritten for journal publication (abstract enclosed).

Results of the pink salmon opercular rate and oxygen consumption studies are being prepared for a manuscript due to be completed by January 1977.

7. Data collection from the scallop field mortality study is continuing. This study will be concluded in October 1976. Results from a scallop growth study (see last quarter) were incolclusive due to little growth in control and exposed scallops.

8. Autotomy response was noted with Hemigrapsus nudus in acute bioassays.

9. The manuscript "Effects of crude oil exposure on King crab (Paralithodes camtschatica) gill morphology" was presented at the 27th annual Alaska Science Conference and is being rewritten for presentation and publication at the NOAA Symposium, November 1976 (abstract enclosed).

Processing of pink salmon tissues is continuing with results due in October 1976.

Field studies

Observations of the exposed limpets (see last quarter's report) at Douglas Island continue at low tide periods until October 1976.

IV. Interpretation of results will occur in manuscripts prepared for publication. Some abstracts of manuscripts in preparation are enclosed. Manuscripts reviewed and accepted for publication will be submitted when available.

V. Problems Encountered

1. This quarter's bioassay, temperature bioassay, and temperature metabolic effects work indicates the continuing need for a constant dosing apparatus. The variable of declining oil concentration in the water caused by volatility and biodegradation of aromatic oil components must be eliminated.

We have started R & D on a generator for continuous preparation of crude oil water-soluble fractions. The apparatus uses a stream of water descending through columns of crude oil. Preliminary analyses of the water soluble fraction from this device is encouraging. We plan to switch from static to continuous dosing for FY-1977.

2. Delivery of the sample oxidizer in October 1976 will allow processing of samples from the uptake studies. The oxidizer will eliminate most tissue preparation problems.

3. We have reached the conclusion that scallops (*Chlamys* spp) are not suitable for growth studies. Over a four month period little or no measurable growth occurred. Additional species are being tested for growth studies.

VI. Estimate of funds expended (in thousands) for this quarter.

Salary costs	$30.2
Travel	2.1
Contracts	34.2
Equipment and Supplies	26.1
Other Direct Costs	1.2
Support Costs	11.1
TOTAL	$104.9

OCSEAP QUARTERLY REPORT - RU 73

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SUBLETHAL EFFECTS AS REFLECTED BY MORPHOLOGICAL, CHEMICAL, PHYSIOLOGICAL, AND BEHAVIORAL INDICES

Donald C. Malins and Harold O. Hodgins

Environmental Conservation Division
National Marine Fisheries Service, NOAA
Northwest Fisheries Center
2725 Montlake Boulevard East
Seattle, Washington 98112

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I. Task Objectives

The objective of these studies is to identify and evaluate in selected marine organisms the effects of chronic exposure to petroleum hydrocarbons and trace metals.

Under the general task objective, physiological, morphological, chemical, and behavioral parameters are being investigated. The specific objectives for results of studies reported on in this quarter are as follows:

(1) Physiological: Effect of ingestion of whole crude oil on reproductive success in salmonids.

(2) Morphological: (a) Effect of ingestion of whole crude oil on structure and ultrastructure of internal tissues of salmonids.
(b) Changes in skin and gill epithelium of flatfish and salmon following exposure to the water-soluble fraction (WSF) of crude oil.

(3) Chemical: Evaluate uptake, accumulation, and discharge of trace metals from mucus, epidermis, and scales of salmonids.

(4) Behavioral: Effect of water-soluble fraction of crude oil on feeding behavior of shrimp.

II. Field or Laboratory Activities

C. Methods - laboratory analysis

1. Physiological:

Prudhoe Bay crude oil was incorporated in the diet of 3-year-old rainbow trout (*Salmo gairdneri*). Upon initiation of the study, in July 1975, the fish were 41-53 cm fork length, 1.0-1.8 kg in weight (wt), and beginning to develop eggs and sperm for the first time.

Oil-containing food was routinely prepared by first mixing 2.6 ml of crude oil with 148 ml of trichlorotrifluorethane solvent. The oil-solvent solution was then mixed with 2 kg of Oregon moist pellet and allowed to air dry for 90 minutes. Control food was prepared identically except crude oil was omitted.

Fish were fed the above diets on weekdays at the rate of 1.5-2.5% of body wt starting in July 1975 through August 1976 for an average dose of 17 mg crude oil/kg body wt/day.

Spawned eggs from control fish were divided into equal aliquots and one aliquot was fertilized with sperm from a test male and the other aliquot from a control male. Eggs of test females were similarly treated for a total of 31 test and 10 control crosses.

From fertilization through the button-up stage, eggs and alevins were monitored for mortality, and samples were taken for histological analysis.

2. Morphological:

a. Tissue samples were collected from both adult trout fed crude oil and their progeny. Trout fry and adult trout tissues consisting of liver, eye lens, kidney, intestine, skin, and gills were embedded in plastic for transmission electron microscopy (TEM) or critically point dried for scanning electron microscopy (SEM). Methods of tissue preparation for TEM and SEM were presented in the first quarterly report of 1975. Of the samples collected, the trout fry, and liver and eye lens tissues from the adults, have been examined and observations are discussed in this report.

b. Samples of skin and gill tissue for SEM studies were taken from coho salmon (*Oncorhynchus kisutch*) and starry flounder (*Platichthys stellatus*) following 5-day exposure to 100 ppb total WSF of Prudhoe Bay crude oil. Details of the flow-through exposure system are given in the behavioral methods section of this report.

3. Chemical:

Coho salmon of average wt of 200 g were exposed, in salt water, to 3 and 150 ppb of water-borne lead (Pb^{210}) and cadmium (Cd^{109}) at 4^{o} and $10^{o}C$. Samples of mucus, skin, and scales were collected at three intervals during the 30-day exposure period. Following exposure, fish were placed in a metal-free environment for depuration up to 6 weeks.

At each data point, three test fish were sampled. Epidermal mucus was collected by gentle scraping with a rubber spatula. After mucus removal, a 10 x 3 cm section of skin was excised from the side (including the lateral line) and washed with isotonic saline. Scales were removed from the skin prior to assessment of metal concentration in the skin and the scales were analyzed separately. Concentrations of metals in the mucus, skin, and scales of the test fish were determined by liquid scintillation spectrophotometry. Periodically, levels of metals in the tissues were also assessed by atomic absorption spectrometry. Data from both methods were in close agreement.

4. Behavioral:

Observations on the feeding response of the spot shrimp (*Pandalus platyceros*) were made during 6-day exposures to the WSF of Prudhoe Bay crude oil. Method of exposure, stimulation, and criteria for evaluating behavior are as follows:

Seawater was pumped from an average depth of 10 m at a 50 m distance offshore from the NMFS biological field station at Mukilteo, Washington. The water was serially filtered through 5 μm and 1 μm polypropylene filter bags into a 1,000 l fiberglass head box which supplied the test chambers and the continuous flow-through oil solubilizer system described in the RU 74 annual report, April 1976. The oil solubilizer produced 1.8 l/min of WSF of Prudhoe Bay crude oil at a concentration of 320 ± 190 (SD) ppb. Samples of the WSF were collected every two days and the WSF concentration was determined by gas chromatography (for details of analysis refer to RU 74 quarterly report, July 1 to September 30, 1976). To obtain different levels of exposure, the WSF from the oil solubilizer was diluted in the mixing box of each shrimp chamber while maintaining a total flow rate of 300 ml/min (Fig. 1).

The shrimp chambers were enclosed in black plastic and observations on feeding behavior made through one-way mirrors. Each data point consisted of three 3-min. observations: background activity; response to seawater control; and response to a 1:10 dilution of artificially mixed squid extract (Mackie, 1973). The seawater control and squid extract stimulus were introduced at the upstream end of the chamber at a flow rate of 10 ml/min. Data on the following activities were collected during each 3-min. observation period:

(1) Antennule clicks/min. Number of times that either the left or right antennule was moved rapidly anterior to posterior and back to its initial anterior position.

(2) Antennule cleaning/min. Number of times both antennules were lowered and drawn through the second maxillipeds.

(3) Lines crossed/min. Each experimental tank was marked in 4 cm intervals and the number of lines crossed during testing was recorded.

(4) Searching movements/min. Number of bouts of rapid movements of walking legs and maxillipeds in response to stimulus.

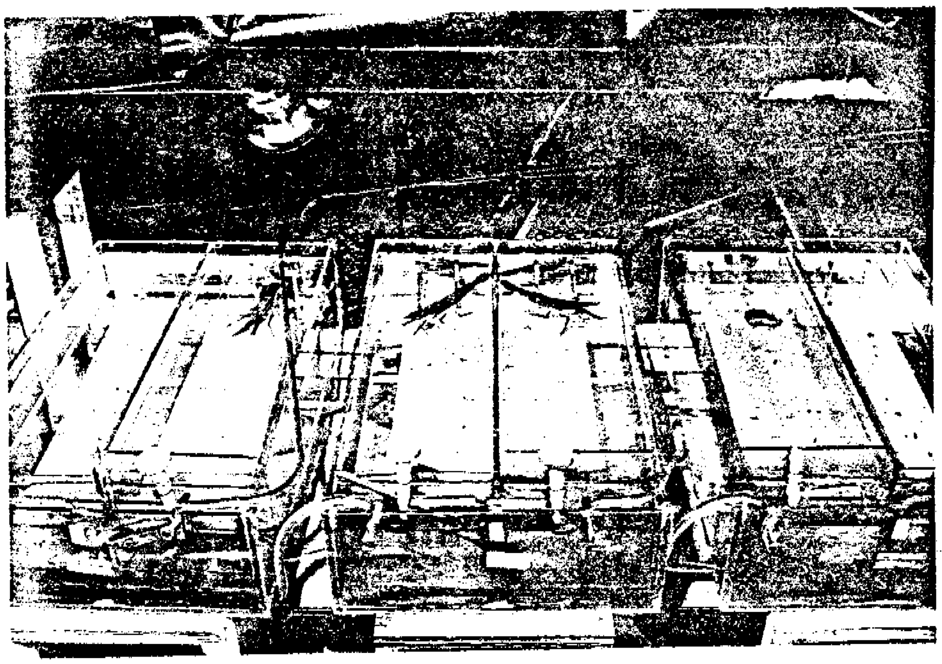


Figure 1.--Glass chambers for testing effect of the WSF on feeding response of spot shrimp. Valves and mixing box in foreground of each chamber are for adjusting flow rate and the WSF concentration.

(5) Feeding response. Contacting of stimulus outlet and picking at it with chelipeds or moving it toward the mouth.

The shrimp were not fed for 3 days prior to exposure or during the 6-day exposure period. The number of shrimp tested and number of observations made at each of 11 WSF concentrations are given in Table I.

III. Results

1. Physiological

A number of parameters were assessed in the study on reproductive success of trout following chronic ingestion of crude oil:

a. Maturation: There was no pronounced acceleration or retardation of maturity for oil-fed fish (Fig. 2).

b. Reproductive products: Oil-exposed females had greater numbers of extruded eggs (Mean; test 2,535:2,283 control), although the average egg size was smaller (number of eggs/10 ml; test 65.2:62.4 control).

c. Embryo survival: Survival through hatching averaged 86% ± 22 (SD) for eggs taken from oil-exposed females, and 90% ± 7 (SD) for eggs taken from non-oil-exposed females. There was no significant difference in egg survival among crosses in which sperm was used from oil-fed males or non-oil-fed males.

d. Alevin survival: Survival of alevins was higher for control (93% ± 10 SD) than test fish (81% ± 18 SD), although not significantly.

e. Adult survival: There was a substantial post-spawning mortality in the oil-fed group in which 30% died 1-3 months after spawning; all of these animals were heavily infected with fungus. None of the controls were similarly affected.

TABLE I

Number of shrimp tested and number of observations made in relation to concentrations of WSF.*

WSF (ppm)	Number of Shrimp	Number of observations	
		Squid extract	Seawater control
Control	6	36	36
0.005	2	12	12
0.007	1	6	--
0.009	2	12	12
0.011	2	12	--
0.014	3	18	--
0.022	4	24	--
0.023	2	12	12
0.028	4	24	--
0.044	2	12	--
0.094	2	6	6
0.188	3	8	8

* = water-soluble fraction.

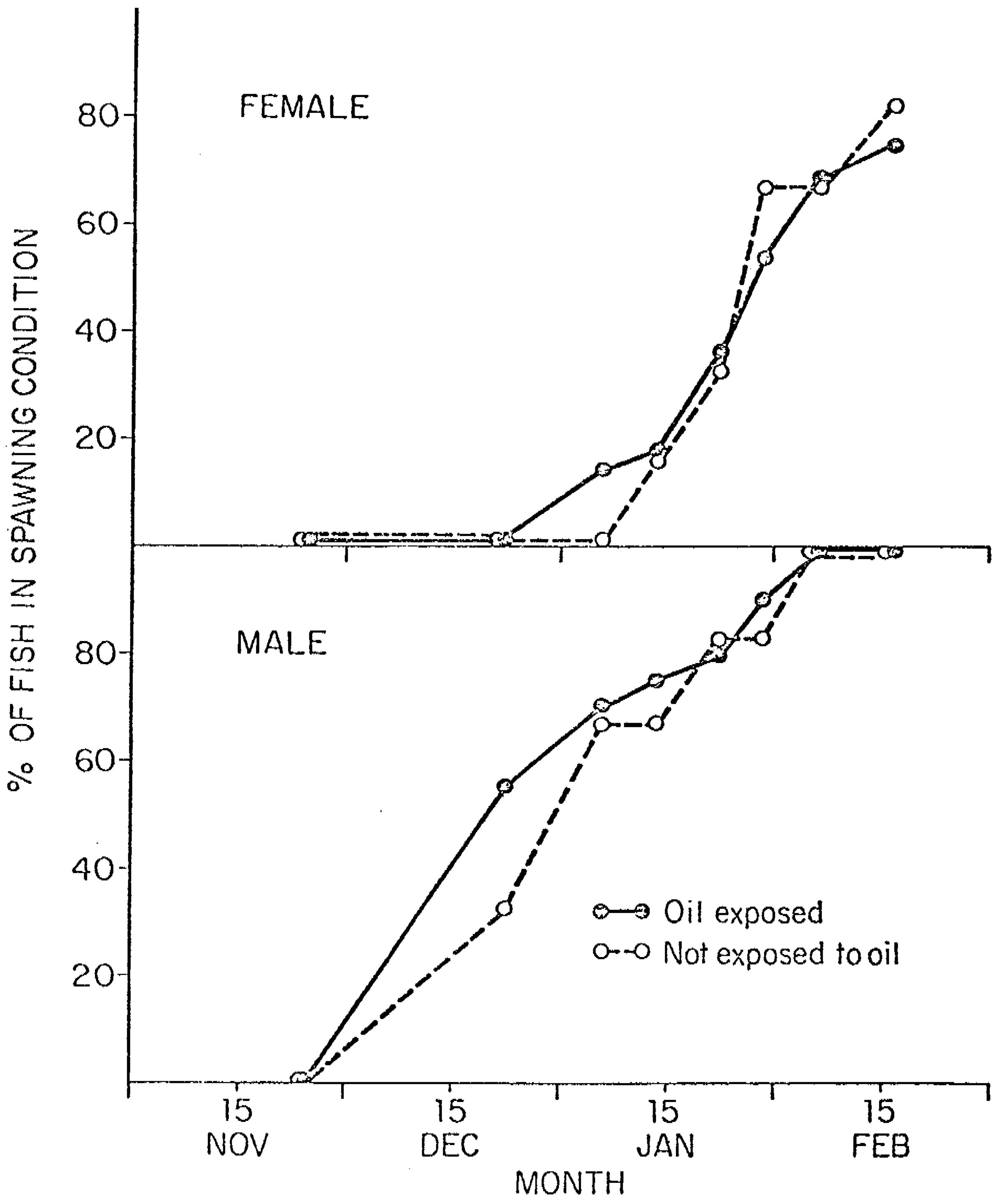


Figure 2.--Time of maturation for oil-exposed and non-oil-exposed trout.

The quantities of oil ingested by test fish represented an extreme case of chronic exposure; however, the fish readily consumed the oil-treated food and continued to grow and develop. Although there were no mortalities of oil-fed fish prior to spawning, the post-spawning mortality of oil-exposed males with fungus infections suggests some possible interaction between oil exposure and recovery from spawning. It is possible, however, that the differential mortality between test and control groups was related to an increased density of fish in the test tank in the later stages of the experiment (45 l water/kg for test fish to 175 l/kg for control).

Of the other parameters measured there did not appear to be any effect of oil ingestion on reproductive success. Survival through hatching was 86% and 90% for test and control eggs, respectively, and test and control males were virtually identical in fertility. Survival from hatching to swim-up fry stage of development was 81% for test and 93% for control fish.

2. Morphological:

a. Two tissues, liver and eye lens, were examined from adult trout fed crude oil for one year at a dose of 17 mg/kg body wt/day. Both the fork length and whole eye diameter were similar for treated and control groups; however, the eye lens from oil-exposed trout were 2.24 times larger in volume than those from control (Table II).

Structurally, the lens is composed of ribbon-like collagen fibers with interdigitating projections on the sides which hold the fibers together. The overall morphology of lens fibers from treated and control fish do not show any differences. From preliminary examination with SEM, only one change is evident; the fiber surfaces from treated fish are undulated, whereas in controls the fiber surfaces are smooth.

TABLE II

Volume of eye lenses from trout fed crude oil for one year.

Group	$\bar{x}$ (mm^3)	Sx	$S\bar{x}$	N
Control	100.9	19.2	9.6	4
Oil-treated	226.10	81.2	33.1	6

The liver from the adult trout fed crude oil also show changes in respect to collagen. TEM examinations show an infiltration of collagen in the lining of the smaller blood vessels of the liver.

Offspring of the oil-fed trout were also examined. There was no indication of abnormality in any tissues from crosses of oil-exposed females with oil-exposed males.

b. Examination of skin and gill epithelium of coho salmon and starry flounder with SEM indicates that the gills may be a more reliable index of any changes which may be induced by exposure to the WSF of crude oil (Figs. 3-8). Samples of skin from both control fish (Fig. 3) and fish exposed to 100 ppb for 5 days show large areas of sloughed tissue. In contrast, the gill epithelium of controls were intact and the cell surface appeared healthy (Figs. 4, 5).

Both control and WSF-exposed coho salmon had a gill parasite, Gyrodactylus. In controls, the epithelium was unchanged by the presence of the parasite (Fig. 5) and in WSF-exposed coho salmon, Gyrodactylus was found near both normal and damaged filament areas (Figs. 6, 7). Thus the presence of this parasite was not associated with surface epithelial disruption.

Necrotic changes after WSF exposure were apparent in the coho salmon gill as sloughed epithelial cells and discharged mucous glands. The gill epithelium of starry flounder also showed lesions following WSF exposure (Fig. 8).

3. Chemical:

Data on uptake and discharge of lead and cadmium in the epidermal mucus, skin, and scales of coho salmon are given in Figures 9-13 and Table III. The results presented in Table III and the text are expressed as

Figure 3.--Skin surface of an untreated coho salmon. The ridged cells are the normal pattern of the cell surface and the area in the left of the picture is a region where the epithelium has sloghed. (Mag. 2000X)

Figure 4.--Gill filaments of a starry flounder control. (Mag. 100X)

Figure 5.--Gill filaments of coho salmon control. No damage to the gill epithelium was noted on the control, regardless of whether the parasite, Gyrodactylus, was present or not. (Mag. 180X)

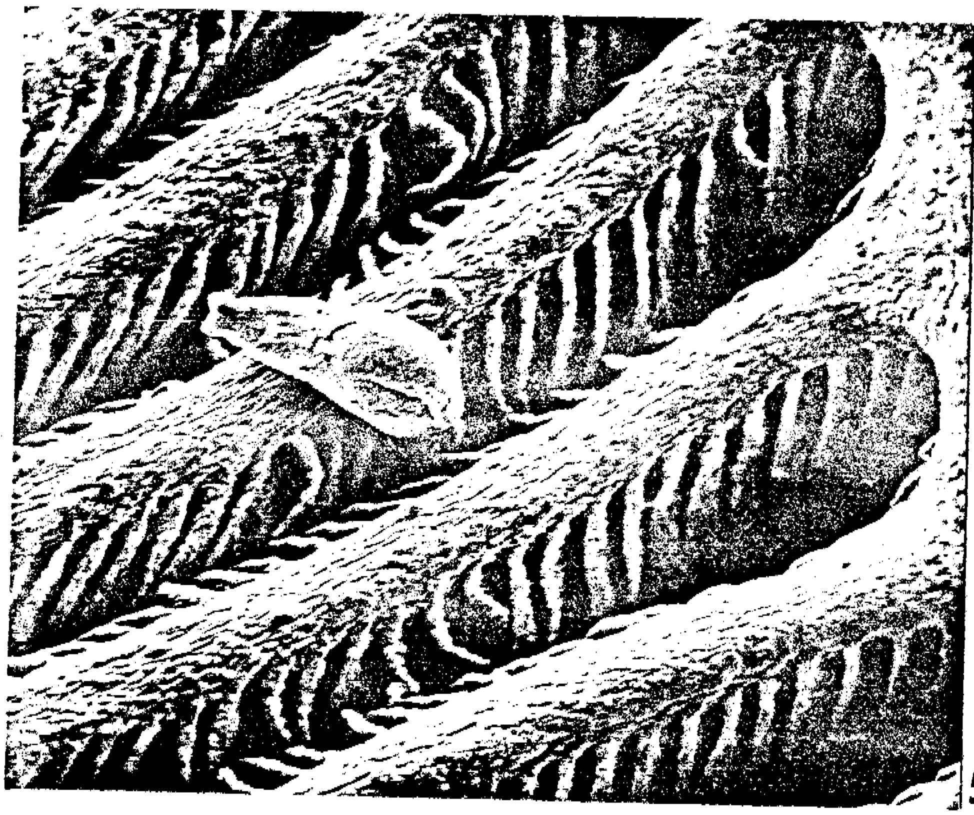
Figure 6.--*Gyrodactylus* on the gill filaments of a coho salmon exposed for 5 days to the WSF of Prudhoe Bay crude oil. The gill epithelium in this area is intact and there is exudate (arrow) from mucous glands. (Mag. 200X)

Figure 7.--Gills from a coho salmon exposed for 5 days to the WSF of Prudhoe Bay crude oil. The gill filaments and surface epithelium are eroded and numerous mucous glands are exposed and discharging. (Mag. 200X)

Figure 8.--Gill filament surface of a starry flounder after WSF exposure for 5 days. Note the lesions where the surface epithelial cells have sloughed. (Mag. 1000X)

3

4



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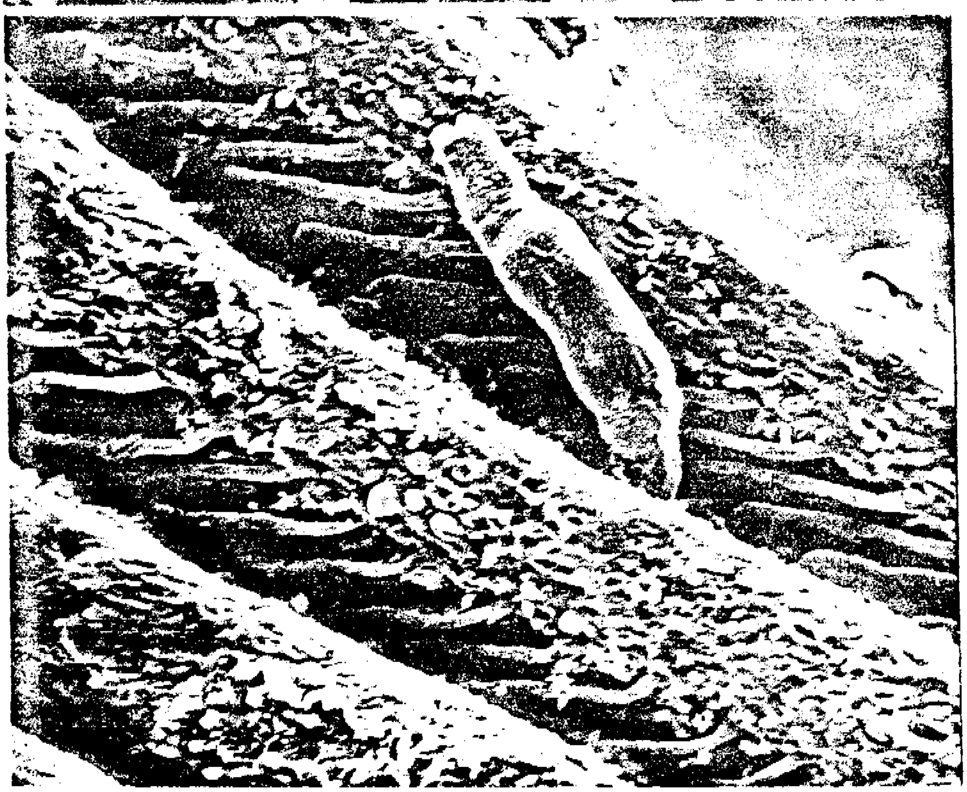

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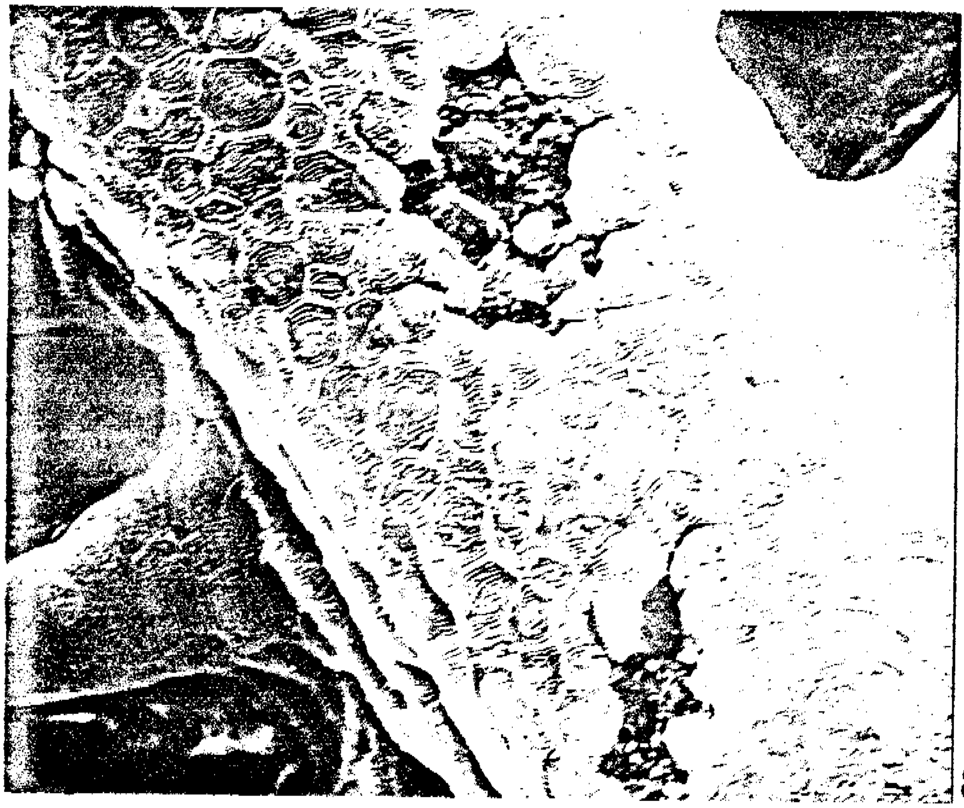


8

Figure 9

COHO SALMON EXPOSED TO 3ppb of $Pb(NO_3)_2$ at 4°C

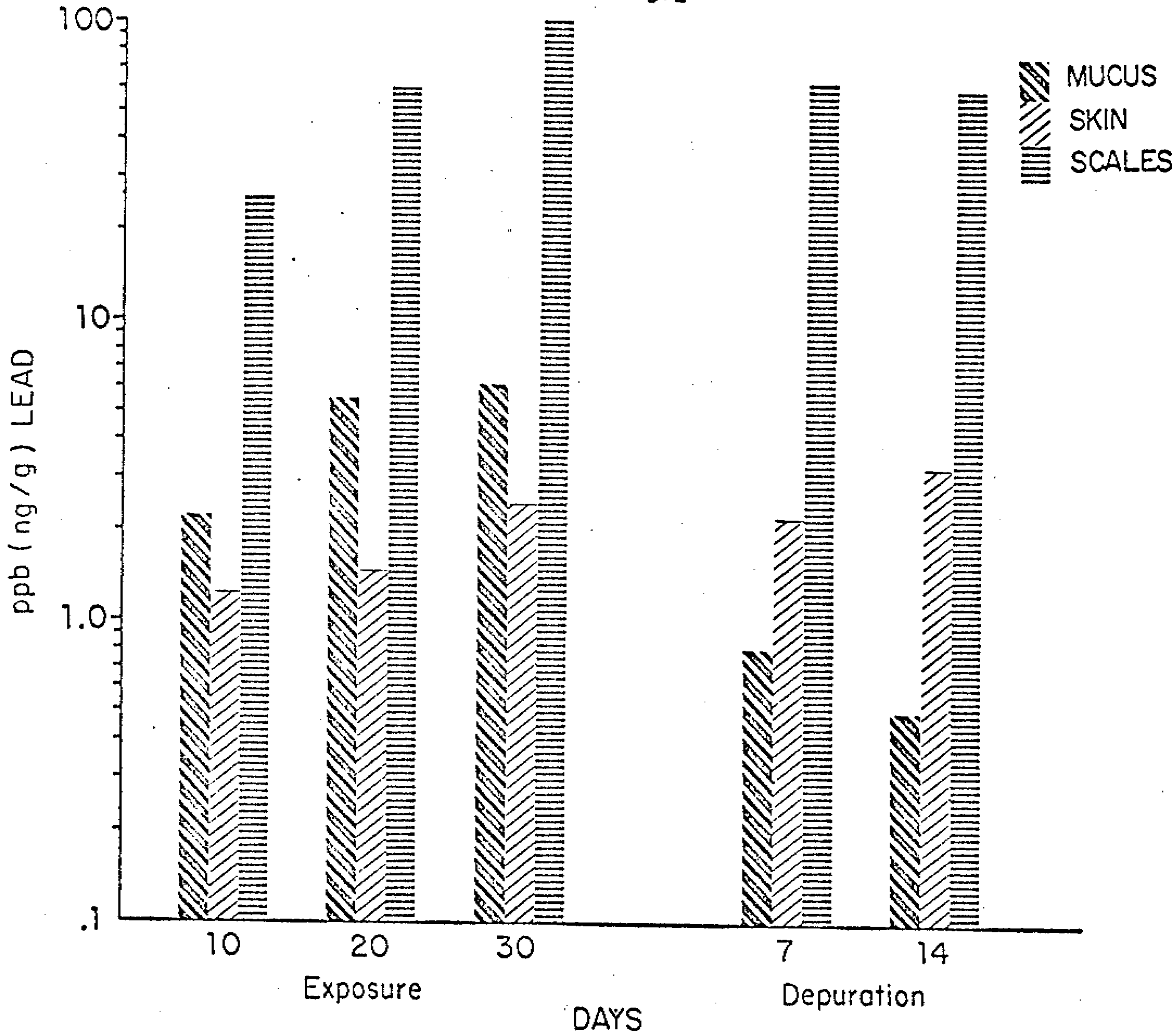


Figure 10

COHO SALMON EXPOSED TO 150ppb of $Pb(NO_3)_2$ at 4° C

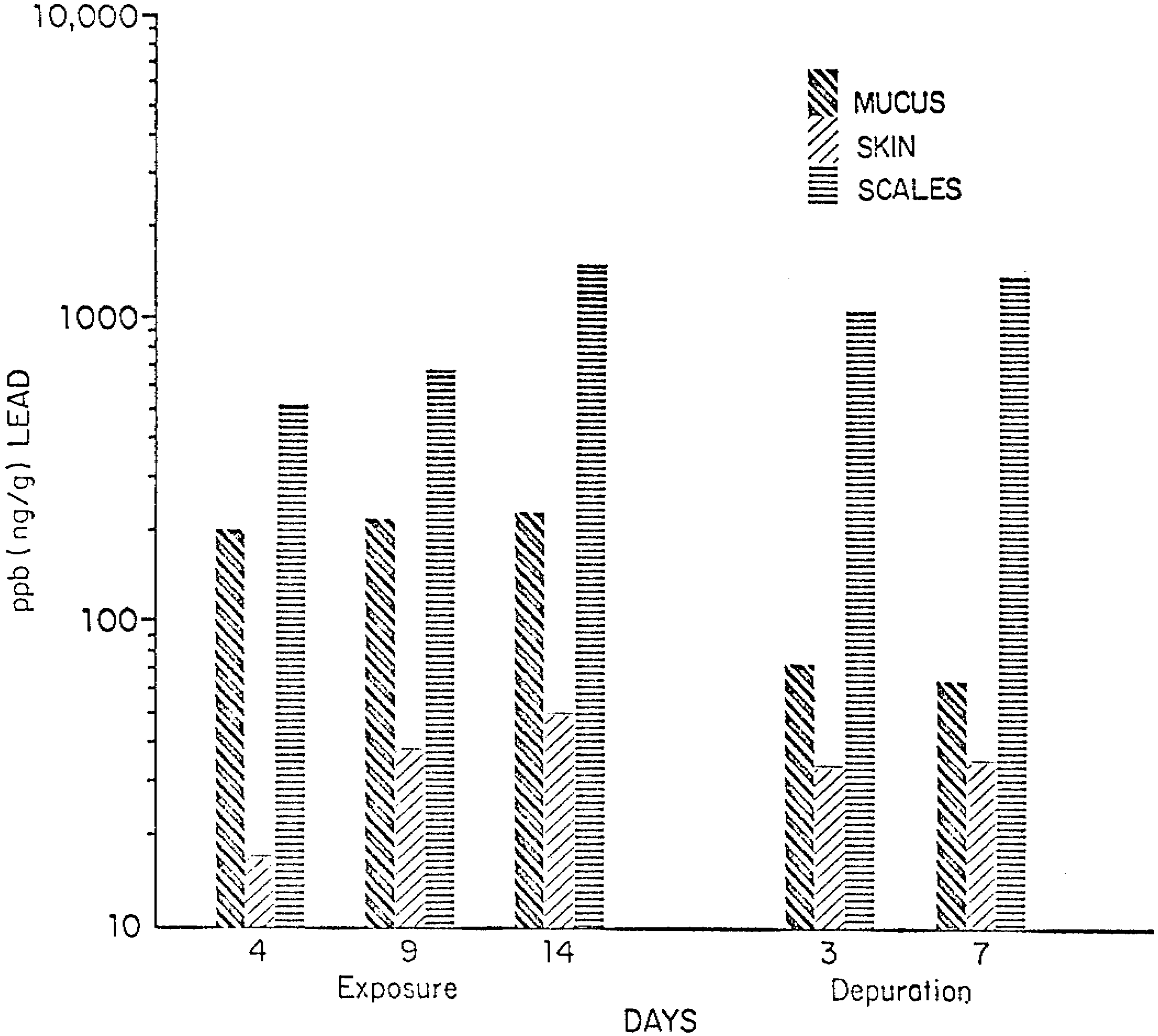


Figure 11

COHO SALMON EXPOSED TO 150 ppb $Pb(NO_3)_2$ at 10°C

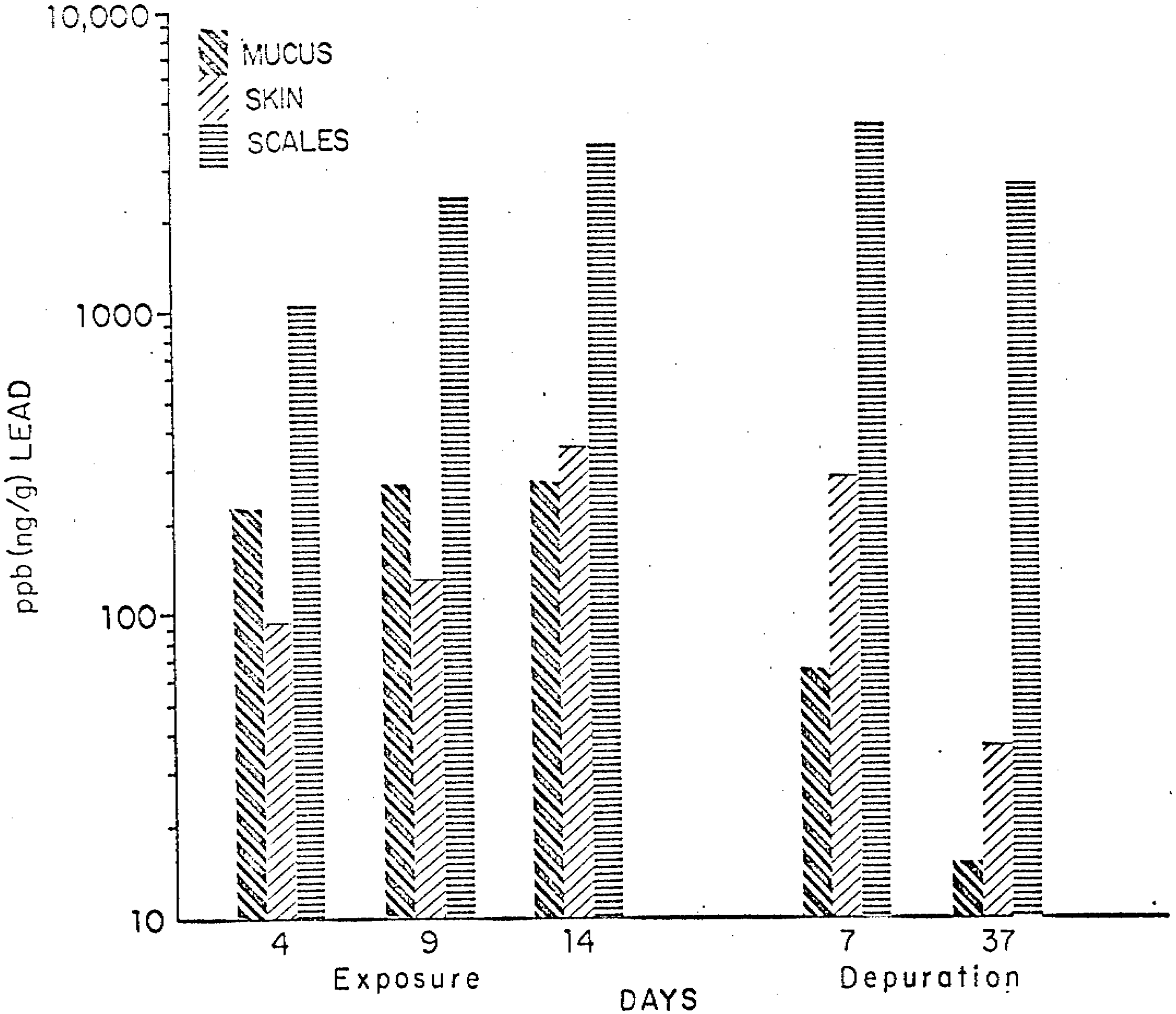


Figure 12

COHO SALMON EXPOSED TO 3ppb $Cd(NO_3)_2$ at 10°C

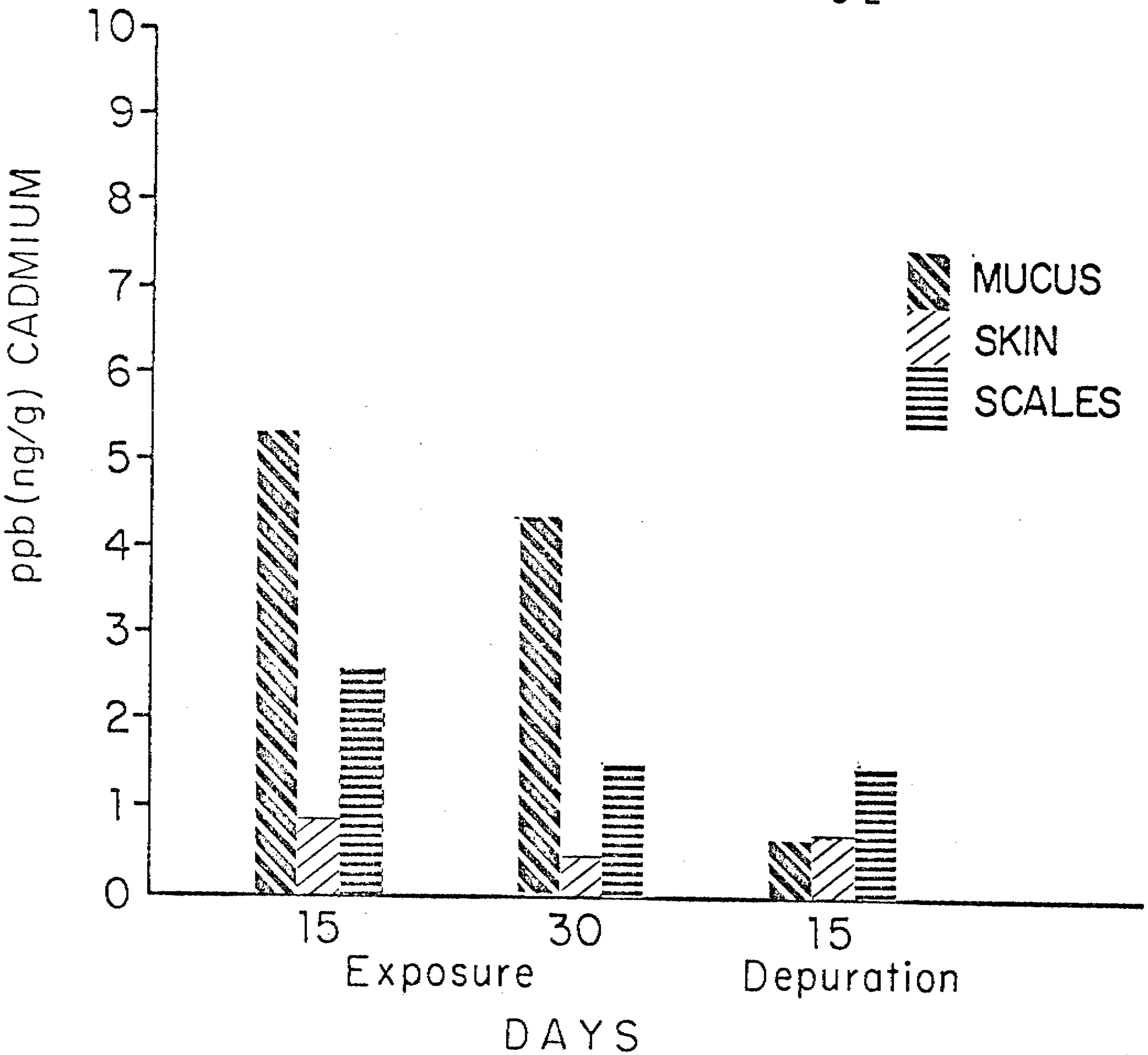


Figure 13

COHO SALMON EXPOSED TO 150ppb of $Cd(NO_3)_2$ at 10°C

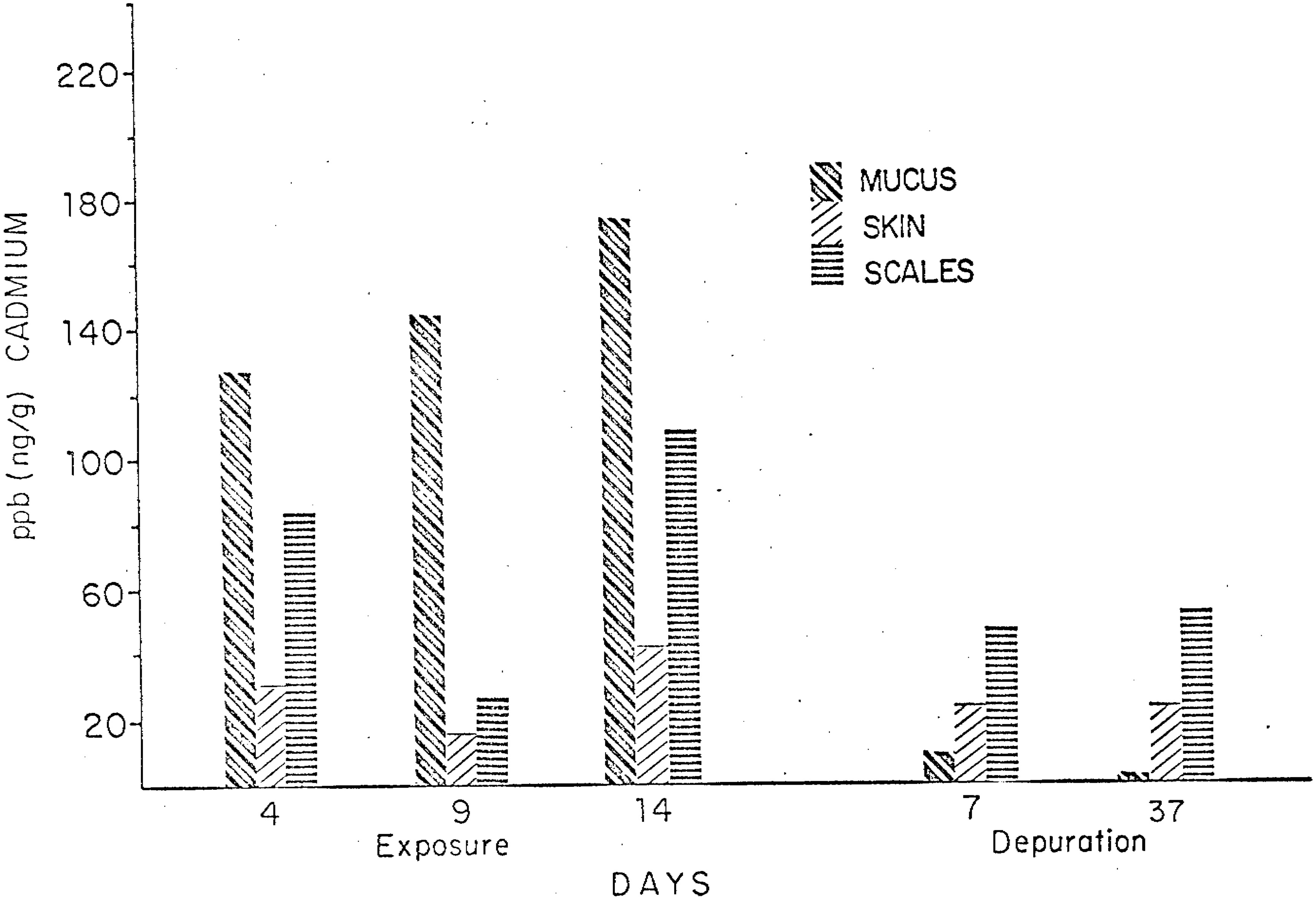


TABLE III

Bioconcentration factors[a] for lead and cadmium in coho salmon[b] (*Oncorhynchus kisutch*) exposed to water-borne $Pb(NO_3)_2$ and $Cd(NO_3)_2$

Metal	Level of Exposure ppb (ng/ml)	Epidermal Mucus		Skin[c]		Scales[d]	
		4°C	10°C	4°C	10°C	4°C	10°C
Pb	3	--[e]	2.1	--	0.24	--	10.1
	150	1.52	1.80	0.28	2.33	9.6	24.93
Cd	3	--	1.76	--	0.26	--	0.56
	150	0.97	1.15	0.095	0.26	0.32	0.72

a Bioconcentration factor = Concentration of metal in tissue (wet wt)/ concentration of metal in water.
b Fish were exposed to metals for a period of 2 weeks.
c The values represent metal content of the skin from which the scales were removed.
d The values represent metal content of the scales (including) lateral line scales) that were extracted from the skin.
e Experiments not conducted.

bioconcentration factor (BCF) which is calculated as the ratio of: concentration of metal in tissue (wet wt)/concentration of metal in water. Some of these results were discussed in detail in the quarterly report, April 1 - June 30, 1976, and these will be only briefly repeated when necessary to place the more recent information in perspective.

Mucus: Coho salmon mucus accumulated both lead and cadmium very rapidly from the surrounding water, often reaching near maximum levels within hours. Thereafter, the concentration of the metals increased only slightly and remained relatively constant during the rest of the exposure period.

Exposure concentration and temperature have a small but significant effect on the concentration of the metals in mucus (Table III). For example, at $10^{o}C$ the BCF for both metals was about 15% greater than the values obtained for fish exposed at $4^{o}C$. At lower exposure levels (3 ppb), the BCF for both metals was 15-30% higher than the values obtained for 150 ppb.

When the test fish were returned to metal-free water, more than 60% of the accumulated metal was discharged from the mucus within the first few hours. A separate, in vitro study, revealed that when mucus containing a known amount of metal was dialyzed against sea water, 70% of the metal was removed within the first 24 hours; the remaining 30% of the metal was retained in the mucus for several days. The data in Figure 11 show that after 7 days of depuration the mucus of the test fish retained about 25-30% of the accumulated lead; however, at the end of a 6-week period only 6% of the accumulated metal was still present. Cadmium was discharged from the mucus faster than lead (Figs. 12 and 13).

The rapid uptake and discharge of metals in coho salmon mucus suggests that metals may be accumulated via passive diffusion. Moreover, our results show that approximately 70% of the accumulated metal exists in a labile equilibrium between the mucus and surrounding water and is discharged rapidly when the concentration of metal in water is decreased. Nevertheless, a certain small fraction ($\cong$ 30%) of the accumulated metal appears to be bound to macromolecules, such as glycoproteins, in the mucus and is released slowly.

Skin: Compared to the mucus, the rate of uptake of metals in the skin was very slow. However, contrary to the mucus, skin continued to accumulate increasing concentrations reaching bioconcentration factors of about 2 for lead and 0.3 for cadmium at 10°C (Table III). Temperature of the experiment had a strong effect on the accumulation of metals in skin. For example, three to seven times as much metal was accumulated in the epidermis of fish challenged at 10°C than those challenged at 4°C. This effect was more pronounced in the lead-exposed fish than in the cadmium-exposed fish.

Scales: Of the sites examined, scales accumulated the highest levels of lead (Table III). The scales of some lead-exposed fish contained up to 28 ppm of lead (BCF $\cong$ 188) when exposed to a sublethal level (150 ppb) of lead nitrate for up to 4 weeks. Additional experiments demonstrated that lead was rapidly accumulated in the scales with only a few hours of exposure of fish to water-borne lead nitrate. Furthermore, when scales removed from control fish were placed in sea water containing 150 ppb of lead nitrate, a significant amount of lead (1 ppm) was taken up in 3 hours. These results indicate that scales of salmonids accumulate metals directly from the water. (It should be noted here that the term scale applies to both the scale proper and some epidermal and dermal cells attached to the scale upon its removal).

Preliminary results on the distribution of metals in scales by X-ray dispersion technique revealed that a high concentration of lead was present in the basal region of the scale which is embedded in the dermis. These results indicate that deposition of lead in the scales also takes place via the blood stream. Oosten (1957) reported that when lead salts were injected in the muscle tissue of fish, lead was deposited in the scales within one day.

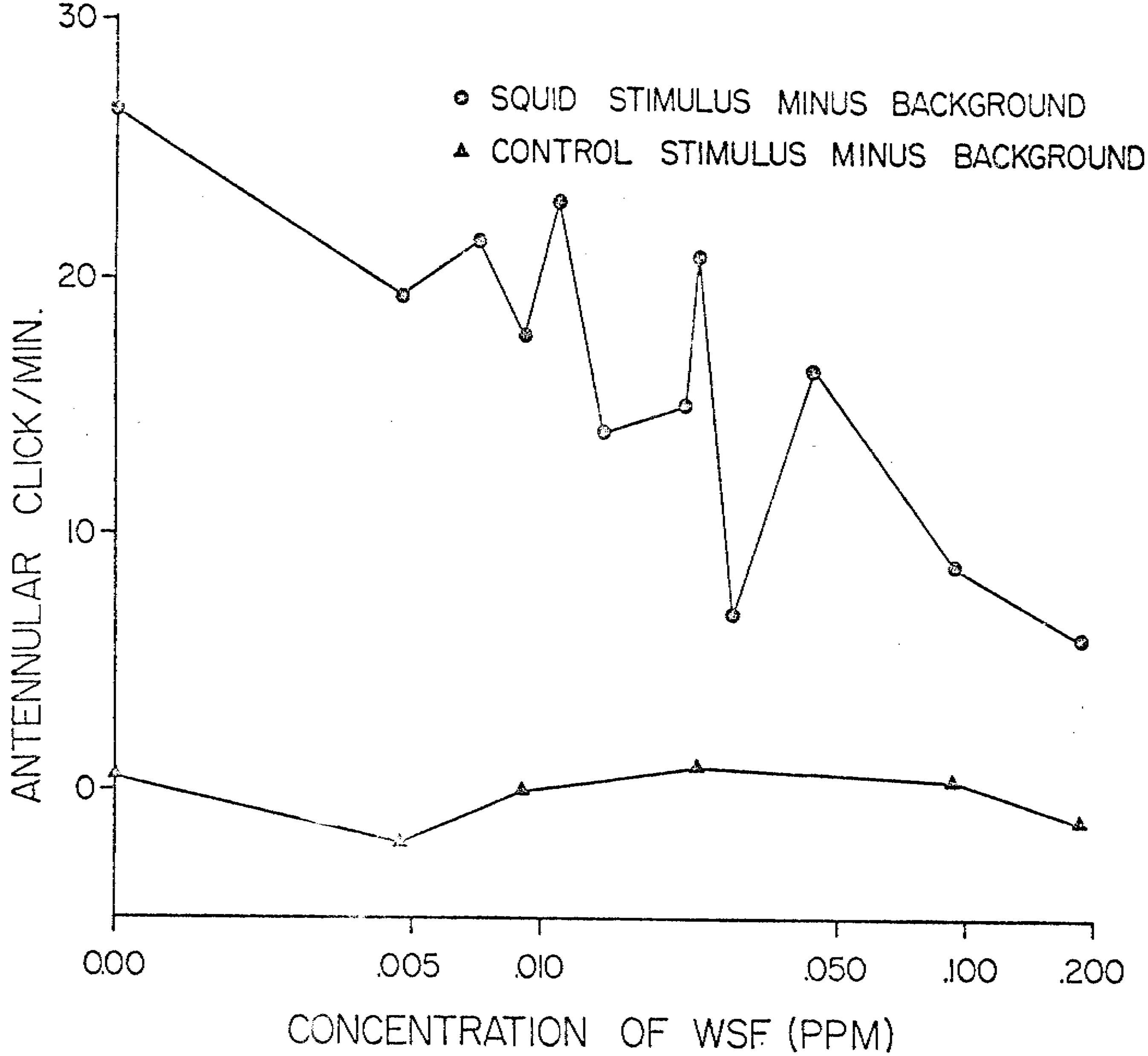
Both lead and cadmium persisted in the scales long after the metal-exposed fish were returned to clean water; more than 50% of the accumulated lead and cadmium was retained in the scales after 37 days of depuration (Figs. 11 and 13). The uptake of metals in the scales is directly related to water temperature; over a twofold increase in the metal concentration was observed when the water temperature was increased from 4°C to 10°C (Table III).

4. Behavioral:

The feeding response of shrimp to a food stimulus can be divided into three discrete stages: (a) initial detection of stimulus, followed by (b) movement up a stimulus gradient with searching activity, which (c) culminates in contact with, and feeding upon, the stimulus source. The result of initial experiments on the feeding response of spot shrimp indicates that exposure to the WSF of Prudhoe Bay crude oil causes a decrease in feeding activity, particularly those activities involving searching and contact with the stimulus source. The results are presented graphically in Figures 14-18.

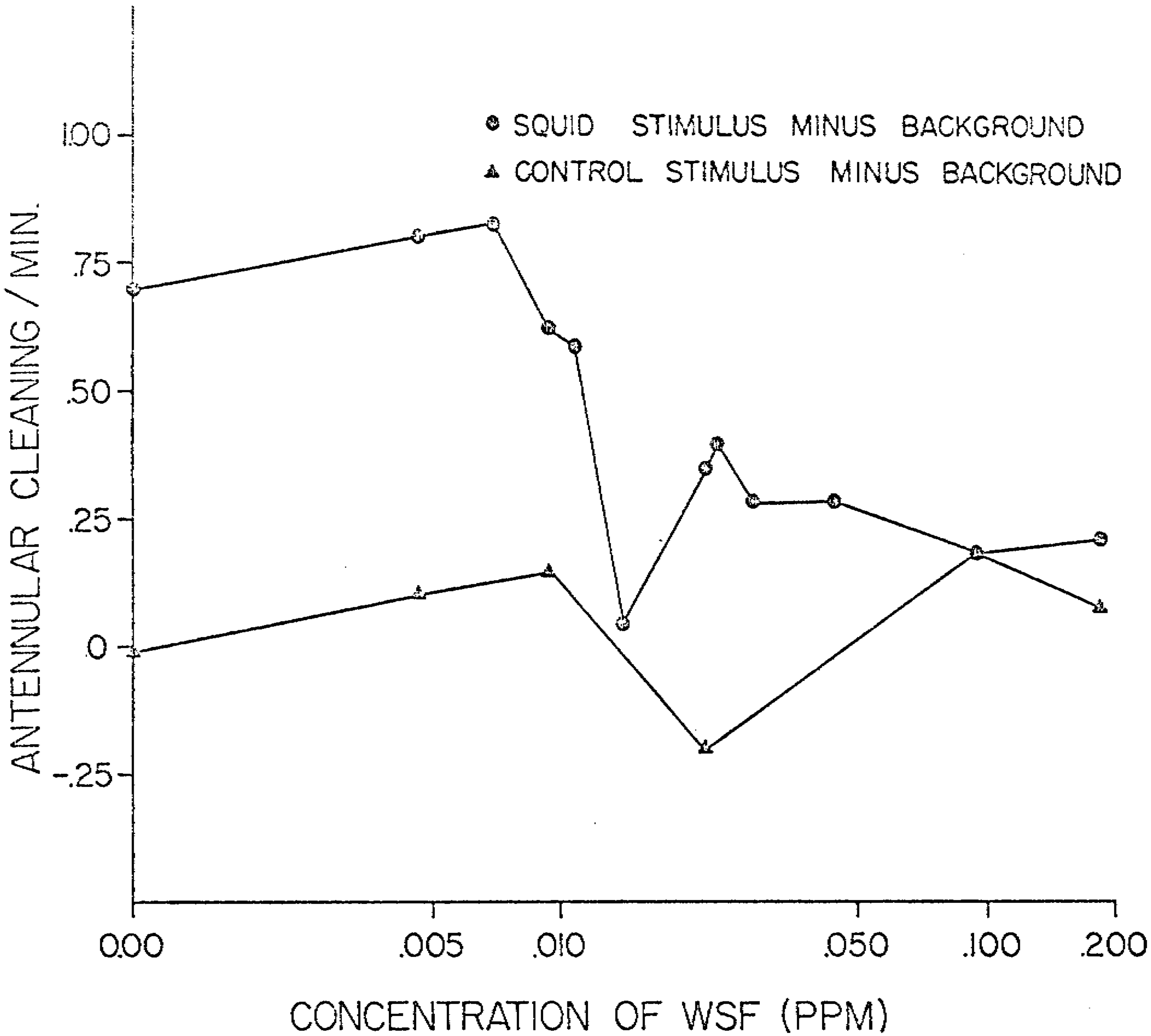
a. Antennule clicks/min: Figure 14 shows the effect of WSF concentrations on the shrimp's sampling of its environment in response to seawater control and squid extract stimuli. Without the WSF present

Figure 14



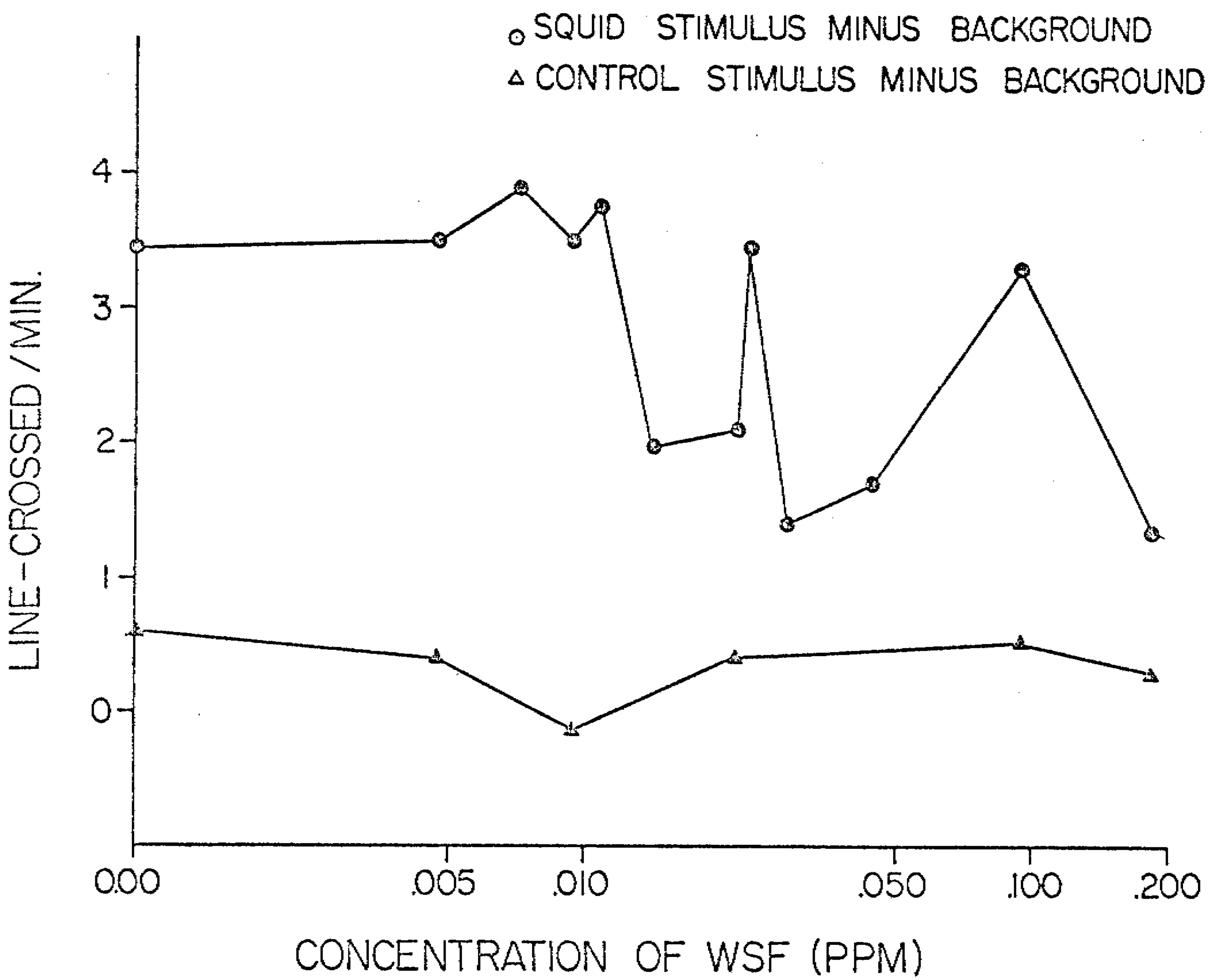
SQUID STIMULUS MINUS BACKGROUND
CONTROL STIMULUS MINUS BACKGROUND
ANTENNULAR CLICK/MIN.
30
20
10
0
0.00
.005
.010
.050
.100
.200
CONCENTRATION OF WSF (PPM)

Figure 15



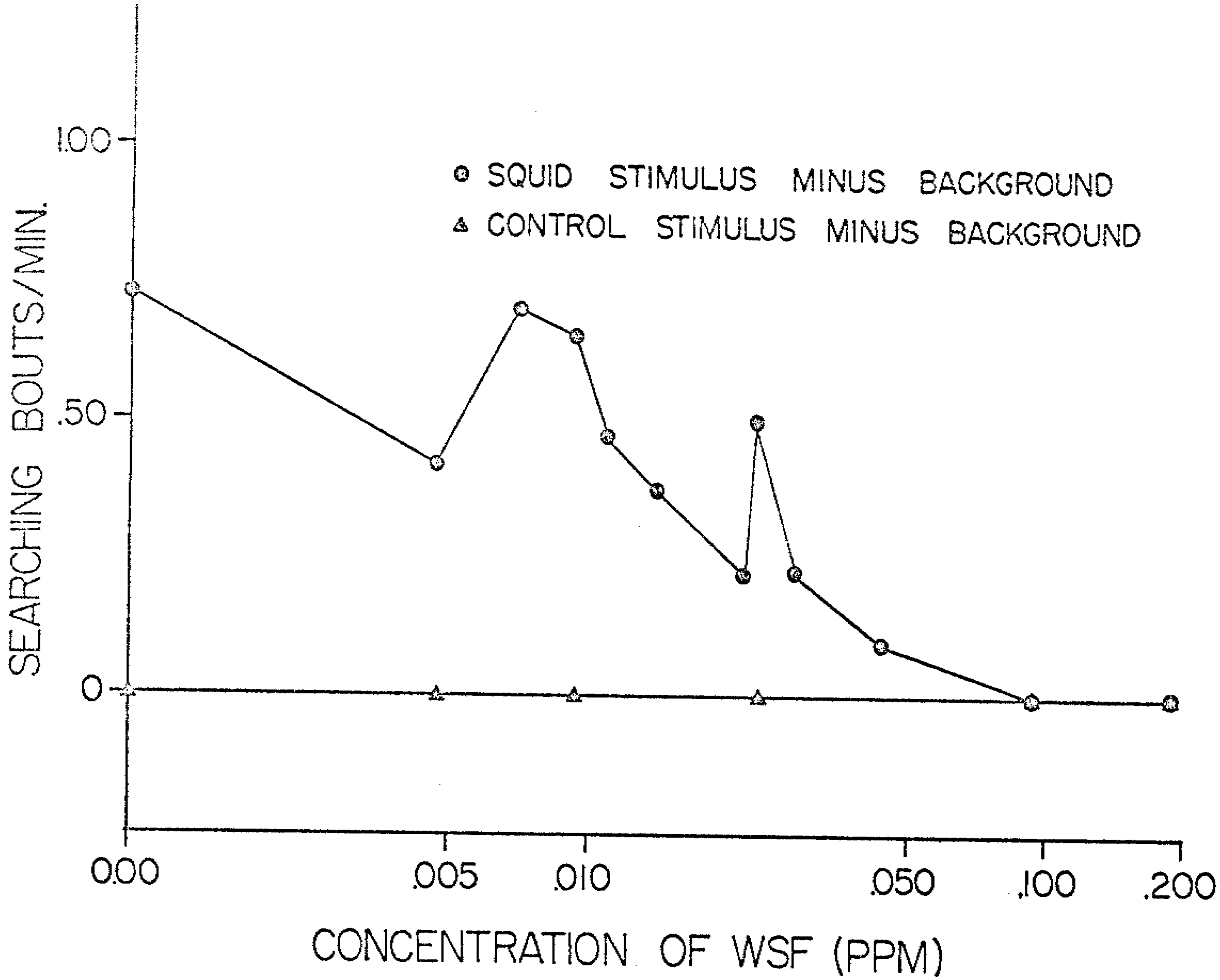
SQUID STIMULUS MINUS BACKGROUND
CONTROL STIMULUS MINUS BACKGROUND
ANTENNULAR CLEANING / MIN.
1.00
.75
.50
.25
0
-.25
0.00
.005
.010
.050
.100
.200
CONCENTRATION OF WSF (PPM)

Figure 16



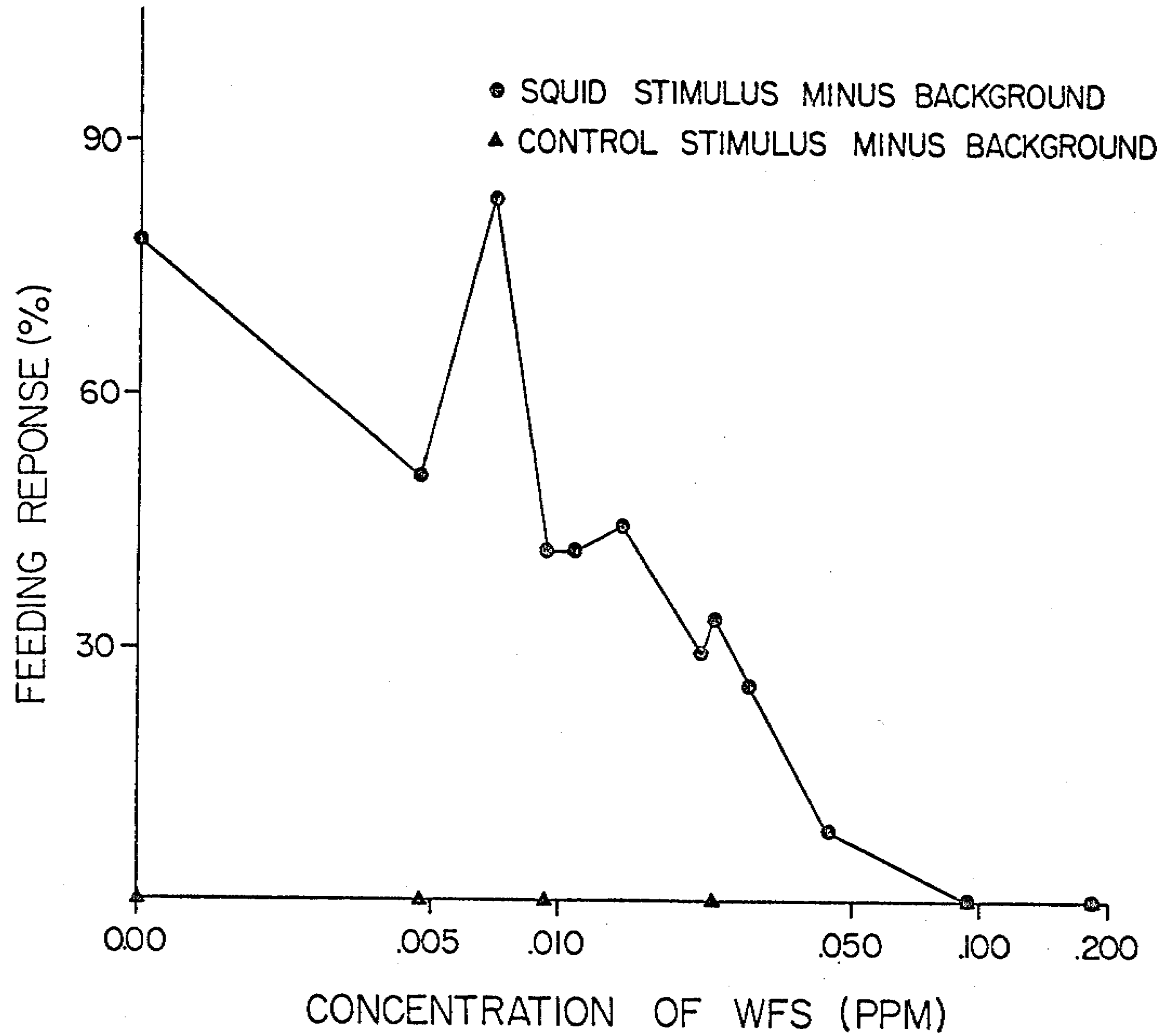
SQUID STIMULUS MINUS BACKGROUND
CONTROL STIMULUS MINUS BACKGROUND
LINE-CROSSED / MIN.
4
3
2
1
0
0.00
.005
.010
.050
.100
.200
CONCENTRATION OF WSF (PPM)

Figure 17



1.00
.50
0
SEARCHING BOUTS/MIN.
SQUID STIMULUS MINUS BACKGROUND
CONTROL STIMULUS MINUS BACKGROUND
0.00
.005
.010
.050
.100
.200
CONCENTRATION OF WSF (PPM)

Figure 18



SQUID STIMULUS MINUS BACKGROUND
CONTROL STIMULUS MINUS BACKGROUND
FEEDING REPONSE (%)
90
60
30
0.00
.005
.010
.050
.100
.200
CONCENTRATION OF WFS (PPM)

squid extract resulted in an increase of antennular clicks/min from less than one to 26.5. Upon exposure of the shrimp to increasing concentrations of WSF, their antennular clicks/min response decreased, while control responses remained relatively stable.

b. Antennule cleaning/min. (Fig. 15). Cleaning of chemoreceptive hairs during the control interval was variable due primarily to inconsistent activity during baseline observations. Following stimulation to squid extract, there is a decided reduction in antennular cleanings with WSF concentrations greater than 10 ppb.

c. Lines crossed/min. Control values of Figure 16 are low at all WSF concentrations. Following introduction of squid extract, there is movement toward the stimulus source. The rate of movement with increasing WSF concentration indicates a decreasing trend; however, the high values at 24 and 94 ppb make the data inconclusive.

d. Searching movements/min. (Fig. 17). Periodic rapid leg movement is characteristic of intensified searching behavior. There are no searching bouts unless squid extract is present, and at 100 ppb WSF concentrations this activity disappears.

e. Feeding response. Figure 18 shows the percentage of shrimp that contacted and began feeding on the stimulus source outlet in the upstream end of the test chamber. Upon addition of squid extract stimulus, 79% of the shrimp fed when the WSF was not present; there was no feeding at 94 or 188 ppb WSF.

The above results represent a composite of observations taken over a 6-day exposure period at each WSF concentration. (Changes in feeding activity with duration of exposure are being analyzed.) Generally there was no observable effect on any of the feeding behaviors measured at WSF concentrations below 10 ppb. At the two highest WSF concentrations (100 and 200 ppb) approximately 40% of the shrimp exhibited a loss of equilibrium following 3 days exposure and died 1-2 days later; observations on these shrimp are not included.

IV. Preliminary Interpretation of Results

1. Physiology:

In the present study, dietary exposure to relatively high levels of Prudhoe Bay crude oil did not significantly disrupt reproductive functions of adult trout or cause a decrease in survival of progeny. There is no evidence, therefore, that chronic exposure to levels of dietary crude oil available environmentally would result in reproductive failure of rainbow or steelhead trout.

It should be noted, however, that many other behavioral and physiological aspects of natural reproduction were not examined. Activities such as homing, mate selection, redd building, or territoriality could be disrupted by crude oil ingestion and contribute to poor reproductive success for fish in the natural environment.

2. Morphology:

a. Potentially deleterious abnormalities of eye lenses and livers were observed in adult trout fed chronic high levels of Prudhoe Bay crude oil.

An increase in size of the eye lens could result from a number of factors. The most probable explanation at this time is either a physiological imbalance leading to hydration of the lens, or increase in lens epithelial cell synthetic activity resulting in an increase in collagen fiber production. The consequence of lens enlargement to the fish is not known; however, in humans an increase in lens diameter of 20% causes myopia; 20/20 visual acuity decreasing to 20/60. We plan to test for myopia in these fish directly with retinoscopy.

The infiltration of collagen into the lining of blood vessels was noted in liver samples. A fibrotic response to toxic materials, such as cadmium, has been observed in the testes of fish (Tafanelli and Summerfelt, 1975), and the liver and kidney of rabbits (Stowe, 1972). Such changes mean that normal, functioning cells, have died and were replaced by "scar" tissue.

The progeny of trout fed oil in the diet did not show any obvious structural aberrations.

b. A 5-day exposure of coho salmon and starry flounder to the WSF of Prudhoe Bay crude oil in a flow-through system caused epithelial sloughing in gill tissue. In addition, considerably more mucous glands in WSF-exposed fish had been discharged than in controls. The discharge of mucus in the presence of WSF compares favorably with results of static WSF bioassays reported on in the first RU 73 quarterly report of 1975.

3. <u>Chemical</u>:

Accumulation of both lead and cadmium in the mucus, skin, and scales of salmonids is temperature-dependent. This effect is more pronounced in the skin and scales, where an increase in water temperature from $4^{\circ}C$ to $10^{\circ}C$ resulted in a three- to sevenfold increase in the metal concentration.

Oosten (1957) reported that when metal salts are injected in fish a layer of metal is deposited in the scales at the site of active calcification. This suggests that the lead found in the scales of our test fish is incorporated in the scale matrix, perhaps, preferentially, or in competition with calcium at the "seeding" site. Pololiak and Holden (1964) demonstrated that a continuous and rapid flux of calcium occurs in the skin and scales of trout, and that calcium in the scales can be mobilized when there is calcium demand elsewhere in the body. Because skin and scales represent a major reservoir of calcium (40% of the total body calcium (Podoliak and Holden, 1964)), high concentrations of lead in the skin and scales may have a deleterious effect on calcium metabolism in fish. Moreover, lead in the skin and scales may adversely affect dermal fibroblasts and collagen in stratum spongiosum, resulting in cytotoxicity.

The presence of high concentrations of metals in the scales, long after the fish are returned to clean waters, raise several important questions with regard to long-term effects:

(1) High concentrations of lead stored in the scales may cause alterations in skin structure which may be related to skin lesions and other cellular and subcellular abnormalities.

(2) The presence of lead in the scales of salmonids may be potentially hazardous when there is a need for calcium in the fish due to environmental stress or during spawning. At spawning, the scales are known to be resorbed and the mineral components of the scales are utilized for general metabolism and production of sexual components (Wallin, 1957). In the lead-exposed fish, resorption of scales would not provide required nutrients such as calcium; instead, lead may be released in the body. The consequence of such a potentially toxic reservoir of metals on the eggs or sperm remains to be assessed.

4. Behavioral:

During exposure of spot shrimp to the WSF of Prudhoe Bay crude oil there is a suppression of feeding activity. The interpretation, and in turn implications, of this suppression is dependent upon the mechanism(s) of action of petroleum hydrocarbons. There are two possible, but hypothetical, modes of action which may explain the observations: (1) masking, blocking, or disruption of chemoreceptor sites, and (2) narcosis. If the effect is narcosis, then the suppressed feeding response is an indication of central nervous system impairment which would have a greater implication in regard to survival than if the chemosensory system alone were temporally disrupted.

Duration of suppression of the feeding response following exposure to the WSF and return to uncontaminated water will be assessed in future studies.

V. Problems Encountered

One major problem area concerns the occurrence of pathogens in experimental organisms. In all our studies particular attention has been paid to the health and viability of test and control animals since reliability of results is suspect when the experimental animals express disease symptoms and the additional stress of hydrocarbon exposure is imposed.

Disease particularly plagued studies assessing the effect of petroleum hydrocarbons on morphology and development of larval spot shrimp. Over 90% mortality occurred at stages II and III, and the marine bacterium, Vibrio parahaemolyticus, biotype alginolyticus, was repeatedly isolated. Further experiments are being conducted to determine measures necessary to control the disease if it reappears in future experiments.

VI. Estimate of Funds Expended

Estimated expenditures - July 1, 1975 to September 30, 1976

$ 149K

REFERENCES

Mackie, A.M.
1973. The chemical basis of food detection in the lobster, Hommaris gammarus. Mar. Biol. 21, 103-108.

Oosten, J. Van.
1957. The skin and scales. In Physiology of fishes (ed. M.E. Brown) Vol. I, p. 207-244, Academic Press, New York.

Podoliak, H.A. and Holden, H.K., Jr.
1964. Distribution of dietary calcium to the skeleton and the skin of fingerling brown trout. Fisheries Research Bulletin No. 28, p. 64-82.

Stowe, A.D., M. Wilson, and R.A. Goyer.
1972. Clinical and morphologic effects of oral cadmium toxicity in rabbits. Arch. Path. 94:389-405.

Tafanelli, R. and Summerfelt, R.C.
1975. Cadmium-induced histopathological changes in goldfish. In The pathology of fishes (eds. W.E. Ribelin, G. Migalsi) Univ. of Wisconsin Press, Madison, p. 613-645.

Wallin, O.
1957. On growth structure and developmental physiology of the scales of fishes. Fish. Bd. Sweden Rep. Inst. Freshwater Res. Drottingholm 38, p. 385-447.

OCSEAP QUARTERLY REPORT

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Number of Pages: 28

IDENTIFICATION OF MAJOR PROCESSES IN BIOTRANSFORMATIONS OF PETROLEUM HYDROCARBONS AND TRACE METALS

Donald C. Malins, William L. Reichert, and William T. Roubal

Environmental Conservation Division
National Marine Fisheries Service, NOAA
Northwest Fisheries Center
2725 Montlake Boulevard East
Seattle, Washington 98112

September 1976

OCSEAP QUARTERLY REPORT - RU 74

I. Task Objectives

A. Petroleum Hydrocarbons

Studies encompass a preliminary investigation of (a) the degree to which different compounds accumulate in biota from continuous exposure to non-lethal doses of hydrocarbons, (b) effects of environmental conditions, such as temperature and exposure concentrations on accumulations, (c) whether or not specific sites exist in fish where accumulation results in damage to normal physiology, and (d) the metabolic stability (biological half-life) of selected aromatic compounds in test organisms.

B. Trace Metals

Studies with trace metals encompass a preliminary investigation of (a) uptake and accumulation of lead and cadmium in salmon and flatfish, employing both radioactive and non-radioactive metals, (b) the relative distributions of lead and cadmium in key tissues (e.g., liver, kidney, gills) in salmon and flatfish, and (c) interactions of lead and cadmium with cellular components.

C. Detoxifying Enzymes in Biota from Norton Sound and Chukchi Sea

Examine and report on the ability of biota in pristine areas to adapt metabolically to an environment with added contaminants from oil operations. Determine the current levels of detoxifying enzymes in a broad spectrum of biota from Norton Sound and the Chukchi Sea.

II. Field or Laboratory Activities

C. Methods - laboratory analysis

1. Biotransformation of petroleum hydrocarbons and trace metals.

a. Hydrocarbons.

(1) Shrimp: Challenge experiments were conducted using a custom-made, high specific activity tritiated naphthalene which facilitates identification of very small amounts of individual metabolites and allows for the autoradiography of tissue sections from exposed larval and postlarval invertebrates.

Postlarval shrimp, *Pandalus hypsinotus*, were exposed in continuous-flowing sea water containing 6 ppb H^3-naphthalene for 144 hours followed by 48 hours depuration. The shrimp were laboratory-hatched and reared from ovigerous females captured in the vicinity of Kodiak Island. Shrimp were sampled at various time intervals, washed, weighed, and aromatic hydrocarbons and metabolic products were determined according to the procedure of Roubal *et al*. (1977). Specimens were sampled and preserved for histology and autoradiography.

One-year-old spot shrimp, *Pandalus platyceros*, were exposed to a water-soluble fraction (WSF) of crude oil at a concentrate of approximately 0.2 ppm (provisional value) for 12 days. The animals were then washed, extracted, and are currently being analyzed for accumulated hydrocarbons by gas liquid chromatography (GLC)/mass spectrometry (MS).

(2) Marine fish:

(a) Experiments using carbon-14 labelled hydrocarbons:

Studies were carried out to determine the extent of incorporation of naphthalene 1-^{14}C into key organs of coho salmon in relation to different environmental temperatures. Also, data on metabolite formation was sought.

Naphthalene-1-^{14}C, dissolved in salmon oil (5.55 μCi), was force-fed to coho salmon (150 ± 50 g). After 8 and 16 hours, the animals were sacrificed and carbon-14 incorporated into brain, liver, kidney, gallbladder, dark muscle, light muscle, stomach, caeca, intestine, stomach contents, caeca contents, intestinal contents, and blood was evaluated. The experiments were conducted at 4° and 10°C. Tissues (each a composite from three animals) were isolated and hydrocarbons and metabolites were extracted according to procedures described by Roubal et al. (1977). Stomach, caeca, and intestinal contents were assayed for carbon-14 after washing of the organ with saline until they became essentially free of radioactivity. Carbon-14 was measured by liquid scintillation spectrophotometry. Other essential aspects of the experimental protocol are given in Table III.

(b) Experiments with coho salmon using water-soluble fractions (WSF) of Prudhoe Bay crude oil:

Analysis of WSF produced in a flow-through system.--The flow-through system for exposure of marine organisms to the WSF of crude oil was described in the annual report for RU 74, April 1976. The methods for the identification of compounds, quantitation of major components, and a method of analysis of the WSF generated in the system are presented: Samples of the WSF were collected in 200-ml glass containers at the point where water enters the experimental aquaria. The sample containers were washed with detergent, rinsed with distilled water and acetone, air-dried, and sealed with aluminum foil-lined lids. All cleaning and extraction reagents were of spectrophotometric grade or distilled in glass. A 100-ml aliquot of the WSF was extracted in 0.5 ml of carbon disulfide (containing 1.725 μg/μl of isooctane as an internal standard) by shaking for 3 min. The organic phase was separated and 8 μl of the extract was injected into the gas chromatograph. Extraction and

TABLE III

Radioactivity in organs of coho salmon, 8 and 16 hours after being force-fed 5.55 μCi naphthalene-1-^{14}C in salmon oil.

Organs	4°C*, 8 hr		4°C, 16 hr		10°C**, 8 hr		10°C, 16 hr	
	Picograms*** HC/mg Dry wt	Percent Admin. Dose	Picograms HC/mg Dry wt	Percent Admin. Dose	Picograms HC/mg Dry wt	Percent Admin. Dose	Picograms HC/mg Dry wt	Percent Admin. Dose
Brain	600	0.02	970	0.04	430	0.02	430	0.02
Liver	2,040	0.64	1,600	0.46	700	0.21	270	0.10
Kidney	350	0.04	640	0.09	370	0.07	160	0.05
Gallbladder	650	0.03	1,700	0.07	290	0.01	1,000	0.04
Dark muscle tissue	860	0.52	1,800	1.2	590	0.39	1,100	0.90
Light muscle tissue	84	0.65	160	1.3	58	0.49	53	0.72
Stomach+	12,100	3.7	4,700	1.5	6,400	2.0	2,200	0.78
Caeca+	6,500	3.4	7,500	4.6	6,900	4.7	390	0.35
Intestine+	5,400	0.77	10,800	1.8	3,500	0.75	1,600	0.38
Stomach contents	NW++	44.9	NW++	22.5	NW++	52.6	NW++	45.6
Caeca contents	NW++	5.2	NW++	14.2	NW++	7.4	NW++	0.18
Intestine content	NW++	9.1	NW++	11.9	NW++	7.5	NW++	9.8
Blood	95	0.04	140	0.13	66	0.07	33	0.04

* Fish maintained at 4°C.
** Fish maintained at 10°C.
*** Average value for three fish.
\+ Digestive tract was divided into stomach, caeca, and intestine. Stomach data also includes that for esophagus.
++ NW: not weighed. Contents were rinsed out and analyzed for radioactivity.

analysis of the WSF was performed on the day of collection. Operating conditions of the gas chromatograph were:

Column:	1-m glass, 6-mm O.D., 2-mm I.D.	
Packing:	0.2% carbowax 1500 on 60/80 mesh Carbopack C. (Supelco, Bellefonte, PA)	
Gas flow:	Carrier flow rate of 46 ml/min, N_2	
Temperature conditions:	Column:	Initial - $40^{\circ}C$ Final - $215^{\circ}C$ Rate - $15^{\circ}C/min$
	Injection temperature:	$200^{\circ}C$
	Detector temperature:	$350^{\circ}C$

A sample chromatogram is shown in Figure 1 and identification of major peaks is given in Table I. Mass spectral data were collected on the sample of WSF shown in Figure 1. The operating conditions of the GLC/mass spectrometer are given below and the data output are given in Figure 2 and Table II.

Column:	0.26-mm WCOT glass capillary; 20 m.	
	SE-30 stationary phase; film thickness 0.4-0.5 μm	
Gas flow:	Carrier flow 2 ml/min, He	
Temperature conditions:	Column:	Initial - $60^{\circ}C$ Time - 2 min Final - $250^{\circ}C$ Rate - $4^{\circ}C/min$
Mass range scanned:	80-260 amu	
Integration time:	6 m/sec	
Scan time:	2 sec/scan	

The average total WSF produced in the flow-through system on a 30-day period was provisionally shown to be 0.5 ppm; however, no correction has been made thus far for extraction efficiencies of sea water. Accordingly, final data on assay of hydrocarbons in the exposure water will be provided later.

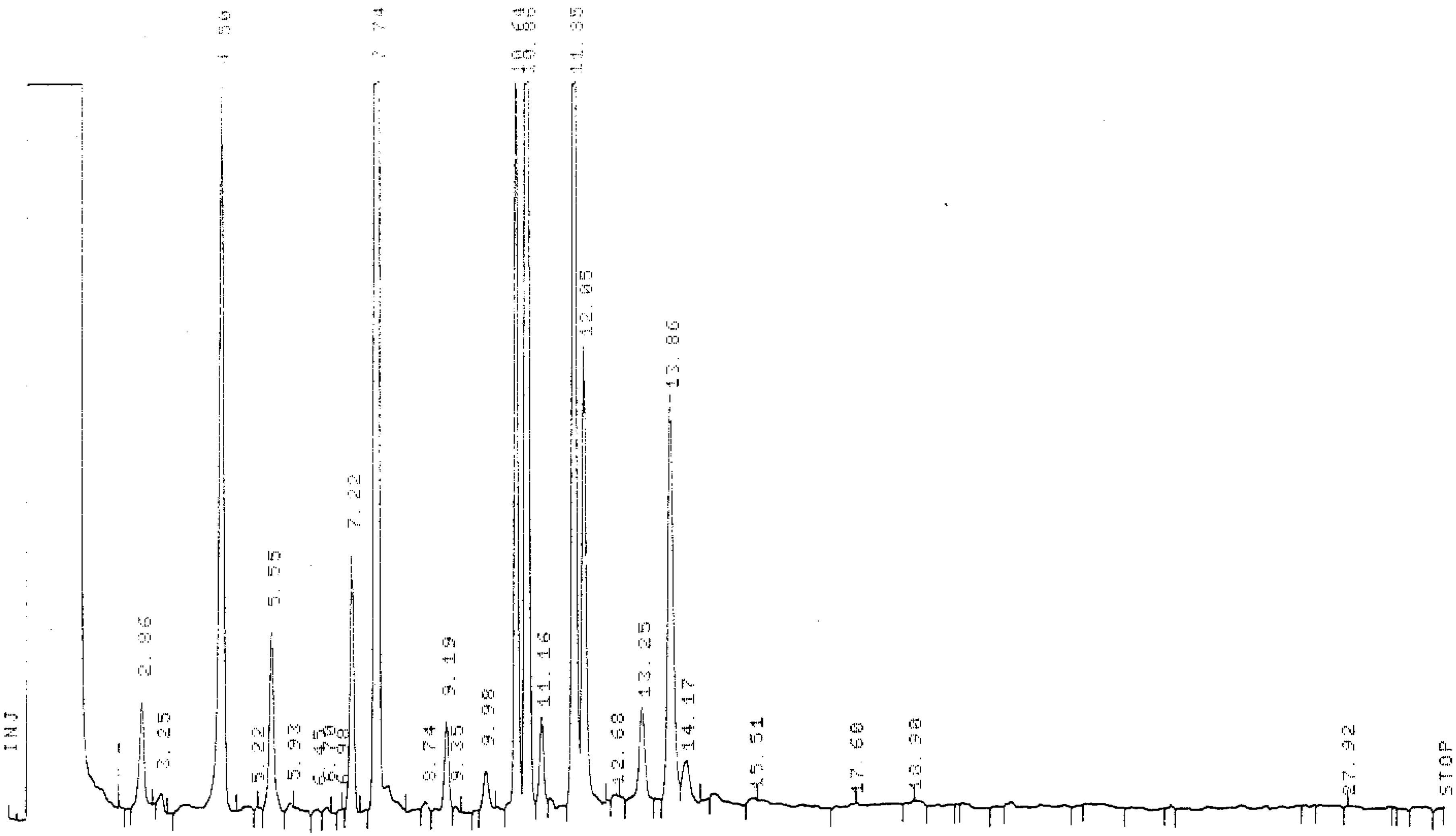

Figure 1.--Gas chromatogram of the water-soluble fraction of Prudhoe Bay crude oil in sea water. Sample collected 7/30/76 from flow-through system.

TABLE I

Gas chromatography data: Compounds present in water-soluble fraction of Prudhoe Bay crude oil collected 7/30/76 from flow-through system. Retention times correlated with gas chromatogram peaks shown in Figure 1.

Retention Time (Minutes)	Peak Area	Peak Area (%)	Compound*
2.86	1,976	1.15	Cyclohexane
3.25	282	.16	--
4.50	13,796	8.0	Benzene
5.55	3,098	1.80	--
5.93	128	.074	--
6.45	200	.12	--
6.70	165	.10	--
7.22	3,737	--	Isooctane (Int. Std.)**
7.74	70,912	41.1	Toluene
8.74	146	.080	--
9.19	1,544	.90	Ethylbenzene
9.35	129	.075	--
9.98	749	.43	Isopropylbenzene
10.64	10,779	6.25	Meta-xylene
10.86	29,230	16.9	Ortho and para-xylene
11.16	1,299	.75	C_3 benzene (unknown)
11.85	18,388	10.7	C_3 benzene (unknown)
12.05	7,570	4.39	C_3 benzene (unknown)
12.68	102	.059	--
13.25	2,056	1.19	1,3,5 trimethylbenzene
13.86	8,368	4.85	1,2,4 trimethylbenzene
14.17	1,244	.72	C_4 benzene (unknown)
15.51	186	.11	--
17.60	132	.076	--
18.90	--	--	Naphthalene

* Hydrocarbon structure provisional (not verified by M.S.).
** Internal Standard.

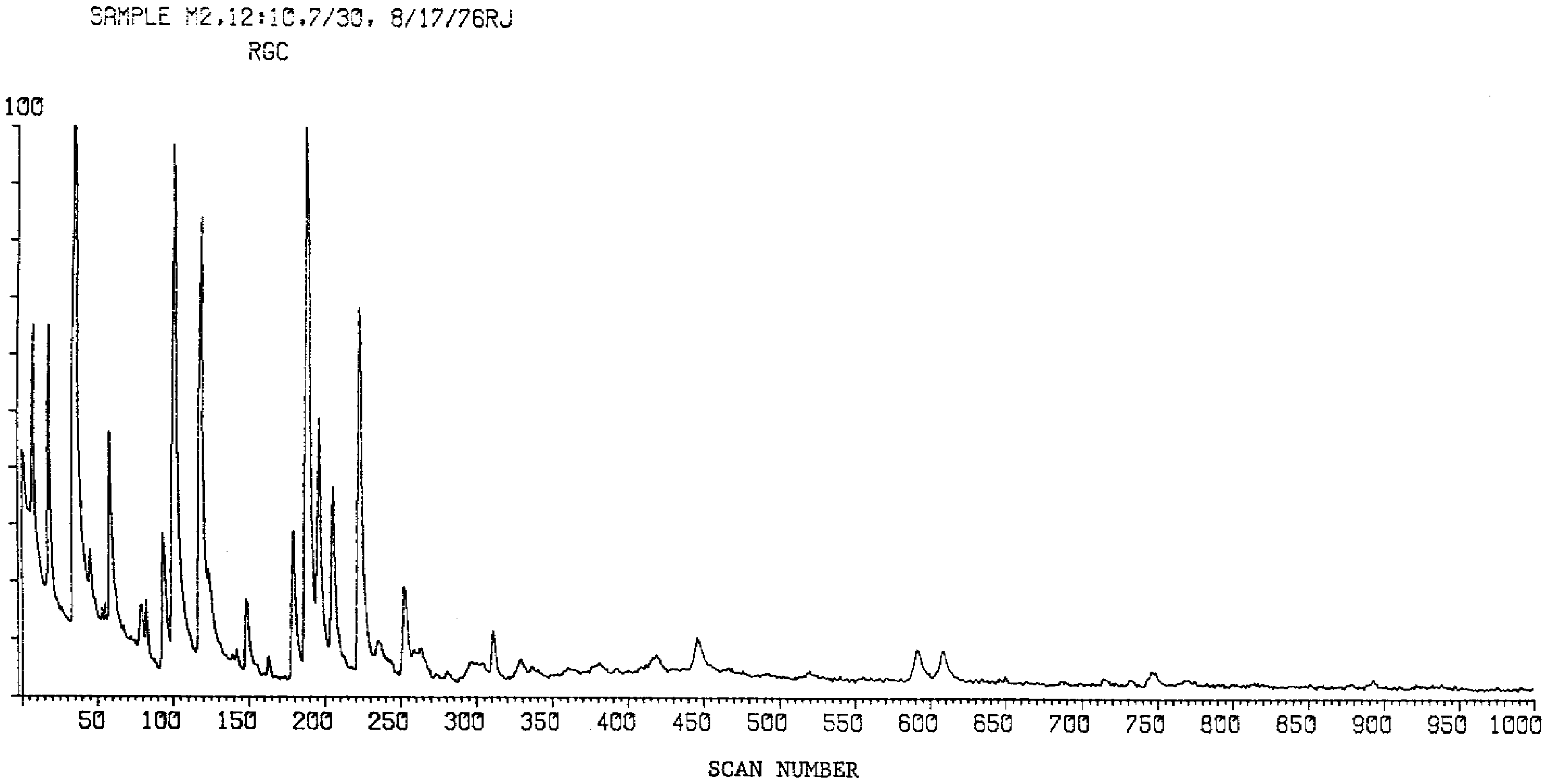

Figure 2.--Reconstructed gas chromatogram of the water-soluble fraction of Prudhoe Bay crude oil in sea water. Sample collected 7/30/76 from flow-through system.

TABLE II

Mass spectral data: Compounds present in water-soluble fraction* of Prudhoe Bay crude oil collected 7/30/76 from flow-through system. Peak identity correlated with scan number shown in Figure 2.

Scan Number	Compound	Remarks
10	Trichloroethylene	Source unknown
20	Methyl cyclohexane	Tentative
35	Toluene	
45	Dimethyl cyclohexane	Tentative
60	Tetrachloroethylene	Source unknown
80	Ethylcyclohexane	Tentative
83	Silica compound	Septum bleed
95-105-120	Xylene	
150	C_3 benzene	
180	Propylbenzene	Tentative
188-195-205-225	C_3 benzene	
235	Dichlorobenzene	
255	C_3 benzene	
260-300	C_4 benzene	
310	Hexachloroethane	Source unknown
330-380-420	C_4 benzene	
445	Naphthalene	
590	2-methyl naphthalene	
610	1-methyl naphthalene	

* Water-soluble fraction of Prudhoe Bay crude oil prepared according to the method of Roubal et al. (1977).

In considering the quantitation of the principal water-soluble fractions (Table I), there is considerable variability in the total WSF produced and in the individual components. The reason for this variability is presently under investigation. Moreover, some problems exist with the determination of hydrocarbons of molecular weight greater than methyl-substituted naphthalenes in the seawater system. It is anticipated that these analytical problems will be resolved shortly.

Exposure of coho salmon to WSF.--Groups of 20 coho salmon (average wt 15 g ± 5 g) were each maintained in twelve 20-gallon aquaria. Fish from control and experimental tanks were sampled weekly during 6 weeks of exposure followed by 6 weeks of depuration. The WSF represented one-sixth of the full strength output of the flow-through system (analytical data presently being evaluated). Gill, liver, and muscle tissues were extracted according to a modification of the technique described by Warner (1976). GLC analysis of hydrocarbons were obtained under the following conditions:

Column:	SE30 stationary phase; 0.26-mm WCOT glass capillary column, 30 m
Detector:	FID
Sample size:	2 μl injection with a split ratio of 10 to 1
Program:	40°C to 250°C @ 4°C/min

b. Trace metals.

Marine fish: Coho salmon (O. kisutch) (average wt 225 ± 40 g) and starry flounder (P. stellatus) (average wt 30 ± 15 g) were exposed to 3 and 150 ppb of lead and cadmium at 4° and 10°C. The gills, liver, kidney, erythrocytes, brain, and blood were examined. Lead-exposed animals were perfused before dissection. To determine the distribution of radioactive metals in subcellular sites, kidney and liver were homogenized and differentially centrifuged to yield cellular debris and mitochondrial, microsomal, and cytosol fractions. The procedure employed was essentially that described by Chen, R.U. et al. (1974). Samples of gills, liver, and kidney were processed for histological examination. Radioactivity was measured by liquid-scintillation spectrometry. Data presented in the last quarterly report for RU 74 were provisional. Final corrections (e.g., quenching factors) have been applied and the data on cadmium are now in final form. Data on lead accumulations and subcellular distributions in exposed coho salmon and starry flounder are presently being verified and will be given at a later date.

c. Detoxifying enzymes in biota from Norton Sound and Chukchi Sea.

An experiment was performed to measure the aryl hydroxylase activity response to petroleum dose. Prudhoe Bay crude oil was incorporated into Oregon moist pellets, which were custom-prepared in our laboratory. Three concentrations of the petroleum in pellets were employed, viz., 0.53, 5.3, and 53 ppm (wet wt). Groups of 10 coho salmon, averaging 18-27g/group, were fed daily the petroleum in food at a rate of 2.5% of the biomass. The temperatures of flowing seawater in separate tanks ranged from 12.0^{o} to 13.1^{o}C during 27 days of the experiment. Liver tissues were collected for pairs of fish to provide samples for the hydroxylase enzyme assays, which are to give data points for each crude petroleum concentration at 4, 8, 16, and 23 days of exposure. Livers were immediately frozen over dry ice, and after 2-4 hours they were placed in a 60^{o}freezer until assays can be performed.

The ultra-low-temperature freezer (7 cu ft) from Revco was received and placed on board the Miller Freeman. Instructions were given to project personnel, notably Mr. W. Gronlund, indicating that the freezer is to be operated at minus 60^{o}C for holding specimens from the enzyme studies.

Protocol (cf., attached Exhibit "A") for handling and storing specimens for enzyme studies was established and copies given to Mr. W. Gronlund, who will supervise and help collect samples for analyses.

III. Results

A. Biotransformation of petroleum hydrocarbons and trace metals.

1. Hydrocarbons

a. Shrimp: Shrimp exposed to a 6 ppb of tritiated naphthalene contained 360 ppb of naphthalene and 20 ppb of metabolites (as 1-naphthol) in 1 hour. The naphthalene levels reached 650 ppb in 3 hours. During the exposure period, the naphthalene concentration declined from 740 ppb at a high of 12 hours to 46 ppb at 72 hours. Subsequently the naphthalene levels did increase somewhat in the remaining 72 hours of the exposure. Metabolites reached a maximum of 50 ppb in 24 hours. Metabolite levels, however, decreased only slightly for the rest of the exposure. During depuration, the naphthalene concentration decreased to 35 ppb in 6 hours, but metabolite concentrations only changed from 50 to 35 ppb in this period. No mortalities were recorded during the exposure and depuration phases of the experiment. Samples for analysis of individual metabolites have not been processed yet. Autoradiography is in progress; however, no interpretations are available at present. GC/MS analyses of the oil-exposed shrimp are complete but interpretation of data remains to be accomplished.

Exhibit "A"

PROTOCOL FOR HANDLING AND STORING SPECIMENS FOR ENZYME STUDIES

1. Record data on specimen record sheet and check-off list, e.g., sex, weight, length of specimen, and whether or not the sample will be bottled or bagged for storage.

2. Samples of liver tissues:

   a. Take samples that weigh between 0.5 g and 5 g; the latter is preferred.

   b. Rinse blood, mucus, and other non-hepatic substances from outer surfaces of liver tissues, using distilled water from a polyethylene wash bottle.

   c. Drop liver into screw-capped vial (20 ml), replace cap on vial, mark the vial and vial cap with an appropriate code number, using black waterproof ink from a felt-tipped pen (vial caps are to be white), and as soon as possible place the sample vial into a -60°C freezer.

   d. If it is necessary to delay placing livers immediately into the freezer, then place vial containing the liver tissues into an ice-water bath (to quickly chill to 0°C), but do not hold at 0°C or higher temperature for more than 30 minutes before placing into the -60°C freezer.

3. Samples of whole organisms:

   a. In the cases of samples with livers, less than 0.5 g and animals with poorly defined hepatic organs, major portions of whole body, should be taken.

      (1) Whole body organisms include mussels, clams, snails, sea slugs, and shrimp.

      (2) Small fish like capelin require whole body sample; however, heads and tails can be removed and discarded.

   b. Whole organisms should be rinsed to remove sand, mud, or other extraneous substances clinging to outer surfaces.

   c. After rinsing, the organism should be weighed, placed in a plastic bag, or--if small enough--into a vial, and the sample stored in a -60°C freezer as soon as practical.

   d. If placement in the freezer is to be delayed more than 15 minutes, then the sample should be packed under ice until freezing becomes practical. At no time should the delay in placement into the freezer exceed one hour after death of the animals.

b. Marine fish:

(1) Experiments using carbon-14 labelled hydrocarbons:

Studies conducted with naphthalene-1-^{14}C force-fed to coho salmon over 8- and 16-hour periods (4° and $10^{\circ}C$) revealed that, aside from tissues comprising the digestive tract, relatively small amounts of radioactivity were incorporated into key organs and tissues (Table III). At each interval of time no more than 5% of the administered dose was found in the combined organs examined. In organs other than digestive tissues, highest levels of naphthalene-1-^{14}C were found in liver, gallbladder, and dark muscle, irrespective of water temperature. The amount of naphthalene did not exceed about 1% the original dose in any organ or tissue examined. Some differences were observed in the amount of incorporated naphthalene-1-^{14}C with respect to water temperature. Lower levels of carbon-14 were found at $10^{\circ}C$, 16 hours after exposure, than at $4^{\circ}C$, 16 hours after exposure ($P < 0.05$ for brain, liver, kidney, and blood); however, with the exception of liver, no pronounced differences existed in accumulations with respect to $4^{\circ}C$ and $10^{\circ}C$ at 8 hours. Significant amounts of metabolic products were found only in the gallbladder 16 hours after administration of the hydrocarbons.

Extremely wide variabilities were observed, consistent with those reported earlier (RU 74 Progress Report, April-June 1976, p 9), in total metabolites formed. For example, at $4^{\circ}C$ (16 hours) values obtained for metabolite levels in gallbladder of individual fish ranged from 20% of total carbon-14 to less than 1%. Wide variations are consistent with results obtained with aryl hydrocarbon hydroxylase (AHH) activities on salmonids and other fish in our laboratories.

(2) Experiments with coho salmon using water-soluble fractions (WSF) of Prudhoe Bay crude oil:

Gas chromatographic analyses were performed on gills, liver, and muscle of coho salmon exposed to WSF for periods up to and including 6 weeks and on animals placed in clean salt water for 6 weeks. Analyses of gill and liver did not reveal detectable amounts of accumulated hydrocarbons at any time period; however, analyses performed on muscle resulted in gas chromatographic data showing the accumulation of the spectrum of hydrocarbons that were present in the surrounding sea water. The apparent absence of petroleum in gill and liver tissue may be related to the fact that the sample was one-twentieth of that used for the analysis of muscle. Larger groups of fish will be employed in the future to increase the amount of tissue for analysis. The data acquired on the analyses of muscle for hydrocarbons are given in Table IV. The values are provisional (e.g., factors such as extraction efficiencies based upon the use of standard compounds have not been taken into account). The analytical data will be given in final form at a later time. The findings in Table IV indicate that xylenes and naphthalenes appear in muscle in readily quantifiable amounts after 2 to 6 weeks of exposure. Moreover, transfer of coho exposed to WSF for 6 weeks to clean sea water results in discharge of virtually all of the quantifiable hydrocarbons from the muscle. This finding is graphically depicted in the GLC profiles given in Figure 3. The apparent increased complexity of the GLC profiles in comparison to those of the WSF is presently under investigation.

The skin and gills of control and exposed coho salmon were examined by scanning electron microscopy (SEM). The results are shown in Figures 3 and 5-7, RU 73 quarterly report for July 1-September 30, 1976. The results (p 11) suggest that changes in gill tissue may indicate exposure to the WSF of crude oil.

TABLE IV

Hydrocarbons found in muscle tissue of coho salmon (<u>Oncorhynchus kisutch</u>) after exposing fish at 8-12°C to the water-soluble fraction of Prudhoe Bay crude oil.*

Hydrocarbon	Weeks of Exposure 2	3	6***
C_2-substituted benzenes (xylenes)	937 μg/gm dry wt**	415 μg/gm dry wt	641 μg/gm dry wt
C_3-substituted benzenes	300	629	499
C_4-substituted benzenes	201	486	609
C_4- and C_5-substituted benzenes (GLC overlap region)	N.D.***	354	216
C_5-substituted benzenes	N.D.	390	N.D.
Naphthalene	N.D.	170	61
1-methyl naphthalene	144	187	309
2-methyl naphthalene	196	275	383
C_2-substituted naphthalenes	N.D.	302	48
C_3-substituted naphthalenes	N.D.	112	176

* Flow-through exposure using method of Roubal et al. (1977).

** μg/gm dry wt: nanograms hydrocarbon/gm dry wt tissue (analysis performed via gas-liquid chromatography (GLC)). Tissues analyzed were from 1-2 fish.

*** After 6 weeks of exposure, fish were transferred to oil-free sea water for several weeks. After 1 week in oil-free water, gas liquid chromatographic analysis of tissue was no different than that observed for control fish.

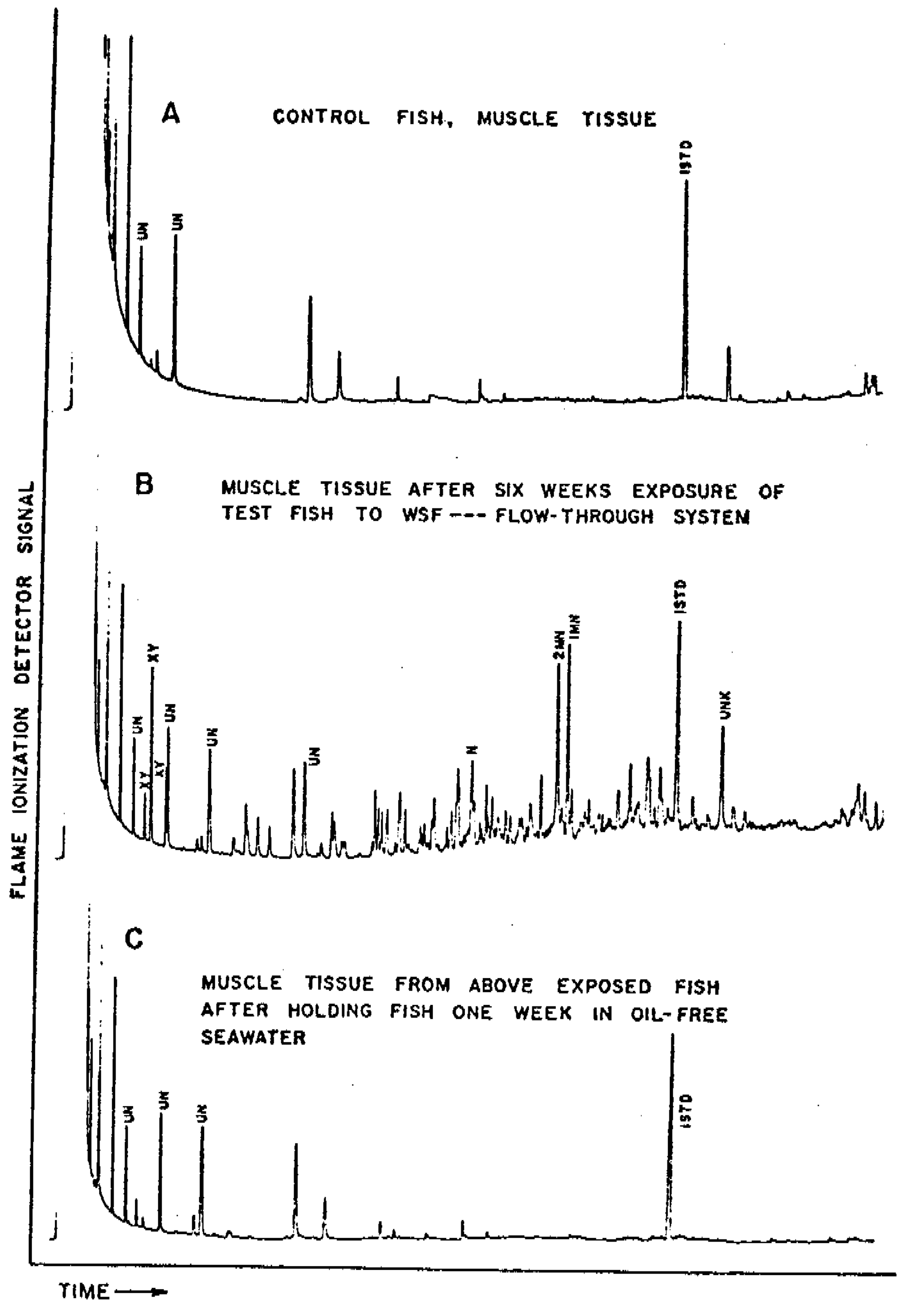

Figure 3.--Gas-liquid chromatography (GLC) of solvent extract of muscle tissue from young coho salmon (15 ± 5 g) (O. kisutch) exposed to a water-soluble fraction (WSF) of Prudhoe Bay crude oil. Data show GLC hydrocarbon profiles of muscle tissue from control (A), exposed (B), and depurating (C) animals. XY = xylenes; N = naphthalene; 1-MN and 2-MN = Mono- and di-methylnaphthalenes, respectively; ISTD - internal standard (hexamethylbenzene); UKN = unknown (compound not confirmed by mass spectrometry).

2. Trace metals

Table V shows the accumulation of cadmium in coho salmon and starry flounder exposed to 150 ppb of the metal for 15 days. Also included are data on the depuration of tissues when animals were placed in metal-free water. The results obtained with both species indicate that gills, liver, and kidney bioconcentrate cadmium to a substantial degree at 10°C; the bioconcentration at 4°C is about 50% less. Very little cadmium accumulates in brain and whole blood. The maximum bioconcentration of cadmium occurred in starry flounder at 10°C in the liver where levels reached one order of magnitude greater than exposure levels. Interestingly, the posterior kidney of both species accumulated a greater amount of lead than did the anterior kidney.

When fish were placed in clean water, cadmium levels of most tissues declined; however, levels in the kidney increased when animals were transferred to a metal-free environment. A notable example was coho salmon, exposed for 15 days to 150 ppb of cadmium, which were placed in "metal-free" water for 37 days. In this case, the cadmium burden doubled while animals were in clean water.

Table VI gives levels of cadmium and lead in unexposed coho salmon and in stock sea water. These values will be evaluated at a later time with respect to accumulation of isotopically labelled metals in exposed fish.

Table VII provides data on the subcellular distribution of cadmium in liver and kidney of coho salmon and starry flounder exposed to 150 ppb of the metal. In each species, the greatest proportion of metal accumulated in cytosol; however, substantial concentrations were also found in cellular debris and the enzyme-rich microsomal fractions. In coho salmon, 8 days in clean water did not result in significant changes in the proportion of cadmium in the subcellular fractions examined (Table VIII).

TABLE V

Accumulation of cadmium in coho salmon (Oncorhynchus kisutch) and starry flounder (Platichthys stellatus) in 15-day exposure.

Metal concentration	150 ppb						
Species	Coho salmon (O. kisutch)				Starry flounder (P. stellatus)		
Temperature	4°C	10°C			4°C	10°C	
Exposure period	15-day U*	15-day U	8-day D**	37-day D	15-day U	15-day U	8-day D
Gills	476	878	628	420	593	1020	1144
Liver	165	299	259	245	443	1572	1651
Kidney, anterior	100	180	267	257	129	228	346
Kidney, posterior	127	380	592	790	75	281	492
Blood	7	28	22	11	86	28	20
Erythrocytes		65	103	37			
Plasma	3	7	4	3			
Brain	1	1	1	3	5	6	10

* U = Uptake
** D = Depuration

TABLE VI

Metal levels in unexposed coho salmon (*Oncorhynchus kisutch*) organs and sea water.

Organ	Flesh	Gills	Liver	Kidney	Blood	Sea Water
Metal						
Cadmium (ppm)	< .02 ppm	.02	.20	.09	.10	.002
Lead (ppm)	.19	.48	.49	.40	.20	<.005

TABLE VII

Subcellular distribution of cadmium in starry flounder (*Platichthys stellatus*) and coho salmon (*Oncorhynchus kisutch*) organs for 30-day exposure to 150 ppb of Cd at 4°C.

Species	Starry flounder (*P. stellatus*)			Coho salmon (*O. kisutch*)		
Organ	Liver	Kidney (Anterior)	Kidney (Posterior)	Liver	Kidney (Anterior)	Kidney (Posterior)
Metal concentration (ppb)	900	37	110	310	215	297
Cell fraction	(%)	(%)	(%)	(%)	(%)	(%)
Cellular debris	12	14	21	9	24	28
Mitochondrial	8	19	7	7	7	6
Microsomal	8	14	10	20	18	15
Cytosol	72	68	80	64	57	56
% of total metal recovered	100	115	118	100	106	105

TABLE VIII

Subcellular distribution of Cd in coho salmon (Oncorhynchus kisutch) organs after Cd exposure (150 ppb) at 10°C.

Exposure	15-day Uptake			8-day Depuration		
Organ	Liver	Kidney (Anterior)	Kidney (Posterior)	Liver	Kidney (Anterior)	Kidney (Posterior)
Metal levels in organ (ppb)	356	231	342	252	425	628
Cell fraction						
Cellular debris	15	21	28	13	30	27
Mitochondrial	4	7	5	11	5	8
Microsomal	17	11	17	18	12	20
Cytosol	56	50	46	51	42	39
% of total recovered	92	89	96	93	89	94

3. Detoxifying Enzymes in Biota from Norton Sound and Chukchi Sea

In the experiment on petroleum dose-enzyme response, fish were observed to attack each other and behave cannibalistically, with the result that mortalities occurred. The greatest numbers of mortalities occurred in the group fed control food. The latter fish were generally sluggish when it came time to feed. The fish fed the highest concentration (53 ppm) of petroleum in food appeared to be more lively than other fish and, as a group, experienced only one mortality.

At this time, liver samples are still in the -60°C freezer awaiting assays. The assays of aryl hydroxylase will be carried out during the next month.

IV. Preliminary Interpretation of Results

A. Biotransformations of petroleum hydrocarbons and trace metals.

1. Hydrocarbons

a. Shrimp: The postlarval P. hypsinotus were capable of concentrating tritiated naphthalene over 100 times the concentration in surrounding water. This data support previous findings of Sanborn and Malins (1976) with larval P. platyceros where comparable bioconcentrations occurred in relation to higher levels of naphthalene in the water. The substantial decrease in naphthalene concentration occurring after 12 hours is not explained at present; however, the same phenomenon has been observed in our previous data from the exposure of spot shrimp (P. platyceros) to naphthalene-1-^{14}C. Metabolites appear to be strongly resistant to discharge, remaining at high levels for 48 hours of depuration. Because of the toxicity attributed to metabolites of aromatic hydrocarbons with respect to animal systems, attention will be given to the nature of the metabolites formed in the larval shrimp.

b. Marine fish:

(1) Experiments using carbon-14 labelled hydrocarbons: The results with naphthalene-1-^{14}C force-fed to coho salmon at 4°C and 10°C provided insight into the amount of hydrocarbon accumulation by salmonids in relation to environmental temperature. Also, data was acquired to evaluate the extent to which naphthalene is absorbed through the digestive epithelium. Although some differences were observed in relation to 4° and 10°C environments, the data generally indicate that profound differences in hydrocarbon accumulation did not occur with respect to temperature. Because less than 5% of the naphthalene was found

in key organs and tissues, regardless of temperature, the digestive tract appears to act as a major barrier to the incorporation of aromatic hydrocarbons into salmonid tissues.

The findings, considered with respect to previous data, imply that the small proportion of naphthalene absorbed through the intestine is rapidly oxidized to metabolic products, although wide variations appear to exist between individual animals. In salmonids, this process undoubtedly contributes to the relatively rapid discharge of hydrocarbons from key tissues, as was discussed earlier [see II (b)].

(2) Experiments with coho salmon using water-soluble fractions (WSF) of Prudhoe Bay crude oil:

The experiments on the accumulation of water-soluble hydrocarbons in coho salmon reveal that quantifiable amounts can accumulate in muscle in about 2 weeks. It is of considerable interest, however, that the GLC profiles become essentially the same as those obtained from control animals when test fish were placed in oil-free sea water for one week. These data imply that hydrocarbons, *per se*, are readily discharged from muscle tissue of coho; however, previous studies with isotopically labelled aromatic hydrocarbons (RU 74 quarterly report, April-June 1976, p 9) revealed that aromatic hydrocarbons, (namely, benzene, naphthalene, and anthracene), are actively converted to metabolites in salmonids. Thus, it is possible that significant levels of metabolic products exist in muscle tissue of the exposed animals, despite the apparent absence of parent hydrocarbons. The results with coho salmon will be compared with those obtained with starry flounder subjected to comparable experimental conditions. A discussion of this subject will be included in a later report.

2. Trace metals

The data on cadmium indicate that substantial bioconcentrations of the metal can occur in both coho salmon and starry flounder exposed to less than 200 ppb in sea water. It is important to note that the kidney is susceptible to continued infusion of cadmium from body fluids for at least 5 weeks after animals are transferred to clean environments. Data to be presented later will show that similar results are found with lead. Thus, termination of exposure should not be interpreted to mean that metal levels will necessarily remain constant or decline in the kidney, and possibly other sites. It is of interest to note that in cases where a decline in cadmium concentrations were observed (e.g., in gills), significant levels still remained even after 5 weeks in clean environments. The strong tendency to sequester cadmium in gills during uptake and depuration periods raises questions about possible interference with osmoregulation and oxygen consumption (Thurberg et al., 1973).

Generally, the findings indicate that ppb levels of cadmium and lead (data to be reported later) in sea water can be translated to ppm levels in key tissues of both coho salmon and starry flounder. This process leads to metal deposition in important subcellular loci.

The subcellular distribution studies with cadmiun clearly show that the metal accumulates in portions of the cell (e.g., cytosol and microsomes) involved in important biochemical processes. Thus, the tendency to bioconcentrate cadmium in certain tissues several fold over ppb levels in sea water deserves further consideration.

V. Problems Encountered/Recommended Changes

Detoxifying enzymes in biota from Norton Sound and Chukchi Sea.

The biochemical research chemist, who is to perform the enzyme assays and carry out the dose-enzyme response studies with additional fish species, has not yet been hired. Eight people from the Civil Service Commission (CSC) listings and certifications have either declined to accept the temporary position or did not reply to inquiries as to their availability. We are continuing the search for an acceptable person by obtaining additional lists of applicants from the CSC.

The lack of an additional research chemist has resulted in reorganizing the sequence of experiments for the enzyme study. The additional dose-enzyme response experiments must be either intermeshed with the baseline assays or be performed after the samples collected in Alaska have been completely assayed. The choice of alternatives depends on the availability of NMFS personnel at the particular times involved.

VI. Estimate of Funds Expended

Estimated expenditures - July 1, 1975 to September 30, 1976

$ 74.7K

REFERENCES

Chen, R.W., Wagner, P.A., Hoekstra, W.G. and H.E. Ganther.
1974. Affinity labeling studies with cadmium-109 in cadmium-induced testicular injury in rats. J. Reprod. Fert. 38, 293-306.

Roubal, W.T., D.H. Bovee, T.K. Collier and S.I. Stranahan.
Flow-through system for chronic exposure of aquatic organisms to seawater-soluble hydrocarbons from crude oil. In 1977 Oil Conference (Prevention, Behavior, Control and Cleanup). Am. Petrol. Inst., Washington, D.C. To be published.

Thurberg, F.P., M.A. Dawson and R.S. Collier.
1973. Effects of copper and cadmium on osmoregulation and oxygen consumption in two species of estuarine crabs. Mar. Biol. 23, 171-175.

Warner, J.S.
1976. Determination of aliphatic and aromatic hydrocarbons in marine organisms. Anal. Chem. 48, 578.

OCSEAP FINAL REPORT

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Number of Pages: 223

ASSESSMENT OF AVAILABLE LITERATURE ON EFFECTS OF OIL POLLUTION ON BIOTA IN ARCTIC AND SUBARCTIC WATERS

Donald C. Malins and Maurice E. Stansby

Environmental Conservation Division
National Marine Fisheries Service, NOAA
Northwest Fisheries Center
2725 Montlake Boulevard East
Seattle, Washington 98112

September 1976

I. Task Objectives

The intent was to prepare a literature review covering data on effects of petroleum oil and its components (to include heavy metals) on marine environments, organisms, and ecosystems, with special reference to arctic and subarctic regions.

II. Activities

C. Methods

Literature was compiled primarily from existing bibliographies or by use of OASIS, the NOAA computerized scientific information system, and other systems. Direct examination of portions of the literature by hand search through abstract journals was also employed. The literature review was undertaken by appropriate specialists in the Environmental Conservation Division, Northwest Fisheries Center, or other institutions. The reviews, which roughly cover the literature through mid-1976, comprise a compilation of information on the chemical and biological effects of petroleum on arctic and subarctic environments. The subject of trace metals was discussed in terms of those elements which are prominent constituents of petroleum and which, by virtue of their innate toxicity, may alter the viability of organisms and ecosystems.

E. Data collected

The material on hydrocarbons will be published in book form shortly after termination date of the contract (October 1, 1976) and submission of the package to OCSEAP. As a consequence, OCSEAP will treat the detailed report as an administrative document with only limited distribution within NOAA and BLM.

It is not practical to attempt a synopsis of the material covered in the literature review, *per se*, which comprises approximately 1,000 pages of detailed information; however, a comprehensive outline of contents is provided to give an overview of the subjects and materials included. A final, updated list of literature references is also included. Although this list is quite voluminous (over 200 pages), it should be emphasized that no attempt was made to insure that the list is a complete one. Undoubtedly there are other references which are not included.

The review document for submission to OCSEAP includes sections titled "Prospectus." These sections are included in chapters where a relatively large amount of complex material is discussed. The "Prospectus" represent the authors' overview of the subjects with respect to the implications of the work to OCSEAP.

IV. Preliminary Interpretation of Findings

Detailed coverage of the material is given in the report which is presently in final typing stages. The report will be submitted as an administrative document at the end of the contract year and published in a book by Academic Press early in 1977.

PETROLEUM IN MARINE ENVIRONMENTS AND ORGANISMS INDIGENOUS TO THE ARCTIC AND SUBARCTIC

Donald C. Malins
Editor

Environmental Conservation Division
National Marine Fisheries Service
Northwest Fisheries Center
2725 Montlake Boulevard East
Seattle, Washington 98112

September 1976

SECTION I

NATURE & FATE OF PETROLEUM
IN ARCTIC AND SUBARCTIC MARINE ENVIRONMENTS

CHAPTER 1. PETROLEUM: PROPERTIES AND ANALYSES IN BIOTIC AND ABIOTIC SYSTEMS

by

Robert C. Clark, Jr.
Environmental Conservation Division

Donald W. Brown
NOAA National Analytical Facility

I. PETROLEUM: GENERAL DESCRIPTION
   - A. Origin
   - B. Recovery
   - C. Refining
   - D. Historical uses

II. PHYSICAL CHARACTERISTICS OF PETROLEUM
   - A. Specific gravity
   - B. Viscosity
   - C. Pour point
   - D. Fractional distillation temperatures

III. CHEMICAL PROPERTIES OF PETROLEUM AND PETROLEUM PRODUCTS
   - A. Characteristics of petroleum
     1. Hydrocarbon components
        - a. Paraffins
        - b. Naphthenes
        - c. Olefins
        - d. Aromatic compounds
     2. Nonhydrocarbon components
        - a. Nitrogen compounds
        - b. Sulfur compounds
        - c. Oxygen compounds
        - d. Metals and organometallic compounds
   - B. Composition of crude petroleum
     1. Prudhoe Bay crude oil
     2. South Louisiana crude oil
     3. Kuwait crude oil
   - C. Composition of refined petroleum products
     1. No. 2 fuel oil

IV. METHODS OF ANALYSIS FOR PETROLEUM HYDROCARBONS
   - A. Sample collection and preservation
     1. Laboratory aspects
        - a. Containers
        - b. Storage
     2. Field aspects
        - a. Intertidal samples
        - b. Oceanic samples
          - (1) Research vessel operations
          - (2) Collecting small organisms with plankton nets

(3) Collecting large organisms
(4) Collecting sediment samples
(5) Collecting water samples

B. Extraction of the organic matter
1. Biological material
2. Sediment
3. Seawater

C. Separation
1. Gravimetric method
2. Ultraviolet absorption spectrophotometry
3. Fluorescence spectrometry
4. Infared spectroscopy
5. Gas chromatography
6. Mass spectrometry

V. DISTRIBUTION IN PETROLEUM AND MARINE ORGANISMS

A. Hydrocarbons
1. Volatile normal paraffinic
2. Volatile branched paraffinic
3. Non-volatile paraffinic
4. Naphthenic
5. Olefinic
6. Aromatic

B. Nonhydrocarbon components

C. Basic differences between abiotic and biotic systems

VI. PROSPECTUS

VII. REFERENCES

VIII. TABLES

IX. FIGURES

CHAPTER 2. INPUTS, TRANSPORT MECHANISMS AND OBSERVED CONCENTRATIONS OF PETROLEUM IN THE MARINE ENVIRONMENT

by

Robert C. Clark, Jr.
Environmental Conservation Division

William D. MacLeod, Jr.
NOAA National Analytical Facility

I. POTENTIAL PETROLEUM HYDROCARBON INPUTS
   A. Land-based discharges
      1. Refineries
      2. Waste oils, run-ff, and sewage
   B. Marine operations
      1. Tankers
      2. Bilge discharges and bunkering
      3. Accidents
   C. Offshore production operations
   D. Oil seeps
   E. Atmospheric input

II. SPILL TRANSPORT AND RELATED MECHANISMS
   A. Spreading
   B. Evaporation
   C. Dissolution
   D. Emulsification
   E. Agglomeration and sinking
   F. Microbial modification
   G. Photochemical modification
   H. Biological ingestion and excretion
   I. Tar ball formation
   J. Interaction of ice with petroleum

III. PETROLEUM HYDROCARBON LEVELS IN THE MARINE ENVIRONMENT
   A. Organisms
      1. Unexposed baseline samples
      2. Exposed samples
      3. Laboratory exposed samples
   B. Sediment
   C. Seawater
   D. Tar balls
   E. Sea slicks

IV. PROSPECTUS

V. REFERENCES

VI. TABLES

VII. FIGURES

CHAPTER 3. ALTERATIONS IN PETROLEUM RESULTING FROM PHYSICO-CHEMICAL AND MICROBIOLOGICAL FACTORS

by

Neva L. Karrick
Environmental Conservation Division

I. INTRODUCTION

II. PHYSICAL FACTORS
- A. Environmental conditions
  1. Water
  2. Temperature
  3. Wind
  4. Oxygen
- B. Physical processes
  1. Spreading
  2. Evaporation
  3. Dissolution
  4. Emulsification
  5. Sedimentation

III. CHEMICAL FACTORS

IV. MICROBIOLOGICAL FACTORS
- A. Distribution of microorganisms
- B. Yeasts and fungi
- C. Microbial processes
  1. Role of temperature in microbial degradation
  2. Role of other environmental factors in microbial degradation
  3. Microbial activity
     - a. Sequence of organisms and degradation of substrates
     - b. Cooxidation
     - c. Extracellular activity
  4. Microbial oxidation of hydrocarbons
     - a. Aliphatics
     - b. Non-benzoid cyclic hydrocarbons
     - c. Monoaromatic compounds
     - d. Naphthalene compounds
     - e. Polyaromatic compounds
     - f. Substituted aromatic compounds
  5. Mathematical modeling
  6. Microbial degradation of petroleum in sediments
  7. Potential changes in petroleum under arctic and subarctic conditions
     - a. Transformation of petroleum compounds
     - b. Studies in Alaskan coastal waters
       - (1) Beaufort Sea
       - (2) Cook Inlet
       - (3) Port Valdez

SECTION II

BIOLOGICAL EFFECTS OF PETROLEUM: ALTERATIONS IN LIFE PROCESSES AND IN COMMUNITY STRUCTURES

CHAPTER 4. ACUTE TOXIC EFFECTS OF PETROLEUM ON ARCTIC AND SUBARCTIC MARINE ORGANISMS

by

Donovan R. Craddock
Environmental Conservation Division

I. INTRODUCTION
   A. Importance
   B. Scope
   C. Limitations

II. ACUTE BIOASSAY TECHNIQUES
   A. Test animals
   B. Holding test fish
   C. Dilution water
   D. Test tanks
   E. Test temperatures
   F. Dissolved oxygen
   G. Number of test animals
   H. Testing procedure
   I. Reporting test results

III. ACUTE TOXICITY OF OIL

IV. INTERPRETATION OF RESULTS

V. CONCLUSIONS

VI. PROSPECTUS

VII. REFERENCES

CHAPTER 5. BIOLOGICAL EFFECTS OF PETROLEUM ON MARINE BIRDS

by

W.N. Holmes
Professor of Zoology

J. Cronshaw
Professor of Biology
University of California
Santa Barbara

CHAPTER 6. MARINE MAMMALS

by

Joseph Geraci
Ontario Veterinary College
University of Guelph
Guelph, Ontario

CHAPTER 7. PATHOLOGY

by

Harold O. Hodgins, Bruce B. McCain & Joyce W. Hawkes
Environmental Conservation Division

I. INTRODUCTION

II. PRINCIPAL DISEASES OF ARCTIC AND SUBARCTIC MARINE SPECIES

- A. Neoplasia
  - 1. Fish
    - a. Oral tumors
    - b. Epidermal tumors
    - c. Epidermal erythrophoroma
    - d. Melanomas
    - e. Fibromas
    - f. Lipofibromas
    - g. Lipomas
    - h. Osteomas and osteosarcomas
    - i. Rhabdomyomas
    - j. Lymphosarcomas
    - k. Neural tumors
    - l. Miscellaenous tumors of internal organs
      - (1) Gastrointestinal tracts
      - (2) Kidney tumors
  - 2. Invertebrates
    - a. Mesenchymal tumors
    - b. Leukemia-like "neoplasma"
    - c. Neoplasia in miscellaneous tissues
- B. Bacterial diseases
  - 1. Fish
    - a. Vibriosis
    - b. Pseudomonas infections
    - c. Aeromonas infections
    - d. Mycobacteriosis
    - e. Pasteurellosis
    - f. Cornebacteriosis
    - g. Myxobacteriosis
  - 2. Invertebrates
    - a. Diseases caused by gram-negative bacteria
    - b. Disease-causing gram-positive bacteria
- C. Viral diseases
  - 1. Fish
    - a. Lymphocystis disease
    - b. Piscine erythrocytic necrosis virus
    - c. Infectious hematopoietic necrosis virus
  - 2. Invertebrates
    - a. Herpes-type virus
    - b. Unclassified viruses

D. Mycoses
   1. Fish
      a. Ichthyophonus sp.
      b. Saprolegnia sp.
      c. Dermocystidium sp.
   2. Invertebrates
      a. Lagenidium sp.
      b. Dermocystidium sp.
      c. Saprolegnia sp.
      d. Miscellaneous fungal infections

E. Helminthiasis and other parasitic infestations
   1. Fish
   2. Invertebrates

F. Miscellaneous abnormalities of unknown etiology
   1. Fish
      a. Mass mortalities
      b. Fin erosion
      c. Ulcerative dermal necrosis
      d. Ulcerative skin conditions of cod (G. macrocephalus)
      e. Fused viscera of salmonids (Oncorhynchus sp.)
   2. Invertebrates
      a. Oyster mortalities

III. DISEASE RESISTANCE MECHANISMS OF VERTEBRATES AND INVERTEBRATES
   A. Introduction
   B. Innate immunity
      1. Mechanisms in higher vertebrates
         a. External
         b. Internal
      2. Mechanisms in lower vertebrates and invertebrates
         a. External
         b. Internal
   C. Acquired immunity
      1. Mechanisms in higher vertebrates
         a. Humoral
         b. Cellular
      2. Mechanisms in lower vertebrates and invertebrates
         a. Humoral
         b. Cellular
   D. Genetic and environmental influences

IV. EFFECTS OF PETROLEUM ON DISEASE AND DISEASE RESISTANCE
   A. Petroleum and petroleum products implicated in neoplasia
   B. Evidence for tissue and cellular damage resulting from exposure to petroleum
   C. Effects of petroleum hydrocarbons on immune responses and disease resistance

V. PROSPECTUS

VI. REFERENCES

CHAPTER 8. SUBLETHAL BIOLOGICAL EFFECTS OF PETROLEUM HYDROCARBON EXPOSURES: BACTERIA, ALGAE AND INVERTEBRATES

by

Fred Johnson
Environmental Conservation Division

CHAPTER 9. LONG-TERM EFFECTS OF CONTAMINATION BY PETROLEUM AND ITS DERIVATIVES ON FISH

by

Benjamin J. Patten
Environmental Conservation Division

CHAPTER 10. METABOLISM OF PETROLEUM HYDROCARBONS: ACCUMULATION AND BIOTRANSFORMATIONS IN MARINE ORGANISMS

by

Usha Varnasi & Donald C. Malins
Environmental Conservation Division

CHAPTER 11. HABITATS, POPULATIONS, COMMUNITIES AND ECOSYSTEMS

by

Herbert R. Sanborn
Environmental Conservation Division

I. BACKGROUND
   A. Type of oil spilled.
   B. Oil dosage
   C. Oceanographic conditions
   D. Meteorological conditions
   E. Biota of the area
   F. Season
   G. Previous exposure of the area to oil
   H. Method of oil spill cleanup

II. HABITAT
   A. Rocky intertidal
   B. Sandy intertidal
   C. Mud flats
   D. Subtidal
   E. Salt march

III. POPULATIONS AND COMMUNITIES
   A. Plankton
      1. Neuston
      2. Nekton
      3. Benthos
   B. Salt march

IV. ECOSYSTEMS
   A. Estuaries
   B. Coastal areas
   C. Open ocean

V. PROSPECTUS

VI. REFERENCES

CHAPTER 12. OBSERVED EFFECTS BASED ON TYPE OF OIL AND TYPE OF ORGANISM

by

Robert C. Clark, Jr. & John S. Finley
Environmental Conservation Division

CHAPTER 13. FLAVORS IN FISH DERIVED FROM PETROLEUM

by

Maurice E. Stansby
Northwest Fisheries Center

SECTION III

ASSESSMENT OF INTRODUCTION OF ADDITIONAL CADMIUM, LEAD, CHROMIUM, AND NICKEL ON ARCTIC AND SUBARCTIC MARINE ENVIRONMENTS

SUBJECT CLASSIFIED LITERATURE REFERENCES

ON EFFECTS OF OIL POLLUTION IN ARCTIC AND SUBARCTIC WATERS

Prepared by Maurice Stansby and Isabell Diamant, NWFC, as a part of OCSEAP Research Unit 75, September 1976

Partial List of Sources of References

1. Marine Biological Association of the United Kingdom. Bibliography on Marine and Estuarine Oil Pollution, June 1975.
2. OASIS computerized search.
3. American Petroleum Institute Annotated Bibliography of Selected Literature on Fate of Oil in a Water Environment, November 1973.
4. Interim Reports, Beaufort Sea Project, Environment Canada, December 1974.
5. Biological Oil Impact Literature Review. (Baseline Study Program, North Puget Sound, October 1975)
6. Other miscellaneous reports.

Codes for the Above References

1. Numbers only.
2. "N" preceding number.
3. "A" preceding number.
4. "O" preceding number indicates miscellaneous items.
5. "P" preceding number.
6. "O" preceding number indicates miscellaneous items.

PETROLEUM LITERATURE SUBJECT CATEGORY LIST

1. Ice and snow (oil under or on ice and snow, its physical movements, etc., and effects of biota).

2. General effects of cold (background information on effects of lowered temperature on significant parameters).

3. Mortality effects (largely studies where the significant measurement was whether the organism was living or dead; this category also includes general effects and toxicity not specified in the title which may go beyond mortality).

4. Effects on reproduction and growth.

5. Effects on behavior (behavior includes wide range of phenomenon, mostly those determinable by mere observation).

6. Effects on physiological processes (includes also unspecified sublethal effects).

7. Effects on biochemical processes (enzymes, metabolism, et al., also photosynthesis).

8. Effects on microorganisms and their activity (overlap in part - No. 11, Weathering).

9. Pathological effects (disease, carcinogens).

10. Composition of oil (chemical composition of oil and emulsions; also spreading action).

11. Weathering of oil (includes fate of oil studies).

12. Metabolites in oil.

13. Levels of oil components and degradation products (in biota and water; also buildup and release).

14. Sediments, mud, silt (including oil and heavy metals therein, adsorption of oil on silt, and geological aspects).

15. Taint as a flavor in fish from oil pickup.

16. General effects of trace metals (includes levels of trace metals, etc., like 13 for oil).

17. Description of spills and subsequent biota recovery.

18. Effects of oil drilling operations (also from refineries and from natural oil seeps).

19. Analytical methods (methods highly specific to pertinent problems; includes bioassays and model systems for testing toxicity).

20. Miscellaneous (includes very general articles; e.g., ecological effects).

NOTE: There is considerable overlap from one category to another. The first nine categories plus category 14 apply to both oil and trace metals.

INTRODUCTION

Although the list of references compiled and classified in this report is quite extensive, it is by no means a complete list of all references in the field available in the literature. The list was compiled for the purpose of giving a group of scientists at Northwest Fisheries Center, some of whom were not completely familiar with the literature in the oil pollution field, an introduction to some of the important literature in this research area. These scientists were participating in writing critical reviews of certain aspects of the field of petroleum pollution and its impact on the marine environment.

In order to assemble this partial list of references in this field, we leaned heavily upon existing recently-published bibliographical reports. In this connection, the most useful general publication which we found was the Marine Biological Association of the United Kingdom, Bibliography on Marine and Estuarine Oil Pollution, which was current up to April 1975 and contained about 2,300 references. Several other bibliographies were included as well as a computerized search of Biological Abstracts and Chemical Abstracts but covering only the recent years which our Agency's OASIS records have covered in their computerized data bank.

Special attention was paid to inclusion of current, new, important literature. For example, Interim and Final Reports of Environment Canada's Beaufort Sea Project, as they appeared during the compilation of our report, have been added.

Nevertheless, this classified subject bibliography is definitely not a complete one, and we have made no effort to make it so. Rather we have left it up to our scientists involved in the OCSEAP RU-75 critical review preparation to seek for additional literature materials in their respective fields of specializtion to be included in their published reviews.

Originally, primarily because material in this report is not a complete literature search and because it was intended merely as an intermediate step toward another endeavor, we had no plan to reproduce the material for use outside our own research group. There has, however, been so much interest among scientists outside our group who have seen the material and felt that such a report, even though not complete, would be of considerable value that we are reproducing it in its present form.

1. <u>ICE AND SNOW (OIL UNDER OR ON ICE AND SNOW, ITS PHYSICAL MOVEMENTS, ETC., AND EFFECTS ON BIOTA).</u>

136. BARBER, F.G.
Oil spilled with ice: some qualitative aspects.
<u>In</u>: American Petroleum Institute. Proceedings of joint conference on prevention and control of oil spills, Washington, D.C., June 15-17, 1971 pp. 133-137. Washington, D.C., American Petroleum Institute, 1971.

148. GLAESER, J.L., and VANCE, G.P.
A study of the behaviour of oil spills in the Arctic. Final Report. 60p. Washington, D.C., U.S. Coast Guard, Office of Research and Development, Applied Technology Division, 1971.

157. LEWIS, E.L.
Laboratory experiments on freezing of oil and seawater. Esquimalt, British Columbia, Atlantic Oceanographic Laboratory, Frozen Sea Research Group, 1970. (Unpublished report)

160. MASON, C.S.
The behaviour of oil in icy waters. Dartmouth, Nova Scotia, Atlantic Oceanographic Laboratory, 1970. (Unpublished report)

600. MALLET, L., PERDRIAU, L.V., and PERDRIAU, J.
Pollution par les hydrocarbures polybenzéniques du type benzo-3.4 pyrène de la région occidentale de l'Océan Glacial Arctique. (Pollution by polybenzic hydrocarbons of the type benzo-3.4 pyrene of the western region of the glacial Arctic ocean.)
C. r. hebd. Séanc. Acad. Sci., Paris, 256, 3487-3489, 1963.

601. MALLET, L., PERDRIAU, L.V., and PERDRIAU, S.
Etendue des pollutions par les hydrocarbures polybenzéniques du type benzo-3,4-pyrène en Mer du Nord et dans l'Océan Glacial Arctique. (Study of pollution by polybenzic hydrocarbons of the type benzo-3,4-pyrene in the North Sea and in the frozen Arctic Ocean.)
Gull. Acad. natn. Méd., 147, 320-325, 1964.

838. BARBER, F.G.
Oil spills in ice: some cleanup options.
Arctic, <u>23</u>, 285-286, 1970.

1023. GLAESER, J.L.
A discussion of the future oil spill problem in the Arctic.
<u>In</u>: American Petroleum Institute. Proceedings of joint conference on prevention and control of oil spills, Washington, D.C., June 15-17, 1971. pp. 479-484. Washington, D.C., American Petroleum Institute, 1971.

1243. GLAESER, J.L., and VANCE, G.P.
A study of the behavior of oil spills in the Arctic. 14p. Paper presented at the 4th annual offshore technology conference, Houston, Texas, May 1-3, 1972. (Paper No. OTC 1551)

1266. MCCLEAN, A.Y.
The behavior of oil spilled in a cold water environment. 12p. Paper presented at the 4th annual offshore technology conference, Houston, Texas, May 1-3, 1972. (Paper No. OTC 1522)

1285. WOLFE, L.S., and HOULT, D.P.
Effects of oil under sea ice. 38p. Cambridge, Massachusetts, Massachusetts Institute of Technology, Department of Mechanical Engineering, Fluid Mechanics Laboratory, 1972. (Fluid Mechanics Laboratory Publ., No. 72-10)

1534. MARKHAM, W.E.
Project Oil. Report on ice conditions in Lennox Passage. 4p. Dartmouth, Nova Scotia, Atlantic Oceanograpbic Laboratory, 1970. (Unpublished Report)

2300. RAMSEIER, R.O.
Oil pollution in ice-infested waters.
In: Proceedings of the international symposium on the identification and measurement of environmental pollutants, Ottawa, 14-17 June 1971. pp. 271-276.

2313. WOLFE, L.S.
Some effects of oilsspills under sea ice. Cambridge, Massachusetts, Massachusetts Institute of Technology, Department of Mechanical Engineering, 1972. M.S. thesis.

*A 81. CAMPBELL, W.J., and S. MARTIN (1973)
Oil and ice in the Arctic Ocean: Possible large-scale interactions, Science, vol. 181, no. 4094, p. 56-58, 1 illus., 1 tabl., 19 refs.

*A 103. HILL, R. A. W. and J. T. Knight (1965)
A kinetic theory of droplet coalescence with application to emulsion stability, Transactions, Faraday Soc., vol. 61, no. 507, pt. 3, p. 571-576, 10 illus., w0 refs.

*A355. BARBER, F.G. (1971)
Oil spilled with ice: Some qualitative aspects, Proceedings of the joint conference on prevention and control of oil spills, Sponsored by API, EPA, and USCG, June 15-17, Washington, D.C., p. 133-137, 3 illus., 11 refs.

*A393. GLAESER, J.L. (1971)
A discussion of the future oil spill problem in the Arctic, Proceedings of the joint conf. on prevention and control of oil spills, Sponsored by API, EPA, and USCG, June 15-17, Washington, D.C., p. 479-484, 6 illus., 12 refs.

*A394. GLAESER, J.L. and G.P. VANCE (1971)
A study of the behavior of oil spills in the Arctic, Office of Res. and Dev., USCG, Washington, D.C., 60p., 18 illus., 3 tabls., 6 refs.

*A403. McMINN, T.J., and P. GOLDEN (1973)
Behavioral characteristics and cleanup techniques of North Slope crude oil in an arctic winter environment, Proceedings of the joint conf. on the prevention and control of oil spills, Sponsored by API, EPA, and USCG, publ. by Amer. Petrol. Inst., Washington, D.C., p. 263-276, 14 illus., 2 tabls. 9 refs.

1.

*A423. VANCE, G.P. (1971)
Control of Arctic oil spills, Ocean Industry, vol. 6, no. 1, p. 14-17.

*O-5. CAMPBELL, WILLIAM J. and SEELYE MARTIN
Quote from a talk given at U.S. Glaciological panel, U.S. Academy of Sciences, Tucson, Arizona, Nov. 11-12, 1971. Personal communication by William J. Campbell, Ice Dynamics Project, U.S. Geological Survey and Seelye Martin, Dept. of Oceanography, Univ. of Washington.

O-26. BARBER, F.G.
Oil spills in ice: some clean-up options. Arctic 23:285-6, 1970.

O-27. VANCE, G.P.
Control of Arctic Oil Spills. Ocean Industry, January 1971, p. 14-17.

O-40. MILNE, A.R.
An investigation of the entrainment of crude oil in Arctic sea ice. Interim Report as Beaufort Sea Project Study A-5, Dec. 1974.

O-46. TOPHAM, D.R.
The hydrodynamic aspects of an oil well blow-out under sea ice. Interim Report of Beaufort Sea Project Study G2a, Dec. 1974. Environment Canada, Victoria, B.C.

O-48. HUNTER, J.A., H.A. MAC AULAY, R.L. GOOD, R.M. GAGNE, and R.A. BURNS.
The study of frozen seabed material in the Southern Beaufort Sea. Interim Report of Beaufort Sea Project Study F-1, Dec. 1974. Environment Canada, Victoria, B.C.

O-49. LOGAN, W.J.
Oil spill countermeasure study for the Southern Beaufort Sea. Interim Report of Beaufort Sea Project Studies H-1, H2, and H3, 1974. Environment Canada, Victoria, B.C.

O-50. MARKHAM, W.E.
Ice Climatology in the Beaufort Sea. Interim Report of Beaufort Sea Project Study G-1, Dec. 1974. Environment Canada, Victoria, B.C.

O-54. ENVIRONMENTAL PROTECTION AGENCY.
International Symposium on Water Pollution Control in Cold Climates. EPA16100, EXH11/71. Proceedings of a symposium held at the University of Alaska, July 22-24, 1970.

O-55. SALTER, JOHN E., A.G. RONHOODE and L.C. VAN ALLEN.
Book: "Arctic Environment and Resources." Arctic Inst. of N. America, 1619 New Hampsire Ave., N.W., Washington, D.C. 20009, price $10. Good 35-page section on sea ice of especial interest.

O-59. ALEXANDER, VERA, RITA HORNER and R.C. CLASBY.
Metabolism of Arctic Sea Ice Organisms. University of Alaska, MS Report R74-4, 120p.

(NOTE: ** Two asterisks means copy available.)

1. Additions to Classified Literature References as of April 15, 1976.

**0-88. MILNE, A.R. & B.D. SMILEY.
Offshore drilling for oil in the Beaufort Sea: a preliminary environmental assessment. Technical Report No. 39, Beaufort Sea Project. Revised Jan. 20, 1976. Beaufort Sea Project, Dept. of the Environment, 1230 Govt. St., Victoria, B.C. V8W 1Y4.

**0-89. DESLAURIERS, PAUL C.
Oil pollution in ice infested waters (a survey of recent development). September 12, 1975.

**0-90. WALKER, E.R.
Oil, ice and climate in the Beaufort Sea. Beaufort Sea Technical Report #35. December 1975. Beaufort Sea Project, Dept. of the Environment, 512 Federal Bldg., 1230 Govt. St., Victoria, B.C. V8W 1Y4.

0-91. ISAKSON, J.S., J.M. STORIE, J. VAGNERS, G.A. ERICKSON, J.F. KRUGER and R.F. CORLETT.
Comparison of ecological impacts of postulated oil spills at selected Alaskan locations. Introduction, summary, methodology, evaluation and appendices. June 1975, final report, Volume 1. Prepared for Dept. of Transportation, U.S. Coast Guard, Office of Research and Development, Washington, D.C. 20590. (Document is available to the public through the NTIS, Springfield, VA 22151.)

**0-95 RAMSEIER, RENE O.
How to melt the Arctic and warm the world. Environment, Vol. 16, No. 4, May 1974.

0-101. BLISS, L.C.
Oil and the ecology of the Arctic. Transactions of the Royal Society of Canada 8: 371-372(1970) (Dept. of Botany, Univ. of Alberta). (Good article.)

0-105. HOLMES, ROBERT W., EDITOR.
Oil pollution - an index, 4 vol., 2 by author, 2 by subject. Library code SZ 7173-W-3 037 or GC 1087-C3.

1595. RAMSEIER, R.O.
Oil spill at Deception Bay, Hudson Strait. (Preliminary Report.) Arctic Circular (Ottawa, Vol. 21, 1, p. 22-27(1971) (mimeograph).

0-117. BOYD, HUGH.
Oil poses urgent problems in Canada. Mar. Poll. Bull. 1(5), p. 69-71 (May 1970).

0-118. ANONYMOUS.
Arctic oil spills. Chem. and Engr. News 49(23): p. 28(1971).

(NOTE: **Two asterisks means copy available.)

1. Additions to Classified Literature References as of 4/26/76.

*0-133. EKELUND, MR. & DAVID JOHNSON.

(1)

EVENT	[illegible]	ST. LOUIS BAY OIL SPILL	25 APRIL 197[illegible]	2[illegible]

EVENT NOTIFICATION REPORT

CATEGORY	[illegible]
EVENT DATE	21 [illegible] 1976
LOCATION	Superior, Wisconsin, USA (42°42'N, 92°05'W)
SOURCE	Mr. Ekelund US Coast Guard, MSO Canal Park Duluth, Minnesota [illegible], USA David Johnson Wisconsin DNR Ranger Station Route 2, Box 3 Hayward, Wisconsin 54843, USA

On 21 February 1976, Standard Oil Co. notified the Wisconsin Department of Natural Resources that No. 2 fuel oil had spilled from a Standard pipeline in Superior, Wisconsin. The [illegible] pipeline is used to transport oil from a Standard dock on St. Louis Bay off Lake Superior to a Standard tank farm 2.5 km away. The pipeline contains several check valves [illegible] oil to flow only in one direction, from the dock [illegible] Investigators determined [illegible] 19 and 20 February, approximately [illegible] liters of oil had [illegible] through a cracked [illegible] valve, [illegible] from the dock. According to a Standard [illegible], [illegible] check valve, 30 meters from the cracked valve, was malfunctioning, allowing approximately 113,500 liters of oil from an 0.9-km-long [illegible] to drain towards the dock past the malfunctioning valve and spill out through the cracked valve. Since the oil that initially [illegible] from the pipeline was less than the total spill volume, the Standard spokesman speculated that additional oil spilled when Standard refilled the line during oil transfer operations a day or two prior to the spill discovery.

Most of the spilled oil drained into a snow-filled ditch under the pipeline. The ditch empties into St. Louis Bay at the Standard dock, 0.6 km from the cracked valve. A small volume of oil reached the bay, which had an ice cover 45 to 60 cm thick.

Standard hired [illegible] Brothers Trucking Co. (Superior, Wisconsin) to conduct the cleanup operations. Oil was pumped from the ditch with vacuum trucks. Oil-saturated snow and earth were removed from the ditch and placed behind a dike for further treatment. A portable pump was used to recover oil from the ice on St. Louis Bay. Observation holes were drilled in the ice, and a small volume of oil was pumped off through the holes. Approximately 2,000 liters of oil which could not be pumped off the ice were burned on 22 and 23 February. As of 4 April, approximately 227,000 liters of oil had been recovered. The recovered oil will be recycled at a nearby Standard refinery. A Coast Guard cutter broke ice around the Standard dock, and, as soon as the ice moves away from the area, Standard plans to install a boom to contain any spilled oil remaining in the bay.

The Center for Short-Lived Phenomena

[illegible] Alewife Brook Parkway Cambridge Mass 02138 U.S.A. Phone [illegible]

1. Additions to Classified Literature References as of 6/29/76.

0-141 AYERS, R.C., JR., H.O. JAHNS, J.L. GLAESER, S. MARTIN and W.J. CAMPBELL, 1974
Oil spills in the Arctic Ocean: extent of spreading and possibility of large-scale thermal effects. Science 186:843-846 (two parts: first part, pp. 843-844 by first three authors addressing previous article by Martin and Campbell, who then reply in pp. 845-846--second part. Therefore citation (above) may be incorrect).

0-142 MACKAY, D., P.J. LEINONEN, J.C.K. OVERALL and B.R. WOOD, 1975
The behavior of crude oil spilled on snow. Arctic, Journal of the Arctic Institute of North America 28:9-20.

0-143 MILLIMAN, J.D., 1975
Arctic environment (a review of: The Coast and Shelf of the Beaufort Sea. Proceedings of a symposium, San Francisco, J. 1974. John C. Reed, John E. Sater and Wade W. Gunn, Eds.) Arctic Institute of North America, Arlington, VA, 1974. 750 p. Illus. Science 189:1081.

2. GENERAL EFFECTS OF COLD (BACKGROUND INFORMATION ON EFFECTS OF LOWERED TEMPERATURE ON SIGNIFICANT PARAMETERS).

148. GLAESER, J.L., and VANCE, G.P.
A study of the behaviour of oil spills in the Arctic. Final Report. 60p. Washington, D.C., U.S. Coast Guard, Office of Research and Development, Applied Technology Division, 1971.

1526. WONG, C.S., CRETNEY, W.J., MACDONALD, R.W., and ERICKSON, P.

Baseline information on chemical oceanography and petroleum-based hydrocarbons in the Southern Beaufort Sea. 51p. Victoria, B.C., Environment Canada, Ocean Chemistry Division, Ocean and Aquatic Affairs, Pacific Region, 1974. (Interim Report)

1534. MARKHAM, W.E.
Project Oil. Report on ice conditions in Lennox Passage. 4p. Dartmouth, Nova Scotia, Atlantic Oceanographic Laboratory, 1970. (Unpublished Report)

2037. ATLAS, R.M., and BARTHA, R.
Biodegradation of petroleum in seawater at low temperatures. Can. J. Microbiol., 18, 1851-1855, 1972.

2054. CUNDELL, A.M., and TRAXLER, R.W.
Microbial degradation of petroleum at low temperatures. Mar. Pollut. Bull., 4, 125-127, 1973.

2066. GIBBS, C.F., PUGH, K.B., and ANDREWS, A.R.
Quantitative studies on marine biodegradation of oil. II. Effect of temperature. Proc. R. Soc. Lond., (B), 188, 83-94, 1975.

2113. TRAXLER, R.W.
Bacterial degradation of petroleum materials in low temperature marine environments. In: Ahearn, D.G., and Meyers, S.P., editors. The microbial degradation of oil pollutants. Proceedings of a workshop, Atlanta, Georgia, 4-6 December 1972. pp. 163-170. Baton Rouge, Louisiana, Louisiana State University, Center for Wetland Resources, 1973.

2123. ZOBELL C.E.
Bacterial degradation of mineral oils at low temperature. In: Ahearn, D.G., and Meyers, S.P., editors. The microbial degradation of oil pollutants. Proceedings of a workshop, Atlanta, Georgia, 4-6 December 1972. pp. 153-161. Baton Rouge, Louisiana, Louisiana State University, Center for Wetland Resources, 1973.

2125. ZOBELL, C.E., and AGOSTI, J.
Bacterial oxidation of mineral oils at sub-zero Celsius. 10p. Paper prepared for presentation at the 72nd annual meeting, American Society for Microbiology, Philadelphia, Pennsylvania, 24 April 1972.

2242. SWIFT, W.H., BROWN, R.E., KIMMEL, L.V., ORGILL, M.M., PETERSON, P.L., and WADDELL, W.W.
Geographical analysis of oil spill potential associated with Alaskan oil production and transportation systems. 267p. Washington, D.C., US Coast Guard, Office of Research and Development, 1974. (Final Report No. CG-D-79-74)

2287. MCMINN, T.J., and GOLDEN, P.
Behavioural characteristics and cleanup techniques of North Slope crude oil in an Arctic winter environment.
In: American Petroleum Institute. Proceedings of joint conference on prevention and control of oil spills, Washington, D.C., March 13-15 1972. pp. 263-276. Washington, D.C., American Petroleum Institute, 1973.

---

*A213. ATLAS, R.M., and R. BARTHA (1972)
Biodegradation of petroleum in seawater at low temperatures, Canada Jour. Microbiol., vol. 18, p. 1851-1855, 5 illus., 14 refs.

*A315. ZoBELL, C.E. (1973)
Bacterial degradation of mineral oils at low temperature. In: The microbial degradation of oil pollutants, D.G. Ahearn and S.P. Meyers (eds.), Center for Wetland Resources, Louisiana State Univ., publ. no. LSU-SG-73-01, p. 153-161, 2 illus., 3 tabls., 17 refs.

*A356. BARRY, T.W. (1970).
Likely effects of oil in the Canadian Arctic, Mar. Pollut. Bull., vol. 1, no. 5, p. 73-74, 1 illus.

*A393. GLAESER, J.L.
1971. A discussion of the future oil spill problem in the Arctic, Proceedings of the joint conf. on prevention and control of oil spills, Sponsored by API, EPA, and USCG, June 15-17, Washington, D.C., p. 479-484, 6 illus., 12 refs.

*394. GLAESER, J.L., and G.P. VANCE
1971. A study of the behavior of oil spills in the Arctic, Office of Res. and Dev., USCG, Washington, D.C., 60 p., 18 illus., 3 tabls., 6 refs.

*A403. McMINN, T.J., and P. GOLDEN (1973)
Behavioral characteristics and cleanup techniques of North Slope crude oil in arctic winter environment, Proceedings of the joint conf. on the prevention and control of oil spills, Sponsored by API, EPA, and USCG, publ. by Amer. Petrol. Inst., Washington, D.C. p. 263-276, 14 illus., 2 tabls., 9 refs.

*A423. VANCE, G.P. (1971)
Control of Arctic oil spills, Ocean Industry, vol. 6, no. 1, p. 14-17.

*A431. FARRELL, J., and A. ROSE (1967).
Temperature effects on microorganisms, Annual Review of Microbiology, vol. 21, p. 101-120, 190 refs.

2.

N3707-3. GIBBS, C. F., K. B. PUGH, and A. R. ANDREWS (1974)
Quantitative studies on marine biodegradation of oil. II. Effect of temperature, Proc. R. Soc. London, Ser. B, vol. 188, no. 1090, p. 83-94.

N3726-1. TRAXLER, F. W. (1973)
Bacterial degradation of petroleum materials in low temperature marine environments, Microbial Degradation Oil Pollutants, Workshop, p. 163-170.

N3733-1. CUNDELL, A. M., and R. W. TRAXLER (1973)
Microbial degradation of petroleum at low temperature, Mar. Pollut. Bull., vol. 4, no. 8, p. 125-127.

N3746-1. PEAKE, E., M. STROSHER, B. L. BAKER, R. GOSSEN, R. G. McCROSSEN, C. J. YORATH, and G. W. HODGSON (1972)
Potential of Arctic sediments. Hydrocarbons and possible precursors in Beaufort Sea sediments, Int. Geol. Congr. Rep., Sess. 24th, Series 5, p. 28-37.

N3757-1. ATLAS, R. M., and R. BARTHA (1972)
Biodegradation of petroleum in seawater at low temperatures, Can. J. Microbiol., vol. 18, no. 12, p. 1851-1855.

O-5. WOLFE, L. STEPHEN and DAVID P. HOULT.
Effects of oil under ice. Fluid Mechanics Lab., Dept. Mech. Eng., MIT, J. of Glaciology 13, No. 69: 473-88(1974). Considerable mathematical treatment but still be worth getting.

O-19. DEVRIES, A.L. and G.N. SOMERO
Symposium on Antarctic ice and water masses. Tokyo, Japan, Sept. 19, 1970. The only item which is of border interest if "The physiology and biochemistry of low temperature adaptation in Antarctic marine organisms."

O-54. ENVIRONMENTAL PROTECTION AGENCY.
International symposium on water pollution control in cold climates. EPA 16100, EXH 11/71. Proceedings of a cymposium held at the University of Alaska, July 22-24, 1970.

O-69. DAYTON, P.K., G.A. ROBILLIARD, and A.L. DEVRIES. 1969.
Anchor ice formation in McMurdo Sound, Antarctica and its biological effects. Science, Vol. 163, p. 273-74.

O-70. DE VRIES, A.L. 1969.
Freezing resistance in fishes of the Antarctic peninsula. Antarctic J. U.S., Vol. 4, p. 104-5.

O-71. DE VRIES, A.L. 1970.
Freezing resistance in Antarctic fishes. In: Antarctic Ecology, Ed. M. Holdgate, Vol. 1, Academic Press, New York, p. 320-28.

O-72. DE VRIES, A.L. 1971a.
Freezing resistance in fishes. In: Fish Physiology, Eds., D. Randall and W. Hoar, Vol. VI, in press.

0-73. DE VRIES, A.L. 1971b.
Glycoproteins as biological antifreeze agents in Antarctic fishes. Science, Vol. 172, p. 1152-55.

0-74. DE VRIES, A.L. and D.E. WOHLSCHLAG. 1969.
Freezing resistance in some Antarctic fishes. Science, Vol. 163, p. 1073-75.

0-75. DE VRIES, A.L., S. K. KOMATSU, and R.E. FEENEY. 1970.
Chemical and physical properties of freezing point-depressing glycoproteins from Antarctic fishes. J. Biol. Chem., Vol. 245, p. 2901-8.

0-76. DE VRIES, A.L., J. VANDENHEEDE and R.E. FEENEY. 1971.
Primary structure of freezing point-depressing glycoproteins. J. Biol. Chem., Vol. 246, p. 305-9.

0-77. KOMATSU, S.K., A.L. DE VRIES, and R.E. FEENEY. 1970.
Studies of the structure of freezing point-depressing glycoproteins from an Antarctic fish. J. Biol. Chem., Vol. 245, p. 2909-13.

0-78. RAY, C. and M.S.R. SMITH. 1968.
Thermoregulation of the pup and adult Weddell seal, *Leptonychotes weddelli* (Lesson), in Antarctica. J. Biol. Chem., Vol. 245, p. 2909-13.

0-79. SMITH, R.N. 1970.
The biochemistry of freezing resistance of some Antarctic fish. In: Antarctic Ecology, Ed. M. Holdgate, Vol. 1, Academic Press, New York, p. 329-3(

0-80. SOMERO, G.N. 1969a.
Enzymic mechanisms of temperature compensation: immediate and evolutionary effects of temperature on enzymes of aquatic poikilotherms. American Naturalist, Vol. 103, p. 517-30.

0-81. SOMERO, G.N. 1969b.
Pyruvate kinase variants of the Alaskan king crab: evidence for a temperature-dependent interconversion between two forms having distinct and adaptive kinetic properties. Biochemical Journal, Vol. 114, p. 237-41.

0-82. SOMERO, G.N. and A.L. DE VRIES. 1967.
Temperature tolerance of some Antarctic fishes. Science, Vol. 156, p. 257-58.

0-83. SOMERO, G.N., A.C. GIESE and D.E. WOHLSCHLOAG. 1968.
Cold adaptation of the Antarctic fish *Trematomus bernacchii*. Comparative Biochemistry and Physiology, Vol. 26, p. 223-33.

0-84. SOMERO, G.N. and P.W. HOCHACHKA. 1968.
The effect of temperature on catalytic and regulatory functions of pyruvate kinases of the rainbow trout and the Antarctic fish *Trematomus bernacchii*. Biochemical Journal, Vol. 110, p. 395-400.

0-85. DE VRIES, ARTHUR L. and GEORGE N. SOMERO. 1970.
The physiology and biochemistry of low temperature adaptation in Antarctic marine organisms. Scripps Institution of Oceanography, University of California at San Diego, La Jolla, California 92037.

(NOTE: **Two asterisks means copy available.)

2. Additions to Classified Literature References as of 4/26/76.

**0-36. PERCY, J.A. and T.C. MULLIN.
Effects of crude oils on arctic marine invertebrates. Arctic Biological Station, Fisheries and Marine Service, Dept. of the Environment, P.O. Box 400, Ste. Anne de Bellevue, Quebec. Beaufort Sea Technical Report #11, Beaufort Sea Project, Dept. of the Environment, 512 Federal Building 1230 Government St., Victoria, B.C. V8W 1Y4, December 1975.

(NOTE: **Two asterisks means copy available.)

2. Additions to Classified Literature References as of 3/31/76.

*0-95. RAMSEIER, RENE O.
How to melt the Arctic and warm the world. Environment, Vol. 16, No. 4, May 1974.

2. Additions to Classified Literature References as of 7/8/76.

0-144 BROWN, V.M., D.M.H. JORDAN, and B.A. TILLER, 1967
The effect of temperature on the acute toxicity of phenol to rainbow trout. Water Research 1:587-594.

0-145 BUSDOSH, M. and R.M. ATLAS, 1975
Response of two Arctic amphipods, Gamarus Zaddachi and Boeckosimus (Onisimus) affinis, to variations in temperature and salinity. J. Fish. Res. Board Can. 32:2564-2568.

0-146 ATLAS, R.M. and E.A. SCHOFIELD, 1975
Petroleum biodegradation in the Arctic. In: Bourquin, A.W., S.P. Meyers and D.G. Ahearn (eds?), Impact of the use of microorganisms on the aquatic environment. Proceedings of workshop-symposium held at Pensacola Beach, FL, April, 1974. EPA, Gulf Breeze Environmental Research Laboratory. EPA 660-3-75-001, Jan. 1975. Govt. Report No. PB 240 159, pp. 183-198.

3. MORTALITY EFFECTS (LARGELY STUDIES WHERE THE SIGNIFICANT MEASUREMENT WAS WHETHER THE ORGANISM WAS LIVING OR DEAD: THIS CATEGORY ALSO INCLUDES GENERAL EFFECTS AND TOXICITY NOT SPECIFIED IN THE TITLE WHICH MAY GO BEYOND MORTALITY).

49. TURNER, C.H., CARLISLE, J.G., Jr., and EBERT, E.E.
Offshore oil drilling, its effect upon the marine environment.
Sacramento, California Department of Fish and Game, Marine Resources Operations, 1962.

348. DOUGLAS, N.H.
Evaluation and relative resistance of sixteen species of fish as test animals in toxicity bioassays of petroleum refinery effluents. 56p.
Oklahoma State University, 1963. (Ph.D. thesis)

351. GRAHAM, R.J., and DORRIS, T.C.
Long-term toxicity bioassay of oil refinery effluents.
Wat. Res., 2, 643-663, 1968.

357. MACADAM, S.
On the poisonous nature of crude paraffin oil and the products of its rectification upon fish.
Rep. Br. Ass. Advmt Sci., 36, 41-43, 1866.

358. MALACEA, I., CURE, V., and WEINER, L.
Contributii la cunoasterea actiunii vatamatoare a titeiului, acizilor naftenici si fenolilor asupra unor pesti si a crustaceului Daphnia magna Straus. (Contributions to the knowledge of the noxious action of oil, naphthenic acids and phenols on certain fish and a crustacea Daphnia magna Straus.) (In Romanian, with English summary.) Studii Prot. Epur. Apelor., 5, 353-397 & 402-405, 1964.

363. REICHENBACH-KLINKE, H.
Auswirkung von Öl- und Teerprodukten im Wasser auf den Fischorganismus. (The effect of oil and petrochemical products in the sea on fish organisms.)
Münchn Beitr. Abwass. Fisch.-Flussbiol., 9, 73-91, 1962.

366. VISHNEVETSKII, F.E.
The pathological morphology of the poisoning of fish by phenol and water soluble components of crude oil, coal tar and fuel oil. (In Russian)
Trusy astrakh. gos. Zapovednika, 5, 350-352, 1961.

367. WARD, C.M.
The relative resistance of fifteen species of fishes to petroleum refinery effluent and the suitability of the species as test animals.
vi, 71p. Oklahoma State University, 1962. (Ph.D. Thesis)

369. ZITKO, V., and TIBBO, S.N.
Fish kill caused by an intermediate oil from coke ovens.
Bull. Envir. Contam. Toxicol., 6, 24-25, 1971.

374. EMERY, R.M.
The comparative acute toxicity of cresol to two benthic crustaceans.
Water Res., 4, 485-491, 1970.

375. GALTSOFF, P.S., PRYTHERCH, H.F., SMITH, R.O., and KOEHRING, V.
Effects of crude oil pollution on oysters in Louisiana waters.
Bull. Bur. Fish., Wash., 48, 143-210, 1935.

376. GOWANLOCH, J.N.
Pollution by oil in relation to oysters.
Trans. Am. Fish. Soc., 65, 293-296, 1935.

377. GRIFFITH, D. de G.
Toxicity of crude oil and detergents to two species of edible molluscs under artificial tidal conditions. 12p. (Preprint of a paper presented at the F.A.O. Technical Conference on marine pollution and its effects on living resources and fishing, Rome, 9-18 December 1970.) (FIR : MP/70/E-16)

379. LEENHARDT, H.
De l'action du mazout sur les coquillages. (The effect of fuel oil on shell-fish.)
Rapp. P.-v. Reun. Cons. perm. int. Explor. Mer, 35, 56-58, 1925.

380. LUND, E.J.
Effect of bleedwater, "soluble fractions" and crude oil on the oyster.
Publs. Inst. mar. Sci. Univ. Tex., 4, 328-341, 1957.

383. MACKIN, J.G.
A study of the effect on oysters of a heavy surface water layer of crude oil. Texas A and M Research Foundation, 1948. (Project Nine - unpublished report)

384. MACKIN, J.G.
Report on a study to determine the effect of subjecting oysters to continuous contact with oil soaked mud. Texas A and M Research Foundation, 1948. (Project Nine - unpublished report)

385. MACKIN, J.G.
Report on a study of the effect of subjecting oysters to continuous applications of emulsified crude oil. Texas A and M Research Foundation, 1948. (Project Nine - unpublished report)

389. MACKIN, J.G.
Report on experiments to determine the effect on oysters of heavy dosages of crude oil over short periods ot time. Texas A and M Research Foundation, 1949. (Project Nine - unpublished report)

390. MACKINS, J.G.
A comparison of the effect of application of crude petroleum to marsh plants and to oysters. Texas A and M Research Foundation, 1950. (Project Nine - unpublished report)

3.

391. MACKIN, J.G.
A report on three experiments to study the effect of oil bleedwater on oysters under aquarium conditions. Texas A and M Research Foundation, 1950. (Project Nine - unpublished report)

392. MACKIN, J.G.
The effect of crude petroleum on oysters heavily infected with Polydora, Cliona, and Martesia. Texas A and M Research Foundation, 1950. (Project Nine - unpublished report)

393. MACKIN, J.G.
Effects of crude oil and bleedwater on oysters and aquatic plants. Texas A and M Research Foundation, 1950.

394. MACKIN, J.G.
A study of the effect of barium sulphate on oysters and some other organisms. Texas A and M Research Foundation, 1950. (Project Nine - unpublished report)

396. MACKIN, J.G.
Studies on the effect of Quebracho on oysters. Texas A and M Research Foundation, 1951. (Project 23 - unpublished report)

397. MACKIN, J.G., and HOPKINS, S.H.
Results of the Projects Nine and 23, a summary report. Volume I. Text. 200 p. Texas A and M Research Foundation, 1958. (Project 23E - unpublished report)

398. MACKIN, J.G., and HOPKINS, S.H.
Studies on oyster mortality in relation to natural environments and to oil fields in Louisiana.
Publs Inst. Mar. Sci. Univ. Tex., 7, [illegible]-131, 1961.

399. MACKIN, J.G., and SPARKS, A.K.
A study of the effect on oysters of crude oil loss from a wild well.
Publs Inst. Mar. Sci. Univ. Tex., 7, 230-261, 1962.

400. MACKIN, J.G., WELCH, B., and KENT, C.
A study of mortality of oysters of the Buras area of Louisiana. 41p. Texas A and M Research Foundation, 1950. (Project Nine - unpublished report)

401. MACKIN, J.G., and WRAY, D.C.
A study of mortality and mortality-producing agents in Barataria Bay, Louisiana. Texas A and M Research Foundation, 1949. (Project Nine - unpublished report)

402. MACKIN, J.G., and WRAY, D.A.
Report on the second study of the mortality of oysters in Barataria Bay, Louisiana, and adjacent areas. Pt. I. Texas A and M Research Foundation, 1950. (Project Nine - unpublished report)

405. MENZEL, R.W.
Effect of deep well gas on the mortality and growth of oysters. 7 p. Texas A and M Research Foundation, 1949. (Project Nine - unpublished report)

406. MENZEL, R.W.
The attachment, survival, and growth of oyster spat on oil-impregnated wood. Texas A and M Research Foundation, 1949. (Project Nine - unpublished report)

412. MENZEL, R.W., and HOPKINS, S.H.
Report on commercial scale oyster planting experiments in Bayou Bas Bleu and in Bay Ste. Elaine oil field. Texas A and M Research Foundation, 1952. (Project Nine - unpublished report)

413. MENZEL, R.W., and HOPKINS, S.H.
Report on oyster experiments at Bay Ste. Elaine oil field. Texas A and M Research Foundation, 1953. (Project Nine - unpublished report)

414. MILLS, E.R., Jr.
The acute toxicity of various crude oils and oil spill removers on two genera of marine shrimp. Louisiana State University, 1970.

415. MIRONOV, O.G.
The effect of oil and oil products upon some molluscs in the littoral zone of the Black Sea. (In Russian, with English summary)
Zool. Zh., 46, 134-136, 1967.

417. PRYTHERCH, H.F.
Report of investigation of oyster mortality in Louisiana in relation to oilwell operations. Unpublished report to U.S. Bureau of Fisheries. Washington, D.C., 1933.

418. ROGER, E.
Contribution à l'étude des pollutions des mollusques par les produits pétroliers. (Contribution to the study of the pollution of molluscs by petroleum products.)
Symp. Commn int. Explor. scient. Mer Medit., Monaco, 1964, 367-369, 1965.

419. SIMPSON, A.C.
Oil, emulsifiers and commercial shell fish.
Fld Stud., 2, (suppl.), 91-98, 1968.

423. BROWNELL, R.L., Jr.
Whales, dolphins and oil pollution.
In: Allan Hancock Foundation. Biological and oceanographical survey of the Santa Barbara Channel oil spill 1969-1970. Vol. 1, compiled by D. Straughan. pp. 255-276. Allan Hancock Foundation, University of Southern California, 1971.

3.

424. BROWNELL, R.L., Jr., and LE BOEUF, B.J.
California sea lion mortality: natural or artifact?
In: Allan Hancock Foundation. Biological and oceanographic survey of the San Barbara Channel oil spill 1969-1970. Vol. 1, compiled by D. Straughan. pp. 287-306. Allan Hancock Foundation, University of Southern California, 1971.

445. GRANT, E.M.
Notes on an experiment upon the effect of crude oil on live corals.
Fish. Notes, Qd, (N.S.), 1, 3p., 1970.

446. GUTSELL, J.S.
Danger to fisheries from oil and tar pollution of waters.
Rep. U.S. Commnr Fish., (Append. 7), 10p., 1921.

449. JENKINS, C.R.
A study of some toxic components in oil refinery effluents.
73p. Oklahoma State University, 1964. (Ph.D. thesis)

456. LE BOEUF, B.
Oil contamination and elephant seal mortality: a "negative" finding.
In: Allan Hancock Foundation. Biological and oceanographical survey of the Santa Barbara Channel oil spill 1969-1970. Vol. 1, compiled by D. Straughan. pp. 277-285. Allan Hancock Foundation, University of Southern California, 1971.

457. LEWIS, J.B.
Effect of crude oil and oil-spill dispersant on reef corals.
Mar. Pollut. Bull., 2, 29-62, 1971.

459. MANSFIELD, A.W.
Field reports of seal investigations in Chedabucto Bay and at Sable Island, Nova Scotia. Quebec, Fisheries Research Board of Canada, 1970. (Unpublished report)

466. OTTWAY, S.
The comparative toxicities of crude oils.
In: Cowell, E.B., editor. Proceedings of the symposium on the ecological effects of oil pollution on littoral communities, London, 30 November-1 December, 1970. London, Institute of Petroleum, 1971.

491. BAKER, J.M.
Comparative toxicities of oils, oil fractions, and emulsifiers.
In: Cowell, E.B., editor. Proceedings of the symposium on the ecological effects of oil pollution on littoral communities, London, 30 November-1 December, 1970. London, Institute of Petroleum, 1971.

503. CURRIER, H.B., and PEOPLES, S.A.
Phytotoxicity of hydrocarbons.
Hilgardia, 23, 155-173, 1954.

3.

542. LANE, F.W., BAUER, A.D., FISHER, H.F., and HARDING, P.N.
Effect of oil pollution on marine and wild life.
Rep. U.S. Commnr Fish., 1925, 171-181, 1925.

543. L'HARDY, J.-P.
La pollution des océans par les hydrocarbures et ses consequences biologiques. (Pollution of the oceans by hydrocarbons and its biological consequences.)
Penn Bed, 6, 123-138, 1967.

544. LÜDEMANN, D.
Gewässerverschmutzung durch Aussenbordmotoren und deren Wirkung auf Fauna und Flora. (Water pollution by outboard motors and its effects on fauna and flora.)
Helgolander wiss. Meeresunters., 17, 356-369, 1968.

545. MANWELL, C., and BAKER, C.M.A.
Oil and detergent pollution, past, present, politics and prospects.
J. Devon Trust Nat. Conserv., (July suppl.), 39-72, 1967.

546. MIRONOV, O.G.
Hydrocarbon pollution of the sea and its influence on marine organisms.
Helgolander wiss. Meeresunters., 17, 335-339, 1968.

547. MIRONOV, O.G.
Biological aspects of pollution of the seas with oil and oil products.
26p. Moscow State University, 1970. (Synopsis of thesis.) (In Russian)

551. MURPHY, T.A.
Environmental effects of oil pollution. Paper presented to the Session on Oil Pollution Control, American Society of Civil Engineers, Boston, Mass., July 13, 1970. 27p. Washington, D.C., Federal Quality Administration, 1970.

553. NELSON-SMITH, A.
The effects of oil pollution and emulsifier cleansing on shore life in south-west Britain.
J. appl. Ecol., 5, 97-107, 1968.

554. NELSON-SMITH, A.
Biological consequences of oil pollution and shore cleansing.
Fld Stud., 2, (suppl.), 73-80, 1968.

555. NELSON-SMITH, A.
Effects of oil on marine plants and animals.
In: Hepple, P., editor. Water pollution by oil: proceedings of a seminar held at Aviemore... 4-8 May, 1970. pp. 273-280.
London, Institute of Petroleum, 1971.

556. NEUSHUL, M., Jr.
Effects of pollution on populations of intertidal and subtidal organisms. Paper presented at Santa Barbara oil symposium, offshore petroleum production - an environmental inquiry, Santa Barbara, California, 16-18 December, 1970.

559. ORTON, J.H.
Effects on marine organisms of oils discharged at sea.
Nature, Lond., 115, 910-911, 1925.

580. TARZWELL, C.M.
Toxicity of oil and oil dispersant mixtures to aquatic life.
In: Hepple, P., editor. Water pollution by oil: proceedings of a seminar held at Aviemore... 4-8 May, 1970. pp. 263-272.
London, Institute of Petroleum, 1971.

699. BONEY, A.D.
Toxicity studies with an oil-spill emulsifier and the green alga *Prasinocladus marinus*.
J. mar. biol. Ass. U.K., 50, 461-473, 1970.

700. BRYAN, G.S.
The effects of oil-spill removers ('detergents') on the gastropod *Nucella lapillus* on a rocky shore and in the laboratory.
J. mar. biol. Ass. U.K., 49, 1067-1092, 1969.

703. CHADWICK, H.K.
Toxicity of Tricon oil spill eradicator to stripped bass (*Roccus saxatilis*).
Calif. Fish Game, 46, 371-372, 1960.

704. CORNER, E.D.S., SOUTHWARD, A.J., and SOUTHWARD, E.C.
Toxicity of oil-spill removers ('detergents') to marine life: an assessment using the intertidal barnacle *Eliminius modestus*. J. Mar. biol. Ass. U.K., 38, 29-47, 1968.

705. CRAPP, G.B.
The biological consequences of emulsifier cleaning.
In: Cowell, E.B., editor. Proceedings of the symposium on the ecological effects of oil pollution on littoral communities, London, 30 November-1 December, 1970.
London, Institute of Petroleum, 1971.

706. CRAPP, G.B.
Laboratory experiments with emulsifiers.
In: Cowell, E.B., editor. Proceedings of the symposium on the ecological effects of oil pollution on littoral communities, London, 30 November-1 December, 1970.
London, Institute of Petroleum, 1971.

707. DOWDEN, B.F.
Toxicity of commercial waste-oil emulsifiers to *Daphnia magna*.
J. Wat. Pollut. Control Fed., 34, 1010-1014, 1962.

3.

708. EISLER, R.
Some effects of a synthetic detergent on estuarine fishes.
Trans. Am. Fish. Soc., 94, 26-31, 1965.

709. ENGEL, R.H., and NEAT, M.J.
Toxicity of oil dispersing agents determined in a circulating aquarium system.
In: American Petroleum Institute. Proceedings of joint conference on prevention and control of oil spills, Washington, D.C., June 15-17, 1971. pp. 297-302.
Washington, D.C., American Petroleum Institute, 1971.

710. FORET-MONTARDO, P.
Etude de l'action des produits de base entrant dans la composition des détergents issus de la pétroléchimie vis-à-vis de quelques invertebrés benthiques marins. (Study of the action of basic groups involved in the composition of detergents issued from oil-chemistry towards several benthic marine invertebrates.)
Tethys, 2, 567-614, 1970 (1971).

712. GOLDACRE, R.J.
The effects of detergents and oils on the cell membrane.
Fld Stud., 2, (suppl.) 131-137, 1968.

720. LATIFF, S.A.
Preliminary results of experiments on the toxicity of oil counteracting agent (Esso Corexit 7664), with and without Iraq crude oil, for selected members of marine plankton.
Arch. FischWiss., 20, 182-185, 1969.

723. MARCHETTI, R.
Critical review of the effects of synthetic detergents on aquatic life.
Stud. Rev. gen. Fish. Coun. Mediterr., 26, 32p., 1965.

727. PEETERS, E.
Le problème biologique de la lutte contre les hydrocarbures par tensioactifs. (The biological problem in the utilization of detergents in actions against hydrocarbons.)
In: North Atlantic Treaty Organization, Committee on the Challenges of Modern Society. Colloquium on pollution of the sea by oil spills, N.A.T.O. Headquarters, Brussels, 2-6 November 1970. pp. 22.1-22.7.
N.A.T.O. 1970.

729. PERKINS, E.J.
The toxicity of oil emulsifiers to some inshore fauna.
Fld Stud., 2, (suppl.), 81-90, 1968.

730. PERKINS, E.J.
Some effects of detergents in the marine environment.
Chemy. Ind., 14-22, 3 January 1970.

731. PORTMANN, J.E., and CONNOR, P.M.
The toxicity of several oil-spill removers to some species of fish and shellfish.
Mar. Biol., 1, 322-329, 1968.

734. SPOONER, M.F.
Preliminary work on comparative toxicities of some oil spill dispersants and a few tests with oils and Corexit. 31p.
Plymouth Marine Biological Association of U.K., 1968.

735. SPRAGUE, J.B.
Toxicity testing of dispersants. St. Andrews, New Brunswick, Fisheries Research Board of Canada, 1970. (Unpublished report)

736. SPRAGUE, J.B., and CARSON, W.G.
Toxicity tests with oil dispersants in connection with oil spill at Chedabucto Bay, Nova Scotia.
Tech. Rep. Fish. Res. Bd Can., No. 201, 30p.,1970.

738. TRACY, H.B., LEE, R.A., WOELKE, C.E., and SANBORN, G.
Relative toxicities and dispersing-evaluations of eleven oil-dispersing products.
J. Wat. Pollut. Control Fed., 41, 2062-2069, 1969.

739. TRITES, R.W.
Summary statement on toxicity of oil dispersants. Dartmouth, Nova Scotia, Marine Ecology Laboratory, 1970. (Unpublished report)

741. WILSON, D.P.
Temporary adsorption on a substrate of an oil-spill remover ('detergent'): tests with larvae of Sabellaria spinulos.
J. mar. biol. Ass. U.K., 48, 183-186, 1968.

742. WILSON, K.W.
The toxicity of oil-spill dispersants to the embryos and larvae of some marine fish. 7p. (Preprint of a paper presented at the F.A.O. Technical Conference on marine pollution and its effects on living resources and fishing, Rome, 9-18 December 1970.) (FIR : MP/70/E-45)

1286. YENTSCH, C.S., GILFILLAN, E.S., and SEARS, J.R.
The fate and behavior of crude oil on marine life, 69p.
Gloucester Marine Station, University of Massachusetts, 1973.

1605. ALYAKRINSKAYA, I.O.
Effect of oil on the survival and rate of growth of young (Black sea) mullets. (In RUSSIAN)
Ryb. Khoz., 42, 16-18, 1966.

1606. BLANTON, W.G., and ROBINSON, M.C.
Some acute effects of low boiling petroleum fractions on the cellular structures of fish gills under field conditions.
In: Ahearn, D.G., and Meyers, S.P., editors. The microbial degradation of oil pollutants. Proceedings of a workshop, Atlanta, Georgia, 4-6 December 1972. pp. 265-273. Baton Rouge, Louisiana, Louisiana State University, Center for Wetland Resources, 1973.

1619. MANKKI, J., and VAURAS, J.
Littoral fish populations after an oil tanker disaster in the Finnish SW archipelago.
Annls zool. Fenn., 11, 120-126, 1974.

1621. MORROW, J.E.
Oil-induced mortalities in juvenile coho and sockeye salmon.
J. mar. Res., 31, 135-143, 1973.

1622. MORROW, J.E.
Effects of crude oil and some of its components on young Coho and Sockeye salmon. 43 p. Washington, D.C., US Environmental Protection Agency, Office of Research and Development, 1974.
(Ecological Research Series No. EPA-660/3-73-018)

1635. AVOLIZI, R.J., and NUWAYHID, M.(A.)
Effects of crude oil and dispersants on bivalves.
Mar. Pollut. Bull., 5, 149-153, 1974.

1636. BLACKMAN, R.A.A.
Effects of sunken crude oil on the feeding and survival of the brown shrimp Crangon crangon. Sp. Copenhagen, International Council for the Exploration of the Sea, Shellfish and Benthos Committee, 1972.
(CM 1972/K:13)

1637. BROWN, A.C., BAISSAC, P. de B., and LEON, B.
Observations on the effects of crude oil pollution on the sandy-beach snail, Bullia (Gastropoda: Prosobranchiata).
Trans. R. Soc. S. Afr., 41, 19-24, 1974.

1629. CONNOR, P.M.
Further investigations into the toxicity of oil and dispersants. 6p. Copenhagen, International Council for the Exploration of the Sea, Fisheries Improvement Committee, 1972. (CM 1972/E:14)

1641. DAVENPORT, J.
A comparison of the effects of oil, BP 1100 and oleophilic fluff upon the procelain crab, Porcellana platycheles.
Chemosphere, No. 1, 3-6, 1973.

1642. DICKS, B.
Some effects of Kuwait crude oil on the limpet Patella vulgata.
Envir. Pollut., 5, 219-229, 1973.

1643. EISLER, R.
Latent effects of Iranian crude oil and a chemical oil dispersant on Red Sea molluscs.
Israel J. Zool., 22, 97-105, 1973.

1645. GALTSOFF, P.S.
Experimental studies of the effect of oil on oysters. Review of the literature.
Bull. Bur. Fish., Wash., 48, (18), 158-159, 1935.

1651. HOWE, C., and OTTWAY, S.(M.)
Some effects of crude oil, oil fractions and products on the prawn Leander squilla.
Rep. Oil Pollut. Res. Unit, Fld Stud. Coun., 1971, 22-28, (1971).

1654. KANTER, R.
Susceptibility to crude oil with respect to size, season and geographic location in Mytilus californianus (Bivalvia). 43p. Los Angeles, California, University of Southern California, Sea Grant Program, 1974. (USC-SG-4-74)

1655. KARINEN, J.F., and RICE, S.D.
Effects of Prudhoe Bay crude oil on molting Tanner crabs, Chionoecetes bairdi.
Mar. Fish. Rev., 36, (7), 31-37, 1974.

1656. KATZ, L.M.
The effects of water soluble fraction of crude oil on larvae of the decapod crustacean Neopanope texana (Sayi).
Envir. Pollut., 5, 199-204, 1973.

1657. KERKHOFF, M.
Oil pollution of the shellfish areas in the Oosterschelde estuary: December 1973. 11p. Copenhagen, International Council for the Exploration of the Sea, Fisheries Improvement Committee, 1974. (CM 1974/E:13)

1660. MILLS, E.R., and CULLEY, D.D., Jr.
Toxicity of various off-shore crude oils and dispersants to marine and estuarine shrimp. 15p. Paper presented at the 25th meeting of the South Eastern Game and Fish Commissioners, Greenville, South Carolina, 1971.

1661. MITCHELL, P.H.
The effect of water-gas tar on oysters.
Bull. Bur. Fish., Wash., 32, 201-206, 1912.

1663. OTTWAY, S.(M.)
The toxicity of oil to animals subjected to salinity stress.
Rep. Oil Pollut. Res. Unit, Fld Stud. Coun., 1972, 24-30, 1973.

1668. PRYTHERCH, H.F.
Survival of oysters in oil-polluted water.
Bull. Bur. Fish., Wash., 48, (18), 159-167, 1935.

1671. SMITH, R.O.
Survey of oyster bottoms in areas affected by oil well pollution 1934.
Bull. Bur. Fish., Wash., 48, (18), 150-157, 1935.

1674. WELLS, P.G.
Influence of Venezuelan crude oil on lobster larvae.
Mar. Pollut. Bull., 3, 105-106, 1972.

1676. ANDERSON, J.W., NEFF, J.M., COX, B.A., TATEM, H.E., and HIGHTOWER, G.M.
Characteristics of dispersions and water-soluble extracts of crude and refined oils and their toxicity to estuarine crustaceans and fish.
Mar. Biol., 27, 75-88, 1974.

1678. BARNETT, C.J., and KONTOGIANNIS, J.E.
The effect of crude oil fractions on the survival of a tidepool copepod, *Tigriopus californicus.*
Envir. Pollut., 8, 45-54, 1975.

1679. BEAN, R.M., VANDERHORST, J.R., and WILKINSON, P.
Interdisciplinary study of the toxicity of petroleum to marine organisms.
48p. Richland, Washington, Battelle Pacific Northwest Laboratories, 1974.

1681. CARDWELL, R.D.
Acute toxicity of No. 2 diesel oil to selected species of marine invertebrates, marine sculpins and juvenile salmon. Seattle, University of Washington, 1973. Ph.D thesis.

1682. CARVACHO, A.B.
Effecto de la contaminación del mar con petróleo en poblaciones de Crustáceos Decápodas litorales. (Effect of pollution of the sea by petroleum on populations of littoral decapod crustacea.)
Noticiario Mensual, 15, (180), 7-12, 1971.

1683. CHIA, F.-S.
Killing of marine larvae by diesel oil.
Mar. Pollut. Bull., 4, 29-30, 1973.

1684. COHEN, Y.
Effects of crude oil on the Red Sea Alcyonarian *Heteroxenia fuscescens.*
Jerusalem, Hebrew University of Jerusalem, Department of Zoology, 1973. M.S. thesis.

1685. CUBIT, J.
The effects of the 1969 Santa Barbara oil spill on marine inter-tidal invertebrates.
In: Holmes, R.E., and DeWitt, F.A., Jr., editors. Proceedings of the Santa Barbara oil symposium, offshore petroleum production, an environmental inquiry. Santa Barbara, California, December 16-18, 1970. pp. 131-136. National Science Foundation, 1972.

1686. EISLER, R., KISSILL, G.W., and COHEN, Y.
Recent studies on biological effects of crude oils and oil-dispersant mixtures to Red Sea macrofauna.
In: Verner, S.S., editor. Proceedings of seminar on methodology for monitoring the marine environment, Seattle, Washington, October 1973. pp. 156-179. Washington, D.C., US Environmental Protection Agency, Office of Research and Development, 1974. (Environmental Monitoring Series No. EPA-600/4-74-004)

1687. EVANS, W.G.
Thalassotrechus barbarae (Horn) and the Santa Barbara oil spill. (Coleoptera: Carabidae)
Pan-Pacif. Ent., 46, 233-237, 1970.

1689. JOHANNES, R.E., MARAGOS, J., and COLES, S.L.
Oil damages corals exposed to air.
Mar. Pollut. Bull., 3, 29-30, 1972.

1690. KASYMOV, A.G., and ALIEV, A.D.
Experimental study of the effect of oil on some representatives of benthos in the Caspian Sea.
Wat. Air Soil Pollut., 2, 235-245, 1973.

1693. KONTOGIANNIS, J.E., and BARNETT, C.J.
The effect of oil pollution on survival of the tidal pool copepod Tigriopus californicus.
Envir. Pollut., 4, 69-79, 1973.

1694. LEVELL, D.
Effects of oil pollution and cleaning on sand and mud fauna - interim report, January 1973.
Rep. Oil Pollut. Res. Unit, Fld Stud. Coun., 1972, 32-34, 1973.

1697. PERCY, J.A.
Oil and Arctic marine invertebrates.
In: Mackay, D., and Harrison, W., editors. Oil and the Canadian environment. Proceedings of a conference... 16 May 1973. pp. 71-74. Toronto, University of Toronto, (1973?)

1698. SANDERS, H.L., GRASSLE, J.F., AND HAMPSON, G.R.
The West Falmouth oil spill. I. Biology. 48p. Woods Hole, Massachusetts, Woods Hole Oceanographic Institution, 1972. (Tech. Report No. 72-120)

1699. SIMPSON, J.G., and GILMARTIN, W.G.
Elephant seal and sealion mortality on San Miguel Island.
In: United States Naval Undersea Research and Development Center. Proceedings of the symposium on environmental preservation, San Diego, California, 20-21 May 1970. pp. 105-110. San Diego US Naval Research and Development Center, 1971.

<u>3</u>.

1701. TSURUGA, H.
The effects of oil pollution on the marine organism. 7p. Paper presented at the meeting of the joint IMCO/FAO/UNESCO/WMO/WHO/IAEA Group of Experts on the Scientific Aspects of Marine Pollution, February 1970. (GESAMP/27)

1703. WEBBER, H.H.
Survey of mortality at two areas of South beach of Guemes Island, April 28 to May 15, 1971
<u>In</u>: Watson, J.A., Smith, J.P., Ehrsam, L.C., Park, R.H., Blanton, W.G., Solomon, D.E., and Blanton, C.J. Biological assessment of diesel spill in the vicinity of Anacortes, Washington, May 1971. Final report, Appendix A. 12p. Dallas, Texas, Texas Instruments Inc., 1971.

1704. WOODIN, S.A., NYBLADE, C.F., and CHIA, F.C.
Effect of diesel oil spill on invertebrates.
Mar. Pollut. Bull., <u>3</u>, 139-143, 1972.

1710. GALTSOFF, P.S., and KOEHRING, V.
Effect of crude oil on diatoms.
Bull. Bur. Fish., Wash., <u>48</u>, 193-204, 1935.

1711. GANNING, B., and BILLING, U.
Effects on community metabolism of oil and chemically dispersed oil on Baltic bladder wrack, <u>Fucus vesiculosus</u>.
<u>In</u>: Beynon, L.R., and Cowell, E.B., editors. Ecological aspects of toxicity testing of oils and dispersants: (Proceedings of a workshop...) pp. 53-61. Barking, Essex, Applied Science Publishers, 1974.

1714. KAUSS, P.R., HUTCHINSON, T.C., and GRIFFITHS, M.
Field and laboratory studies of the effects of crude oil spills on phytoplankton.
<u>In</u>: Proceedings 18th annual technical conference environmental progress in science and education, pp. 22-26, 1972.

1719. MITCHELL, D.M., and BENNETT, H.J.
The susceptibility of bluegill sunfish <u>Lepomis macrochirus</u>, and channel catfish, <u>Ictalurus punctatus</u>, to emulsifiers and crude oil. (and marine diatom <u>Cylindrotheca fusiformis</u>.)
Proc. Louisiana Acad. Sci., <u>25</u>, 20-26, 1972.

1720. MOMMAERTS-BILLIET, F.
Growth and toxicity tests on the marine nanoplanktonic alga <u>Platymonastetrathele</u> G.S. West in the presence of crude oil and emulsifiers.
Envir. Pollut., <u>4</u>, 261-282, 1973.

1722. NUZZI, R.
Effects of water soluble extracts of oil on phytoplankton.
<u>In</u>: American Petroleum Institute. Proceedings of joint conference on prevention and control of oil spills, Washington, D.C., March 13-15, 1973. pp. 809-813. Washington, D.C., American Petroleum Institute, 1973.

1729. SHIELS, W.E., GOERING, J.J., and HOOD, D.W.
Crude oil phytotoxicity studies.
In: Hood, D.W., Shiels, W.E., and Kelley, E.J., editors. Environmental studies of Port Valdez, Chapter 11, pp. 413-446. Fairbanks, Alaska, University of Alaska, Institute of Marine Science, 1973. (Occasional Publication No. 3)

1730. TKACHENKO V.N., and AĬVAZOVA, L.E.
Influence of dissolved oil products on marine and fresh-water monocell algae. (In RUSSIAN)
Trudý vses. nauchno-issled. Inst. Morsk. rýb. Khoz, Okeanogr., 100, 68-73, 1974.

1737. COWELL, E.B.
Some biological effects of oil pollution.
Your Envir. 1, 84 & 93-94, 1970.

1739. CRAPP, G.B.
The effects of oil pollution and emulsifier cleansing on littoral animals and plants.
Rep. Oil Pollut. Res. Unit, Fld Stud. Coun., 1971, 7-13 (1971)

1743. HYLAND, J.L.
Acute toxicity of No. 6 fuel oil to intertidal organisms in the lower York river, Virginia. 57p. Williamsburg, Virginia, College of William and Mary, 1973. M.S. thesis.

1747. MOORE, S.F., CHIRLIN, G.R., PUCCIA, C.J., and SCHRADER, B.P.
Potential biological effects of hypothetical oil discharges in the Atlantic coast and Gulf of Alaska. 126p. Cambridge, Massachusetts, Massachusetts Institute of Technology, Sea Grant Program, 1974. (Report No. MITSG 74-19)

1761. THOMAS, M.L.H.
Effects of bunker C oil on intertidal and lagoonal biota in Chedabucto Bay, Nova Scotia.
J. Fish. Res. Bd Can., 30, 83-90, 1973.

1762. VAUGHAN, B.E.
Effects of oil and chemically dispersed oil on selected marine biota - a laboratory study. 120p. Richland, Washington, Battelle Pacific Northwest Laboratories, 1973.

2215. ATLAS, R.M., and BARTHA, R.
Fate and effects of polluting petroleum in the marine environment.
Residue Rev., 49, 49-85, 1973.

2218. BUTLER, M.J.A., and BERKES, F.
Biological aspects of oil pollution in the marine environment. A review.
Manuscr. Rep. mar. sci. Centre, McGill Univ., No. 22, 118p., 1972.

3.

2219. BUTLER, M.J.A., BERKES, F., and POWLES, H.
Biological aspects of oil pollution in the marine environment: a review. (Enlarged edition.) 133p. Montreal, McGill University, Marine Science Centre, 1974. (Manuscr. Rep. No. 22A)

2221. CLARK, R.B.
The biological consequences of oil pollution of the sea.
In: David Davies Memorial Institute of International Studies. Report of a conference on water pollution as a world problem, Aberystwyth, 11-12, July 1970. pp. 53-77. London, Europa Publications, 1971.

*A22. GRAHAM, R.J., and T.C. DORRIS (1968).
Long-term toxicity bioassay of oil refinery effluents, Water Res., vol. 2, p. 643-663, 3 illus., 11 tabls., 25 refs.

*A123. MARTIN, A.E. (1971.
Water pollution by oil--some health considerations. In Water Pollution by Oil, P. Hepple (ed.), Inst. of Petrol., Elsevier Publ. Co., New York, p. 153-158, 17 refs.

*A176. CHIPMAN, W.,A., and P.S. GALTSOFF (1949).
Effects of oil mixed with carbonized sand on aquatic animals. U.S. Fish and Wildlife Service, Spec. Sci. Rept., Fisheries, No. 1, 52 p., 19 illus., 23 tabls., 29 refs.

*A275. MIRONOV, O.G. (1969).
Effect of oil pollution upon some representatives of the Black Sea zooplankton. Zoologischeski Zhurnal, vol. 48, no. 7, p. 980-984, 3 illus., 1 tabl., 4 refs. (in Russian).

*A318. ALJAKRINSKAYA, I.O. (1966)
On the behavior and ability to filtrate of the Black Sea Mytilus galloprovincialis on oil polluted water, Zool. Zh., vol. 45, no. 7, p. 998-1003, 2 tabls., 5 refs. (in Russian).

*A320. BAKER, J.M. (1970).
The effects of oils on plants. Environ. Pollut., vol. 1, p. 27-44, 3 tabls., 88 refs.

*A327. CRAPP, G.B. (1971)
The ecological effects of stranded oil. Proceedings of the ecological effects of oil pollution on littoral communities, E.B. Cowell (ed.). Inst. of Petrol., London, p. 181-186, 4 tabls., 7 refs.

*A329. GALTSOFF, P.S., H.F. PRYTHERCH, R.O. SMITH, AND V. BOEHRING (1935)
Effects of crude oil pollution on oysters in Louisiana waters. Bureau of Fish. Bull., No. 18, col. 48, p. 143-210, 20 illus., 23 tabls., 40 refs.

*A332. GRIFFITH, D. de G (1970)
Toxicity of crude oil and detergents to two species of edible molluscs under artificial tidal conditions, FAO tech. conf. on marine pollut. and its effects on living resources and fishing. Rome, Italy, 12 p., 6 illus., 4 tabls., 10 rfs.

3.

*A337. MIRONOV, O.G. (1970).
The effect of oil pollution on flora and fauna of the Black Sea, FAO tech. conf. on marine pollution and its effects on living resources and fishing. Rome, Italy, Dec. 9-18, 4p., 2 tabls.

*A338. OTTWAY, S. (1971).
The comparative toxicities of crude oils. Proceedings of the ecological effects of oil pollution on littoral communities. E. B. Cowell (ed.), Inst. of Petrol., London, p. 172-180, 4 illus., 2 tabls., 3 refs.

*A340. ROBERTS, C.H. (1926).
The effect of oil pollution upon certain forms of aquatic life and experiments upon the rate of absorption, through films of various fuel oils, of atmospheric oxygen by seawater. J. of Cons. Perm. Int. Explor. Mer., vol. 1, p. 245-275, 3 illus., 20 refs.

*A433. HUFFORD, G.L. (1971)
The biological response to oil in the marine environment, a review, USCG, Office of Res. and Dev., project no. 714141003, 23 p., 1 illus., 1 tabl., 28 refs.

*A442. NELSON-SMITH, A. (1970).
The problem of oil pollution ot the sea, Adv. Mar. Biol., vol. 8, p. 215-306, 19 illus., 2 tabls., 353 refs.

*A443. RADCLIFFE, D.R., and T.A. MURPHY (1969).
Biological effects of oil pollution--bibliography. A collection of reference concerning the effects of oil on biological systems, Fed. Water Pollut. Control Admin., rept. no. 15080, FHU 10/69, 46p., 513 refs.

O-1. HOOD, DONALD W., EDITOR.
Impingement of Man on the Ocean. Book. John Wiley, 1971.

*O-3. ALASKA CORPS OF ENGINEERS.
Final environmental impact statement. Offshore oil and gas development in Cook Inlet, Alaska. Anchorage Alaska, Sept. 1974, 450 pages.

O-9. NELSON-SMITH, A.
The problem of oil pollution in the North Sea. Adv. Mar. Biol. 8:215-306 (1970).

O-10. MOORE, STEPHEN F. et al.
Potential biological effects of hypothetical oil discharges on the Atlantic Coast and Gulf of Alaska. Report to Mass. Inst. of Tech., Council on Environmental Quality. Report No. MITSG 74-19, April 1, 1974.

3.

N3665-3. MOORE, S. F., and R. L. DWYER (1974)
Effects of oil on marine organisms: A critical assessment of published data, Water Res., vol. 8, no. 10, p. 819-8281

N3676-2. PESSAH, E., J. S. LOCH, and J. C. MacLEOD (1973)
Preliminary report on the acute toxicity of Canadian petroleum refinery effluents to fish, Fish. Res. Board Can. Tech. Rep. 408, p. 1-43.

N3682-3. KASIMOV, R. Y., and S. A. RUSTAMOV (1971)
Effect of petroleum and petroleum products on sturgeon and other fish, Tr. Tsentr. Mauchno-issled Inst. Osetrovogo Khoz., vol. 3, p. 191-195.

N3683-2. AUBERT, M., J. AUBERT, J. P. GAMBAROTTA, B. DONNIER, M. BARELLI, and S. DANIEL (196)
General study of chemical pollutants thrown into seawater inventory and toxicity studies:Part 1 - Methodology; Part 2 - Mediterranean, Rev. Int. Oceangr. Med., 1 (Suppl.) p. 1-72; 2 (Suppl.) p. 1-135.

N3685-4. BARSDATE, R. J., and V. ALEXANDER (1971)
The effect of petroleum hydrocarbons on aquatic communities, U.S. I B P (Int. Biol. Program) Anal. Ecosyst. Program Interbiome Abstr., vol. 1, no. 4, p. 292-293.

N3685-5. KASYMOV, A. G., and S. I. GRANOVSKIY (1971)
The effect of petroleum on bottom animals in the Caspian Sea, Hydrobiol. J., vol. 6, no. 5, p. 85-88.

N3698-2. PARKER, B. L., and J. D. BRAMMER (1974)
Effects of chronic oil contamination on aquatic dipterans. State of the art report, U.S. NTIS, PB Rep. No. 237499/9GA, 35 pp.

N3699-2. CLARK, R. C., JR. (1975)
Acute effects of outboard motor effluent on two marine shellfish, Environ. Sci. Technol., vol. 9, no. 4, p. 365.

N3702-4. ABADZHIEV, V. (1974)
Effect of petroleum and petroleum derivatives on aquatic organisms, Priroda (Sofia), vol. 23, no. 4, p. 66-68 (Language-Bulgarian).

N3711-1. ANDERSON, J. W., J. M. NEFF, B. A. COX, H. E. TATEM, and G. M. HIGHTOWER (1974)
Characteristics of dispersions and water-soluble extracts of curde and refined oils and their toxicity to estuarine curstaceans and fish, Mar. Biol., vol. 27, no. 1, p. 75-88.

0-15. CARTHY, J.D. and DON R. ARTHUR, EDITORS.
The Biological Effects of Oil Pollution on littoral communities. Supplement to Vol. 2 of Field Studies published by Field Studies Council, July 1968. Proceedings of a symposium held at the Ancelton Field Center, Pembroke, Wales, Feb. 17, 18, 19, 1968. About 200 p. including 30 p. bibliography.

0-19. SMITH, ROBERT O.
Survey of oyster bottoms in areas affected by oil well pollution. Old Bureau of Fisheries Reference Bulletin 18 (1935), many pages.

*0-3. ENVIRONMENTAL DATA STUDY.
Baseline data survey for Valdez pipeline terminal. Environmental data study, Institute of Marine Science, Report No.___, p. 69-17, Dec. 1969.

0-23. BLUMER, MAX, JOHN M. HUNT, JELLE ATEMA and LAUREN STEIN.
Two EPA Reports - Interaction between marine organisms and oil pollution. EPA-R3-73-042, May 1973. Ecological Research Series, Supt. of Documents, Price $1.25 or $1.00 at GPO bookstore.

0-33. WEIN, R.H., W.H. LAKE AND B.T. THACKERAY.
Acute toxicity of ten selected Arctic drilling sumps to rainbow trout. EPS Bioassay Laboratory, Edmonton, Alberta, 1974.

0-57. SHELTON, R.G.J.
Effects of oil and oil dispersants on the marine environment. Ref: Proceedings Royal Society (B), 177:411-22 (1971).

0-67. AMERICAN SOCIETY FOR TESTING MATERIALS. (1916 Race St., Philadelphia PA 19103, 1975)
Book: "Water Quality Parameters - A Symposium" by Canada Center for Inland Waters and Anal. Chem. Division of Chem. Institute of Canada, Burlington, Ontario, Canada. List price $2[illegible]. Includes: Environmental impact of experimental oil spills in Canadian Arctic, et al., 20 p. Much of book is on pollutants other than petroleum oil, e.g., pesticides and heavy metals.

0-64. NATL. TECH. INFO. SVCE., U.S. DEPT. OF COMMERCE.
Potential biological effects of hypothetical oil discharges in Atlantic Coast and Gulf of Alaska, April 1, 1974. MIT COM-74-[illegible].

(NOTE: **Two asterisks means copy available.)

3. Additions to Classified Literature References as of 3/31/76.

**0-36. PERCY, J.A. and T.C. MULLIN.
Effects of crude oils on arctic marine invertebrates. Arctic Biological Station, Fisheries and Marine Service, Dept. of the Environment, P.O. Box 400, Ste. Anne de Bellevue, Quebec. Beaufort Sea Technical Report #11, Beaufort Sea Project, Dept. of the Environment, 512 Federal Building 1230 Government St., Victoria, B.C. V8W 1Y4, December 1975.

**0-88. MILNE, A.R. & B.D. SMILEY.
Offshore drilling for oil in the Beaufort Sea: a preliminary environmental assessment. Technical Report No. 39, Beaufort Sea Project. Revised Jan. 20, 1976. Beaufort Sea Project, Dept. of the Environment, 1230 Government Street, Victoria, B.C. V8W 1Y4.

0-91. ISAKSON, J.S., J.M. STORIE, J. VAGNERS, G.A. ERICKSON, J.F. KRUGER and R.F. CORLETT.
Comparison of ecological impacts of postulated oil spills at selected Alaskan locations. Introduction, summary, methodology, evaluation and appendices. June 1975, final report, Volume 1. Prepared for Dept. of Transportation, U.S. Coast Guard, Office of Research and Development, Washington, D.C. 20590. (Document is available to the public through the NTIS, Springfield, VA 22151.)

**0-92. MC AULIFFE, C.D. and L.L. PALMER.
Environmental aspects of offshore disposal of drilling fluids and cuttings. SPE 5864.

**0-94 McAULIFFE, CLAYTON D., ALFRED E. SMALLEY, ROBERT D. GROOVER, W. MARVIN WELSH, STEWART PICKLE and GEORGE E. JONES.
Chevron main pass block 41 oil spill: chemical and biological investigations. API Conference on Prevention and Control of Oil Pollution, 1975(?)

**0-95. RAMSEIER, RENE O.
How to melt the Arctic and warm the world. Environment, Vol. 16, No. 4, May 1974.

697. BLOOM, STEPHEN.
An oil dispersants effect on the microflora of beach sand. J. Marine Biol. Assoc., United Kingdom, 50(4), 919-23(1970).

0-110. REIMAN, K.
Lethal effects of oil and tar products on lower aquatic animals. Muenchen Beitrage Abwasser, Fisch-Flussbiol., 9, 187-199, (1967).

0-114. LINDEN, O.
Acute effects of oil and oil dispersant mixture on larvae of Baltic herring. Ambio 4(3): 130-133(1975).

0-115. BARRY, M. and P.P. YEVICH.
Ecological, chemical, and histopathological evaluation at an oil spill site. Part I. Ecological Studies. Marine Pollut. Bull. 6, 164-72(1975).

3.

0-128. RENZONI, A.
Toxicity of three oils to gametes and larvae (Prudhoe Bay Oil and two others). Marine Pollut. Bull. 6, 125-128(1975).

484. BAKER, J.M.
Effects of oils on plants. Environmental Pollution 1, 27-44, 1970. 88 references.

0-124. LOFTUS, TONY.
Unseen dangers of oil. New Scientist 49(737), p. 228, Feb. 4, 1971.

(NOTE: **Two asterisks means copy available).

3. Additions to Classified Literature References as of 6/14/76.

P20-2 AVOLIZI, R.J. and NUWAYHID, 1974
Effects of crude oil and dispersants on bivalves. Mar. Pollution Bull., 5(10): 149-152.

P21-2 BAKER, J.M., 1970
The effects of oil on plants. Environ. Pollution, 1:27-44.

P21-3 BAKER, J.M., 1970
(pp. 44-51), Refinery Effluent (pp. 33-43), Growth Stimulation Following Oil Pollution (pp. 72-77), Comparative Toxicities of Oils, Oil Fractions and Emulsifiers (pp. 78-87), the Effects of Oils on Plant Physiology (pp. 88-98).

In Cowell, E.B. (Ed.) the Ecological Effects of Oil Pollution on Littoral Communities. Proceedings of a symposium by the Inst. of Petro. held at the Zoological Society, London, Nov. 30-Dec. 1, 1970. Elsevier Pub. Co., Ltd., Amsterdam. 250 pp.

P27-2 BATTELLE PACIFIC NORTHWEST LABORATORIES, 1973
Effects of oil and chemically dispersed oil on selected marine biota--a laboratory study. Report to American Petroleum Institute, Committee on Environmental Affairs, Battelle Laboratories, Richland, Washington.

P28-2 BATTELLE PACIFIC NORTWEST LABORATORIES, 1973
Field and laboratory studies to obtain a comparative baseline for assessing the impact of refinery discharge and potential oil spillage on the Cherry Point environs of the Strait of Georgia. Battelle Pacific Northwest Laboratories, Richland, WA.

P30-2 BEAN, R.M., J.R. VANDERHORST, & P. WILKINSON, 1974 (BATTELLE NORTHWEST LABS)
Interdisciplinary study of the toxicity of petroluem to marine organisms. Battelle Pacific Northwest Laboratories, Richland, WA., 31 pp.

P43-2 BLUMER, M., 1969
Oil pollution of the ocean. PP. 5-14, in: Hoult, D.P. (ed.) Oil on the sea. Proceedings of a symposium on the scientific and engineering aspects of oil pollution of the sea, sponsored by M.I.T. and Woods Hole Oceanographic Inst., May 16, 1969. Plenum Press, New York, 1969. 114 pp.

P47-1 BOSWELL, J.L., 1950
The effect of crude oil on oysters (Gowenloch Method). Texas A&M University Research Foundation. Project #9.

P50-2 BOURNE, W.R.P., 1968
Observation of an encounter between birds and floating oil. Nature, 219:632.

P51-1 BOYLE, C.L., 1969
Oil pollution of the sea: Is the end in sight? Biological Conservation, 1(4): 319-327.

P54-2 BROWN, R.G.B., 1974
Section 5: The possible effects of oil spills on marine birds. PP. 161-171, in: Summary of physical, biological, socio-economic and other factors relevant to potential oil spills in the Passamaquoddy region of the Bay of Fundy. Fisheries Research Board of Canada, Technical Report No. 428.

*P54-3 BROWNELL, R.L. JR., & B.J. LEBOEUF, 1971
California sea lion mortality: Natural or artifact? PP. 287-312, in: Straughan, D. (ed.), Biological and oceanographic survey of the Santa Barbara Channel oil spill. Vol. I. Allan Hancock Foundation, University of Southern California. 477 pp.

*P55-2 BROWNELL, R.L., JR. 1971
Whales, dolphins and oil pollution. In: Biological and oceanographical survey of the Santa Barbara Channel oil spill. 1969-1970, Vol. 1, Biology and Bacteriology. Allan Hancock Foundation, U. of S. Calif., 477 pp.

*P65-2 CARDWELL, R.D., 1973
Acute toxicity of No. 2 diesel oil to selected species of marine invertebrates, marine sculpins, and juvenile salmon. University of Washington Ph.D. thesis, Seattle, WA.

*P76-3 CHIA, F., 1973
Killing of marine larvae by diesel oil. Marine Pollution Bull., Feb. 1973, 4(2): 29-30.

*P77-3 CHIPMAN, W.A. & P.S. GALTSOFF, 1949
Effects of oil mixed with carbonized sand on aquatic animals. U.S. Fish & Wildlife Service, special scientific report: Fisheries No. 1, 51 pp.

*P78-4 CLARK, R.B. & J.R. KENNEDY, 1968
Rehabilitation of oiled seabirds. U. of Newcastle upon Tyne, England, 57 pp.

*P79-3 CLARK, R.B., 1968
Oil pollution and conservation of sea birds. On oil pollution of the sea. October 7-9, 1968. PP. 76-112, in: Proceedings of the international conference, Rome, Italy, 414 pp.

*P105-2 DICKASON, O.E., 1970
Center for short-lived phenomena event report. Center for short-lived phenomena event report, 36:70/926, Smithsonian Institution, Cambridge,

*P106-2 DICKMAN, M., 1971
Preliminary notes on changes in algal primary productivity following exposure to crude oil in the Canadian Arctic. Can. Field Nat. 85(3):249-251.

*P137-4 GALTSOFF, P.S., 1935
Effects of oil pollution on oysters in Louisiana waters. Bull. Bur. Fish. Wash., 18:143-210.

*P140-2 GEORGE, J.D., 1971
The effects of pollution by oil and oil-dispersants on the common intertidal Polychaetes, Cirriformia tentaculata and Cirratulus cirratus. J. Appl. Ecol. 8(2):411-420. Illus. Maps.

*P143-2 GIFFITH, D. DE. G., 1972
Toxicity of crude oil and detergents to two species of edible mollusks under artificial tidal condtions. In: Ruivo, M. (ed.) Marine Pollution and Sea Life, Fishing News (Books) Ltd. 1972. Surrey, England. 624 pp.

*P148-3 GOWANLOCK, J.N., 1935
Pollution by oil in relation to oysters. Trans. Amer. Fish Soc., 65:293-6.

*P150-3 GREENWOOD, J.J.D., and J.P.F. KEDDIE, 1968
Birds killed by oil in the Tay Estuary (Scotland), March and April, 1968. Scot Birds 5(4):189-196.

*P151-2 GRIFFITH, D. DE G., 1970
Toxicity of crude oil and detergents to two species of edible mollusks under artificial tidal conditions. FAO Technical Conference on Marine Pollution and its Effects on Living Resources and Fishing, FIR:MP/70/e-16. 12 pp.

*P197-4 KASYMOV, A.G. and S.I. GRANOVSKIY, 1971
The effects of petroleum on bottom animals in the Caspian Sea. Hydrobiological J., 6(5):85-88.

*P223-4 LEBOEUF, B.J., 1971
Oil contamination and elephant seal mortality: A negative finding. PP. 277-285, in: Straughan, D. (ed.), Biological and Oceanographic Survey of the Santa Barbara Channel Oil Spill. Vol. I. Allan Hancock Foundation, University of Southern California. 477 pp.

*P234-3 LUND, E.J., 1957
Effect of bleedwater, soluble fractions and crude oil on the oyster. Pub. Inst. Mar. Sci., U. of Texas, 4(2):328-341.

*P235-1 LUNZ, G.R., 1950
The effect of bleedwater and of water extracts of crude oil on the pumping rate of oysters. Texas A&M University Research Foundation. Project #9.

*P237-3 MACKIN, J.G., 1948ABC
Report on first, second, and third spraying experiments. Texas A&M University Research Foundation. Project #9.

*P238-4 MACKIN, J.G., 1950
A comparison of the effect of application of crude petroleum to marsh plants and to oysters. Texas A&M University Research Foundation Project #9.

*P237-4 MACKIN, J.G., 1948D
A study of the effect of a heavy surface layer of crude oil. Texas A&M Univ. Research Foundation Project #9.

*P238-2 MACKIN, J.G., 1948E
Report on the study of the effect of subjecting oysters to continuous applications of emulsified crude oil. Texas A&M Univ. Research Foundation. Project #9.

*P238-3 MACKIN, J.G., 1949
Report on experiments to determine the effect on oysters of heavy doses of crude oil over short periods of time. Texas A&M Univ. Research Foundation. Project #9.

*P239-2 MACKIN, J.G., 1950C
A report on three experiments to study the effect of oil bleedwater on oysters under aquarium conditons. Texas A&M Univ. Research Foundation. Project #9.

*P239-3 MACKIN, J.G. & A.K. SPARKS, 1962
A study of the effect on oysters of crude oil loss from a wild well. Publications of the Institute of Marine Science, U. of Texas, 7:230-261.

*P239-4 MACKIN, J.G. & S.H. HOPKINS, 1962
Studies on oyster mortality in relation to natural environments and to oil fields in Louisiana. Texas University Inst. Mar. Sci. 131 pp.

*P241-1 MACKIN, J.G. & A.K. SPARKS, 1962
A study of the effect on oysters of crude oil loss from a wild well. Publicati of the Institute of Marine Science, U. of Texas. 7:230-261.

*P241-2 MACKIN, J.G. & A.K. SPARKS, 1962
A study of the effect on oysters of crude oil loss from a wild well. Texas Uni Institute of Marine Science.

*P257-4 MENZEL, R.W., 1949
The attachment, survival, and growth of oyster spat on oil impreganted wood. Texas A&M Univ. Research Foundation, Project #9.

*P258-2 MENZEL, R.W., 1950A
Report on oyster studies in Caillou Island oil field, Terrebonne Parish, Louisiana. Texas A&M Univ. Research Foundation Project #9.

*P258-3 MENZEL, R.W., 1950B
Report on oyster studies at Lake Pelto Oil Field, Terrebonne Parish, Louisiana. Texas A&M Univ. Research Foundation, Project #9.

*P258-4 MENZEL, R.W., 1950C
Report on oyster investigation at the Dog Lake oil field, Terrebonne Parish, Texas. Texas A&M Univ. Research Foundation, Project #9.

*P259-2 MENZEL, R.W. & S.H. HOPKINS, 1951
Report on experiments to test the effects of oil well brine or bleedwater on oysters at Lake Barre oil field. Texas A&M Univ. Research Foundation, Proje #9.

*P265-2 MINEAR, R. & P.S. PAGORIA, 1974
Nature and analysis of chmical species: organic. J. Water Poll. Ctrl. Fed. 46(6):1064-5.

*P266-2 MIRONOV, O.G., 1967
Effect of oil and oil products upon some mollusks on the littoral zone of the Black Sea, USSR. Zool. ZH 46(1):134-136.

*P266-4 MIRONOV, O.G. & L.A. LANSKAYA, 1968
Survival ability of some marine planktonic and benthoplanktonic algae in sea water, polluted by oil products. Both. ZH 53(5):661-669. Illus.

*P267-2 MIRONOV, O.G., 1969
Development of some Black Sea fish in sea water polluted by petroleum products. Vop. Ikhtiol, 9(6):919-922.

*P268-2 MITCHELL, C.T., E.K. ANDERSON, L.G. JONES, & W.J. NORTH, 1970
What oil does to ecology. J. Water Pollut. Control Fed., 45(2):812-8.

*P269-2 MOFFITT, J. & R.T. ORR, 1938
Recent diseastrous effects of oil pollution on birds in the San Francisco Bay region. California Fish and Game, 24(3):239-244.

*P271-2 MORROW, J.E., 1973
Oil-induced mortalities in juvenile coho and sockeye salmon. J. Marine Research, 31(3):135-143.

*P271-3 MORROW, J.E., 1974
Effects of crude oil and some of its components on young coho and sockeye salmon. Office of Research & Development of the U.S. EPA, Washington.

*P295-2 NELSON-SMITH, A., 1968
The effects of oil pollution and emulsifier cleansing on shore life in southwest Britain. J. Appl. Ecol., 5(1):97-107.

*P295-3 NELSON-SMITH, A., 1971
Effects of oil on marine plants and animals. PP. 273-280, in: Hepple, Peter (ed.) Water Pollution by Oil. Proceedings of a siminar held at Aviemore, Invernessshire, in Scotland. Sponsored by the Institute of W.P.C. and the I. of P. with assistance of the European offices of W.H.O. May 4-8, 1970. Institute of Petroleum, 61 Cavendish Street, London Wimbar, England. 393 pp.

*P296-2 NELSON-SMITH, A., 1973
Oil pollution and marine ecology. Plenum Press, New York.

*P300-1 NICHOLSON, N.L. & R.L. CIMBERG, 1971
Document of the condition of intertidal populations following the oil spill. Data from line intercepts were compared to pre-spill data. Article contains 26 pp. of tables and figures.

*P311-2 OTTWAY, S., 1970
The comparative toxicities of crude oils. PP. 172-80, in: Cowell, E.B. (ed.), the ecological effects of oil pollution on littoral communities. Proceedings of a symposium by the Inst. of Petro. Held at the Zoological Society, London, Nov. 30-Dec. 1, 1970. El Sevier Pub. Co. Ltd., Amsterdam. 250 pp.

*P312-3 OWEN, H.M., 1955
The Louisiana oyster industry. Special report to the division of water bottoms, Department of Wildlife and Fisheries of Louisiana, pp. 1-387.

*P353-3 RICE, S.D., 1973
Toxicity and avoidance tests with Prudhoe Bay oil and pink salmon fry. PP. 667-670 in: Proceedings of a joint conference on prevention and control of oil spills, March 13-15, 1973. Washington, D.C. Sponsored by the Am. Petro. Inst., EPA, & U.S. Coast Guard. 834pp.

*P372-2 SCARRATT, D.J., 1974
Section 4: Impact of spills and clean-up technology on living natural resources, and resource-based industry. PP. 141-158, in: Summary of physical, biological, socio-economic and other factors relevant to potential oil spills in the Passamaquoddy region of the Bay of Fundy. Fisheries Research Board of Canada, Technical Report No. 428.

*P386-3 SIMPSON, A.C., 1968
Oil, emulsifiers and commercial shellfish. In: Carthy, J.D. & D.R. Arthur (ed.), The biological effects of oil pollution on littoral communities, field studies, July 1968, supplement to Vol. 2, 198 pp.

*P387-2 SMAIL, J., D. AINLEY, & H. STRONG, 1972
Notes on birds killed in the 1971 San Francisco oil spill. Calif. Birds, 3(2):25-32

*P389-2 SMITH, A.L., 1974
The effects of effluents from the Canadian petrochemical industry on aquatic organisms: A literature review. Fish. Mar. Ser., Tech. Report No. 472.

*P410-2 TANIS, J.J.C. & M.F. MORZER BRUIJNS, 1968
The impact of oil pollution on sea birds in Europe. PP. 67-74, in: Proceedings of the International Conference on Oil Pollution of the Sea. October 7-9, 1968. Rome, Italy, 414 pp.

*P410-3 TARZWELL, C.A., 1971
Toxicity of oil and oil dispersant mixtures to aquatic life. PP. 263-72, in: Hepple, Peter (ed.) Water pollution by oil. Proceedings of a seminar held at Aviemore, Inverness-Shire, Scotland, sponsored by the Institute of W.P.C. & the I. of P. with assistance of the European office of W.H.O., May 4-8, 1970. Institu of Petro., 61 Cavendish St., London Wimbar, 1971, 393 pp.

*P452-2 WOELKE, C.E., 1972
Development of a receiving water quality bioassay criterion based on the 48-hour Pacific oyster "Crassostrea gigas" embryo. Wash. Dept. of Fish. Tech. Report No. 9, 93 pp.

*P455-3 WOODIN, S.A. & C.F. NYBLADE, 1972
Effects of diesel oil spill on invertebrates. Marine Pollut. Bull., 3(9):139-143

*P461-3 ZABELL, C.E., 1963
The occurrence, effects and fate of oil polluting the sea. Intern. J. Air-Wat. Poll., 7:173-197.

*P463-3 ZILKO, V., 1971
Fish kill caused by an intermediate oil from coke ovens. Bull. Environ. Cont. Toxicol., 6:24-5.

0-136 BATTELLE PACIFIC NORTHWEST LABORATORIES, 1974
Study of effects of oil discharges and domestic and industrial wastewaters on the fisheries of Lake Maracaibo, Venezuela. Battelle Pacific Northwest Laboratories, Richland, WA. 99352. 84 p. Vol. I. Ecological Characterization and domestic and industrial wastes.

0-135 BATTELLE PACIFIC NORTHWEST LABORATORIES, 1974
Study of effects of oil discharges and domestic and industrial wastewaters on the fisheries of Lake Maracaibo, Venezuela. Vol. II. Fate and effects of oil. Battelle Pacific Northwest Laboratories, Richland, WA. 99352.

0-147 ANDERSON, J.W. (ed.), 1975
Laboratory studies on the effects of oil on marine organisms: An overview. American Petroleum Institute. API Publication #4249. 70 p.

0-148 ANDERSON, R.D., 1973
Effects of petroleum hydrocarbons on the physiology of the American oyster, Crassostrea virginica Gmelin. Texas A&M Univ.)Ph.D. thesis).

0-149 ANON., 1974
FY 1974 - Status of knowledge about impact on marine ecosystems from oil pollution. First draft for Annual Report on Ocean Pollution. 20 p.

0-141 AYERS, R.C., JR., H.O. HAHNS, J.L. GLAESER, S. MARTIN, and W.J. CAMPBELL, 1974
Oil spills in the Arctic Ocean: Extent of spreading and possibility of large scale thermal effects. Science 186:843-846 (two parts: first part, pp. 843-

0-141 844 by first three authors addressing previous article by Martin and Campbell, who then reply in pp. 845-846 - second part. Therefore citation (above) may by incorrect).

0-150 BROWN, V.M., D.G. SHURBEN, and J.K. FAWELL, 1967
The acute toxicity of phenol ot rainbow trout in saline waters. Water Research 1:683-685.

0-151 CLARK, R.C., JR., 19??
Chemical and biological effects of oil pollution (paper addressed to ?; unpublished). 13 pp.

0-152 CLARK, R.C., JR., J.S. FINLEY and G.G. GIBSON, 1974
Acute effects of outboard motor effluent on two marine shellfish. Environmental Science & Technol. 8:1009-1014.

0-153 EISLER, R., and G.W. KISSIL, 1975
Toxicities of crude oils and oil-dispersant mixtures to juvenile rabbitfish, Siganus rivulatus. Trans. Am. Fish. Soc. 104(3):571-578.

0-154 EPA, 1974
Biological effects of water-soluble fractions of oils. In: July 1 - Dec. 1974 Semi-annual Report, Environmental Protection Agency, Narragansett, Rhode Island laboratory, pp. 120-123.

0-155 EVANS, D.R. and S.D. RICE, 1974
Effects of oil on marine ecosystems: a review for administrators and policy makers. Fishery Bulletin 72(3):625-638.

0-156 GUARD, H.E., L. HUNTER, and L.H. DISALVO, 1975
Identification and potential biological effects of the major components in the seawater extract of a bunker fuel. Bull. of Environ. Contam. & Toxicol. 14:395-400.

0-157 HELLEBUST, J.A., B. HANNA, R.G. SHEATH, M. GERGIS, and T.C. HUTCHINSON, 1975
Experimental crude oil spills on a small subarctic lake in the Mackenzie Valley, N.W.T.: Effects on phytoplankton, periphyton, and attached aquatic vegetation. In: Amer. Petrol. Instit. 1975. Conference on prevention and control of oil pollution. Proceedings, Mar. 25-27, 1975, San Francisco, CA. API/EPA/USCG, pp. 509-515.

0-158 KARRICK, N.L., R.C. CLARK, JR., and R.R. MITSUOKA, 1972
Symposium on oil pollution, the environment and Puget Sound. 23-24 Feb., 1972, Seattle, WA. Environmental Protection Agency, NOAA, WAshington State Dept. of Ecology. 36 p.

0-159 NELSON-SMITH, A., 1972
Effects of oil on marine organisms. Ch. 6 of: A. Nelson-Smith, Oil pollution and marine ecology. London: Paul Elek (Scientific Books) Ltd. 1972, pp. 99-150.

0-160 PERCY, J.A., 1976
Responses of Arctic marine crustaceans to crude oil and oil-tainted food. Environ. Pollut. 10:155-162.

3.

0-161 ROSSI, S.S., J.W. ANDERSON, and G.S. WARD, 1976
Toxicity of water-soluble fractions of four test oils for the polychaetous annelids, Neanthes arenaceodentata and Capitella capitata. Environ. Pollut. 10:9-18.

0-162 SANDBERG, D.M., A.D. MICHAEL, B. BORWN and R. BEEBE-CENTER, 1972
Toxic effects of fuel oil on haustoriid amphipods and pagurid crabs. Biol. Bull. 143:475-476.

0-163 SHUSTER, W.W., 1971
Control of pollution from outboard engine exhausts: A reconnaissance study, Water Pollut. Control Research Series 15020 ENN 09/71. Washington, D.C.: U.S. Govt. Print. Office. 38 p.

0-164 SWEDMARK, M., A. GRANMO and S. KOLLBERG, 1973
Effects of oil dispersants and oil emulsions on marine animals. Water Research 7:1649-1672.

0-165 THOMAS, M.L.H., 1973
Effects of Bunker C oil on intertidal and lagoonal biota in Chedabucto Bay, Nova Scotia. J. Fish. Res. Board Can. 30:83-90.

0-166 TURNBULL, H., J.G. DEMANN, and R.F. WESTON, 1954
Toxicity of various refinery materials to fresh water fish. Industrial and Engineering Chemistry 46:324-333.

0-167 ZAHNER, R., 1968
Effects of motor fuels and oils on rainbow trout. Fisheries Research Board of Canada, Translation Series No. 1025 (orig. German), 57 p.

0-168 ZITKO, V., 1975
Aromatic hydrocarbons in aquatic fauna. Bull. of Environ. Contam. & Toxicol. 14:621-631.

4. EFFECTS ON REPRODUCTION AND GROWTH.

92. AUBERT, M., AUBERT, J., DANIELS, S., AND GAMBAROTTA, J.P.
Etude des effets des pollutions chimiques sur le plancton. Dégradabilite du fuel par les microorganismes telluriques et marins. (Study of the effects of chemical pollution on plankton. Degradability of fueld oil by marine and terrestrial microorganisms)
Revue int. Oceanogr. méd., 13-14, 107-123, 1968.

353. JAMES, M.C.
Preliminary investigation of the effect of oil pollution on marine pelagic eggs.
In: U.S. Bureau of Fisheries, Interdepartmental Committee. Oil pollution of navigable waters, Appendix 6. pp. 83-92, 1926.

354. KÜHNHOLD, W.W.
Effect of water soluble substances of crude oil on eggs and larvae of cod and herring. 15p. Copenhagen, International Council for the Exploration of the Sea, Fisheries Improvement Committee, 1969. (CM 1969/E 17)

355. KÜHNHOLD, W.W. 2
Der Einfluss wasserlöslicher Bestandteile von Rohölen und Rohölfraktionen auf die Entwicklung von Heringsbrut. (The influence of water soluble compounds of crude oils and their fractions on the ontogenic development of herring fry.)
Ber. dt. Kommn wiss. Meeresforsch., 20, 165-171, 1969.

356. KÜHNHOLD, W.W.
The influence of crude oils on fish fry. 10p. (Preprint of a paper presented at the F.A.O. Technical Conference on marine pollution and its effects on living resources and fishing, Rome, 9-18 December 1970.) (FIR : MP/70/E-64)

360. MIRONOV, O.G.
Effect of low concentrations of oil and oil products on the developing eggs of the Black Sea flatfish. (In Russian) Vop. Ikhtiol., 7, 577-580, 1967.

365. TAGATZ, M.E.
Reduced oxygen tolerance and toxicity of petroleum products to juvenile American shad.
Chesapeake Sci., 2, 65-71, 1961.

405. MENZEL, R.W.
Effect of deep well gas on the mortality and growth of oysters. 7p.
Texas A and M Research Foundation, 1949. (Project Nine - unpublished report)

406. MENZEL, R.W.
The attachment, survival, and growth of oyster spat on oil-impregnated wood. Texas A and M Research Foundation, 1949. (Project Nine - unpublished report)

4.

416. MIRONOV, O.G.
Viability of larvae of some crustacea in the sea water polluted with oil-products. (In Russian, with English summary)
Zool. Zh., 48, 1734-1737, 1969.

476. STRAUGHAN, D.
Breeding and larval settlement of certain intertidal invertebrates in the Santa Barbara Channel following pollution by oil.
In: Allan Hancock Foundation. Biological and oceanographical survey of the Santa Barbara Channel oil spill 1969-1970. Vol. 1, compiled by D. Straughan. pp. 223-244. Allan Hancock Foundation, University of Southern California, 1971.

290. BAKER, J.M.
Growth stimulation following oil pollution.
In: Cowell, E.B., editor. Proceedings of the symposium on the ecological effects of oil pollution on littoral communities, London, 30 November - 1 December, 1970.
London Institute of Petroleum, 1971.

503. DALBY, D.H.
Some factors controlling plant growth in the intertidal environment.
Fld Stud., 2, (suppl.), 31-37, 1968.

702. CALABRESE, A., and DAVIS, H.C.
Effects of "soft" detergents on embryos and larvae of the American oyster (*Crassostrea virginica*).
Proc. natn. Shellfish. Ass., 57, 11-16, 1967.

714. HIDU, H.
Effects of synthetic surfactants on the larvae of clams (*M. mercenaria*) and oysters (*C. virginica*).
J. Wat. Pollut. Control Fed., 37, 262-270, 1965.

715. KIDDER, G.W., DEWEY, V.C., and HEINRICH, M.R.
The effect of non-ionic detergents on the growth of *Tetrahymera*.
Expl. Cell Res., 7, 256, 1954.

718. LACAZE, J.-C.
Etude de la croissance d'une algue planctonique en presence d'un detergent utilisé pour la destruction des nappes de pétrole en mer. (Study of the growth of a planktonic algae in the presence of a detergent used for the destruction of oil slicks at sea.)
C. r. hebd. Séanc. Acad. Sci., Ser. D, Paris, 265, 1489-1491.

732. ROSENTHAL, H., and GUNKEL, W.
Wirkungen von Rohöl-Emulgatorgemischen auf marine Fischbrut und deren Nährtiere. (Effects of crude oil-emulsifier mixtures on marine fish fry and their food animals.)
Helgoländer wiss. Meeresunters., 16, 315-320, 1967.

740. WILSON, D.P.
Long-term effect of low concentrations of an oil-spill remover ('detergent'): studies with the larvae of Sabellaria spinulosa.
J. mar. biol. Ass. U.K., 48, 177-183, 1968.

741. WILSON, D.P.
Temporary adsorption on a substrate of an oil-spill remover ('detergent'): tests with larvae of Sabellaria spinulosa.
J. mar. biol. Ass. U.K., 48, 183-186, 1968.

742. WILSON, K.W.
The toxicity of oil-spill dispersants to the embryos and larvae of some marine fish. 7p. (Preprint of a paper presented at the F.A.O. Technical Conference on marine pollution and its effects on living resources and fishing, Rome, 9-18 December 1970.) (FIR : MP/70/E-45)

1603. ALYAKRINSKAYA, I.O.
Effect of oil on the survival and rate of growth of young (Black sea) mullets. (In RUSSIAN)
Rhb. Khoz., 42, 16-18, 1966.

1611. HÄKKILÄ, K., and NIEMI, A.
Effects of oil and emulsifiers on eggs and larvae of northern pike (Esox lucius) in brackish water.
Aqua Fennica, 1973, 44-59, 1973.

1615. KÜHNHOLD, W.W.
Untersuchungen über die Toxizität von Rohölextrakten un-Emulsionen auf Eier und Larven von Dorsch und Hering. (An examination of the toxicity of extracts of crude oil and crude oil emulsions to eggs and larvae of cod and herring.) 174p. University of Kiel, Institute of Oceanography, 1972. Ph.D. thesis.

1616. KÜHNHOLD, W.W.
Investigations on the toxicity of sewater-extracts of three crude oils on eggs of cod (Gadus morhua L.)
Ber. dt. wiss. Kommn. Meeresforsch., 23, 165-180, 1974.

1624. RICE, S.D.
Toxicity and avoidance tests with Prudhoe Bay oil and pink salmon fry. In: American Petroleum Institute. Proceedings of joint conference on prevention and control of oil spills, Washington, D.C., March 13-15 1973. pp. 667-670. Washington, D.C., Amercian Petroleum Institute, 1973.

1656. KATZ, L.M.
The effects of water soluble fraction of crude oil on larvae of the decapod crustacean Neopanope texana (Sayi).
Envir. Pollut., 5, 199-204, 1973.

1669. RENZONI, A.
Influence of crude oil, derivatives and dispersants on larvae.
Mar. Pollut. Bull., 4, 9-13, 1973.

1675. ALLEN, H.
Effects of petroleum fractions on the early development of a sea urchin.
Mar. Pollut. Bull., 2, 138-140, 1971

1683. CHIA, F.-S.
Killing of marine larvae by diesel oil.
Mar. Pollut. Bull., 4, 29-30, 1973.

1706. BONEY, A.D.
Aromatic hydrocarbons and the growth of marine algae.
Mar. Pollut. Bull., 5, 185-186, 1974.

1715. LACAZE, J.-C.
De la production primaire d'écosystèmes expérimentaux établis dans l'estuaire de la Rance. Effet d'un pétrole brut. (On the primary productivity of experimental ecosystems set up in the Rance estuary. Effect of a crude petroleum.)
C.r.hebd.Séanc. Acad. Sci., Paris, Sér. D, 278, 2531-2534, 1974.

1717. MIRONOV, O.G., and LANSKAYA, L.A.
The influence of oil on the development of marine phytoplankton. 5p.
Paper presented at the 2nd international oceanographic congress, Moscow, 1966. (IN RUSSIAN)

1718. MIRONOV, O.G., and LANSKAYA, L.A.
Growth of marine microscopic algae in seawater contaminated with hydrocarbons. (In RUSSIAN)
Biologiya Morya, 17, 31-38, 1969.

1720. MOMMAERTS-BILLIET, F.
Growth and toxicity tests on the marine nanoplanktonic alga Platymonastetrathele G.S. West in the presence of crude oil and emulsifiers.
Envir. Pollut., 4, 261-282, 1973.

1723. PROUSE, N.J., and GORDON, D.C., Jr.
The effects of three oils on the growth of the dinoflagellate Dunaliella tertiolucta and the diatom Fragilaria sp. in axenic batch cultures. 6p.
Copenhagen, International Council for the Exploration of the Sea, Fisheries Improvement Committee, 1974. (CM 1974/E:41)

1724. PULICH, W.M., Jr., WINTERS, K., and VAN BAALEN, C.
The effects of a No. 2 fuel oil and two crude oils on the growth and photosynthesis of microalgae.
Mar. Biol., 23, 87-94, 1974.

4.

*A317. ALLEN, H. (1971)
Effects of petroleum fractions on the early development of a sea urchin, Mar. Pollut. Bull., vol. 2, no. 9, p. 138-140, 3 tabls., 4 refs.

*A334. KUHNHOLD, W.W. (1970)
The influence of crude oils on fish fry, FAO tech. conf. on mar. pollut. and its effects on living resources and fishing, Rome, Italy, Dec. 9-18, 10 p., 4 illus., 2 tabls., 7 refs.

N3664-4. CEAS, M. P. (1974)
Effects of 3-4 benzopyrene on sea-urchin egg development, Acta Embryol Exp., vol. 3 p. 267-272.

N3671-1. DE ANGELIS, E. and G. G. GIORDANO (1974)
Sea-urchin egg development under the action of benzo-a-pyrene and 7-12-dimethyl benz-a-anthracene, Cancer Res., vol. 34, no. 6, p. 1275-1280.

N3685-2. ALLEN, H. (1971)
Effects of petroleum fractions on the early development of a sea urchin, Mar. Pollut. Bull., vol. 2, no. 9, p. 138-140.

N3686-1. DE ANGELIS, E., and G. G. GIORDANO(1971)
Effect of 9-10-dimethyl-1-2-benz-anthracene on the developmentof sea-urchin embryos, Tumori, vol. 57, no. 3, p. 208.

N3698-4. CEAS, M. P. (1974)
Effects of 3-4-benzopyrene on sea urchin egg development, Acta Embryol. Exp., issue 3, p. 367-372.

N3717-4. CALABRESE, A., and D. A. NELSON (1974)
Inhibition of embryonic development of the hard clam, <u>Mercenaria mercenariaa</u>, by heavy metals, Bull. Environ. Contam. Toxicol., vol. 11, no. 1, p. 92-97.

N3720-2. DE ANGELIS, E., and G. G. GIORDANO (1974)
Sea urchin egg development under the action of benzo(a)pyrene and 7,12-dimethylbenz(a)anthracene, Cancer Res., vol. 34, no. 6, p. 1275-1280.

N3747-4. CALABRESE, A., R. S. COLLIER, D. A. NELSON, and J. R. MacINNES (1973)
Toxicity of heavy metals to embryos of the American oyster <u>Crassostrea virginica</u>, Mar. Biol., vol. 18, no. 3, p. 162-166.

N3769-3. ALLEN, H. (1971)
Effects of petroleum fractions on the early development of a sea urchin, Mar. Pollut. Bull., vol. 2, no. 9, p. 138-140.

4.

*0-18. SHIELS, WILLIAM E., III.
Effects of crude oil treated seawater on the metabolism of phytoplankton and seaweeds. M.S. thesis June 1973, in College of Mathematics, Physical Sciences, and Engineering, University of Alaska.

0-37. GRAINGER, E.H.
Biological productivity of the southern Beaufort Sea: the physical-chemical environmental of plankton. Interim Report of Beaufort Sea Project Study B6 (Part 1) Dec. 1974, Environment Canada, Victoria, B.C.

(NOTE: **Two asterisks means copy available.)

4. Additions to Classified Literature References as of 3/31/76.

**0-36. PERCY, J.A. and T.C. MULLIN.
Effects of crude oils on arctic marine invertebrates. Arctic Biological Station, Fisheries and Marine Service, Dept. of the Environment, P.O. Box 400, Ste. Anne de Bellevue, Quebec. Beaufort Sea Technical Report #11, Beaufort Sea Project, Dept. of the Environment, 512 Federal Building, 1230 Government St., Victoria, B.C. V8W 1Y4, December 1975.

0-114. LINDEN, O.
Acute effects of oil and oil dispersant mixture on larvae of Baltic herring. Ambio 4(3): 130-133(1975).

0-128. RENZONI, A.
Toxicity of three oils to gametes and larvae (Prudhoe Bay Oil and two others). Marine Pollut. Bull. 6, 125-128(1975

0-127. SHELTON, EDWARD H.
An historical review of oil spills along the Maine Coast 1953-1973. Bull. prepared for The Maine State Planning Office, Coastal Group and The Research Institute of the Gulf of Maine (TRIGOM) August 1973, 191 pages.

4. Additions to Classified Literature References as of 6/10/76.

P7-2 ALLEN, H., 1971
Effects of petroleum fractions on the early development of a sea urchin. Mar. Pollut. Bull., 2(9):138-40.

P27-2 BATTELLE PACIFIC NORTHWEST LABORATORIES, 1973
Effects of oil and chemically dispersed oil on selected marine biota--a laboratory study. Report to American Petroleum Institute, Committee on Environmental Affairs, Battelle Laboratories, Richland, Washington.

P46-2 BONEY, A.D., 1974
Aromatic hydrocarbons and the growth of marine algae. Mar. Poll. Bull., 5(12): 185-186.

P164-2 HARTUNG, R., 1965
Some effects of oiling on reproduction of ducks. J. Wildl. Mgmt., 29:872-874.

P210-2 KOPISCHKE, E.D., 1972
The effect of 2,4-D and diesel fuel on egg hatchability. J. Wildl. Mgmt., 36: 1353-1356.

P215-2 KUHNHOLD, W.W., 1972
The influence of crude oils on fish fry. In: Ruivo, M. (ed.) Marine Pollution and Sea Life, Fishing News (Books) Ltd., Surrey, England, 624pp.

P237-4 MACKIN, J.G., 1948D
A study of the effect of a heavy surface layer of crude oil. Texas A&M Univ. Research Foundation. Project #9.

P257-4 MENZEL, R.W., 1949
The attachment, survival, and growth of oyster spat on oil impregnated wood. Texas A&M Univ. Research Foundation, Project #9.

P259-2 MENZEL, R.W. & S.H. HOPKINS, 1951
Report on experiments to test the effects of oil well brine or bleedwater on oysters at Lake Barre oil field. Texas A&M Univ. Research Foundation, Project #9.

P259-3 MENZEL, R.W. & S.H. HOPKINS, 1952
Report on commercial scale oyster planting experiments in Bayou Bas Blue and in Bay Ste. Elaine Oil Field. Texas A&M Univ. Research Foundation, Project #9.

P260-1 MENZEL, R.W. & S.H. HOPKINS, 1953
Experiments to determine if bleedwater from drilling operations affects oyster mortality and growth. Texas A&M Univ. Research Foundation, Project #9.

P266-3 MIRONOV, O.G, 1970
Division of some diatoms in sea water containing petroleum products. Biol. Nauk. 13(7):69-72. Illus.

P267-1 MIRONOV, O.G., 1969
Development of some Black Sea fish in sea water polluted by petroleum products. Vop. Ikhtiol., 9(6):919-922.

P351-2 RENZONI, A., 1973
Influence of crude oil derivatives and dispersants on larvae. Mar. Poll. Bull., 4(1):9-13.

4.

0-169 KAUSS, P.B. and T.C. HUTCHINSON, 1975
The effects of water-soluble petroleum components on the gorwth of Chlorella vulgaris Beijerinck. Environ. Pollut. 9:157-174.

0-170 RICE, S.D., D.A. MOLES and J.W. SHORT, 1973 ?
The effect of Prudhoe Bay crude oil on survival and growth of eggs, alevins, and fry of pink salmon, Oncorhynchus gorbuscha. In: Proceedings Joint Conference on Prevention and Control of Oil Spills. API/EPA/USCG, pp. 503-507.

0-171 U.S. BUREAU OF FISHERIES, 1926
Preliminary conference on oil pollution of navigable waters, Washington, June 8-16, 1926. Appendix 6. Report of the U.S. Bur. of Fish.: preliminary investigation on effect of oil pollution on marine pelagic eggs, April 1925. P. 85-92.

5. EFFECTS ON BEHAVIOR (BEHAVIOR INCLUDES WIDE RANGE OF PHENOMENON MOSTLY THOSE DETERMINABLE BY MERE OBSERVATION).

371. ALYAKRINSKAYA, I.O.
On the behaviour and ability to filter of the Black Sea mussel Mytilus galloprovincialis in oil polluted water. (In Russian, with English summary) Zool. Zh., 45, 998-1003, 1966.

381. LUNZ, G.R.
The effect of bleedwater and of water extracts of crude oil on the pumping rate of oysters. Texas A and M Research Foundation, 1950. (Project Nine - unpublished report)

695. BARDACH, J.E., FUJIYA, M., and HOLL, A.
Detergents: effects on the chemical senses of the fish Ictalurus natalis (Le Sueur).
Science, N.Y., 148, 1605-1607, 1965.

1604. BLACKMAN, R.A.A.
Effects of sunken oil on the feeding of plaice on brown shrimps and other benthos. 7p. Copenhagen, International Council for the Exploration of the Sea, Fisheries Improvement Committee, 1974. (CM 1974/E:24)

1624. RICE, S.D.
Toxicity and avoidance tests with Prudhoe Bay oil and pink salmon fry. In: American Petroleum Institute. Proceedings of joint conference on prevention and control of oil spills, Washington, D.C., March 13-15 1973. pp. 667-670. Washington, D.C., American Petroleum Institute, 1973.

1631. ANDERSON, G.E.
The effects of oil on the gill filtration rate of Mya arenaria. Va. J. Sci., 23, (2), 45-47, 1972.

1632. ATEMA, J., JACOBSON, S., TODD, J., and BOYLAN, D.(B.)
The importance of chemical signals in stimulating behavior of marine organisms: effects of altered environmental chemistry on animal communication. In: Glass, G.E., editor. Bioassay techniques and environmental chemistry, pp. 177-197. Ann Arbor, Michigan, Ann Arbor Science Publishers, 1973.

1633. ATEMA, J. and STEIN, L.(S.)
Sublethal effects of crude oil on lobster, (Homarus americanus) behavior. viii, 76p. Woods Hole, Massachusetts, Woods Hole Oceanographic Institution, 1972. (Tech. Report No. 72-74)

1634. ATEMA, J., and STEIN, L.S.
Effects of crude oil on the feeding behaviour of the lobster (Homarus americanus.
Envir. Pollut., 6, 77-86, 1974.

1636. BLACKMAN, R.A.A.
Effects of sunken crude oil on the feeding and survival of the brown shrimp Crangon crangon. 8p. Copenhagen, International Council for the Exploration of the Sea, Shellfish and Benthos Committee, 1972. (CM 1972/K:13)

1646. GALTSOFF, P.S., and SMITH, R.O.
The effect of oil on feeding of oysters.
Bull. Bur. Fish., Wash., 48, (18), 167-193, 1935.

1650. HARGRAVE, B.T., and NEWCOMBE, C.P.
Crawling and respiration as indices of sublethal effects of oil and a dispersant on an intertidal snail Littorina littorea.
J. Fish. Res. Bd. Can., 30, 1789-1792, 1973.

1652. JACOBSON, S.M., and BOYLAN, D.B.
Effect of seawater soluble fraction of kerosene on chemotaxis in a marine snail, Nassarius obsoletus.
Nature, Lond., 241, 213-215, 1973.

1655. KARINEN, J.F., and RICE, S.D.
Effects of Prudhoe Bay crude oil on molting Tanner crabs, Chionoecetes bairdi.
Mar. Fish. Rev., 36, (7), 31-37, 1974.

1658. KITTREDGE, J.S.
Effectsof the water-soluble component of oil pollution on chemoreception by crabs. 5p. Duarte, California, City of Hope National Medical Center, 1971.

1662. NUWAYHID, M.A.
The effect of Arabian light crude oil and Corexit on the respiration of the bivalved molluscs Brachidontes variablis and Donax trunculus.
xiv, 145p. Beirut, American University of Beirut, 1973. M. Sc. thesis.

1673. TAKAHASHI, F.T., and KITTREDGE, J.S.
Sublethal effects of the water soluble component of oil: chemical communication in the marine environment.
In: Ahearn, D.G., and Meyers, S.P., editors. The microbial degradation of oil pollutants. Proceedings of a workshop, Atlanta, Georgia, 4-6 December 1972. pp. 259-264. Baton Rouge, Louisiana, Louisiana State University, Center for Wetland Resources, 1973.

1692. KITTREDGE, J.S.
The effects of crude oil pollution on the behaviour of marine invertebrates. 14p. Duarte, California, City of Hope National Medical Center, Division of Neurosciences, 1973.

1620. MIYAKE, Y.
Studies on abnormal odor fish by oil pollution in Mizushima industrial area. Part 1. Distribution of abnormal odor fish.
Okayama- Igakkai- Zasshi, 81, (3-4), 193-197, 1967.

(NOTE: **Two asterisks means copy available.)

5. Additions to Classified Literature References as of 4/26/76.

**0-36. PERCY, J.A. and T.C. MULLIN.
Effects of crude oils on arctic marine invertebrates. Arctic Biological Station, Fisheries and Marine Service, Dept. of the Environment, P.O. Box 400, Ste. Anne de Bellevue, Quebec. Beaufort Sea Technical Report #11, Beaufort Sea Project, Dept. of the Environment, 512 Federal Building, 1230 Government St., Victoria, B.C. V8W 1Y4, December 1975.

6. EFFECTS ON PHYSIOLOGICAL PROCESSES (INCLUDES ALSO UNSPECIFIED LETHAL EFFECTS).

349. FLEROV, B.A.
Effect of phenol on the conditioned reflex activity of fish. (In Russian)
Gidrobiol. Zh., Kiev, 1, (3), 49-50, 1965.

351. GRAHAM, R.J., and DORRIS, T.C.
Long-term toxicity bioassay of oil refinery effluents.
Wat. Res., 2, 643-663, 1968.

370. ALBEAUX-FERNET, M., and LAUR, C.-M.
Influence de la pollution par le mazout sur les testicules de crabes (étude histologique). (Influence of pollution by fuel oil on crab testicles (histologic study).)
C. r. hebd. Séanc. Acad. Sci., Ser. D, Paris, 270, 170-173, 1970.

371. ALYAKRINSKAYA, I.O.
On the behaviour and ability to filter of the Black Sea mussel *Mytilus galloprovincialis* in oil polluted water. (In Russian, with English summary)
Zool. Zh., 45, 998-1003, 1966.

381. LUNZ, G.R.
The effect of bleedwater and of water extracts of crude oil on the pumping rate of oysters. Texas A and M Research Foundation, 1950. (Project Nine - unpublished report)

382. MACKIN, J.G.
Report on a study of the effect of crude oil pollution on feeding of oysters. Texas A and M Research Foundation, 1948. (Project Nine unpublished report)

442. GEORGE, J.D.
Sub-lethal effects on living organisms.
Mar. Pollut. Bull, 1, 107-109, 1970.

444. GRAHAM, R. J.
Long-term toxicity bioassay of oil refinery effluents. 55p.
Oklahoma State University, 1963. (Ph.D. thesis)

492. BAKER, J.M.
The effects of oils on plant physiology.
In: Cowell, E.B. Proceedings of the symposium on the ecological effects of oil pollution on littoral communities, London, 30 November-1 December, 1970. London, Institute of Petroleum, 1971.

497. BELLAMY, D.J., and WHITTICK, A.
Problems in the assessment of the effects of oil pollution on inshore marine ecosystems dominated by attached macrophytes.
Fld Stud., 2, (suppl.), 49-54, 1968.

6.

695. BARDACH, J.E., FUJIYA, M., and HOLL, A.
Detergents: effects on the chemical senses of the fish Ictalurus natalis (Le Sueur).
Science, N.Y., 148, 1605-1607, 1965.

716. KISHIMOTO, U., and ADELMAN, W.J.
Effect of detergent on electrical properties of squid (Loligo pealii) axon membrane.
J. ge. Physiol., 47, 975-986, 1964.

722. MANWELL, C., and BAKER, C.M.A.
A study of detergent pollution by molecular methods: starch gel electrophoresis of a variety of enzymes and other proteins.
J. Mar. Biol. Ass. U.K., 47, 659-675, 1967.

728. PERKINS, E.J.
Some sub-lethal effects of B.P. 1002 upon marine gastropod molluscs.
J. Devon Trust Nat. Conserv., 19, 794-798, 1968.

740. WILSON, D.P.
Long-term effect of low concentrations of an oil-spill remover ('detergent'): studies with the larvae of Sabellaria spinulosa.
J. Mar. Biol. Ass. U.K., 48, 177-183, 1968.

1286. YENTSCH, C.S., GILFILLAN, E.S., and SEARS, J.R.
The fate and behavior of crude oil on marine life. 69p.
Gloucester Marine Station, University of Massachusetts, 1973.

1606. BLANTON, W.G., and ROBINSON, M.C.
Some acute effects of low boiling petroleum fractions on the cellular structures of fish gills under field conditions.
In: Ahearn, D.G., and Meyers, S.P., editors. The microbial degradation of oil pollutants. Proceedings of a workshop, Atlanta, Georgia, 4-6 December 1972. pp. 265-273. Baton Rouge, Louisiana, Louisiana State University, Center for Wetland Resources, 1973.

1613. KLOTH, T.C., and WOHLSCHLAG, D.E.
Size-related metabolic responses of the pinfish, Lagodon rhomboides, to salinity variations and sublethal petrochemical pollution.
Contr. Mar. Sci. Univ. Tex., 16, 125-137, 1972.

1614. KRISTOFFERSSON, R., BROBERG, S., and OIKARI, A.
Physiological effects of a sublethal concentration of phenol in the pike (Esox Lucius L.) in pure brackish water.
Annls. Zool. Fenn., 10, 392-396, 1973.

1624. RICE, S.D.
Toxicity and avoidance test with Prudhoe Bay oil and pink salmon fry.
In: American Petroleum Institute. Proceedings of joint conference on prevention and control of oil spills, Washington, D.C., March 13-15 1973. pp. 667-670. Washington, D.C., American Petroleum Institute, 1973.

1625. SAWARD, D.
Some physiological and behavioural aspects of the effects of phenol upon plaice. 5p. Copenhagen, International Council for the Exploration of the Sea, Fisheries Improvement Committee, 1972. (CM 1972/E:23)

1631. ANDERSON, G.E.
The effects of oil on the gill filtration rate of Mya arenaria.
Va J. Sci., 23, (2), 45-47, 1972.

1632. ATEMA, J., JACOBSON, S., TODD, J., and BOYLAN, D.(B.)
The importance of chemical signals in stimulating behavior of marine organisms: effects of altered environmental chemistry on animal communication.
In: Glass, G.E., editor. Bioassay techniques and environmental chemistry, pp. 177-197. Ann Arbor, Michigan, Ann Arbor Science Publishers, 1973.

1647. GILFILLAN, E.S.
Effects of seawater extracts of crude oil on carbon budgets in two species of mussels.
In: American Petroleum Institute. Proceedings of joint conference on prevention and control of oil spills, Washington, D.C., March 13-15 1973. pp. 691-695. Washington, D.C., American Petroleum Institute, 1973.

1648. GILFILLAN, E.S.
Decrease of net carbon flux in two species of mussels caused by extracts of crude oil.
Mar. Biol., 29, 53-57, 1975.

1649. HARGER, J.R.E., and STRAUGHAN, D.
Biology of sea mussels (Mytilus californianus (Conrad) and M. edulis (Linn.)) before and after the Santa Barbara oil spill (1969).
Wat. Air Soil Pollut., 1, 381-388, 1972.

1652. JACOBSON, S.M., and BOYLAN, D.B.
Effect of seawater soluble fraction of kerosene on chemotaxis in a marine snail, Nassarius obsoletus.
Nature, Lond., 241, 213-215, 1973.

1653. JEFFRIES, H.P.
A stress syndrome in the hard clam, Mercenaria mercenaria.
J. Invert. Path., 20, 242-251, 1972.

1655. KARINEN, J.F., and RICE, S.D.
Effects of Prudhoe Bay crude oil on molting Tanner crabs, Chionoecetes bairdi.
Mar. Fish. Rev., 36, (7), 31-37, 1974.

1658. KITTREDGE, J.S.
Effects of the water-soluble component of oil pollution on chemoreception by crabs. 5p. Duarte, California, City of Hope National Medical Center, 1971.

1662. NUWAYHID, M.A.
The effect of Arabian light crude oil and Corexit on the respiration of the bivalved molluscs Brachidontes variablis and Donax trunculus.
xiv, 145p. Beirut, American University of Beirut, 1973. M.Sc. thesis.

1663. OTTWAY, S.(M.)
The toxicity of oil to animals subjected to salinity stress.
Rep. Oil Pollut. Res. Unit, Fld Stud. Coun., 1972, 24-30, 1973.

1665. PARSONS, R.
Note on the recovery of Littorina saxatilis from pollution with refinery effluent when under osmotic stress.
Rep. Oil Pollut. Res. Unit, Fld Stud. Coun., 1972, 31, 1973.

1666. PARSONS, R.
Some sublethal effects of refinery effluent upon the winkle Littorina saxatilis.
Rep. Oil Pollut. Res. Unit, Fld Stud. Coun., 1972, 21-23, 1973.

1673. TAKAHASHI, F.T., and KITTREDGE, J.S.
Sublethal effects of the water soluble component of oil: chemical communication in the marine environment.
In: Ahearn, D.G., and Meyers, S.P., editors. The microbial degradation of oil pollutants. Proceedings of a workshop, Atlanta, Georgia, 4-6 December 1972. pp. 259-264. Baton Rouge, Louisiana, Louisiana State University, Center for Wetland Resources, 1973.

1677. ANDREWS, A.R., and FLOODGATE, G.D.
Some observations on the interactions of marine protozoa and crude oil residues.
Mar. Biol., 25, 7-12, 1974.

1679. BEAN, R.M., VANDERHORST, J.R., and WILKINSON, P.
Interdisciplinary study of the toxicity of petroleum to marine organisms.
48p. Richland, Washington, Battelle Pacific Northwest Laboratories, 1974.

1707. BROWN, D.H.
The effect of Kuwait crude oil and a solvent emulsifier on the metabolism of the marine lichen Lichina pygmaea.
Marine Biol., 12, 309-315, 1972.

1711. GANNING, B., and BILLING, U.
Effects on community metabolism of oil and chemically dispersed oil on Baltic bladder wrack, Fucus vesiculosus.
In: Beynon, L.R., and Cowell, E.B., editors. Ecological aspects of toxicity testing of oils and dispersants: (Proceedings of a workshop...) pp. 53-61. Barking, Essex, Applied Science Publishers, 1974.

1726. SCHRAMM, W.
The effects of oil pollution on gas exchange in Porphyra umbilicalis when exposed to air.
Int. Seaweed Symp., 7, 309-315, 1972.

1727. SCHRAMM, W.
Untersuchungen über den Einfluss von Ölverschmutzungen auf Meeresalgen. I. Die Wirkung von Roholfilmen auf den CO_2-Gaswechsel ausserhalb des Wassers. (Investigations on the influence of oil pollution on marine algae. 1. The effect of crude-oil films on the CO_2 gas exchange outside the water.)
Mar. Biol., 14, 189-198, 1972.

1728. SHIELS, W.E.
Effects of crude oil treated seawater on the metabolism of phytoplankton and seaweeds. Fairbanks, University of Alaska, 1973.
M.S. thesis.

1761. THOMAS, M.L.H.
Effects of bunker C oil on intertidal and lagoonal biota in Chedabucto Bay, Nova Scotia.
J. Fish. Res. Bd. Can., 30, 83-90, 1973.

1762. VAUGHAN, B.E.
Effects of oil and chemically dispersed oil on selected marine biota - a laboratory study. 120p. Richland, Washington, Battelle Pacific Northwest Laboratories, 1973.

2047. BUTTON, D.K.
Petroleum - ciological effects in the marine environment.
In: Hood, D.W., editor. Impingement of man on the oceans. pp. 421-294. Willey-Interscience, 1971.

2215. ATLAS, R.M., and BARTHA, R.
Fate and effects of polluting petroleum in the marine environment.
Residue Rev., 49, 49-85, 1973.

2218. BUTLER, M.J.A., and BERKES, F.
Biological aspects of oil pollution in the marine environment. A review.
Manuscr. Rep. Mar. Sci. Centre, McGill Univ., No. 22, 118p., 1972.

2219. BUTLER, M.J.A., BERKES, F., and POWLES, H.
Biological aspects of oil pollution in the marine environment: a review. (Enlarged edition.) 133p. Montreal, McGill University, Marine Science Centre, 1974. (Manuscr. Rep. No. 22A)

---

*A32. GRAHAM, R.J., and T.C. DORRIS (1968)
Long-term toxicity bioassay of oil refinery effluents, Water Res., vol. 2, p. 643-663, 3 illus., 11 tabls., 25 refs.

*A330. GEORGE, J.D. (1970)
Sub-lethal effects on living organisms, Mar. Pollut, Bull., vol. 1, p. 107-109, 22 refs.

6.

N3681-2. WALSH, F. M., and M. MITCHELL (1972)
A comparative study of spontaneous human dimethylbunzanthracene induced hamster transplanted Rouse Cloudman S-91 and hereditary fish Melanopas, Am. J. Pathol., vol. 70, no. 2, p. 9A.

N3699-3. ANDERSON, J. W., J. M. NEFF, and S. R. PETROCELLI (1974)
Sublethal effects of oil, heavy metals, and PCB's (polychlorinated biphenyls) on marine organisms, Survival Toxic Environ., (Pap. Synp.), p. 83-121.

N3728-4. BROCKSEN, R. W., and H. T. BAILEY (1973)
Respiratory response of juvenile chinook salmon and striped bass exposed to benzene, a water-soluble component of crude oil, Proc. of Joint Conf. Prev. Contr. Oil Spills, p. 783-791.

N3736-1. WALSH, F., and R. MITCHELL (1973)
Inhibition of bacterial chemoreception by hydrocarbons, Microbial Degradation Oil Pollutants, Workshop, p. 275-278.

O-6. HOOD, DONALD W., Editor.
Impingement of man on the ocean. John Wiley, 1971. (Price $24.95).

O-15. CARTHY, J.D. and DON R. ARTHUR, Editors.
The biological effects of oil pollution on littoral communities. Supplement to Vol. 2 of Field Studies published by Field Studies Council, July 1968. Proceedings of a symposium held at the Ancelton Field Center, Pembroke, Wales, Feb. 17, 18, 19, 1968. About 200 p., including 30 p. bibliography.

O-36. PERCY, J.A.
Effects of crude oils on Arctic marine invertebrates. Interim report of Beaufort Sea Project, Study B5b. Dec. 1974, Environment Canada, Victoria, B.C.

O-41. SMITH, THOMAS G. and JOSEPH R. GERACI.
The effect of contact and ingestion of crude oil on ringed seals of the Beaufort Sea. Interim Report of Beaufort Sea Project Study A-5, Dec. 1974. Environment Canada, Victoria, B.C.

O-59. ALEXANDER, VERA, RITA HORNER, and R.C. CLASBY.
Metabolism of Arctic Sea Ice Organisms. University of Alaska, MS Report R74-4, 120 p.

O-67. AMERICAN SOCIETY FOR TESTING MATERIAL, PUBLISHER, 1916 Race St., Philadelphia, PA 19103, 1975.
Water quality parameters - a symposium (book), by Canada Center for Inland Waters and Anal. Chem. Div. of Chem. Inst. of Canada, Burlington, Ontario, Canada. List price $29.50. Includes: Environmental impact of experimental oil spills in Canadian Arctic, et al., 20 p. Much of book is on pollutants other than petroleum oil, e.g., pesticides and heavy metals.

(NOTE: **Two asterisks means copy available.)

6. Additions to Classified Literature References as of 3/31/76.

**0-36. PERCY, J.A. and T.C. MULLIN.
Effects of crude oils on arctic marine invertebrates. Arctic Biological Station, Fisheries and Marine Service, Dept. of the Environment, P.O. Box 400, Ste. Anne de Bellevue, Quebec. Beaufort Sea Technical Report #11, Beaufort Sea Project, Dept. of the Environment, 512 Federal Building, 1230 Government St., Victoria, B.C. V8W 1Y4, December 1975.

0-9. NELSON-SMITH, A.
Problems of oil pollution at sea. In: Advances in Marine Biology, 8, p.215-306. London, New York, Academic Press, 1970, 354 references.

*1635 AVOLIZI, R.J. and NUWAYHID.
1974. Effects of crude oil and dispersants on bivalves. Marine Pollution Bulletin 5(10):149-152.

6.

0-78. RAY, C. and M.S.R. SMITH. 1968.
Thermoregulation of the pup and adult Weddell seal, *Leptonychotes weddelli* (Lesson), in Antarctica. Zoologica, Vol. 53, p. 33-48.

0-85. DE VRIES, ARTHUR L. and GEORGE N. SOMERO. 1970.
The physiology and biochemistry of low temperature adaptation in Antarctic marine organisms. Scripps Institution of Oceanography, University of California at San Diego, LaJolla, CA 92037.

6. Additions to Classified Literature References as of 6/24/76.

P13-2 ALYAKRINSKAYA, I.O., 1966
Behavior and filtering ability of the Black Sea Mytilus Galloprovincialis ce in oil polluted water. Zooh. Zh. 45(7):998-1003.

P14-2 ANDERSON, G.E., 1972
The effects of oil on the gill filtration rate of "Mya arenaria." Va. J. Sci., 23(2):45-47.

P20-2 AVOLIZI, R.J. & NUWAYHID, 1974
Effects of crude oil and dispersants on bivalves. Mar. Poll. Bull., 5(10):149-152.

P27-2 BATTELLE PACIFIC NORTHWEST LABORATORIES, 1973
Effects of oil and chemically dispersed oil on selected marine biota--a laboratory study. Report to American Petroleum Institute, Committee on Environmental Affairs, Battelle Laboratories, Richland, WA.

P43-3 BLUMER, M., 1972
Oil contamination and living resources of the sea. In: Ruivo, Mario (ed.), Marine Pollution and Sea Life, Fishing New (Books) Ltd., Surrey, England.

P52-3 BROCKSEN, R.W. & H.T. BAILEY, 1973
Respiratory response of juvenile chinook salmon and striped bass exposed to benzene, a water soluble component of crude oil. PP. 783-91, in: Proceedings of a joint conference on prevention and control of oil spills. March 13-15, 1973. Washington, D.C., sponsored by the American Petroleum Institute, EPA, & U.S. Coast Guard, 834 pp.

P65-2 CARDWELL, R.D., 1973
Acute toxicity of No. 2 diesel oil to selected species of marine invertebrates, marine sculpins, and juvenile salmon. Univ. of Washington Ph.D. thesis, Seattle, Washington.

P79-2 CLARK, R.B. & K.G. GREGORY, 1971
Feather wetting in cleaned birds. Marine Pollut. Bull., 2(5):78-79.

P79-3 CLARK, R.B., 1968
Oil pollution and conservation of sea birds. On oil pollution of the sea. Oct. 7-0, 1968. PP. 76-112, in: Proceedings of the International Conference Rome, Italy, 414 pp.

P149-3 GRAHAM, R.J. & T.C. DORRIS, 1968
Long term toxicity bioassay of oil refinery effluents. Water Resources, 2:643-663.

P151-4 GRINER, L.A. & R. HERDMAN, 1970
Effects of oil pollution on waterfowl: A study of salvage methods. Environmental Protection Agency, 35 pp.

P164-3 HARTUNG, R., 1967
Energy metabolism in oil covered ducks. J. Wildl. Mgmt., 29:872-874.

P224-3 LEE, R.F., R. SAUERHEBER, & G.H. DOBBS, 1972
Uptake, metabolism and discharge of 2 polycyclic aromatic hydrocarbons by marine fish. Mar. Biol. (Berl.) 17(3):201-208. Illus.

P255-1 MCEWAN, E.H. & A.F.C. KOELINK, 1973
The heat production of oiled mallards and scaup. Can. J. Zool., 51(1):27-31.

*P372-2 SCARRATT, D.J., 1974
Section 4: Impact of spills and clean-up technology on living natural resources, and resource-based industry. PP. 141-158, in: Summary of physical, biological, socio-economic and other factors relevant to potential oil spills in the Passamaquoddy region of the Bay of Fundy. Fisheries Research Board of Canada, Technical Report No. 428.

*P376-2 SCHRAMM, W., 1971
The effects of oil pollution on gas exchange in "Porphyra umbilicalis" when exposed to air. Proc. 7th Internat. Seaweed Symposium Sapporo, Japan. 8-12 August, 1971. U. Tokyo Press, pp. 309-315.

*P377-2 SCHRAMM, W. 1971
The effects of oil pollution on gas exchange in "Porphyra umbilicalis" when exposed to air. PP. 309-315, in: Proceedings of the seventh International Seaweed symposium, Sapporo, Japan, 8-12 August, 1971, Univ. of Tokyo Press.

O-147 ANDERSON, J.W. (ed.), 1975
Laboratory studies on the effects of oil on marine organisms: An overview. Amer. Petrol. Instit., API Publication #4249, 70 p.

O-148 ANDERSON, R.D., 1973
Effects of petroleum hydrocarbons on the physiology of the American oyster, Crassostrea virginica Gmelin. Texas A&M University (Ph.D. thesis)

O-149 ANONYMOUS, 1974
Status of knowledge about impact on marine ecosystems from oil pollution. First draft for Annual Report on Ocean Pollution, 20 p.

O-172 BROCKSEN, R.W., and H.T. BAILEY, 1973
Respiratory response of juvenile chinook salmon and striped bass exposed to benzene, a water-soluble component of crude oil. In: American Petroleum Institute. Proceedings of joint conference on prevention and control of oil spills. March 13-15, 1973, Washington, D.C. American Petroleum Institute. Environ. Protection Agency & U.S. Coast Guard, pp. 783-791.

O-173 BROOKS, J. & W. SACKETT, 19??
Sub-lethal effects of light hydrocarbon. (Source unknown), 4 p.

O-174 CRAPP, G.B., 1971
Chronic oil pollution. In: Cowell, E.B. (ed.). The ecological effects of oil pollution on littoral communities. Proceedings of a symposium organized by the Instit. of Petroleum held at the Zoological Society of London, Nov. 30 - Dec. 1, 1970. London: Institute of Petroleum, Elsevier Pub. Co., Ltd., Amsterdam, London, New York, pp. 187-207.

O-154 EPA, 1974
Biological effects of water-soluble fractions of oils. In: July 1 - Dec, 1974 Semi-annual Report, EPA, Narragansett, Rhode Island laboratory, pp. 120-123.

O-175 GARDNER, G.R., P.P. YEVICH, and P.F. ROGERSON, 1975
Morphological anomalies in adult oyster, scallop, and Atlantic silversides exposed to waste motor oil. In: Amer. Petrol. Instit. 1975 conference on prevention and control of oil pollution. Proceedings, March 25-27, 1975, San Francisco, CA. API/EPA/USCG, pp. 473-477.

6.

176 HARGRAVE, B.T. & C.P. NEWCOMBE, 1973
Crawling and respiration as indices of sublethal effects of oil and a dispersant on an intertidal snail Littorina littorea. J. Fish. Res. Board Can. 30:1789-1792.

160 PERCY, J.A., 1976
Responses of Arctic marine crustaceans to crude oil and oil-tainted food. Environ. Pollut. 10:155-162.

177 THOMAS, R.E. and S.D. RICE, 1975
Increased opercular rates of pink salmon (Oncorhynchus gorbuscha) fry after exposure to the water-soluble fraction of Prudhoe Bay crude oil. J. Fish. Res. Board Can. 32:2221-2224.

7. EFFECTS ON BIOCHEMICAL PROCESSES (ENZYMES, METABOLISM, ET AL., ALSO PHOTOSYNTHESIS).

1627. STURDEVANT, D.C.
The influence of crude oil on the serum proteins of the sockeye salmon. 43p. Fairbanks, University of Alaska, 1972. M.S. thesis.

1708. DAVAVIN, I.A., MIRONOV, O.G., and TSIMBAL, I.M.
Influence of oil on nucleic acids of algae.
Mar. Pollut. Bull., 6, 13-14-, 1975.

1712. GORDON, D.C., JR., AND PROUSE, N.J.
The effects of some crude and refined oils on marine phyto photosynthesis. 10p. Copenhagen, International Council for the Exploration of the Sea, Fisheries Improvement Committee, 1972. (CM 1972/E:33)

1713. GORDON, D.C., JR., AND PROUSE, N.J.
The effects of three oils on marine phytoplankton photosynthesis.
Mar. Biol., 22, 329-333, 1973.

1724. PULICH, W.M., JR., WINTERS, K., and VAN BAALEN, C.
The effects of a No. 2 fule oil and two crude oils on the growth and photosynthesis of microalgae.
Mar. Biol., 28, 87-94, 1974.

1744. LEE, R.F., HIROTA, J., NEVENZEL, J.C., SAUERHEBER, R., BENSON, A.A., and LEWIS, A.
Lipids in marine environment.
Rep. Calif. Coop. Ocean. Fish. Invest., 16, 95-102, 1972.

722. MANWELL, C., and BAKER, C.M.A.
A study of detergent pollution by molecular methods: starch gel electrophoresis of a variety of enzymes and other proteins.
J. Mar. biol. Ass. U.K., 47, 659-675, 1967.

7.

N3668-2. SABO, D. J., J. J. STEGEMAN, and L. S. GOTTLIEB (1975)
Petroleum hydrocarbon pollution and hepatic lipogenesis in the marine fish Fundulus heteroclitus, Fed. Proc., vol. 34, no. 3, p. 810.

N3668-3. BURNS, K. A., and D. SABO (1975)
Environmental contamination and the induction of microsomal mixed function oxidases in anes tuarine fish Fundulus heteroclitus, Fed. Proc., vol. 34, no. 3, p. 810.

N3699-3. ANDERSON, J. W., J. M. NEFF, and S. R. PETROCELLI (1974)
Sublethal effects of oil, heavy metals, and PCB's (polychlorinated biphenyls) on marine organisms, Survival Toxic Environ. (Pap. Symp.), p. 83-121.

N3701-1. TURNER, J. C., and R. S. GREEN (1974)
Effect of hexachlorobenzene on microsomal enayme systems, Biochem., vol. 23, no. 17, p. 2387-2390.

N3701-2. CORNER, E. D. S., C. C. KILVINGTON, and S. C. M. O'HARA (1973)
Qualitative studies on the metabolism of naphthalene in Maja squinado, J. Mar. Biol. Assoc. U.K., vol. 53, no. 4, p. 819-832.

N3708-2. MORRIS, R. J., and F. CULKIN (1974)
Lipid chemistry of eastern Mediterranean surface layers, Nature (London), vol. 250, no. 5468, p. 640-642.

N3714-3. SCHMIDT-NIELSEN, B. (1974)
Osmoregulation. Effect of salinity and heavy metals, Fed. Proc., vol. 33, no. 10,p. 2137-2146.

N3716-4. ALYATRINSKAYA, I. O. (1974)
Biochemical changes in the hemolymph of the Black Sea mussel Mytilus galloprovincialis during petroleum pollution, Zool. Zh., vol. 53, no. 2, p. 179-183 (Language-Russian).

N3720-1. DIVAVIN, I. A. (1974)
DNA of Black Sea mussels under normal conditions and during petroleum pollution, Gidrobiol. Zh., vol. 9, no. 6, p. 86-88 (Language-Russian).

N3730-1. KATO, T. (1973)
Toxicity of chemical substances (heavy metals, etc.) to fish and animal, Magoya Shiritsu Daigaku Igakkai Zasshi, vol. 24, no. 1, p. 11-34 (Language-Japanese).

N3740-4. FARRINGTON, J. W., J. M. TEAL, J. G. QUINN, T. WADE, and K. BURNS (1973)
Intercalibration of analyses of recently bioxynthesized hydrocarbons and petroleum hydrocarbons in marine lipids, Bull. Environ, Contam. Toxicol., vol. 10, no. 3, p. 129-136.

N3756-1. LEE, R. F., R. SAUERHEBER, and G. H. DOBBS (1972)
Uptake, metabolism, and discharge of polycyclic aromatic hydrocarbons by marine fish, Mar. Biol., vol. 17, no. 3, p. 201-208.

7.

N3763-2. LEE, R. F., R. SAUERHEBER, and A. A. BENSON (1972)
Petroleum hydrocarbons. Uptake and discharge by the marine mussel *Mytilus edulis*, Geol. Nefti Gaza, vol. 7, p. 14-20 (Language-Russian).

0-18. SHIELS, WILLIAM E., III. (Thesis)
Effects of crude oil treated seawater on the metabolism of phytoplankton and seaweeds. M.S. thesis June, 1973, in College of Mathematics, Physical Sciences, and Engineering, University of Alaska.

0-69. DAYTON, P.K., G.A. ROBILLIARD, AND A.L. DE VRIES. 1969.
Anchor ice formation in McMurdo Sound, Antarctica and its biological effects. Science, Vol. 163, p. 273-74.

0-75. DE VRIES, A.L., S.K. KOMATSU, and R.E. FEENEY. 1970.
Chemical and physical properties of freezing point-depressing glycoproteins from Antarctic fishes. J. Biol. Chem., Vol. 245, p. 2901-8.

0-76. DE VRIES, A.L., J. VANDENHEEDE, and R.E. FEENEY. 1971.
Primary structure of freezing point-depressing glycoproteins. J. Biol. Chem., Vol. 246, p. 305-9.

0-77. KOMATSU, S.K., A.L. DE VRIES, and R.E. FEENEY. 1970.
Studies of the structure of freezing point-depressing glycoproteins from and Antarctic fish. J. Biol. Chem., Vol. 245, p. 2909-13.

0-80. SOMERO, G.N. 1969a.
Enzymic mechanisms of temperature compensation: immediate and evolutionary effects of temperature on enzymes of aquatic poikilotherms. American Naturalist, vol. 103, p. 517-30.

0-84. SOMERO, G.N. and P.W. HOCHACHKA. 1968.
The effect of temperature on catalytic and regulatory functions of pyruvate kinases of the rainbow trout and the Antarctic fish *Trematomus bernacchii*. Biochemical Journal, vol. 110, p. 395-400.

0-85. DE VRIES, ARTHUR L. and GEORGE N. SOMERO. 1970.
The physiology and biochemistry of low temperature adaptation in Antarctic marine organisms. Scripps Institution of Oceanography, University of California at San Diego, La Jolla, CA 92037.

0-83. SOMERO, G.N., A.C. GIESE, and D.E. WOHLSCHLAG. 1968.
Cold adaptation of the Antarctic fish *Trematomus bernacchii*. Comparative Biochemistry and Physiology, vol. 26, p. 223-33.

0-62. DAVIS, J.B., Editor.
Book: Petroleum Microbiology. Elsevier Publishing Co., NY,NY, 1967.

7. Additions to Classified Literature References as of 6/28/76

*P224-3 LEE, R.F., R. SAUERHEBER, & G.H. DOBBS, 1972
Uptake, metabolism and discharge of polycyclic aromatic hydrocarbons by marine fish. Mar. Biol. (Berl.) 17(3):201-208. Illus.

*P225-3 LEE, R.F., R. SAUERHEBER, & G.H. DOBBS, 1972
Uptake, metabolism and discharge of polycyclic aromatic hydrocarbons by marine fish. Mar. Biol., 17(3):201-208.

(NOTE: **Two asterisks means copy available.)

7. Additions to Classified Literature References as of 4/28/76.

**O-132. STURDEVANT, DAVID C.
The influence of crude oil on the serum proteins of the sockeye salmon, Oncorhynchus Nerka. (A thesis presented to the faculty of the University of AK in partial fulfillment of the requirements for the Degree of Master of Science.) College, AK May 1972. copy rec'd 5/5/76

8. EFFECTS ON MICRO-ORGANISMS AND THEIR ACTIVITY (OVERLAP IN PART - NO. 11, WEATHERING).

100. DAVIS, J.B.
Petroleum microbiology. x,v, 604p. Elsevier, 1967.

103. GUNKEL, W., and TREKEL, H.-H.
Zur Methodik der quantitativen Erfassung Ölabbadauender Bakterien in verölten Sedimenten und Böden, Öl-Wassergemischen, Ölen und teerartigen Substanzen. (On the method of quantitative determination of oil decomposing bacteria in oil polluted sediments and soils, oil-water mixtures, oils and tarry substances.)
Helgoländer wiss. Meeresunters., 16, 336-348, 1967.

104. JONES, J.G.
The determination of microbial hydrocarbon metabolism in natural environments.
Arch. Mikrobiol., 67, 397-407, 1969.

119. TRAXLER, R.W.
Microbiological aspects of oil pollution. Paper presented at the 1970 Evangeline Section Regional Meeting of the Society of Petroleum Engineers of AIME on 'Oilfield Pollution,' Lafayette, Louisiana, November 9-10, 1970.

120. WALLHÄUSER, K.H.
Ölabbauende Mikroorganismen in Natur und Technik. (Oil decomposing microorganisms in nature and technique.)
Helgoländer wiss. Meeresunters., 16, 328-335, 1967.

123. ZOBELL, C.E.
Bacterial release of oil from sedimentary materials
Oil Gas J., 46, (13), 62-69, 1947.

127. ZOBELL, C.E.
Demonstration of bacteria in mud samples from Barataria Bay region which oxidize crude oil from Louisiana. Texas A and M Research Foundation, 1949. (Project Nine - unpublished report)

140. BROWN, L.R., PHILLIPS, W.E., JR., PABST, G.S., JR. and LADNER, C.M.
Physical, chemical, and microbiological changes occurring during degradation of oil in aquatic and brackish water environments.
American Society Mechanical Engineers Winter Annual Meeting, November 16-20, Los Angeles, California. pp. 1-11, 1969.

697. BLOOM, S.A.
An oil dispersant's effect on the microflora of beach sand.
J. Mar. Biol. Ass. U.K., 50, 919-923, 1970.

1606. BLANTON, W.G., and ROBINSON, M.C.
Some acute effects of low boiling petroleum fractions on the cellular structures of fish gills under field conditions.
In: Ahearn, D.G., and Meyers, S.P., editors. The microbial degradation of oil pollutants. Proceedings of a workshop, Atlanta, Georgia, 4-6 December 1972. pp. 265-273. Baton Rouge, Louisiana, Louisiana State University, Center for Wetland Resources, 1973.

2033. ANDERES, E.A.
Distribution of hydrocarbon oxidizing bacteria in some Pacific Ocean water masses.
In: Ahearn, D.G., and Meyers, S.P., editors. The microbial degradation of oil pollutants. Proceedings of a workshop, Atlanta, Georgia, 4-6 December 1972. pp. 311-312. Baton Rouge, Louisiana, Louisiana State University, Center for Wetland Resources, 1973.

2038. ATLAS, R.M., and BARTHA, R.
Abundance, distribution and oil biodegradation potential of micro-organisms in Raritan Bay.
Envir. Pollut., 4, 291-300, 1973.

2041. ATLAS, R.M., and BARTHA, R.
Inhibition by fatty acids of the biodegradation of petroleum.
Antonie van Leeuwenhoek, 39, 257-271, 1974.

2050. COBET, A.B., and GUARD, H.E.
Effect of a bunker fule on the beach bacterial flora.
In: American Petroleum Institute. Proceedings of joint conference on prevention and control of oil spills, Washington, D.C., March 13-15, 1973. pp. 815-819. Washington, D.C., American Petroleum Institute, 1973.

2055. CUNDELL, A.M., and TRAXLER, R.W.
The isolation and characterization of hydrocarbon-utilizing bacterial from Chedabucto Bay, Nova Scotia.
In: American Petroleum Institute. Proceedings of joint conference on prevention and control of oil spills, Washington, D.C., March 13-15 1973. pp. 421-426. Washington, D.C., American Petroleum Insitute, 1973.

2057. FINNERTY, W.R., KENNEDY, R.S., LOCKWOOD, P., SPURLOCK, B.O., and YOUNG, R.A.
Microbes and petroleum: perspectives and implications.
In: Ahearn, D.G., and Meyers, S.P., editors. The microbial degradation of oil pollutants. Proceedings of a workshop, Atlanta, Georgia, 4-6 December 1972. pp. 105-125. Baton Rouge, Louisiana, Louisiana State University, Center for Wetland Resources, 1973.

2069. GUNKEL, W.
Distribution and abundance of oil oxidizing bacterial in the North Sea.
In: Ahearn, D.G., and Meyers, S.P., editors. The microbial degradation of oil pollutants. Proceedings of a workshop, Atlanta, George, 4-6 December 1972. pp. 127-139. Baton Rouge, Louisiana, Louisiana State University, Center for Wetland Resources, 1973.

2070. HASHAM, S.R.
Microbiology of crude oil in sea water. 133p. Cardiff, University College of South Wales and Monmouthshire, Department of Microbiology, 1971. M.Sc. thesis.

2080. MEYERS, S.P., AHEARN, D.G., CROW, S., and BERNER, N.
The impact of oil on marshland microbial ecosystems.
In: Ahearn, D.G., and Meyers, S.P., editors. The microbial degradation of oil pollutants. Proceedings of a workshop, Atlanta, Georgia, 4-6 December 1972. pp. 221-228. Baton Rouge, Louisiana, Louisiana State University, Center for Wetland Resources, 1973.

2083. MIRCEA, V., and SERBANESCU, O.
Etudes microbiologiques dan les eaux du littoral roumain de la Mer Noire. (Microbiological studies in the waters of the Roumanian shore of the Black Sea.)
Cerc. mar., 4, 17-24, 1972.

2085. MIRONOV, O.G., and LEBED', A.A.
Hydrocarbon-oxidizing microorganisms in the North Atlantic.
Hydrobiol. J., 8, (1), 71-74, 1972.

2088. MULKINS-PHILLIPS, G.J., and STEWART, J.E.
Distribution of hydrocarbon-utilizing bacteria in Northwestern Atlantic waters and coastal sediments.
Can. J. Microbiol., 20, 955-962, 1974.

2090. O'MALLEY, M.L.
Hydrocarbon-oxidizing ability of bacteria isolated from Long Island waters. 60p. Garden City, New York, Adelphi University, 1970.
M.S. thesis No. 1309.

2097. REISFELD, A., ROSENBERG, E., and GUTNICK, D.
Microbial degradation of crude oil: factors affecting the dispersion in seawater by mixed and pure cultures.
Appl. Microbiol., 24, 363-368, 1972.

2119. WALKER, J.D., SEESMAN, P.A., and COLWELL, R.R.
Effects of petroleum on estuarine bacteria.
Mar. Pollut. Bull., 5, 186-188, 1974.

2120. WALSH, F., and MITCHELL, R.
Inhibition of bacterial chemoreception by hydrocarbons.
In: Ahearn, D.G., and Meyers, S.P., editors. The microbial degradation of oil pollutants. Proceedings of a workshop, Atlanta, George, 4-6 December 1972. pp. 275-278, Baton Rouge, Louisiana, Louisiana State University, Center for Wetland Resources, 1973.

---

*A122. LUDZAK, F.L., and D. KINKEAD (1956)
Persistence of oily wastes in polluted water under aerobic conditions; motor oil class of hydrocarbons, Industrial and Engineering Chem., vol. 48, no. 2, p. 263-267, 3 illus., 5 tabls., 7 refs.

*A190. AHLFIELD, T.E., and P.A. LaROCK (1973)
Alkane degradation in beach sands, In The microbial degradation of oil pollutants, D.G. Ahearn and S.P. Meyers (eds.), Center for Wetland Resources, Louisiana State University, Publ. no. LSU-SG-73-01, p. 199-203, 2 tabls., 6 refs.

8.

*A200. LE PETIT, J., M.H. N'GUYEN, and L. DEVEZE (1970)
Etude de l'intervention des levures dans la biodegradation en mer des hydrocarbures, Ann. Inst. Pasteur, vol. 118, p. 709-720, 2 illus., 3 tabls., 10 refs., (in French).

*A230. BYROM, J.A., S. BEASTALL, and S. SCOTLAND (1970)
Bacterial degradation of crude oil, Mar. Pollut. Bull., vol. 1, no. 2, p. 25-26, 1 illus., 1 tabl.

*A231. CARLSON, V., E.O. BENNETT, and J.A. ROWE, JR. (1961)
Microbial flora in a number of oilfield water-injection systems, Soc. Petrol. Engineers Jour., vol. 1, p. 71-80,14 illus., 9 tabls., 9 refs.

*A236. COTY, V.F., R.L. GORRING, I.J. HEILWEIL, R.I. LEAVITT, and S. SRINIVASAN (1971)
Growth of microbes in an oil-continuous environment, Biotech. and Bioeng. vol. 12, no. 6, p. 825-842, 12 illus., 6 tabls., 9 refs.

*A241. FINNERTY, W.R., R.S. KENNEDY, P. LOCKWOOD, B.O. SPURLOCK, and R.A. YOUNG (1973).
Microbes and petroleum: Perspectives and implications, In The microbial degradation of oil pollutants, D.G. Ahearn and S.P. Meyers (eds.), Center for Wetland Resources, publ. no. LSU-SG-73-01, p. 105-125, 20 illus., 4 tabls., 30 refs.

*A249. GUNKEL, W. (1968)
Bacteriological investigations of oil-polluted sediments from the Cornish coast following the Torrey Canyon disaster, Proceedings of the biological effects of oil pollution on littoral communities, Field Studies Council, London, p. 151-158, 5 illus., 8 refs.

*A250. GUNKEL, W. (1973)
Distribution and abundance of oil-oxidizing bacteria in the North Sea, In The microbial degradation of oil pollutants, D.G. Ahearn and S.P. Meyers (eds.), Center for Wetland Resources, Louisiana State Univ., publ. no. LSU-SG-73-01, p. 127-139, 4 illus., 2 tabls., 20 refs.

*A251. GUNKEL, W., and H.H. TREKEL (1967)
On the method of quantitative determination of oil decomposing bacteria in oil polluted sediments and soils, oil-water mixtures, oils and tarry substances, Helgolander wiss Meeresunters, vol. 16, p. 336-348, 6 illus., 18 refs.

*A255. HOUSTON, C.W. (1970)
Biochemical oxidation of hydrocarbons in natural waters, Rhode Island Univ., Kingston, Water Resources Center, 34p., 15 illus., 4 tabls., 10 refs.

*A300. STONE, R.W., M.R. FENSKE, and A.G.C. WHITE (1942)
Bacteria attacking petroleum and oil fractions, Jour. Bacteriol., vol. 44, p. 169-178, 4 tabls., 15 refs.

8.

*A308. VAN DER LINDEN, A.C., and G.J.E. THIJSSE (1965)
The mechanisms of microbial oxidations of petroleum hydrocarbons, In Advances in Enzymology, F.F. Nord (ed.), Interscience Publishers, New York, vol. XXVII, p. 469-546, 13 illus., 285 refs.

*A316 ZoBELL, C.E., C.W. GRANT, and H.F. HAAS (1943)
Marine microorganisms which oxidize petroleum hydrocarbons, Bull. Amer. Assoc. Petrol. Geol., vol. 27, no. 9, p. 1175-1193, 4 tabls., 83 refs.

*A387. FASOLI, U., and W. NUMANN (1973)
A proposal for the application of Monod's mathematical model to the biodegradation of mineral oil in natural waters, Water Res., vol. 7, p. 409-418, 4 illus., 11 refs.

*A430. DAVIS, J.G. (1967)
Petroleum Microbiology, Elsevier Publ. Co., New York, 604 p., 208 illus., 160 tabls.

*431. FARRELL, J., and A. ROSE (1967)
Temperature effects on microorganisms, Annual Review of Microbiology, vol. 21, p. 101-120, 190 refs.

*A439. LEE, R.W.H. (1963)
Microbiological activities in petroleum and petroleum products, An annotated bibliography, Prevention of Deterioration Center, Div. of Chemistry and Chem. Tech., National Academy of Science--National Res. Council, Washington, D.C., 102 p.

8.

N3663-3. SEKI, H., H. ABE, Y. YAMAGUCHI, and S-E. ICHIMURA (1974)
Bacteria on petroleum globules in the Philippine Sea in January, J. Oceangr. Soc. JPW., vol. 30, no. 3, p. 151-156.

N3666-2. SEKI, H., T. NAKAI, and H. OTOBE (1974)
Petroleumlytic bacteria in different water masses of the Pacific Ocean in January 1973, MER (Tokyo), vol. 12, no. 1, p. 16-19.

N3673-1. SEKI, H. (1973)
Relation between total body weight and concentrations of manganese, iron, copper, zinc, and mercury in white muscle of bluefish (Pomatomus saltatrix) and a bathyal demersal fish antimore-rostrata, Appl. Microbiol., vol. 26, no. 3, p. 318-320.

N3705-4. SCHWARZ, J. R., J. D. WALKER, and R. R. COLWELL (1974)
Growth of deep-sea bacteria on hydrocarbons at ambient and in situ pressure, Dev. Ind. Microbiol., Series 15, p. 239-249.

N3725-1 JONES, G. E. (1973)
Ecological survey of open ocean and estuarine microbial populations. I. Importance of trace metal ions to microorganisms in the sea, Estuarine Microbial Ecol., Pap. Belle W. Baruch Symp. Mar. Sci., p. 233-241.

N3726-1. TRAXLER, R. W. (1973)
Bacterial degradation of petroleum materials in low temperature marine environments, Microbial Degradation Oil Pollutants, Workshop, p. 163-170.

N3726-2. KATOR, H. (1973)
Utilization of crude oil hydrocarbons by mixed cultures of marine bacteria, Microbial Degradation Oil Pollutants, Workshop, p. 47-65.

N3733-1. CUNDELL, A. R. and R. W. TRAXLER (1973)
Microbial degradation of petroleum at low temperature, Mar. Pollut. Bull., Series 4, Issue 8, p. 125-127.

N3766-2. SOLI, G. and E. M. BENS (1972)
Bacteria which attack petroleum hydrocarbons in a saline medium, Biotechnol., Series 14, issue 3, p. 319-320.

O-42. BUNCH, J.N.
Biodegradation of crude oil by the indigenous microbial flora of the Beaufort Sea. Interim Report of Beaufort Sea Project Study B5a, Dec. 1974. Environment Canada, Victoria, B.C.

(NOTE: **Two asterisks means copy available.)

8. Additions to Classified Literature References as of 4/26/76.

**0-131. BUNCH, J.N. and R.C. HARLAND.
Biodegration of crude petroleum by the indigenous microbial flora of the Beaufort Sea. Beaufort Sea Project Technical Report No. 10. Beaufort Sea Project, Dept. of the Environment, 512 Federal Bldg., 1230 Government St., Victoria, B.C. V8W 1Y4.

8. Additions to Classified Literature References as of 7/9/76.

0-178 ATLAS, R.M., E.A. SCHOFIELD, F.A. MORELLI, and R.E. CAMERON, 1976
Effects of petroleum pollutants on Arctic microbial populations. Environ. Pollut. 10:35-43.

0-179 MITCHELL, R., 1972
Ecological control of microbial imbalances. In: Mitchell, R. (ed.), Water Pollution Microbiology. Wiley-Interscience, New York, pp. 273-288.

9. PATHOLOGICAL EFFECTS (DISEASE, CARCINOGENS).

132. ZOBELL, C.E.
Sources and biodegradation of carcinogenic hydrocarbons.
In: American Petroleum Institute, Proceedings of a joint conference on prevention and control of oil spills, Washington, D.C., June 15-17, 1971. pp. 441-451. Washington, D.C., American Petroleum Institute, 1971.

584. ANDELMAN, J.B., and SUESS, M.J.
Polynuclear aromatic hydrocarbons in the water environment.
Bull. Wld Hlth Org., 43, 479-508, 1970.

585. BOURCART, J., and MALLET, L.
Pollution marine des rives de la région centrale de la mer Tyrrhienne (baie de Naples) par les hydrocarbures polybenzéniques du type benzo-3,4 pyrène. (Marine pollution on the shores of the central region of the Tyrrhenian sea (Bay of Naples) by polybenzic hydrocarbons of the type benzo-3,4 pyrene.)
C. r. hebd. Séanc. Acad. Sci., Paris, 260, 3729-3734, 1965.

587. CICATELLI, M.S.
Il benzo 3.4 pirene, idrocarburo cancerigeno, nell'ambiente marino. (Benzo 3.4 pyrene, cancerogenous hydrocarbon in the marine environment.)
Archo zool. ital., 51, 747-774, 1966.

588. GREFFARD, J., and MEURY, J.
Note sur la pollution en rade de Toulon par les hydrocarbures cancerigens. (Carcinogenic hydrocarbon pollution in Toulon harbour.)
Cah. océanogr., 19, 457-468, 1967.

591. LIMA-ZANGHI, C. de
Bilan des acides gras du plancton marin et pollution par le benzo-3-4-pyrène. (Balance of fatty acids in marine plankton and pollution by benzo-3-4-pyrene.) 80p. University of Paris, Faculty of Sciences, 1967.

592. LIMA-ZANGHI, C. de
Bilan des acides gras du plancton marin et pollution par le benzo-3,4 pyrène. (Balance of fatty acids of marine plankton and pollution by benzo-3,4 pyrene.)
Cah. océanogr., 20, 203-216, 1968.

593. MALLET, L.
Recherche des hydrocarbures polybenzeniques du type benzo-3,4 pyrène dans la faune des milieux marins (Manche, Atlantique et Méditerranée). (Examination of polybenzic hydrocarbons of the type benzo-3,4 pyrene in the fauna of the marine environment (the English Channel, the Atlantic and Mediterranean).)
C. r. hebd. Séanc. Acad. Sci., Paris, 253, 168-170, 1961.

595. MALLET, L.
Study of pollution of the North Sea and Arctic ocean by polyaromatic hydrocarbons of the 3-4-benzpyrene type.
Bull. Acad. natn. Méd., 147, 320-325, 1963.

597. MALLET, L.
Pollutions marines par les hydrocarbures polycondenses du type benzo-3,4 pyrène des côtes nord et ouest de France. Leur incidence sur le milieu biologique et en particulier sur le plancton. (Marine pollution by polycondensed hydrocarbons of the type benzo-3,4 pyrene of the north and west coasts of France. Their incidence on the biological environment and in particular on the plankton.)
Cah. océanogr., 19, 237-243, 1967.

598. MALLET, L., and LAMI, R.
Recherche sur la pollution du plancton par les hydrocarbures polybenzéniques du type benzo 3.4-pyrène dans l'estuaire de la Rance. (Examination of the pollution of plankton by the polybenzic hydrocarbons of the type benzo 3.4-pyrene in the Rance estuary.)
C. r. Séanc. Soc. Biol., 158, 2261-2262, 1964.

599. MALLET, L., and LE THEULE, M.-T.
Recherche du benzo-3,4 pyrène dans les sables vaseux marins des régions cotières de la Manche et de l'Atlantique. (Examination of benzo-3,4 pyrene in marshy marine sands of the coastal regions of the English Channel and the Atlantic.)
C. r. hebd. Séanc. Acad. Sci., Paris, 252, 565-567, 1961.

600. MALLET, L., PERDRIAU, L.V., and PERDRIAU, J.
Pollution par les hydrocarbures polybenzéniques du type benzo-3.4. pyrène de la région occidentale de l'Océan Glacial arctique. (Pollution by polybenzic hydrocarbons of the type benzo-3.4 pyrene of the western region of the glacial Arctic ocean.)
C. r. hebd. Séanc. Acad. Sci., Paris, 256, 3487-3489, 1963.

601. MALLET, L., PERDRIAU, L.V., and PERDRIAU, S.
Etendue des pollutions par les hydrocarbures polybenzéniques du type benao-3,4-pyrène en Mer du Nord et dans l'Océan Glacial Arctique. (Study of pollution by polybenzic hydrocarbons of the type benzo-3,4-pyrene in the North Sea and in the frozen Arctic Ocean.)
Bull. Acad. natn. Méd., 147, 320-325, 1964.

602. MALLET, L., and PRIOU, M.-L.
Sur la rétention des hydrocarbures polybenzéniques du type benzo-3.4 pyrène par les sédiments, la faune et la flore marines de la baie de Saint-Malo. (On the retention of polybenzic hydrocarbons of the type benzo-3,4 pyrene by the sediments, marine fauna and flora of the St. Malo Bay.)
C. r. hebd. Séanc. Acad. Sci., Ser. D, Paris, 264, 969-971, 1967.

603. MALLET, L., PRIOU, M.-L., and LEON, M.
Biosynthèse et bioréduction de l'hydrocarbure polybenzénique benzo 3-4 pyrène dans les vases de la baie de Saint-Malo. (Biosynthesis and bioreduction of the polybenzic hydrocarbon benzo 3-4 pyrene in the mds of the St. Malo Bay.)
C. r. hebd. Séanc. Acad. Sci. Ser. D, Paris, 268, 202-205, 1969.

604. MALLET, L., and SARDOU, J.
Recherche de la présence de l'hydrocarbure polybenzénique benzo 3-4 pyrène dans le milieu planctonique de la région de la Baie de Villefranche. (Examination of the presence of the polybenzic hydrocarbon benzo 3-4 pyrene in the planktonic environment of the Bay of Villefranche region.)
Symp. Comn int. Explor. scient. Mer Médit., Monaco, 1964, 331-334, 1965.

605. MALLET, L., ZANGHI, L., and BRISOU, J.
Recherches sur les possibilites de biosynthèse des hydrocarbures polybenzéniques du type benzo-3.4 pyrene par un Clostridium putride en présence des lipides du plancton marin. (Examination of the possibilities of biosynthesis of polybenzic hydrocarbons of the type benzo-3.4 pyrene by a putrid Clostridium in the presence of lipids of a marine plankton.)
C. r. hebd. Séanc. Acad. Sci., Ser. D, Paris, 264, 1534-1537, 1967.

606. NIAUSSAT, P.
Pollution, par bio-synthese "in situ" d'hydrocarbures cancérigènes, d'une biocoenose lagunaire. Reproduction "In vitro" de ce phénomène. (Pollution, by biosynthesis in situ of carcinogenic hydrocarbons, of a lagoon biocoenosis: in vitro reproduction of this phenomenon.)
Revue int. Océanogr. méd., 17, 87-93, 1970.

607. NIAUSSAT, P., and AUGER, C.
Mise en évidence et répartition du Benzo-3-4 Pyrène et du Pérylène chez differents organismes de la biocoenose lagunaire de Clipperton. (Evidence and distribution of benzo-3-4 pyrene and perylene in different organisms of the Clipperton lagunar biocoenosis.)
C. r. hebd. Séanc. Acad. Sci., Ser. D., Paris, 270, 2702-2705.

608. NIAUSSAT, P., EHRHARDT, J.-P., and OTTENWALDER, J.
Présence de benzo-3-4-pyrène dan les eaux isolées du lagon de l'atoll de Clipperton. (Presence of benzo-3-4-pyrene in the isolated waters of the lagoon of the Clipperton Atoll.)
C. r. hebd. Séanc. Acad. Sci., Ser. D, Paris, 267, 1772-1774, 1968.

609. NIAUSSAT, P., MALLET, L., and OTTENWALDER, J.
Apparition de benzo-3-4-pyrène dan diverses souches de phytoplankton marin cultivées in vitro. Role eventuel des bacteries associées. (Appearance of benzo-3-4-pyrene in several stocks of marine phytoplankton cultivated in vitro. Eventual role of associated bacteria.)
C. r. hebd. Séanc. Acad. Sci., Ser. D, Paris, 268, 1109-1112, 1969.

610. PERDRIAU, J.
Pollution marine par les hydrocarbures cancérigènes du type benzo-3,4 pyrène; incidences biologiques. (Marine pollution by cancerogenous hydrocarbons of the type benzo-3,4 pyrene; biological casulaties.)
Cah. océanogr., 16, 125-229, 1964.

611. PICCINETTI, C.
Diffusione dell'idrocarburo cancerogeno benzo 3-4 pirene nell'Alto e Medio Adriatico. (Diffusion of the carcinogenic hydrocarbon benzo 3-4 pyrene in the north and middle Adriactic Sea.)
Archo Oceanogr. Limnol., 15, (suppl.), 169-184, 1967.

612. SCACCINI, A., and SCACCINI-CICATELLI, M.
Données préliminaires sur la diffusion de l'hydrocarbure cancérigène Benzo 3-4 Pyrène dans les matériaux du fond et dans certains organismes des mers italiennes. (Preliminary data on the diffusion of the cancerogenous hydrocarbon benzo 3-4 pyrene in bottom materials and in certain organisms of the Italian seas.)
Rapp. P.-v. Réun. Commn int. Explor. scient. Mer Méditerr., 19, 761-763, 1969.

613. SCACCINI-CICATELLI, M.
Studio dei fenomeni di accumulo del benzo 3-4 pirene nell'organismo di Tubifex. (Study of the phenomena of accumulation of benzo 3-4 pyrene in the organism Tubifex.)
Boll. Pesca Piscic. Idrobiol., 20, 245-250, 1965.

614. SCACCINI-CICATELLI, M.
Il benzo 3-4-pirene, idrocarburo cancerigeno nell'ambiente marino. (Benzo 3-4 pyrene, a cancerogenous hydrocarbon in the marine environment.)
Archo zool. ital., 51, 747-774, 1966.

615. SHIMKIN, M.B., KOE, B.K., and ZECHMEISTER, L.
An instance of the occurrence of carcinogenic substances in certain barnacles.
Science, N.Y., 113, 650-651, 1951.

616. SUESS, M.J.
Presence of polynuclear aromatic hydrocarbons in coastal waters and the possible health consequences.
Revue int. Oceanogr. med., 18-19, 181-190, 1970.

617. SUESS, M.J.
Vorkommen polyzyklischer, aromatischer Kohlenwasserstoffe in Kistengewassern und deren mogliche Auswirkungen auf die menschliche Gesundheit. (Occurence of polycyclic aromatic hydrocarbons in coastal waters and their possible effects on human health.)
Arch Hyg. Bakt., 154, 1-7, 1970.

619. VASSEROT, J.
La pollution des animaux marins comestibles par des hydrocarbures cancérigenes. (Pollution of edible marine animals by cancerogenous hydrocarbons.)
Penn Bed, 3, 183-186, 1962.

1767. GIACCIO, M.
Idrocarburi policiclici aromatici in alcune specie ittiche. (Polycyclic aromatic hydrocarbons in some species of fish.) (IN ITALIAN with ENGLISH summary)
Quad. Merceologia, 10, 21-26, 1971.

1769. MALLET, L.
Pollution des milieux marins par les hydrocarbures cancérigènes. (Pollution of marine environments by cancerogenous hydrocarbons.)
Bull. Acad. Méd., 144, 271-274, 1960.

1770. MALLET, L.
Pollution des milieux vitaux par les hydrocarbures polybenzeniques du type benzo, 3, 4 pyrène. (Pollution of important environments by polybenzic hydrocarbons of the type benzo-3-4-pyrene.)
Gaz. Hôp., Paris, Numero Spécial 10 Juin, 136, 803-808, 1964.

1771. MALLET, L.
Pollutions marines par les hydrocarbures polycondensés du type Benzo 3.4 pyrène de la côte occidentale Francaise. Leur incidence sur le milieu biologique, et en particulier le plancton. (Marine pollution by polycondensed hydrocarbons of the type benzo 3-4 pyrene off the west coast of France. Their incidence on the biological environment, and in particular the plankton.)
Bull. Ass. fr. Avanc. Sci., 74, 11-16, 1967.

1772. MALLET, L., and SARDOU, J.
Recherche de la présence de l'hydrocarbure polybenzénique benzo-3, 4 pyrène dans le milieu planctonique de la région de la baie de Villefranche (Alpes-Maritimes). (Research on the presence of the polybenzic hydrocarbon benzo-3-4-pyrene in the planktonic environment of the region of the bay of Villefranche (Alpes-Maritimes).)
C. r. hebd. Séanc. Acad. Sci., Paris, Ser. D, 258, 5264-5267, 1964.

1773. NIAUSSAT, P., and OTTENWALDER, J.
Apparition de benzo 3-4-pyrène dans des culture "in vitro" de phytoplancton marin. Importance des souillures bactérienees associées. (Apparition of benzo 3-4 pyrene in "in vitro" cultures of marine phytoplankton. Incidence of associate bacteria.)
Revue Hyg. Méd. soc., 17, 487-496, 1969.

1774. PALMORK, K.H., WILHELMSEN, S., and NEPPELBERG, T.
Report on the contribution of polycyclic aromatic hydrocarbons (PAH) to the marine environment from different industries. 21p.
Copenhagen, International Council for the Exploration of the Sea, Fisheries Improvement Committee, 1973. (CM 1973/E:33)

1775. SCACCINI, A., SCACCINI-CICATELLI, M., MARANI, F., and LEONARDI, V.
Dosaggi spettrofotofluorimetrici ed osservazioni mediante microscopia a fluorescenza del benzo 3-4 pirene su organi e tessuti di *Carassius auratus*. (Spectrophotofluorometric dosage and fluorescence microscope observations on benzo 3-4-pyrene in organs and tissues of *Carassius auratus*.)
Note Lab. Biol. mar. Fano, 3, 105-144, 1970.

1776. SCACCINI-CICATELLI, M.
Sui fenomeni di accumulo del benzo-3, 4-pirene, nell'organismo di Tubifex.
(On the phenomena of accumulation of benzo 3-4-pyrene in the organism Tubifex.)
Boll. Soc. itel. Biol. sper., 42, 957-959, 1966.

1777. SULLIVAN, J.B.
Marine pollution by carcinogenic hydrocarbons.
In: US National Bureau of Standards. Marine pollution monitoring (petroleum). Proceedings of a symposium and workshop... May 13-17 1974. pp. 261-263, Washington, D.C. US Government Printing Office, 1974.

1778. ZECHMEISTER, L., and KOE, B.K.
The isolation of carcinogenic and other polycyclic aromatic hydrocarbons from barnacles.
Arch. Biochem. Biophys., 35, 1-11, 1952.

*A33. HEIDELBERGER, C. (1964)
Studies on the molecular mechanism of hydrocarbon carcinogenesis, Jour. Cell. and Comp. Phys., Suppl. no. 1, p. 129-148, 9 illus., 1 tabl., 35 refs.

*A346. WALLCAVE, L., H. GARCIA, R. FELDMAN, W. LIJINSKY, and P. SHUBIK (1971).
Skin tumorigensis in mice by petroleum saphalts and coal-tar pitches of known polynuclear aromatic hydrocarbon content, Toxicol. Appl. Pharmacol., vol. 18, no. 1, p. 41-52, 9 illus., 2 tabls., 14 refs.

*A442. NELSON-SMITH, A. (1970)
The problem of oil pollution of the sea, Adv. Mar. Biol., vol. 8, p. 215-306, 19 illus., 2 tabls., 353 refs.

*A11. CARRUTHERS, W., H.N.M. STEWART, and D.A.M. WATKINS (1967)
1, 2-Benzanthracene derivatives in a Kuwait mineral oil, Nature, vol. 213, p. 691-692, 3 tabls., 4 refs.

9.

N3664-4. CEAS, M. P. (1974)
Effects of 3-4-benzopyrene on sea-urchin egg development, Acta Embroyl. Exp., no. 3, p. 267-272.

N3671-1. DE ANGELIS, E., and G. G. GIORDANO (1974)
Sea-urchin egg development under the action of benzo-a-pyrine and 7-12, dimethylbenz-a-anthracene, Cancer Res., vol. 34, no. 6, p. 1275-1280.

N3677-3. LEE, R. F., R. SAUERHEBER, and G. H. DOBBS (1972)
Uptake metabolism and discharge of polycyclic aromatic hydrocarbons by marine fish, Mar. Biol. (BEBL), vol. 17, no. 3, p. 201-208.

N3678-4. BROWN, E. R., J. J. HAZDRA, L. KEITH, I. GREENSPAN, J. B. G. KWAPINSKI, and P. BEAMER (1973)
Frequency of fish tumors found in a polluted watershed as compared to nonpolluted Canadian waters, Cancer Res., vol. 33, no. 2, p. 189-198.

N3679-2. BOURNE, E. W., and R. W. JONES (1973)
Effects of 7-12,dimethylbenz-a-anthracene in fish cells in vitro, Trans. Am. Microsc. Soc., vol. 92, no. 1, p. 140-142.

N3680-4. BROWN, E. R., L. KEITH, J. B. G. KWAPINSKI, J. HAZDRA, and P. BEAMER (1973)
Frequency of tumors in fish populating a polluted water system, Proc. Am. Assoc. Cancer Res., vol. 14, p. 1.

N3682-2. GRIMMER, G., and A. HILDEBRANDT (1971)
Concentration and estimation of 14 polycyclic aromatic hydrocarbons at low levels in high protein foods, oils, and fats, J. Assoc. Off. Anal. Chem., vol. 55, no. 3, p. 631-635.

N3684-2. BROWN, E. R., L. KEITH, J. B. G. KWAPINSKI, and J. HAZDRA (1972)
Incidence of tumors found in a polluted watershed as compared to nonpolluted Canadian waters, Proc. Am. Assoc. Cancer Res., vol. 13, p. 45.

N3691-3. SULLIVAN, J. R. (1974)
Marine pollution by carcinogenic hydrocarbons, Natl. Bur. Stand. (U.S.), Spec. Publ., Series 409, p. 261-263.

N3698-4. CEAS, M. P. (1974)
Effects of 3-4-benzopyrene on sea urchin egg development, Acta Embryol. Exp., vol. 74, no. 3, p. 267-272.

N3720-2. DE ANGELIS, E., and G. G. GIORDANO (1974)
Sea urchin egg development under the action of benzo(a)pyrene and 7,12-dimethylbenz(a)anthracene, Cancer Res., vol. 34, no. 6, p. 1275-1280.

N3720-4. PALMORK, K. H. (1974)
Polycyclic aromatic hydrocarbons in the marine environment, Nordforsk, Miljoevardssidretariatet, Publ., vol. 4, p. 99-125.

9.

N3742-2. Contamination of some coastal areas of the Black and Baltic Seas by carcinogenic hydrocarbons, Nekot. Itoqi Izuch. Zagryazneniya Vnesh. Sredy Kantserogen, p. 47-51 (Language-Russian).

N3749-3. ACKMAN, R. G., and D. NOBLE (1973)
Steam distillation. Simple techniqe for recovery of petroleum hydrocarbons from tainted fish, J. Fish. Res. Board Can., vol. 30, no. 5, p. 711-714.

N3766-4. GIACCIO, M. (1971)
Polycyclic aromatic hydrocarbons in fish, Quad. Merceol., vol. 10, no.1, p. 21-26 (Language-Italian).

(NOTE: **Two asterisks means copy availabe.)

9. Additions to Classified Literature References as of 3/31/76.

0-106. ANONYMOUS.
Fighting oil pollution - carcinogens claim by scientist. SURVR Local Govt. Technol 135 No. 5 4066-4069, 38-43(1970).

0-113. BARRY, M. and P.P. YEVICH.
III. Histological studies (tumors in clams and petroleum). Marine Pollution Bulletin 6(11): 171-173 (1975).

0-122. ANONYMOUS.
Marine scientists warn of possible cancer buildup in shellfish from oil spills. Air/Water Pollution Report 8(33), p. 333. Aug. 17, 1970.
Note: This reference from Holmes Bibliog.

0-123. MARTIN, A.E.
Some health considerations. In: Waddington, J.I. - Water Pollution by oil - proceedings of a seminar at Aviemore Inverness-Shine, Scotland, May 4-8, 1970. London Inst. of Petroleum, 1970, p. 153-158, 17 references.

9. Additions to Classified Literature References as of 6/25/76

*P43-3 BLUMER, M., 1972
Oil contamination and living resources of the sea. In: Ruivo, Mario (ed.), Marine Pollution and Sea Life, Fishing News (Books) Ltd., Surrey, England.

*P46-2 BONEY, A.D., 1974
Aromatic hydrocarbons and the growth of marine algae. Mar. Poll. Bull., 5(12): 185-186.

*P61-2 CAHNMANN, H.J. & M. KURATSUNE, 1957
Determination of polycyclic aromatic hydrocarbons in oysters collected in polluted water. Anal. Chem., 29(9):1312-1317.

*P224-3 LEE, R.F., R. SAUERHEBER, & G.H. DOBBS, 1972
Uptake, metabolism and discharge of polycyclic aromatic hydrocarbons by marine fish. Mar. Biol. (Berl.) 17(3):201-208. Illus.

*P225-3 LEE, R.F., R. SAUERHEBER, & G.H. DOBBS, 1972
Uptake, metabolism and discharge of polycyclic aromatic hydrocarbons by marine fish. Mar. Biol., 17(3):201-208.

*365-2 SAINSBURY, J., & J. WILLMAN, 1972
Intertidal biota surveys--Admiralty Inlet to Commencement Bay. Unpublished report.

180 AMES, B.N., P. SIMS and P.L. GROVER, 1972
Epoxides of carcinogenic polycyclic hydrocarbons are frameshift mutagens. Science 176:47-49.

180 ANDELMAN, J.B. and J.E. SNODGRASS, 1974
Incidence and significance of polynuclear aromatic hydrocarbons in the water environment. CRC Critical Reviews in Environmental Control, Jan. 1974, pp. 69-83.

181 HUEPER, W.C., 1963
Enviromental carcinogenesis in man and animals. Annals New York Academy of Sciences :963-1038.

10. COMPOSITION OF OIL (CHEMICAL COMPOSITION OF OIL AND EMULSIONS; ALSO SPREADING ACTION).

466. OTTWAY, S.
The comparative toxicities of crude oils.
In: Cowell, E.B., editor. Proceedings of the symposium on the ecological effects of oil pollution on littoral communities, London, 30 November-1 December, 1970.
London, Institute of Petroleum, 1971.

1228. BAIER, R.E.
Organic films on natural waters: their retrieval, identification and modes of elimination.
J. geophys. Res., 77, 5062-5075, 1972.

1229. BARGER, W.R., DANIEL, W.H., and GARRETT, W.D.
Surface chemical properties of banded sea slicks.
Deep-Sea Res., 21, 83-89, 1974.

*A11. CARRUTHERS, W., H.N.M. STEWART, and D.A.M. WATKINS (1967)
1, 2-Benzanthracene derivatives in a Kuwait mineral oil, Nature, vol. 213, p. 691-692, 3 tabls., 4 refs.

*A13. COLEMAN, H.J., R.L. HOPKINS, and C.J. THOMPSON (1970)
Highlights of some 50 man-years of petroleum sulfur studies by the Bureau of Mines, preprint, Div. of Petrol. Chem., Amer. Chem. Soc., Chicago, Sept. 13-18, p. A17-A36, 9 illus., 4 tabls., 64 refs.

*A14. DEAN, R.A. (1968)
The chemistry of crude oils in relation to their spilllage on the sea, Proceedings of the biological effects of oil pollution on littoral communities, Field Studies Council, London, p. 1-6, 1 tabl.

*A17. EHRHARDT, M., and M. BLUMER (1972).
The source identification of marine hydrocarbons by gas chromatography, Environ. Pollut., vol. 3, p. 179-194, 8 illus., 2 tabls., 21 refs.

*A20. FERRERO, E.P., and D.T. NICHOLS (1972)
Analyses of 169 crude oils from 122 foreign oilfields, Bureau of Mines Information Circular 8542, 113 p., 6 tabls., 69 refs.

*A36. LUDWIG, H.F., and R. CARTER (1961)
Analytical characteristics of oil-tar materials on southern California beaches, Jour. of Water Pollut. Control Fed., vol. 33, no. 11, p. 1123-1139, 9 illus., 6 tabls., 5 refs.

*A40. McAULIFFE, C. (1966)
Solubility in water of paraffin, cycloparaffin, olefin, acetylene, cycloolefin, and aromatic hydrocarbons, Jour. Phys. Chem., vol. 70, p. 1267-1275, 5 illus., 4 tabls., 21 refs.

*A7. ANONYMOUS (1973)
Animal contribution to petroleum proved, Chem. & Eng. News, vol. 51, no. 26, p. 13-14, 1 illus.

10.

*A43. MILLER, J.W. (1973)
A multiparameter oil pollution source identification system, Proceedings of the joint conf. on prevention and control of oil spills, Sponsored by API, EPA, and USCG, publ. by Amer. Petrol. Inst., Washington, D.C., p. 195-203, 6 illus., 2 tabls., 10 refs.

*A45. MULIK, J.D., and J.G. ERDMAN (1963)
Genesis of hydrocarbons of low molecular weight in organic-rich aquatic systems, Science, vol. 141, p. 806-807, 1 tabl., 14 refs.

*A54. SMITH, H.J. (1964)
Hydrocarbon-type relationships of eastern and western hemisphere high-sulfur crude oils, U.S. Dept. of the Interior, Bureau of Mines, rept. of investigations, no. 6542, 89 p., 28 illus., 7 tabls., 35 refs.

*A55. SMITH, H.M. (1968)
Qualitative and quantitative aspects of crude oil composition, U.S. Dept. of the Interior, Bureau of Mines, Bull. 642, 125 p., 65 illus., 40 tabls., 199 refs.

*A57. SPEERS, G.C., and E.V. WHITEHEAD (1969)
Crude petroleum, In Organic Geochem., G. Eglinton and M.T.J. Murphy (eds.), Springer-Verlag, New York, p. 638-675, 12 illus., 3 tabls., 206 refs.

* A60. WENGER, W.G., and J.C. MORRIS (1971)
Utah crude oils: Characteristics of 67 samples, U.S. Dept. of the Interior, Bureau of Mines, rept. of investigations BM-RI-7532, 51 p., 7 illus., 5 tabls., 20 refs.

*A64. ZITKO, V., and W.V. CARSON (1970)
The characterization of petroleum oils and their determination in the aquatic environment, Fisheries Res. Board of Canada, Tech. rept. no. 217, 29p., 9 illus., 12 tabls., 19 refs.

*A72. BERRIDGE, S.A., R.A. DEAN, R.G. FALLOWS, and A. FISH (1968)
The properties of persistent oils at sea, Jour. Inst. Petrol., London Jour., vol. 54, no. 539, p. 300-309, 3 illus., 4 tabls., 15 refs.

*A73. BERRIDGE, S.A., M.T. THEW, and A.G. LORISTON-CLARKE (1968)
The formation and stability of emulsions of water in crude petroleum and similar stocks, Jour. Inst. Petrol., vol. 54, no. 539, p. 333-357, 17 illus., 13 tabls., 21 refs.

*A74. BLOKKER, P.C. (1966)
Die Ausbreitung con ol auf wasser, Oil spreading on water, Deutsche Gewasserkundl Mitteilungen, Jg. 10, H. 4, p. 112-114, 6 refs.

*A83. COCHRAN, R.A., and P.R.SCOTT (1971)
The growth of oil slicks and their control by surface chemical agents, Jour. Pet. Tech., p. 781-787, 10 illus., 2 tabls., 9 refs.

10.

*A90. FAY, J.A., and D.P. HOULT (1971)
Physical processes in the spread of oil on a water surface, U.S. Dept. of Transportation, USCG (Accession no. AD 726281), 18 p., 6 illus, 2 tabls., 7 refs.

*A96. GARRETT, W.D. (1970)
Impact of petroleum spills on the chemical and physical properties of the air-sea interface, Proceedings of the Santa Barbara oil symposium, Dec. 16-18, Univ. of Calif., Santa Barbara, p. 87-104, 4 illus., 47 refs.

*A107. HOULT, D.P. (1970)
Physical effects of oil on aqueous surfaces, Proceedings of the Santa Barbara oil symposium, Dec. 16-18, Univ. of Calif., Santa Barbara, p. 75-86, 4 illus., 6 refs.

*A108. HOULT, D.P. (1972)
Oil spreading on the sea, In Annual review of fluid mechanics, vol. 4, M. Van Dyke, W.G. Vincenti, and J.V. Wehausen (eds.), p. 341-368, 23 illus., 24 refs

*A144. PREMACK, J., and G.A. BROWN (1973)
Prediction of oil slick motions in Narragansett Bay, Proceedings of the joint conff. on prevention and control of oil spills, Sponsored by API, EPA, and USCG, publ. by Amer. Petrol. Inst., Washington, D.C., p. 531-540, 11 illus, 3 tabls., 11 refs.

*A146. PRITCHARD, D.W. (1969)
Dispersion and flushing of pollutants in estuaries, ASCE proceedings, Jour. Hydraulics Div., vol. 95, no. HY1, paper 6344, p. 115-124, 3 refs.

*A147. SCHWARTZBERG, H.G. (1970)
Spreading and movement of oil spills, Water Pollut. Control Res. Series, New York Univ., Bronx, Dept. of Chem. Engineering, March 1970, 103p., 82 refs.

*A153. SHULEIKIN, V.V. (1953)
Molecular physics of the sea, Part III, excerpted from Fizika Morya, 3rd ed., Ezdatel'stvo, Akademii Nauk., SSSR, Moscow, p. 786-819, translated for Naval Res. Lab., Washington, D.C. 1960.

*A171. MACKAY, D., and A.W. WOLKOFF (1973).
Rate of evaporation of low-solubility contaminants from water bodies to atmosphere, Environ. Sci. and Tech., vol. 7, no. 7, p. 611-614, 1 tabl., 17 refs.

*A172. SIVADIER, H.O., and P.G. MIKOLAJ (1973)
Measurement of evaporation rates from oil slicks on the open sea, Proceedings of the joint conf. on prevention and control of oil spills, Sponsored by API, EPA, and USCG, publ. by Amer. Petrol. Inst., Washington, D.C., p. 475-484, 9 illus., 3 tabls., 14 refs.

*A394. GLAESER, J.L., and G.P. VANCE (1971)
A study of the behavior of oil spills in the Arctic, Office of Res. and Dev., USCG, Washington, D.C., 60 p., 18 illus., 3 tabls., 6 refs.

*A403. McMINN, T.J., and P. GOLDEN (1973)
Behavioral characteristics and cleanup techniques of North Slope crude oil in an arctic winter environment, Proceedings of the joint conf. on the prevention and control of oil spills, Sponsored by API, EPA, and USCG, publ. by Amer. Petrol. Inst., Washington, D.C., p. 263-276, 14 illus., 2 tabls., 9 refs.

*A423. VANCE, G.P. (1971)
Control of Arctic oil spills, Ocean Industry, vol. 6, no. 1, p. 14-17.

*A442. NELSON-SMITH, A. (1970)
The problem of oil pollution of the sea, Adv. Mar. Biol., vol. 8, p. 215-306, 19 illus., 2 tabls., 353 refs.

*A110. IRMANN, F. (1965)
A simple correlation between the water-solubility and structure of hydrocarbons and chlorinated hydrocarbons, Chem. Ing. Tech., vol. 37, no. 8, p. 789-798, 2 illus., 5 tabls., 60 refs., (in German).

N3737-4. MEYERS, PHILIP A.
Association of fatty acids and hydrocarbons with mineral particles in sea water. Diss. Abstr. Int. B 1973, 34(1), 333.

N3740-4. FARRINGTON, JOHN W., TEAL, JOHN M., QUINN, JAMES G., WADE, TERRY, BURNS, KATHRYN.
Intercalibration of analyses of recently biosynthesized hydrocarbons and petroleum hydrocarbons in marine lipids. Bull. Environ. Contam. Toxicol., 1973, vol. 10, no. 3, p. 129-36.

N3672-3. BOEHM, P.D., QUINN, J.G.
Solubilization of hydrocarbons by the dissolved organic matter in sea water. Geochim. Cosmochim. Acta 37(11), 1973, 2459-2477.

N3703-2. NOVIKOV, P.D., CHEPENKO, B.A., KANDYBINA, G.M.
Form of trace elements in sea water and their adsorbability by ion-exchange resins. Formy Elem. Radionuklidov Morsr. Vode, (Water. Vses. Simp., Probl. Izuch. Fiz.-Khim. Sostoyaniya Elem. Radionuklidov Okeane), P: 74, p. 55-7, Language: Russ.

N3708-2. MORRIS, R.J., CULKIN, R.
Lipid chemistry of eastern Mediterranean surface layers. Nature (London) P: 74, S: 250, I: 5468, p. 640-2.

N3726-3. WASIK, STANLEY P., and BROWN, ROBERT L.
Determination of hydrocarbon solubility in sea water and the analysis of hydrocarbons in water-extracts. Proc. Joint Conf. Prev. Contr. Oil Spills, P: 73, p. 223-7.

N3721-4. SALMANOV, F.K.
Relation between the composition of petroleums and their formation conditions. Sovrem. Probl. Geol. Geokhim. Goryuch. Iskop, 1973, p. 85-88, in Russian.

10.

0-10. LOGAN, W.J.
Oil spill countermeasure study for the Southern Beaufort Sea. Interim Report of Beaufort sea Project Studies H-1, H2, and H3, 1974. Environment Canada, Victoria, B.C.

0-66. PRICE, LEIGH CHARLES (Ph.D. thesis)
The solubility of hydrocarbons and petroleum in water as applied to primary migration of petroleum. U. of Cal., Riverside, CA., Geo. Sciences, March 17, 1973, 298 p. Many data and curves.

(NOTE: **Two asterisks means copy available.)

10. Additions to Classified Literature References as of 3/31/76.

0-91. ISAKSON, J.S., J.M. STORIE, J. VAGNERS, G.A. ERICKSON, J.F. KRUGER and R.F. CORLETT
Comparison of ecological impacts of postulated oil spills at selected Alaskan locations. Introduction, summary, methodology, evaluation and appendices. June 1975, final report, Volume 1. Prepared for Dept. of Transportation, U.S. Coast Guard, Office of Research and Development, Washington, D.C. 20590. (Document is available to the public through the NTIS, Springfield, VA 22151.)

**0-93. MC AULIFFE, CLAYTON D.
Surveillance of the marine environment for hydrocarbons. Chevron Oil Field Research Company, La Habra, California 90631, U.S.A.

0-119. MC KEE, J.E.
Report on oily substances and their effects on beneficial uses of water. Sacramento, 1954, 71 p., Publ. #16, 388 ref., tables. Note: This reference taken from Holmes Biblio. is incomplete as given above.

*A340. ROBERTS, C.H.
Oil pollution: the effect of oil pollution upon certain forms of aquatic life and experiments upon the rate of absorption. J. de Consel.Conseil Permanent Pour L'Exploration de la Mer. Vol. 1, p. 245-275(1926). 20 references.

0-120. SMITH, DAVID D.
Characteristics of major oil spills - review of the problem. In: Industry-Government Seminar on oil spill treating agents, Washington, D.C., 1970, April 8-9, 1970. Also in Proceedings, American Petroleum Institute, Committee for Air and Water Conservation, 1970, p. 9-56(1970).

0-121. ANONYMOUS.
Oil on Arctic waters. Oceanology Internationa, Vol. 6(5), p. 25 (May 1971).

10. Additions to Classified Literature References as of 6/28/76

*P43-3 BLUMER, M., 1972
Oil contamination and living resources of the sea. In: Ruivo, Mario (ed.), Marine Pollution and Sea Life, Fishing News (Books) Ltd., Surrey, England.

-137 DUCE, R.A., P.L. PARKER, C.S. GIAM, 1974
Pollutant transfer to the marine environment. Deliberations and recommendations of the NSF/IDOE pollutant transfer workshop held in Port Aransas, Texas, Jan. 11-12, 1974, Pub. in Kingston, Rhode Island, 55 p.

)-182 BOEHM, P.D. and J.G. QUINN, 1974
The solubility behaviour of no. 2 fuel oil in sea water, Marine Pollution Bulletin 5(7):101-104.

)-183 FAY, J.A., 1969
The spread of oil slicks on a calm sea. In: Hoult, D.P. (eds.) Oil on the sea. Proceedings of a symposium on the scientific and engineering aspects of oil pollution of the sea, sponsored by MIT and Woods Hole Oceanographic Institution, Cambridge, Mass, May 16, 1969, N.Y.: Plenum Press, pp. 53-63.

)-184 MURTY, T.S. and M.L. KHANDEKAR, 1973
Application of the concept of rectilinear vortices to the movement of oil slicks. Manuscript Report Series No. 32, Department of Environment, Ottawa, Canada, 26 p.

)-185 SUTTON, C. and J.A. CALDER, 1974
Solubility of higher-molecular-weight n-paraffins in distilled water and seawater. Environ. Sci. & Technol. 8:654-657.

11. WEATHERING OF OIL (INCLUDES FATE OF OIL STUDIES)

93. BARTHA, R.
Biodegradation of oil slicks in the marine environment. 10p. New Brunswick, Rutgers University, 1970.

97. BYROM, J.A., BEASTALL, S., and SCOTLAND, S.
Bacterial degradation of crude oil.
Mar. Pollut. bull., 1, 25-26, 1970.

99. DAVIES, J.A., and HUGHES, D.E.
The biochemistry and microbiology of crude oil degradation.
Fld. Stud., 2, (suppl.), 139-144, 1968.

100. DAVIS, J.B.
Petroleum microbiology. xiv, 604p. Elsevier, 1967.

101. GUNKEL, W.
Experimentell-ökologische Untersuchungen über die limitierden Faktoren des mikrobiellen Ölabbaues im marinen Milieu. (Experimental-ecological investigations regarding the limiting factors of microbial oil degradation in the marine environment.) Helgölander wiss. Meeresunters., 15, 210-225, 1967.

106. KATOR, H., OPPENHEIMER, C.H., and MIGET, R.J.
Microbial degradation of a Louisiana crude oil in closed flasks and under simulated field conditions.
In: American Petroleum Institute. Proceedings of joint conference on prevention and control of oil spills, Washington, D.C., June 15-17, 1971. pp. 287-296. Washington, D.C., American Petroleum Institute. 1971.

110. MIGET, R.J., OPPENHEIMER, C.H., KATOR, H.I., and LAROCK, P.A.
Microbial degradation of normal paraffin hydrocarbons in crude oil.
In: American Petroleum Institute. Proceedings of a joint conference on prevention and control of oil spills, New York, December 15-17, 1969. pp. 327-331. New York, American Petroleum Institute, 1970.

117. ROSENFELD, W.D.
Anaerobic oxidation of hydrocarbons by sulfate-reducing bacteria.
J. Bact., 54, 664-665, 1947.

118. STONE, R.W., FENSKE, M.R., and WHITE, A.G.C.
Bacteria attacking petroleum and oil fractions.
J. Bact., 44, 169-178, 1942.

119. TRAXLER, R.W.
Microbiological aspects of oil pollution. Paper presented at the 170 Evangeline Section Regional Meeting of the Society of Petroleum Engineers of AIME on 'Oilfield Pollution,' Lafayette, Louisiana, November 9-10, 1970.

120. WALLHÄUSER, K.H.
Ölabbauende Mikroorganismen in Natur und Technik. (Oil decomposing microorganisms in nature and technique.)
Helgoländer wiss. Meeresunters., 16, 328-335, 1967.

121. ZOBELL, C.E.
The role of bacteria in the formation and transformation of petroleum hydrocarbons.
Science, N.Y., 102, 364-369, 1945.

122. ZOBELL, C.E.
Action of microorganisms on hydrocarbons.
Bact. Rev., 10, 1-49, 1946,

124. ZOBELL, C.E.
Microbial transformation of molecular hydrogen in marine sediments, with particular reference to petroleum.
Bull. Am. Ass. Petrol. Geol., 31, 1709-1752, 1947 .

126. ZOBELL, C.E.
Rate at which oil is oxidized by bacteria. Texas A and M Research Foundation, 1949. (Project Nine - unpublished report.)

128. ZOBELL, C.E.
Assimilation of hydrocarbons by microorganisms. Adv. Enzymol., 10, 443-486, 1950.

131. ZOBELL, C.E.
Microbial modification of crude oil in the sea.
In: American Petroleum Institute. Proceedings of a joint conference on prevention and control of oil spills, New York, December 15-17, 1969. pp. 317-335. New York, American Petroleum Institute, 1970.

132. ZOBELL, C.E.
Sources and biodegradation of carcinogenic hydrocarbons.
In: American Petroleum Institute. Proceedings of a joint conference on prevention and control of oil spills, Washington, D.C., June 15-17, 1971. pp. 441-451. Washington, D.C. American Petroleum Institute, 1971.

140. BROWN, L.R., PHILLIPS, W.E., Jr., PABST, G.S., Jr., and LADNER, C.M.
Physical, chemical, and microbiological changes occurring during degradation of oil in aquatic and brackish water environments.
American Society Mechanical Engineers Winter Annual Meeting, November 16-20, Los Angeles, California. pp. 1-11, 1969.

141. BROWN, L.R., PHILLIPS, W.E., Jr., and TENNYSON, J.M.
The effect of salinity on the oxidation of hydrocarbons in estuarine environments. 28p. Water Resources Research Institute, Mississippi State University, 1970.

142. BROWN, L.R., and TISCHER, R.G.
The decomposition of petroleum products in our natural waters. 31p. Water Resources Research Institute, Mississippi State University, 1969. (PB 188 839)

151. IZ'IUROVA, A.I.
The rate of oxidation of petroleum products in water without the addition of nitrogen. (In Russian)
Gig. i Sanit., 7, 12-17-, 1952.

154. KINNEY, P.J., BUTTON, D.K., and SCHELL, D.M.
Kinetics of dissipation and biodegradation of crude oil in Alaska's Cook Inlet.
In: American Petroleum Institute. Proceedings of a joint conference on prevention and control of oil spills, New York, December 15-17, 1969. pp. 333-340. New York, American Petroleum Institute, 1970.

162. PARKER, C.A., FREEGARDE, M., AND HATCHARD, C.G.
The effect of some chemical and biological factors on the degradation of crude oil at sea.
In: Hepple, P., editor. Water pollution by oil; proceedings of a seminar held at Aviemore... 4-8 May, 1970. pp. 237-244. London, Institute of Petroleum, 1971.

1230. BETANCOURT, O.J.
Effect of natural weathering on the shore-bound oil after the Chedabucto Bay spill.
In: Mackay, D., and Harrison, W., editors. Oil and the Canadian environment. Proceedings of a conference... 16 May 1973. pp. 87-89. Toronto, University of Toronto, (1973?).

1237. FELDMAN, M.H.
Petroleum weathering: some pathways, fate and disposition on marine waters. 22p. Corvallis, Oregon, US Environmental Protection Agency, Office of Research and Development, 1973. (Ecological Research Series No. EPA 660/3-73-013)

1238. FRANKENFELD, J.W.
Factors governing the fate of oil at sea: variations in the amounts and types of dissolved or dispersed materials during the weathering process.
In: American Petroleum Institute. Proceedings of joint conference on prevention and control of oil spills, Washington, D.C., March 13-15 1973. pp. 485-495. Washington, D.C., American Petroleum Institute, 1973.

1240. FREEGARDE, M., and HATCHARD, C.G.
The ultimate fate of crude oil at sea. Interim report No. 7. An investigation of the photodecomposition of crude oil. 10p. Holton Heath, Poole, Dorset, Admiralty Materials Laboratory, 1970. (Unpublished Report No. AML/5/70)

1247. HANSEN, H.P.
On photochemical degradation of surface films of petroleum hydrocarbons. 19p. Copenhagen, International Council for the Exploration of the Sea, Fisheries Improvement Committee, 1974. (CM 1974/E:12)

1254. JEFFERY, P.G.
Large-scale experiments on the spreading of oil at sea and its disappearance by natural factors.
In: American Petroleum Institute. Proceedings of joint conference on prevention and control of oil spills, Washington, D.C., March 13-15, 1973. pp. 469-474. Washington, D.C. American Petroleum Institute, 1973.

1255. JOHNSON, B.D.
Some aspects of the formation, stabilization and behaviour of water-in-petroleum emulsions.
In: Mackay, D., and Harrison, W., editors. Oil and the Canadian environment. Proceedings of a conference... 16 May 1973. pp. 98-103. Toronto, University of Toronto, (1973?).

1257. KLEIN, A.E., and PILPEL, N.
The effects of artificial sunlight upon floating oils.
Wat. Res., 8, 79-83, 1974.

1258. KONDO, G., MUKOHARA, S., NISHIDA, O., and SANO, H.
Studies on the change of spilled oil with the time elapsed.
1. Physical change of floating oil. (In JAPANESE)
Kankyo Gijutsu (Envir. Technol.), 1, (10), 5p., 1972.

1261. LYSYJ, I., and RUSSELL, E.C.
Dissolution of petroleum-derived products in water.
Wat. Res., 8, 863-868, 1974.

1262. MCAULIFFE, C.(D.)
Solubility in water of paraffin, cycloparaffin, olefin, acetylene, cycloolefin, and aromatic hydrocarbons.
J. Phys. Chem., 70, 1267-1275, 1966.

1263. MACKAY, D., and WOLKOFF, A.W.
Rate of evaporation of low-solubility contaminants from water bodies to atmosphere.
Envir. Sci. Technol., 7, 611-614, 1973.

1265. MCKAY, G.D.M., MCLEAN, A.Y., BETANCOURT, O.J., and JOHNSON, B.D.
The formation of water-in-oil emulsions subsequent to an oil spill.
J. Inst. Petrol., 59, 164-172, 1973.

1268. MAYO, D.W., DONOVAN, D.J., and JIANG, L.
Long term weathering characteristics of Iranian crude oil: the wreck of the "Northern Gulf."
In: US National Bureau of Standards. Marine pollution monitoring (petroleum). Proceedings of a symposium and workshop... May 13-17 1974. pp. 201-208. Washington, D.C., US Government Printing Office, 1974.

1272. MINISTRY OF DEFENCE, (NAVY DEPARTMENT)
The effects of natural factors on the movement, dispersal, and destruction of oil at sea. 42p. Select Committee Report, 26 July 1968, Para. 61 (iii), London, Ministry of Defence, 1971.

1273. MINISTRY OF DEFENCE, (NAVY DEPARTMENT)
The fate of oil spilt at sea. A report on the effects of natural factors on the movement, dispersal, and destruction of oil at sea. Report by a Ministry of Defence working party. 54p. Orpington, Kent, Defence Research Information Centre, 1973.

11.

1274. NAGY, E.
Evaporation of oil from slicks.
In: Mackay, D., and Harrison, W., editors. Oil and the Canadian environment. Proceedings of a conference... 16 May 1973. pp. 112-117. Toronto, University of Toronto, (1973?).

1275. NAGY, E.
Water-in-oil emulsions.
In: Mackay, D., and Harrison, W., editors. Oil and the Canadian environment. Proceedings of a conference... 16 May 1973. pp. 107-111. Toronto, University of Toronto, (1973?) .

1281. RASHID, M.A.
Degradation of Bunker C oil under different coastal environments of Chedabucto Bay, Nova Scotia.
Estuar. cstl mar. Sci., 2, 137-144, 1974.

1282. SANO, H., HONDA, S., SOUMA, Y., and NISHIDA, O.
Studies on the change of spilled oil with the time elapsed.
2. Chemical change of floating oil. (In JAPANESE). Kankyo Gijutsu (Envir. Techol.), 1, (11), 6p., 1972.

1283. SIVADIER, H.O., and MIKOLAJ, P.G.
Measurement of evaporation rates from oil slicks on the open sea.
In: American Petroleum Institute. Proceedings of joint conference on prevention and control of oil spills, Washington, D.C., March 13-15 1973. pp. 475-484. Washington, D.C., American Petroleum Institute, 1973.

1521. SACKETT, W.M., and BROOKS, J.M.
Use of low molecular-weight-hydrocarbon concentrations as indicators of marine pollution.
In: US National Bureau of Standards. Marine pollution monitoring (petroleum). Proceedings of a symposium and workshop... May 13-17 1974. pp. 171-173. Washington, D.C., US Government Printing Office, 1974.

1664. PARKER, C.A.
The ultimate fate of crude oil at sea. Interim report No. 5. Uptake of oil by zooplankton. 15p. Holton Heath, Admiralty Materials Laboratory, 1969. (AML Report No. B/198(M)).

2030. AGOSTI, J., and AGOSTI, T.
Oxidation of certain Prudhoe Bay hydrocarbons by microorganisms indigenous to a natural oil seep at Umiat, Alaska.
In: McCown, B.H., editor. Proceedings of the American Association for the Advancement of Science Alaskan science conference, Fairbanks, Alaska, 1972.

11.

2031. AHEARN, D.G., MEYERS, S.P., and STANDARD, P.G.
The role of yeasts in the decomposition of oils in marine environments.
Devs ind. Microbiol., 12, 126-134, 1971.

2032. AHLFELD, T.E., and LAROCK, P.A.
Alkane degradation in beach sands.
In: Ahearn, D.G., and Meyers, S.P., editors. The microbial degradation of oil pollutants. Proceedings of a workshop, Atlanta, Georgia, 4-6 December 1972. pp. 199-203. Baton Rouge, Louisiana, Louisiana State University, Center for Wetland Resources, 1973.

2037. ATLAS, R.M., and BARTHA, R.
Biodegradation of petroleum in seawater at low temperatures.
Can. J. Microbiol., 18 1851-1855, 1972.

2038. ATLAS, R.M., and BARTHA, R.
Abundance, distribution and oil biodegradation potential of micro-organisms in Raritan Bay.
Envir. Pollut., 4, 291-300, 1973.

2039. ATLAS, R.M., and BARTHA, R.
Effects of some commercial oil herders, dispersants and bacterial inocula on biodegradation of oil in seawater.
In: Ahearn, D.G., and Meyers, S.P., editors. The microbial degradation of oil pollutants. Proceedings of a workshop, Atlanta, Georgia, 4-6 December 1972. pp. 283-289. Baton Rouge, Louisiana, Louisiana State University, Center for Wetland Resources, 1973.

2043. BARTHA, R., and ATLAS, R.M.
Biodegradation of polluting oil.
Naval Res. Rev., 25, (6-7), 17-22, 1972.

2045. BARTHA, R., and ATLAS, R.M.
Biodegradation of oil in seawater: limiting factors and artificial stimulation.
In: Ahearn, D.G., and Meyers, S.P., edistors. The microbial degradation of oil pollutants. Proceedings of a workshop, Atlanta, Georgia, 4-6 December 1972. pp. 147-152. Baton Rouge, Louisiana, Louisiana State University, Center for Wetland Resources, 1973.

2046 BRIDIE, AL.L., and BOS, J.
Biological degradation of mineral oil in seawater.
J. Inst. Petrol., 57, (557), 270-277, 1971.

2058. BYROM, J.A., and BEASTALL, S.
Microbial degradation of crude oil with particular emphasis on pollution.
In: Institute of Petroleum. Microbiology 1971 (a symposium), pp. 73-86. Amsterdam, Applied Science Publishers, 1971.

2049. CERNIGLIA, C.E., and PERRY, J.J.
Crude oil degradation by microorganisms isolated from the marine environment.
Z. allg. Mikrobiol., 13, (4), 299-306, 1973.

2052. COLWELL, R.R., WALKER, J.D., and NELSON, J.D., Jr.
Microbial ecology and the problem of petroleum degradation in Chesapeake Bay.
In: Ahearn, D.G., and Meyers, S.P., editors. The microbial degradation of oil pollutants. Proceedings of a workshop, Atlanta, Georgia, 4-6 December 1972. pp. 185-197. Baton Rouge, Louisiana, Louisiana State University, Center for Wetland Resources, 1973.

2053. COONEY, J.J., and WALKER, J.D.
Hydrocarbon utilization by Cladosporium resinae.
In: Ahearn, D.G., and Meyers, S.P., editors. The microbial degradation of oil pollutants. Proceedings of a workshop, Atlanta, Georgia, 4-6 December 1972. pp. 25-32. Baton Rouge, Louisiana, Louisiana State University, Center for Wetland Resources, 1973.

2054. CUNDELL, A.M., and TRAXLER, R.W.
Microbial degradation of petroleum at low temperatures.
Mar. Pollut. Bull, 4, 125-127, 1973.

2058. FLOODGATE, G.D.
Biodegradation of hydrocarbons in the sea.
In: Mitchell, R., editor. Water pollution microbiology. pp. 153-171, New York, John Wiley & Sons, 1972.

2059. FLOODGATE, G.C.
Microbial degradation of oil.
Mar. Pollut. Bull, 3, 41-43, 1972.

2060. FLOODGATE, G.D.
A threnody concerning the biodegradation of oil in natural waters.
In: Ahearn, D.G., and Meyers, S.P., editors. The microbial degradation of oil pollutants. Proceedings of a workshop, Atlanta, Georgia, 4-6 December 1972. pp. 17-24. Baton Rouge, Louisiana, Louisiana State University, Center for Wetland Resources, 1973.

2061. FLOODGATE, G.D., GIBBS, C.F., and PUGH, K.B.
The biodegradation of oil.
Mar. Pollut. Bull., 2, 143, 1971

2063. FUSEY, P., and OUDOT, J.
Note sur l'accélération de la biodégradation d'un pétrole brut par les bactéries. (Note on the acceleration of the degradation of a crude oil by bacteria.)
Material Organismen, 8, 157-164, 1973.

2065. GIBBS, C.F.
Quantitative studies on marine biodegradation of oil. I. Nutrient limitation at 14°C.
Proc.R.Soc.Lond.,(B), 188, 83-94, 1975.

2066. GIBBS, C.F., PUGH, K.B., and ANDREWS, A.R.
Quantitative studies on marine biodegradation of oil. II. Effect of temperature.
Proc.R.Soc.Lond.,(B), 188, 83-94, 1975.

2067. GIBSON, D.T.
Initial reactions in the degradation of aromatic hydrocarbons.
In: Proceedings of the conference on degradation of synthetic organic molecules in the biosphere, natural, pesticidal and various other man-made compounds, San Francisco, California, 12-13 June 1971. pp. 116-136. Washington, D.C., National Academy of Sciences, 1972.

2070. HASHAM, S.R.
Microbiology of crude oil in sea water. 133p. Cardiff, University College of South Wales and Monmouthshire, Department of Microbiology, 1971. M. Sc. thesis.

2072. JOBSON, A., COOK, F.D., and WESTLAKE, D.W.S.
Microbial utilization of crude oil.
Appl. Microbiol., 23, 1082-1089, 1972.

2073. KATOR, H.
Utilization of crude oil hydrocarbons by mixed cultures of marine bacteria.
In: Ahearn, D.G., and Meyers, S.P., editors. The microbial degradation of oil pollutants. Proceedings of a workshop, Atlanta, Georgia, 4-6 December 1972. pp. 47-65. Baton Rouge, Louisiana, Louisiana State University, Center for Wetland Resources. 1973.

2074. LAROCK, P.A., and AHLFELD, T.E.
The relative changes in n-alkane composition in surface water slicks.
In: Ahearn, D.G., and Meyers, S.P., editors. The microbial degradation of oil pollutants. Proceedings of a workshop, Atlanta, Georgia, 4-6 December 1972. pp. 233-236. Baton Rouge, Louisiana, Louisiana State University, Center for Wetland Resources, 1973.

11.

2075. LIU, D.L.S.
Microbial degradation of crude oil and the various hydrocarbon derivatives.
In: Ahearn, D.G., and Meyers, S.P., editors. The microbial degradation of oil pollutants. Proceedings of a workshop, Atlanta, Georgia, 4-6 December 1972. pp. 95-104. Baton Rouge, Louisiana, Louisiana State University, Center for Wetland Resources, 1973.

2077. MACIEJOWSKA, M., and RAKOWSKA, E.
Badania nad rozkladem paliw cieklych przez mikroorganizmy morskie. (Investigations on decomposition of liquid fuels by marine organisms.) (In POLISH with ENGLISH summary)
Pr. morsk. Inst. ryb. Gdyni, Ser. A, 17, 181-203, 1973.

2079. MECHALAS, B.J., MEYERS, T.J., and KOLPACK, R.L.
Microbial decomposition patterns using crude oil.
In: Ahearn, D.G., and Meyers, S.P., editors. The microbial degradation of oil pollutants. Proceedings of a workshop, Atlanta, Georgia, 4-6 December 1972. pp. 67-79. Baton Rouge, Louisiana, Louisiana State University, Center for Wetland Resources, 1973.

2084 MIRONOV, O.G.
Oil-oxidising microorganisms in the sea. 234p. Kiev, Naukova Dumka, 1971. (In RUSSIAN)

2085. MIRONOV, O.G., and LEBED', A.A.
Hydrocarbon-oxidizing microorganisms in the North Atlantic.
Hydrobiol. J., 8, (1), 71-74, 1972.

2100. ROBERTSON, B.(R.), ARHELGER, S.(D.), KINNEY, P.J., and BUTTON, D.K.
Hydrocarbon biodegradation in Alaskan water.
In: Ahearn, D.G., and Meyers, S.P., editors. The microbial degradation of oil pollutants. Proceedings of a workshop. Atlanta, Georgia, 4-6 December 1972. pp. 171-184. Baton Rouge, Louisiana, Louisiana State University, Center for Wetland Resources, 1973.

2101. ROBERTSON, B.R., ARHELGER, S.D., LAW, R.A.T., and BUTTON, D.K.
Hydrocarbon biodegradation.
In: Hood, D.W., Shiels, W.E., and Kelley, E.J., editors. Environmental studies of Port Valdez, Chapter 12, pp. 449-479. Fairbanks, Alaska, University of Alaska, Institute of Marine Science, 1973. (Occasional Publication No. 3)

2107. SHECKET, G.
Oxidation of naphthalene by a marine bacterium.
In: Robbins, P.W. Student projects on the oxidation by marine bacteria of aromatic compounds found in oil. pp. 17-31. Cambridge, Massachusetts, Massachusetts Institute of Technology, Sea Grant Project Office, 1971. (Report No. MITSG 71-10)

2113. TRAXLER, R.W.
Bacterial degradation of petroleum materials in low temperature marine environments.
In: Ahearn, D.G., and Meyers, S.P., editors. The microbial degradation of oil pollutants. Proceedings of a workshop, Atlanta, Georgia, 4-6 December 1972. pp. 163-170. Baton Rouge, Louisiana, Louisiana State University, Center for Wetland Resources, 1973.

2114. VAN DER LINDEN, A.C., and THIJSSE, G.J.E.
The mechanisms of microbial oxidations of petroleum hydrocarbons.
Adv. Enzymol., 23, 469-546, 1965.

2118. WALKER, J.D., and COLWELL, R.R.
Microbial petroleum degradation: the use of mixed hydrocarbon substrates.
Appl. Microbiol., 27, 1053-1060, 1974.

2121. WESTLAKE, D.W.S., JOBSON, A., PHILLIPPE, R., and COOK, F.D.
Biodegradability and crude oil composition.
Can. J. Microbiol., 20, 915-928, 1974.

2122. Zajic, J.E., and SUPPLISON, B.
Emulsification and degradation of 'Bunker C' fuel oil by microorganisms.
Biotechnol. Bioengng, 14, 331-343, 1972.

2123. ZOBELL, C.E.
Bacterial degradation of mineral oils at low temperatures.
In: Ahearn, D.G., and Meyers, S.P., editors. The microbial degradation of oil pollutants. Proceedings of a workshop, Atlanta, Georgia, 4-6 December 1972. pp. 153-161. Baton Rouge, Louisiana, Louisiana State University, Center for Wetland Resources, 1973.

2124. ZOBELL, C.E.
Microbial degradation of oil: present status, problems, and perspectives.
In: Ahearn, D.G., and Meyers, S.P., editors. The microbial degradation of oil pollutants. Proceedings of a workshop, Atlanta, Georgia, 4-6 December 1972. pp. 3-16. Baton Rouge, Louisiana, Louisiana State University, Center for Wetland Resources, 1973.

2125. ZOBELL, C.E., and AGOSTI, J.
Bacterial oxidation of mineral oils at sub-zero Celsius. 10p. Paper prepared for presentation at the 72nd annual meeting. American Society for Microbiology, Philadelphia, Pennsylvania, 24 April 1972.

*A72. BERRIDGE, S.A., R.A. DEAN, R.G. FALLOWS, and A. FISH (1968.
The properties of persistent oils at sea, Jour. Inst. Petrol., London Jour., vol. 54, no. 539, p. 300-309, 3 illus., 4 tabls., 15 refs.

*78. BROWN, L.R., W.E. PHILLIPS, JR., and J.M. TENNYSON (1970)
The effect of salinity on the oxidation of hydrocarbons in estuarine environments, Mississippi State Univ., Water Resources Res. Inst., State College rept., 28 p., 10 illus, 2 tabls., 5 refs.

<u>11</u>.

*A113. JEFFERY, P.G. (1973)
Large-scale experiments on the spreading of oil at sea and its disappearance by natural factors, Proceedings of the joint conf. on prevention and control of oil spills, Sponsored by API, EPA, and USCG, publ. by Amer. Petrol. Inst., Washington, D.C., p. 469-474, 6 illus., 1 tabl., 5 refs.

*A116. KINNEY, P.J., D.K. BUTTON, and D.M. SCHELL (1969)
Kinetics of dissipation and biodegradation of crude oil in Alaska's Cook Inlet, Proceedings of the joint conf. on prevention and control of oil spills, Sponsored by API, FWPCA, Dec. 15-17, New York, p. 333-340, 5 illus., 21 refs.

*A122. LUDZAK, F.L. and D. KINKEAD (1956)
Persistence of oily wastes in polluted water under aerobic conditions; motor oil class of hydrocarbons, Industrial and Engineering Chem., vol. 48, no. 2, p. 263-267, 3 illus., 5 tabls., 7 refs.

*A154. SMITH, C.L., and W.G. MacINTYRE (1971)
Initial aging of fuel oil films on sea water, Proceedings of the joint conf. on prevention and control of oil spills, Sponsored by API, EPA, and USCG, publ. by Amer. Petrol. Inst., Washington, D.C., p. 457-461, 6 illus, 3 tabls., 2 refs.

*A172. SIVADIER, H.O., and P.G. MIKOLAJ (1973)
Measurement of evaporation rates from oil slicks on the open sea, Proceedings of the joint conf. on prevention and control of oil spills, Sponsored by API, EPA, and USCG, publ. by Amer. Petrol. Inst., Washington, D.C., p. 475-484, 9 illus., 3 tabls., 14 refs.

*A180. JOHNSTON, R. (1970)
The decomposition of crude oil residues in sand columns, Jour. Mar. Biol. Assoc., U.K., vol. 50, p. 925-937, 5 illus., 8 refs.

*A190. AHLFELD, T.E., and P.A. LaROCK (1973)
Alkane degradation in beach sands, <u>In</u> The microbial degradation of oil pollutants, D.G. Ahearn and S.P. Meyers (eds.), Center for Wetland Resources, Louisiana State University, publ. no. LSU-SG-73-01, p. 199-203, 2 tabls., 6 refs.

*A191. BAKER, J.M. (1971)
Oil and salt-marsh soil, Proceedings of the ecological effects of oil pollution on littoral communities, E.B. Cowell (ed.), Inst. of Petrol., London, p. 62-71, 8 illus., 19 refs.

*A192. BLUMER, M., M. EHRHARDT, and J.H. JONES (1973)
The environmental fate of stranded crude oil, Deep-Sea Research, vol. 20, p. 239-259, 5 illus., 6 tabls., 11 refs.

11.

*A210. ATLAS, R.M., and R. BARTHA (1971)
A. Degradation and mineralization of petroleum by two bacteria isolated from coastal waters. B. Degradation and mineralization of petroleum in sea water: Limitation by nitrogen and phosphorous, Tec. Rept. no. 2, ONR project No. 137-843, 39 p., 11 illus., 1 tabl., 39 refs.

*A211. ATLAS, R.M., and R. BARTHA (1972)
Degradation and mineralization of petroleum by two bacteria isolated from coastal waters, Biotech. & Bioeng., vol. 14, no. 3, p. 297-308, 6 illus., 1 tabl., 24 refs.

*A212. ATLAS, R.M., and R. BARTHA (1972).
Degradation and mineralization of petroleum in sea water: Limitation by nitrogen and phsophorous, Biotech. & Bioeng., vol. 14, no. 3, p. 309-318, 5 illus., 15 refs.

*A213. ATLAS, R.M., and R. BARTHA (1972)
Biodegradation of petroleum in seawater at low temperatures, Canada Jour. Microbiol., vol. 18, p. 1851-1855, 5 illus., 14 refs.

*A219. BAILEY, N.J.L., A.M. JOBSON, and M.A. ROGERS (1973)
Bacterial degradation of crude oil: Comparison of field and experimental data, Chem. Geol., vol. 11, p. 203-221, 15 illus., 2 tabls., 11 refs.

*A220. BARNHART, E.L., and G.J. KEHRBERGER (1970)
The ability of biological systems to assimilate oils, Am. Petrol. Inst. Proceedings, Division of Refining, col. 50, p. 436-465.

*A229. BUTTON, D.K. (1971)
Petroleum--Biological effects in the marine environment, In Impingement of Man on the Oceans, D.W. Hood (ed.), Wiley Interscience, New York, p. 421-429, 27 refs.

*A237. DAVIES, J.A., and D.E. HUGHES (1968)
The biochemistry and microbiology of crude oil degradation, Proceedings of the biological effects of oil pollution on littoral communities, Field Studies Council, London, p. 139-144, 1 illus., 1 tabl., 22 refs.

*243. FLOODGATE, G.D. (1972)
Biodegradation of hydrocarbons in the sea, In Water pollution microbiology, R. Mitchell (ed.), Wiley Interscience, p. 153-171, 2 illus., 92 refs.

*A244. FLOODGATE, G.D. (1973)
A threnody concerning the biodegradation of oil in natural waters, In The microbial degradation of oil pollutants, D.G. Ahearn and S.P. Meyers (eds.), Center for Wetland Resources, Louisiana State Univ., publ. no. LSU-SG-73-01, p. 17-24, 25 refs.

11.

*A245. FOSTER, J.W. (1962)
Bacterial oxidation of hydrocarbons, In Oxygenases, O. Hayaishi (ed.), Academic Press, New York, p. 241-271, 4 illus., 2 tabls., 91 refs.

*A246. FRIEDE, J., P. GUIRE, R.K. GHOLSON, E. GAUDY, and A.F. GAUDY, JR. (1972)
Assessment of biodegradation potential for controlling oil spills on the high seas, Final Rept., Dept. of Transportation, USCG, #4110.1/3.1, 130 p., 19 illus., 4 tabls., 203 refs.

*A313. ZoBELL, C.E. (1971)
Sources and biodegradation of carcinogenic hydrocarbons, Proceedings of the joint conf. on prevention and control of oil spills, Sponsored by API, EPA, USCG, June 15-17, Washington, D.C., p. 441-451, 2 illus., 8 tabls., 107 refs.

*A314. ZoBELL, C.E. (1973)
Microbial degradation of oil: Present status, problems, and perspectives, In The microbial degradation of oil pollutants, D.G. Ahearn and S.P. Meyers (eds.), Center for Wetland Resources, Louisiana State Univ., publ. no. LSU-SG-73-01, p. 3-16, 1 tabl., 46 refs.

*A315. ZoBELL, C.E. (1973)
Bacterial degradation of mineral oils at low temperature, In The microbial degradation of oil pollutants, D.G. Ahearn and S.P. Meyers (eds.), Center for Wetland Resources, Louisiana State Univ., publ. no. LSU-SG-73-01, p. 153-161, 2 illus., 3 tabls., 17 refs.

*A316. ZoBELL, C.E., C.W. GRANT, and H.F. HAAS (1943)
Marine microorganisms which oxidize petroleum hydrocarbons, Bull. Amer. Assoc. Petrol. Geol., vol. 27, no. 9, p. 1175-1193, 4 tabls., 83 refs.

*A393. GLAESER, J.L. (1971)
A discussion of the future oil spill problem in the Arctic, Proceedings of the joint conf. on prevention and control of oil spills, Sponsored by API, EPA, and USCG, June 15-17, Washington, D.C., p. 479-484, 6 illus., 12 refs.

*403. McMINN, T.J., and P. GOLDEN (1973).
Behavioral characteristics and cleanup techniques of North Slope crude oil in an arctic winter environment, Proceedings of the joint conf. on the prevention and control of oil spills, Sponsored by API, EPA, and USCG, publ. by Amer. Petrol. Inst., Washington, D.C., p. 263-276, 14 illus., 2 tabls., 9 refs.

*A439. LEE, R.W.H. (1963)
Microbiological activities in petroleum and petroleum products, An annotated bibliography, Prevention of Deterioration Center, Div. of Chemistry and Chem. Tech., National Academy of Science--National Res. Council, Washington, D.C. 102 p.

11.
*A92. FRANKENFELD, J.W. (1973)
Factors governing the fate of oil at sea; variations in the amounts and types of dissolved or dispersed materials during the weathering process, Proceedings of the joint conf. on prevention and control of oil spills, Sponsored by API, EPA, and USCG, publ. by Amer. Petrol. Inst., Washington, D.C., p. 485-495, 8 illus., 10 tabls., 13 refs.

N3665-4. LYSYJ, I., and E.C. RUSSELL
Sea gasoline water pollution bilge ballast waste water. Water Res. 8 (11), 1974, 863-868.

N3675-1. WALKER, J.D., CALOMIRIS, J.J., and COLWELL, R.B.
Hydrocarbon degradation by ocean sediment bacteria. Anstr. Ann. Meet. Am. Soc. Microbiol., 74, 1974, 64.

N3681-3. ATLAS, R.M., and BARTHA, R.
Limiting factors of oil biodegradation in the sea.
Abstr. Ann. Meet. Am. Soc. Microbiol, 72(3), 1972.

N3684-3. MIRONOV, O.G.
Distribution of hydrocarbon oxidizing microorganisms in some seas. Rev. Int. Ockanogr. Med., 24, 1971, 135.

N3692-4. RAYMOND, DEBORAH D.
Metabolism of methylnapthalenes and other related aromatic hydrocarbons by marine bacteria. Diss. Abstr. Int. B 1975, 35(10), 5014.

N3695-2. DAVIS, S.J., and GIBBS, C.F.
Effect of weathering on a crude oil residue exposed at sea. Water Res. P: 75, S: 9, I:3, p. 275-85.

N3706-2. MULKINS-PHILLIPS, G.J., STEWART, JAMES E.
Effect of environmental parameters on bacterial degradation of Bunker C oil, crude oils, and hydrocarbons. Appl. Microbiol., P: 74, S:28, I: 6, p. 915-22.

N3710-3. FLOODGATE, G.D.
Biodegradation of hydrocarbons in the sea.
Water Poll. Microbiol, P: 72, p. 153-71.

N3726-1. TRAXLER, R.W.
Bacterial degradation of petroleum materials in low temperature marine environments. Micro. Degradation Oil Pollutants, Workshop, P: 73, p. 163-70.

N3737-2. LEFCOURT, PAUL
Early weathering of south Louisiana crude oil in the marine environment.
Diss. Abstr. Int. B 1973, 34(5), 2078.

N3729-2. FRANKENFELD, JOHN W.
Factors governing the fate of oil at sea. Variations in the amounts and types of dissolved or dispersed materials during the weathering process. J. Proc. Joint Conf. Prev. Contr. Oil Spills, P: 73, P. 385-95.

N3733-1. CUNDELL, A.M., TRAXLER, R.W.
Microbial degradation of petroleum at low temperature.
Mar. Poll. Bull., P:73, S:4, I:8, p. 125-7.

11.

N3738-1. LACAZE, JEAN C.
Effect of illumination on the biodegradation of a nonionic surfactant used for the dispersion of petroleum deposits in the sea. C. R. Acad. Sci., Ser. D, P: 73, S:277, I:4, p. 409-12, in French.

N3744-2. GIBBS, C.F.
Measurement of rate of oxidation of crude oil in sea water systems. Chemosphere, P:72, S:1, I:3, p. 119-24.

N3755-3. ATLAS, RONALD M.
Biodegradation of petroleum in the marine environment. Diss. Abstr. Int., B 1973, 33(8), 3802-3.

N3757-1. ATLAS, R.M., BARTHA, R.
Biodegradation of petroleum in seawater at low temperatures. Can. J. Microbiol., P: 72, S: 18, I: 12, p. 1851-5.

N3770-4. PARKER, CECIL ALLEN, FREEGARDE, M., HATCHARD, C.G.
Effect of some chemical and biological factors on the degradation of crude oil at sea. Water Pollut. Oil, Proc. Semin. P: 71, p. 237-44.

N3679-4. ATLAS, R.M. and R. BARTHA
Microorganisms carbon dioxide evolution degradation ratis volatile components. Can. J. Microbiol 18(12), 1972, p. 1851-1855.

N3725-4. COLWELL, R.R., J.D. WALKER, and J.D. NELSON, JR.
Microbial ecology and the problem of petroleum degradation in Chesapeake Bay. Microbial Degradation Oil Pollutants, Workshop. 1973, p. 185-97.

O-21. ROBERTSON, ARHELGER, KINNEY and BUTTON.
Hydrocarbon biodegradation in Alaskan Waters. Center for Wetland Resources, LSU, Sea Grant - 73-01 (1973).

O-24. FELDMAN, E.H.
Petroleum Weathering: Some pathways, fate and deposition in Marine Waters, EPA 660/3-73-013, Sept. 1974. Ecological Research Series, Corvallis, OR.

O-42. BUNCH, J.N.
Biodegradation of crude oil by the indigenous microbial flora of the Beaufort Sea. Interim Report of Beaufort Sea Project Study B5a, Dec. 1974. Environment Canada, Victoria, B.C.

O-52. AHEARN, D.G. and MEYER, S.P., Editors.
Microbiological degradation of oil pollution workshop at Georgia State Univ., Atlanta, GA, Dec. 1972. Published by Center for Wetland Resources, Louisiana State University, Baton Rouge, LA, Pub. No. LSU-SG-73-01. (Bob Clark has copy)

O-58. PAINTER, H.A.
Biodegradability. Proceedings Royal Society, London B, 185:149-58(1974).

11.

0-86. YOUNG, R.N. and A.J. SETHI.
Compositional changes of a fuel oil from an oil spill due to natural exposure. Water A S P, 1975, 5(2), p. 195-205, 15 refs.

(NOTE: **Two asterisks means copy available.)

11. Additions to Classified Literature References as of 3/31/76.

**0-36. PERCY, J.A. and T.C. MULLIN.
Effects of crude oils on arctic marine invertebrates. Arctic Biological Station, Fisheries and Marine Service, Dept. of the Environment, P.O. Box 400, Ste. Anne de Bellevue, Quebec. Beaufort Sea Technical Report #11, Beaufort Sea Project, Dept. of the Environment, 512 Federal Building, 1230 Government St., Victoria, B.C. V8W 1Y4, December 1975.

**0-93. MC AULIFFE, CLAYTON D.
Surveillance of the marine environment for hydrocarbons. Chevron Oil Field Research Company, La Habra, California 90631, U.S.A.

**0-94. MC AULIFFE, CLAYTON D., ALFRED E. SMALLEY, ROBERT D. GROOVER, W. MARVIN WELSH, STEWART PICKLE and GEORGE E. JONES.
Chevron main pass block 41 oil spill: chemical and biological investigations. API Conference on Prevention and Control of Oil Pollution, 1975(?)

0-109. SHELTON, THEODORE BRYANT.
Decomposition of oil pollutants in natural bottom sediments. Rutgers University, 165 p. Available from University Microfilms, Ann Arbor, Mich. Order #73-4778.

(NOTE: **Two asterisks means copy available.)

11. Additions to Classified Literature References as of 4/26/76.

**0-131. BUNCH, J.N. and R.C. HARLAND.
Biodegradation of crude petroleum by the indigenous microbial flora of the Beaufort Sea. Beaufort Sea Project Technical Report No. 10. Beaufort Sea Project, Dept. of the Environment, 512 Federal Bldg., 1230 Government St., Victoria, B.C. V8W 1Y4.

11. Additions to Classified Literature References as of 7/1/76.

0-135 BATTELLE PACIFIC NORTHWEST LABORATORIES, 1974
Study of effects of oil discharges and domestic and industrial wastewaters of on the fisheries of Lake Maracaibo, Venezuela. Vol. II. Fate and effects of oil. Battelle Pacific Northwest Laboratories, Richland, WA. 99352.

0-137 DUCE, R.A., P.L. PARKER, C.S. GIAM, 1974
Pollutant Transfer to the Marine Environment. Deliberations and recommendation of the NSF/IDOE pollutant transfer workshop held in Port Aransas, Texas, Jan. 11-12, 1974. Pub. in Kingston, Rhode Island, 55 p.

0-146 ATLAS, R.M. & E.A. SCHOFIELD, 1975
Petroleum biodegradation in the Arctic. In: Bourquin, A.W., S.P. Meyers and D.G. Ahearn (eds.), Impact of the use of microorganisms on the aquatic environme Proceedings of workshop-symposium held at Pensacola Beach, FL, April, 1974, EPA, Gulf Breeze Environmental Research Laboratory. EPA 660-3-75-001, Jan. 1975. Govt. Report No. PB 240 159, pp. 183-198.

0-186 BURWOOD, R. & G.C. SPEERS, 1974
Photo-oxidation as a factor in the environmental dispersal of crude oil. Estuar and Coastal Marine Science 2:117-135.

0-179 MITCHELL, R., 1972
Ecological control of microbial imbalances. In: Mitchell, R. (ed.), Water Pollution Microbiology. Wiley-Interscience, New York, pp. 273-288.

12. METABOLITES IN OIL.

1640. CORNER, E.D.S., C.C. KILVINGTON, and S.C.M. O"HARA.
Qualitative studies on the metabolism of napthalene in Maia squinado (Herbst). J. Mar. Biol. Ass., U.K. 53, 819-832, 1973.

*237. DAVIES, J.A. and D.E. HUGHES (1968).
The biochemistry and microbiology of crude oil degradation. Proceedings of the biological effects of oil pollution on littoral communities, Field Studies Council, London, p. 139-144, 1 illus., 1 tabl., 22 refs.

N3692-4. RAYMOND, DEBORAH.
Metabolism of methylnaphthalenes and other related aromatic hydrocarbons by marine bacteria. Diss. Abstr. Int. B, 1975, 35(10), 5014.

O-21. ROBERTSON, ARHELGER, KINNEY, and BUTTON.
Hydrocarbon biodegradation in Alaskan Waters. In Center for Weland Resources, LSU, Sea Grant - 73-01 (1973).

12. Additions to Classified Literature References as of 6/29/76.

*P46-1 BLUMER, M., J.C. ROBERTSON, J.E. CORDON, & J. SASS, 1969
Phytol-derived C-14 di- and triolefinic hydrocarbons in marine zooplankton and fishes. Biochem., 8(10):4067-4074.

13. LEVELS OF OIL COMPONENTS AND DEGRADATION PRODUCTS (IN BIOTA AND WATER: BUILDUP AND RELEASE).

347. CLARK, R.C., JR., and FINLEY, J.S.
Puget Sound fisheries and oil pollution: a status report.
In: American Petroleum Institute. Proceedings of joint conference on prevention and control of oil spills, Washington, D.C., June 15-17, 1971. pp. 139-145. Washington, D.C., American Petroleum Institute, 1971.

422. BLUMER, M., ROBERTSON, J.C., GORDON, J.E., and SASS, J.
Phytol-derived C_{19} di- and triolefinic hydrocarbons in marine zooplankton and fishes.
Biochemistry, 8, 4067-4074, 1969.

499. CLARK, R.C., JR., and BLUMER, M.
Distribution of n-paraffins in marine organisms and sediment.
Limnol. Oceanogr., 12, 79-87, 1967.

602. MALLET, L., and PRIOU, M.-L.
Sur la rétention des hydrocarbures polybenzeniques du type benzo-3.4. pyrène par les sédiments, la faune et la flore marines de la baie de Saint-Malo. (On the retention of a polybenzic hydrocarbons of the type benzo-3,4 pyrene by the sediments, marine fauna and flora of the St. Malo Bay.)
C. r. hebd. Séanc. Acad. Sci., Ser. D, Paris, 264, 969-971, 1967.

1016. EMIG, C.C.
Essai d'e ude de la teneur en gaz d'hydrocarbures dans le mileu marin. (Study of the hydrocarbon gas content in the marine environment.)
Recl Trav. Stn mar. Endoume, 57, (Bull. 41), 9-16, 1966.

1488. BARBIER, M., JOLY, D., SALIOT, A., and TOURRES, D.
Hydrocarbons from seawater.
Deep Sea Res., 20, 305-314, 1973.

1489. BROOKS, J.M., FREDERICKS, A.D., SACKETT, W.M., and SWINNERTON, J.W.
Baseline concentrations of light hydrocarbons in Gulf of Mexico.
Envir. Sci. Technol., 7, 639-642, 1973.

1490. BROOKS, J.M., and SACKETT, W.M.
Sources, sinks, and concentrations of light hydrocarbons in the Gulf of Mexico.
J. geophys. Res., 78, 5248-5258, 1973.

1491. BROWN, R.A., SEARL, T.D., ELLIOTT, J.J., MONAGHAN, P.H., and BRANDON, D.E.
Measurement and interpretation of nonvolatile hydrocarbons in the ocean. Part 1. Measurements in Atlantic, Mediterranean, Gulf of Mexico, and Persian Gulf. 221p. Linden, New Jersey, Exxon Research and Engineering Co., 1974.

1492. BROWN, R.A., SEARL, T.D., ELLIOTT, J.J., PHILLIPS, B.G., BRANDON, D.E., and MONAGHAN, P.H.
Distribution of heavy hydrocarbons in some Atlantic Ocean water.
In: American Petroleum Institute. Proceedings of joint conference on prevention and control of oil spills, Washington, D.C., March 13-15 1973. pp. 505-519. Washington, D.C., American Petroleum Institute, 1973.

1493. BURNS, K.A., and TEAL, J.M.
Hydrocarbons in the pelagic Sargassum community.
Deep-Sea Res., 20, 207-211, 1973.

1494. CARLBERG, S.R.
A three year study of the occurrence of non-polar hydrocarbons (oil) in Baltic waters 1970-1973. 8p. Copenhagen, International Council for the Exploration of the Sea, Fisheries Improvement Committee, 1973. (CM 1973/E:28)

1496. EHRHARDT, M., and HEINEMANN, J.
Hydrocarbons in blue mussels from the Kiel Bight.
In: US National Bureau of Standards. Marine pollution monitoring (petroleum). Proceedings of a symposium and workshop... May 13-17 1974. pp. 221-225. Washington, D.C., US Government Printing Office, 1974.

1497. FARRINGTON, J.W.
Benthic lipids of Narragansett Bay - fatty acids and hydrocarbons. 157p. Kingston, Rhode Island, University of Rhode Island, 1972. Thesis.

1499. FARRINGTON, J.W., and QUINN, J.G.
Petroleum hydrocarbons in Narragansett Bay. 1. Survey of hydrocarbons in sediments and clams.
Estuar. cstl mar. Sci., 1, 71-79, 1973.

1500. FOSSATO, V.U., and SIVIERO, E.
Oil pollution monitoring in the lagoon of Venice using the mussel Mytilus galloprovincialis.
Mar. Biol., 25, 1-6, 1974.

1501. GORDON, D.C., JR., KEIZER, P.D., and CHAMUT, P.S.
Estimation of hydrocarbon concentrations in the water column of Come-by-Chance Bay; 1971-1973.
Tech. Rep. Fish. Res. Bd. Can., No. 442, 15p., 1974.

1502. GORDON, D.C., JR., KEIZER, P.D., and DALE, J.
Estimates using fluorescence spectroscopy of the present state of petroleum hydrocarbon contamination in the water column of the northwest Atlantic ocean.
Mar. Chem., 2, 251-261, 1974.

1503. GORDON, D.C., JR., and MICHALIK, P.A.
Concentration of Bunker C fuel in the waters of Chedabucto Bay, April 1971
J. Fish. Res. Bd Can., 28, 1912-1914, 1971.

1504. ILIFFE, T.M., and CALDER, J.A.
Dissolved hydrocarbons in the eastern Gulf of Mexico loop current and the Caribbean sea.
Deep-Sea Res., 21, 481-488, 1974.

1505. JARDAS, I., and MUNJKO, I.
Preliminary observations of oil and phenol distribution in the central Adriatic.
Bilj. Inst. Oceanogr. Ribarst., No. 29, 6p., 1972.

1506. KINNEY, P.J.
Baseline hydrocarbon concentrations.
In: Hood, D.W., Shiels, W.E., and Kelley, E.J., editors.
Environmental studies of Port Valdez, Chapter 10, pp. 397-41 0.
Fairbanks, Alaska, University of Alaska, Institute of Marine Science, 1973. (Occasional Publication No. 3).

1507. KOONS, C.B., and MONAGHAN, P.H.
Petroleum derived hydrocarbons in Gulf of Mexico waters.
Trans. Gulf-Cst Ass. geol. Socs, 23, 170-181, 1973.

1508. LEDET, E.J., and LASETER, J.L.
Alkanes at the air-sea interface from offshore Louisiana and Florida.
Science, N.Y., 186, 261-263, 1974.

1509. LEE, C.C., CRAIG, W.K., and SMITH, P.J.
Water-soluble hydrocarbons from crude oil.
Bull. envir. Contam. Toxicol., 12, 212-217, 1974.

1510. LEVY, E.M.
The presence of petroleum residues off the east coast of Nova Scotia, in the Gulf of St. Lawrence, and the St. Lawrence river.
Wat. Res., 5, 723-733, 1971.

1511. LEVY, E.M., and WALTON, A.
Dispersed and particulate petroleum residues in the Gulf of St. Lawrence.
J. Fish. Res. Bd Can., 30, 261-267, 1973.

1512. MACKIE, P.R., WHITTLE, K.J., and HARDY, R.
Hydrocarbons in the marine environment. 1. n-alkanes in the Firth of Clyde.
Estuar. cstl mar. Sci., 2, 359-374, 1974.

1515. MICHALIK, P.A., and GORDON, D.C., JR.
Concentration and distribution of oil pollutants in Halifax Harbor 10 June to 20 August 1971
Tech. Rep. Fish. Res. Bd Can., No. 284, 26p., 1971.

1516. MONAGHAN, P.H., SEELINGER, J.H., and BROWN, R.A.
The persistent hydrocarbon content of the sea along certain tanker routes - a preliminary report.
In: American Petroleum Institute. Report on the 18th tanker conference, Hilton Head Island, South Carolina, May 7-9 1973. pp. 232-259.

1517. MORRIS, R.J.
Lipid composition of surface films and zooplankton from the eastern Mediterranean.
Mar. Pollut. Bull., 5, 105-109, 1974.

1518. MORRIS, R.J., and CULKIN, F.
Lipid chemistry of eastern Mediterranean surface layers.
Nature, Lond., 250, 640-642, 1974.

1519. PARKER, P.L., WINTERS, J.K., and MORGAN, J.
A baseline study of petroleum in the Gulf of Mexico. 25p.
Port Aransas, Texas, Univerity of Texas, Marine Science Institute, 197-?
(Unpublished Report)

1522. SCARRATT, D.J., and ZITKO, V.
Bunker C oil in sediments and benthic animals from shallow depths in Chedabucto Bay, N.S.
J. Fish. Res. Bd Can., 29, 1347-1350, 1972.

1525. WHITTLE, K.J., MACKIE, P.R., HARDY, R., and MCINTYRE, A.D.
A survey of hydrocarbons in Scottish coastal waters. 9p. Copenhagen, International Council for the Exploration of the Sea, Fisheries Improvement Committee, 1973. (CM 1973/E:30)

1526. WONG, C.S., CRETNEY, W.J., MACDONALD, R.W., and ERICKSON, P.
Baseline information on chemical oceanography and petroleum-based hydrocarbons in the Southern Beaufort Sea. 51p. Victoria, B.C. Environment Canada, Ocean Chemistry Division, Ocean and Aquatic Affairs, Pacific Region, 1974. (Interim Report)

1528. ZSOLNAY, A.
The relative distribution of saturated and olefinic hydrocarbons in the Baltic in September 1971. 14p. Copenhagen, International Council for the Exploration of the Sea, Fisheries Improvement Committee, 1972. (CM 1972/E:12)

1529. ZSOLNAY, A.
Measurements made at sea of the saturated and aromatic hydrocarbons in the Baltic in April 1973. 13p. Copenhagen, International Council for the Exploration of the Sea, Fisheries Improvement Committee, 1973.
(CM 1973/E:22)

1530. ZSOLNAY, A.
The relative distribution of non-aromatic hydrocarbons in the Baltin in September 1971.
Mar. Chem., 1, 127-136, 1973.

1531. ZSOLNAY, A.
Hydrocarbon content and chlorophyll correlation in the waters between Nova Scotia and the Gulf Stream.
In: US National Bureau of Standards. Marine pollution monitoring (petroleum). Proceedings of a symposium and workshop... May 13-17 1974. pp. 255-256. Washington, D.C., US Government Printing Office, 1974.

1541. SCARRATT, D.J., and ZITKO, V.
Sublittoral sediment and benthos sampling and littoral observations in Chedabucto Bay April 1973.
In: Mackay, D., and Harrison, W., editors. Oil and the Canadian environment. Proceedings of a conference... 16 May 1973. pp. 78-79. Toronto, University of Toronto, (1973?)

1544. ZITKO, V., and CARSON, W.V.
Analysis of water and sediment samples. 5p. St. Andrews, New Brunswick, Fisheries Research Board of Canada, Biological Station, 1970. (Report No. 2. Project Oil - Chemistry) (Unpublished Report)

1605. BLACKMAN, R.A.A., and MACKIE, P.(R.)
Preliminary results of an experiment to measure the uptake of n-alkane hydrocarbons by fish. 9p. Copenhagen, International Council for the Exploration of the Sea, Fisheries Improvement Committee, 1973. (CM 1973/E:23)

1612. HARDY, R., MACKIE, P.R., WHITTLE, K.J., and MCINTYRE, A.D.
Discrimination in the assimilation of n-alkanes in fish.
Nature, Lond., 252, 577-578, 1974.

1644. FOSSATO, V.U.
Elimination of hydrocarbons by mussels.
Mar. Pollut. Bu 11., 6, 7-10, 1975.

1659. LEE, R.F., SAUERHEBER, R., and BENSON, A.A.
Petroleum hydrocarbons: uptake and discharge by the marine mussel *Mytilus edulis*.
Science, N.Y., 177, 344-346, 1972.

1672. STEGEMAN, J.J., and TEAL, J.M.
Accumulation, release and retention of petroleum hydrocarbons by the oyster *Crassostrea virginica*. Marine Biology 22:37-44.

1767. GIACCIO, M.
Idrocarburi policiclici aromatici in alcune specie ittiche. (Polycyclic aromatic hydrocarbons in some species of fish.) (In ITALIAN with ENGLISH summary)
Quad. Merceologia, 10, 21-26, 1971.

1768. LEE, R.F., SAUERHEBER, R., and DOBBS, G.H.
Uptake, metabolism and discharge of polycyclic aromatic hydrocarbons by marine fish.
Mar. Biol., 17, 201-208, 1972.

1696. MORRIS, R.J.
Uptake and discharge of petroleum hydrocarbons by barnacles.
Mar. Pollut. Bull., 4, 107-109. 1973.

13.

1770. MALLET, L.
Pollution des milieux vitaux par les hydrocarbures polybenzèniques du type benzo, 3, 4, pyrène. (Pollution of important environments by polybenzic hydrocarbons of the type benzo-3-4-pyrene.)
Gaz. Hôp., Paris, Numero Spécial 10 Juin, 136, 803-808, 1964.

1771. MALLET, L.
Pollutions marines par les hydrocarbures polycondensés du type Benzo 3.4. pyrène de la côte occidentale Francaise. Leur incidence sur le milieu biologique, et en particulier le plancton. (Marine pollution by polycondensed hydrocarbons of the type benzo 3-4 pyrene off the west coast of France. Their incidence on the biological environment, and in particular the plankton.)
Bull. Ass. fr. Avanc. Sci., 74, 11-16, 1967.

1772. MALLET, L., and SARDOU, J.
Recherche de la présence de l'hydrocarbure polybenzenique benzo-3, 4 pyrène dans le milieu planctonique de la région de la baie de Villefranche (Alpes-Maritimes). (Research on the presence of the polybenzic hydrocarbon benzo-3-4-pyrene in the planktonic environment of the region of the bay of Villefranche (Alpes-Maritimes))
C. r. hebd. Séanc. Acad. Sci., Paris, Ser. D. 258, 5264-5267, 1964.

1773. NIAUSSAT, P., and OTTENWALDER, J.
Apparition de benzo 3-4-pyrène dans des cultures "in vitro" de phyto-plancton marin. Importance des souillures bactériennes associées. (Apparition of benzo 3-4-pyrene in "in vitro" cultures of marine phytoplankton. Incidence of associate bacteria.)
Revue Hyg. Méd. soc., 17, 487-496, 1969.

1776. SCACCINI-CICATELLI, M.
Sui fenomeni di accumulo del benzo-3, 4-irene nell-organismo di Tubifex. (On the phenomena of accumulation of benzo 3-4-pyrene in the organism Tubifex.)
Boll. Soc. ital. Biol. sper., 42, 957-959, 1966.

*A70. BARBIER, M., D. JOLY, A. SALIOT, and D. TOURRES (1973)
Hydrocarbons from sea water, Deep-Sea Res., vol. 20, p. 305-314, 9 illus. 16 refs.

*A75. BLUMER, M. (1970)
Dissolved organic ompounds in sea water: Saturated and olefinic hydrocarbons and singly branched fatty acid, Symposium on organic matter in natural waters, University of Alaska, Sept. 2-4, D.W. Hood (ed.)., Inst. of Marine Science, Occasional publ., no. 1, p. 153-167, 3 tabls., 19 refs.

*A79. BROWN, T.A., T.D. SEARL, J.J. ELLIOTT, B.G. PHILLIPS, D.E. BRENDON, and P.H. MONAGHAN (1973)
Distribution of heavy hydrocarbons in some Atlantic Ocean waters, Proceedings of the joint conference on prevention and control of oil spills, Sponsored by API, EPA, and USCG, publ. by Amer. Petrol. Inst., Washington, D.C., p. 505-519, 10 illus., 4 tabls., 14 refs.

13.

*A94. GARRETT, W.D. (1967)
The organic chemical composition of the ocean surface, Deep-Sea Research, vol. 14, p. 221-227, 3 tabls., 20 refs.

*A119. LEVY, E.M. (1971)
The presence of petroleum residues off the east coast of Nova Scotia, in the Gulf of St. Lawrence and the St. Lawrence River, Water Res., vol. 5, no. 9, p. 723-733, 3 illus., 4 tabls., 11 refs.

*A120. LEVY, E.M., and A. WALTON (1972)
Dispersed and particulate petroleum residues in the Gulf of St. Lawrence (unpublished manuscript), Atlan. Ocean Lab., Bedford Inst., Conn., 29 p., 7 illus., 20 refs.

*A132. MORRIS, B.F., and J.N. BUTLER (1973)
Petroleum residues in the Sargasso Sea and on Bermuda beaches, Proceedings of the joint conf. on prevention and control of oil spills, Sponsored by API, EPA, and USCG, publ. by Amer. Petrol. Inst., Washington, D.C., p. 521-529, 8 illus., 1 tabl., 29 refs.

*167. BARGER, W.R., and W.D. GARRETT (1970)
Surface active organic material in the marine atmosphere, Jour. Geophys. Res., vol. 75, no. 24, p. 4561-4566, 3 illus., 2 tabls., 17 refs.

*A168. BLANCHARD, D.C. (1964)
Sea-to-air transport of surface active material, Science, Vol. 146, p. 396-397, 13 refs.

*A169. CAVANAGH, L.A., C.F. SCHADT, and E. ROBINSON (1969)
Atmospheric hydrocarbon and carbon monoxide measurements at Point Barrow, Alaska, Environ. Sci. & Tech., vol. 3, no. 3, p. 251-257, 5 illus., 1 tabl., 12 refs.

*A174. BLUMER, M. and J. SASS (1972)
Oil pollution: Persistence and degradation of spilled fuel oil, Science, vol. 176, p. 1120-1122, 3 illus., 8 refs.

*A175. BLUMER, M., J. SASS, G. SOUZA, H.L. SANDERS, J.F. GRASSLE, and G.R. HAMPSON (1970)
The West Falmouth oil spill: Persistence of the pollution eight months after the accident, Tech. Rept. WHO1-70-44, Sept. 1970, (unpublished manuscript), 32 p., 18 illus., 3 tabls., 7 refs.

*A177. FARRINGTON, J.W., and J.G. QUINN (1973)
Petroleum hydrocarbons in Narragansett Bay, I. Survey of hydrocarbons in sediments and clams, Estuarine and Coastal Mar. Sci., vol. 1, p. 71-79, 2 illus., 1 tabl., 31 refs.

*A233. CLARK, R.C., JR., and M. BLUMER (1967)
Distribution of n-paraffins in marine organisms and sediment, Limnol. and Oceanogr., vol. 12, no. 1, p. 79-87, 7 illus., 1 tabl., 33 refs.

<u>13</u>.

*A328. DiSALVO, L.H., H.E. GUARD, L. HUNTER, and A.B. COBET (1973)
Hydrocarbons of suspected pollutant origin in aquatic organisms of San Francisco Bay: Methods and preliminary results, <u>In</u> The microbial degradation of oil pollutants, D.G. Ahearn and S.P. Meyers (eds.), Center for Wetland Resources, Louisiana State Univ., publ. no. LSU-SH-73-01, p. 205-220, 9 illus., 2 tabls., 20 refs.

*A335. LEE, R.F., R. SAUERHEBER, and A.A. BENSON (1972)
Petroleum hydrocarbons: Uptake and discharge by the marine mussel <u>Mytilus edulis</u>, Science, vol. 177, no. 4046, p. 344-346, 2 tabls., 11 refs.

*A164. ALTSHULLER, A.P., W.A. LONNEMAN, F.D. SUTTERFIELD, and S.L. KOPCZYNSKI (1971
Hydrocarbon composition of the atmosphere of the Los Angeles Basin--1967, Environ, Sci. & Tech., vol. 5, no. 10, p. 1009-1016, 11 illus., 6 tabls., 14 refs.

13.

N3667-4. MORRIS, R.J.
Lipid composition of surface films and zoo plankton from the Eastern Mediterranean. Mar. Pollut. Bull. 5(7), 1974, 105-109.

N3675-2. MATSUI, S., WATANABE, K., YOSHIDA, T., and KAWABATA, T.
Hydrocarbon components of floating oil pollutants of sea water. Bull. Jap. Soc. Sci. Fish 40(1), 1974, p. 111-116.

N3677-3. LEE, R.F., SAUERHEBER, R., DOBBS, G.H.
Uptake metabolism and discharge of poly cyclic aromatic hydrocarbons by marine fish. Mar. Biol. (BEBL) 17(3), 1972, p. 201-208.

N3682-2. GRIMMER, G. and HILDEBRANDT, A.
Concentration and estimation of 14 polycyclic aromatic hydrocarbons at low levels in high protein foods oils and fats. J. Assoc. Off. Anal. Chem. 55(3), 1972, p. 621-635.

N3690-1. FARRINGTON, J.W., and MEYER, P.A.
Hydrocarbons in the marine environment. Environ. Chem., P: 75, S: 1, p. 109-36.

N3696-1. BROWN, R.A., SEARL, T.D., ELLIOTT, J.J., MONAGHAN, P.H., and BRANDON, D.E.
Measurement and interpretation of nonvolatile hydrocarbons in the ocean. I. Measurements in Atlantic, Mediterranean, Gulf of Mexico, and Persian Gulf. Govt. Rep. Announce. (U.S.) 1975, 75(3), 54.

N3704-3. HARRISON, WYMAN, WINNIK, MITCHELL, A., KWONG, PAUL T.Y., and MACKAY, DONALD.
Crude oil spills. Disappearance of aromatic and aliphatic components from small sea--surface slicks. Environ. Sci. Technol. P: 75, S: 9, I:3, p. 231-4.

N3708-3. ILIFFE, THOMAS M., and CALDER, JOHN A.
Dissolved hydrocarbons in the eastern Gulf of Mexico Loop Current and the Caribbean Sea. Deep-Sea Res. Oceanogr. Abstr., P: 74, S:21, I: 6, p. 481-8.

N3709-3. WHITTLE, K., MACKIE, P.R., and HARDY, R.
Hydrocarbons in the marine ecosystem. S. Afr. J. Sci., P: 74, S: 70, I: 5, p. 141-4.

N3714-4. LAMONTAGNE, R.A., SWINNERTON, J.W., and LINNENBON, V.J.
Hydrocarbons in the North and South Pacific. Tellus, P: 74, S: 26, I: 1-2, p. 71-77.

N3720-4. PALMORK, KARSTEN H.
Polycyclic aromatic hydrocarbons in the marine environment. Nordforsk, Havforskningsinst., Fiskeridir., Bergen, Norway, P: 74, I: 4, p. 99-125, language: Norwegian.

N3729-3. ATLAS, RONALD M., and BARTHA, RICHARD.
Fate and effects of polluting petroleum in the marine environment. Residue Rev., P: 73, S: 49, p. 49-85.

N3731-2. FARRINGTON, JOHN W., QUINN, JAMES G.
Petroleum hydrocarbons in Narragansett Bay. I. Survey of hydrocarbons in sediments and class. (Mercenaria mercenaria) Estuarine Coastal Mar. Sci., P: 73, S:1, I:1, p. 71-9.

N3731-4. DI SALVO, L.H., GUARD, H.E., HUNTER, L., and COBET, A.B.
Bicrobial degradation oil pollutants, Workshop. P: 73, p. 205-20.

N3737-3. JARDAS, IVAN, MUNJKO, IGNAC
Preliminary observations of oil and phenol distribution in the central Adriatic. Inst. Oceanogr. Fisch., Split, Yugoslavia. Biljeske, Inst. Oceanogr. Ribar., Split. P: 72, I: 29, p. 7 pp.

N3739-1. MORRIS, R.J.
Uptake and discharge of petroleum hydrocarbons by barnacles. Mar. Pollut. Bull., P: 73, S: 4, I: 7, p. 107-9.

N3742-2. GORTALUA, G.M., and L.P. SMIRNOVA
Contamination of some coastal areas of the Black and Baltic Seas by carcinogenic hydrocarbons. Nekot. Itogi Izuch. Zagryazneniya Vnesh. Sredy Kantserogen. Veshestvami. P: 72, p. 4751 (Ref. Zh., Khim. 1973, Abstr. No. 41498)

N3743-3. FARRINGTON, JOHN W.
Atmospheric input of hydrocarbons to the sea. Mar. Pollut. Bull, P: 73, S: 4, I: 6, pages 96.

N3745-3. BROOKS, JAMES M., ALAN D. FREDERICKS, WILLIAM M. SACKETT and JOHN W. SWINNETAN.
Baseline concentrations of light hydrocarbons in Gulf of Mexico. Environ. Sci. Technol., P: 73, S: 7, I: 7, p. 639-42.

N3746-1. PEAKE, ERIC, M. STROSHER, B.L. BAKER, R. GOSSEN, R.G. MCCROSSEN, C.J. YORATH, and G.W. HODGSON.
Potential of Arctic sediments. Hydrocarbons and possible precursors in Beaufort Sea sediments. Int. Geol. Congr., Rep. Sess., 24th, P: 72, S: 5, p. 2837.

N3756-1. LEE, R.F., R. SAUERHEBER, and G.H. DOBBS.
Uptake, metabolism, and discharge of polycyclic aromatic hydrocarbons by marine fish. Mar. Biol., P: 72, S: 17, I: 3, p. 201-8.

N3763-2. LEE, RICHARD F., RICHARD SAUERHEBER, and A.A. BENSON.
Petroleum hydrocarbons. Uptake and discharge by the marine mussel Mytilus edulis. Science, P: 72, S: 177, I: 4046, p. 344-6.

N3766-4. GIACCIO, MARIO
Polycyclic aromatic hydrocarbons in fish. Quad. Merceol., P: 71, S: 10, I: 1, p. 21-6, in Italian.

<u>13</u>.

0-38. WONG, C.S., D. MAC DONALD and R.D. BELLEGAY.
Distributions of tar and other particulants along the Beaufort Sea coast. Interim Report of Beaufort Sea Project, Study Cl, Dec. 1974. Environment Canada, Victoria, B.C.

0-39. WONG, C.S., W.J. CRETNEY, R.W. MAC DONALD, and P. ERICKSON.
Baseline information on chemical oceanography and petroleum-based hydrocarbons in the Southern Beaufort Sea. Interim Report of Beaufort Sea Project Study C-3, Dec. 1974. Environment Canada, Victoria, B.C.

0-41. SMITH, THOMAS G. and JOSEPH R. GERACI.
The effect of contact and ingestion of crude oil on ringed seals of the Beaufort Sea. Interim Report of Beaufort Sea Project Study A-5, Dec. 1974. Environment Canada, Victoria, B.C.

(NOTE: **Two asterisks means copy available.)

13. Additions to Classified Literature References as of 3/31/76.

**0-87. KOONS, C.B., D.C. McAULIFFE, and F.T. WEISS (X-ref. Sheen Tech. Subcommittee, Offshore Operators Committee)
Environmental aspects of produced waters from oil and gas extraction operations in offshore and coastal waters. Prepared by Sheen Tech. Subcommittee, Offshore Operators Committee, September 30, 1975.

**0-93. McAULIFFE, CLAYTON D.
Surveillance of the marine environment for hydrocarbons. Chevron Oil Field Research Company, La Habra, California 90631, U.S.A.

**0-94. MC AULIFFE, CLAYTON D., ALFRED E. SMALLEY, ROBERT D. GROOVER, W. MARVIN WELSH, STEWART PICKLE and GEORGE E. JONES.
Chevron main pass block 41 oil spill: chemical and biological investigations. API Conference on Prevention and Control of Oil Pollution, 1975(?).

0-103. NOAA BULLETIN. (No author.)
National program for continual environmental monitoring for the marine leg of the trans-Alaska pipeline system. Rockville, MD, Oct. 1973. NOAA. Federal Coordination for Marine Environmental Prediction.

0-112 FOSSATO, V.U.
Elimination of hydrocarbons by mussels. Mar. Pollut. Bull. 6(1), 7-10(1975).

0-125. BUTLER, JAMES NEWTON, BYRON F. MORRIS, and JEREMY SASS.
Pelagic tan from Bermuda and the Sargasso Sea. Bermuda Biological Station for Research, Spec. Pub. No. 10, 1973, 346 p.

13. Additions to Classified Literature References as of 6/28/76

*P14-3 ANDERSON, J.W., 1973
Uptake and depuration of specific hydrocarbons from oil by the bivalves "Rangia cuneata" and "Crassostrea virginica." Background papers for a workshop on inputs, fates, and effects of petroleum in the marine environment. Ocean Affairs Board. National Academy of Sciences, 2:690-708.

*P44-2 BLUMER, M., ET. AL., 1971
A small oil spill. Environment, 13(2):2-12.

*P46-1 BLUMER, M. J.C. ROBERTSON, J.E. GORDON, & J. SASS, 1969
Phytol-derived C-14 di- and triolefinic hydrocarbons in marine zooplankton and fish Biochem., 8(10):4067-4074.

*P61-2 CAHNMANN, J.J. & M. KURATSUNE, 1957
Determination of polycyclic aromatic hydrocarbons in oysters collected in polluted water. Anal. Chem., 29(9):1312-1317.

*P115-2 EHRHARDT, M., 1972
Petroleum hydrocarbons in oysters from Galveston Bay. Environ. Pollut., 3(4): 257-271.

*P133-2 FOSSATO, V.U., 1975
Elimination of hydrocarbons by mussels. Marine Pollut. Bull., 6(1).

*P224-3 LEE, R.F., R. SAUERHEBER, & G.H. DOBBS, 1972
Uptake, metabolism and discharge of polycyclic aromatic hydrocarbons by marine fish. Mar. Biol. (Berl.) 17(3):201-208. Illus.

*P225-2 LEE, R.F., R. SAUERHEBER, & A.A. BENSON, 1972
Uptake and discharge by the marine mussel, "Mytilus edulis." Science 177(4046):344

*P225-3 LEE, R.F., R. SAUERHEBER, & G.H. DOBBS, 1972
Uptake, metabolism and discharge of polycyclic aromatic hydrocarbons by marine fish Mar. Biol., 17(3):201-208.

*P271-1 MORRIS, R.J. 1973
Uptake and discharge of petroleum hydrocarbons by barnacles. Mar. Poll. Bull., 4(7):107-109.

*P372-2 SCARRATT, D.J., 1974
Section 4: Impact of spills and clean-up technology on living natural resources, and resource-based industry. PP. 141-158, in: Summary of physical, biological, socio-economic and other factors relevant to potential oil spills in the Passamaquoddy region of the Bay of Fundy. Fisheries Research Board of Canada, Technical Report No. 428.

*P397-2 STEGEMAN, J.J. & J.M. TEAL, 1973
Accumulation, release, and retention of petroleum hydrocarbons by the oyster "Crassostrea vrginica." Marine Biology, 22:37-44.

*P412-1 TEAL, J.M., 1973
Accumulation, release, and retention of petroleum hydrocarbons by the oyster Crassostrea virginica. Background papers for a workshop on inputs, fates, and effects of petroleum in the marine environment. Ocean Affairs Board, National Academy of Sciences, 2:571-602.

*P455-3 WOODIN, S.A. & C.F. NYBLADE, 1972
Oil spill on Guemes Island, Washington. Friday Harbor Labs, U. of Wash. preliminary report. 8 pp.

*P464-1 ZITKO, V., 1970
Determination of residual fuel oil contamination of aquatic animals. Bull. Environ. Contamin. Toxicol., 5:559-64.

0-139 STEGEMAN, J.J., 1974
Hydrocarbons in shellfish chronically exposed to low levels of fuel oil. Reprint from: Pollution & Physiology of Marine Organisms, Academic Press, Inc., 1974, p. 329-347. (Copy in library)

0-140 WONG, C.S., D. MACDONALD, & W.J. CRETNEY, 1976
Distribution of tar and other particulate pollutants along the Beaufort Sea coast. Ocean Chemistry Division Ocean & Aquatic Sciences, Pacific Region, Department of the Environment, 211 Harbour Road, Victoria, B.C.

Beaufort Sea Project, 512 Federal Building, 1230 Government Street, Victoria, B.C. V8W 1Y4. Beaufort Sea Technical Report No. 13.

0-180 ANDELMAN, J.B. & J.E. SNODGRASS, 1974
Incidence and significance of polynuclear aromatic hydrocarbons in the water environment. CRC Critical Reviews in Environmental Control, Jan. 1974, pp. 69-83.

0-187 CLARK, R.C., JR, 1966
Saturated hydrocarbons in marine plants and sediments. (M.S. thesis) Massachusetts Institute of Technology, June, 1966, 96 p.

0-188 COX, B.A., J.W. ANDERSON, & J.C. PARKER, 1975
An experimental oil spill: the distribution of aromatic hydrocarbons in the water, sediment, and animal tissues within a shrimp pond. In: American Petroleum Institute. 1975 Conference on prevention and control of oil pollution. Proceedings March 25-27, 1975, San Francisco, Calif. API/EPA/USCG, pp. 607-612.

0-189 DISALVO, L.H., H.E. GUARD, & K. TRY, 1974 ?
(unpubl. manuscript) Comparative hydrocarbon content of algae from a San Francisco Bay wharf and a California coastal inlet. Naval Biomedical Research Laboratory, School of Public Health, Univ. of Calif., Berkeley, Calif., 94720, 10 p.

0-190 EHRHARDT, M., 1972
Petroleum hydrocarbons in oysters from Galveston Bay, Environ, Pollut. 3:257-271.

0-191 FARRINGTON, J.W. & J.G. QUINN, 1973
Petroleum hydrocarbons and fatty acids in wastewater effluents. J. Water Pollut. Control Federation 45:704-712.

-192 FOSSATO, V.U., 1975
Elimination of hydrocarbons by mussels. Marine Pollut. Bull. 6:7-10.

-193 HORN, M.H., J.M. TEAL & R.H. BACKUS, 1970
Petroleum lumps on the surface of the sea. Science 168:245-246.

-194 HOULT, D.P. (ED.), 1969
Oil on the sea. Proceedings of a symposium on the scientific and engineering aspects of oil pollution of the sea, sponsored by Massachusetts Institute of Technology and Woods Hole Oceanographic Institution and held at Cambridge, Mass.,

0-194 May 16, 1969. New York-London: Plenum Press, 114 p.

0-195 NIAUSSAT, P., J. TRICHET, M. HEROS, N.T. LUONG, & J.P. EHRHARDT, 1975
Occurrence of benzo-3-4-pyrene in water and sediments of briny ponds of some Polynesian atolls. C.R. Acad. Sc. Paris Ser. D 281:1031-1033.

0-196 ROUBAL, W.T. & T.K. COLLIER, 1974 (draft)
Interaction, metabolism and discharge of some paraffin and aromatic hydrocarbons in young coho salmon--distribution and binding in neural membranes.

0-197 STAINKEN, D.M., 1975
Preliminary observations on the mode of accumulation of #2 fuel oil by the soft shell clam, _Mya arenaria_. In: American Petroleum Institute, 1975 conference on prevention and control of oil pollution. Proceedings, March 25-27, 1975, San Francisco, Calif. API/EPA/USCG pp. 463-468.

0-198 WASHINGTON, STATE OF, DEPARTMENT OF ECOLOGY, 1974 (draft)
Baseline study (on petroleum oil pollution), 17 p.

0-199 WHITTLE, K.J., J. MURRAY, P.R. MACKIE, R. HARDY & J. FARMER, 1975
Fate of hydrocarbons in fish. In: International Council for the Exploration of the Sea, Workshop: Petroleum hydrocarbons in the marine environment No. F5 (October, 1975?--this paper not to be cited without prior reference to author--c/o Torrey Research Station, Aberdeen, UK), 7 p.

0-200 WILKINSON, D.R., J.M. JONES & B.M. TRIBBITT, 197 ?
Concentration and determination of monomethylnaphthalenes in petroleum distillat spills. American Laboratory ? : 31-33.

0-201 YOUNGBLOOD, W.W. & M. BLUMER, 1975
Polycyclic aromatic hydrocarbons in the environment: homologous series in soils and recent marine sediments. Geochimica et Cosmochimica Acta 39:1303-1314.

0-202 YOUNGBLOOD, W.W., M. BLUMER, R.L. GUILLARD & F. FIORE, 1971
Saturated and unsaturated hydrocarbons in

14. SEDIMENTS, MUD, SILT (INCLUDING OIL AND HEAVY METALS THEREIN, ADSORPTION OF OIL ON SILT, AND GEOLOGICAL ASPECTS).

102. GUNKEL, W.
Bacteriological investigations of oil-polluted sediments from the Cornish coast following the "Torrey Canyon" disaster.
Fld Stud., 2, (suppl.), 151-158, 1968.

103. GUNKEL, W., and TREKEL, H.-H.
Zur Methodik der quantitativen Erfassung Ölabbadauender Bakterien in in verölten Sedimenten und Böden, Öl-Wassergemischen, Ölen und teerartigen Substanzen. (On the method of quantitative determination of oil decomposing bacteria in oil polluted sediments and soils, oil-water mixtures, oils and tarry substances.)
Helgoländer wiss. Meeresunters., 16, 336-348, 1967.

105. JUGE, D.M.
A study of the bacterial population of bottom sediments in the Santa Barbara Channel after the oil spill.
In: Allan Hancock Foundation. Biological and oceanographical survey of the Santa Barbara Channel oil spill 1969-1970.
Vol. 1, compiled by D. Straughan. pp. 179-222. Allan Hancock Foundation, University of Southern California, 1971.

123. ZOBELL, C.E.
Bacterial release of oil from sedimentary materials.
Oil Gas J., 46, (13), 62-69, 1947.

124. ZOBELL, C.E.
Microbial transformation of molecular hydrogen in marine sediments, with particular reference to petroleum.
Bull. Am. Ass. Petrol. Geol., 31, 1709-1752, 1947.

125. ZOBELL, C.E.
Bacteriological analysis of mud samples. Nine reports and a summary on analysis of mud samples, taken in Louisiana Bays and around oil fields, for hydrocarbon oxidizing bacteria.
Texas A and M Research Foundation, 1948-1949. (Project Nine - unpublished report)

127. ZOBELL, C.E.
Demonstration of bacteria in mud samples from Barataria Bay region which oxidize crude oil from Louisiana. Texas A and M Research Foundation, 1949. (Project Nine - unpublished report)

152. JOHNSTON, R.
The decomposition of crude oil residues in sand columns.
J. Mar. Biol. Ass. U.K., 50, 925-937, 1970.

384. MACKIN, J.G.
Report on a study to determine the effect of subjecting oysters to continuous contact with oil soaked mud. Texas A and M Research Foundation, 1948. (Project Nine - unpublished report)

421. BEYER, F.
Zooplankton, zoobenthos, and bottom sediments as related to pollution and water exchange in the Oslofjord.
Helgoländer wiss. Meeresunters., 17, 496-509, 1968.

428. CHIPMAN, W.A., and GALTSOFF, P.S.
Effects of oil mixed with carbonized sand on aquatic animals. Spec. Scient. Rep. U.S. Fish Wildl. Serv. (Fisheries, 1, 52p., 1949.

437. CRAPP, G.B., WITHERS, R.G., and SULLIVAN, C.E.
Investigations on sandy and muddy shores.
In: Cowell, E.B., editor. Proceedings of the symposium on the ecological effects of oil pollution on littoral communities, London, 30 November-1 December, 1970.
London, Institute of Petroleum, 1971.

478. WINSTON, J.E., and ANDERSON, F.E.
Bioturbation of sediments in a northern temperate estuary.
Mar. Geol., 10, 39-49, 1971.

499. CLARK, R.C., JR., and BLUMER, M.
Distribution of n-paraffins in marine organisms and sediment.
Limnol. Oceanogr., 12, 79-87, 1967.

599. MALLET, L., and LE THEULE, M.-T.
Recherche du benzo-3,4 pyrène dans les sables vaseux marins des régions cotières de la Manche et de l'Atlantique. (Examination of benzo-3,4 pyrene in marshy marine sands of the coastal regions of the English Channel and the Atlantic.)
C. r. hebd. Séanc. Acad. Sci., Paris, 252, 565-567, 1961.

602. MALLET, L., and PRIOU, M.-L.
Sur la rétention des hydrocarbures polybenzéniques du type benzo-3.4 pyrène par les sédiments, la faune et al flore marines de la baie de Saint-Malo. (On the retention of polybenzic hydrocarbons of the type benzo-3,4 pyrene by the sediments, marine fauna and flora of the St. Malo Bay.)
C. r. hebd. Séanc. Acad. Sci., Ser. D, Paris, 264 969-971, 1967.

603. MALLET, L., PRIOU, M.-L., and LEON, M.
Biosynthèse et bioréduction de l'hydrocarbure polybenzénique benzo 3-4 pyrène dans les vases de la baie de Saint-Malo. (Biosymthesis and bio-reduction of the polybenzic hydrocarbon benzo 3-4 pyrene in the muds of the St. Malo Bay.)
C. r. hebd. Séanc. Acad. Sci., Ser. D, Paris, 268, 202-205, 1969.

1017. EMIG, C.C.
Etude de la teneur en gaz d'hydrocarbures des sediments. II. Etang de Berre. (Study of the hydrocarbon gas content of sediments. II. Berre Pond.)
Recl Trav. Stn mar. Endoume, 61, (Bull. 45), 359-365, 1969.

1027. HARTUNG, R., and KLINGLER, G.W.
Concentration of DDT by sedimented polluting oils.
Envir. Sci. Technol., 4, 407-410, 1970.

1065. STEVENS, N.P., BRAY, E.E., and EVANS, E.D.
Bull. Am. Ass. Petrol. Geol., 40, 975-983, 1956.

1068. SUGIMOTO, H., SUZUKI, M., and TAKEUCHI, O.
Studies of the oil pollution on the fishing ground in Seto Inland Sea. II. Distribution of oily wastes in the mud of sea bottome. (In Japanese, with English summary)
Bull. Jap. Soc. scient. Fish., 31, 24-32, 1965.

1245. GUARD, H.E., and COBET, A.B.
Fate of petroleum hydrocarbons in beach sand. 89p. Oakland, California, US Naval Biochemical Research Laboratory, 1972. (Final Report)

1246. GUARD, H.E., and COBET, A.B.
The fate of bunker fuel in beach sand.
In: American Petroleum Institute. Proceedings of joint conference on prevention and control of oil spills, Washington, D.C., March 13-15 1973. pp. 827-834. Washington, D.C., American Petroleum Institute, 1973.

1248. HARTUNG, R., and KLINGER, G.W.
Sedimentation of floating oils.
Pap. Mich. Acad. Sci., 53, 23-27, 1968.

1498. FARRINGTON, J.W., and QUINN, J.G.
Biogeochemistry of fatty acids in recent sediments from Narragansett Bay, Rhode Island.
Geochem. cosmochim. Acta, 37, 259-268, 1973.

1499. FARRINGTON, J.W., and QUINN, J.G.
Petroleum hydrocarbons in Narragansett Bay. 1. Survey of hydrocarbons in sediments and clams.
Estuar. cstl mar. Sci., 1, 71-79, 1973.

1522. SCARRATT, D.J., and ZITKO, V.
Bunker C oil in sediments and benthic animals from shallow depths in Chedabucto Bay, N.S.
J. Fish. Res. Bd Can., 29, 1347-1350, 1972.

1523. SHAW, D. G.
Lipids in shallow bottom sediments.
Envir. Sci. Technol., 7, 740-742, 1973.

1541. SCARRATT, D.J., and ZITKO, V.
Sublittoral sediment and benthos sampling and littoral observations in Chedabucto Bay April 1973.
In: Mackay, D., and Harrison, W., editors. Oil and the Canadian environment. Proceedings of a conference... 16 May 1973. pp. 78-79. Toronto, University of Toronto, (1973?).

1544. ZITKO, V., and CARSON, W.V.
Analysis of water and sediment samples. 6p. St. Andrews, New Brunswick, Fisheries Research Board of Canada. Biological Station, 1970. (Report No. 2. Project Oil - Chemistry) (Unpublished Report)

1694. LEVELL, D.
Effects of oil pollution and cleaning on sand and mud fauna - interim report, January 1973.
Rep. Oil Pollut. Res. Unit, Fld Stud. Coun., 1972, 32-34, 1973.

*A42. MEINSCHEIN, W.G. (1969)
Hydrocarbons--saturated, unsaturated and aromatic, In Organic Geochemistry, G. Eglinton and M.T.J. Murphy (eds.), Springer-Verlag, New York, chapter 13, p. 330-356, 9 illus., 6 tabls., 45 refs.

*A45. MULIK, J.D., and J.G. ERDMAN (1963)
Genesis of hydrocarbons of low molecular weight in organic-rich aquatic systems, Science, vol. 141, p. 806-807, 1 tabl., 14 refs.

*A47. PHILIPPI, G.T. (1965)
On the depth, time and mechanism of petroleum generation, Geochim. et. Cosmochim Acta, vol. 29, p. 1021-1049, 12 illus., 6 tabls., 27 refs.

*A56. SMITH, P.V., JR. (1954)
Studies on origin of petroleum: Occurrence of hydrocarbons in recent sediments, Bull. Amer. Assoc. Petrol. Geol., vol. 38, no. 3, p. 377-404, 6 illus., 16 tabls., 26 refs.

*A59. VAN HOEVEN, W. (1969)
Organic geochemistry, Ph.D. thesis, Univ. of Calif., Berkeley, 243 p., 52 illus., 2 tabls., 217 refs.

*A173. BLUMER, M., AND J. SASS (1972)
Indigenous and petroleum-derived hydrocarbons in a polluted sediment, Mar. Pollut. Bull., vol. 3, no. 6, p. 92-94, 1 illus., 1 tabl., 17 refs.

*A176. CHIPMAN, W.A., and P.S. GALTSOFF (1949)
Effects of oil mixed with carbonized sand on aquatic animals, U.S. Fish and Wildlife Service, Spec. Sci. Rept., Fisheries, No. 1, 52 p., 19 illus., 23 tabls., 29 refs.

*A177. FARRINGTON, J.W., and J.G. QUINN (1973)
Petroleum hydrocarbons in Narragansett Bay, I. Survey of hydrocarbons in sediments and clams, Estuarine and Coastal Mar. Sci., vol. 1, p. 71-79, 2 illus., 1 tabl., 31 refs.

*A179. HARTUNG, R., and G.W. KLINGLER (1967)
Sedimentation of floating oils, Papers of the Mich. Acad. of Sci., Arts and Letters, vol. LIII, p. 23-27, 2 illus., 15 refs.

*A180. JOHNSTON, R. (1970)
The decomposition of crude oil residues in sand columns, Jour. Mar. Biol. Assoc., U.K., vol. 50, p. 925-937, 5 illus., 8 refs.

14.

*A182. MARK, H.B., JR., T. YU, J.S. MATTSON, and R.L. KOLPACK (1972)
Infrared estimation of oil content in sediments in presence of biological matter, Environ. Sci. and Tech., vol. 6, no. 9, p. 833-834, 1 illus., 2 tabls., 7 refs.

*A183. OLAUSSON, E. (1970)
Water sediment exchange and recycling of pollutants through biogeochemical processes, FAO tech. conf. of mar. pollut. and its effects on living resources and fishing, Rome, Italy, Dec. 9-18, 8 p., 5 illus., 19 refs.

*A184. PALACAS, J.G., A.H. LOVE, and P.M. GERRILD (1972)
Hydrocarbons in estuarine sediments of Choctawhatchee Bay, Florida, and their implications for genesis of petroleum, Amer. Assoc. Petrol. Geol. Bull., vol. 56, no. 8, p. 1402-1418, 7 illus., 6 tabls., 43 refs.

*A185. POIRIER, O.A., and G.A. THIEL (1941)
Deposition of free oil by sediments settling in sea water, Bull. Amer. Assoc. Petrol. Geol., vol. 25, no. 12, p. 2170-2180, 5 illus., 5 tabls., 8 refs.

*A186. SHAW, D.G. (1973)
Lipids in shallow bottom sediments, Environ. Sci. and Tech., vol. 7, no. 8, p. 740-742, 1 illus., 8 refs.

*A187. STEVENS, N.P., E.E. BRAY, AND E.D. EVANS (1956)
Hydrocarbons in sediments of Gulf of Mexico, Bull. Amer. Assoc. Petrol. Geol., vol. 40, no. 5, p. 975-983, 6 illus., 3 tabls., 5 refs.

*A188. TISSIER, M., and J.L. OUDIN (1973)
Characteristics of naturally occurring and pollutant hydrocarbons in marine sediments, Proceedings of the joint conf. on prevention and control of oil spills, Sponsored by API, EPA, and USCG, publ. by Amer. Petrol. Inst., Washington, D.C., p. 205-211, 12 illus., 1 tabl., 31 refs.

*A189. ZAFIRIOU, O.C. (1973)
Petroleum hydrocarbons in Narragansett Bay, Part II. Chemical and isotopic analyses, Estuarine and Coastal Mar. Sci., vol. 1, p. 81-87, 1 illus., 2 tabls., 15 refs.

*A190. AHLFELD, T.E., and P.A. LaROCK (1973)
Alkane degradation in beach sands, In The microbial degradation of oil pollutants, D.G. Ahearn and S.P. Meyers (eds.), Center for Wetland Resources, Louisiana State University, publ. no. LSU-SG-73-01, p. 199-203, 2 tabls., 6 refs.

*A191. BAKER, J.M. (1971)
Oil and salt-marsh soil, Proceedings of the ecological effects of oil pollution on littoral communities, E.B. Cowell (ed.), Inst. of Petrol., London, p. 62-71, 8 illus., 19 refs.

*A233. CLARK, R.C., JR., and M. BLUMER (1967)
Distribution of n-paraffins in marine organisms and sediment, Limnol. and Oceanogr., vol. 12, no. 1, p. 79-87, 7 illus., 1 tabl., 33 refs.

N3670-1. GIGER, W., M. REINHARD, C. SCHAFFNER, and W. STUMM.
Petroleum derived and indigenous hydrocarbons in recent sediments of Lake Zug Switzerland. Environ. Sci. Technol. 8(5), 1974, p. 454-455.

N3675-1. WALKER, J.D., J.J. CALOMIRIS, and R.P. COLWELL.
Hydrocarbon degradation by ocean sediment bacteria. Abstr. Ann. Meet. Am. Soc. Microbiol. 74, 1974, p. 64.

N3676-3. SEGAR, D.A. and R.E. PELLENBARG.
Trace metals in carbonate and organic-rich sediments. Mar. Pollut. Bull. 4(9), 1973, 138-142.

N3676-5. PEARCE, J.B. and R.E. YASSO.
Trace metals in sediments of New-York Bight. Mar. Pollut. Bull 4(9), 1973, 132-135.

N3695-3. HUNT, JOHN M.
Origin of gasoline range alkanes in the deep sea. Nature (London), No. 75, 254, 5499, p. 411-13.

N3696-2. CHEN, KENNETH Y., and JAMES C.S. LU.
Marine studies of San Pedro Bay, California. VII. Sediment investigations. Sediment compositions in Los Angeles-Long Beach harbors and San Pedro Basin. Govt. Rep. Announce. (B.S.) 1975, 75(2), 108.

N3709-3. WHITTLE, K., P.R. MACKIE, and R. HARDY.
Hydrocarbons in the marine ecosystem. Afr. J. Sci. P: 74, S:70, I: 5, p. 141-4.

N3712-3. KIRYUKHINA, L.W., M.I. KUCHERENKO, and O.G. MIRONOV.
Pollution and self-purification of marine soils. Gidrobiol. Zh. P: 74, S:10, I:2, p. 55-9, in Russian.

N3714-2. PEAKE, ERIC, DANIEL J. CASAGRANDE, and GORDON W. HODGSON.
Fatty acids, chlorins, hydrocarbons, sterols, and carotenoids from a Black Sea core. Mem., Amer. Ass. Petrol. Geol. 1974, 20, 505-23.

N3716-3. ROMERIL, M.G.
Trace metals in sediments and bivalve mollusca in Southampton water and the Solent. Rev. Int. Oceanogr. Med., 1974, 33, p. 3147.

N3721-1. ZOR'KIN, L.M., and V.I. BAGIROV.
Gaseous hydrocarbons in bottom sediments of the Barents Sea. Izv. Akad. Nauk SSSR, Ser. Geol. 1974, vol. 2, p. 144-6, In Russian.

N3722-3. ELIAS, ROBERT W.
Role of sea grasses and benthic algae in the biogeochemistry of trace metals in Texas estuaries. Diss. Abstr. Int. B1974, 34(9), 4241-2.

N3675-4. CLAYPOOL, G.E., J.R. KAPLAN, and PRESLEY, B. J.
Generation of light hydro carbon gases in deep sea sediments. Am. Assoc. Pet. Geol. Bull. 57(4), 1973, 773.

N3722-3. FARRINGTON, JOHN W., and JAMES G. QUINN.
Petroleum hydrocarbons in Narragansett Bay. I. Survey of hydrocarbons in sediments and class. (Mercenaria mercenaria). Estuarine Coastal Mar. Sci., 1973, 1(1), p. 71-9.

N3737-4. MEYERS, PHILIP A.
Association of fatty acids and hydrocarbons with mineral particles in sea water. Diss. Abstr. Int. B 1973, 34(1), 333.

N3739-2. DUCHART, PATRICIA, S.E. CALVERT, and N.B. PRICE.
Distribution of trace metals in the pore waters of shallow water marine sediments. Limnol. Oceanogr.,1973, vol. 18(4), p. 605-10.

N3746-1. PEAKE, ERIC, M. STROSHER, B.L. BAKER, R. GOSSEN, R.G. MC CROSSEN, C.J. YORATH, and G. W. HODGSON.
Potential of Arctic sediments. Hydrocarbons and possible precursors in Beaufort Sea sediments. Int. Geol. Congr., Rep. Sess., 24th, 1972, vol. 5, p. 28-37.

N3748-4. SMITH, PETER A., J.R. MOORE.
Distribution of trace metals in the surficial sediments surrounding Keweenaw Point, upper Michigan. Proc., Conf. Gt. Lakes Res., 1972, 15, p. 383-93.

N3762-4. PEAKE, ERIC, BRUCE L. BAKER, and G.W. HODGSON.
Hydrogeochemistry of the surface waters of the Mackenzie River drainage basin, Canada. II. Contribution of amino acids, hydrocarbons, and chlorins to the Beaufort Sea by the MacKenzie River system. Geochim. Cosmochim. Acta, 1972, vol. 36(8), p. 367-83.

N 3698-3. VEBER, V.V., M.L. SAZONOV, S.N. MOROZOVA, and D.E. GERSHANOVICH.
Generation of gaseous hydrocarbons in recent sediments in the Peruvian region of the Pacific Ocean. Geol. Nefti Gaza, 1974 vol. 10, p. 56-62 (Language Russian).

N3726-4. TISSIER, M. and J.L. OUDIN.
Characteristics of naturally occurring and pollutant hydrocarbons in marine sediments. Proc. Joint Conf. Prev. Contr. Oil Spills, 1973, p. 205-14.

O-43. KNOWLES, R. and C. WISHART.
Nitrogen fixation in Arctic marine sediments. Interim Report of Beaufort Sea Study B-4, Dec. 1974. Environment Canada, Victoria, B.C.

O-47. LEWIS, C.P. and D.Z. FORBES.
Sediments and sedimentary processes - Yukon Beaufort Sea Coast. Interim Report of Beaufort Sea Project Study F-3, Dec. 1974. Environment Canada, Victoria, B.C.

O-45. PELLETIER, B.L.
Sediment dispersal in the Sourthern Beaufort Sea. Interim Report of Beaufort Sea Study Project F-4, Dec. 1974. Environment Canada, Victoria, B.C.

O-48. HUNTER, J.A., H.A. MAC AULAY, R.L. GOOD, R.M. GAGNE, and R.A. BURNS. The study of frozen seabed material in the Southern Beaufort Sea. Interim Report of Beaufort Sea Project Study F-1, Dec. 1974. Environment Canada, Victoria, B.C.

(NOTE: **Two asterisks means copy available.)

14. Additions to Classified Literature References as of 3/31/76.

**0-92. McAULIFFE, C.D. and L.L. PALMER.
Environmental aspects of offshore disposal of drilling fluids and cuttings. SPE 5864.

**0-93. McAULIFFE, CLAYTON D.
Surveillance of the marine environment for hydrocarbons. Chevron Oil Field Research Company, La Habra, California 90631, U.S.A.

**0-94. MCAULIFFE, CLAYTON D., ALFRED E. SMALLEY, ROBERT D. GROOVER, W. MARVIN WELSH, STEWART PICKLE and GEORGE E. JONES.
Chevron main pass block 41 oil spill: chemical and biological investigations. API Conference on Prevention and Control of Oil Pollution, 1975(?).

0-109 SHELTON, THEODORE BRYANT.
Decomposition of oil pollutants in natural bottom sediments. Rutgers University, 165 p. Available from University Microfilms, Ann Arbor, Mich. Order #73-4778.

(NOTE: **Two asterisks means copy available.)

14 Additions to Classified Literature References as of 4/26/76.

**0-36. PERCY, J.A. and T.C. MULLIN.
Effects of crude oils on arctic marine invertebrates. Arctic Biological Station, Fisheries and Marine Service, Dept. of the Environment, P.O. Box 400, Ste. Anne de Bellevue, Quebec. Beaufort Sea Technical Report #11, Beaufort Sea Project, Dept. of the Environment, 512 Federal Building, 1230 Government St., Victoria, B.C. V8W 1Y4, December 1975.

14. Additions to Classified Literature References as of 6/29/76

*P125-2 FARRINGTON, J.W. & J.G. QUINN, 1973
Petroleum hydrocarbons in Narrangansett Bay, Part I: Survey of hydrocarbons in sediments and clams ("Mercenaria mercenaria"). Estuarine and Coastal Marine Science, 1:71-79.

*P372-1 SCARRATT, D.J. & V. ZITKO, 1972
Bunker C oil in sediments and benthic animals from shallow depths in Chedabucto Bay, Nova Scotia. J. Fish. Res. Bd. Canada, 29(9):1347-1350.

0-202 BLUMER, M, & W.W. YOUNGBLOOD, 1975
Polycyclic aromatic hydrocarbons in soils and recent sediments. Science 188:53-55.

0-187 CLARK, R.C., JR., 1966
Saturated hydrocarbons in marine plants and sediments. (M.S. thesis) Massachusetts Institute of Technology, June 1966. 96 p.

0-188 COX, B.A., J.W. ANDERSON & J.C. PARKER, 1975
An experimental oil spill: The distribution of aromatic hydrocarbons in the water, sediment, and animal tissues within a shrimp pond. In: American Petrol. Institute, 1975 conference on prevention and control of oil pollution. Proceedings, March 25-27, 1975, San Francisco, Calif. API/EPA/USCG, pp. 607-612.

0-203 FARRINGTON, J.W. & J.G. QUINN, 1971
Fatty acid diagnosis in Recent sediment from Narragansett Bay, Rhode Island. Physical Science 230:67-69.

0-204 FARRINGTON, J.W. & J.G. QUINN, 19??
Studies on the fatty acids and hydrocarbons in Recent sediments and benthic animals from Narragansett Bay, Rhode Island. In: Abstract Volume, Second National Coastal and Shallow Water research conference, sponsored by Geography Programs, Office of Naval Research.

0-205 GIGER, W. & C. SCHAFFNER, 1975 (manuscr.)
Aliphatic, olefinic, and aromatic hydrocarbons in Recent sediments of a highly eutrophic lake, 21 p., 5 figs. Submitted for publication in Advances in Organic Geochemistry. Authors' affiliation: Swiss Federal Institute for water resources and water pollution control (EAWAG), CH-8600 Dübendorf, Switzerland.

0-206 SHELTON, T.B. & J.V. HUNTER, 1974
Aerobic decomposition of oil pollutants in sediments. J. Water Poll. Control Federation 46:2172-2182.

0-207 SHELTON, T.B. & J.V. HUNTER, 1975
Anaerobic decomposition of oil in bottom sediments. J. Water Poll. Control Fed. 47:2256-2270.

0-208 WALKER, J.D., COLWELL, M.C. HAMMING & H.T. FORD, 1975
Petroleum hydrocarbons in Baltimore Harbour of Chesapeake Bay: distribution in sediment cores. Environ. Pollut. 9:231-238.

15. TAINT AS A FLAVOR IN FISH FROM OIL PICKUP.

352. GRANT, E.M.
"Kerosene" taint in sea mullet (*Mugil cephalus* Linnaeus).
Fish. Notes, Qd, 3, 1-13, 1969.

359. MANN, H.
Effects on the flavour of fishes by oils and phenols.
Symp. Commn int. Explor. scient. Mer Medit., Monaco, 1964, 371-374, 1965.

362. NITTA, T., ARAKAWA, K., OKUBO, K., OKUBO, T., and TABATA, K.
Studies on the problems of offensive odours in fish caused by wastes from petroleum industries. (In Japanese, with English summary)
Bull. Tokai reg. Fish. Res. Lab., 42, 23-37, 1965.

364. SIDHU, G.S., VALE, G.L., SHIPTON, J., and MURRAY, K.E.
Nature and effects of a kerosene-like taint in mullet (*Mugil cephalus*). 9p. (Preprint of a paper presented at the F.A.O. Technical Conference on marine pollution and its effects on living resources and fishing, Rome, 9-18 December 1970.) (FIR : MP/70/E-39)

403. MENZEL, R.W.
Observations and conclusions on the oily tasting oysters near the tank battery of the Texas Company in Crooked Bayou at Bay Ste. Blaine. 6p. Texas A and M Research Foundation, 1947. (Project Nine - unpublished report)

404. MENZEL, R.W.
Report on two cases of "oily tasting" oysters at Bay Ste. Elaine Oilfield. 9p. Texas A and M Research Foundation, 1948. (Project Nine - unpublished report)

420. WILDER, D.G.
The tainting of lobster meat by Bunker C oil alone or in combination with the dispersant corexit. St. Andrews, New Brunswick, Fisheries Research Board of Canada, 1970. (Unpublished report)

1607. CONNELL, D.W.
Kerosene-like tainting in Australian mullet.
Mar. Pollut. Bull., 2, 188-190, 1971.

1608. CONNELL, D.W.
A kerosene-like taint in the sea mullet *Mugil cephalus* (Linnaeus).
I. Composition and environmental occurrence of the tainting substance.
Aust. J. mar. Freshwat. Res., 25, 7-24, 1974.

1609. DESHIMARU, O.
Studies on the pollution of fish meat by mineral oils. I. Deposition of crude oil in fish meat and its detection.
(In JAPANESE with ENGLISH summary)
Bull. Jap. Soc. scient. Fish., 37, 297-301, 1971.

15.

1618. MACKIE, P.R., MCGILL, A.S., and HARDY, R.
Diesel oil contamination of brown trout (Salmo trutta L.)
Envir. Pollut., 3, 9-16, 1972.

1620. MIYAKE, Y.
Studies on abnormal odor fish by oil pollution in Mizushima industrial area. Part 1. Distribution of abnormal odor fish.
Okayama- Igakkai- Zasshi, 81, (3-4), 193-197, 1967.

1623. OGATA, M., and MIYAKE, Y.
Offensive-odor substance in fish in the sea along petrochemical industries.
Jap. J. Publ. Hlth, 17, 1125-1130, 1970.

1626. SHIPTON, J., LAST, H.J., MURRAY, K.E., and VALE, G.L.
Studies on a kerosene-like taint in mullet (Mugil cephalus). II. Chemical nature of the volatile constituents.
J. Sci. Fd Agric., 21, 433-436, 1970.

1628. VALE, G.L., SIDHU, G.S., MONTGOMERY, W.A., and JOHNSON, A.R.
Studies on a kerosene-like taint in mullet (Mugil cephalus). I. General nature of the taint.
J. Sci. Fd Agric., 21, 429-431, 1970.

1629. YOSHIDA, K., and UEZUMI, N.
On the problem of offensive-odor fish in petrochemical industrial area. I. (In JAPANESE)
Hygiene in Life (Japan), 5, (4), 11-17, 1961.

1630. YOSHIDA, K., UEZUMI, N., and KOSAMA, K.
On the problem of offensive-odor fish in petrochemical industrial area. II. (In JAPANESE)
Hygiene in Life (Japan), 11, (2), 8-13-, 1967.

1638. BRUNIES, A.
Mineralölgeschmack bei Miesmuscheln. (Taint of mineral oil in mussels.)
Arch. Lebensmittelhyg., 63-64, March 1971.
(English translation available from British Library, Lending Division, Boston Spa, Yorkshire. (Translation T 674))

1670. ST. AMANT, L.S.
Investigations of oily taste in oysters caused by oil drilling investigations. 4p. 7th biennial report Louisiana Wildlife and Fisheries Commission, 1956-1957.

1612. HARDY, R., MACKIE, P.R., WHITTLE, K.J., and MCINTYRE, A.D.
Discrimination in the assimilation of n-alkanes in fish.
Nature, Lond., 252, 577-578, 1974.

15.

*A326. CONNELL, D.W. (1971)
Kerosene-like tainting in Augstralian Mullet, Mar. Pollut. Bull., vol. 2, no. 12, p. 188-189, 1 illus., 13 refs.

*A336. MACKIE, P.R., A.S. McGILL, and R. HARDY (1972)
Diesel oil contamination of brown trout (Salmo trutta), Environ. Pollut., vol. 3, p. 9-16, 4 illus., 1 tabl., 9 refs.

N3677-2. ACKMAN, R.G. and D. NOBLE.
Steam distillation a simple technique for recovery of petroleum hydro carbons from tainted fish. J. Fish. Res. Board Can. 30(5), 1973, 711-714.

N3683-1. OGATA, M. and F. MIYAKE.
Offensive odor substance in the evil smelling fish from the sea polluted by petroleum and petrochemical industrial waste, par 1 Identification of offensive odor substance. Acta Med Okayama 24(4), 1970, p. 471-481.

N3736-3. OGATA, MASANA and YOSHIO MIYAKE.
Identification of substances in petroleum causing objectionable odor in fish. Water Res., 1973, vol. 7(10), p. 1493-504.

N3745-1. MOTOHIRO, TERUSHIGE and KIYOKO HIYASHITA.
Odors imparted to fish meats from the contamination of sea water with petroleum. Kogai To Taisaku, 1972, vol. 8(11), p. 1080-4. In Japanese.

N3749-2. ACKMAN, R.G. and D. NOBLE.
Steam distillation. Simple technique for recovery of petroleum hydrocarbons from tainted fish. J. Fish. Res. Board Can., 1973 vol. 30(5), p. 711-14.

N3670-4. OGATA, M. and Y. MIYAKE.
Identification of substances in petroleum causing objectionable odor in fish. Water Res. 1973, 7(10, p. 1493-1504.

(NOTE: **Two asterisks means copy available.)

15. Additions to Classified Literature References as of 3/31/76.

**O-36. PERCY, J.A. and T.C. MULLIN.
Effects of crude oils on arctic marine invertebrates. Arctic Biological Station, Fisheries and Marine Service, Dept. of the Environment, P.O. Box 400, Ste. Anne de Bellevue, Quebec. Beaufort Sea Technical Report #11, Beaufort Sea Project, Dept. of the Environment, 512 Federal Building, 1230 Government St., Victoria, B.C. V8W 1Y4, December 1975.

*P-213-3 KRISHNASWAMI, S.K. and E.E. KUPCHANKO.
Relationship between odor of petroleum refinery waste water and occurrence of "oily" taste-flavor in rainbow trout. J. Water Pollut. Control Fed., 1969, 41(2):R189-R196.

15. Additions to Classified Literature References as of 6/29/76.

*P55-3 BRUNIES, A., 1971
Taste of mineral oil in sea mussels. Arch. Lebensmittel-Hyg.22(3):63-64.

*P213-2 KRISHNASWAMI, S.K. & E.E. KUPCHANKO, 1969.
Relationship between petroleum refinery watewater and occurrence of "oily" taste flavor in Rainbow Trout "Salmo gairdnerii." J. Water Pollut. Control Fed., 41(2 R189.

*P237-1 MACKIE, P.R., A.S. MC GILL AND R. HARDY, 1972
Diesel oil contamination of brown trout (Salmo trutta l.). Environ. Pollut. 3(1):9-16. Illus.

*P243-3 MANN, H., 1964
Effects on the flavor of fishes by oils and phenols. PP. 331-4, in: Pollutions marines par les microorganismes et les produits petroliers. Symposium de Monaco (Avril, 1964). Secretariat General de la Commission, 59 Avenue Raymond Poincare, Paris 16, France. 384 pp.

*P257-2 MENZEL, R.W., 1947
Observations and conclusions on the oily tasting oysters near the tank battery of the Texas Company in Crooked Bayou at Bay Ste. Elaine. Texas A&M Univ. Research Foundation Project 9. 9 pp.

*P257-3 MENZEL, R.W., 1949
The attachment, survival, and growth of oyster spat on oil impregnated wood. Texas A&M Univ. Research Foundation. Project #9.

*P301-2 NITTA, T, K. ARAKAWA, K. OKUBO, T. OKUBO, & K. TABATA, 1965
Studies on the problems of offensive odors in fish caused by wastes from petroleum industries. Bull. Tokairec. Fish Mes. Lab. (42):23-37. Illus.

*P308-2 OGATA, M., & Y. MIYAKE, 1970
Offensive-odor substance in the evil-smelling fish from the sea polluted by petroleum and petrochemical industrial waste. 1. Identification of offensive odor substance. Acta. Med. Okayama 24(4):471-481. Illus.

0-226 ACKMAN, R.G. & D. NOBLE, 1973
Steam distillation: A simple technique for recovery of petroleum hydrocarbons from tainted fish. J. Fish. Res. Board Can 30:711-714.

16. GENERAL EFFECTS OF TRACE METALS (INCLUDES LEVELS OF TRACE METALS, ETC., LIKE NO. 13 FOR OIL)

N3665-2. DUCE, R.A., G.L. HOFFMAN, and W.H. ZOLLER.
Atmospheric trace metals at remote northern and southern hemisphere sites pollution or natural. Science 1975, vol. 187 (4171), p. 59-61.

N3667-1. PEETERS, E., J. DAS, M. MERTENS, and M.A. CASTIAUX.
Trace metals and pollution of the Belgian coast and of the Schelt estuary. Bull. Inst. R. Sci. Nat. Belg. Biol. 1973, vol. 49(13), p. 1-13.

N3667-3. ANDERSON, P.V., S.A. CASTLE, J. DELANEY, D.R. JOHNSON, A. JOZEFIAK, R.J. KLEUPPEL, R. PETERSON, D. READ, M.L. TORTORELLO, et al.
Cadmium copper lead and zinc trace metal pollution in an aquatic ecosystem. Student-originated studies projects, 1973. Abstract reports. Presented at meetings in Washington, D.C., U.S.A., Dec. 26-39, 1973. VII+279p. National Science Foundation, Washington, D.C., 1973, 90-93.

N3694-2. RICE, H.V., LEIGHTY, D.A. and G.C. MC LEOD.
Effects of some trace metals on marine phytoplankton. CRC Crit. Rev. Microbiol., 1973, vol. 3(1), p. 27-49.

N3694-4. PATIN, S.A. and M.P. MOROZOV.
Aspects of contamination of the marine environment with heavy metals. Tr. Vses. Mauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr., 1974, vol. 100, p. 7-12. (In Russian)

N3695-1. CRANSTON, R.E.
Geochemical interaction in the recently industrialized Strait of Canso. Proc. Int. Conf. Transp. Persistent Chem. Aquat. Ecosyst., 1974, p. I, 59-67.

N3697-4. HARMS, OWE.
Levels of heavy metals manganese, iron, cobalt, nickel, copper, zinc, cadmium, lead, and mercury in fish from onshore and offshore waters on the German bight. Z. Lebansm.-Unters. Porsch., 1975, 157(3), pl. 125-32.

N3700-2. CORRILL, L.S., E.D. COPENHAVER, and H.V. LELAND.
Heavy metals and other trace elements in aquatic environments. Book: 1974, Editor NTIS, Springfield, VA., 159 p.

N3703-3. WILLIAMS, SHERMAN L., DONALD B. AULENBACH, and NICHOLAS L. CLESCERI.
Sources and distribution of trace metals in aquatic environments. Aqueous-Environ. Chem. Met., 1974, p. 77-127.

N3706-4. DUCE, ROBERT A., GERALD L. HOFFMAN, and WILLIAM H. ZOLLER.
Atmospheric trace metals at remote northern and southern hemisphere sites. Pollution or natural. Science, 1975, vol. 187(4171), p. 59-61.

N3710-1. GARDNER, LEONARD ROBERT.
Organic vs inorganic trace metal complexes in sulfidic marine waters. Speculative calculations based on available stability constants. Geochim. Cosmochim. Acta, 1974, vol. 38(8), p. 1297-302.

16.

N3685-1. HABEHER, K. and S. NORMANN.
Von wasser. Band XXXVIII. Ein jahrbuch fuer wassercresie und wasserreinigumgstechnik. (About water, vol. XXXVIII. An annual for water chemistry and water purification technique). VIII+463p.. Illus. Verlag chemie: Weinheim-Bergstr.. West Germany. 1971, 158-182.

N3711-4. ANAS, RAYMOND E.
Heavy metals in the northern fur seal, Callorhinus ursinus, and harbor seal, Phoca vitulina richardi. Nat. Oceanic Atmos. Admin. (U.S.)., Fish. Bull. 1974, vol. 72(1), p. 133-7.

N3712-2. CHAPMAN, GARY.
Effect of heavy metals on fish. Heavy Met. Environ., Semin., 1973, p. 141-62. Oregon St. Univ., Corvallis, OR.

N3713-4. TOPPING, G.
Heavy metals in fish from Scottish waters. Aquaculture, 1974 Vol. 1(4), p. 373-7.

N3716-3. ROMERIL, M.G.
Trace metals in sediments and bivalve mollusca in Southampton water and the Solent. Rev. Int. Oceanogr. Med. 1974, vol. 33, p. 31-47.

N3717-1. KNEIP, THEO J. and GERALD J. LAUER.
Trace metal concentration factors in aquatic ecosystems. Progr. Anal. Chem., 1973, 5, p. 43-62.

N3717-2. LELAND, HARRY V., EMILY D. COPENHAVER, and LYDIA S. CORRILL.
Heavy metals and other trace elements (in aquatic environments). J. Water Pollut. Contr. Fed., 1974, vol. 46(6), p. 1452-76.

N3718-2. BITTEL, R.
Behavior of heavy metals in a marine environment with regard to evaluating the tolerance limit of oceanic ecosystems for chemical pollution. Rev. Int. Oceanogr. Med., 1973, vol. 30, p. 3-37 (Language FR).

N3719-3. YOUNG, D.R., C.S. YOUNG, and G.E. HLAVKA.
Sources of trace metals from highly-urbanized southern California to the adjacent marine ecosystem. Cycling Contr. Metals, Proc. Environ. Resour. Conf., 1973, p. 21-39, meeting date, 1972.

N3729-4. CHESTER, R. and J.H. STONER.
Average trace element composition of low level marine atmospheric particulates. Nature(lOndon), 1973, vol. 246(5429), p. 138-9.

N3730-1. KATO, TAKETOSHI.
Toxicity of chemical substances (heavy metals, etc.) to fish and animal. Nagoya Shiritsu Daigaku Igakkai Zasshi, 1973, vol. 24(1), p. 11-34, Language: Japanese.

16.

N3748-3. SCHNEIDER, ROBERT F.
Impact of various heavy metals on the aquatic environment. U.S. Nat. Tech. Inform. Serv., PB Rep. 1971, Vol. No. 214562/1, 26 p.

N3748-4. SMITH, PETER A., and J.R. MOORE.
Distribution of trace metals in the surficial sediments surrounding Keweenaw Point, upper Michigan. Proc. Conf. Gt. Lakes Res., 1972, Vol. 15, p. 383-93.

N3755-1. KNAUER, GEORGE ANDREW.
Trace metal relations in a marine pelagic food chain. Diss. Abstr. Int. B1973, 33(8), 3481-2.

N3761-1. RONK, RICHARD J.
Heavy metals in United States fish. Trans. N. Amer. Wildl. Natur. Resour. Conf., 1971, vol. 36, p. 133-8.

N3761-4. PIOTROWICZ, STEPHEN R., BARBARA J. RAY, GERALD L. HOFFMAN, and ROBERT A. DUCE.
Trace metal envrichment in the sea-surface microlayer. J. Geophys. Res., 1972, vol. 77(27), p. 5243-54.

N3763-3. PRESTON, A., D.F. JEFFERIES, J.W.R. DUTTON, B.R. HARVEY, and A.K. STEELE.
British Isles coastal waters. Concentrations of selected heavy metals in sea water, suspended matter and biological indicators. Pilot survey. Environ. Pollut., 1972, vol. 3(1), p. 69-82.

N3767-3. BELYAEV, L.I., and E.I. OVSYANYI.
Forms of the existence of trace elements in waters of the Black Sea. Morsk. Gidrofiz. Issled., 1971, vol. 4, p. 162-70, in Russian.

N3774-4. TABATA, KENJI.
Toxicity of heavy metals to aquatic animals and factors which decrease the toxicity. IV. Relation between toxicity of heavy metals and quality of environmental water. Tokaiku Suisan Kenkyusho Kenkyu Hokoku, 1969, Vol. 58, p. 243-53, in Japanese.

O-1. HOOD, DONALD W., Editor.
Impingement of Man on the Ocean. Book: Publisher, John Wiley, 1971.

O-67. AMERICAN SOCIETY FOR TESTING MATERIAL, PUBLISHER, 1916 Race St., Philadelphia, PA 19103, 1975.
Book: "Water Quality Parameters - A Symposium" by Canada Center for Inland Waters and Anal. Chem. Division of Chem. Institute of Canada, Burlington, Ontario, Canada. List price $29.50. Includes: Environmental impact of experimental oil spills in Canadian Arctic, et al., 20 p. Much of book is on pollutants other than petroleum oil, e.g., pesticides and heavy metals.

(NOTE: **Two asterisks means copy available.)

16. Additions to Classified Literature References as of 3/31/76.

**0-87. KOONS, C.B., D.C. McAULIFFE, and F.T. WEISS (x-ref. Sheen Tech. Subcommittee, Offshore Operators Committee)
Environmental aspects of produced waters from oil and gas extraction operations in offshore and coastal waters. Prepared by Sheen Tech. Subcommittee, Offshore Operators Committee, September 30, 1975.

0-104. SMITH, W. EUGENE and EILEEN M. SMITH
"Minamata" - book. Chatto and Windus, Ltd. 1975. 192 p. $20. 1st 176 pages almost 50% pictures; p. 177-192, chronology and medical report.

16. Additions to Classified Literature References as of 7/14/76.

-209 U.S. DEPARTMENT OF INTERIOR, BUREAU OF LAND MANAGEMENT, MARINE MINERALS DIVISION, 1975
Outer Continental Shelf Environmental Studies Program. Summary recommendations of the trace metal and hydrocarbon seminars sponsored by the Bureau of Land Management, Washington, D.C., Sept. 8-12, 1975. Prepared for Dept. Interior, B.L.M., Marine Minerals Division (and the) Energy and Transportation Division, the Aerospace Corporation, El Segundo, Calif. Aerospace Report No. ATR-76 (7504)-5. (Section 2: Hydrocarbon Seminar) - 23 p.

17. DESCRIPTION OF SPILLS AND SUBSEQUENT BIOTA RECOVERY.

238. CANADA. ROYAL COMMISSION
Report of the Royal Commission. Pollution of Canadian waters by oil and formal investigation into grounding of steam tanker "Arrow." xxii, 247p. Ottawa, Information Canada, 1971. (Final Report)

239. DRAPEAU, G.
Reconnaissance of survey of oil pollution on south shore of Chedabucto Bay, March 24-25, 1970. Dartmouth, Nova Scotia, Atlantic Oceanographic Laboratory, 1970. (Unpublished report)

245. MURPHY, T.A.
An on-scene report: the sinking of the tanker, "Arrow," Chedabucto Bay, Nova Scotia, February 1970. 12p. New Jersey, Edison Water Quality Laboratory, 1970. (Unpublished report)

247. SCARRATT, D.J., SPRAGUE, J.B., WILDER, D.G., ZITKO, V., and ANDERSON, J.M.
Some biological and chemical investigations of a major winter oil spill on the Canadian east coast. 8p. International Council for the Exploration of the Sea, Fisheries Improvement Committee, 1970. (CM 1970/E 14)

396. MACKIN, J.G.
Studies on the effect of Quebracho on oysters. Texas A and M Research Foundation, 1951. Project 23 - unpublished report)

430. CONOVER, R.J.
Some relationships between zooplankton and Bunker C grade fuel oil in Chedabucto Bay following the wreck of the tanker Arrow. Dartmouth, Nova Scotia, Marine Ecology Laboratory, 1970. (Unpublished report)

433. CRAPP, G.B.
Monitoring the rocky shore.
In: Cowell, E.B., editor. Proceedings of the symposium on the ecological effects of oil pollution on littoral communities, London, 30 November-1 December, 1970.
London, Institute of Petroleum, 1971.

438. DALZIEL, J.A.
Oil pollution and the fishing industry in Chedabucto Bay.
Halifax, Nova Scotia, Canadian Department of Fisheries and Forestry, 1970. (Unpublished report)

448. JACKMAN, L.A.J.
Re-colonisation following a natural disaster.
J. Devon Trust Nat. Conserv., (July suppl.), 27-28, 1967.

501. COWELL, E.B., and BAKER, J.M.
Recovery of a salt marsh in Pembrokeshire, South-west Wales, from pollution by crude oil.
Biol. Conserv., 1, 291-296, 1969.

17.

502. CRAIGIE, J.S., and McLACHLAN, J.
Observations on the littoral algae of Chedabucto Bay following the Arrow oil spill. Halifax, Nova Scotia, Atlantic Regional Laboratory, 1970. (Unpublished report, ARL-8; NRC 11489)

511. RANWELL, D.S.
Extent of damage to coastal habitats due to the "Torrey Canyon" incident. Fld Stud., 2, (suppl.), 39-47, 1968.

512. RANWELL, D.S.
Extent of damage to coastline habitats due to the "Torrey Canyon" incident. 11p. Wareham, Nature Conservancy Furzebrook Research Station, 1968. (Unpublished report)

513. RANWELL, D.S.
Lichen mortality due to 'Torrey Canyon' oil and decontamination measures. Lichenologist, 4, 55-56, 1968.

516. STEBBINGS, R.E.
'Torrey Canyon' oil pollution on salt marshes and a shingle beach in Brittany 16 months after. 12p. Wareham, Nature Conservancy Furzebrook Research Station, 1968. (Unpublished report)

517. STEBBINGS, R.E.
Recovery of salt marsh in Brittany sixteen months after heavy pollution by oil.
Envir. Pollut., 1, 163-167, 1970.

535. FOSTER, M., NEUSHUL, M., and ZINGMARK, R.
The Santa Barbara oil spill. II. Initial effects on littoral and kelp bed organisms.
Wat. Pollut. Control Res. Rep., 15080 DZR 11/70, 25-44, 1970.

538. GRINER, L.A., and HERDMAN, R.
Effects of oil pollution on waterfowl - a study of salvage methods.
Wat. Pollut. Control Res. Rep., 15080 EBZ 12/70, 35p., 1970.

539. HENDEY, N.
"Torrey Canyon" - the effects of crude oil on marine life in the intertidal zone on some Cornish beaches. 41p. Poole, Admiralty Materials Laboratory, 1967. (Unpublished report)

540. HOLME, N.A.
Effects of "Torrey Canyon" pollution on marine life.
In: Hoult, D.P., editor. Oil on the sea. pp. 1-3. Plenum Press, 1969.

557. NORTH, W.J., NEUSHUL, M., JR., and CLENDENNING, K.A.
Successive biological changes observed in a marine cove exposed to a large spillage of oil.
Symp. Comn int. Explor. scient. Mér Médit., Monaco, 1964, 335-354, 1965.

583. THOMAS, M.L.H.
Effects of Bunker C oil on intertidal and lagoonal organisms in Chedabucto Bay, Nova Scotia. Dartmouth, Nova Scotia, Marine Ecology Laboratory, 1970. (Unpublished report)

<u>17</u>.

563. PANELLA, S.
Preliminary report on the pollution of Italian coastal waters in relation to the biological environment and fisheries.
Proc. Int. Conf. Oil Pollut. Sea, Rome, <u>1968</u>, 50-62, 1969.

572. SPOONER, M.F.
Biological effects of the "Torrey Canyon" disaster.
J. Devon Trust Nat. Conserv., (July suppl.), 12-19-, 1967.

574. SPOONER, M.F.
Effects of oil and emulsifiers on marine life.
<u>In</u>: Hepple, P., editor. Water pollution by oil: proceedings of a seminar held at Aviemore... 4-8 May, 1970. pp. 375-376.
London, Institute of Petroleum, 1971.

577. STRAUGHAN, D.
What has been the effect of the spill on the ecology in the Santa Barbara Channel?
<u>In</u>: Allan Hancock Foundation. Biological and oceanographical survey of the Santa Barbara Channel oil spill 1969-1970.
Vol. 1, compiled by D. Straughan. pp. 401-426. Allan Hancock Foundation, University of Southern California, 1971.

578. STRAUGHAN, D.
The influence of oil and detergents on recolonization in the upper intertidal zone.
<u>In</u>: American Petroleum Institute. Proceedings of joint conference on prevention and control of oil spills, Washington, D.C., June 15-17, 1971. pp. 437-440. Washington, D.C., American Petroleum Institute, 1971.

1532. GREENHAM, M.S.
Operation oil: Chedabucto Bay 1970. Operation Scour: report on the re-pump of the sunken tanker 'Arrow."
<u>In</u>: Taks Force Arrow Oil Spill. Report of the Task Force - Operation Oil (Clean-up of the Arrow oil spill in Chedabucto Bay) to the Minister of Trasport, Vol. 4, pp. 115-138. Ottawa, Ministry of Transport (Information Canada), 1973.

1533. LEVY, E.M.
Evidence for the recovery of the waters off the east coast of Nova Scotia from the effects of a major oil spill.
Wat. Air Soil Pollut., <u>1</u>, 144-148, 1972.

1534. MARKHAM, W.E.
Project Oil. Report on ice conditions in Lennox Passage. 4p. Dartmouth, Nova Scotia, Atlantic Oceanographic Laboratory, 1970. (Unpublished Report)

1541. SCARRATT, D.J., and ZITKO, V.
Sublittoral sediment and benthos sampling and littoral observations in Chedabucto Bay April 1973.
<u>In</u>: Mackay, D., and Harrison, W., editors. Oil and the Canadian environment. Proceedings of a conference... 16 May 1973. pp. 78-79. Toronto, University of Toronto, (1973?)

1543. THOMAS, M.L.H., and HARLEY, M.L.
Long term effects of Bunker C oil from the tanker "Arrow" on intertidal and lagoonal biota.
In: Mackay, D., and Harrison, W. Oil in the Canadian environment. pp. 84-85. University of Toronto, Institute of Environmental Sciences and Engineering, (1973?).

1545. ZITKO, V., and CARSON, W.F.
Some analytical characteristics of Bunker C oil from the tanker Arrow. 6p. St. Andrews, New Brunswick, Fisheries Research Board of Canada, Biological Station, 1970. (Report No. 1. Project Oil - Chemistry) (Unpublished Report)

1566. AGES, A.(B.)
Oil reconnaissance in the Magdalen Islands - 1970. 22p.
Dartmouth, Nova Scotia, Atlantic Oceanographic Laboratory, Bedford Institute, 1971 (AOL Report No. 1971-8)

1567. AGES, A.B.
The 'Vanlene' accident, March 1972. 17p. Victoria, British Columbia, Department of the Environment, Marine Sciences Branch, Pacific Region, 1972. (Pacific Marine Science Report No. 72-4)

1570. BLUMER, M., and SASS, J.
The West Falmouth oil spill. Data available in November 1971. II. Chemistry. 122p. Woods Hole, Massachusetts, Woods Hole Oceanographic Institution, 1972. (Tech. Report No. 72-19)

1571. BURNS, K.A., and TEAL, J.M.
Hydrocarbon incorporation into the salt marsh ecosystem from the West Falmouth oil spill. 24p. Woods Hole, Massachusetts, Woods Hole Oceanographic Institution, 1971. (Tech. Report No. 71-69)

1572. CHAN, G.L.
A study of the effects of the San Francisco oil spill on marine organisms.
In: American Petroleum Institute. Proceedings of joint conference on prevention and control of oil spills. Washington, D.C., March 13-15, 1973. pp. 741-781. Washington, D.C., American Petroleum Institute, 1973.

1573. CLARK, R.C., JR., FINLEY, J.S., PATTEN, B.G., STEFANI, D.F., and DENIKE, E.E.
Interagency investigation of a persistent oil spill on the Washington coast. Animal population studies, hydrocarbon uptake by marine organisms, and algae response following the grounding of the troopship General M.C. Meigs.
In: American Petroleum Institute. Proceedings of joint conference on prevention and control of oil spills, Washington, D.C., March 13-15 1973. pp. 793-808. Washington, D.C., American Petroleum Institute, 1973.

1577. DICKMAN, G.H.
Report on major oil spill in San Francisco Bay on 18 January 1971, caused by a collision between the M/T Arizona Standard and the M/T Oregon Standard. 10p. Washington, D.C., US Coast Guard, 1971. (Unpublished Report)

1578. GREEN, D.R., BAWDEN, C., CRETNEY, W.J., and WONG, C.S.
The Alert bay oil spill: a one-year study of the recovery of a contaminated bay. 42p. Victoria, B.C., Environment Canada, Fisheries and Marine Service, Marine Sciences Directorate, Pacific Region, 1974. (Pacific Marine Science Rep. No. 74-9) (Unpublished Manuscript)

1581. HEINO, A.
The Palva oil tanker disaster in the Finnish southwestern Archipelago. I. The extent of oil pollution in the sea area between Utö and Kökar in 1969 and 1970.
Aqua Fennica, 1972, 116-121, 1972.

1582. HERLINVEAUX, R.H.
Preliminary report on the oil spill from the grounded freighter 'Vanlene', March, 1972. 21p. Victoria, British Columbia, Marine Sciences Directorate, Pacific Region, 1972. (Pacific Marine Science Report No. 72-11)

1584. LEPPAKOSKI, E.
Effects of an oil spill in the northern Baltic.
Mar. Pollut. Bull., 4, 93-94, 1973.

1586. MUSTONEN, M., and TULKKI, P.
The Palva oil tanker disaster in the Finnish SW Archipelago. IV. Bottom fauna in oil polluted area.
Aqua Fenn., 1972, 137-141, 1972.

1592. PELKONEN, K., and TULKKI, P.
The Palva oil tanker disaster in the Finnish SW Archipelago. III. The littoral fauna of the oil polluted area.
Aqua Fenn., 1972, 129-136, 1972.

1593. QUAYLE, D.B.
The Vanlene oil spill. 21p. Nanaimo, B.C., Environment Canada, Fisheries and Marine Service, Pacific Biological Station, 1974.
(Manuscrip Report No. 1289)

1595. RAMSEIER, R.O.
Oil spill at Deception Bay, Hudson Strait (preliminary report).
Arct. Circ., 21, 22-27, 1971.

1596. RAMSEIER, R.O., GANTCHEFF, G.S., and COLBY, L.
Oil spill at Deception Bay, Hudson Strait. 60p. Ottawa, Inland Waters Directorate, Water Resources Branch, 1973. (Scientific Series No. 29)

1602. WATSON, J.A., SMITH, J.P., EHRSAM, L.C., PARKER, R.H., BLANTON, W.G., SOLOMON, D.E., and BLANTON, C.J.
Biological assessment of diesel spill in the vicinity of Anacortes, Washington, May 1971. Final Report. 196p. Dallas, Texas, Texas Instruments, 1971.

1610. EBELING, A.W., DEWITT, F.A., JR., WERNER, W., and CAILLIET, G.M.
Santa Barbara oil spill: fishes.
In: Holmes, R.E., and Dewitt, F.A., Jr., editors. Proceedings of the Santa Barbara oil symposium: offshore petroleum production, an environmental inquiry. Santa Barbara, California, December 16-18, 1970. pp. 138-164. National Science Foundation, 1972.

1649. HARGER, J.R.E., and STRAUGHAN, D.
Biology of sea mussels (*Mytilus californianus*) (Conrad) and *M. edulis* (Linn.)) before and after the Santa Barbara oil spill (1969).
Wat. Air Soil Pollut., 1, 381-388, 1972.

1657. KERKHOFF, M.
Oil pollution of the shellfish areas in the Oosterschelde estuary: December 1973. 11p. Copenhagen, International Council for the Exploration of the Sea, Fisheries Improvement Committee, 1974. (CM 1974/E:13)

1665. PARSONS, R.
Note on the recovery of *Littorina saxatilis* from pollution with refinery effluent when under osmotic stress.
Rep. Oil Pollut. Res. Unit, Fld Stud. Coun., 1972, 31, 1973.

1687. EVANS, W.G.
Thalassotrechus barbarae (Horn) and the Santa Barbara oil spill. (Coleoptera: Carabidae)
Pan-Pacif. Ent., 46, 233-237, 1970.

1688. FAUCHALD, K.
A survey of the benthos off Santa Barbara following the January 1969 oil spill.
Rep. Calif. coop. ocean. Fish. Invest., 16, 125-129, 1972.

1698. SANDERS, H.L., GRASSLE, J.F., and HAMPSON, G.R.
The West Falmouth oil spill. I. Biology, 48p. Woods Hole, Massachusetts, Woods Hole Oceanographic Institution, 1972.
(Tech. Report No. 72-20)

1702. UNIVERSITY OF CALIFORNIA, SANTA BARBARA
Santa Barbara oil spill: short-term analysis of macroplankton and fish. (68p) Washington, D.C., US Environmental Protection Agency, Water Quality Office, 1971. (Water Pollution Control Research Series No. 15080 EAL 02/71)

1703. WEBBER, H.H.
Survey of mortality at two areas of South beach of Guemes Island, April 28 to May 15, 1971.
In: Watson, J.A., Smith, J.P., Ehrsam, L.C., Park, R.H., Blanton, W.G., Solomon, D.E., and Blanton, C.J., Biological assessment of diesel spill in the vicinity of Anacortes, Washington, May 1971.
Final report. Appendix A. 12p. Dallas, Texas, Texas Instruments, Inc., 1971.

1705. BAKER, J.M.
Recovery of salt marsh vegetation from successive oil spillages.
Envir. Pollut., 4, 223-230, 1973.

1709. DICKS, B.
Changes in salt-marsh vegetation around a refinery effluent outfall at Fawley.
Rep. Oil Pollut. Res. Unit, Fld Stud. Coun., 1972, 14-20, 1973.

1725. RAVANKO, O.
The Palva oil tanker disaster in the Finnish S.W. Archipelago
V. The littoral and aquatic flora of the polluted area.
Aqua Fenn., 1972, 142-144, 1972.

1740. GLUDE, J.B.
Observations on the effects of the Santa Barbara oil spill on intertidal species. 21p. Unpublished report to the Director, Bureau of Commercial Fisheries, 1969.

1741. GUSEY, W.F., and MATURGO, Z.D.
Petroleum production and fish and wildlife resources: the Gulf of Mexico, Louisiana. 38p. New York, Shell Oil Company, Environmental Conservation Department, 1971.

1742. HUFFORD, G.L.
The biological response to oil in the marine environment: a review.
23p. Washington, D.C., US Coast Guard, Oceanographic Unit, 1971.

1755. STRACHAN, A.
Santa Barbara oil spill - intertidal and subtidal surveys.
Rep. Calif. coop. ocean. Fish. invest., 16, 122-124, 1972.

1756. STRAUGHAN, D.
Biological effects of oil pollution in the Santa Barbara channel.
Cstl Res. Notes, 3, (5), 11-17, 1971.

1757. STRAUGHAN, D.
Oil pollution and wildlife and fisheries in the Santa Barbara channel.
In: Transactions 36th North American Wildlife and Natural Resources Conference, Portland, Oregon, 7-10 March 1971. pp. 219-229.
Washington, D.C., Wildlife Management Institute, 1971.

1758. STRAUGHAN, D.
Ecological effects of the Santa Barbara oil spill.
In: Holmes, R.E., and DeWitt, F.A., Jr., editors. Proceedings of the Santa Barbara oil symposium: offshore petroleum production, an environmental inquiry, Santa Barbara, California, December 16-18 1970.
pp. 173-182. National Science Foundation, 1972.

1759. STRAUGHAN, D.
Factors causing environmental changes after an oil spill.
J. Petrol. Technol., 24, 250-254, 1972.

1760. STRAUGHAN, D.
Biological studies of the Santa Barbara oil spill.
In: 1973 annual meeting, American Association of Petroleum Geologists, Santa Barbara channel revisited, AAPG Trip 3. SEPM Seg. pp. 4-16. American Association of Petroleum Geologists, 1973.

1761. THOMAS, M.L.H.
Effects of bunker C oil on intertidal and lagoonal biota in Chedabucto Bay, Nova Scotia.
J. Fish. Res. Bd Can., 30, 83-90, 1973.

1766. ZOUTENDYK, P.
Oil pollution of the Cape Infanta coastline.
Zoologica Afr., 7, 533-536, 1972.

2220. CANADA. FISHERIES RESEARCH BOARD OF CANADA.
Summary of physical, biological, socio-economic and other factors relevant to potential oil spills in the Passamaquoddy region of the Bay of Fundy.
Tech. Rep. Fish. Res. Bd Can., No. 428, 231p., 1974.

2228. MACKIN, J.G.
A review of significant papers on effects of oil spills and oil-field brine discharges on marine biotic communities. 171p.
Texas A & M Research Foundation, University of Texas, 1973.

2229. MASSACHUSETTS INSTITUTE OF TECHNOLOGY. OFFSHORE OIL TASK GROUP
The Georges Bank Petroleum Study. Summary. v, 84p. Cambridge, Massachusetts, Massachusetts Institute of Technology, 1973.
(Report No. MITSG-73-5)

2230. MASSACHUSETTS INSTITUTE OF TECHNOLOGY. OFFSHORE OIL TASK GROUP
The Georges Bank Petroleum Study. Vol. 1. Impact on New England real income of hypothetical regional petroleum developments. 284p. Cambridge, Massachusetts Institute of Technology, 1973. (Report No. MITSG-73-5)

2231. MASSACHUSETTS INSTITUTE OF TECHNOLOGY. OFFSHORE OIL TASK GROUP
The Georges Bank Petroleum Study. Vol. 2. Impact on New England environmental quality of hypothetical regional petroleum developments. ii, 311p. Cambridge, Massachusetts, Massachusetts Institute of Technology, 1973.
(Report No. MITSG-73-5)

2302. SAGE, B.L.
Oil in the North Sea, an outline of geological exploration, production, and environmental aspects. 16p. Paper presented at a symposium on oil in Scottish waters, Stirling, April 18 1973, sponsored by the Scottish Marine Biological Association, Oban.

1680. BENDER, J.E., HYLAND, J.L., and DUNCAN, T.K.
Effect of an oil spill on benthic animals in the lower York River, Virginia. In: US National Bureau of Standards. Marine pollution monitoring (petroleum). Proceedings of a symposium and workshop... May 13-17 1974. pp. 257-259. Washington, D.C., US Government Printing Office, 1974.

1535. PAYNE, F.A.
Measurement of the quantity of Bunker-C in the Arrow. In: Project Oil. A report on some aspects of Operation Oil. pp. 1-7. Dartmouth, Nova Scotia, Defence Research Establishment Atlantic, 1970. (Unpublished Report)

*A91. FORRESTER, W.D. (1971)
Distribution of suspended oil particles following the grounding of the tanker ARROW, Jour. Mar. Res., vol. 29, no. 2, p. 151-170, 4 illus., 3 tabls., 2 refs.

*A119. LEVY, E.M. (1971)
The presence of petroleum residues off the east coast of Nova Scotia in the Gulf of St. Lawrence and the St. Lawrence River, Water Res., vol. 5, no. 9, p. 723-733, 3 illus., 4 tabls., 11 refs.

*A136. MURRAY, S.P., W.G. SMITH, and C.J. SONU (1970).
Oceanographic observations and theoretical analysis of oil slicks during the Chevron spill, March 1970, Coastal Studies Inst., Louisiana State Univ. Tech. Rept. 87, 106p., 34 illus., 6 tabls., 37 refs.

*A140. NEUMANN, H. (1969)
Bemerkungen zur trift der olschmutzstoffe in der Deutschen bucht, Deut. Hydrogr. Z., vol. 22, no. 2, p. 57-65, 6 refs.

*A174. BLUMER, M., and J. SASS (1972)
Oil pollution: Persistence and degradation of spilled fuel oil, Science, vol. 176, p. 1120-1122, 3 illus., 8 refs.

*A175. BLUMER, M., J. SASS, G. SOUZA, H.L. SANDERS, J.F. GRASSLE, and G.R. HAMPSON (1970)
The West Falmouth oil spill: Persistence of the pollution eight months after the accident, Tech. Rept. WHO1-70-44, Sept. 1970, (unpublished manuscript), 32 p., 18 illus., 3 tabls., 7 refs.

*A198. FOSTER, M., M. NEUSHUL, and R. ZINGMARK (1971)
The Santa Barbara oil spill, Part II: Initial effects on intertidal and kelp bed organisms, Environ. Pollut., vol. 2, p. 115-134, 10 illus., 3 tabls., 19 refs.

*A194. COWELL, E.B. (1968)
The effects of oil pollution on salt-marsh communities in Pembrokeshire and Cornwall, Jour. Appl. Ecol., vol 6, no. 2, p. 133-142, 2 illus., 24 refs., 1 tabl.

17.

*A195. COWELL, E.B., and J.M. BAKER (1969)
Recovery of a salt-marsh in Pembrokeshire, southwest Wales, from pollution by crude oil, Biological Conservation, vol. 1, no. 4, p. 291-296, 2 illus., 2 tabls., 8 refs.

*A196. COWELL, E.B., J.M. BAKER, and G.B. CRAPP (1970)
The biological effects of oil pollution and oil-cleaning materials on littoral communities, including salt marshes, FAO tech. conf. on mar. pollut. and its effects on living resources and fishing, Rome, Italy, 1970, 11p., 3 illus., 26 refs.

*A202. MERZ, R.C. (1959)
Determination of the quantity of oily substances on beaches and in the near-shore waters, Calif. State Water Pollut. Control Board, publ. 21, part 1, 45 p., 6 illus., 9 tabls., 7 refs.

*A203. MIKOLAJ, P.G., and J.P. AMPAYA (1973)
Tidal effects on the activity of natural submarine oil seeps, Mar. Tech. Soc. Jour., vol. 17, no. 1, p. 25-28, 3 illus., 2 tabls., 5 refs.

*A205. STEBBINGS, R.E. (1970)
Recovery of salt marsh in Brittany sixteen months after heavy pollution by oil, Environ. Pollut., vol. 1, no. 2, p. 163-167, 3 refs.

*A206. STRAUGHAN, D. (1973)
Biological studies of the Santa Barbara oil spill, Annual meeting of the AAPG, SEPM and SEG, Fieldtrip guide, AAPG no. 3, Santa Barbara Channel region revisited, 8 illus., 2 tabls., 58 refs.

*A234. CONOVER, R.J. (1971)
Some relations between zooplankton and Bunker C oil in Chedabucto Bay following the wreck of the tanker Arrow, Jour. Fish. Res. Bd., Canada, vol. 28, no. 9, p. 1327-1330, 2 illus., 6 refs.

*A324. BLUMER, M., G. SOUZA, and J. SASS (1970)
Hydrocarbon pollution of edible shellfish by an oil spill, Mar. Biol., vol. 5, no. 3, p. 195-202, 4 illus., 1 tabl., 17 refs.

*A344. UNIV. CALIF. SANTA BARBARA (1970)
A study of the biological effects of the oil spill which occurred at Santa Barbara, Calif., in 1969, Fed. Water Pollut. Control Admin., rept. 15080DZR 10/70, 49p., 8 illus., 10 tabls., 33 refs.

*A352. ANONYMOUS (1972)
Tamano oil spill, Mar. Pollut. Bull., vol. 3, no. 9, p. 133.

*A353. ATLANTIC OCEANOGRAPHIC LABORATORY (1970)
Report of the task force--operation oil (clean-up of the Arrow oil spill in Chedabucto Bay), to the Minister of Transport, Bedford Inst., Dartmouth, Nova Scotia, vol. II, 104p., 24 illus., 9 tabls., 83 refs.

17.

*A359. BEYNON, L.R. (1968)
The Torrey Canyon disaster: Part I--Here's what the industry learned by experience, Oil and Gas International, vol. 8, no. 1, p. 52-59.

*A367. BLUMER, M., H.L. SANDERS, J.F. GRASSLE, and G.R. HAMPSON (1971)
An ocean of oil, Environment, vol. 13, no. 2, p. 2-12, 13 refs.

*A370. BRUNDALL, L.L. (1973)
Platform "A": The oil spill that spread around the world, 12th. Annual Inst. of Petrol. Exploration and Economics, 58 p., 27 refs.

*A382. DEPT. OF INTERIOR, FWPCP (1971)
Oil pollution incident, platform Charlie, main pass, block 41 field, Louisiana, Water Pollut. Control Res. Series 15080FTU05/71, p. 31-38, 6 refs.

*A395. GOODING, R.M. (1971)
Oil pollution on Wake Island from the tanker R.C. STONER, U.S. Dept. of Commerce, GPO 999-027, 12 p., 8 illus., 2 tabls.

*A407. MURPHY, T.A. (1971)
Environmental effects of oil pollution, Jour. Sant. Eng. Div. Proc. of ASCE, vol. 97, no. SA3, p. 361-371, 70 refs.

*A410. O'SULLIVAN, A.J. (1971)
Some aspects of the "Hamilton Trader" oil spill, In Water Pollution by Oil, P. Hepple (ed.), Inst. of Petrol., Elsevier Publ. Co., New York, p. 307-316, 4 illus., 3 refs.

*A416. SMITH, J.E. (1968)
Torrey Canyon pollution and marine life, Cambridge, Univ. Press, Great Britain, 1968 p., 29 illus., 27 tabls., 56 refs.

*A421. SWIFT, W.H., C.J. TOUHILL, W.A. HANEY, R.E. NAKATANI, P.L. PETERSON, and D.S. DES VOIGNE (1969)
Review of Santa Barbara Channel oil pollution incident, Fed. Water Pollut. Control Admin., Res. Series 15080, 156 p., 51 illus., 7 tabls., 29 refs.

*A422. U.S. COASTGUARD (1970)
Polluting spills in U.S. water 1970, USCG, Washington, D.C., 13 p.

N3777-2. BUTTON, D.K.
Petroleum biological effects in the marine environment. Impingement Man Oceans, 1971, -. 421-9.

O-14. INFORMATION CANADA, OTTAWA, 1971.
Report of the Task Force - Operation Oil, vol. 2 (cleanup of the Arrow oil spill in Chedabucto Bay). Compiled at Atlantic Oceanography of Bedford Institute, Dartmouth, N.S. Catalog No. T22-2470/2.

17.

-17. SPRAGUE and CARSON.
Toxicity tests with oil dispersants in connection with the oil spill at Chedabucto Bay, N.S., Tech. Report #201, 1970, Biological Station, St. Andrews, N.B.

(NOTE: **Two asterisks means copy available.)

17. Additions to Classified Literature References as of 3/31/76.

**O-95. RAMSEIER, RENE O.
How to melt the Arctic and warm the world. Environment, Vol. 16, No. 4, May 1974.

O-97. GAINES, T.H.
Pollution control at a major oil spill. Water Pollution Control Federation (Wash., D.C.) Journal 43(4): 651-657(1971). Relates to cleanup procedures used at Santa Barbara spill.

O-127. SHELTON, EDWARD H.
An historical review of oil spills along the Maine Coast 1953-1973. Bull. prepared for the Main State Planning Office, Coastal Group, and the Research Institute of the Gulf of Maine (TRIGOM) August 1973, 191 pages.

17. Additions to Classified Literature References as of 6/29/76

*P42-2
BLACKMAN, R.A.A., J.M. BAKER, J. JELLY, & S. REYNARD, 1973
The "Dona Marika" oil spill. Mar. Poll. Bull., 4(12):181-182.

*P44-2 BLUMER, M. ET. AL., 1971
A small oil spill. Environment, 13(2):2-12.

*P45-1 BLUMER, M., J. SASS, G. SOUZA, H.L. SANDERS, J.F. GRASSLE, & G.R. HAMPSON, 1970
The West Falmouth oil spill. Unpublished manuscript of the National Technical Information Service. 32 pp.

*P50-3 BOURNE, W.R.P., 1970
Special review: After the "Torrey canyon" disaster. Ibis. 112(1):120-125.

*P68-3 CHAN, G., 1972
A study of the effects of the San Francisco oil spill on marine organisms. College of Marin, Kentfield, California, 78 pp.

*P69-2 CHAN, G.L., 1973
A study of the effects of the San Francisco oil spill on marine organisms. PP. 741-781 in: American Petroleum INstitute, Proceedings of joint conference on prevention and control of oil spills, March 13-15, 1973. Washington, D.C., 834 pp.

*P76-2 CHIA, F., 1971
Diesel oil spill at Anacortes. Mar. Poll. Bull. 2(7):105-107.

*P80-2 CLARK, R.C., JR., ET. AL., 1973
Interagency ingestigation of a persistent oil spill on the Washington coast. PP. 973-808, in: Proceedings of a joint conference on prevention and control of oil spills, March 13-15, 1973, Washington, D.C. Sponsored by the Am. Petro. Inst., EPA, & U.S. Coast Guard. 834 pp.

*P87-3 CONOVER, R.J., 1971
Some relations between zooplankton and Bunker C oil in Chedabucto Bay following the wreck of the tanker Arrow. J. Fish. Res. Board Can. 28(9):1327-1330. Illus, map.

*P114-3 EBELING, A.W., W. WERNER, F.A. DEWITT, JR., & G.M. GAILLIET, 1971
Santa Barbara oil spill: Short-term analysis of macroplankton and fish. Prepared for the Office of Water Quality Research, EPA, by the U. of California, Santa Barbara. 68 pp.

*P128-1 FISHER, J. & S. CHARLTON, 1967
A tragedy of errors. Audubon Mag., 69:72-85.

*P133-3 FOSTER, M., M. NEUSHUL, & R. ZINGMARK, 1971
The Santa Barbara oil spill. Part II: Initial effects on intertidal and kelp bed organisms. Environ. Pollut. 2:115-34.

*P158-2 HARGER, J.R.E. & STRAUGHAN, D., 1972
Biology of sea mussels "Mytilus californianus" and "Mytilus edulis" before and after the Santa Barbara oil spill (1969). Water, Air and Soil Pollution, 1(4):381-388.

*P175-3 HOLMES, R.W., 1969
The Santa Barbara oil spill. PP. 15-28, in: Hoult, D.P. (ed.) Oil on the Sea. Proceedings of a symposium on the scientific and engineering aspects of oil pollution of the sea.

*P192-3 JOENSEN, A.H., 1973
Danish seabird disasters in 1972. Mar. Pollut. Bull., 4(8):117-118.

*P195-2 JONES, P.H., G. HOWELLS, E.I.S. REES, & J. WILSON, 1970
Effect of "Hamilton Trader" oil on birds in the Irish Sea in May 1969. British Birds, 63(3):97-110.

*P209-2 KOLPACK, R.L., 1971
Biological and oceanographical survey of the Santa Barbara Channel oil spill 1969-1970. Vol. II. Physical, chemical, and geological studies. V+477 p. Illus. Allan Hancock Foundation: Univ. of Southern Calif.. Los Angeles, Calif.

*228-3 LEVY, E.M., 1972
Evidence for the recovery of the waters of the east coast of Nova Scotia from the effects of a major oil spill. Water, Air, Soil Pollut. 1(2):144-148. Illus.

*P268-1 MITCHELL, C.T., E. ANDERSON, L. JONES, & W. NORTH, 1970
What oil does to ecology. J. Water Poll. Control Federation, 42:812-818.

*P299-2 NICHOLSON, N., 1972
The Santa Barbara oil spill in perspective. Calif. Cooperative Oceanic Fish. Invest. Rep., 16:130.

*P299-3 NICHOLSON, N.L. & R.L. CIMBERG, 1971
The Santa Barbara oil spill of 1969: A postspill survey of the rocky intertidal. In: Biological and oceanographical survey of the Santa Barbara Channel oil spill, 1969-1970. Vol. 1, Biology and Bacteriology. Allan Hancock Foundation, Univ. of S. Calif. 477 pp.

*P303-1 NORTH, W.J., M. NEUSCHUL, JR., & K.A. CLENDENNING, 1964
Successive biological changes observed in a marine cove exposed to a large spill of mineral oil. PP. 335-354, in: Pollutions marines par les microorganismes et les produits petroliers. Symposium de Monaco (Avril 1964). Secretariat General de la Commision, 59 Avenue Raymond Poincare, Paris 16, France. 384 pp.

*P307-3 O'SULLIVAN, A.J. & A.J. RICHARDSON, 1967
The "Torrey Canyon: disaster and intertidal marine life. Nature, 214:448.

*P357-2 RICHARDSON, F., 1956
Sea birds affected by oil from the freighter "Seagate." Murrelet, 37(2):20-22.

*P402-2 STRACHAN, A., 1972
Santa Barbara oil spill: Intertidal and subtidal surveys. Calif. Mar. Res. Comm., Calif. Cofi. Rept., 16:122-124.

*P402-3 STRAUGHAN, D., 1971
Breeding and larval settlement of certain intertidal invertebrates in the Santa Barbara Channel following pollution by oil. In: Biological and oceanographical survey of the Santa Barbara Channel oil spill. 1969-1970. Vol. 1, Biology and Bacteriology, Allan Hancock Foundation, U. of S. Calif., 1971. 477 pp.

*P403-2 STRAUGHAN, D., 1971
Oil pollution and sea birds. In: Straughan, D. (ed.), Biological and oceanographic survey of the Santa Barbara Channel oil spill. Vol. I. Allan Hancock Foundation, U. of S. Calif. 477 pp.

*P403-3 STRAUGHAN, D., 1971
Biological and oceanographical survey of the Santa Barbara Channel oil spill 1969-1970. Vol. I. Biology and Bacteriology. VI+426 p. Illus. Allan Hancock Foundation: U. of S. Calif., L.A.

*P404-2 STRAUGHAN, D., & C. ABBOTT, 1971
The Santa Barbara oil spill: Ecological changes and natural oil leaks. PP. 257-62, in: Hepple, Peter (ed.) Water Pollution by oil. Proceedings of a seminar held at Aviemore, Inverness-Shire, Scotland, sponsored by the Institute of W.P.C. and the I. of P. with assistance of the European office of W.H.O., May 4-9, 1970. Institute of Petrol, 61 Cavendish St., London Wimbar, 1971. 393 pp.

*P405-2 STRAUGHAN, D., 1971
Oil pollution and wildlife and fisheries in the Santa Barbara Channel. Trans. N. Am. Wildlf. Conf., 36:219-229.

*P415-2 THOMAS, M.L., 1973
Effects of bunker C oil on intertidal and lagoonal biota in Chedabucto Bay, Nova Scotia. J. Fish. Res. Bd. Canada, 30(1):83-90.

*P441-2 WATSON, J.A., J.P. SMITH, L.C. ERSHAM, R.L. PARKER, W.G. BLANTON, D.E. SOLOMON, & C.J. BLANTON, 1971
Biological assessment of diesel spill, Anacortes, Washington, May, 1971. Final report, prepared for the EPA by Texas Instruments, Inc. 168 pp.

*P442-2 WEBBER, H.H., 1971
Survey of mortality at two areas of South Beach of Guemes Island, April 28-May 16, 1971. PP. A-, 1-12, in: Watson, J.A., et. al., Biological assessment of diesel spill, Anacortes, Washington, May 1971. Final report. Texas Instruments, Inc.

*P455-4 WOODIN, S.A., C.F. NYBLADE, F. CHIA., 1971
Oil spill on Guemes island, Washington. Friday Harbor Labs, U. of Wash. Preliminary report. 8 pp.

O-210 ALLEN, A.A., R.S. SCHLUETER & P.G. MIKOLAJ, 1970
Natural oil seepage at Coal Oil Point, Santa Barbara, Calif. Science 170:974-977.

-211 ALLEN, A.A., & R.S. SCHLUETER, 1969
Estimates of surface pollution resulting from submarine oil seeps at platform A and Coal Oil Point. Technical Memorandum 1230. General Research Corporation, Santa Barbara, Calif., 43 p.

-212 ALLEN, J.F., 1971
Ecology of oil spills: II: The impact of oil spills on biota. Presented at the Second National Biological Congress, Miami Beach, Florida, Oct. 24, 1971.

-213 BLUMER, M. & J. SASS, 1972
The West Falmouth oil spill. Data available in Nov., 1971. II: Chemistry. Woods Hole Oceanographic Institution, Tekchnical Report No. WHOI-72-19.

-214 CLARK, R.C., JR., 1972
Preliminary report on possible environmental damage associated with the grounding of the Gen. M.C. Meigs on the Washington coast on Jan. 9, 1972. NOAA, National Marine Fisheries Service, Northwest Fisheries Center, Seattle, WA 98112. 5 p.

-215 CLARK, R.C., JR., J.S. FINLEY, B.G. PATTEN, & E.E. DENIKE, 1975
Long-term chemical and biological effects of a persistent oil spill following the grounding of the General M.C. Meigs. In: Proceedings of the 1975 conference on prevention and control of oil pollution, API/USCG/EPA, San Francisco, Calif., March 25-27, 1975, pp. 479-487.

-216 ENVIRONMENTAL PROTECTION AGENCY, OFFICE OF WATER PROGRAMS, 1972
Studies and investigations of the fate and effect of the Shell Oil spill, platform B, block 26, South Timbalier Bay (December 1, 1970 - November 30, 1971). Final Report, Jan. 1972, Contr. No. 68-01-0051. Oil and hazardous materials program series OHM 72 05 001.

-217 GUMTZ, G.D., 1972
Restoration of beaches contaminated by oil. Environmental Protection Agency report no EPA-R2-72-045, Sept. 1972 (Environmental Protection Technology Series), 138 p.

-218 KOLPACK, D.L. (ED.), 1971
Biological and oceanographical survey of the Santa Barbara Channel oil spill 1969-1970, Vol. II. Physical, chemical and geological studies. Allan Hancock Foundation, Univ. of Southern Calif., 1971. Sea Grant Publication No. 2, 477 p.

-219 MICHAEL, A.D., C.R. VAN RAALTE, & L.S. BROWN, 1975
Long term effects of an oil spill at West Falmouth, Massachusetts. In: Proceeds Joint Conference Prevention and Control of Oil Spills, API/EPA/USCG, pp. 573-582.

-220 NICHOLSON, N.L., 1972
The Santa Barbara oil spills in perspective. Calif. Mar. Res. Comm., CalCOFI Rept. 16:130-149.

18. EFFECTS OF OIL DRILLING OPERATIONS (ALSO FROM REFINERIES AND FROM NATURAL OIL SEEPS).

42. KAISER, R.D., and VAN CLEAVE, H.D.
Methods and procedures for preventing oil pollution from onshore and offshore facilities.
In: American Petroleum Institute. Proceedings of joint conference on prevention and control of oil spills, Washington, D.C., June 15-17, 1971. pp. 85-89. Washington, D.C., American Petroleum Institute, 1971.

398. MACKIN, J.G., and HOPKINS, S.H.
Studies on oyster mortality in relation to natural environments and to oil fields in Louisiana.
Publs Inst. mar. Sci. Univ. Tex., 7, 1-131, 1961.

399. MACKIN, J.G., and SPARKS, A.K.
A study of the effect on oysters of crude oil loss from a wild well.
Publs Inst. mar. Sci. Univ. Tex., 7, 230-261, 1962.

439. ELMHIRST, R.
Investigation on the effects of oil-tanker discharge.
Rep. Scott. mar. biol. Ass., 1922, 8-9, 1922.

444. GRAHAM, R.J.
Longterm toxicity bioassay of oil refinery effluents. 55p. Oklahoma State University, 1963. (Ph.D. thesis)

469. REISH, D.J.
The effect of oil refinery wastes on benthic marine animals in Los Angeles Harbor, California.
Symp. Commn int. Explor. scient. Mer Médit., Monaco, 1964, 355-361, 1965.

470. ST. AMANT, L.S.
Biological effects of petroleum exploration and production in the Mississippi delta. Paper presented at the Santa Barbara oil symposium. Offshore petroleum production - an environmental inquiry, Santa Barbara, California, 16-18 December 1970.

487. BAKER, J.M.
Refinery effluent.
In: Cowell, E.B., editor. Proceedings of the symposium on the ecological effects of oil pollution on littoral communities, London, 30 November-1 December, 1970.
London, Institute of Petroleum, 1971.

531 COPELAND, B.J., and DORRIS, T.C.
Community metabolism in ecosystems receiving oil refinery effluents.
Oceanogr. Limnol., 9, 431-447, 1964.

532. COWELL, E.B.
Chronic oil pollution caused by refinery effluent water.
In: Hepple, P., editor. Water pollution by oil: proceedings of a seminar held at Aviemore... 4-8 May, 1970. pp. 380-381.
London, Institute of Petroleum, 1971.

541. KÖNIG, D.
Biologische Auswirkung des Abwassers einer 'Ö'-Raffinerie in einem Vorlandgebiet an der Nordsee. (Biological effect of the waste water of an oil refinery on a foreshore area of the North Sea.)
Helgoländer wiss. Meeresunters., 17, 321-334, 1968.

558. OGLESBY, R.T., and SYLVESTER, R.O.
Marine biological monitoring of oil refinery liquid waste emissions.
Engng Bull. Purdue Univ., 49, 167-179, 1965.

1047. PISTOLE, H., and TAYLOR, C.C.
Recent and anticipated advances in offshore oil production.
Paper presented at the Santa Barbara oil symposium, Offshore petroleum production - an environmental inquiry, Santa Barbara, California, 16-18 December 1970.

1731. BAKER, J.M.
Ecological effects of refinery effluents.
Rep. Oil Pollut. Res. Unit, Fld Stud. Coun., 1972, 7-13, 1973.

1732. BAKER, J.M.
Biological effects of refinery effluents.
In: American Petroleum Institute. Proceedings of joint conference on prevention and control of oil spills, Washington, D.C., March 13-15, 1973. pp. 715-723. Washington, D.C., American Petroleum Institute, 1973.

1754. SPEARS, R.W.
Evaluation of the effects of oil, oilfield brine and oil removing compounds.
In: A.I.M.E. Environmental quality conference, Washington, D.C., June 7-9 1971. pp. 199-216. New York, American Institute of Mining, Metallurgical and Petroleum Engineers, 1971.

2216. BERTRAND, A.R.V., BRIANT, J., CASTELA, A., DEGOBERT, P., GATELLIER, C., MASSON, M., OUDIN, J.L., and POTTIER, J.
Prévention et lutte contre la pollution au cours des opérations de forage et de production en mer. (Prevention and the fight against pollution in the course of drilling operations and production in the sea.)
Revue Inst. fr. Pétrole, 26, 757-848, 1971.

2254. BATTELLE MEMORIAL INSTITUTE. PACIFIC NORTHWEST LABORATORIES.
Study of effects of oil discharges and domestic and industrial wastewaters on the fisheries of Lake Maracaibo, Venezuela. 18p. Richland, Washington, Battelle Pacific Northwest Laboratories, (1974).

2255. BATTELLE MEMORIAL INSTITUTE. PACIFIC NORTHWEST LABORATORIES
Study of effects of oil discharges and domestic and industrial wastewaters on the fisheries of Lake Maracaibo, Venezuela. Vol. I. Ecological characterization and domestic and industrial wastes. 184p. Richland, Washington, Battelle Pacific Northwest Laboratories, 1974.

18.

2255. BATTELLE MEMORIAL INSTITUTE. PACIFIC NORTHWEST LABORATORIES
Study of effects of oil discharges and domestic and industrial wastewaters on the fisheries of Lake Maracaibo, Venezuela. Vol. II. Fate and effects of oil. 142p. Richland, Washington, Battelle Pacific Northwest Laboratories, 1974.

2258. BRIANT, J., and GATELLIER, C.(R.)
Prévention et lutte contre la pollution au cours des opérations de forage et de production en mer. Annexe B. Effets généraux de la pollution pétrolière. (Prevention and the fight against pollution in the course of drilling operations and production in the sea. Appendix B. General effects of petroleum pollution.) Revue Inst. fr. Pétrole, 26, 839-848, 1971.

2281. LAIR, M.D., ROGERS, R.G., and WELDON, M.R.
Environmental effects of petrochemical waste discharges on Tallaboa and Guayanilla Bays, Puerto Rico. 102p. Athens, Georgia, US Environmental Protection Agency, Region IV, 1971.

2298. POTTIER, J.
Prévention et lutte contre la pollution au cours des operations de forage et de production en mer. VII. Conclusion. (Prevention and the fight against pollution in the course of drilling operations and production in the sea. VII. Conclusions.) Revue Inst. fr. Pétrole, 26, 828-830, 1971.

2301. RITCHIE, J.E., Jr., ALLEN, F.J., Jr., FELTES, R.M., FOOTE, R.Q., and SHORTT, W.A.
Study of offshore and onshore crude oil petroleum systems. 82p. Washingtton, D.C., US Environmental Protection Agency, Office of Research and Monitoring, 1973. (Environmental Protection Technology Series No. EPA-R2-73-280a)

*A66. ALLEN, A.A., R.S. SCHLUETER, and P.G. MIKOLAJ (1970)
Natural oil seepage at Coal Oil Point, Santa Barbara, Calif., Science, col. 170, p. 974-977, 2 illus., 1 tabl., 5 refs.

*A76. BLUMER, M. (1972)
Submarine seeps: Are they a major source of open ocean oil pollution?, Science, vol. 176, p. 1257-1258, refs.

*A178. FISCHER, P.J., and A.J. STEVENSON (1973).
Natural hydrocarbon seeps along the northern shelf of the Santa Barbara Basin, California, Annual meeting of the Amer. Assoc. Petrol. Geol., SEPM and SEG. Fieldtrip Guide No. 3, Santa Barbara Channel Region Revisited, p. 17-27, 9 illus., 18 refs.

*A203. MIKOLAJ, P.G. and J.P. AMPAYA (1973).
Tidal effects on the activity of natural submarine oil seeps, Mar. Tech. Soc. Jour., vol. 17, no. 1, p. 25-28, 3 illus., 2 tabls., 5 refs.

*A339. REISH, O.J. (1964).
The effect of oil refinery wastes on benthic marine animals in Los Angeles Harbor, Calif., Comm. Int. Explor. Sci. Mer Medit., In Symposium pollut. mar. par microorgan. Prod. Petrol., Monaco, p. 355-361, 2 illus, 2 tabls., 13 refs.

*A350. ANONYMOUS (1969).
Natural oil seepage, Oceanus, vol. 15, No. 2, p. 12.

*A363. BLOKKER, P.C. (1971).
Prevention of water pollution from refineries, In Water Pollution by Oil, P. Hepple (ed.)., Inst. of Petrol., Elsevier Publ. Co., New York, p. 21-36, 6 tabls., 34 refs.

*A396. HANNA, G.D. (1963).
Oil,seepages on the Arctic coastal plain, Alaska, Occasional paper of the Calif. Academy of Science, no. 38, 18p., 2 illus., 37 refs.

*A424. WILKINSON, R.E. (1972).
California offshore oil and gas seeps, Calif. summary of operations, Div. of Oil and Gas, vol. 57, p. 5-28, 8 illus., 1 tabl., 25 refs.

*A437. JOHNSON, T.C. (1971).
Natural oil seeps in or near the marine environment: A literature survey, USCG, Office of Res. and Dev., project no. 714141 002, 30p., 8 illus., 40 refs.

N3697-1. VAISHNIKOVA, E.A., DEDUSENKO, G.Ya, OGLOBLINA, G.P., SINENKOVA, V.S., and MAMEDOVA, S.Ya.
Effective method for treating drilling fluids for wells in areas of the Baku Archipelago (Svinoi Island, Kamen Persiyanin, Sangachaly Sea, Duvannyi Sea Island). Tr., Azerb. Gos. Nauchno-Issled. Proektn. Inst. Neft. Prom-sti. Publ. 72, series 11, p. 61-6. (In Russian)

N3708-4. ABDULLAEV, M.M., TRIFEL, M.S., and RAGIMOVA, S.A.
Designs of suspended ferrosilide anodes for cathodic protection of piles of marine petroleum-well structures. Korroz. Zashch. Neftegazov. Pro., Publ. 74, issue 6, p. 15-18. (In Russian)

N3709-1 ABDULLAEV, M.M., TRIFEL, M.S., and RAGIMOV, S.A.
Use of lead and its alloys as anodes for cathodic protection of piles of marine petroleum-extracting rigs. Journal: Korroz. Zashch. Neftegazov. Promsti. Publ. 74, issue 7, p. 14-17. (In Russian)

N3724-1. GEYER, RICHARD AL., and SWEET, WILLIAM M., JR.
Natural hydrocarbon seepage in the Gulf of Mexico. Gulf Coast Ass. Geol. Soc., Pub. 73, series 23, p. 158-69.

N3724-2. WILSON, R.D., and MONOAGHAN, P.H.
Estimate of annual input of petroleum to the marine environment from natural marine seepage. Gulf Coast Ass. Geol. Soc., Publ. 73, series 23, p. 182-93.

N3733-4. HSIEH, TE-LUNG.
Sea water drilling mud for Bantayan, Cebu, Philippines. Shih You Tsuan T'sai Kung Ch'eng, Publ. 71, series No. 12, pages 73-81, language: Chinese.

*P21-3. BAKER, J.M.
Refinery effluent, etc. In: Cowell, E.B. (Ed.) The Ecological Effects of Oil Pollution on Littoral Communities. Proceedings of a Symposium by the Inst. of Petro. held at the Zoological Soc., London, Nov. 30-Dec. 1, 1970. Elsevier Pub. Co. Ltd., Amsterdam. 250 pp.

*P22-2. BAKER, J.M.,
Biological effects of refinery effluents. In: Proceedings of a Joint Conference on Prevention and Control of Oil Spills, March 13-15, 1973, Washington, D.C. sponsored by the Am. Petro. Inst., EPA, and U.S. Coast Guard, p. 715-23.

*P24-2. BARCLAY-SMITH, P., 1969.
International Conference on oil pollution of the sea. 414 p. Illus. maps. British Museum of Natural History: London, England. Paper.

*P213-3. KRISHNASWAMI, S.K. and E.E. KUPCHENBO, 1969.
Relationship between petroleum refinery wastewater and occurrence of "oily" taste-flavor in rainbow trout "Salmo gairdnerii."
J. Water Pollut. Control Fed., 41(2):R189.

*P350-2. REISH, D.J., 1964.
The effects of oil refinery wastes on benthic marine animals in Los Angeles Harbor, California. p. 355-61, In: Pollutions Marines par les Microoganismes et les Produits Petroliers. Symposium de Monaco (Avril 1964). Secretariat General de la Commission, 59 Avenue Raymond Poincare, Paris 16, France. 384 pp.

O-11. FALK, M.R. and M.J. LAWRENCE, 1973.
Acute toxicity of petrochemical drilling fluids and wastes to fish. Freshwater Institute, Winnipeg, April 1973, 108 p. Tech. Report No. CEN-T-73-1.

O-12. FALK, M.R. and M.J. LAWRENCE, 1973.
Seismic Exploration: its nature and effect on fish. Freshwater Institute, Winnipeg, April 1973, 108 p. Tech. Report No. CEN-T-73-9.

O-13. ASPINWALL, NEVIN and GORDON TETSELL, 1966.
Observation of Bristol Bay Seismic Operation, Aug. 2-10, 1965 and Jan. 20, 1966. Alaska Dept. Fish & Game, Informational Leaflet 73, Juneau, Alaska.

O-16. PESSAH, LOCK, and MAC LEOD
Preliminary report on toxicity of Canadian petroleum refinery effluents to fish. Tech. Report #408, Freshwater Institute, Winnipeg.

O-29. MC COWN, B.H., BROWN, S., and MURRMAN, R.D. 1971.
Effect of oil seepages and spills on the ecology and biochemistry in cold dominated environments. U.S. Army Cold Regions Research and Engineering Laboratory, Annual Report 1971, 18 p.

0-30. CABRERA, J., 1968.
Survival of the oyster in the laboratory under effects of oil drilling fluids spilled in Laguna de Tomiahua. Instituto de Biologica, Universidad Nacional Autonoma Mexico, Mexico, DF.

0-31. DAUGHERTY, F.M., 1951.
Effects of some chemicals used in oil well drilling in marine animals. Sewage and Industrial Wastes 20, #10, 1282-7(1951).

0-32. LAND, B., 1974.
Literature review of the aquatic toxicity of drilling fluid components. Environmental Protection Service, Edmonton, Alberta.

0-33. WEIN, R.H., LAKE, W.H., and THACKERAY, B.T., 1974.
Acute toxicity of ten selected Arctic drilling sumps to rainbow trout. EPA Bioassay Laboratory, Edmonton, Alberta, 1974.

0-34. BROOKS, J.W., BARTONEK, D.R., KLEIN, D.L., and TAHYER, A.S.
Environmental influence of oil and gas development in the Arctic slop and Beaufort Seas. U.S. Dept. of Interior, Resources Report #96, 24 p., 1971.

0-46. TOPHAM, D.R.
The hydrodynamic aspects of an oil well blow-out under sea ice. Interim Report of Beaufort Sea Project Study F-3, Dec. 1974. Environment Canada, Victoria, B.C.

0-48. HUNTER, J.A., MAC AULAY, H.A., GOOD, R.L., GAGNE, R.M. and BURNS, R.A.
The study of frozen seabed material in the Southern Beaufort Sea. Interim Report of Beaufort Sea Project Study F-1, Dec. 1974. Environment Canada, Victoria, B.C.

(NOTE: **Two asterisks means copy available.)

18. Additions to Classified Literature References as of 3/31/76.

**0-87. KOONS, C.B., D.C. McAULIFFE, and F.T. WEISS (x-ref. Sheen Tech. Subcommittee, Offshore Operators Committee)
Environmental aspects of produced waters from oil and gas extraction operations in offshore and coastal waters. Prepared by Sheen Tech. Subcommittee, Offshore Operators Committee, September 30, 1975.

**0-88. MILNE, A.R. & B.D. SMILEY.
Offshore drilling for oil in the Beaufort Sea: a preliminary environmental assessment. Technical Report No. 39, Beaufort Sea Project. Revised Jan. 20, 1976. Beaufort Sea Project, Dept. of the Environment, 1230 Government Street, Victoria, B.C. V8W 1Y4.

**0-92. McAULIFFE, C.D. and L.L. PALMER.
Environmental aspects of offshore disposal of drilling fluids and cuttings. SPE 5864.

*0-96. EXXON.
Exxon and the environment. Exxon Corporation, 1251 Avenue of the Americas, New York, NY 10020, November 1975.

18. ADDitions to Classified Literature References as of 6/29/76.

*P21-3 BAKER, J.M., 1970
(pp. 44-51), refinery effluent (pp. 33-43), growth stimulation following oil pollution (pp. 72-77, comparative toxicities of oils, oil fractions and emulsifiers (pp. 78-87), the effects of oils on plant physiology (pp. 88-98).

In Cowell, E.B. (ed.) the ecological effects of oil pollution on littoral communities. Proceedings of a symposium by the INst. of Petrol. held at the Zoological Society, London, Nov. 30-Dec. 1, 1970. Elsevier Pub. Co., Ltd., Amsterdam, 250 pp.

*P22-2 BAKER, J.M., 1973
Biological effects of refinery effluents. PP. 715-23, in: proceedings of a joint conference on prevention and control of oil spills, March 13-15, 1973. Washington, D.C. sponsored by the AM. Petro. Inst., EPA, & U.S. Coast Guard. 834 pp

*P24-2 BARCLAY-SMITH, P., 1969
International conference on oil pollution of the sea. 414 p. Illus. Maps. British Museum of Natural History: London England.

*P213-2 KRISHNASWAMI, S.K. & E.E. KUPCHANKO, 1969
Relationship between petroleum refinery wastewater and occurrence of "oily" taste-flavor in rainbow trout "Salmo gairdnerii." J. Water Pollut. Control Fed., 41(2):R189.

*P350-2 REISH, D.J., 1964
The effects of oil refinery wastes on benthic marine animals in Los Angeles Harbor, Calif. PP. 355-61, in: Pollutions marines par les microorganismes et les produits petroliers. Symposium de Monaco (Avril 1964). Secretariat General de la Commission, 59 Avenue Raymond Poincare, Paris 16, France, 384 pp.

0-211 ALLEN, A.A. & R.S. SCHLUETER, 1969
Estimates of surface pollution resulting from submarine oil seeps at platform A and Coal Oil Point. Technical Memorandum 1230. General Research Corporation, Santa Barbara, Calif. 43 p.

0-210 ALLEN, A.A., R.S. SCHLUETER, & P.G. MIKOLAJ, 1970
Natural oil seepage at Coal Oil point, Santa Barbara, Calif. Science 170:974-977.

0-221 PALMER, I.F., JR., 1971
Oil seeps. Alaska/magazine of life on the last frontier. August, 1971, pp. 48-49.

0-222 POLISOIS, C., A. TESSIER, P.G.C. CAMPBELL, & J.P. VILLENEUVE, 1975
Degradation of phenolic compounds downstream from a petroleum refinery complex. J. Fish. Res. Board Can 32:2125-2131.

0-223 POLIAKOFF, M.Z., 1969
Oil dispersing chemicals. A study of the composition, properties and use of chemical for dispersing oil spills. U.S. Dept. Interior, Federal Water Pollution Control Administration. Water Pollution Control Research Series ORD-3, May 1969, 27 p.

0-224 U.S. DEPARTMENT OF COMMERCE, NATIONAL BUREAU OF STANDARDS AND ENVIRONMENTAL PROTECTION AGENCY, 1975
Workshop on SRM's for offshore drilling-petroleum. Oct. 607, 1975, Santa Barbara, Calif. (Program and list of attendees, some personal notes of Karrick).

O-225 WILSON, R.D., P.H. MONAGHAN, A. OSANIK, L.C. PRICE & M.A. ROGERS, 1974
Natural marine oil seepage, Science 184:857-865.

19. ANALYTICAL METHODS (METHODS HIGHLY SPECIFIC TO PERTINENT PROBLEMS; INCLUDES BIOASSAYS AND MODEL SYSTEMS FOR TESTING TOXICITY)

155. KONDO, G., SANO, H., HONDA, S., and MURAKAMI, Y.
Oil-thickness meter. (In Japanese, with English summary)
Osaka Ind. Tech. Lab. Q., 19, 209-212, 1968.

156. KONDO, G., SANO, H., HONDA, S., and MURAKAMI, Y.
Measurement of oil-thickness of spilt oil on the sea.
(In Japanese, with English summary)
Osaka Ind. Tech. Lab. Q., 21, 12-16, 1970.

348. DOUGLAS, N.H.
Evaluation and relative resistance of sixteen species of fish as test animals in toxicity bioassays of petroleum refinery effluents. 56p. Oklahoma State University, 1963. (Ph.D. thesis)

350. GOULD, W.R.
The suitabilities and relative resistance of twelve species of fish as bioassay animals for oil refinery effluents. 51p. Oklahoma State University, 1964. (Ph.D. Thesis)

367. WARD, C.M.
The relative resistance of fifteen species of fishes to petroleum refinery effluent and the suitability of the species as test animals. vi, 71p. Oklahoma State University, 1962. (Ph.D. Thesis)

455. LAROCHE, G., EISLER, R., and TARZWELL, C.M.
Bioassay procedures for oil and oil dispersant toxicity evaluation.
J. Wat. Pollut. Control Fed., 42, 1982-1989, 1970.

737. TARZWELL, C.M.
Standard methods for determination of relative toxicity of oil dispersants and mixtures of dispersants and various oils to aquatic organisms.
In: American Petroleum Institute. Proceedings of a joint conference on prevention and control of oil spills, New York, December 15-17, 1969. pp. 179-186. New York, American Petroleum Institute, 1970.

830. O'SULLIVAN, A.J.
Organisation and methods to combat oil pollution of beaches.
Effluent Wat. Treat. J., 3p., April 1969.

1228. BAIER, R.E.
Organic films on natural waters: their retrieval, identification and modes of elimination.
J.geophys.Res., 77, 5062-5075, 1972.

1521. SACKETT, W.M., and BROOKS, J.M.
Use of low molecular-weight-hydrocarbon concentrations as indicators of marine pollution.
In: US National Bureau of Standards. Marine pollution monitoring (petroleum). Proceedings of a symposium and workshop...May 13-17 1974. pp. 171-173. Washington, D.C., US Government Printing Office, 1974.

19.

1609. DESHIMARU, O.
Studies on the pollution of fish meat by mineral oils. I. Deposition of crude oil in fish meat and its detection. (In JAPANESE with ENGLISH summary) Bull. Jap. Soc. scient. Fish., 37, 297-301, 1971.

1617. LICHATOWICH, J.A., STRAND, J.A., and TEMPLETON, W.L.
Development of toxicity test procedures for marine zooplankton. In: American Institute of Chemical Engineers. Proceedings of a symposium on pollution of the sea by oil: problems and technology. San Francisco, November 28-December 2 1971. Am. Inst. Chem. Engrs Symp. Ser., 68, 372-378, 1972.

1700. SPOONER, M.F., and CORKETT, C.J.
A method for testing the toxicity of suspended oil droplets on planktonic copepods used at Plymouth.
In: Beynon, L.R., and Cowell, E.B., editors. Ecological aspects of toxicity testing of oils and dispersants: (Proceedings of a workshop...) pp. 69-74. Barking, Essex, Applied Science Publishers, 1974.

1716. LACAZE, J.-C.
Ecotoxicology of crude oils and the use of experimental marine ecosystems. Mar. Pollut. Bull., 5, 153-156, 1974.

1721. NADEAU, R.J., and ROUSH, T.H.
A salt marsh microcosm: an experimental unit for marine pollution studies. In: American Petroleum Institute. Proceedings of joint conference on prevention and control of oil spills, Washington, D.C., March 13-15 1973. pp. 671-683. Washington, D.C., American Petroleum Institute, 1973.

1733. BAKER, J.M., and CRAPP, G.B.
Toxicity tests for predicting the ecological effects of oil and emulsifier pollution on littoral communities.
In: Beynon, L.R., and Cowell, E.B., editors. Ecological aspects of toxicity testing of oils and dispersants: (Proceedings of a workshop...) pp. 23-40. Barking, Essex, Applied Science Publishers, 1974.

1734. BECKER, C.D., LICHATOWICH, J.A., SCHNEIDER, M.J., and STRAND, J.A.
Regional survey of marine biota for bioassay standardization of oil and oil dispersant chemicals. 102p. Richland, Washington, Battelle Pacific Northwest Laboratories, 1973. (American Petroleum Institute Publication No. 4167).

1745. LICHATOWICH, J.A., O'KEEFE, P.W., STRAND, J.A., and TEMPLETON, W.L.
Development of methodology and apparatus for the bioassay of oil.
In: American Petroleum Institute. Proceedings of joint conference on prevention and control of oil spills, Washington, D.C., March 13-15, 1973. pp. 659-666. Washington, D.C., American Petroleum Institute, 1973.

1750. NOTINI, M., and HAGSTRÖM, A.
Effects of oils on Baltic littoral community, as studied in an outdoor model test system.
In: US National Bureau of Standards. Marine pollution monitoring (petroleum). Proceedings of a symposium and workshop...May 13-17, 1974. pp. 251-254. Washington, D.C., US Government Printing Office, 1974.

1764. WILSON, K.W.
Toxicity testing for ranking oils and oil dispersants.
In: Beynon, L.R., and Cowell, E.B., editors. Ecological aspects of toxicity testing of oils and dispersants: (Proceedings of a workshop...) pp. 11-22. Barking, Essex, Applied Science Publishers, 1974.

1765. WILSON, K.W., COWELL, E.B., and BEYNON, L.R.
The toxicity testing of oils and dispersants: a European view.
In: American Petroleum Institute. Proceedings of joint conference on prevention and control of oil spills, Washington, D.C., March 13-15 1973. pp. 255-261. Washington, D.C., American Petroleum Institute, 1973.

1775. SCACCINI, A., SCACCINI-CICATELLI, M., MARANI, F., and LEONARDI, V.
Dosaggi spettrofotofluorimetrici ed osservazioni mediante microscopia a fluorescenza del benzo 3-4 pirene su organi e tessuti di Carassius auratus. (Spectrophotofluorometric dosage and fluorescence microscope observations on benzo 3-4-pyrene in organs and tissues of Carassius auratus.)
Note Lab. Biol. mar. Fano, 3, 105-144, 1970.

2261. CRAPP, G.(B.), and BAKER, J.(M.)
Toxicity tests for predicting the ecological effects of oils and emulsifiers on littoral communities.
Rep. Oil Pollut. Res. Unit, Fld Stud. Coun., 1972, 35-39, 1973.

2297. OVERFIELD, J.L.
Development of a non-toxic simulated oil for marine testing programs. 8p. Paper presented at the fourth annual offshore technology conference, Houston, Texas, May 1-3 1972. (Paper No. OTC 1524)

*A1. ADLARD, E.R. (1972).
A review of the methods for the identification of persistent hydrocarbon pollutants on seas and beaches. Jour. Inst. Petrol., vol. 58, no. 560, p. 63-74, 12 illus., 3 tabls., 37 refs.

*A2. ADLARD, E.R., L.F. CREASER, and P.H.D. MATTHEWS (1972).
Identification of hydrocarbon pollutants on seas and beaches by gas chromatography. Anal. Chem., vol. 44, no. 1, p. 64-73, 9 illus., 11 refs.

*A3. AGAZZI, E.J., D.C. BURTNER, D.J. CRITTENDEN, and D.R. PATTERSON (1963).
Determination of trace metals in oils by sulfur incineration and spectrophotometric measurements. Anal. Chem., vol. 35, no. 3, p. 332-335, 1 illus., 2 tabls., 21 refs.

*A8. BLAYLOCK, J.W., P.W. O'KEEFE, J.N. ROEHM, and R.E. WILDUNG (1973).
Determination of n-alkane and methylnaphthalene compounds in shellfish. Proceedings f the joint conference on prevention and control of oil spills Sponsored by API, EPA, and USCG, publ. by Amer. Petrol. Inst., Washington, D.C., p. 173-177, 2 illus., 2 tabls., 5 refs.

*A9. BLUMER, M., P.C. BLOKKER, E.B. COWELL, and D.F. DUCKWORTH (1971).
Report of the seminar on methods of detection, measurement and monitoring of pollutants in the marine environment. Petroleum FAO Fisheries reports, no. 99, suppl. 1, p. 17-36, 4 illus., 1 tabl., 76 refs.

*A12. CLARK, R.C., JR., and J.S. FINLEY (1973).
Techniques for analysis of paraffin hydrocarbons and for interpretation of data to assess oil spill effects in aquatic organisms. Proceedings of the joint conference on prevention and control of oil spills. Sponsored by API, EPA, and USCG, published by Amer. Petrol. Inst., Washington, D.C., p. 161-172, 4 illus., 5 tabls., 15 refs.

*A13. COLEMAN, H.J., R.L. HOPKINS, and C.J. THOMPSON (1970).
Highlights of some 50 man-years of petroleum sulfur studies by the Bureau of Mines, preprint, Div. of Petrol. Chem., Amer. Chem. Soc., Chicago, Sept. 13-18, p. A17-A36, 9 illus., 4 tabls., 64 refs.

*A15. DESBAUMES, E., and C. IMHOFF (1972).
Determination of hydrocarbon residues in water. Water Res., vol. 6, p. 885-893, 8 illus., 15 refs.

*A16. DUCKWORTH, D.F. (1970).
Aspects of petroleum pollutant analysis. Preprint of a paper. Seminar on Water Pollution by Oil, Inst. Water Pollut. Control, Aviemore, Scotland, 4-8 May, 15 p., 8 illus., 5 tabls., 20 refs.

*A18. FARRINGTON, J.W. (1973).
Analytical techniques for the determination of petroleum contamination in marine organisms. Woods Hole Ocean. Inst., Tech. Rept. 73-57, 24 p., 1 illus., 53 refs.

*A23. GRUENFELD, M. (1973).
Identification of oil pollutants: A review of some recent methods. Proceedings of the joint conf. on prevention and control of oil spills. Sponsored by API, EPA, and USCG., publ. by Amer. Petrol. Inst., Washington, D.C., p. 179-193, 9 illus., 12 tabls., 5 refs.

*A24. HAN, J.C. (1970).
Chemical studies of terrestrial and extraterrestrial life, Ph.D. thesis, Univ. of Calif., Berkeley, 286p., 56 illus., 22 tabls., 325 refs.

*A25. HINDS, G.P., JR. (1971).
Utilization of analytical techniques for the heavy ends of crude oil. Proceedings of the Amer. Petrol. Inst., p. 391-404, 1 illus., 7 tabls., 17 refs.

*A26. HINDS, G.P., JR. (1972).
Calculating process yields from heavy ends analyses using project 60 techniques. Proceedings of the Amer. Petrol. Inst., p. 691-699, 5 illus., 6 tabls., 10 refs.

*A27. HOROWITZ, J., G.D. GUMTZ, R. G. NEMCHIN, and T.P. MELOY (1969).
Identification of oil spills: comparison of several methods. Proceedings of the joint conf. on prevention and control of oil spills. Sponsored by API, FWPCA, Dec. 15-17, New York, p. 283-296, 88 refs.

*A28. INSTITUTE OF PETROLEUM, STANDARDIZATION COMMITTEE (1970).
Analytical methods for the identification of the source of pollution by oil of the seas, rivers, and beaches. J. Inst. Petrol., vol. 56, no. 548, p. 107-117, 9 illus., 11 refs.

*A29. JELTES, R. (1969).
Gas-chromatographic determination of mineral oil in water. Water Res., vol. 3, p. 931-941, 2 illus., 2 tabls., 23 refs.

*A30. JELTES, R., and W.A.M. den TONKELAAR (1972).
Gas chromatography versus infra-red spectrometry for determination of mineral oil dissolved in water. Water Res., vol. 6, p. 271-278, 3 illus., 4 tabls., 15 refs.

*A31. JOHANNESSON, J.K. (1955).
The identification of fuel oils polluting coastal waters. Analyst, vol. 80, p. 840-841, 2 tabls., 7 refs.

*A33. KREIDER, R.E. (1971)
Identification of oil leaks and spills. Proceedings of the joint conf. on prevention and control of oil spills. Sponsored by API, EPA, and USCG., June 15-17, Washington, D.C., p. 119-124, 6 illus., 4 tabls., 15 refs.

*A35. LEVY, E.M. (1972).
The identification of petroleum products in the marine environment by absorption spectrophotometry. Water Res., vol. 6, p. 57-69, 8 illus., 8 tabls., 4 refs.

*A37. McKAY, J.F., and D.R. LATHAM (1973).
Polyaromatic hydrocarbons in high-boiling petroleum distillates--isolation by gel permeation chromatography and identification by fluorescence spectrometry. Anal. Chem., vol. 45, no. 7, p. 1050-1055, 11 illus., 2 tabls., 17 refs.

*A38. MALUEG, N.J., and D.F. KRAWCZK (1970).
Tracing oil as a pollutant in water. 45th meeting of the Soc. of Petrol. Eng. of AIME, Houston, Texas, Oct. 4-7, preprint, 13 p., 10 tabls., 12 refs.

*A39. MATTSON, J.S., H.B. MARK, JR., R. L. KOLPACK, and C. E. SCHUTT (1970).
A rapid nondestructive technique for infrared identification of crude oils by internal reflection spectrometry. Anal. Chem., vol. 42, p. 234-238, 5 illus., 2 tabls., 17 refs.

*A40. McAULIFFE, C. (1966).
Solubility in water of paraffin, cycloparaffin, olefin, acetylene, cycloolefin, and aromatic hydrocarbons. J. Phys. Chem., vol 70, p. 1267-1275, 5 illus., 4 tabls., 21 refs.

*A41. McAULIFF, C. (1971).
GC determination of solutes by multiple phase equilibration. Chem. Tech., vol. 1, no. 1, p. 46-51, 8 illus., 2 tabls., 10 refs.

*A43. MILLER, J.W. (1973).
A multiparameter oil pollution source identification system. Proceedings of the joint conf. on prevention and control of oil spills. Sponsored by API, EPA, and USCG, publ. by Amer. Petrol. Inst., Washington, D.C., p. 195-203, 6 illus., 2 tabls., 10 refs.

*A44. MILNER, O.I., J.R. GLASS, J.P. KIRCHNER, and A.N. YURICK (1952).
Determination of trace metals in crudes and other petroleum oils. Anal. Chem., vol. 24, no. 11, p. 1728-1732, 4 illus., 8 tabls., 16 refs.

*A46. OELERT, H.H., D.R. LATHAM, and W.E. HAINES (1970).
Characterization of crude oils by gel permeation chromatography. Separation Science, vol. 5, no. 5, p. 657-668, 5 illus., 1 tabl., 15 refs.

*A48. RAMSDALE, S.J., and R.E. WILKINSON (1968).
Identification of petroleum sources of beach pollution by gas-liquid chromatography. J. Inst. Petrol., vol. 54, no. 539, p. 326-332, 6 illus.

*A49. ROGERS, M.A., N.J.L. BAILEY, and C.R. EVANS (1971)
A plea for inclusion of basic sample information when reporting geochemical analyses of crude oils. Geochim. et Cosmochim. Act, vol. 35, no. 6, p. 632-636, 2 illus., 2 tabls., 10 refs.

*A51. SCALAN, R.S., and J.E. SMITH (1970).
An improved measure of the odd-even predominance in the normal alkanes of sediment extracts and petroleum. Geochim. et Cosmochim. Acta, vol. 34, p. 611-620, 7 illus., 1 tabl., 7 refs.

*A52. SCHENCK, P.A., and E. EISMA (1964).
Quantitative determination of n-alkanes in crude oils and rock extracts by gas chromatography. In Advances in organic geochemistry, U. Colombo and G.D. Hobson (eds.), Pergamon Press, New York, p. 403-415, 9 illus., 4 tabls., 10 refs.

*A53. SHOTT, J.E., JR., T.J. GARLAND, and R.O. CLARK (1961).
Determination of traces of nickel and vanadium in petroleum distillates. Anal. Chem., vol. 33, no. 4, p. 506-510, 1 illus., 4 tabls., 10 refs.

*A57. SPEERS, G.C., and E.V. WHITEHEAD (1969).
Crude petroleum, In Organic Geochem., G. Eglinton & M.T.J. Murphy (eds.), Springer-Verlag, New York, p. 638-675, 12 illus., 3 tabls., 206 refs.

19.

*A62. ZAFIRIOU, O.C.J., J. MEYERS, R. BOURBONNIERE, and F. J. FREESTONE (1973). Oil spill--source correlation by gas chromatography: an experimental evaluation of system performance. Proceedings of the joint conf. on prevention and control of oil spills, Sponsored by API, EPA, and USCG, Publ. by Amer. Petrol. Inst., Washington, D.C., p. 153-59, 3 illus., 5 tabls., 5 refs.

*A63. ZITKO, V. (1971). Determination of residual fuel oil contamination of aquatic animals. Bull. Environ. Contamination and Toxicology, vol. 5, no. 6, p. 559-564, 1 illus., 1 tabl., 15 refs.

*A64. ZITKO, V., and W.V. CARSON (1970). The characterization of petroleum oils and their determination in the aquatic environment. Fisheries Res. Board of Canada, Tech. report no. 217, 29 p., 9 illus., 12 tabls., 19 refs.

*A65. ALLEN, A.A., and J.E. ESTES (1970). Detection and measurement of oil film. Proceedings of the Santa Barbara oil symposium, December 16-18, University of California, Santa Barbara, p. 47-74, 6 illus., 2 tabls., 37 refs.

*A68. BAIER, R.E. (1970). Surface quality assessment of natural bodies of water. Proc. 13th Conf. Great Lakes Res., p. 114-127, 7 illus., 40 refs.

*A69. BAIER, R.E. (1972). Organic films on natural waters: Their retrieval, identification, and modes of elimination. J. Geophys. Res., vol. 77, no. 27, p. 5062-5075, 5 illus., 1 tabl., 16 refs.

*A70. BARBIER, M., D. JOLY, A. SOLIOT, and D. TOURRES (1973). Hydrocarbons from sea water. Deep-Sea Res., vol. 20, p. 305-314, 9 illus., 16 refs.

*A77. BOYLAN, D.B., and B.W. TRIPP (1971). Determination of hydrocarbons in seawater extracts of crude oil and crude oil fractions. Nature, London, vol. 230, no. 5288, p. 44-47, 4 illus., 3 tabls., 11 refs.

*A82. CARLBERG, S.R., and C.B. SKARSTEDT (1972). Determination of small amounts of non-polar hydrocarbons (oil) in sea water. J. Cons. Int. Explor. Mer., vol. 34, no. 3, p. 506-515, 3 illus., 2 tabls.,13 refs.

*A84. CORWIN, J.F. (1970). Volatile organic material in sea water. Symposium on organic matter in natural waters, Univ. of Alaska, Sept. 2-4, 1968, D.W. Hodd (ed.). Inst. of Mar. Sci., Occasional publ., no. 1, p. 169-180, 3 illus., 3 tabls., 14 refs.

19.

*A88. ESTES, J.E., and B. GOLOME (1970).
Oil spills: Method for measuring their extent on the sea surface. Science, vol. 168, p. 676=678, 3 illus., 4 refs.

*A104. HOLLINGER, J.P., and R.A. MENNELLA (1973).
Oil spills: Measurements of their distributions and volumes by multifrequency microwave radiometry. Science, vol. 181, no. 4094, p. 54-56, 2 illus., 19 refs.

*A117. KINSEY, D.W. (1973).
Small-scale experiments to determine the effects of crude oil films on gas exchange over the coral back-reef at Heron Island. Environ. Pollut., vol. 4, p. 167-182, 5 illus., 3 tabls., 12 refs.

*A125. McAULIFFE, C. (1969).
Determination of dissolved hydrocarbons in subsurface brines. Chem. Geol., vol 4, p. 225-233, 4 illus., 3 tabls., 11 refs.

*A126. McAULIFFE, C. (1969). Solubility in water of normal C_9 and C_{10} alkane hydrocarbons. Science, vol. 158, p. 478-479, 1 illus., 8 refs.

*A131. MORRIS, B.F. (1971). Petroleum: Tar quantities floating in northwestern Atlantic taken with a new quantitative Neuston net. Science, vol. 173, p. 430-432, 2 illus., 2 tabls., 10 refs.

*A134. MUNDAY, J.C., JR., W. G. MACINTYRE, M.E. PENNEY, and J.D. OBERHOLTZER (1971).
Oil slick studies using photographic and multispectral scanner data. Proceedings 7th Inter. Symp. of Remote Sensing, Univ. of Mich., Ann Arbor, p. 1027-1043, 11 illus., 4 tabls., 36 refs.

*A142. ORTHLIEB, F.L. (1971)
Forecasting oil slick behavior--A preliminary guide. USCG Res. and Dev., rept. 724107.1, 12 p., 3 refs.

*A161. TEESON, D., F.M. WHITE, and H. SCHENCK, JR. (1970).
Studies of the simulation of drifting oil by polyethylene sheets. Ocean Engineering, vol. 2, p. 1-11.

*A172. SIVADIER, H.O., and P.G. MIKOLAJ (1973).
Measurement of evaporation rates from oil slicks on the open sea. Proceedings of the joint conf. on prevention and control of oil spills. Sponsored by API, EPA, and USCG, publ. by Amer. Petrol. Inst., Washington, D.C., p. 475-484, 9 illus., 3 tabls., 14 refs.

*A182. MARK, H.B., JR., T. YU, J.S. MATTSON, and R.L. KOLPACK (1972).
Infrared estimation of oil content in sediments in presence of biological matter. Environ. Sci. and Tech., vol. 6, no. 9, p. 833-834, 1 illus., 2 tabls., 7 refs.

*A115. KAWAHARA, F.K., and D.G. BALLINGER (1970)
Characterization of oil slicks on surface waters, Ind. Eng. Chem. Prod. Res. Develop., vol. 9, no. 4, p. 553-558, 5 illus., 5 tabls., 4 refs.

*A193. BRUNNOCK, J.V., D.F. DOCKWORTH, and G.G. STEPHENS (1968).
Analysis of beach pollutants. J. Inst. Petrol., vol. 54, no. 539, p. 310-325, 9 illus., 12 tabls., 8 refs.

*A201. LUDWIG, H.F., and L.G. RICH (1964).
Study of oil-tar deposition on beaches. In: Advances in water pollution research, vol. 3, E.A. Pearson (ed.), Pergamon Press, New York, p. 113-118, 2 illus., 10 refs.

*A204. ROSEN, A.A., L.R. MUSGRAVE, and J.J. LICHTENBERG (1959).
Characterization of coastal oil pollution by submarine seeps. Cal. State Water Pollut. Control Board, publ. 21, pt. 2, 61 p., 7 illus., 1 tabl., 17 refs.

*A209. ATKINSON, J.H., and F.H. NEWTH (1968).
Microbiological transformation of hydrocarbons. In: Microbiology, Proceedings of a conference, P. Hepple (ed.), Inst. of Petrol., London, p. 35-44, 5 illus., 2 tabls., 14 refs.

*A221. BARTHA, R. (1970).
Biodegradation of oil slicks in the marine environment. Tech. Rept. Office of Naval Research, Arlington, Virginia, project no. NR-137-843, 10 p., 3 illus., 3 tabls., 6 refs.

*A224. BLUMER, M., R.R.L. GUILLARD, and T. CHASE (1971).
Hydrocarbons of marine phytoplankton. Mar. Biol., vol. 8, p. 183-189, 1 illus., 1 tabl., 17 refs.

*A247. GATELLIER, C.R., J.L. OUDIN, P. FUSEY, J.C. LACAZE, and M.L. PRIOU (1973).
Experimental ecosystems to measure fate of oil spills dispersed by surface active products. Proceedings of the joint conf. on prevention and control of oil spills, Sponsored by API, EPA, and USCG, publ. by Amer. Petrol. Inst., Washington, D.C., p. 497-504, 4 illus., 3 tabls. 13 refs.

*A292. ROY, V.M., J. DUPUY, W.G. MacINTYRE, and W. HARRISON (1970).
Abundance of marine phytoplankton in surface films: A method of sampling. Proceedings of the symposium on hydrobiology, Miami Beach, Florida, June 24-27, p. 371-380, 3 illus., 2 tabls., 12 refs.

*A322. BAKER, J.M. (1971)
Successive spillages. Proceedings of the ecological effects of oil pollution on littoral communities, E.B. Cowell (ed.)., Inst. of Petrol., London, p. 21-32, 9 illus.

*A384. EDISON WATER QUALITY LABORATORY (1969).
Oil sampling techniques. Water Pollut. Control Admin., 63 p., 11 illus., 19 tabls., 8 refs.

*A414. SCHATZBERG, P., and D.F. JACKSON (1973).
Remote sampler for determining residual oil contents of surface waters. Proceedings of the joint conf. on prevention and control of oil spills. Sponsored by API, EPA, USCG, publ. by Am. Petrol. Inst., Washington, D.C. p. 139-144, 3 illus., 6 tabls., 2 refs.

19.

N3664-1. DONNELLY, T.H., J. FERGUSON and A.J. ECCLESTON.
A high speed method of continuous background correction in atomic absorption spectrometry part 3 direct determination of trace metals in sea water using the Varian techtron carbon rod atomizer Model 63. Appl. Spectrosc. 29(2), 1975, p. 158-163.

N3664-2. GORDON, D.C., JR., P.D. KEIZER, and J. DALE.
Estimates using fluorescence spectroscopy of the present state of petroleum hydrocarbon contamination in the water column of the Northwest Atlantic Ocean. Mar. Chem. 1(40, 1974, p. 251-262.

N3665-5. RED'KIN, YU R, A.M. VOITENKO, and P.A. TEPLYAKOV.
Studies of the aromatic compounds content in sea water by low temperature luminescent spectroscopy. Okeanologiya 13(5), 1973, p. 908-913.

N3674-3. LACAZE, J.F.
The utilization of a simple experimental device for study of water pollution in situ comparative effects of 3 anti-petroleum emulsifying agents. Tethys 3(4), 1971, p. 705-715.

N3677-1. ACKMAN, R.G. and D. NOBLE.
Steam distillation a simple technique for recovery of petroleum hydro carbons from tainted fish. J. Fish. Res. Board Can. 30(5), 1973, p. 711-714.

N3682-4. ADLARD, E.R., L. F. CREASER, and P.H.D. MATTHEWS.
Identification of hydro carbon pollutants on seas and beaches by gas chromatography. Anal. Chem. 44(1), 1972, p. 64-73.

N3683-1. OGATA, M. and F. MIYAKE.
Offensive odor substance in the evil smelling fish from the sea polluted by petroleum and petrochemical industrial waste. Part 1. Identification of offensive odor substance. Acta Med. Okayama 1970 24(4), 471-481.

N3690-2. LENGES, J. and D. LUKS.
Determination of 3,4-benzopyrene in smoked meat and fish. 1. Quantitative determination of 3,4-benzopyrene in smoked meat products. Rev. Ferment. Ind. Aliment, 1974, 29(5), p. 134-9, In French.

N3690-3. SIELDER, LUIS T.S.
Determination of benzo(a)pyrene in smoked fish. An. Assoc. Bras. Quim, 1972, 28(1-2), p. 17-21, In Portuguese.

N3692-3. PARADIS, M., and R.G. ACKMAN.
Differentiation between natural hydrocarbons and low level diesel oil contamination in cooked lobster meat. J. Fish. Res. Board Can., 1975, 32(2), p. 316-20.

N3698-1. DONNELLY, T.H., J. FERGUSON, and A.J. ECCLESTON.
High speed method of continuous background correction in atomic absorption spectrometry. III. Direct determination of trace metals in sea water using the Varian Techtron carbon rod atomizer model 63. Appl. Spectrosc., 1975, 29(2), p. 158-63.

19.

N3701-3. PERRAS, JAMES C.
Portable gas chromatographic technique to measure dissolved hydrocarbons in sea water. U.S.N.T.I.S., Ad Rep., 1973, No. 786583/5GA, 53 p.

N3703-1. WASIK, STANLEY P.
Determination of hydrocarbons in sea water using an electrolytic stripping cell. J. Chromatogr. Sci., 1974, 12(12), p. 845-8.

N3703-2. NOVIKOV, P.D., B.A. CHEPENKO, and G.M. KANDYBINA.
Form of trace elements in sea water and their adsorbability by ion-exchange resins. Formy Elem. Radionuklidov Morsr. Vode, (Water. Vses. Simp., Probl. Izuch, Fiz.-Khim. Sostoyaniya Elen. Radionuklidov Okeane), 1974, p. 55-7, in Russian.

N3715-1. CLARK, ROBERT C., JR. and JOHN S. FINLEY.
Techniques for analysis of paraffin hydrocarbons and for interpretation of data to assess oil spill effects in aquatic organisms. Proc. Joint Conf. Prev. Contr. Oil Spills, 1973, p. 161-72.

N3718-1. FARRINGTON, JOHN W.
Problems associated with the collection of marine samples and analysis of hydrocarbons. U.S. Nat. Tech. Inform. Serv., AD Rep., 1974, No. 777695/GA, 24 p.

N3719-1. FINEGOLD, L., ELIZABETH A. BAKER, and D. EPEL.
Sea urchin egg fertilization studied with a fluorescent probe (ANS (8-anilino-1-naphthalene sulfonate)). Exp. Cell Res., 1974, vol. 86(2), p. 248-52.

N3719-2. ZIRINO, ALBERTO, S. H. LIEBERMAN, and MICHAEL L. HEALY.
Anodic stripping voltametry of trace metals in sea water. Mar. Electrochem., Pap. Symp., 1973, p. 319-32. meeting date, 1972.

N3722-4. ANDERSEN, KENNETH K., PAUL R. JONES, GLORIA G. LYLE, ROBERT E. LYLE, and CHARLES W. OWENS.
Possibility study of a research program on the source, degradative removal and secondary consequences of petroleum products in water. U.S. Nat. Tech. Inform. Serv., PB Rep., 1973, No. 227240/9GA, 6 pp.

N3723-4. ZHARIKOV, V.F., and M.M. SENYAVIN.
Sorption of heavy metals from sea water on ion exchangers. Khim. Morei Okeanov. Mater. Vses. Konf. Khim. Morya, 5th, 1973, p. 93-100, in Russian.

N3724-4. MANCY, K.H.
Trace metal characterization by anodic stripping voltammetry. Progr. Water Technol., 1973, vol. 3, p. 63-72.

N3725-2. ZSOLINAY, ADAM.
Determination of total hydrocarbons in sea water at the microgram level with a flow calorimeter. J. Chromatogr., 1974, vol. 90(1), p. 79-85.

19.

N3731-1. CLARK, ROBERT C., JR. and JOHN S. FINLEY.
Paraffin hydrocarbon patterns in petroleum-polluted mussels. Mar. Pollut. Bull., 1973, vol. 4(11), p. 172-6.

N3731-3. RED'KIN, YU. R., A.M. VOITENKO, and P.A. TEPLYAKOV.
Low-temperature luminescence spectroscopic studies of the content of aromatic compounds in sea water. Okeanologiya, 1973, vol. 13(5), p. 908-13.

N3731-4. DI SALVO, L.G., H.R. GUARD, L. HUNTER and A.B. COBET.
Hydrocarbons of suspected pollutant origin in aquatic organism of San Francisco Bay. Methods and preliminary results. Microbial Degradation Oil Pollutants, Workshop, 1973, p. 205-20.

N3732-1. FARRINGTON, JOHN W.
Analytical techniques for the determination of petroleum contamination in marine organisms. U.S. Nat. Tech. Inform. Serv., AD Rep., 1973, No. 766792/6, 30 p.

N3733-2. LAO, R.S., ROBERT S. THOMAS, J.L. MONKMAN, and R.F. POTTIE.
Mass spectroscopic identification and measurement of polycyclic aromatic hydrocarbons in air pollutants. Int. Symp. Identification Meas. Environ. Pollut., (Proc.), 1971, p. 144-6.

N3738-5. GRAY, J.S. and R.J. VENTILLA.
Growth rates of sediment-living marine protozoan as a toxicity indicator for heavy metals. Ambio, 1973, vol. 2(4), p. 118-21.

N3739-3. HUGHES, D.R., R.S. BELCHER, and E.J. O'BRIEN.
Modified extraction method for determination of mineral oil in sea water. Bull. Environ. Contam. Toxicol., 1973, vol. 10,(3), p. 170-1.

N3741-4. ACKMAN, R.G.
Influence of methyl substituent position on retention times in the GLC (gas liquid chromatography) of higher monomethylbranched fatty acid esters and hydrocarbons. J. Chromatogr. Sci., 1972, vol. 10(4), p. 243-6.

N3742-3. KEIZER, P.D. and D.C. GORDON, JR.
Detection of trace amounts of oil in sea water by fluorescence spectroscopy. J. Fish. Res. Board Can, 1973, vol. 30(8), p. 1039-46.

N3746-2. BLACK, JEFFREY A., RAYMON F. ROBERTS, DAVID M. JOHNSON, DAVID D. MINICUCCI, KHALIL H. NANCY, and HERBERT E. ALLEN.
Significance of physicochemical variables in aquatic bioassay of heavy metals. Bioassay Tech. Environ. Chem., 1973, p. 259-75.

N3749-2. ACKMAN, R.G. and D. NOBLE.
Steam distillation. Simple technique for recovery of petroleum hydrocarbons from tainted fish. J. Fish. Res. Bd Can., 1973, vol. 30(5), p. 711-14.

N3751-4. CARLBERG, STIG R. and C. BO. SKARSTEDT.
Determination of small amounts of nonpolar hydrocarbons (oil) in sea water. J. Cons., Cons. Int. Explor. Mer., 1972, 34:3, p. 506-15.

19.

N3760-1. EHRHARDT, MANFRED and MAX BLUMER.
Source identification of marine hydrocarbons by gas chromatography. Environ. Pollut., 1972, vol. 3(3), p. 179-94.

N3762-2. ANDERSON, JIM.
Wet digestion versus dry ashing for the analysis of fish tissue for trace metals. At. Absorption Newslett., 1972, vol. 11(4), p. 88-9.

N3766-1. MIRONOV, O.G.
Methodology for conducting toxicological studies with marine organisms. Metod. Biol. Issled. Vod. Toksikol., 1971, p. 276-83, in Russian.

N3767-2. SEGAR, D.A.
Determination of trace metals in saline waters and biological tissues using the heated graphite atomizer. Joint Conf. Sensing Environ. Pollutants, Collect. Tech. Pap., 1972, vol. 2, p. 71-1051, 5 pp.

N3768-4. KARBE, L.
Marine hydroids as test organisms for assessing the toxicity of water pollutants. Effect of heavy metals on colonies of Eirene viridula. Mar. Biol., 1972, vol. 12(4), p. 316-28, in German.

N3769-2. FLORENCE, T.M.
Determination of trace metals in marine samples by anodic stripping voltammetry. J. Electroanal. Chem. Interfacial Electrochem., 1972, vol. 35, p. 237-45.

O-1. HOOD, DONALD W., Editor.
Impingement of man on the ocean. Book. John Wiley, 1971. (Price $24.95).

O-44. CLODMAN, J.
Real-time environmental prediction system. Interim Report of Beaufort Sea Project Study E-1, Dec. 1974. Environment Canada, Victoria, B.C.

O-19. AMERICAN PETROLEUM INSTITUTE, EPA MARINE TECHNICAL SOC. $18.00.
Marine Bioassay. Obtainable from Marine Technology Society, 1730 M. St., N.W., Washington, D.C. 20036 (Bob Clark has this item).

(NOTE: **Asterisks means copy available.)

19. Additions to Classified Literature References as of 3/31/76.

**0-36. PERCY, J.A. and T.C. MULLIN.
Effects of crude oils on arctic marine invertebrates. Arctic Biological Station, Fisheries and Marine Service, Dept. of the Environment, P.O. Box 400, Ste. Anne de Bellevue, Quebec. Beaufort Sea Technical Report #11, Beaufort Sea Project, Dept. of the Environment, 512 Federal Building, 1230 Government St., Victoria, B.C. V8W 1Y4, December 1975.

0-91. ISAKSON, J.S., J.M. STORIE, J. VAGNERS, G.A. ERICKSON, J.F. KRUGER and R.F. CORLETT.
Comparison of ecological impacts of postulated oil spills at selected Alaskan locations. Introduction, summary, methodology, evaluation and appendices. June 1975, final report, Volume 1. Prepared for Dept. of Transportation, U.S. Coast Guard, Office of Research and Development, Washington, D.C. 20590. (Document is available to the public through the NTIS, Springfield, VA 22151.)

0-103. NOAA BULLETIN (no author).
National program for continual environmental monitoring for the marine leg of the trans-Alaska pipeline system. Rockville, MD, Oct. 1973. NOAA. Federal Coordination for Marine Environmental Prediction.

0-107. JEFFERY, P.G.
Apparatus for the analysis of oil pollution residues. Lab. Practice 1971, 20(1) 48. (Warren Springs Lab., Stevenage, Herts, England.

0-108. GEORGE, A.E., G.T. SMILEY, S.D. MONTGOMERY and H. SAWATZKY.
Gas liquid, gas solid chromatographic method for identification of sources of oil pollution. Fuels Res. Cent., Dept. Energy Mines Resource, Ottawa, Ontario. Mines Branch Res. Report 1973, R267, 15 p. (copy rec'd)

0-111. DiSALVO, L.H., H.E. GUARD and L. HUNTER
Tissue hydrocarbon burden of mussels as potential monitor of environmental hydrocarbon insult. Envir. Sci. Technol. 9(3), 247-51 (Mar. 1975).

**0-129. FEDERAL WATER POLLUTION CONTROL ADMIN. (x-ref. - MELPAR)
Oil tagging system study (Summary). By Research Division, Environ. & Applied Sciences Center. MELPAR (An American Standard Co., 7700 Arlington Boulevard, Falls Church, VA 22046. For the Federal Water Pollution Control Admin., Dept. of the Interior. Contract No. 14-12-500, MELPAR Ref. 9059, October 1969.

19. Additions to Classified Literature References as of 6/29/76.

*P22-2 BAKER, J.M., 1973
Biological Effects of refinery effluents. PP. 715-23, in: Proceedings of a joint conference on prevention and control of oil spills, March 13-15, 1973. Washington, D.C., sponsored by the Am. Petrol. Inst., EPA, & U.S. Coast Guard. 834 pp.

*P30-2 BEAN, R.M., J.R. VANDERHORST, & P. WILKINSON, 1974 (BATTELLE NORTHWEST LABS)
Interdisciplinary study of the toxicity of petroleum to marine organisms. Battelle Pacific Northwest Laboratories, Richland, Wa. 31 pp.

*P51-2 BOYLON, D.B. & B.W. TRIPP, 1971
Determination of hydrocarbons in seawater extracts of crude oil and crude oil fractions. Nature, 230:44-47.

*P215-3 LA ROCHE, G. R. EISLER, & C.M. TARZWELL, 1970
Bioassay procedures for oil and oil dispersant toxicity evaluation. J. Water Pollut. Control Fed., 42(11):1982-9.

*P452-2 WOELKE, C.E., 1972
Development of a receiving water quality bioassay criterion based on the 48-hour Pacific Oyster "Crassostrea gigas" embryo. Wash. Dept. of Fish. Tech. Report No. 9. 93 pp.

*P452-3 WOELKE, C.G., 1968
Development and validation of a field bioassay method with the Pacific Oyster "Crassostrea gigas" embryo. Ph.D. thesis, U.of Washington, Seattle, Wa. 141 pp.

*P453-2 WOLF, E.G. & J.A. STRAND, 1973 (BATTELLE NORTHWEST LABS)
Determination of acute and chronic effects of treated ballast water on selected aquatic biota from Port Valdez, Alaska. Final report to Alyeska Pipeline Service Company, Bellevue, Wash., prepared by Battelle-Pacific Northwest Laboratories, Richland, WA. 37 pp.

0-134 BECKER, C.D., J.A. LICHATOWICH, M.J. SCHNEIDER, 1973 (BATTELLE NORTHWEST LABS)
Regional survey of marine biota for bioassay standardization of oil and oil dispersant chemicals. Battelle Pacific Northwest Laboratories, Richland, Washington, 99352. For the American Petrol. Inst. Committee on Environmental Affairs. API Publication No. 4167.

0-135 BATTELLE PACIFIC NORTHWEST LABORATORIES, 1974
Study of effects of oil discharges and domestic and industrial wastewaters on the fisheries of Lake Maracaibo, Venezuela. Vol. II. Fate and effects of oil. Battelle Pacific Northwest Labs., Richland, WA, 99352.

0-226 ACKMAN, R.G. & D. NOBLE, 1973
Steam distillation: A simple technique for recovery of petroleum hydrocarbons from tainted fish. J. Fish. Res. Board Can. 30:711-714.

0-227 ANONYMOUS, 1975
GC/MS units advance in state of the art. Chemical and Engineering News, March 24, 1975, p. 65.

0-228 BATTELLE MEMORIAL INSTITUTE, PACIFIC NORTHWEST LABORATORY, 1971
Concept development of a hydraulic skimmer system for recovery of floating oil. EPA, Water Quality Office. Water Poll. Control Res. Series 15080FWP04/71. April 1971, 88 p.

0-229 BROWN, C.W., P.F. LYNCH, M. AHMADJIAN & C.D. BAER, 1975
Weathered petroleum. Advantages of using infrared spectroscopy for identification
American Laboratory 61:59-66.

0-230 CAHNMANN, J.J. & M. KURATSUNE, 1957
Determination of polycyclic aromatic hydrocarbons in oysters collected in polluted water. Analytical Chemistry 29:1312-1317.

0-231 CLARK, R.C., JR., M. BLUMER & S.O. RAYMOND, 1967
A large water sampler, ruptured-disc triggered, for studies of dissolved organic compounds. Deep-Sea Research 14:125-128.

0-232 COLE, R.D., 1971
Recognition of crude oils by capillary gas chromatography. Nature 233:546-548.

0-233 COLEMAN, H.J., J.E. DOOLEY, D.E. HIRSCH & C.J. THOMPSON, 1973
Compositional studies of a high-boiling 370-535 C distillate from Prudhoe Bay, Alaska, crude oil. Analytical Chemistry 45:1724-1737.

0-234 DESHIMARU, O., 1971
Studies on the pollution of fish meat by mineral oils. I: Deposition of crude oil in fish meat and its detection (orig. Japanese). Fisheries Research Board of Canad Translation Series No. 2038. 14 p. (1972).

0-235 DISALVO, L.H., H.E. GUARD & L. HUNTER, 1975
Tissue hydrocarbon burden of mussels as potential monitor of environmental hydrocarbon insult. Environmental Science & Technol. 9:247-251.

0-236 DUNN, B.P. & H.F. STICH, 1975
The use of mussels in estimating benzo(a)pyrene contamination of the marine environment (38971). Proceedings of the Society for Experimental Biology and Medicine 150:49-51.

0-237 FALK, M.R., 1973
Simple apparatus for conducting acute toxicity bioassays under field conditions. Water Research 7:821-822.

0-238 FARRINGTON, J.W. & J.G. QUINN, 1971
Comparison of sampling and extraction techniques for fatty acids in recent sediment Geochimica et Cosmochimica Acta 35:735-741.

0-239 FARRINGTON, J.W. & B.W. TRIPP, 1975
A comparison of analysis methods for hydrocarbons in surface sediments. In: American Chemical Society, ACS Symposium Series, No. 18, Marine Chemistry in the Coastal Environment, pp. 267-284.

0-240 FIELD, F.H. & S.H. HASTINGS, 1956
Determination of unsaturated hydrocarbons by low voltage mass spectrometry. Analytical Chemistry 28:1248-1255.

0-241 FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS (FAO), 1970
Seminar on methods of detection, measurement and monitoring of pollutants in in the marine environment. In: FAO Technical Conference on Marine Pollution and its Effects on Living Resources and Fishing, Rome, Italy, Dec. 9-18, 1970. FIR: MP/70? Rep. 1. 17 p.

-242 GIGER, W. & M. BLUMER, 1974
Polycyclic aromatic hydrocarbons in the environment: isolation and characterization by chromatography, visible, ultraviolet, and mass spectrometry. Analytical Chemistry 46:1663-1671.

-243 GRUENFELD, M., 1973
Extraction of dispersed oils from water for quantitative analysis by infrared spectrophotometry. Environmental Science & Technol. 7:636-639.

-244 GRUGER, E.H., 1975
Round table discussion of assays of petroleum hydrocarbons in research. Outline of discussion. Nov. 21, 1975 (sponsor and/or location unknown).

0-245 GUARD, H.E., L. HUNTER & L.H. DISALVO, 1975
Identification and potential biological effects of the major components in the seawater extract of a bunker fuel. Bull. of Environ. Cont. & Toxicol. 14:395-400.

0-246 HOWARD, J.W., T. FAZIO, R.H. WHITE & B.A. KLIMECK, 1968
Extraction and estimation of polycyclic aromatic hydrocarbons in total diet composites. J. of A.O.A.C. (Association of Official Analytical Chemists) 51: 122-129.

0-247 HUNTER, L., 1975
Quantitation of environmental hydrocarbons by thin-layer chromatography, gravimetry/densitometry comparison. Environ. Sci. & Technol. 9:241-246.

0-248 KAWAHARA, F.K., 1969
Recent developments in the identification of oils by instrumental analyses, Part 1. (and) Part 2: Analyses of oil slicks. CH. Met. ir. 1.11.69 (for the Federal Water Pollution Control Administration ?), pp. 1-10.

0-249 LIJINSKY, W., I. DOMSKY, G. MASON, H.Y. RAMAHI & T. SAFAVI, 1963
The chromatographic determination of trace amounts of polynuclear hydrocarbons in petrolatum, mineral oil, and coal tar. Analytical Chemistry 35:952-956.

0-250 MARTIN, A. & M. BLUMER, 1975
Polycyclic aromatic hydrocarbons: Occurrence and analysis- a partial bibliography. Woods Hole Oceanographic Institute Technical Report, WHOI-75-22. Woods Hole, Mass.

0-251 MIYAHARA, S. & Y. NOZAKI, 1975
Fundamental studies on the thickness of crude oil films on sea-water surfaces. Bull. of the Japanese Society of Scientific Fisheries 41(4):377-382.

0-252 NEFF, J.M. & J.W. ANDERSON, 1973? (manuscr.)
An ultraviolet spectrophotometric method for the determination of naphthalene and alkylnaphthalenes in the tissues of oil-contaminated marine animals. (authors' affiliation: Dept. Biology, Texas A&M Univ.)

0-253 PANCIROV, R.J., 1974
Compositional data on API reference oils used in biological studies: a #2 fuel oil, a bunker C, Kuwait crude oil, and South Louisiana crude oil. (Supported by API under supervision of Chemical Analysis Panel-Task Force on fate of oil of the Committee on Environmental Affairs. Report No. AID/1BA/74. Feb. 5, 1974, 16 p.

O-253 ROBINSON, ?.J., 1971
Low-resolution mass spectrometric determination of aromatics and saturates in petroleum fractions. Analytical Chemistry 43:1425-1434.

O-254 ROSEN, A.A. & F.M. MIDDLETON, 1955
Identification of petroleum refinery wastes in surface waters. Analytical Chemistry 27:790-794.

O-255 VANDERHORST, J.R., C.I. GIBSON & L.J. MOORE, 197? (draft)
The role of dispersion in fuel oil bioassay. 8 p. Battelle, Pacific Northwest Laboratories, Marine Research Laboratory.

O-256 ZAFIROU, O.C., 1973
Improved methods for characterizing environmental hydrocarbons by gas chromatograp
Analytical Chemistry 45:952-956.

O-257 ZITKO, V., 1975
The detection of aromatic and chlorinated hydrocarbons in marine lipids. Fisheries Research Board of Canada, Manuscript Report Series, No. 1349, 14 p.

O-258 ZSOLNAY, A., 1973
Determination of aromatic hydrocarbons in submicrogram qantities in aqueous syster
by means of high performance liquid chromatography. Chemosphere 6:253-260.

20. MISCELLANEOUS (INCLUDES VERY GENERAL ARTICLES; e.g., ECOLOGICAL EFFECTS).

425. CALIFORNIA DEPARTMENT OF FISH AND GAME
Progress report on wildlife affected by the Santa Barbara Channel oil spill (January 28-March 31, 1969). Sacramento, California Department of Fish and Game, 1969.

426. CALIFORNIA DEPARTMENT OF FISH AND GAME
Second progress report on wildlife affected by the Santa Barbara oil spill (April 1-May 31, 1969). Sacramento, California Department of Fish and Game, 1969.

447. IGNATIADES, L., and BECACOS-KONTOS, T.
Ecology of fouling organisms in a polluted area.
Nature, Lond., 225, 293-294, 1970.

474. SIMPSON, A.C.
The Torrey Canyon disaster and fisheries.
Lab. Leafl. Fish. Lab. Lowestoft, No. 18, 43p., 1968.

481. BAKER, J.M.
The effects of oil pollution on salt marsh communities.
Rep. Oil Pollut. Res. Unit, Fld Stud. Coun., 1968, B1-B11, 1968.

482. BAKER, J.M.
The effects of oil pollution and cleaning on salt marsh ecology.
Rep. Fld Stud. Coun., 1969, 3-26, 1969.

483. BAKER, J.M.
Oil pollution in salt marsh communities.
Mar. Pollut. Bull., 1, 27-28, 1970.

484. BAKER, J.M.
The effects of oils on plants.
Envir. Pollut., 1, 27-44, 1970.

549. MITCHELL, C.T., ANDERSON, E.K., and JONES, L.G.
Ecological effects of oil spillages in the sea. Abstract of a paper given at the 42nd Annual Conference of the Water Pollution Control Federation, October 5-10, 1969, Dallas, Texas. 11p. 1969.

550. MITCHELL, C.T., ANDERSON, E.K., JONES, L.G., and NORTH, W.J.
What oil does to ecology.
J. Wat. Pollut. Control Fed., 42, 812-818, 1970.

564. PRIOU, M.-L., and MALLET, L.
Les pollutions par les produits pétroliers et leur conséquences sur le milieu biologique marin. (Pollution by petroleum products and their consequences for the marine biological environment.)
Cah. oceanogr., 20, 445-449, 1968.

839. BATTELLE MEMORIAL INSTITUTE. PACIFIC NORTHWEST LABORATORIES
Oil spill treating agents - A compendium, prepared for the American Petroleum Institute. iv, 281p. Richaldn, Washington, Pacific Northwest Laboratories, 1970.

840. BATTELLE MEMORIAL INSTITUTE. PACIFIC NORTHWEST LABORATORIES
Oil spill treating agents. Test procedures: status and recommendations. Final report, prepared for the American Petroleum Institute. 278p. Richland, Washington, Pacific Northwest Laboratories, 1970.

842. BEYNON, L.R.
The Torrey Canyon disaster: Part two. How to handle the oil once it has started to pollute the sea and the coastline. Oil Gas Int., 8, 6p., February 1968.

851. EDISON WATER QUALITY LABORATORY
Chemical treatment of oil slicks: a status report on the use of chemicals and other materials to treat oil spilled on water. v, 20p. Edison, N.J., Water Quality Laboratory, 1969. (Report ORD-3)

866. LITTLE, ARTHUR D., INC.
Combating oil pollution created by oil spills: report to the Department of Transportation, United States Coast Guard. Vol. 1. Methods. xiv, 151p. Arthur D. Little, Inc., 1969.

867. LITTLE, ARTHUR D., INC.
Oil spill treating agents. Selection based on environmental factors. Report to the American Petroleum Institute prepared by Arthur D. Little, Inc. 55p. Cambridge, Massachusetts, Arthur D. Little, Inc., 1970. (Publication No. 4068)

870. MARCINOWSKI, H.-J.
Removal of oil from water surfaces. A literature survey. 119p. The Hague, Stichting CONCAWE, 1970. (Report No. 27/70)

872. MAYO, F.
Dealing with oil pollution on water and shores.
In: Hepple, P., editor. Pollution prevention. pp. 165-186. London, Institute of Petroleum, 1968.

876. SMITH, J. WARDLEY
Recommended methods for dealing with oil pollution. 22p. Stevenage, Warren Spring Laboratory, 1968. (LR 79 (EIS))

877. SMITH, J. WARDLEY
Problems in dealing with oil pollution on sea and land. J. Inst. Petrol., 54, 358-365, 1968.
Also in: Hepple, P., editor. Scientific aspects of pollution of the sea by oil. pp. 60-67. London, Institute of Petroleum, 1968.

878. SMITH, J. WARDLEY
Oil in the sea. 18p. Stevenage, Warren Spring Laboratory, 1969. (LR 104 (EI))

20.

881. SMITH, J. WARDLEY
Methods of dealing with oil pollution on and close to the shore.
In: Hepple, P., editor. Water pollution by oil: proceedings of a seminar held at Aviemore... 4-8 May, 1970. pp. 205-215.
London, Institute of Petroleum, 1971.

888. WALKUP, P.C., PETERSON, P.L., POLENTZ, L.M., PHINNEY, E.H., SMITH, J.D., and BLACKLAW, J.D.
Study of equipment and methods for removing oil from harbour waters. 189p.
Richland, Washington, Battelle Memorial Institute, Pacific Northwest Laboratories, 1969. (NCEL-CR-70.001)

955. EDISON WATER QUALITY LABORATORY
Research, development, and demonstration projects on oil pollution control.
Oil hazard Mater. Res. Newsl., Suppl. 1, 43p., 1970.

963. CHRISTOL, C.Q.
Oil pollution of the marine environment - a legal bibliography.
University of Southern California, Los Angeles, 1970. (Sea Grant Publication No. 1)

964. INDUSTRIAL INFORMATION SERVICES
Water pollution by oil spillage: a bibliography. 2 vols. Dallas, Texas, Industrial Information Services, Southern Methodist University, 1970.

965. KÄMPFER, M.
Ölverschmutzung: Ursachen - Folgen - Abwehr. 2. (Oil pollution: Origin - consequence - defence. 2. Expanded edition.) 57p. Bonn-Bad Godesberg. Bundesanstalt für Vegetationskunde, 1970. (Bibliography No. 16)

966. NELSON-SMITH, A.
A bibliography of oil pollution.
Fld Stud., 2, (suppl.) 165-196, 1968.

967. RADCLIFFE, D.R., and MURPHY, T.A.
Biological effects of oil pollution - bibliography: a collection of references concerning the effects of oil on biological systems. iv, 46p.
Washington, D.C., Federal Water Pollution Control Administration, 1969.

968. YEE, J.E.
Oil pollution of marine waters: bibliography. 27p. Washington, D.C., U.S. Department of the Interior, Department Library, 1967. (Bibliography No. 5)

986. BATTELLE MEMORIAL INSTITUTE. PACIFIC NORTHWEST LABORATORIES
Oil spillage study: literature search and critical evaluation for selection of promising techniques to control and prevent damage; to Department of Transportation, United States Coast Guard, Washington, D.C. (by G.J. Alkire and others). 280p. Richland, Washington, Pacific Northwest Laboratories, 1967.

987. DEGLER, S.E., editor
Oil pollution problems and policies. iii, 142p.
Washington, D.C., U.S. Bureau of National Affairs, 1969.

988. DENNIS, J.V.
Oil pollution survey of the United States Atlantic coast, with special reference to Southeast Florida coast condition. 83p. Washington, D.C. American Petroleum Institute, Division of Transportation, 1959.

992. MOSS, J.E.
Character and control of sea pollution by oil. vi, 124p. Washington, D.C., American Petroleum Institute, Division of Transportation, 1963.

993. NELSON-SMITH, A.
The problem of oil pollution of the sea.
Adv. mar. Biol., 8, 215-306, 1970.

995. SELECT COMMITTEE ON SCIENCE AND TECHNOLOGY
Report, session 1967-68. Coastal pollution. 47p. London, H.M.S.O., 1968.

997. UNITED STATES. DEPARTMENT OF THE INTERIOR, AND DEPARTMENT OF TRANSPORTATION
A report on pollution of the nation's waters by oil and other hazardous substances. 31p. Washington, D.C., 1968.

998. UNITED STATES. SECRETARY OF THE INTERIOR AND THE SECRETARY OF TRANSPORTATION
Oil pollution: a report to the President.
In: Degler, S.E., editor. Oil pollution: problems and policies. pp. 62-109. Washington, D.C., U.S. Bureau of National Affairs, 1969.

999. WIELOCHOWSKI, A. L.
Oil pollution of the sea - literature review. 44p. 1970. (Unpublished Report)

1005. BIGLANE, K.E.
International aspects of oil pollution control. 31p. Washington, D.C., Division of Technical Support, Federal Water Pollution Control Administration, 1968.

1007. BLUMER, M.
Scientific aspects of the oil spill problem.
Envir. Affairs, 1, (1), 54-73, 1971.

1016. EMIG, C.C.
Essai d'étude de la teneur en gaz d'hydrocarbures dans le mileu marin.
(Study of the hydrocarbon gas content in the marine environment.)
Recl. Trav. Stn mar. Endoume, 57, (Bull. 41), 9-16, 1966.

1017. EMIG, C.C.
Etude de la teneur en gaz d'hydrocarbures des sédiments. II. Etang de Berre.
(Study of the hydrocarbon gas content of sediments. II. Berre Pond.)
Recl Trav. Stn mar. Endoume, 61, (Bull. 45), 359-365, 1969.

20.

1018. FELDMAN, M.L.
The 50-mile ballast-oil dumping prohibited zone off Alaska reconsidered in the light of available data gleaned from significant incidents. 23p. Corvallis, Oregon, Pacific Northwest Wate Laboratory, 1970. (Working Paper No. 77)

1019. GALTSOFF, P.S.
Oil pollution in coastal waters.
Proc. N. Am. Wildl. Conf., 1, 550-555, 1936.

1035. KINNEY, P.J.
Quantitative assessment of oil pollution problems in Alaska's Cook inlet. University of Alaska, Institute of Marine Science, 1970. (Report R-69-16)

1036. LUDWIGSON, J.O.
Oil pollution at sea.
In: Degler, S.E., editor. Oil pollution: problems and policies. pp. 1-20. Washington, D.C., U.S. Bureau of National Affairs, 1969.

1056. ROSEN, A.A., MUSGRAVE, L.R., and LICHTENBERG, J.J.
Pollution of California beaches by oil and grease. Cincinnati, Ohio, R.A. Taft Sanitary Engineering Centre, 1958. (Progress Reports 1-2)

1057. SCOTT, J.
Perspective on offshore pollution.
Petrol. Engr, 41, (5), 61-68, 1969.

1059. SHACKLETON, L.R.B., DOUGLAS, E., and WALSH, T.
Pollution of the sea by oil.
Trans. Inst. Mar. Engrs, 72, 409-439, 1960.

1060. SMITH, D.D., GILMORE, G.A., RICE, A.H., SHENTON, E.H., and ROSER, W.H.
A review of the problem. Characteristics of major oil spills.
In: Proceedings of Industry-Government Seminar on Oil Spill Treating Agents, Washington, D.C., April 8-9, 1970. pp. 9-56. 1970.

1716. LACAZE, J.-C.
Ecotoxicology of crude oils and the use of experimental marine ecosystems.
Mar. Pollut. Bull., 5, 153-156, 1974.

1735. BLUMER, M., HUNT, J.M., ATEMA, J., and STEIN, L.(S.)
Interaction between marine organisms and oil pollution. 97p. Washington, D.C., US Environmental Protection Agency, Office of Research and Monitoring, 1973. (Ecological Research Series No. EPA-R3-73-042)

1736. BOESCH, D.F., and HERSHNER, C.H.
The ecological effects of oil pollution in the marine environment.
In: Boesch, D.F., Hershner, C.H., and Milgram, J.H. Oil spills and the marine environment: (A report to the Energy Policy Project of the Ford Foundation). pp. 1-55. Cambridge, Massachusetts, Ballinger Publishing Company, 1974.

1738. COWELL, E.B.
A critical examination of present practice.
In; Beynon, L.R., and Cowell, E.B., editors. Ecological aspects of toxicity testing of oils and dispersants: (Proceedings of a workshop...) pp. 97-104. Barking, Essex, Applied Science Publishers, 1974.

1746. MIRONOV, O.G.
Biological resources of the sea and oil pollution. 105p. Moscow, Pishchevaya Promyshlennost', 1972. (In RUSSIAN)

1747. MOORE, S.F., CHIRLIN, G.R., PUCCIA, C.J., and SCHRADER, B.P.
Potential biological effects of hypothetical oil discharges in the Atlantic coast and Gulf of Alaska. 126p. Cambridge, Massachusetts, Massachusetts Institute of Technology, Sea Grant Program, 1974. (Report No. MITSG 74-19)

1748. MOORE, S.F., and DWYER, R.L.
Effects of oil on marine organisms: a critical assessment of published data. Wat. Res., 8, 819-827, 1974.

1749. NELSON-SMITH, A.
The effects of oil pollution on shore life.
In: Proceedings of the symposium on the effects of industry on the environment, Orielton, Pembroke, 1970. pp. 36-42. London, Field Studies Council, 1970.

1751. PROGRAMMES ANALYSIS UNIT
The environmental and financial consequences of oil pollution from ships. Appendix 3: the biological effects of oil pollution of the oceans. 276p. Didcot, Programmes Analysis Unit, 1973.

1752. ST. AMANT, L.S.
The petroleum industry as it affects marine and estuarine ecology.
J. Petrol. Technol., 24, 385-392, 1972.

1753. SCARRATT, D.J.
Impact of spills and clean-up technology on living natural resources, and resource-based industry.
Tech. Rep. Fish. Res. Bd Can., No. 428, 141-158, 1974.

1763. WARNER, R.E.
Marine oil pollution - its biological effects and implications.
In: Proceedings of a conference on pollution. pp. 25-29.
Chemical Institute of Canada, 1969.

2200. NADEAU, R.J., and ROUSH, T.H.
Biological effects of oil pollution. Selected bibliography II. 69p. Cincinnati, Ohio, US Environmental Protection Agency, Office of Research and Monitoring, 1972. (Environmental Protection Technology Series No. EPA-R2-72-055)

2215. ATLAS, R.M., and BARTHA, R.
Fate and effects of polluting petroleum in the marine environment.
Residue Rev., 49, 49-85, 1973.

2217. BOESCH, D.F., HERSHNER, C.H., and MILGRAM, J.H.
Oil spills and the marine environment: (A report to the Energy Policy Project of the Ford Foundation) xv, 114p. Cambridge, Massachusetts, Ballinger Publishing Company, 1974.

2222. CLARK, R.B.
Oil pollution and its biological consequences. A review of current scientific literature. 111p. Paper prepared for Great Barrier Reef Petroleum Drilling Royal Commissions. University of Newcastle upon Tyne, Department of Zoology, 1971.

2224. GALTSOFF, P.S.
Biological effects of oil pollution of the sea. 49p. Paper presented at the symposium on biological effects of oil pollution of the sea, Canadian Society of Zoologists and American Society of Zoologists, Burlington, Vermont, USA, 1969.

2225. HOOD, D.W., SHIELS, W.E., and KELLEY, E.J., editors
Environmental studies of Port Valdez. Text, ix, 495p. Data Volume, 800p. Fairbanks, Alaska, University of Alaska, Institute of Marine Science, 1973. (Occasional Publication Nos. 3 & 3A)

2232. MIRONOV, O.G.
Oil pollution and life in the sea. 86p. Kiev, Naukova Dumka, 1973. (In RUSSIAN)

2234. MOSS, J.E.
Petroleum - the problem.
In: Hood, D.W., editor. Impingement of man on the oceans.
pp. 381-419. Wiley-Interscience, 1971.

2235. NELSON-SMITH, A.
Oil pollution and marine ecology. ix, 260p. London, Paul Elek (Scientific Books), 1972.

2236. OTTWAY, S.M.
Some effects of oil pollution on the life of rocky shores. vii, 136p.
University of Wales, 1972. M.Sc. thesis.

2237. PAISH, H., and ASSOCIATES LTD
The west coast oil threat in perspective - An assessment of the natural resource, social and economic impacts of marine oil transport in Southwest B.C. coastal waters. Vol. I. Summary. Vol. II. Main report, 304p. Vol. III. Maps, 34p. Environment Canada, 1972.

2241. REVELLE, R., WENK, E., KETCHUM, B.H., and CORINO, E.R.
Ocean pollution by petroleum hydrocarbons.
In: Matthews, W.H., Smith, F.E., and Goldberg, E.C., editors.
Man's impact on terrestrial and oceanic ecosystems, pp. 297-318. Cambridge, Massachusetts, Massachusetts Institute of Technology Press, 1971.

2242. SWIFT, W.H., BROWN, R.E., KIMMEL, L.V., ORGILL, M.M., PETERSON, P.L., and WADDELL, W.W.
Geographical analysis of oil spill potential associated with Alaskan oil production and transportation systems. 267p. Washington, D.C., US Coast Guard, Office of Research and Development, 1974. (Final Report No. CG-D-79-74)

2243. TEMPLETON, W.L.
Ecological effects of oil pollution.
J. Wat. Pollut. Control Fed., 43, 1081-1088, 1971.

2244. TEMPLETON, W.L.
Ecological effects of oil pollution.
J. Wat. Pollut. Control Fed., 44, 1128-1134, 1972.

2245. UNITED STATES. BUREAU OF MINES.
General report of the Bureau of Mines on pollution by oil of the coast waters of the United States, January 6, 1926.
In: United States. Interdepartmental committee on oil pollution of navigable waters. Oil pollution of navigable waters.
Appendix 3. pp. 35-69. Washington, D.C., US Government Printing Office, 1926.

2246. UNITED STATES. COUNCIL ON ENVIRONMENTAL QUALITY
OCS oil and gas - an environmental assessment. 388p. Washington, D.C., US Council on Environmental Quality, 1974.

2247. UNITED STATES. INTERDEPARTMENTAL COMMITTEE ON OIL POLLUTION OF NAVIGABLE WATERS
Oil pollution of navigable waters. Report to the Secretary of State. 119p. Washington, D.C., US Government Printing Office, 1926.

2248. UNITED STATES. NATIONAL ACADEMY OF SCIENCES. NATIONAL RESEARCH COUNCIL. ENVIRONMENTAL STUDIES BOARD
Issues in the assessment of environmental impacts of oil and gas production in the outer continental shelf.
In: US Council on Environmental Quality. OCS oil and gas - an environmental assessment, pp. NAS-1 to NAS-43. Washington, D.C., US Council on Environmental Quality, 1974.

2249. VAGNERS, J., and MAR, P.
Oil on Puget Sound: an interdisciplinary study in systems engineering. xviii, 629p. Seattle, University of Washington Press, 1972.

2250. WALKUP, P.C.
Water pollution by oil spillage.
J. Wat. Pollut. Control Fed., 43, 1069-1080, 1971.

2251. WASHINGTON, D.C., THE GEORGE WASHINGTON UNIVERSITY
Legal, economic, and technical aspects of liability and financial responsibility as related to oil pollution. 347p. Washington, D.C., George Washington University, Program of Policy Studies in Science and Technology, 1970.

2253. BAALJ, P.K.
Fysische, chemische en biologische aspecten von olieverontreiniging op zee en de bestrijdingervan. (Physical, chemical and biological aspects of oil pollution of the sea and its control.)
Ingenieur,'s Grav., 84, (7), A136-A140, 1972.

2257. BLUMER, M.
Verunreinigung der Gewässer durch Oel. Zum Problem der persistenten Chemikalien in der Umwelt. (Pollution of water by oil. On the problem of persistent chemicals in the environment.) 21p. Paper presented at Eidgenoessische Anstalt fuer Wasserversorgung, Abwassereinigung und Gewaesserschutz, Zurich, Switzerland, May 11 1971. (Separatum No. 398)

2259. BYBEE, R.W.
Compatability of petroleum exploitation with marsh and estuarine ecosystems in Louisiana.
In: Chabreck, R.H., editor. Proceedings of second coastal marsh and estuary management symposium, Baton Rouge, Louisiana, July 17-18 1972. pp. 193-209. Baton Rouge, Louisiana, Louisiana State University, Division of Continuing Education, 1973.

2260. COWELL, E.B.
Oil pollution of the sea.
Nat. Wales, 13, 12-20-, 1972.

2265. DEVANNEY, J.W., III, and STEWART, R.J.
Bayesian analysis of oil spill statistics.
Mar. Technol., SNAME, 11, 365-382, 1974.

2266. DODD, E. N.
Oils and dispersants: chemical considerations.
In: Beynon, L.R., and Cowell, E.B., editors. Ecological aspects of toxicity of oils and dispersants: (Proceedings of a workshop...) pp. 3-9. Barking, Essex, Applied Science Publishers, 1974.

2274. GRAHAM, F., JR.
Oil and Maine coast: Is it worth it? 43p. Augusta, Maine, Natural Resources Council of Maine, 1970.

2275. HERLINVEAUX, R.H.
The impact of oil spillage from tankers moving from Alaska southward along the British Columbia coast. Part 1. Review of significant environmental factors. 48p. West Vancouver, British Columbia, Pacific Environment Institute, (197-?). (Unpublished Report)

20.

2277. JAGGER, H.
The environment aspect: the risks - the weapons.
In: Peters, A.F., editor. Impact of offsho- oil operations, p. 121-144. Barking, England, Applied Science Publishers, 1974.

2286. MACINTYRE, W.G., SMITH, C.L., MUNDAY, J.C., GIBSON, V.M., LAKE, J.L., WINDSOR, J.G., DUPUY, J.L., HARRISON, W., and OBERHOLTZER, J.D.
Investigation of surface films - Chesapeake Bay entrance. 176p. Washington, D.C., US Environmental Protection Agency, Office of Research and Development, 1974. (Environmental Protection Technology Series No. EPA-670/2-73-099)

2295. NELSON-SMITH, A.
Effects of the oil industry on shore life in estuaries.
Proc. R. Soc. (B), 180, 487-496, 1972.

2301. RITCHIE, J.E., JR., ALLEN, F.J., JR., FELTES, R.M., FOOTE, R.Q., and SHORTT, W.A.
Study of offshore and onshore crude oil petroleum systems. 82p. Washington, D.C., US Environmental Protection Agency, Office of Research and Monitoring, 1973. (Environmental Protection Technology Series No. EPA-R2-73-280a)

2310. WARNER, R.E.
Environmental effects of oil pollution in Canada: an evaluation of problems and research needs. 35p. Canadian Wildlife Service, 1969. (Unpublished Report)

20.

*A42. MEINSCHEIN, W.G. (1969)
Hydrocarbons- saturated, unsaturated and aromatic, In Organic Geochemistry, G. Eglinton and M.T.J. Murphy (eds.), Springer-Verglag, New York, chapter 13, p. 330-356, 9 illus., 6 tabls., 45 refs.

*A143. PARKER, B., and G. BARSOM (1970)
Biological and chemical significance of surface microlayers in aquatic ecosystems, Bioscience, vol. 20, no. 2, p. 87-93, 78 refs.

*A162. VAN DER WAARDEN, M., A.L.A.M. BRIDIE, and W.M. GROENEWOUD (1971).
Transport of mineral oil components to grount-water, Part I, Water Res., vol. 5, p. 213-226, 7 illus., 3 tabls., 12 refs.

*A322. BAKER, J.M. (1971)
Successive spillage, Proceedings of the ecological effects of oil pollution on littoral communities, E.B. Cowell (ed.), Inst. of Petrol., London, p. 21-32, 9 illus.

*A388. FELDMAN, M.H. (1970)
The 50-mile ballast-oil dumping prohibited zone off Alaska, reconsidered in the light of available data gleaned from significant incidents, Fed. Water Qual. Admin., Corvallis, Oregon, Pacific Northwest Water La., working paper No. 77, 22 p., i illus., 12 refs.

*A393. GLAESER, J.L. (1971)
A discussion of the future oil spill problem in the Arctic, Proceedings of the joint conf. on prevention and control of oil spills, Sponsored by API, EPA, and USCG, June 15-17, Washington, D.C., p. 479-484, 6 illus., 12 refs.

*A428. BATTELLE MEMORIAL INSTITUTE (1967)
Oil spillage study literature search and critical evaluation for selection of promising techniques to control and prevent damage, Report to Dept. of Transportation, USCG, Washington, D.C., 266 p., 2 illus., 16 tabls. 807 refs.

*A436. HUTCHISON, V.V (1972)
Selected list of Bureau of Mines publications on petroleum and natural gas, 1961-1970, U.S. Dept. of the Interior, Bus. Mines Info. Circular No. 8534, 163 p., 829 refs.

*A440. MOULDER, D.S., and A. VARLEY (1971)
A bibliography on marine and estuarine oil pollution, Lab. of the Mar. Biol. Assoc. of the United Kingdom, 129 p., 1073 refs.

*A442. NELSON-SMITH, A. (1970)
The problem of oil pollution of the sea, Adv. Mar. Biol., vol. 8, p. 215-306, 19 illus., 2 tabls., 353 refs.

N3723-1. MAJORI, L., F. PETRONIO, G. MEDOCLAN, and A. BARBIERI.
Marine pollution by hydrocarbons in the Northern Adriatic Sea. Rev. Int. Oceanogr. Med., 1973, 31-32, p. 137-69.

N3729-3. ATLAS, RONALD M. and RICHARD BARTHA.
Fate and effects of polluting petroleum in the marine environment. Residue Rev., 1973, 49, p. 49-85.

N3740-3. WALDEN, H.
Overloading the sea with waste products. Nucl. Sci. Abstr., 1973, 28(3), 5529.

N3745-2. MOORE, STEPHEN F., ROBERT L. DWYER and ARTHUR M. KATZ.
Preliminary assessment of the environmental vulnerability of Machias Bay, Maine to oil supertankers. Govt. Rep. Announce. (U.S.) 1973, 73(11), 56.

N3760-4. CARSIN.
Pollution of the sea by hydrocarbons. Causes, consequences, protection. Rev. Corps Sante Armees, 1972, vol. 13(3), p. 241-54, in French.

N3765-1. TEMPLETON, W.L.
Industrial wastes. Ecological effects of oil pollution. J. Water Pollut. Contr. Fed., 1972, vol. 44(6), p. 1128-34.

N3770-3. SEVER, JULIA R.
Organic geochemistry of hydrocarbons in coastal environments. Diss. Abstr. Int. B 1972, 32(7), 3825.

N3777-2. BUTTON, D.K.
Petroleum, biological effects in the marine environment. Impingement Man Oceans, 1971, p. 421-9.

O-20. HOOD, DONALD W., Editor.
BOOK: Impingement of Man on the Ocean. John Wiley, 1971 (Price $24.95).

O-2. MASSACHUSETTS INSTITUTE OF TECHNOLOGY.
Staff members. Offshore Oil Task Group Report, 3 volumes. One on primary physical impact of offshore petroleum developments. Two on George Bank petroleum study. These 3 reports not pertinent to our immediate interests. Little or nothing on impact on marine biota.

O-3. ALASKA CORPS OF ENGINEERS.
Final Environmental Impact Statement. Anchorage Alasaka, Sept. 1974, 450 p. Offshore oil and gas development in Cook Inlet, Alaska.

O-4. BOESCH, D.F., C.H. HERSHNER, and J.H. MILGRAM.
BOOK: "Oil Spills and the Marine Environment." Subtitle papers prepared for the energy policy of the Ford Foundation. Ballinger Publishing Co., Cambridge, Mass. (a subsidiary of J.B. Lippincott Co.) 115 p., 1974, price $3.00. This book is pertinent primarily for the lists of references, p. 47-55 and 107-110.

20.

XXX 0-6. FAO.
Directory of Experts on Marine Pollution, FAO Fisheries, Tech. Paper #99 Revision. FAO Rome 1973.

XXXX 0-8. BURISSE, JOHN J. and JAMES E. MORROW.
The Alaskan Arctic Marine Mammals and Fisheries from 5th International Congress on Arctic Oil and Gas Problems and Possibilities, held in May, 1973. Authors: John J. Burisse, Alaska Dept. Fish & Game, Fairbanks and James E. Morrow, Dept. of Biol. Sci., U of Alaska, Fairbanks.

0-9. NELSON-SMITH, A.
The problem of oil pollution in the North Sea. Adv. Mar. Biol. 8: 215-306 (1970).

0-10. MOORE, STEPHEN F. et al.
Potential biological effects of hypothetical oil discharges on the Atlantic Coast and Gulf of Alaska. Report to MIT, Council on Environmental Quality. Report No. MITSG 74-19, April 1, 1974.

0-15. CARTHY, J.D. and DON R. ARTHUR, Editors.
The biological effects of oil pollution on littoral communities. Supplement to Vol. 2 of Field Studies published by Field Studies Council, July 1968. Proceedings of a symposium held at the Ancelton Field Center, Pembroke, Wales, Feb. 17, 18, 19, 1968. About 200 p., including 30 p. bibliography.

0-25. COUNCIL ON ENVIRONMENTAL QUALITY.
OCS Oil and Gas - an environmental assessment. A report to the President by the Council on Environmental Quality. There are 5 volumes - all have the date of April 1974.

0-27 VANCE, G.P.
Control of Arctic Oil Spills. Ocean Industry, Jan. 1971, p. 14-17.

0-28. MAC KAY, D. and W. HARRISON, EDITORS.
Oil in the Canadian Environment. Proceedings of Conference, May 16, 1973, University of Toronto.

0-34. BROOKS, J.W., D.R. BARTONEK, KD.L. LEIN, and A.S. TAHYER.
Environmental influence of oil and gas development in the Arctic slope and Beaufort Seas. U.S. Dept. of Int. Resources Rpt #96, 24 p., 1971.

0-35. GLAESER, J.L. and G.P. VANCE.
A study of behavior of oil spills in the Arctic. Office of Research and Development, U.S. Coast Guard, Washington, 1971.

0-37. GRAINGER, E.H.
Biological productivity of the Southern Beaufort Sea: The physical-chemical envirnoment of plankton. Interim Report of Beaufort Sea Project Study B6 (Part 1) Dec. 1974, Environment Canada, Victoria, B.C.

0-49. LOGAN, W.J.
Oil spill countermeasure study for the Southern Beaufort Sea. Interim Report of Beaufort Sea Project Studies H-1, H2, and H3, 1974. Environ. Canada, Victoria, B.C.

20.

0-51. ENVIRONMENTAL PROTECTION BOARD.
Environmental impact assessment of the portion of the MacKenzie. Gas pipeline from Alaska to Alberta. Write EPA Board, 528 James St., Winnipeg, Manitoba, Canada. Vol. 1, The Board's Opinion, Sept. 1974; Vol. 2, Toward an Environmental Code, Sept. 1974; Vol. 4, Research Reports, Sept. 1974; (Note: Vol. 3 is an Atlas).

0-53. API
Prevention and Control of Oil Spills. June 15-17, 1971. Sheraton Park Hotel, Washington, D.C. API, 1801 K St., N.W., Washington, D.C. (Bob Clark has a copy).

0-56. ENVIRONMENTAL SECRETARIAT.
Environmental cause/effect phenomena relating to technological developments in the Canadian Arctic. Pub. No. NRCC 13688 of the Environ. Secretariat, April 1974, Cost $12.00. Available from publications, NRCC/CNR C, Ottawa, Canada, KIA-OR6.

0-60. BARTHOLOMEW, NAGY and UMBERTO COLOMBO.
Book: Fundamental Aspects of Petroleum Geochemistry. Elsevier Publishing Co., New York, 1967.

0-61. COWELL, E.B., EDITOR.
Book: Ecological effects of oil on littoral community. Applied Science Publishers, Ltd.

0-63. MASSACHUSETTS INSTITUTE OF TECHNOLOGY.
Primary physical impacts of offshore petroleum developments. MIT COM-74-11125. Distributed by National Technical Information Service, U.S. Dept. of Commerce, 5285 Port Royal Road, Springfield, VA 22151, April 1974.

0-65. HOULT, DAVID P. ET AL.
Oil in the Arctic. (Highly theoretical) AD-A010-269, 211 p. Distr. by NTIS, U.S. Dept. of Commerce, 5285 Port Royal Road, Springfield, VA 22151.

(NOTE: **Two asterisks means copy available.)

20. Additions to Classified Literature References as of 3/31/76.

0-91. ISAKSON, J.S., J.M. STORIE, J. VAGNERS, G.A. ERICKSON, J.F. KRUGER and R.F. CORLETT.
Comparison of ecological impacts of postulated oil spills at selected Alaskan locations. Introduction, summary, methodology, evaluation and appendices. June 1975, final report, Volume 1. Prepared for Dept. of Transportation, U.S. Coast Guard, Office of Research and Development, Washington, D.C. 20590. (Document is available to the public through the NTIS, Springfield, VA 22151.)

**0-93 McAULIFFE, C. D.
Surveillance of the marine environment for hydrocarbons. Chevron Oil Field Research Company, La Habra, CA 90631, U.S.A.

**0-95. RAMSEIER, RENE O.
How to melt the Arctic and warm the world. Environment, Vol. 16, No. 4, May 1974.

0-98 ANONYMOUS.
Mechanical removal of surface oil. Effluent and Water Control Journal 11(3): 157(1971).

0-99. BOYLE, C.
Oil pollution of the sea; is the end in sight? Biol. Conserv. 1: 319-27(1969).

0-100. KORNBERG, WARREN.
Concern for the Arctic environment. Science News 97: 486-488 (year not given.)

0-101. BLISS, L.C.
Oil and the ecology of the arctic. Transactions of the Royal Society of Canada 8: 371-372(1970) (Dept. of Botany, Univ. of Alberta) (Good article.)

0-102. SAGE, BRYAN L.
Oil and the Alaskan ecology. New Scientist, Apr. 23, 1970, 175-177.

0-105. HOLMES, ROBERT W., EDITOR.
Oil pollution - an index, 4 vol., 2 by author, 2 by subject. Library code SZ 7173-W-3 037 or GC 1087-C3.

1027. HARTUNG,R. and C.W. KLINGLER.
Concentration of DDT by sedimented polluting oils. Environ. Sci. Technol. 4(5), 407-10(1970).

1228. BAIER, R.E.
Organic films on natural waters: their retrieval, identification and modes of elimination. J. Geophys. Res. 77(27), 5062-75(1972).

O-116. SPANGLER, MILLER B.
Offshore oil developments and policy issues in his "New Technology and Marine Resource Development: A Study in Govt.-Business Coop. New York, Praeger C.1970, p. 129-203, 119 references.

O-124. LOFTUS, TONY.
Unseen dangers of oil. New Scientist 49(737), p. 228, Feb. 4, 1971.

O-126. ROSS, WILLIAM M.
Oil pollution as an international problem. A study of Puget Sound and the Strait of Georgia. Univ. of Washington Press, 1973.

**O-129. FEDERAL WATER POLLUTION CONTROL ADMIN. (x-ref. - MELPAR)
Oil tagging system study (Summary). By Research Division, Environ. & Applied Sciences Center. MELPAR (An American Standard Co., 7700 Arlington Boulevard, Falls Church, VA 22046. For the Federal Water Pollution Control Admin., Dept. of the Interior. Contract No. 14-12-500, MELPAR Ref. 9059, October 1969.

**O-130. PERCY, ROGER.
Fishes of the outer Mackenzie Delta. Beaufort Sea Technical Report #8. December 1975. Beaufort Sea Project, Dept. of the Environment, 512 Federal Bldg 1230 Govt. St., Victoria, B.C. V8W 1Y4.

20. Additions to Classified Literature References as of 6/29/76.

*P24-2 BARCLAY-SMITH, P., 1969
International conference on oil pollution of the sea. 414 p. Illus. Maps. British Museum of Natural History: London England.

*P32-2 BEER, J.V., 1968
The attempted rehabilitation of oiled sea birds. Wildfowl, 19:120-124.

*P196-3 KARRICK, N.L., R.C. CLARK, JR., & R.R. MITSUOKA, EDS., 1972
Symposium on oil pollution, the environment, and Puget Sound. Sponsored by the EPA, NOAA, Wash. DOE, 23-24 Feb. 1972. Seattle, Wash. 36 pp.

*P269-3 MOORE, S.F., G.R. CHIRLIN, C.H. PUCCIA, & B.P. SCHRADER, 1974
Potential biological effects of hypothetical oil discharges in the Atlantic coast and Gulf of Alaska. Report to Council on Environmental Quality, Massachusetts Institute of Technology, Cambridge, Mass. 121 pp.

*P389-2 SMITH, A.L., 1974
The effects of effluents from the Canadian petrochemical industry on aquatic organisms: A literature review. Fish. Mar. Ser., Tech. report No. 472.

*P396-2 ST. AMANT, J.S., 1971
Impacts of oil on the Gulf coasts. Trans. N. Am. Wildlf. Conf., 36:207-219

*P423-3 UNIVERSITY OF WASHINGTON, 1972
Oil on Puget Sound. An interdisciplinary study in systems engineering. U of Wash., Seattle, Wash. 629 pp.

*P461-3 ZABELL, C.E. 1963
The occurrence, effects and fate of oil polluting the sea. Intern. J. Air, Wat. Poll., 7:173-197.

0-138 SMITH, S.Y., & G. SNYDER, 1976
Report for Waterways Experiment Station. Contract #96X3123 0+M General, CE, (607-Y160.66YV6Q). An Annotated Bibliography on the Duwamish River-Elliott Bay Complex w/special reference to biological effects of dredge disposal. Environmental Conservation Division, NWFC, Montlake Blvd. E. Seattle, WA., 79 p.

0-259 ALDRICH, J.W., 1970
Review of the problem of birds contaminated by oil and their rehabilitation. U.S. Dept. of Interior, Division of Wildlife Research, Bureau of Sport Fisheries and Wildlife. Resource Publication 87, Wash., D.C., May, 1970, 23 p.

0-260 AMERICAN PETROLEUM INSTITUTE, 1969
Proceedings joint conference on prevention and control of oil spills. Amer. Petrol. Inst. & Federal Water Pollution Control Administration. Dec. 15-17, 1969, New York, N.Y., 345 p.

0-261 AMERICAN PETROLEUM INSTITUTE, 1973
Proceedings of joint conference on prevention and control of oil spills. March 13-15, 1973, Wash., D.C. Amer. Petrol. Inst., EPA & USCG, 834 p.

0-262 AMERICAN PETROLEUM INSTITUTE, 1975
1975 conference on prevention and control of oil pollution. Proceedings, March 25-27, 1975, San Francisco, Calif. API/EPA/USCG, 612 p.

0-263 ANONYMOUS, 1971
The Borden report of the Trans-Alaska pipeline. Congressional Record- House, June 15, 1971, p. H5226.

0-264 BATTELLE MEMORIAL INSTITUTE, PACIFIC NORTHWEST LABORATORIES, 1967
Oil spillage study, literature search and critical evaluation for selection of promising techniques to control and prevent damage. To Department of Transportation, USCG, Wash., D.C., Nov. 20, 1967. Richland, WA: Battelle Memorial Institute. (Section on "Oil Pollution and Waterfowl," 6-39 to 6-56).

0-265 BOURNE, W.R.P., 1968
Oil pollution and bird populations. In: J.D. Carthy and D.R. Arthur (eds.), the biological effects of oil pollution on littoral communities. Supplement to Vol. 2 of Field Studies. London: Field Studies Council Ltd., pp. 99-121.

0-266 DICKMAN, M., 1971
Preliminary notes on changes in algal primary productivity following exposure to crude oil in the Canadian Arctic. Canadian Field-Naturalist 85:249-251.

0-155 EVANS, D.R. & S.D. RICE, 1974
Effects of oil on marine ecosystems: a review for administrators and policy makers. Fishery Bulletin 72(3):625-638.

0-267 FARRINGTON, J., C.S. GIAM, G.R. HARVEY, P. PARKER & J. TEAL, 1973?
Marine pollution monitoring: strategies for a national program. Deliberations of a workshop held at Santa Catalina Marine Biological Laboratory of the Univ. of Southern Calif., Allen Hancock Foundation, Oct. 25-28, 1973. Sponsored by NOAA 203 p.

0-268 GRAY, W.H. & J. EVERITT (EDS), 1974
Oil on Northern Puget Sound. Proceedings of a seminar, Mount Vernon, Washington, March, 1974. Sponsored and supported by Huxley College of Environmental Studies. Office of Community Development, St. Washington: Univ. Wash., Div. Marine Resources; Wash. St. Univ., Cooperative Extension Service. Publ. by Washington State University, cooperative Extension Service, Pullman, Wash. 99163, Dec. 1974.

0-269 NATIONAL BUREAU OF STANDARDS (U.S.), 1974
Marine pollution monitoring (petroleum). Symposium and workshop. (Preprint, contributed papers). May 13-17, 1974. National Bureau of Standards, Gaithersburg, Maryland. Issued May 20, 1974, 178 p.

0-270 PORRICELLI, J.D., V.F. KEITH & R.L. STORCH, 1971
Tankers and the ecology. The Society of Naval Architects & Marine Engineers, advance copy of paper to be presented at the Annual Meeting, New York, N.Y., Nov. 11-12, 1971, 30 p.

0-271 STANTON, P.B., 1972
Operation Rescue, Cleaning and Care of Oiled Waterfowl. American Petrol. Institute, Wash., d.C., 31 p.

0-224 U.S. DEPARTMENT OF COMMERCE, NATIONAL BUREAU OF STANDARDS AND ENVIRONMENTAL PROTECTION AGENCY, 1975
Workshop on SRM's for offshore drilling-petroleum. Oct. 6-7, 1975, Santa Barbara, Calif. (Program and list of attendees, some personal notes of Karrick).

-272 U.S. FISH AND WILDLIFE SERVICE, 19??
Appendix: ecological and physiological effects of oil on birds. (draft). U.S. Fish and Wildlife Service, Patuxent Wildlife Research Center, 7p.

-273 WARD, N.C. & W.J. EDWARDS, 1969
Seattle area oil waste disposal facility study. City of Seattle, Port of Seattle, Municipality of Metropolitan Seattle, King County, Washington Water Pollution Control Commission. Prepared by: Cornell, Howland, Hayes & Merryfield, Engineers and Planners, Seattle, Washington, Aug., 1969, Record No. S5064.0. 51 p.

QUARTERLY REPORT

Contract No. 03-5-022-56
Research Unit # 123
Reporting Period 7/1-9/30/76
Number of Pages 2

ACUTE TOXICITY-PACIFIC HERRING ROE IN THE GULF OF ALASKA

Dr. Ronald L. Smith
Associate Professor of Zoology/Marine Science
University of Alaska
Fairbanks, Alaska 99701

October 1, 1976

QUARTERLY REPORT

I. Task Objectives

Objectives for this quarter included hiring and overseeing a technician for the hydrocarbon analyses. We have also tried to make arrangements for scanning electron microscopy of control and experimental herring larvae.

II. Field and Laboratory Activities

Activities were confined to the laboratory. Laboratory procedures involved extraction of both water samples and tissue samples. In addition, we began gas chromatographic analysis of both tissue and water extracts.

III. Results

To date, most of the samples necessary for meaningful interpretation have been run through the gas chromatograph. We have yet to quantify the peaks on the chromatograph charts (the instrument doesn't integrate for us). Arrangements have been made to have our larvae processed for scanning EM. This activity will be completed in October.

IV. Problems Encountered

The only problems encountered in this quarter have been associated with instrumentation. The GC has been "down" for a total of about two and a half weeks.

OCS COORDINATION OFFICE

University of Alaska

ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: September 30, 1976

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 18 R.U. NUMBER: 123

PRINCIPAL INVESTIGATOR: Dr. R. L. Smith

No environmental data are to be taken by this task order as indicated in the Data Management Plan. A schedule of submission is therefore not applicable[1].

NOTE: [1] Data Management Plan has been approved and made contractual.

RU# 183

&

RU# 305

NO REPORTS WERE RECEIVED

Final reports are expected next quarter

Quarterly Report

Contract R7120817
Research Unit 332
Reporting Period June-Sept 1976
Number of Pages 39

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

Bruce B. McCain,[1,2] Harold O. Hodgins,[1]
S. R. Wellings,[2] and William D. Gronlund[1]

[1]Environmental Conservation Division
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
Northwest Fisheries Center
Seattle, Washington 98112

[2]Department of Pathology
School of Medicine
University of California
Davis, California 95616

(1)

Quarterly Report

I. Task Objectives

Task A-28. Determine by field and literature studies the incidence and pathology of disease presently existing in fish, shellfish, birds, and mammals for use in evaluating future impacts of petroleum-related activity.

II. Field and Laboratory Activities

A. Ship Schedule

Vessel: NOAA Ship MILLER FREEMAN

Cruise: RP-4-MF-76B

Dates: Leg I: September 1 - 24, 1976

Leg II: September 29 to October 15, 1976

B. Scientific Party

1. Field Activities

Leg I and Leg II:

William D. Gronlund

NMFS, NOAA, NWFC

Role: Party Chief, Assisting in the examination of fish and invertebrates for pathological conditions, processing of biological data, autopsying of animals, and preparation of the cruise report.

Katherine King

NMFS, NOAA, NWFC

Role: Invertebrate pathologist, concerned primarily with the examination and autopsy of invertebrates for abnormalities, and also participating in the processing of fish.

2. Laboratory Activities

Bruce B. McCain, PhD

Cooperating Investigator

NMFS, NOAA, NWFC; and employed by the Department of Pathology, School of Medicine, University of California (Davis).

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

Mark S. Myers

Affiliation in the same as Dr. McGain

Role: Performs microbiological tests and participates in data analysis and computer analyses.

S. R. Wellings, MD, PhD

Department of Pathology, School of Medicine, University of California (Davis).

Role: Coordinates histopathological analyses of tissue specimens.

Glen McCarn, PhD

Affiliation is the same as Dr. Wellings.

Role: Performs histopathological analyses of tissue specimens.

C. Methods

1. Field procedures

During the present cruise of the NOAA ship MILLER FREEMAN our personnel will be using the same procedures for examining fish as described in our June 1976 Quarterly Report. Because of our increased emphasis on invertebrates during this cruise, some modifications in our protocol were made. Invertebrates decompose rapidly, therefore special precautions are being taken to keep animals alive until they can be examined. These precautions include using aerators in cooled storage containers, and examining the most fragile organisms first. Also, new dimensions, such as carapace and shell diameters, are replacing the length measurements of fish.

In addition, invertebrates with no obvious pathological conditions are being collected at various sampling sites and will be returned to the laboratory for histological examination. This procedure was necessitated by the fact that a large number of abnormalities in invertebrates are detectable only by microscopic examination of sectioned and stained tissue.

The protocol used by our personnel for handling and storing specimens for enzyme studies, performed by OCSEAP RU 74, is described in the Quarterly Report submitted by RU 74.

2. Laboratory Procedures

Specimens and data obtained during cruise M761 of the NOAA ship MILLER FREEMAN (March 28 to June 4, 1976) in the Bering Sea have been subjected to three main laboratory procedures: histopathological, microbiological, and data analysis.

Tissue specimens received for histopathological examination were processed using standard procedures. Briefly, the blocked, paraffin-embedded and sectioned tissues were stained by a variety of techniques, including hematoxylin and eosin, Masson's trichrome, Oil-Red-O, and the Fuelgen technique. These sections were examined by at least three histopathologists, and the resulting interpretations were a composite of their opinions.

The microbiological procedures performed were concerned primarily with characterizing disease-specific bacteria isolated from Pacific cod (Gadus macrocephalus) skin ulcers. Standard taxonomic tests used included Gram stain, Kovac's oxidase test, sugar utilization media, motility determinations, flagella stains, gelatin liquefaction, and pigment production on Trypticase Soy Agar.

Data analysis has consisted of preparing a data management format for a computer program and corresponding data sheets, transcribing all of our 1976 biological data to the new data sheets, and the information on the data sheets was keypunched on computer cards. In addition, a large portion of the data concerning fish with pathological conditions was analyzed manually in order to establish the geographical distribution of diseased fish, and to determine the age and length frequencies and growth rates of fish with abnormalities versus similar parameters for the total population of fish of the same species captured in the same general areas of the Bering Sea. Data for total populations were obtained from the Resource Assessment and Conservation Engineering Division (OCSEAP RU 175) NWFC, Seattle.

D. Sample Localities

The sampling stations used during cruises M761 and RP-4-MF-76B by the NOAA ship MILLER FREEMAN in the Bering Sea were/are the same as RU 175.

E. Data collected or analyzed

1. Number and types of samples

The only new samples collected are those fish and invertebrates presently being collected aboard the NOAA ship MILLER FREEMAN in the Norton Sound and the Chukchi Sea.

2. Number and types of analyses

About 50 tissue samples have been examined histologically, and 58 bacterial isolates were classified using 30 taxonomic criteria.

III. Results

A. Field activities

Field activities aboard the NOAA ship MILLER FREEMAN during cruise RP-4-MF-76B are presently underway and will not be completed until around October 15, 1976.

We have continued to cooperate with Mr. Terry Bendock of the Alaska Department of Fish and Game (OCSEAP RU 233) in his study of fishes in the Beaufort Sea. In July 1976, he was sent a manual describing the types of pathological conditions that might be encountered in the Beaufort Sea and the procedures necessary for preserving specimens and transporting them to our laboratory. The manual contained both black and white and color prints of known fish diseases. As yet, no samples have been received from Mr. Bendock.

B. Laboratory activities

As was mentioned in the previous Quarterly Report, five main pathological conditions were found among demersal fishes in the Bering Sea during the spring of 1976. The affected species, associated pathological conditions, and the overall average frequencies of each condition were as follows: Pacific cod, pseudobranchial tumors, 8.7%; Pacific cod, skin lesions, 1.6%; pollock (*Theragra chalcogramma*), pseudobranchial tumors, 1.7%; yellowfin sole (*Limanda aspera*), lymphocystis, 2.8%; and rock sole (*Lepidopsetta bilineata*), epidermal papillomas, 1.3%. The results of laboratory analyses of these diseases to be described here will be divided into histopathology, microbiology, and data analysis.

1. Histopathology

Pseudobranchial tumors of cod. The gross appearance of the cod tumors was the same as previously described by us in the April 1976 Annual Report. Briefly, they ranged in color from yellow, to pink, to brown. They were oval-shaped, smooth-surfaced, extended into the pharyngeal cavity, and ranged in size from just larger than the normal pseudobranch to 50 x 30 x 20 mm. With two possible exceptions, all of the tumors were bilateral. Bilateral tumors usually had similar dimensions. The tumors often had necrotic areas on the surface and normal-appearing pseudobranchial tissue was located on the surface or in the interior of each tumor. In one cod with bilateral tumors, a metastasized tumor was also found attached to a gill filament. This tumor was oval, cream-colored, about 5 mm in diameter. The identity of the metastisized tumor was confirmed by histological examination (Figure 1).

The most common histopathological properties of the pseudobranchial tumors were the separation of normal-appearing pseudobranchial tissue from the tumor tissue by a connective tissue capsule, and the presence of disease-specific cells known as X-cells, These cells are also found in other marine fish tumors, and are characterized by having a pale nucleus and a large intensely staining nucleolus. The metastasized cod tumor also contained X-cells (Figure 2).

Pollock Pseudobranchial Tumors. The pollock pseudobranchial tumors and the cod tumors were usually grossly similar in color, shape and texture (Figure 3). However, the pollock tumors were often less protruding, tending to extend up into the roof of the pharynx; and six pollock had unilateral tumors. Also, several pollock were found to have metastasized tumors in the gills and in the peritoneal cavity. In general, the primary tumors were smaller than cod tumors, ranging up to 35 x 20 x 10 mm. The histological characteristics of the pollock tumors were often similar to those described for cod (Figure 4). The primary tumors were often found to be invading the adjoining operculum. Both primary and metastasized tumors contained X-cells.

Epidermal Papillomas of Rock Sole. The epidermal papillomas of rock sole grossly and histologically resembled similar tumors described for several species of pleuronectids along the western coast of North America (see April 1976 Annual Report). The tumors ranged in size from 3 x 3 x 2 mm to 100 x 70 x 10 mm. They were brown to black, elevated, with a papillary appearance. The tumors were located randomly on the body surface, and frequently a tumor had extended to both sides of a fish, with both sides being mirror images of each other. No metastasized tumors were identified.

Lymphocystis of Yellowfin Sole. Lymphocystis (a virus-caused disease) of yellowfin sole has been characterized in previous reports as having variously shaped and colored growths on fins and body surfaces. These growths, ranging in size from 1 mm in diameter to 20 x 10 x 5 mm, were of three basic types:(1) single or clusters of translucent, round bodies about 1 mm in diameter, (2) small red sacs on the ends of fin rays, and (3) red to grey amorphous growths. All these types had in common the presence of small round bodies, which, as will be mentioned below, are hypertrophied fish cells. Fin erosion was associated with about 10% of the cases where lymphocystis growths were on fins. Most growths were found on the "blind" side.

The histological properties of lymphocystis growths were extensively described in the previous Annual Report. The growths on yellowfin sole contained hypertrophied cells about 0.1 to 1.5 mm in diameter. These cells contained cytoplasmic inclusion bodies which were composed of hexagonally-shaped virions about 200 mm in diameter.

Skin Lesions of Pacific Cod. Two main types of lesions were observed on Pacific cod, an ulcer (Figure 5) and a ring-shaped lesion (Figure 6). The ulcers were roughly circular and ranged in size from approximately 1 to 50 mm in diameter. The colors of the ulcers were either pale white or red (hemorrhagic) with dark pigment concentrated in the margin of the surrounding epidermis. Between 1 and 25 ulcers were observed for each affected fish. The ring-shaped lesions were characterized by a 0.5 to 1 cm wide, cream colored strip, sometimes having hemorrhagic foci, around a normal-appearing circular patch of epidermis. These lesions were about 1 to 4 cm in diameter. The number of ring-shaped lesions per diseased fish ranged from 1 to 5.

Histological examinations of the skin ulcers revealed that in most cases the epidermis, including scales, was absent from the center of the lesion. Less often, portions of the dermis were also gone. The white covering over some ulcers was residual necrotic epidermis. The periphery of the lesions was hyperemic, hemorrhagic, and contained numerous inflammatory cells (lymphocytes and macrophages) and fibrous cells (Figure 7). Microorganisms have not yet been observed histologically in the ulcers.

The ring-like lesions had very unusual, but as yet undefined, histological properties. The epidermis and the stratum spongiosum (tissue directly beneath the epidermis) were the only layers of the skin obviously affected by this condition (Figure 8). In the epidermis were large bodies, about four times the size of a normal mucous cell, which contained a very basophilic center surrounded by an eosinophilic margin (Figure 9). Small eosinophilic bodies were observed in this margin and were distributed in the basophilic center. Occasionally the large bodies were seen in the process of releasing their contents into the spaces surrounding the epidermis (Figure 9). At this time, the identity of the large bodies or the eosinophilic bodies is not known. In some cases, the stratum spongiosum adjacent to the large bodies contained infiltrates of inflammatory cells, suggesting the bodies were infectious organisms.

2. Microbiology

Attempts were made to isolate bacteria and fungi from all of the above mentioned pathological conditions, with the exception of lymphocystis. The only condition from which bacteria were routinely isolated was the skin ulcers of Pacific cod. Ulcers from 7 different cod yielded bacterial isolates, sometimes in pure culture, which so far have proven to be essentially taxonomically identical. These isolates have in common the following properties: they are Gram negative, motile by means of a polar flagella, rod-shaped, generally unable to utilize sugars, Kovac's oxidase positive, able to liquefy gelatin, and they produce 0.5 to 2 mm white colonies on agar media.

3. Biological Data Analysis

Three main types of analyses have so far been performed on available data on the biological properties (age, sex, length, etc.) of fish with pathological conditions and of fish representing the total catches of each of the affected species. These analyses include: the geographical distribution of each condition, age frequency distribution, and growth curves.

Geographical Distribution. The distributions of each of the five major pathological conditions are plotted in Figures 10 to 14. Pacific cod (Figure 10) and pollock (Figure 11) with pseudobranchial tumors were captured over most of the area where these species were present. The distribution of rock sole with epidermal papillomas appeared to be depth related, with the shallowest stations (47 to 55 meters) having the highest tumor frequencies (Figure 12). Yellowfin sole with lymphocystis were most often captured in the southeastern Bering Sea, north of Unimak Island (Figure 13). The highest prevalence of Pacific cod with skin ulcers was located northwest of Unimak Island (Figure 14).

Age Frequency Analyses. Figures 15 to 18 contain age frequency plots for pollock and Pacific cod with pseudobranchial tumors, skin tumors of rock sole, and yellowfin sole with lymphocystis. Similar data for Pacific cod with skin lesions was not treated in this manner because the variety of skin lesions found suggests that more than one type of disease process may be present.

The patterns of age distribution for the total Pacific cod population and tumor-bearing cod were similar, except that the modal frequencies differed by one year (Figure 15). This difference may simply reflect that the data for the tumor-bearing fish was obtained in 1976 and the data for the general cod population was taken in 1975.

Both male and female pollock in the total population had very similar age distributions for fish 1 to 5 years old (Figure 16). During this same period, however, 2.3 times more male pollock had tumors than did female pollock. After age six, there were about twice as many females as males in the total population, while the relative numbers of tumor-bearing pollock of both sexes decreased to very low levels. As will be discussed below, there are several explanations for the difference between the numbers of male and female pollock after age 6. One of these possibilities is that most of the tumor-bearing male pollock are removed from the general population by age 6.

The age distribution among females in the total rock sole population was bimodal in 1975, while males had a unimodal pattern (Figure 17). Of interest is the fact that about 20 times more male rock sole of ages 2 to 3 had epidermal papillomas than did females. The implications of these findings will be mentioned later.

Lymphocystis growths on yellowfin sole were detected on fish 5 years and older. Although the total population had a bimodal distribution with peaks at 6 and 8 years, the diseased sole had a single mode corresponding to a mode at 8 years for the total population.

Growth Analyses. Age versus the average length of each age class was plotted for all of the diseases except cod skin lesions (Figures 19 to 22). The data used to prepare these plots are listed in Tables 2 to 5.

The growth of tumor-bearing cod appeared to be consistently depressed for fish aged 2 to 4 years (Figure 19). After 4 years of age, the difference in growth continued for females, but became difficult to interpret for males. Determinations of significant differences between the age/length characteristics of diseased cod and the total cod samples have not been performed, pending the arrival of the 1976 data on total cod samples and computer analyses.

Because significant numbers of tumor-bearing pollock were found only between the ages of 2 and 5 years, only the growth characteristics during this period will be considered. The growth rates of the total population and diseased pollock were quite similar between 2 and 3 years of age (Figure 20). After 3 years of age, however, an apparent depression in growth among fish with tumors continued up through age 5.

The growth characteristics of the total population and rock sole with skin tumors (Figure 21) and yellowfin sole with lymphocystis (Figure 22) show no clear differences.

IV. Preliminary Interpretation of Results

The causes of all but possibly two of the pathological conditions of demersal fishes found near the outer continental shelf of the Bering Sea 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. The remaining conditions, cod and pollock pseudabranchial tumors and epidermal papillomas of rock sole, are neoplasia of unknown cause (s).

The age ranges of tumor-bearing cod and pollock were 2 to 5 years and 2 to 11 years, respectively. The upper age limit of the tumor-bearing cod corresponds to that of the total cod sample. Cod normally live to 10 years or older. Tumors were not found in fish of both species younger than 2 years; this either suggests that fish less than 2 years are not susceptible to the tumor-inducing factor, or that tumors are not as easily detected in younger fish. The latter possibility is favored.

Several cod and pollock with pseudobranchial tumors were found to have secondary tumors. The existence of these metastasized tumors indicates that the primary tumors should be called pseudobranchial carcinomas. In addition, since secondary tumors have been found associated with tissues besides the pseudobranchs, the possibility exists that critical organs could be invaded and their function impaired.

Therefore, the depressed growth rate observed for cod and pollock with tumors could be brought about by the above-mentioned effect of secondary tumors; by competition between tumor and normal tissue for nutrients; by physical obstruction of the pharynx by primary tumors; by the primary tumors, since they are often necrotic, serving as sites for invasion by bacteria and other organisms; and by unknown physiological and toxicological effects of tumors on their hosts.

Another indication of the deleterious effects of pseudobranchial tumors was suggested by the age frequency distributions. Twice as many pollock males between the ages of 2 to 4 years had tumors than did females of the same age. Correspondingly, twice as many females as males between the ages of 6 and 14 years were captured. Thus, pollock males may be predisposed to having the tumors at an early age and may be subsequently removed from the population. Other possible explanations for the reduced males may be the following: (1) males may move away in greater numbers from the sampling area, (2) males may not live as long as females, and (3) males may be more susceptible to certain environmental hazards.

Rock sole larvae are initially pelagic, then they settle onto beaches. Gradually, as they grow older, they move into deeper water. Therefore, since epidermal papillomas are most commonly found on young fish, it was not surprising that two of the shallowest stations sampled during 1976 yieldest rock sole with epidermal papillomas at frequencies of 59 and 21%.

Approximately 20 times more rock sole males between 2 and 3 years of age had skin tumors than did females of the same age. This result could be interpreted to mean that the rock sole males are more predisposed to the papillomas, and may be partially account for the decline in the number of males over 5 years old as compared to females in the later age classes.

Lymphocystis was not detected on yellowfin sole younger than age 5. Catch data from the Bering Sea from previous years indicate that these fish do not join the characteristically dense schools until approximately age 5. Thus, this crowding phenomenon may facilitate the initiation and spread of the disease. In support of this theory is the concentration of sampling stations yielding yellowfin sole with high disease frequencies north of Unimak Island. This area corresponds to the location of such large schools.

Cod skin ulcers were of two basic types: one type was white and the other red and hemorrhagic. Both appear to be histogenically related, with the white ulcer being the earlier form of the hemorrhagic lesion. A bacterial cause for this condition is presently favored because identical bacteria were isolated from similar ulcers on 7 different fish from separate hauls.

The ring-like lesions found on cod skin may or may not be related to the skin ulcers. The large basophilic bodies located in the epidermal portion of the rings appear to be caused by an as yet unclassified protozoan parasite.

V. Problems encountered/recommended changes.

No significant problems were encountered.

VI. Estimate of funds expended

Subcontracted to the University of California (Davis)

Table 1. Disease frequency data for each station plotted in Figures 10 to 14.

STATION POSITION	NO. OF HAULS	COD #	COD ULCER%	COD TUMOR%	POLLOCK #	POLLOCK %	YELLOWFIN SOLE #	YELLOWFIN SOLE %	ROCK SOLE #	ROCK SOLE %
		NUMBER OF FISH EXAMINED AND FREQUENCY OF DISEASES								
1	1	NC*	-	-	NC	-	42	29	17	59
2	2	3	0	0	12	0	337	12	316	21
3	2	109	2	15	452	0	NC	-	418	0.2
4	3	563	0	15	706	0.4	NC	-	901	0
5	1	29	0	10	128	1	96	31	113	0
6	2	44	0	9	374	11	278	14	231	0
7	1	55	0	27	215	0	171	17	374	0
8	1	17	0	0	7	0	118	11	NC	-
9	2	NC	-	-	NC	-	477	4	18	6
10	2	24	0	25	395	5	170	5	161	1
11	2	52	0	19	115	2	602	4	515	1
12	2	45	7	31	332	14	NC	-	299	0.3
13	1	99	10	11	175	5	NC	-	203	0
14	2	109	17	6	531	1	NC	-	224	0
15	2	108	5	4	NC	-	NC	-	NC	-
16	3	90	17	2	165	0	NC	-	NC	-
17	2	64	2	0	146	1	NC	-	NC	-
18	2	88	3	2	483	0.2	NC	-	NC	-
19	2	39	5	10	462	1	NC	-	NC	-
20	2	64	0	19	202	5	NC	-	193	0
21	5	379	3	3	NC		NC	-	249	0
22	1	51	0	0	53	2	NC	-	70	0
23	2	121	2	6	253	1	NC	-	173	0
24	2	64	2	16	202	5	NC	-	193	0
25	1	NC	-	-	NC	-	79	0	NC	-
26	2	73	0	23	92	0	14	0	163	0
27	2	166	0	21	62	0	62	0	25	0
28	1	659	0	28	NC	-	NC	-	110	0
29	2	NC	-	-	NC	-	NC	-	263	0
30	2	27	0	7	148	1	192	3	298	1
31	2	180	0	16	125	0	94	0	131	0
32	2	27	0	52	41	2	41	2	185	0
33	1	33	0	0	NC	-	104	0	12	0
34	2	134	0	0	2	0	386	0	235	0
35	2	184	0	1	11	0	383	0	161	1
36	1	NC	-	-	NC	-	517	0	NC	-
37	2	NC	-	-	NC	-	112	0	NC	-
38	2	144	0	6	434	1	NC	-	112	0
39	2	28	0	0	321	1	560	0	81	0
40	1	12	0	0	266	5	105	0	39	0
41	1	NC	-	-	NC	-	75	0	NC	-
42	3	118	0	4	279	0	NC	-	94	0
43	2	34	0	3	575	0	147	0	138	0
44	1	30	0	7	82	1	88	0	3	0
45	1	11	0	9	165	4	191	0	NC	-
46	1	2	0	0	56	5	603	0	NC	-
47	2	6	0	0	20	0	NC	-	9	0
48	1	44	0	14	265	1	NC	-	54	0
49	1	12	0	25	120	2.5	NC	-	NC	-
50	3	99	0	5	74	0	NC	-	35	0
51	2	3	0	0	76	0	NC	-	38	0
52	1	18	0	6	41	0	9	0	8	0
53	1	NC	-	-	NC	-	250	0	NC	0
54	1	NC	-	-	NC	-	433	0	NC	-
55	1	NC	-	-	NC	-	543	0	NC	-
56	1	342	0	0	NC	-	240	0	NC	-
57	1	18	0	0	NC	-	112	5	4	0
58	1	NC	-	-	NC	-	240	0	NC	-
59	1	NC	-	-	NC	-	137	0	NC	-
60	1	97	0	6	124	1	NC	-	112	0

*NC = none caught.

Table 2

Average fork length related to age in "Total Catch" of Pacific cod (*Gadus macrocephalus*) in the Bering Sea, and in cod affected with pseudobranchial tumors in the same region.

DESCRIPTION OF SAMPLE	AGE (years) 0	1	2	3	4	5	6	7
TOTAL CATCH MALES								
frequency	12	36	105	33	2			
ave. length(mm)	236.7	367.2	472.2	616.9	630.0			
TOTAL CATCH FEMALES								
	10	33	79	57	3			
	243.0	375.2	483.5	611.9	823.0			
DISEASED MALES								
	0	0	30	85	54	12	1	
	-	-	337.2	469.5	561.0	700.4	780.0	
DISEASED FEMALES								
	0	2	21	70	66	13		
	-	297.0	329.1	461.3	563.6	704.9		
TOTAL CATCH MALES&FEMALES								
(Observer	0	27	67	67	51	27	23	16
Program Data)	-	356.0	440.0	551.0	630.0	692.0	745.0	793.0

Note: The age and length data for "Total Catch" of cod was derived from an area-wide sampling program conducted by the National Marine Fisheries Service in the Bering Sea in 1975. Additional general age data was derived from scale sampling of cod throughout the Bering Sea by U.S. fisheries observers aboard Japanese, Russian and Polish fishing vessels. Age-length data for diseased cod was collected on the spring 1976 cruise of the NOAA ship Miller Freeman.

Table 3

Average fork length related to age in "Total Catch" of pollock (<u>Theragra chalcogramma</u>) in the Bering Sea, and for pollock affected with pseudobranchial tumors in the same region.

DESCRIPTION OF SAMPLE	AGE (years) 1	2	3	4	5	6	7	8	9	10	11	12	13	14
TOTAL CATCH MALES(1976)														
frequency	16	96	62	81	11	10	19	30	29	22	7	2	2	1
ave. length(mm)	135.0	226.5	317.3	369.1	441.8	463.0	508.9	505.0	523.8	522.7	544.3	585.0	565.0	640.0
TOTAL CATCH FEMALES(1976)														
	16	89	66	81	19	11	25	47	50	42	44	11	7	1
	136.3	222.3	312.9	372.2	450.0	484.6	509.6	524.9	553.2	573.0	581.0	602.0	623.0	670.0
TOTAL CATCH MALES(1975)														
	129	344	526	121	51	60	65	82	76	22	17	8	2	
	169.2	254.4	332.7	405.6	441.2	469.3	486.0	499.3	517.1	533.3	508.1	535.0	640.0	
TOTAL CATCH FEMALES(1975)														
	127	367	489	143	74	72	73	96	111	87	44	24	15	8
	173.1	254.3	335.2	413.1	437.8	480.6	504.4	517.7	547.3	572.6	600.9	643.7	601.0	662.0
DISEASED MALES														
	0	20	27	21	10	1	2	0	0	0	0	0	0	0
	-	222.8	282.5	316.6	371.1	390.0	476.5	-	-	-	-	-	-	-
DISEASED FEMALES														
	0	11	9	12	3	0	0	2	0	1	2	0	0	0
	-	225.8	302.3	330.8	382.0	-	-	45.5	-	490.0	560.0	-	-	-

Note: Age and length data for "Total Catch" of pollock was derived from an area-wide sampling program conducted by the National Marine Fisheries Service (NMFS) in 1975 and 1976. The data for diseased pollock was collected on the spring 1976 cruise of the NOAA ship <u>Miller Freeman</u> in the Bering Sea.

Table 4

Average fork length related to age in "Total Catch" of rock sole (<u>Lepidopsetta bilineata</u>) in the Bering Sea, and in rock sole affected with epidermal papillomas from the same region.

DESCRIPTION OF SAMPLE	AGE (years) 2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
TOTAL CATCH MALES															
frequency	16	43	29	125	78	50	48	33	22	9	3				
ave. length(mm)	137.5	161.4	188.3	224.6	245.3	274.2	276.3	277.6	290.5	324.4	316.7				
TOTAL CATCH FEMALES															
	6	35	47	157	119	26	40	60	149	61	23	8	5	0	1
	136.7	166.9	198.1	237.5	267.0	286.0	320.0	336.7	359.3	375.7	400.4	401.3	438.0	-	400.0
DISEASED MALES															
	20	26	8	3	3	1	2	0	1	1					
	93.0	134.1	164.9	201.0	224.7	271.	268.5	-	360.0	325.0					
DISEASED FEMALES															
	2	8	3	4	0	1	1	1							
	138.5	194.4	245.7	241.8	-	275.0	340.0	273.0							

Note: Age and length data for "Total Catch" of rock sole is derived from Bering Sea cruises in 1975 by various NOAA vessels, and data for diseased fish is from the spring 1976 cruise of the <u>Miller Freeman</u> in the Bering Sea.

Table 5

Average fork length related to age in "Total Catch" of yellowfin sole (<u>Limanda aspera</u>) in the Bering Sea, and yellowfin sole affected with lymphocystis in the same area.

DESCRIPTION OF SAMPLE	AGE (years) 2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
TOTAL CATCH MALES															
frequency	24	21	38	41	112	64	129	63	33	17	13	17	5	12	6
ave. length(mm)	87.5	109.1	126.1	149.0	184.6	216.4	235.0	262.1	282.7	297.7	292.3	306.5	318.0	339.0	338.0
TOTAL CATCH FEMALES															
	6	30	42	61	135	77	119	95	37	22	17	23	11	13	8
	85.0	107.0	124.5	154.4	188.5	222.7	245.8	271.5	300.3	310.4	316.5	323.9	328.2	345.4	338.7
DISEASED MALES															
				1	7	15	22	9	9	2	1	2	1		
				163.0	193.0	209.0	227.0	241.0	252.0	275.0	260.0	283.0	313.0		
DISEASED FEMALES															
					6	19	20	18	8	4	3	1	4		
					196.3	211.6	232.0	257.3	274.5	265.0	286.0	300.0	322.2		

Discussion: Figure describes the growth pattern of "Total Catch" of male and female yellowfin sole (<u>Limanda aspera</u>), compared to the growth pattern of the same species affected with lymphocystis disease.

Note: The "Total Catch" data is derived from 1975 sampling cruises throughout the Bering Sea by various NOAA vessels. The disease data was collected on Leg I of the <u>Miller Freeman</u>'s spring 1976 cruise in the same area.

Figure 1. Section of a secondary pseudobranchial tumor attached to the gill filament of a cod.(Hematoxylin and Eosin)

Figure 2. Higher magnification of the section shown in Figure 1.

Figure 3. Bilateral pseudobranchial tumors (just above card) in the pharynx of a pollock.

Figure 4. Section of a pollock pseudobranchial tumor. Numerous X-cells can be seen. (Hematoxylin and Eosin)

Figure 5. Skin ulcers on the ventrolateral surface of a Pacific cod.

Figure 6. Two ring-like lesions near the caudal region of a Pacific cod.

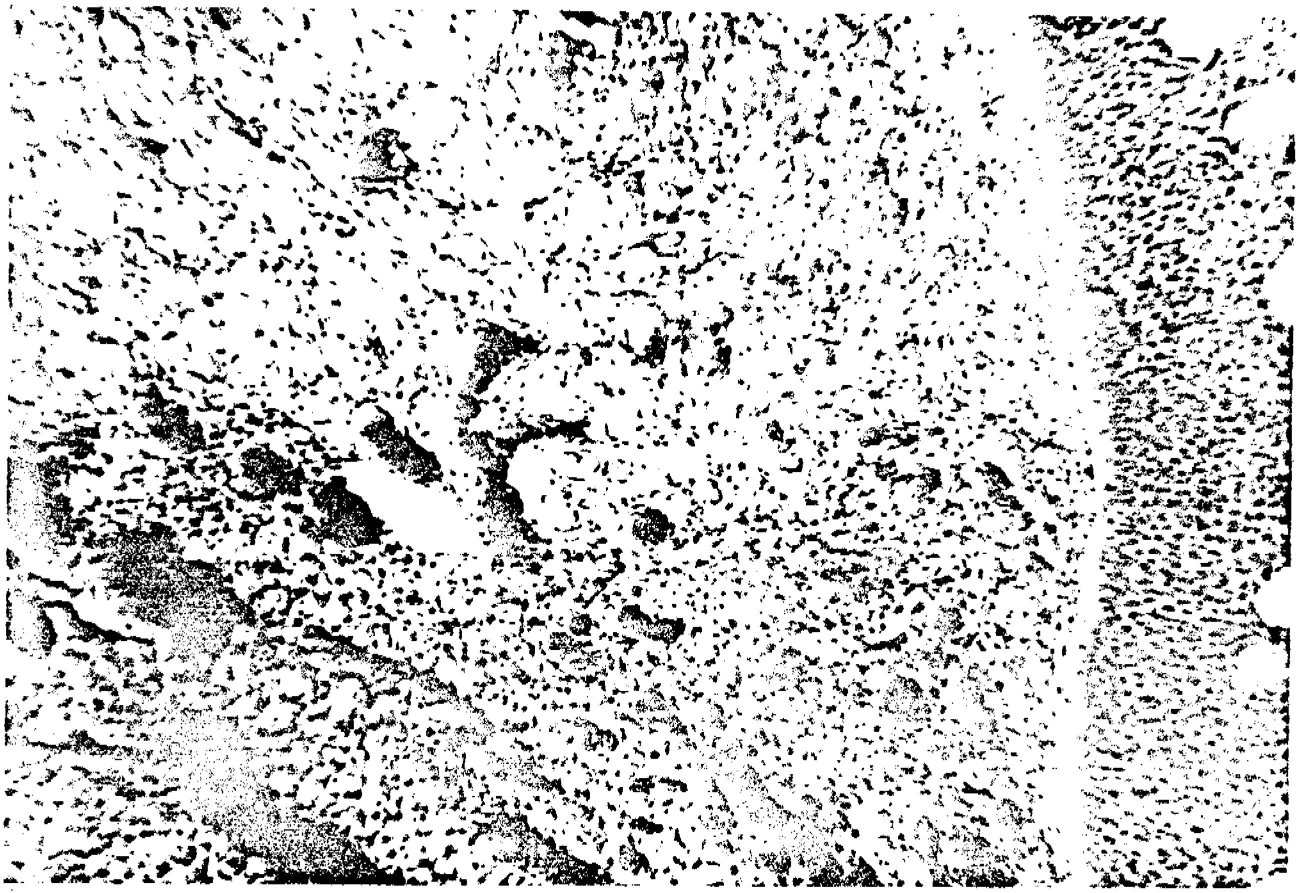


Figure 7. Section of a skin ulcer on a Pacific cod. Normal-appearing epidermis is on the right. The stratum compactum contains extensive hyperemia and various infiltrating cells.

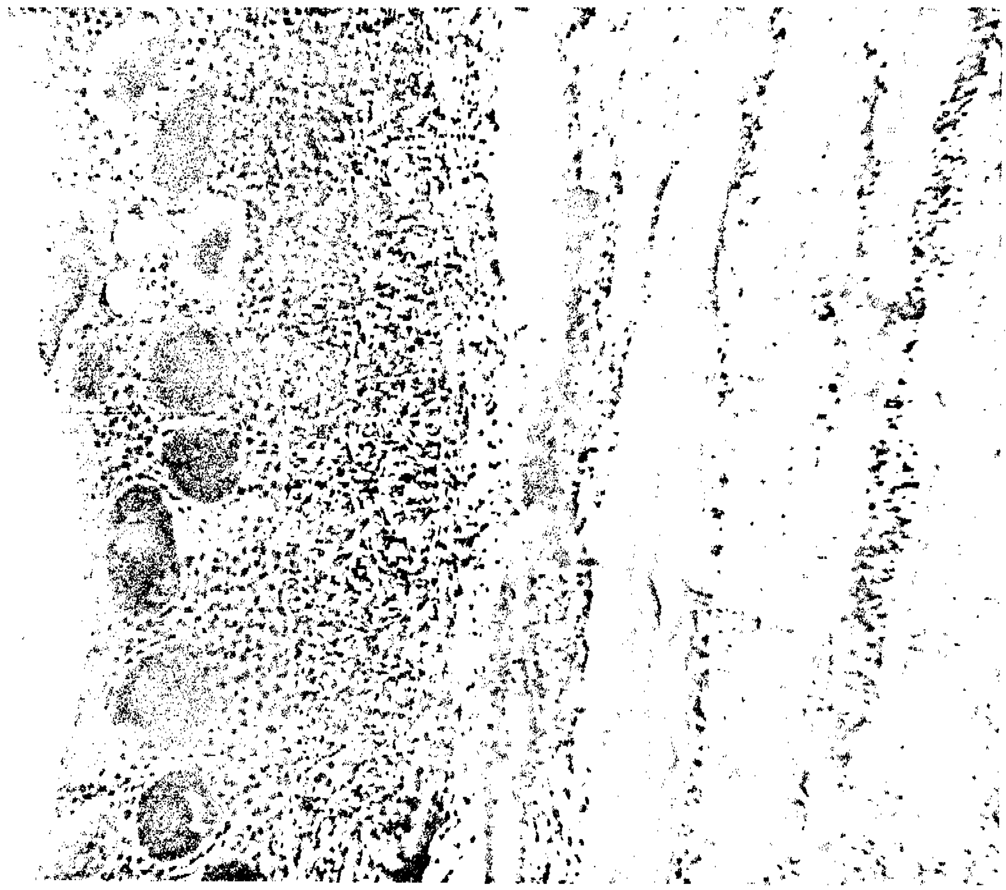


Figure 8. Low magnification photograph of the epidermis and dermis of cod skin with a ring-like lesion.

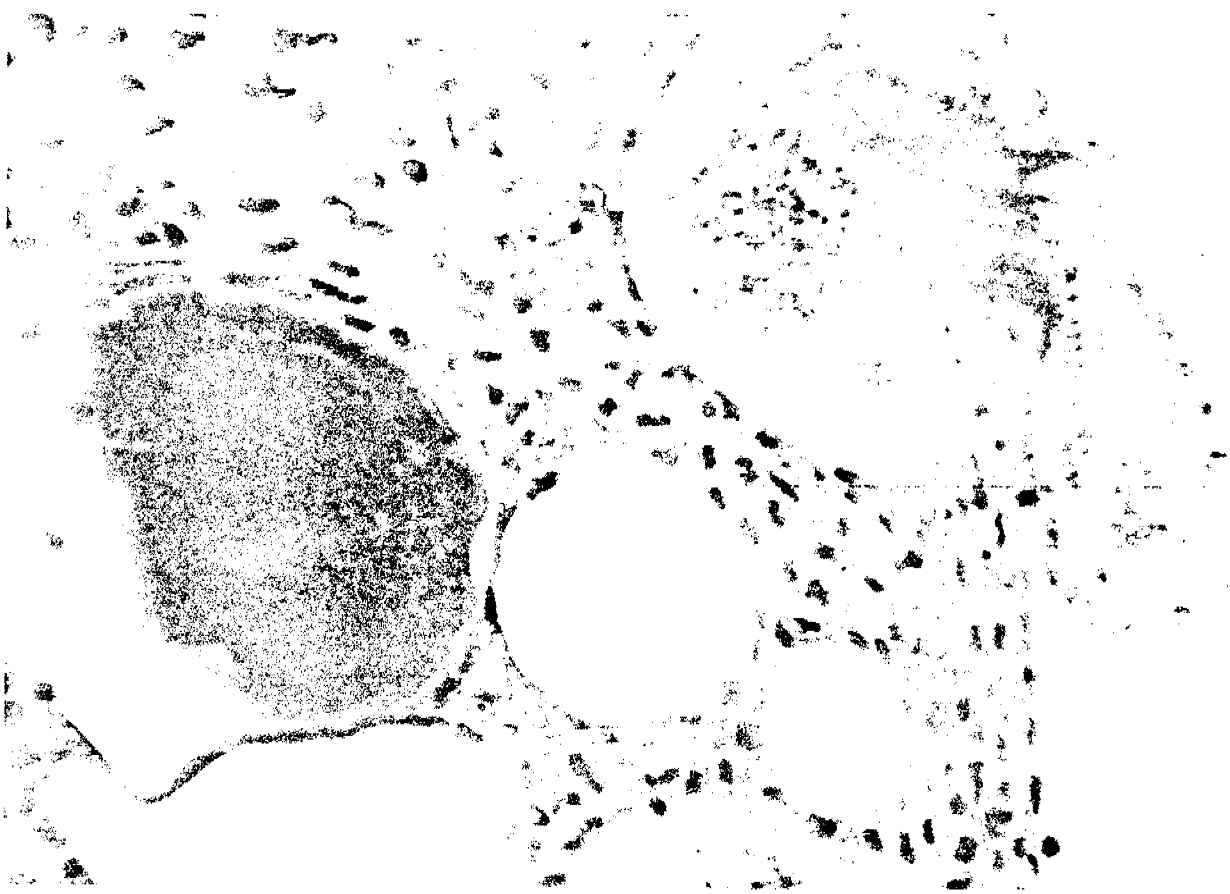


Figure 9. Section of a ring-like lesion of a cod with the contents of a basophilic body emptying through the epidermal surface.

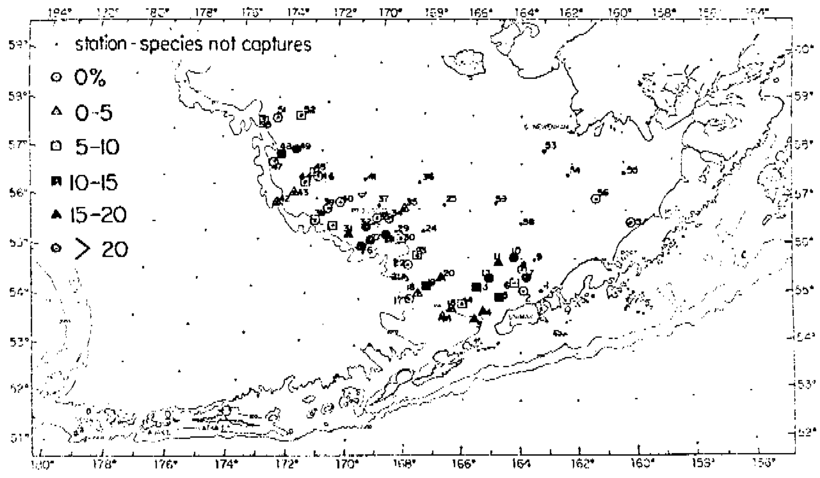


Figure 10. The distribution and frequencies of cod with pseudobranchial tumors in the Bering Sea.

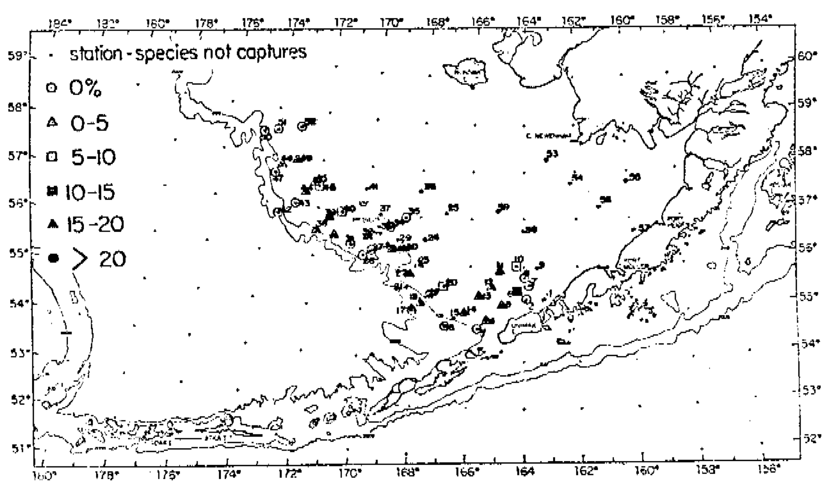


Figure 11. The distribution and frequencies of pollock with pseudobranchial tumors in the Bering Sea.

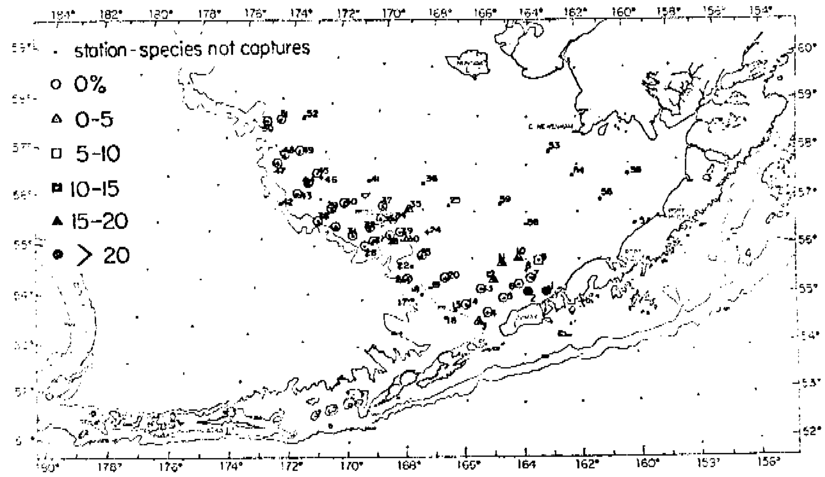


Figure 12. The distribution and frequencies of rock sole with epidermal papillomas in the Bering Sea.

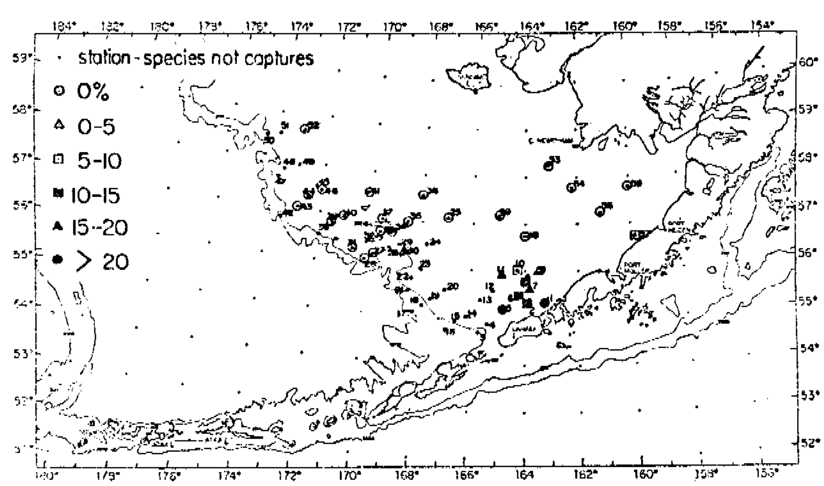


Figure 13. The distribution and frequencies of yellowfin sole with lymphocystis in the Bering Sea.

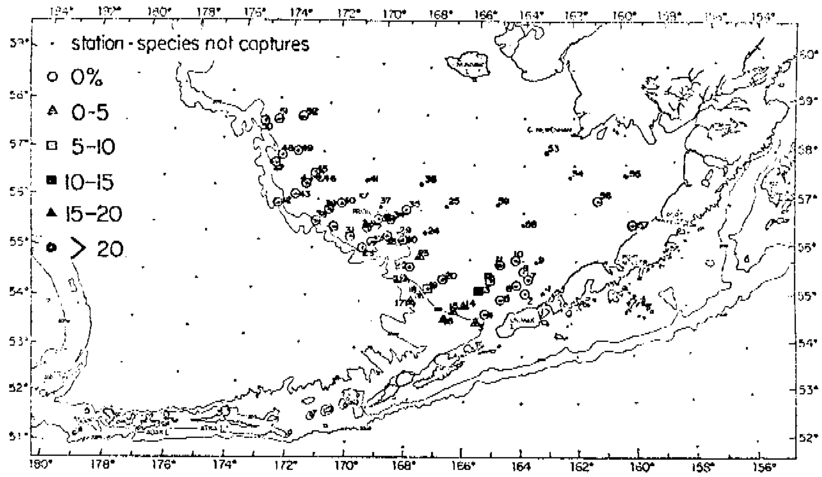


Figure 14. The distribution and frequencies of cod with skin ulcers in the Bering Sea.

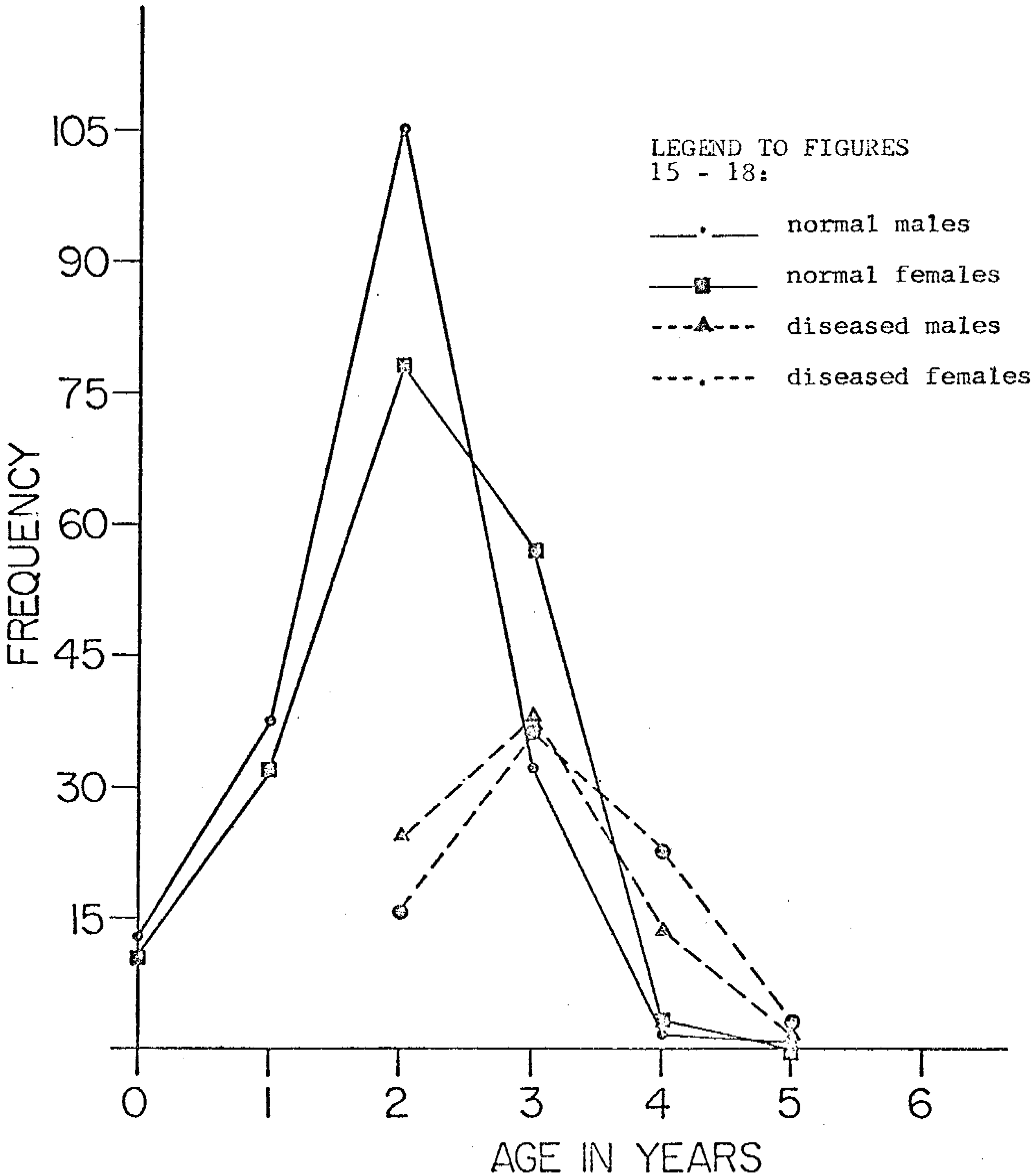


Figure 15. Age distributions for normal Pacific cod and cod with pseudobranchial tumors in the Bering Sea. Normal age data was obtained from NMFS sampling programs in the Bering Sea in 1975.

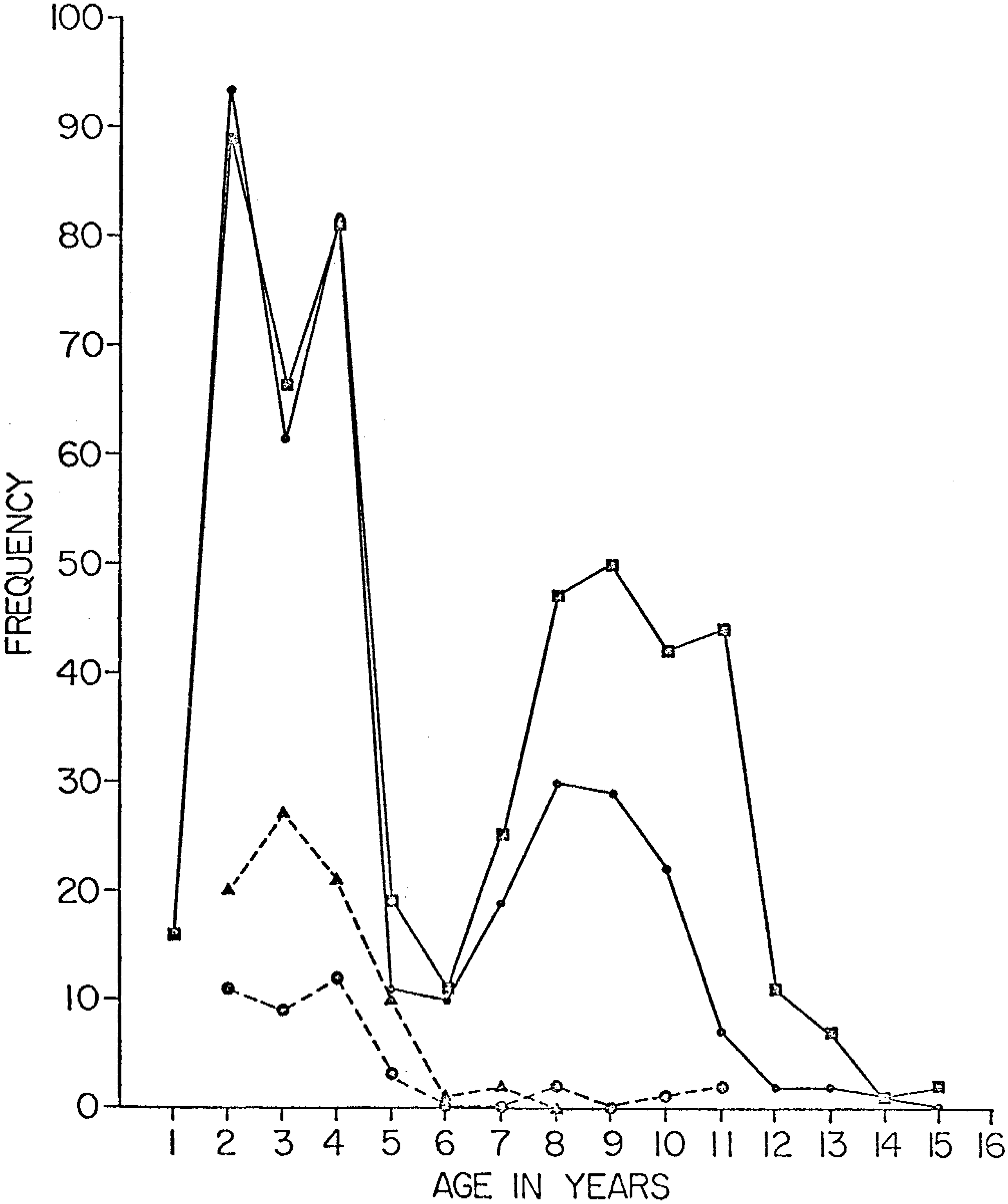


Figure 16. Age distributions for 1976 for normal pollock and pollock with pseudobranchial tumors in the Bering Sea.

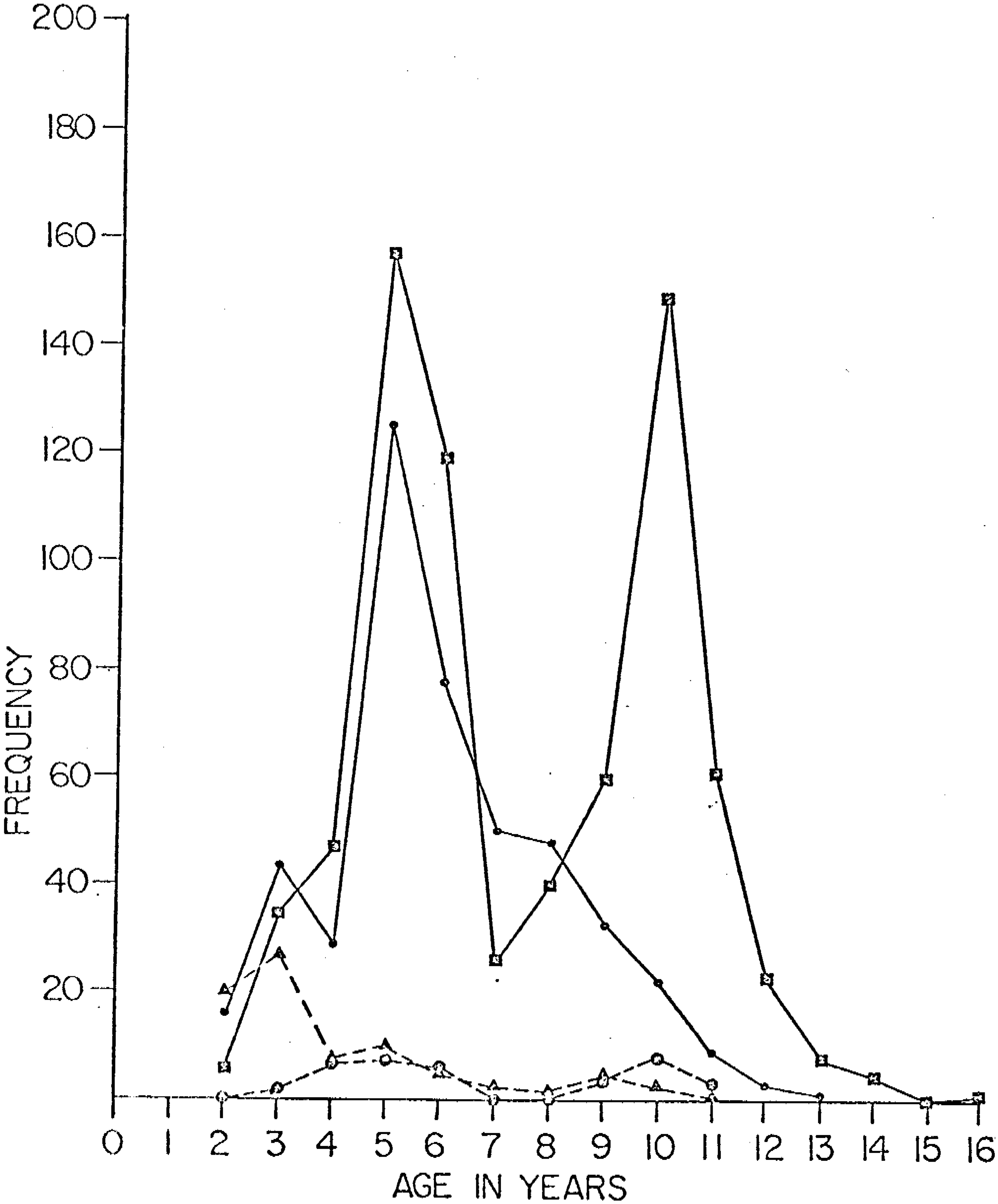


Figure 17. Age distributions for normal rock sole and rock sole with epidermal papillomas in the Bering Sea Normal age data was obtained from NMFS sampling programs in the Bering Sea in 1975.

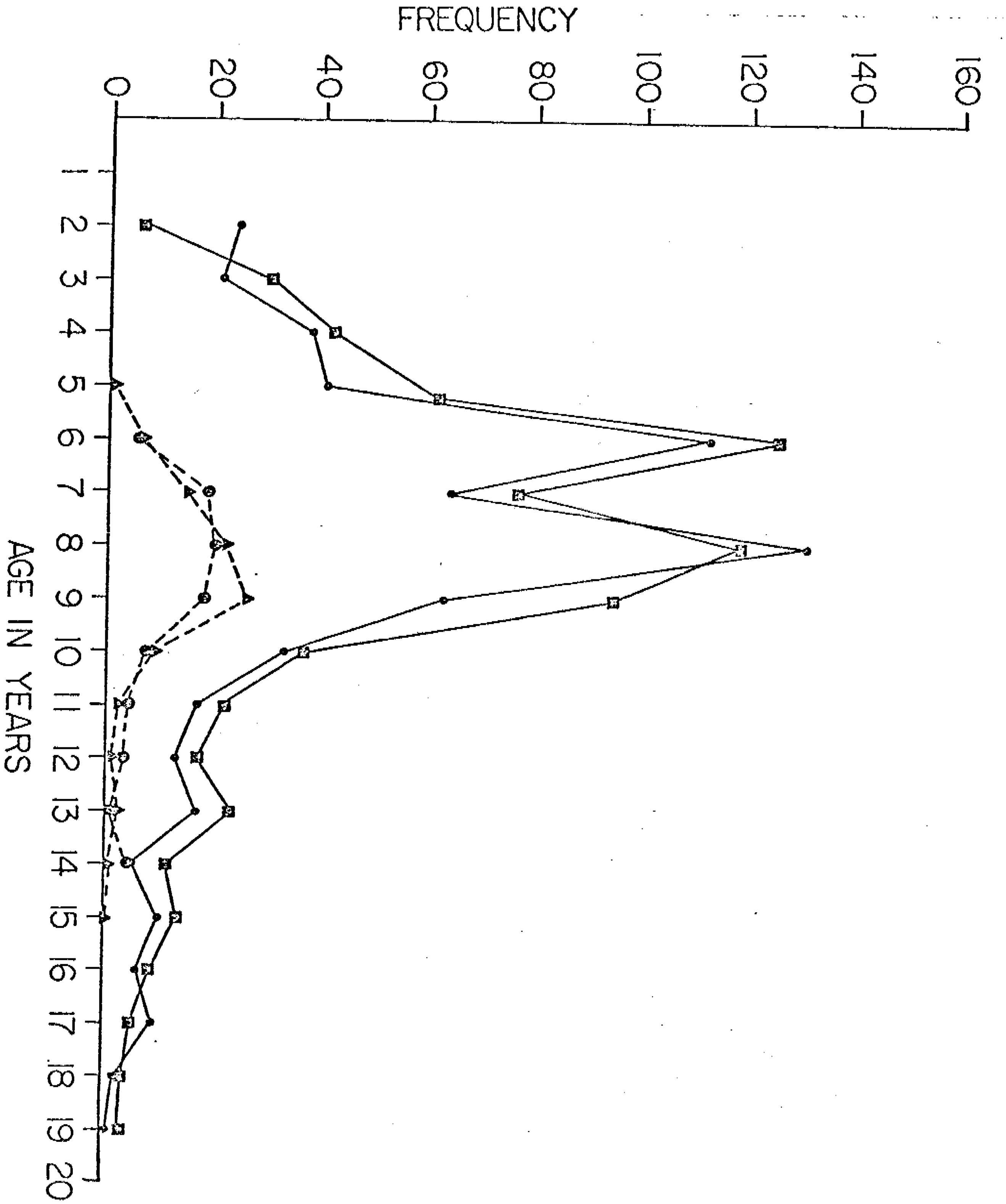


Figure 18. Age distributions for normal yellowfin sole and yellowfin sole with lymphocystis disease in the Bering Sea. Normal age data was obtained from NMFS sampling programs in the Bering Sea in 1975.

Average fork length related to age in "Total Catch" of Pacific cod (Gadus macrocephalus) in the Bering Sea, and in cod affected with pseudobranchial tumors in the same region

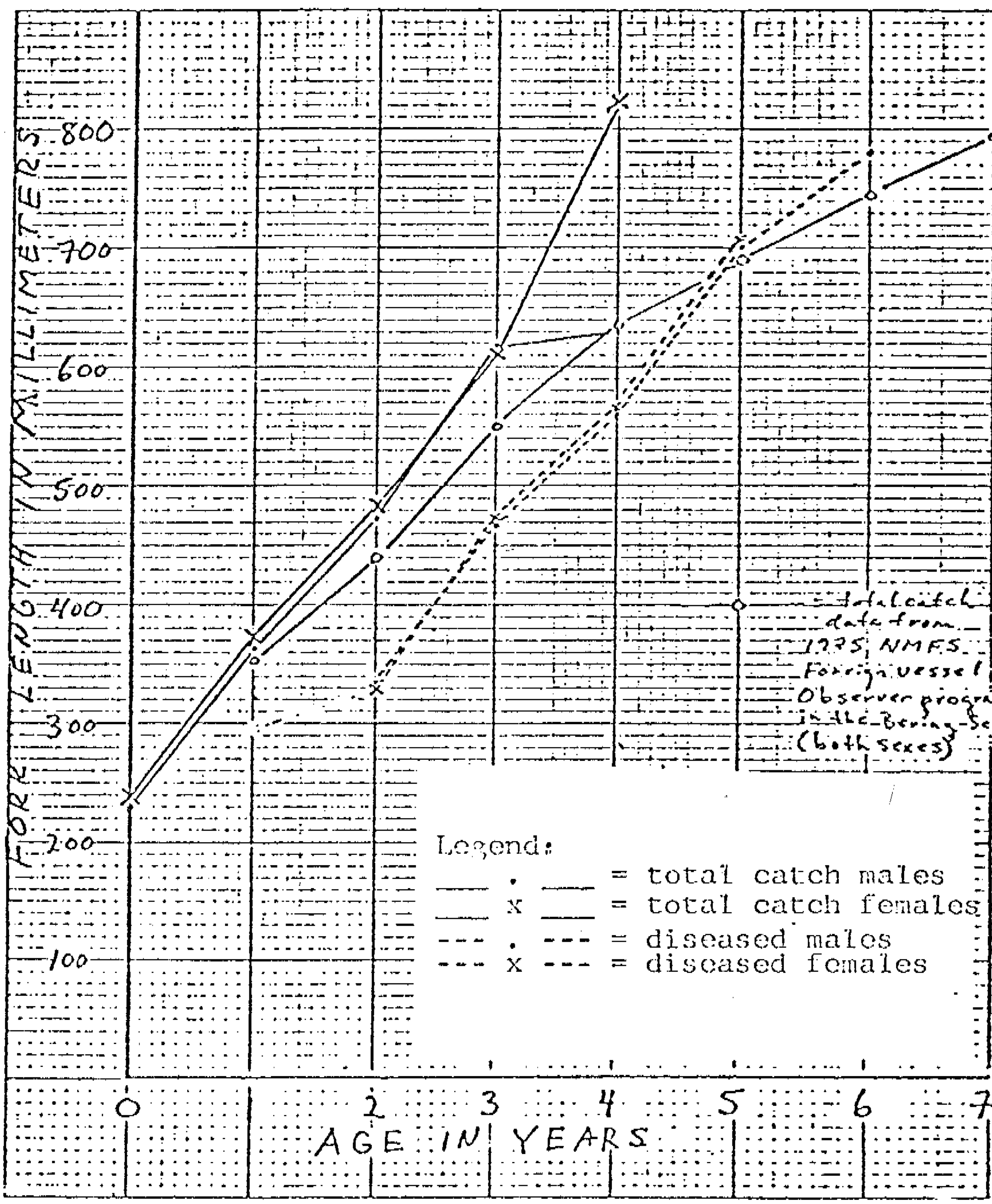


Fig. 19

Average fork length related to age in "Total Catch" of pollock (*Theragra chalcogramma*) in the Bering Sea, and for pollock affected with pseudobrancial tumors in the same region

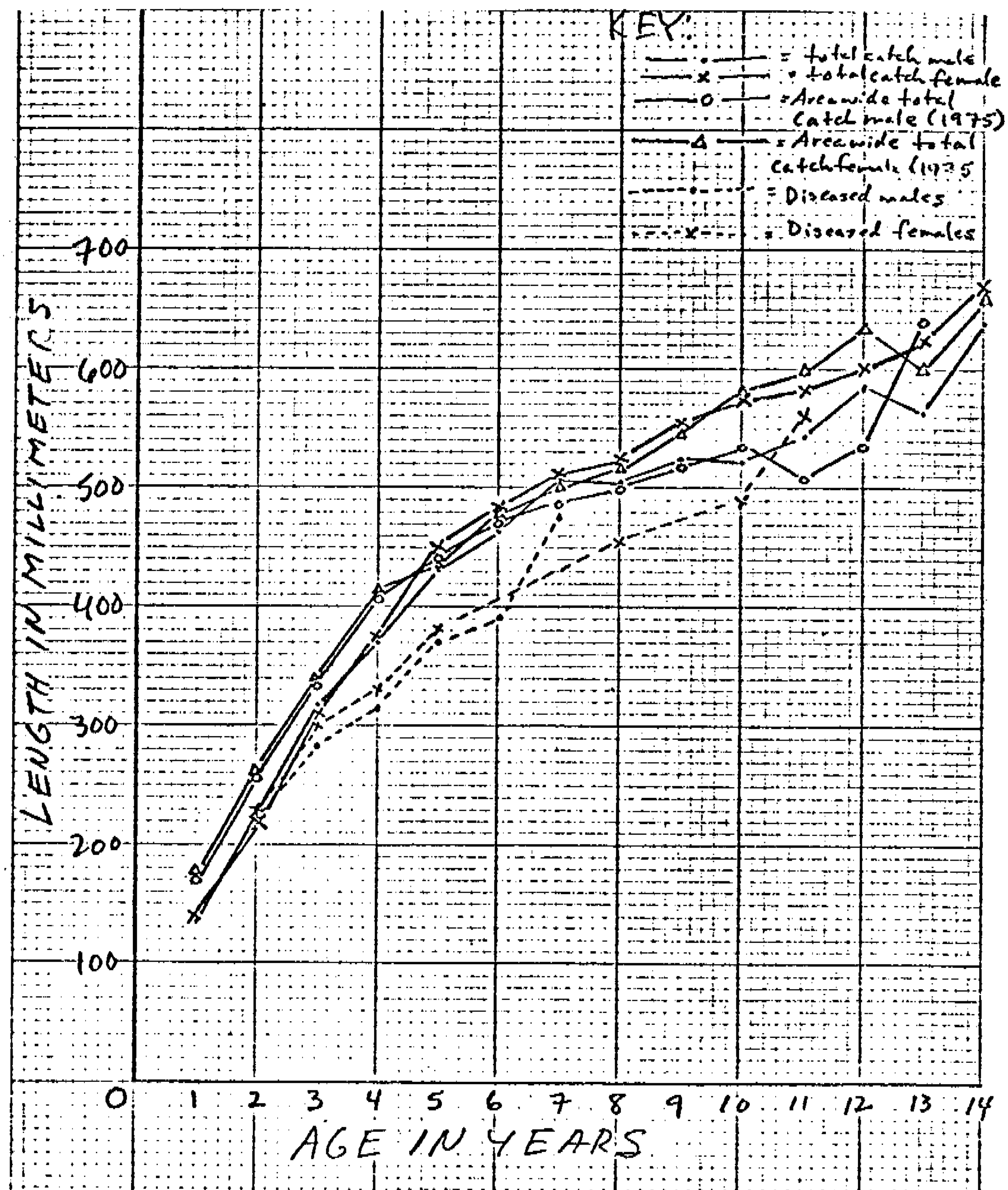


Fig. 20

Average fork length related to age in "Total Catch" of rock sole (Lepidopsetta bilineata) in the Bering Sea, and in rock sole affected with epidermal papillomas from the same region

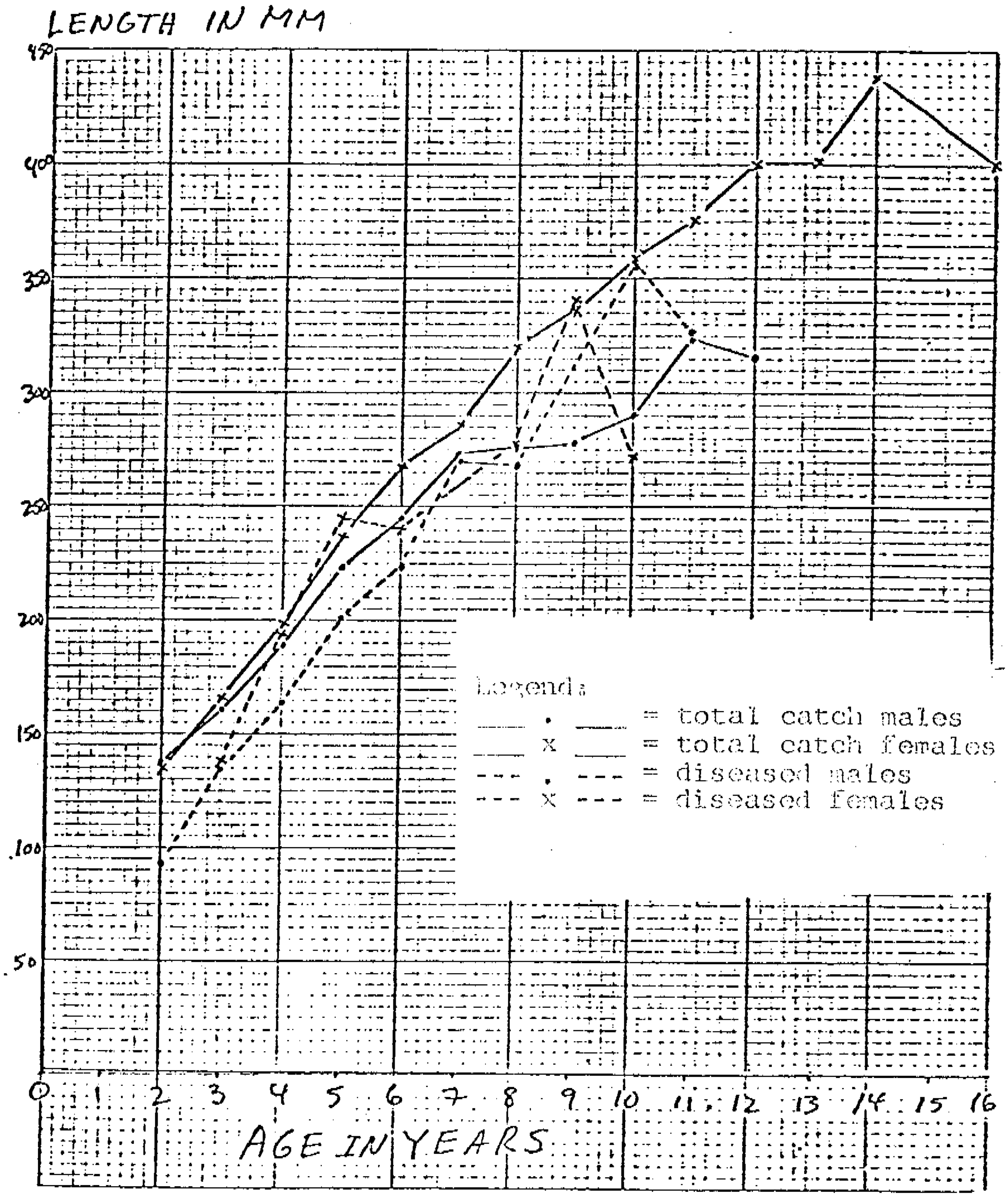


Fig. 21

Average fork length related to age in "Total Catch" of yellowfin sole (Limanda aspera) in the Bering Sea, and yellowfin sole affected with lymphocystis in the same area.

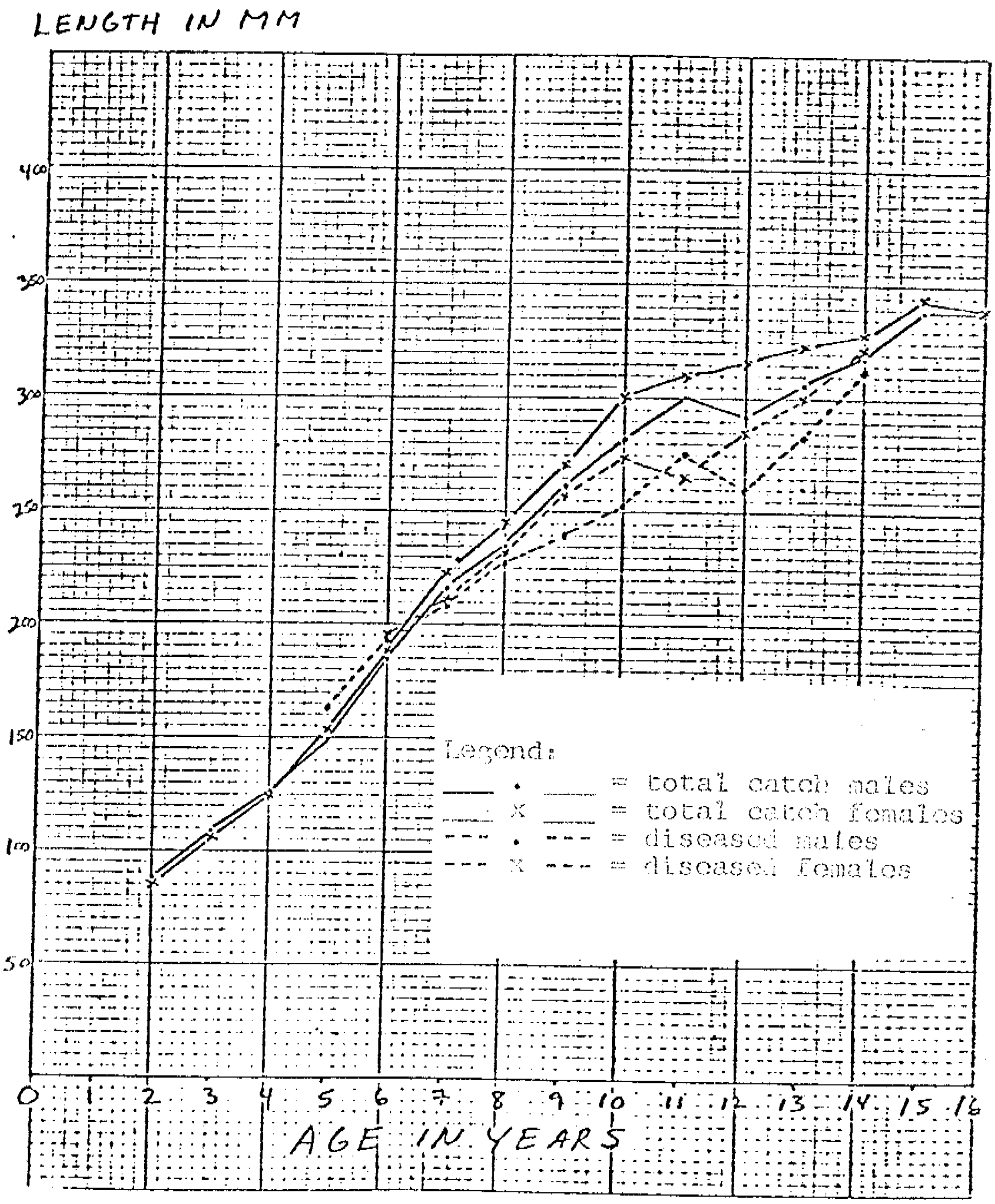


Fig. 22

CHEMISTRY AND MICROBIOLOGY

CHEMISTRY AND MICROBIOLOGY

Quarterly Report

Contract #03-5-022-85
Research Unit 29
Period 7/1 - 9-30

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

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

October 1, 1976

I. Task Objectives

A. To characterize marine microbiological communities in sufficient detail to establish a baseline description of microbiological community characteristics on a seasonal basis.

B. To determine the role of microorganisms in the biodegradation of petroleum hydrocarbons.

II. Field and Laboratory Activities

A. Field Activities

1. Schedule - August 13 thru September 20

NARL, Barrow, Alaska

U.S.C.S. Glacier

2. Party - Mr. George Roubal

Mr. Craig Short

Department of Biology

University of Louisville

Louisville, Kentucky 40208

3. Methods - Water and sediment samples were collected as described in previous reports. Samples were processed for enumeration of microorganisms and for determination of oil biodegradation potential.

4. Locations - Sample locations have not yet been supplied by the Chief Scientist.

5. Results - Enumeration procedures require incubation periods of one month and will not be completed until early October.

B. Laboratory Activities

1. Methods - Cluster analyses were performed on 625 microorganisms isolated from the August-September sampling. These analyses were performed using the GTP 2 clustering program at the National Institute of Health. Both simple matching (Sm) and Jacquard coefficients (Sj) were **calculated,** but only Sj's are included in this report.

Laboratory testing on an additional 1000 isolates from the April sampling has been completed. This testing included 300 taxonomic tests for each organism. Data is being now processed for analysis.

$^{14}CO_2$ released from ^{14}C hexadecane spiked Prudhoe crude oil was quantitated as a measure of oil biodegradation potential.

III. Results

Figures 1 an 2 show dendrograms of Sj for the 4 and 20 C isolates respectively. Dendrograms are one graphic representation of the results of a cluster analysis. Each of the dendrograms in this report occupy multiple pages. In reading the dendrogram, the strain name is shown in the left column. These strain names are the same ones used in reporting properties and sources for the organisms in the last annual report. The vertical lines show at what percent similarity level organisms are related. For example, strains B00299L and B00117L are related at the 62% level. The scale for percent similarity is shown at the top of the first page of the dendrograms. The more closely organisms are related, the greater the percent similarity. As one can see in examining the dendrograms, there are hierarchial arrangements of the strains forming clusters of multiple strains related at a particular level. Although there is no absolute value, a cutoff of 70-80% was used to determine the boundaries of a cluster. This level probably is equivalent to the taxonomic level of a Genus in many cases.

Examination of the dendrograms and cluster triangles, a second type of graphic representation of cluster analysis not shown in this report, showed fifteen clusters for the 4 C isolates and 15 clusters for the 20 C isolates. The clusters for the 4 C isolates were larger and better defined than for the 20 C isolates. The larger the cluster the more predominant are the organisms of that type in the environment sampled.

Further analysis of the clusters is now underway to determine the feature frequencies of the dominant organisms. Comparisons with known organisms are planned to identify the isolated organisms. Feature frequency analyses should be completed during the next quarter.

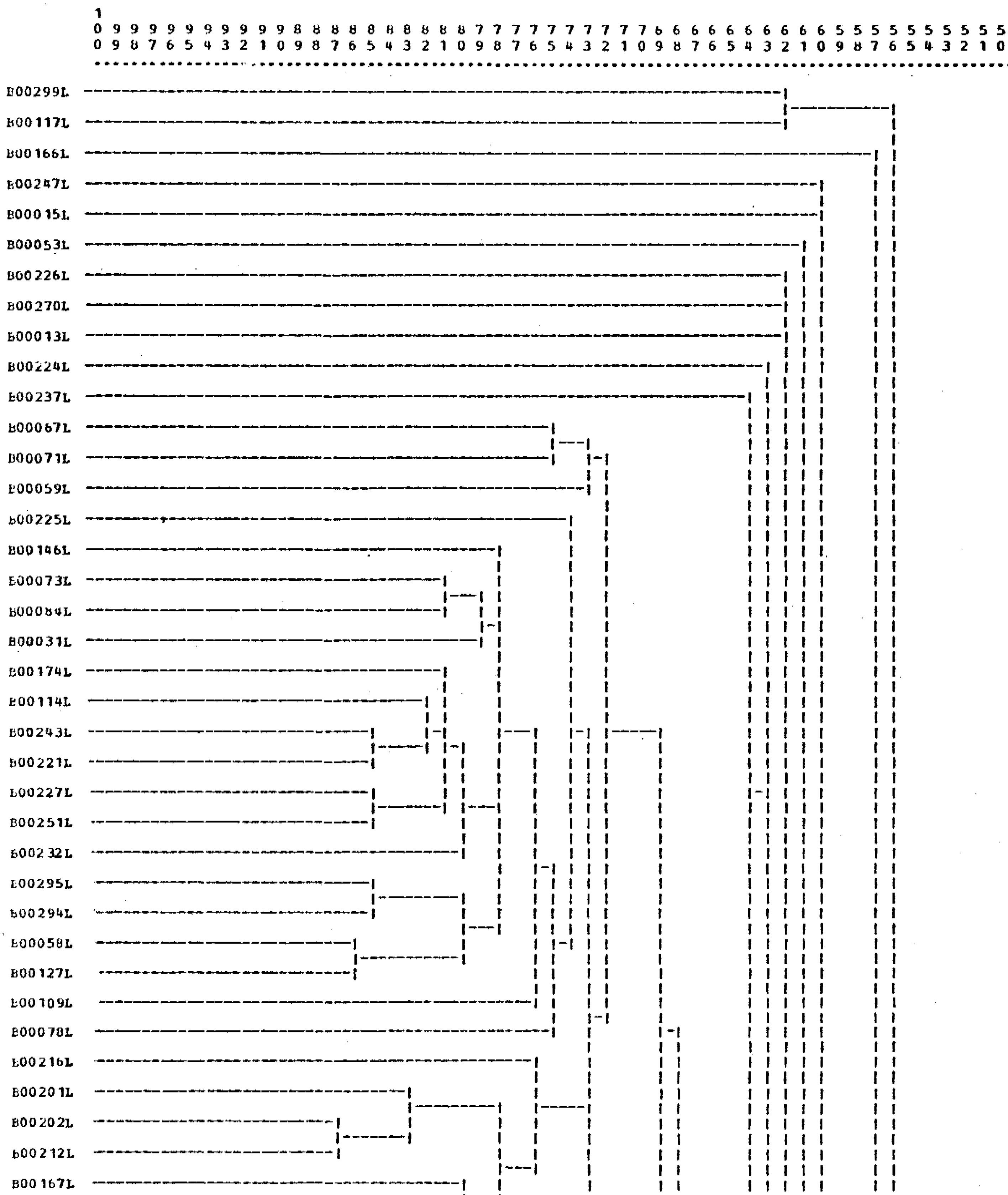
The results of $^{14}CO_2$ biodegradation potential experiments for samples collected in March are shown in Table I. Figure 3 shows a map of the sites of sample collections. Data on the abiotic parameters and microbial populations of these samples has been included in previous reports. The biodegradation potentials showed that 50% of the ice samples had a very limited ability to biodegrade petroleum hydrocarbons. Water samples at Stations 14, 15 and 16 had very high biodegradation potentials. This may indicate a history of prior exposure to petroleum hydrocarbons in this region. Several sediment samples also showed high biodegradation potentials.

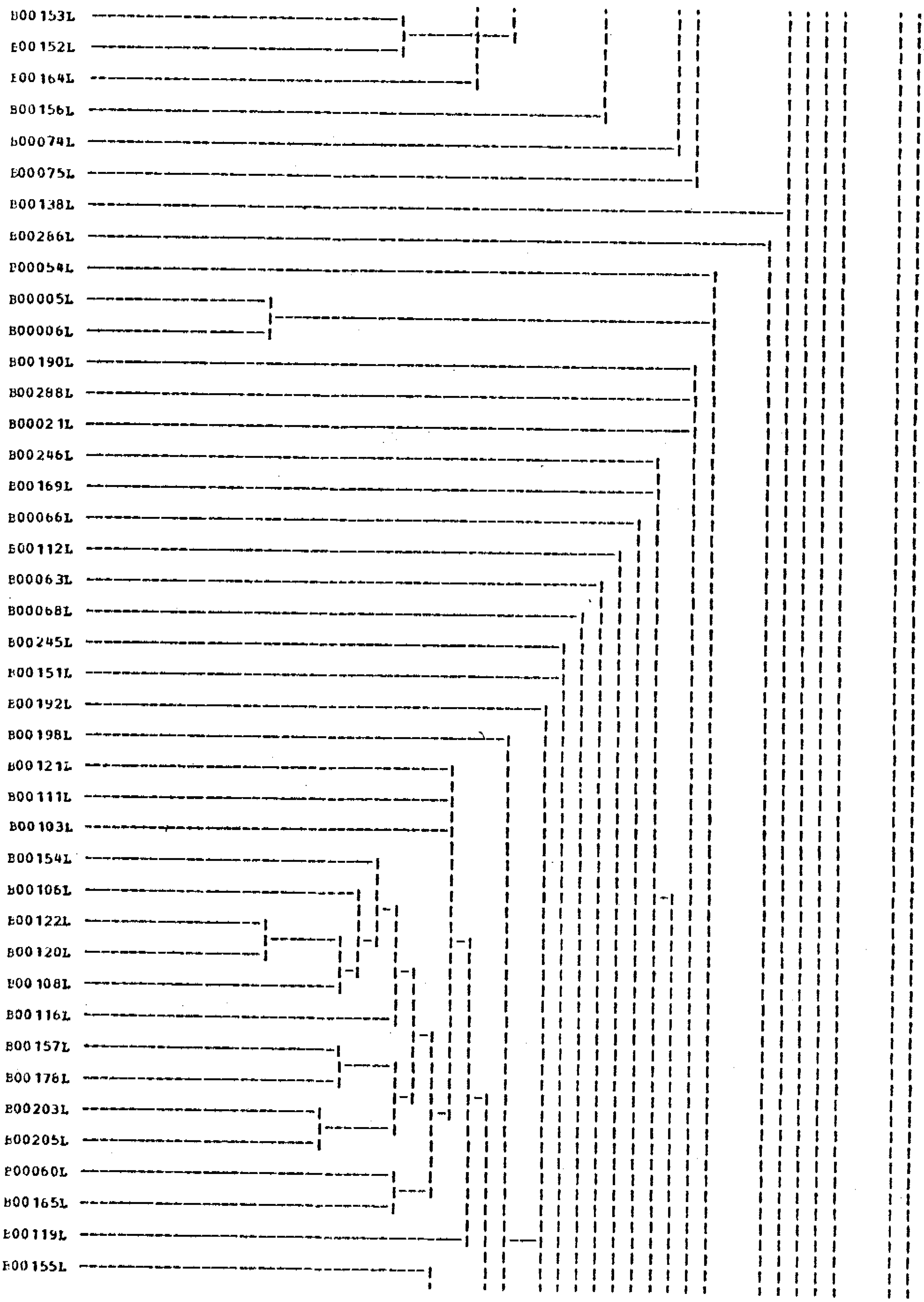
IV. Budget

It is expected that all funds will have been expended as of October 1.

Figure 1

DENDROGRAM

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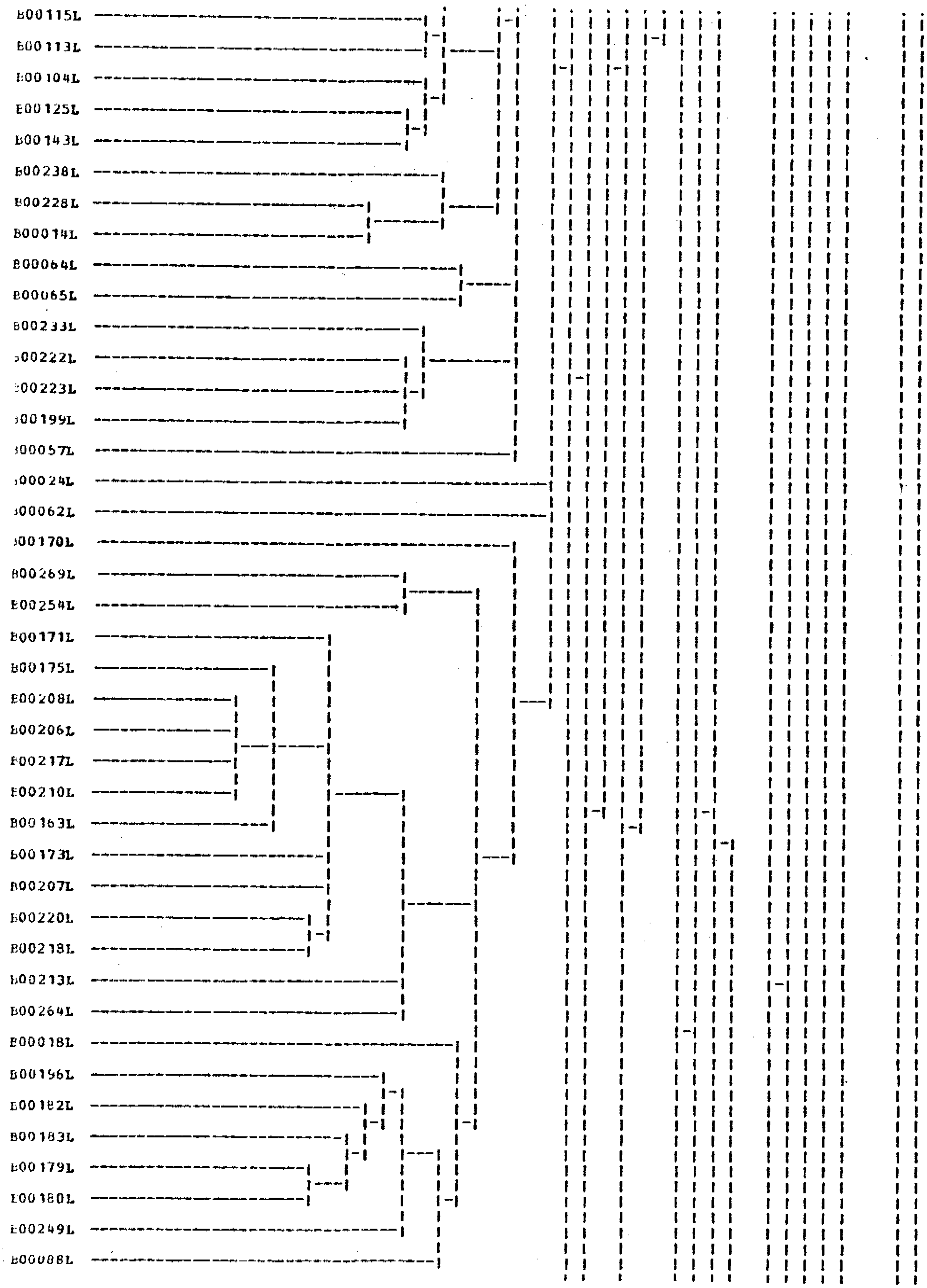
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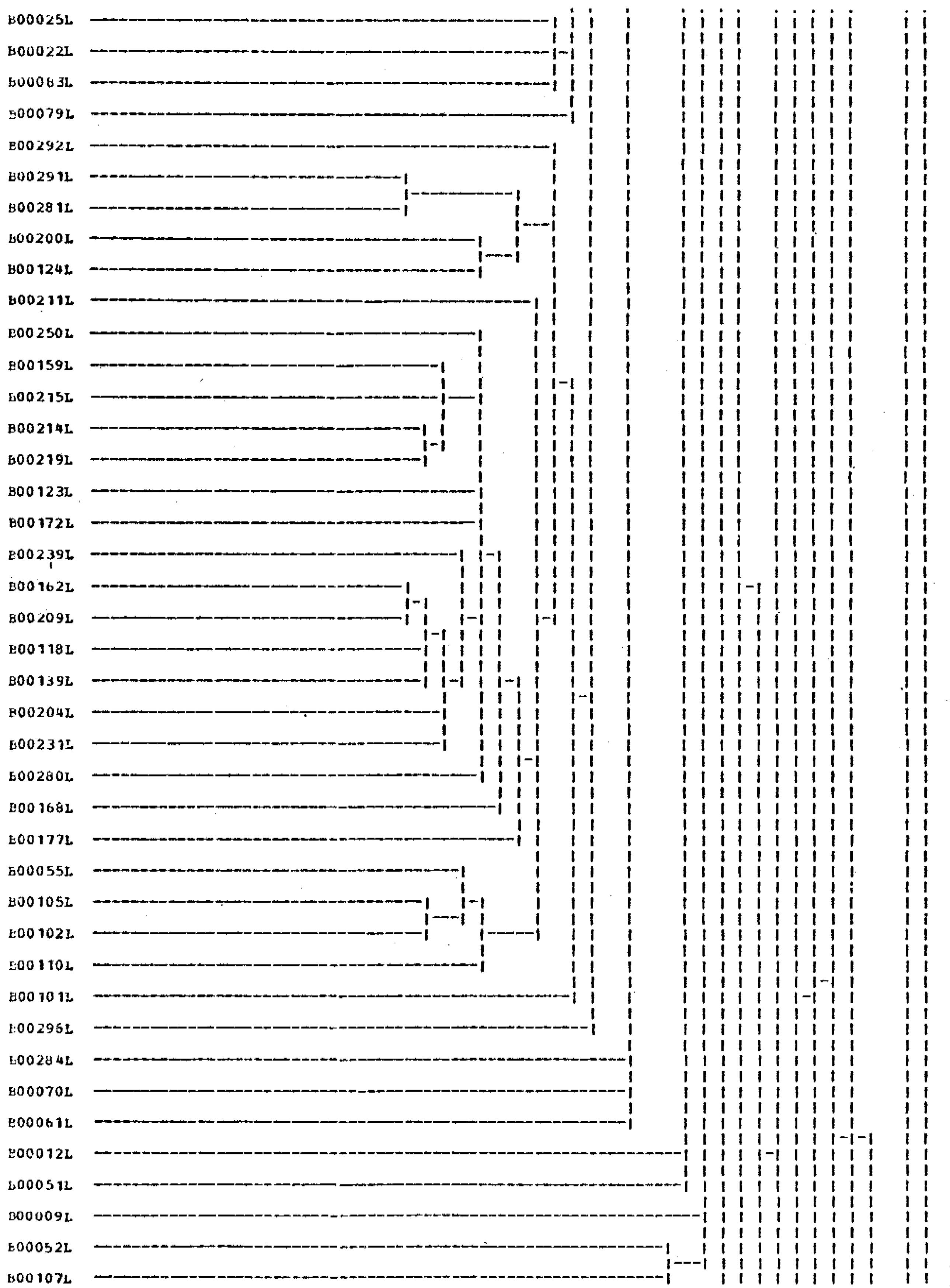
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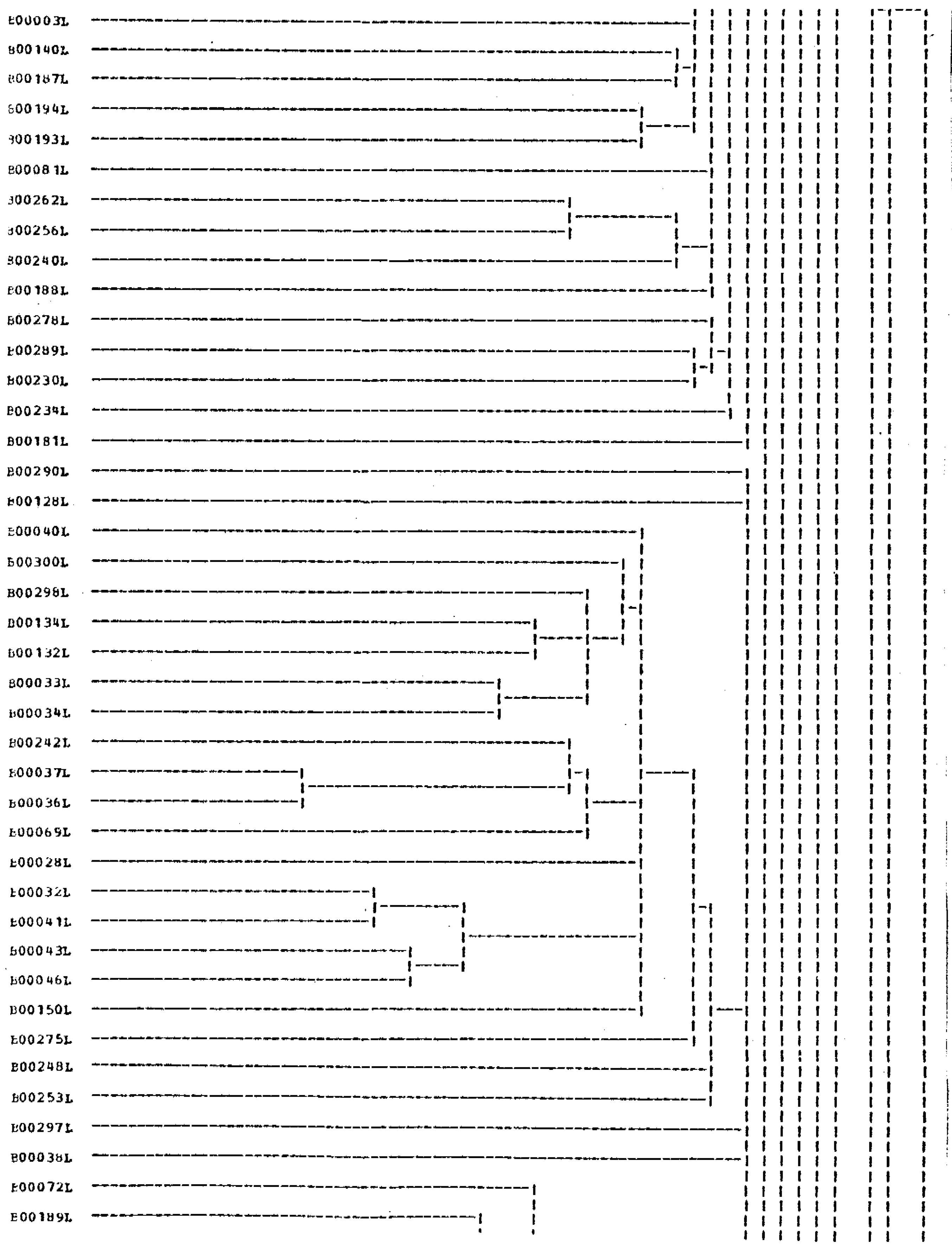
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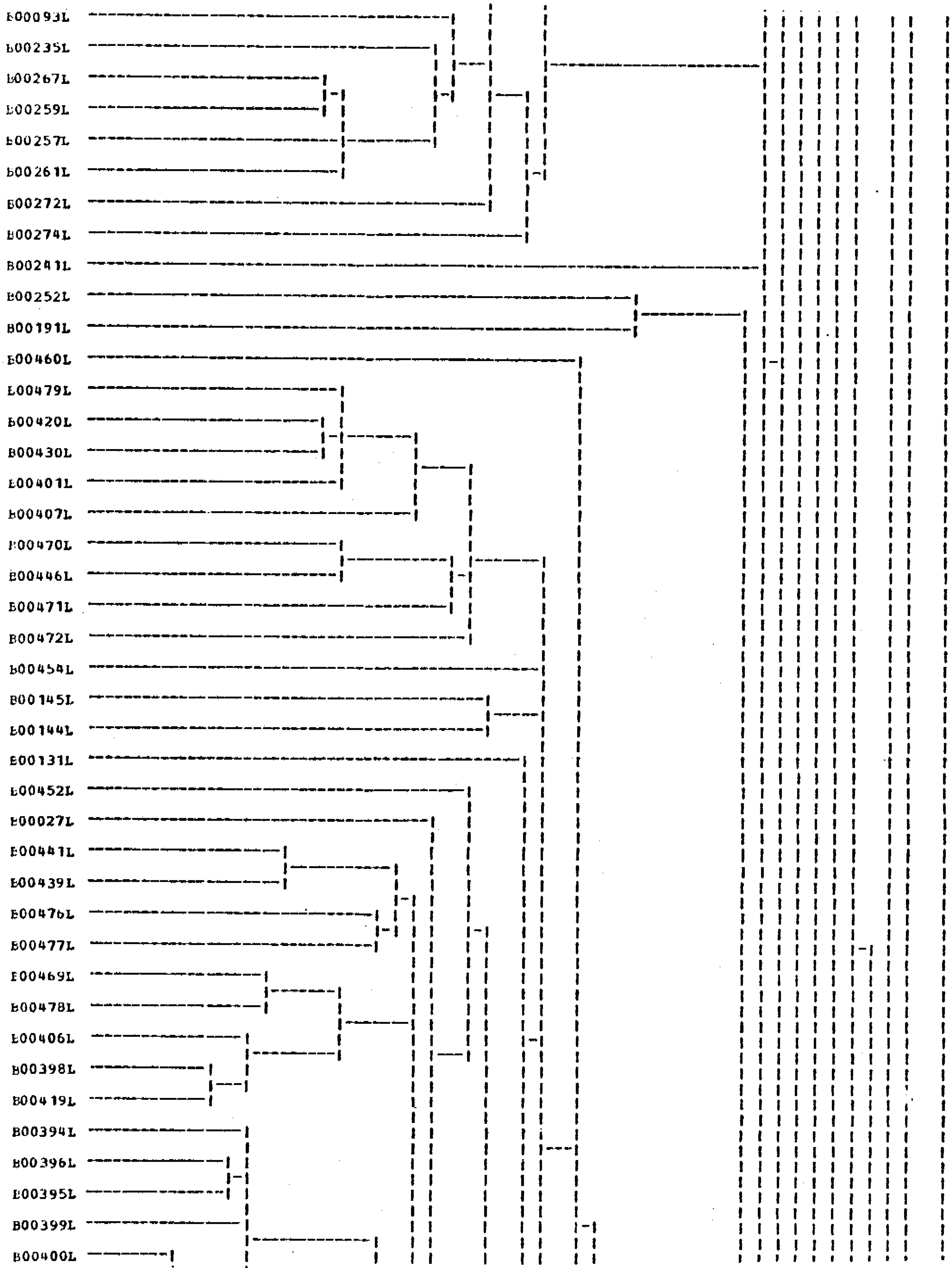
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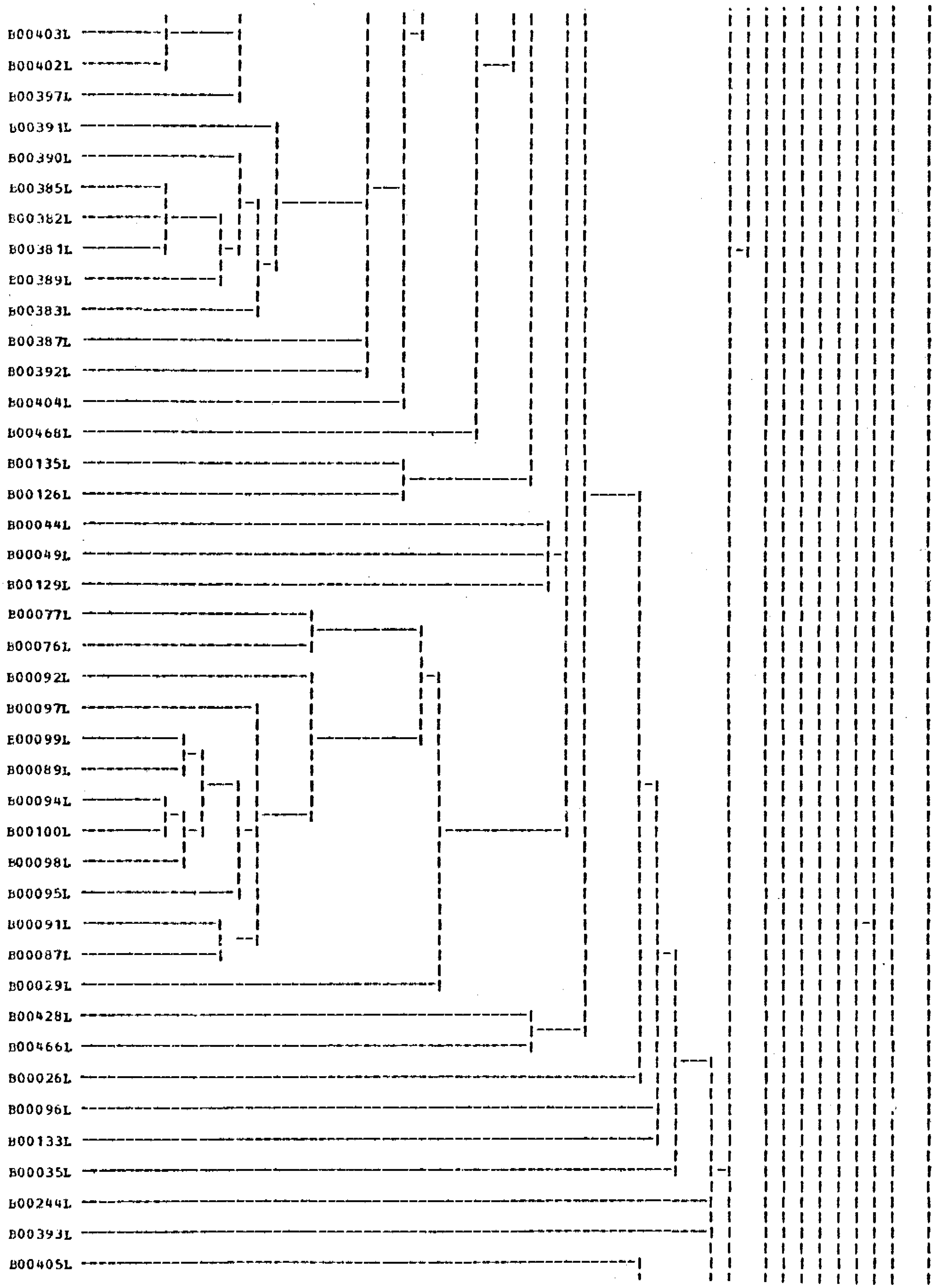
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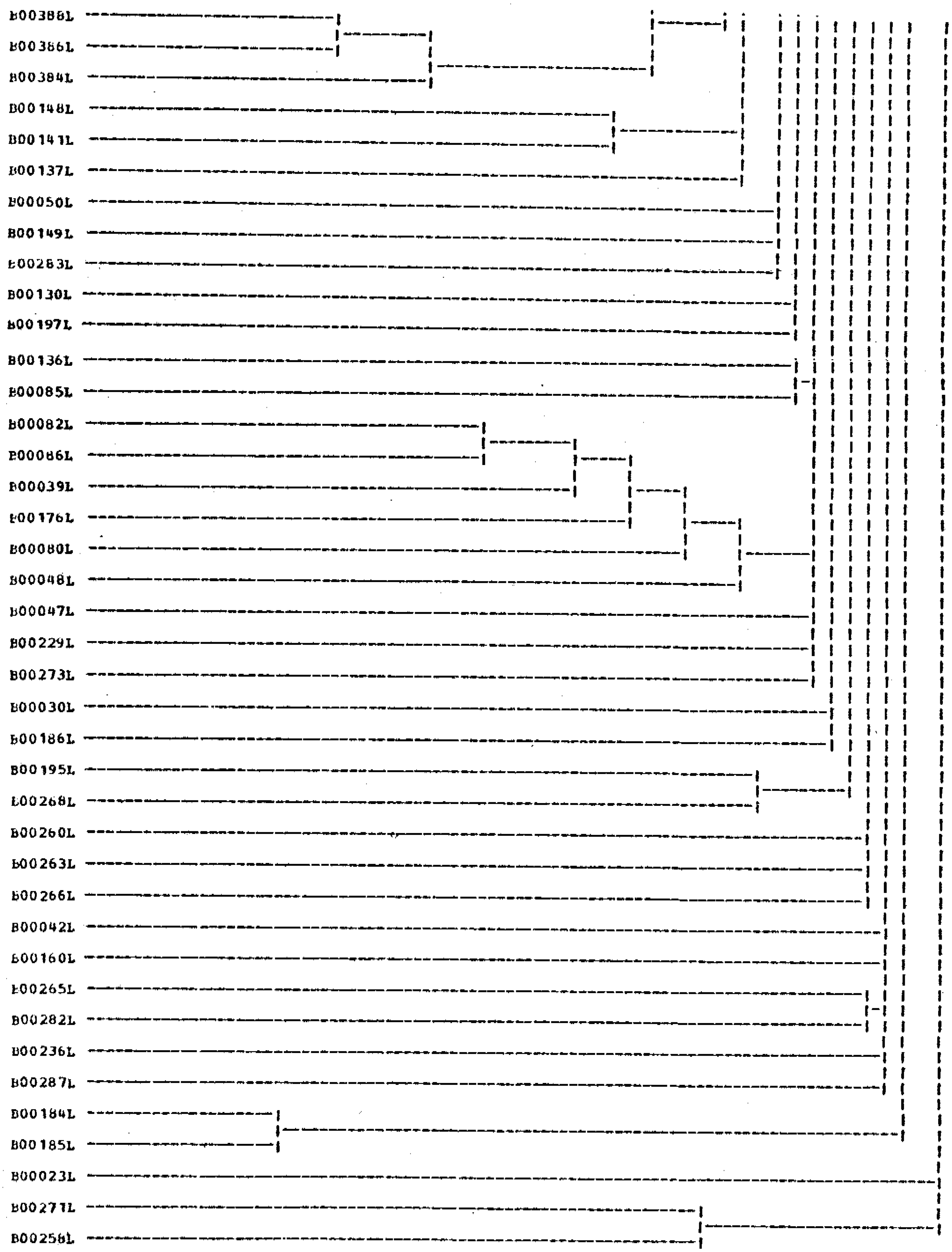
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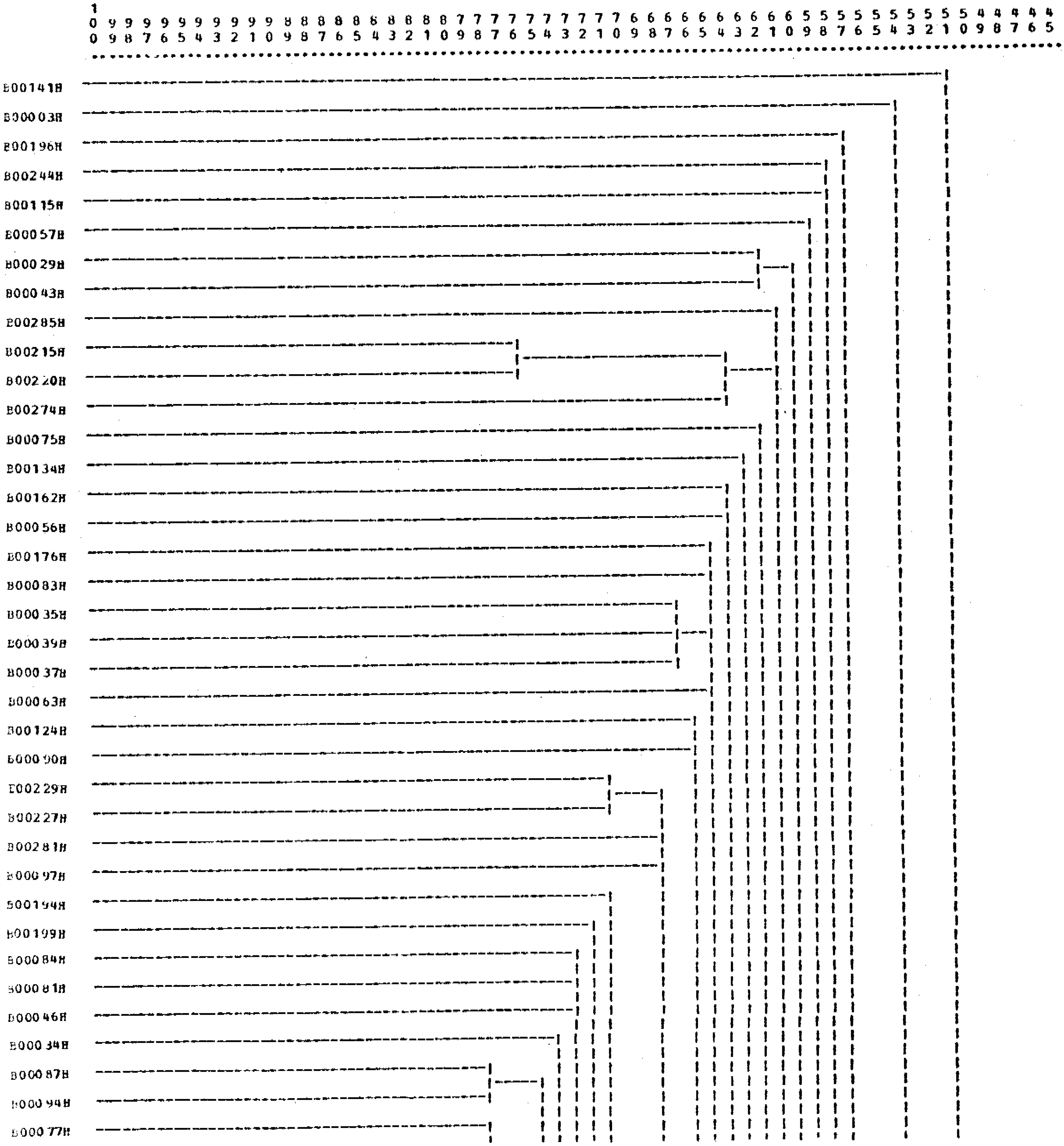
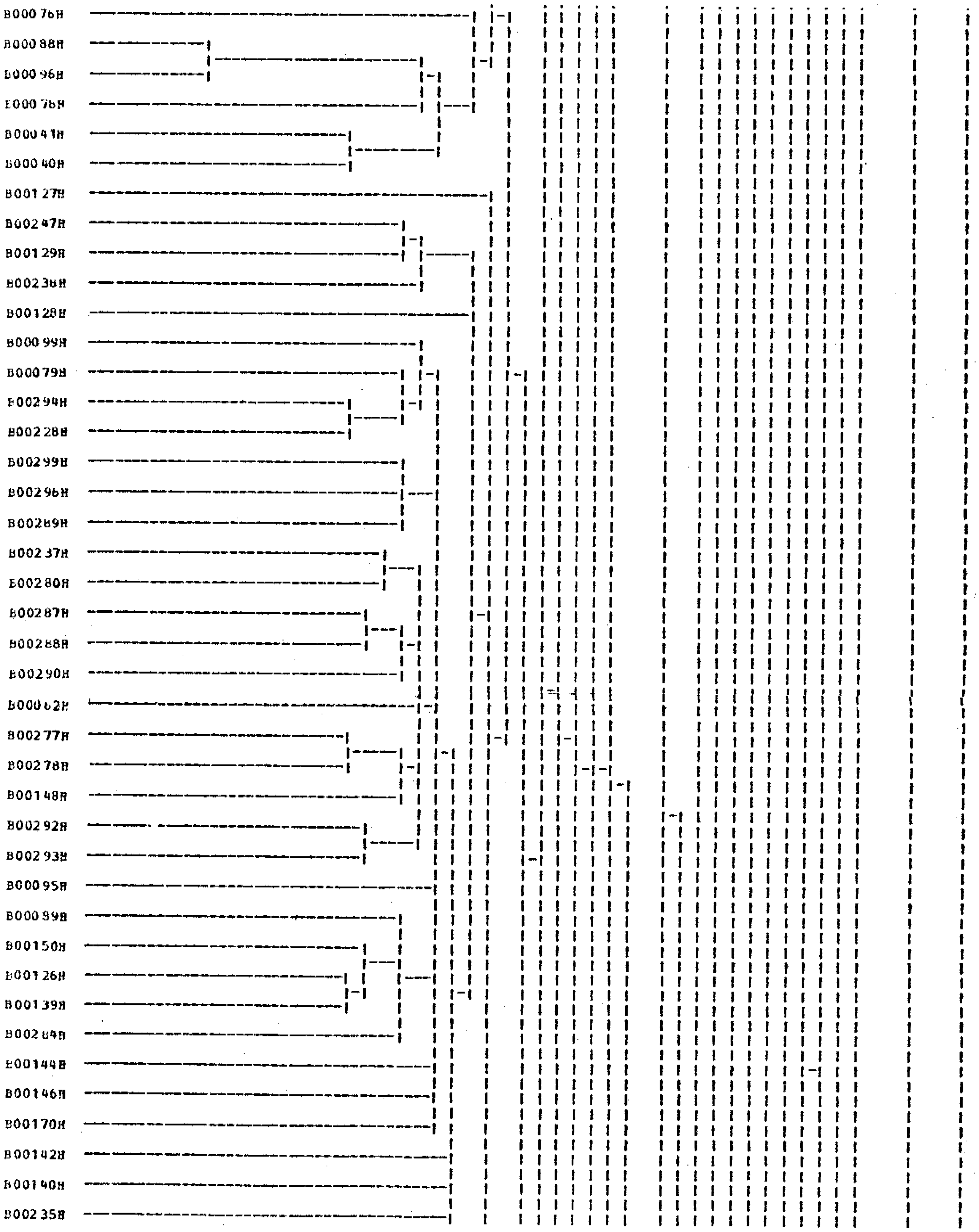
Figure 2

DENDROGRAM

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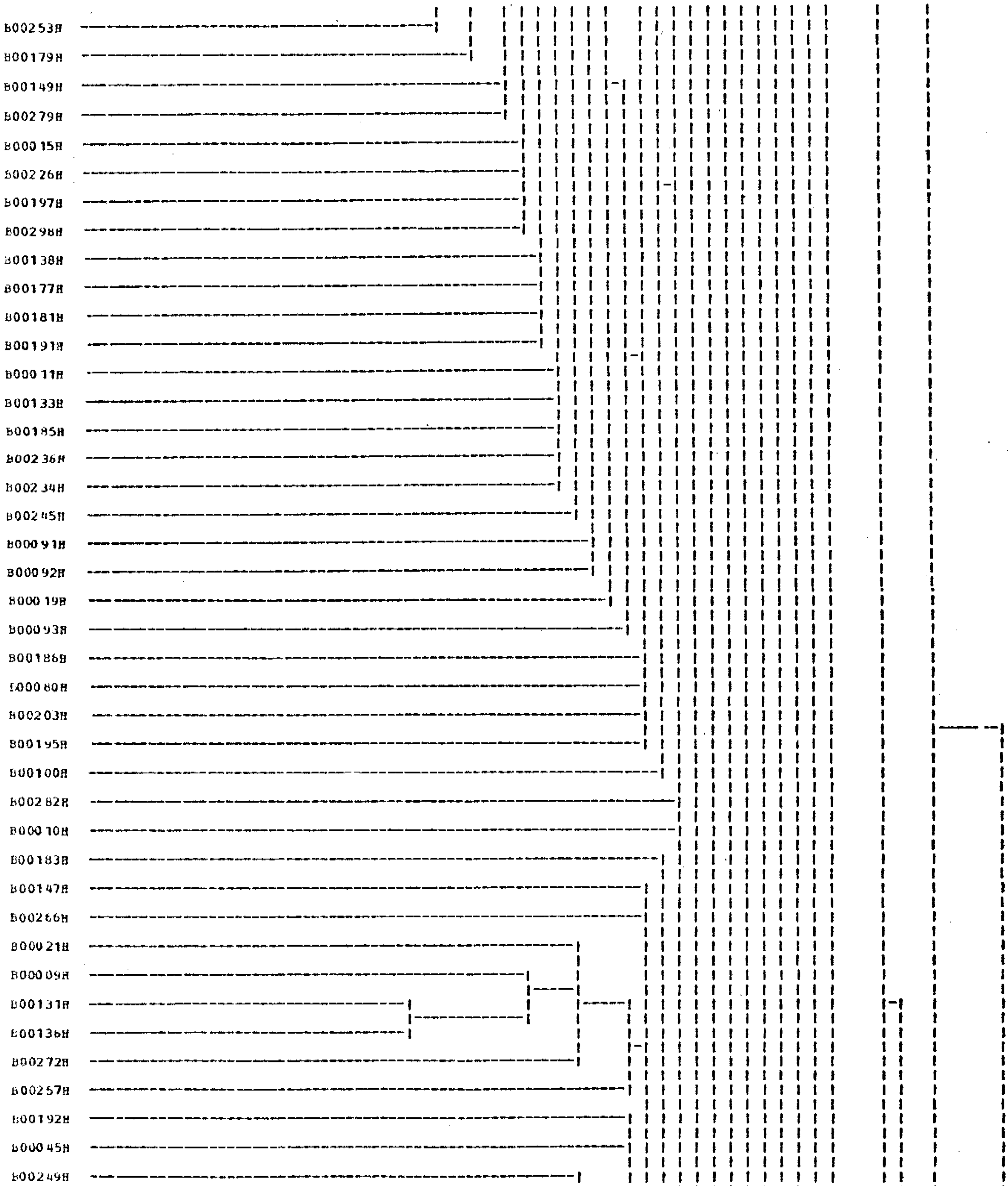

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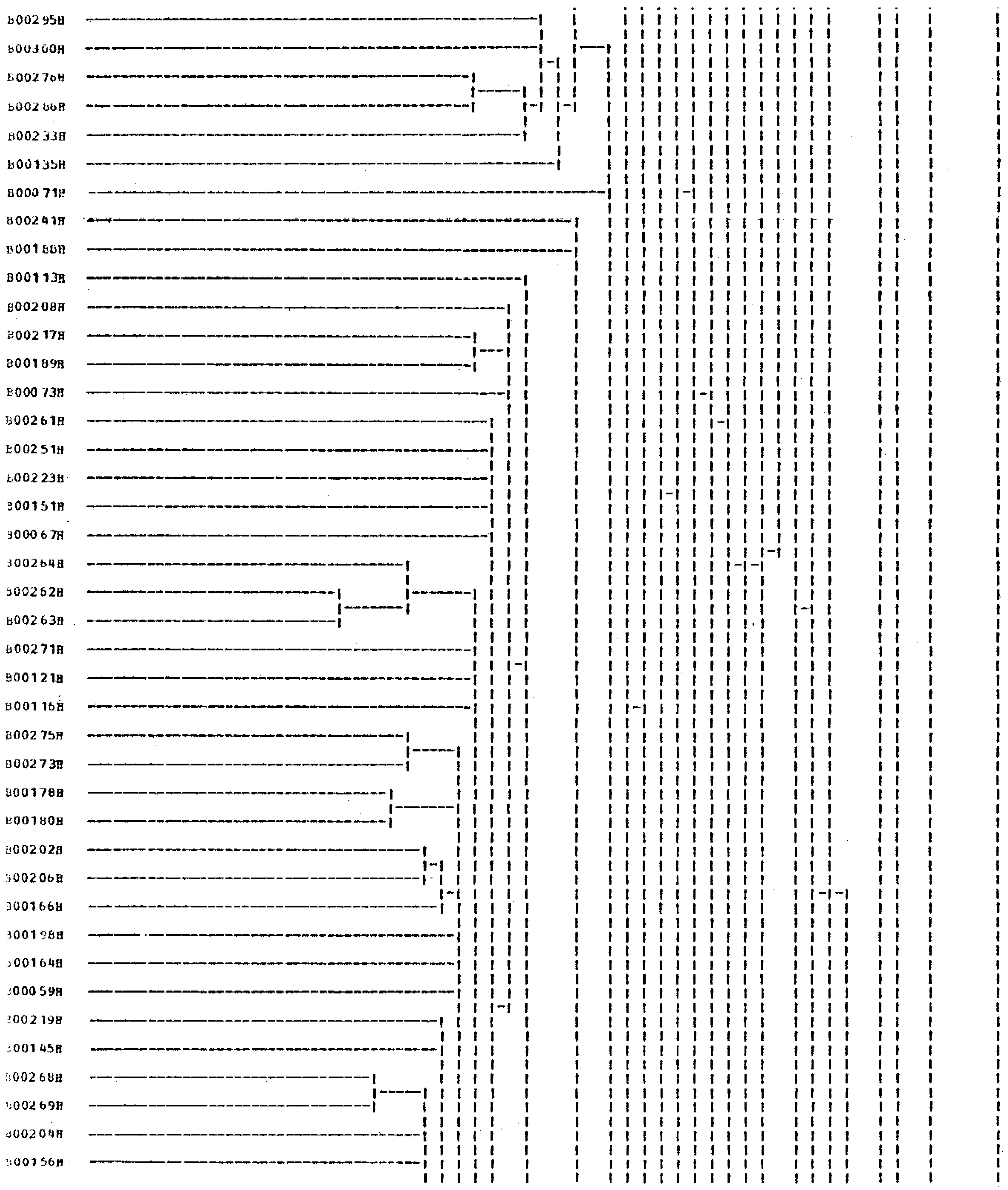
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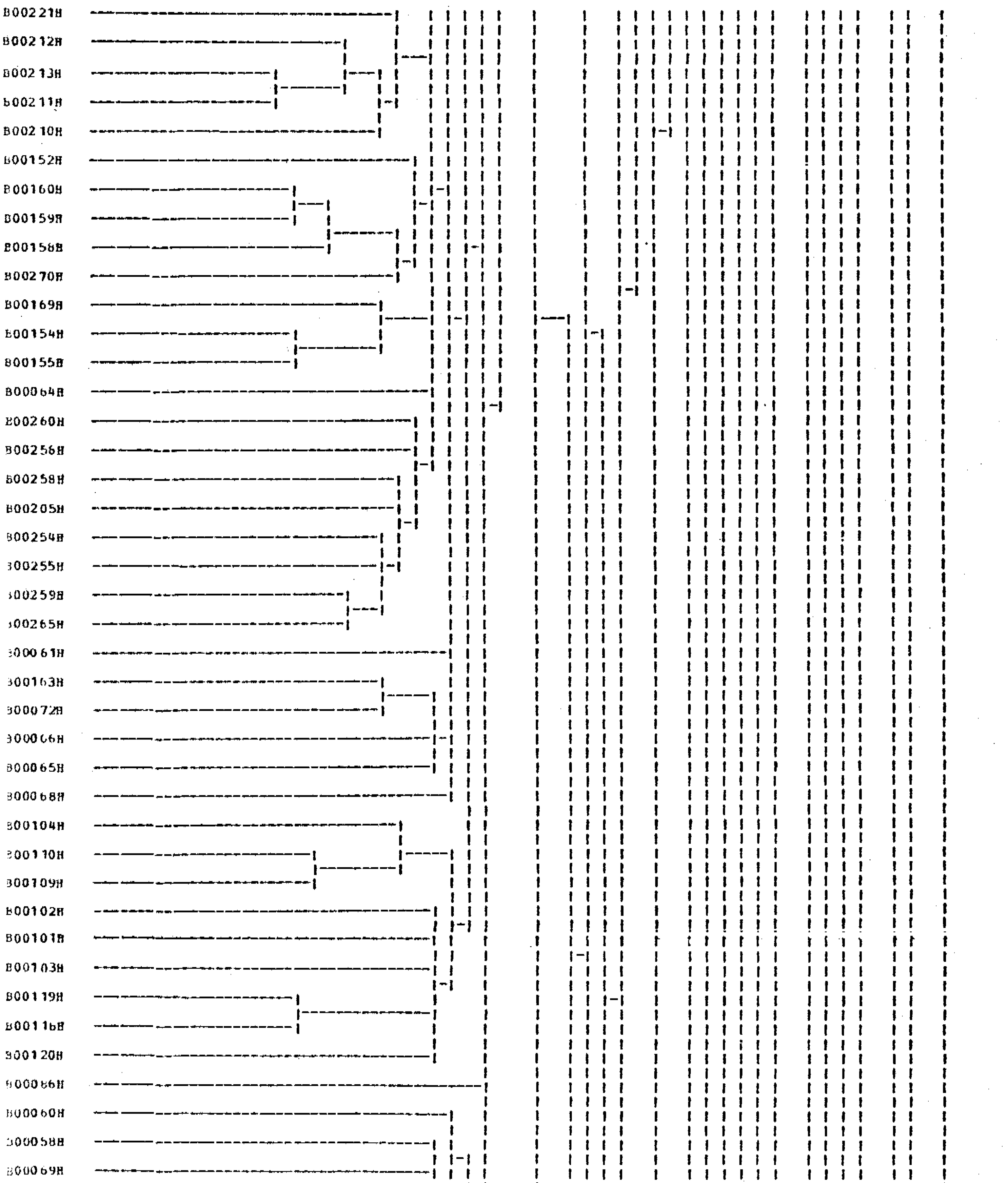
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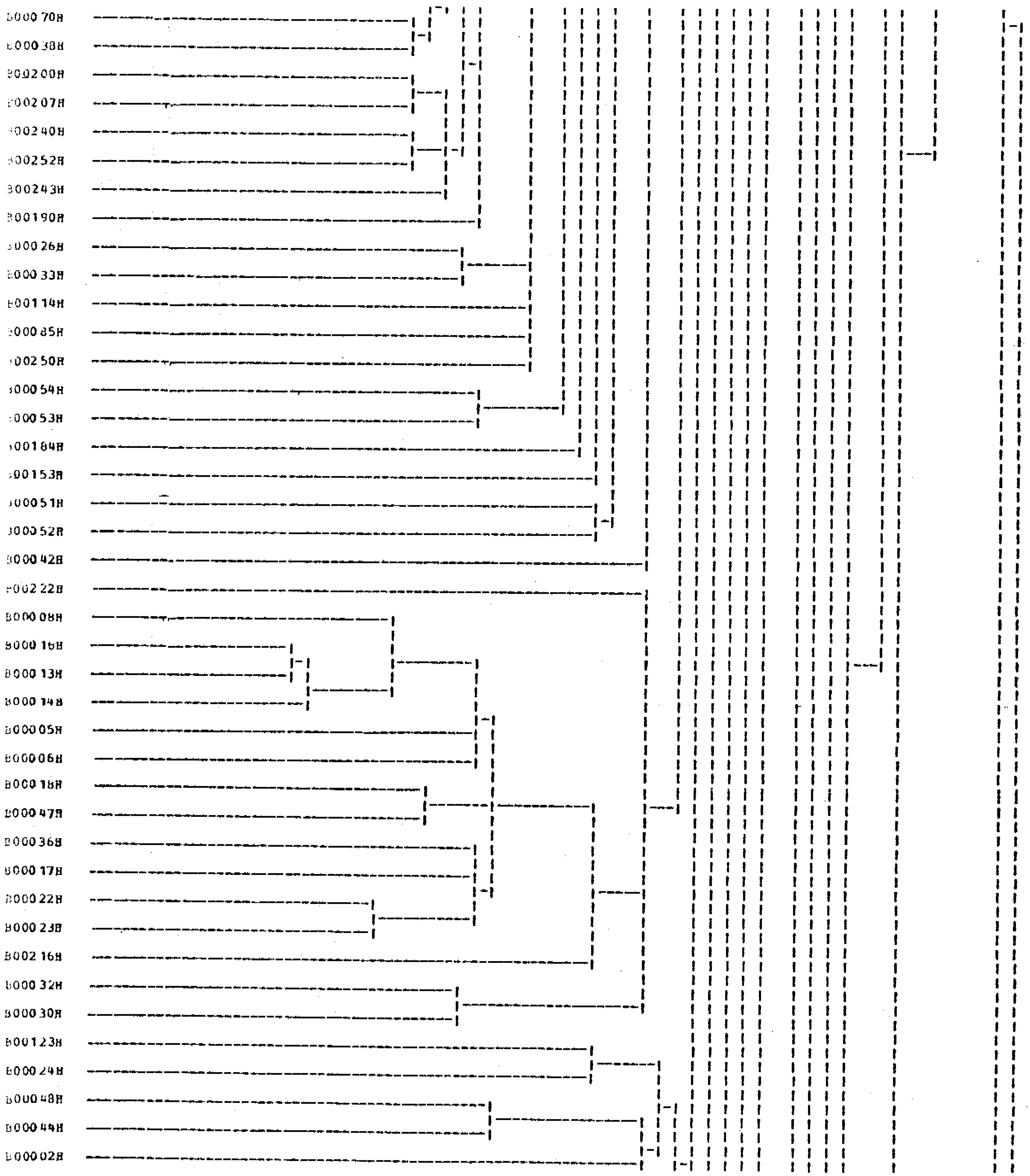
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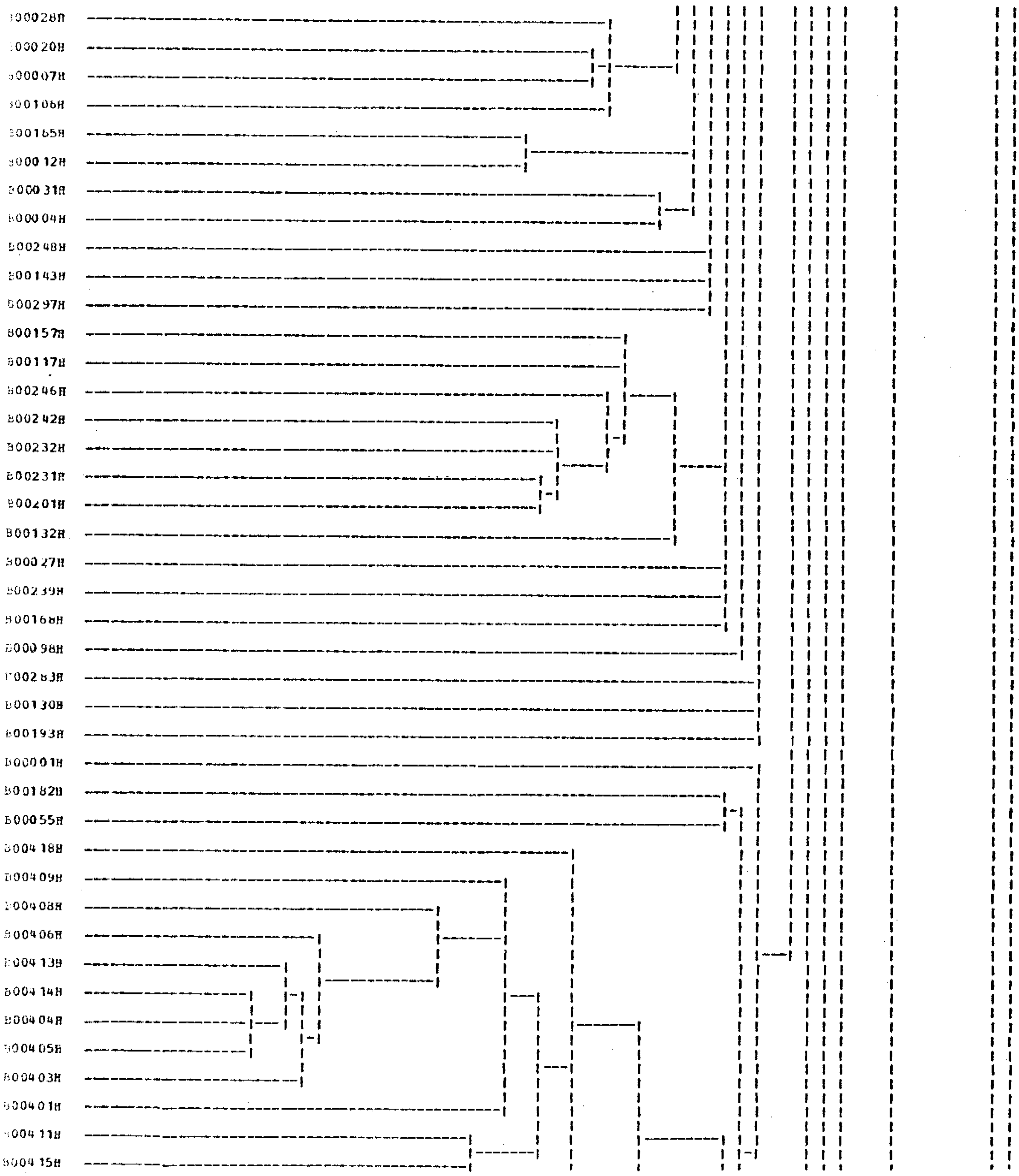
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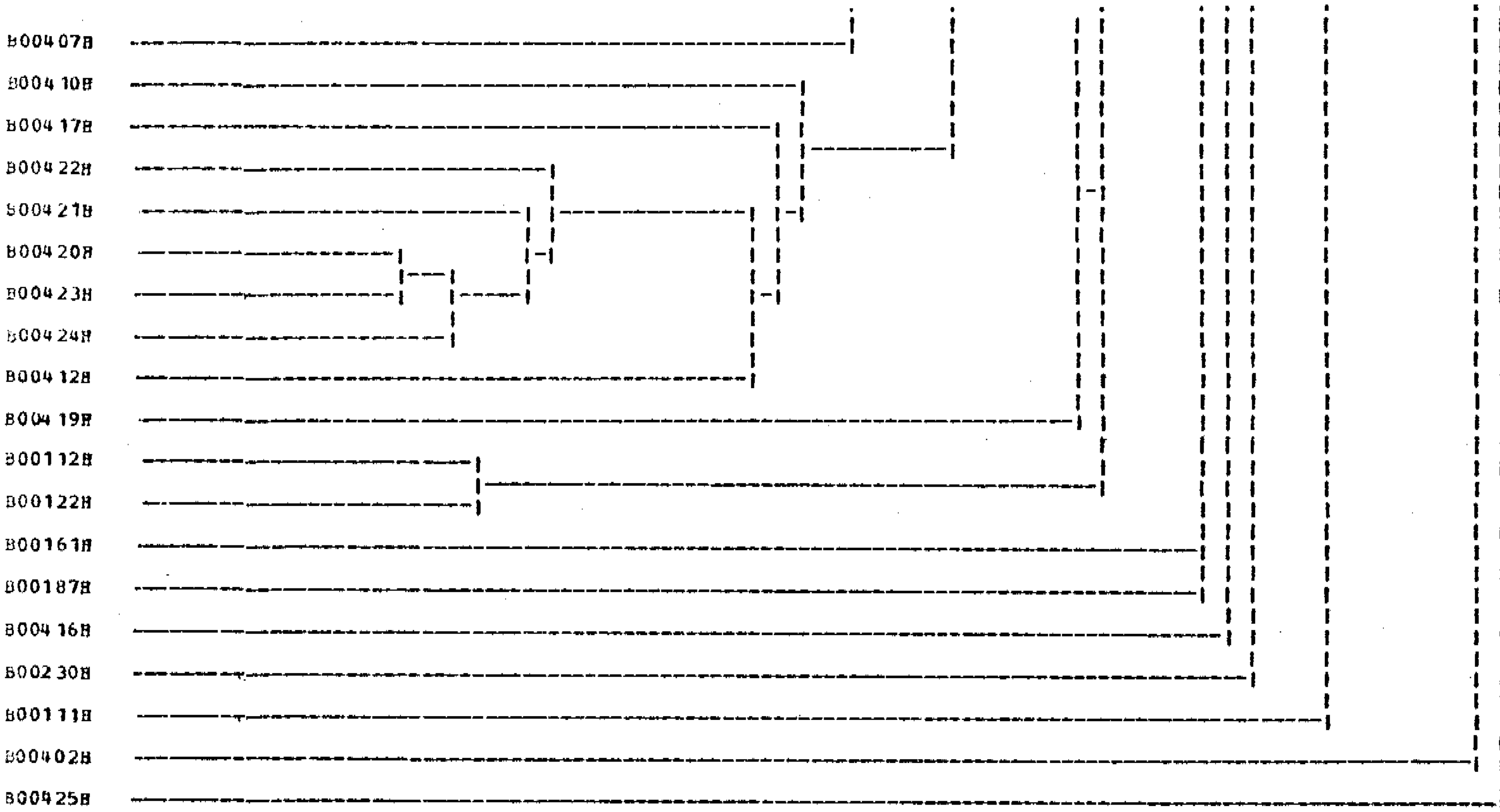
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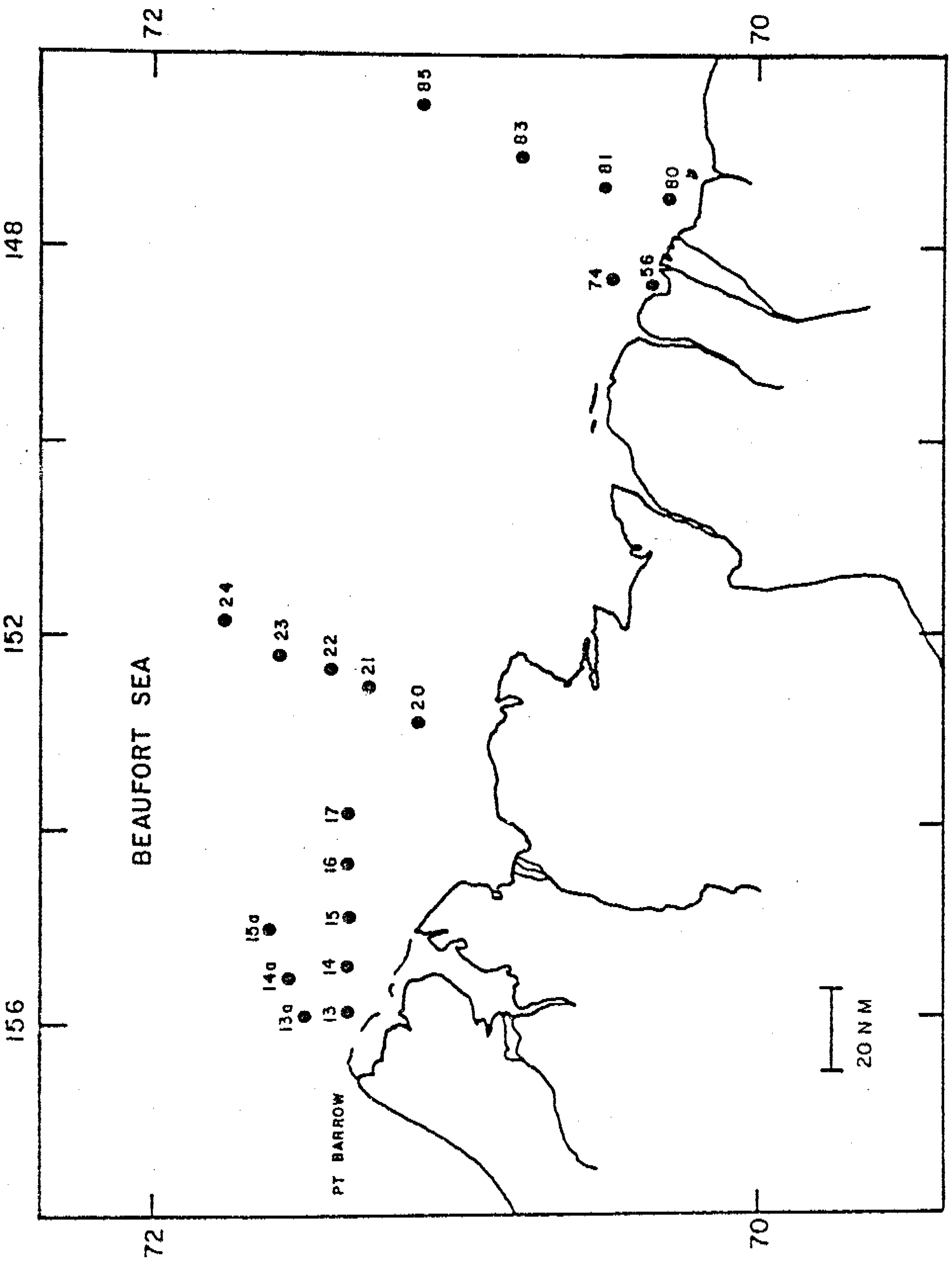
Figure 3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16
15
15a
14
14a
13
13a

Table I

	SAMPLE NUMBER	STATION NUMBER	CPM $^{14}CO_2$ PRODUCED
WATER	108	2	1,050
	109	3	4,000
	123	14a	2,100
	105	13	13,200
	106	14	9,950
	107	15	13,600
	121	16	1,500
	122	17	2,800
	120	20	1,900
	119	21	1,000
	118	22	3,400
	117	23	1,900
	116	24	1,600
	111	74	6,800
	113	80	4,250
	112	81	4,350
ICE	108	2	2,400
	109	3	2,150
	123	14a	226
	105	13	1,200
	106	14	2,700
	107	15	2,100
	121	16	857
	122	17	339
	120	20	124
	119	21	2,300
	118	22	533
	117	23	330
	116	24	398
	111	74	1,200
	112	81	145
	114	83	3,000
	110	85	1,800
SEDIMENT	104	2	9,500
	105	3	1,650
	101	13	2,500
	102	14	11,000
	103	15	2,200
	114	16	2,450
	115	17	1,550
	113	20	2,600
	112	21	3,500
	111	22	8,000
	110	56	2,500
	106	74	5,300
	108	80	4,100
	107	81	6,600

Quarterly Report

Contract #03-6-022-35109
Research Unit 30
Period 7/1 - 9/30

Assessment of Potential Interactions of Microorganisms and Pollutants Resulting from Petroleum Development in the Gulf of Alaska

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

October 1, 1976

I. Task Objectives

A. To characterize marine microbiological communities in sufficient detail to establish a baseline description of microbiological community characteristics on a seasonal basis.

B. To determine the role of microorganisms in the biodegradation of petroleum hydrocarbons.

II. Field and Laboratory Activities

A. Field Activities - No sampling was done during this period.

B. Laboratory Activities

1. Methods - Cluster analyses were performed on 247 microorganisms isolated from the October 1975 northwest Gulf of Alaska sampling. These analyses were performed using the GTP 2 clustering program at the National Institute of Health.

Laboratory testing on an additional 1000 isolates from the March northeast Gulf of Alaska sampling have been completed. This testing included 300 taxonomic tests for each organism. Data is being processed for analysis.

Isolates from crab samples collected in March by the Alaska Department of Fish and Game were also identified using the API identification system.

III. Results

Figure 1 shows a dendrogram for the organisms isolated at both 4 and 20 C during October 1975. Dendograms are graphic representations of the results of a cluster analysis. The dendrogram in Fig. 1 was calculated for Jacquard coefficients. Simple matching coefficients have also been calculated, isolated from crabs collected near and away from Kodiak Harbor, an area of human population. Figure 2 shows the locations of the crab collections. Table I for crabs collected in October was included, in part, in the last annual report, but several new isolates from these crabs have now been identified and included. As shown in both tables, the crabs collected near Kodiak Lagoon had many more species of microorganisms associated with them than the crabs collected away from this area. The isolates from the near Kodiak Harbor crabs included some human pathogens and some associated with fecal contamination. It would appear that these crabs have been contaminated with sewage. The microorganisms associated with fecal contamination were found in gill, gut and muscle tissues of the crabs collected in March.

IV. Budget

It is estimated that all funds will be expended as of October 1.

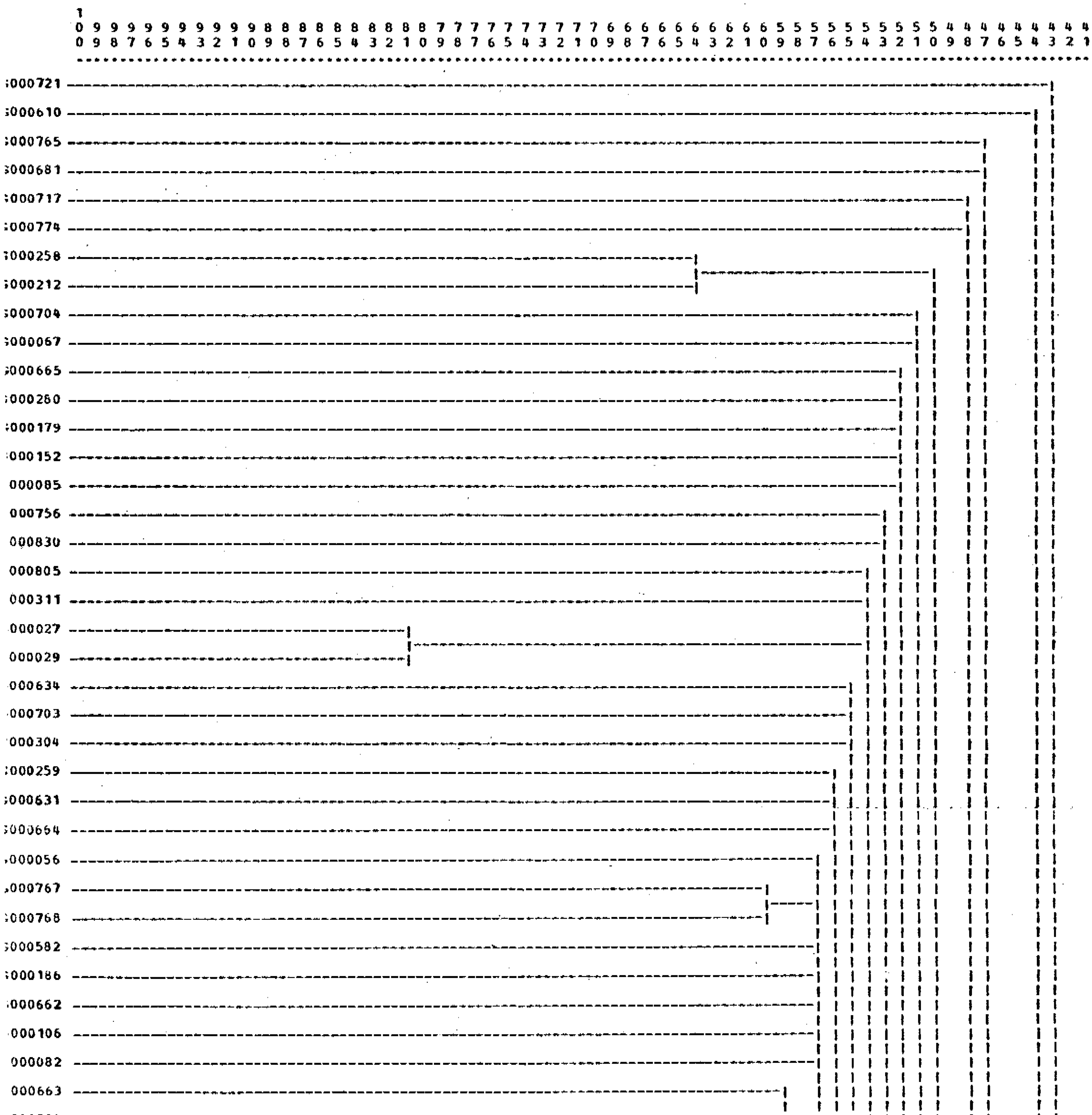
but are not included in this report. Also, cluster triangles, another graphic representation of a cluster analysis, have been prepared but are not included in this report due to their large size.

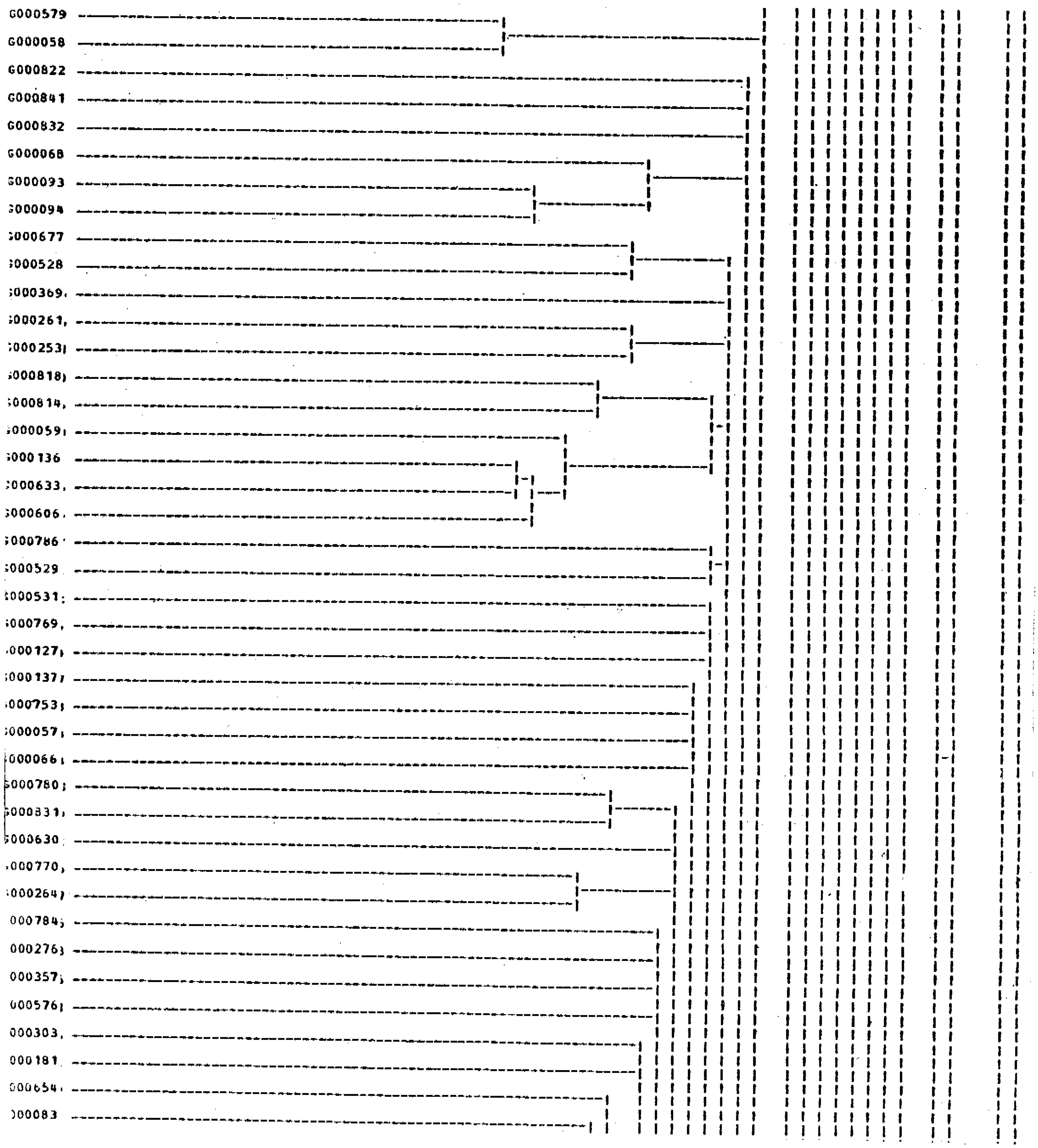
In reading the dendrogram, the strain name is shown in the left column. These strain names are the same ones used in reporting the properties and sources of these organisms in previous reports. The vertical lines of the dendrogram show at what percent similarity level organisms are related. For example, strains G000258 and G000212 are related at the 64% level. The scale for percent similarity is shown at the top of the first page of the dendrogram. The more closely organisms are related, the greater the percent similarity. As one can see in examining the dendrogram, there are hierarchial arrangements of the strains forming clusters of multiple strains related at a particular level. Although there is no absolute value for a cutoff, 70-80% was used to determine the boundaries of a cluster. This level probably is equivalent to the taxonomic level of a Genus in many cases. Examination of the dendrogram and cluster triangle showed 23 clusters. In all but five cases these clusters were composed of less than 5 organisms each. Most strains failed to cluster at any significant level. This indicates a very diverse microbial community, not dominated by any one type of organism. Further analyses are now underway to determine the feature frequencies, ie. characteristics of the dominant organisms. Comparisons with known organisms are planned to identify the isolated organisms. Feature frequency analyses should be completed during the next quarter.

The identifications of microorganisms found to be associated with commercial crabs are shown in Tables I and II. Both tables show microorganisms

Figure 1

DENDROGRAM

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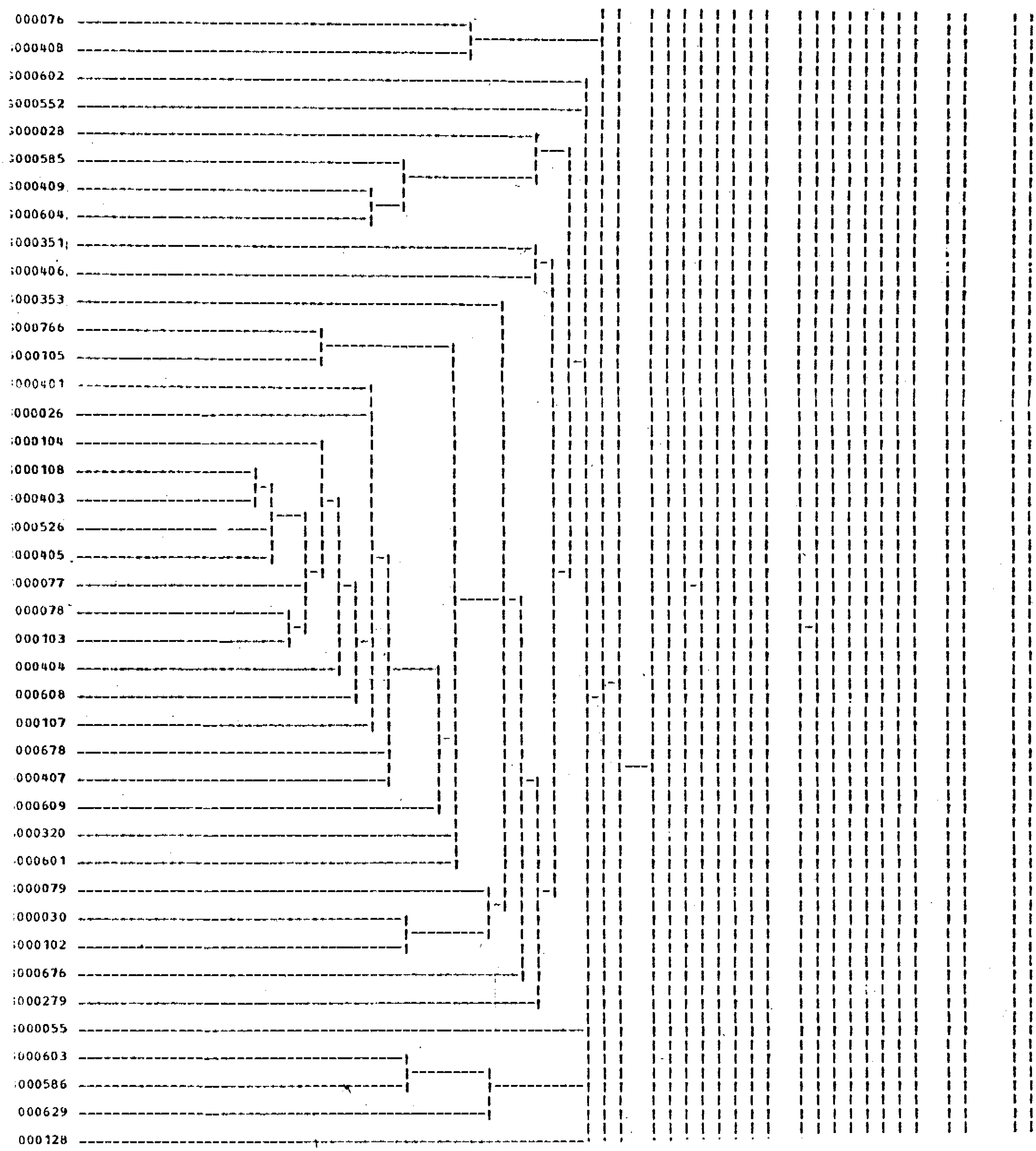
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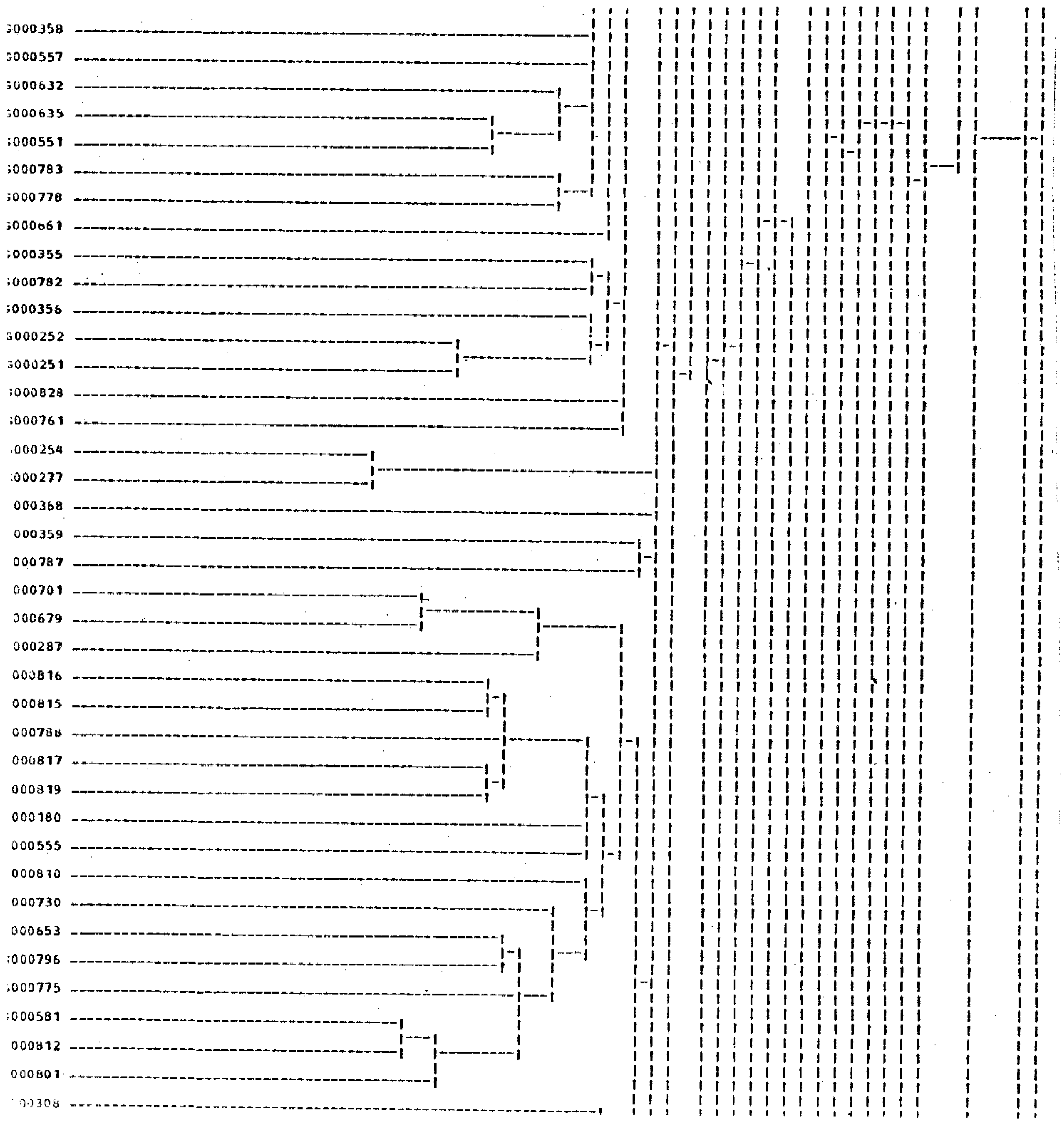
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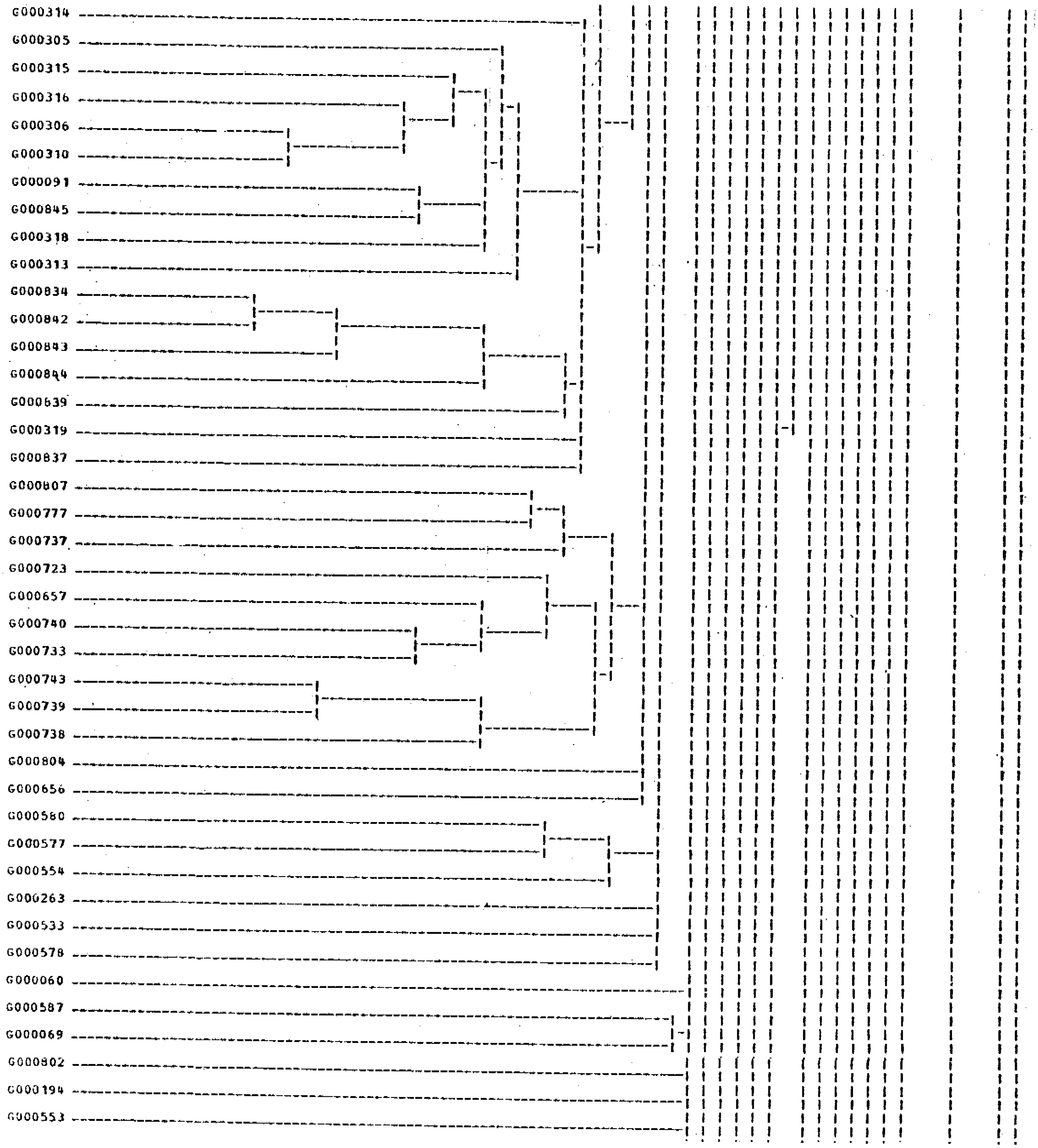
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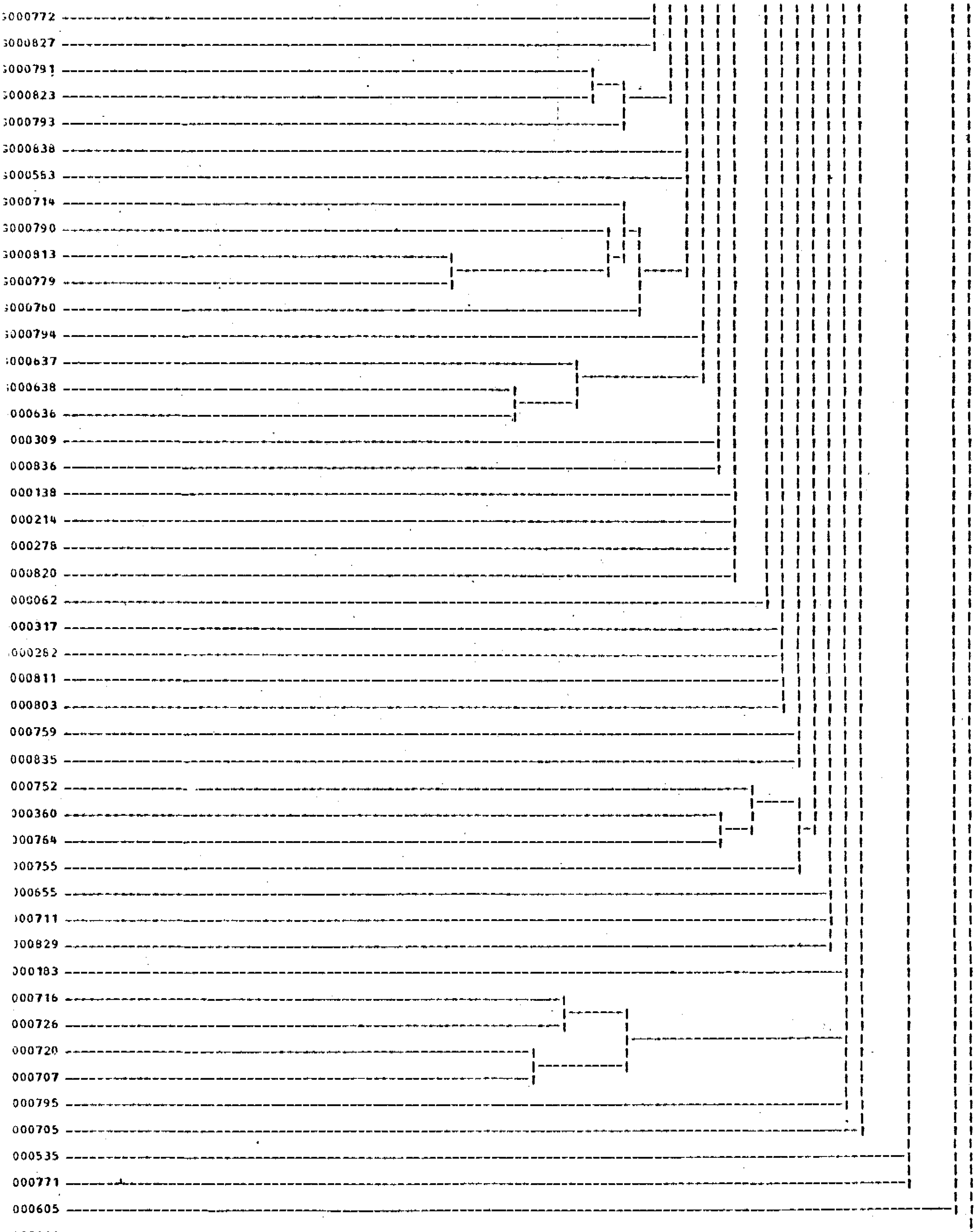
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Figure 2

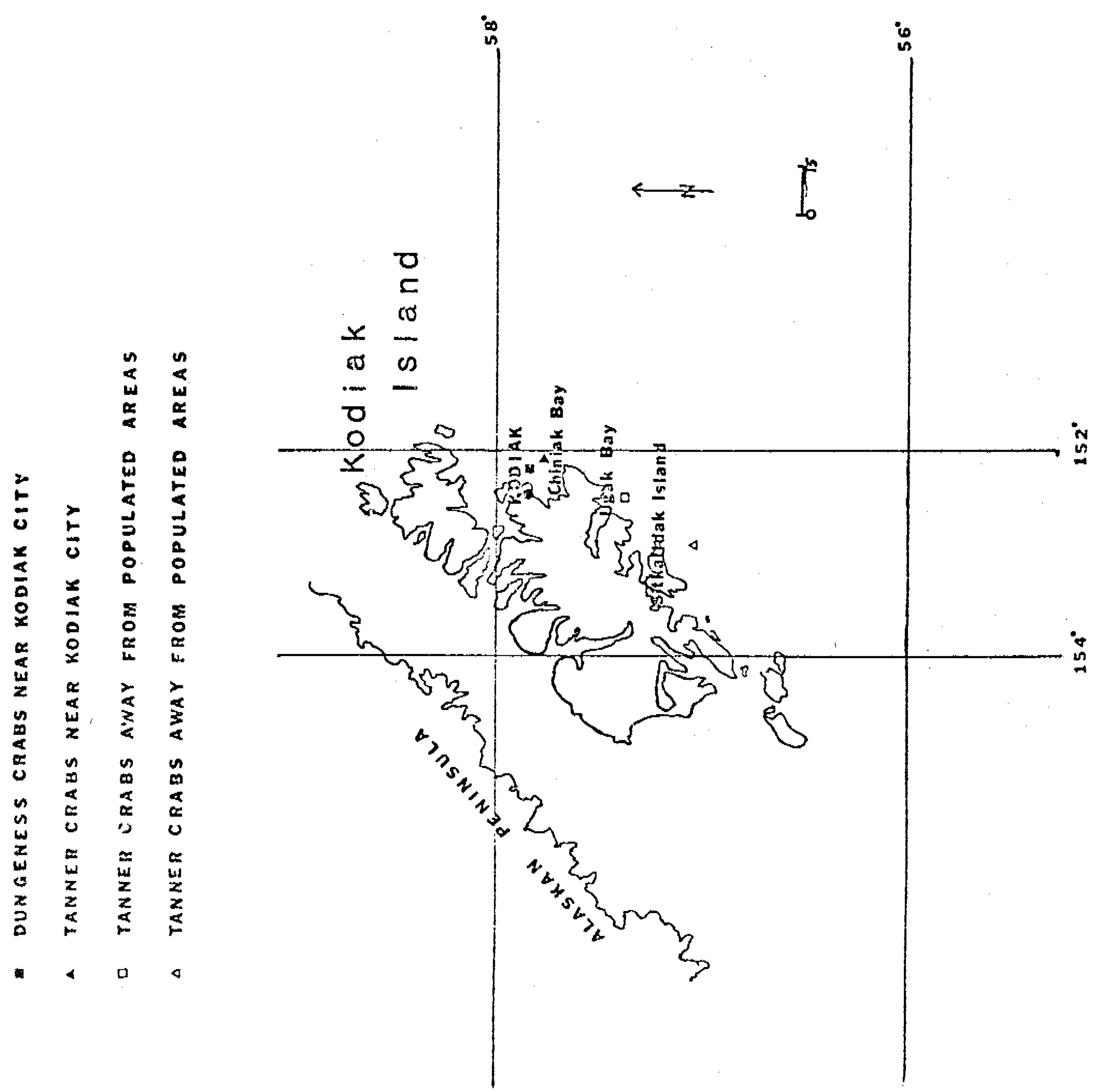
DUNGENESS CRABS NEAR KODIAK CITY
TANNER CRABS NEAR KODIAK CITY
TANNER CRABS AWAY FROM POPULATED AREAS
TANNER CRABS AWAY FROM POPULATED AREAS
Kodiak Island
KODIAK
Chiniak Bay
Ugak Bay
Sitkalidak Island
ALASKAN PENINSULA
58°
56°
152°
154°
N

Table I

OCTOBER SAMPLES

ORGANISMS ISOLATED FROM TANNER CRABS TAKEN OUT OF UGAK BAY AWAY FROM KODIAK HARBOR

MUSCLE	GILL	EGGS
Micrococcus spp.	*Acinetobacter calcoaceticus*	*Alcaligenes* spp.
Staphylococcus epidermidis	*Alcaligenes* spp.	*Acinetobacter calcoaceticus*
	Micrococcus spp.	*Bacillus* spp.
	Moraxella spp.	*Micrococcus* spp.
	Staphylococcus epidermidis	*Moraxella* spp.
		Pseudomonas fluorescens
		Pseudomonas putida
		Pseudomonas spp.
		Sarcina spp.
		Staphylococcus epidermidis

ORGANISMS ISOLATED FROM DUNGENESS CRABS TAKEN NEAR KODIAK HARBOR WITHIN CHINIAK BAY

MUSCLE	GILL
Sarcina spp.	*Acinetobacter calcoaceticus*
Staphylococcus epidermidis	*Aeromonas* spp.
Streptococcus group D	*Alcaligenes* spp.
Bacillus spp.	*Aeromonas hydrophila*
Pseudomonas spp.	*Bacillus* spp.
Alcaligenes spp.	*Moraxella* spp.
Moraxella spp.	*Pseudomonas maltophila*
Pasteurella spp.	*Pseudomonas fluorescens*
Acinetobacter calcoaceticus	*Pseudomonas* spp.
	Sarcina spp.
	Staphylococcus epidermidis
	Streptococcus group D
	* *Yersinia enterocolitica*
	* *Klebsiella pneumoniae*
	* *Pasteurella* spp.
	* *Klebsiella ozaenae*
	* *Citrobacter freundii*
	* *Enterobacter agglomerans*
	* *Enterococcus*

* - Organisms that are pathogenic to humans or that are commonly associated with fecal contamination.

Table II

MARCH SAMPLES

ORGANISMS ISOLATED FROM TANNER CRABS COLLECTED WITHIN CHINIAK BAY NEAR KODIAK HARBOR

MUSCLE	GILL	GUT
Staphylococcus epidermidis	*Staphylococcus epidermidis*	*Staphylococcus epidermidis*
Acinetobacter calcoaceticus	*Aeromonas hydrophila*	*Acinetobacter calcoaceticus*
Bacillus spp.	*Bacillus* spp.	*Bacillus* spp.
Pseudomonas aeruginosa	*Pseudomonas aeruginosa*	*Pseudomonas fluorescens*
Pseudomonas fluorescens	*Pseudomonas fluorescens*	*Pseudomonas* spp.
Pseudomonas spp.	*Pseudomonas cepacia*	*Sarcina* spp.
Sarcina spp.	*Pseudomonas putida*	*Serratia liquefaciens*
Serratia liquefaciens	*Pseudomonas* spp.	*Streptococcus group D*
* *Enterobacter aerogenes*	*Serratia liquefaciens*	* *Citrobacter freundii*
* *Enterobacter cloacae*	* *Citrobacter freundii*	* *Enterobacter cloacae*
	* *Enterobacter cloacae*	* *Enterobacter aerogenes*
	* *Enterobacter hafniae*	* *Klebsiella pneumoniae*

ORGANISMS ISOLATED FROM TANNER CRABS TAKEN OFF SITKALIDAK ISLAND AWAY FROM KODIAK HARBOR

MUSCLE	GILL	GUT
Sarcina spp.	*Alcaligenes* spp.	*Sarcina* spp.
Staphylococcus epidermidis	*Bacillus* spp.	*Staphylococcus epidermidis*
Streptococcus group D	*Flavobacterium* spp.	*Streptococcus group D*
	Moraxella spp.	
	Pseudomonas fluorescens	
	Pseudomonas putrefaciens	
	Pseudomonas spp.	
	Sarcina spp.	
	Staphylococcus epidermidis	

* - Organisms that are pathogenic to humans or that are commonly associated with fecal contamination.

Semi-Annual Report

Contract #01-6-022-11469
Research Unit #43/44/45

Reporting Period
March 16, 1976 - September 15, 1976
Pages

Stephen N. Chesler
Barry H. Gump
Harry S. Hertz
Willie E. May
Trace Organic Analysis Group
Bioorganic Standards Section
Analytical Chemistry Division
National Bureau of Standards
Washington, D.C. 20234

October 1, 1976

I. TASK OBJECTIVES

The objectives of the work reported herein are threefold: 1) to serve as a quality assurance laboratory for hydrocarbon analyses; 2) to demonstrate on "real" samples the liquid chromatography-fluorescence procedures developed at NBS for the analysis of polynuclear aromatic hydrocarbons (PAH's) in the marine environment; and 3) to complete methodology development for trace level hydrocarbons in marine tissue.

II. FIELD OR LABORATORY ACTIVITIES

A. Ship or Field Trip Schedule

There was one field trip during the period covered by this report: May 30-June 4, 1976 - chartered helicopter from Anchorage Helicopter Service.

B. Scientific Party

Willie E. May, National Bureau of Standards - principal investigator;

Stephen A. Wise, National Bureau of Standards - research chemist.

C. Methods

The results of methods development for trace hydrocarbons in marine tissue are presented below (Section III. Results).

D. Sample Localities

For use in hydrocarbon intercomparison studies the following sediment and Mytilus samples were collected: (a) 100 kg sediment from the Katalla River sampling site, (b) 100 kg sediment from the Hinchinbrook Island sampling site, and (c) 25 kg Mytilus from Simpson Bay.

III. Results

A. Sediment Round Robin

Sediment samples have been sent to 12 laboratories for participation in the first round robin. These laboratories include the 4 NOAA hydrocarbon contract labs and 8 laboratories involved in BLM, EPA and ASTM programs. Each laboratory received approximately 700 g each of Katalla and Hinchinbrook sediment. The sediment samples were stored frozen until shortly before homogenization. Both sediments were homogenized for three hours in a cement mixer and then individual samples were bottled with the mixer rotating. The samples were refrozen and shipped frozen to participating laboratories.

Before homogenization the cement mixer was sandblasted inside and out to remove the paint. The seams were then welded and sandblasted again. The mixer was rinsed with concentrated hydrochloric acid, hydrocarbon-free water, methanol, distilled pentane and then allowed to dry 1 h before introducing the sediment.

A sample letter indicating the parameters to which participating laboratories are to respond is appended to the report. The following investigators have received samples:

Dwight G. Ballinger - EPA, Cincinnati
John A. Calder - Florida State U.
Ronald A. Hites - M.I.T.
Isaac R. Kaplan - UCLA
C. Bruce Koons - Exxon, Houston
John L. Laseter - U. of New Orleans
William MacLeod - NOAA, Seattle
John McGuire - EPA, Athens
Steven J. Martin - Geochem Labs
Patrick L. Parker - U. of Texas
David Shaw - U. of Alaska
J. Scott Warner - Battelle Columbus

In addition, NBS is performing detailed analyses on both sediments. As mentioned in the letter that accompanied the samples, analyses are due back at NBS on October 1, 1976.

B. Liquid Chromatography (LC) - Fluorescence Analysis for Polynuclear Aromatic Hydrocarbons (PAH's)

The Annual Report (April 1, 1976) gave the results of methods development for LC-fluorescence analysis.

Several sediment and tissue samples have now been analyzed by this procedure. Sediment samples are analyzed by Soxhlet or ultrasonic extraction and injection of the concentrated extract directly into the LC system. Low level PAH's have been identified in both Santa Barbara and a Bahama tanker facility extracts. In the Bahamas extract benz(a)pyrene is the predominant peak, however it is a minor component coeluting with the major component in the Santa Barbara extract. Katalla River sediment extract gives four major peaks each of which is fluorescent at 400 nm. None of these peaks have been identified at present. Extracts of sediments taken from Siwash Bay, Wells Bay and Hinchinbrook Island show no measurable PAH content.

Figure 1 is a chromatogram of an extract of "Elizabeth River Oysters." LC-fluorescence has been used to identify chrysene (compound 1) and benz(a)pyrene (compound 2). Extracts of Alaskan *Mytilus* show no measurable PAH content.

C. Hydrocarbon Analysis in Tissue Matrix

An analytical method has been developed for the determination of petroleum hydrocarbons in various marine tissue samples. Initial efforts have been reported previously (Annual Report 7/1/75-3/15/76); in short, the method involves dynamic headspace sampling of the tissue homogenate followed by liquid chromatographic removal of the biogenic polar components extracted High resolution gas chromatography is then used for quantitation of the petroleum hydrocarbons present after LC clean-up.

As previously reported (Annual Report 7/1/75-3/15/76), aliphatic hydrocarbon recoveries for the headspace sampling of tissue homogenate were much lower than for aromatic hydrocarbons. Recovery data for aliphatic and aromatic internal standards are compared in Table I. It was assumed that the aliphatic hydrocarbons were being retained in the lipid fraction in the tissue homogenate and the partition coefficient for these hydrocarbons between the headspace sampling gas and the organophilic lipid fraction was quite unfavorable. It was found that the addition of 2 M KOH and ∿4 M KCl to digest the tissue matrix also improved the aliphatic recoveries slightly. By extending the headspace sampling period from 4 hours (2 hours at room temperature and 2 hours at 70 °C) to ∿16 hours at 70 °C, recoveries for the higher aromatics and aliphatics from water were increased to nearly 100%. Recoveries from the mussel tissue homogenate for the extended headspace sampling period were also approximately 100% for the aromatics but only ∿30% for the aliphatic components. Loss of the internal standard due to the LC clean-up was previously discussed (Annual Report 3/15/76), and additional data confirm that the losses are acceptable (see Table I).

The method which we presently employ for tissue analysis involves the addition of 2 M NaOH or KOH to the homogenate to aid in the disruption of the tissue matrix and subsequent headspace sampling for ∿16 hours at 70 °C. The LC clean-up and subsequent quantitation by GC are carried out as previously described (Annual Report, 3/15/76).

The effective removal of the more polar biogenic components by LC using a μBondapak NH_2 column is illustrated in Figure 2 (compare 2A and 2B). Figure 2C is the gas chromatogram of the polar biogenic components after removal from the μBondapak NH_2 column with methanol. A comparison of hydrocarbon levels obtained with and without LC clean-up is given in Table II for various tissue samples and a sediment sample. The data indicate that the LC removal of the polar biogenic components is necessary in order to accurately measure baseline hydrocarbon levels in tissue. The LC data for the clams exposed to 1 ppm crude oil indicate a level of ∿100 ppb above that of the control clams. This result is in line with previous experiments which have shown that only ∿10% of crude oil is in the gas chromatographic range covered by headspace sampling. The difference between the data for the control clams and those exposed to 10 ppm oil was also found to be ∿10% of the added level. The data for the Katalla River sediment (a sediment with a low level hydrocarbon burden) indicate that the petroleum hydrocarbon level is, as expected, unaffected by the LC clean-up. Figure 3 is a concentration histogram of the control clams with (B) and without (A) LC clean-up. The major components in the gas chromatogram are not hydrocarbons as indicated by their removal during the LC clean-up.

The results of initial analyses of Mytilus from various sites in the Prince William Sound/Northeastern Gulf of Alaska are listed in Table III. Work is continuing on the analyses from these sites and additional sites in order to determine the baseline hydrocarbon levels.

IV. PRELIMINARY INTERPRETATION OF RESULTS

Interpretation of the results of the first sediment round robin will be included in the next quarterly report, since the participating laboratories have not yet returned their analytical data. Some FY 76 funds have been reserved for the round robin evaluation.

V. PROBLEMS ENCOUNTERED/RECOMMENDED CHANGES

The only problem encountered is that we are not receiving sample splits of 10% of the samples collected by the hydrocarbon contract laboratories. We have received a copy of a letter from Dr. Rice of Auke Bay to Dr. Warner at Battelle indicating that samples are being transmitted to Battelle and also indicating which samples are to be split with NBS.

A helicopter was used on our sampling trip for collection of the intercalibration samples. When a few sites are to be sampled (at considerable distances), the helicopter seems to be by far the best means of transportation.

VI. ESTIMATE OF FUNDS EXPENDED

At the end of the transition quarter ∿\$20K remain for use in analyzing and interpreting the sediment round robin results.

Table I. Internal Standard Recovery (%)

Sample	Mesitylene	Naphthalene	Trimethyl-naphthalene	Phenanthrene	MeC_{11}	MeC_{14}	MeC_{16}	MeC_{18}
Water (4 hour headspace sampled)	8±6 (6)*	29±10 (6)	---	12±10 (6)	17±12 (6)	62±8 (6)	74±8 (6)	57±18 (6)
Water (16 hour headspace sampled)	6±1 (3)	52±16 (3)	95±9 (3)	92±7 (3)	31±14 (3)	84±6 (3)	97±6 (3)	94±5 (3)
Mussels (4 hours)	18±16 (2)	76±31 (3)	47±19 (3)	12±7 (3)	12±6 (3)	11±4 (4)	4±0.5(4)	2±1 (4)
Mussels, KOH+KCl (4 hours)	13 (1)	52 (1)	56 (1)	19 (1)	9 (1)	19 (1)	17 (1)	13 (1)
Mussels 0.1M KOH + 4M KCl (16 hours)	30±2 (2)	66±8 (6)	105±22 (6)	107±14 (6)	28±15 (2)	33±2 (2)	32±1 (2)	26±5 (2)
Mussels, 2M NaOH (16 hours) LC clean-up	---	26±6 (8)	80±20 (8)	80±14 (8)	---	---	15±4 (4)	7±5 (4)

*( ) denotes number of samples analyzed,

Table II

Comparison of Volatile Hydrocarbon Levels Obtained with and without LC cleanup (μg/kg)

	No LC	LC
Mytilus (site unknown)	1406 ± 139 (2)***	540 ± 79 (3)
Oysters (Middle Marsh, S.C.)	1834 (1)	652 (1)
Clams A (control)	509 ± 16 (2)	377 ± 124 (2)
Clams B (1 ppm oil)*	1421 ± 161 (2)	491 ± 153 (3)
Clams C (10 ppm oil)**	1704 (1)	1413 ± 560 (2)
Katalla River sediment	566 ± 52 (2)	574 (1)

*exposed to 1 ppm crude oil in the water.

**exposed to 10 ppm crude oil in the water.

***( ) denotes number of samples analyzed.

Table III

Mytilus Tissue Analysis

Site	Hydrocarbon Level (μg/kg)
Simpson Bay	411 ± 51 (2)*
Bligh Island	364 ± 85 (3)
Hinchinbrook Island	250 ± 68 (3)
Wells Bay	179 ± 111 (4)

*( ) denotes number of samples analyzed.

LC analysis of Elizabeth River oysters with UV (A) and fluorescence detection (C) with identification by fluorescence spectra (B)

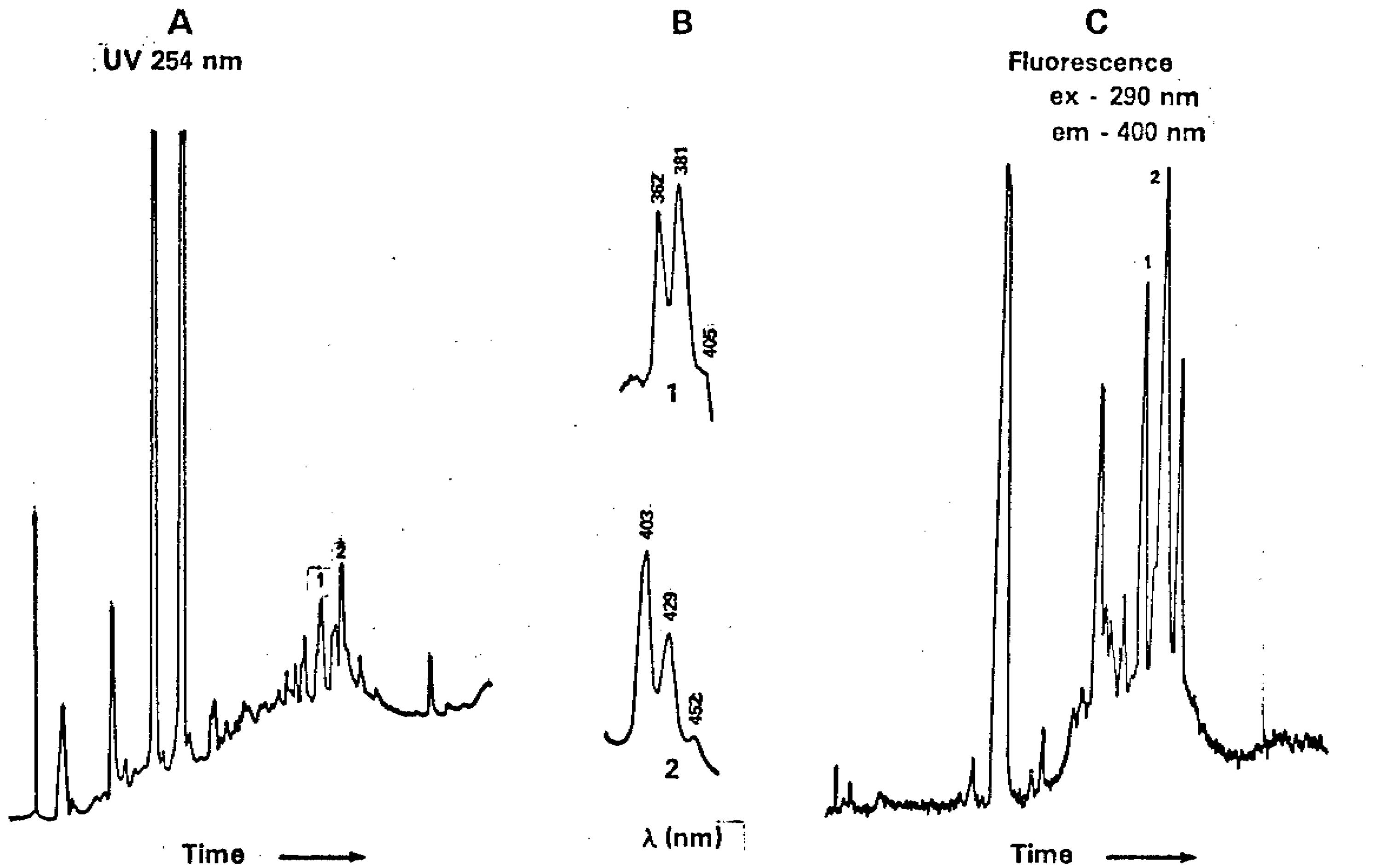

Figure 1

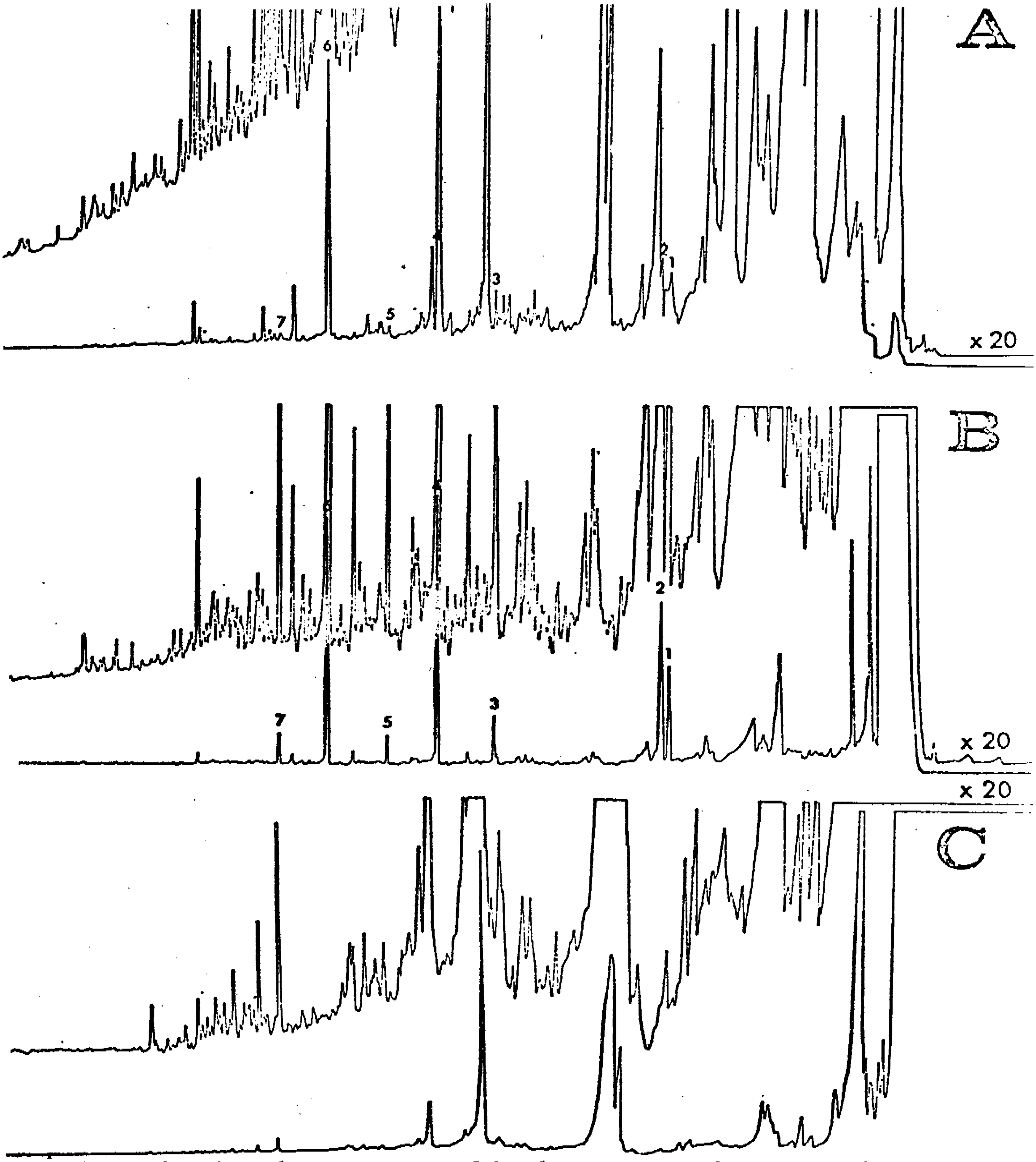

Figure 2. Gas chromatograms of headspace sampled <u>Mytilus</u> tissue with 50 µg crude oil added without any LC cleanup of the TENAX-GC pre-column (A) and with LC cleanup using a µBondapak NH_2 column (B). Numbered peaks correspond to the internal standard compounds each added at the ∿50 µg/kg level (1 = 2-methylundecane, 2 = naphthalene, 3 = 5-methyltetradecane, 4 = trimethylnaphthalene, 5 = 7-methylhexadecane, 6 = phenanthrene, and 7 = 2-methyloctadecane). Gas chromatogram of biogenic compounds removed from LC column with methanol (C).

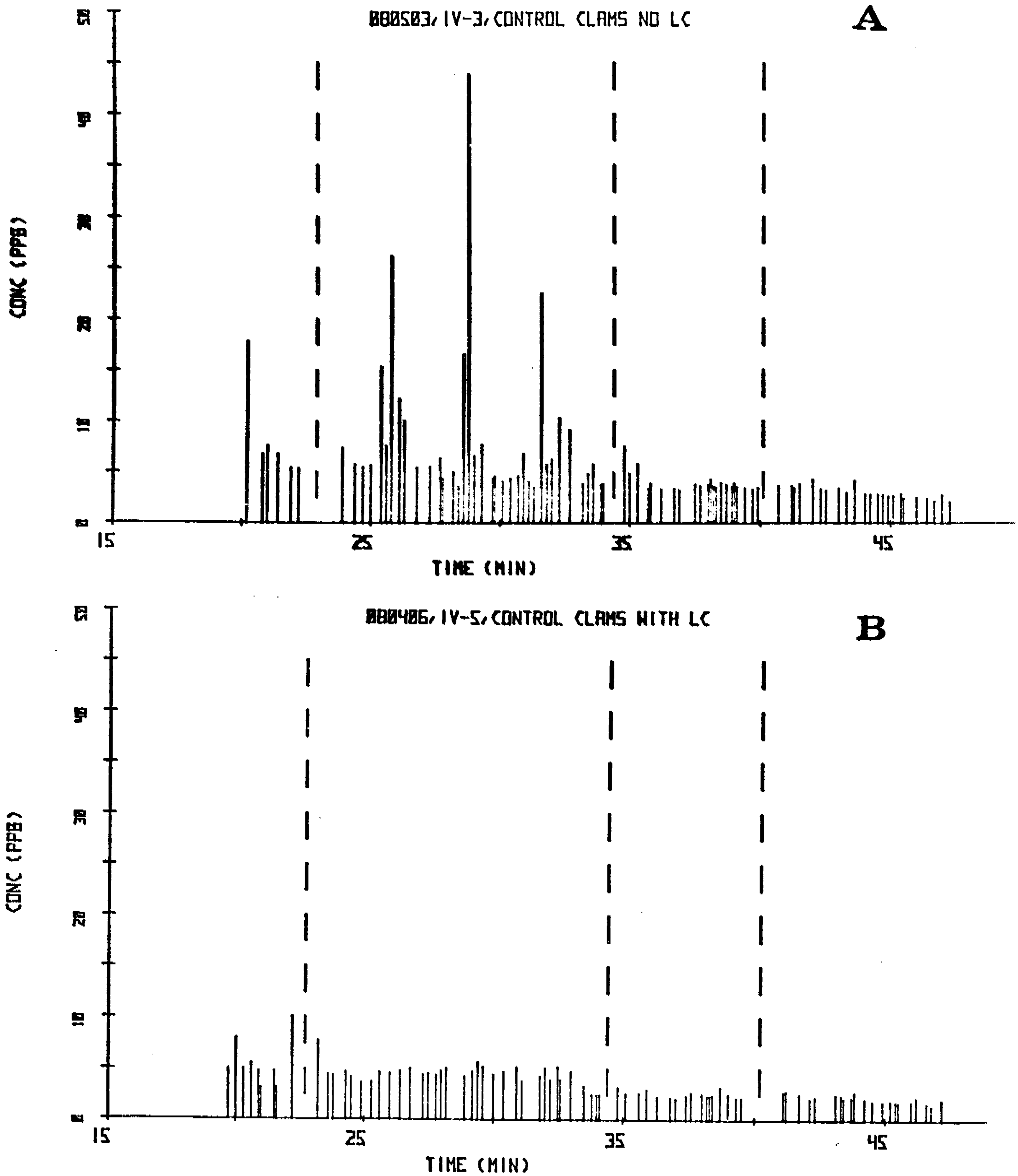

Figure 3. Concentration histogram generated from gas chromatogram of control clams prior to LC clean-up (A) and with LC clean-up (B).

August 27, 1976

Dr. David Shaw
Institute of Marine Sciences
University of Alaska
Fairbanks, AK 99701

Dear Dave:

We are sending out under separate cover four jars of frozen sediment. These samples came from two different sites in Alaska; one sample site is near a low-level oil seep (K-series bottles) and the other site is considered pristine (H-series bottles). Except for a 24 h period during which each sample was homogenized, these samples have been frozen since the time of collection. If you do not receive the samples by Friday, Sept. 3, 1976, please call our lab: 301-921-2153 (FTS---921-2153).

For the purposes of intercomparison we are interested in obtaining the following data:

1) total hydrocarbons in the GC elution range (roughly C_{10}-C_{30}); please specify the exact range you are reporting.

2) total extractable hydrocarbons.

3) pristane/phytane ratio and the amount of each of these present.

4) % water.

5) identities and amounts of the three most abundant aliphatic and the three most abundant aromatic hydrocarbons.

6) total polynuclear aromatic hydrocarbon (PAH) concentration.

7) identity and amount of the most abundant PAH (4 rings or larger).

Please respond to as many of these categories as you can and give results on a dry weight basis. Please report precision data when replicate analyses are performed. Also, please enclose as much of your raw data as possible. Finally, intercomparison of results is facilitated if you include a description of the methodology used in doing the analyses.

We look forward to receiving your results as soon as possible and we would like to have all results by October 1, 1976.

Sincerely yours,

Harry S. Hertz, Ph.D.
Research Chemist
Trace Organic Analysis Group
Bioorganic Standards Section

310.07 HSH:vm 8-27-76

RU# 47

NO REPORT WAS RECEIVED

A final report is expected next quarter

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DISTRIBUTION OF LIGHT HYDROCARBONS, C_1-C_4, IN THE NORTHEAST GULF OF ALASKA AND THE SOUTHEASTERN BERING SHELF

Dr. Joel Cline

Dr. Richard Feely

Pacific Marine Environmental Laboratory
3711 - 15th Avenue N.E.
Seattle, Washington 98105

September 29, 1976

I. OBJECTIVES

The low molecular weight hydrocarbon program was initiated in the OCS of Alaska in response to the environmental guidelines set forth in the Environmental Study Plan for the Gulf of Alaska, Southeastern Bering Sea and the Beaufort Seas (January, 1975). Briefly, the purpose was to establish the spatial and temporal variations (seasonal and diurnal) in the low molecular weight hydrocarbon fraction prior to exploration, development and production of fossil fuel reserves in the proposed lease areas. These components have proven to be valuable indicators of petroleum input arising from drilling, production, and transportation of crude oil and refined products.

In support of the basic objectives, attention was given to natural hydrocarbon sources, namely gas and oil seeps, production of hydrocarbons from near-surface bottom sediments, and biogenic hydrocarbon sources within the water column. Of particular importance is the ephemeral nature of the low molecular weight hydrocarbon fraction arising from local sources and their importance as reliable indicators of petroleum accumulations.

The aliphatic components measured in this study include methane, ethane, ethylene, propane, propylene, iso- and n-butanes. Chromatograms also are scrutinized for pentanes, but the results are not quantitative.

II. FIELD ACTIVITIES

A. Field Schedule

During the reporting period July 1 thru September 30, 1976, we participated on three cruises to the Alaskan OCS. The first was aboard the R/V MOANA WAVE to southeastern Bering Sea (Bristol Bay). During transit from Kodiak to the Bering Sea, surface water samples were taken approximately every two hours. However, the results of this surface transect and others in the vicinity of the Pribilof Islands are not available at this time because of lengthy delays in obtaining station positions. These data will be reported in the next reporting period. The second and third cruise was aboard the NOAA research vessel DISCOVERER to the northeast Gulf of Alaska and Norton Sound (Bay) and Chukchi Sea, including Kotzebue Sound. The results of this last field program will not be reported here because of insufficient time to process and synthesize the data. Below is a summary of our field activities for the reporting period.

Cruise No.	Research Vessel	Dates
RP-4-MW-76B-8 Bristol Bay	MOANA WAVE (Charter)	June 25 - July 8, 1976
RP-4-DI-76B-1 NEGOA	DISCOVERER (NOAA)	July 19 - 31, 1976
RP-4-DI-76B-4 Norton Sound/ Chukchi Sea	DISCOVERER (NOAA)	Sept. 8 - 24, 1976

B. Scientific Party

The participants on the cruises were:

NEGOA	Mr. Anthony Young, PMEL Lt. Cmdr. Larry Keister (NOAA) Mr. Charles Katz, University of Washington
Bristol Bay	Dr. Joel Cline, PMEL Ms. Susan Hamilton, University of Washington Mr. Charles Katz, University of Washington
Norton Sound/ Chukchi Sea	Dr. Joel Cline, PMEL Ms. Marilyn Pizzello, PMEL Mr. Charles Katz, University of Washington

C. Field Sampling and Shipboard Analysis

Water was taken from either 5 or 10-liter Niskin® samplers and stored in 1-liter glass-stoppered bottles to which was added approximately 100 mg sodium azide (NaN_3) to retard microbial activity.

LMWH are stripped from 1 ℓ volume of seawater using the procedure recommended by Swinnerton and Linnenbom (1967). A diagram of the gas phase equilibrator is shown in Figure 1. Although the system actually used in these studies is somewhat simpler in detail than that shown in Figure 1, the principle remains the same.

Hydrocarbons are removed in a stream of ultra-pure He (120 ml/min) and condensed on an activated alumina trap maintained at -196 C. Approximately 12 minutes of stripping are required to quantitatively remove the hydrocarbons (>98%) from solution, after which time the trap is warmed to 90-100 C and the absorbed gases are allowed to pass into the gas chromatograph (GC).

The hydrocarbons were chromatographed on a column (3/16" x 4') of Poropak® Q, 50-80 mesh, and detected sequentially by flame ionization (FID) as they emerged from the column. Enhanced separation of the olefins (i.e., ethylene and propylene) was accomplished by supplementing the above column with an activated alumina column (3/16" x 2") impregnated with 1% silver nitrate by weight. Chromatographic analysis of saturates and unsaturates requires approximately six minutes when columns are temperature programmed from 110 - 140°C.

D. Cruise Tracks

The sampling grids for NEGOA, Bering Sea (Bristol Bay), Norton Sound and Chukchi Sea are shown in Figures 2 - 5.

E. Data Collected and Analyzed

The following table depicts a summary of individual cruise activities during the reporting quarter. These activities include the number of stations occupied, samples analyzed, quality control procedures, miles of trackline and number of time series studies.

	NEGOA	BRISTOL BAY	NORTON BAY/CHUKCHI S.
Stations Occupied	47	55	79
Miles Trackline	1354	2827 [a]	2440
Samples Analyzed	276	319 [b]	339
Standard Analyzed	55	68	125
Reproducibility Studies	3	4	8
Number of Analyses	12	11	32
Time Series Station	0	0	2
Obs. Freq./Duration	-	-	2 hr./24 hr.
No. Analysis	-	-	78

a) This figure includes approximately 600 miles of surface profiling in the western Gulf between Kodiak and Unimak Pass.

b) This total includes 86 analyses performed during surface transects in the Western Gulf and Western Bristol Bay near the Pribilof Islands.

III. Results and Discussion

A. Bering Sea (Bristol Bay)

The spatial distribution of low molecular weight hydrocarbons (LMWH) were determined during the month of July 1976 as a continuation of our seasonal sampling program in the southeastern Bering Sea. These results will be compared to our previous observations conducted last year during the months of September and October.

The sampling grid employed during the cruise is shown in Figure 2 and is similar to that used last year. Because of a shortage of time, most of the EBB's stations were deleted as well as the time series stations.

1. Methane

The areal concentrations of methane in nl/l (STP) are shown in Figures 6 and 8 for the surface layers and 5 meters from the bottom. Concentrations of methane in the surface layers are generally between 100 - 150 nl/l, except in the central portion of the basin and near Herendeen Bay. The lowest values observed in the surface layers was 60 nl/l north of Unimak Pass, the highest concentration of methane was nearly 1600 nl/l near the entrance to Herendeen Bay (Figure 6). Surface values near Unimak Pass were generally in the range 100 - 200 nl/l.

In contrast, Figure 7 shows conditions as they existed in Sept. - Oct. of 1975. Surface concentrations of methane were generally less than 80 nl/l except near Herendeen Bay, and presumably reflect atmospheric equilibrium conditions.

The near-bottom concentrations of methane were little different from those observed in the surface layers (Figure 8). As before the highest values noted were near Herendeen Bay and Unimak Pass. In both regions, the maximum concentration of methane was near 300 nl/l.

Conditions as they existed in 1975 are shown in Figure 9. The major difference between the two seasons appears to be the high concentrations of methane observed in the "Golden Triangle" region north of Unimak Pass during 1975, where concentrations in excess of 700 nl/l were noted. Concentrations of methane observed in July of this year in the central basin were generally greater than 100 n/l, whereas they were less than this amount in the Fall of 1975.

In Figure 10 is shown the relative saturation values (C/C*) of methane in the surface layers. Assuming that the surface layers should be in equilibrium with the concentration of methane in the atmosphere, the solubility data of Atkinson and Richards (1967) were used to compute the equilibrium saturation value (C*). Although these solubilities are not highly precise, it appears that much of the surface waters are supersaturated with respect to methane. A small core of water north of Unimak Pass appears to be undersaturated ($\sim$ 20%) and may reflect our uncertainty in the actual methane solubility or its local partial pressure. Near Herendeen Bay, methane is supersaturated in the surface layers approximately 20-fold.

2. Ethane and Ethylene

Surface and near-bottom concentrations of ethane are shown in Figure 11 and 12. Concentrations of ethane in the surface layer were generally greater than 1 nl/l over the entire region. Values less than 0.5 nl/l were usually observed in the central basin north of Unimak Island and with the highest concentrations observed near Izembeck Lagoon and Herendeen Bay.

The distribution of ethane in the surface layers is similar to that observed in Fall of 1975, but the concentrations are regionally higher. During Sept. - Oct. 1975 surface concentrations rarely exceeded 0.6 nl/l in contrast to summer conditions where values in excess of 1 nl/l were not uncommon (Cline and Feely, 1976). As before, Herendeen Bay and Izembeck Lagoon appear to be sources of ethane as well as methane.

Near-bottom concentrations of ethane are shown in Figure 12. Concentrations less than 1 nl/l generally were observed in the north near

Nunivak Island increasing to values near 2 nl/l near the Alaskan Peninsula. Concentrations in excess of 2nl/l were found near Izembeck Lagoon. During Sept. - Oct. of 1975, near-bottom concentrations of ethane ranged from 0.5 - 1 nl/l (Cline and Feely, 1976).

The surface and near-bottom concentrations of ethylene are depicted in Figures 13 and 14. In contrast to distributions observed in Fall of 1975, concentrations of ethylene were near 5 nl/l over most of eastern Bristol Bay. It is suspected that the four-fold increase in the concentration of ethylene is the result of elevated rates of primary productivity. Although no carbon fixation rates were obtained during this cruise, dark green water and enormous numbers of birds signified vigorous organic productivity.

Apparent in both the surface and near-bottom areal distributions of ethylene are strong depletions in the central basin area. This situation presumably arises from the surface advection of ethylene-depleted waters from the west. The distribution that emerges is in qualitative agreement with general circulation patterns in Bristol Bay.

3. Propane, Propylene, iso- and n-Butanes

The areal distributions of propane are shown in Figures 15 and 16. Surface concentrations ranged from 0.2 - 0.8 nl/l except near the Kuskokwim River, where a single value of 1.8 nl/l was observed. Ignoring this as a possible spurious value, the highest concentrations were observed near the boundaries of Bristol Bay followed by systematically lower concentrations in the central basin area (0.2 - 0.3 nl/l).

Near bottom concentrations of propane ranged from 0.2 - 0.9 nl/l with no discernible geographical pattern (Figure 16). Both the surface and near-bottom concentrations are similar to those observed in Sept. - Oct. of 1975.

The distribution of propylene in the surface layers in shown in Figure 17. Concentrations are nearly a factor of three greater than the sum of propane plus propylene observed in Fall of 1975. The higher concentrations of propylene are attributed to high levels of primary production.

Unusually high concentrations of propylene were observed near the Kuskokwim River. Concentrations in excess of 7 nl/l in the Kuskokwim river plume are presumed to have originated from the river proper or from processes in the estuary. The nature of the process resulting in elevated concentrations of propylene not accompanied by similarly high concentrations of ethylene is unknown.

The distribution of propylene near the bottom is similar to that observed for ethylene (see Figure 14). Concentrations of propylene were systematically higher than those observed in Sept. - Oct. 1976. Amounts of propylene generally exceeded 1 nl/l near shore and less than 0.5 nl/l in the central portion of the basin. This distribution is similar to that observed for other low molecular weight hydrocarbons in Bristol Bay and is believed to result from the intrusion of cold bottom water containing low concentrations of propylene along the east-west axis of the basin (cf. Figure 21).

The concentrations of iso- and n-butanes were near or below their detection level. Normally the concentrations of the C_4 hydrocarbons ranged from a trace (0.03 nl/l) to approximately 0.1 nl/l.

4. Discussion

The concentrations of most low molecular weight hydrocarbons throughout the water column were greater than similar observations taken in Sept. - Oct. of 1975. This is believed to be the result of increased biological activity, both in the water column and in surficial sediments. There is no question that components such as ethylene and propylene are produced in the water column as the result of elevated biological activity, but the specific source is not known at this time. It may be the direct result of primary production or microbial degradation of organic material, or zooplankton respiration and excretion products.

The source or sources of methane is not clearly discernible at this time. While it is obvious that organic-rich sediments are a likely source, production in the water column can't be ruled out at this time. High surface concentrations observed this year in contrast to conditions last fall suggest that significant quantities of methane may be produced in the water column proper. Since methanogenesis is a strict anaerobic process, we conclude that if methane is produced in the water column, it probably has arisen from microbial degradation of fecal material.

A characteristic parameter used in the identification of hydrocarbon sources is the ratio (R) of methane to ethane plus propane (Brooks and Sackett, 1973). Because biological production of low molecular weight hydrocarbon usually leads to a preponderance of methane relative to other components, a low value of R is indicative of low temperature thermal cracking of organic matter in sediments or the seepage of petroleum and/or natural gas containing relatively high concentrations of ethane, propane, butane, etc. We have formed the ratio from our analysis in Bristol Bay and the results are depicted in Figure 19. It can be readily seen that the values range from a low of 13 near Nunivak Island to a high of 357 north of Unimak Pass. Ignoring the low values as being spurious, R values now range from 40 to 357. According to Brooks and Sackett (1973), this range of values is indicative of microbial production of light hydrocarbons. In the final report, a detailed discussion of the applicability of the R ratio to the OCS areas will be presented.

The surface and near-bottom distributions of the low molecular weight hydrocarbons reveal a strong correlation with the distribution of temperature (Figure 20 and 21). Concentrations of ethylene near the bottom correlates well with temperature whereas similar comparisons with methane are significantly poorer. From this we would conclude that the bottom is probably a strong source for methane and a weak source of ethylene. This fact also is borne out by the methane-ethylene relationship shown in Figure 22b where the concentrations are reported for the near-bottom waters only. Here methane production in bottom sediments appears to be largely independent of ethylene production. It is concluded that during periods of high productivity, the water column is probably the major source of ethylene. Based on the methane concentrations observed this summer, it would appear that significant quantities of methane are produced in the water column and that its relationship to other low molecular weight components is different than that observed arising from sediments.

B. NEGOA

The spatial distribution of low molecular weight hydrocarbons was determined in July of 1976 from observations conducted at the stations shown in Figure 3. This survey is the last of three scheduled cruises to the region during the past year for the purpose of investigating seasonal changes. In this report, only salient seasonal features will be presented with an indepth analysis to follow in the final report. Hopefully, studies to be conducted next year in Cook Inlet, on the Kodiak Shelf and Tarr Bank will be useful in the identification of regional sources and sinks of low molecular weight hydrocarbons.

1. Methane

Surface concentrations of methane are shown in Figure 23 for the period July 1976. As stated previously, concentrations over the shelf are everywhere greater than 100 nl/l diminishing to 70 - 80 nl/l offshore. Conditions observed offshore presumably represent near-equilibrium conditions with the partial pressure of CH_4 in the atmosphere. Of special note are the enormous concentrations of methane detected in the surface layers near Icy and Yakutat Bays. Station 9, at the entrance of Yakutat Bay, showed a surface concentration of methane of nearly 1700 nl/l, a value approximately 20-fold over equilibrium saturation. Insomuch as bottom concentrations are significantly lower in the region (cf. Figure 26), it is concluded that these high surface values represent *in-situ* biological production or entrainment of methane in surface water originating in Yakutat Bay. The presence of elevated concentrations of ethane and propane (see below), in addition to methane, strongly suggests that seep (s) in Yakutat Bay may have been active during the time of the cruise. Estuarine flow would have suppressed the subsurface distributions of these gases.

It is not known at this time whether the source of methane was biological in nature or, as suggested above, the result of seep activity in Yakutat Bay. Because ethane and propane concentrations were high whereas rather typical concentrations of ethylene and propylene were found, a non-biological origin for the hydrocarbons (i.e., seeps, low temperature thermal cracking) is suspected.

If the seep occurred in Yakutat Bay, the zonal distribution along the coast would be explained by normal estuarine circulation out of Yakutat Bay and the prevailing westerly surface drift along the coast. What is difficult to conceive, however, is the persistence of excess quantities of methane in surface waters, which are in direct contact with the atmosphere. The plume extends about 200 km down the coast from Yakutat Bay to Kayak Island.

In the Tarr Bank - Kayak Island area, surface concentrations of methane are in the range of 100 - 300 nl/l, not unlike the conditions observed in Oct. - Nov. 1975 and Apr. 1976 (Figures 24 and 25). In all cases a surface divergence of waters rich in methane from depth is indicated.

Near-bottom concentrations of methane are depicted in Figure 26. The highest concentrations of methane (>1500 nl/l) were observed over and to the north of Tarr Bank, extending south through the Hinchinbrook Sea Valley. Concentrations of methane exceed 600 nl/l over much of the region. Another ridge of high methane concentrations exists to the east of Kayak Island, where concentrations exceed 700 nl/l.

A common feature of the near-bottom methane distribution is its variability. Comparison of Figure 26 with similar observation, taken in Oct. - Nov. 1975 and April 1976 (Figures 27 and 28) reveal that both the bottom sources and strengths appear to change with season. In April, near-bottom concentrations of methane did not exceed 500 nl/l and were nominally 200 - 400 nl/l (Figure 28). Strong bottom sources of methane appear to exist in the fine-grained sediments found around the perimeter of Tarr Bank and to a lesser extent to the east of Kayak Island. The strength of the sources may change with season (i.e., organic matter flux, temperature, etc.), but local circulation probably plays a dominant role in the seasonality of the distribution. (Compare Figures 26, 27, and 28).

2. Ethane and Ethylene

The areal distributions of ethane in the surface layers and near the bottom is shown in Figures 29 and 30. Surface values in the vicinity of Tarr Bank are 0.4 - 0.6 nl/l, increasing significantly to concentrations in excess of 1 nl/l to the east of Kayak Island. Mentioned previously, these high concentrations of ethane appear to arise from Yakutat Bay and were found in association with high concentrations of methane. The maximum concentration of ethane was 11.4 nl/l (Figure 29, Station 9). Concentrations of ethane observed in Oct. -Nov. 1975 and Apr. 1976 were uniformly in the range 0.2 - 0.4 nl/l, similar to the aforementioned values obtained in the Tarr Bank area.

Near-bottom concentrations of ethane range from 0.2 - 1.3 nl/l, the average being 0.4 $\pm$ 0.2 nl/l. The average near-bottom ethane concentration observed in Oct. - Nov. 1975 was 0.5 $\pm$ 0.2 nl/l, and 0.3 $\pm$ 0.2 nl/l in April of 1976.

With the exception of the observations taken near Yakutat Bay in July, ethane shows little seasonal variability in the surface layers or of depth.

The concentration of ethylene in the surface layers is shown in Figure 31. It is rather uniform over most of the region, ranging from a low of 1.5 nl/l near the Copper River to values in excess of 3 nl/l in the region of Icy Bay and Yakutat Bay. The mean concentration of ethylene is 2.6 $\pm$ 0.5 nl/l. This compares to an average surface value of 0.7 nl/l observed in Oct. - Nov. of 1975 (Cline and Feely, 1976). These differences are attributable to seasonal variations in primary productivity.

The near-bottom distribution of ethylene is reflected in Figure 32. A core of relatively high concentrations of ethylene is found over Tarr Bank and to the west of the Copper River delta. The average concentration over the entire region is 1.1 $\pm$ 0.6 nl/l, which is the same mean observed in Oct. - Nov. of 1975, but significantly higher than the average value of 0.6 nl/l observed in April 1976. Whether the sources of ethylene are related to processes occurring in the near bottom waters or in the surface layers of the sediments, it appears that little change occurs seasonally.

3. Propane, Propylene, iso-, and n-Butane

The areal distributions of propane are reflected in Figures 33 and 34. Surface concentrations of propane are rather uniform in the Tarr Bank - Kayak Island Area, but increase dramatically near Icy Bay and Yakutat Bay. The high concentration (4.6 nl/l) observed at the entrance to Yakutat Bay is correlative with anomalous concentrations of methane and ethane, mentioned previously. Ignoring the high values along the eastern extremities of the survey region (propane $\geq$ 1 nl/l), the average concentration is 0.4 $\pm$ 0.1 nl/l, which compares to a mean of 0.2 nl/l observed in Oct. - Nov. 1975. With the exception of the unusual occurrence of propane observed near Icy and Yakutat Bays, the distribution of propane in surface layers appears to be spatially and temporally uniform.

Areal distribution of propane near the bottom, shown in Figure 34, also in spatially uniform. The average concentration is 0.25 $\pm$ 0.1 nl/l, identical to the mean observed in Oct. - Nov. 1975.

The surface distribution of propylene is shown in Figure 35. Concentrations over most of the region are in excess of 1 nl/l, averaging 1.3 $\pm$ 0.3 nl/l. The low value of 0.2 nl/l observed south of Icy Bay was considered spurious and ignored in the calculation of the average. In Fall of 1975, surface propylene concentrations were uniformly low (< 0.3 nl/l), reflecting a significant increase in the production of this olefin during the summer months. This is attributed to higher levels of organic productivity occurring in the month of July, as compared to other seasonal measurements.

Near-bottom concentrations of propylene are revealed in Figure 36. Concentrations are uniform throughout the region, averaging 0.35 $\pm$ 0.16 nl/l. These levels are similar to concentrations observed in Oct. - Nov. 1975.

Concentrations of iso- and n-butane were everywhere below 0.1 nl/l. Because of inherent low-level contamination of water samples, the uncertainty in the concentration of butanes below 0.1 nl/l is very large. In most cases, the concentration of the C_4 aliphatics, after correction for blanks, was below the detection limit of 0.03 nl/l.

4. Discussion

The distribution of methane in the water column is highly variable in both time and space. Comparison of results with past cruises indicates that biological activity and local circulation are the major processes responsible for the distribution of dissolved methane. The fine-grained sediments surrounding Tarr Bank appear, as they have in the past, to be a large source of methane, presumably biological in origin. The effect of this source on the overlying water column is difficult to interpret however. For example, comparison of Figures 26, 27, and 28 indicates that the methane distribution just above the bottom is controlled by circulation patterns, seasonal sources or both. If methane appearing in the water column is the result of a diffusive flux from depth in the sediments (eg. > 10cm), we would not expect strong seasonal changes in the source of methane since processes at depth in the sediment are relatively unaffected by temporal changes occurring at the sediment water interface. On the other hand, if most of methane is generated at the sediment-water interface, seasonal changes might well be predicted because of temporal fluxes of organic matter to the bottom (e.g. fecal material), or changes in bottom water temperatures.

From our studies to date, it appears that during late Fall and probably winter, the major source of methane to the water column is from the benthos. However, observations conducted this summer reveal a significant number of local regions in which negative surface-to-bottom gradients were observed. (See Figures 23 and 24). We conclude that during periods of strong biological activity, methane appears to be formed in the water column, presumably from the decay of organic matter in microenvironments (e.g. fecal pellets).

Shown in Figures 37 and 38 are the horizontal distributions of methane away from the coast near Resurrection Bay (Figure 37) and Yakutat Bay (Figure 38). Also depicted as inserts are the isopycnal surfaces for each transect. In both cases, the major source of methane appears to be the bottom with dispersion along isentropic density surfaces. Both transects reveal the influence of a surface current, low in methane, located over the shelf break which has greatly modified the subsurface distribution. This is in stark contrast to conditions observed in Oct. - Nov. of 1975, when a core of methane-rich water penetrated to more than 100 km offshore (Figures 39 and 40).

We have also attempted to characterize sources of low molecular weight hydrocarbons by utilizing certain component ratios. Two of these relationships are shown in Figures 41 and 42. The first diagram shows the relationship of methane to ethane near-bottom samples only. Assuming that the components observed in the lower water column have arisen mainly from sediments, methane concentrations in excess of 200 nl/l appear to be independent of ethane concentrations. If seep activity or thermal cracking processes were operative in a dominant way, a linear relationship between the concentrations of methane and ethane should prevail. The three points lying above the general data grouping are all from the Tarr Bank region (Figure 30), and conceivably might represent input from petroleum or natural gas sources. This is purely speculative at this point.

The relationship between ethane and ethylene for the near-bottom samples is shown in Figure 42. As it was observed in Oct. - Nov. 1975, a good correlation exists between these two variables and would suggest a common source for both.

The ethane/ethylene ratio is near 0.5; most of the variation about the regression being due to analytical uncertainty in both variables.

At the time of this writing, all of the data has not been synthesized. R ratios (methane/ethane + propane) and equilibrium solubilities of methane have not been computed, nor have ratio tests such as methane-ethane for the surface layers been completed. It is our intent that prior to the final report, work will be completed on the analysis of all survey data and test parameters useful in distinguishing petroleum-derived hydrocarbons. Their applicability to tracing of petroleum hydrocarbons and as indicators of hydrocarbon accumulations will be emphasized.

IV. PROBLEMS ENCOUNTERED AND RECOMMENDED CHANGES

During the initial phase of the program, numerous analytical and shipboard contamination problems were encountered. The first of these was resolved through intensive laboratory studies conducted last winter. As a result, we now feel confident that we have a highly reliable field procedure. Quantitative separation of all components has been significantly enhanced, while at the same time chromatographic analysis has been reduced from 15 minutes to under 6 minutes.

Hydrocarbon analysis and sampling aboard the NOAA vessel DISCOVERER is still hampered by excessive emissions of oil and gases from the stacks. To counteract these effects, we have initiated several precautions to minimize hydrocarbon contamination. The first of these includes special cleaning and deployment procedures of the rosette prior to and during sampling. The second step taken was to include a TENAX-GC® absorbent trap downstream from the aqueous stripper to eliminate all aliphatic and aromatic hydrocarbons above C_6. This procedure has been highly successful, although the recovery and analytical precision of C_4 butanes have been affected.

Analytical precision aboard the DISCOVERER also has been affected adversely due to electrical noise in the 120 v a.c. power supplied to the laboratory. Monitoring of the quality of a.c. power with an oscilloscope revealed frequent voltage spiking, which can be quite severe and is related to the degree of ship motion. Voltage spiking results in false peak integrations. Since we believe that the quality of power supplied to the laboratory should be at least equal to typical shore-based facilities, we recommend that a separate power generation facility be supplied to the ship's laboratory that might be used to house sensitive electronic hardware.

In the meantime, we will initiate communications with Hewlett-Packard on how we might best minimize the impact of less-than-optimum power quality on our instrumentation.

V. ESTIMATE OF FUNDS EXPENDED THROUGH 30 JUNE 1976

	Allocated	Expended to Date	Balance
Salaries and overhead	83.5K	81.3	2.0
Major equipment	27.3K	27.3	0
Expendable supplies	13.7K	12.4	1.3
Travel and per diem	7.5K	8.5	-1.2
Shipping	3.5K	3.0	0.5
Publications	2.0K	1.0	1.0
	137.5K	133.5	4.0K

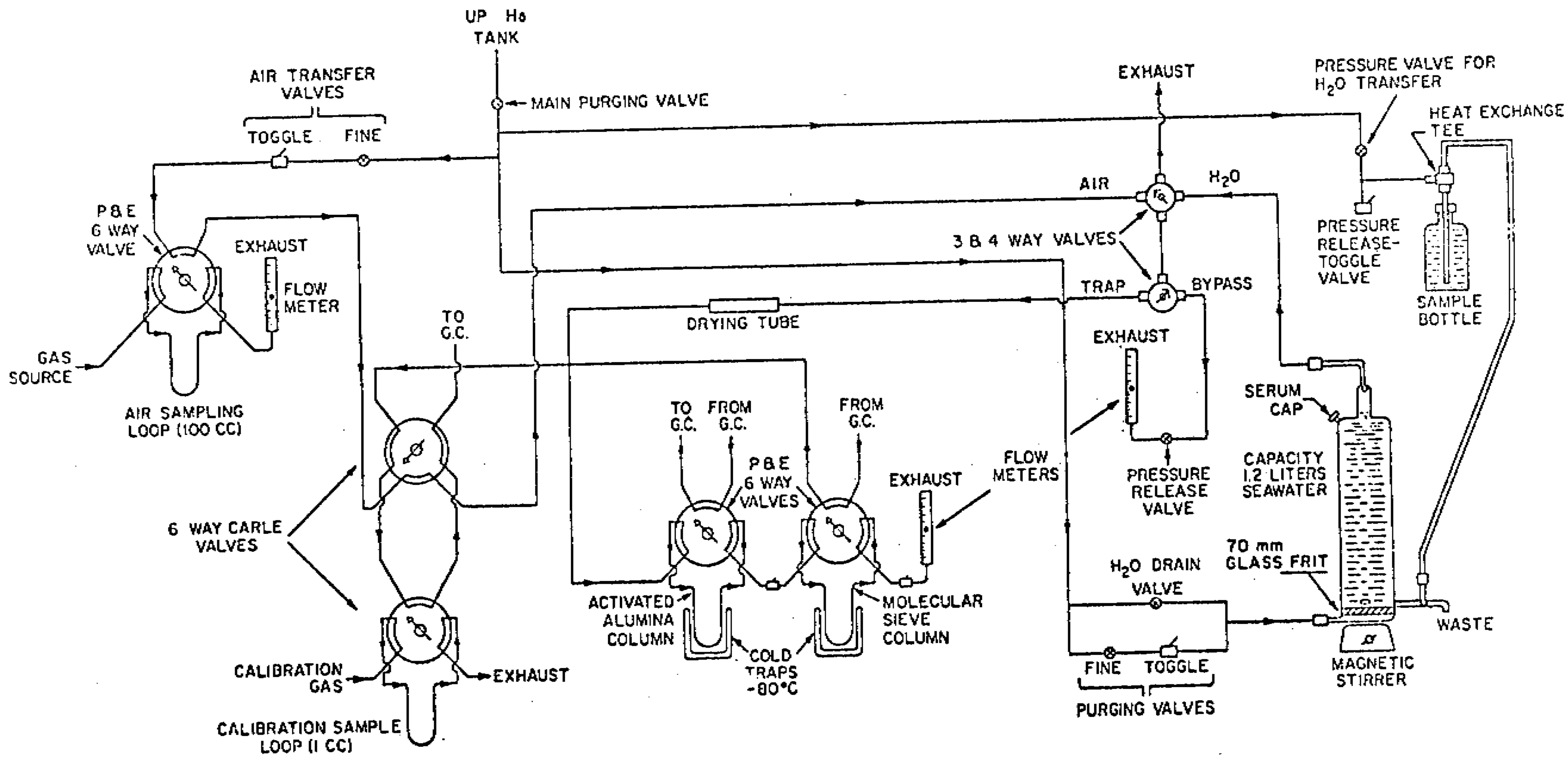


Figure 1.. Low molecular weight hydrocarbon extraction system (Swinnerton and Linnenbom, 1967). The extraction system shown is a recent modification given to us by Mr. R. Lamontagne of the Naval Research Laboratories, Washington D.C.

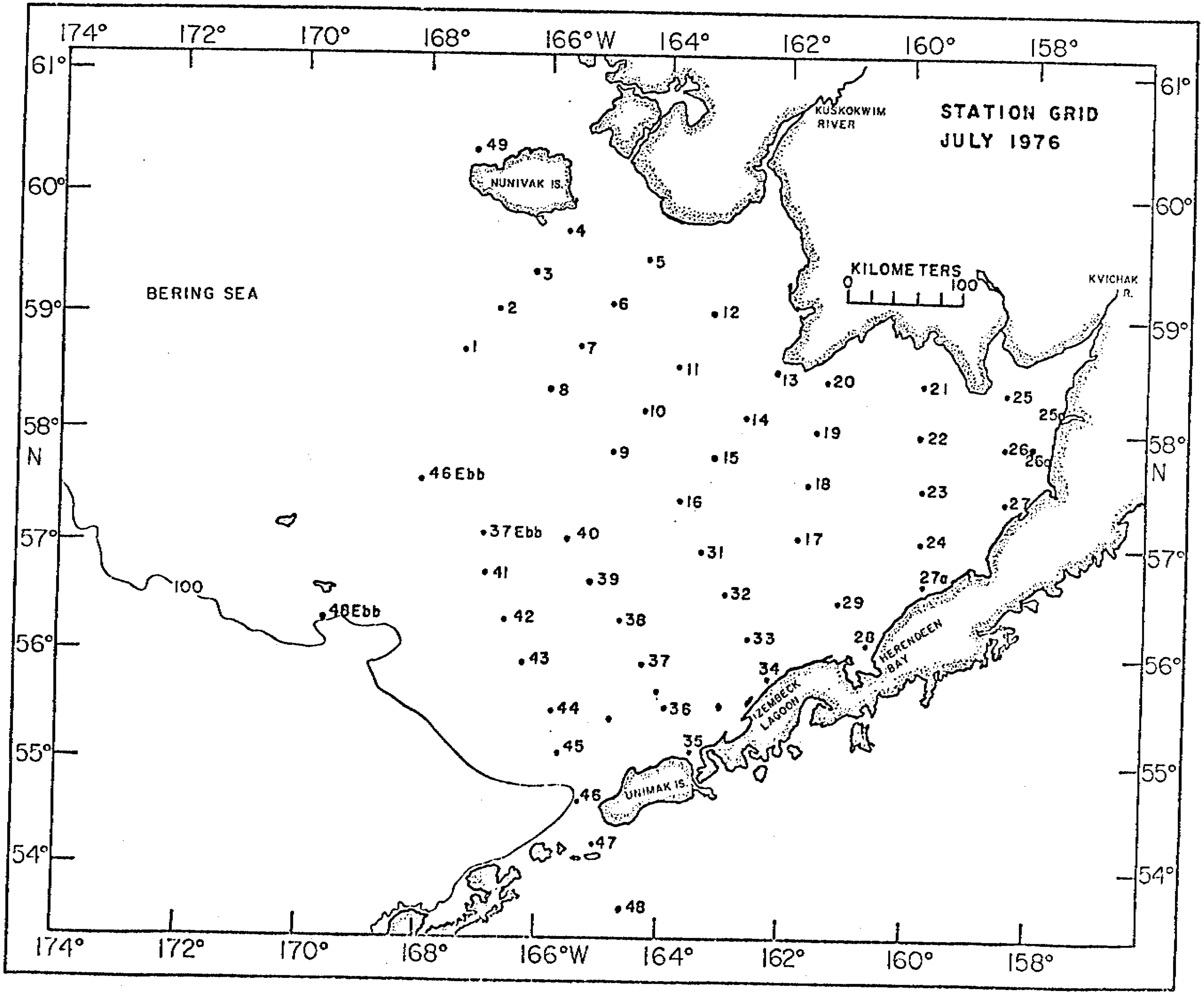


Figure 2. Station locations in the southeastern Bering Sea.

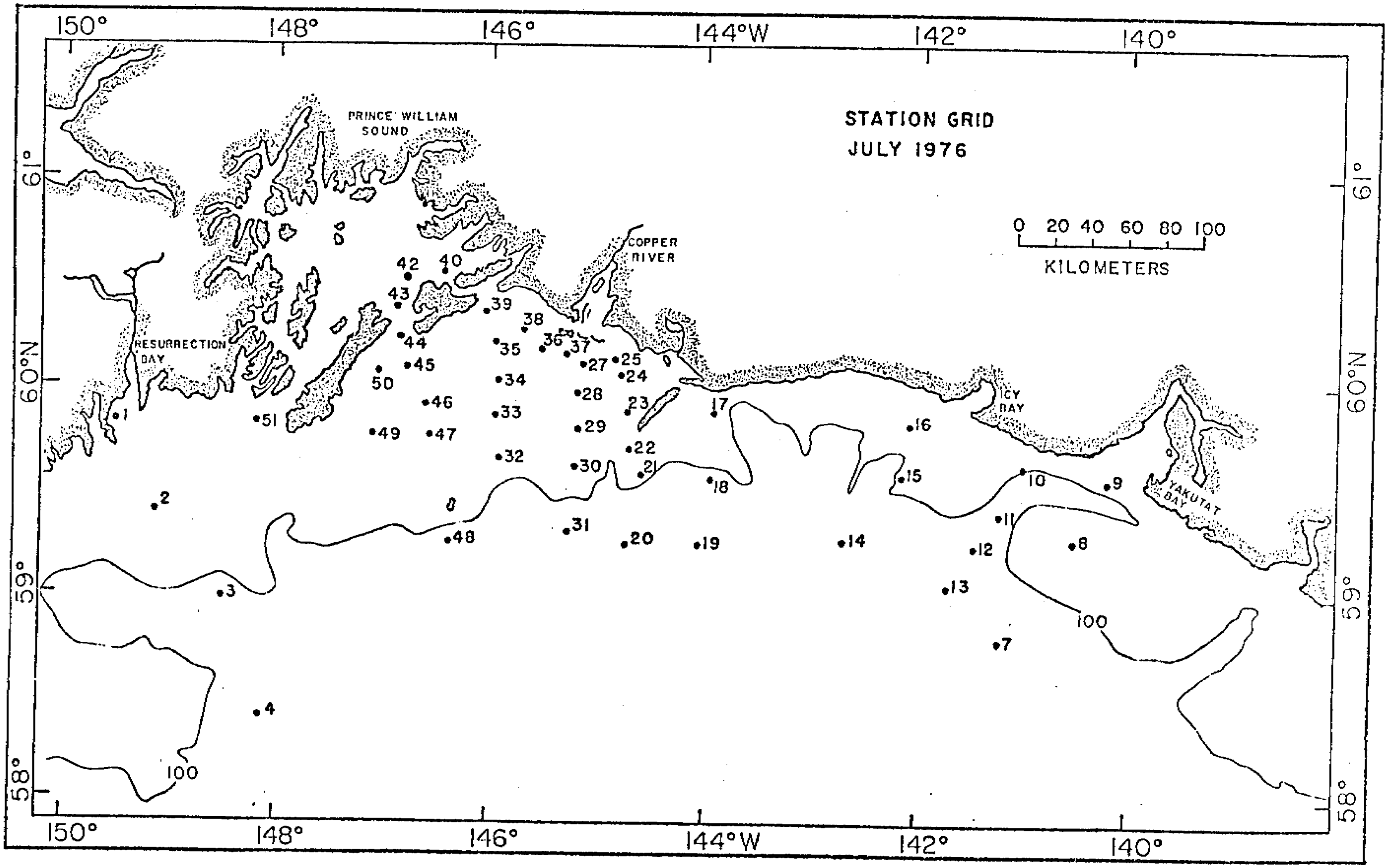


Figure 3. Station location in the northeastern Gulf of Alaska.

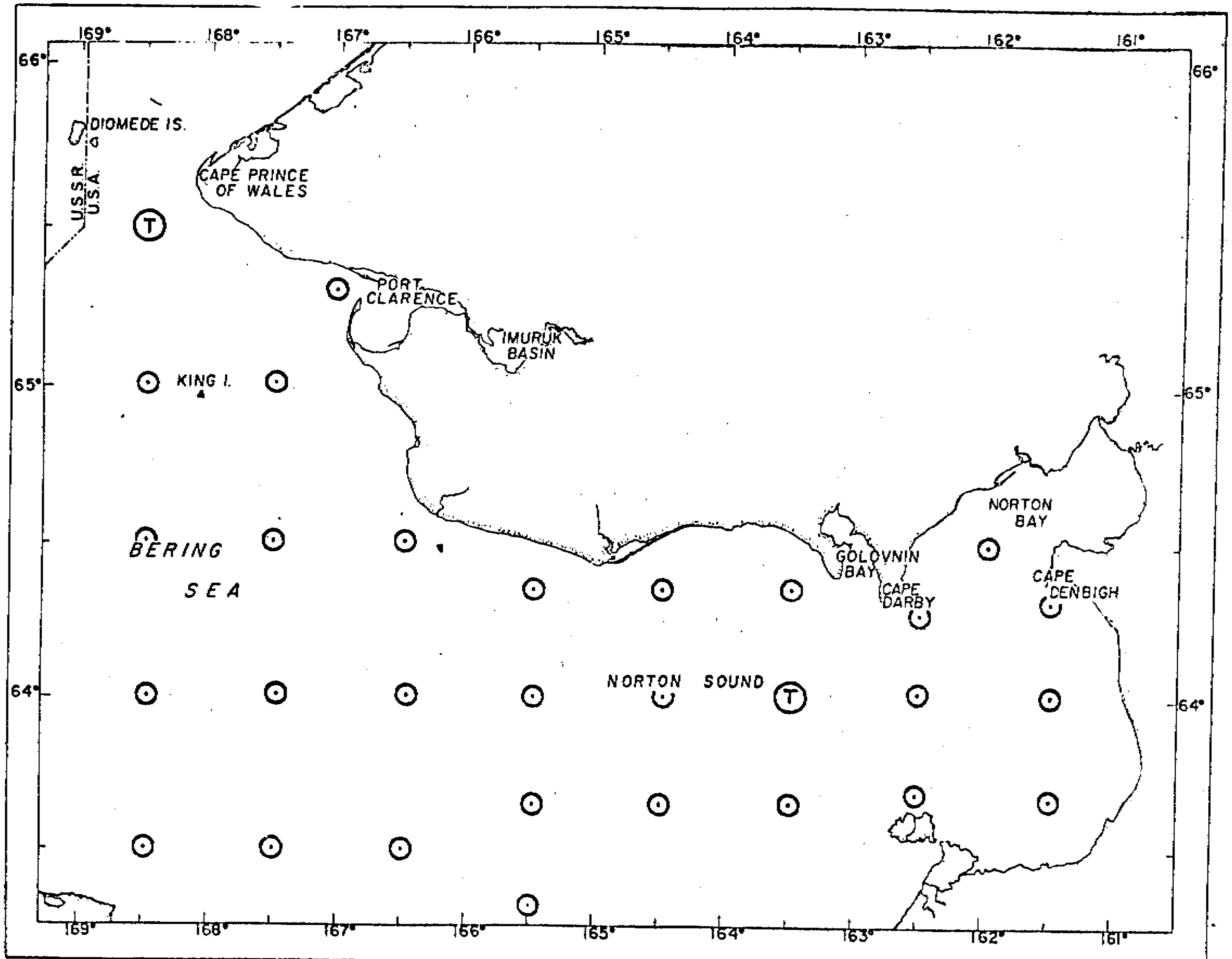


Figure 4. Station locations in Norton Sound.

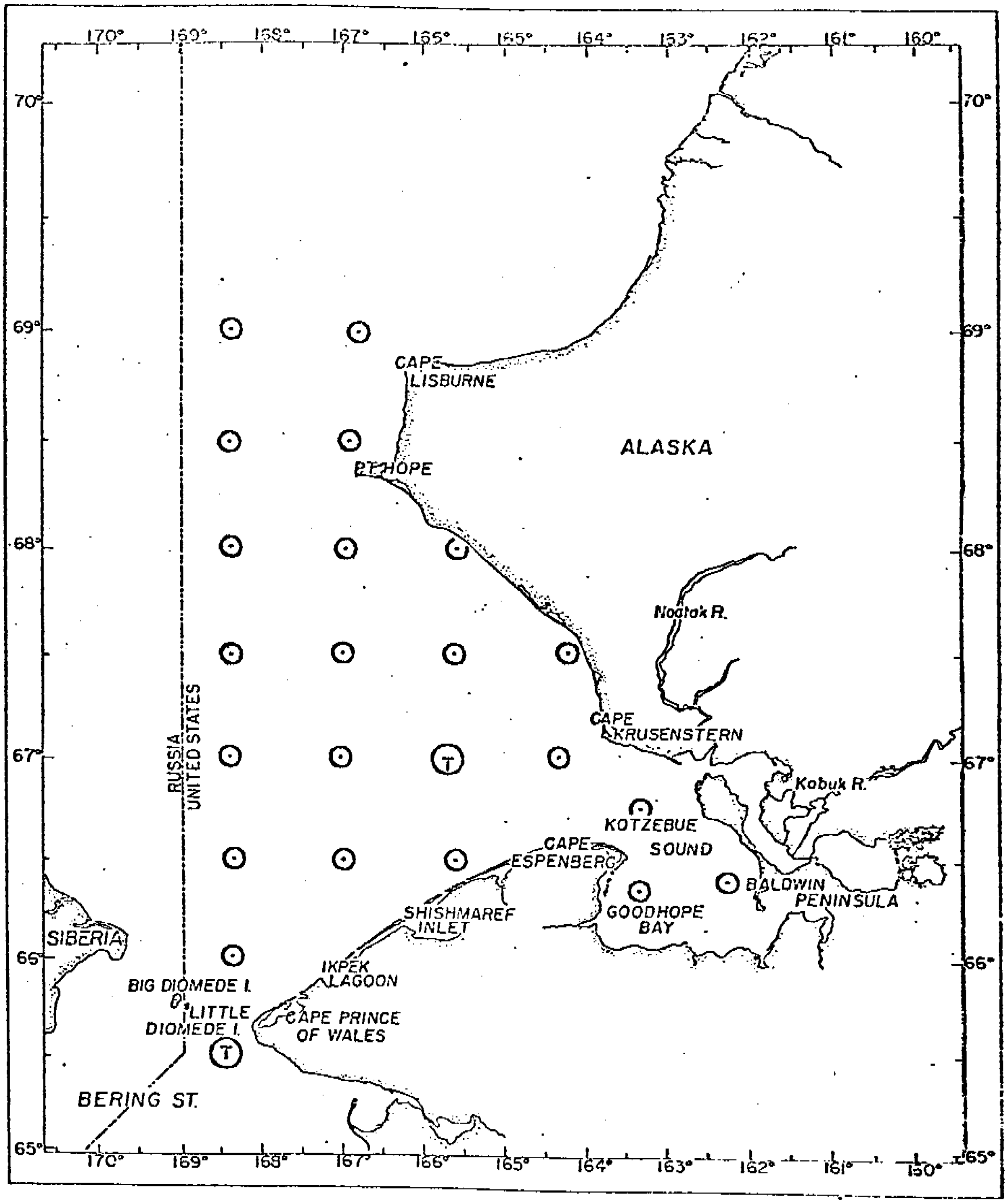


Figure 5. Station locations in Chukchi Sea including Kotzebue Sound.

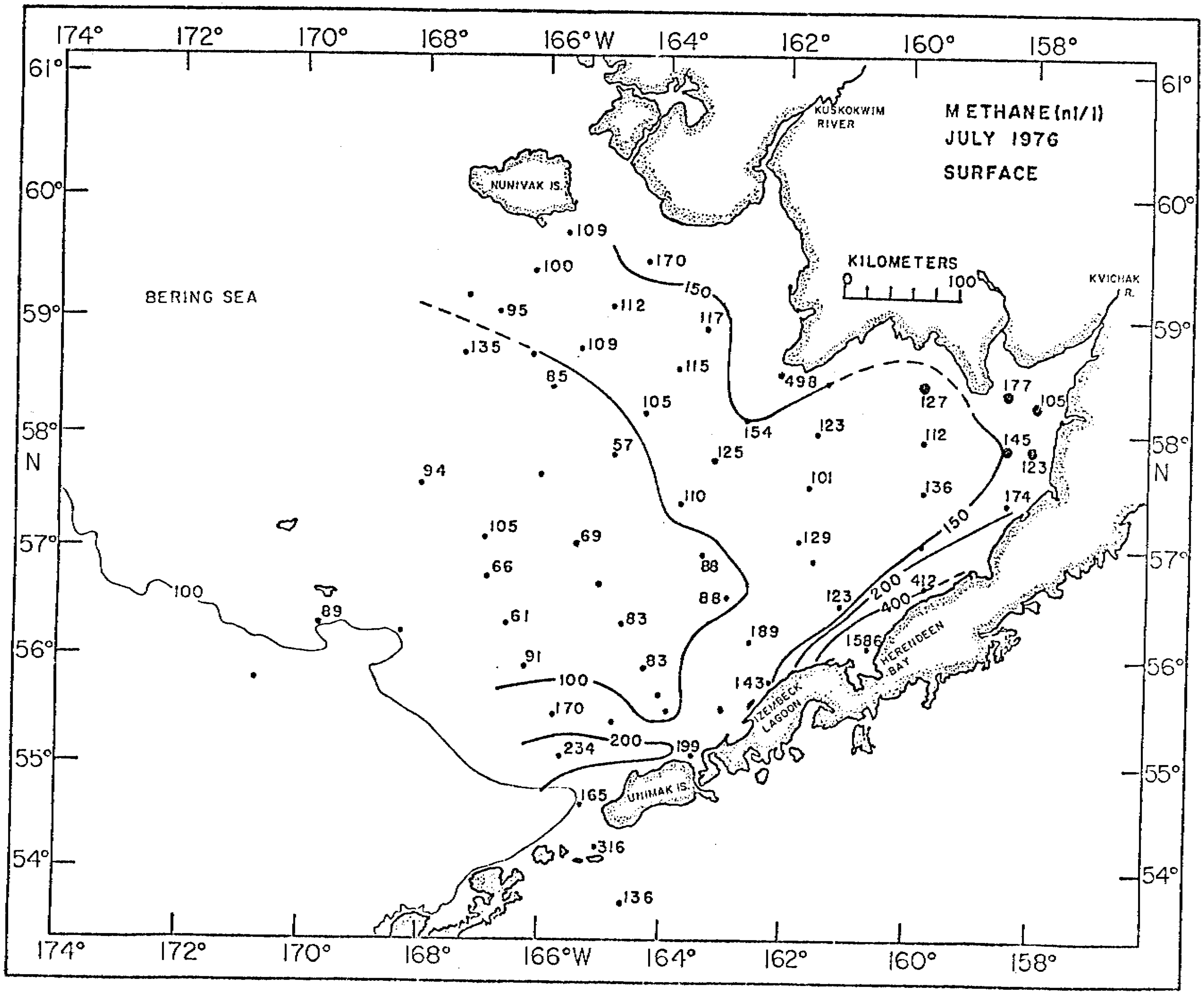


Figure 6. Surface distribution of methane in Bristol Bay in July 1976. Concentrations are given in nl/l.

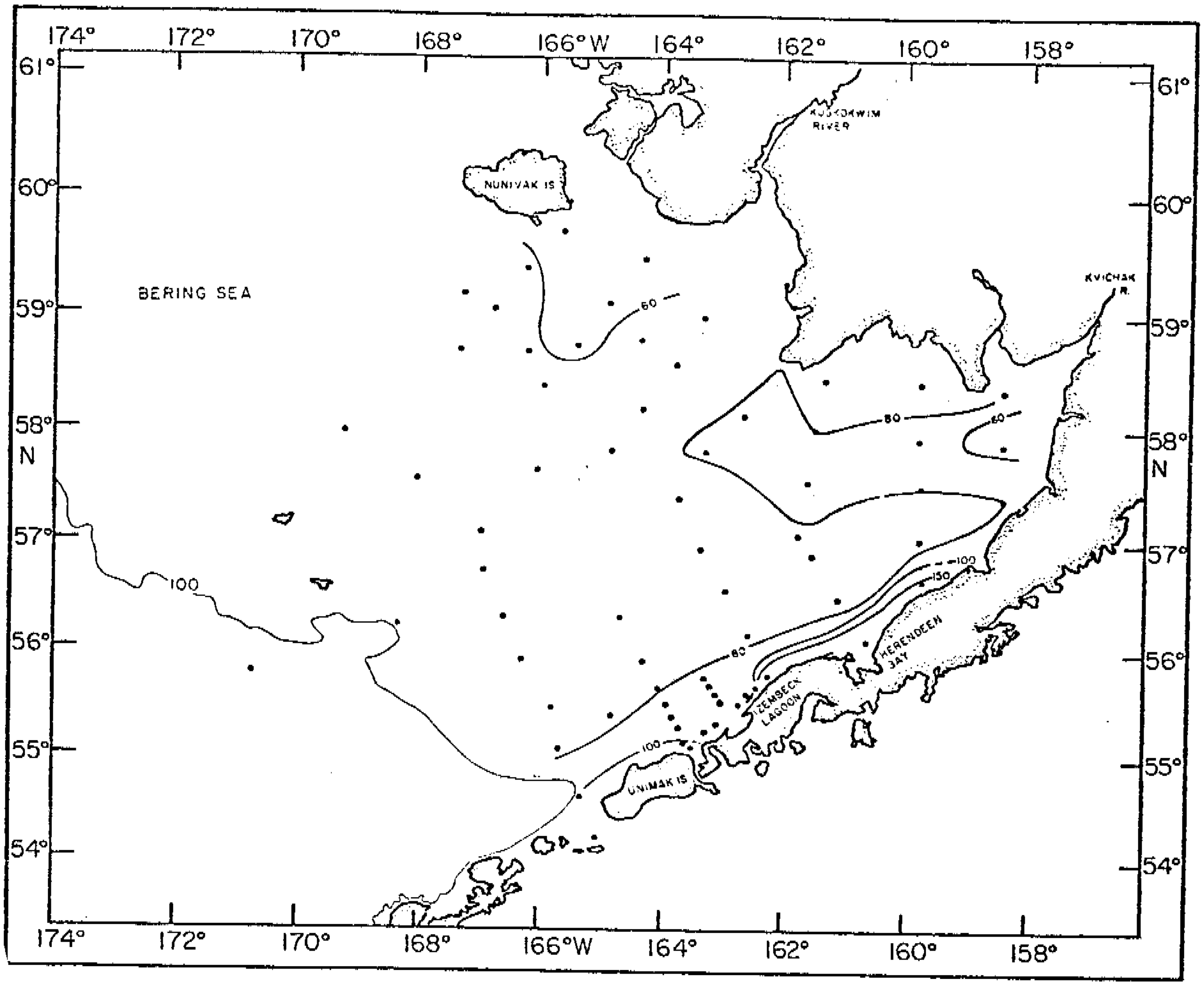


Figure 7. Surface distribution of methane in Bristol Bay in Sept.-Oct. 1975. Concentrations are given in nl/l.

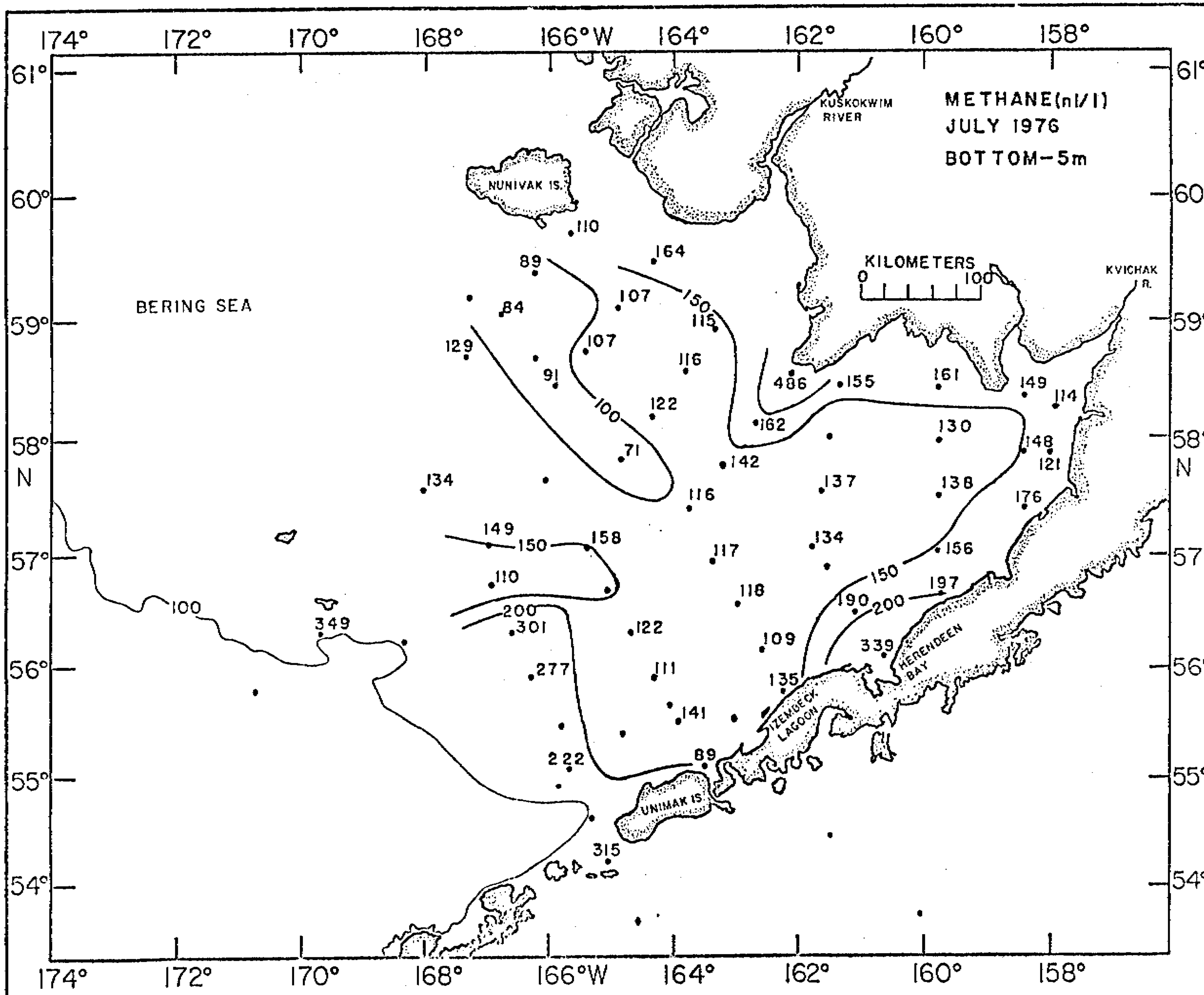


Figure 8. Areal distribution of methane 5m from the bottom in Bristol Bay during July 1976. Concentrations are given in nl/l.

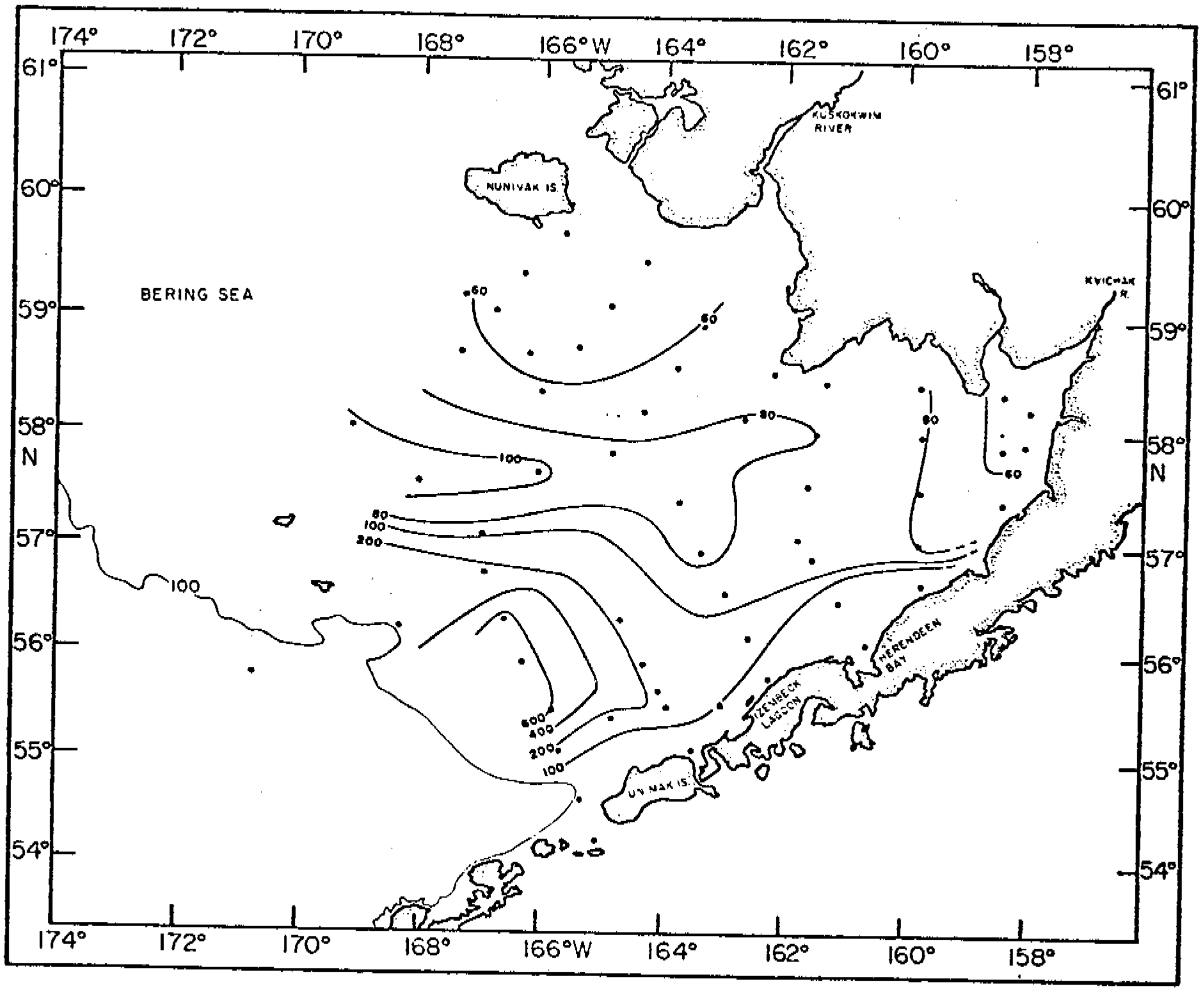


Figure 9. Areal distribution of methane 5m from the bottom in Bristol Bay during Sept. - Oct. 1975. Concentrations are given in nl/l.

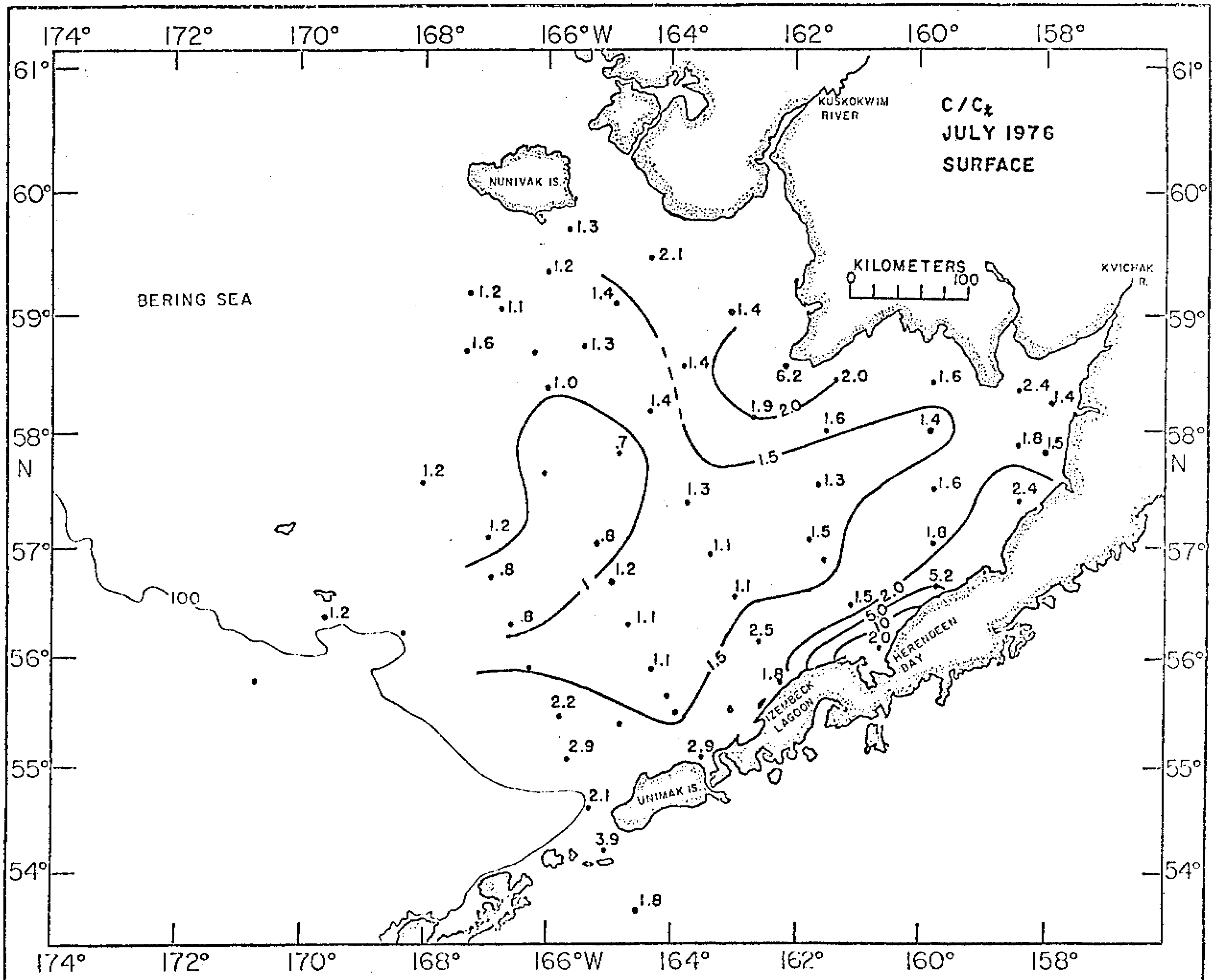


Figure 10. Relative saturation concentrations (C/C*) of methane in the surface layer of Bristol Bay in July 1976. The equilibrium concentration of methane (c*) was calculated from the Bunsen coefficients given by Atkinson and Richards (1967).

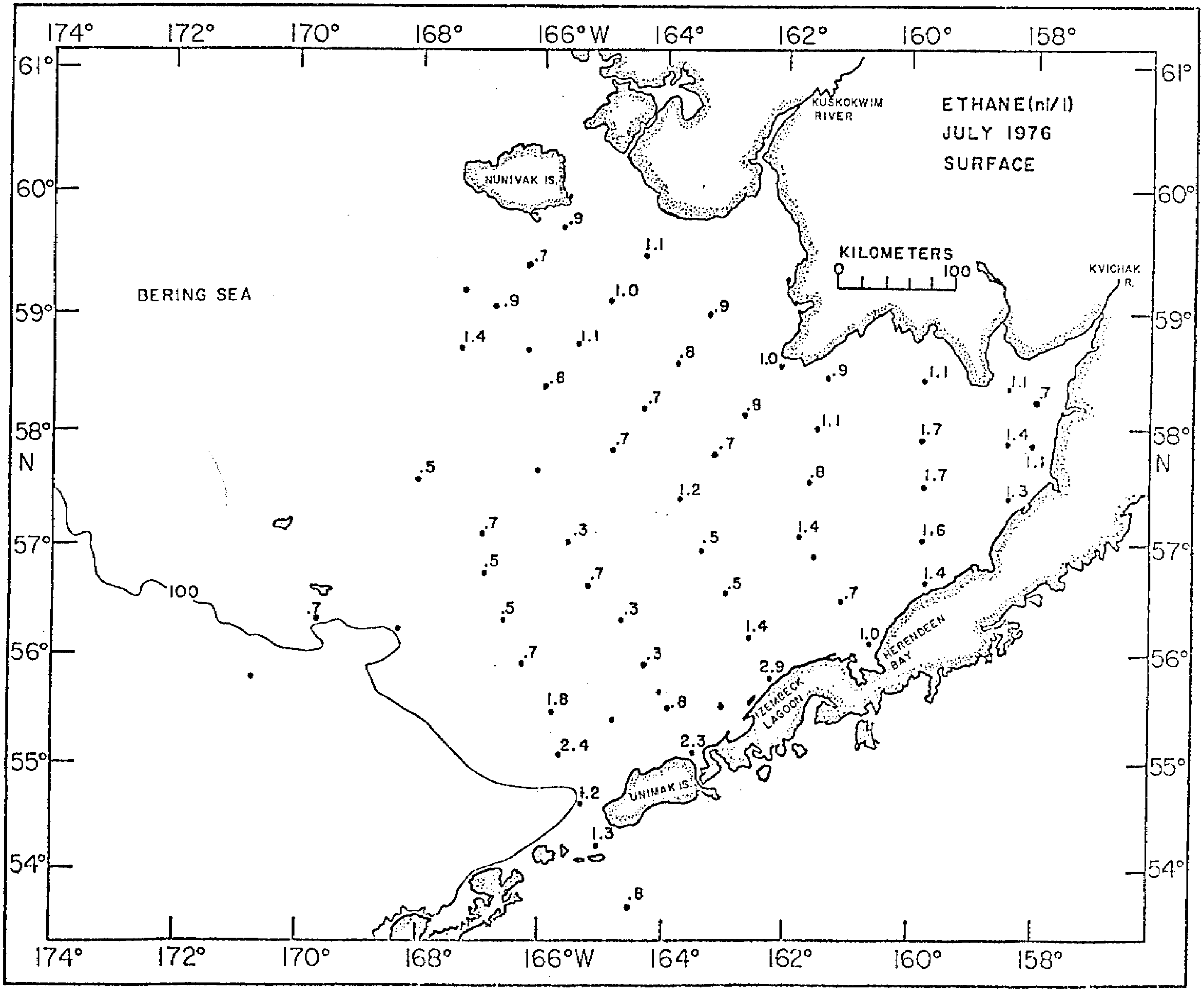


Figure 11. Surface distribution of ethane in Bristol Bay in July 1976. Concentrations are given in nl/l.

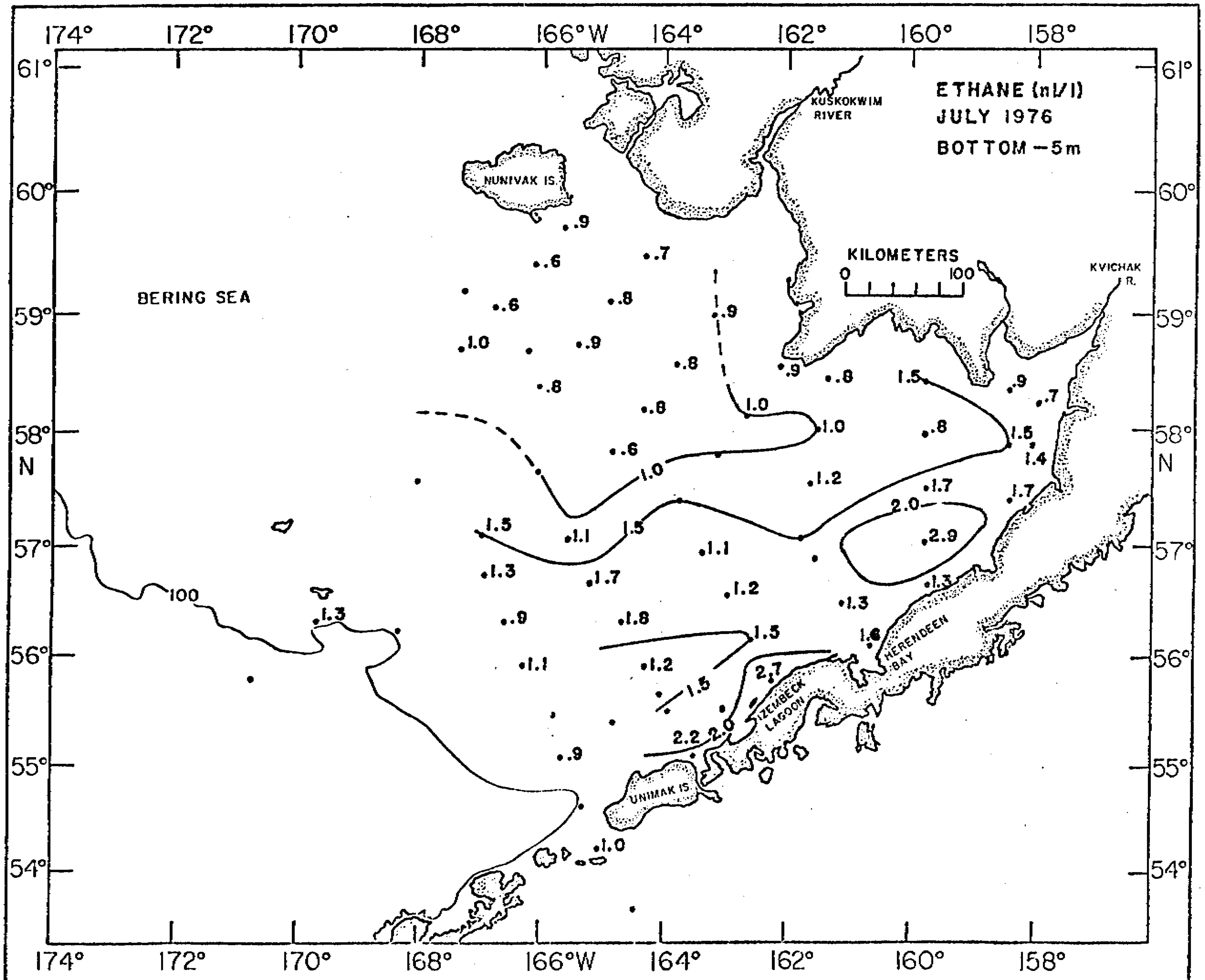


Figure 12 Areal distribution of ethane 5m from the bottom in Bristol Bay in July 1976. Concentrations are given in nl/l.

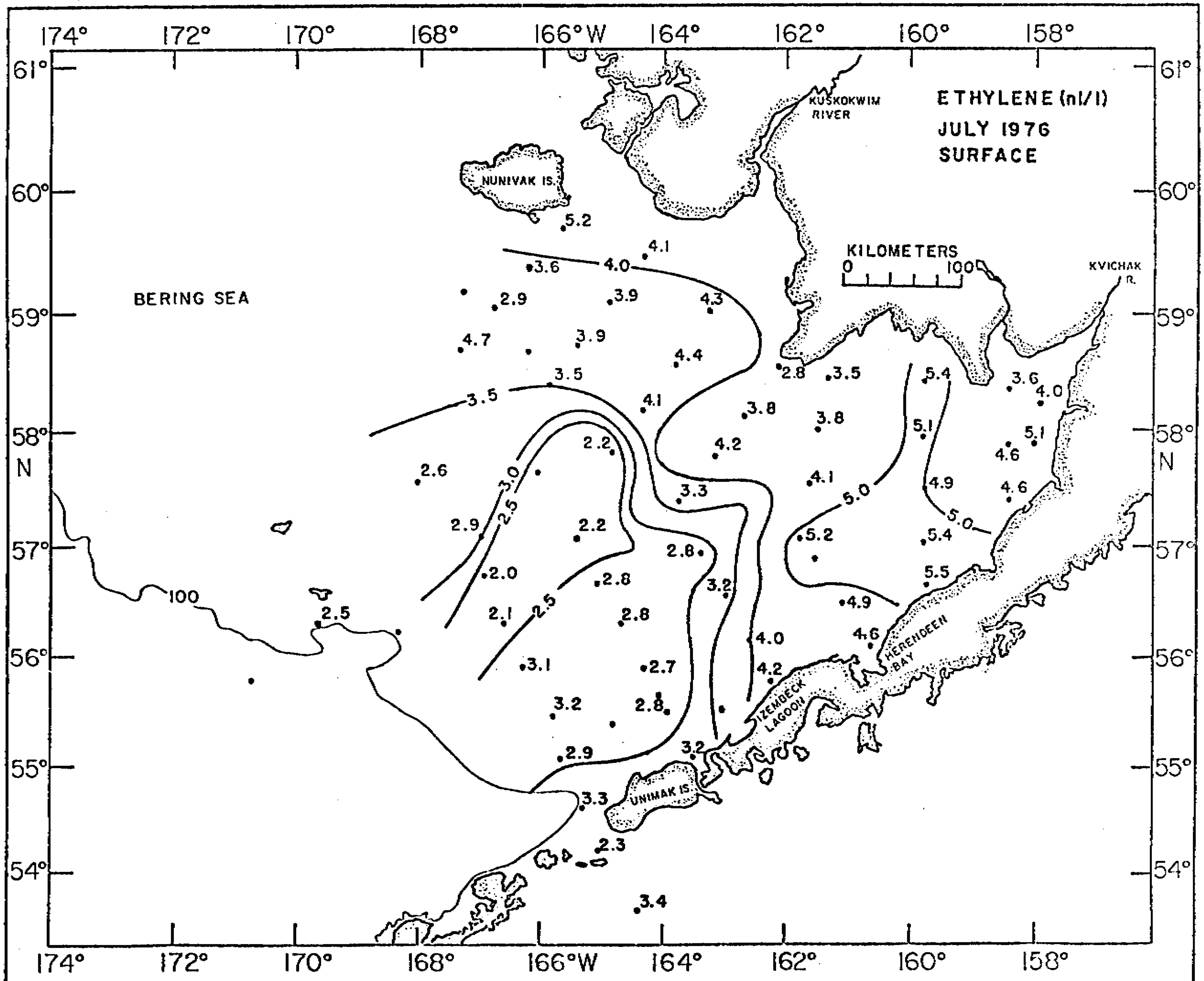


Figure 13. Surface distribution of ethylene in Bristol Bay in July 1976. Concentrations are given in nl/l.

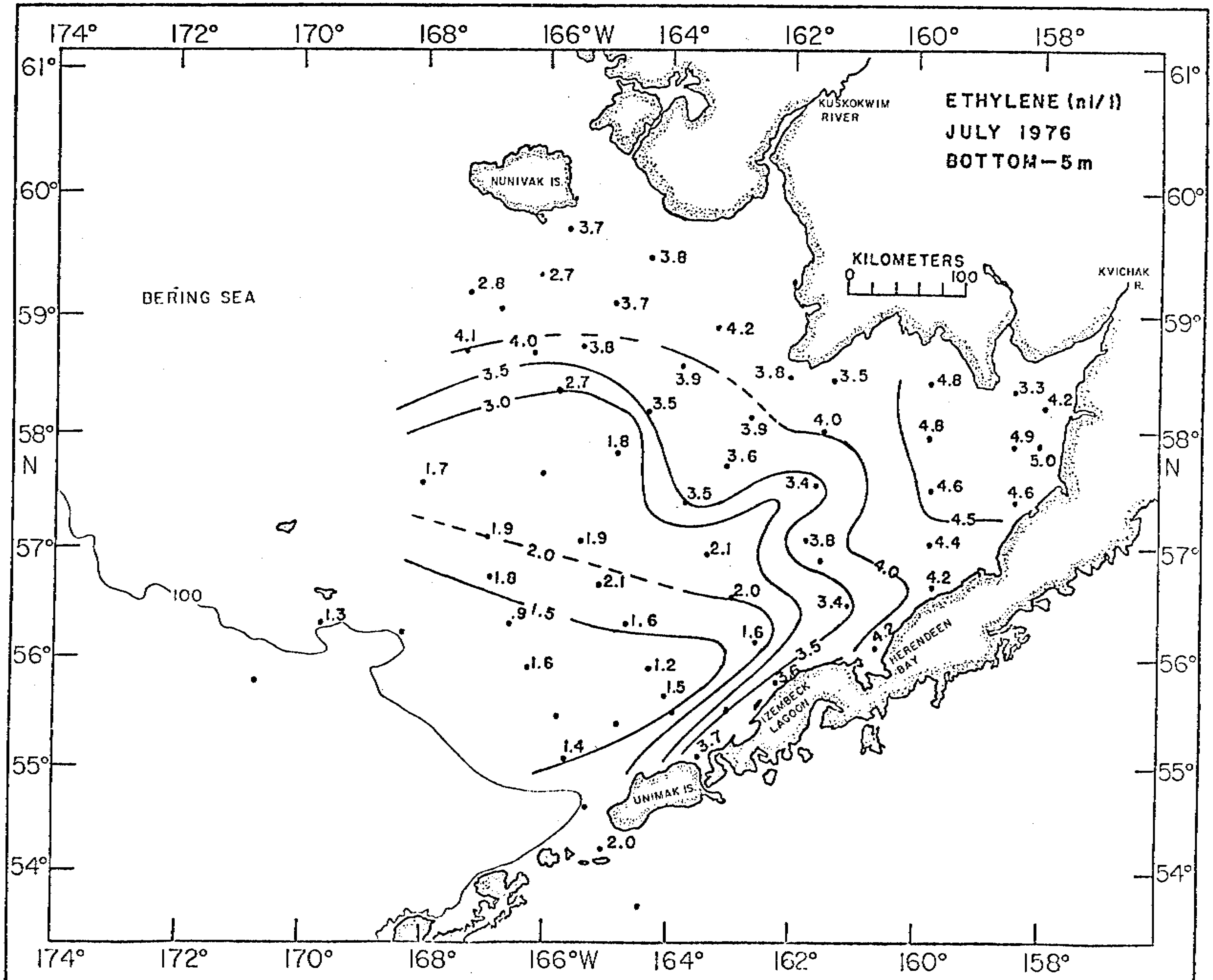


Figure 14. Areal distribution of ethylene 5m from the bottom in Bristol Bay in July 1976. Concentrations are given in nl/l.

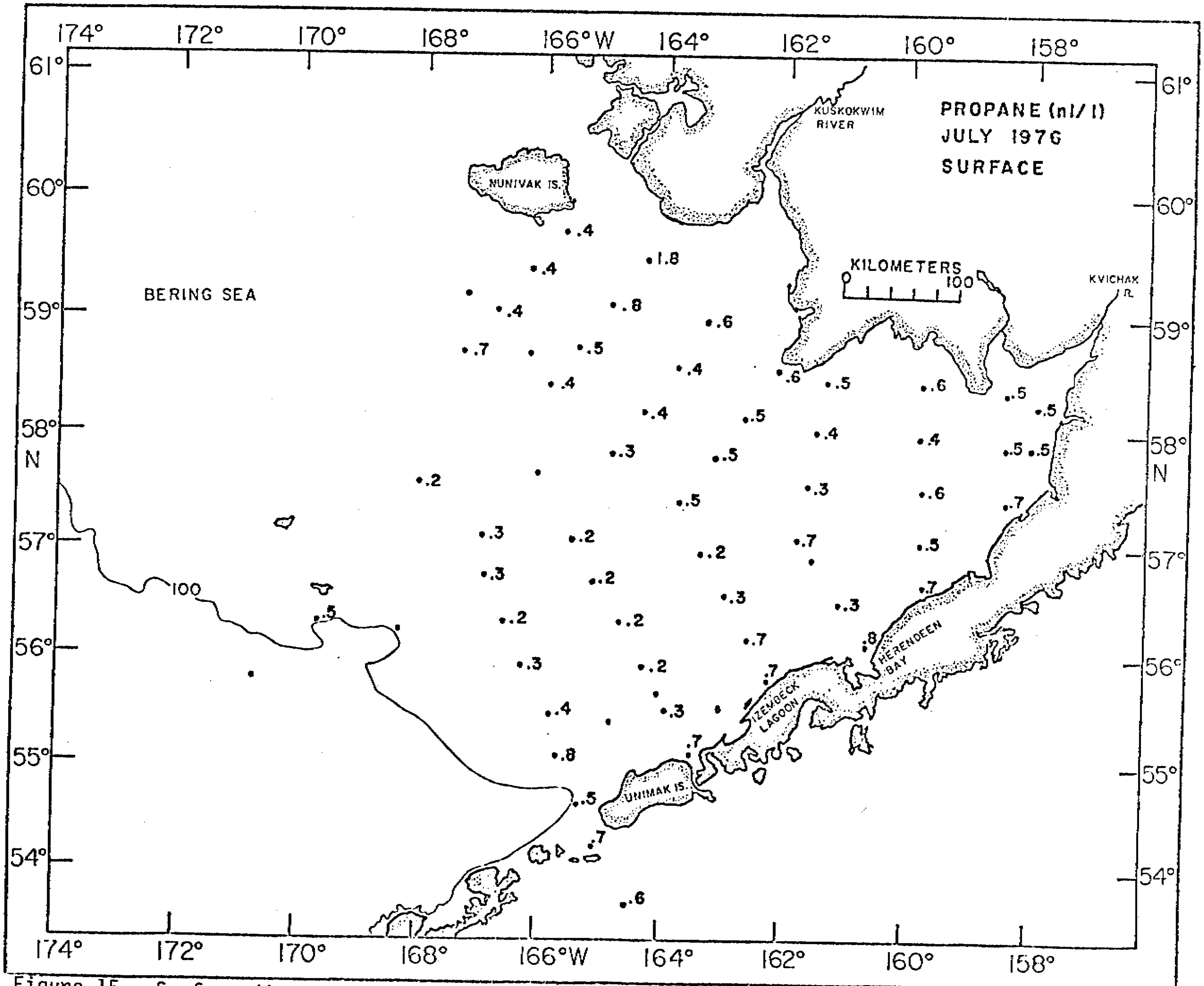


Figure 15. Surface distribution of propane in Bristol Bay in July 1976. Concentrations are given in nl/l.

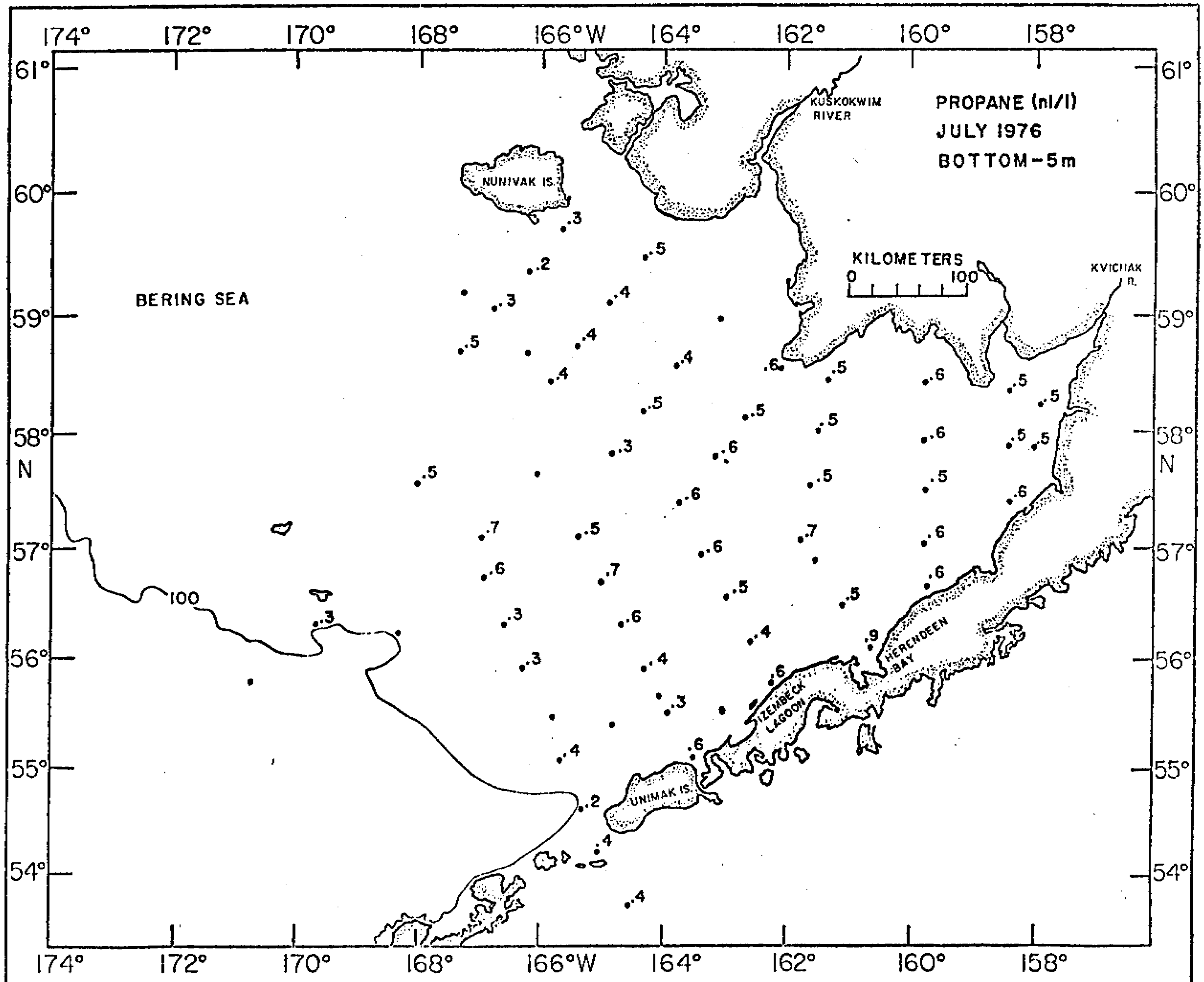


Figure 16. Areal distribution of propane 5m from the bottom in July 1976. Concentrations are given in nl/l.

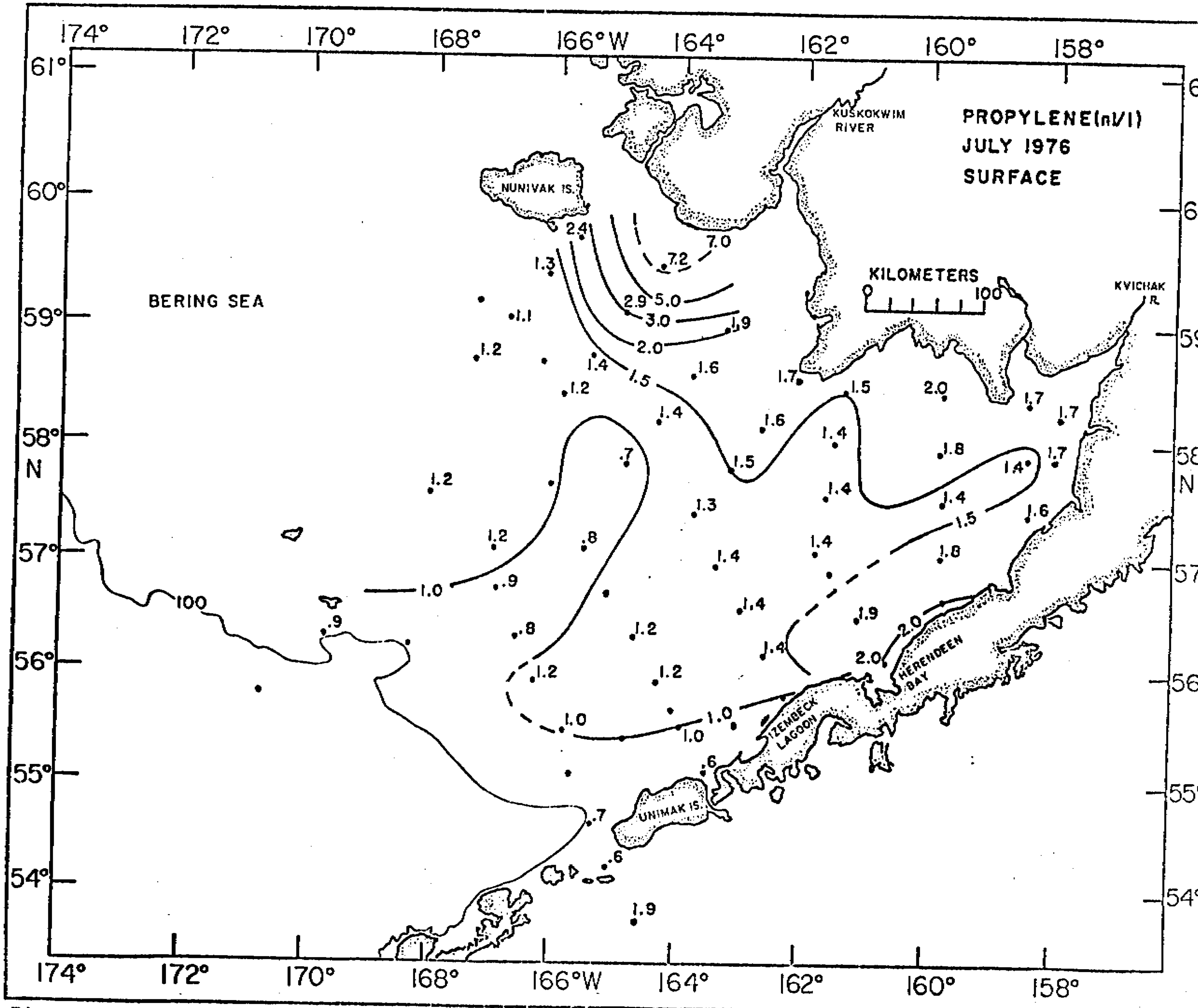


Figure 17. Surface distribution of propylene in Bristol Bay in July 1976. Concentrations are given in nl/l.

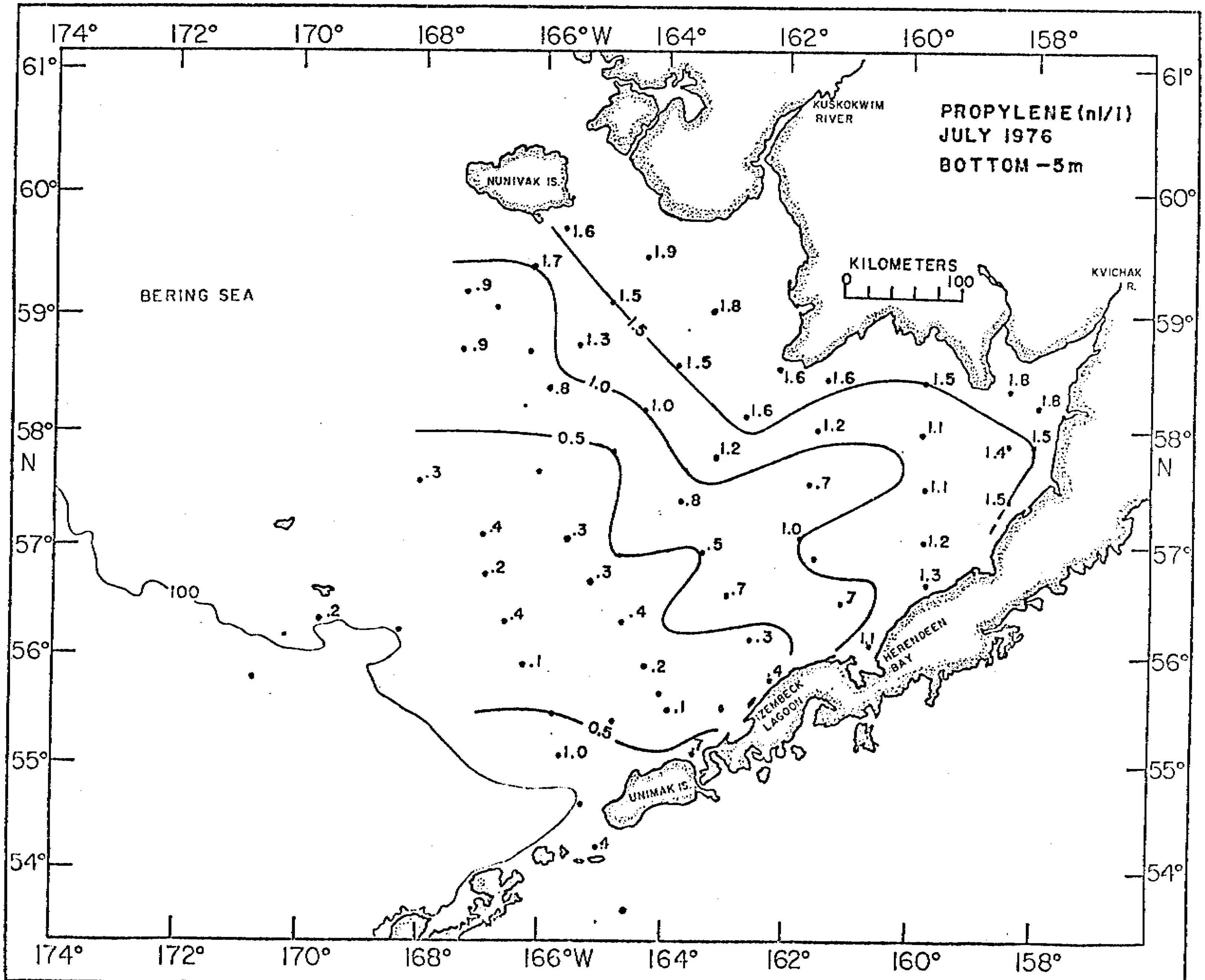


Figure 18. Areal distribution of propylene 5m from the bottom in Bristol Bay in July 1976. Concentrations are given in nl/l.

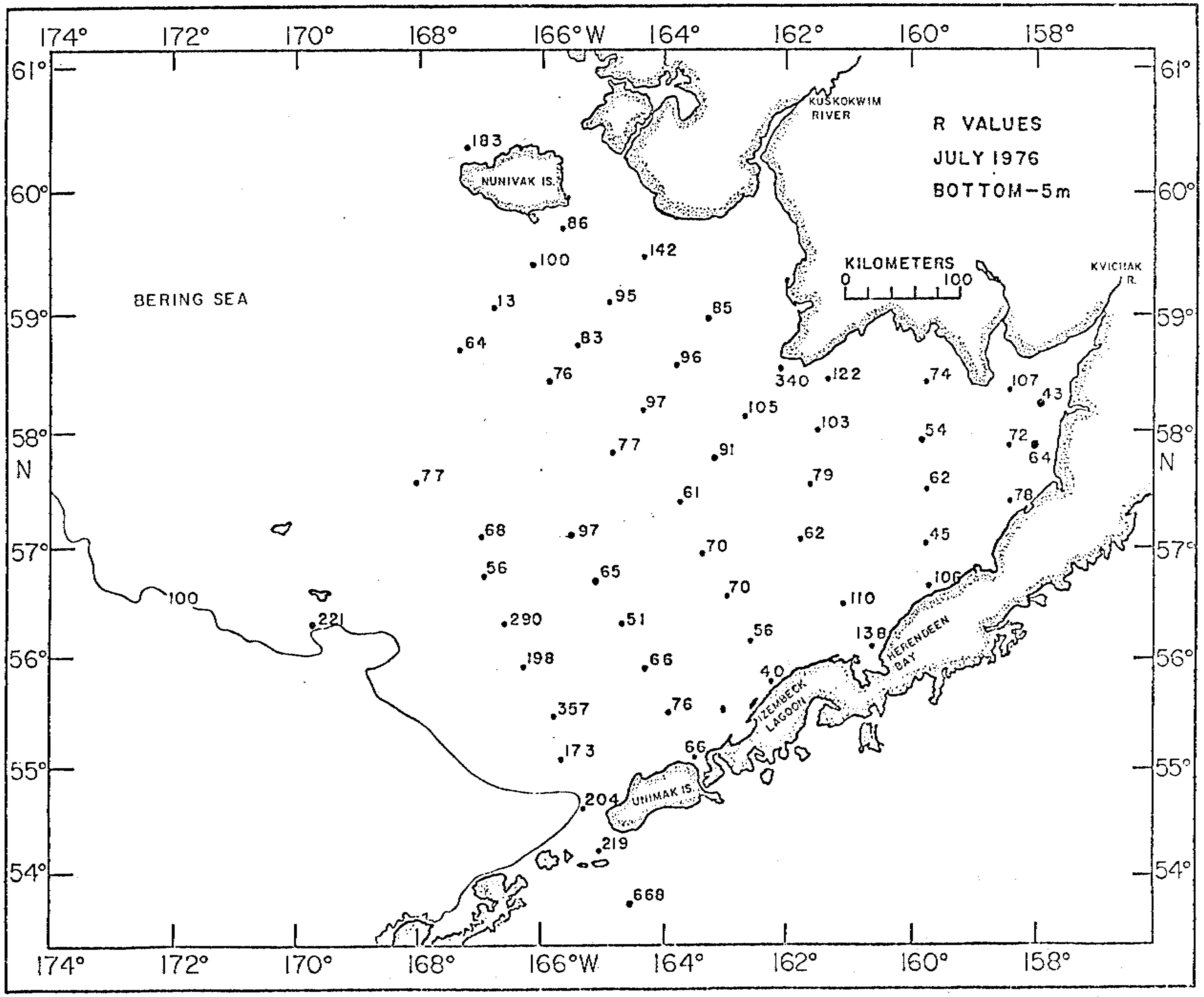


Figure 19. The ratio of the concentrations of methane to ethane plus propane ($C_1/C_2 + C_3$) 5m from the bottom in Bristol Bay in July 1976.

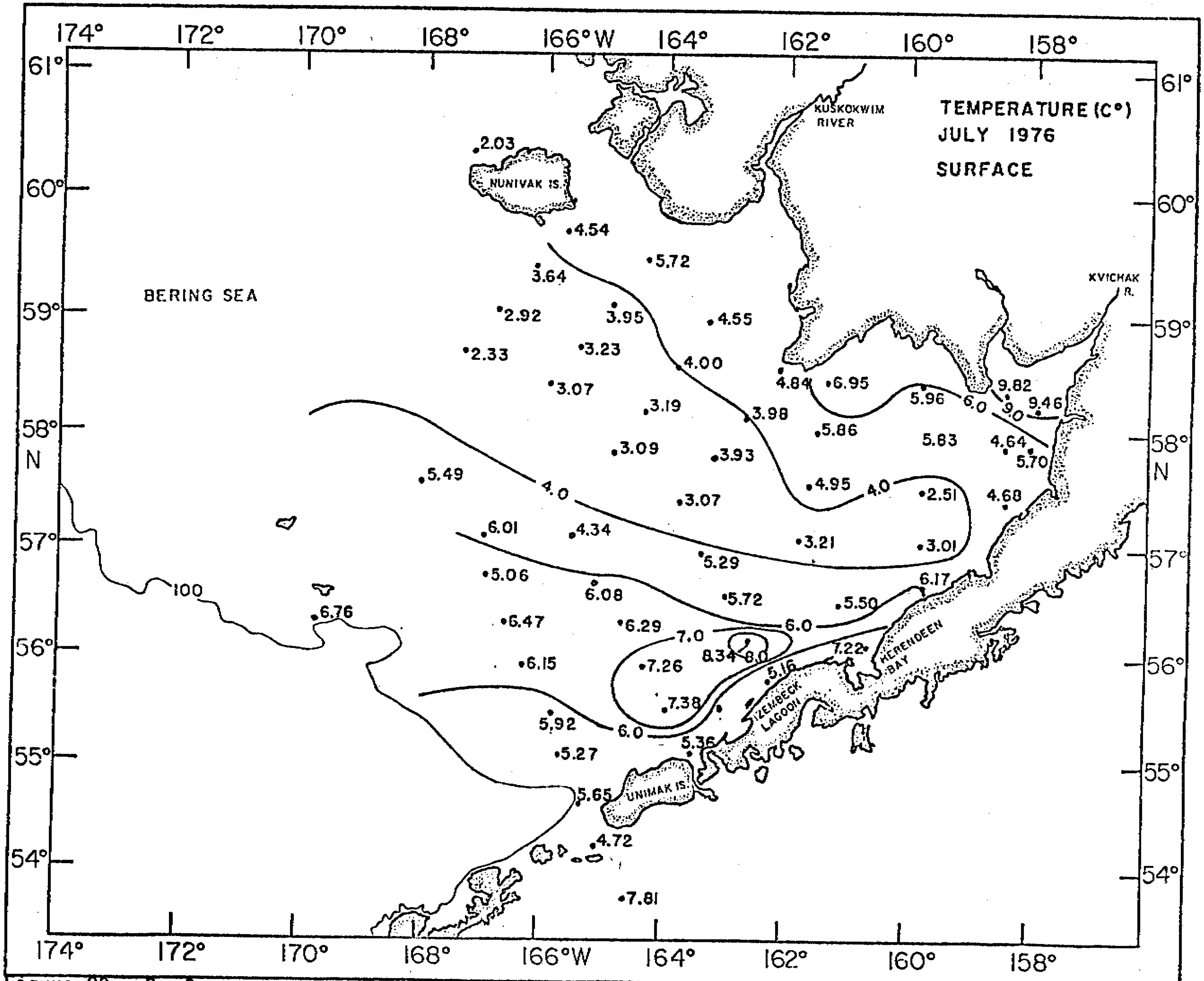


Figure 20. Surface temperature distribution in Bristol Bay in July 1976.

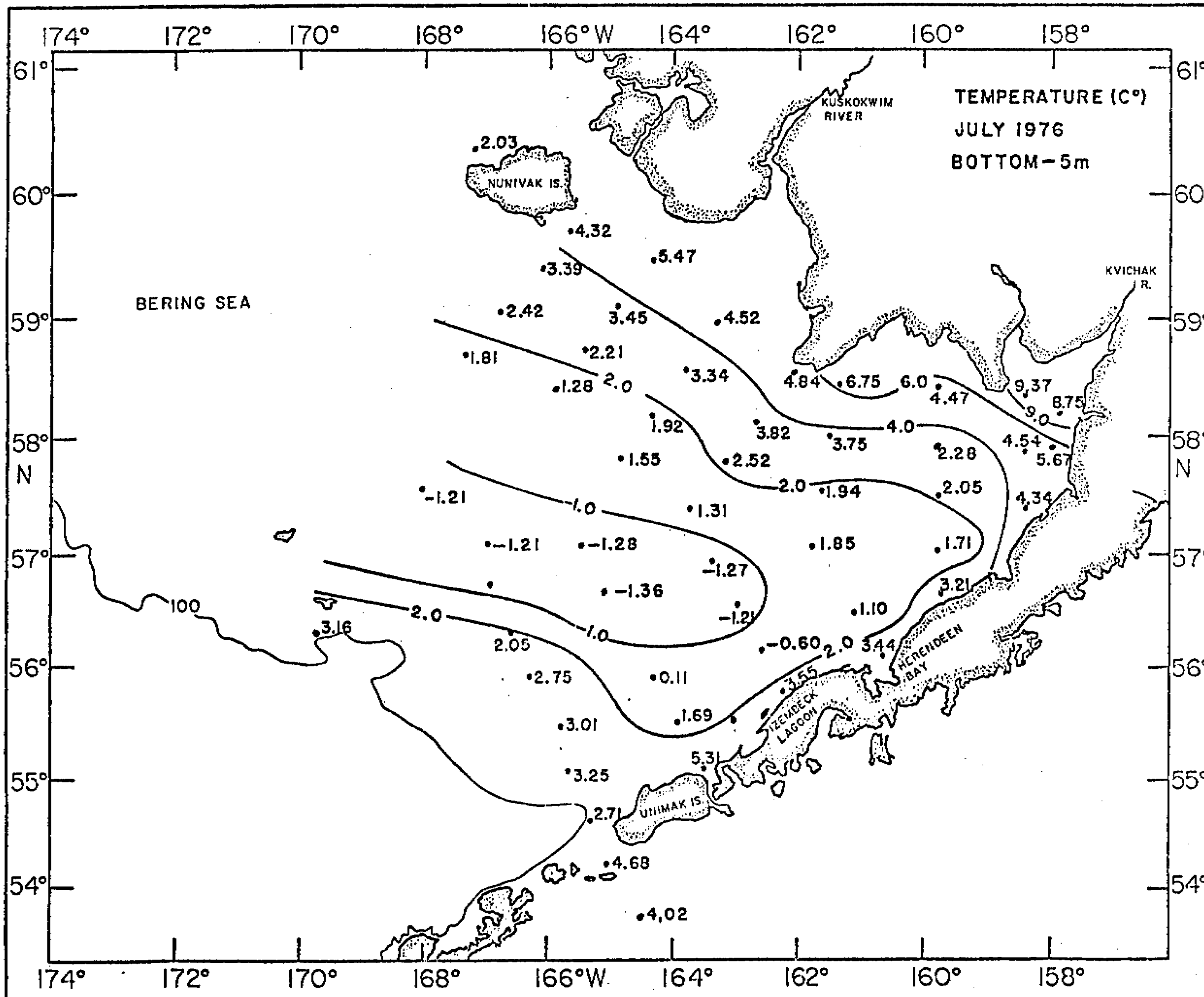


Figure 21. Temperature distribution 5m from the bottom in Bristol Bay in July 1976.

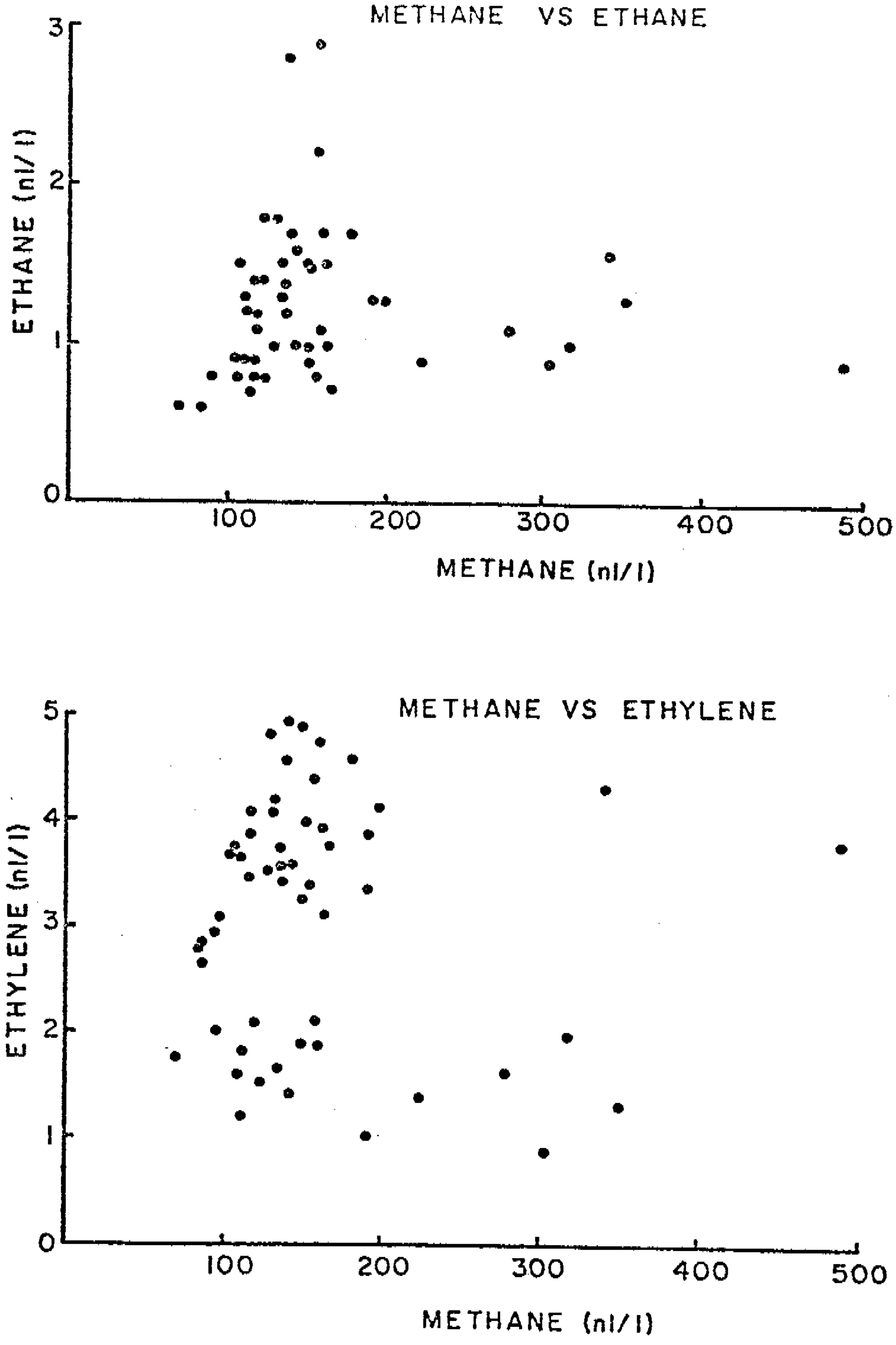


Figure 22. a) A plot of methane versus ethane for all samples taken 5m from the bottom.
b) A plot of methane versus ethylene for all samples taken 5m from the bottom.

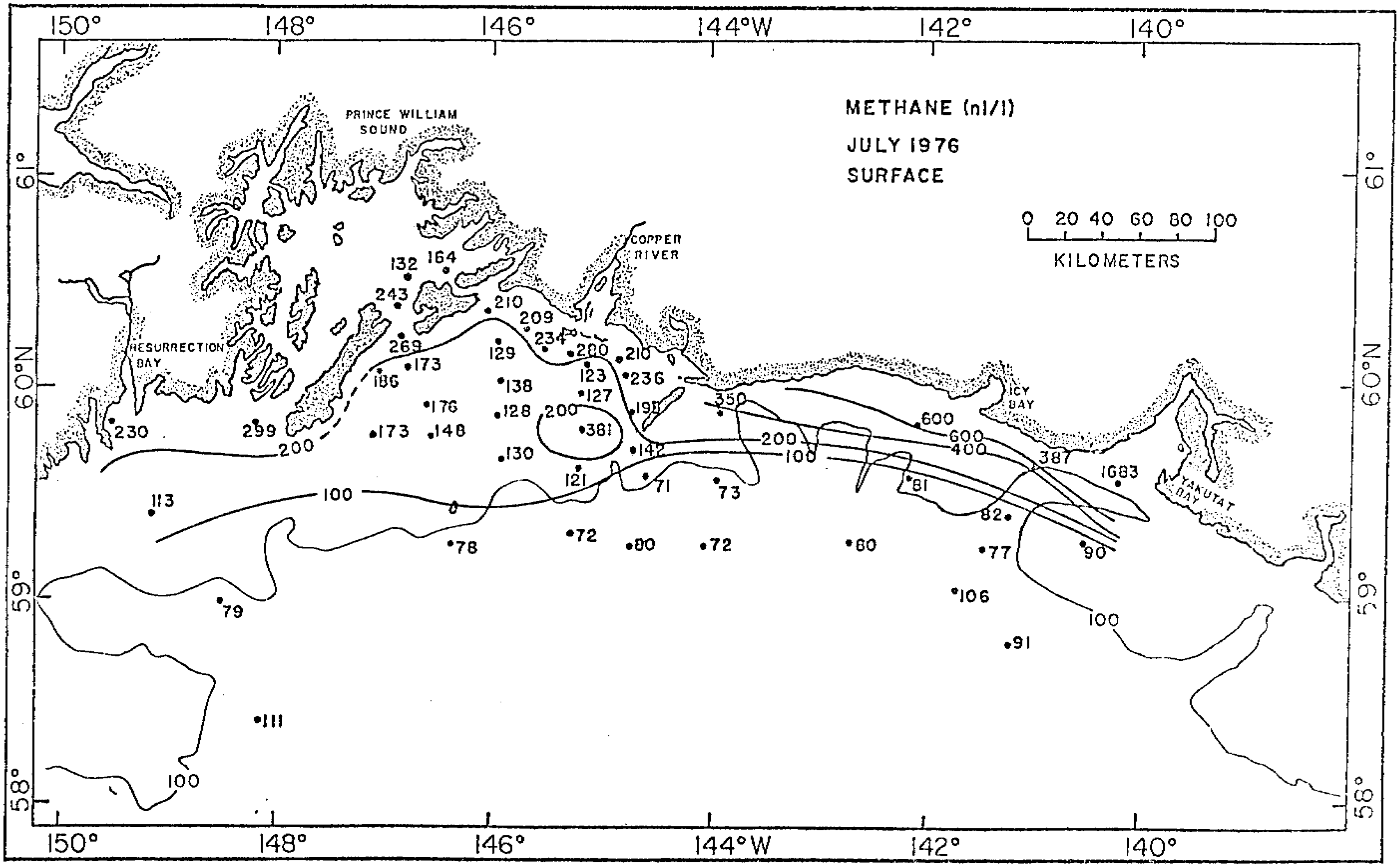


Figure 23. Surface distribution of methane in the northeast Gulf of Alaska in July 1976. Concentrations are given in nl/l.

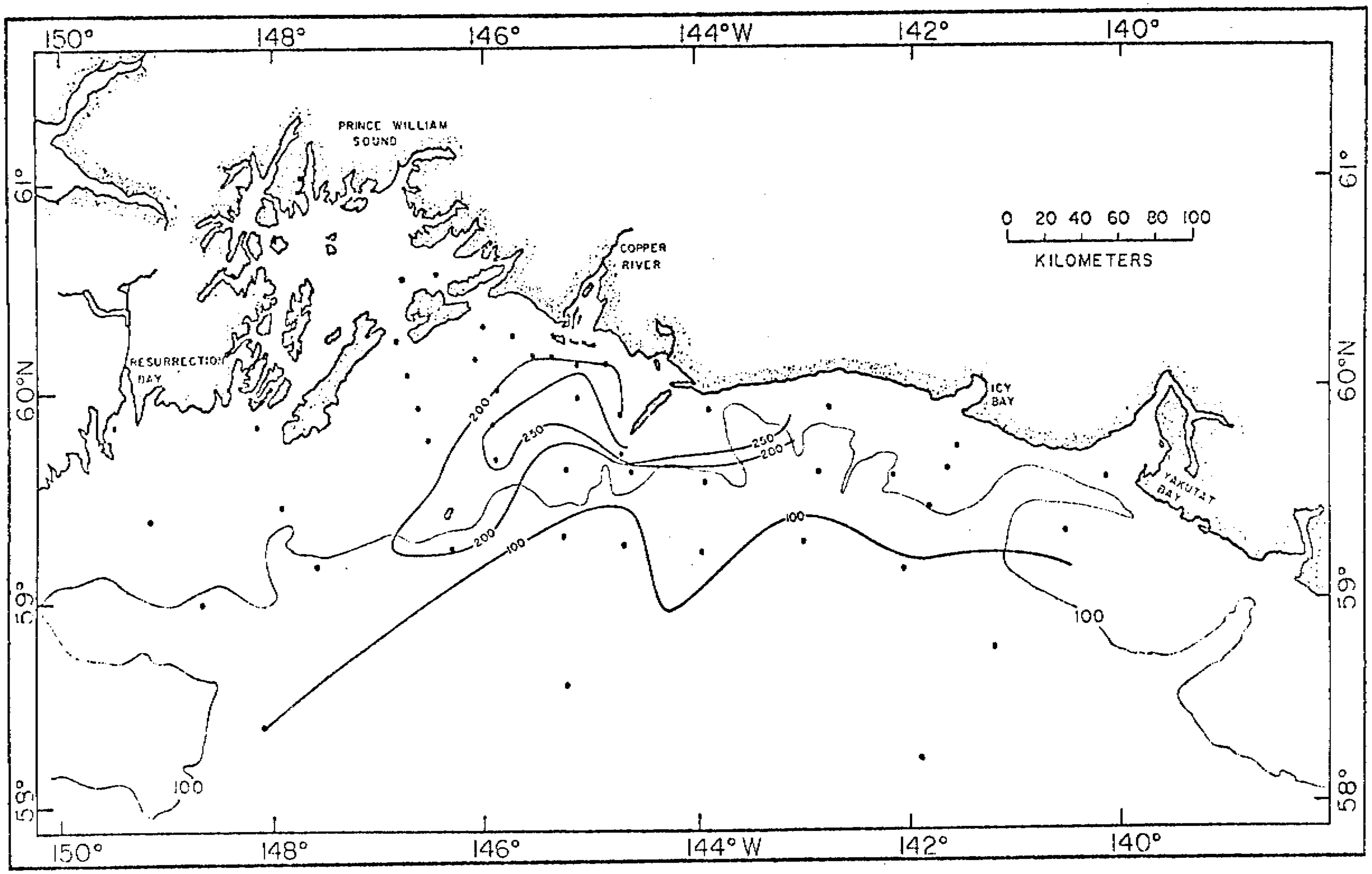


Figure 24. Surface distribution of methane in the northeast Gulf of Alaska in Oct. - Nov. 1975. Concentrations are given in nl/l.

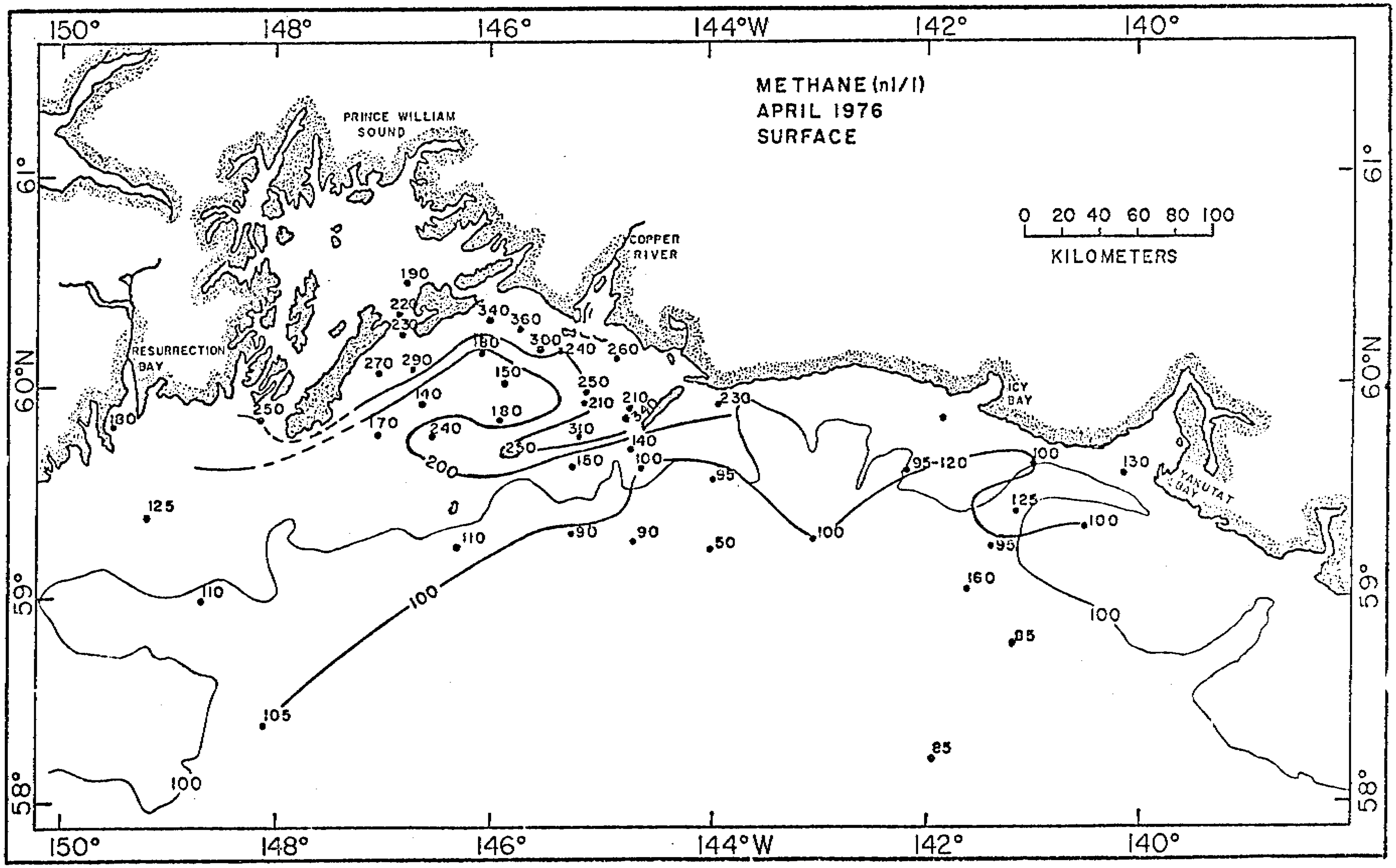


Figure 25. Surface distribution of methane in the northeast Gulf of Alaska in April 1976. Concentrations are given in nl/l.

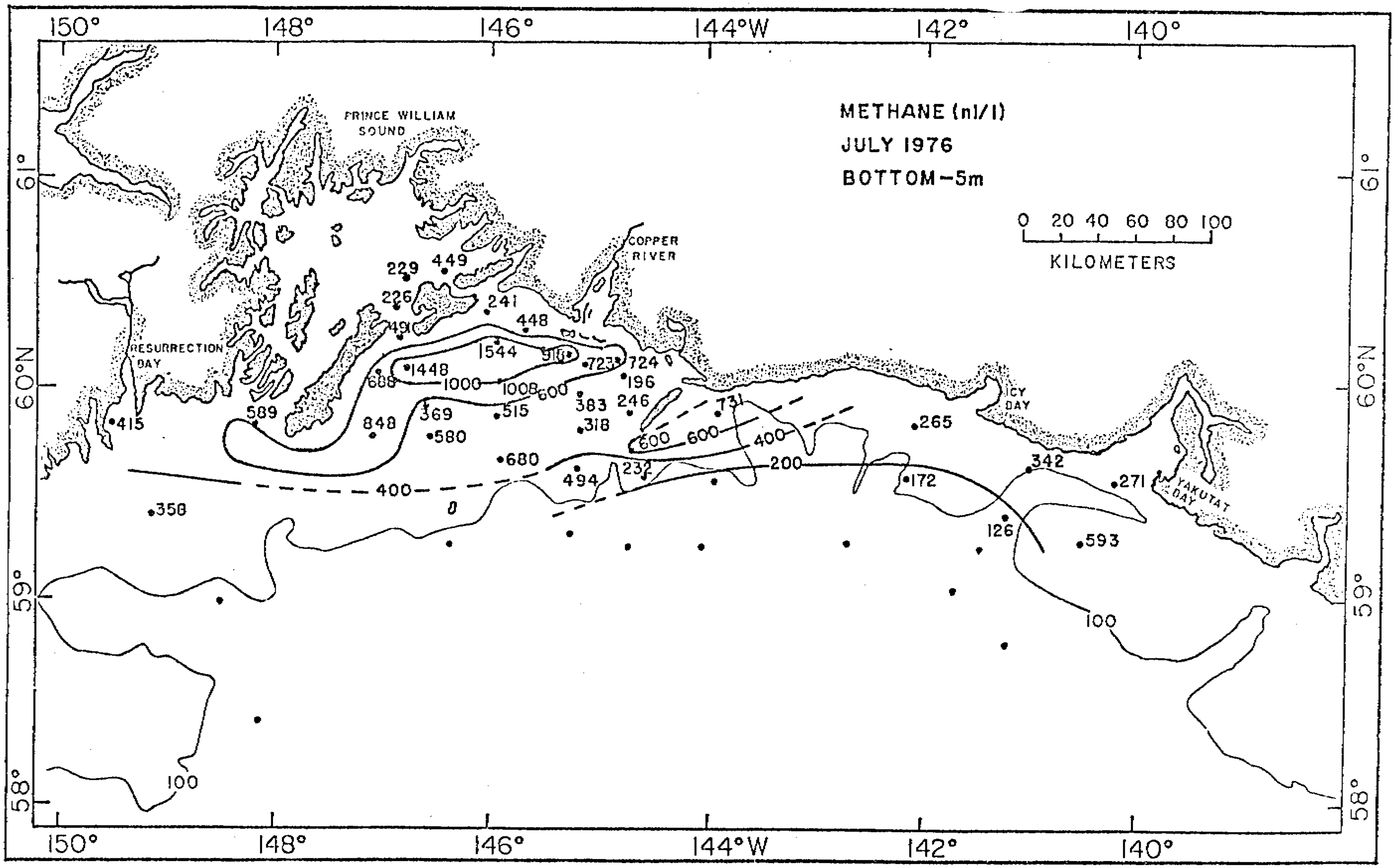


Figure 26. Areal distribution of methane 5m from the bottom in the northeast Gulf of Alaska in July 1976. Concentrations are given in nl/l.

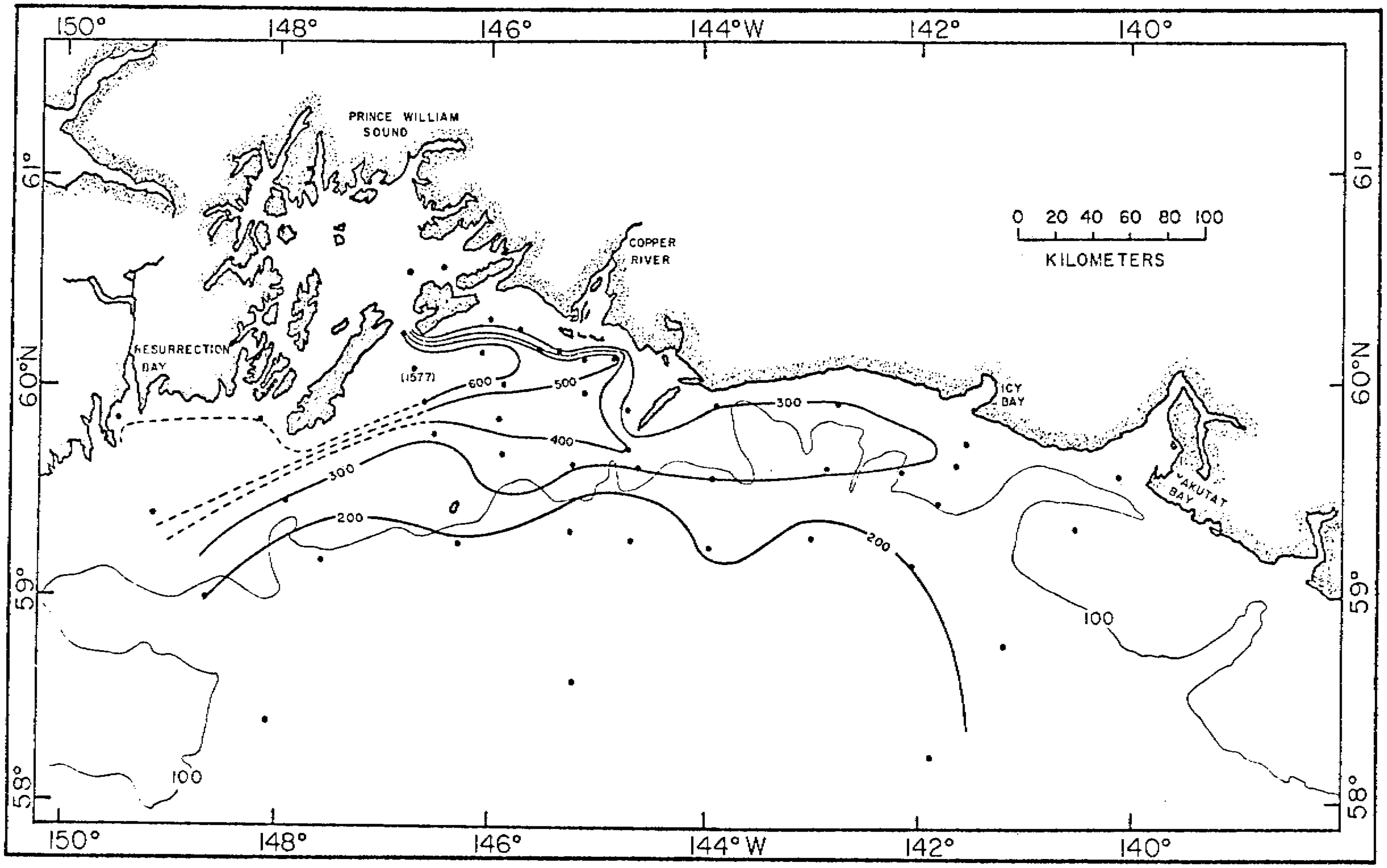


Figure 27. Areal distribution of methane 5m from the bottom in the northeast Gulf of Alaska in Oct. - Nov. 1975. Concentrations are given in nl/l.

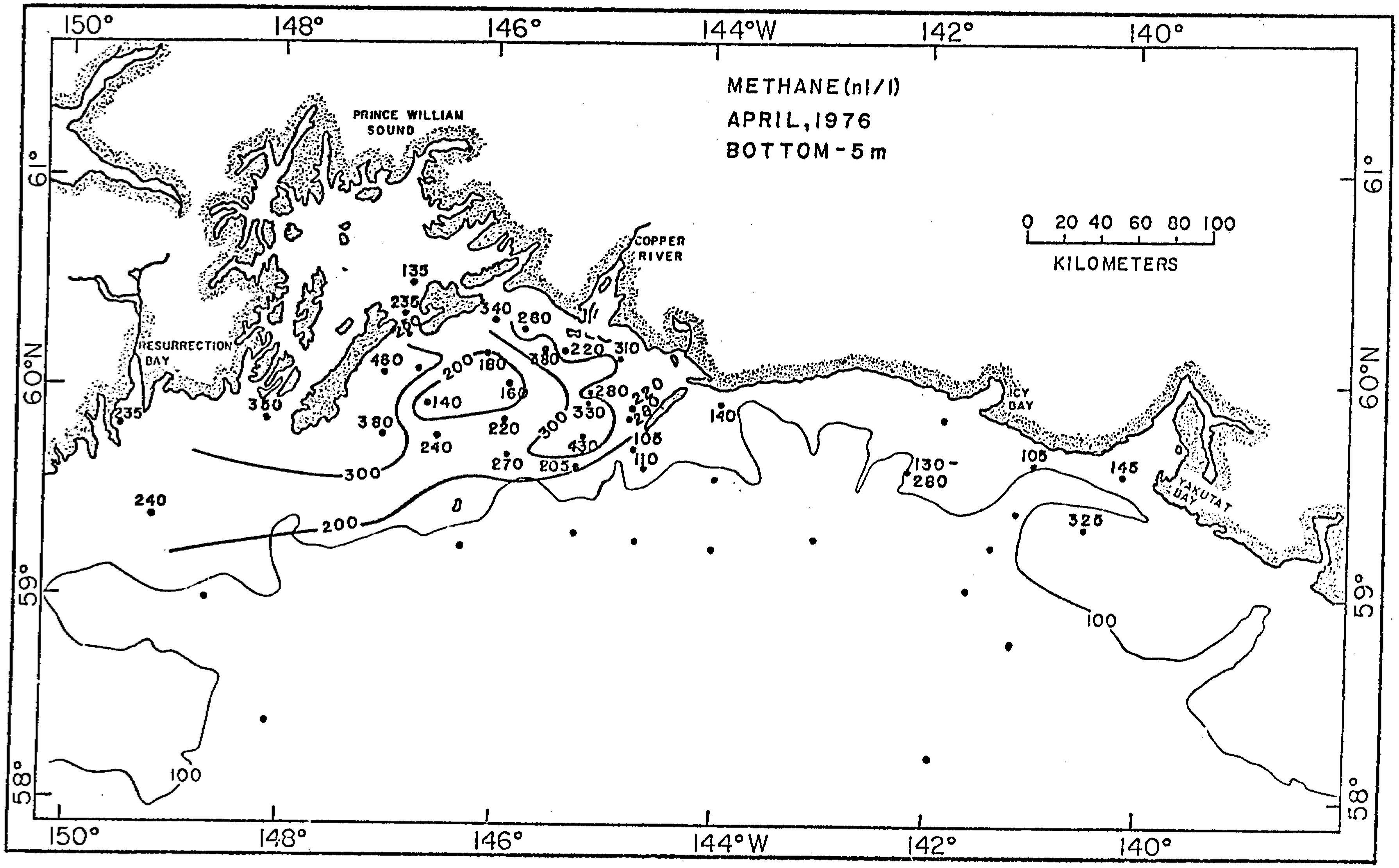


Figure 28. Areal distribution of methane 5m from the bottom in the northeast Gulf of Alaska in April 1976. Concentrations are given in nl/l.

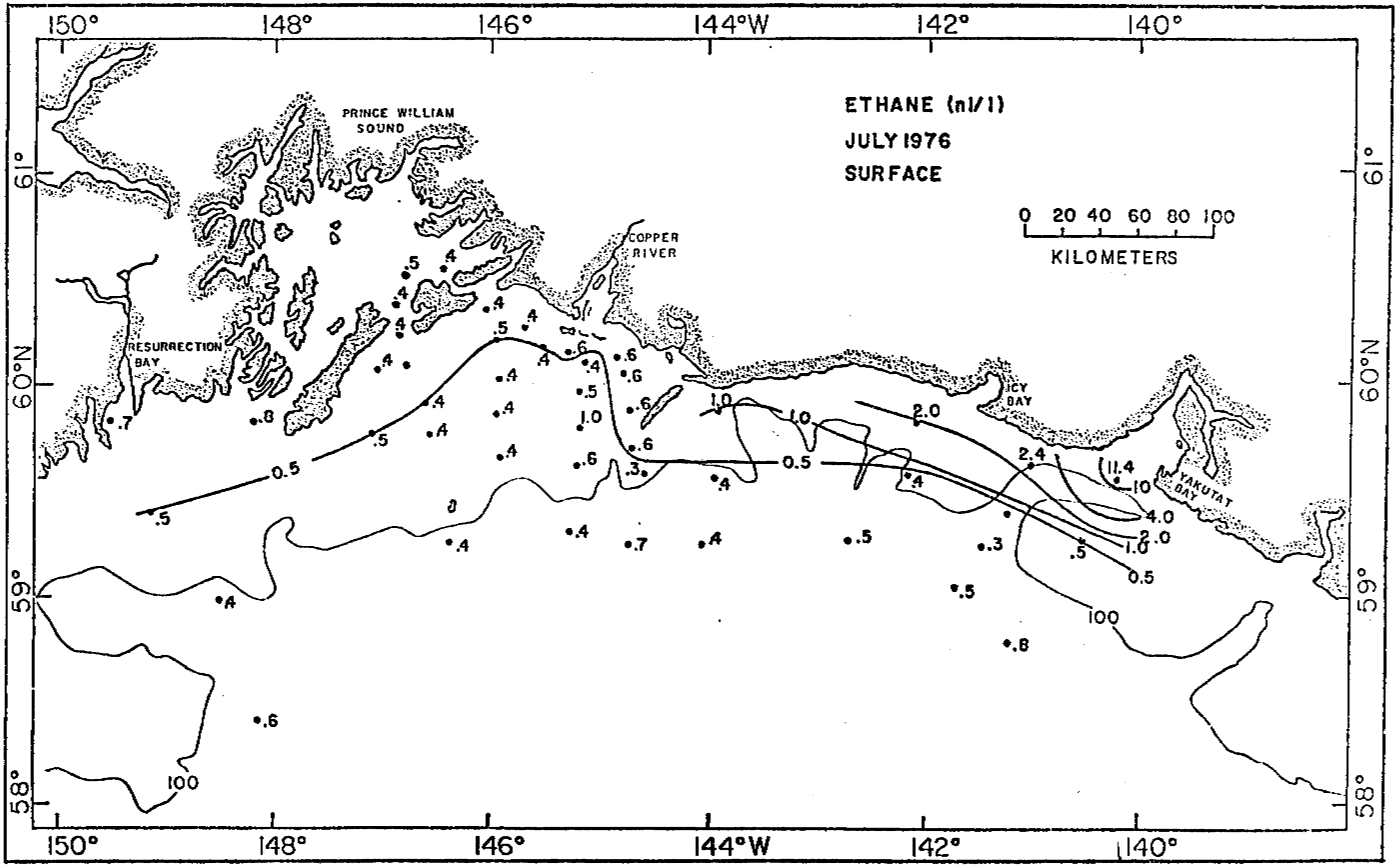


Figure 29. Surface distribution of ethane in the northeast Gulf of Alaska in July 1976. Concentrations are given in nl/l.

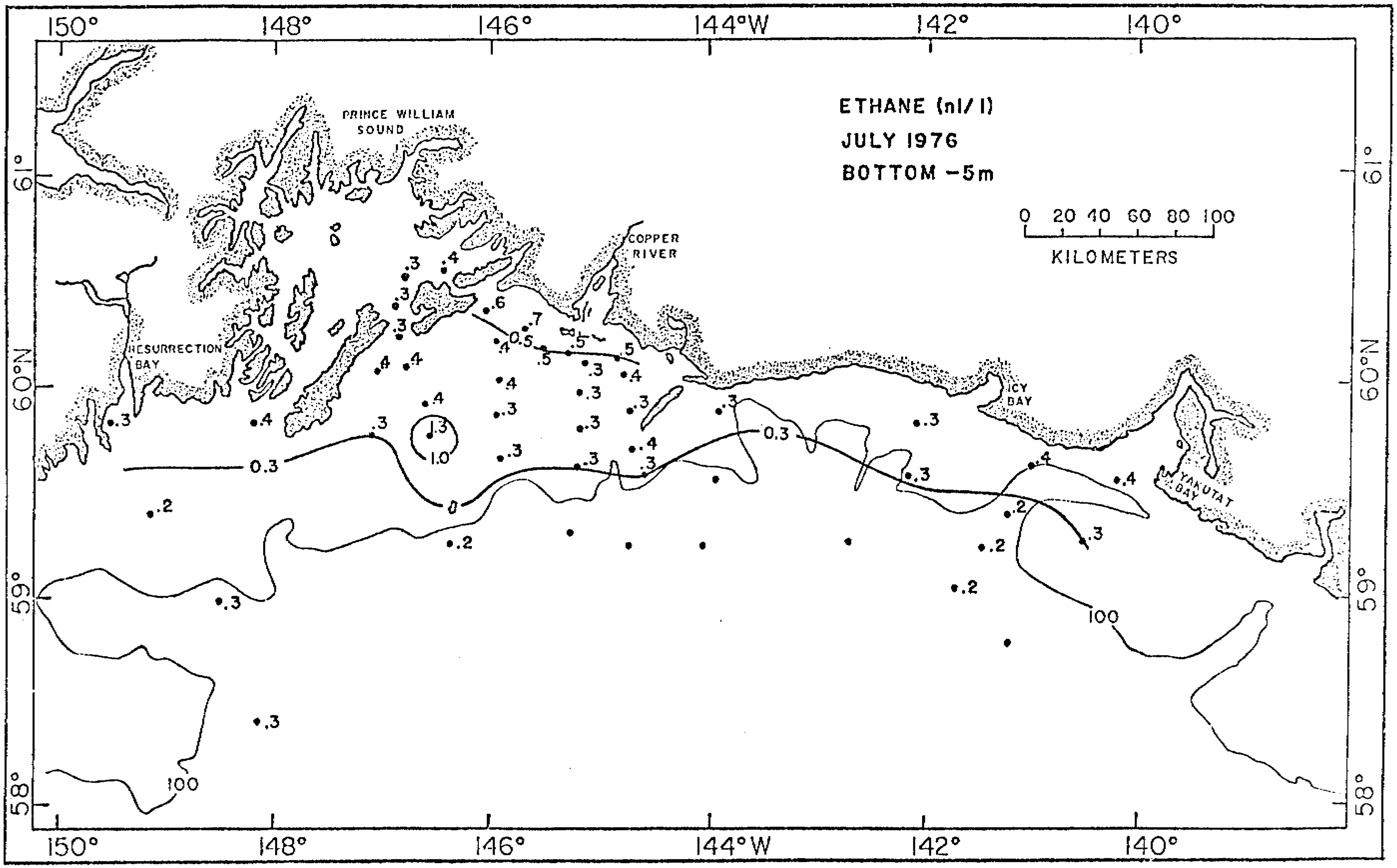


Figure 30. Areal distribution of ethane 5m from the bottom in the northeast Gulf of Alaska in July 1976. Concentrations are given in nl/l.

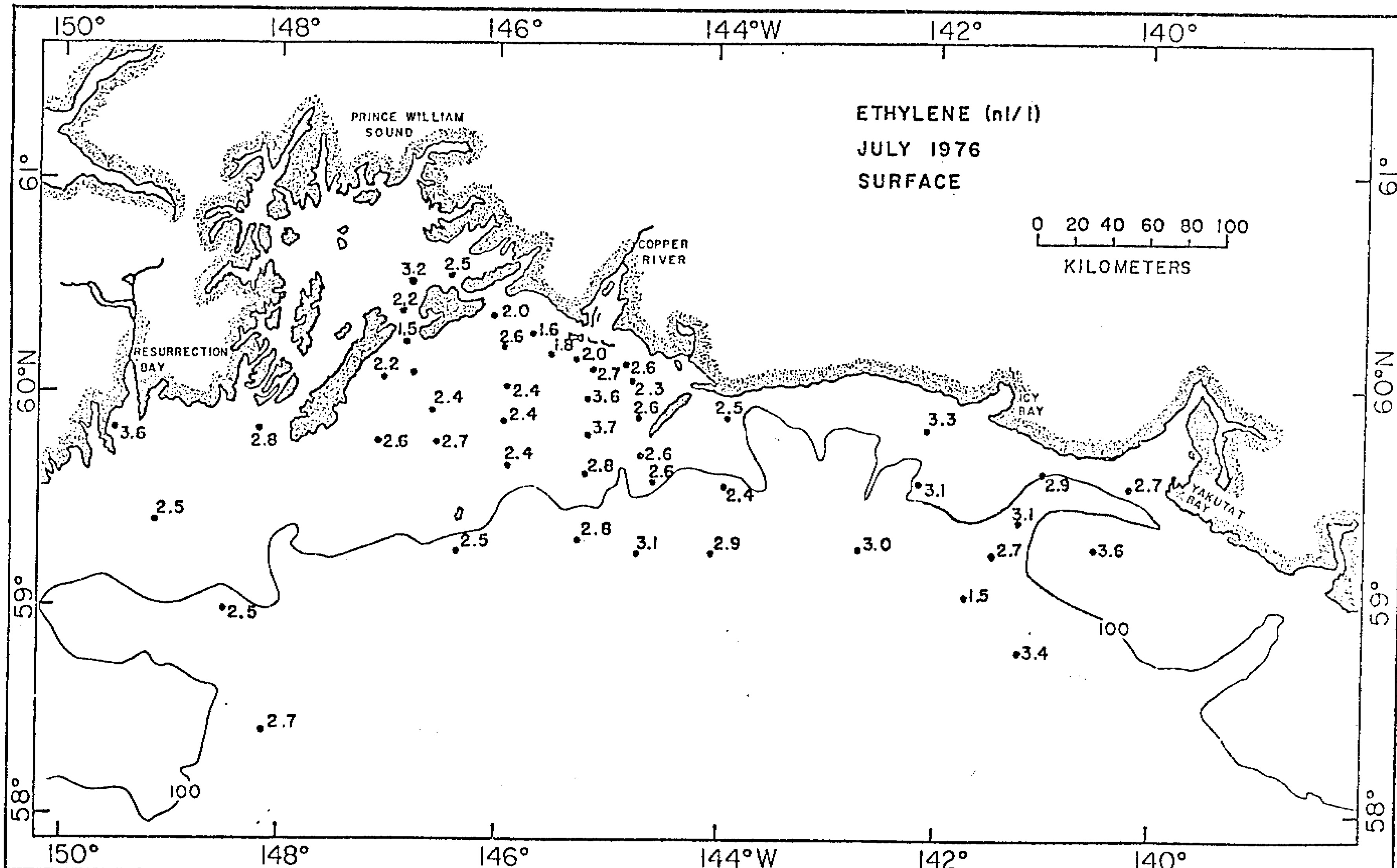


Figure 31. Surface distribution of ethylene in the northeast Gulf of Alaska in July 1976. Concentrations are given in nl/l.

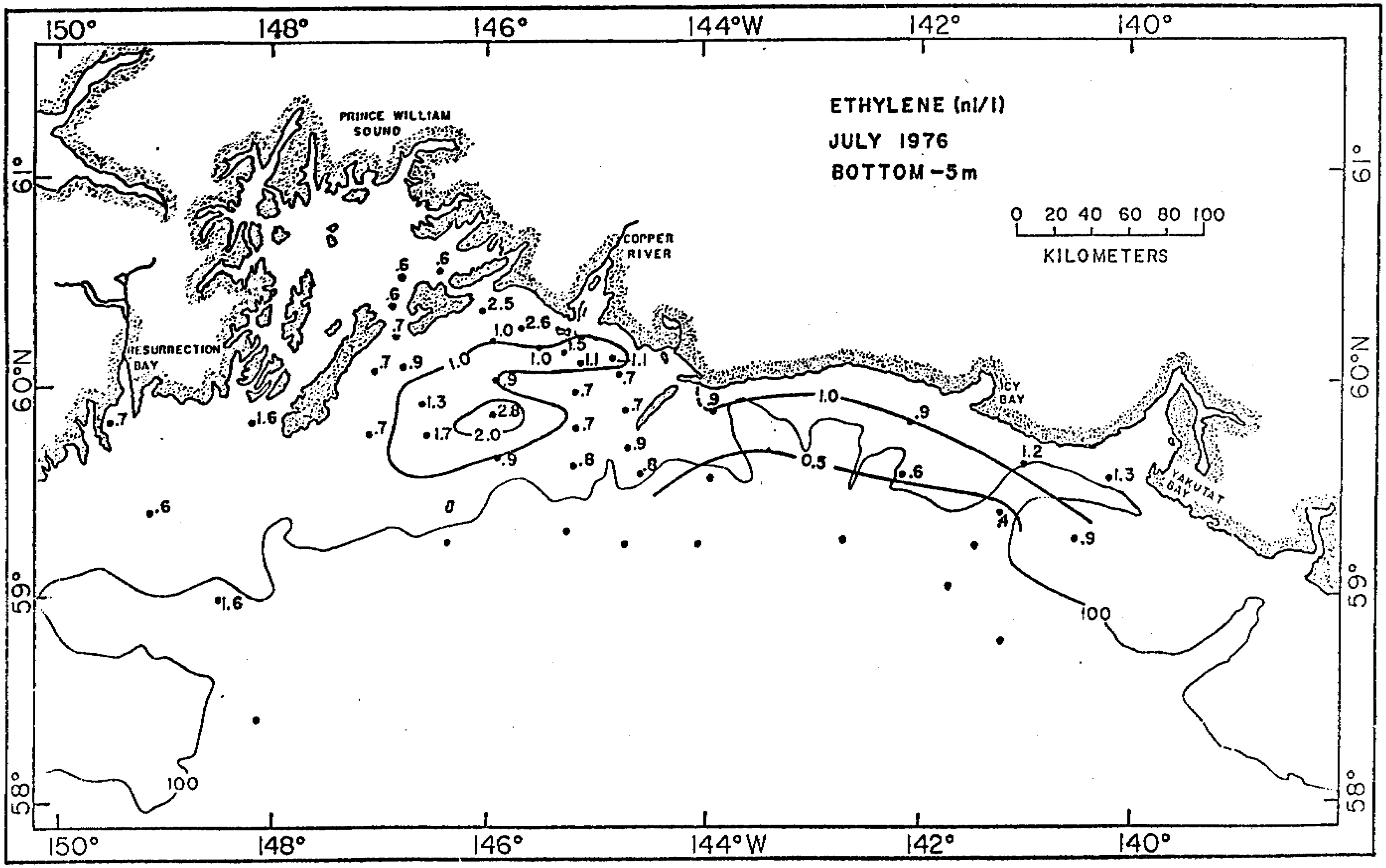


Figure 32. Areal distribution of ethylene 5m from the bottom in the northeast Gulf of Alaska in July 1976. Concentrations are given in nl/l.

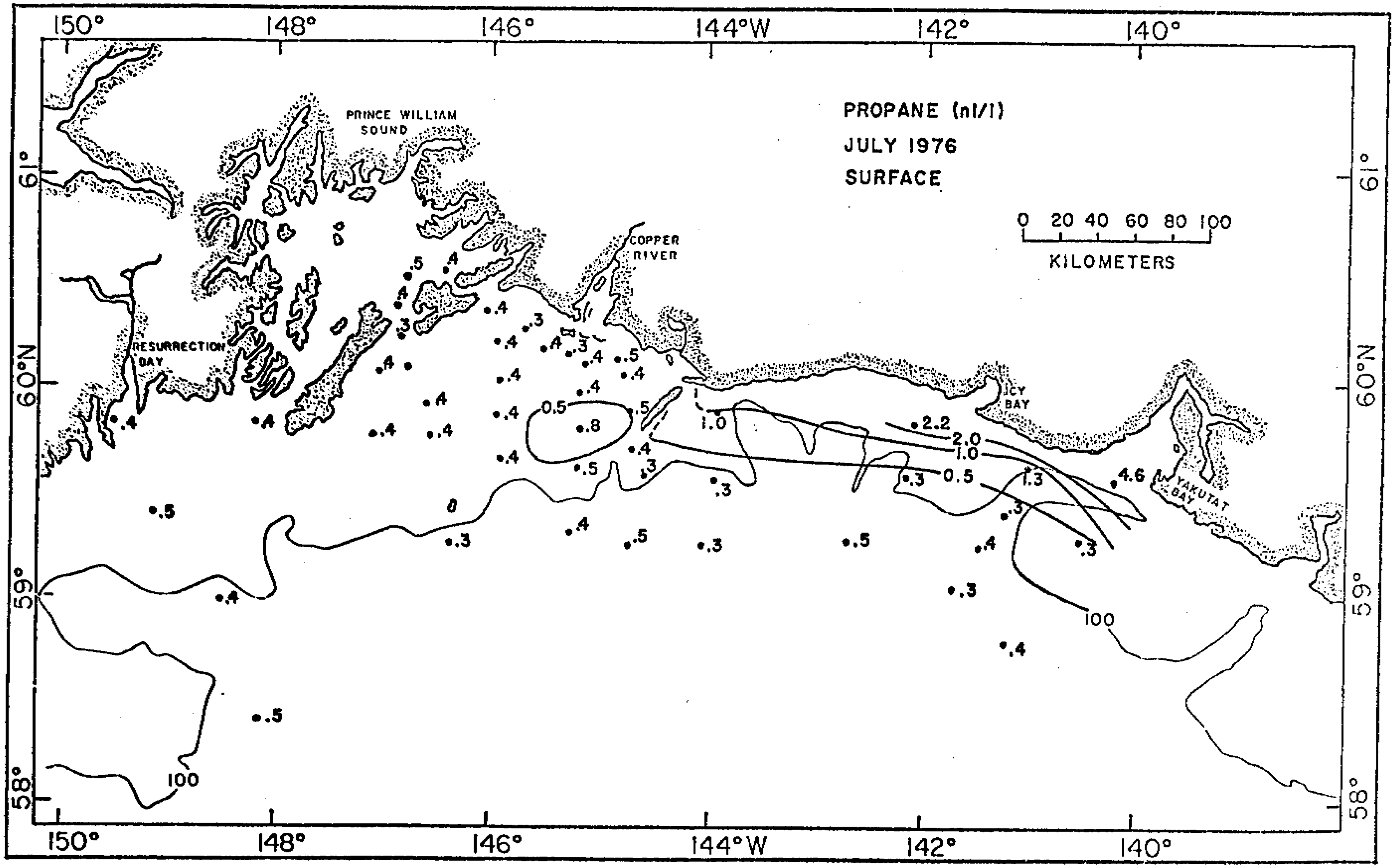


Figure 33. Surface distribution of propane in the northeast Gulf of Alaska in July 1976. Concentrations are given in nl/l.

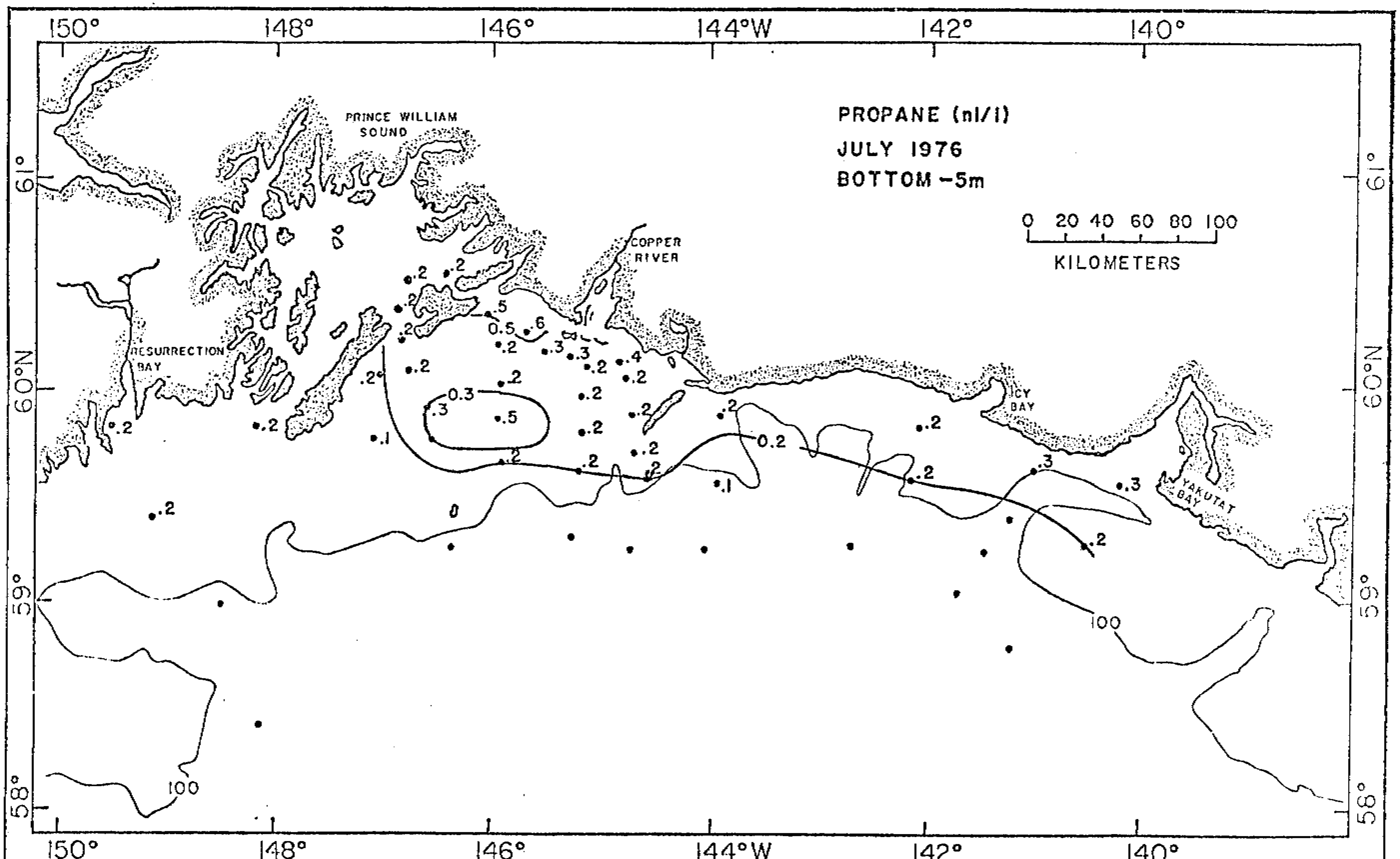


Figure 34. Areal distribution of propane 5m from the bottom in the northeast Gulf of Alaska in July 1976. Concentrations are given in nl/l.

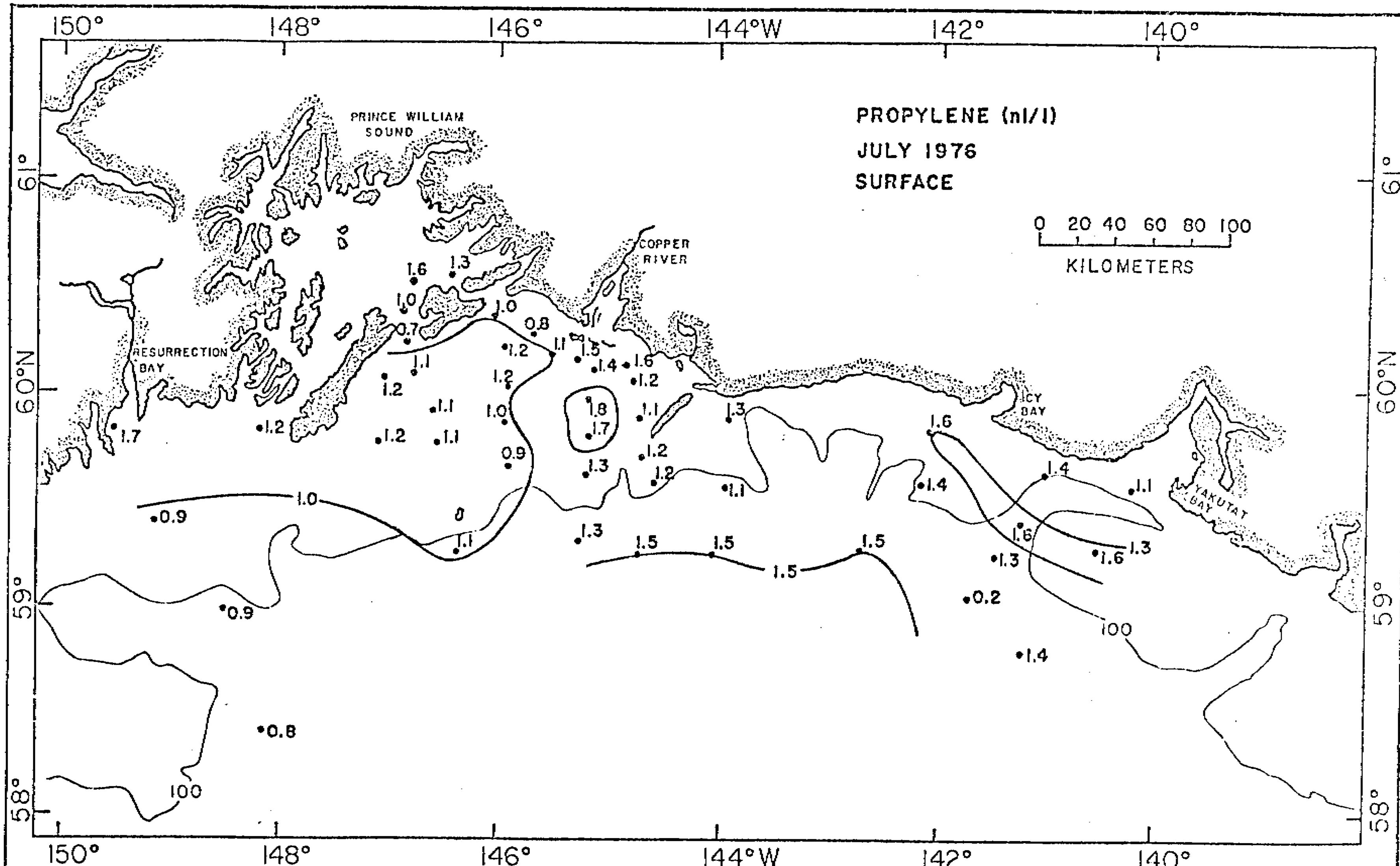


Figure 35. Surface distribution of propylene in the northeast Gulf of Alaska in July 1976. Concentrations are given in nl/l.

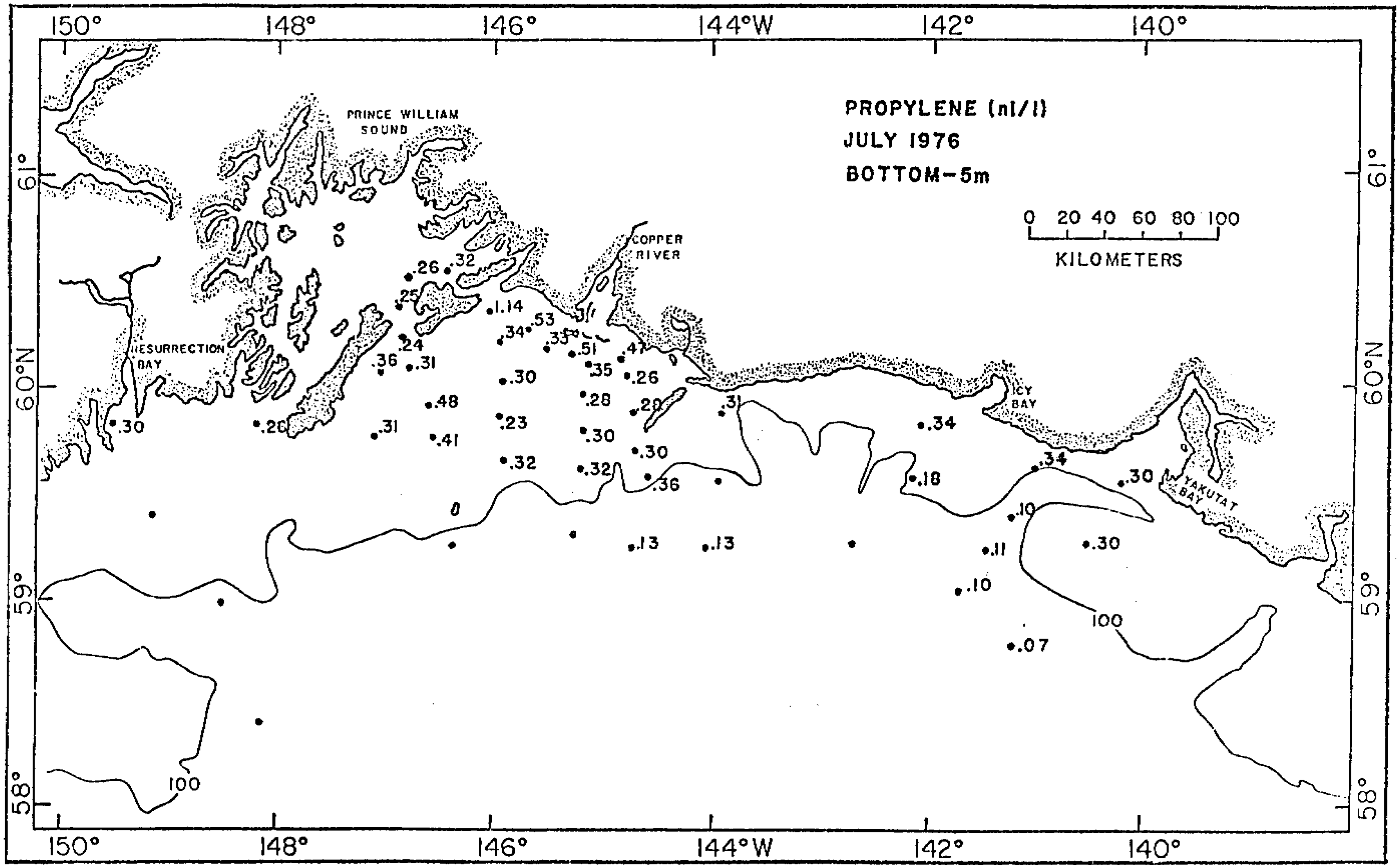


Figure 36. Areal distribution of propylene 5m from the bottom in the northeast Gulf of Alaska in July 1976. Concentrations are given in nl/l.

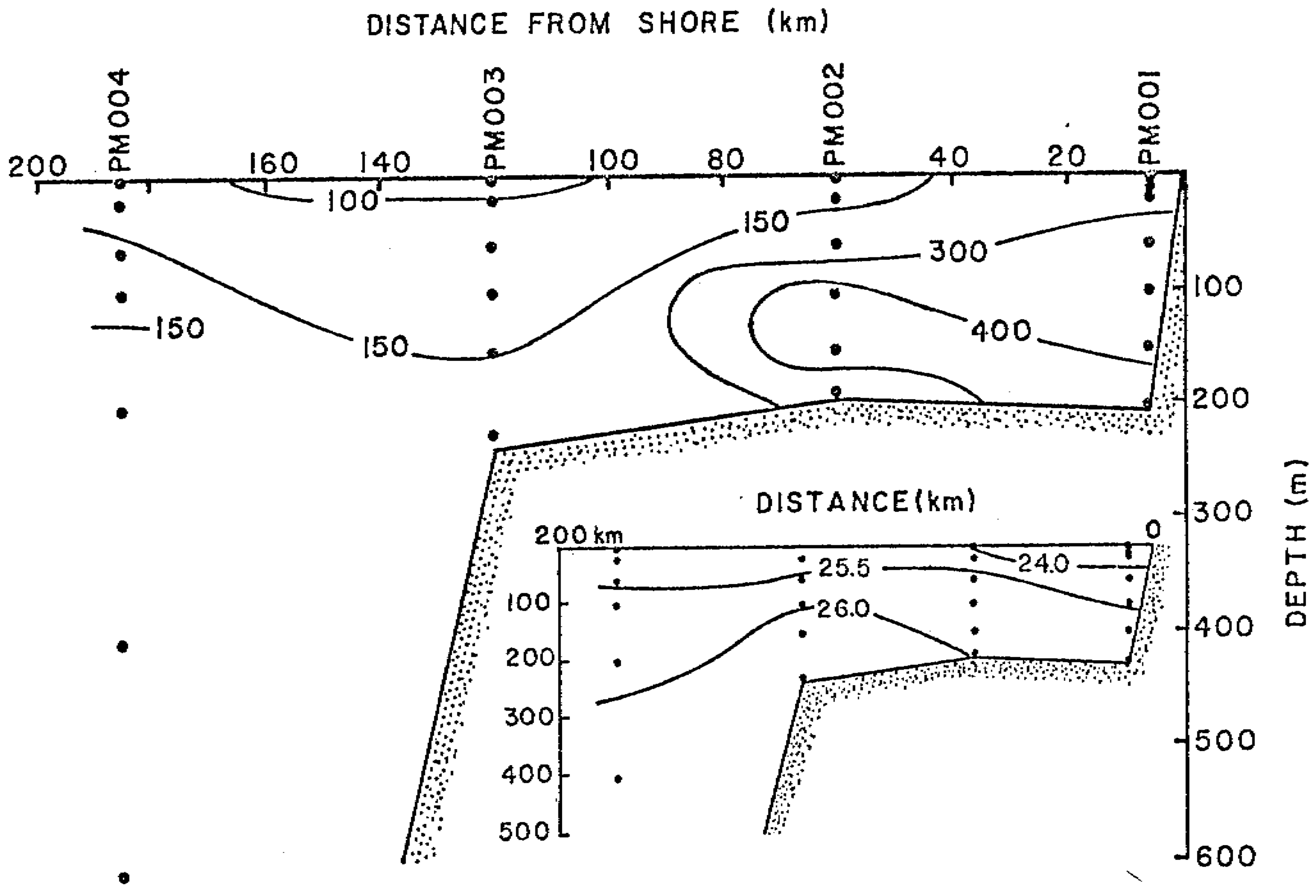


Figure 37. The distribution of methane in July 1976 along a north-south transect originating in Resurrection Bay. Isopleths of methane are given in nl/l. The inset shows the corresponding density surfaces (σ_t) for the same transect.

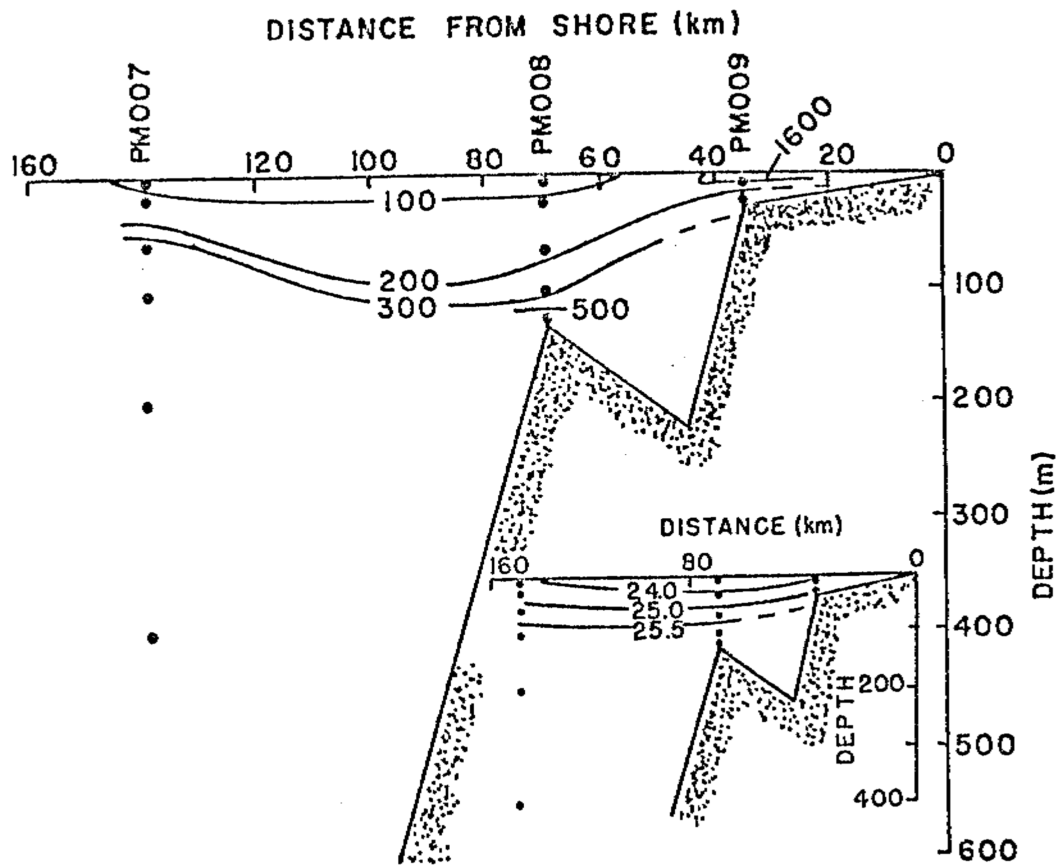


Figure 38. The distribution of methane in July 1976 along a north-south transect originating in Yakutat Bay. Isopleths of methane are given in nl/l. The inset shows the corresponding density surfaces (σ) for the same transect.

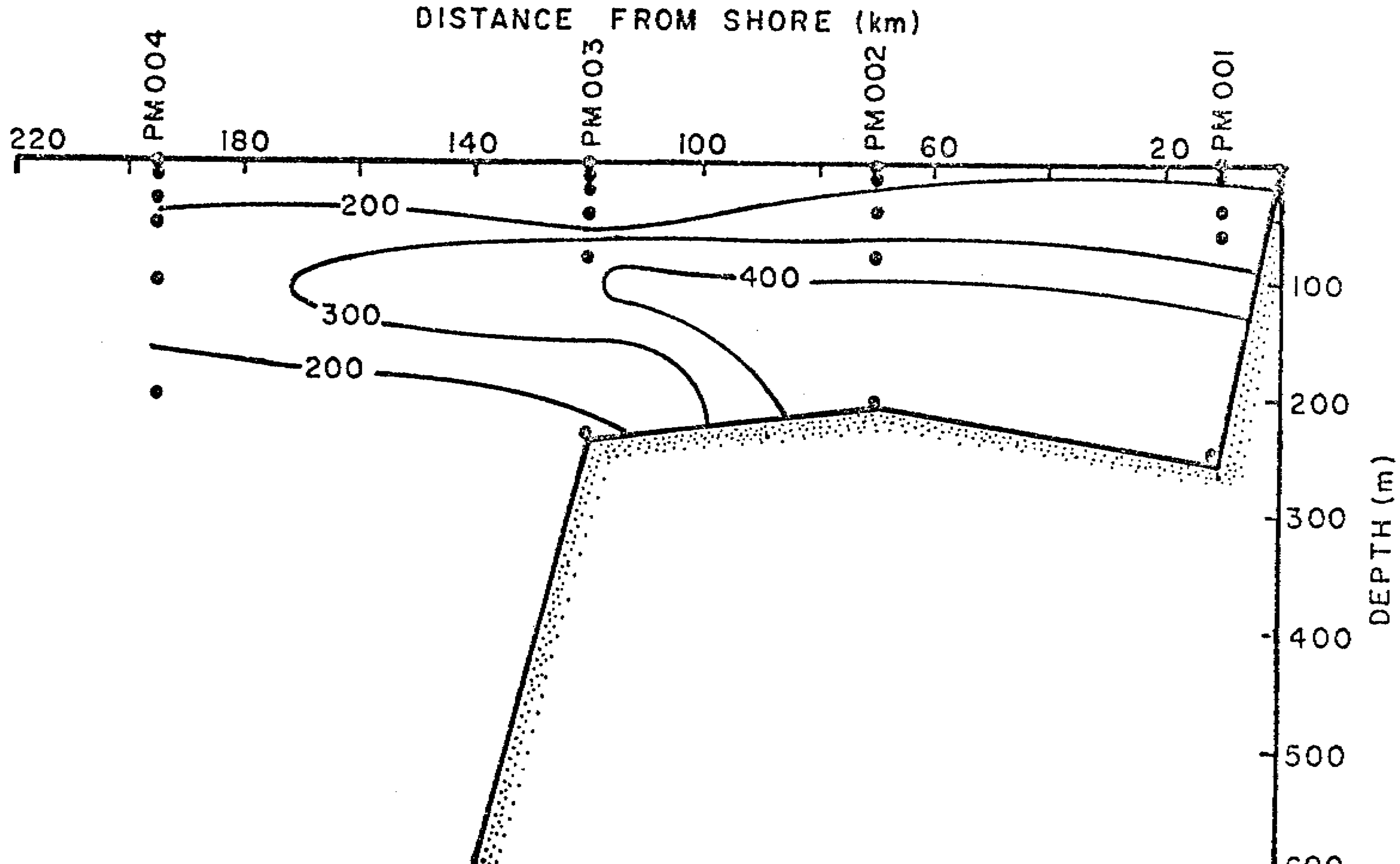


Figure 39. The distribution of methane in Oct. - Nov. 1975 along a north-south transect originating in Resurrection Bay. Isopleths of methane are given in nl/l.

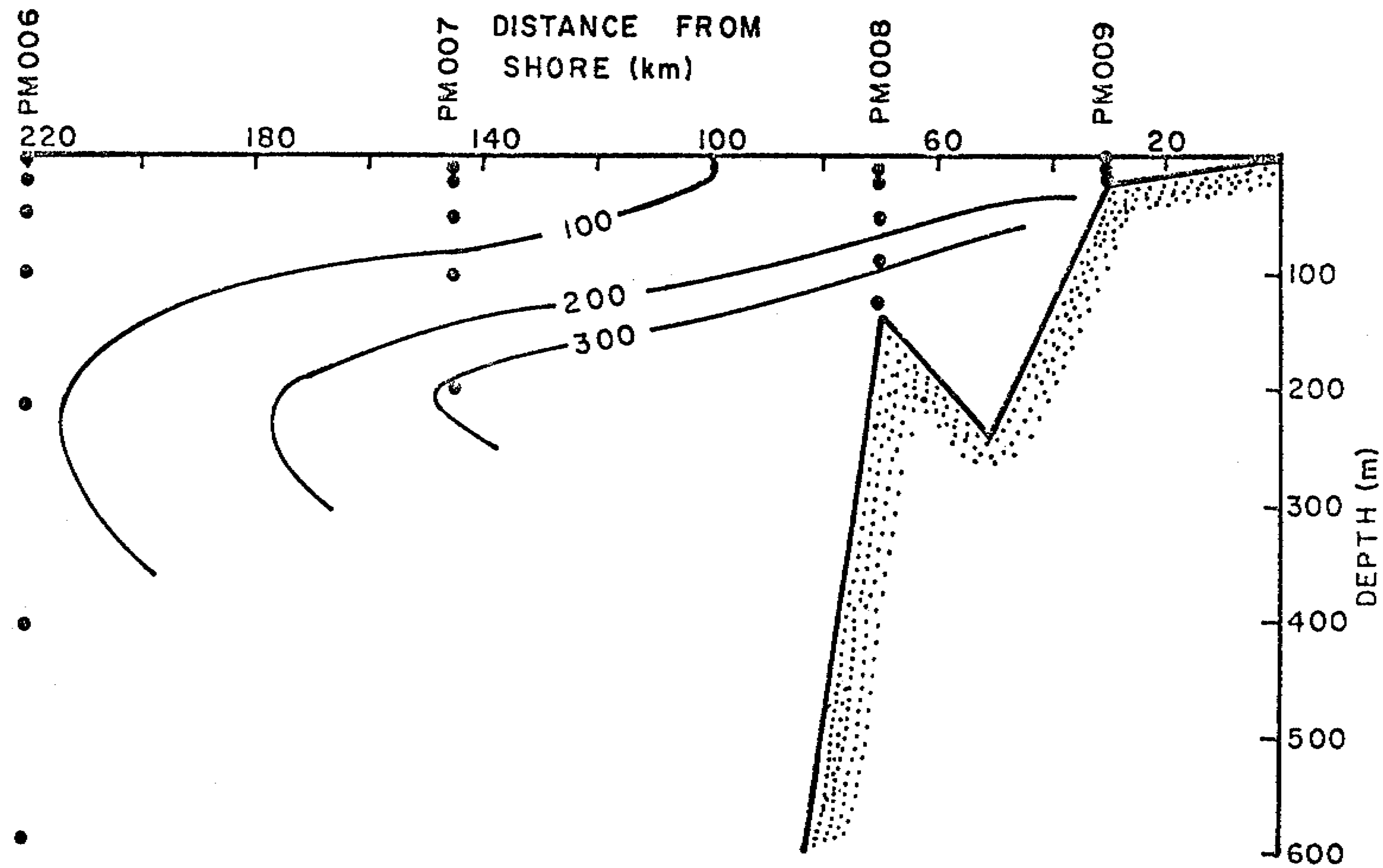


Figure 40. The distribution of methane in Oct. - Nov. 1975 along a north-south transect originating in Yakutat Bay. Isopleths of methane are given in nl/l.

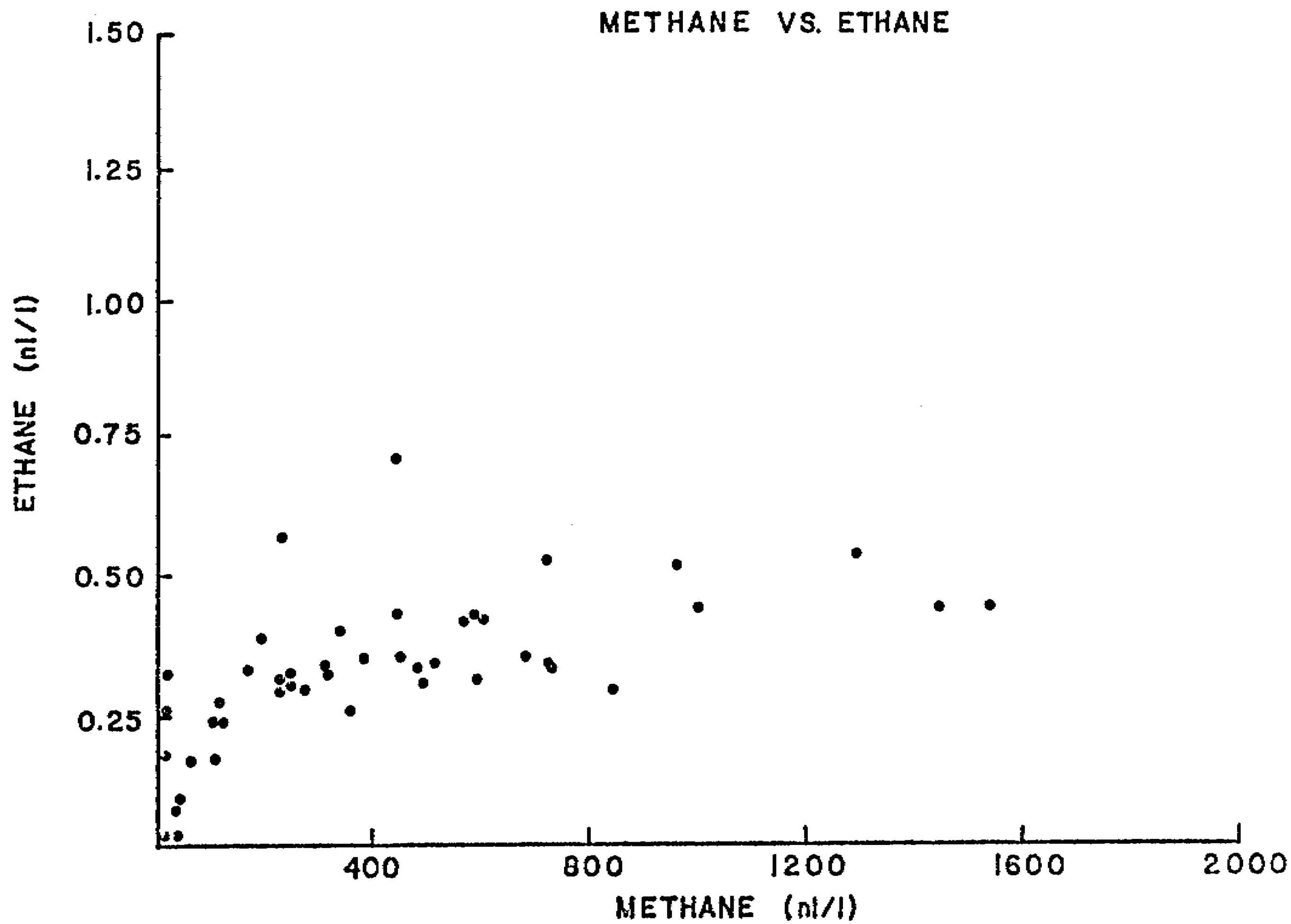


Figure 41. A plot of methane versus ethane for all near-bottom samples taken in the northeast Gulf of Alaska, during July 1976.

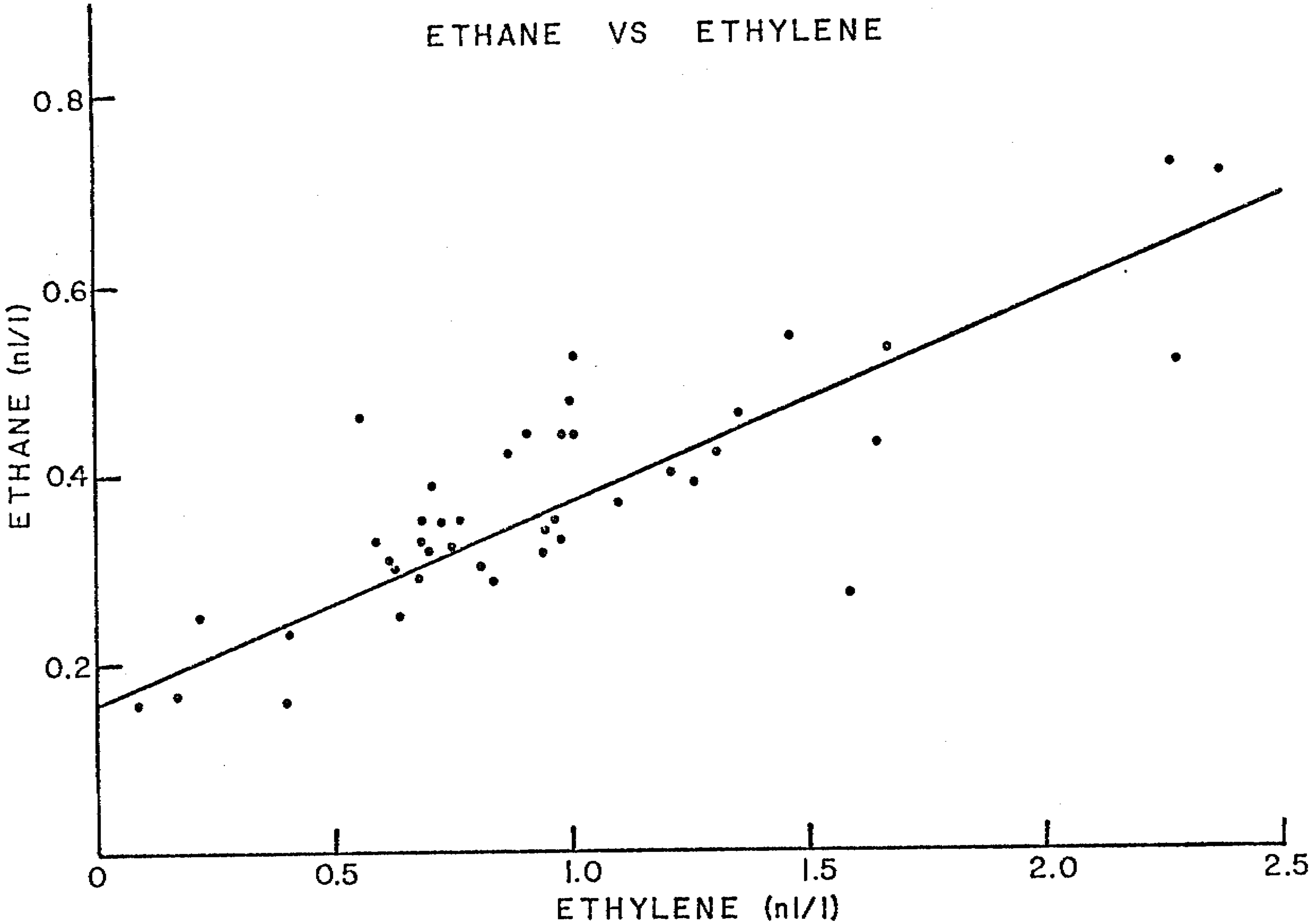


Figure 42. A plot of ethane versus ethylene for all near-bottom samples taken in the northeast Gulf of Alaska during July 1976.

References

Atkinson, L. P. and F. A. Richards. 1967. The occurrence and distribution of methane in the marine environment. Deep-Sea Res., 14, 673-684.

Brook, J. M. and W. M. Sackett. 1973. Sources, sinks, and concentrations of light hydrocarbons in the Gulf of Mexico. J. Geophys. Res., 78: 5248-5258.

Cline, J. D. and R. Feely. 1976. Distribution of Light hydrocarbons, C_1 - C_4, in the Gulf of Alaska and Southeastern Bering Sea, RU #153.

Swinnerton, J. E. and U. J. Linnenbom. 1967. Determination of C_1 - C_4 hydrocarbons in seawater by gas chromatography. J. Gas Chromatogr., 5: 570-573.

Quarterly Report

Contract #03-5-022-56
Research Unit #162/163/288/293/312
Reporting Period 7/1 - 9/30/76
Number of Pages 49

NATURAL DISTRIBUTION AND ENVIRONMENTAL BACKGROUND OF TRACE HEAVY METALS IN ALASKAN SHELF AND ESTUARINE AREAS

(Title modification April 16, 1976)

Dr. David C. Burrell
Professor of Marine Science
Institute of Marine Science
University of Alaska
Fairbanks, Alaska 99701

October 1, 1976

I. TASK OBJECTIVES

The primary objective of this program is to characterize the trace metal contents of seawater, sediment, and selected indigenous animal and plant species in the three originally specified study areas (Gulf of Alaska, S. Bering Sea, Beaufort Sea) plus those regions added (Lower Cook Inlet, Norton Sound) through later contract modifications. This program also incorporates sediment grain-size analysis, clay mineralogy analysis, and "previous work" literature searches as described in the original Work Statement.

II. FIELD AND LABORATORY ACTIVITIES

A. Field Work

1. Lower Cook Inlet - R/V *Acona* cruise June 25 - July 2, 1976

   A single *Fucus* sample was collected for us by the organic chemistry group.

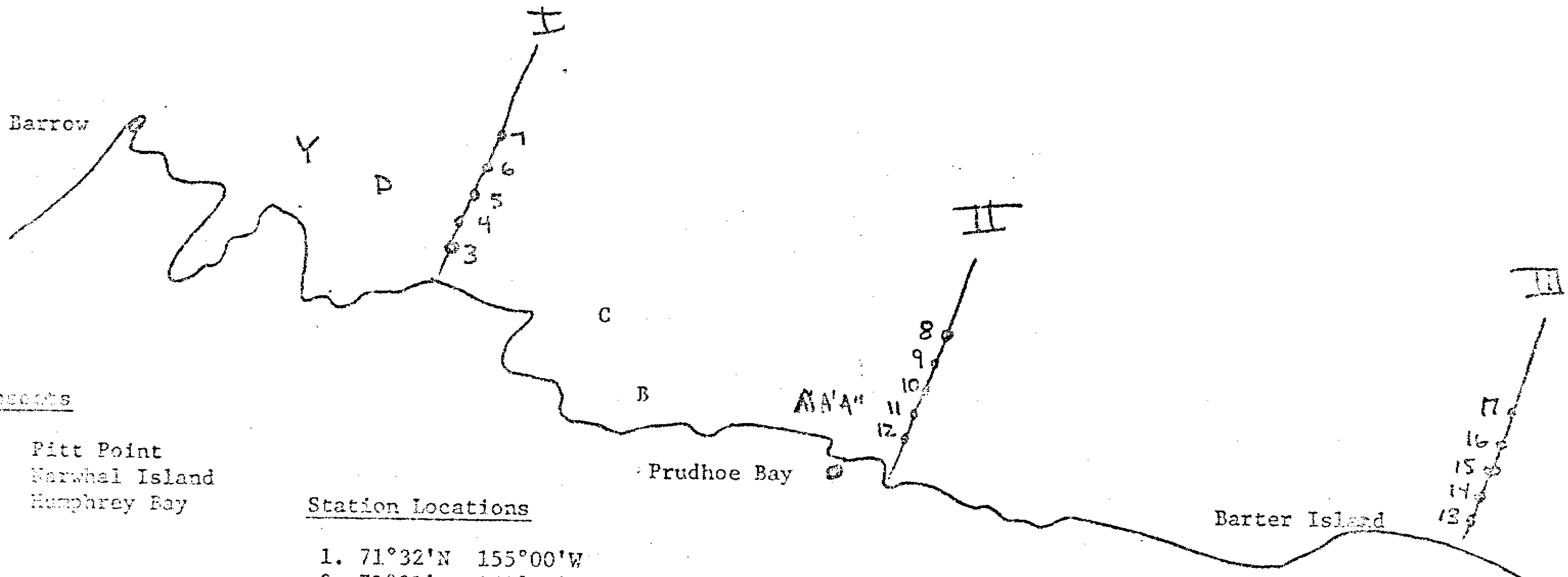
2. Beaufort Sea - C.G.C. *Glacier* Leg I - first half of August

   Chemical technician for Dr. Weiss's laboratory (Naval Under-Sea Center, San Diego) participated. Sediment samples collected for mercury analysis. Sampler for water column did not function correctly. No cruise report received.

   C.G.C. *Glacier* Leg II - 23 August - 3 September 1976

   Personnel: T. Gosink and G. Landreth

   Station localities are shown on the accompanying figure. Number and types of samples taken: 11 sediment samples taken with the Haps corer for sediment extract and activation analysis work; 22 water samples taken for shipboard Se and Cr analysis. Additional water samples were collected also for the soluble heavy



Transects

I. Pitt Point
II. Narwhal Island
III. Humphrey Bay

Station Locations

1.	71°32'N	155°00'W
2.	71°21'N	153°50'W
3.	71°08'N	152°55'W
4.	71°19'N	152°33'W
5.	71°26'N	152°2[illegible]'W
6.	71°36'N	152°12'W
7.	71°46'N	151°52'W
8.	71°08'N	146°30'W
9.	70°57'N	146°50'W
10.	70°47'N	147°00'W
11.	70°25'N	147°15'W
12.	70°31'N	147°24'W
13.	70°06'N	142°43'W
14.	70°18'N	142°08'W
15.	70°29'N	141°53'W
16.	70°40'N	141°37'W
17.	70°51'N	141°22'W

Precise locations to be supplied by the chief scientist, Dr. Rita Horner, along with salinity and temperature time data and station depth data. Eleven stations - 3, 4, 5, 7, 11, 12, A, B, C, D, and Y were occupied.

2. (Continued)

metal analysis program. Unfortunately, the trace-metal free water sampler required for this work were apparently damaged in transit to Long Beach so that it was necessary to utilize ship-provided sampler. It is likely, therefore, that these samples will be contaminated and no data will result.

3. Gulf of Alaska - R/V *Acona* cruise September 11-15, 1976

Personnel: D. C. Burrell

A reconnaissance survey of Icy Bay. Approximately 10 miles of bathymetric track were taken and two hydrographic stations occupied.

4. N. Bering Sea (Norton Sound) - O.S.S. *Discoverer* - Mid-September

Participant: T. Manson

Haps core and water column samples to be collected. Cruise in progress at the time of writing this report.

B. Scientific Parties

As noted above.

C. Field Collection Methods

Sample collection and storage methods have been essentially as described in the Annual Report. Specific deviations are noted in the following section.

D. Sample Localities

Except for the single biota sample from Lower Cook Inlet noted above, and the Beaufort Sea stations shown in the previous figure, all samples have been taken at the standard stations given in the Annual Report. Coordinates of the intertidal benthic sampling

D. (Continued)

localities referred to by name in this and previous quarterly reports, are given in Tables I - IV for the N.E. and N.W. Gulf of Alaska, Kodiak Island, and the S. Bering Sea respectively.

E. Laboratory Analysis Programs

1. Voltammetry (Dr. D. C. Burrell):

   Free zinc data, as determined voltammetrically in filtered water samples at pH 8 (see discussion in previous quarterly report) are given in Table V and Tables VI and VII for the N.E. and N.W. Gulf of Alaska, respectively. With the exception of some nickel data this set of data completes this portion of the contractural program.

2. Flame-less atomic spectrometry (Dr. D. C. Burrell): Efforts are continuing to calibrate filament and furnaces atomic absorption spectrometric analytical procedures with the voltammetry data. A progress report on this work will be included in the next quarterly report.

3. Neuton Activation Analysis (Dr. D. E. Robertson): The main effort during this period centered on analysis of suspended sediment samples. This work has involved "rabbit" irradiations, using the Washington State University reactor, for the measurement of both major and trace elements having short lived activation products. Data for one major constituent - aluminum - are given in Tables VIII through X for the N.E. and N.W. Gulf of Alaska and the S. Bering Sea respectively. Data for the trace heavy metals manganese and vanadium are given in Tables XI - XIII respectively for the same geographical areas. The values given in Tables VIII through XIII are for the total contents of these elements in suspended particulate

TABLE I

N.E. GULF OF ALASKA

Localities of intertidal benthos samples.

Name	Locality	
Port Dick	59 13.3	151 10.0
Day Harbor	59 59.7	149 06.0
La Touche Point	59 57.1	148 03.4
Macleod Harbor	59 53.4	147 47.7
Middleton Island	59 25.2	146 22.5
Zaikof Bay	60 17.9	147 00.0
Port Etches	60 21.2	146 36.3
Boswell Bay	60 24.6	146 06.3
Katalla	60 16.5	144 36.5
Cape Yakataga	60 03.8	142 25.9
Yakutat	59 32.3	139 52.5
Kayak Island	59 48.2	144 35.9

TABLE II

N.W. GULF OF ALASKA

Localities of intertidal benthos samples.

Name	Locality			
Spectacle Island	55	07.2	159	44.6
Chirikof Island	55	49.6	156	44.1
Cape Nukshak	58	23.4	153	59.4

TABLE III

KODIAK ISLAND

Localities of intertidal benthos samples.

Name	Locality			
Sundstrom Island	56	41.5	154	08.6
Three Saints Bay	57	07.8	153	28.7
Sud Island	58	54.3	152	12.4

TABLE IV

S. BERING SEA

Localities of intertidal benthos samples.

Name	Locality			
Akun Island	54	08.5	165	38.7
Amak Island	55	24.1	163	09.3
Crooked Island	58	39.5	160	16.5
Cape Pierce	58	34.4	161	45.5
Point Edward	55	59.5	160	51.6
Cape Mordvinof	54	55.8	164	26.8
Makushin Bay	53	44.0	166	45.8
Zapadai Bay	56	34.1	169	39.8
Otter Island	57	03.0	170	23.8

TABLE V

N.E. GULF OF ALASKA
Discoverer Leg III 23 November - 2 December 1975

Free zinc contents at pH 8 in filtered (0.4 μm) water.

Station No.	Depth (m)	Zn (μg/ℓ)
02	10	n.d.
	175	0.22
05	10	n.d.
	80	0.15
08	10	n.d.
	245	0.13
11	10	n.d.
	1350*	0.28
15	10	–
	1500*	0.34
24	10	–
	410*	0.48
26	10	–
	135	0.21
29	70	0.15
30	40	n.d.
33	10	0.35
	205	n.d.
44	10	0.22
	165	0.14
48	10	0.20
	500	n.d.
49	10	0.18
	120	0.45
50	10	0.20
	165	–
51	10	0.31
	135	n.d.
52	75	0.13
53	10	–
	285	0.16
54	10	0.20
	200	0.45
55	10	0.45
	110	0.70
56	65	0.20
57	60	0.24
58	81	0.60
59A	10	–
	370	–

*Intercalibration station

TABLE VI

N.W. GULF OF ALASKA
Discoverer 8-16 October 1975

Free zinc contents at pH 8 in filtered (0.4 μm) water (μg/ℓ).

Station No.	Depth (m)	Zn (μg/ℓ)
101	0	0.70
	80	0.30
102	0	n.d.
	100	0.25
104	0	0.28
	95	n.d.
119	0	n.d.
	240	n.d.
120	0	0.50
	280	n.d.
121	0	0.42
	220	n.d.
122	0	0.24
	40	0.20
124	0	0.40
	105	n.d.
133	0	n.d.
	65	n.d.
135	0	n.d.
	140	n.d.
137	0	0.20
	95	n.d.
145	0	n.d.
	60	n.d.
146	0	0.35
	65	n.d.
147	0	0.15
	95	n.d.
148	0	0.28
	100	n.d.
156	0	0.32
	150	0.25
157	0	0.50
	50	0.45
158	0	–
	90	n.d.
159	0	0.33
	90	n.d.
160	0	0.45
	135	0.15

TABLE VII

N.W. GULF OF ALASKA
Discoverer Leg III 23 November - 2 December 1975

Free zinc contents at pH 8 in filtered (0.4 μm) water.

Station No.	Depth (m)	Zn (μg/ℓ)
106	80	0.17
108	10	n.d.
	220	n.d.
110	10	0.20
	175*	n.d.

*Intercalibration station

TABLE VIII

N.E. GULF OF ALASKA

Discoverer Leg III 23 November - 2 December 1975

D. E. Robertson, Analyst

Total major cation contents of suspended sediment.
(>0.4 μm; μg/ℓ)

Station	Depth	Al
02	10	18.7 ± 0.8
	178	32.2 ± 1.0
05	10	26.9 ± 1.2
	162	40.6 ± 1.8
08	10	16.8 ± 0.9
	274	81.5 ± 1.4
11	10	5.7 ± 1.2
	1350	7.0 ± 1.1
15	10	8.4 ± 1.1
	1500	3.9 ± 1.1
24	10	1.3 ± 0.8
	410	5.4 ± 0.9
26	10	8.9 ± 1.0
	136	34.9 ± 0.7
29	71	43.9 ± 0.8
30	42	395 ± 4
33	10	0.91 ± 0.66
	205	9.0 ± 1.1
44	10	107 ± 1
	165	46.2 ± 1.2
48	10	3.4 ± 1.1
	447	26.0 ± 1.1
49	10	141.0 ± 2.0
	120	84.9 ± 1.7
50	10	74.6 ± 1.7
	161	58.6 ± 0.5
51	10	42.6 ± 1.1
	133	83.1 ± 1.1
52	74	38.0 ± 0.9
53	10	35.9 ± 1.2
	284	222.0 ± 3.0
54	10	57.3 ± 1.6
	212	66.2 ± 1.5
55	10	83.1 ± 1.1
	110	87.8 ± 1.9
56	58	63.9 ± 1.0
57	67	44.7 ± 1.8
58	82	76.7 ± 1.3
59A	10	97.3 ± 1.2
	370	17.6 ± 1.5

TABLE IX

N.W. GULF OF ALASKA
Discoverer Leg IV 3-16 October 1975
D. E. Robertson, Analyst

Total major cation contents of suspended sediment.
(>0.4 μm; μg/ℓ)

Station	Depth	Al
102	1	10.03 ± 0.15
	98	9.56 ± 0.08
103	1	3.79 ± 0.43
	125	7.40 ± 0.19
104	1	2.46 ± 0.08
	96	27.38 ± 0.13
106		
	81	26.3 ± 1.0
108	10	4.53 ± 0.86
	226	30.1 ± 0.8
110	10	4.42 ± 0.82
	173	17.1 ± 1.5
119	1	32.4 ± 1.0
	204	35.3 ± 0.8
120	1	16.5 ± 0.6
	281	103 ± 1
121	1	15.0 ± 0.6
	220	69.9 ± 0.8
122	1	15.1 ± 1.0
	35	28.3 ± 0.5
124	1	14.6 ± 0.4
	105	25.5 ± 0.6
133	1	5.0 ± 0.58
	68	18.3 ± 0.5
135	1	2.04 ± 0.65
	141	24.8 ± 2.1
137	1	3.73 ± 1.15
	95	20.6 ± 1.0

TABLE IX

(Continued)

Station	Depth	Al
145	1	7.68 ± 2.19
	63	4.88 ± 0.70
146	1	3.63 ± 0.54
	63	6.79 ± 0.75
147	1	< 2.25
	94	11.0 ± 0.5
148	1	4.30 ± 0.60
	100	15.5 ± 0.6
156	1	11.0 ± 0.9
	150	56.4 ± 2.1
157	1	5.65 ± 0.16
	59	17.1 ± 1.1
158	1	4.95 ± 2.28
	92	12.2 ± 2.0
159	1	
	96	9.25 ± 0.94
160	1	1.30 ± 0.46
	132	10.3 ± 0.6

TABLE X

S. BERING SEA
Discoverer 2-19 June 1975
D. E. Robertson, Analyst

Total major cation contents of suspended sediment.
(>0.4 µm; µg/ℓ)

Station	Depth	Al
02	S	9.4 ± 0.2
	B	20.6 ± 0.2
08	S	64.4 ± 0.2
	B	68.0 ± 0.4
14	S	10.1 ± 0.6
	B	24.1 ± 0.2
17	B	72.2 ± 0.2
19	B	114 ± 1
24	B	77.4 ± 0.6
31	S	6.32 ± 0.20
	B	18.3 ± 0.2
30	B	102 ± 1
34	S	12.0 ± 0.2
	B	18.4 ± 0.1
37	B	28.8 ± 0.2
41	B	21.0 ± 0.2
43	B	23.0 ± 0.2
48	S	15.4 ± 0.1
	B	14.4 ± 0.1
53	S	7.34 ± 0.14
	B	14.0 ± 0.1
56	B	13.8 ± 0.1
59	B	17.2 ± 0.2
64	B	16.0 ± 0.1

TABLE XI

N.E. GULF OF ALASKA

Discoverer Leg III 23 November - 2 December 1975

D. E. Robertson, Analyst

Total heavy metal contents of suspended sediment.

(>0.4 μm; μg/ℓ)

Station	Depth	Mn	V
02	10	0.59 ± 0.12	< 0.051
	178	0.82 ± 0.13	0.063 ± 0.061
05	10	0.47 ± 0.14	< 0.070
	162	0.72 ± 0.19	< 0.091
08	10	0.27 ± 0.11	0.080 ± 0.051
	274	0.79 ± 0.21	0.16 ± 0.09
11	10	< 0.12	< 0.061
	1350	< 0.11	< 0.056
15	10	< 0.12	< 0.058
	1500	< 0.11	< 0.055
24	10	0.10 ± 0.10	< 0.044
	410	< 0.11	< 0.047
26	10	0.15 ± 0.12	< 0.057
	136	0.63 ± 0.09	0.095 ± 0.045
29			
	71	0.47 ± 0.11	0.11 ± 0.05
30			
	42	0.39 ± 0.35	0.77 ± 0.23
33	10	< 0.084	< 0.035
	205	0.24 ± 0.11	< 0.060
44	10	1.02 ± 0.20	0.20 ± 0.09
	165	0.63 ± 0.12	0.11 ± 0.07
48	10	0.11 ± 0.10	< 0.053
	447	0.33 ± 0.12	0.067 ± 0.061
49	10	1.59 ± 0.21	0.29 ± 0.10
	120	0.97 ± 0.23	0.16 ± 0.10
50	10	0.81 ± 0.18	0.12 ± 0.09
	161	0.60 ± 0.09	0.14 ± 0.06

TABLE XI

(Continued)

Station	Depth	Mn	V
51	10	0.59 ± 0.13	0.090 ± 0.065
	133	1.21 ± 0.21	0.15 ± 0.08
52			
	74	0.62 ± 0.12	< 0.058
53	10	0.78 ± 0.12	0.067 ± 0.065
	284	3.79 ± 0.25	0.42 ± 0.14
54	10	0.96 ± 0.22	0.11 ± 0.09
	212	1.03 ± 0.19	0.11 ± 0.09
55	10	0.97 ± 0.21	0.19 ± 0.07
	110	1.13 ± 0.20	0.15 ± 0.10
56			
	58	0.86 ± 0.12	0.16 ± 0.06
57			
	67	0.56 ± 0.12	0.13 ± 0.08
58			
	82	0.74 ± 0.19	0.21 ± 0.08
59A	10	1.02 ± 0.20	0.18 ± 0.08
	370	< 0.18	< 0.076

TABLE XII

N.W. GULF OF ALASKA
Discoverer Leg IV 8-16 October 1975
D. E. Robertson, Analyst

Total heavy metal contents of suspended sediments.
(>0.4 μm; μg/ℓ)

Station	Depth	Mn	V
102	1	0.22 ± 0.02	.019 ± 0.011
	98	0.27 ± 0.02	.018 ± 0.009
103	1	0.13 ± 0.04	< 0.020
	125	0.26 ± 0.02	.021 ± 0.012
104	1	0.061± 0.010	< 0.0056
	96	0.67 ± 0.03	.059 ± 0.014
106			
	81	0.54 ± 0.12	< 0.057
108	10	0.19 ± 0.12	< 0.052
	226	0.33 ± 0.13	< 0.055
110	10	0.17 ± 0.10	< 0.046
	173	0.27 ± 0.20	< 0.080
119	1	0.68 ± 0.09	.070 ± 0.051
	204	6.48 ± 0.08	.094 ± 0.045
120	1	0.38 ± 0.07	< 0.036
	281	7.10 ± 0.09	.224 ± 0.063
121	1	0.26 ± 0.04	< 0.025
	220	2.64 ± 0.08	.148 ± 0.051
122	1	0.24 ± 0.04	< 0.036
	35	0.35 ± 0.04	.053 ± 0.024
124	1	0.28 ± 0.03	.028 ± 0.020
	105	0.30 ± 0.04	.030 ± 0.029
133	1	0.11 ± 0.04	< 0.025
	68	0.44 ± 0.04	< 0.026
135	1	0.066± 0.043	< 0.028
	141	0.36 ± 0.06	< 0.066
137	1	0.21 ± 0.05	< 0.040
	95	0.57 ± 0.06	< 0.044

TABLE XII

(Continued)

Station	Depth	Mn	V
145	1	0.33 ± 0.12	< 0.090
	63	0.23 ± 0.05	< 0.029
146	1	0.23 ± 0.04	< 0.023
	63	0.35 ± 0.07	< 0.036
147	1	0.090± 0.064	< 0.069
	94	0.38 ± 0.04	.026 ± 0.023
148	1	0.15 ± 0.04	< 0.028
	100	0.26 ± 0.04	.030 ± 0.026
156	1	0.29 ± 0.05	< 0.036
	150	0.94 ± 0.15	.120 ± 0.099
157	1	0.16 ± 0.01	.021 ± 0.008
	59	0.22 ± 0.04	< 0.040
158	1	0.31 ± 0.11	< 0.093
	92	0.44 ± 0.11	< 0.081
159	1		
	96	0.28 ± 0.06	< 0.038
160	1	0.073± 0.034	< 0.020
	132	0.43 ± 0.03	< 0.024

TABLE XIII

S. BERING SEA
Discoverer 2-19 June 1975
D. E. Robertson, Analyst

Total heavy metal contents of suspended sediment.
(>0.4 μm; μg/ℓ)

Station	Depth	Mn	V
02	S	0.56 ± 0.03	0.019 ± 0.014
	B	0.50 ± 0.04	0.051 ± 0.016
08	S	1.41 ± 0.02	0.072 ± 0.016
	B	2.22 ± 0.60	0.12 ± 0.03
14	S	0.096 ± 0.064	< 0.017
	B	0.17 ± 0.02	< 0.007
17	B	0.51 ± 0.02	0.085 ± 0.016
19	B	1.45 ± 0.13	0.31 ± 0.06
24	B	2.80 ± 0.03	0.12 ± 0.02
31	S	0.040 ± 0.014	< 0.007
	B	0.13 ± 0.01	0.019 ± 0.008
30	B	0.89 ± 0.05	0.18 ± 0.04
34	S	0.054 ± 0.014	< 0.008
	B	0.12 ± 0.01	0.016 ± 0.008
37	B	0.51 ± 0.02	0.030 ± 0.010
41	B	0.93 ± 0.02	0.034 ± 0.010
43	B	0.60 ± 0.02	0.028 ± 0.010
48	S	0.082 ± 0.012	0.014 ± 0.007
	B	0.14 ± 0.03	0.019 ± 0.014
53	S	0.046 ± 0.028	< 0.012
	B	0.13 ± 0.03	0.044 ± 0.014
56	B	1.48 ± 0.04	0.044 ± 0.014
59	B	0.51 ± 0.04	0.021 ± 0.019
64	B	1.00 ± 0.03	0.049 ± 0.014

3. (Continued)

material retained on a 0.4 μm membrane filter, presented in units of μg of element per liter of seawater passed through the filter. As always, station numbers are for the standard stations given in the Annual Report.

4. Gas chromatography (Dr. T. A. Gosink): Data for chromium and selenium in both unfiltered and filtered (0.4 μm) water samples collected in the Beaufort Sea are given in Table XIV.

Analyses of sediment extracts for chromium for the same lease area are given in Table XV. These are the archived sediment samples which were discussed in the Annual Report. This latter source also gives station localities. Approximately 12 additional values for sediment collected on the above referenced *Glacier* cruise will be given in the next quarterly report.

Tables XVI - XVIII contain data for chromium for sediment extracts from the N.E. Gulf of Alaska, Lower Cook Inlet, and the S. Bering Sea, respectively. Station localities are standard. (See accompanying figure for the N.W. Gulf.)

These sets of data now complete the contractural requirements for water; the sediment program is approximately 90% complete.

5. Heavy metal contents of sediment extracts (Dr. D. C. Burrell): Heavy metal contents (mg/kg) for sediment extracts from samples collected in the N.E. Gulf of Alaska are given in Table XIX. These samples were collected using the Haps corer on the *Silas Bent* in the fall of 1975. Station localities are given in the accompanying figure. Data for Fe and Mn for extracts from Lower Cook

TABLE XIV

BEAUFORT SEA
C.G.C. *Glacier* 23 August – 3 September 1976
T. A. Gosink, Analyst

Cr and Se in untreated and filtered (0.4 μm) water (μg/ℓ).

Sta.	Sta. Depth(m)	Sample Depth(m)	μg/ℓ Cr(total)	μg/ℓ Cr(filtrate)	μg/ℓ Se(total)	μg/ℓ Se(filtrate)
A	24	0	Tr	ND	ND	ND
		20	ND	Tr	ND	ND
A'		0	Tr	ND	Tr	ND
		20	Tr	ND	Tr	ND
A"		0	–	–	0.56	–
		20	–	–	ND	–
B	–	0	0.24	ND	0.22	0.02
		(20)	0.12	ND	ND	ND
C	–	0	0.42	Contaminated	Tr	ND
		(20)	0.44	Contaminated	ND	ND
D	32	0	1.8	Contaminated	0.09	ND
		20	1.5	Contaminated	Tr	ND
Y	175	0	ND	ND	ND	ND
	–	130	0.16	ND	ND	ND
3	–	0	1.12	0.68	ND	ND
		20	0.8	0.76	ND	ND
4	49	0	2.1	0.56	0.15	ND
		45	1.9	1.2	ND	ND
5	–	0	0.8	Tr	ND	ND
		65	0.66	Tr	ND	ND
7	1900	0	0.8	0.24	Tr	Tr
		500	0.6	0.48	Tr	Contaminated
11	25	0	0.92	0.24	1.12	0.16
		20	ND	ND	Tr	ND
12	25	0	0.6	ND	1.1	ND
		22	ND	ND	0.4	ND

TABLE XIV

(Continued)

Chronological Order of Sampling:

A, A' and A"	24 August
12	25 August
11	26 August
B	27 August
C	29 August
7	29 August
5	30 August
4	31 August
3	1 September
D	2 September
Y	2 September

Cr ND = not detected above blank level or < 0.05 μg/ℓ
Tr = trace = < 0.1 μg/ℓ

Se ND = not detected
Tr = trace = < 0.01 μg/ℓ

TABLE XV

BEAUFORT SEA
T. A. Gosink, Analyst
Archived Sediment Samples (see Annual Report)

Chromium contents of sediment extracts
(mg/kg; 2 or 3 analyses per sample).

Station No.	Depth (m)	Cr (mg/kg)
72AER129	–	2.5
GLA27	–	1.3
PDB7431	–	1.4
GLA7144	–	1.7
72AER137	–	1.0
72AJT8	–	2.1
GLA7171	–	3.2
72AER166	–	1.4
GLA7180	–	1.9
GLA7129	–	2.7
GLA7163	–	3.0
71AER15	–	1.5
70BS22	–	1.6
GLA7172	–	2.7
GLA711	–	1.5
GLA7118	–	2.1
GLA7184	–	2.7
GLA718	–	3.5
GLA7125	–	1.4
72AJT6	–	0.7
BSS32	–	1.8
PDB7439	–	1.5
72AJT2	–	1.3
GLA715	–	2.5
GLA7123	–	2.2
72AJT5	–	1.5
GLA7112	–	6.5

Station No.	Depth (m)	Cr (mg/kg)
PDB7434	-	1.7
72AGR168	-	1.8
GLA7119	-	3.0
PDB39	-	1.9
PDB34D	-	2.0
BSS62	-	2.3
GLA7178	-	3.0
PDB743	-	4.0
GLA7174	-	2.3
72AER134	-	5.0
BSS80a	-	2.3
GLA7180b	-	3.0
GLA7180c	-	1.3

TABLE XVI

N.E. GULF OF ALASKA
Silas Bent 31 August - 17 September 1975
T. A. Gosink, Analyst

Chromium contents of sediment extracts (mg/kg).

Station No.	Depth (m)	Cr (mg/kg)
1	–	1.5
3	–	1.9
4	–	0.5
6	–	1.2
7	–	3.4
25	–	2.0
27	–	0.2
28	–	0.9
31	–	4.5
32	–	0.9
39	–	0.2
42	–	1.5
43	–	ND
48	–	1.5
50	–	2.1
51	–	0.8

ND = not detected above blank level

TABLE XVII

LOWER COOK INLET
Moana Wave March 31 - April 15, 1976
T. A. Gosink, Analyst

Chromium contents of sediment extracts (mg/kg).

Station No.	Depth (m)	Cr (mg/kg)
4	-	2.0
10	-	2.5
11	-	3.2
12	-	2.3
18	-	2.4
19	-	1.9
25	-	1.9
26	-	2.7
30	-	1.7

TABLE XVIII

S. BERING SEA
Discoverer 2-19 June 1975
T. A. Gosink, Analyst

Chromium contents of sediment extracts.

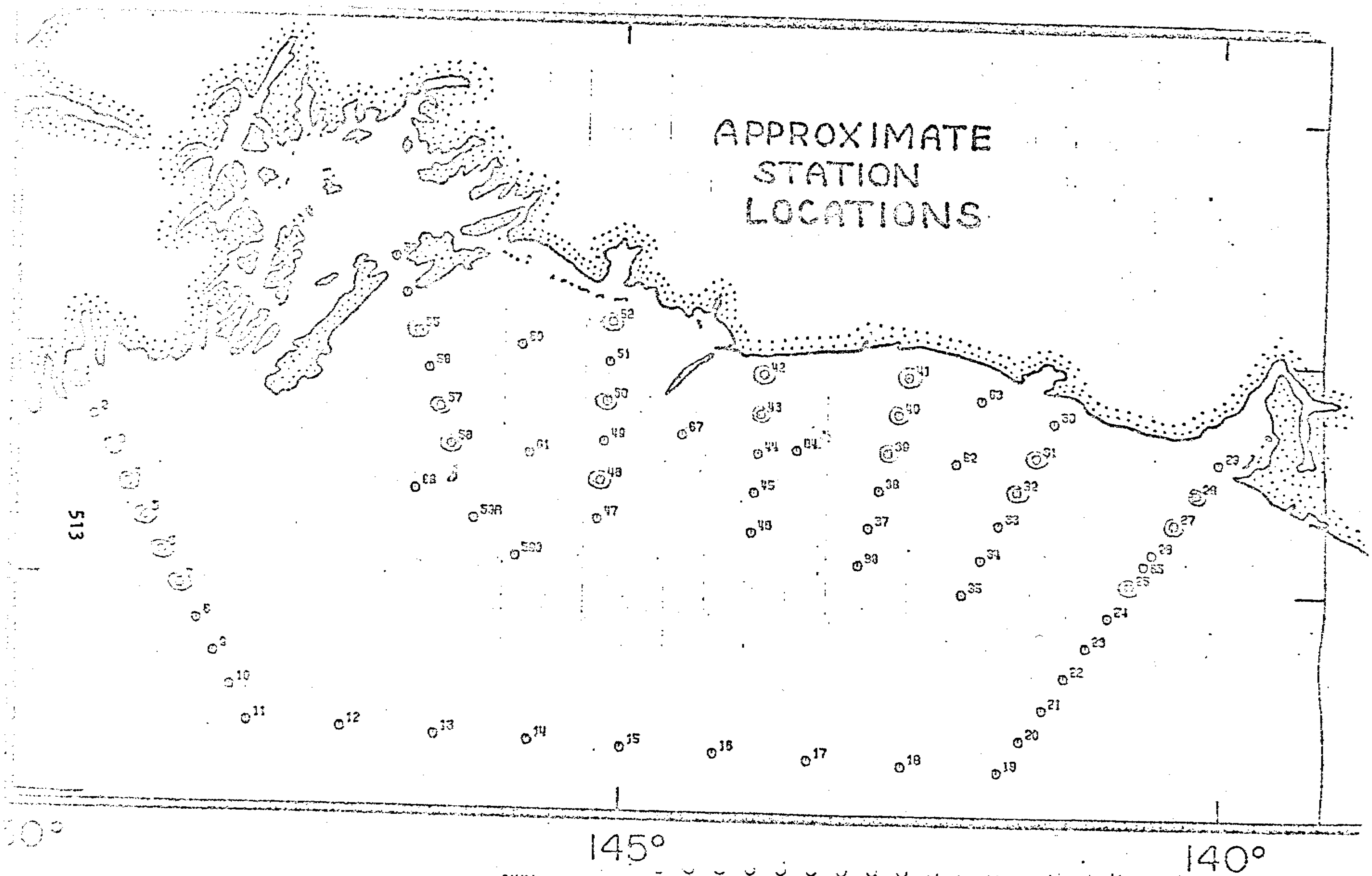
Station No.	Depth (m)	Cr (mg/kg)
24	–	2.5
28	–	1.5
41	–	0.6
46	–	1.7
59	–	0.9
59	–	1.6
64	–	2.8
65	–	2.9

TABLE XIX

N.E. GULF OF ALASKA
Silas Bent 31 August - 17 September 1975

Heavy metal contents of sediment extracts.
(mg/kg)

Station	Cd	Cu	Ni	Zn	Fe	Mn
1	<0.25	13.9	12.4	37	6380	125
3	"	9.3	9.1	27	6350	116
4	"	9.3	10.4	30	6740	106
6	"	6.7	4.3	17	2210	63
7	"	5.6	4.0	23	2770	50
25	"	3.8	2.9	13	1200	48
27	"	7.6	5.5	21	2260	117
28	"	12.8	7.4	19	2590	103
31	"	14.7	9.2	23	6375	110
32	"	13.8	8.0	22	5105	89
39	"	14.0	6.7	29	4000	79
41	"	19.4	6.7	30	4420	98
42	"	15.1	9.8	24	6780	115
43	"	12.3	11.1	22	6660	88
48	"	10.0	6.2	19	3470	87
50	"	13.9	9.4	27	7250	130



Silas Bent August 31 to September 17, 1975 - Haps core stations.

5. (Continued)

Inlet samples are given in Table XX. These latter values complete the sediment extract analysis program for this lease area; results for other metals were given in the previous quarterly report.

The extraction technique used for this program has been fully discussed in the Annual Report.

6. Atomic absorption biota analysis (Dr. D. C. Burrell): Total heavy metal contents of tanner crab samples taken from the S. Bering Sea are given in Table XXI. The station localities for these samples were given in the previous (June) quarterly report. Data for a recent accuracy test are given in Table XXII.

7. Grain-size analysis program (Dr. A. S. Naidu): As mentioned in the last quarterly report (June 1976), grain size analyses on sediments of the Gulf of Alaska have been completed as per the contract stipulations. Over and above the 20 analyses that were promised, 9 additional analyses have been conducted. Results of the size analyses which have not been reported earlier are being presented in Table XXIII.

8. Clay mineral analysis program (Dr. A. S. Naidu): During the July - September 1976 quarter, analyses on the Mg^{++} and K^{+} saturated samples of the <1 mμ size fractions of the Gulf of Alaska sediments were completed and the data was quantified. In addition to the above, the results of the X-ray diffraction analyses on the untreated, as well as the Mg^{++} and K^{+} saturated and glycolated sample of the <2 mμ size fraction of the Gulf of Alaska sediments were quantified. Therefore, as of this report writing all analyses pertaining to the clay mineral studies of the Gulf of Alaska sediments

TABLE XX

LOWER COOK INLET
Moana Wave 31 March - 15 April 1976

Heavy metal contents of sediment extracts.
(mg/kg)

Station	Fe	Mn
4	2810	176
10	3830	113
11	3685	112
12	3310	100
18	500	70
19	690	136
25	1125	40
26	1240	62
30	3230	420

TABLE XXI

S. BERING SEA

Miller Freeman April 1976

Heavy metal contents of tanner crab.
(μg/g dry weight)

Sample #	Cd	Cu	Ni	Zn
3	<1.3	27.7	<1.3	157
7	"	20.1	"	104
9	"	23.9	"	100
10	"	61.3	"	111
12	"	36.7	"	117
14	1.8	40.0	"	135
16	<1.3	30.3	"	138
20	"	29.1	"	113
26	1.3	38.8	"	188
29	<1.3	25.0	"	182
32	"	20.4	"	117
33	"	27.5	"	169
37	3.8	20.4	"	158
40	"	21.3	"	109
48	"	21.4	"	155

TABLE XXII

Accuracy data for biota analysis.
(μg/g dry wt ± one standard deviation)

a. NBS Standard #1571 Orchard leaves

Element	This study	NBS Certified
Cd	–	0.11 ± 0.02
Cu	11.4 ± 0.5	12 ± 1
Ni	1.8 ± 0.2	1.3 ± 0.2
Zn	31 ± 5	25 ± 3

b. NBS Standard #1577 Bovine liver

Element	This study	NBS Certified
Zn	140 ± 8	130 ± 10

TABLE XXIII

N.E. GULF OF ALASKA
Silas Bent 31 August - 17 September 1975
A. S. Naidu, analyst

Sediment grain-size analyses (weight %).

Station No.	Gravel %	Sand %	Silt %	Clay %
3	0	0.4	31.92	67.68
25	1.18	44.96	33.42	20.44
28	0.27	6.87	52.66	40.20
31	0	1.68	62.70	35.62
39	0	0.10	61.15	38.75
41	0	0.31	49.57	50.12
42	0	10.58	58.88	30.54
48	19.95	15.54	33.51	31.00
57	26.59	14.20	29.39	29.82
58	0	3.41	47.00	49.59

8. (Continued)

have been completed and quantified according to the contract stipulations, except data relating to the heat treatments of the clays. The latter work is in the process of being gathered now. X-ray diffraction patterns on the <1 mμ size fractions of the S. Bering Sea sediments, which were separated earlier, were run under untreated and glycolated conditions. The expandable, illite, and the kaolinite plus chlorite contents have been quantified on the latter samples (Table XXIV). It would seem that only a few samples from the <1 mμ size fraction of the S. Bering Sea clays may be available for detailed studies (i.e., subsequent to K^+ and Mg^{++} saturation and heat treatment) as there is an overall dearth of this size fraction in the sediments. X-ray diffraction pattern on the K^+ and Mg^{++} saturated samples, as well as on samples subjected to step-wise heat treatment, on the <2 mμ fraction of the southeast Bering Sea sediments are being conducted now.

Five splits of a Gulf of Alaska sediment have been taken and separately subjected to clay mineral analysis for the purpose of establishing our analytical precision. This analysis has been completed; however, the percent coefficient of variation - a measure of precision - has not been calculated as of this report submission.

9. Beaufort Sea sediment geochemistry (Dr. A. S. Naidu): As of this report writing all chemical analyses, as stipulated by the contract, have been completed and the results have been quantified and tabulated. During the last quarter, Ni was analyzed by atomic absorption spectrophotometry (using a graphite furnace) on samples of leachates that were extracted from the Beaufort Sea sediments. The above

TABLE XXIV

S. BERING SEA
Discoverer 2-19 June 1975
. A. S. Naidu, analyst

Clay mineralogy of < 1 μm (e.s.d.) glycolated sediment fraction (% weighed peak areas).

Station No.	Expandable Mineral	Illite	Kaolinite & Chlorite
2	2	61	37
8	50	17	33
10	46	25	29
13	36	26	38
14	35	32	33
19	40	20	40
21	35	29	36
26	32	26	42
31	30	35	35
34	33	33	34
41	28	31	41
43	36	33	31
48	36	36	28
57	29	38	33
60	21	43	36
62	25	42	33
64	22	39	39
65	27	40	33
69	25	42	33

9. (Continued)

number of analysis includes a few duplicate analysis, which was conducted for precision calculation. In addition to Ni, V was analyzed from 28 leachate samples by Neutron activation analysis, using the isotope dilution technique. The latter work was accomplished using the laboratory and Triga Reactor facilities at the Naval Under-Sea Centre, San Diego and the University of Irving, respectively. In the following table are shown the concentrations of Ni and V in the gross sediments and the non-lithogenous (relatively more "mobile") phase of the Beaufort Sea sediments.

Element	Number of samples analyzed	Average conc. in gross sediments	Average conc. nonlithogenous component	Average percent nonlithogenous component in gross sediment
Ni	36	44	4	9
V	28	108	9	8

From the above data it would seem that bulk of the Ni and V are partitioned in the terrigenous sediment component and are lattice-held in the detrital crystal grains.

III. RESULTS

Results obtained during this quarter, which were available to the principle investigator by September 15, have been given in Tables V through XXIV.

IV. PRELIMINARY INTERPRETATION OF RESULTS

1. Cd, Cu, Ni, Pb and Zn in seawater (Dr. D. C. Burrell): Apart from a number of nickel analyses, this sub-program is essentially complete. A discussion of the data will be deferred until the next report.

2. Heavy metal and major ion contents of suspended sediments (Dr. D. E. Robertson): No systematic geographical variations were noted for the three OCS areas, but it was observed that particulate metal concentrations in seawater sampled near the seafloor were almost always higher than in surface waters. This presumably reflects the presence of a slight turbidity current near the seafloor which resuspends bottom sediments and creates higher concentrations of particulate matter in the bottom waters. Compared to open ocean waters the levels of Mn and Al were relatively very high. Although not much data exists in the literature to compare with the vanadium levels in suspended particulate matter, it appears that particulate vanadium in the Alaskan OCS waters is very low. Riley and Taylor (1968) report 3.12 μg/ℓ of soluble vanadium in filtered Irish Sea coastal waters, and van der Sloot and Das (1974) report 1.27 and 1.82 μg/ℓ of vanadium in centrifuged seawater collected off Holland. It therefore appears that less than 10% of the vanadium in Alaskan coastal waters is present in a particulate form. An accurate particulate/soluble ratio will be obtained when we analyze the filtered seawater for vanadium.

3. Heavy metal contents of biota (Dr. D. C. Burrell): A large number of crab analyses have been included in this report. No anomalies are apparent. Use of benthic index species has been discussed in the Annual Report.

4. Se and Cr analyses (Dr. T. A. Gosink): There was a large quantity of organic material in the Beaufort water samples. The surface waters rapidly plugged 0.45 μ filters with only slight discoloration to the filter observed. Filters from the bottom waters contained large

4. (Continued)

quantities of dark colored material, believed to be chlorophyl containing material.

Surface waters were noticibly enriched in both Se and Cr over the bottom water at those stations when they were detected.

5. Sediment extract data (Dr. D. C. Burrell): A large amount of these data are now being accumulated. Interpretation is impossible until all the grain-size analysis data are available.

6. Clay mineral analysis program (Dr. A. S. Naidu): At the 27th Alaska Science Conference, held in Fairbanks in August 1976, a paper was presented by us (Naidu *et al.*, 1976) on the clay mineral compositions of the Gulf of Alaska sediments. An abstract of the paper is appended with this report, which summarise the highlights of our observations. Results on the southeast Bering Sea sediments have not been evaluated completely because of a lack of additional analytical data. However, it may be of interest to note that on the basis of simple glycolated sample analysis of the <2 mμ and <1 mμ (e.s.d.) size fractions, it would seem that there are notable size sorting of clay minerals in the clay-sized particles. The <2 mμ size fraction has relatively less of the expandable component and more of illite than the <1 mμ size fraction. Presumably this is related to the inherent character of the primary source material and/or to the nature of weathered material under glacial weathering conditions.

V. PROBLEMS ENCOUNTERED

A. This program is now feeling fully the effects of the drastic reductions ordered for FY 77. Although we have managed to complete the originally proposed sampling program, it is entirely unclear to us how much analysis work will be possible. These difficulties were noted also in the previous report.

B. Because we were unable to persuade the relevent authorities to schedule a stop for the *Glacier* in S.E. or S. Central Alaska on its way north, we were forced to send much of our equipment to Long Beach. This undoubtedly resulted in the damage to the water samplers noted previously, thus ruining a large part of the planned chemistry program in the Beaufort Sea.

C. Due to a strike among craftsmen at the Hanford site the Hanford "N" reactor in which our seawater neutron activation analysis is to be performed has been shut down. This is the only reactor possessing the necessary highly-thermalized neutron flux to permit direct, instrumental neutron activation analysis of sea salts. It is hoped that later this summer the reactor will resume operations.

APPENDIX

Abstract of paper presented to the 27th Alaska Science Conference (August 1976) covering work sponsored by this program.

CLAY MINERALS IN RECENT SEDIMENTS OF THE CONTINENTAL SHELF, CENTRAL AND WEST GULF OF ALASKA

A. S. Naidu and G. Freitag

Institute of Marine Science
University of Alaska
Fairbanks, Alaska 99701

and

T. C. Mowatt

U. S. Bureau of Mines
Anchorage, Alaska 99510

ABSTRACT

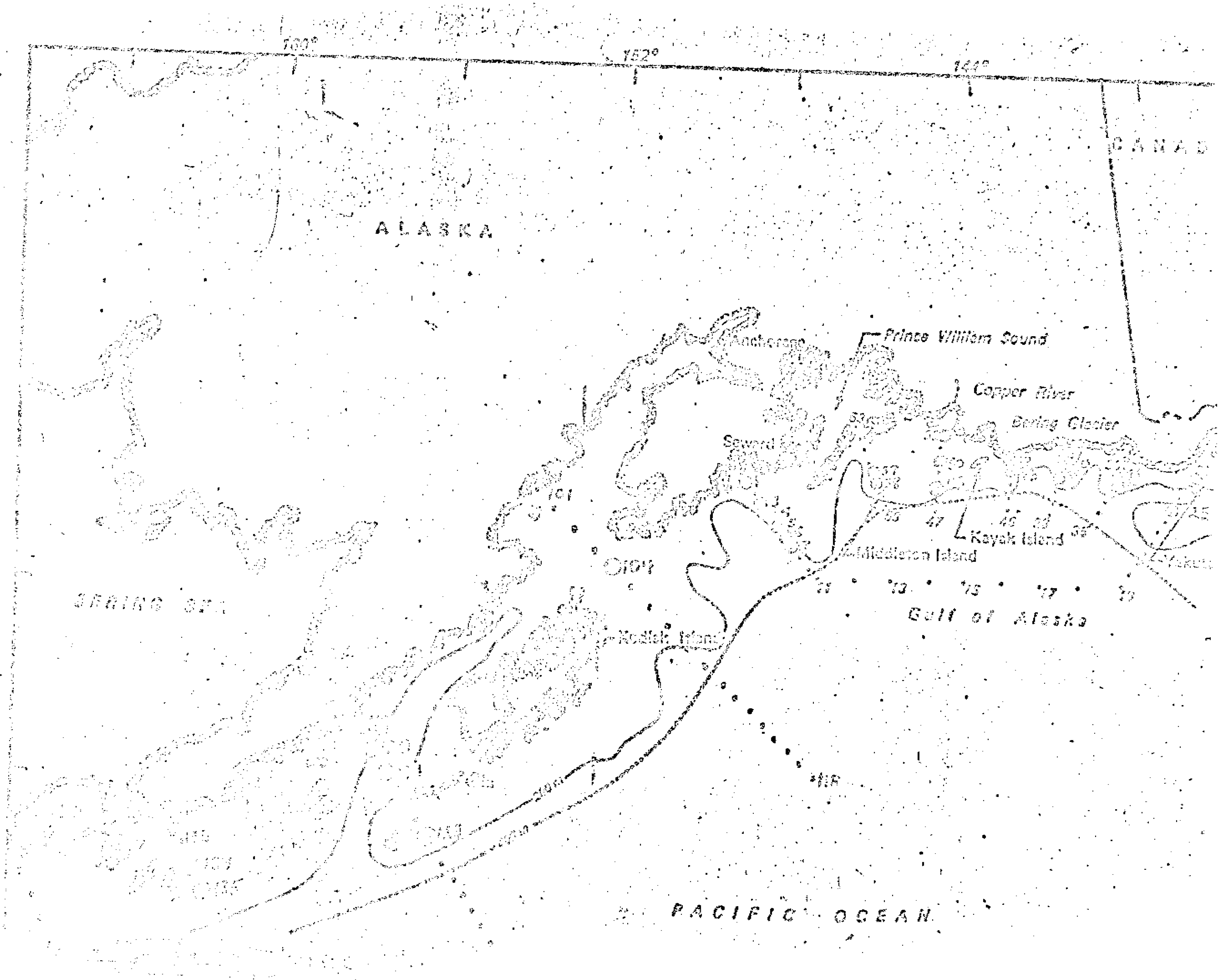
Preliminary analysis of bottom-sediment samples by X-ray diffraction has resulted in the recognition of differences between the clay mineral (< 2 mμ equivalent spherical diameter layer silicates) assemblages from each of these areas.

Central Gulf of Alaska suites are characterized by predominant illitic (40 to 50%) and chloritic (40 to 50%) components, with a subordinate (generally < 10%) expandable component, and only occasional traces of kaolinite. While the western Gulf of Alaska sediments are not too dissimilar in aspect, there does seem to be somewhat more (~ 10%) expandable mineral in this region, together with a slightly greater (50 to 60%) proportion of illite, and correspondingly less (30 to 40%) chlorite. These slight but discernible geographic differences would seem most likely to be attributable to the differing lithology of the proximal land-masses, (i.e., predominantly metamorphic terrane of the Chugach Mountains vs the Alaska Peninsula, where volcanic materials are more abundant).

X-ray diffraction analyses of the above clays, subsequent to K^{+} and Mg^{++} saturation, suggest that significant portions of the expandable mineral components are degraded illites.

Additional work is in progress, endeavoring to characterize the clay mineral components more thoroughly, in hopes of increasing our understanding of the sedimentologic, mineralogic, and geochemical relationships in these portions of the continental shelf of Alaska.

NOTE: The appended map shows the area of study and the locations of sediment samples. Data presented in Table XXV support the view that almost all of the expandable component in the clay-sized particles are degraded (depotassicated) illites and not smectite.



160°
152°
144°
ALASKA
Anchorage
Prince William Sound
Copper River
Bering Glacier
Seward
Kayak Island
Middleton Island
Kodiak Island
Gulf of Alaska
PACIFIC OCEAN

TABLE XXV

Estimated percent of clay minerals from Gulf of Alaska.
(<1 μ size)

	Expandable Clays 17A	Illite 10A	Chlorite + Kaolinite 7A
Sample 121			
Glycolated	8	49	43
1N KCl Glycolated	0	58	42
1N $MgCl_2$ Glycolated	7	45	48
Sample 124			
Glycolated	12	39	49
1N KCl Glycolated	0	54	46
1N $MgCl_2$ Glycolated	10	39	51
Sample 135			
Glycolated	14	45	41
1N KCl Glycolated	2	49	49
1N $MgCl_2$ Glycolated	11	43	46
Sample 4			
Glycolated	7	44	49
1N KCl Glycolated	0	50	50
1N $MgCl_2$ Glycolated	6	43	51
Sample 32			
Glycolated	5	37	58
1N KCl Glycolated	0	44	56
1N $MgCl_2$ Glycolated	3	34	63
Sample 41			
Glycolated	6	31	63
1N KCl Glycolated	0	41	59
1N $MgCl_2$ Glycolated	3	37	60

REFERENCES

Riley, J. P., and D. Taylor. 1968. The Use of Chelating Iron Exchange in the Determination of Molybdenum, Vanadium in Sea Water. *Analytical Chem. Acta* 41:175-178.

Vander Sloot, H. A., and H. A. Das. 1974. Determination of Mercury in Air by Neutron Activation Analysis. *Analytical Chem. Acta* 70:439-442.

OCS COORDINATION OFFICE

University of Alaska

ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: September 30, 1976

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 12 R.U. NUMBER: 162/163/288/293/312

PRINCIPAL INVESTIGATOR: Dr. D. C. Burrell

Submission dates are estimated only and will be updated, if necessary, each quarter. Data batches refer to data as identified in the data management plan.

Cruise/Field Operation	Collection Dates		Estimated Submission Dates[1]			
	From	To	Batch 1	2	3	4
Discoverer Leg II #808	6/2/75	6/19/75	*	9/30/76	None	*
Silas Bent Leg I #811	8/31/75	9/11/75	None	None	None	None
Discoverer Leg IV #812	10/8/75	10/15/75	*	9/30/76	None	*
Miller Freeman	8/16/75	10/20/75	None	None	Unknown	None
Discoverer Leg III #810	9/12/75	10/3/75	None	None	None	*
North Pacific	4/25/75	5/7/75	None	None	Unknown	None
Intertidal Biota		1975	None	None	Unknown	None
Discoverer #816	11/12/75	12/2/75	*	9/30/76	None	9/30/76
Contract 03-5-022-34	1st	Year	*	None	None	None
USCGC Glacier	--	--	Data batches as yet not determined			
Discoverer	9/10/76	9/24/76	Data batches as yet not determined			

Note: [1] Data Management Plan has been approved by M. Pelto, we await approval by the Contract Office.

Cruise/Field Operation	Collection Dates		Estimated Submission Dates[1]			
	From	To	Batch 5	6	7	8
Discoverer Leg II 808	6/2/75	6/19/75	*	None	None	None
Silas Bent Leg I 811	8/31/75	9/14/75	None	None	None	None
Discoverer Leg IV 812	10/8/75	10/16/75	*	*	None	None
Miller Freeman	8/16/75	10/20/75	None	Lost	9/30/76	*
Discoverer Leg III 810	9/12/75	10/3/75	None	*	None	None
North Pacific	4/25/75	8/7/75	None	Lost	Lost	Lost
Intertidal Biota		1975	None	None	*	*
Discoverer 816	11/23/75	12/2/75	*	None	None	None
Contract 03-5-022-34	Last	year	*	None	*	*
Glacier	8/23	9/3/76				

Cruise/Field Operation	Collection Dates		Estimated Submission Dates[1]	
	From	To	Batch 9	10
Discoverer Leg II 808	6/2/75	6/19/75	*	*
Silas Bent Leg I 811	8/31/75	9/14/75	*	*
Discoverer Leg IV 812	10/8/75	10/16/75	9/30/76	*
Miller Freeman	8/16/75	10/20/75	none	none
Discoverer Leg III 810	9/12/75	10/3/75	none	none
North Pacific	4/25/75	8/7/75	none	none
Intertidal Biota		1975	none	none
Discoverer 816	11/23/75	12/2/75	*	*
Contract 03-5-022-34	Last	year	*	none
[illegible]	3/76	4/15/76	*	none
Beaufort Sea Sediments			*	*

[1] These data have been submitted in tabular form in the Annual and Quarterly Reports [illegible] the Final Report of contract 03-5-022-34.

Sixth Quarterly Report

Contract # 03-5-022-68
Research Unit 190
Reporting Period 1 July 1976 to
30 September 1976
Number of pages 37

Baseline study of microbial activity in the Beaufort Sea and Gulf of Alaska and analysis of crude oil degradation by psychrophilic bacteria.

SUBMITTED BY:

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

Robert P. Griffiths
Co-Investigator
Research Associate
Department of Microbiology
Oregon State University
Corvallis, OR 97331

Date Submitted
October 1, 1976

I. Task Objectives

A. General nature and scope of study

Our objective was to study the baseline levels of microbial activity in the Beaufort Sea and Gulf of Alaska during both the summer and winter seasons. In addition, we were to evaluate the effects of crude oil on microbial activity and to analyze the process of hydrocarbon degradation by psychrophilic hydrocarbon utilizing bacteria isolated from the Beaufort Sea.

B. Specific objectives

1. Determination of the relative heterotrophic potential in natural marine microbial populations (task number A-27). Studies include representitive samples of both water and sediments in different geological locations and under contrasting seasonal conditions. These studies were to be designed to give an estimate of the natural variations to be expected in microbial activity in the waters and sediments of the Beaufort Sea and Gulf of Alaska.

2. Isolation and characterization of psychrophilic hydrocarbon utilizing marine bacteria which are capable of degrading and/or emulsifying crude oil at relatively high rates under the conditions found in the Beaufort Sea (task number B-9). Strains of bacteria having the above characteristics were to be isolated from crude oil enrichment cultures using natural samples taken from the Beaufort Sea as the inoculum. After isolation and purification, the strains were to be subjected to a number of basic physiological studies which would determine the function of these organisms under the conditions found in the Beaufort Sea.

3. Determination of the acute effects of crude oil on the heterotrophic activity of the natural microbial populations found in the Beaufort Sea (task number C-2). These studies were to be supplemented with longer term studies which would be designed to obtain information about how crude oil affects the natural population and how, in turn, the natural population alters the crude oil.

4. Coordination of our studies with the microbial studies of Dr. Atlas and his associates to obtain the most comprehensive data possible on the role of marine bacteria in the marine ecosystems in both the Beaufort Sea and the Gulf of Alaska. To accomplish this end, our baseline studies were to be made using the same samples. In addition, a close liaison was to be established to insure the least possible duplication of effort. In addition, we were to collect subsamples to be analyzed for inorganic nutrient concentrations by Dr. Alexander.

C. Suggested objectives for future research

1. Potential *in situ* rates of crude oil degradation and emulsification by microbial processes.

To date, there have been very few studies of crude oil biodegradation in polar marine ecosystems. This information is absolutely required if informed managerial decisions are to be made concerning the best possible course of action to take in the event of an oil spill and to properly assess the potential long term effects of a spill under a given set of circumstances. These types of data are currently being collected by our research team but a great deal more must be learned before a comprehensive picture is obtained.

2. The effects of crude oil on the bacteria involved in nutrient and geochemical cycles.

Bacteria are the single most important factor in the recycling of sulfur, phosphorous, nitrogen, and carbon in the marine ecosystem. It is also important in such vital functions as nitrogen fixation and the degradation of relatively recalcitrant compounds such as chitin. At the present time, very little is known about the effects of crude oil on the function of the bacteria involved in these transformations. It is possible that crude oil may perturb one or more of these vital functions which would, in turn, greatly affect the potential recovery of the entire ecosystem. Without information about these vital functions, long term effects of crude oil spills on primary productivity and biological activity at the higher trophic levels will be impossible to assess.

3. Assessment of the long term effects of crude oil pollution on restricted ecosystems.

An interdisciplinary study of the potential long term impact of crude oil on a well defined representative ecosystem should be attempted. Since the function of bacteria in such a system is basic to what will eventually occur at higher trophic levels, an assessment of bacterial function must be made.

II. Field and Laboratory Activities

A. Field trip schedule

1. During this period, we participated in a field trip in the Beaufort Sea. This consisted of a cruise on board the US Coast Guard ship Glacier from August 22 to September 5, 1976.

B. Scientific party

1. All of the personnel involved in this project are in the Department of Microbiology, Oregon State University. Dr. Griffiths and Mr. McNamara participated in the field trip mentioned above and conducted related laboratory studies at Oregon State University.

2. Personnel:

Dr. Robert P. Griffiths, Co-Investigator
Mr. Thomas McNamara, Technician

C. Methods

1. Sampling procedures

a. Discoverer cruise (March, 1976)

The water samples were taken in sterile Niskin plastic water sample bags fitted on Niskin "butterfly" water samplers. All samples were taken within two meters of the surface and were processed within two hours after they were collected.

All sediment samples except the beach samples taken at stations a, b, d and f were taken with a Van Veen grab. Approximately 150 grams of surface sediment were taken as a representitive sample at each station.

b. Beaufort Sea field trip (April, 1976)

Nine inch holes were drilled through the ice using a power head and 9 inch auger. Water samples were taken using the Niskin "butterfly" water samplers in all but four samples (#BW101, 102, 103 and 104). These four samples were taken using a sterile vacuum flask sampler (our own design). The water samples were kept in an ice chest from the time they were taken to the time they were received at NARL for processing. This procedure prevented the samples from freezing while enroute to the laboratory. All samples were processed within four hours after they were taken.

The sediment samples were taken with a Kahl scientific mud snapper. One or two grap samples were taken at the same time and location and combined with the seawater within the grab. These samples were placed into sterile 250 ml wide mouth glass sample bottles for transport to the laboratory. All samples were maintained at or slightly below the in situ temperature during sampling and transport.

Ice samples were taken from the ice shavings that resulted from drilling the hole through the ice. These samples were placed into sterile sample bags for transport to and storage at the laboratory. The ice samples were melted at 5 C for 24 hours prior to processing.

c. Glacier Cruise (August, 1976) The same sampling methods were used that are described for the Discoverer cruise.

2. Heterotrophic potential studies

The techniques used in this study were basically those of Hobbie and Crawford (1969) as further modified by Harrison, Wright, and Morita (1971). This procedure involves the addition of different concentrations of U-^{14}C labeled substrate to identical subsamples. After addition of the 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 toleune based scintillation fluor (Omnifluor, 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 the field laboratory or they were counted on a Nuclear Chicago Mark I liquid scintillation counter located in our laboratory at Oregon State University.

In the sediment samples, a 1.0 ml subsample was diluted with a 32 o/oo (w/v) solution of sterile artificial seawater. After dilution, the sediment sample was treated the same way as a water sample. Duplicate one ml subsamples of the sediment slurry were dried and weighed to determine the dry weights. These dry weights were used to calculate the V_{max} values in terms of grams dry weight of sediment.

During the Discoverer cruise, (U-^{14}C) L-glutamic acid with a specific activity of 230 mCi/mmole (New England Nuclear) was used in all water samples. The range of glutamic acid concentrations in the reaction vessels was from 0.6 μg/liter to 4.6 μg/liter. With the exception of sediment sample number 101GB, all sediment samples were exposed to glutamic acid concentrations in the range of 10.5 μg/liter to 84 μg/liter using (U-^{14}C) L-glutamic acid with a specific activity of 10 mCi/mmole. Duplicate subsamples were used at each of four substrate concentrations. The average incubation temperature used during the cruise was 4 C which was within 1 C of the in situ surface water temperature. The length of incubation varied from 9 to 12 hours.

During the Beaufort Sea study, all sediment and water samples were exposed to glutamic acid with a specific activity of 230 mCi/mmole. The range of glutamic acid concentrations in the reaction vessels was from 0.6 μg/liter to 4.6 μg/liter. The average incubation temperature used was -1.0 C and the length of incubation varied from 8 to 11 hours. All samples were incubated in the dark.

During the Glacier cruise, the heterotrophic potential determinations in water and sediment samples were made using the same concentrations of ^{14}C glutamic acid that were used during the Discoverer cruise. In addition, the uptake and respiration of algal protein hydrolysate and glucose were monitored in both seawater and sediment samples. One concentration of each of these substrates were used in these determinations (38 ng of ^{14}C glucose or 0.9 ng At. carbon of algal protein hydrolysate were added per 10 ml subsample). The average incubation temperature was 0^{o}C and the incubation times ranged from 8 to 12 hrs.

3. Calculations

Calculation of the kinetic parameters was made from the relationship:

$$\frac{Cut}{c} = \frac{K_t + S_n}{V_{max}} + \frac{A}{V_{max}}$$

where c = radioactivity assimulated plus that respired as $^{14}CO_2$ by the heterotrophic population in disintegrations/min; S_n = the natural substrate concentration in µg/liter; A = the added substrate in µg/liter; C = 2.2×10^6 µCi of ^{14}C; u = amount of ^{14}C labeled substrate added/sample bottle in µCi; t = incubation time in hours; V_{max} = the maximum velocity of uptake in µg x liter^{-1} x h^{-1}; and K_t = the transport constant in µg/liter. From this equation can also be calculated the time (T_t) in hours required by the natural microbial population to utilize the natural substrate in the seawater sample. For the derivation of this equation and the assumptions on which it is based, see Wright and Hobbie (1966). Saturation curves were converted to the best fitting straight line using least squares and a modified Lineweaver-Burk equation.

The percent respired was calculated by dividing the amount of labeled carbon associated with the CO_2 fraction by the total amount of substrate taken up by the cells (both cell and $^{14}CO_2$ radioactivity) and multiplying this ratio by 100.

4. Microbial activity changes with time in oil enrichment cultures

A series of three experiments were conducted. The first experiment (#1) was designed to measure the variations found between two "identical" subsamples neither of which were exposed to crude oil. In this experiment, the uptake of ^{14}C labeled algal protein hydrolysate and D (U-^{14}C) glucose was measured at one substrate concentration. These factors were measured in addition to those mentioned below. The algal protein hydrolysate had a specific activity of 55 mCi/m atom carbon and a final concentration in the reaction vessel of 0.95 µg atom carbon/liter. The D (U-^{14}C) glucose had a specific activity of 284 mCi/mmole with a final substrate concentration of 0.33 µg/liter. The other two experiments, (#2 and 3) were designed to measure the effects of crude oil on the natural microbial population found in the seawater samples.

Twenty gallon samples were taken from Yaquina Bay, Oregon and transported to our laboratory at Oregon State University. Within two hours after the samples were taken, they were split into two equal portions which were placed into 15 gallon aquaria fitted with an aeration system. Forty ml of Prudhoe Bay crude oil was added to one aquarium and nothing was added to the control. The water samples were incubated in the dark with aeration at 8 C (the water sample temperature *in situ*). At various times, subsamples were removed via a syphon system which allowed crude oil free samples to be collected from the system. These subsamples were used to make measurements of relative microbial activity and percent respiration using ^{14}C-labeled glutamic acid and sodium acetate. They were also used to measure the bacterial concentrations using epifluorescent microscopy, Lib X agar plates (Baross, Hanus, and Morita, 1974) and crude oil agar plates (Atlas and Bartha, 1972).

The agar plates were incubated in the dark at 8 C. Colonies were counted in the Lib X agar plates after incubating one week and the colonies on the crude oil plates were counted after 6 weeks incubation.

The relative microbial activity and percent respiration was determined using the techniques described under "heterotrophic potential studies". The subsamples were incubated in the dark for two hours at 8 C. The same two concentrations of ^{14}C-labeled glutamic acid were used in these experiments as were used in the field studies. The ^{14}C-labeled acetate (New England Nuclear) used had a specific activity of either 54 or 8.7 uCi/uMole. The concentration ranges used were either from 2 to 32 µg/liter or 6 to 100 µg/liter.

5. 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 Zimmermann and Meyer-Reil (1974). This procedure involves staining the cells trapped on the membrane filter with acridine orange and then destaining with isopropyl alcohol. The membranes were dried and mounted on microscopic slides.

The bacterial cells were counted using a Zeiss IV Fl epi-fluorescence condenser microscope fitted with filters KP 500, KP 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.

6. References

Atlas, R. M. and R. Bartha. 1972. Biodegradation of petroleum in seawater at low temperatures. Can. J. Microbiol. 18:1851-1855.

Bain, N. and J. M. Shewan. 1969. Identification of *Aeromonas*, *Vibrio*, and related organisms. *In* B. M. Gibbs and D. A. Shapton (ed.), Identification Methods for Microbiologists, Part B. pp 79-84.

Baross, J. A., F. J. Hanus and R. Y. Morita. 1974. The effects of hydrostatic pressure on uracil uptake, ribonucleic acid synthesis and growth of three obligately psychrophilic marine vibrios, *Vibrio alginolyticus*, and *Escherichia coli*. p. 180-202. In R. R. Colwell and R. Y. Morita (ed.) Effect of the ocean environment on microbial activities. Univ. Park Press. Baltimore, Md.

Harrison, M. J., R. T. Wright, and R. Y. Morita. 1971. Methods for measuring mineralization in lake sediments. Appl. Microbiol. 21: 698-702.

Hobbie, J. E., and C. C. Crawford. 1969. Respiration corrections for bacterial uptake of dissolved organic compounds in natural waters. Limnol. Oceanogr. 14:528-532.

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

D. Sample Locations

The locations and sampling dates for all work in the Gulf of Alaska are given in Table 1 and Figure 1 in the 5th quarterly report.

The sample locations and dates for work conducted during April, 1976 in the Beaufort Sea area are given in Table 5 and Figure 2 in the 5th quarterly report.

E. Data collected

During the Gulf of Alaska cruise, we measured heterotrophic potential and bacterial concentrations in 27 water samples and 20 sediment samples. Of these samples 7 water samples and 4 sediment samples were taken along the beach.

During the Beaufort Sea study, 23 water and 14 sediment samples were studied. In addition, three ice melt samples were analyzed.

During the Glacier cruise, 18 water and 13 sediment samples were analyzed. The results of these experiments will be presented in the next report.

III. Results

A. Field Studies

The data given in Table 1-3 were collected during our March cruise on the Discoverer and during our April field study period in the Beaufort Sea. The balance of the data collected during these studies was reported in our fifth quarterly report.

Table 1 shows the total bacterial concentrations in seawater samples taken from both the Gulf of Alaska and the Beaufort Sea as determined by direct microscopic counts. Twenty seven water samples were analyzed in the Gulf of Alaska. The observed values varied from 1.2×10^5 to 2.7×10^5 cells per ml with an average value of 1.9×10^5 cells per ml. This is roughly ½ of the average bacterial concentration observed in the Beaufort Sea during our summer 1975 field study period. The bacterial concentrations in seawater and ice melt observed in the Beaufort Sea during our April, 1976 studies are also given in Table 1. The average figure was 1.5×10^5 cells/ml for the seawater samples studied. This is roughly the same as the average concentration of cells found in the Gulf of Alaska and about the same as the average bacterial count observed in the three ice melt samples tested. The average concentration of bacteria in the Beaufort Sea and the Gulf of Alaska water samples do not reflect the same trends that were observed in the V_{max} data observed in the same samples. The average V_{max} value was roughly twice as high in the Beaufort Sea as in the Gulf of Alaska even though the average incubation was 5 C lower in the Beaufort Sea samples. The average concentration of bacteria; however, was about the same in both regions (Table 1).

The bacterial concentrations found in twenty Gulf of Alaska sediment samples are given in Table 2. The range of values observed was from 1×10^7 to 3.1×10^9 cells per gram dry weight sediment. The average value of 1.5×10^9 cells per gram was somewhat higher than the average figure of 0.74×10^9 cells per gram observed in the Beaufort Sea during the summer of 1975 and slightly higher than the average figure of 1.0×10^9 cells per gram observed in the Beaufort Sea during the April, 1976 study (Table 3). The maximum potential rate of glutamic acid uptake (V_{max}) values for the same sediment samples are also given in Table 2. These values ranged from 0.1 to 27.5 μg glutamic acid x gram dry weight sediment^{-1} x hr^{-1}. The average value was 4.5 μg x gr^{-1} x hr^{-1}. This value is significantly higher than that observed in the Beaufort Sea in the summer of 1975 when an average value of 0.52 μg x gr^{-1} x hr^{-1} was observed and it is approximately two orders of magnitude higher than that observed in the April Beaufort Sea study (Table 3).

The bacterial concentrations and V_{max} values observed in 15 sediment samples taken from the Beaufort Sea are given in Table 3. The observed V_{max} values ranged from 0.4×10^{-2} to 17.8×10^{-2} μg x gram dry weight^{-1} x hr^{-1} with an average value of 5.0×10^{-2}.

The average bacterial concentration observed in the Beaufort Sea sediments was 1.0×10^{9} cells/gram dry weight sediment. The range was from 0.5×10^{9} to 1.7×10^{10} cells/gram dry weight (Table 3).

The results from the data collected during the Glacier cruise will be given in the next quarterly report.

B. Laboratory studies

Two experiments were conducted to determine the effects of crude oil on the potential rates of glutamic acid and acetate uptake and the present respiration of these two substrates in natural microbial populations (experiments 2 and 3). In addition to these factors, bacterial cell counts on Lib X agar plates and crude oil plates and total bacterial concentrations were measured using direct microscopic observations. These same factors were also measured in a control experiment designed to determine the variations found in two identical subsamples that had not been perturbed with crude oil (experiment #1).

The results of the glutamic acid uptake studies in the three experiments are given in Figures 1, 2, and 3. The percent respiration of glutamic acid taken up is given in Figures 7, 8, and 9. The results of the acetate uptake studies are given in Figures 4, 5, and 6. The percent respiration of acetate taken up is given in Figures 10, 11, and 12. The concentration of bacteria per ml was also followed during the course of these three experiments. "Total" bacterial counts were made using Lib X agar plates; these results are reported in Figures 13, 14, and 15. The concentration of crude oil degrading bacteria was determined by plate counts on crude oil agar plates; these results are reported in Figures 16, 17, and 18.

During the course of experiment #1, the uptake of a ^{14}C-labeled algal protein hydrolysate was also followed at one substrate concentration; these results are reported in Figure 19. During this experiment, the uptake of ^{14}C-labeled glucose was also measured at one substrate concentration; these data are reported in Figure 20.

Bacterial concentrations were also measured during the course of these experiments; these data will be reported in the next quarterly report.

The results of observations made during the Glacier cruise in the Beaufort Sea (August, 1976) will be presented in the next quarterly report since there has been insufficient time to prepare and analyze these data.

Table 1. Total numbers of bacteria found in seawater samples taken from the Gulf of Alaska and the Beaufort Sea as determined by direct microscopic observation.

Gulf of Alaska

Sample Number	Cells/ ml x 10^5
GW 201	2.0
GW 202	1.4
GW 203	1.4
GW 204	1.9
GW 205	1.6
GW 206	2.0
GW 207	1.2
GW 208	2.6
GW 209	2.0
GW 210	1.2
GW 211	1.6
GW 212	1.6
GW 213	1.5
GW 214	2.3
GW 215	2.0
GW 216	2.3
GW 217	1.8
GW 218	2.7
GW 219	2.0
GW 220	1.5
GW 221	2.2
GW 222	1.6
GW 223	2.1
GW 224	2.2
GW 225	2.5
GW 226	2.7
GW 227	2.4
Average value	1.9 x 10^5

Beaufort Sea

Sample Number	Cells/ ml x 10^5
BW 101	1.7
BW 102	0.8
BW 103	1.5
BW 104	1.3
BW 105	1.4
BW 106	1.5
BW 107	1.7
BW 107A	1.9
BW 108	2.2
BW 109	1.0
BW 110	1.2
BW 111	2.6
BW 112	1.4
BW 113	1.3
BW 114	1.1
BW 116	1.4
BW 117	1.8
BW 118	1.7
BW 119	1.2
BW 120	1.2
BW 121	1.7
BW 122	2.7
BW 123	1.3
Average	1.5 x 10^5
Ice Melt Samples	
BI 120	1.3
BI 122	1.6
BI 123	2.2
Average	1.7 x 10^5

Table 2. Total number of bacteria found in sediment samples taken from the Gulf of Alàska using direct microscopic observation and the maximum potential velocity for glutamic acid uptake (V_{max}) in the same samples.

Sample Number	Cells/gram dry weight x 10^9	V_{max} (μg x gram dry weight^{-1}x hr^{-1})
GB 201	0.02	0.2
GB 202	2.2	3.6
GB 203	1.4	10.3
GB 204	1.9	5.9
GB 206	1.4	---
GB 207	2.1	2.0
GB 210	---	4.7
GB 211	1.4	2.9
GB 212	2.6	1.0
GB 213	3.0	5.2
GB 214	1.6	1.0
GB 216	0.1	0.5
GB 217	3.1	3.2
GB 218	0.3	0.1
GB 219	1.3	1.3
GB 220	0.01	---
GB 223	1.2	2.0
GB 224	2.4	5.8
GB 225	0.9	---
GB 226	1.7	27.5
Average values	1.5 x 10^9	4.5

Table 3. Total number of bacteria found in sediment samples taken from the Beaufort Sea using direct microscopic observation and the maximum potential velocity for glutamic acid uptake (V_{max}) in the same sample.

Sample Number	Cells/gram dry weight $\times 10^8$	V_{max} (µg x gram dry weight^{-1} x hr^{-1}) $\times 10^{-2}$
BB 101	0.5	8.7
BB 102	2.3	2.1
BB 103	19	0.4
BB 104	10	17.8
BB 105	7.7	2.7
BB 106	2.2	2.0
BB 107	17	7.5
BB 108	1.6	4.5
BB 109	17	6.3
BB 111	16	2.5
BB 112	13	1.8
BB 113	13	5.6
BB 114	---	1.8
BB 115	15	5.6
Average values	1.0×10^9	5.0×10^{-2}

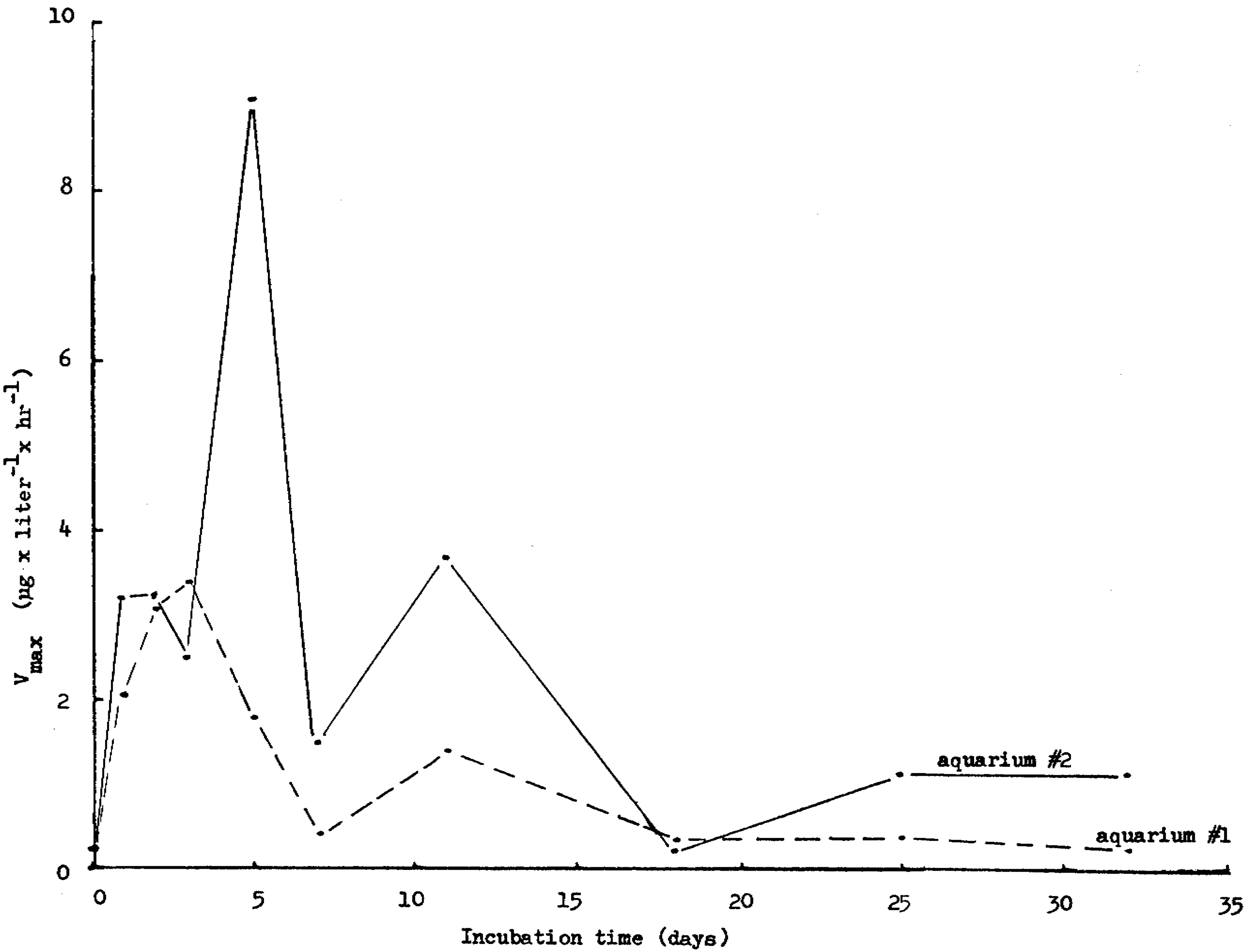


Figure 1. V_{max} of glutamic acid uptake in both seawater samples. Experiment #1.

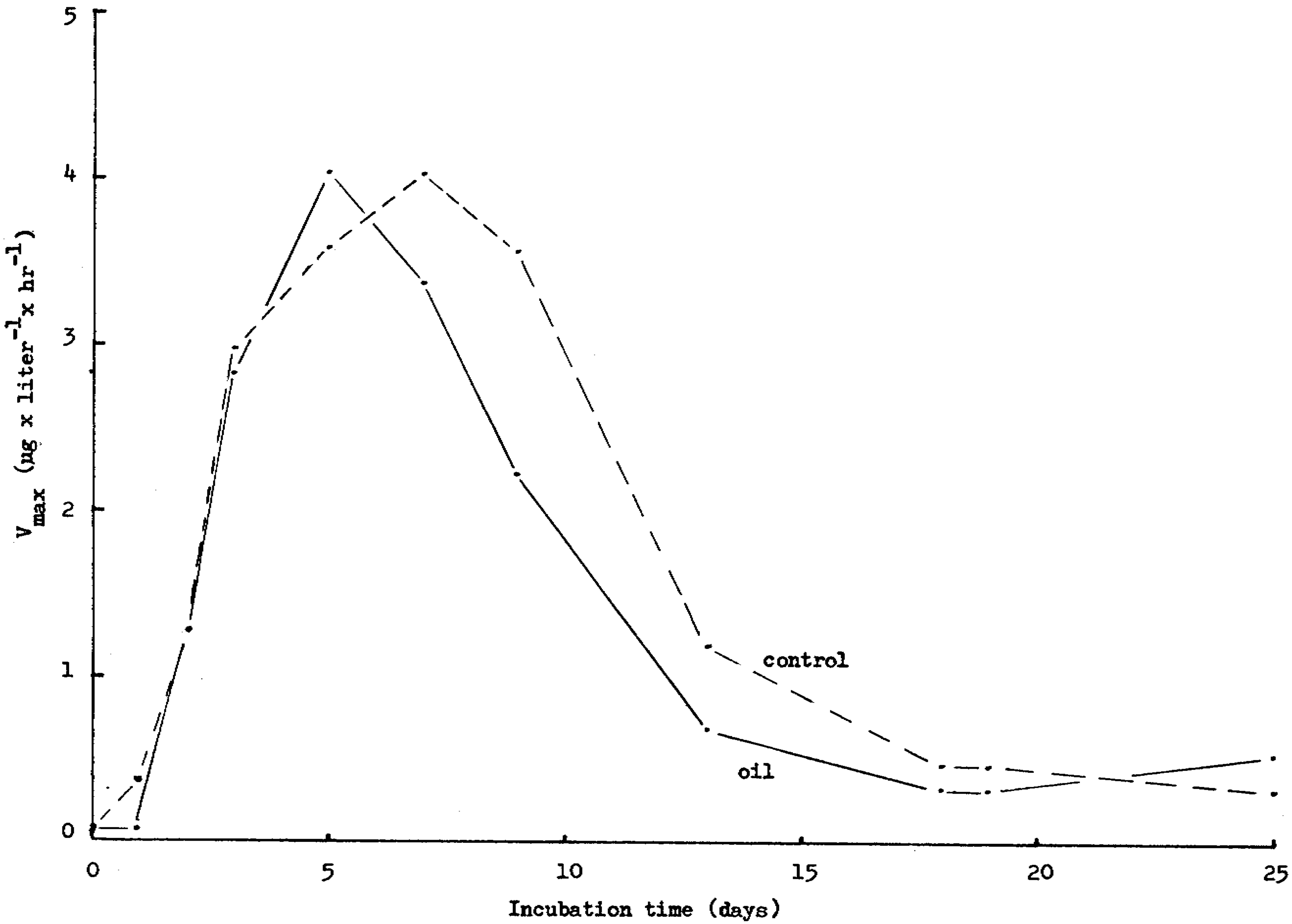


Figure 2. V_{max} of glutamic acid uptake in both the control and oil enrichment cultures. Experiment #2.

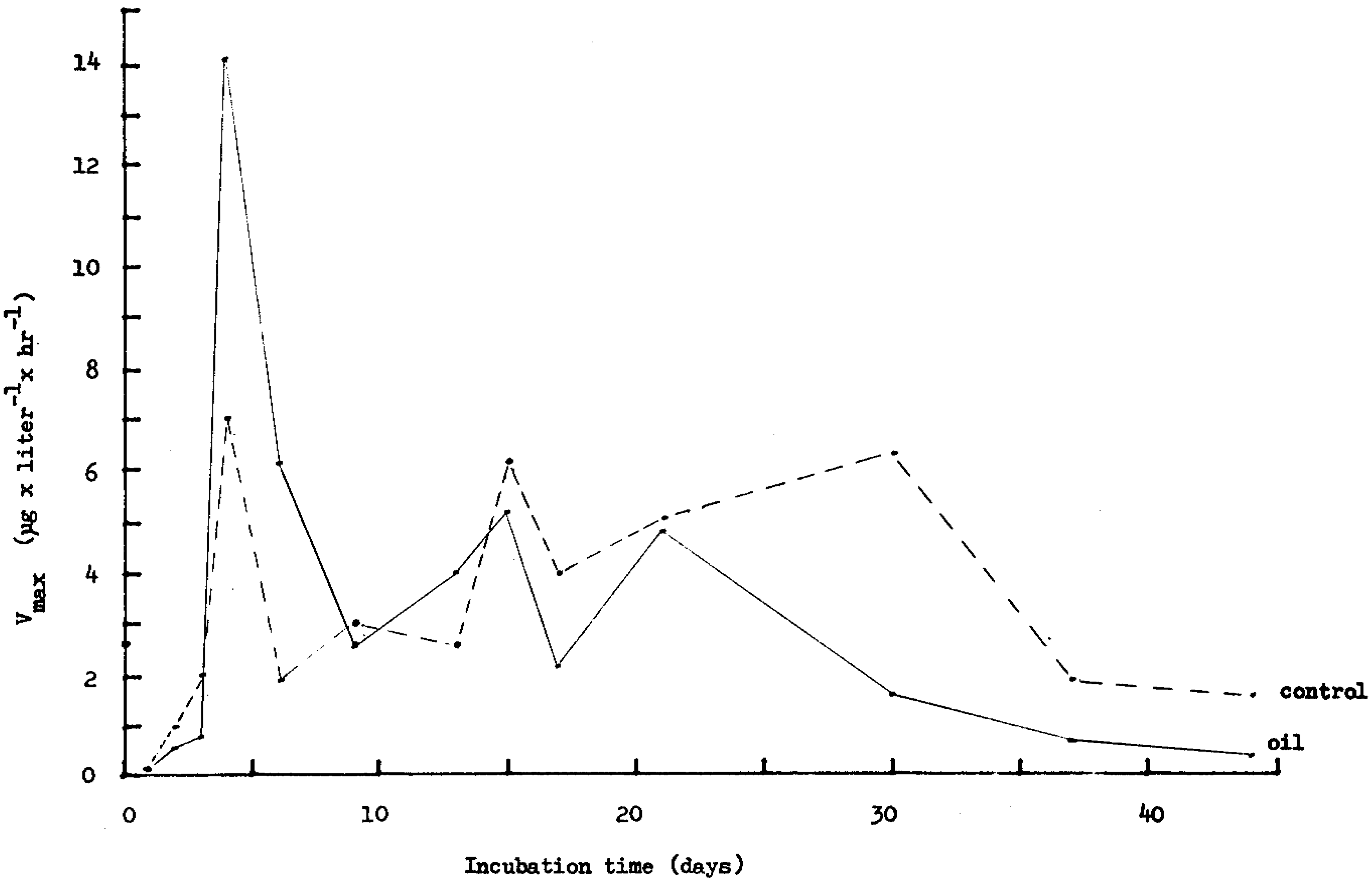


Figure 3. V_{max} of glutamic acid uptake in both the control and oil enrichment cultures. Experiment #3.

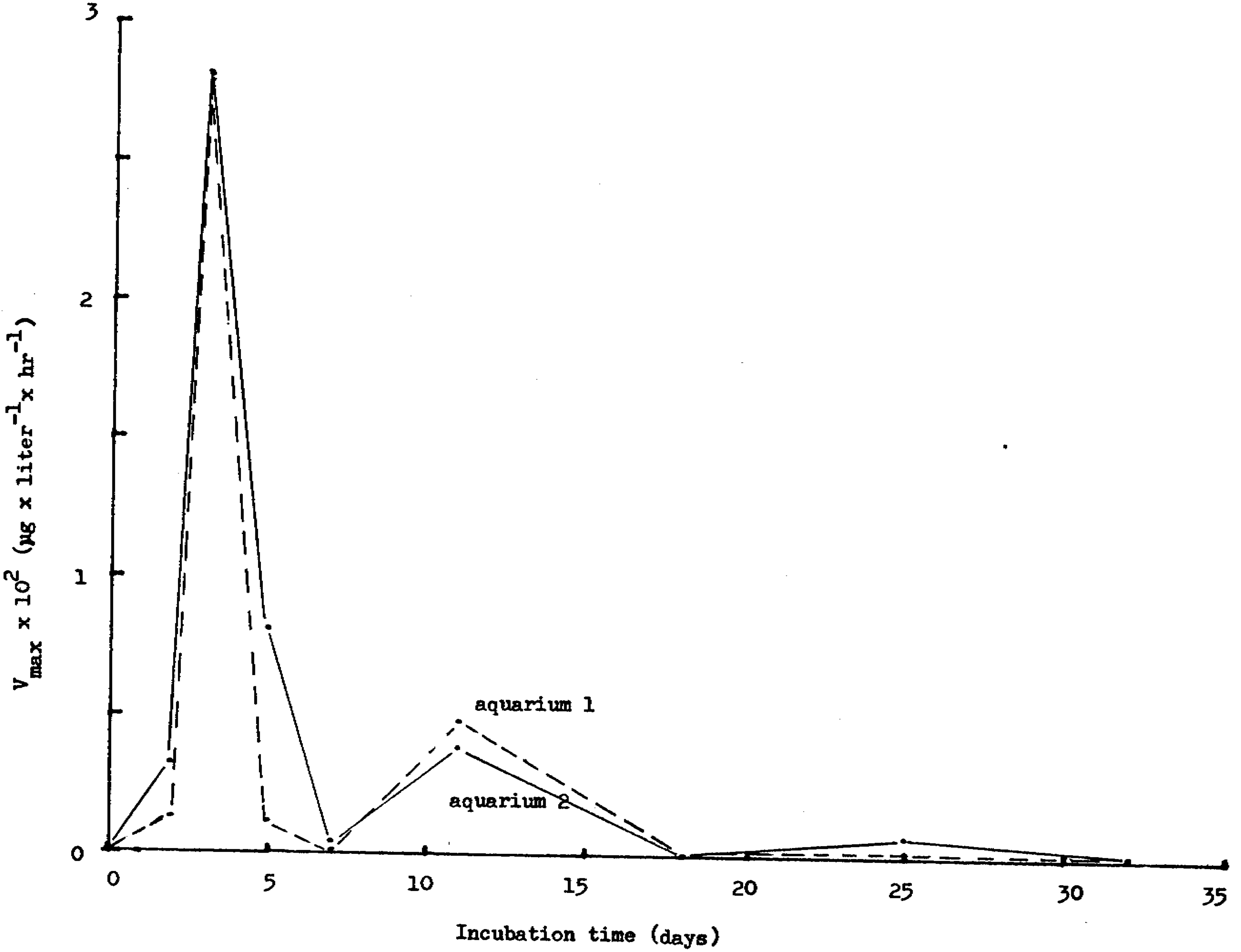


Figure 4. V_{max} of acetate uptake in both the water samples tested. Experiment #1.

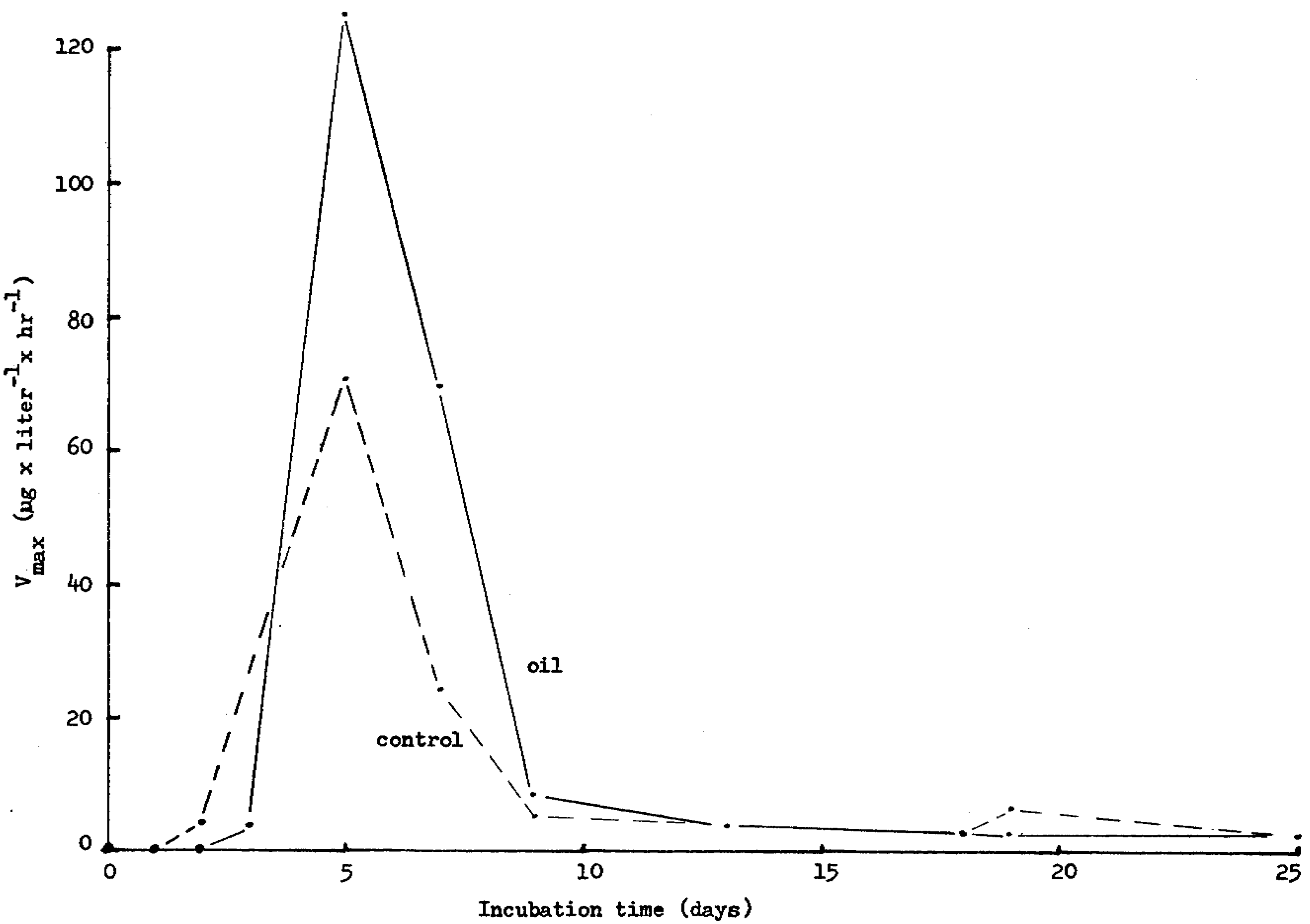


Figure 5. V_{max} of acetate uptake in both the control and oil enrichment cultures. Experiment #2.

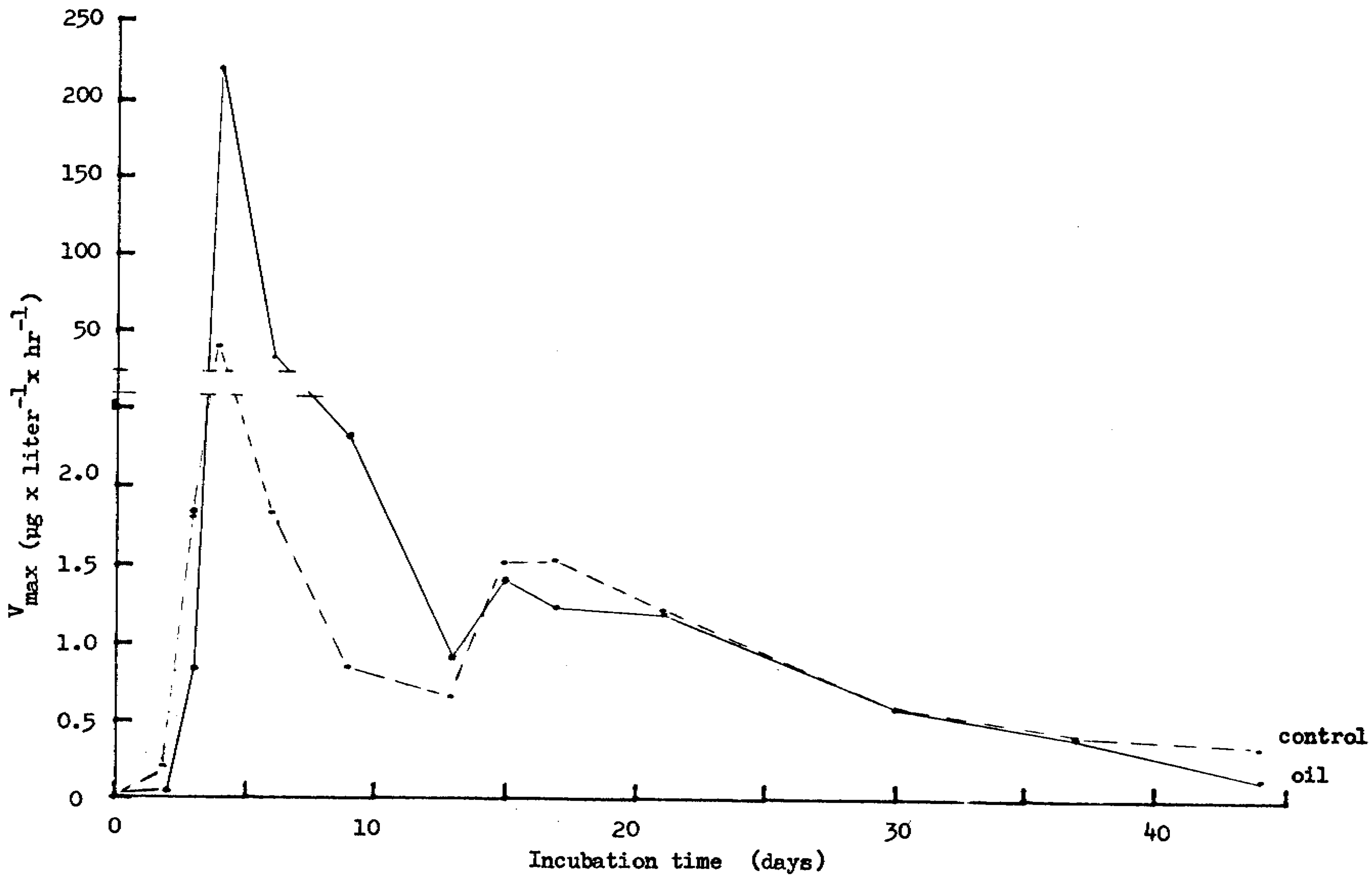


Figure 6. V_{max} of acetate uptake in both the control and oil enrichment cultures. Experiment #3.

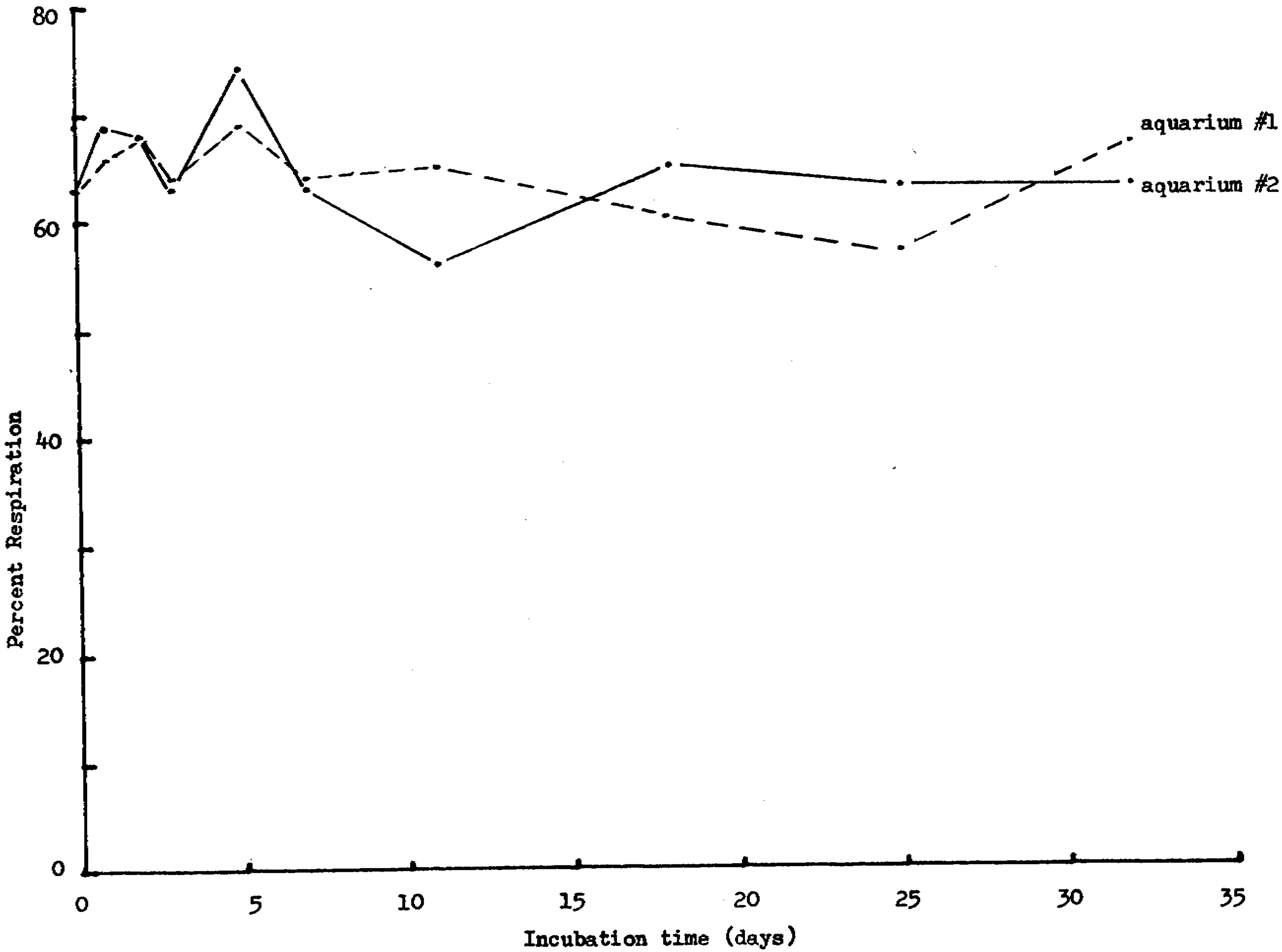


Figure 7. Percent respiration of glutamic acid utilization in both seawater samples. Experiment #1.

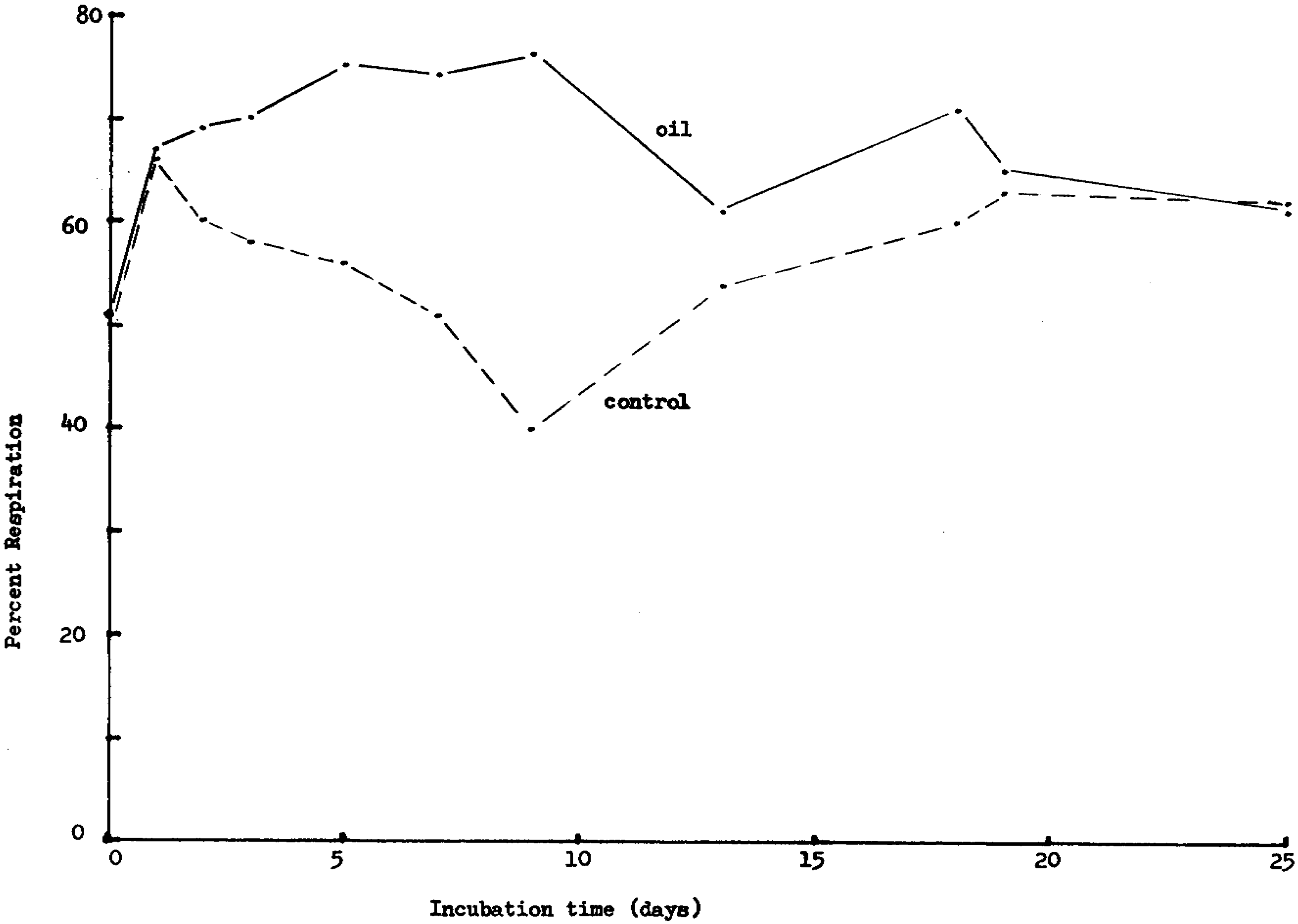


Figure 8. Percent respiration of glutamic acid utilization in both the control and oil enrichment cultures. Experiment #2.

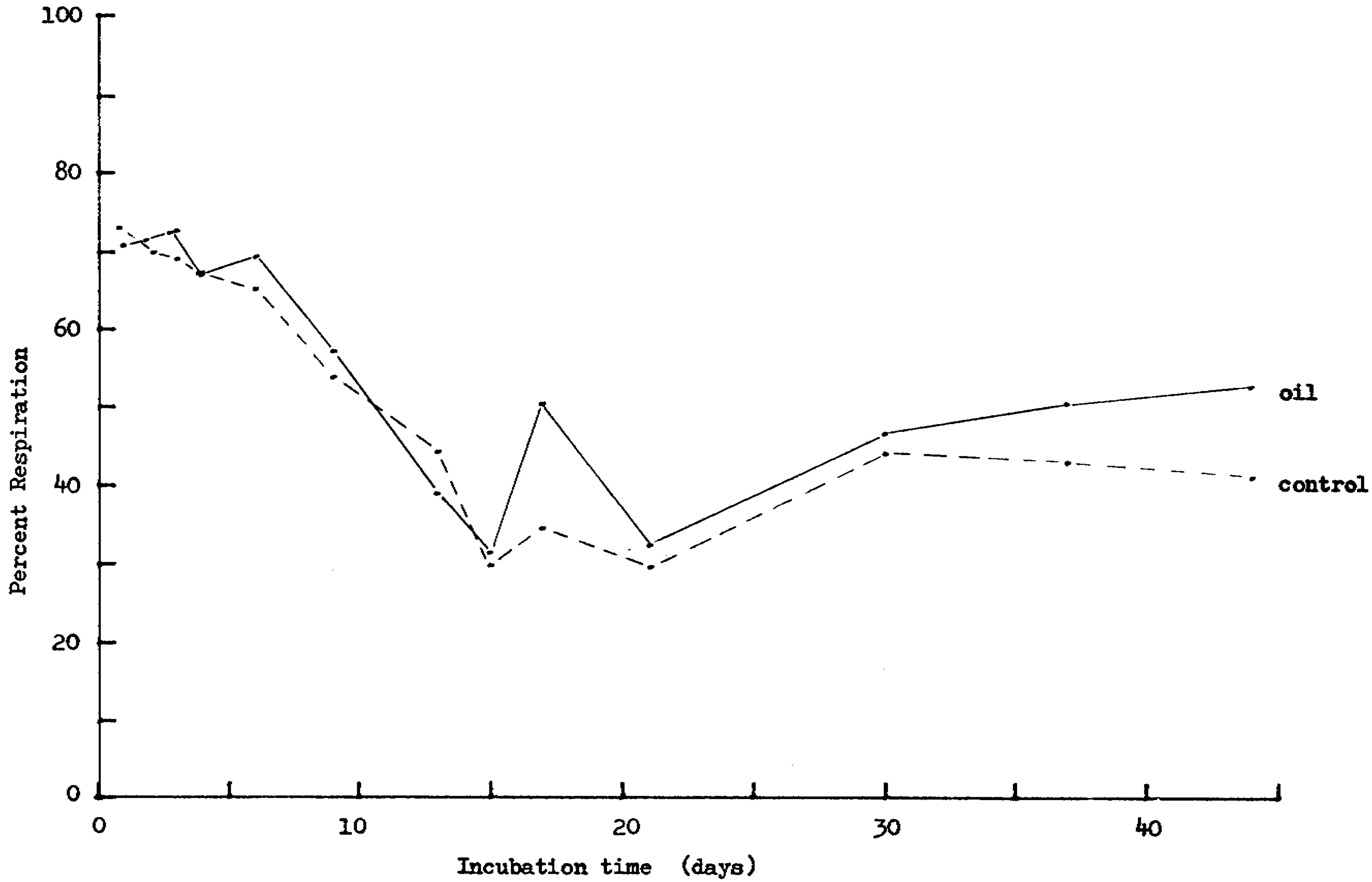


Figure 9. Percent respiration of glutamic acid utilization in both the control and oil enrichment cultures. Experiment #3.

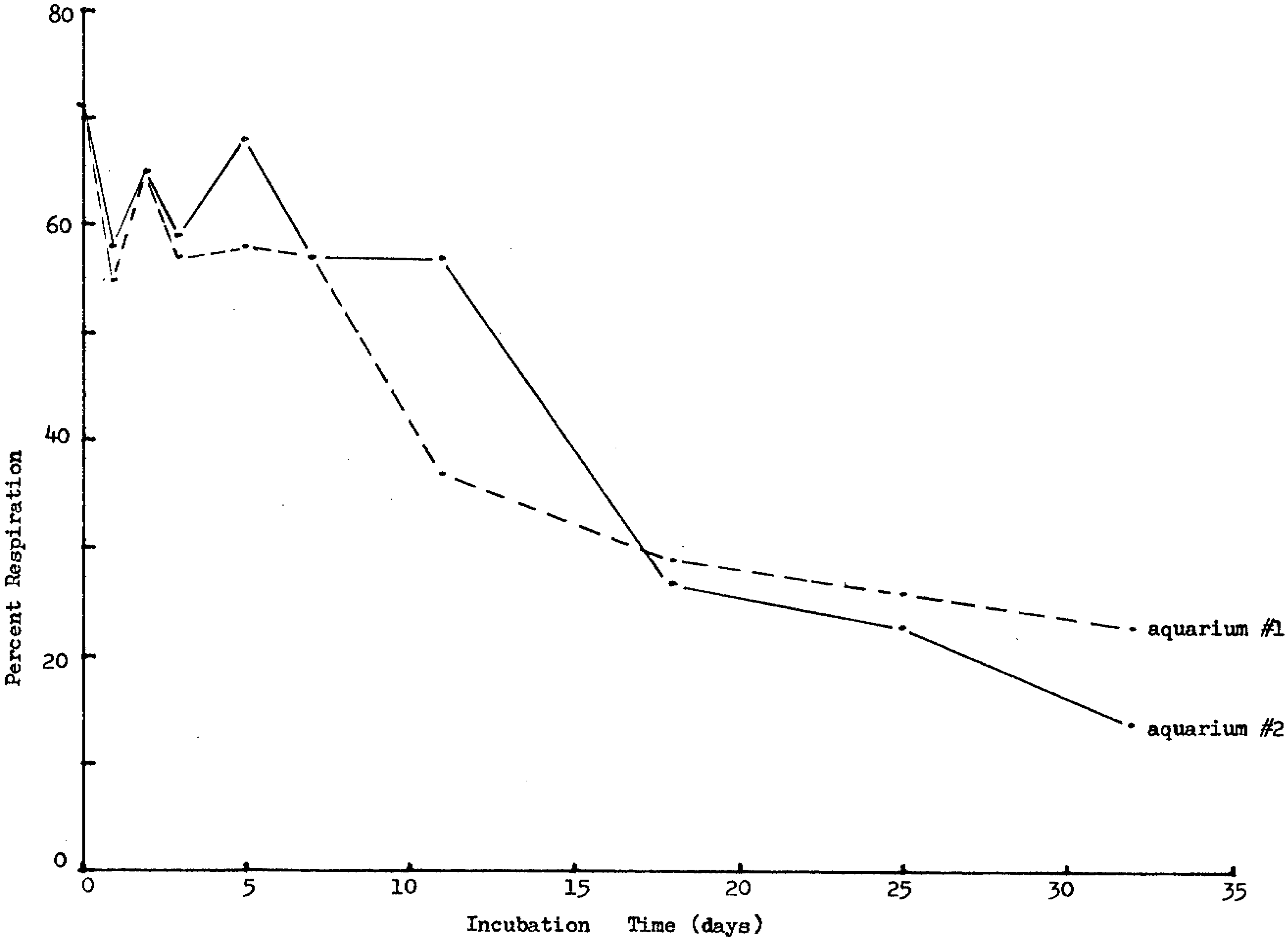


Figure 10. Percent respiration of acetate utilization in both seawater samples. Experiment # 1.

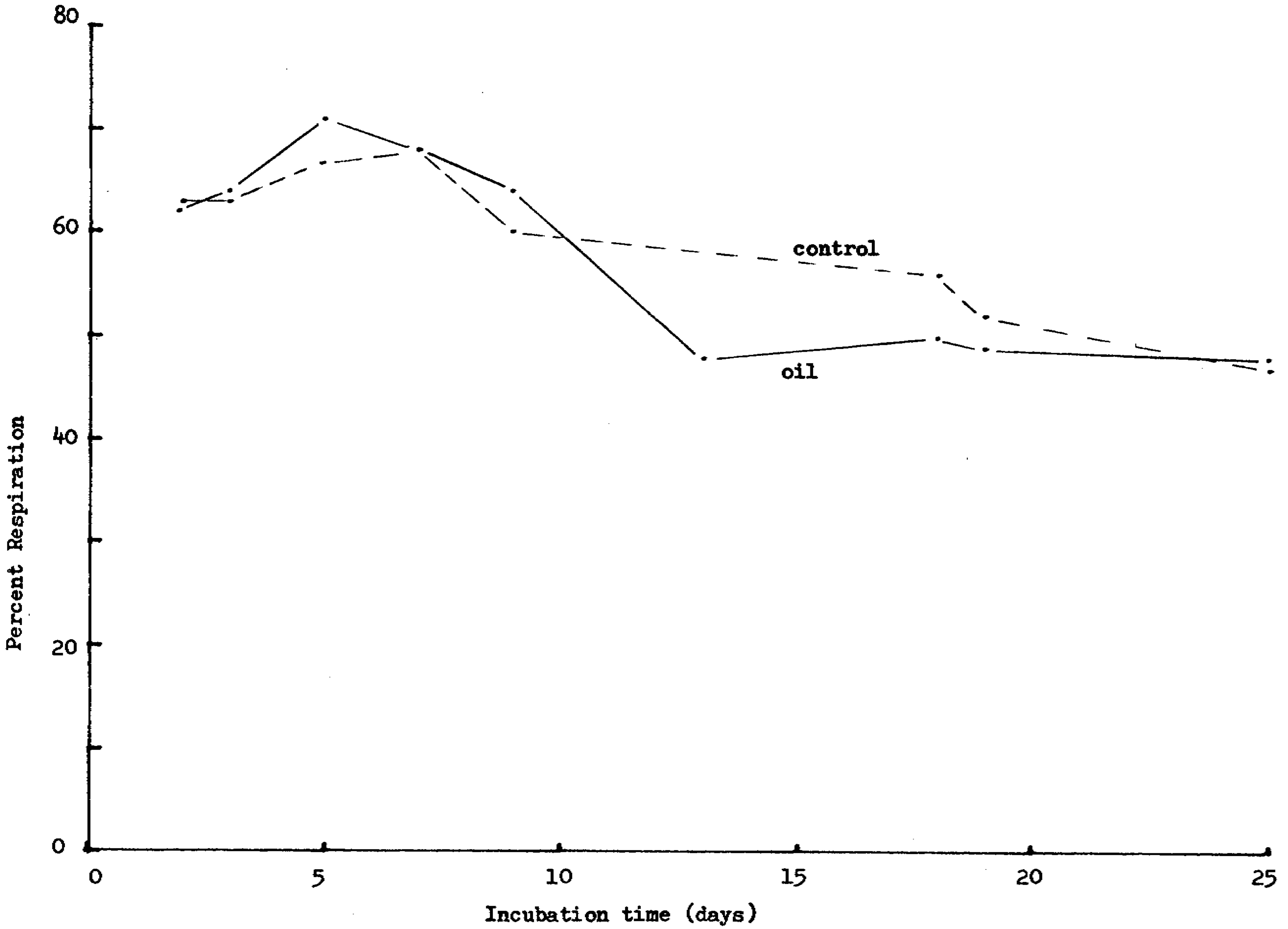


Figure 11. Percent respiration of acetate utilization in both the control and oil enrichment cultures. Experiment #2.

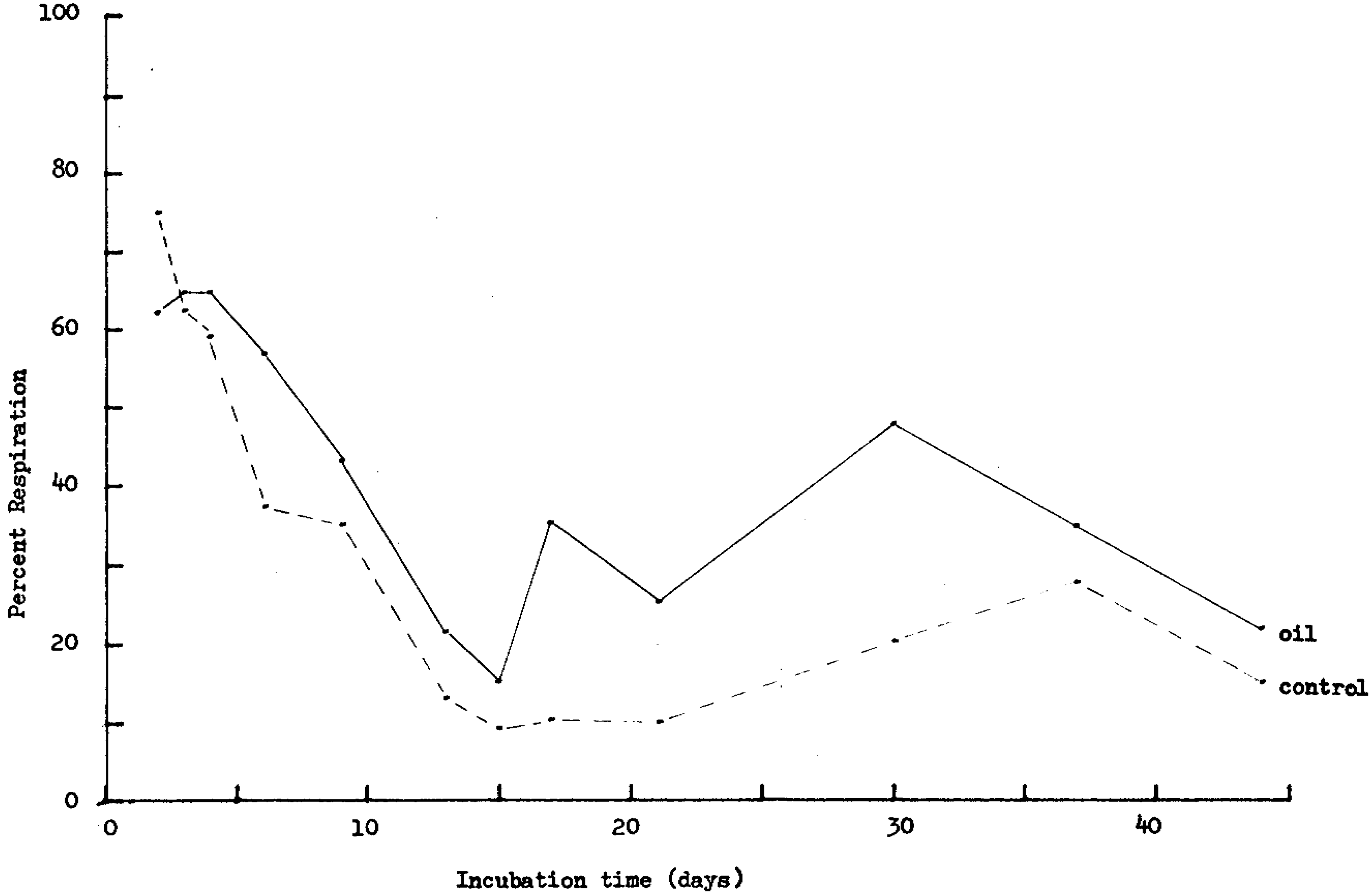


Figure 12. Percent respiration of acetate utilization in both the control and oil enrichment cultures. Experiment # 3.

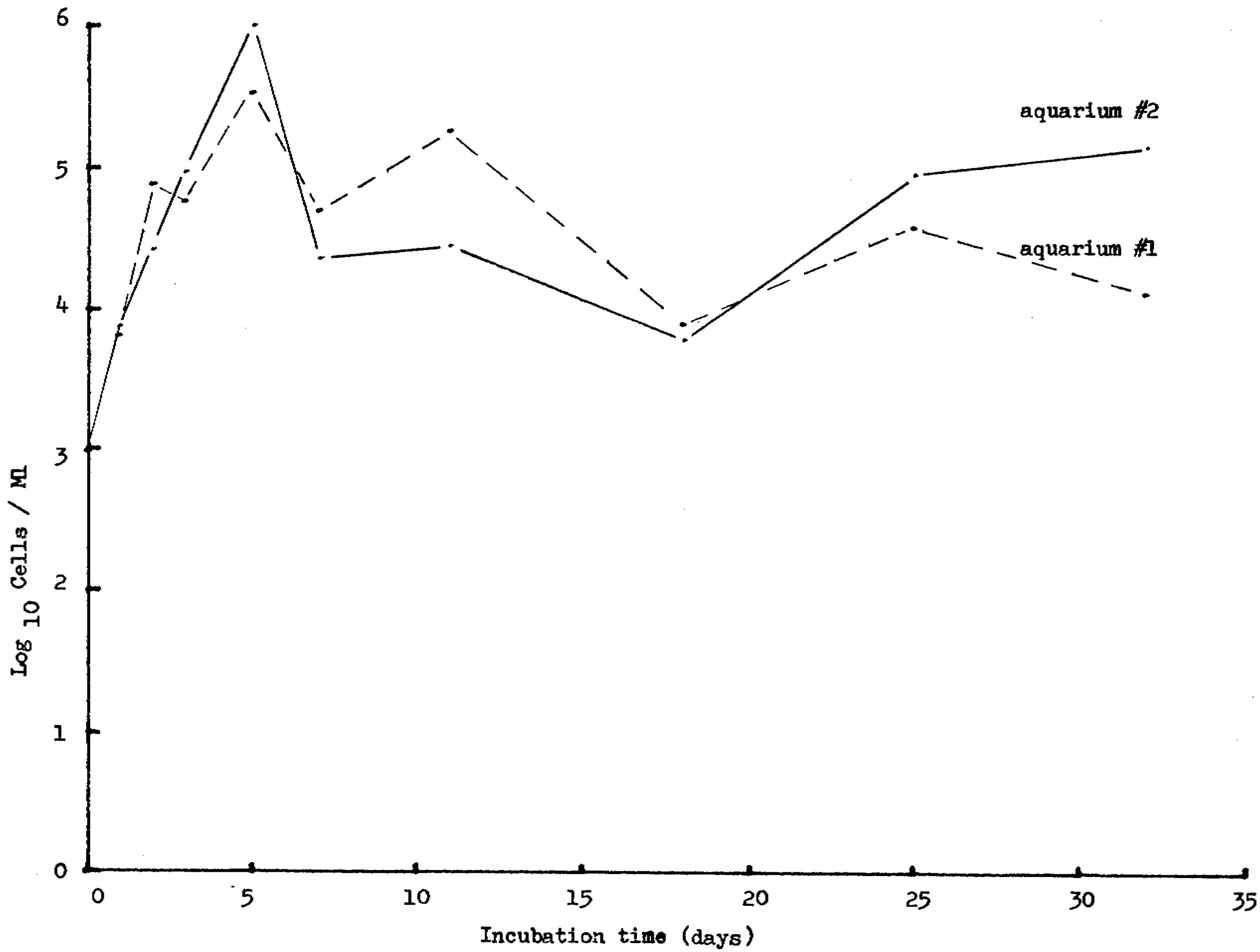


Figure 13. Total number of bacteria per ml as determined by plate counts on Lib X agar plates. Experiment #1

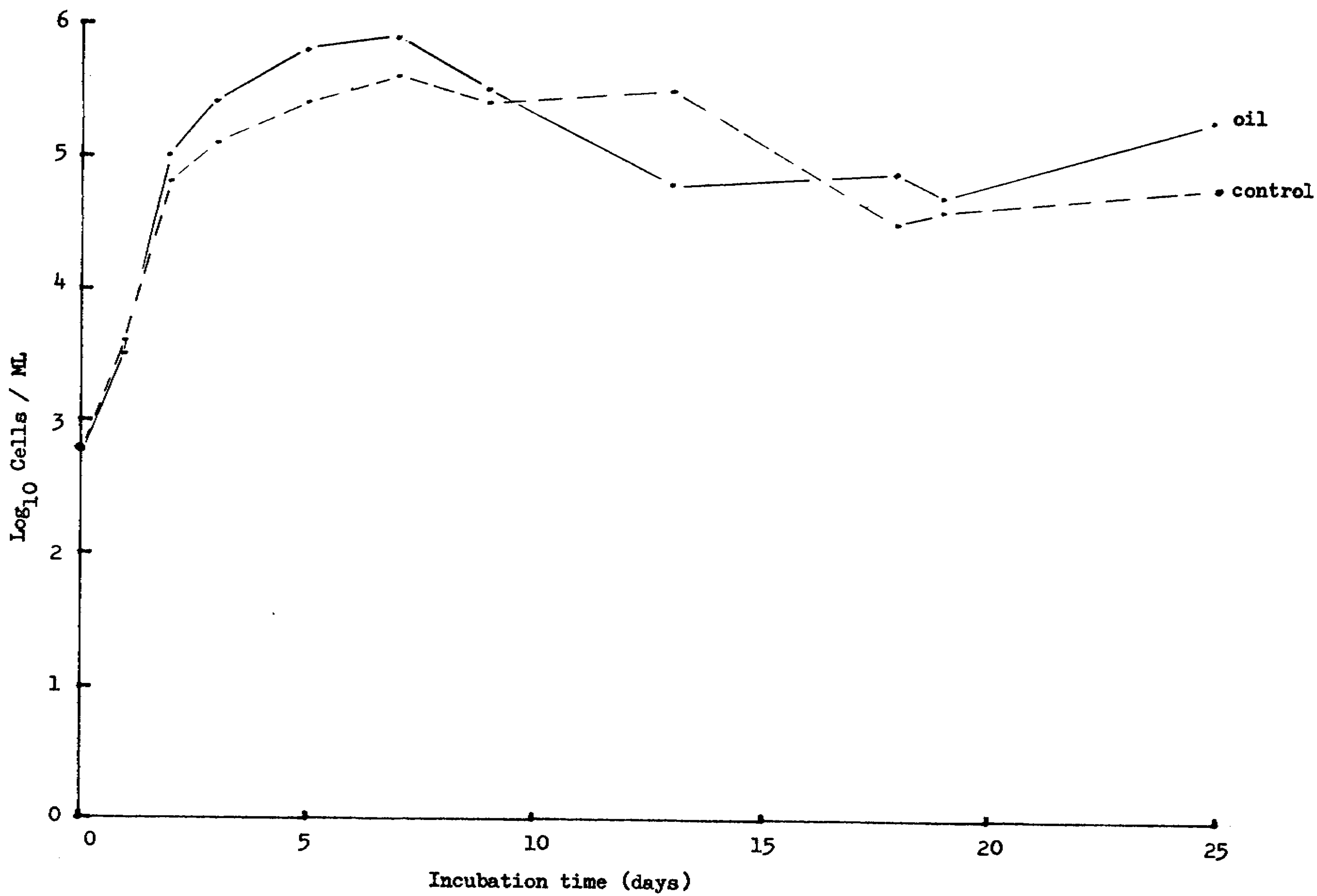


Figure 14. Log of total bacterial cell numbers per ml as measured on "Lib X" agar plates. Experiment # 2.

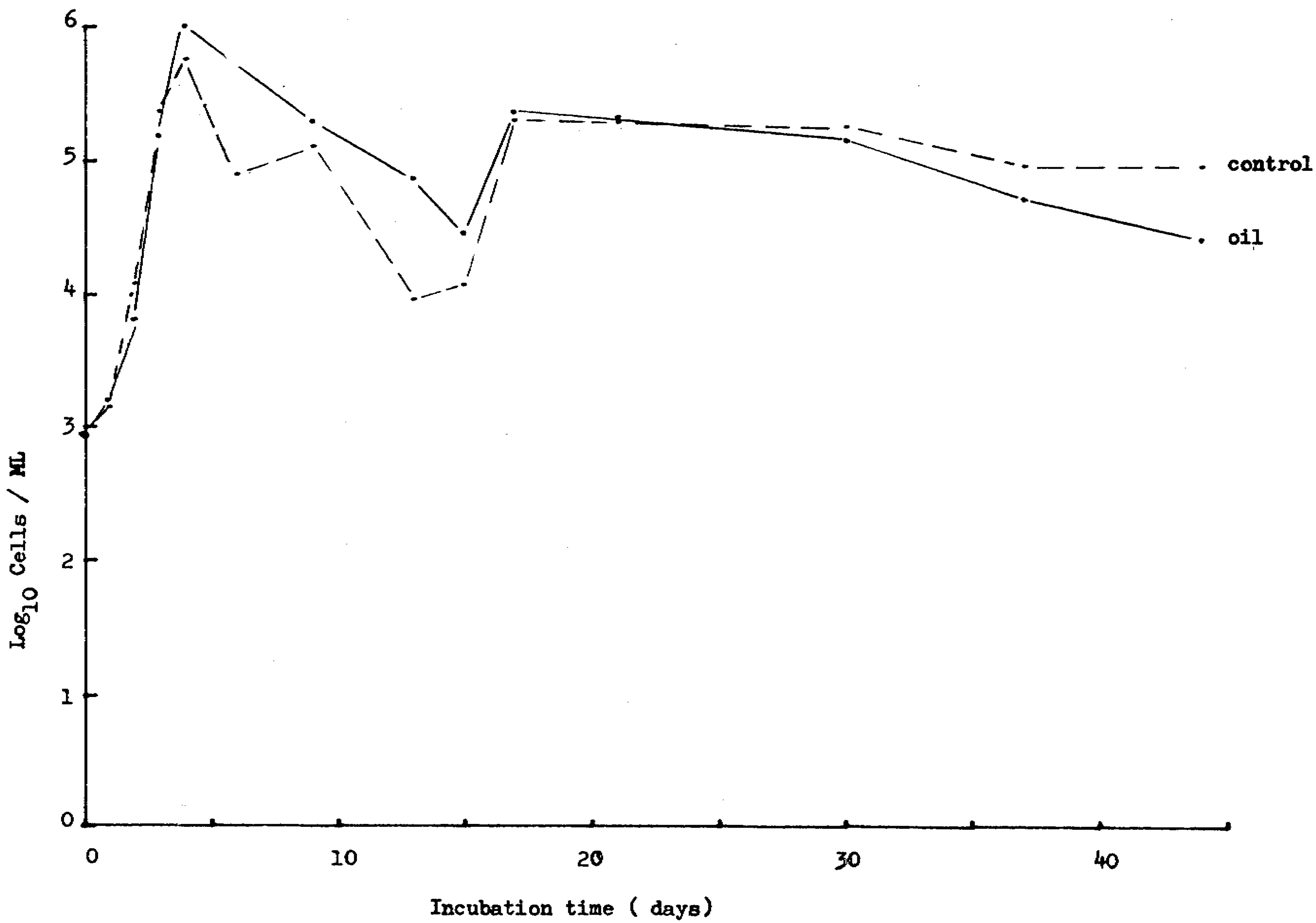


Figure 15. Log of total bacterial cell numbers per ml as measured on "Lib X" agar plates. Experiment # 3.

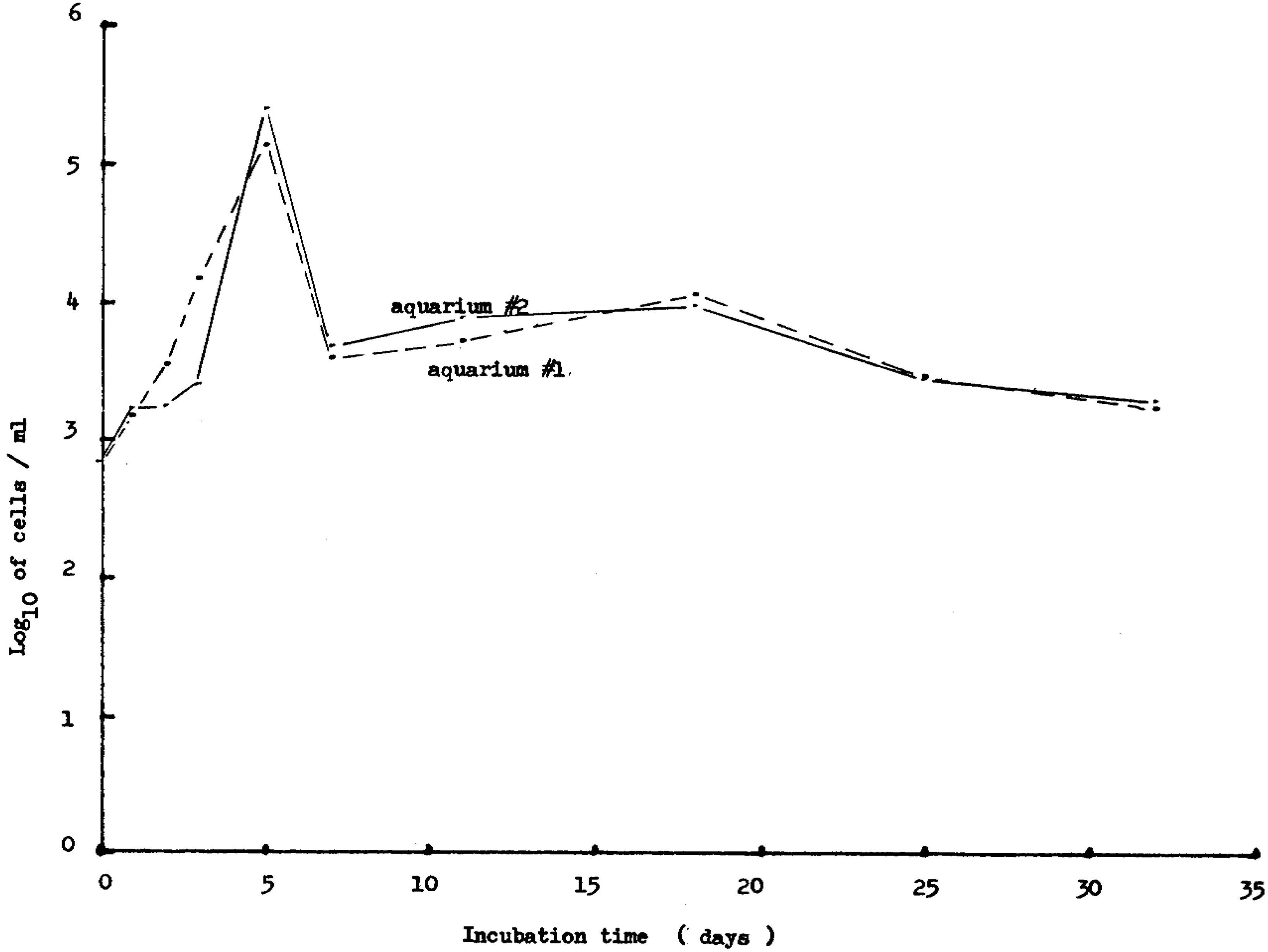


Figure 16 Log of hydrocarbon utilizing bacteria per ml as measured on crude oil agar plates. Experiment # 1.

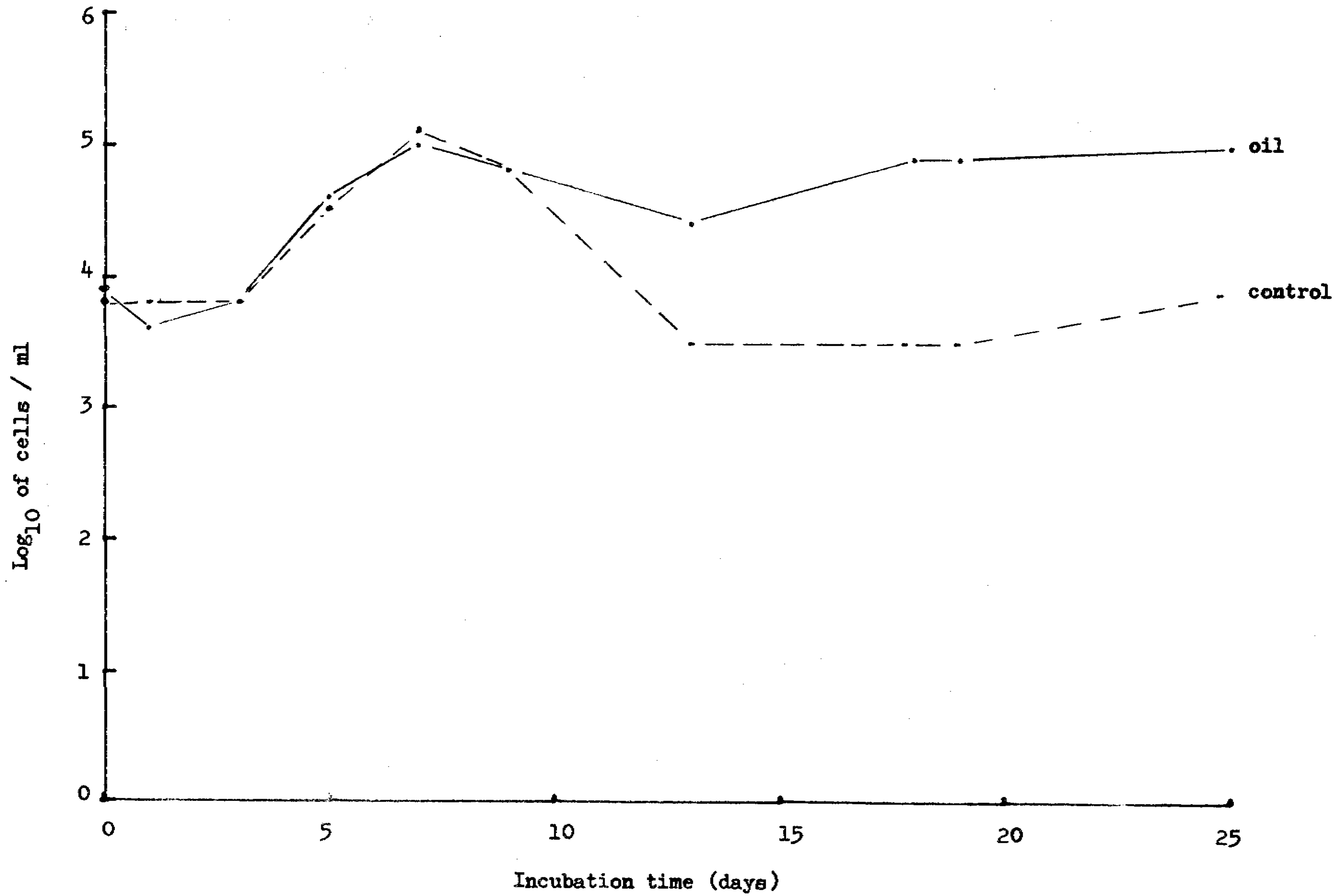


Figure 17. Log of hydrocarbon utilizing bacteria per ml as measured on crude oil agar plates. Experiment # 2.

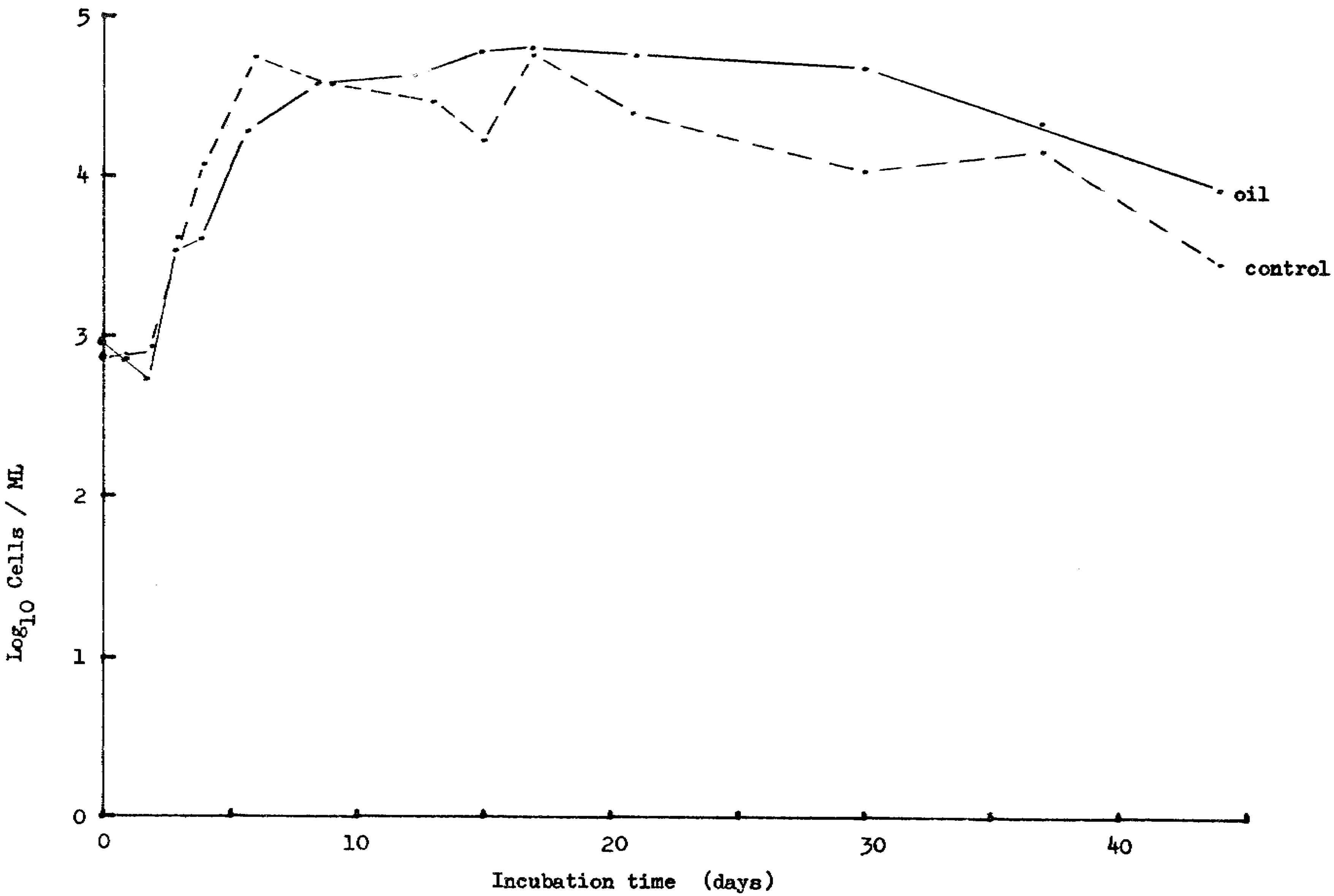


Figure 18. Log of hydrocarbon utilizing bacteria per ml as measured on crude oil plates. Experiment # 3.

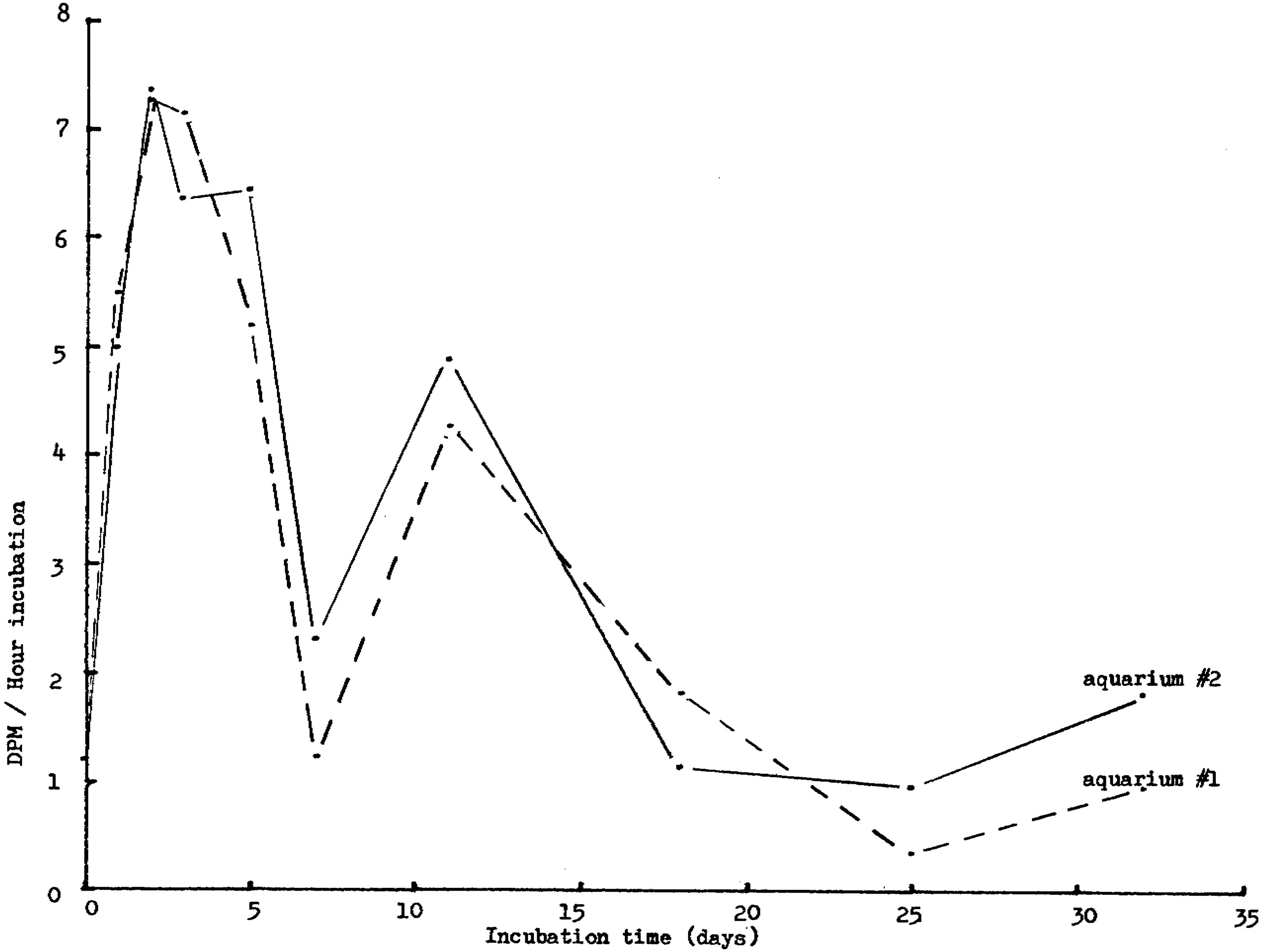


Figure 19. Algal protein hydrolysate uptake in both seawater samples reported as DPM per hour incubation. Experiment #1.

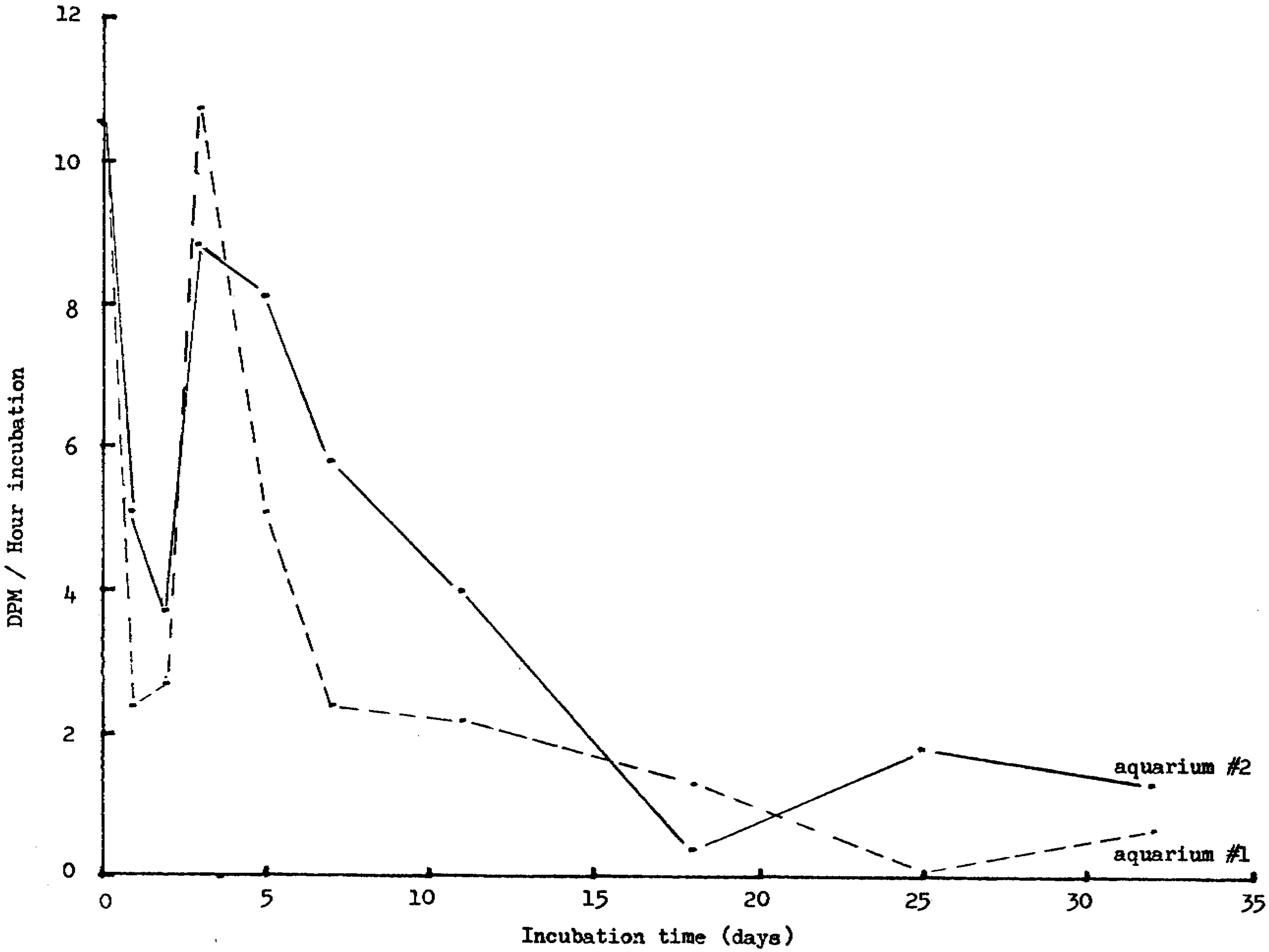


Figure 20. Glucose uptake in both seawater samples reported in DPM / hour incubation. Experiment #1.

IV. Preliminary interpretation of results

A. Field studies

1. As we have observed before, there appears to be very little difference between the bacterial cell concentrations found in the seawater and ice melt.

2. There was little difference in the bacterial concentration found in seawater samples analyzed in the Gulf of Alaska and those analyzed from the Beaufort Sea. There was, however, a significant difference between the potential microbial activity observed in these two regions; the average activity in the Beaufort Sea being roughly twice that found in the Gulf of Alaska.

3. The situation was reversed for potential activity observed in the sediments i.e., the sediments in the Gulf of Alaska showed potential activities roughly two orders of magnitude higher than that found in the Beaufort Sea even though the cell concentrations were about the same.

4. When comparing the Beaufort Sea data taken in the summer and winter sampling periods, there were also some interesting trends. The average cell concentration in the sediments did not vary much but the average relative activity observed in April was about one order of magnitude less than that observed during the previous September. In the water samples tested, the cell concentration decreased by about a third and the potential activity decreased by about an order of magnitude during the same period.

B. Laboratory studies (oil enrichment experiments)

Three experiments were conducted; the first was designed to determine the variation that might be expected between two "identical" subsamples neither of which had been perturbed by crude oil. The second and third experiments were designed to show the effects of crude oil on microbial function and cell concentrations in natural seawater samples.

If the V_{max} data for glutamic acid uptake in the three experiments are compared, the variations seen in experiment 1 would account for the differences seen between the oil and nonoil controls in experiments 2 and 3. When the differences in the percent respiration for glutamic acid in the nonoil and control aquaria are compared, there was a significant difference seen in experiment 2 but not in experiment 3 (Figures 7, 8 and 9).

A similar analysis of the acetate uptake data (Figures 4, 5 and 6) reveals that there might be a positive effect of crude oil on the V_{max} of acetate uptake in the early stages of incubation before the 10th day; however, the data presented in Figure 4 (experiment #1) are only rough estimates of the true values so that not much weight can be given to relative comparison with experiments #2 and #3. It can thus be stated at this time that crude oil might have a positive effect on acetate V_{max} in the early stages of exposure to crude oil.

When the effect of crude oil on the percent of acetate respiration was studied (Figures 10, 11, and 12), there was no significant consistent effect observed. The same was true of the effect of crude oil on the relative levels of "total" bacterial numbers as determined by plate counts on Lib X agar plates (Figures 13, 14 and 15). In contrast to these data are the results of the effects of crude oil on hydrocarbon utilizing bacteria as determined by plate counts on crude oil plates. The results of both experiments 2 and 3 show that the levels of hydrocarbon utilizing bacteria were higher in the crude oil enrichments than in the control after about two weeks incubation (Figures 16, 17 and 18).

During the course of experiment #1, the uptake of algal protein hydrolysate and glucose at one substrate concentration was also followed (Figures 19 and 20). These data suggest that it might be profitable to include similar measurements into the routine analysis of sediment and water samples taken in the field. Although these types of data do not generate information about the maximum potential rates of substrate uptake, they do produce percent respiration data and may produce useful information about relative uptake rates of a complex substrate in various natural populations. The glucose data generated patterns of substrate utilization which were different from any of the other substrates tested. It is quite possible that these uptake patterns reflect the metabolism of a different population than that measured using the other substrates. This difference was especially noticable at time 13 days.

In view of these results, we will start measuring glucose uptake at one substrate concentration on all samples taken in the field. These data, along with the uptake of algal protein hydrolysate and glutamic acid uptake kinetics should give us a more complete picture of relative heterotrophic potential in seawater and sediment samples taken during future field studies.

In summary, this series of experiments showed that of the parameters that we studied, only the concentration of hydrocarbon utilizing bacteria in the seawater samples appeared to be significantly altered in <u>both experiments</u>. It should not be concluded on the basis of these results that crude oil has no effect on the heterotrophic populations found in seawater in general for the following reasons: (1) the number of factors measured were few relative to all functions in heterotrophic bacterial populations (2) the variability between two "identical" subsamples was relatively large; thus there might have been effects that we were not able to measure using the two aquaria system (3) the system that we studied was a highly artifical one in that the seawater samples were contained within a vessel; this is a condition which is known to greatly alter bacterial populations because of surface effects, the accumulation of metabolic byproducts and the depletion of nutrients (4) the water samples were taken from temperate bay waters which may not be typical of colder, less perturbed waters.

V. Problems encountered, recommended changes and acknowledgments

A. Problem areas

Due to the problems of ice and fog encountered during the Glacier cruise, roughly ½ of the planned stations were occupied. Since weather conditions did not permit trips to shore, no beach samples were taken.

B. Recommended changes

1. We still recommend that certain representative sampling sties be established and that interdisciplinary studies be planned which would continue without interruption for 2 to 3 years. As an integral part of these experiments, a controlled oil spill should be studied to determine the long term *in situ* effects of a crude oil spill on that environment. This would require continuous year round monitoring of those parameters which are most subject to rapid change.

2. In addition to the above studies, we strongly recommend that more funds be made available for laboratory studies on the biodegradation and emulsification of crude oil by bacterial isolates taken from Arctic and Subarctic marine environments. These studies would produce information about the effects of physical and chemical factors on the biodegradation process. From these data, some estimate of potential crude oil degradation rates could be made for a specific set of environmental conditions. Without this information, informed managerial decisions can not be made on how best to cope with an oil spill under all of the environmental conditions that might be encountered in Arctic and Subarctic marine waters.

C. Acknowledgments

We would like to extend a special thanks to the officers and crew of the U.S. Coast Guard Ship Glacier for their support during the summer Beaufort Sea cruise and for the logistics support provided by NARL.

VI. Estimate of funds expended through September 30, 1976.

Salaries and Wages	$ 46,276
Other Payroll Expenses	6,942
Supplies	15,768
Travel	6,143
Equipment	29,998
Indirect Costs	18,300
Total	$123,427

Quarterly Report

Contract #03-5-022-56
Research Unit #275/276/294
Reporting Period 7/1 - 9/30/76
Number of Pages 2

HYDROCARBONS: NATURAL DISTRIBUTION AND DYNAMICS ON THE ALASKAN OUTER CONTINENTAL SHELF

Dr. David G. Shaw
Associate Professor of Marine Science
Institute of Marine Science
University of Alaska
Fairbanks, Alaska 99701

October 1, 1976

Quarterly Report

I. Task Objectives

The primary objectives of this program are to produce data on the kinds and amounts of hydrocarbon in waters, biota and sediments of the Alaskan OCS areas and to develop a quantitative understanding of factors that control those distributions.

II. Field and Laboratory Activities

A. Field

1. Surface water samples (14) were collected during a cruise of the *USCGC Glacier* in the Beaufort Sea during the month of August. Ice and weather conditions prevented the collection of seston or benthic biota on this cruise.

2. As this report is being transmitted, surface water and seston are being collected during a cruise of the *USNOSS Discoveror* in Norton Sound and the Chukchi Sea.

B. Laboratory

Analysis of biota, water and seston have proceeded smoothly and steadily during this quarter.

C. Program development

In concert with other chemistry principal investigators and OCSEAP management staff the development of research plans for a group of site specific studies have been begun. The present tentative plan is to study the physical transport of pollutants at Icy Bay, the migration of pollutants through intertidal biological communities at Kachemak Bay and the migration of pollutants through pelagic communities in the "golden triangle" region of the Bering Sea. The need for a coastal study in the Beaufort Sea is recognized; however, further reconnaissance work is required before a sound plan can be developed.

III. Results

Analyses of water, biota, sediment and seston from Lower Cook Inlet show hydrocarbon patterns and abundances comparable with the open Gulf of Alaska. Petroleum was not detected even in Kamishak Bay, an area of reported natural oil seeps.

IV. Subcontractor Activities

A quarterly report describing I. R. Kaplan's progress in sediment collection and analysis will be forwarded when available.

OCS COORDINATION OFFICE

University of Alaska

ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: September 30, 1976

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 5 R.U. NUMBER: 275/276/294

PRINCIPAL INVESTIGATOR: Dr. D. G. Shaw

Submission dates are estimated only and will be updated, if necessary, each quarter. Data batches refer to data as identified in the data management plan.

Cruise/Field Operation	Collection Dates		Estimated Submission Dates[1]		
	From	To	Batch 1	2	3
Silas Bent Leg I #811	8/31/75	9/14/75	None	submitted	submitted
Discoverer Leg III #810	9/12/75	10/3/75	None	None	submitted
Discoverer Leg IV #812	10/3/75	10/16/75	9/30/76	None	submitted
Surveyor #814	10/28/75	11/17/75	None	submitted	None
North Pacific	4/25/75	8/7/75	submitted	None	None
Contract 03-5-022-34	Last	Year	submitted	submitted	submitted
Moana Wave MW 001	2/21/76	3/5/76	None	9/30/76	9/30/76
Miller Freeman	5/17/76	6/4/76	9/30/76	None	None
Glacier	-	-	None	(a)	None
Discoverer	9/10/76	9/24/76	None	(a)	(a)

Note: [1] Data Management plan has been approved and made contractual.

(a) Data will be processed and submitted in FY '77, contingent upon receiving funding for Fy '77.

RU# 278

NO REPORT AVAILABLE AT THIS TIME

PHYSICAL OCEANOGRAPHY

PHYSICAL OCEANOGRAPHY

PHYSICAL OCEANOGRAPHY

RU# 48

NO REPORT AVAILABLE AT THIS TIME

RU# 81

NO REPORT AVAILABLE AT THIS TIME

Quarterly Report

Contract No:
02-5-022-67, TA 3

Research Unit No:
91

Reporting Period:
1 July 1976 - 30 September 1976

Number of Pages:
3

Current Measurements in the Beaufort Sea

Knut Aagaard
Department of Oceanography

Dean Haugen
Applied Physics Laboratory

University of Washington
Seattle, Washington 98195

30 September 1976

I. Objectives

The general objective of this research unit is to provide long-term Eulerian time series of currents at selected locations on the outer shelf and the slope of the Beaufort Sea, so as to describe and understand the circulation and dynamics of the outer shelf and slope.

II. Field activities

A. Field trip schedule

1. 2-6 September 1976
2. U.S.C.G.C. Glacier with helicopters

B. Scientific party

1. Knut Aagaard, Department of Oceanography, University of Washington, principal investigator.

C. Methods

1. This was an attempt to retrieve from aboard ship the current meter moorings deployed last April in outer Barrow Canyon and north of Oliktok.

D. Sample localities

As per previous quarterly report.

E. Data collected

The current meters are recording temperature, current speed, and direction.

III. Results

Heavy ice precluded any attempts to retrieve the moorings north of Oliktok from aboard ship. Helicopter reconnaissance over the Barrow Canyon area showed relatively high ice concentrations as late as 5 September, and it was deemed inadvisable to attempt recovery from the Glacier.

IV. Preliminary interpretation

None.

V. Problems encountered

A heavy ice year has thus precluded shipboard recovery of the moorings and we shall have to do it in October, using a helicopter and working through the ice. The preparations for this work are underway.

In regard to deployment of instruments during the coming fiscal year, there have been some further construction and testing delays in the telemetry modules. These have been detailed in a letter to Dr. Weller from Dean Haugen, APL, dated 13 September 1976. In order to ensure deployment of the current meters themselves during the critical early months of rapid freezing, we have suggested the following procedural changes to Dr. Weller. We plan to deploy the two moorings in October-November as planned, but without the telemetry modules. Instead, we'll use transponding acoustic releases and recover the moorings in late winter (February-March) through the ice, using a helicopter. At that time we would then deploy new moorings with the telemetry modules and carry on as per our original plan. This procedure seems to optimize the situation; Dr. Weller concurs.

VI. Estimate of funds expended (31 August 1976)

A. Original allocation	
1. Aagaard, Oceanography	$ 74,651
2. Haugen, APL	100,349
3. Total	175,000
B. Expended: Aagaard	
1. Salaries	6,508
2. Benefits	776
3. Indirect costs	2,851
4. Supplies and other direct costs	16,734
5. Equipment	34,334
6. Travel	1,387
Total	62,590
Remaining balance	12,061
C. Expended: Haugen	
1. Salaries	39,400
2. Benefits and indirect costs	39,400
3. Purchases, travel and supplies	21,165
Fee	3,758
Total	103,723
Remaining balance	-3,374

QUARTERLY REPORT

Contract 03-5-022-56
Research Unit #111
Reporting Period 7/1-9/30/76
Number of Pages 2

EFFECTS OF SEASONABILITY AND VARIABILITY OF STREAMFLOW ON NEARSHORE COASTAL AREAS

Dr. Robert F. Carlson
Institute of Water Resources
University of Alaska
Fairbanks, Alaska 99701

October 1, 1976

QUARTERLY REPORT

I. Activities

We have asked for a non-additional funding three month extension to December 31, 1976. All our present effort is aimed at producing the final report.

II. Results

Results will be presented in the final report as soon as it is available.

III. Problems Encountered

None.

OCS COORDINATION OFFICE

University of Alaska

ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: September 30, 1976

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 4 R.U. NUMBER: 111

PRINCIPAL INVESTIGATOR: Dr. Robert F. Carlson

No environmental data are to be taken by this task order as indicated in the Data Management Plan. A schedule of submission is therefore not applicable[1].

NOTE: [1] Data Management Plan has been approved and made contractual.

QUARTERLY REPORT

Contract #R7120846
#R7120847

Research Unit #138, 139, 147

Reporting Period: 1 July -
30 September 1976

Number of Pages : 1

GULF OF ALASKA STUDY OF MESOSCALE OCEANOGRAPHIC PROCESSES (GAS-MOP)

Dr. S. P. Hayes

Dr. J. D. Schumacher

Pacific Marine Environmental Laboratory
National Oceanic and Atmospheric Administration
3711 - 15th Avenue, N.E.
Seattle, Washington 98105

October 1, 1976

I. TASK OBJECTIVES

- Eulerian measurements of the velocity field at several positions and levels
- Measurement of the along- and cross-shelf sea surface slope
- Process study to understand the interrelations among the velocity field, the bottom pressure gradient, the density field, and the wind field in order to determine the dynamics of the circulation on the continental shelf.

II. FIELD OR LABORATORY ACTIVITIES

A. Cruises:

1. R/V MOANA WAVE Leg 3, 18-27 August 1976
   See attached cruise report.

B. Methods:

Plessey 9040 CTD
Plessey 8400 Digital Data Logger
Aanderaa RCM-4 current meters
PTG pressure temperature gauges
AMF releases

III. RESULTS

These new data sets are being processed and analyzed. Results of previous analyses are contained in the appended manuscript.

R/V *MOANA WAVE* OCSEAP LEG 3 18-27 AUGUST 1976

Cruise Report

Dr. S. P. Hayes

Objective:

This cruise was one of several which have as their principal objective the study of the physical oceanographic regime in the Northeast Gulf of Alaska. In particular, the oceanic circulation west of Kayak Island and in the region near Icy Bay were the focal points for this cruise. The Kayak Island study was designed to investigate the semipermanent gyre which had previously been detected in this region. The Icy Bay work is part of a continuing study aimed at understanding the barotropic response of the ocean currents to wind forcing.

Narrative:

The R/V *Moana Wave* departed Kodiak at 0600Q 18 August enroute to the Kayak Island moored array. We arrived on station #69 at 0800Q 19 August. Mooring recoveries began and were completed by 1600Q. A test CTD lowering was conducted and the system performed satisfactorially.

We proceeded to the Icy Bay region and began CTD work at 0100Q 20 August. A line of CTD stations were taken perpendicular to the coast. At daybreak attempts were made to interrogate mooring SLS-12. These were unsuccessful. Similarly, SLS-11 and STATION 62 failed to respond to interrogation. At SLS-10, it was decided to attempt to release the mooring in spite of the failure of the interrogation. The mooring came up about 200 m from the ship. The problem in the interrogation mode was traced to the AMF Model 301

Release Deck Set. We requested a Model 200 Deck Set to be sent to Yakutat. Arrangements were made to pick up the gear on Sunday 22 August.

21 August was a clear calm day. We decided to continue mooring retrieval. All remaining moorings (SLS-11, 12, STA 62) were recovered and all redeployments were completed.

On Sunday 22 August we went into Yakutat to pick up the release deck unit. By 2100Q we were back in the work area, and the night was spent taking CTD casts.

At daybreak on 23 August we maneuvered into position to drag for SLS-7. The next two days were spent unsuccessfully dragging for this mooring. Similarly, we attempted to drag for ICY-2 with no success.

At 2300Q 25 August we abandoned the dragging operation due to increasing sea state and lack of results. We headed back to Kodiak. We arrived at the Kodiak Coast Guard Base at 0930Q 27 August.

Accomplishments:

Moorings recovered:

69A	59° 49.2'N	145° 43'W
60C	60° 06.9'N	145° 48.6'W
61C	59° 32.6'N	145° 49.7'W
SLS-10	59° 59'N	142° 17'W
SLS-11	59° 52.2'N	142° 24.6'W
62H	59° 38.1'N	142° 05.0'W
SLS-12	59° 43.3'N	142° 34.6'W

Moorings deployed:

SLS-16	59° 59.0'N	142° 19.0'W	52.4 m
SLS-17	59° 49.5'N	142° 31.3'W	98.5 m
SLS-18	59° 42.1 N	142° 41.9 W	262 m
62I	59° 38.1'N	142° 04.0'W	190 m

STD: A total of 15 CTD stations were taken in the Icy Bay region.

All mooring operations were successful and a total of 14 current meters and three pressure gauges were recovered. While the dragging operations were not successful, such work is difficult at best. Perhaps a line drag using two fishing vessels would be useful for SLS-7.

Personnel:

Dr. Stanley P. Hayes	PMEL	Chief Scientist
John Glenn	PMEL	Electronics Technician
Rick Miller	U.W.	Mooring Technician
Dave Pashinski	PMEL	Mooring Engineer
Dean Dale	PMEL	Data Recorder
Andrew Anschell	U.W.	Mammal Observer

Acknowledgements:

The cooperation of the officers and crew of the R/V *MOANA WAVE* is greatly appreciated. The advice and abilities of Capt. Willis were especially helpful.

Extreme Value Analysis Applied to Current Meter Data

R. L. Charnell
J. D. Schumacher
C. A. Pearson *

Pacific Marine Environmental Laboratory
3711 15th Avenue N.E.
Seattle, Washington 98105

Abstract

The statistical method of extreme value analysis is applied to 15 month current meter observations on the continental shelf in the Northeast Gulf of Alaska. The technique is used to characterize the data and suggests the utility of extrapolating data to obtain estimates of extreme flow over time periods in excess of the observation period. For the data at 50 m, a maximum speed of over 112 cm/sec probably will occur in an observation period of 5000 days (13.7 yr). A model is presented that allows extrapolation of the data to other levels in the water column. By comparison, at 10 m and for the same 5000 days, an extreme speed of 155 cm/sec would occur.

Introduction

During 1974, NOAA's Pacific Marine Environmental Laboratory (PMEL) began a series of direct current measurements on the continental shelf in the Northeast Gulf of Alaska. These measurements are in support of a multi-discipline effort to predict and assess the environmental impacts of oil exploration and development in shelf waters. Since so few direct current measurements have been made in

*employed by NOAA's National Ocean Survey and assigned to PMEL

this area, one objective of the PMEL program was to obtain a long time series with which to examine seasonal variations in the flow and determine the typical range of speeds. These data are useful for estimating transport of pollutants as well as establishing design criteria for offshore structures. Since beginning the project, PMEL has continuously occupied a single subsurface taut-wire mooring on the Alaskan Shelf that has yielded nearly continuous records from four depths.

We have used these data to characterize flow at this site with emphasis on occurance of extreme flow events. This paper discusses the application of the technique of extreme value analysis to current meter data; the appropriateness of the technique is borne out by the consistency of projected extreme estimates. Further we present a technique that allows extrapolation of extreme flow information for other levels throughout the water column.

The Alaska data were chosen as an example of the technique's usefulness. The station is located in an area within the Gulf of Alaska circulation which is dominated by the Alaska Stream. The Stream is formed as the North Pacific Current splits at the North American land mass; the Northwestward flowing limb forms a counterclockwise gyre in the Northeast Gulf and develops into a strong westward flowing current along the continental shelf break intensifying to the west (Dodimead et al., 1963). Description of the water mass structure and its seasonal variation can be found in such reviews as Dodimead and Pickard (1967) and Royer (1975).

Current meter observations

The long time series station, #62 used for this study is located just off Icy Bay at 59° 34'N and 142° 10'W (Figure 1). It has been maintained continuously since 17 August 1974. The most recent record from this station was recovered in May 1976; the station will continue to be occupied until the summer, 1977. The array consists of a large (1.1 meter diam) sub-surface float approximately 17 m below the surface and four Aanderaa RCM-4 Savonious-Rotor current meters. Nominal depths for the meters have been 20, 50, 100 and 175 m below the surface in 185 m of water. These current meters record an instantaneous flow direction with an integrated speed over a 20 minute time interval. During winter when it was not feasible to occupy the station as often as during summer, the sampling time interval was increased to 30 minutes. To remove very high frequency noise, the current data was processed with a 2.9 hr low pass filter. This filter has an energy response such that less than 0.1% of the energy is passed at a period of 2 hours and greater than 99% of the energy is passed at a period of 5 hours. Theoretically, the data should still include all the observed tidal and wind induced flow components.

No record was complete for the entire period of observation; but for the 50 m and 100 m depths there are continuous records over 15 months long. Figure 2 shows the 5-day mean speeds over the entire available record lengths. The 5-day mean speeds for the 20 m observations range from 9-57 cm/sec while for the 180 m observation the mean ranges from 8-28 cm/sec. The data clearly show the marked seasonal behavior of flow associated with the annual variation in storm activity described by Royer (1975). The data from the 50 and 100 m levels show an increase in the very low frequency flow from a mean of about 15 cm/sec in summer to a mean of over 25 cm/sec in winter; variation about this mean in winter is considerably higher than during summer. This low frequency flow is due to the effect of the Alaska Stream on shelf water. Response of shelf water to the passage of storm events during winter at this site is the subject of Hayes and Schumacher (1976).

The ensemble averaged energy spectra for all available data at each of the four depths are shown in Figure 3. Tidal and inertial periods are indicated. Data from all levels show marked tidal peaks. However, the proportion of diurnal tidal energy is barely above background energy at the 20 meter level but increases with depth. Only the 20 m data show significant energy at the inertial frequency, although most of this occurred during the winter of 1974-75 when the records from the other levels were incomplete.

Local topography greatly controls the direction of flow; flow tends to parallel isobaths at this location. While there are seasonal as well as higher frequency variations in these trends the mean is stable and variations small. Generally, flow strongly adheres to this bathymetric constraint and tends to have a mean direction of around 315°T. Variation of maximum flow about this axis is apparently quite low since mean speed values along this axis for the 50 m data are only 5 percent less than those using mean speed alone. This direction stability allows analysis of extreme flow events to be carried out on a scalar rather than a vector quantity; consequently, subsequent discussion is related to extreme speeds.

Extreme speeds

It is desirable to summarize these data in some manner that allows a characterization of significant flow events. A promising technique is that of extreme value analysis. This technique has been used successfully on other environmental data sets and has a large volume of literature describing its application. Gumbel (1954) presents the technique in detail and can be used readily for application. The theory supposes that the magnitude of extreme flow events increases with the logarithm of observation time. Such a distribution fit through observed data allows the definition of a return period for extreme values. This concept does not state that the specific value is the largest value to be obtained at a certain time, but only that it is the most probable largest value to be obtained within a certain time and gives limits within which this value may be expected to lie, with a certain probability.

The procedure is to section the record into N segments of length ΔT, select the largest value of each segment and order the new set by increasing magnitude. For this new data set a mean cumulative probability function, $P(s_m)$, is calculated for each ranked speed, s_m;

$$P(s_m) = \frac{m}{N+1} \tag{1}$$

The probability of the m^{th} speed equaling or exceeding other speeds of the set thus is equal to $P(s_m)$. A return period, T_R, may be defined for the m^{th} speed as:

$$T_R(s_m) = \frac{\Delta T}{(1-P(s_m))} \tag{2}$$

Significance of the return period is such that on the average, a speed s_m or greater will occur once every $T_R(s_m)$ days. Assuming the data follow the proposed logarithmic distribution, extreme speeds should vary linearly with a logarithmic function of $P(s_m)$. Gumbel's model for the logarithmic function is called the reduced variate, Y:

$$Y = -\ln(-\ln(P(s))) \tag{3}$$

A straight line can be fit through these data using least squares methods; from the equation for that line, expected extreme speed as a function of return period and segment length can be calculated:

$$s = A+B\cdot Y = A+B\cdot(-\ln(-\ln(1-\Delta T/T_R))) \tag{4}$$

A measure of the fit of these data to the probability distribution can be determined from the calculated linear correlation coefficient, r. The percentage of the total variation of the expected speeds that is accounted for by the linear relationship with the observed speeds can be estimated as $100\ r^2$. Further, the confidence intervals can be computed using Student's t distribution. For our data the confidence interval was chosen for a 95% level of significance.

There are several important restrictions to the technique that require attention and make interpretation of the analysis for a small data set such as represented by the Alaska current meter data, somewhat tentative. The application of statistical theory of extreme values is ideally suited to a large data set covering many years such as occurance of flood conditions in streams. For the Alaska current meter data we have one year of data with many storm events producing extreme flow during that year. The question immediately arises about the representativeness of the extremes in this year. While conclusions based on one year of data offer guidelines, it must be remembered that additional data may modify actual values somewhat. Since obtaining long time series of current meter data is at best difficult, it is worth stretching this technique to the limit to examine the typical ranges likely to be encountered in further observations.

Another important restriction is that the data extremes represent independent events. Since extremes are likely to result from storm events this restriction can be ameliorated by examining the extremes in segments of the record coincident with storm frequency. Major storm activity during this period in the Gulf of Alaska is reported to have an average period of roughly 5 days (Hayes and Schumacher, 1976). In application, the technique is fairly insensitive to the segment length, and our analysis shows almost no difference using 3, 4, 5 or 7 day elements.

With these restrictions in mind, extreme value analysis was applied to the Gulf of Alaska data. Figure 4 shows the speed data for levels 50 m and

100 m of station 62 in such a representation. Extreme values are along the ordinate with return period in days along the abscissa. The fit of each line has a correlation greater than 0.99. Since these levels had records longer than 12 months, stability of these data fits were examined by varying the record length from 9 to 15 months and moving the start times. For records less than 11 months the distribution became unstable with discrepancies introduced in the slope and intercept of the fitted curves induced by changing record length or start time. This suggests that an observation covering an entire year is fairly representative of the extreme conditions.

If one remembers the limitations imposed by representativeness of the sample and proper interpretation of the return period concept it is possible to extrapolate these data and estimate the extreme values likely to occur over longer periods. For example, the data at the 50 m level suggest that with a return period 5000 days we are likely to observe an extreme speed of around 112.2 cm/sec within ± 2.4 cm/sec. Similarly, extreme flow at 100 m is likely to be 99.6 cm/sec ± 1.9 cm/sec for the same period of 5000 days.

Depth dependence

Webster (1969) suggested that the vertical profile of mean speed has a power law dependence on depth. Were this situation universal, extreme speeds might similarly show this power law dependence. Unfortunately, records from the 20 m and 175 m levels were not continuous for an entire year. However, by comparing the sections of those records which were concurrent with the records from the 50 m and 100 m levels, an approximation of the differences in the slopes and intercepts of the respective lines was obtained. It was then possible to estimate what slopes and intercepts of the top and bottom records may have been, had they been concurrent with the records from the 50 m and 100 m levels for an entire year. Once these estimates were made, it was possible to examine the behavior of the entire water column to extreme flow events.

To test the hypothesis of power law depth dependence, logarithms of the slopes (coefficients A), and similarly intercepts (coefficients B), of the observed and estimated straight lines, fit through the year long records of extreme values of all four measured levels, were plotted versus the logarithm of depth of that observation. These data and the least square fit lines through them are shown in the upper left inset of figure 4. The fit of each line through its four points is good with a correlation coefficient of greater than 0.99.

This suggests that the power law dependence proposed for mean speed can be extended to extreme values as well. Further, a station with two current meters maintained at a site for a year might be usable to predict extreme events at other levels of the water column as well as projected extreme values solely at the level of observation. This uniform behavior is likely to break down near the surface and bottom boundaries where external forces become important.

The data from station 62 allows calculation of the coefficients of equation 4:

$$A = 83\ Z^{-0.22}\ ;\ B = 23\ Z^{-0.18}$$

where Z is the depth in meters. Using this model then, for a return period of 5000 days, the expected extreme value at 10 m would be 155 cm/sec. This estimate is made for data beyond the period of observation and at a level where no observations were made. Consequently, the error limits on this value are larger than for the previous estimates. A confidence interval may be estimated by vectorially summing the confidence intervals of the A and B coefficients. For a 95% confidence interval this gives an upper bound of 175 cm/sec and a lower bound of 138 cm/sec.

Conclusions

Extreme value analysis can be used to characterize current meter observations that are comprised of records for a year or longer. Further, the technique allows estimates of extreme flows probable in longer time intervals and thus allows practical estimates of extreme flow ranges.

Extreme flow appears to have a power law dependence with depth. Using a simple model of this behavior it may be possible to characterize the range of flow throughout most of the water column from data at two observation levels.

Acknowledgements

This work was supported in part by the U.S. Bureau of Land Management through a grant administered by the Outer Continental Shelf Environmental Assessment Program Office, NOAA. Our thanks go to H.O. Mofjeld who offered valuable suggestions on the structure of this paper.

References

1) Dodimead, A.J., F. Favorite and T. Herano, Review of Oceanography of the subarctic Pacific Region, *In* Salmon of the North Pacific Ocean, Bull. Intl. N. Pac. Fish. Comm. 13, 195 pp., 1963.

2) Dodimead, A.F. and G.L. Pickard, Annual changes in the oceanic-coastal waters of the eastern subarctic Pacific, J. Fish. Res. Bd. Canada, 24, 2207-2227, 1967.

3) Gumbel, E.J., Statistical Theory of Extreme Values and Some Practical Applications, NBS Applied Mathematics Series 33, 51 pp. 1954.

4) Hayes, S.P. and J.D. Schumacher, Preliminary description of circulation on the continental shelf in the N.E. Gulf of Alaska: Feb-May 1975, In Press, 1976.

5) Royer, T.C., Seasonal variations of water in the northern Gulf of Alaska, Deep-Sea Res., 22, 403-416, 1975.

6) Webster, F., Vertical profiles of horizontal ocean currents, Deep-Sea Res., 16, 85-98, 1969.

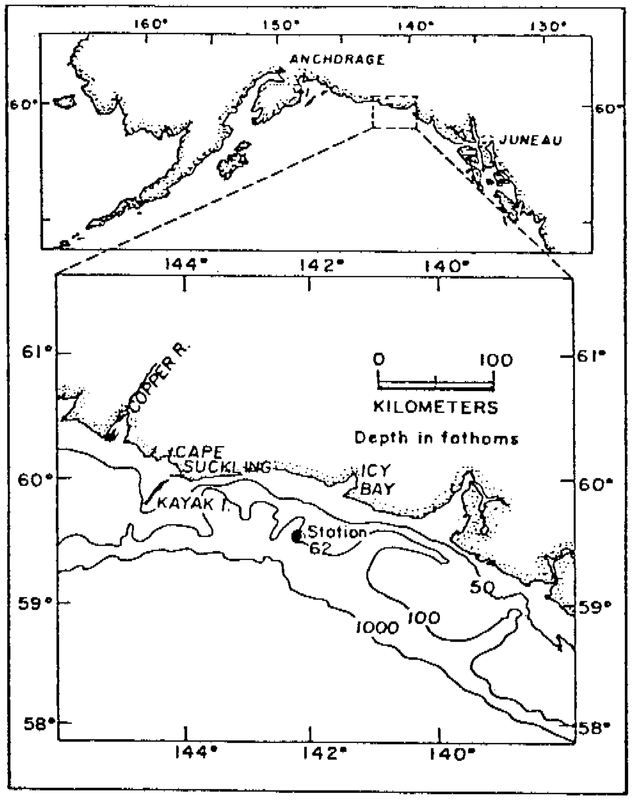


Figure 1. Location of current meter station 62 in the Northeast Gulf of Alaska.

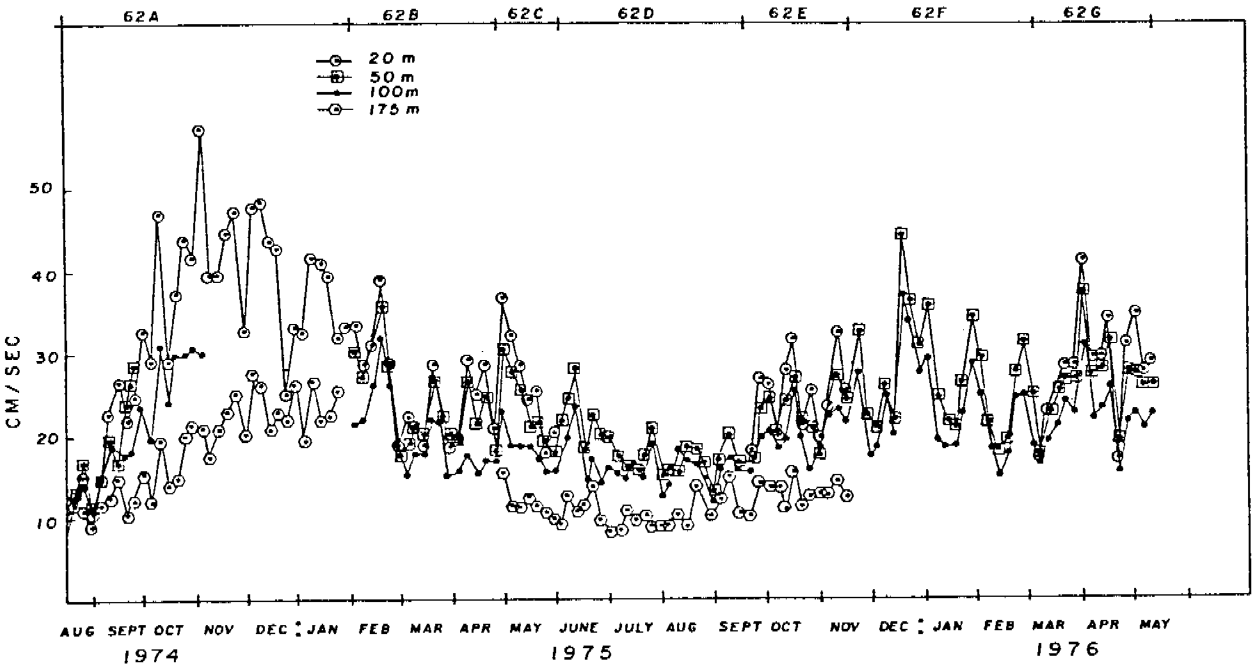


Figure 2. Five-day speeds for all available data from station 62 from August 1974 through May 1976. Data from the 50 m and 100 m current meters were continuous from February 1975 through May 1976. Mean speeds were higher in winter than in summer.

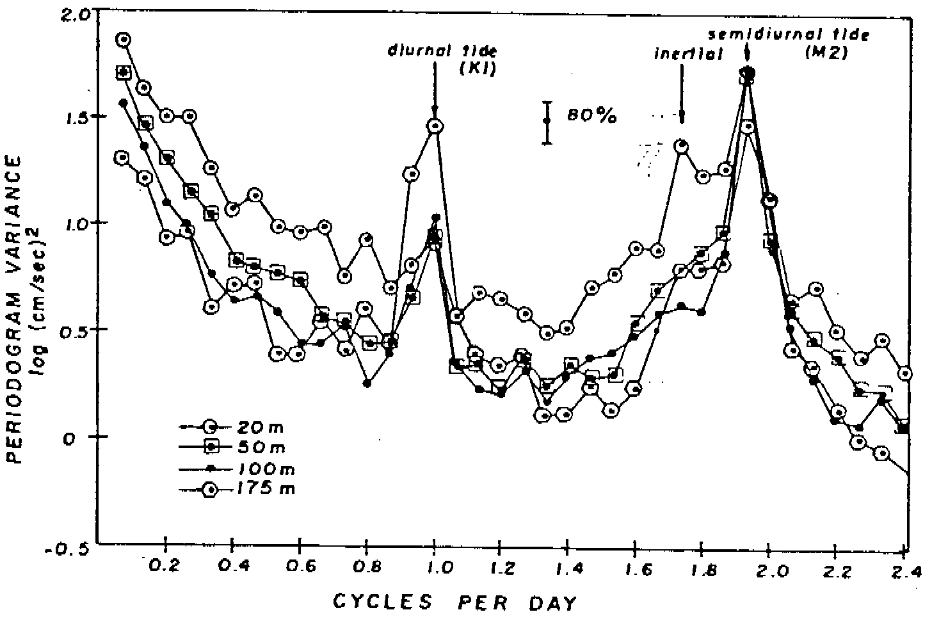


Figure 3. Ensemble averaged energy spectra for the station 62 data. Tidal and inertial frequencies are denoted. Energy is given by logarithm of periodogram variance.

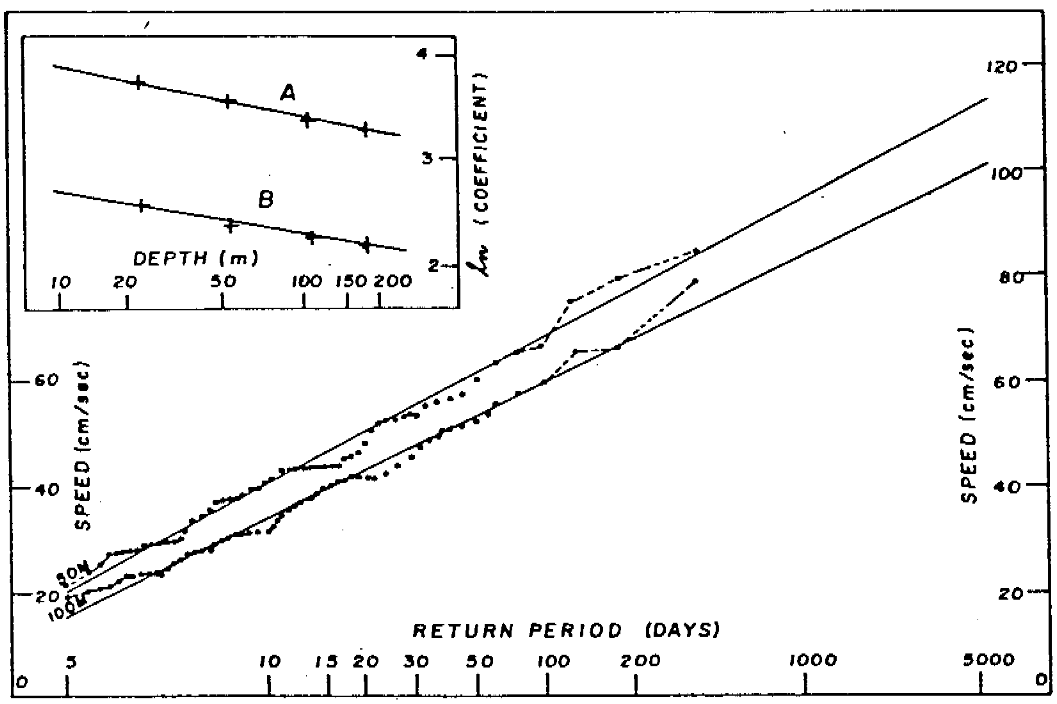


Figure 4. Fits of the ranked extreme speeds for 12 months of the 50 m and 100 m data to the "reduced variate" Y, where Y is a function of return period (see text). The inset shows fits of the observed and estimated coefficients A (intercept) and B (slope) of with the four observed depths on a log-log scale.

RU# 140

NO REPORT AVAILABLE AT THIS TIME

QUARTERLY REPORT

Contract No.:
R7120849

Research Unit Nos.:
141, 145, 148

Reporting Period:
1 July 1976 - 30 September 1976

Number of Pages:
57

Bristol Bay Oceanographic Processes
(B-BOP)

J.D. Schumacher
Pacific Marine Environmental Laboratory

L.K. Coachman
Department of Oceanography
University of Washington

20 September 1976

Task Title: BRISTOL BAY OCEANOGRAPHIC PROCESSES (B-BOP)

PI: Dr. James D. Schumacher
NOAA/PMEL
3711 15th Avenue N.E.
Seattle, WA 98105

Dr. L.K. Coachman
Department of Oceanography
University of Washington
Seattle, WA 98195

Report Period 1 July - 30 September 1976

I. Task Objectives:

1) Determine spatial and temporal variability in the velocity-field and obtain indications of spatial coherence at various length scales across Bristol Bay.
2) Determination of sea level perturbation time and length scales.
3) Examination of meteorological factors related to observed pulses in mean flow.
4) Characterization of temporal and spatial variability of hydrographic properties.

II. Field and Laboratory Activities:

A. Cruises: See attached cruise reports.

III. Results:

Data from mooring BC-3B (3/16/76-5/29/76) have been processed and sent to the OCSEAP Juneau Project Office.

IV. Preliminary Interpretation of Results:

A scientific paper titled, "Fine Structure Instability in Outer Bristol Bay" by L.K. Coachman and R.L. Charnell, based on the 10-23 March 1976 CTD data has been submitted to Deep Sea Research for publication (see attachment).

Cruise Report RP-4-MW-76C - Leg II

MOANA WAVE

I. Itinerary

8/3 - 1800 Departed Kodiak
8/5 - 2000 Arrived working area
8/7 - Electrical problems began
8/9 - Electrical and navigational problems had become severe enough that return to Kodiak was ordered.
8/12 - 1015 Arrived in Kodiak

II. Narrative

The success of the cruise was marred by the problems which developed. Apparently a number of them were corrected by the time the ship arrived in Kodiak. However, the technicians working on the problems were still finding some although I do not know the seriousness of them.

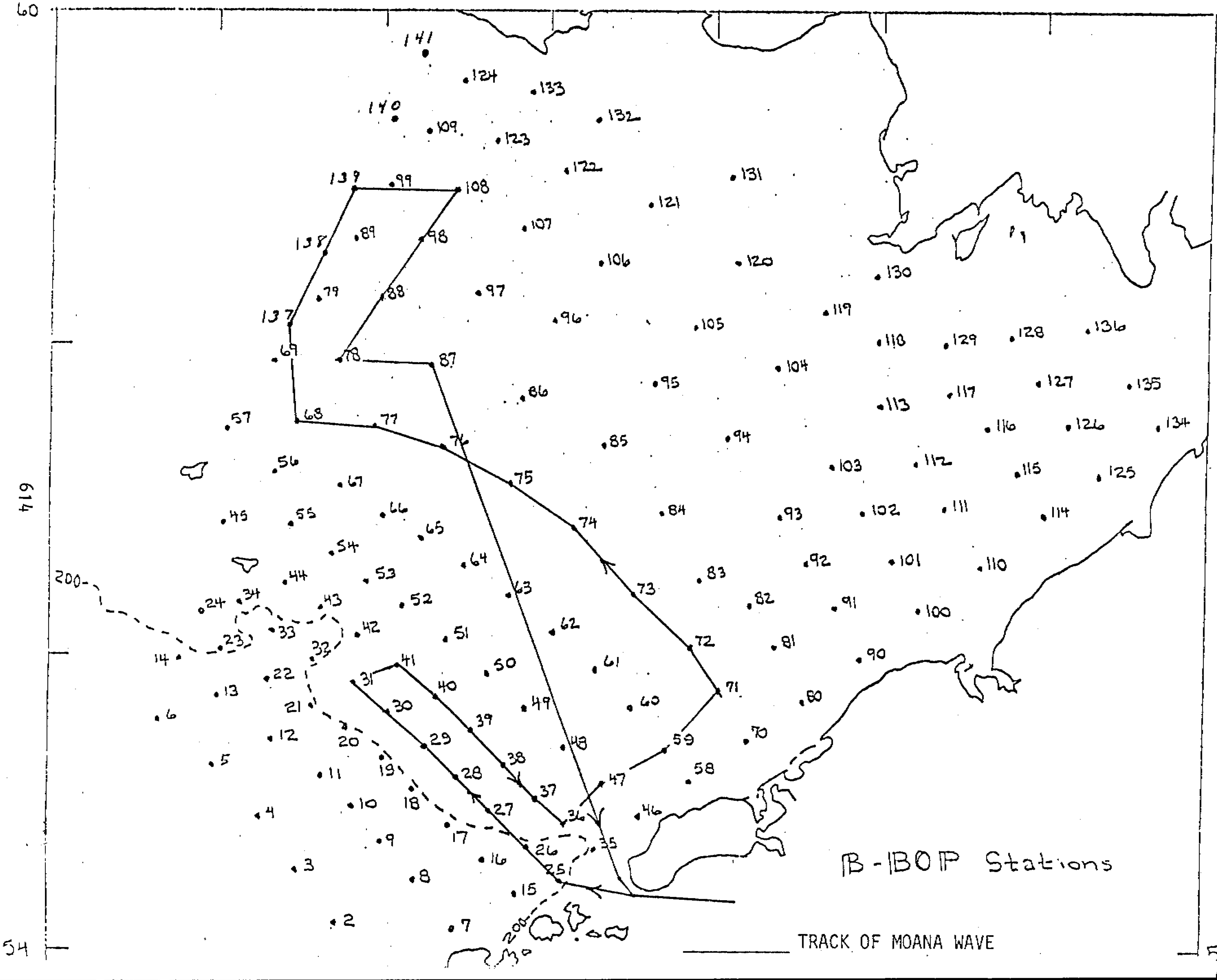
It appeared that the magnetic tape containing the CTD data could not be read because of parity errors occurring on records made early in the cruise. However, Scott Raaum of PMEL has been able to recover nearly all the data on the tape.

III. Personnel

Andrew Anschell	Mammal Observer	NMF and WS
Steven Harding	Technician	U of W
James Haslett	Chief Scientist	PMEL
Dale Ripley	Technician	U of W
Kevin Uhlinger	Technician	U of W

IV. Attachments

1. List of CTD stations occupied.
2. Chartlet of B-BOP grid showing cruise track.


60
54
200
B-BOP Stations
TRACK OF MOANA WAVE

B-BOP Station Grid

25	54-29	165-47
26	54-42	166-10
27	54-57	166-38
28	55-11	167-03
29	55-24	167-26
30	55-37	167-54
31	55-49	168-19
36	54-52	165-44
37	55-03	166-05
38	55-17	166-28
39	55-30	166-53
40	55-44	167-18
41	55-56	167-46
47	55-08	165-16
59	55-23	164-31
68	57-31	169-02
71	55-46	163-54
72	56-04	164-14
73	56-24	164-56
74	56-50	165-40

75	57-07	166-27
76	57-21	167-16
77	57-29	168-06
78	57-54	168-31
88	58-18	168-00
98	58-39	167-34
108	58-57	167-08
137	58-05	169-04
138	58-32	168-42
139	58-58	168-19

University of Washington
Department of Oceanography
Seattle, Washington 98195

PRELIMINARY REPORT

R/V *ACONA* CRUISE 233

Bristol Bay Oceanographic Processes

2-13 August 1976

by

Thomas H. Kinder

NOAA Contract 03-5-022-67 TA 4

Approved by:

L. K. Coachman, Professor
Principal Investigator

Francis A. Richards, Professor
Associate Chairman for Research

Ref: M76-70

BRISTOL BAY OCEANOGRAPHIC PROCESSES (B-BOP)

1. Objectives

This study is a joint program with the Pacific Marine Environmental Laboratory (PMEL), Environmental Research Laboratories (ERL), NOAA to provide water mass and circulation information over the southeastern Bering Sea Shelf region for the Outer Continental Shelf Environmental Assessment Program (OCSEAP). Originally, the specific objective of the mid-summer field program was to occupy all stations on the B-BOP grid quasi-synoptically using two ships. However, limited ship time precluded adequate coverage of the entire area. Instead, the boundary region between Bering Sea Water (AS) and Shelf Water (CW) (see, e.g., B-BOP Annual Report by J. D. Schumacher and L. K. Coachman, 1976) was intensively surveyed by R/V *Acona* and R/V *Moana Wave*. Because the historical and B-BOP data indicate that this boundary lies along the southern continental shelf, long transits to and from Unimak Pass (or Dutch Harbor) were avoided and the limited ship time could be utilized efficiently.

2. Cruise Track and Narrative

The scientific party arrived at Dutch Harbor, Alaska at about 2300 2 August 1976 and departed about 1240 3 August 1976 aboard R/V *Acona*. (All times herein are GMT.) The first STD station (B-BOP grid number 15) was occupied at 1330 3 August. The STD grid was covered as shown in the Figure without interruption until the last station (designated B-BOP 60.18) at 1056 10 August; thence *Acona* departed the Bering Sea via Unimak Pass and arrived in Seward, Alaska at 1730 13 August where the scientific party debarked.

In order to provide increased spatial resolution, stations between B-BOP grid points were occupied and designated with the same number as the previous

B-BOP station, plus a decimal. Thus, if two intermediate stations were occupied after B-BOP station 42, they would be designated 42.1 and 42.2. Stations were occupied in the same sequence as listed in the Table (also see Figure).

3. Methods

Each STD station consisted of a cast to within 3 m of the bottom (or as close as the sea state and bottom slope would permit) with a Model 9040 Bissett-Berman STD. Data was recorded by a Plessey Model 8114 Digitizer on seven-track magnetic tape for processing in Seattle. A Nansen bottle with two protected reversing thermometers was attached above the STD sensors for calibration on each cast. Replicate salinity samples were analyzed on board using either an Autosal Model 8400 or a Bissett-Berman Model 6230N salinometer.

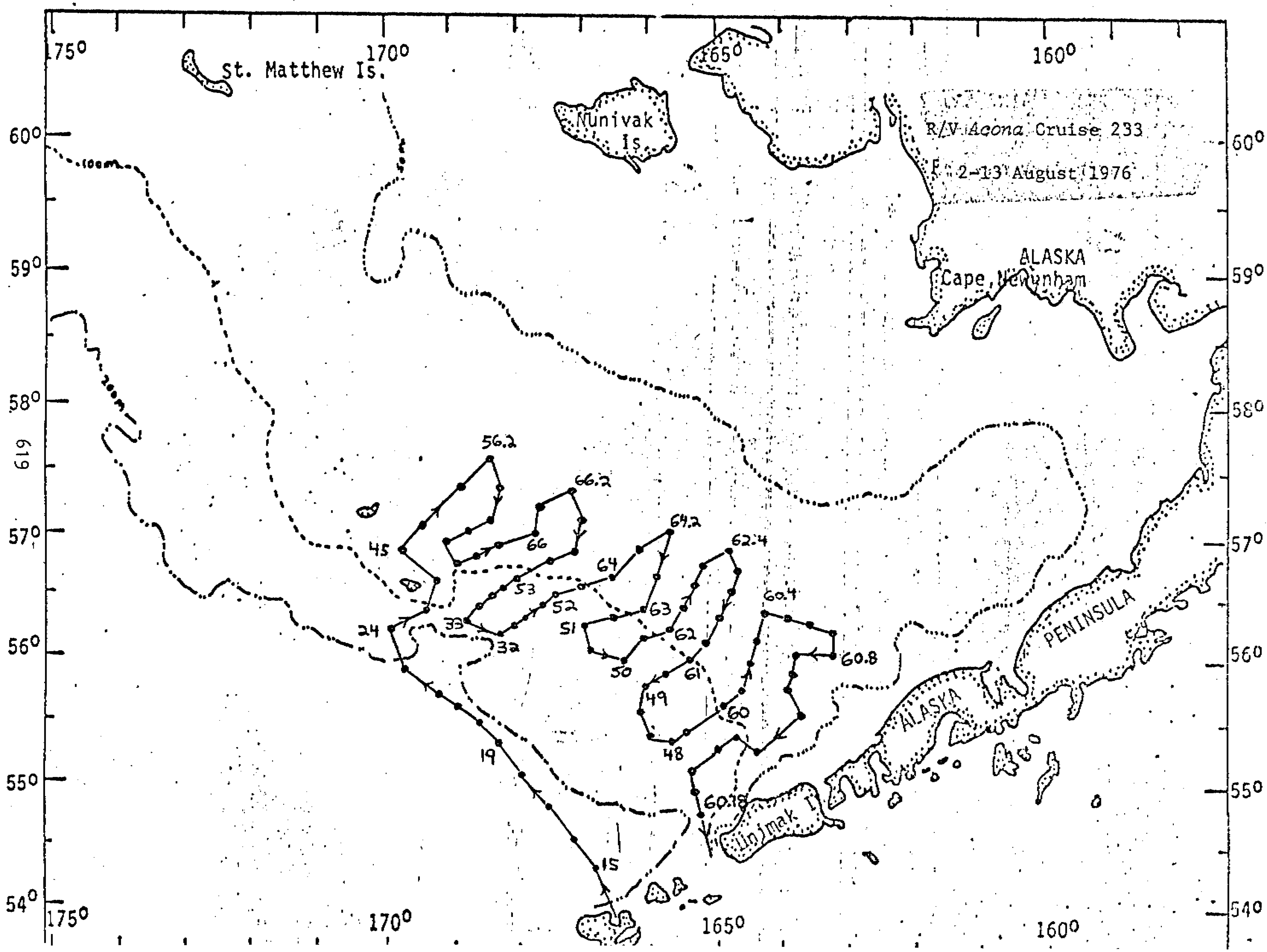
4. Personnel

L. K. Coachman	Professor, Chief Scientist	UW
T. H. Kinder	Student	UW
B. J. Glantz	Student Helper	UW
J. D. Severn	Student Helper	UW
F. L. Waite	Marine Technician	IMS*
K. R. Turner	Master	R/V *Acona*

*Institue of Marine Science, University of Alaska

5. Summary

STD Stations Occupied	85
Salinity Samples	184


R/V Acona Cruise 233
2-13 August 1976
St. Matthew Is.
Nunivak Is.
ALASKA
Cape Newenham
ALASKA
PENINSULA
Unimak I
175°
170°
165°
160°
60°
59°
58°
57°
56°
55°
54°
56.2
66.2
64.2
62.4
60.4
60.8
45
66
64
53
52
51
63
62
61
50
49
60
48
33
32
24
19
15
60.18

TABLE

STD Stations

B-BOP Station	Consecutive Number	Latitude (North)	Longitude (West)
15	1	54-23.0	166-20.0
16	2	54-37.0	166-43.0
17	3	54-08.7	166-24.8
18	4	55-06.0	167-34.0
19	5	55-19.0	167-56.0
20	6	55-31.0	168-22.0
21	7	55-39.0	168-50.0
22	8	55-50.0	169-21.0
23	9	56-02.0	169-55.0
24	10	56-17.0	170-10.0
34	11	56-20.0	169-42.0
44	12	56-30.0	169-09.0
45	13	56-51.0	169-54.0
56	14	57-11.0	169-18.0
56.1	15	57-30.7	168-42.3
56.2	16	57-46.5	168-12.5
56.3	17	57-20.3	168-12.5
67	18	57-06.2	168-29.2
67.1	19	56-52.3	168-49.1
55	20	56-51.0	169-06.0
55.1	21	56-37.5	168-58.3
54	22	56-39.0	168-36.0
54.1	23	56-45.2	168-16.7
66	24	56-55.0	167-58.0
66.1	25	57-04.4	167-36.1
66.2	26	57-06.6	167-04.5
66.3	27	56-56.0	167-11.0
65	28	56-46.0	167-30.0
65.1	29	56-37.8	167-50.5
53	30	56-29.0	168-10.0
53.1	31	56-24.0	168-27.0
43	32	56-19.3	168-44.0
43.1	33	56-15.0	169-01.1
33	34	56-10.0	169-18.0
32	35	55-58.0	168-49.0
32.1	36	56-03.0	168-33.2
42	37	56-08.0	168-17.0
42.1	38	56-15.0	168-00.0
52	39	56-20.0	167-44.0
52.1	40	56-27.6	167-21.0
64	41	56-35.0	166-58.0
64.1	42	56-46.2	166-34.3
64.2	43	56-40.5	166-09.5
64.3	44	56-35.3	166-10.0
63	45	56-24.0	166-26.0
63.1	46	56-15.2	166-49.4
51	47	56-06.0	167-12.0

B-BOP Station	Consecutive Number	Latitude (North)	Longitude (West)
51.1	48	55-52.8	167-05.0
50	49	55-53.0	166-41.0
50.1	50	56-01.7	166-11.7
62	51	56-10.0	165-54.0
62.1	52	56-23.4	165-45.0
62.2	53	56-36.5	165-36.1
62.3	54	56-49.0	165-29.3
62.4	55	56-48.0	165-07.0
62.5	56	56-36.0	164-56.2
62.6	57	56-27.7	164-57.8
62.7	58	56-18.0	165-10.0
62.8	59	56-07.0	165-16.7
61	60	55-55.0	165-24.0
61.1	61	55-49.0	165-46.5
49	62	55-39.5	166-13.0
49.1	63	55-26.8	166-19.0
49.2	64	55-19.5	166.04.0
48	65	55-24.0	165-44.0
48.1	66	55-32.0	165-17.5
60	67	55-40.0	164-50.0
60.1	68	55-51.5	164-45.5
60.2	69	56-03.2	164-40.5
60.3	70	56-15.3	164-35.5
60.4	71	56-26.7	164-30.2
60.5	72	56-15.9	164-11.2
60.6	73	56-05.0	163-53.1
60.7	74	55-54.0	163-35.2
60.8	75	55-40.0	163-33.0
60.9	76	55-54.0	164-14.0
60.10	77	55-44.0	164-18.7
60.11	78	55-35.0	164-26.5
60.12	79	55-25.9	164-06.4
60.13	80	55-13.0	164-39.0
60.14	81	55-24.6	164-59.5
60.15	82	55-18.0	165-19.8
60.16	83	55-10.2	165-40.4
60.17	84	54-58.8	165-30.0
60.18	85	54-47.2	165-20.0

FINESTRUCTURE IN OUTER BRISTOL BAY, ALASKA

L. K. Coachman
University of Washington
Seattle, Washington

and

R. L. Charnell
NOAA/Pacific Marine Environmental Laboratory
Seattle, Washington

ABSTRACT

An STD cruise in Bristol Bay in the Bering Sea during March, 1976 showed the existence of a subsurface layer with large density inversions. This finestructure layer, which covered a horizontal distance of some 100 km, showed a maximum negative density gradient of 55 x $10^{-6}m^{-1}$. Stations showing these inversions were located in the zone of interaction between Bering Sea water and the shelf water of Bristol Bay. The layer appears to form when Bering Sea water, driven by the general circulation of the area and the baroclinic shear across the pycnocline intrudes within the Bristol Bay water near the top of the pycnocline. Calculations using the station data from the area, suggest that these finestructure inversions are in fact dynamically stable and are not greatly altered by vertical diffusion of heat and salt for considerable periods of time.

INTRODUCTION

Several STD cruises have been made in Bristol Bay, Alaska as part of an investigation of transport processes on the continental shelves of Alaska. Data from one such cruise, in March 1976, indicated the existence of an apparently unstable subsurface layer, about 10 m thick, that covered a distance of at least 100 km. This layer, depicted by a density inversion, occurred in the region of interaction between oceanic water at the western edge of the Bristol Bay shelf and coastal water of the Bay itself. We feel that the layer is a clue to the regional exchange processes; description of the layer and its implication are the subjects of this paper.

Gravitational instabilities in the density-stratified ocean, away from the immediate surface layers, are rarely observed. Prior to development of continuous vertical profiling systems, vertical sample spacing from serial oceanographic stations on which to base stability calculations was order 10 m and greater. Based on such data, persistent, large negative values of 10^8E ($E = \frac{1}{\rho}\frac{\delta\rho}{\partial z}$; Hesselberg, 1918) were reported only from shallow (50 m) sub-tropical regions and from near-surface waters of other regions in winter (see, e.g., Neumann and Pierson, 1966). In other than the surface layer, where exchange can modify water properties, serial observations which show instabilities are considered suspect. Cooper (1967), in an investigation of the interaction of Mediterranean water with North Atlantic water in the Bay of Biscay, used a sampling interval of 3 m. He reported temperature and salinity steps with potential density inversions amounting to $0.003\text{-}0.010\sigma_\theta$, but, as pointed out by Pingree (1969), these water columns were still stable over the scale of observation because $\rho_{s,t,p}$ actually increased across the steps.

Development of C-T-D and S-T-D systems has allowed measurement of temperature and salinity on finer vertical scales. Oceanographic literature of the last decade includes numerous reports of vertical profiles with resolutions < 1 m, and with special instrumentation, resolutions of several mm has been achieved (cf. Gregg and Cox, 1971). Fulfilling a prophecy of Cooper (op. cit.), the ocean has been found to contain a great deal of "structure," viz., over scales of 10 to 10^{-2}m relatively abrupt changes in values of temperature and/or salinity are frequently observed. Structure has the form of "steps" or even inversions in property values, and is most frequently encountered in regions of strong property gradients (thermocline and halocline regions) or where two water masses with diverse property values interact. Osborn and Cox (1972) termed the structure with larger (> 1 m) scales "finestructure" and that with vertical scales < 1 m, "microstructure".

Static instabilities in microstructure layers are common. For example, Gregg and Cox (1972) reported a station from the San Diego trough in which 8% of the record over the layer containing microstructure was unstable at separations of 84 cm. Gregg (1976) also reported a number of microstructure records at stations from the equatorial Pacific. In addition to numerous instabilities in the microstructure, one ~80 m vertical section of uniform temperature and low stratification (termed the "thermostad") evidenced numerous instabilities of 1 m scale, though well stratified over scales of 10 m. The reported data are not suitable for estimating the scales greater than 1 m over which the instabilities may have extended. In all the reports we located only two stations with static instabilities extending over layers significantly > 1 m, both reported in Gregg and Cox (1972). In a personal communication, M. C. Gregg informs us he has found three or four other cases. The statistics of the most unstable published case, a station from the San Diego trough, are:

TABLE 1

Depth interval, m	Between depths, m	$10^5 \frac{\Delta\sigma_t}{\Delta z}$, m^{-1} *
1	224.5-225.5	-1600
2	223.5-225.5	-500
3	222.5-225.5	-300
5	220.5-225.5	-40

The oceanographic setting for the station was not reported, so we cannot interpret whether this instability was due to a strong lateral advective intrusion of a different water mass or an unusual vertical extension of what is normally microstructure activity. The unstable layer was immediately underlain by a layer of water markedly warmer and more saline.

In cases where the structure is larger than 1 m and clearly due to lateral advection, layers always appear to be density-compensated. For example, in the classic example of Mediterranean water interaction with Atlantic water there are numerous temperature and salinity inversions traceable over 10's of km, but they are always density-compensated on scales > 1 m such that the water columns are stable (Pingree, 1971; Howe and Tait, 1972; Elliott, Howe and Tait, 1974). We have found only one case, in an embayment, which evidenced a significant instability based on a static criterion. Ebbesmeyer (1973) documented the formation and subsequent history of extra-dense parcels of water intruding into Dabob Bay, Washington. The larger

*We will throughout approximate 10^8 E by $10^5 \frac{\Delta\sigma t}{\Delta z}$ which is sufficiently accurate for the shallow depths and large values of instability with which we are dealing (Sverdrup, et al., 1942).

parcels (vertical scales of 30-40 m) showed, on a finer scale (1-10 m), frequent instabilities of 0.01-0.02 σ_t. The largest observed instability was ~0.1 σ_t over 10 m, equivalent to 10^8 E ≈ -1000 m^{-1}, and persisted for order of one week.

Vertical structure seemingly can be caused by a variety of processes. One possibility is breaking internal waves (Garrett and Munk, 1972). Hayes, Joyce and Millard (1975), in an examination of finestructure in MODE data, noted that on scales smaller than 10 m in the main thermocline the characteristic signatures of sheets and layers began to appear. Spectral analysis showed the probable causal agent to be high wave number internal waves. Hart (1971) hypothesized, based on model experiments, that internal waves propagating over a slope might form layers with inverted density gradients on scales different from those created by viscous action, especially if the slope is a characteristic for the internal wave. Another proposed mechanism is an active turbulence phenomenon termed "billow" turbulence (Woods and Wiley, 1972) in which energy is presumably derived from a shear other than that associated with a wave motion.

In the open ocean away from direct bathymetric influences, finestructure frequently occurs where water masses of diverse characteristics interact. Lateral advection along isopycnal surfaces appears to be a dominant process (Hayes, 1975). Possible combinations of water masses that could produce finestructure laminae were postulated by Stommel and Fedorov (1967), and one case was added by Pingree (1969). These all involve lateral advection and interleaving of various combinations of warm, saline and cool, less saline water. In most reported cases the horizontal extent does not appear to be great (a few km at the greatest, see Roden, 1971; Gargett, 1975). The laminae of 5- to 10- m thickness reported by Stommel and Fedorov (1967) from the South Pacific with a total range of 20 km and certain layers in the Mediterranean outflow continuous over ~50 km (Elliott, et al., 1974) appear to be relatively rare exceptions.

In the smaller vertical scale range, various other phenomena can be responsible for structure, all of which are tending to smooth gradients and dissipate turbulence. Examples are double-diffusive phenomena like salt-fingering (see, e.g., Turner, 1967; Tait and Howe, 1968; Johannessen and Lee, 1974) and its inverse (cool water above warm and more saline water; Neshyba, et al., 1971; Gregg and Cox, 1972).

We conclude that there is a physical basis for Osborn and Cox's (1972) separation of structure into "finestructure" and "microstructure". As noted by Roden (1971), at low wave numbers buoyancy forces dominate and the vertical density stratification tends to remain stable even after disturbance by internal waves and other types of motion, whereas at high wave numbers the buoyancy forces become subordinate to heat and salt diffusion effects. The boundary is the approximate maximum vertical range of influence of the dissipative phenomena. Gargett (1976) concluded from analysis of many data from a towed vehicle that there was such a break-over point, and it was "roughly a meter". Even though much structure is created of order 1-10 m this is gravitationally stable, and it is only after the layers and laminae have begun to breakdown, utilizing in part energy derived from vertical shear (internal wave or other) or even horizontal shear (Pingree and Plevin, 1972) are significant instabilities observed, and then the vertical scales are only rarely greater than 1 m.

The criterion normally used to decide the state of stability is $E \gtrless 0$, the static criterion. Lord Rayleigh (1916) pointed out that dynamic regimes with $E < 0$ could be stable, and Neumann (1948) developed the criterion

$$-E \geq \frac{\Lambda_o A^2}{\rho g h^4}$$

to define neutral stability, where $\Lambda_o = 1.1 \times 10^3$, A^2 is the product of the eddy viscosity and eddy conductivity, and h the layer thickness. Table 2 presents values of $10^8 E$ based on this criterion for vertical separations of 1 to 5 m and eddy coefficients of 1, 10 and 100 c.g.s.

TABLE 2

$10^8 E$, m^{-1}, of neutral stability for various vertical separations and eddy coefficients

Z(m) \ A(c.g.s.)	10^2	10	1
1	-1.1×10^6	-1.1×10^4	-112
2	-7×10^4	-702	-7
3	-1.4×10^4	-140	-1.4
4	-4400	-44	-0.4
5	-1796	-18	-0.2

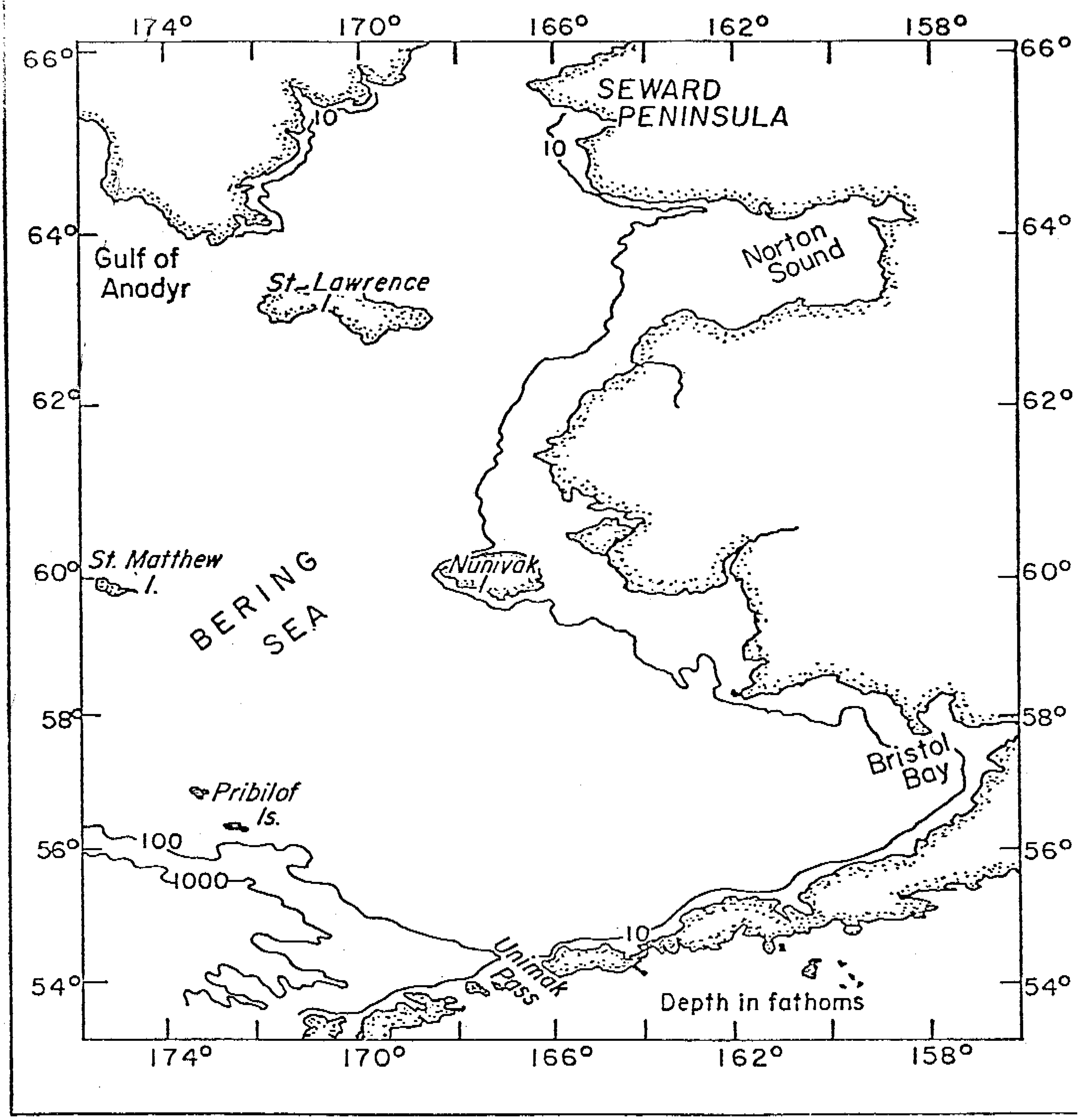
In dynamic regimes with vigorous eddy fluxes, 10^6 E for neutral stability, particularly at smaller vertical separations, could take on large negative values. Or, in other words, the regime could support large negative density gradients (inversions) without being unstable. We conclude that the microstructure-sized phenomena frequently reported unstable based on a static stability criterion may well be dynamically stable. It also seems possible that, if Neumann's criterion has validity, laminae, layers or patches of fine-structure scales which show appreciable gravitational instability but are dynamically stable could be formed under oceanic conditions. However, with the exception of Dabob Bay, we cannot find any reports of significant fine-structure-sized density inversions.

OCEANOGRAPHIC SETTING

It is apparent from the foregoing that large density inversions are rare in the world's oceans. Existence of large density inversions in Bristol Bay suggest that this may be a region where a particular combination of factors leads to significantly unstable water columns persistant over large distances and long times. To describe formation and persistance of the layer it is necessary to understand the oceanography of outer Bristol Bay.

Bristol Bay is the southeasternmost portion of the very large continental shelf of the eastern Bering Sea (Figure 1). It is bounded on the south by the Alaska Peninsula and on the east by the Alaskan coast north to Nunivak Island. A line connecting Nunivak Island with the Pribilofs makes a convenient northern boundary. The western (seaward) boundary is the shelf break and slope, which runs northwest from Unimak Pass, the easternmost pass in the Aleutian chain, to the Pribilofs. The observation area in this paper is outer Bristol Bay, extending from Unimak Pass to the Pribilofs and onto the shelf approximately 200 km.

The shelf of outer Bristol Bay is very flat and uniform, with only a


174°
170°
166°
162°
158°
66°
64°
62°
60°
58°
56°
54°
SEWARD
PENINSULA
10
Gulf of
Anadyr
St. Lawrence
I.
Norton
Sound
St. Matthew
I.
BERING
SEA
Nunivak
I.
Bristol
Bay
Pribilof
Is.
100
1000
Unimak
Pass
Depth in fathoms

gradual deepening seaward to the 150 m isobath. The positions of the 150- and 200 m isobaths mark the shelf break, seaward of which lies an abrupt continental slope. The slope shows two indentations: the northerly one, immediately south of St. George Island (southernmost of the Pribilofs), is Pribilof Submarine Canyon, and the southern one, just north of Unimak Pass, is Bering Canyon. These are two of the world's largest known slope valleys (Scholl, et al., 1970) but their presence is evidenced only in the deeper bathymetry; no trace of Bering Canyon can be seen landward of the 150 m isobath.

Water masses in Bering Sea were classified by Takenouti and Ohtani (1974). Data used for classification were from continuing cruises of the *Oshoro Maru*, which every June and July since the 1950's has occupied stations on the Bering Sea shelf (Data Record of Oceanographic Observations and Exploratory Fishing, Fac. of Fisheries, Hokkaido University). Though areal coverage has not been systematic and stations have generally been widely spaced (>50 km), the data are suitable for defining water masses, their gross features and distributions.

Three water masses occupy Bristol Bay. Their distribution is shown in Figure 2. They are:

(AS): a relatively saline (32 to $33^{o}/oo$) source water from the Alaskan Stream via Unimak Pass and/or the southeasternmost corner of the deep Bering Sea Basin. At its coldest this water is always relatively warm (3-4°C);

(CA): the resident shelf water of slightly lower salinity ($32.0 \pm 0.5^{o}/oo$), which in summer shows little salinity stratification but is strongly thermally stratified. Temperature of the bottom layer varies considerably year to year (-1° to +2° in June data) but is always the lowest of all water on the shelf; and

(CW): a coastal water, of lowest salinity ($<31.6^{o}/oo$) indicating a direct influence of coastal run-off, and typically either stratified in both temperature and salinity in two layers (warm and fresher above, cold and more saline below) or, in shallow water (<20 m), isothermal and isohaline.

Circulation deduced by Takenouti and Ohtani is denoted in Figure 2 by arrows. Also shown is the approximate position of the southern limit of ice in winter, and an approximate mean position of the $32^{o}/oo$ isohaline in the bottom water (from Maeda, et al., 1968). We have examined all the *Oshoro Maru* data, as well as other, and though we do not agree with their every detail, the general conclusions about water masses and deduced circulation in our area of

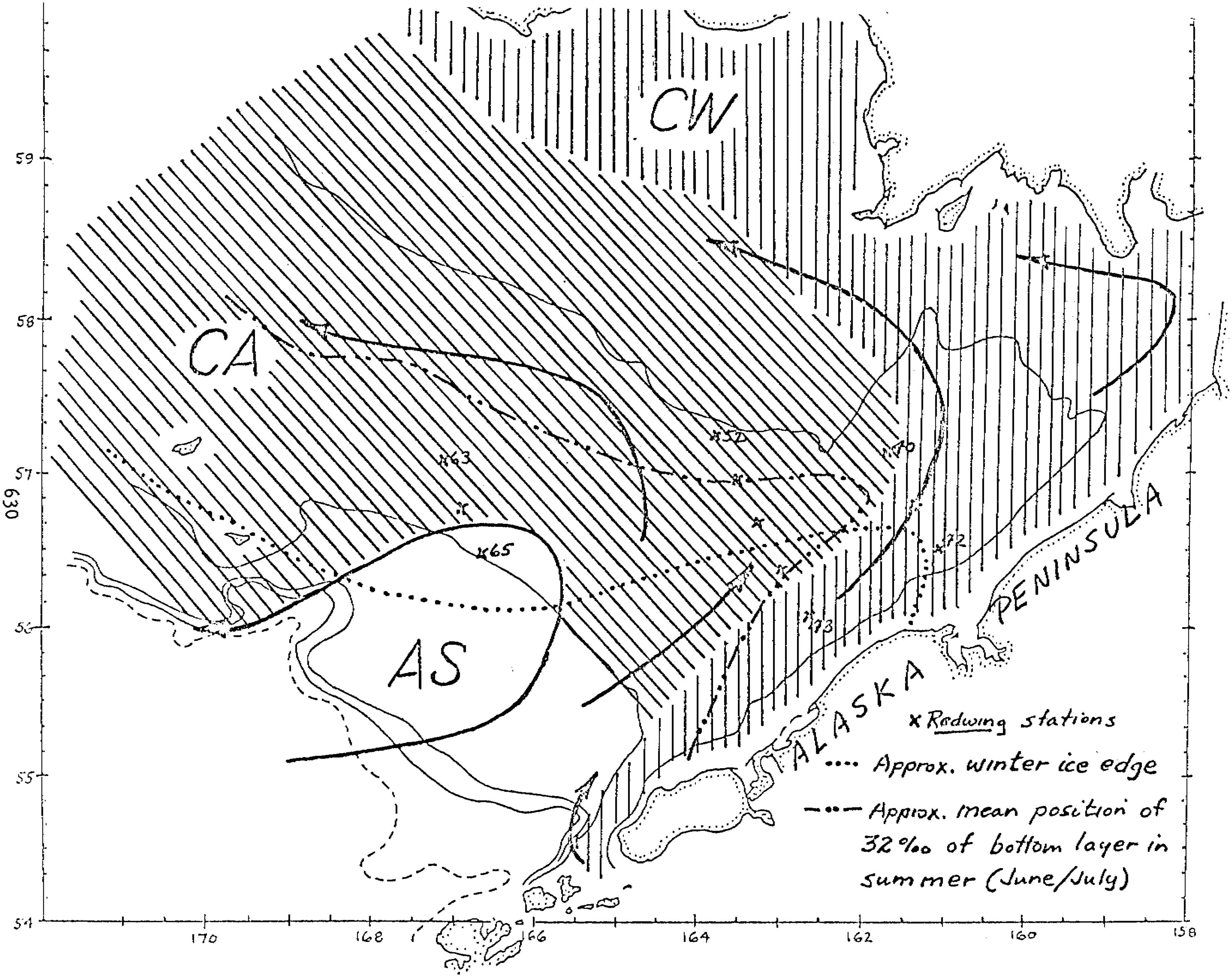
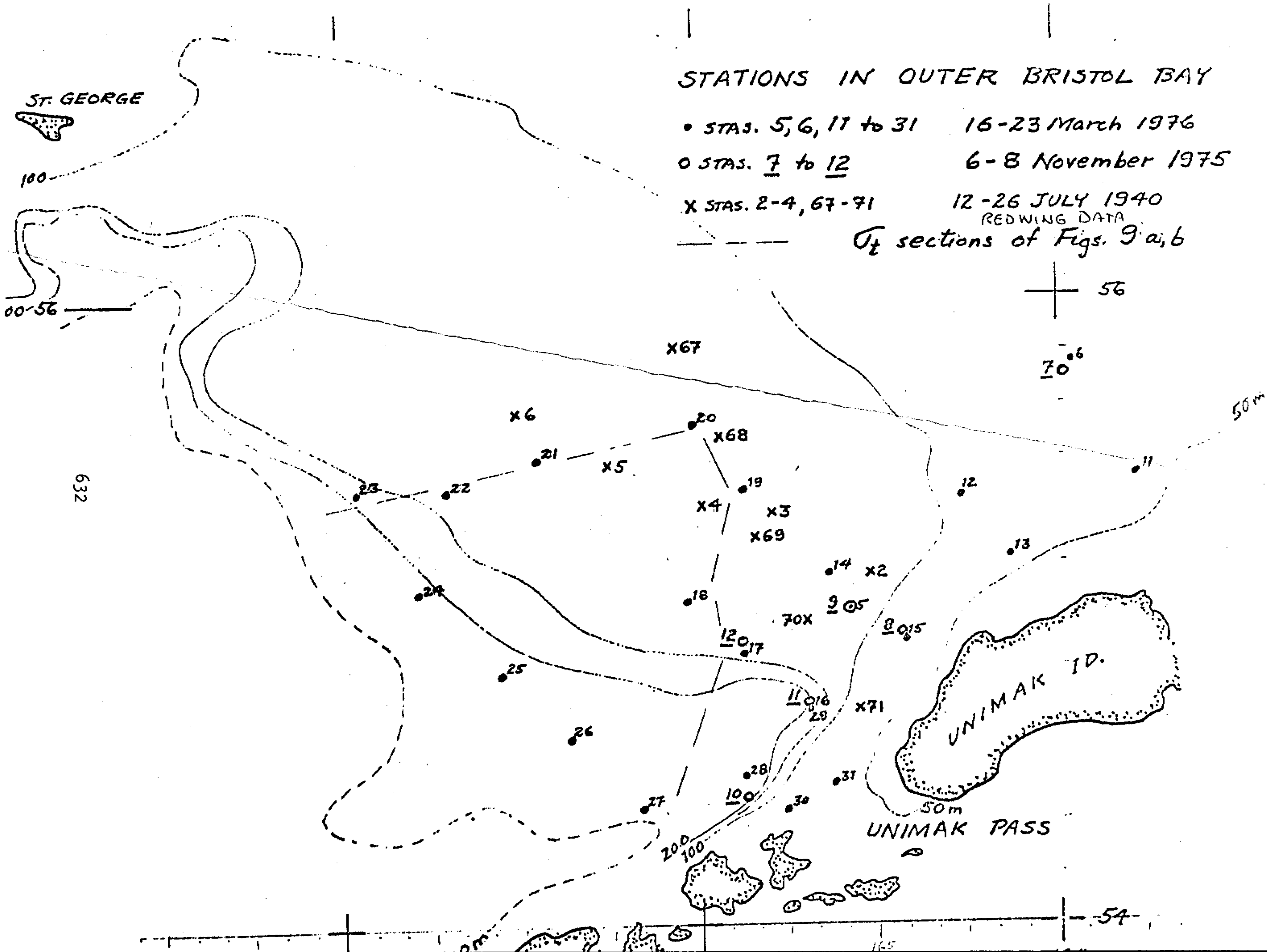

CW
CA
AS
ALASKA PENINSULA
x Redwing stations
.... Approx. winter ice edge
—•— Approx. mean position of 32‰ of bottom layer in summer (June/July)
59
58
57
56
55
54
170
168
166
164
162
160
158
63
65
52
70
72
73

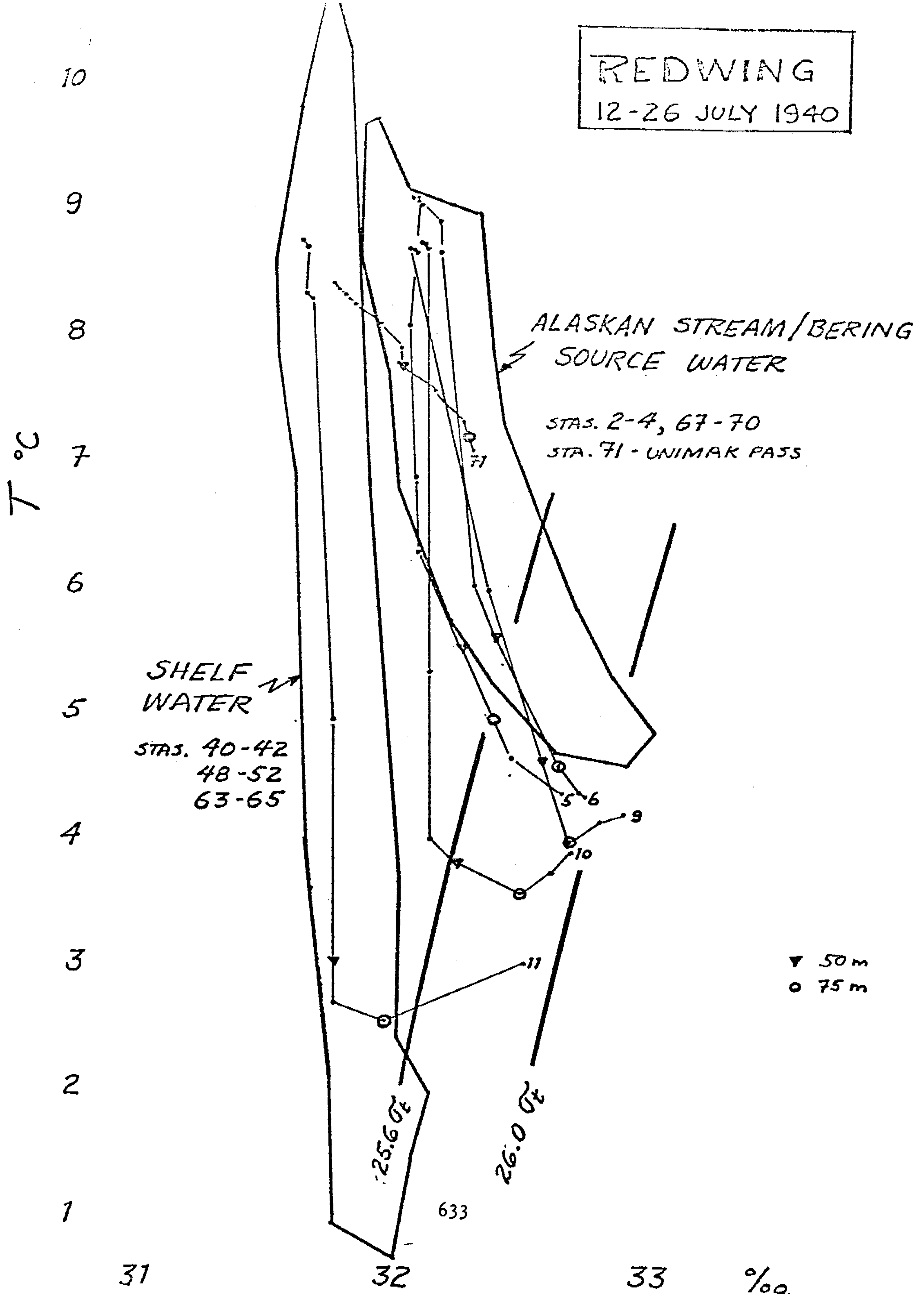
FIG. 2

interest seem correct. In general, Bristol Bay is the site of a more or less continuous influx of a relatively saline and warm source water from the Alaska Stream and the southeast corner of the deep Bering Sea. This water does not enter uniformly across the bay mouth, but rather primarily across the central and southern parts of the entrance. It then progresses toward the head of the bay approximately parallel to the Alaska Peninsula, interacting with resident shelf water enroute. The source water also appears at times to penetrate onto the shelf east of the Pribilofs, but this seems to be an intermittent event.

Interaction of Bering Sea source water with shelf water, the primary physical process occurring in our area of interest, is illustrated by use of data from the cruise of USCGT *Redwing*, 12-26 July 1940 (Favorite, et al., 1961), as this cruise provided the most comprehensive coverage of the outer bay. Location of these stations and the current program's stations are shown in Figure 3. The *Redwing* data were checked against *Oshoro Maru* data from 1963 through 1973 and were found to exhibit representative values of temperature and salinity for summer.

The T-S relationships of selected *Redwing* stations are presented in Figure 4. One envelope was constructed from all stations from the south and central portions of the bay mouth (stas. 2-4, 67-70, and sta. 71 close to Unimak Pass is shown separately). This envelope illustrates the character of pure source water to the bay. The deepest layers of the water column (>100 m) are close to 33°/oo and 4.5°C (in June of other years the deep temperatures were closer to 4°C). The columns then grade upward quite uniformly, without sharp kinks or steps, to surface salinities of ~32°/oo and 8-10°C temperatures. Thus, the source water columns do not have strong pycnoclines, and relatively uniform vertical mixing throughout is suggested. It is interesting to note, however, that the columns do not reflect simple linear mixtures of salt and heat from surface to deep, rather, the station T-S plots from this water mass are almost always curved in the T-S plane in the sense clearly indicated by the envelope (cf. also stas. 5,6). This curvature would seem to be characteristic of this water mass, as it is confirmed in all the appropriate *Oshoro Maru* data. We hypothesize that the curvilinear characteristic prevails because of a slightly more rapid vertical diffusion of heat than of salt. Salt is introduced at the bottom (the deeper, more saline water of the deep Bering Sea) and the source of heat is at the surface (climatic warming in summer). If the vertical flux of heat down is more rapid than the upward salt flux, intermediate points in a T-S presentation will be displaced from positions on the straight line connect-


STATIONS IN OUTER BRISTOL BAY
• STAS. 5, 6, 11 to 31 16-23 March 1976
o STAS. 7 to 12 6-8 November 1975
X STAS. 2-4, 67-71 12-26 JULY 1940
REDWING DATA
— — — σt sections of Figs. 9 a, b
ST. GEORGE
100
00-56
56
50m
UNIMAK ID.
UNIMAK PASS
200
100
-54-



REDWING
12-26 JULY 1940
ALASKAN STREAM/BERING SOURCE WATER
STAS. 2-4, 67-70
STA. 71 - UNIMAK PASS
SHELF WATER
STAS. 40-42
48-52
63-65
T °C
10
9
8
7
6
5
4
3
2
1
31
32
33
‰
25.6 σt
26.0 σt
▼ 50 m
o 75 m
71
5
6
9
10
11

ing source characteristics toward cooler and less saline values.

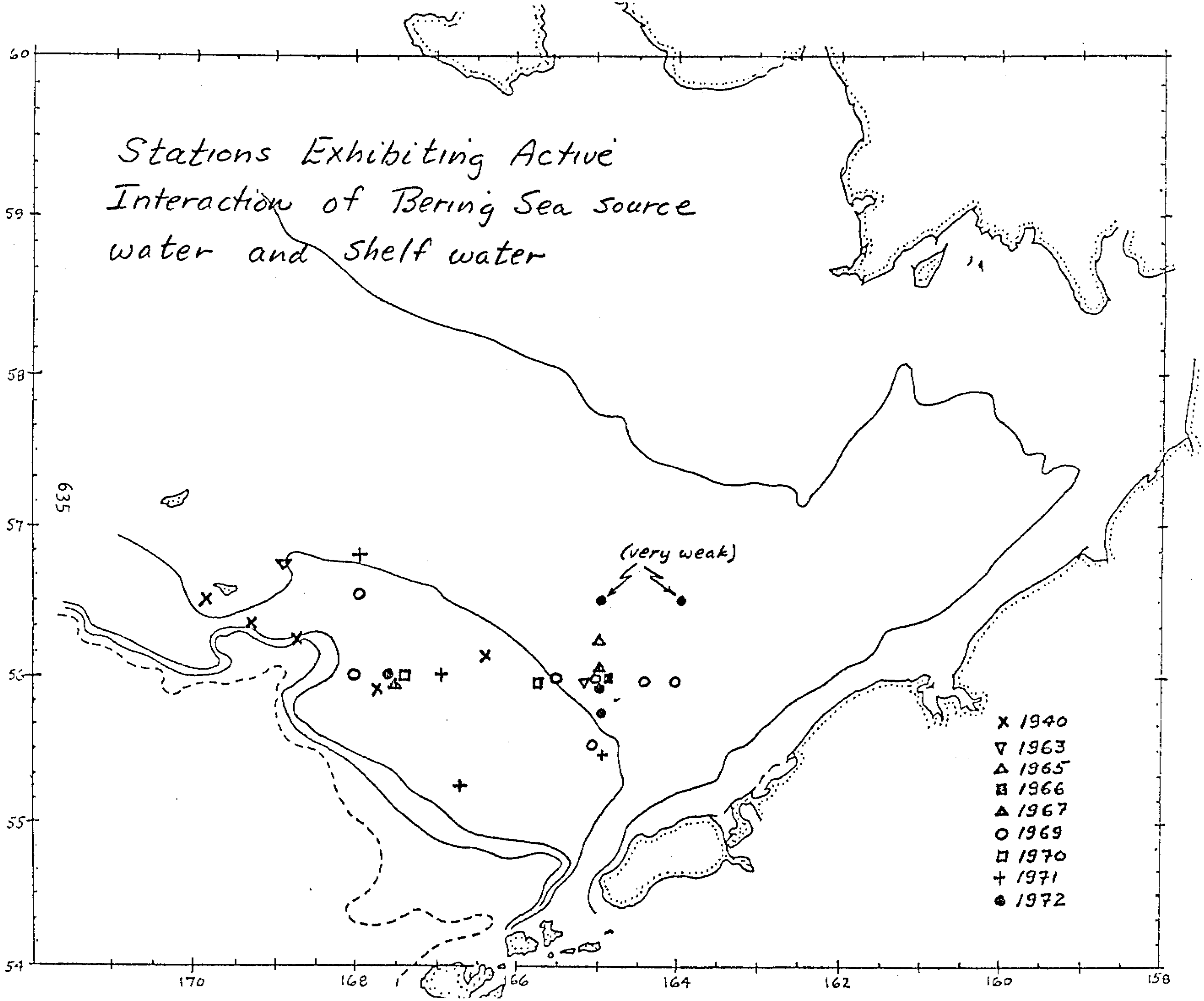
The shelf water envelope of Figure 4 was constructed from stations on the central shelf that showed no direct influence of either coastal water (a trend toward the left in the T-S plane in the near-surface layers) or Bering Sea source water. These water columns are each nearly isohaline, and the total salinity range of the envelope ($\sim 0.5^{0}$/oo) is due to the differing positions of the stations in relation to the general cross-shelf salinity gradient (sta. 52 $\overline{S} \sim 31.5^{0}$/oo, sta. 65 $\overline{S} \sim 32.0^{0}$/oo).

Redwing stations 9-11 are plotted in Figure 4 to illustrate the nature of interaction between these water masses in summer. The hook shape is evidence of layering and preferential lateral mixing, analogous to the interaction in the Gulf of Anadyr of Bering Sea water with shelf water (described and modeled in Coachman, et al., 1975). The denser deep source water tends to layer at the bottom, and its characteristics dominate there, while the less dense bottom shelf water tends to layer above (where its characteristics predominate).

The area over which the two water masses actively interact is not large. In Figure 5 are plotted all stations from *Redwing*, 1940, and *Oshoro Maru*, 1963 through 1973, at which the characteristic hook shape T-S curve was observed. The available data are not sufficient to provide a detailed description of the interaction zone, but we get the impression that the zone appears much like a front oriented in a generally E-W direction across the central outer bay from about the 100 m depth contour to Pribilof Canyon, that it does not have great width (<100 km), but is quite variable in location depending on the amounts and degree of penetration of the Bering Sea source water. Even though Bering Sea water penetrates much further into the bay with the general circulation, it has lost any identifying T-S trace by blending into the resident shelf water, probably because Bering Sea source water is always in limited supply compared with the resident water.

OBSERVED FINESTRUCTURE

For the present project, the temperature and salinity data which exhibit the marked finestructure in outer Bristol Bay were collected during March, 1976, aboard the R/V *Moana Wave*. The data were obtained with a Plessey model 9040,


Stations Exhibiting Active Interaction of Bering Sea source water and shelf water
(very weak)
X 1940
▽ 1963
△ 1965
⊠ 1966
▲ 1967
○ 1969
□ 1970
+ 1971
● 1972
60
59
58
57
56
55
54
170
168
166
164
162
160
158

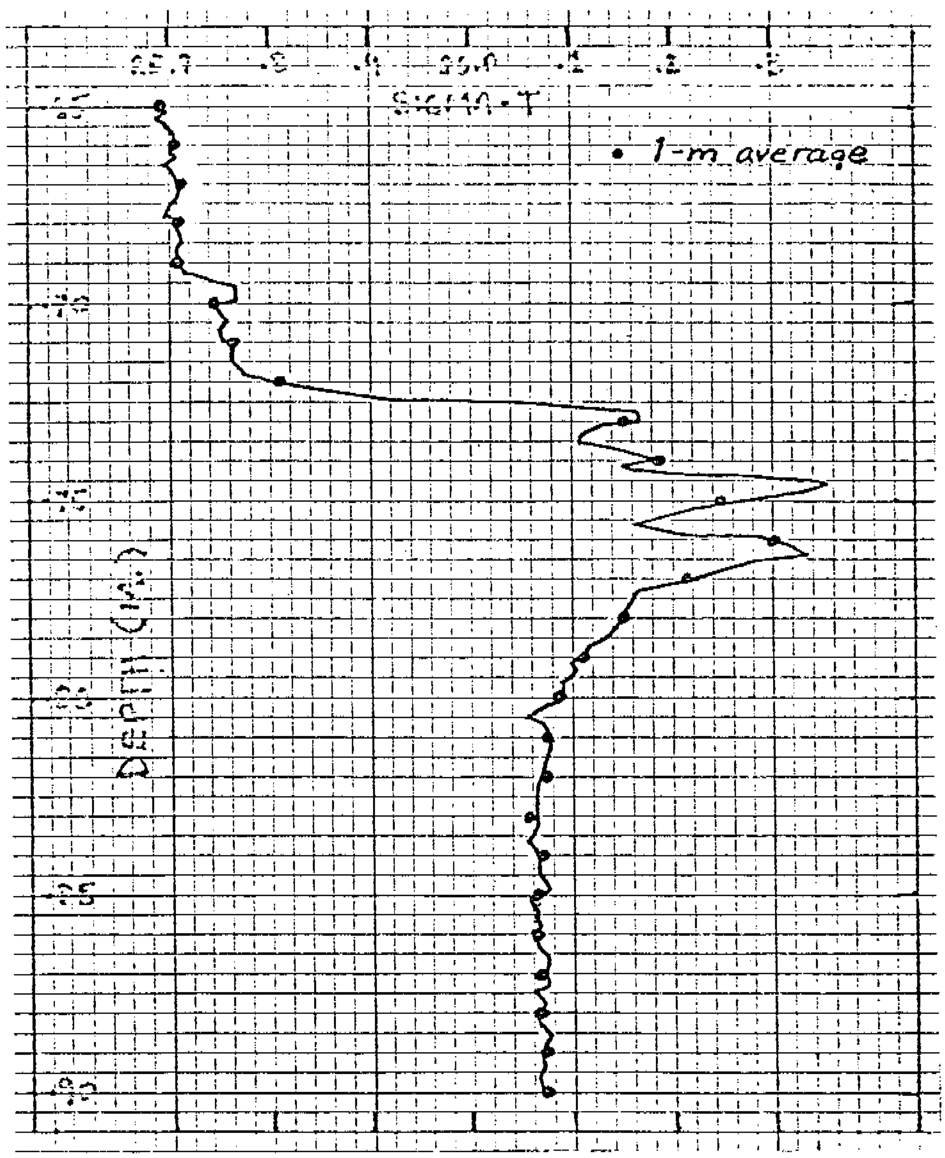
5800 series, CSTD. This system samples 5 times a second for simultaneous value of conductivity, temperature and depth. Data were recorded from the down cast using a lowering rate of 30 m per minute. Water samples were collected on each cast to provide salinity calibration data.

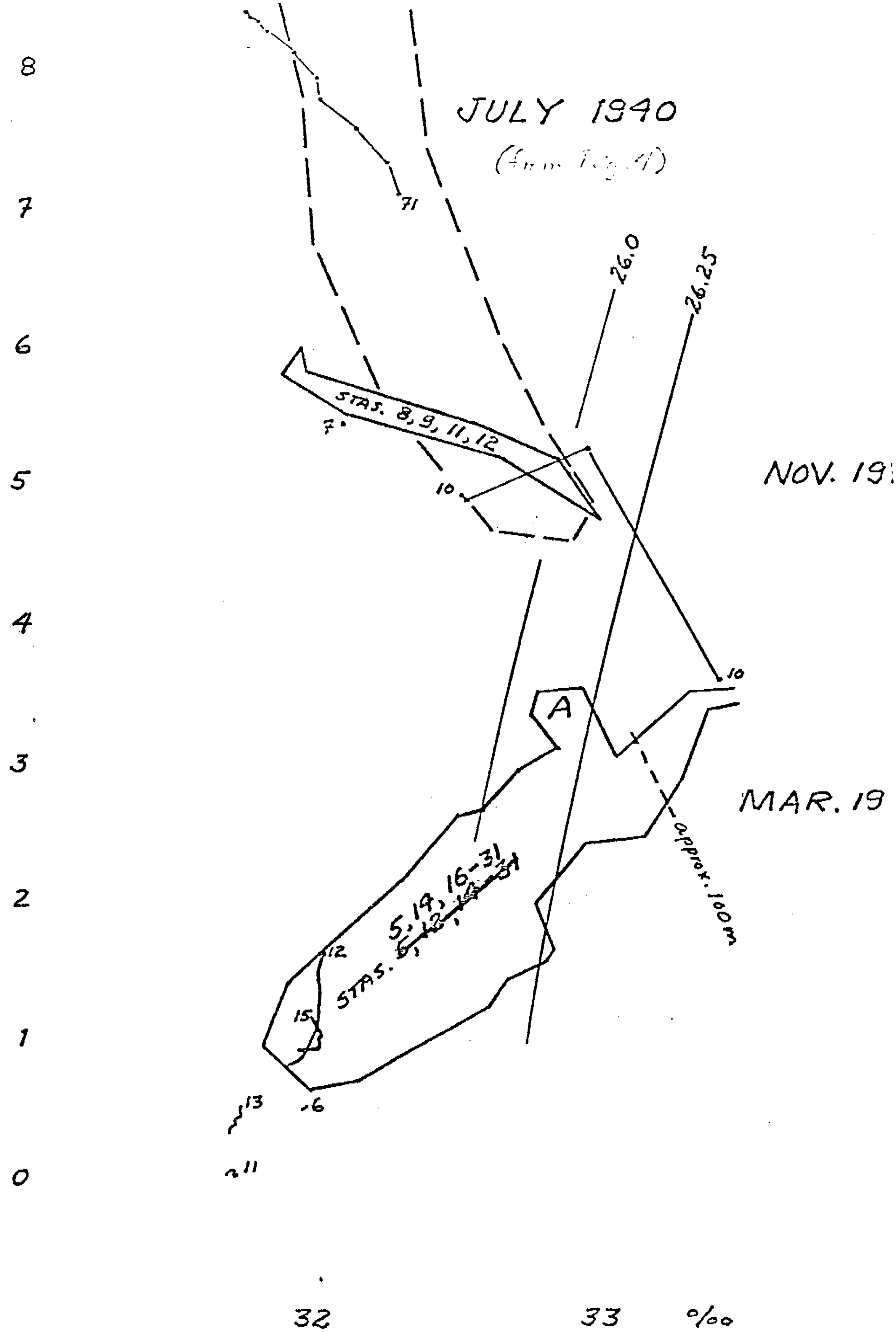
To calculate salinity a correction was applied to compensate for differing response times of the conductivity and temperature sensors. For this process, we adopted the Scarlet (1975) method using a time constant of 0.3 sec. This value for time constant is larger than might be considered necessary for the specified equipment but was chosen to eliminate all possibility of spurious salinity (and hence density) excursions. Additionally, this larger value was adopted to offset any possibility of increased lowering rates due to ship-roll. Comparisons were made using several time constants, and showed that for the selected value microstructure spikes were reduced but not eliminated and that finestructure gradients were only slightly reduced.

Following salinity calculations, calibration data were applied, sigma-t values calculated, and data sets, which increased monotonically in depth, were created by eliminating temperature, salinity and sigma-t values associated with intermediate decreases in depth. These were then reduced to 1 m value data sets by interpolating a value of each parameter from the values immediately preceding and immediately following the nominal depth.

The effect of the averaging procedure on the data is illustrated in Figure 6, which shows a selected portion of sta. 20 containing large finestructure density inversions. Choosing a curve of the 1 m values eliminates microstructure but preserves the major inversion of the finestructure; however, numerical values of $\frac{\Delta\sigma t}{\Delta z}$ for vertical separations close to the break-over scale size (i.e., 1 m) are notably reduced. We choose to adopt this procedure because (1) the finestructure feature of greatest interest is still well described by the smoothed data and (2) we feel somewhat uncertain about the accuracy of the data at microstructure scales. Even though we tend to believe the corrected individual data points the instrument used was a stock model CTD not designed for microstructure sampling.

The March cruise data from the outer bay are plotted in a T-S diagram in Figure 7. Points from depths <250 m from all stations in water deeper than 100 m are included in the envelope (stas. 5, 14, 16-31; for locations, see Fig. 3). Stations in depths <100 m were practically isothermal and isohaline (cf. stas. 6, 11) though stas. 12, 13, 15, just north of Unimak Island and close to the 100 m contour, evidenced some thermal stratification. We deduce (from the relatively dense station coverage in the central and southern


• 1-m average


JULY 1940
26.0
26.25
STAS. 8, 9, 11, 12
NOV. 19
A
MAR. 19
STAS. 5, 19, 16-31
approx. 100m
8
7
6
5
4
3
2
1
0
32
33
‰

outer bay) that the envelope exposes the basic T-S characteristic of Bering Sea source water mass in March: surface values of $S\sim33^{0}/oo$ $T\sim1 \pm 0.5°C$ grade downward to bottom values of $S\sim33^{0}/oo$ $T\sim3°C$.

Also included in Fig. 7 are data from five stations from a November, 1975 , cruise on R/V *Miller Freeman* (locations shown in Fig. 3) which characterize the Bering Sea source water mass in autumn. The seasonal cycling of this water mass is now clear. There appears to be little variation in salinity, the water columns being salinity stratified at all seasons between $\sim32^{0}/oo$ and $\sim33.1^{0}/oo$. Surface temperature values cycle widely, from 8-10°C in summer to <1°C in winter, while the bottom water cycles over a much narrower range: ~4.5°C in summer to ~3°C in winter.

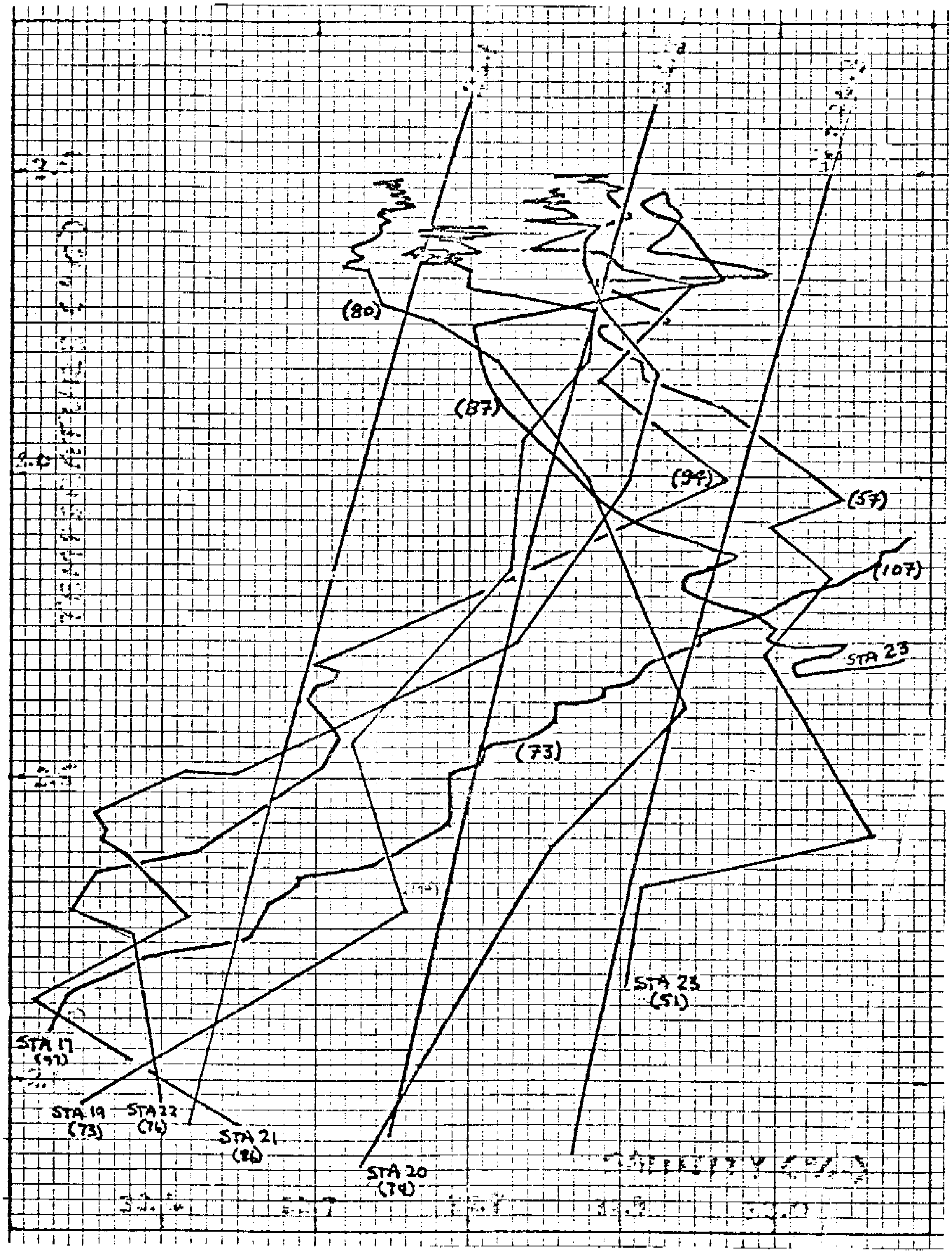
The March T-S envelope shows a lobe protruding from the main envelope toward warmer and slightly less saline values (labelled A). This lobe is created by points from 5 stations (19-23), portions of which are shown in an expanded-scale T-S diagram (Figure 8). Also shown in Figure 8 is sta. 17, located 57 km closer to Unimak Pass than sta. 19, which exhibits no evidence of the "lobe" effect. We see that the lobe is caused by an abrupt change in the vertical variation of T, S in these columns: going downward T-S follows the general water mass trend from colder and less saline toward warmer and higher salinity until, at about $32.9\text{-}33^{0}/oo$ and 3°C, they change direction toward $32.8\text{-}32.9^{0}/oo$ and 3.4°C. The depths at which the abrupt change took place are given in Table 3.

TABLE 3

Depth and Gross Instability of Finestructure

Sta.	Depth, m, of abrupt change	Max. gross instability over a 5 m increment $10^5 \frac{\Delta\sigma_t}{\Delta z}$, m^{-1}
19	77	-3000
20	76	-4600
21	96	-2400
22	94	-2000
23	57	-2600

At stations 19-22, the water columns from below the change to the bottom were occupied by the water with new and significantly different T-S signature. At Station 23 (located off the shelf), beginning at about 86 m the T-S curve


(80)
(87)
(94)
(57)
(107)
STA 23
(73)
STA 23
(51)
STA 17
STA 19
(73)
STA 21
STA 20

trends back toward the main envelope curve, rejoining it at about 94 m, below which the water column was the same as the other deep stations.

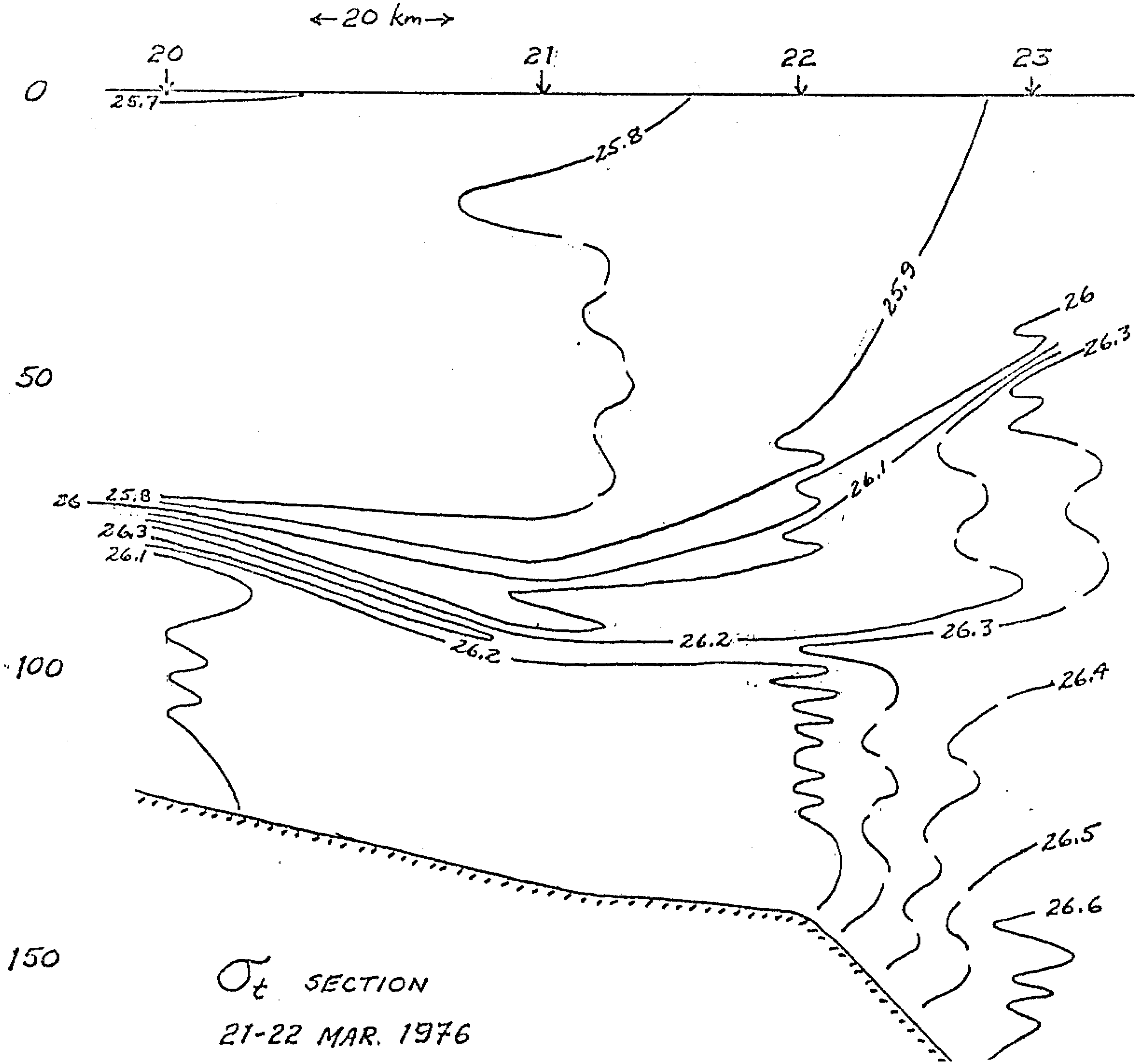
Thus, we identify a bottom water mass several 10's of meters thick which occupied the central outer Bristol Bay shelf during March, 1976, which was ∿1°C warmer than water with equivalent salinities on the southern outer shelf and in deep water off the shelf. At one location the water mass was observed to extend off-shelf over the slope as a layer ∿30 m thick. The vertical water mass structure was such that immediately above this water mass lay denser water, giving rise to finestructure instabilities of 0.1-0.2σ_t($10^8E <$ $-2000\ m^{-1}$; Table 3).

Another view of the outer shelf water structure is presented in Figs. 9a, b, which are σ_t sections slicing across the shelf from deep water to the limit of station coverage on-shelf, sta. 20 (see Fig. 3 for location of these sections). We see that the deep basin water exhibited high densities very shallow in the water column, and this water extended to the shelf break almost like a wall. Over the outer shelf, between ∿70-80 m depth, there was a preferential intrusion of this denser water, under a quite homogeneous (in σ_t) upper layer and over a bottom layer 30-40 m thick, also of uniform σ_t. The apparent intrusion extended on-shelf to the limit of the data, nearly 100 km. The finestructure instability was associated with this intrusion.

CIRCULATION AND WATER MASSES

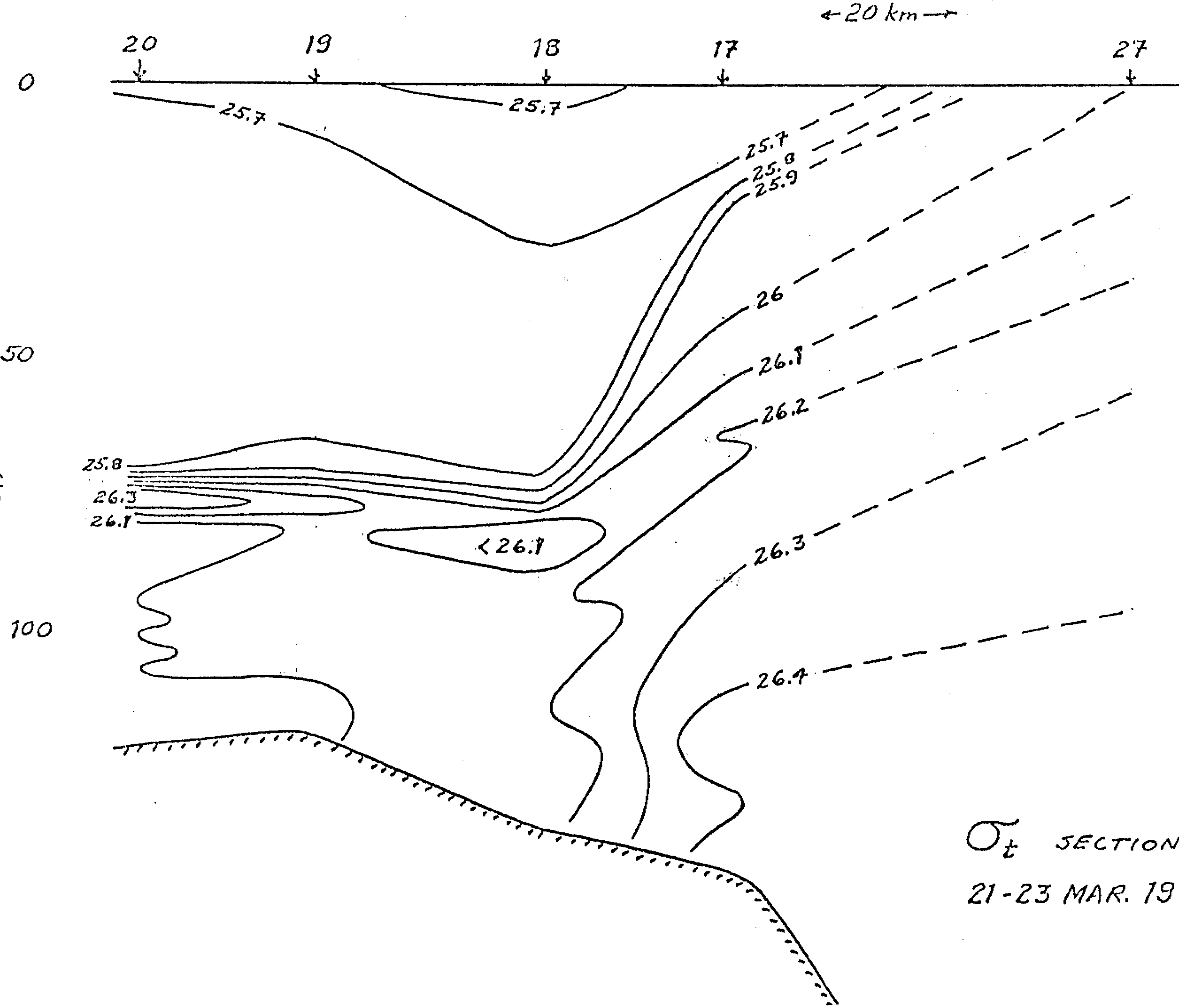
To illuminate the circumstances of this phenomenon we examine the circulation and water masses in closer detail. There are no direct current measurements available. Figure 10 shows the dynamic topography of the surface over 120 db, and though calculated flows in such shallow water must be regarded with considerable caution, in this case in light of our other knowledge, we believe Figure 10 to be a good qualitative depiction of the upper layer flow field.

There was strong inflow of water from the southeast corner of the deep basin onto the shelf in the vicinity of Bering Canyon, where it was subjected to strong cyclonic curvature. The western portion of incoming water then progressed over the shelf break from whence it curved anticyclonically back on shelf, and in general followed the bathymetric contours toward the northwest. The eastern portion of the incoming water after the initial turning recurved onto the shelf toward the north and northeast. There is a suggestion that flow bifurcated, in the neighborhood of sta. 18, with little penetration of the in-



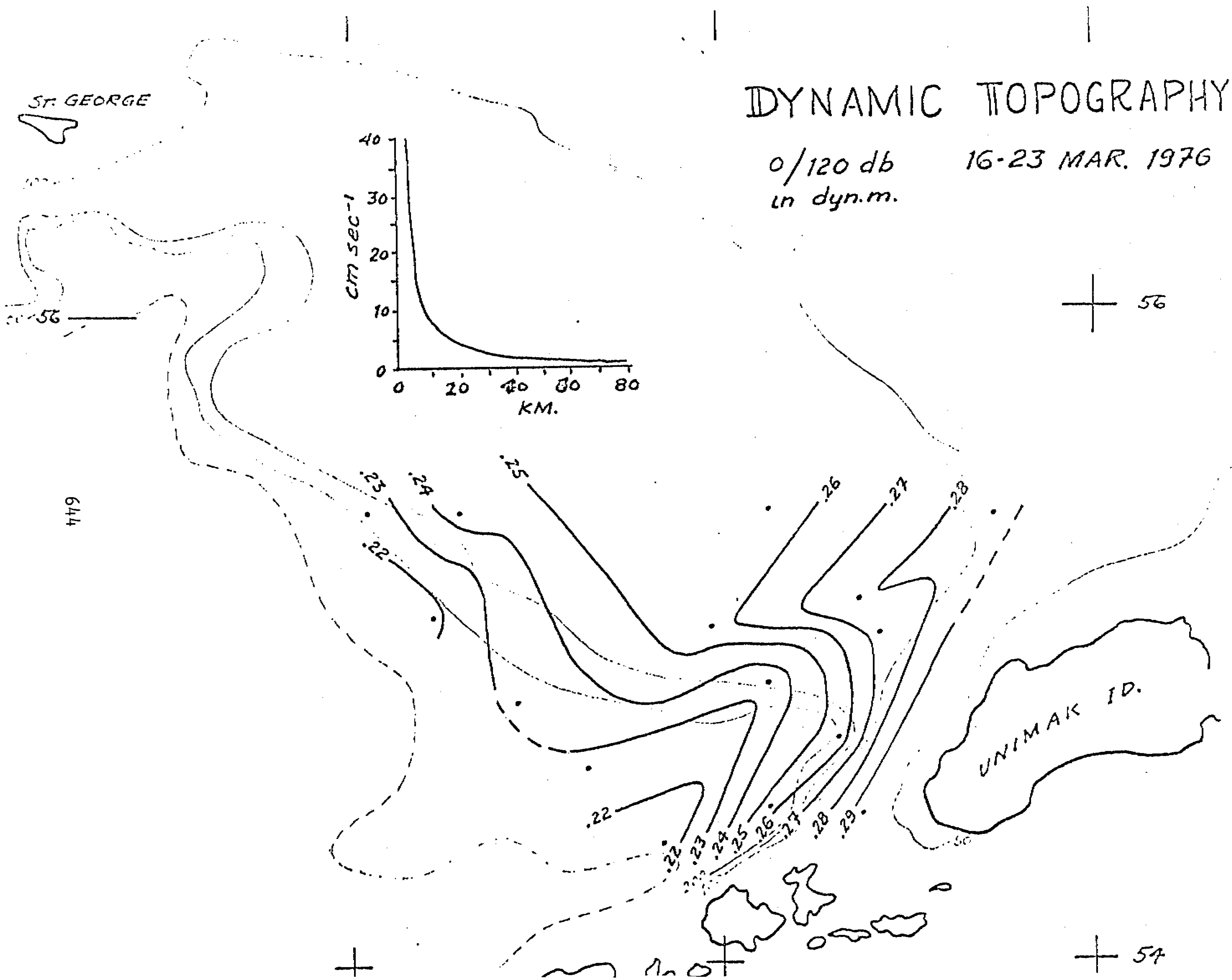
642

σ_t SECTION
21-22 MAR. 1976



σ_t SECTION

21-23 MAR. 1976


DYNAMIC TOPOGRAPHY
0/120 db
in dyn.m.
16-23 MAR. 1976
ST. GEORGE
UNIMAK ID.
cm sec-1
KM.
56
54
.22
.23
.24
.25
.26
.27
.28
.29

coming water into the north-central part of the survey area.

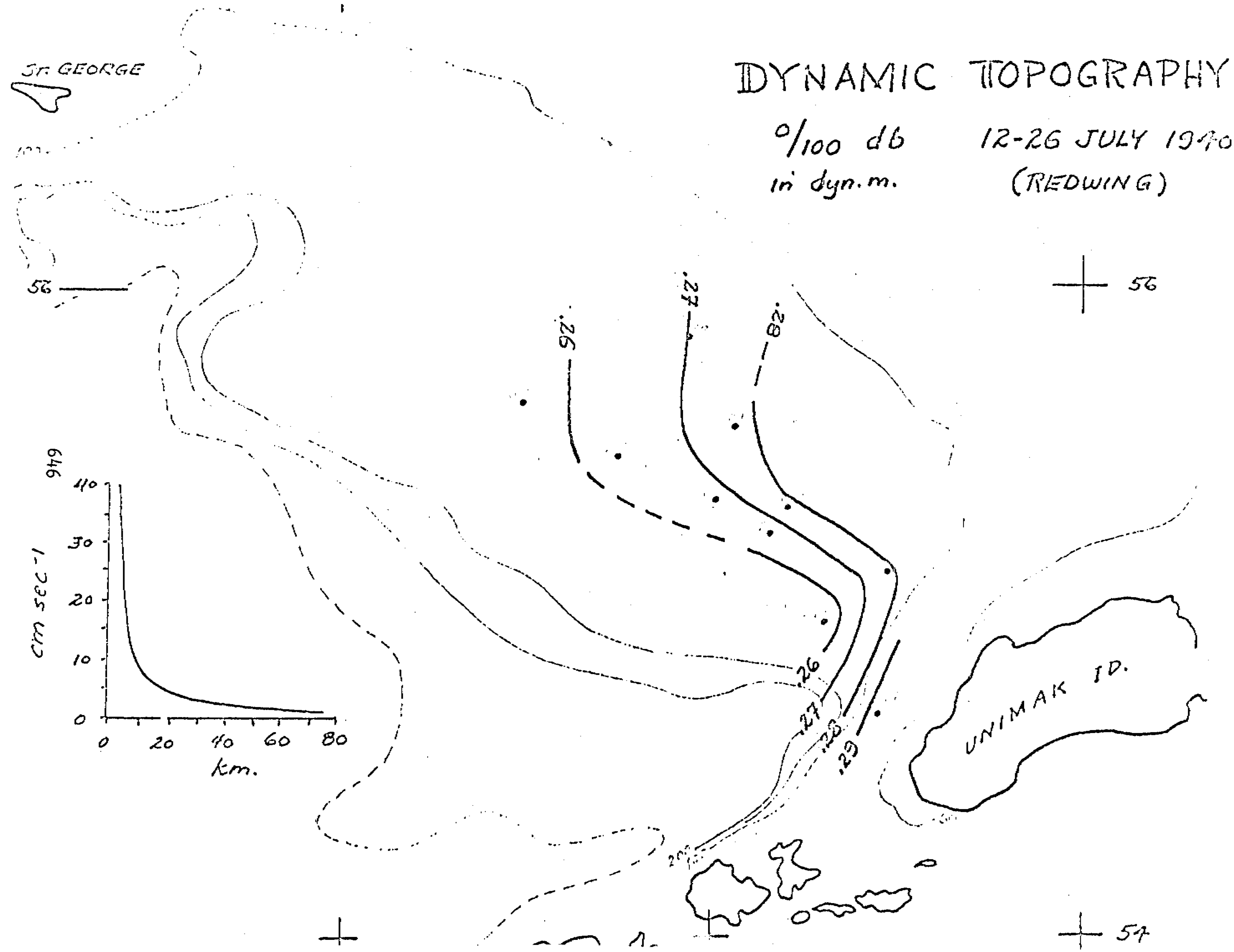
To check whether the March data reflected typical or anomalous flow conditions for the incoming source water, the dynamic topography from the *Redwing* (July, 1940) is shown in Figure 11. This topography does not show the same sense of flow bifurcation; following the initial cyclonic curvature the incoming water in general appears to have recurved north and northeast deeper onto the shelf. In attempting to reconcile the apparently different flow behavior, our thinking is directed toward a resisting horizontal pressure gradient force field present in March associated with the water mass of the central outer shelf, or sufficient strength to prevent a direct "sweeping away" of the upper layers of shelf water and forcing a bifurcation in the incoming water mass flow.

It also appears that during March, 1976, source water was not penetrating as deeply onto the shelf as it does typically during June-July; the zone of interaction betweeen source and shelf waters in summer (Fig. 5) seems to be located at least 50-80 km farther north and on-shelf than the apparent contact zone during March, 1976. We of course have no way of knowing whether this is true generally in winter or peculiar to conditions in March, 1976.

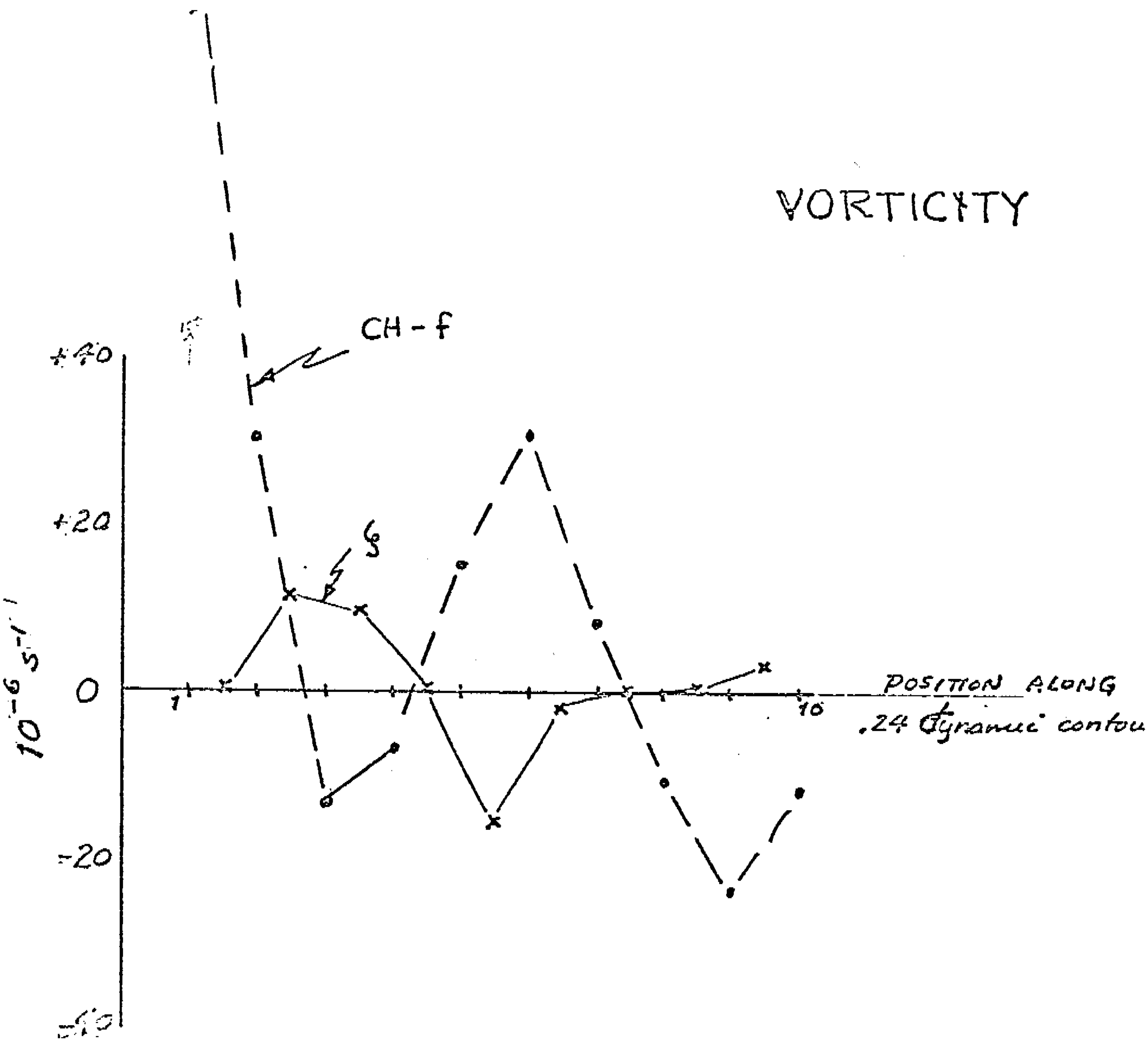
The strong cyclonic curvature of the inflow initially and the subsequent meander pattern of the western portion of the flow, suggests a dominant role by potential vorticity conservation. As the water columns move over the shelf break, their vertical extent is considerably reduced and they are strongly torqued cyclonically. In March when much of the flow did not penetrate deeply on the shelf (Fig. 10), the cyclonic movement carried the columns over the shelf break again into deeper water, the columns stretched and anticyclonic curvature was generated. A numerical estimate of the vorticity conservation from the March data was made as follows. The 0.24 dyn. m contour was assumed a streamline and divided into 10 arbitrary segments of approximately 20 km each. Conservation of potential vorticity is expressed by

$$\frac{\zeta + f}{H} = C$$

The relative vorticity ζ was estimated as $\frac{\Delta V}{\Delta X} - \frac{\Delta U}{\Delta Y}$ between adjacent points, with U and V taken from the geopotential topography (Fig. 10). The constant C was evaluated by assuming $\zeta = 0$ at two locations along the 0.24 dyn. m contour which suggested an inflection in its curvature; both locations occur where H $\sim$160 m depth. A comparison of ζ with (CH-f) is shown in Fig. 12; the out of phase oscillation of each tends to demonstrate the dominant role of po-



DYNAMIC TOPOGRAPHY
0/100 db
in dyn.m.
12-26 JULY 1970
(REDWING)
St. GEORGE
56
56
.26
.27
.28
.29
UNIMAK ID.
cm sec-1
0
10
20
30
40
0
20
40
60
80
km.


VORTICITY
CH - f
+40
+20
0
-20
10^-6 s^-1
1
10
POSITION ALONG
.24 dynamic contou

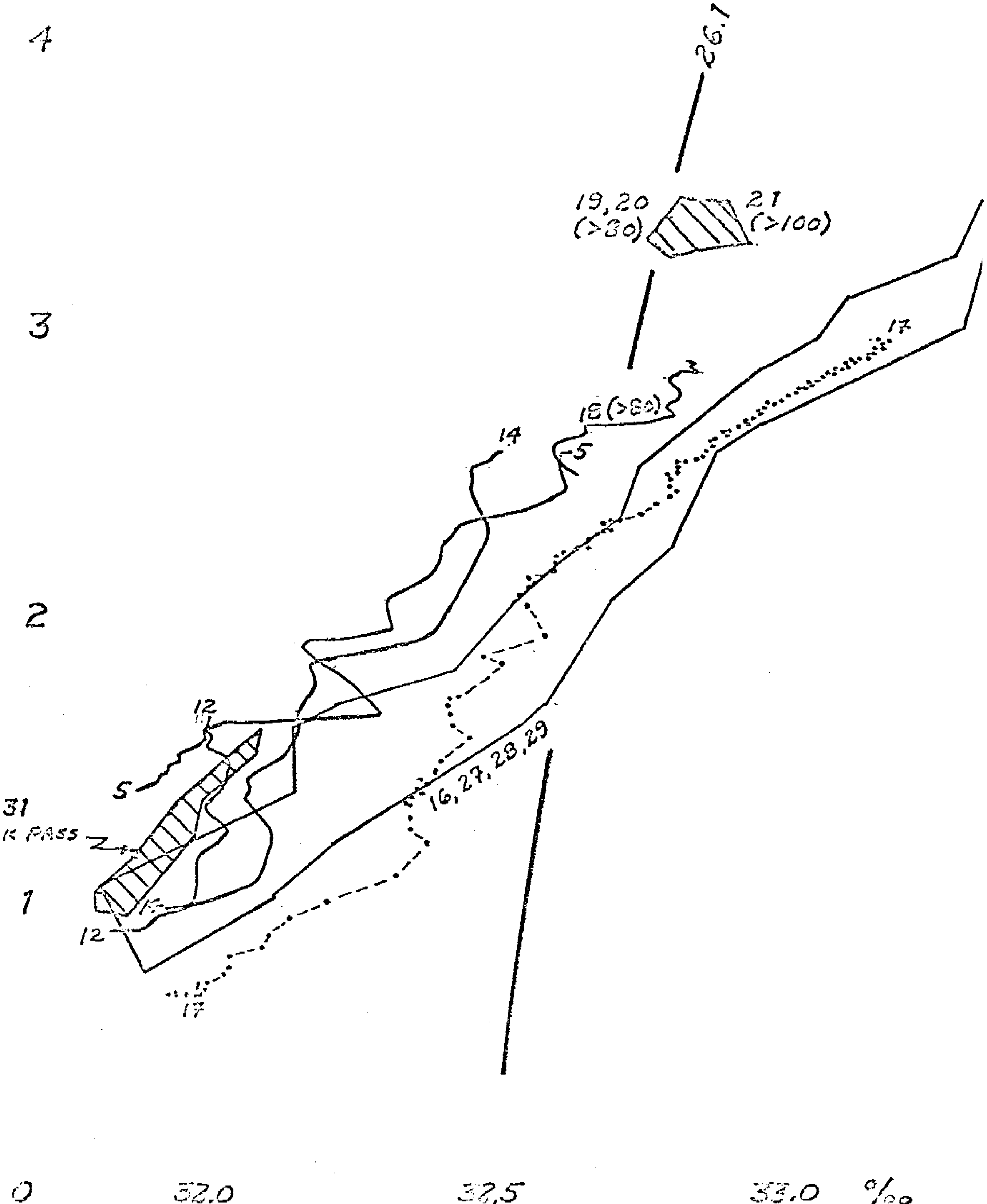
tential vorticity conservation in controlling flow.

The flow pattern of incoming source water will only be strongly governed by potential vorticity when it flows back and forth across the shelf break where large stretching and shrinking of the water columns is required. When this water can penetrate substantial distances onto the shelf, as in July (Fig. 11) or the eastern branch in March, the initial cyclonic curvature does not direct the columns into water with large depth changes, rather, the water remains on the very flat shelf where its flow patterns must be governed by considerations not connected with the small variations in water depth obtaining (except close to Unimak Island and the Alaskan Peninsula).

Subtle distinctions among the various water masses are also evident in the March data. In a T-S diagram (Fig. 13) stas. 16, 27, 29 from the extreme southeast corner of the deep basin (see Fig. 3) are shown as an envelope. Stas. 30, 31 (enveloped separately) from Unimak Pass showed the same characteristics as the surface water of the deep-water envelope. As these stations were the most "up-stream" stations (cf. Fig. 10) they disclose the T-S characteristics of the "pure" Bering Sea source water input to the shelf at this time. The upper layer salinities were centered around 32^{o}/oo, with temperatures between 0.5 and 1.5°C, and the water columns increased regularly downward in T and S to $\sim$33.3^{o}/oo and $\sim$3.1°C at $\sim$250 m.

The eastern portion of inflow may have contained a large proportion of the Alaskan Stream inflow through Unimak Pass, and thus was predominantly composed of the least saline, coolest fraction. Downstream, at shelf stations <100 m deep along the eastern, shallower side of the inflow, the water columns exhibited the same characteristics (e.g., at sta. 15 (Fig. 7) and sta. 12). Station 13 (Fig. 7) showed to be even cooler and less saline, an extension of the envelope trend in that direction. This may have been characteristic of the near-shore water not otherwise sampled, and/or reflected a cooling of the shallow water columns in transit (sta. 11, 50 km beyond sta. 13, was 0.4° C cooler).

Of the deeper shelf stations, the only one exhibiting "pure" source water was sta. 17 (plotted separately in Fig. 13), directly downstream from the input. The next stations downstream (5, 14, deep water at 18) show a significantly different vertical water mass trend than that of the source water; at comparable values of salinity the corresponding temperatures were warmer. The culmination of this trend is the bottom water mass of the central outer shelf (the envelope of deep observations from stas. 19-21).

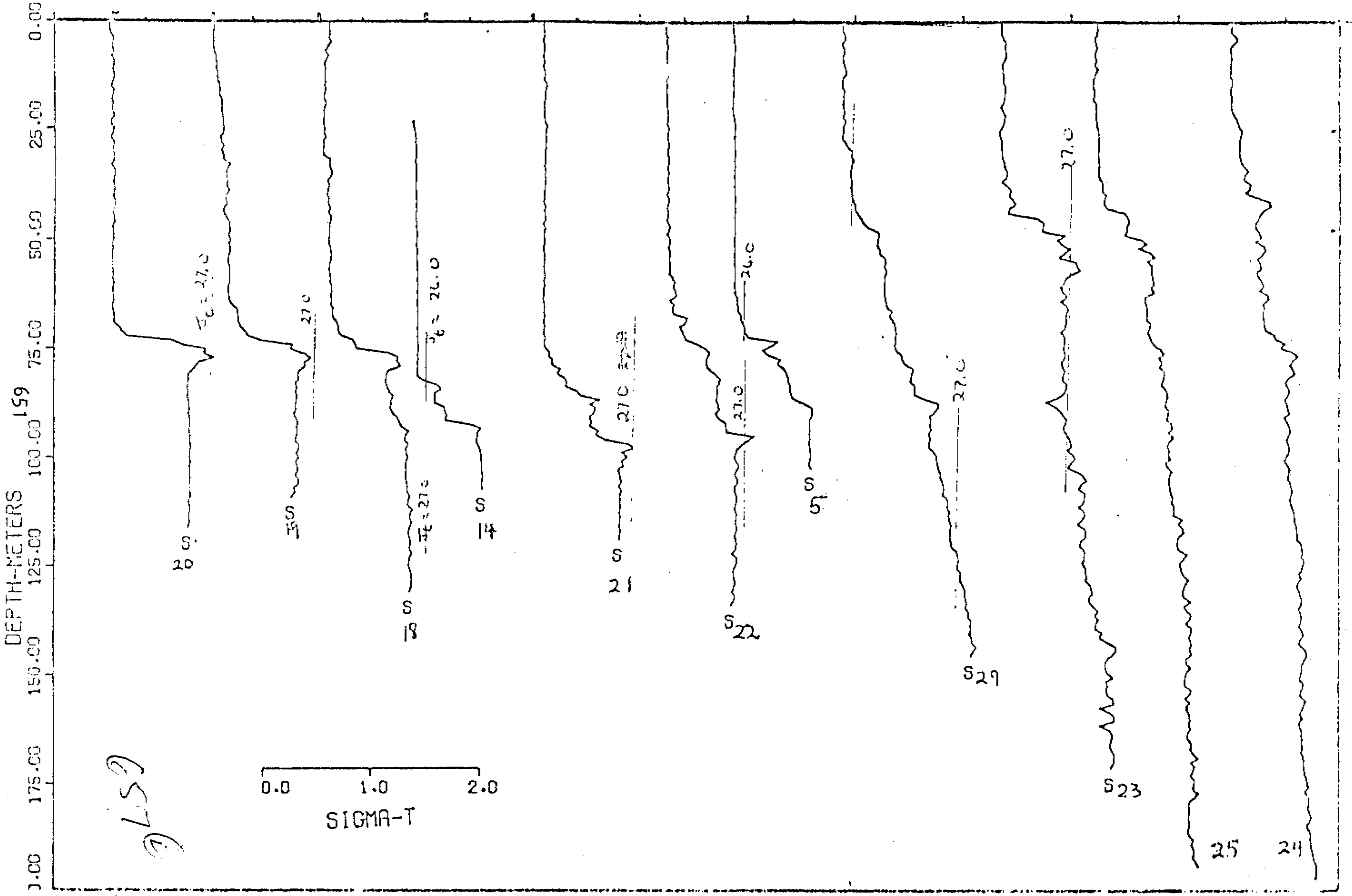


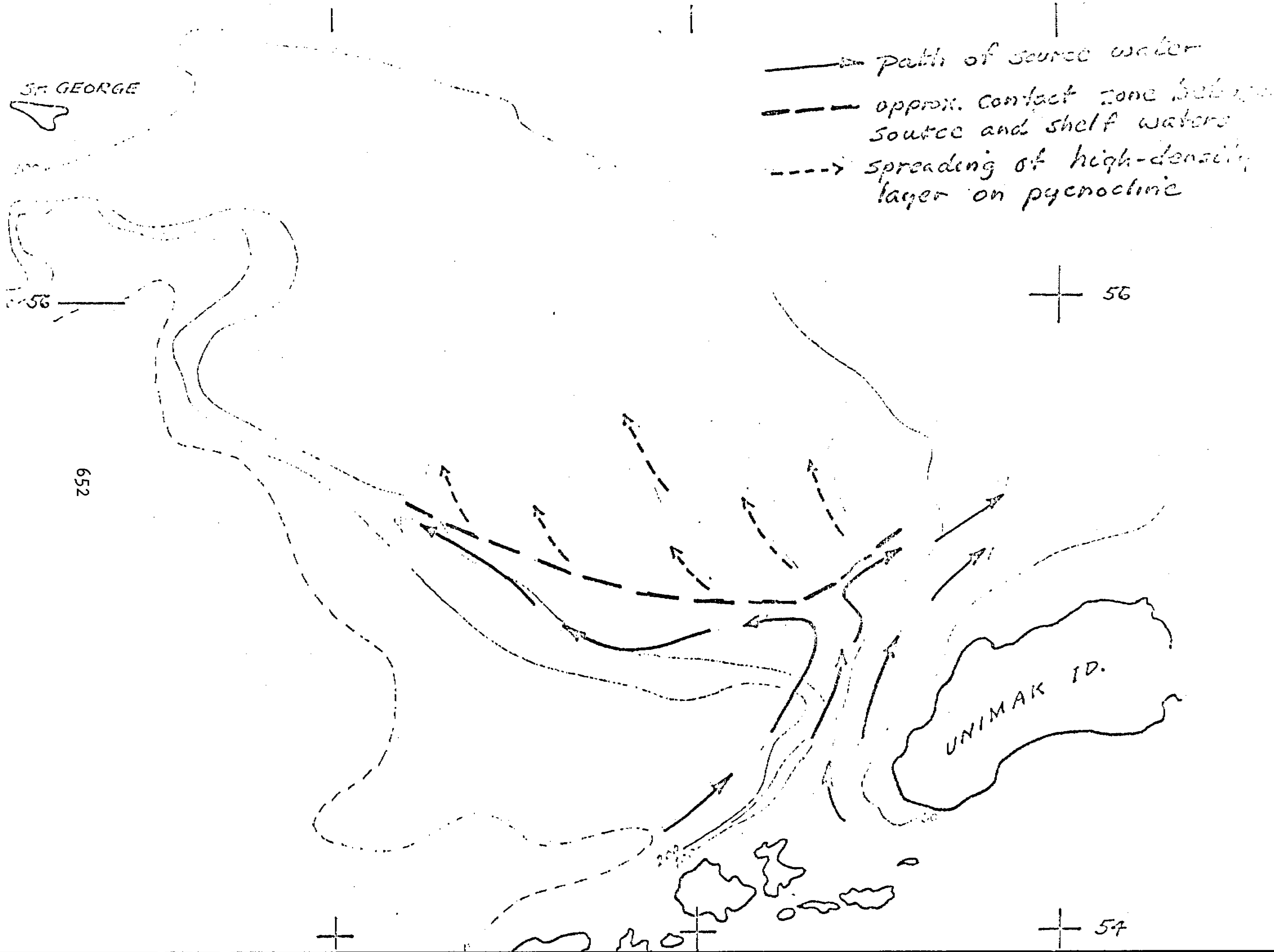
26.1
19,20
(>30)
21
(>100)
18 (>80)
14
5
17
12
30,31
UNIMAK PASS
16,27,28,29
4
3
2
1
0
32.0
32.5
33.0 ‰

This difference in vertical trends of water masses in the T-S plane differentiates the source water from the water ubiquitous to the outer shelf at this time. Examination of property variations with depth shows that these waters differed in vertical density structure. In Figure 14 the vertical profiles of density (sigma-T) show that the stations located well on the shelf are best characterized as strongly two-layered, in contrast to the deep-basin and input waters which showed more regular, monotonic increases of density with depth. The shelf stations showed a quite homogeneous upper layer of $\sim$75 m thickness separated from a more dense and quite homogeneous bottom layer by a relatively sharp pycnocline, which subtended 10-25 m thickness. We also see (Fig. 14) that the fine structure feature is uniquely associated with the pycnocline separating the two water mass layers on the shelf (cf. particularly stas. 18-21).

A schematic view of our interpretation of the water mass movements and interactions is given in Figure 15. Incoming source water was penetrating the southeast corner of the shelf in the vicinity of Bering Canyon. There it encountered a strongly two-layered residual water occupying much of the outer shelf. This water had a bottom layer $\sim$1°C warmer than the source water at equivalent depths probably because of isolation over the winter by the pycnocline from a more rapid heat loss through the surface. The source water was prevented from penetrating very far on the shelf, and its flow bifurcated. The eastern portion, in shallower water, ultimately progressed into Bristol Bay parallel to the Alaska Peninsula, where its water mixed and became indistinguishable from shelf water. The western branch was constrained to curve strongly left, in part probably by a resisting pressure gradient force field and in part by potential vorticity conservation, and progressed to the northwest meandering along the bathymetric contours.

The incoming source water was considerably denser from the pycnocline up than were the shelf water columns. The denser source water penetrated the shelf water regime preferentially along the pycnocline interface, and spread laterally along this surface for 10's of km. The finestructure phenomenon was associated with the preferential penetration and spreading of source water into the shelf water regime.


DEPTH-METERS
0.00
25.00
50.00
75.00
100.00
125.00
150.00
175.00
SIGMA-T
0.0
1.0
2.0
S 20
S 39
S 18
S 14
S 21
S 22
S 5
S 29
S 23
25
24
27.0
26.0
659



path of source water
approx. contact zone
source and shelf waters
spreading of high-
layer on pycnocline
ST GEORGE
56
56
54
UNIMAK ID.

FINESTRUCTURE FORMATION

The reader should appreciate that our initial reaction to discovery of this apparent finestructure instability was incredulity; this led to a re-examination of the raw data and data processing techniques. Once satisfied the phenomenon was real, we concluded that the structure was somehow dynamically stable. We cannot offer a coherent hypothesis, but do see some relationships which may aid in formulating a viable explanation. These are discussed in two aspects, formation and apparent persistence.

Interaction between Bering Sea source water and shelf water is markedly different in summer than in March, 1976. The source water is always denser, particularly deeper in the water column. In summer the density contrast is typically 0.4-0.5 σ_t (cf. Figure 4), and this layer physically moves under the bottom layer of shelf water, which layers above. This occurs in a relatively limited area, variable in position but usually well in from the shelf break. There is considerable mixing within layers so the zone is not large and may act as a front. This problem has not been investigated in Bristol Bay and available data are inadequate to provide a more complete description.

The differences we see in the March situation are (1) the region of interaction lay much closer to the shelf break, and (2) the density contrast between deep layers was less, only 0.1-0.2 σ_t. This smaller density contrast was due to significantly higher salinities of the bottom layer of shelf water as compared with June/July data from many years (Table 4).

TABLE 4

Approximate salinity range of shelf water bottom layer in summer

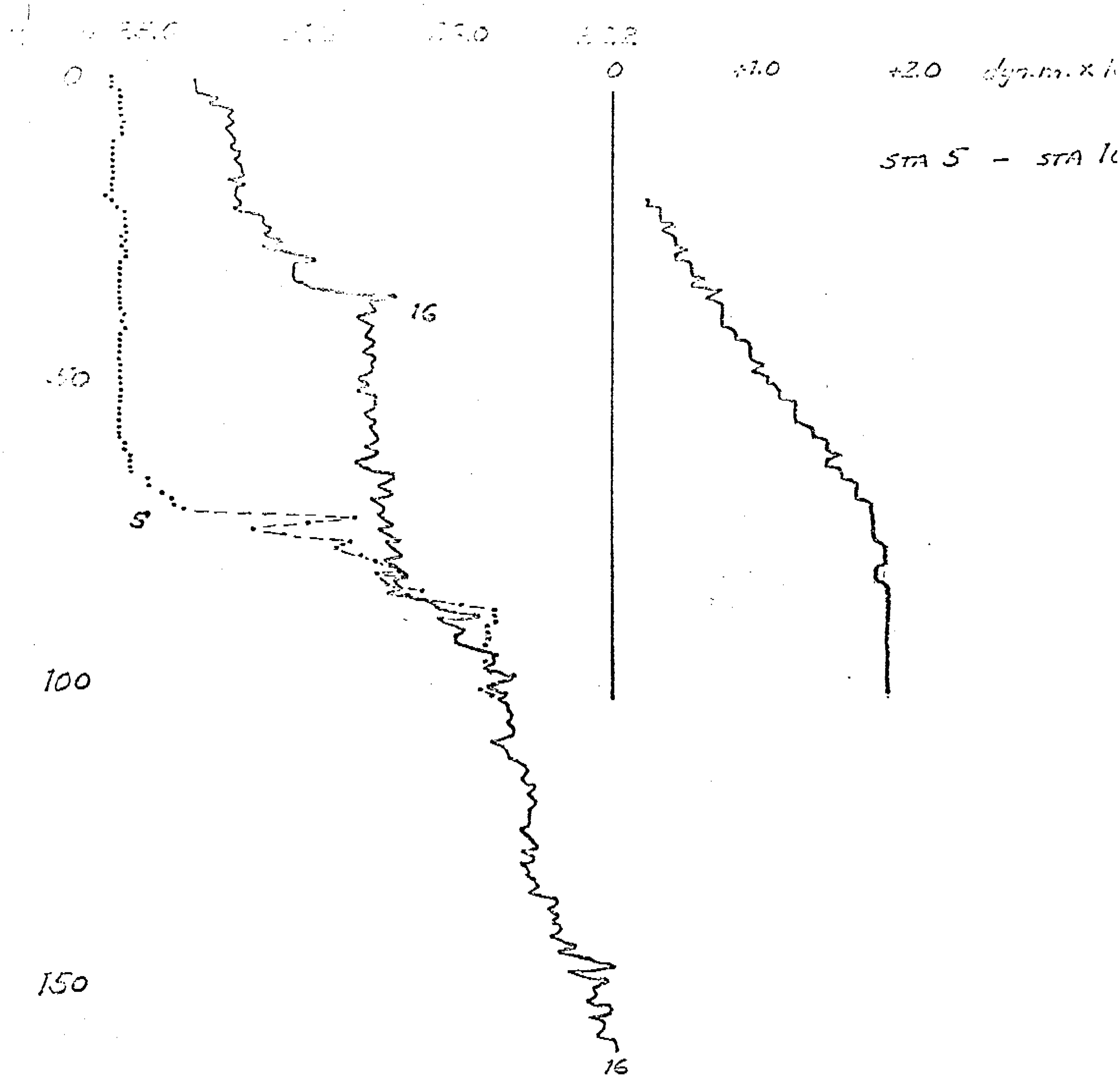
Year	S, $^o/oo$	Year	S, $^o/oo$
1940	31.7-32.1	1969	32.1-32.4
1963	31.9-32.2	1970	31.8-32.2
1964	31.8-32.2	1971	31.8-32.2
1965	32.1-32.5	1972	31.9-32.3
1966	31.9-32.3	1973	31.7-32.1
1967	32.2-32.5		
1968	31.9-32.3	1976 March	32.5-33.0

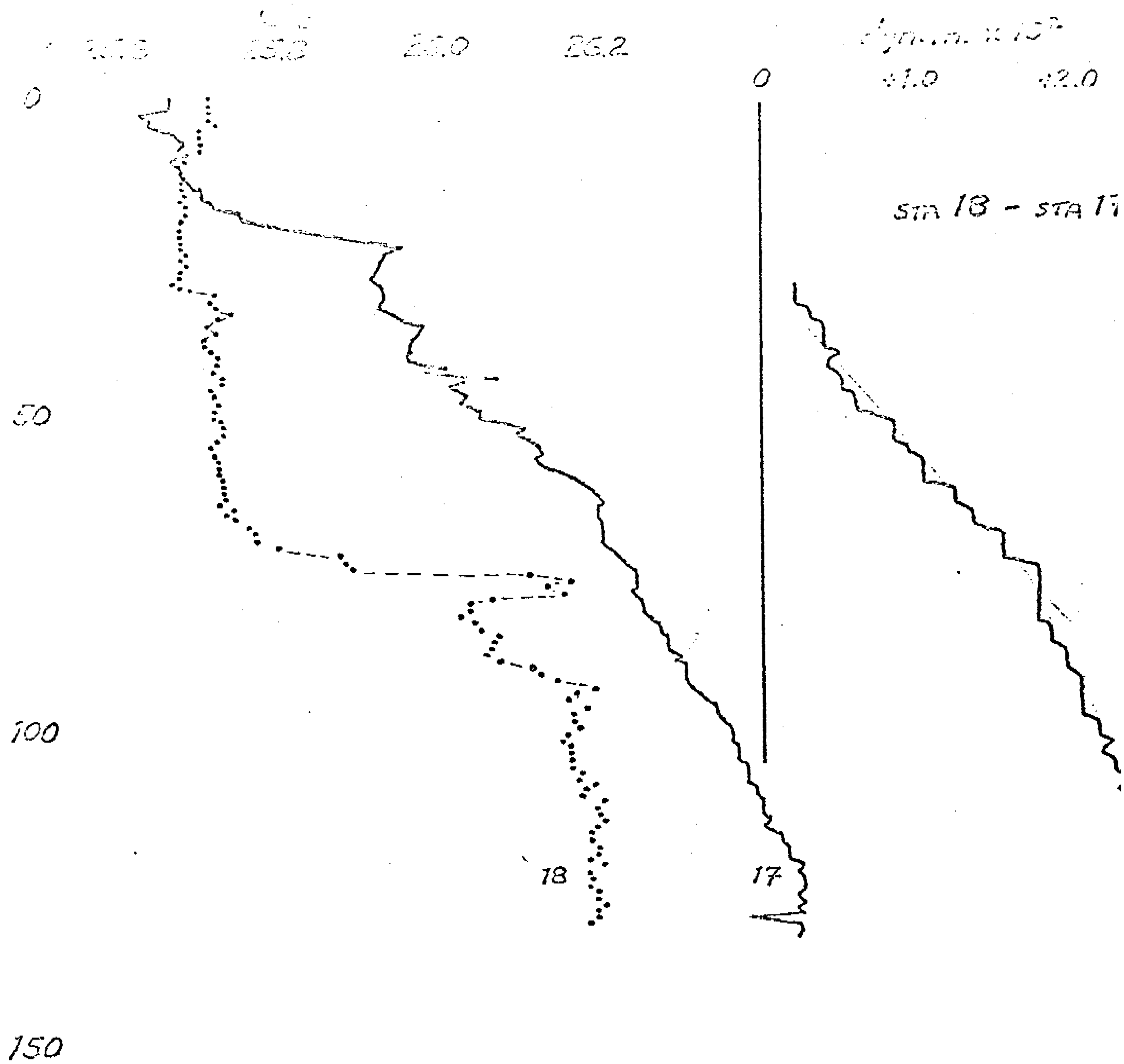
Thus, bottom shelf water was denser in March, 1976 than in summer but, as noted previously, we have no idea whether this is typical of winter or peculiar to 1976

This lack of strong density contrast between the shelf bottom layer and incoming source water at equivalent depths appears to be an important clue as to why the source water did not layer under, or bodily displace, the bottom shelf water. Figure 16 compares a station with pure source water characteristics (station 16) with the station most nearly downstream which showed the two-layered shelf characteristics (station 5; see Figures 3 and 10). The density of the two columns was identical below ∿85 m, near the bottom of the pycnocline, while above this depth the source water was considerably denser. Two other stations are compared in Figure 17, but in this case they are arranged almost perpendicular to the flow field. Again there was less density contrast between the water layers below the bottom of the pycnocline than above.

Also shown in Figures 16 and 17 are the horizontal pressure gradient forces between the stations, plotted as the differences in dynamic height summed downward from the surface to equal depths. In both curves there is an inflection point coinciding with approximately the middle of the pycnocline. If and when the sea surface was isobaric, there was a strong horizontal pressure gradient force deeper than this point (∿75 m depth in both cases) directed from the shelf bottom layer against the source water. Shallower than this depth the h.p.g.f. diminished rapidly. Interpreted in terms of geostrophic flow, significant baroclinic shear is indicated above approximately the middle of the pycnocline.

We offer the following qualitative interpretation of the formation of the inverted density layer in outer Bristol Bay. The source water, from the southeast corner of the deep basin and Unimak Pass, encroached on the shelf in the vicinity of Bering Canyon. There it impinged on the two-layered shelf water mass, horizontal pressure gradient forces resisted its direct penetration northward over the central outer shelf, and the flow bifurcated. Shelf water beneath the pycnocline was sufficiently dense that the source water could not layer under it. The shelf water was quasi-stationary while the source water was constrained to flow around it, in a sense. Source water on the shallower, eastern side was able to flow on into the bay, where it mixed and lost its identity. The western branch, in part conserving its angular momentum, was turned toward the northwest. In the course of this progress along the shelf break, from about station 18 to beyond the limit of the survey (station 22), the flow was in quasi-geostrophic balance, moving along beside the shelf water, and there would be relatively little tendency for lateral interaction between


0
0
+1.0
+2.0
dyn.m. x
STA 5 - STA
16
5
100
150
16


26.2
0
+1.0
+2.0
STA 18 - STA 17
0
50
100
150
18
17

the source and shelf waters.

The main interaction was in the center, in the areas between stations 18-5 (see Figure 3). Here the source water, much denser than shelf water above mid-pycnocline depths, sought its maximum density level where there was the least resistance, and slipped between the shelf water layers as a layer ~5 to 10 m thick. This intrusion was at least in part driven by the baroclinic shear across the pycnocline (evidenced in Figures 16 and 17). This much denser water entering near the top of the pycnocline would show in a vertical sounding as a very strongly stable layer, and if the bottom part of the pycnocline was unaffected, that is, retained its shelf characteristics, it would be less dense and show as a gravitationally unstable layer. Vertical plots of $10^5 \frac{\Delta\sigma t}{\Delta z}$ for all stations exhibiting the finestructure instability (Figure 18) show that in every case the maximum instability is overlain, 3-5 m above, by an extremely stable layer.

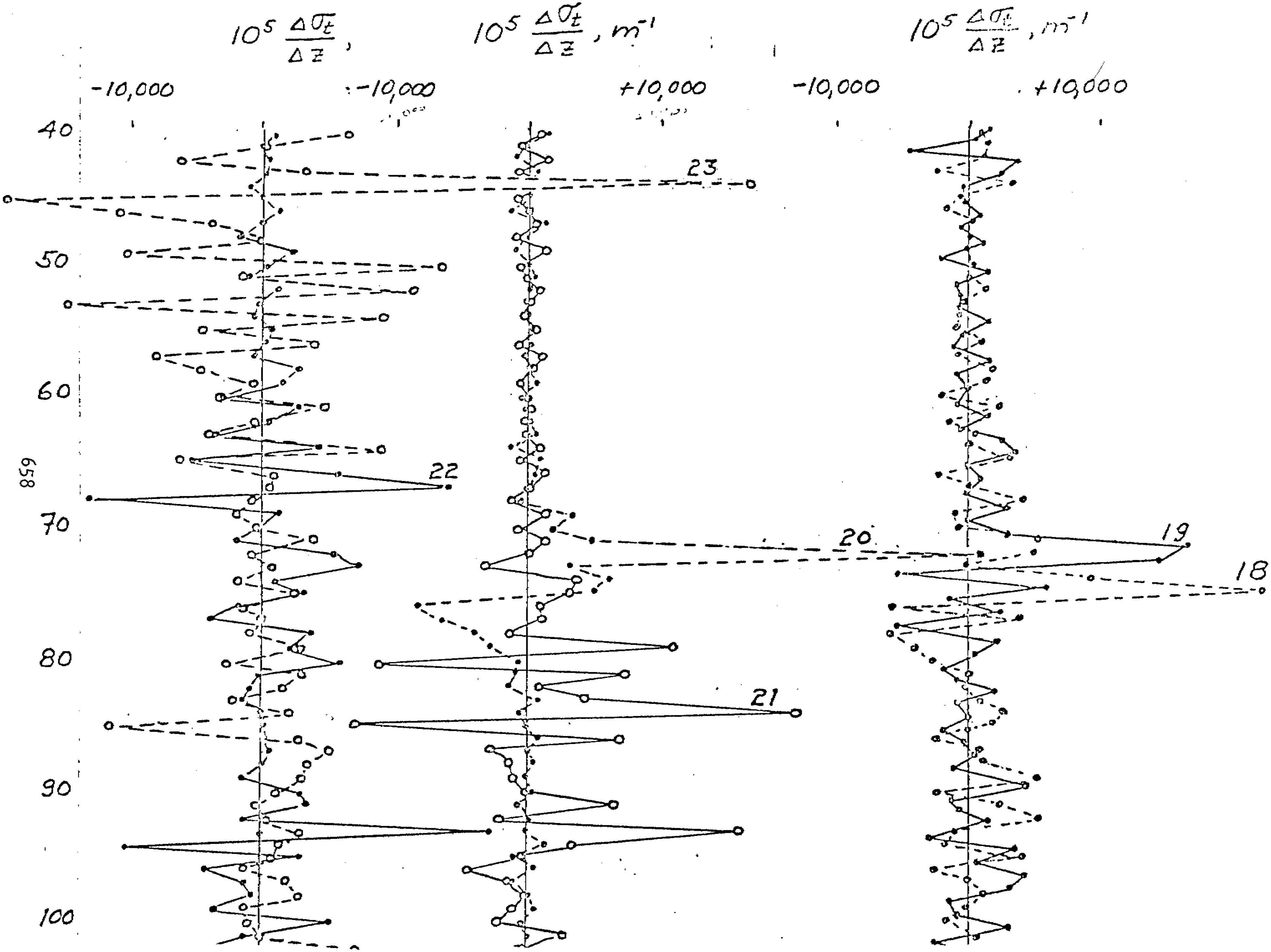
The presence of the finestructure feature over the central outer shelf (to beyond the limit of the survey) seemingly at least 100 km beyond its initial formation area, is more difficult to explain. Bering Sea source water must be involved, because a high salinity layer above is the primary cause of the calculated instability. Thus, the source water was being advected northward across the outer shelf. Though the dynamic topography calculated over the whole water column does not suggest such flow (Figure 10), the baroclinic shear across the pycnocline (Figure 19) does suggest that the layer above was being advected northward relative to the bottom layer.

One clue to its persistance lies in the association of this layered intrusion with a strong pycnocline. Strong vertical density gradients are thought to strongly damp vertical fluxes of momentum, mass and energy. If vertical eddy viscosity were one-to-two orders smaller within the pycnocline than above or below, water intruding generally in the upper or lower portions of the depth range would lose momentum much more rapidly than that in the mid-range. In a sense the pycnocline might act as a greased tube and permit a forced advection to travel much greater distances within it.

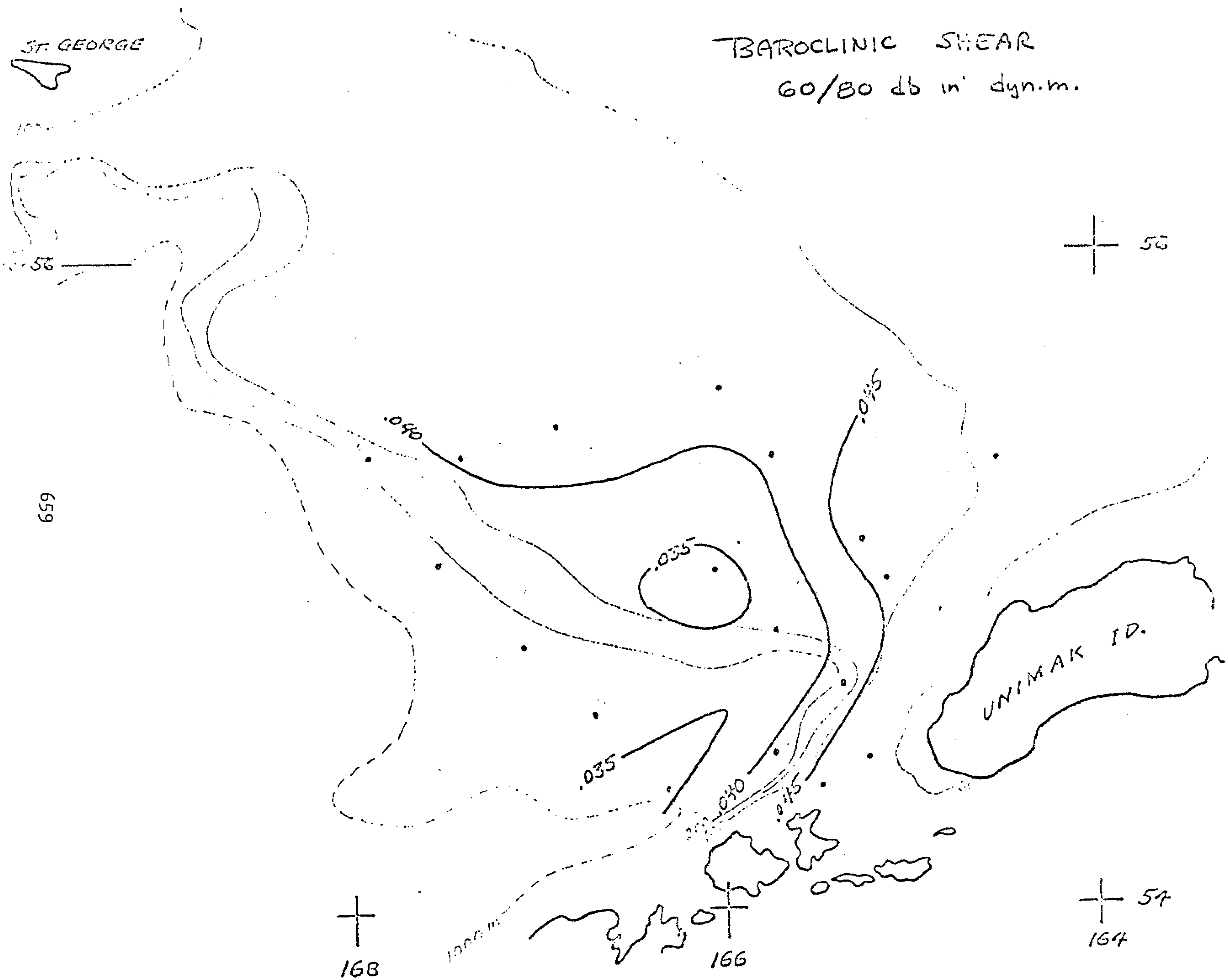
Likewise, suppression of vertical fluxes of heat and saltare probably also important to the longevity of the phenomenon. If the primary alteration of T, S at any level was due to a vertical eddy flux, then

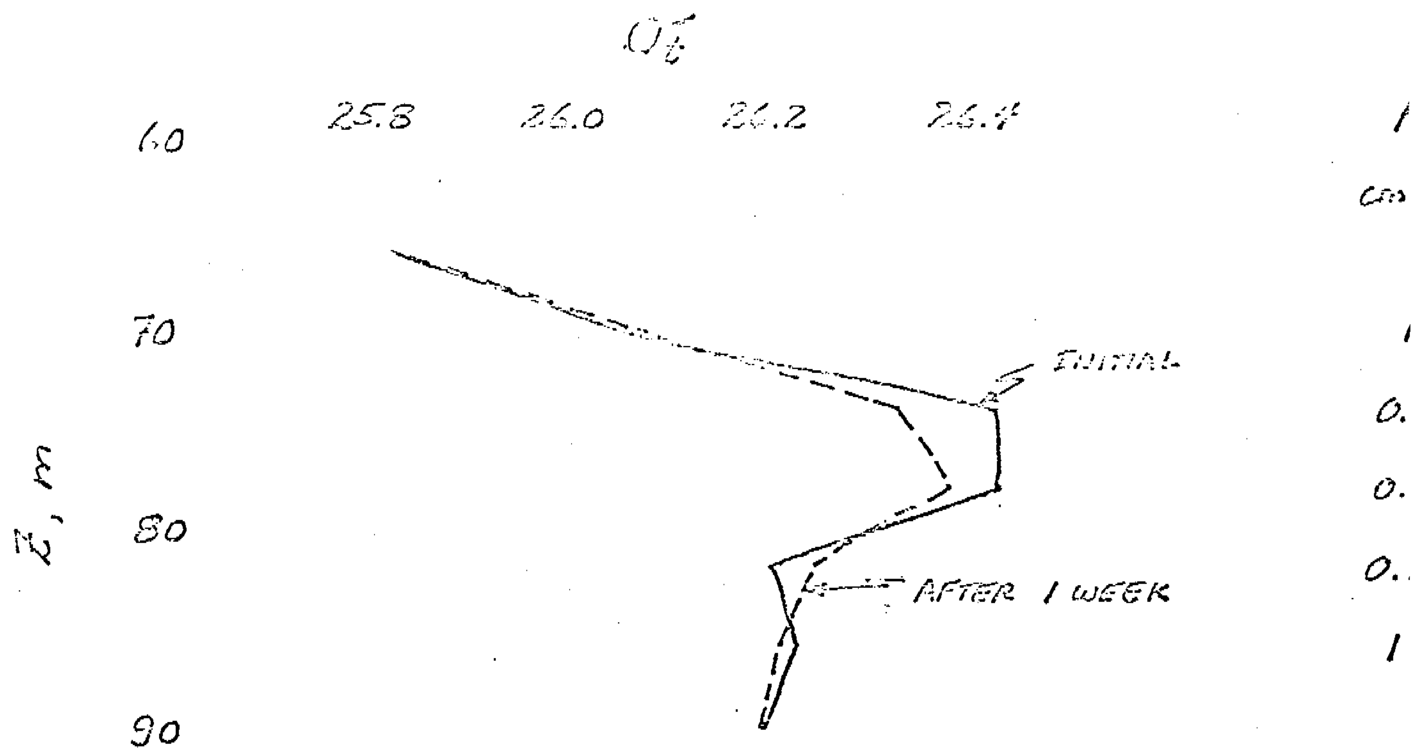
$$\frac{\Delta T}{\Delta t} = K_T \frac{\Delta^2 T}{\Delta z^2} \text{ and } \frac{\Delta S}{\Delta t} = K_S \frac{\Delta^2 S}{\Delta z^2} .$$

We assumed vertical profiles of T, S typical of the initial intrusion as shown in Figure 20 (cf. data for stations 5 and 18 in Figures 16 and 17 respectively).

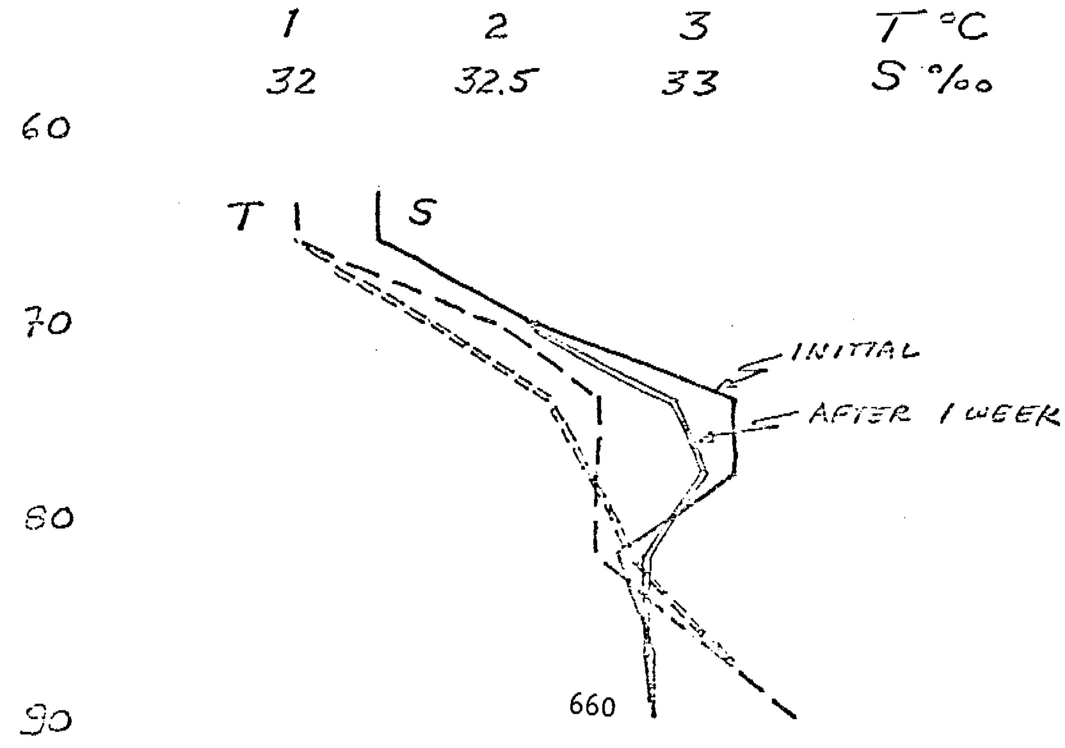


$10^5 \frac{\Delta \sigma_t}{\Delta z}$,
$10^5 \frac{\Delta \sigma_t}{\Delta z}$, m^{-1}
$10^5 \frac{\Delta \sigma_t}{\Delta z}$, m^{-1}
-10,000
-10,000
+10,000
-10,000
+10,000
40
50
60
70
80
90
100
23
22
21
20
19
18


BAROCLINIC SHEAR
60/80 db in dyn.m.
ST. GEORGE
56
.040
.045
.035
.035
.040
.045
UNIMAK ID.
1000 m
168
166
164
54



From: $\dfrac{\Delta T}{\Delta t} = K \dfrac{\Delta^2 T}{\Delta z^2}$; $\dfrac{\Delta S}{\Delta t} = K \dfrac{\Delta^2 S}{\Delta z^2}$



We then assumed $K_T = K_S$ and their magnitude was an order smaller in the pycnocline than above or below, as indicated. The hypothetical water columns were then integrated in time and the vertical distributions of T, S, and σ_t after one week are shown. The results suggest that with reasonable values of K, and its value reduced by an order in the region of strong vertical density gradient, that the finestructure instability would not be greatly altered by vertical diffusion of heat and salt for considerable periods of time.

We must assume that the phenomenon was at least meta-stable to persist over such a large horizontal distance. If Neumann's relationship is valid we can estimate whether the level of turbulence, represented by the eddy coefficients of heat and momentum flux, seem reasonable to support the observed negative density gradients. If each negative density gradient exists in a neutrally stable layer, the limiting case, then

$$A = \frac{10^{-3} \frac{\Delta\sigma t}{\Delta z} \cdot g \cdot h^4}{\Lambda_o}$$

Now if, as seems to be generally assumed, the eddy conductivity (K, $cm^2 sec^{-1}$) is an order smaller than the eddy viscosity (A, $gm\ cm^{-1}\ sec^{-1}$), minimum estimates of K can be made. We have done this for the data of station 20 (Fig. 6).

The eddy conductivities so estimated are of order 1 to 10 (Table 5). These are reasonable values for a regime with a modest amount of turbulence. Furthermore, the values are smaller in the middle of the pycnocline and increase by an order toward the bottom and/or toward increasing scale sizes, seemingly a confirmation of our previous assumption.

TABLE 5

Eddy coefficients associated with density inversions of Station 20 (Fig. 6)

Depths, m.	$10^3 \frac{\Delta\sigma_t}{\Delta z}$, m^{-1}	A^2, gm cm sec^{-2}	K_T, cm^2 sec^{-1} ($K_T = 0.1 A_V$)
73.0-73.6	0.95	10.96	1.0
74.0-74.1	3.60	0.032	0.1
74.6-75.6	1.87	166.4	4.1
76.4-77.3	1.90	110.9	3.3
76-77	0.85	76	2.8
76-78	0.75	1068	10.3
76-79	0.63	4542	21.3
76-80	0.55	12531	35.4
76-81	0.45	25031	50.0

SUMMARY AND CONCLUSIONS

Oceanic conditions extant in Bering Sea during March, 1976 were such that a large subsurface layer, marked by a large density inversion, was formed. The layer appeared to be coherent for up to 100 km downstream from the formation area. The horizontal location of this layer appears to have coincided with the zone of interaction between the Bering Sea water flowing northeastward into Bristol Bay and the shelfwater of Bristol Bay itself. The zone of intersection holds the key to the formation of the observed finestructure. In the interaction zone the Bering Sea water, though more dense than Bristol Bay water, interleaves with the shelfwater of Bristol Bay near the top of the pycnocline. Further, vertical fluxes of salt and heat are low enough to allow the persistence of the intruded water for 10's of kilometers downstream from the formation area. We conclude that the physical conditions associated with the Bristol Bay outer shelf water mass in March were such that, once formed, water layers creating negative density gradients might have been advected for considerable distances in a meta-stable condition. The amount of turbulence required would not appear to be unreasonable. The source for the turbulent energy may have been in part the apparent shear between the upper and lower water mass layers, but may also have come from other sources; for example, this region would appear to have been ideal for the propagation of internal waves.

ACKNOWLEDGEMENTS

We wish to acknowledge the large number of contributions to support of this program. In particular, we thank the officers and crews of the R/Vs *Moana Wave* and *Miller Freeman*. We greatly appreciate the support rendered by the staff at both our institutions, specifically, but not limited to R. B. Tripp, J. C. Haslett and J. D. Schumacher. This project was supported in part by NOAA's Outer Continental Shelf Environmental Assessment Program which administers oil exploration hazard research in Alaska for the U.S. Bureau of Land Management.

LIST OF FIGURES

Figure 18. Vertical profiles of stability for March, 1976 stations showing marked density inversions. 1-m average values.

19. Distribution of the baroclinic shear across the thermocline for the March, 1976 stations.

20. Qualitative representation of profile history after one week using March, 1976 data for initial conditions and assumed mixing coefficients.

<u>REFERENCES</u>

Coachman, L. K., K. Aagaard and R. B. Tripp. 1975. Bering Strait: The Regional Physical Oceanography. Seattle and London: Univ. Wash. Press, 172 pp.

Cooper, L. H. N. 1967. Stratification in the deep ocean. Sci. Prog., Oxf. <u>55</u>: 73-90.

Defant, A. 1961. Physical Oceanography Vol. I. London: Pergamon Press. 729 pp.

Ebbesmeyer, C. E. 1973. Some observations of medium scale water parcels in a fjord: Dabob Bay, Washington. Dept. Ocean. U. Wash. Ph.D. Thesis. 212 pp.

Elliot, A. J., M. R. Howe and R. I. Tait. 1974. The lateral coherence of a system of thermo-haline layers in the deep ocean. D.-S.R. <u>21</u>(2): 95-107.

Favorite, F., J. W. Schantz and C. R. Hebard. 1961. Oceanographic observations in Bristol Bay and the Bering Sea 1939-41 (USCGT Redwing). U.S.F.W.S. Spec. Sci. Rpt. No. 381, 323 pp.

Gargett, A. E. 1975. Horizontal coherence of oceanic temperature structure. D.-S.R. <u>22</u>(11): 767-76.

Gargett, A. E. 1976. An investigation of the occurrence of oceanic turbulence with respect to finestructure. J.P.O. <u>6</u>(2): 139-56.

Garrett, C. and W. Munk. 1972. Oceanic mixing by breaking internal waves. D.-S.R. <u>19</u>(12): 823-32.

Gregg, M. C. 1976. Temperature and salinity microstructure in the Pacific Equatorial Undercurrent. J.G.R. <u>81</u>(6): 1180-96.

Gregg, M. C. and C. S. Cox. 1971. Measurements of the oceanic microstructure of temperature and electrical conductivity. D.-S.R. <u>18</u>(9): 925-34.

Gregg, M. C. and C. S. Cox 1972. The vertical microstructure of temperature and salinity. D.-S.R. <u>19</u>(5): 355-76.

Hart, J. E. 1971. A possible mechanism for boundary layer mixing and layer formation in a stratified fluid. J.P.O. <u>1</u>(4): 258-262.

Hayes, S. P. 1975. The temperature and salinity structure of the Mediterranean Water in the Western Atlantic. D.-S.R. <u>22</u>(1): 1-11.

Hayes, S. P., T. M. Joyce and R. C. Millard, Jr. 1975. Measurements of vertical fine structure in the Sargasso Sea. J.G.R. 80(3): 314-19.

Hesselberg, T. 1918. Über die Stabilitätsverhältnisse bei vertikalen Verschiebungen in der Atmosphäre und im Meer. Ann. D. Hydr. u. Mar. Meteor., pp. 118-29.

Howe, M. R. and R. I. Tait. 1972. The role of temperature inversions in the mixing processes of the deep ocean. D.-S.R. 19(11): 781-91.

Johannessen, O. M. and O. S. Lee. 1974. A deep stepped thermo-haline structure in the Mediterranean. D.-S.R. 21(8): 629-39.

Maeda, T., T. Fujii and K. Masuda. 1968. Studies on the trawl fishing grounds of the eastern Bering Sea - II. On the annual fluctuation of oceanographical conditions in summer season. Bull., Japan Soc. Sci. Fish. 34(7): 586-93 (in Japanese).

Neshyba, S., V. T. Neal and W. Denner. 1971. Temperature and conductivity measurements under Ice Island T-3. J.G.R. 76(33): 8107-20.

Neumann, G. 1948. Bemerkungen zur Zellularkonvektion im Meer und in der Atmosphäre und die Beurteilung des statischen Gleichgewichts. Ann. D. Meteorol., July-Aug., pp. 235-44. (Hamburg).

Neumann, G. and W. J. Pierson, Jr. 1966. Principles of Physical Oceanography. Englewood Cliffs, N.J.: Prentice-Hall. 545 pp.

Osborn, T. R. and C. S. Cox. 1972. Oceanic fine structure. Geophys. Fluid Dyn. 3: 321-45.

Pingree, R. D. 1969. Small-scale structure of temperature and salinity near Station Cavall. D.-S.R. 16(3): 275-95.

Pingree, R. D. 1971. Analysis of the temperature and salinity of small-scale structure in the region of Mediterranean influence in the N.E. Atlantic. D.-S.R. 18(5): 485-91.

Pingree, R. D. and J. Plevin. 1972. A description of the upper 100 m at Ocean Weather Station Juliett (53°30'N, 20°00'W). D.-S.R. 19(1): 21-34.

Rayleigh, Lord. 1916. On convection currents in a horizontal layer of fluid when the higher temperature is on the under side. Phil. Mag., Series 6, vol. 32, pp. 529-46.

Roden, G. I. 1971. Spectra of North Pacific temperature and salinity perturbations in the depth domain. J.P.O. 1(1): 25-33.

Scarlet, R. J. 1975. A data processing method for salinity, temperature, depth profiles. D.-S.R. 22(7): 509-515.

Scholl, D. W., E. C. Buffington, D. M. Hopkins and T. R. Alpha. 1970. The structure and origin of the large submarine canyons of the Bering Sea. Mar. Geology 8: 187-210.

Stommel, H. and K. N. Fedorov. 1967. Small-scale structure in temperature and salinity near Timor and Mindanao. Tellus 19(2): 306-25.

Sverdrup, H. V., M. W. Johnson and R. H. Fleming. 1942. The Oceans. New York: Prentice-Hall, 1087 pp.

Tait, R. I. and M. R. Howe. 1968. Some observations of thermohaline structure in the deep ocean. D.-S.R. 15(3): 275-80.

Takenouti, A. Y. and K. Ohtani. 1974. Currents and water masses in the Bering Sea: a review of Japanese work. Chap. 2, pp. 39-57 in Oceanography of the Bering Sea. D. W. Hood and E. J. Kelley, eds. Inst. Mar. Sci. Univ. Alaska Occas. Publ. no. 2.

Turner, J. S. 1967. Salt fingers across a density interface. D.-S.R. 14(5): 599-611.

Woods, J. D. and R. L. Wiley. 1972. Billow turbulence and ocean microstructure. D.-S.R. 19(2): 87-122.

QUARTERLY REPORT

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141E

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Number of Pages:
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NORTON - CHUKCHI OCEANOGRAPHIC PROCESSES (N-COP)

L.K. Coachman

Department of Oceanography
University of Washington

R.L. Charnell

Pacific Marine Environmental Laboratory

J.D. Schumacher

Pacific Marine Environmental Laboratory

K. Aagaard

Department of Oceanography
University of Washington

R.D. Muench

Pacific Marine Environmental Laboratory

30 September, 1976

Task Title: NORTON - CHUKCHI OCEANOGRAPHIC PROCESSES (N-COP)

PI's: Dr. L.K. Coachman
Dr. K. Aagaard
both at:
Dept. of Oceanography
University of Washington
Seattle, WA 98195

Mr. R.L. Charnell
Dr. J.D. Schumacher
Dr. R.D. Muench
all at:
Pacific Marine Environmental Laboratory
3711 15th Avenue N.E.
Seattle, WA 98105

Report Period 1 July - 30 September, 1976

I. Task Objectives:

1) Verify fluctuations in the predominantly northward transport through the system.
2) Delineate the bifurcation of northward flow which occurs west of Pt. Hope.
3) Define time and space scales of eddies ubiquitous in the system and provide data toward a dynamical description.
4) Define the circulation in Norton and Kotzebue sounds.

II. Field and Laboratory Activities:

A. Cruises: All field gear requested, including current meters, acoustic releases, bottom pressure gauges and meteorological instruments, have been acquired since the inception of this project. Eighteen moorings have been deployed in the study area, and a highly successful program of CTD and anchored current meter observations carried out. The actual field program is detailed in the attached cruise report and preliminary cruise report. Additionally, a specially designed low profile mooring configuration, structured so as not to be contacted by surface ice, was utilized.

B. Laboratory Activities: None proposed or carried out.

III. Results:

Data from first field work are being processed. Results are not yet available.

IV. Preliminary Interpretation of Results:

Not yet available.

CRUISE REPORT
RP-4-DI-76B, Leg III
18 August - 3 September 1976

TO: Clinton D. Upham
Captain NOAA
Commanding Officer
NOAA Ship DISCOVERER

FROM: Richard B. Tripp (Chief Scientist - Leg III)
Principal Oceanographer
Department of Oceanography
University of Washington
Seattle, Washington

INTRODUCTION

This cruise accomplished phase I in a physical oceanography survey of Norton Sound, Bering Strait, Kotzebue Sound, and the Chukchi Sea. This is a joint program between NOAA/PMEL and the University of Washington.

The flow regime throughout the region is generally northward. This program will address the following questions: 1) verification of the fluctuations in the northward transport; 2) temporal and spatial description of the bifurcation of north flow which occurs off Point Hope; 3) provide data on temporal spatial scales of eddies ubiquitous to the system; and 4) define the circulation of Norton and Kotzebue Sound.

Marine Mammal Observation and Collection programs were undertaken on this cruise. These programs and their accomplishments are discussed in Attachments C and D.

These data, when completed, will: 1) provide comprehensive environmental and biological data on the Alaska Outer Continental Shelf, 2) define the probable ecological impact of petroleum exploration, production, storage, and trans-shipment on the Continental Shelf; and 3) refine our understanding of key ecological dynamic processes.

SCIENTIFIC PARTY

The following personnel comprised the scientific party during this leg.

1. Physical Oceanography Program

   Richard B. Tripp, Oceanographer, University of Washington (C/S)
   Dale Ripley, Technician, University of Washington
   Steve Harding, Technician, University of Washington
   David Spell, Electronics Engineer, PMEL/NOAA

2. Marine Mammal Collection Program

   Kathy Frost, Alaska Department Fish & Game
   David James, Alaska Department Fish & Game

3. Marine Mammal Observation Program

   Renee Engel, MMD/NOAA

METHODS AND ACCOMPLISHMENTS

1. Physical Oceanography Program

Eighteen current meter moorings consisting of: 1) an Aanderaa RCM-4 Current Meter at a depth 10 meters off the bottom (7 meters in Kotzebue Sound); 2) an AMF Model 242 or Model 395 Acoustic Release; and 3) sub-surface floatation at a depth sufficient to escape the keel of the winter ice cover, were deployed throughout the survey area. In addition, three of the moorings (NC-6, NC-10, and NC-18) which are arranged longitudinally in the system have an Anderaa TG-2A or TG-3A Water Level Gauge housed in the concrete anchor. This is to aid to the study of the major driving force for the northward flow. As these moorings will not be recovered until Summer 1977, the sampling interval on the current meters was set at 40 minutes, and the magnetic tape capacity increased to accomodate the added data records. The sampling interval of the TG-2A gauge was set at 30 minutes and the TG-3A gauge was set at 60 minutes. Mooring locations and other pertinent mooring information are listed in attachment A.

Salinity/Tempbrature/Depth measurements were made along all sections including the moored current meters. A grid of STD stations were occupied in Norton Sound and in Kotzebue Sound. In addition, a 54-hour time series of STD stations near the ice-edge, and a line of STD stations between the ice-edge and Bering Strait were accomplished. All STD station locations are listed in aatachment B.

During the deployment of mooring NC-7, we had a mishap and lost some instrumentation (1 Current Meter; and 1 Acoustic Release). The position of the mooring minus the floatation is as follows: 68-55.6 North; 167-21.5 West (X=17348.89, Y=28034.71, Z=45985.00); in water depth of 46.5 meters. Mooring NC-7 was then deployed east of this position. However, this left us short of enough instrumentation to complete all planned mooring deployments. Therefore, mooring NC-16 will be deployed at a later date.

2. Marine Mammal Collection Program

Attachment C.

3. Marine Mammal Observation Program

Attachment D.

CONSTRUCTIVE SUGGESTIONS

I was very pleased, and also quite impressed with the ship's ability to accomplish the physical oceanography program. One event which I wish to make a comment on is in the initial deployment of mooring NC-7 where we were unfortunate to get the mooring line cut by the ship's propellor. I am convinced that this mishap came about as arresult of overconfidence and lack of awareness. Personnel should be constantly reminded that mooring deployments and recoveries are a serious and often difficult task, and one should not take a casual approach to them.

ACKNOWLEDGEMENTS

In every respect this was a most successful cruise. The time on this leg was very well utilized, as the accomplishments obviously indicate. It is difficult to single out personnel as everyone gave a 110% effort. However, I would like to thank Captain Upham for his keenness, and flexibility throughout the cruise. He personally provided the impetus for our success. Lt. Commander McGee's drive in getting the job done was greatly appreciated. I thoroughly enjoyed working with him. Also, Lt(jg) Simpson's extra effort in providing hard copy from the DAS was greatly appreciated. Lastly, I would like to thank CST Murray and his survey technicians, along with with CBM Sherrill and his personnel. They did most of the work. Without them we would'nt have had such success. From my personal standpoint it was a rewarding and delightful cruise.

ATTACHMENT A

MOORING No.	AGENCY	DEPLOYMENT Date/Time GMT Aug 76	POSITION Latitude N	Longitude W	DEPTH M	LORAN-C RATES X	Y	Z	RECEIVER CHANNEL No.
				NORTON SOUND					
NB-15	PMEL	20-2039	64-06.5	165-17.7	19.2	18012.66	28823.87	46023.86	1
NB-14	PMEl	21-0016	64-21.6	165-21.6	31.5	17975.25	28654.95	46017.83	6
				BERING STRAIT					
NC-10	PMEL	21-1849	65-45.1	168-26.8	55	17555.80	28155.28	46334.16	5
NC-11	PMEL	21-2016	65-40.3	168-38.5	52	17545.90	29187.33	46367.43	9
NC-12	PMEL	21-2222	65-40.4	168-26.5	55	17563.82	28168.15	46342.76	2
NC-13	PMEL	21-2329	65-40.5	168-17.5	51	17577.13	28145.98	46323.90	7
				KOTZEBUE SOUND					
NC-9	UW	23-1825	66-43.5	164-08.8	22.5	17775.11	28045.35	45742.70	3
NC-8	UW	23-2005	66-54.7	164-02.2	24.5	17761.40	28039.63	45724.39	9
				CAPE LISBURNE SECTION					
NC-7	UW	24-2045	68-55.2	167-21.3	46.5	17349.75	28034.50	45985.08	5
NC-6	UW	24-2324	68-57.2	168-18.6	50.7	17281.64	28062.25	46067.39	10
NC-5	UW	25-0219	69-00.3	169-09.9	53	17217.11	28092.71	46137.60	3
NC-4	UW	25-0502	69-00.7	169-59.2	54	17156.61	28128.21	46218.92	4
NC-1	UW	25-2104	68-15.4	172-40.6	49	16984.36	28324.53	46499.92	9
NC-2	UW	25-2248	68-29.7	171-55.3	53	17036.11	28255.44	46414.45	1
NC-3	UW	26-0102	68-44.2	171-06.2	55	17088.40	28193.50	46324.61	6
				WEST/EAST ST. LAWRENCE IS.					
NC-19	PMEL	30-1914	64-04.1	172-09.1	49.5	17316.98	29420.93	47014.90	5 (395)
NC-17	PMEL	31-2009	62-48.1	167-27.1	31	18013.68	29819.10	46530.65	10
NC-18	PMEL	31-2239	63-09.1	168-22.5	46	17873.75	29627.07	46640.05	6 (395)

ATTACHMENT B

Consec. No.	Grid No.	Date/Time GMT	Latitude N	Longitude W	STD Depth M	Water Depth M
			NORTON SOUND			
1	22	19-0157	64-26.0	165-30.7	18	23
2	32	0433	64-21.0	164-57.8	27	32
3	31	0532	64-15.3	164-48.1	10	15
4	30	0639	64-07.2	164-49.4	12	17.1
5	29	0753	63-58.0	164-46-3	15.5	19.5
6	28	0922	63-50.1	164-20.0	13.5	18.5
7	35	1123	64-06.0	164-02.8	18	22
8	38	1410	63-53.0	163-17.1	13	18
9	42	1617	63-58.9	162-34.3	14	19
10	44	1835	63-52.1	161-46.5	14	19
11	45	2044	64-05.4	161-50.7	14.5	19.5
12	46	2210	64-11.7	162-18.8	13	18
13	41	2352	64-16.5	162-42.8	19	24
14	39	20-0125	64-16.0	163-12.1	16	20.5
15	40	0309	64-23.1	163-33.9	13	18
16	34	0455	64-18.2	164-08.9	10	15
17	33	0615	64-26.4	164-30.4	19.5	24.5
18	25	0905	63-54.1	165-18.9	14	19
19	26	1054	63-37.6	165-01.7	13	18
20	27	1311	63-17.7	165-24.0	15	20
21	16	1411	63-22.1	165-44.2	17	22
22	17	1604	63-42.6	165-54.5	20	25
23	18	1759	64-03.9	166-08.7	19	24
24	NC-15	2001	64-06.4	165-17.1	14	19.2
25	24	2119	64-11.1	165-23.8	15	20
26	23	2249	64-19.4	165-28.8	18	23
27	NC-14	2336	64-21.4	165-21.1	24	29.3
28	NC-14	21-0041	64-21.8	165-22.5	26	31.5
29	21	0210	64-28.9	165-57.9	17	22
30	20	0331	64-22.2	166-08.9	22	27
31	19	0420	64-14.3	166-14.1	19	24
			BERING STRAIT			
32	NC-10	21-1743	65-45.8	168-25.7	45	50
33	50	22-0152	65-38.2	168-13.6	34	38
34	51	0236	65-37.6	168-22.2	44	49
35	52	0321	65-37.5	168-32.2	49	52
36	53	0401	65-37.2	168-40.6	46	51
37	54	0438	65-37.4	168-49.5	45	50

Consec. No.	Grid No.	Date/Time GMT	Latitude N	Longitude W	STD Depth M	Water Depth M
			BERING STRAIT			
38	55	22-0520	65-37.1	168-56.8	43	45
39	56	0644	65-26.0	169-04.7	51	56
40	57	0804	65-25.2	169-17.4	49	54
41	58	0852	65-26.7	169-26.2	43.5	48.5
42	59	0934	65-28.6	169-32.5	45	50
43	60	1016	65-30.0	169-38.4	46	51.2
44	61	1056	65-32.0	169-45.3	44	49
45	NC-11	1429	65-40.7	168-36.4	46	51
46	NC-12	1517	65-40.8	168-25.3	47	52
47	NC-13	1552	65-40.8	168-16.1	39	44
			KOTZEBUE SOUND			
48	63	23-0209	66-41.5	165-11.5	17	22
49	73	0326	66-40.5	164-41.8	13	18
50	74	0450	66-41.0	164-08.4	15	20
51	80	0605	66-38.6	163-34.7	21	26.5
52	81	0708	66-32.4	163-13.8	17	22
53	86	0816	66-22.7	163-20.8	11	14.6
54	87	0924	66-19.6	162-59.8	9	14.5
55	88	1053	66-19.8	162-37.1	10	15
56	85	1203	66-28.2	162-44.3	10	15
57	82	1323	66-37.9	162-01.0	10	15.2
58	83	1415	66-43.2	162-53.8	10	15
59	79	1544	66-47.3	163-26.1	10.5	15.5
60	75	1716	66-42.9	164-04.9	19	24
61	NC-9	1754	66-43.5	164-09.4	17.5	22.5
62	NC-8	2021	66-54.7	164-01.4	21.5	24.5
63	76	2110	66-54.9	163-53.1	19.5	24.5
64	77	2205	67-01.4	164-00.4	21	24
65	69	2316	67-10.0	164-09.9	20	24
66	70	24-0018	67-04.9	164-23.8	25	28
67	71	0115	66-58.4	164-36.8	23.5	28.5
68	72	0210	66-50.9	164-42.7	22.5	25.6
69	64	0320	66-52.5	165-13.0	20.5	25.6
70	65	0420	67-02.1	165-15.2	25	28
71	66	0548	67-11.7	164-51.9	26	31
72	67	0653	67-18.5	164-29.7	22.5	25.5
73	68	0748	67-22.9	164-10.9	16.5	21.5

Consec. No.	Grid No.	Date/Time GMT	Latitude N	Longitude W	STD Depth M	Water Depth M
			CAPE LISBURNE SECTION			
74	93	24-1718	68-49.8	166-37.7	39	44
75	94	1830	68-52.4	167-13.0	39	44.5
76	NC-7	1912	68-54.8	167-21.9	42.5	46.5
77	95	2203	68-54.3	167-52.6	44	49
78	NC-6	2347	68-57.0	168-18.6	22	50.5
79	NC-6	25-0009	68-57.6	168-18.9	45	50.5
80	96	0112	68-58.9	168-43.4	47	52
81	NC-5	0240	69-00.1	169-09.9	48	53
82	97	0337	69-01.0	169-32.2	48.5	53.5
83	NC-4	0438	69-00.6	169-59.3	49	54
84	98	0612	68-55.8	169-55.2	50	55
85	99	0718	68-49.2	170-21.2	50	55
86	100	0906	68-38.3	171-11.8	50	55
87	101	1050	68-23.7	171-54.1	47	52
88	102	1215	68-11.6	172-30.5	42.5	47.5
89	103	1404	67-54.3	173-01.2	43	48
90	104	1535	67-41.1	173-29.5	41	46
91	105	1649	67-30.8	173-44.2	35	40
92	NC-1	2040	68-15.3	172-40.8	44	49
93	NC-2	2303	68-29.6	171-54.6	48.5	53
94	NC-3	26-0113	68-43.8	171-05.9	51	55
			ICE-EDGE AREA			
95		26-2028	72-05.8	166-58.4	45	49.5
96		2224	72-04.7	166-54.3	45	49
97		27-0012	72-04.9	166-52.7	44	48.5
98		0158	72-03.1	166-53.1	43	48
99		0422	72-04.2	166-57.8	46.4	49.4
100		0636	72-05.9	166-56.1	44	49
101		0803	72-06.9	166-52.8	44	49
102		1007	72-07.2	166-50.5	45	49.5
103		1204	72-06.6	166-50.0	45	49.5
104		1406	72-06.3	166-48.3	45	49
105		1602	72-05.3	166-48.2	44	49
106		1804	72-05.4	166-45.7	44	49
107		2003	72-06.1	166-43.4	44	49
108		2203	72-06.6	166-42.0	44.5	49.5
109		28-0007	72-06.2	166-39.2	45.9	49
110		0158	72-05.7	166-37.9	43	48

Consec. No.	Grid No.	Date/Time GMT	Latitude N	Longitude W	STD Depth M	Water Depth M
			ICE-EDGE AREA			
111		28-0355	72-05.2	166-36.7	42.5	47.5
112		0609	72-05.1	166-36.2	43.5	48.5
113		0813	72-06.1	166-33.9	43	48
114		1006	72-05.8	166-32.7	44	48
115		1207	72-04.5	166-31.9	44.5	48
116		1359	72-04.9	166-29.5	42.5	47.5
117		1605	72-04.8	166-27.2	42.5	47.5
118		1832	72-04.6	166-25.7	44	47
119		2020	72-05.6	166-23.2	45	48
120		2208	71-58.2	166-21.5	43	48
121		29-0007	71-58.7	166-19.2	43	48
122		0205	72-01.5	166-18.5	42.5	47.5
			ICE-EDGE TO BERING STRAIT			
123		29-0315	71-59.0	166-37.0	41	46
124		0536	71-30.8	166-32.0	40	45
125		0744	71-00.9	166-36.8	41	45.5
126		1006	70-30.1	166-53.2	44.5	49.5
127		1213	70-02.7	167-00.3	42.5	47.5
128		1443	69-31.2	167-13.6	42.5	47.5
129		1917	68-28.9	167-38.4	46.5	51.5
130		2136	68-00.4	167-47.2	48.5	53.5
131		2354	67-30.6	167-56.6	41.5	46.5
132		30-0217	67-00.4	168-07.5	30	34.5
133		0439	66-31.0	168-16.4	30	35
134		0712	65-59.9	166-28.0	50	55
			WEST ST. LAWRENCE IS.			
135	NC-19	30-1844	64-03.9	172-09.4	45	49.5
136	2	2030	64-04.3	172-19.2	46.5	51.5
137	3	2137	64-01.4	172-08.7	48	53
138	4	2231	63-57.6	172-04.5	52	55
139	5	2323	63-52.3	171-55.5	35	40.2
140	6	31-0010	63-49.0	171-48.4	26	31

Consec. No.	Grid No.	Date/Time GMT	Latitude N	Longitude W	STD Depth M	Water Depth M
			EAST ST. LAWRENCE IS.			
141	7	31-0840	63-11.3	168-36.6	23	28
142	8	1031	63-05.7	168-21.4	35	40
143	9	1125	63-00.0	168-08.0	27	32
144	10	1222	62-54.4	167-54.8	19	24
145	11	1326	62-49.1	167-37.0	20	25
146	12	1432	62-44.1	167-22.6	30	35
147	13	1528	62-39.3	167-08.8	30	35
148	14	1631	62-34.3	166-53.4	25	30
149	15	1726	62-29.5	166-41.0	19	24
150	NC-17	1939	62-47.9	167-27.2	26	31
151	NC-18	2252	63-09.3	168-21.9	40	45

Attachment C. Marine Mammal Collection and Otter Trawls

INTRODUCTION

Investigations of the trophic relationships of ice inhabiting phocid seals and of the natural history of ringed and bearded seals in Norton Sound and the Chukchi Sea were primary objectives of the ADF&G marine mammal work on Leg III (OCSEAP RU#s 230 & 232). Information provided by such investigations should enable delineation of key prey species and critical habitat areas for different species of seals, and make possible identification of potentially sensitive parts of the animals life histories with relation to outer continental shelf offshore development.

Seals were collected to provide:
1) Qualitative and quantitative information on the food habits of animals inhabiting the ice front in the Chukchi Sea.

2) Information on the reproductive history, age at sexual maturity and age structure of populations.

3) Tissue samples for heavy metal and hydrocarbon analysis.

4) Information on parasitology and pathology of different species.

Otter trawls were conducted as an integral part of the seal trophics study in order to:
1) Determine what species of fish and invertebrates are present to serve as possible food items for seals.

2) Provide reference material for identification of food items (invertebrate specimens, fish skeletal parts, otoliths).

3) Provide material for other OCSEAP projects studying fishes of the Bering and Chukchi Seas.

METHODS AND ACCOMPLISHMENTS

Marine Mammal Collection

One collection attempt was made early in the cruise off Rocky Point and Cape Darby in Norton Sound, but no seals were sighted. Three days were spent at the southern edge of the ice front in the Chukchi Sea. Small boats were utilized for collection of seals. All hunting was done inside the ice edge.

Three seals were taken in three days of hunting: one adult female bearded seal, *Erignathus barbatus*, and two female ringed seals, *Phoca (Pusa) hispida*. Animals were returned to the ship and processed, or frozen whole to be shipped to Fairbanks and examined at a future date.

Otter Trawls

Bottom trawls were conducted with a 3/4" mesh, 19' Marinovich otter trawl for a duration of 10-20 minutes at 2-4 knots. Some experimentation with speed and scope of winch cable was necessary to obtain satisfactory fishing results. Trawl locations were chosen to coincide with existing collections of seal stomach specimens, or to sample areas where seals are known to reside for some part of the year.

A total of 23 trawls was conducted, 3 in Norton Sound, 4 off St. Lawrence Island, 4 at the ice edge in the Chukchi SEa, and the remainder at various points off coastal hunting villages in the Chukchi Sea. A large variety of invertebrates was found, but very few fish were caught.

COMMENTS AND SUGGESTIONS

Small boat operations were extremely smooth. I was most pleased with the ease with which the Boston whaler was on and off loaded. A 17' whaler with a 60hp engine is a convenient vessel to work/hunt from. For future work in the ice a small 10-15hp auxiliary motor would be desirable for emergency use.

Helicopter capabilities would greatly facilitate work in the ice. Reconnaissance flights to locate animals would expedite collecting efforts, as well as enable the ship to locate large lead systems to work up. Aerial survey efforts could also be undertaken. Greater use could be made of shorter periods of time.

ACKNOWLEDGMENTS

I want to express appreciation to all of these on the ship who helped us so much in making our project a success. The enthusiasm and interest shown by so many was great. It made the difference between just getting the job done, and having fun doing/sharing it.

Thanks to Captain Upham for giving us the freedom to operate within the ice, to Commander Speer and Commander McGee for cooperation and assistance in logistics and scheduling, and to all the officers who helped on the fantail and in the small boats.

Special thanks to all the deck force and survey techs for help with otter trawls, and to the small boat cockswains for long hard days in the cold and fog. We couldn't have done it without you.

Kathryn J Frost
1 September 1976

ATTACHMENT D

RENEE ENGEL
MARINE MAMMAL DIVISION
BLDG. # 32, 442-4734
SANDPOINT NAVAL BASE
SEATTLE, WA.

MARINE MAMMAL OBSERVATION REPORT:

PURPOSE:

Marine mammals have been exploited for hundreds of years with little or no regard for proper management of existing stocks. One reason for such a lack of management is the difficulty and expense associated with assessment of most marine mammal stocks. The National Marine Fisheries Service has instituted the Platforms of Opportunity Program (POP) which, will allow volunteer observers to contribute a significant amount of data to the relatively sparse data base now in existence. Presently, the NOAA Fleet is providing POP with its largest single source of marine mammal observation data.

An important aspect of the NOAA Fleet marine mammal reporting program involves the presence of a Marine Mammal Officer (MMO) who can provide guidance to those who are logging sightings and act as a first level filtering agent by supplementing or down-classifying questionable reports.

ACCOMPLISHMENTS:

Marine mammal sightings in the Norton and Kotzebue Sounds were practically non-existent. Even these lack of sightings are important, for this tells us what mammals aren't in these areas during the month of August. This information is important when mapping out migration paths.

The Bering and Chukchi Seas, the Bering Strait and the Arctic Ocean were the areas of the majority of marine mammal sightings. These sightings included the following; fin whale (B. physalus), killer whale (Orcinus orca), walrus (O. rosmarus), polar bear (U. maritimus), ringed seal (P. hispida), bearded seal (E. barbatus).

I have obtained flippers from a bearded seal which was shot at the ice edge. I will bring these with me to Seattle, to aid scientists in studying the anatomy and physiology of marine mammals.

I also took a number of colored slides of the marine mammal sightings, whenever time permitted. The slides will be valuable in the training of future observers for the purpose of recognizing and differentiating between various marine mammals.

CONCLUSION:

The NOAA Officers and crew aboard the Discoverer have all been extremely helpful.. They have made my job of logging locations, recording correct times, and observing run smooth and easy.

When I return to the Marine Mammals Division in Seattle, I will take with me five weeks of data collection. This information will help us achieve our goal of obtaining more precise marine mammal counts, and the understanding of their migration paths.

Preliminary Cruise Report

RP-4-MW-76C, Leg IV MOANA WAVE

31 August - 17 September 1976

I. Itinerary (UT)

9/Ø1 - 0300	Departed Kodiak
9/Ø3 - 1200	Wayne Hoffman landed on Akutan Island for bird observations.
9/Ø5 - 2230	Arrived at first station (NCOP-15)
9/14 - 0130	Completed last station (NCOP-T)
9/14 - 2030	Arrived Nome to off-load equipment
9/15 - 0100	Departed Nome for Dutch Harbor

II. Methods and Accomplishements

The physical oceanographic aspect of this cruise was a complete success. An Aanderaa RCM-4 was used with a deck readout system for the 52 anchored current meter stations. The instrument was lowered at 5m intervals and two min readings of temperature, speed, and direction were taken at each depth.

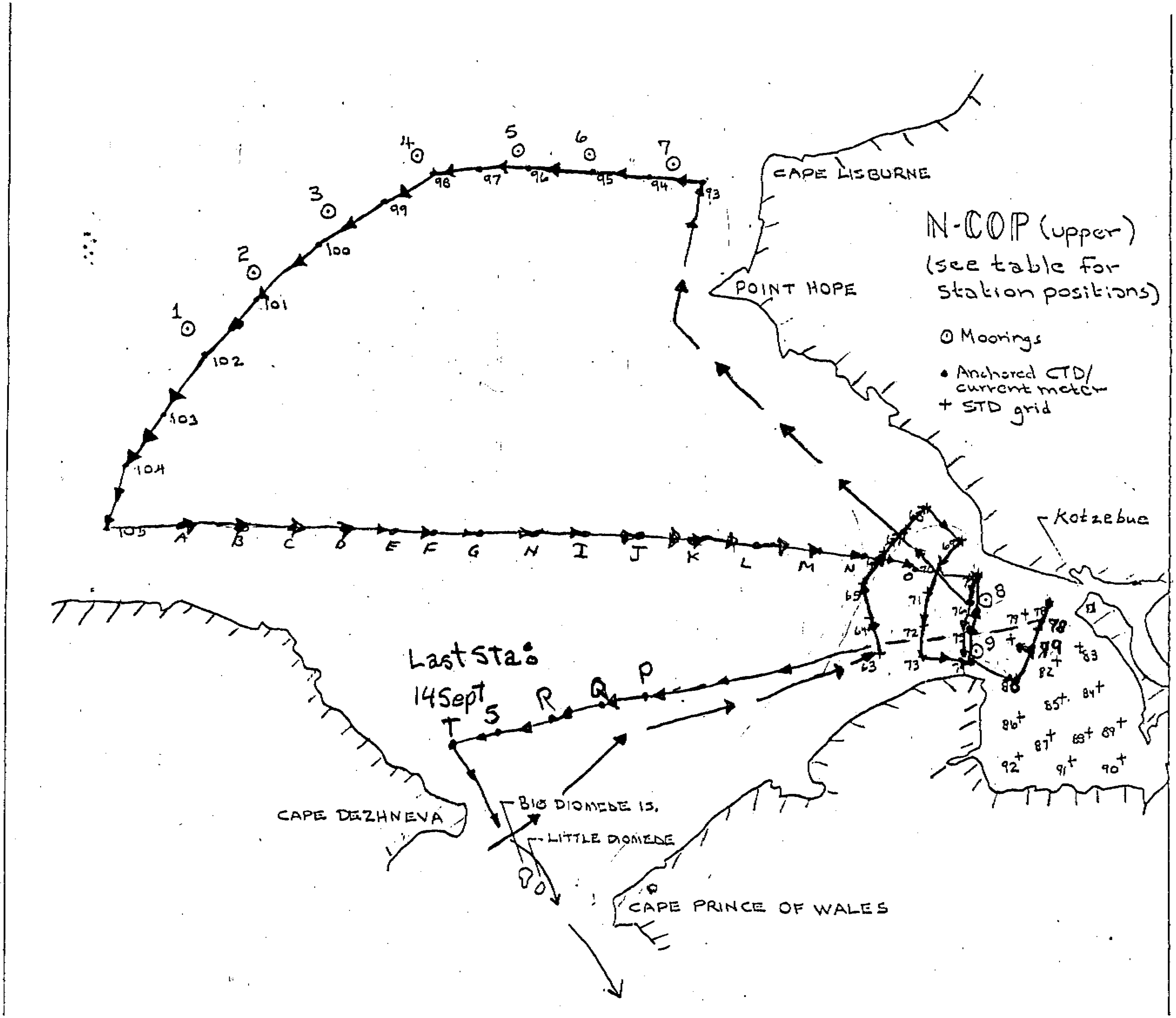
A total of 83 CTD casts were taken, including 20 stations not on the standard NCOP CTD grid (see Figure 1b).

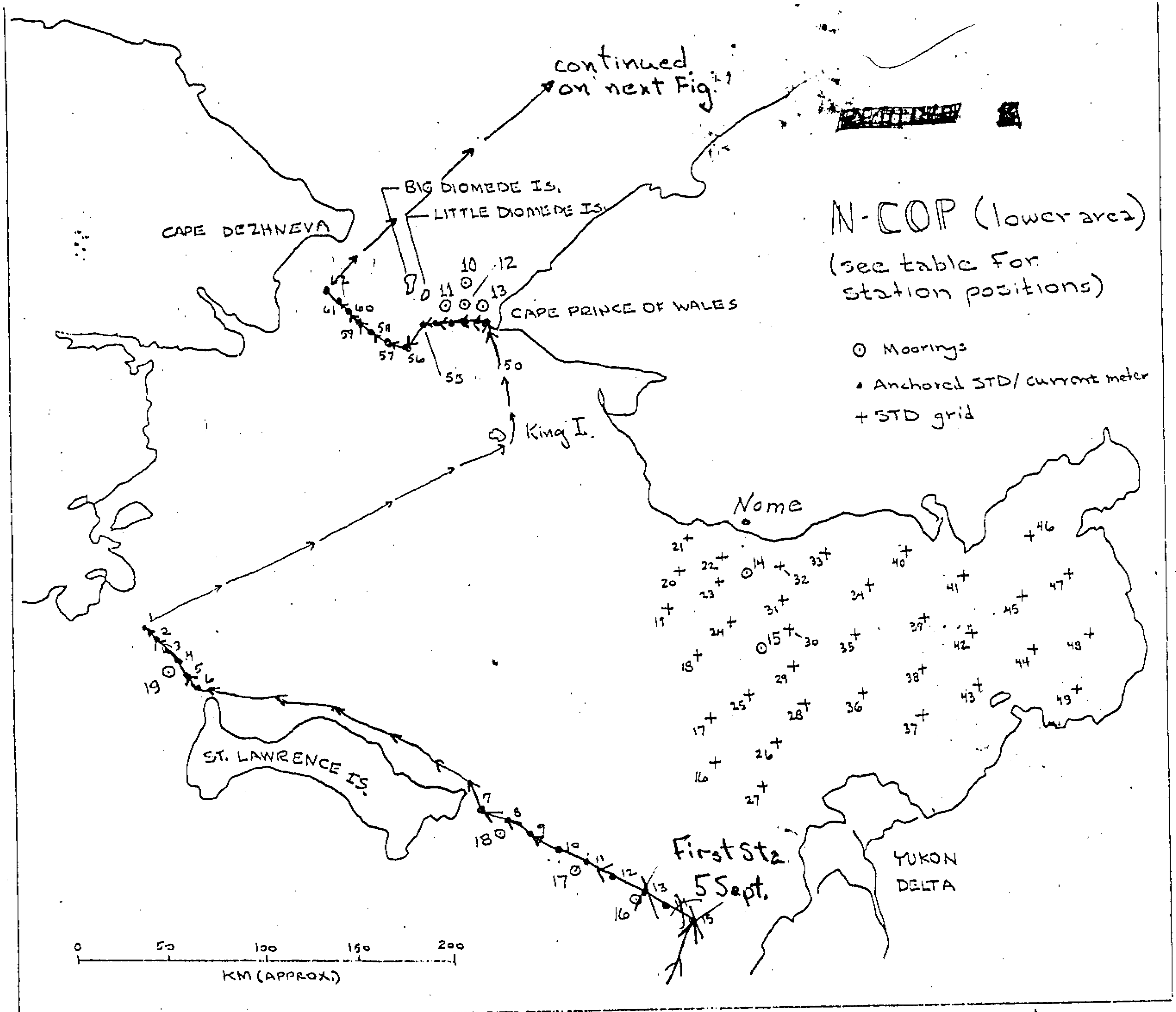
At the request of Dr. Pat Gould, cruise track lines were run towards and from King Island in order to gain a better understanding of bird distributions and densities in this region.

Carl Brooks, the mammal observer, became ill and departed the cruise at Dutch Harbor on September 3.

III. Personnel

L.K. Coachman	Chief Scientist	UW
J.D. Schumacher	Technician	PMEL
K. Uhlinger	Technician	UW
J. Severn	Technician	UW
C. Brooks	Mammal Observer	NMF
P. Gould	Bird Observer	USFWS


CAPE LISBURNE
N-COP (upper)
(see table for station positions)
POINT HOPE
⊙ Moorings
• Anchored CTD/current meter
+ STD grid
Kotzebue
Last Sta: 14 Sept
CAPE DEZHNEVA
BIG DIOMEDE IS.
LITTLE DIOMEDE
CAPE PRINCE OF WALES


continued on next Fig.
BIG DIOMEDE IS.
LITTLE DIOMEDE IS.
CAPE DEZHNEVA
CAPE PRINCE OF WALES
N-COP (lower area)
(see table for station positions)
Moorings
Anchored STD/current meter
+ STD grid
King I.
Nome
ST. LAWRENCE IS.
First Sta
5 Sept.
YUKON DELTA
0 50 100 150 200
KM (APPROX.)

Norton Sound/
Chukchi Sea
Oceanographic Processes   University of Washington

VI. Estimate of funds expended (31 August 1976)

	University of Washington	
	Original allocation	$52,000
	Received to date	20,800
A.	Salaries	2,306
B.	Benefits	326
C.	Indirect Costs	1,010
D.	Supplies and other direct costs	8,379
E.	Equipment	19,639
	Digi-print printer $975	
	Model 322 acoustic transponder $13,720	
	TG-3A water level recorder $5,925	
F.	Travel	2,621
	Total	$34,281
	Balance	-$13,481

Quarterly Report

Contract No:
03-5-022-67, TA 1

Research Unit No:
151

Reporting Period:
1 July 1976 - 30 September 1976

Number of Pages:
2

STD Mappings of the Beaufort Sea Shelf

Knut Aagaard

Department of Oceanography
University of Washington
Seattle, Washington 98195

30 September 1976

I. Objectives

To provide seasonally distributed temperature-salinity mappings of the Beaufort Sea shelf and the dynamically related region of the slope. Such mappings are an essential prerequisite to, and component of, all physical oceanographic studies on the shelf. These mappings are necessary input for the accomplishment of task elements B-2 to B-4.

II. Field activities

The last field trip of this fiscal year terminated 29 May 1976 and was described in the previous quarterly report.

III. Results

Processing and analysis of data are continuing, and tapes from the first two cruises have been interpolated and submitted. Prior to the May work, the electronics had been partially redesigned to provide better filtering, and this resulted in much clearer signals than had been the case previously.

IV. Preliminary interpretation of results

Preliminary examination of the May data indicates a hydrographic regime quite similar to that in February. There is still some indication of subsurface temperature inversions (cf. annual report pp. 6-7).

V. Problems encountered

The earlier problems in data reduction (cf. previous quarterly report) have been largely solved.

VI. Estimate of funds expended (31 August 1976)

	Original allocation:	$51,726
A.	Salaries	5,698
B.	Benefits	630
C.	Indirect costs	2,677
D.	Supplies and other direct costs	16,776
E.	Equipment	20,863
F.	Travel	3,555
	Total	50,199
	Remaining balance	$ 1,527

QUARTERLY REPORT

Research Unit:#217
Reporting Period:
1 April - 4 Oct 1976
Number of pages: 6
Figures 9

Principal Investigator: D.V. Hansen
Affiliation: Atlantic Oceanographic and
Meteorological Laboratories
NOAA, Miami, Florida

10 September 1976

I. Objective: To obtain and interpret Lagrangian surface current data in the Gulf of Alaska, and by amendment, in the S.E. Bering Sea.

II. Activities:

A. Three free drifting buoys were deployed in the Gulf of Alaska in April from NOAA Ship Discoverer, three in May in the S.E. Bering Sea from R/V Moana Wave, and three in the Gulf of Alaska from NOAA Ship Discoverer.

B,C. Mr. David Pashinski, presently of PMEL has handled logistics and instructions to ship's personnel and scientific parties. Once deployed, the buoys operate autonomously; position and environmental data are collected by the NIMBUS-6 satellite, translated at Goddard Space Center (NASA),and mailed to AOML.

D. Buoy trajectories are the primary reportable data. These are summarized on appended chartlets (Polyconic projection at $1{:}10^6$ scale).

E. A total of nearly 550 buoy days of drift data have been collected during this period. See III for synopsis.

III. Results:

Design modifications effected following the problems experienced in the severe environmental conditions of last Winter have proven effective, at least for Summer conditions in the North. Of nine buoys deployed in this reporting period, five are still working, two have beached, one was "salvaged" by a crab boat, and but a single engineering failure has been experienced. A mean time to failure statistic has little meaning in this situation. In addition, an expected high latitude boon is being realized. The polar orbit of NIMBUS-6 produces 2-3 times as many positions from buoys in this region as from buoys deployed in the Caribbean,Sea Sargasso Sea,or equatorial oceans. This greater number of fixes will provide better spatial resolution, which appears to be needed especially in the Bering Sea.

Gulf of Alaska

Debris from a buoy that failed immediately upon deployment off Yakutat Bay in November was found on Kayak Island. Buoys 1105, 1133, and 1174 were deployed off Yukatat Bay in April. Buoys 1105 and 1133 initially moved south for 15-20 miles at which time 1105 stopped reporting, and 1133 reverted to the westward movement indicated by the conventional wisdom for this region. Notable features of the trajectory of 1133 are (1) its movement crosses isobaths quite dramatically, suggesting that topographic control may not be a strong constraint for surface flows in this area and (2) the trajectory terminates on Middleton Island, extraordinarily bad luck from the point of view of the principal investigator, but probably indicative of expected behavior of surface pollutants. Buoy 1133 evidently fouled in a kelp bed or otherwise hung up offshore and continued transmitting for several days. This stationary position sequence suggests (our only assurance at present) that the drogue assembly remained attached to the buoy until the end. It also provides a special data base by which to evaluate accuracy of the locating system, and on the basis of which an objective data editing and filtering system is being designed. The location precision in this area turns out to be very close to NASA design specification.

The trajectory of buoy 1174 turned out to be especially interesting. Subsequent to a drift similar to those obtained in September 1975 as far as Cape Suckling, it closely skirted the east shore of Kayak Island, evidently to become trapped in an anticyclonic (clockwise) eddy just west of Kayak Island, and ultimately to beach on Montague Island. This particular occurrence provides some very strong evidence of the existence of an eddy west of Kayak, and presumeably has considerable relevance to lease activity in the area. It is notable however that this buoy, deployed some 250 miles to the east, also entered the eddy.

All three of the buoys, 1142, 1203, and 1235, deployed in the Gulf of Alaska are following the previous general pattern of flow to the west and north. The details and eddy structure which are a large part of the project objective are of course quantitatively different. It appears that these buoys also may beach in the northern Gulf of Alaska.

S.E. Bering Sea

The three buoys (503, 535, 544) deployed in the S.E. Bering Sea are of a new (PRL) design intended to provide position data only. From an engineering point of view they have been completely successful in the relatively benign summertime Bering Sea. Buoy 503 was salvaged by a crab boat after 2 1/2 months and will be examined to evaluate the longer term survival potential of the new design. These hulls could not be equipped with a drogue so the trajectories probably are influenced by wind, but nonetheless the trajectories indicate much weaker,more spasmodic surface currents than are found in the Gulf of Alaska. The general impression gained from these preliminary data plots is of weak but spatially coherent cyclonic circulation in Bristol Bay, with a high level of temporal variability imposed.

IV. Preliminary Interpretations

A. Gulf of Alaska

1. Some results indicate that topography is not a strong constraint on movement of surface materials.

2. Definitive evidence is obtained for the existence of an eddy (anticyclonic) west of Kayak Island.

3. The statistics are still extremely poor, but it may be significant that buoys deployed off Yakutat are consistently going ashore east of Kodiac Island. Three out of these tracked buoys have done so, and one

out of 7 terminations from other causes was incidentally found ashore. This statement can be generalized to include all potential deployment sites on the continental shelf between Yakutat Bay and Prince William Sound, i.e.,all points transited by the buoys. The implications for surface contaminants are pretty clear. The drift time scale will be developed in the final report.

B. Bering Sea

The primary impression gained to date is that the several day average surface current is relatively weak, but coherent over substantial distance. Present results suggest that the observational strategy preposed for this area in 1977 can be improved upon by distributing buoys more generally over the region of interest rather than on a line between Unimah and St. Paul Islands in order to get better coverage during the working season. These possibilities will be discussed at the Fall workshop.

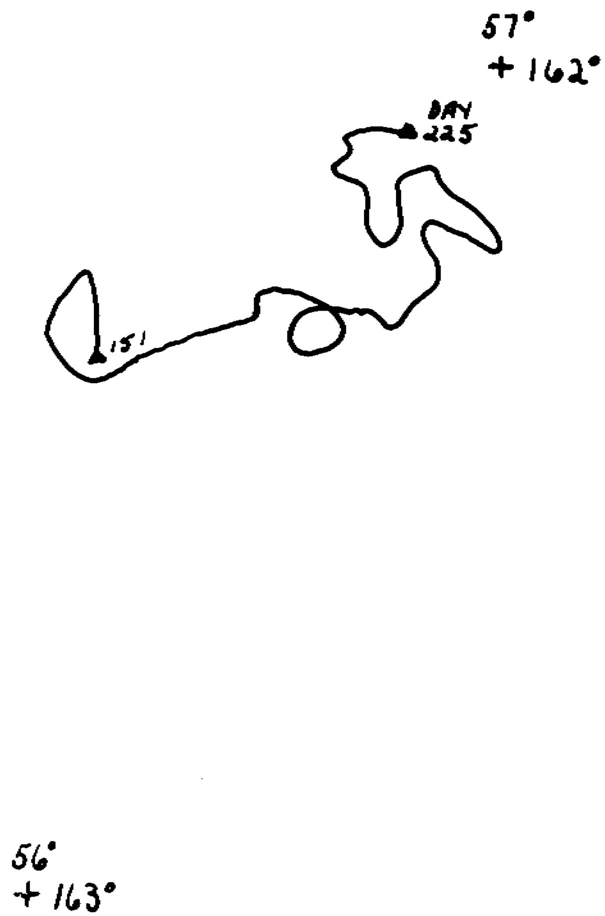
V. Problems

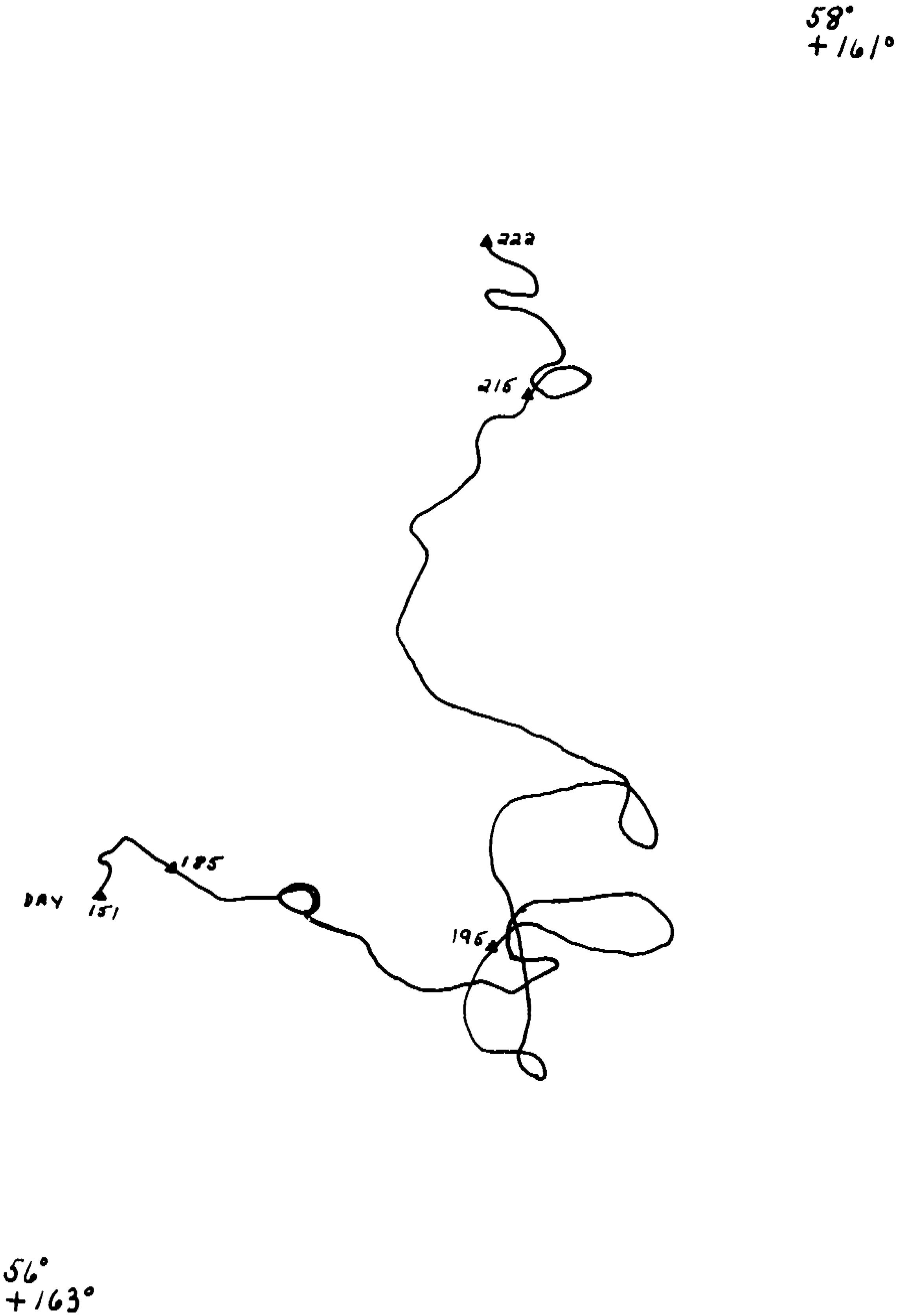
The important design problems for survivability appear to have been solved by NDBO, at least for Spring/Summer conditions;the data are now coming in about as planned. The losses to beaching in the Gulf of Alaska are greater than anticipated, and lead to poorer coverage in time and space. That however is just the geophysical reality that OCSEAP particularly requires knowledge of.

VI. Funds expended

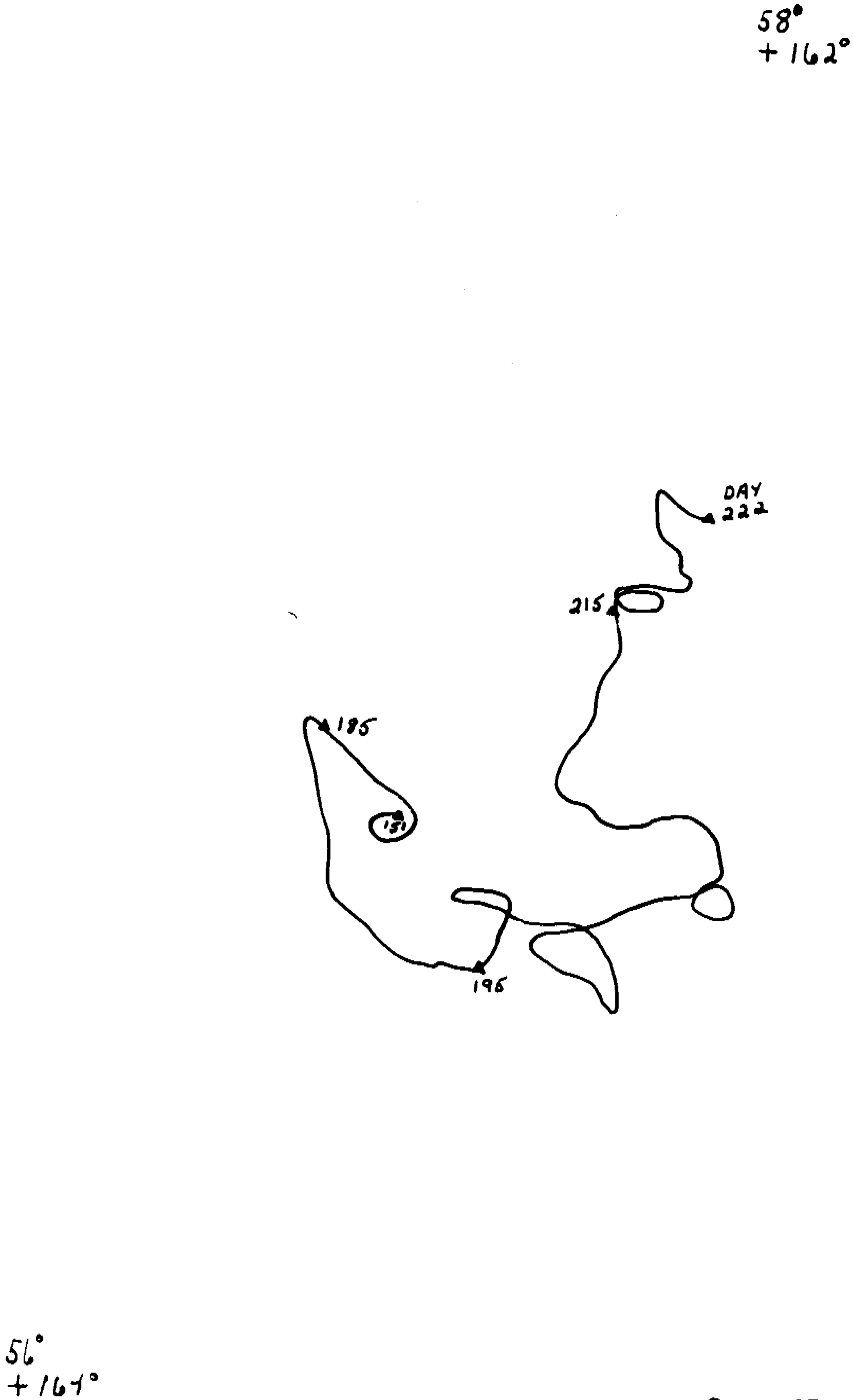
All funds allocated for FY 1976 (and TQ) will have been expended by 1 October, including procurement of 3 buoys yet to be deployed in the Gulf of Alaska. (Planned for October).

Buoy I.D. 0503

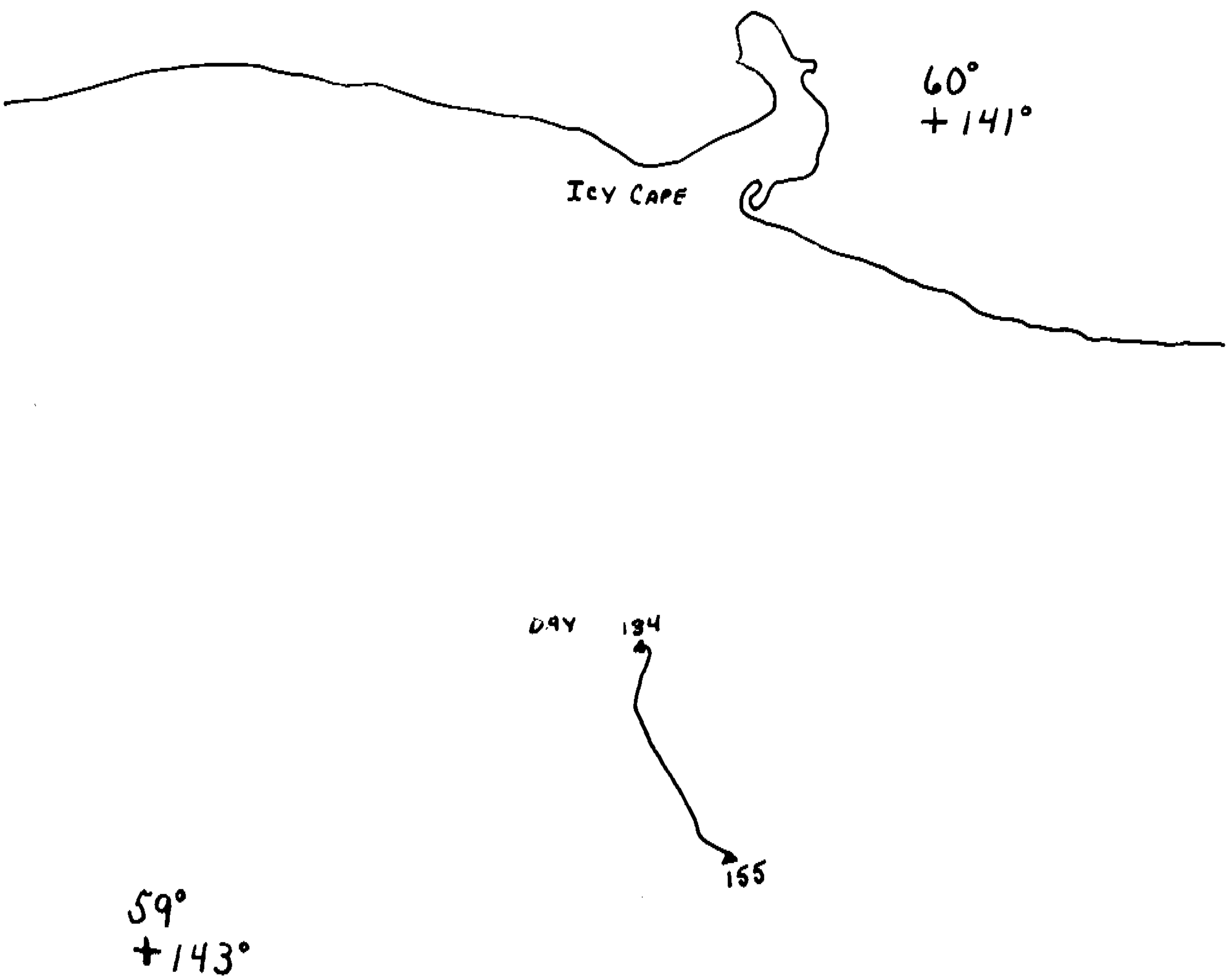




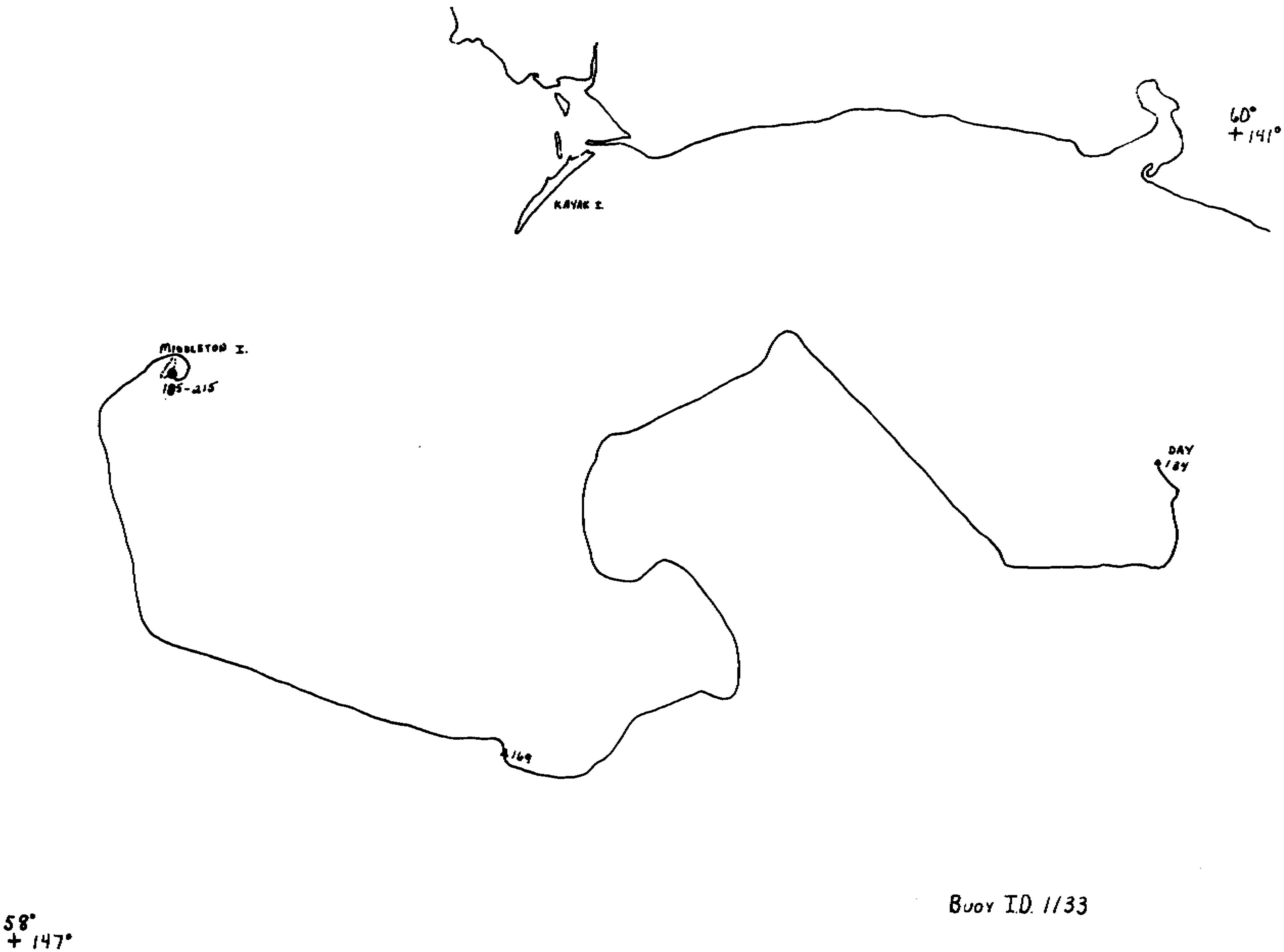
Buoy I.D. 0535



Buoy I.D. 0544



Buoy I.D. 1105



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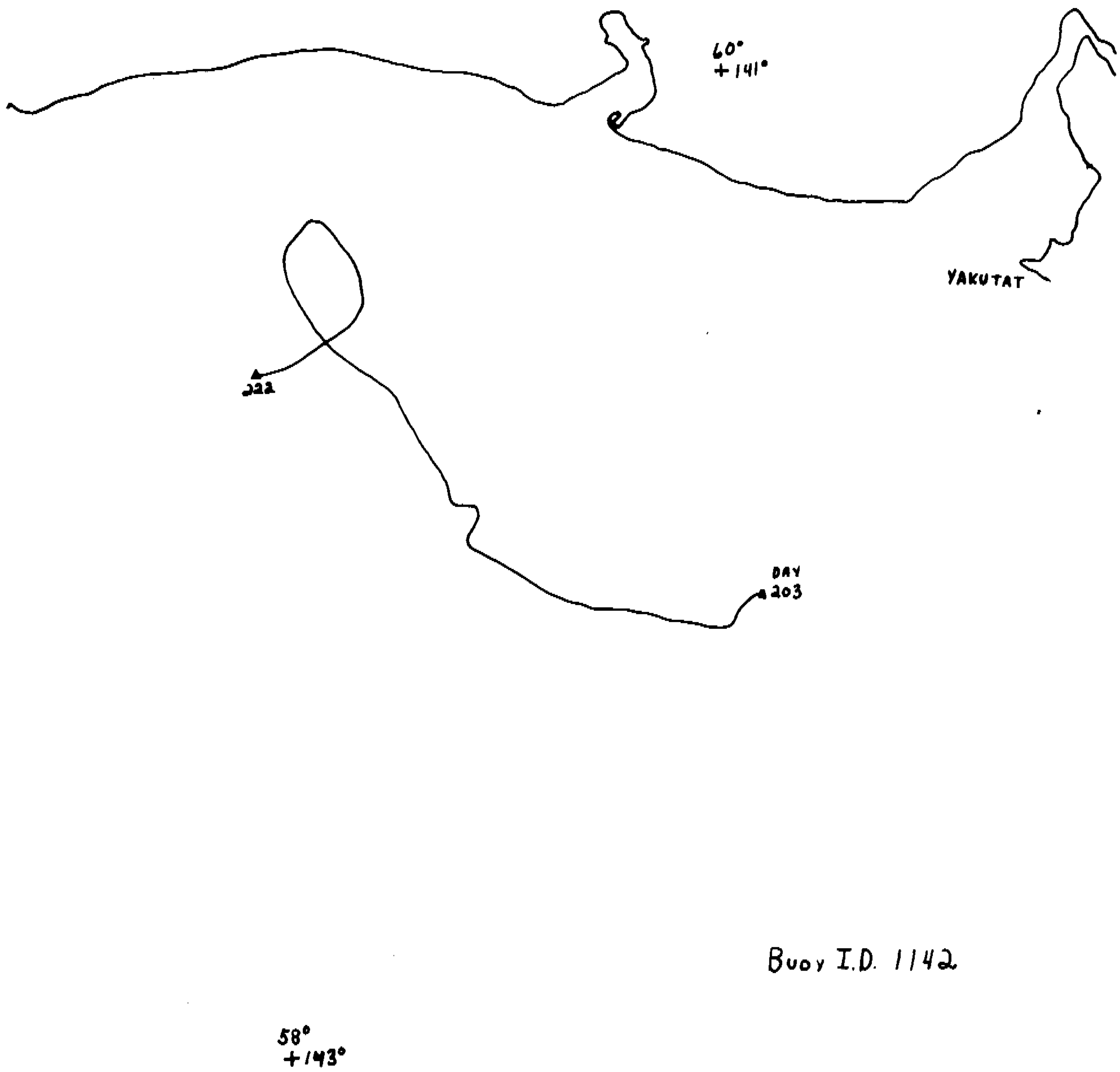
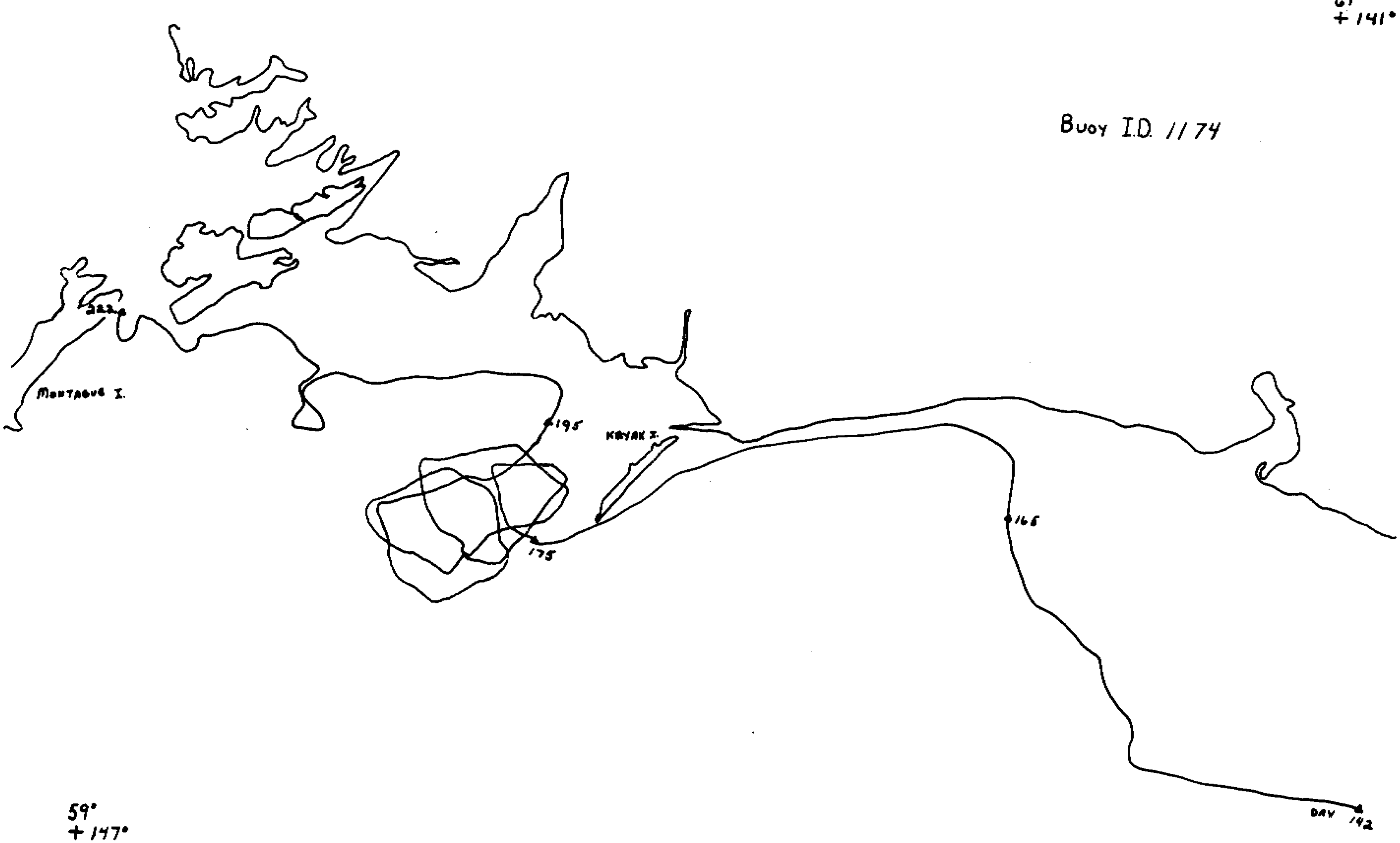
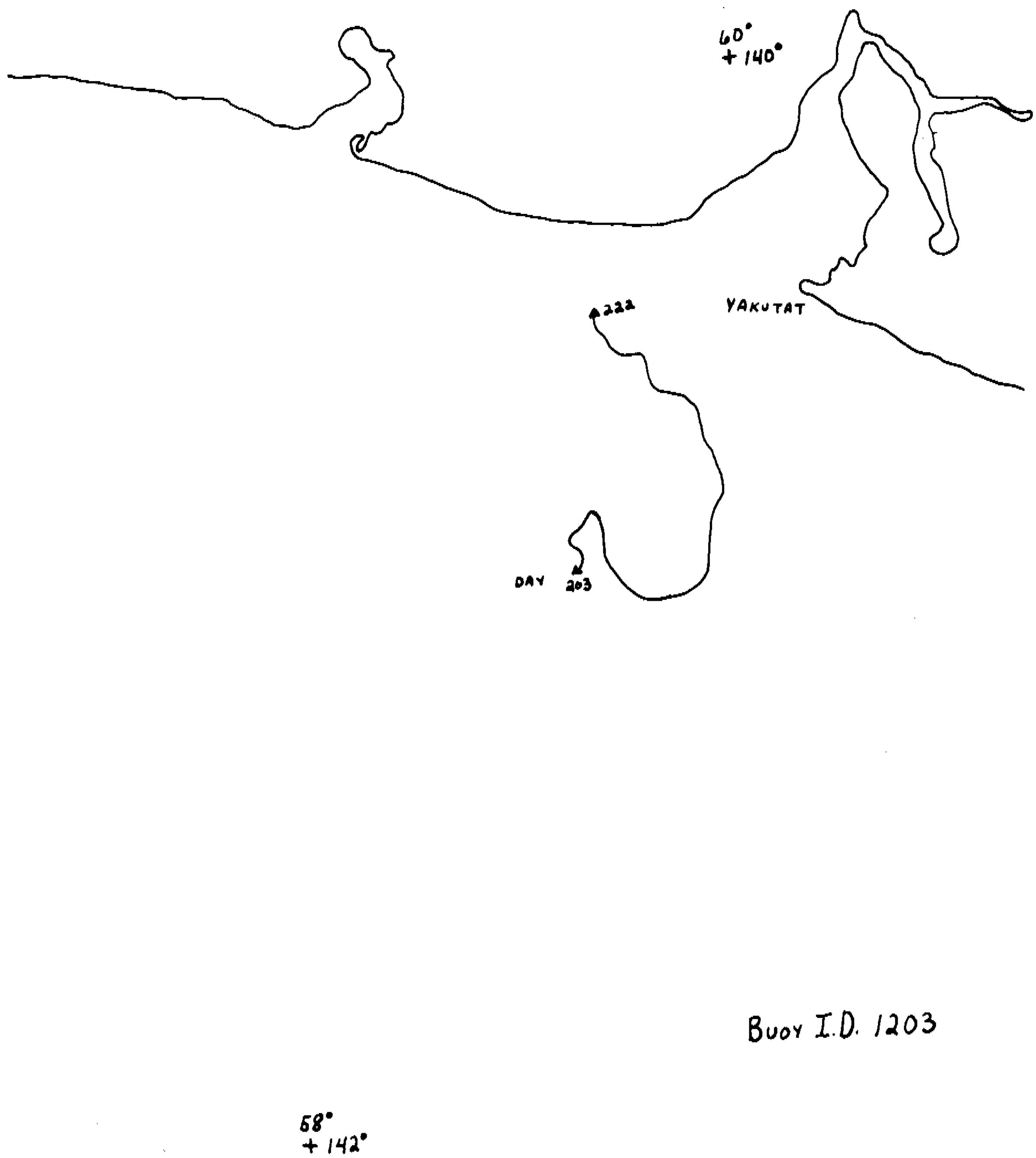
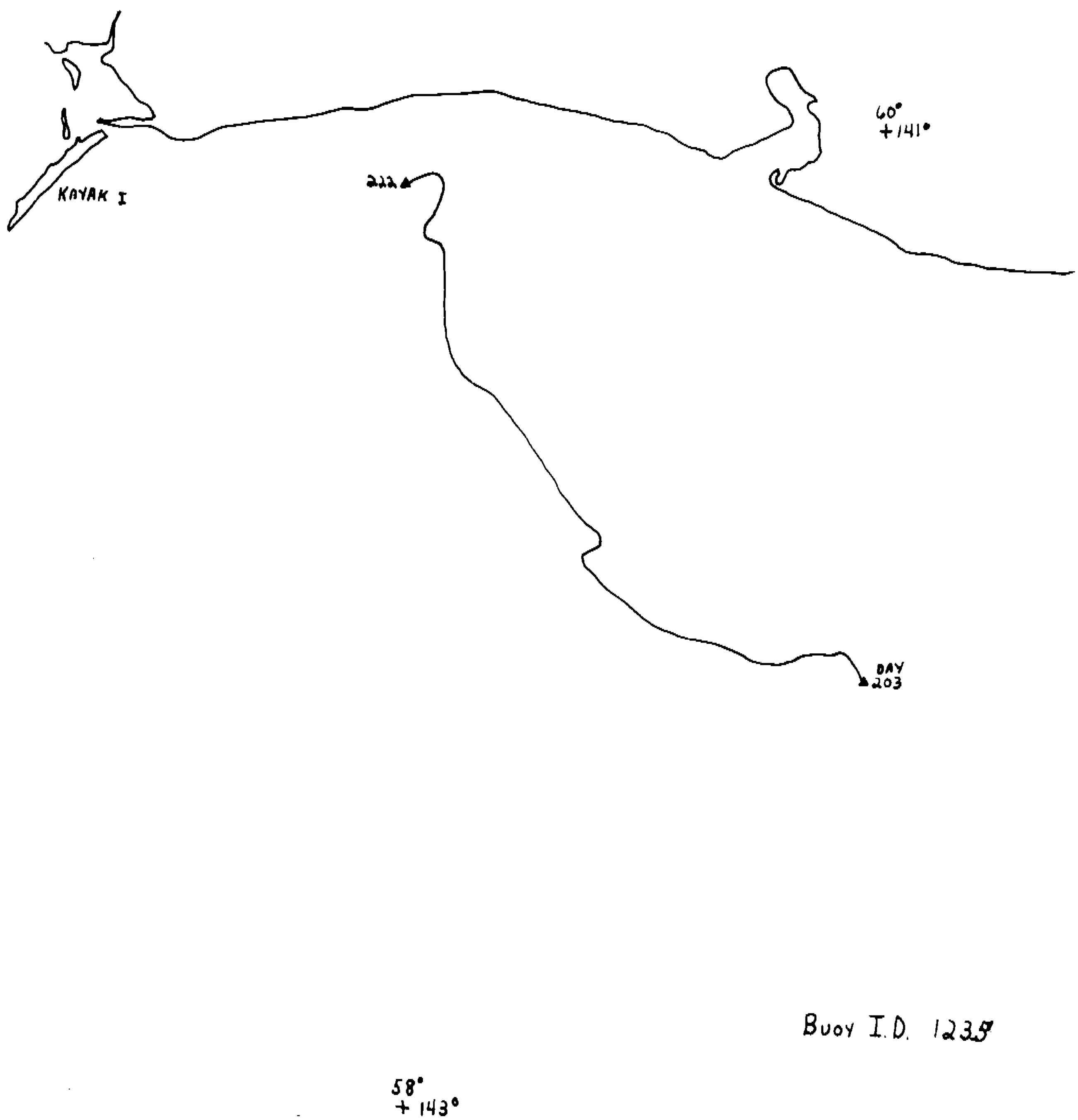


Buoy I.D. 1142


61°
+141°
Buoy I.D. 1174
222
Montague I.
195
Kayak I.
175
165
Day 142
59°
+147°


60°
+ 140°
222
YAKUTAT
DAY
203
Buoy I.D. 1203
58°
+ 142°


KAYAK I
222
60°
+141°
DAY
203
Buoy I.D. 1235
58°
+ 143°

LINKAGE OF THE BENGTSSON LIMITED AREA FORECAST MODEL AND THE OPTIMIZED HYDRODYNAMICAL-NUMERICAL MODEL OF W. HANSEN TYPE

by

R.Bauer, S. Larson, T. Laevastu and A.Stroud

RU #235
Part I

Northwest Fisheries Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
2725 Montlake Boulevard East
Seattle, Washington 98112
July 1976

Abstract

The operational quasi-geostrophic three-parameter model developed by Dr. L. Bengtsson for the Swedish Meteorological and Hydrological Institute has been linked with the optimized multi-layer hydrodynamical-numerical model based on the work of Professor W. Hansen at the University of Hamburg, Germany for use in the study of the wind and tide driven circulation along the southern Alaskan coast, sponsored by the Outer Continental Shelf Energy Programme (BLM/NOAA).

The Bengtsson forecast model was used to increase the resulution of the surface pressure field to a 74.08 km grid in an area where the coastal elevations are a major determining factor. The initial states and the variable boundaries were prescribed for the Bengtsson model by extracting data from the Fleet Numerical Weather Central (FNWC) archived files for two storm periods in June and November, 1973.

This document describes the programs and procedures used to link the FNWC fields to the Bengtsson model and the Bengtsson model to the Hydrodynamical-Numerical (HN) model, and provides supplemental information for the Bengtsson and HN models described fully in references (1) and (2).

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ACKNOWLEDGEMENTS

The authors wish to thank Dr. L. Bengtsson, who spent a very difficult week with us testing his model in its revised form, and LT. Byron Maxwell, who provided us with a carefully documented listing and his notes on the Bengtsson model.

1. INTRODUCTION

This report describes the linking of the Naval Environmental Prediction Research Facility (NEPRF) version of the Bengtsson three parameter quasi-geostrophic atmospheric (AT) model for limited area forecasting and the NEPRF Optimized version of the Hydrodynamical-Numerical (HN) model for use in the Gulf of Alaska.

The AT model has been tested in a hindcast mode using initial and variable boundary conditions computed from the northern hemisphere 63x63 polar stereographic Fleet Numerical Weather Central (FNWC) grids. The AT model was used to compute the surface winds over the Gulf of Alaska at 6 hour intervals in a 74.08 kilmeter grid for two periods beginning 1 June and 17 November 1973. The wind fields were converted to the smaller HN model area grids with grid spaces of 14.816 kilometers by extracting and reanalyzing the relative wind U and V components and then interpolating them to one hour intervals. Winds were introduced into the HN models after a six hour initialization period and updated each hour.

1.1 OVERVIEW OF THE AT-HN MODEL LINKAGE

There are three separate programs in the existing linkage between the models. Two of these, the grid preparation and data extraction programs, were written for the NEPRF CDC 3100 computer and are used to prepare FNWC 63x63 data for input into the AT field analysis program. The third program in the linkage started as the field analysis program on the CDC 3100 but was later converted to a dual function program on the CDC 6500. The field analysis program analyzes the FNWC grid values into AT fields and also analyzes the AT generated wind component fields into the smaller HN grids. Figure 1 shows the program sequencing. Program ANOMALY calculates the M,N coordinates for each polar stereographic I,J grid point in a specified range of I and J points and punches the I,J and HN M,N grid values on cards. Program COAMDAT reads a tape containing FNWC 63x63 fields, extracts an I,J value from each field for each coordinate card in its input deck and generates the COAM tape containing values at I,J points with their HN M,N coordinates. The COAM tape is read by the ATANAL program which analyzes the FNWC values into the AT fields. The AT model in turn generates a wind component tape which is processed by ATANAL into the coastal grid HN wind fields.

1.2 DESCRIPTION OF GRID CONVENTIONS

One of the confusing factors in dealing with the programs in this sequence arises because each program borrowed code from a different source and these elements do not have common grid conventions. Figure 2 is presented to reduce the confusion. The arrows within the grid indicate the sequence in which the elements are stored in the arrays and show the array limits and principal indices.

To further complicate the matter there are actually four different HN grids involved. The original AT model grid was developed as a compromise grid for both the AT and HN models. Although the 74.08 kilometer HN model was not used the input and output tapes for and from the AT model are formatted in terms of the 74.08 kilometer HN model. The three HN models that are a part of the BLM Gulf of Alaska project all

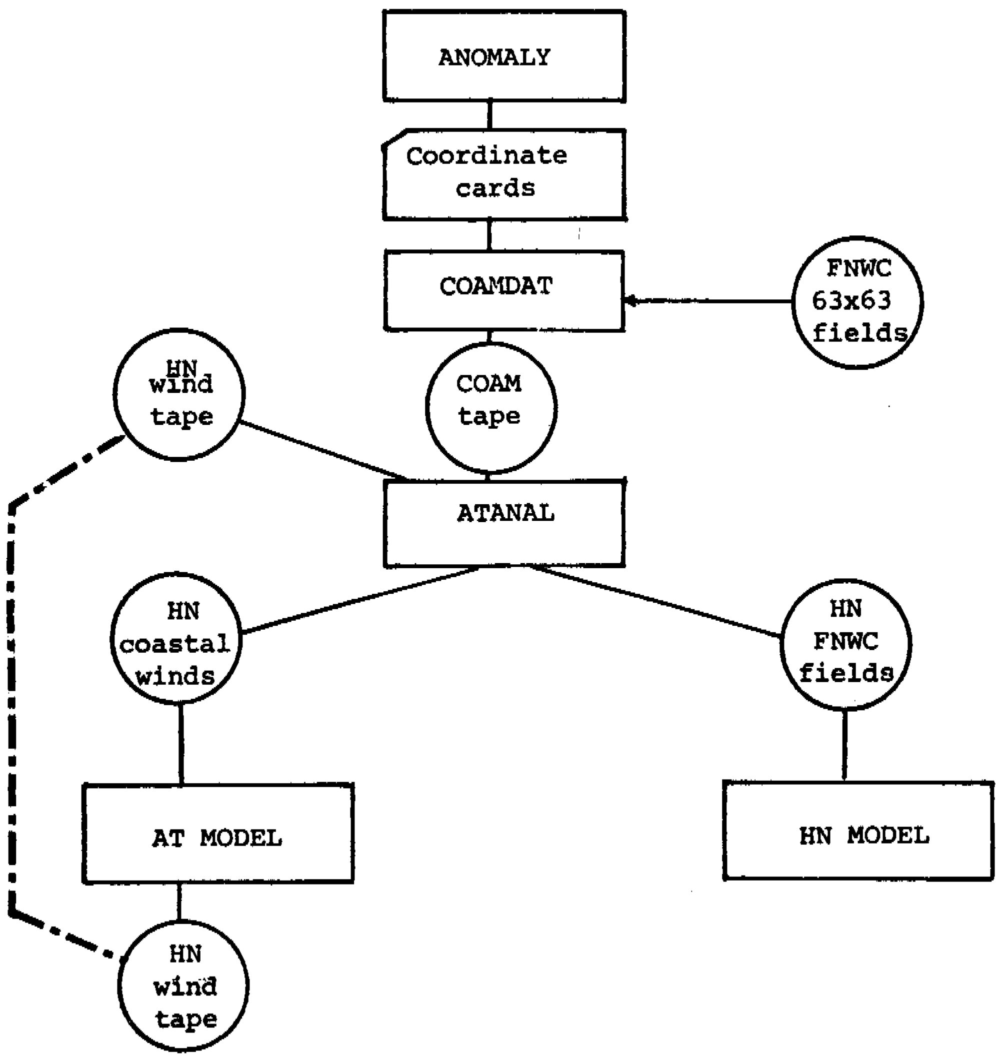
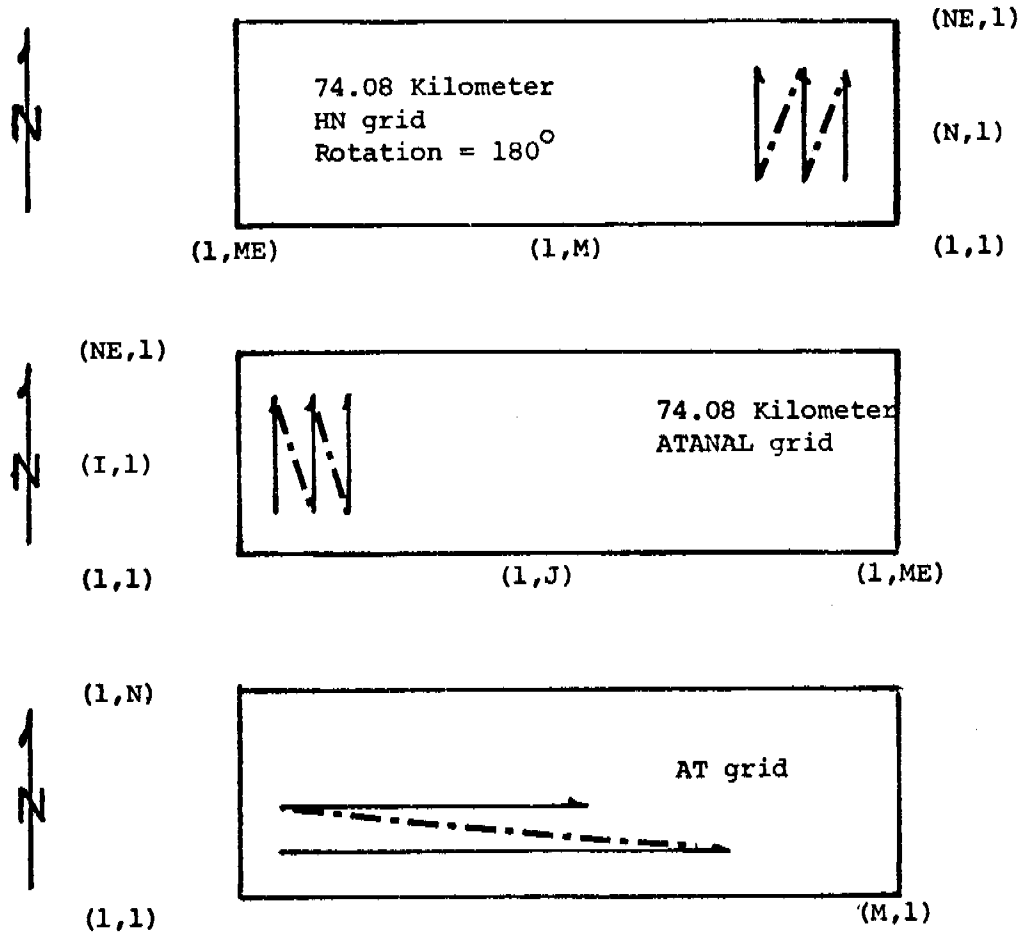


Figure 1. Program sequence



Arrows show order of data storage in a single dimensioned array.

Figure 2. Grid conventions

have 14.816 kilometer grids. To distinguish between the HN models the 74.08 kilometer grid will be assumed unless the area is also specified.

Programs ANOMALY and COAMDAT both use HN grid M,N coordinates. FNWC 63x63 grid points in the programs are in FNWC standard I,J notation. The HN convention is for the upper left corner of the grid to be identified as (1,1) with the row index varying faster. However, the 74.08 kilometer HN grid was rotated 180° so that (1,1) is in the southeast corner.

The HN grid convention indices are used on all tapes in the linkage. The input sections of the ATANAL and AT programs convert from the HN coordinate sequence to the indices used in the models. The output sections of these programs restore the local indices to the HN grid conventions. In the case of ATANAL when the wind fields are being processed the outputted fields match the HN grids for the three coastal areas.

Within the ATANAL program the row index varies faster and the origin is in the southwest corner. The AT model has the same origin as the ATANAL program but the column index varies faster.

All three coastal grids are rotated HN grids. The east coastal grid is rotated counterclockwise 309° with the northern corner as the origin. The western and central grids are rotated 39° so their western corners are their origin.

1.2.1 Description of the 74.08 Kilometer Grid

The 74.08 kilometer grid is defined by the base lines 40° North and center line 143.86333333° West, which corresponds to row 1 and column

TABLE 1

HN Grid Relationships

	HN	HN Western	HN Central	HN Eastern
Model Number	1000	100	70	1
Grid Length (Kilometers)	74.08	14.816	14.816	14.816
Rotation Angle	180	39	39	309
No. Rows	32	27	32	18
No. Columns	47	60	50	40

24, as shown in Figure 3. The distance between rows is 2/3° latitude (74.08 kilometers) and columns are spaced at 2/3° of latitude intervals measured out from the center line. This grid preserves distance measurements but distorts angles at the edge of the grid. This distortion was not considered important.

1.2.2 Description of the Coastal Grids

The coastal grids have grid lengths of 14.816 kilometers and overlap. The specifications for the grids are given in Table 1 and are shown in Figures 4 through 6.

1.3 TAPE FORMATS

There are three tape formats involved in the sequence. The first is an extract of FNWC 63x63 fields. The second is the COAM tape and the third is the HN format tapes. All tapes are recorded at 556 BPI in 7 tracks, in binary mode, as a single file.

1.3.1 FNWC 63x63 Field Tapes

The field format on the FNWC tapes is described in the FNWC User Guide (6). The fields required by the AT model in order for a date-time group set are: the sea temperature (TSEA), the 1000 mb pressure level (D1000), the 500 mb pressure level (D500), the 300 mb pressure level (D300) and the dew point depression (TP850).

1.3.2 The COAM Tape

The COAM tape format is shown in Figure 7. The file contains reocrds which are all identical in length but the length may vary

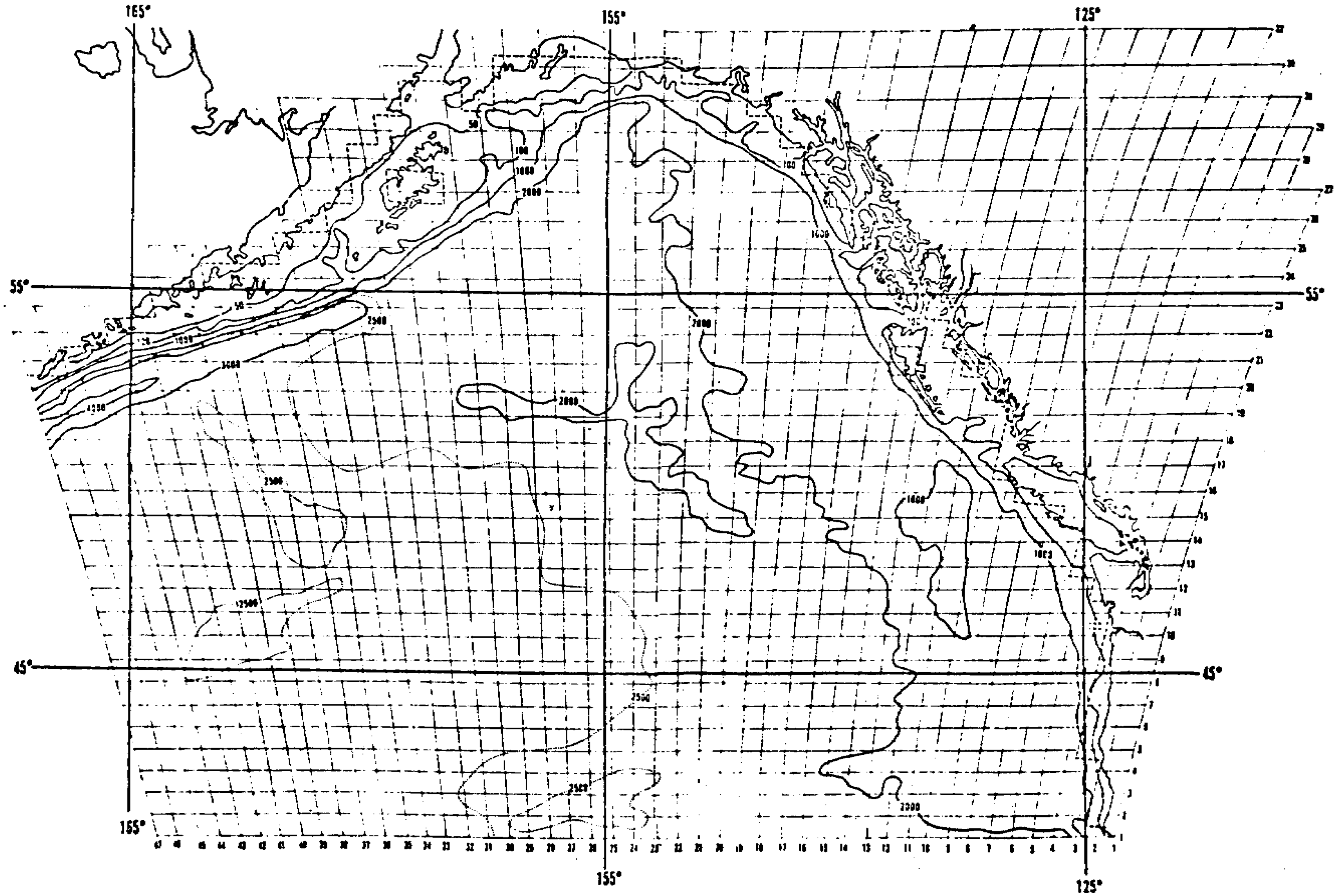


Figure 3. HN 74.08 kilometer grid

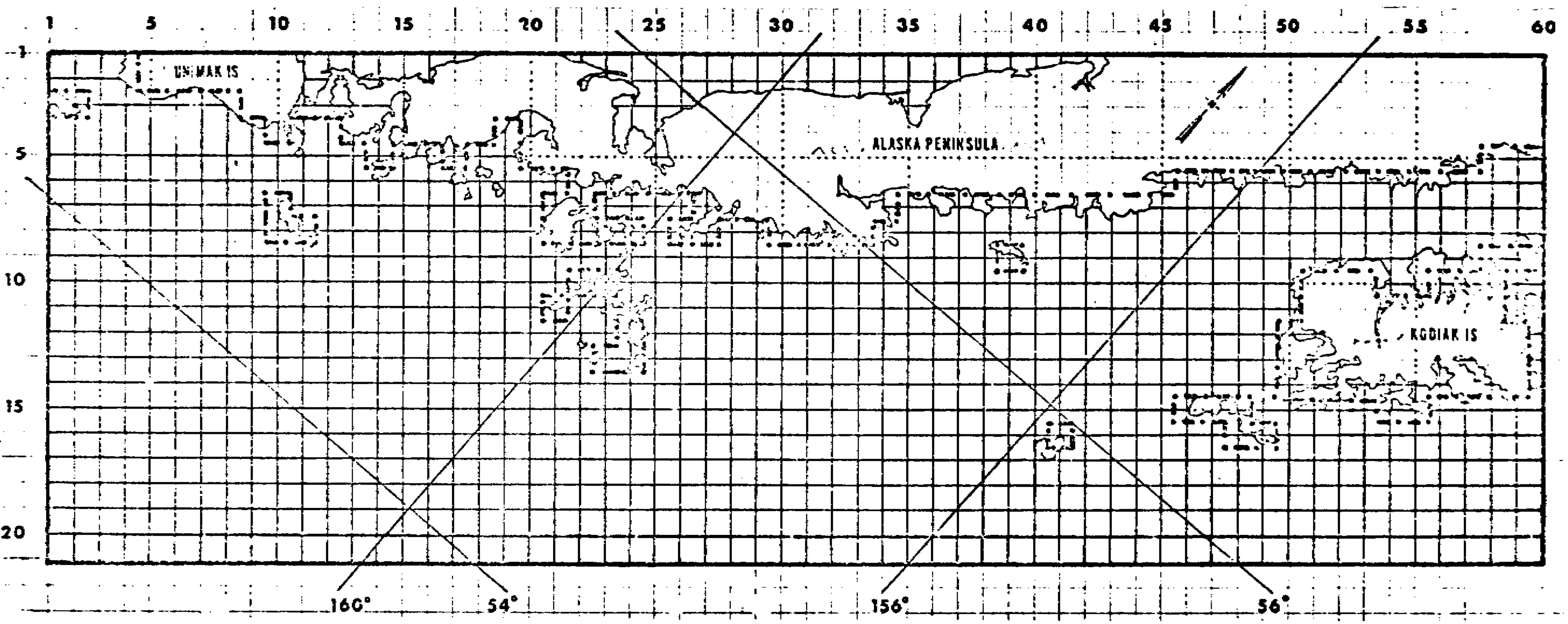


Figure 4. HN 14.816 kilometer western grid

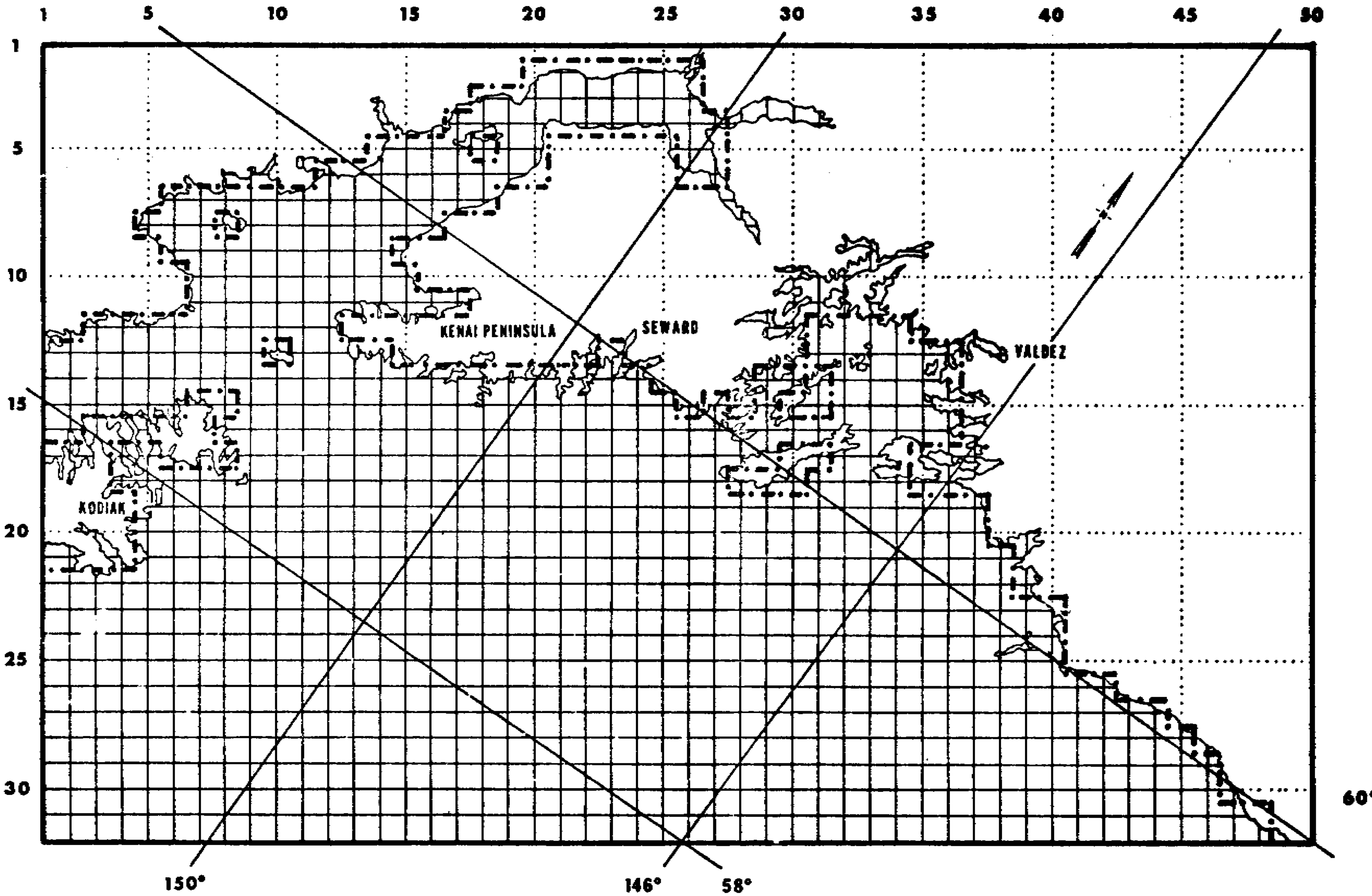


Figure 5. HN 14.816 kilometer center grid

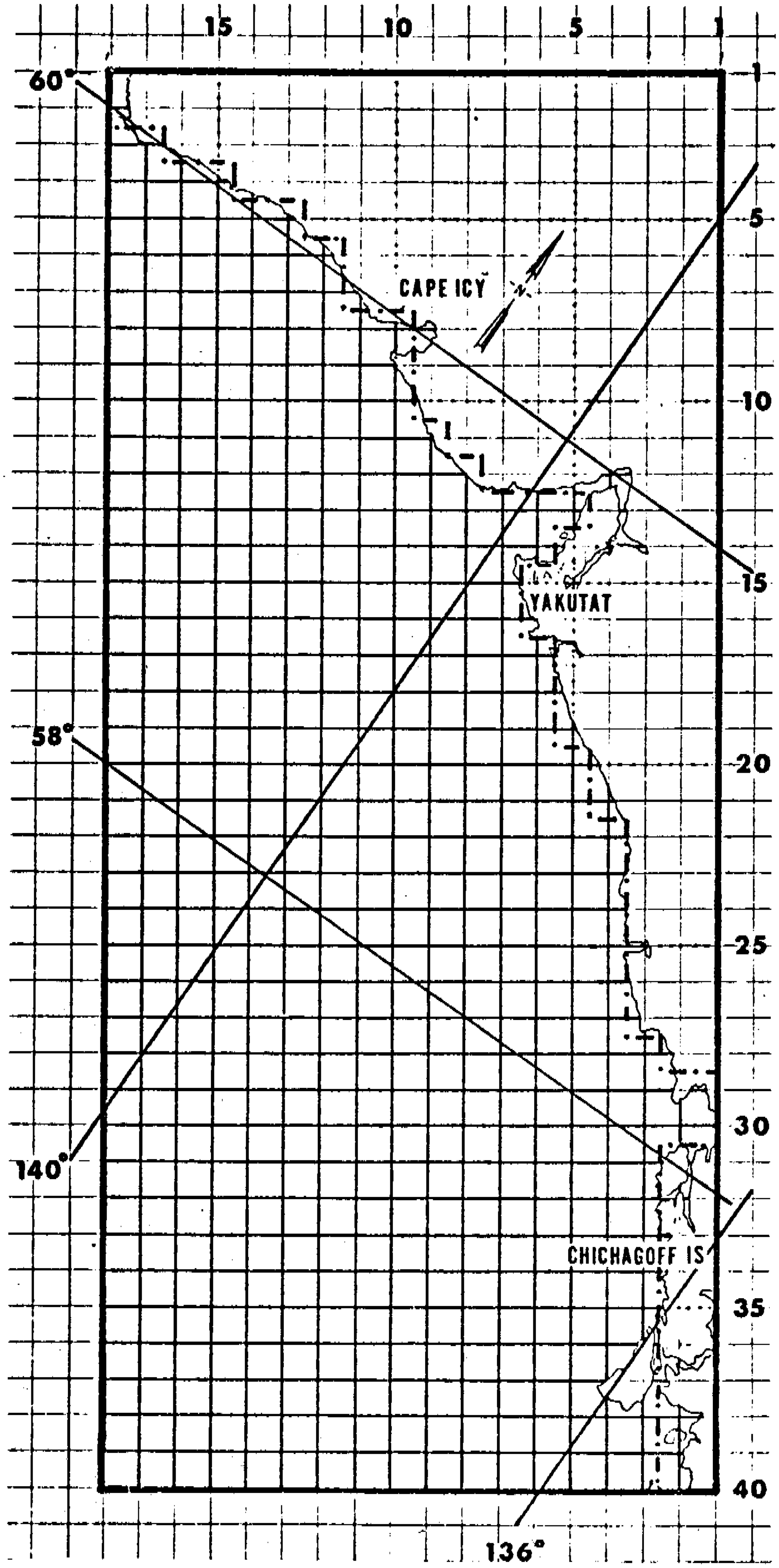


Figure 6. HN 14.816 kilometer eastern grid

556 BPI
Odd parity
48 bit logical record blocked so that there is 1 field in each physical record.
1 file on each tape

For Gulf of Alaska grid there are 75 logical records per physical record.

T SEA	N*10	M*10	Val*100	#2	etc.
	12	12	24		bits
D1000			Val*10000		
D 500			Val*10000		
D 300			Val*10000		
TP 850			Val*100		

All fields are binary integers

0 = N = NE+1

0 = M = ME+1

Val maybe + or -. Final Val = Val * Scale + offset

	Scale	offset	
T SEA	.01	.0	°C
D1000	.0001	111.	Z height Meters
D 500	.0001	5574.	"
D 300	.0001	9164.	"
TP 850	.01	.0 ,	°C

Figure 7. COAM format

depending on the number of coordinate cards in the COAMDAT deck. The file consists of a single record for each FNWC field processed and is composed of 48 bit fields with the M,N coordinate and the value in two 12 and one 24 bit field. All fields represent scaled integers. The coordinate fields are always positive but the value field may be positive or negative. The COAM tape presently serves as a bridge between the 24 bit CDC 3100 computer and the 60 bit CDC 6500 computer.

1.3.3 HN Tape Format

The HN tape has records which are of variable length from 144 bits to 30000 bits with a fixed length header of 120 bits. The header bits, as shown in Figure 8, are divided into 24 and 12-bit fields. All values in the header are positive binary integers. The header is followed by from 1 to 1245, 24-bit fields. These data fields contained scaled integers which may be positive or negative. Negative numbers are expressed in CDC 1's complement (in octal (B):0001B=1, 0000B=0, 7777B=-0, 7776B=-1).

A logical record will require more than one physical record if the grid contains more than 1245 values. Any number of physical records can make up a logical record but no logical records share a physical record. Records with type numbers less than 8 are assumed to be grouped logical records with 3 logical records per group. In grouped records, since all logical records have identical headings, the Z logical record must be first followed by the U and then the V logical record.

Logical records are ordered on the tape in ascending type sequence within the time group.

HEADER FORMAT

TIME in seconds	LAYER or LEVEL	TYPE*	ROWS	COLS	MODEL NO.	
24	24	24	12	12	24	No of bits

Layer or Level	Type		Scaling
1 2 3	1 = sumbolic HTZ, depth HTU and HTV 2 = water height Z, U and V vectors		*10 *1000
0	8	Wind component U and V	*10
0	11	TSEA	*10
1000	12	D1000	*10000
500	12	D500	*10000
300	12	D300	*10000
0	14	TP850	*10

*types 1-7 reserved for grouped records (Z,U,V)

Value = tape field integer/scale

Figure 8. HN tape format

Type 8 records are reserved for wind components and are paired with the U component field followed by the V component field.

2. HINDCAST DATA PREPARATION

The two sets of hindcast data selected for this trial effort consist of two storm periods in the Gulf of Alaska from 1-7 June 1973 and 17-23 November 1973. The FNWC 63x63 fields for these periods at 0000 and 1200 GMT were processed through the sequence into the HN format tape for input to the AT model. The AT model runs were started at 0000, 1 July 1973 and 0000 17 November 1973, using as the initial state the analyzed grid obtained from the FNWC values. The edge values for variable boundary conditions were interpolated between the 12 hour pressure fields for each time step. The TSEA and TP850 were not considered in the variable boundary conditions.

The AT model was run out to 36 hours saving the wind component fields at 6 hour intervals in HN format. The wind components were then analyzed into the coastal grids at 6 hour intervals and linearly interpolated into 1 hour fields for input to the coastal HN models starting at 6 hours.

The three linking programs required to prepare the hindcast data are described in this section. The AT model and HN model instructions are described in the following sections of this report.

2.1 GENERAL PROGRAM NOTES

All programs are written in FORTRAN and could be modified to run on other configurations by revising the relatively small sections involving input and output activities that are computer word size dependent. The general description of the programs, the grid convention and the tape formats has already been given in section 1 of this report. This section contains the run instructions, program organization, methods and variable description.

After the conversion of the analysis program from the CDC 3100 to the CDC 6500 computer was completed, the need for separating the grid calculation, data extraction steps and data analysis steps disappeared, but in the present research effort there was nothing to be gained by converting and combining the functions of the grid preparation and extraction procedures with the input phase of the AT field generation. Consequently, streamlining of procedures will have to await a new application.

2.2 PROGRAM ANOMALY

Program ANOMALY was borrowed from another project and was modified to compute the HN grid values from the FNWC I,J latitude longitude coordinates. The program produces both a listing and a deck of coordinate cards.

The relevant part of program ANOMALY consists of the main program ANOMALY, routines IJTOLL and TOLL.

2.2.1 Run Instructions

To run program ANOMALY the user must determine the FNWC I,J grid window containing the area to be extracted. When choosing the I,J minimum and maximum values the user should be sure to include the I,J points that lie within one grid cell interval outside the final grid to be used by the AT model. Values in this band outside the grid row and column are used to determine the boundary values in the final grid and to minimize the distortion on the edge caused by relaxation in the ATANAL program.

The I,J limits are used as limits on loops 999 in program ANOMALY. The parameters given in the call to TOST (an initialization entry for TOLL) specifies the base line latitude, the center line longitude, the HN grid row number for the base latitude and the HN grid column number for the center line. The spacing is set in routine TOLL.

This program punches extra cards that are outside the final grid by more than one row and column. These cards are discarded.

2.2.2 Routine Descriptions

ANOMALY

This is the main program. It calls routine TOLL twice: once through entry TOST to start the calculations and once for each coordinate point through entry TOMN to get the HN M,N coordinates for a latitude longitude pair. The routine calls IJTOLL once each for each coordinate point to convert from FNWC I,J coordinate indices to latitude longtidue. The routine lists the coordinates and punches coordinate cards for use in program COAMDAT.

IJTOLL

This routine is given an I,J index in the FNWC northern hemisphere polar stereographic grid and then it returns the latitude longitude coordinates in degrees.

TOLL

This routine computes the HN grid M,N index for the Gulf of Alaska grid. It is not a general purpose routine in the normal sense; since the indices are computed directly for the HN grid rotated 180°. The routine requires an initial call giving the correspondence between latitude-longitude base and center lines and the N,M grid numbers. In the Gulf of Alaska grid these are 40°N=row 1, 143.863333=column 24. In successive calls to TOMN the routine computes the M,N coordinates using the method described in Bowditch (3) to compute distance along a latitude line.

2.2.3 Variables

I,J	FNWC Northern Hemisphere polar stereographic grid indices
XLAT,YLONG	Latitude and longitude of an FNWC grid point
XN,YM	HN grid indices
N,M	Scaled HN grid values=XN*10,YM*10
X1 Y1	Factors to compute distances between longtiudes from Bowditch (3).

2.3 PROGRAM COAMDAT

Program COAMDAT was written to extract the required I,J values from the tape containing FNWC 63x63 fields using a preexisting standard NEPRF subroutine, READ63. The program as it presently exists processes the PS and D850 fields which are not needed by the AT model. This routine is not a general purpose routine since it will require code modification to change areas from the Gulf of Alaska HN grid to any other grid.

2.3.1 Run Instructions

The program requires card input on the standard input unit, the FNWC 63x63 fields on logical unit 1 and the output COAM tape on logical unit 2.

The data used to locate the field on the FNWC tape is computed as follows:

Year	Set into XI
Month	Computed into XJ using loop 500
Day	Computed into XK using loop 400 with limits given in the data statement to KD and KE
Hour	Computed into XL using loop 300

The fields extracted are given in the data statement using variables NAME, ITAU and ISK and are controlled by loop 200.

The program is set to extract the 75 I,J points in the Gulf of Alaska HN grid. The coordinate cards produced by program ANOMALY are read in loop 10. The points are selected out of the FNWC field in loop 100, are buffered out to unit 2 and are printed with format 1220. All of these coordinate related operations have fixed indexing for 75 points.

2.3.2 Routine Description

COAMDAT

This routine is described by the run instructions.

READ63

This routine is a standard NEPRF CDC 3100 subroutine to read FNWC 63x63 fields.

2.3.3 Variables

A	FNWC 63x63 field
IA	Double subscript array equal in length to the floating point array B. Used to store values in the lower 24 bits and the prepared coordinates in the upper 24 bits of the B array. (On the CDC 3100 integers are 24 bits; floating point values are 48 bits). Note: In the Gulf of Alaska grid IA is overlaying part of the A array that is not referenced.
B	Output array of M,N and value logical records.

Other relevant variables are given in the run instructions.

2.4 PROGRAM ATANAL

Program ATANAL is the program in the linkage that converts fields from one grid to another. It is used both before and after the AT model is the sequence. The program consists of a main program ATANAL and the subroutines FLDANL, READIN, OUTPUT, PRTMAE, INFLD, TIMINT and XMIT.

2.4.1 Run Instructions

The program uses stored input for the control cards described below. It uses ECS to store the wind component fields where time interpolation is required between the 6 hour fields. The program uses logical unit 1 for the input tape which is either the COAM tape or the HN grid tape generated by the AT model. The program writes the fields generated on logical unit 5. No provisions are made to preposition the tapes within the program, but this can be accomplished with standard CDC Scope control cards.

There are two separate control cards. Only the grid card is required to run the program in the mode to convert from the FNWC grid values to the HN grid. Both the grid and the transform card are required to convert from the HN grid wind component fields to the coastal HN grids.

Grid Card

The grid card specifies the grid and analysis constants required on output.

Col	Variable	Format(6I5,4F10.3)
1-5	IGRID	Type of grid process 0= convert from FNWC I,J values to HN grid 1=convert wind components in HN grid to coastal HN grid
6-10	NPASS	Number of iterations allowed in the relaxation
11-15	NE	Number of rows
16-20	ME	Number of columns
21-25	IDBG	Debugging option 0=no debug printouts, 1=debug
26-30	MODEL	Model number to be used on the output tape

31-40	P1	Smoothing parameter
41-50	EPS	Convergence tolerance for relaxation
51-60	ZLMBD4	Convergence factor/4 for relaxation

Transform Card

The transform card is used to specify the grid dimension of the HN grid being inputted, the scaling and rotation factors and the interval between output fields.

Col		Format(2I5,I10,6F5.0,2F10.0)	
1-5	NEI	Number of rows in input grid	
6-10	MEI	Number of columns in input grid	
11-20	ITINT	Interval between output fields If=0 no time interpolation is performed and only 10 words of ECS are used by the program	
21-25	YOF	Row index	Point of rotation in the input grid coordinates*
26-30	XOF	Column index	
31-35	ROTIN	Rotation of input HN grid	
36-40	YC	Row index	Point of rotation in output grid coordinates*
41-45	XC	Column index	
46-50	ROTOUT	Rotation of output grid	
51-60	OLDGRDL	Grid length of input grid	
61-70	GRDLENN	Grid length of output grid	

*Rotation angles are specified as counter-clockwise angles in degrees from North to the +Y axis.

2.4.2 Routine Description

ATANAL

This is the main program where the control cards are read and printed. If the program is processing FNWC data into the HN grid, the program assigns the time and type on the basis of COAM tape position. The COAM data are read by routine READIN. When the program is converting from one HN grid to another the data are read by routine INFLD. In both cases the data are placed in the DATA array containing values identified by the output grid coordinates.

Array DATA is passed to routine FLDANL where the data are placed at the grid points using a weight based on distance, are interpolated to obtain a guess field, are relaxed and finally smoothed.

The result field is returned in array GUESS, which is printed and then placed on the output tape together with any preceeding time interpolated field by routines PRTMAE and OUTPUT.

FLDANL

This routine uses a modified FNWC field analysis technique with no guess field and no error checking. The data values are weighted by distance from a grid point and are applied to any grid point within a circle of grid unit radius. Input values within one grid unit outside the final grid are permitted.

To reduce the time required to relax the field after all data points are placed in the grid, guess values are computed at the no data intersection using a normalized squared distance weighted to the neighboring observed data points in the row and column.

The relaxation procedure is then applied to the field allowing the Laplacian to be recomputed during each iteration until the residual is less than the tolerance specified.

When the smoothing factor is specified (not zero) the field is smoothed using a 4 point smoother. In this smoother the points outside the border are given the value at the border.

INFLD

This routine reads an HN tape containing wind components and translates the coordinates based on the values given on the transform card. Values on the input tape that lie more than a grid length outside the final output grid are discarded. Other values are stored in array DATA.

This routine does not check the model or grid size of the input field. If the grid size does not match the NEI, NEI values given on the transform card all data and index returned will be incorrect.

PRTMAE

This routine prints out the final field. The indices are in the ATANAL grid not the HN grid. The origin for the ATANAL grid is the lower left corner. In the case of the FNWC to HN grid translation the READIN routine places the data in the ATANAL grid so that the grid is printed geographically correct with North at the top and East to the right. Because of this convention in the HN to HN grid conversion, the coastal HN grid are printed with grid position 1,1 in the lower right hand corner.

READIN

This routine reads the COAM tape and places the coordinates and values in the DATA array. This read in process is dependent on the COAM tape being in the proper sequence.

TIMINT

This routine stores and reads the wind component fields to and from ECS and interpolates fields at the interval specified on the transform card.

XMIT

This routine transfers data from one array to another. The from array (or element) is the first parameter. The to array is the second parameter. The number of words to transfer is the third. The increment between words in the from array is next (0 is used if the from array is a single word). The last parameter is the increment between words being stored in the to array.

2.4.3 Variables

CO	Cosine of the rotation angle between HN grids
D	Array of 4 values containing the weighted contribution of an observation to the 4 surrounding grid points
DATA	Values to be passed to FLDANL (1,n)=Y coordinate	in ATANAL coor- (2,n)=X coordinate	dinates (3,n)=value
EPS	See grid card
FA	Array being placed on output tape
GRDLENN	See transform card

GUESS	Work array for FLDANL containing final field
IA	Base address of array data is being transferred from
IB	Base address of array data in being placed in
IBUF	Tape input buffer
ICNT	Counter to match COAM tape records with HN header data
IDBG	See grid card
IGRID	See grid card
IK	Page counter index
IREC	Number of records read/written on tape
IT	Number of output tapes per input field
ITIM	Time of the output field
ITINT	See transform card
ITNEW	Time of present field
ITOLD	Time of oldest field
ITY	Type code for the output field
ITYP	Array of ITY values used for field being processed for input to AT model
IW	Work array used to write HN fields
IWW	Byte counter for 12 bit bytes in READIN. Word of the array being processed
J	Index used to unpack 24 bit bytes from 60 bit words
JA	Index for incrementing base address of IA array between transfers

JB	Index for incrementing base address of IB between transfers
JJ	Index to reverse the row index to a line number
JM	Index equal to (I,J-1) if inside the grid, otherwise set to (I,J)
JP	Index equal to (I,J+1) if inside the grid, otherwise set to (I,J)
K	Unpacked integer quantity from a for HN tape. Column index in PRTMAE
KA	Index used in XMIT for the next value to be transferred
KB	Index used in XMIT for the next value to be stored
KKM	Squared distance from KM to the point being interpolated
KKP	Squared distance from KP to the point being interpolated
KM	Index of the last grid point influenced by an observed value in the colnmn
KP	Index to the next grid point influenced by an observed value in the column
L	Length of the COAM tape record
LAYER	Layer number for output field
LEN	Number of words in tape buffer IBUF
LEV	Array of layer numbers used in HN headers
LLM	Squared distance from LM to the point being interpolated
LLP	Squared distance from LP to the point being interpolated

LM	Index to the last grid point influenced by an observed value in the row
LP	Index to the next grid point influenced by an observed value in the row
M	Used in some subroutines in place of ME
MAXOBS	Size of the DATA array
ME	See grid card
MEI	See transform card
MF	First column to be printed on page
ML	Last column to be printed on page
MMF	Index offset for first column to be printed on the page
MN	Number of words in input field
MODEL	See grid card
M12	12 bit mask used to format HN tapes
M24	24 bit mask used to format HN tapes
N	Used in some subroutines in place of NE Date-time group increment switch in ATANAL Index for DATA array in READIN Number of transfers in XMIT
NAME	Title for matrix printout
NCNT	Number of field being written to ECS
NE	See grid card
NECS	Array in ECS for 4 fields (a U and a V component field for each time ITOLD and ITNEW)
NEI	See transform card
NEW	Field at ITNEW

NM	Number of elements in output field
NN	Index relating the HN tape output buffer to the ATANAL grid
NOBS	Number of values stored in DATA
NOP	Number of pages required to print array
NPASS	See grid card
NW	Word being packed or unpacked in IW array
OFFSET	Scale offset for integer values on HN tape
OLD	Field at ITOLD
OLDGRDL	See transform card
P1	See grid card
P2	(1.-P1)/4.
R	Array of 4 values containing weights for the 4 grid points surrounding the observed value
RDIFF	Sum of the squared distances passing the unit circle test
RMAX	Maximum change between iteration of the relaxation procedure
RTIME	Ratio of time to interpolate for intermediate wind component fields
ROTATE	Rotation angle between HN grids
ROTIN	See transform card
ROTOLD	See transform card
S	Sum of the squared distances in FLDANL Array to be printed
SC	Ratio of grid scales=input grid size/ output grid size

SCALE	Scale factor for integer values on HN tape
SI	Sine of the rotation angle between HN grids
W	Work array required by FLDANL to weight the observed values. In other routines used as a buffer space
X	Input grid index
XC	See transform card
XINC	Fractional difference between XI and the truncated index I=XI
XINC1	1-XINC
XJ	Coordinate of an observed value
XLAP	Contribution to the relaxation field in one iteration
XMA	Number of column in the rotated array+1
XOF	See transform card
XS	XINC*XINC
XX	Rotate grid coordinate
XZ	XINC*XINC1
Y	Input grid coordinate
YC	See transform card
YINC	Fractional difference between YJ and the truncated index J=YJ
YINC1	1-YINC
YJ	Coordinate of an observed value
YMA	Number of rows in the rotated array+1
YOF	See transform card

YS	YINC*YINC
YY	Rotated grid coordinate
YZ	YINC*YINC1
ZLMBD4	See grid card

3. LIMITED AREA ATMOSPHERIC FORECAST MODEL

The Bengtsson model (2) was adopted for this project to produce the local wind data. Since only minor changes have been made in the formulation of the model since 1974 this report will concentrate on the instructions to run the model and the way the model is organized and coded, all of which have changed considerably.

Since 1974 the Bengtsson model has been almost completely recoded at NEPRF to eliminate options reported earlier that were not needed for this project or were no longer needed, to provide a linkage with the FNWC fields through HN formatted tape, to generate and save the wind components, to change the formulation of the stream function, and to add experimental surface heating effects.

3.1 SUMMARY OF CHANGES

The polar stereographic grid used in the earlier model with the options to cut off the corners of the grid has been replaced by the equal distance grid, described in Section 1.2, which is always rectangular.

The experimental optional terms in the vorticity equation have been reduced from 4 to 2 by eliminating the advection of vorticity by divergent winds and the product of relative vorticity and divergence.

Since the model is being used in this project to forecast in a very small area that is nested within the hemispheric grid, the assumption that there was no net inflow or outflow used in the stream function computation has been discarded in favor of a much simpler numerical relationship between F and Ψ given by $\Psi = Zg/f$.

The linkages with the FNWC fields and the HN model using HN format tapes through program ATANAL have been added using code borrowed from the HN model.

The wind computation routine added to compute the surface winds was adapted from Larson (5).

The channel data cases coded into the initialization routine have been changed to a simplified test case for use with the new surface heating routine based on Laevastu (4).

3.2 RUN INSTRUCTION FOR AT MODEL

The AT model was developed for operational use in a fixed area so all control variables have been compiled into the program rather than being supplied on control cards. The two modes that have been used during the project are the real data case and a channel case with cyclic boundaries. Although the real data case has the option of using static or variable boundaries, in the real data case the boundaries have been varied. In the channel case mode there have been several sets of data used, including both barotropic and baroclinic cases with and without latent and sensible heating. In both modes the step extended calculations have been optional.

To define these different modes and cases the model employs the CDC UPDATE system, which allows temporary modification of a source deck through a correction deck. Unfortunately, this technique, while very simple to use, is difficult to document in a way that is independent of a particular UPDATE program library. Instead of a card by card description of the UPDATE sets, the following sections provide checklists for the data that must be provided and functions that are required.

3.2.1 Real Data Case Checklist

Variables Set in PROG3P

Setting	Meaning
KIND=0	Real data case
IVAR=1	Variable boundaries (see input tape rules)
DS=7.408E+4	Size of the Gulf of Alaska grid
N=32	Number of rows in Gulf of Alaska grid
M=47	Number of columns in Gulf of Alaska grid
MODEL=1000	Model number used on HN tape to identify Gulf of Alaska grid
ROT=180.	Rotation of HN input grid. Used to compute wind direction.
NEND=36	Length of forecast period in hours
NTSTEP=12	Number of time steps in the forecast interval
NBLOCK=3	Forecast interval in hours (see input tape rules)
MAPHOUR=0,72,6	Start printouts at time 0, printout at 6 hour intervals until NEND or 72 hour have passed. (also see output tape rules).
LETACC NSMUTT MSMUTT NELLIPT MELLIPT	All must be set to appropriate values that are even multiples of NBLOCK to zero accumulated precipitation, to smooth the field and to check for ellipticity.

IEXT3=1 or=0	Option to include the vertical advection of vorticity and divergence terms
IEXT4=1 or=0	Option to include the twisting term in the vorticity equation
ITIME=0	Initial time on the HN tape in seconds
NTIME=0	Initial time for computation (matching ITIME) in hours

Variables set in INITIAL

For the real data case no variables need be set in INITIAL unless the grid size is changed to 14.816E+4 meters. In this case the grid indices are modified before calls to INOUT and the number of grid points is reduced by the elimination of every other grid point. The reduced grid has been used for a number of tests during the project since it more closely matches the Atlantic grid size for which the model was developed.

Input Tape Rules

The two input tapes used for the project contain a single set of data for either the 1 June 1973 or 17 November 1973 cases and since they contain only relative times they could be used interchangeably by simply changing the tape assigned to logical unit 1. The relative time of the initial fields must match the time specified by ITIME. When variable boundary conditions are used the input tape must have fields in the proper sequence at 12 hour intervals. To have the proper calls 12 must be an integer multiple of NBLOCK.

Output Tape Rules

The output tape is used to store the wind components and is called from within MAP3P. It is called each time the surface pressure field is printed when the first parameter in the call sequence to MAP3P is equal to 2. The data are written directly on the tape if a tape is pre-assigned to TAPE2.

Land Elevation Table

The land elevation table is read by routine INITIAL when it is entered for the real data case. The land elevation table has been read from a card deck where each card represents a row of the Gulf of Alaska grid and each column is a column in the grid. Punches in the land elevation table are the index to the surface pressure table STANPS, which gives the pressure for 0, 200, 500, 1000, 2000, 3000, 4,000 5,000 6,000 and 7,000 meters--the levels on the MONACO charts for the Gulf of Alaska.

3.2.2 Channel Case Checklist

Setting	Meaning
KIND=1	Channel case
IVAR=0	The boundaries are not updated with real data. The channel is connected on the right-left ends.
DS=200km or 100 km	Grid sides used in experimental grids
N=15	Number of rows
M=30	Number of columns
MODEL=0	No input tape is used so the model number does not matter

ROT=0	This does not matter if the winds are not computed.
NEND=36 or 72	Length of forecast period in hours
NTSTEP=12 NBLOCK=6	Number of time steps in the forecast interval and forecast period
MAPHOUR=0, 72,6	Start printout at time 0. Printout at 6 hour intervals until NEND hours or 72 hours have passed.
NSMUTT, MSMUTT=72,0,0	In the channel cases no smoothing is used
LETACC NELLIPT MELLIPT	All must be set to even multiples of NBLOCK
IEXT3=1 or 0 IEXT4=1 or 0	Option to include or exclude extended calculations
ITIME=0 NTIME=0	Time counters should both be equal =0 for the channel case start

For the channel case all data are generated during the execution of routine INITIAL. The calls to routine GENCH are used to create the initial stream function and the calls to FILL are used to generate the surface pressure and temperature fields.

Table 2 shows several test cases using the channel option that were used in conjunction with the optional extended calculations and heating. The dimensions of the in core arrays must be large enough to contain the M*N array.

Test Cases / Variable	1 (Barotropic)	2	3 (Baroclinic 2 wave)	4
UPS	30.	7.	5.,5.	0.,3.,4.,6., 5.,4.,3.,2., 0.
UPM	30.	20.	35.,35.	0.,12.22,16.26, 21.31,18.31,15.31 12.12,8.92,0.
UP1	30.	35.	50.,50.	0.,24.,32.,42., 36.,30.,24.,17., 0.
PSIS	0.			.2E7
PSIM	5.4E8			5.144E8
PSI1	9.2E8			9.04E8
FIM	50.			60.
BETA	1.14542E-11		16.E-12	1.14542E-11
NWAVE	1		2	0
NU	1		2	9
NX	1		1,4	0
NY	0		1,1	0
PSIC	0.		0.,0.	0.
PSIS	0.		1.5E5,1.5E5	0.
LAMC	0.		0.,0.	0.
LAMS	0.		-90.,-90.	0.
DS	200./100.			
M	30/60			
N	15/30			
IDIM	450/1800			
IEXT3	0/1			
IEXT4	0/1			

Table 2. Specifications of channel test cases

3.3 DESCRIPTION OF ROUTINES

The following routines are described in the order shown in the program organization, Figure 9.

PROG3P

This is the main program which contains most of the DATA statements that control the functioning of the program. The program sequence is to set initial constants, call INITIAL to read or generate the time 0 fields, convert the initial fields into the forms required by the computation, initialize and store initial fields in ECS fields and then loop for each forecast interval. Within the forecast loop the fields are mixed with boundary values, smoothed, checked for ellipticity and printed.

BMOVE

This routine is used to impose the cyclic boundary on the channel computation. It is used when KIND=0. It moves the next to last column in the array to the first column, and the second column to the last column position.

XMIT

This routine is used to move data vectors and zero data arrays within core.

RANWT/RANRD

Routine to link the program with an external storage device capable of storing the work arrays. Presently used to transmit to and read data from ECS.

FIELD

Debugging aid that prints the entire set of incore work arrays F1-F10.

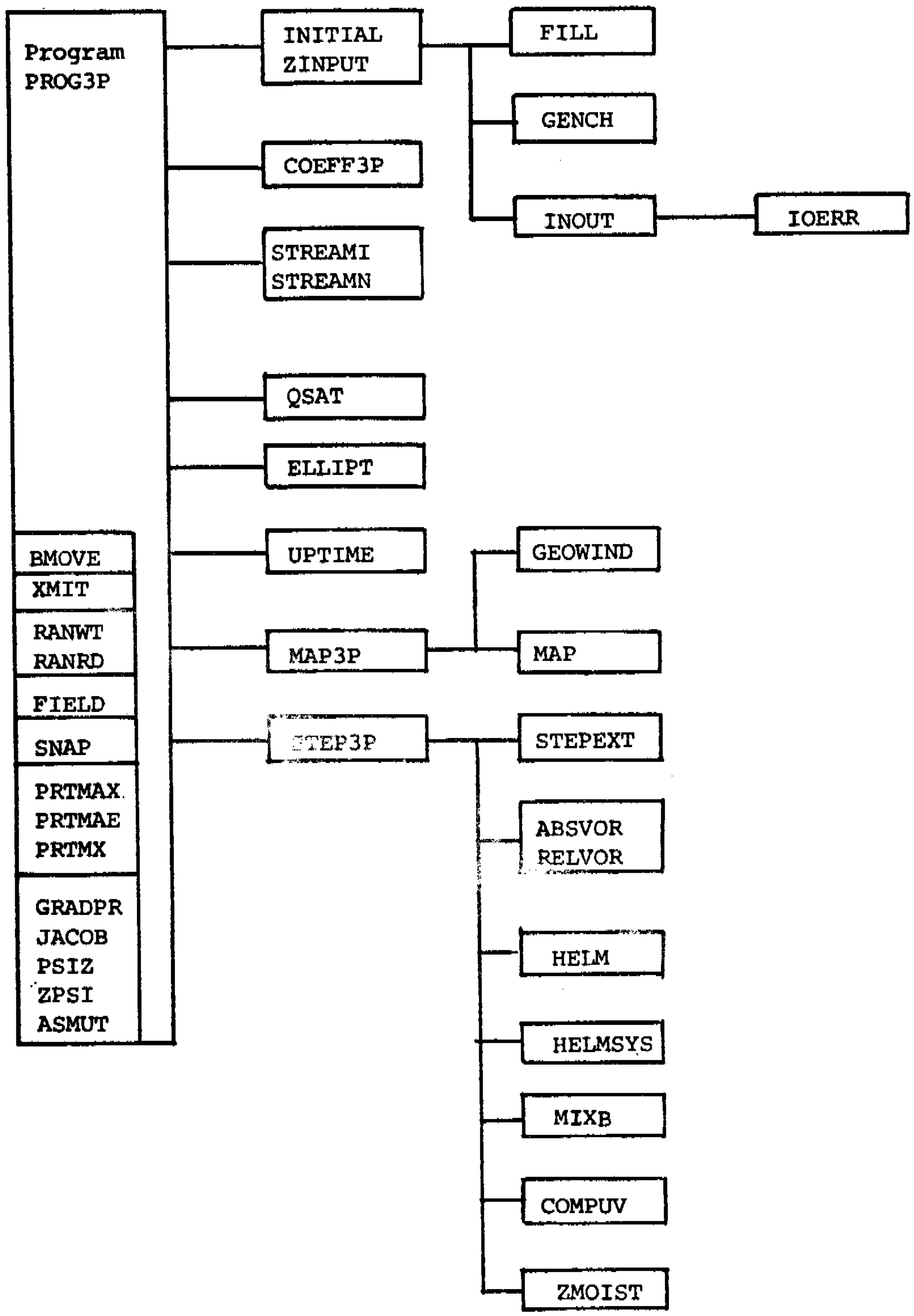


Figure 9. AT model call sequences

SNAP

Debugging aid. Prints a 10x10 corner of the specified sequential set of the work arrays F1-F10.

PRTMAX/PRTMAE/PRTMX

Routine to print an array with title, row and column numbers. The three entires provide F12.2, E12.6 and I12 formats for the array values.

GRADPR/JACOB/PSIZ/ZPSI/ASMUT

This routine combines a number of array to array mathematical processes. Entry GRADPR computes $\nabla A \cdot \nabla B$ as a finite difference.

```
GRADPR(I,J)  = (A(I+1,J)-A(I,J))*(B(I+1,J)-B(I,J))+(A(I,J)
               -A(I-1,J))*(B(I,J)-B(I-1,J))+(A(I,J+1)
               -A(I,J))*(B(I,J+1)-B(I,J))+(A(I,J)
               -A(I,J-1))*(B(I,J)-B(I,J-1))
```

Entry JACOB computes the Jacobian operator

```
J(A,B)  = ((A(I+1,J)-A(I-1,J))*(B(I,J+1)-B(I,J-1))
          -((B(I+1,J)-B(I-1,J))*A(I,J+1)-A(I,J-1))
```

Entry PSIZ converts heights to thicknesses.

Entry ZPSI converts thicknesses to heights.

Entry ASMUT smooths the field

INITIAL/ZINPUT

This routine contains the portion of the initialization process not included in program PROG3P. The data statements in this subroutine are used to control the generation of "canned" channel cases or the reading of real data.

In the real data case (KIND=1) the surface elevations are read and converted to pressures, the input tape is read and the vapor pressure is computed from the 850 mb dew point temperature. The MARK, MY and F arrays are created and selected data are printed. In the variable boundary cases (IVAR=1) the routine is re-entered through ZINPUT to read the boundary fields that are to be mixed with the forecast field.

In the canned data case, the MARK, MY and F fields are computed and then routine GENCH is called to generate the height fields. Routine FILL is used to create the surface temperatue and pressure fields.

FILL

This routine is used to fill a selected part of an array with a value that is constant for each column and may vary with the row index by a constant interval.

GENCH

This routine is used to generate a 2 dimensional array containing a sine-cosine wave form.

INOUT

This routine is used to read and write the fields in or out to tape. The tape format used is described separately. The routine is called by INITIAL to read data and by GEOWIND to write the wind component tape.

IOERR

This routine is called by INOUT whenever a parity error or end of file is detected on input or output tapes.

COEFF3P

This routine precomputes the simple variable constants used by STEP3P and STEPEXT.

STREAMI/STREAMN

This routine rescales pressure fields by the constant g/f.

QSAT

Computes the integrated mixing ratio at saturation given the mean temperature.

ELLIPT

Modifies the array so that the criterion of ellipticity is satisfied.

UPTIME

Increments the action time by the time interval and then sets the time to a large number if the new time is greater than the end time specified.

MAP3P

Retrieves desired fields from ECS and calls MAP to print the zebra grid points for selected fieelds. Also calls GEOWIND.

GEOWIND

Routine using Larson formula to compute wind components, speed and direction for use in the HN model.

MAP

Routine to make zebra pattern grid printouts.

STEP3P

Main computation forecasting routine.

STEPEXT

Routine for extended terms

RELVOR

Computes relative and absolute vorticity terms

HELMSYS

Solves the couble set of Helmholz equations

HELM

Solves the single Helmholz equations

MIXB

Mixes the forecast field with the input fields on the outer three rows and columns.

COMPUV

Computes the heating effects from the sea surface temperature in the surface layer if the air temperature is colder than the sea.

ZMOIST

Routine to simulate sensible heating based on the sea surface temperature. It is the elevation in meters at which the wind or stream function representative of the wind is calculated, essentially the midpoint of the surface layer (≈ 750 mb).

3.4 DESCRIPTION OF VARIABLES

A	A formal parameter array in GRADPR, XMIT, BMOVE	
AB4	Intermediate variable used in solving HELMSYS	
ADIFF	Diffusion coefficient for humidity	
ALFA	Overrelaxation coefficient	
ALFAM	Overrelaxation coefficient used in HELM	
ALFAPSI	Not used	
ANG	Latitude in degress of a grid point used in GEOWIND	
ARG	Ratios of pressure level used in COEFF3P to compute the ALOG of the ratios	
AX	Angle between pure geostrophic and surface wind vectors	
A1	Used in computation of divergence, a_1	$=2.0828\ 10^{-3}$
A2	a_2	$=1.3546\ 10^{-3}$
A3	a_3	$=0.044374$
B	Output array in XMIT Input array in GRADPR	
BETA	Constant used to compute Beta plane for channel case	
B1	Used in computation of divergence, b_1,	$=1.0475\ 10^{-3}$
B2	b_2	$=1.6261\ 10^{-3}$
B3	b_3	$=0.012258$

C	Formal parameter used in GRADPR call sequence for result and work arrays. Constant in COMPUV	= .12
CC1	1./TO	
CC2	e · L/R	
CC3	e · L/C_p	
CC4	CC2·CC3	
CC5	DEL1·DEL2	
CF	Friction over land or over ocean =FCONT or FOCEAN	
CK	Constant used in COMPUV	= .35
CLX	Height of a print character on a CDC printer in meters	= .00425
CLY	Width of a print character on a CDC printer in meters	= .00254
CO	Cosine of geostrophic wind vectors	
CONV	Convergence parameter used in ELLIPT	= .43
COS1	Cosine of angle between geostrophic and surface wind vectors	
CP	Specific heat at constant pressure C_p	=1004.
CX	Interpolation interval for computing values at zebra grid print position	
CY	Interpolation interval for computing values at zebra grid print position	
C1	$c_1 = \frac{2P_m}{2P_0 - P_1} = \frac{10}{17}$	=0.588235

C2	$c_2 = \dfrac{2(P_0 - P_m)}{2P_0 - P_1} = \dfrac{10}{17}$	=0.588235
C3	$c_3 = \dfrac{6P_0 - 4P_1}{6P_0 - 3P_1} = \dfrac{48}{51}$	=0.941176
C4	$c_4 = \dfrac{6P_m - 2P_1}{6P_0 - 3P_1} = \dfrac{24}{51}$	=0.470588
C5	$c_5 = \dfrac{8P_0 - 8P_m}{6P_0 - 3P_1} = \dfrac{40}{51}$	=0.784314
C6	$c_6 = \dfrac{8P_m}{6P_0 - 3P_1} = \dfrac{40}{51}$	=0.784314
C7	$c_7 = \dfrac{P_1}{6P_0 - 3P_1} = \dfrac{3}{51}$	=0.0588235
C8	$c_8 = \dfrac{2}{2P_0 - P_1} = \dfrac{2}{170}$	=0.0117647
D	Combined scaling constant in MAP	
DELP	Δ_p used to compute rainfall	
DELT	Time step in seconds Δt=NBLOCK·3600/NTSTEP	
DEL1	∂_2 tolerance	=.0001
DEL2	∂_2 tolerance	=.001
DEW	Used in advection formula in COMPUV	
DIV	M1·N2-N2·M2	
DIV1	ECS storage array for divergence field D_1	
DIV 2	ECS storage array for divergence field D_2	
DEPS	Time between fields being integrated = DELT·EPS	
DS	Grid distance (meters)	

DSS	.5/DS used in GEOWIND	
DT	Time step in hours =DELT/3600.	
DX	North-South dimension of a cell in meters represented by a print character in the zebra grid print	
DY	East-West dimension of a zebra cell in meters	
D1	Wind contraction factor	
E	Entry flag used in INITIAL to distinguish between the initial entry and calls to ZINPUT 1.=INITIAL entry 0.=ZINPUT entry	
EC2	ECS address of forecast field to be mixed	
EC3	ECS address of boundary value field to be mixed	
EE	E	=.622
EM	Coefficient for computing mean stream function, e_m	=0
EPS	Number of time steps between fields in the time integration	
EP	E_0	=.611
E1	Coefficients for computing mean stream functions, e_1	=-1.3589
E2	e_2	=0
F	Coriolis parameter field =F_0·2.·SIN (lat degrees)	
FA	Array contains data to be written on the output tape or array to be filled from data on the input tape.	
FACT	Time ratio used to mix boundary values into field at each integration step	

FCONT	Friction coefficient over land	=1.
FF	In routine INITIAL latitude in degrees, Coriolis parameter at a grid point	
FIM	Mid-latitude of channel	
FLD	Surface pressure field given to GEOWIND	
FM	Mean latitude Coriolis parameter used in computing Beta plane for channel case	
FMY	f^2/M	
FOCEAN	Friction coefficient over oceans	=.62
FORC	2D array for the forcing function	
FORC1 / FORC2	Formal parameters in HELMSYS routine representing forcing function arrays	
FO	Radial velocity of the earth	=1.03E-4
FOFO	FO squared	
F1-F10	In core work arrays. All must be of equal size equal to IDIM words	
G	Gravity	=9.806
GDFO	g/F_0	
HEAT	ECS storage array for Heating	
HL	L	$=2.5.10^6$
HM3	ECS storage array for the twisting terms for the mean field	
HUM1	ECS storage array for humidity field	
HUM2	ECS storage array for humidity field	

H1	$h_1 = \frac{R}{4c_p} \ln \left(\frac{p_0}{p_m}\right)$	$=0.495351\cdot 10^{-1}$
H2	$h_2 = \frac{2f_0}{R \ln \left(\frac{p_0}{p_m}\right)} \left(1 + \frac{0.75\, R(p_0 - p_m)}{c_p(p_0+p_m)}\right)$	$=0.110953\cdot 10^{-5}$
H3	h_3	$=1.03552\cdot 10^{-6}$
H4	h_4	$=0$
H6	h_6	$=1.03552\cdot 10^{-6}$
H13	ECS storage array for the twisting terms for the thickness field 1	
H23	ECS storage array for the twisting terms for the thickness field 2	
IA	Increment for array index for the array data is being taken from in XMIT	
IB	Increment for array index for the array data is placed into in XMIT	
IDAY	Day number	
IDIM	True dimensional size of the arrays	
ID1 ID2	Two word ident used to find data on input tapes and to identify output records	
IERR	Index to tape messages in IOERR 1=parity error on input 2=eof input 3=parity error on output 4=eof output	
IEXT3	Switch to include or exclude the vertical advection of vorticity, $\omega\, \partial\zeta / \partial P$, in forecasting equation 0=exclude 1=include	

IEXT4	Swith to include or exclude the twisting term in the forecasting equation o=exclude 1=include
IFMT	Array used for variable format in PRTMAX
IMM	Simple index = (1,n)
IND	Simple index to locate the two points before and following a grid point I in the row or column. Used in GEOWIND to compute the second order approximation to the gradient.
IP	Simple index = (I+1,J)
IPOINT	Number of points that fail the criterion of ellipticity in ELLIPT
IPP	Simple index = (M,n)
IQ	Print value and then the position index in the zebra grid print row
IREC	Number of records read from input tape
IS	Line spacing control in PRTMAX 1H‸ no extra spacing 1HO double space
ISL	Index used to build LS table
IT	Time in seconds of the desired input field
ITIME	Time in seconds when reading or writing tapes. Time in hours during remainder of the program
ITY	Type of field on tape -indicates field is to be read +indicates field is to be written 11=FNWC Sea temperature field T SEA 12=FNWC Pressure field D1000,D500 or D300 14=FNWC TP850 field 8=U or V wind component

IVAR	Indicator for constant or variable boundary conditions 0=constant boundaries 1=variable boundaries
IW	500 word buffer used to read and write tape
IWW	The word that is presently being packed or unpacked for or from the tape buffer in INOUT
I1	In QSAT index to precomputed values of integrated mixing ratios in the range 1 to 71 from temperature in the range -20 to +50. InPROG3P =0 if no smoothing this time step =1 if smoothing is required In GRADPR=beginning point in array for storing smoothed values. Excludes first rows from computation.
I2	In PROG3P =0 if ellipticity is bypassed this time step =1 if fields are modified to meet ellipticity criterion In GRADPR=end point in array for storing smoothed values. Excludes last row from computation
	Indicator for when zebra grids are to be printed 0=no print, 1=print
I1	Surface pressure (2=print and call GEOWIND)
I2	Height for level p_m
I3	Height for level p_1
I4	Thickness (p_m-p_1)
I5	Lower vertical velocity $\bar{\omega}_1$
I6	Precipitable water
I7	Accumulated precipitation
I8	Relative humidity
I9	Stream function for level p_s
I10	Stream function for level p_m
I11	Stream function for level p_1
JJ	Row number in PRTMAX

JK	Index to first column being printed on the page in PRTMAX	
JMA	Maximum row index for the page	
JMI	Minimum row index for the page	
JMP	Number of column being printed in this page of the zebra grid print	
J3	ECS storage array for $J_3 = J(\Psi_m;\Psi_1)$	
J4	ECS storage array for $J_4 = J(\Psi_m;\Psi_2)$	
J12	ECS storage array for $J_1+J_2 = J(\Psi_m;\zeta_1) + J(\Psi_1;\beta_2)$	
J56	ECS storage array for $J_5+J_6 = J(\Psi_m;\zeta_2) + J(\Psi_2;\beta_6)$	
J789	ECS storage array for $J_7+J_8+J_9 = J(\Psi_m;\beta_7) + J(\Psi_1;\beta_8) + J(\Psi_2;\beta_9)$	
KIND	Type of run flag 1=canned data channel case (cyclic boundary conditions) 0=real data	
KT	In STEP3P: Index in the integration loop In MAP: Array of print characters used for the zebra print	
K1	$k_1 = c_2(c_2 - \frac{4}{3})$	=-0.438291
K2	$k_2 = -c_2c_4$	=-0.276816
K3	$k_3 = c_2c_7$	=-0.034602
K4	$k_4 = -c_1c_2$	=-0.346020
K10	$k_{10} = 2t_2c_8$	=-0.438294
K11	$k_{11} = -2(t_3+t_7)c_8$	=-0.276817
K12	$k_{12} = -t_7c_8$	=0.034602
K13	$k_{13} = -2t_3c_8$	=-0.346021

K14	$k_{14} = 2(t_5-t_8)c_8$	=-0.507498
K15	$k_{15} = -t_8c_8$	=0.083045
K16	$k_{16} = 2t_1c_8$	=0.016609
K17	$k_{17} = 2(t_4-t_6)c_8$	=0.005536
K18	$k_{18} = -t_6c_8$	=-0.000692
K19	$k_{19} = 2t_2c_8$	=-0.438293
K20	$k_{20} = 2t_3c_8$	=-0.346021
K21	$k_{21} = 2t_1c_8$	=0.016609
K22	$k_{22} = -2(t_3+t_7)c_8$	=-0.276817
K23	$k_{23} = 2(t_5-t_8)c_8$	=-0.507497
K24	$k_{24} = 2(t_4-t_6)c_8$	=0.005536
K25	$k_{25} = -t_7c_8$	=0.034602
K26	$k_{26} = -t_8c_8$	=0.083045
K27	$k_{27} = -t_6c_8$	=-0.000692
K31	$k_{31} = -\frac{t_{10}}{(p_0-p_m)}$	=0.411765
K32	$k_{32} = -\frac{t_{11}}{(p_0-p_m)}$	=0.588235
K33	$k_{33} = \frac{1-t_9}{(p_0-p_m)}$	=0.0117647
K36	$k_{36} = \frac{t_{10}-t_{13}}{(p_m-p_1)}$	=-0.588235
K37	$k_{37} = \frac{t_{11}-t_{14}}{(p_m-p_1)}$	=-0.411765
K38	$k_{38} = \frac{t_9-t_{12}}{(p_m-p_1)}$	=0.0117647
LAMC	Phase differences for the cosine functions (λc)	

LAMS	Phase differences for the sine functions (λ_s)
LCM	Address of ECS where array transfer starts
LEN	Length of input output buffer in INOUT=500 words on CDC 6000-7000 series machine
LETACC	(1) Times when the accumulated precipitation shall be interrupted in hours (multiple of NBLOCK) (2) End time after which no interruption takes place (3) Time interval between interruption (multiple of NBLOCK)
LEV	Level in tape record header 300 for D300 500 for D500 1000 for D1000 0 for all other fields
L	Counter used in COMPUV indicating the number of times the routine has been entered
LS	ECS array contains the flag field used by COMPUV
LU	Logical unit number for output tape in INOUT, for zebra grid prints in MAP
M	Row dimension
MAPHOUR	(1) Time when forecast is to be printed in hours (multiple of NBLOCK) (2) Time of last printout desired (3) Time interval between forecast printouts (multiple of NBLOCK)

MARK — Flag field used to control computations in the outside 3 rows and columns of the arrays defined as follows (origin of grid=lower left corner):

20	10	10	10	10	10	10	19
14	-9	-8	-8	-8	-8	-7	6
14	-9	-10	-10	-10	-10	-7	6
14	-9	-10	-1	-1	-10	-7	6
14	-9	-10	-1	-1	-10	-7	6
14	-9	-10	-10	-10	-10	-7	6
14	-9	-6	-6	-6	-6	-7	6
17	2	2	2	2	2	2	18

MAXNAME — Maximum number of words in matrix header line = 10

MELLIPT — (1) Time at which ellipticity correction is to be made in hours (multiple of NBLOCK)
(2) Time of last correction
(3) Time interval between corrections (multiple of NBLOCK)

MF — Index to the first column being printed on the page in PRTMAX

MI — In F[illegible] number of columns to be filled

ML — Index to last column being printed on the page in PRTMAX

MN — Number of elements used in the arrays=number of rows times number of columns

MODEL — Model number used when reading or writing tapes. Used to uniquely define the data tapes.

MSMUTT — Same as NSMUTT for a second time sequence except it cannot be used to control smoothing at time 0.

MT	UPTIME parameter (1) Time action desired (multiple of NBLOCK) (2) Last time action desired (3) Time interval between actions (multiple of NBLOCK)	
MY	Map scale factor μ	
M1	Number of columns-1, m_1	=-826.330
M2	m_2	=-688.40
M12	12 bit mask used to pack and unpack tapes	
M24	24 bit bask used in packing and unpacking takes	
N	Column dimension	
NAME	Page header word in SNAP and FIELD	
NAME1	Header for the matrix printout NC characters in length 1 to 80 characters long	
NBLOCK	Forecast interval in hours (usually 6)	
NC	Number of characters in NAME1 header line $1 \leq NC \leq 80$	
NCNT	Counter for the number of times SNAP has been called	
NCPW	Number of characters per word=10	
ND	NTSTEP+1 Number of times the integration loop is executed during one forecast computation	
NELLIPT	Same as MELLIPT but used for a second time sequence	
NEND	End time for forecast in hours	

NI	In FILL number of rows to be filled	
NN	Number of print column available for zebra print grid	
NOP	Number of pages required to print a matrix in PRTMAX	
NSMUTT	(1) Time of the first smoothing, may be 0 if the initial fields are to be smoothed (in hours) (2) Last time for a smoothing operation (3) Time interval between smoothing operations	
NTIME	Time in hours	
NTSTEP	Number of time steps for an integration interval	
NU	Resolution of zonal wind speed	
NW	Number of words being packed or unpacked in INOUT, in PRTMAX number of words in heading	
NWAVE	Number of waves	
NX	Wave numbers as a function of channel length in X direction (nx)	
NY	Wave numbers as a function of channel width in Y direction (ny)	
N1	Number of rows-1, n_1	=-532.92
N2	n_2	
OFFSET	Constant added to input values from tape after the values are scaled and subtracted from output values before scaling	
PI	Radians in 180°	=3.141593
PNIVM	Pressure level p_m	=50CB

PNIVS	Pressure level p_0	=100CB
PNIV1	Pressure level p_1	=30CB
PM	p_m Intermediate pressure level that divides the atmosphere into 2 layers	=50CB
PMEAN	$.5 \cdot P_m + P_s$	
PP	Intermediate value used in STEP3P computations. Ratio of time step to grid size used in COMPUV	
PPM	$2./(P_0 - P_m)$	
PQ	Intermediate value used in STEP3P computation	
PREC	ECS storage array for accumulated precipitation	
PS	ECS storage array for surface pressure field	
PSI	Result field Ψ field Array being modified to satisfy the criterion of ellipticity in ELLIPT	
PSIC	Amplitudes of the cosine functions (Ψc)	
PSIM1	ECS storage array for Ψ_m at time 1	
PSIM2	ECS storage array for Ψ_m at time 2	
PSIPM PSIPS PSIP1	Pressure levels for channel case	
PSIS	Amplitudes of the sine function (Ψs)	
PSI11	ECS storage array for Ψ_1 at time 1	

PSI12	ECS storage array for Ψ_1 at time 2	
PSI21	ECS storage array for Ψ_2 at time 1	
PSI22	ECS storage array for Ψ_2 at time 2	
P0	P_0 Lower pressure level near the surface of the earth	=100 CB
P1	P_1 Upper pressure level near the tropopause	= 30 CB
Q	Field to be printed	
QD	Resolution indicator for isolines	
QZ	Isoline corresponding to 000 on the printed grid	
R	Gas constant for air	=287.
RESIDUE	Formal parameter in HELMSYS=RESM Formal parameter in HELMSYS= RESSYS	
RESM	Allowed residual in the HELM routine	$=.5\cdot10^5$
RESPSI	Not used	
RESSYS	Allowed residual in the HELMSYS routine	$=.5\cdot10^5$
RESZ	Not used	
RMAX	Maximum residual remaining at the end of an iteration in HELM	
ROT	Grid rotation defined as counter clockwise angle from the North to the +Y axis in degrees	
RPD	Radians per degree. Constant used to convert to and from degrees	
RW	Precomputed values mixing ratios at saturation	

S	Array to be printed in PRTMAX Vorticity term at one grid point in ABSVOR	
SATUR	Saturation temperature	
SCALE	Map scale factor for grid print (unit 10° m) Scale factor in INOUT = .01 for all input fields except for ITY=12 (D300, D500, D1000) when the factor is .0001	
SCM	Beginning word of an array to be transferred to or from ECS	
SI	Sine of the geostrophic wind vector	
SIN1	Sine of the angle between the geostrophic and surface wind vectors	
SS1	Coefficients for computing mean divergences	=E1+EM·C2
SS2		=E2-EM·C1
SS3		=-EM·C8
STANPS	Standard pressures at mean levels defined on Monoco charts.	
SURPS	Standard atmospheric pressure at sea level	=101.325 CB
STAB1	$(\Gamma_d-\Gamma)_1$ the dry adiabatic lapse rate-lapse rate; assume	=.422222
STAB2	$(\Gamma_d-\Gamma)_2$ Γ=.75 $_d$	=.511111
S1	Used in computations of divergence, s_1	=28.230856
S2	s_2.	=10.645832
TA	ECS storage array for the air temperature	

TERM1 TERM2	Values used in the computation of divergence	
TM	Temperature in °K	
TOL	Tolerance	
TS	ECS storage array for surface temperature in °K	
TWT	Air-sea temperature difference	
TO	Conversion factor to convert from °C to Kelvin=273.	
T1	$t_1 = \frac{p_0+p_m-p_1}{2p_0-p_1}$	=0.705882
T2	$t_2 = \frac{1}{3} \frac{(2p_1-3p_m-p_0)(p_0-p_m)}{2p_0-p_1}$	=-18.627500
T3	$t_3 = \frac{p_m(p_0-p_m)}{2p_0-p_1}$	=14.705900
T6	$t_6 = c_8 \frac{p_1}{6}$	=0.0588235
T7	$t_7 = -c_2 \frac{p_1}{6}$	=-2.941175
T8	$t_8 = (c_1-2) \frac{p_1}{6}$	=-7.058825
T10	$t_{10} = (c_2-1)(p_0-p_m)$	=-20.588250
T11	$t_{11} = -c_1(p_0-p_m)$	=-29.411750
T12	$t_{12} = c_8 \frac{p_1}{2}$	=0.176471
T13	$t_{13} = -c_2 \frac{p_1}{2}$	=-8.823525

T14	$t_{14} = (c_1-2) \frac{p_1}{2}$	=-21.176475
U	Zonal wind speed	
UKUA	Air temperature gradient in the U direction	
UKUW	Water temperature gradient in the U direction	
UPM	Zonal wind profiles at the levels p_s, p_m and p_1 for the initial fields in the channel case	
UPS		
UP1		
V	In FILL value placed in the row	
VKVA	Air temperature gradient in the V direction	
VKVW	Water temperature gradient in the V direction	
VI	In FILL value that the initial value is incremented by when incrementing to next row	
VM	ECS storage array for the velocity potential for the mean field	
VOR	η or ζ field	
VS	In FILL initial value to be placed in the row	
V1	ECS storage array for the velocity potential for the thickness field 1	
V2	ECS storage array for the velocity potential for the thickness field 2	
WF	Weighting factor used to interpolate between boundary value fields in time	

	Weights for mixing the boundary fields
WGT1	Outside row or column
WGT2	Next inner row or column
WGT3	Third row or column inside boundary
WI	Easterly component of wind vector
WJ	Northerly component of wind vector
WS	ECS sotrage array for ω_s, the vertical velocity at the lower boundary
WT	Wind speed
WX	Adjustment of wave near rigid boundaries Boundary WX=0 +1 row from the boundary, wx=0.33 +2 rows from the boundary, wx=.64 +3 or more rows from the boundary, wx=1.
XIX	Row in index-1 used to compute latitude in GEOWIND
XP	Midpoint in a zebra grid print position
YP	Midpoint in a zebra grid print position
YZ	Midpoint in a zebra grid print position
Z	Formal parameter in STREAM1 routine= height field
ZD	Wind direction computed in GEOWIND
ZM	Data array used to store precomputed values for ZMOIST

ZM1	Z_m fields stored in ECS for boundary mixing at times 1 and 2
ZM2	
ZS	Wind speed computed in GEOWIND
Z1	Arrays used in HELMSYS
Z2	
Z11	Z_1 fields stored in ECS for boundary mixing at times 1 and 2
Z12	$Z_1=.5(Z_m-Z_{1000})$
Z21	Z_2 fields stored in ECS for boundary mixing at times 1 and 2
Z22	$Z_2=.5(Z_{300}-Z_m)$

4. HYDRODYNAMICAL-NUMERICAL MODEL

The Optimized HN model run instructions are contained in Bauer (1) and additional documentation of the model is in preparation for the Environmental Protection Agency, Corvallis Environmental Research Laboratory so it is not repeated in this report. Figure 10 is an overview of the HN model program sequence showing where the AT model links in. The HN model requires a preprocessed initial grid contained on an HN format tape. This tape is prepared by a program on the NEPRF CDC 3100 computer by Phase I. The HN model reads the initial tape and the optional wind component tape generated by the ATANAL program from the water heights and and velocity fields. The output tape can then be processed by the display program Phase III which produces pen plots on CalComp plotters, by HNCNTR which produces contour plots of the fields on the NEPRF 3100 Varian plotter or by ADVECT which is a program to advect pollutants based on the velocity fields.

4.1 SUMMARY OF CHANGES

The HN model reported in (1) has undergone a number of revisions since the report was prepared. Most of the changes were to add capabilities to the model or to alter the boundary conditions that are treated in detail in the forthcoming EPA report. The only change made specifically for this project was the addition of the variable wind input option. This change was made using the CDC UPDATE system to replace the source program statements that converted the WIND card parameters

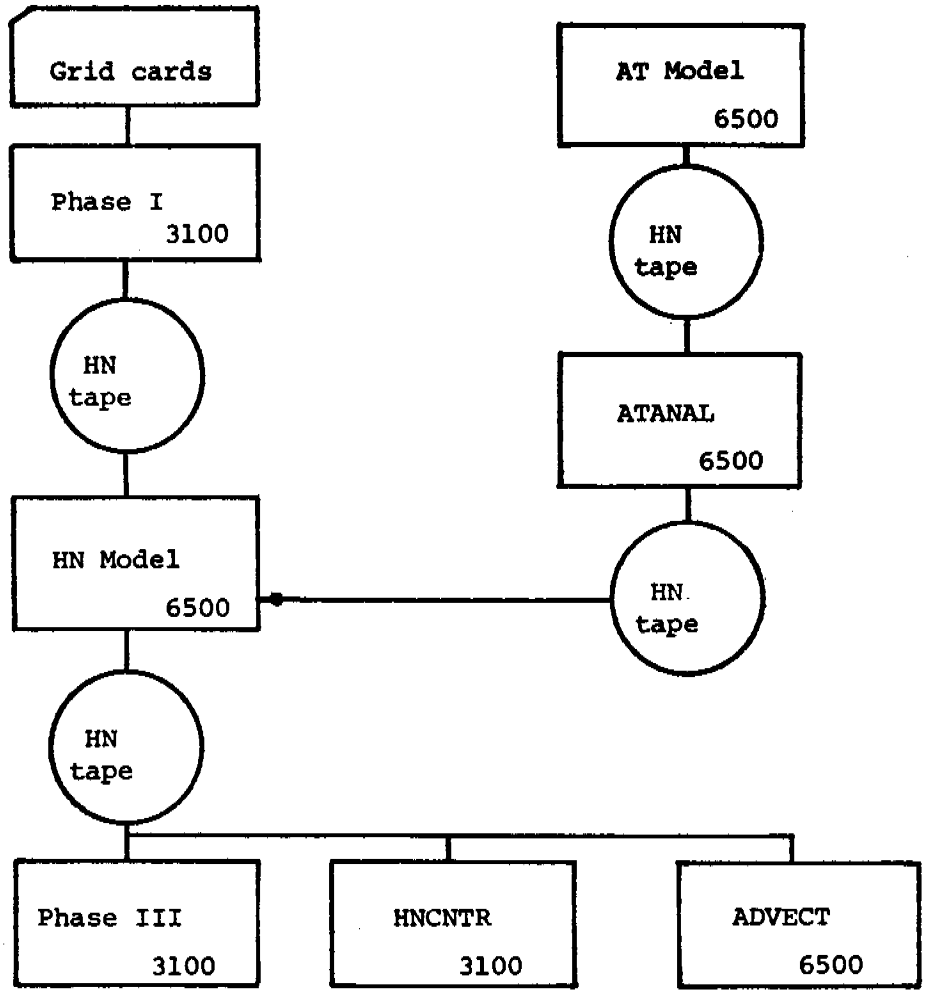


Figure 10. HN program sequence

into constant wind fields with a call to INPOUT to read the wind component fields, to add the capability to INPOUT to read a second tape, and to update the field each hour once it is turned on. The facilities of starting and ending the wind field were left under the control of the WIND card.

4.2 ADDITIONAL NOTES ON VARIABLE WIND DATA INPUT

The wind component tape contains components of the wind expressed as force vectors relative to the HN model grid and does not require additional rotations. The start time and update times, grid size, and model number must all match those supplied to the Phase I card ATANAL programs or the records will be bypassed by INPOUT routine. Normally the wind is not started in the HN model until at least 6 hours to avoid initial program shock which can cause the HN model to become numerically unstable.

TIDAL CURRENTS AND POLLUTANT DISPERSAL IN THE WESTERN GULF OF ALASKA AS DERIVED FROM A HYDRODYNAMICAL-NUMERICAL MODEL

by

John M. Harding

RU #235

Part II

Northwest Fisheries Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
2725 Montlake Boulevard East
Seattle, Washington 98112
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1. INTRODUCTION

The computation of tides and currents using hydrodynamical-numerical (HN) models was originally proposed in 1938 by Professor Walter Hansen of the University of Hamburg. However, it was not until the advent of the electronic computer that this approach became feasible. These models, based on the equations of motion modified to operate on vertically integrated mass transport, have been well tested over the past 20 years for single-layer cases. Since 1967, in collaboration with Professor Hansen, Dr. Taivo Laevastu of the Oceanography Department, Naval Environmental Prediction Research Facility, has extended these models to allow multiple open boundaries, multiple layers, and various auxiliary computations [1-5]. The analysis and prediction of advection and diffusion of pollutants is easily incorporated into the HN formulation since current components are computed in short time intervals.

An optimized multilayer HN model [6], in two-layer mode, was applied to three overlapping areas in the Gulf of Alaska. The results described here concern the westernmost grid which extends along the Alaskan Peninsula from eastern Kodiak Island, southwestward to Unimak Pass and offshore to an approximate distance of 300 km (Figure 1).

The project was funded by the Outer Continental Shelf Energy Project of NOAA. The Project Officer was Dr. Mauri Pelto, OCSEP office of NOAA. Appreciation is expressed to the following members of the NEPRF staff for the technical support services noted: Mrs. P. Mousseau and Mrs. W. Carlisle, manuscript typing; Mr. R. Clark, graphics; Mr. S. Myrick, photography; and Mr. S. Bishop, editing.

2. THE EQUATION SET

The basic set of equations includes: (a) vertically integrated equations of motion for each layer; (b) two interdependent continuity equations, one for each layer; and (c) the equations setting the boundary conditions.

(a) Equations of Motion:

$$\dot{U}1 + \frac{r\sqrt{U1^2 + V1^2}}{H_u} U1 - fV1 + g\zeta_{1x} = K^{(x)}$$

(Layer 1)

$$\dot{V}1 + \frac{r\sqrt{U1^2 + V1^2}}{H_{v1}} V1 + fU1 + g\zeta_{1y} = K^{(y)}$$

$$\dot{U}2 + \frac{r\sqrt{U2^2 + V2^2}}{H_{u2}} U2 - fV2 + g\frac{\rho_1}{\rho_2} \zeta_{1x} +$$

$$g(1 - \frac{\rho_1}{\rho_2}) \zeta_{2x} = 0$$

(Layer 2)

$$\dot{V}2 + \frac{r\sqrt{U2^2 + V2^2}}{H_{v2}} V2 + fU2 + g\frac{\rho_1}{\rho_2} \zeta_{1y} +$$

$$g(1 - \frac{\rho_1}{\rho_2}) \zeta_{2y} = 0$$

(b) Continuity Equations:

$$\dot{\zeta}_1 - \dot{\zeta}_2 + (H_1\ U1)_x + (H_1\ V1)_y = 0 \qquad \text{(Layer 1)}$$

$$\dot{\zeta}_2 + (H_2\ U2)_x + (H_2\ V2)_y = 0 \qquad \text{(Layer 2)}$$

where:

ζ_1 = surface elevation

ζ_2 = deviation of MLD (mixed layer depth) from its mean (initially prescribed) depth

U1, V1 = u,v components in first layer

U2, V2 = u,v components in second layer

r = friction coefficient (internal friction)

f = Coriolis parameter

r_b = bottom friction coefficient

g = acceleration of gravity

H = layer thickness

ρ_1, ρ_2 = densities of the respective layers

$K^{(x)}$, $K^{(y)}$ = external forces

$(\ )_x$ = partial with respect to x = $\frac{\partial()}{\partial x}$

Detailed descriptions of these equations as well as their finite difference formulations are available in [1].

(c) Boundary Conditions

For the two-layer mode of the optimized HN model used in the Gulf of Alaska region, the boundary conditions were: (1) No normal flow at land-sea boundaries; and (2) flow through open boundaries, as computed internally one grid distance from the boundary.

Wind stress on the surface layer was parameterized using

$$\tau^{(x)} = \lambda \frac{\omega_x \sqrt{\omega_x^2 + \omega_y^2}}{H}$$

$$\tau^{(y)} = \lambda \frac{\omega_y \sqrt{\omega_x^2 + \omega_y^2}}{H}$$

where:

λ = the drag coefficient

ω = the wind speed

ω_x, ω_y = components of wind vector

$\tau^{(x)}, \tau^{(y)}$ = components of the stress vector

Water surface elevations of several grid boundary locations were specified as the driving force for tidal currents within the area. Because of a lack of actual tidal data along the boundaries, values from Kodiak Island and Sanak Island were utilized as described below and depicted in Figure 4.

Kodiak tides were used along the Shelikof Straits boundary and Sanak tides were used through the Unimak Pass. For the offshore oceanic grid boundary parallel to the Alaska Peninsula, a linearly interpolated tide from southwest to northeast was specified using Sanak tides at the westernmost corner and Kodiak tides at the easternmost corner. The amplitude, phase speed and phase angle of each component of the Sanak and Kodiak tides are given in Table 1. The eastern grid boundary south of Kodiak and the western grid boundary are not externally forced. Due to the extreme thickness of the second layer (relative to the first) over the Aleutian

Table 1. Values of tidal components.

Location	Component	Amplitude (cm)	Phase Angle (deg)	Phase Speed (deg/hr)
Kodiak Is. 57°47'N 152°24'W	M_2	98.4	8	28.984
	K_1	40.5	139	15.041
	O_1	27.3	122	13.943
	S_2	32.8	41	30.000
Sanak Is. 54°23'N 162°38'W	M_2	58.6	355	28.984
	K_1	41.6	124	15.041
	O_1	23.6	97	13.943
	S_2	22.1	18	30.000

Trench, water surface elevations specified at the forced boundaries were assumed to result solely from tidally induced variations in the thickness of the second layer. A general and more complete discussion of boundary conditions for HN models can be found in Kagan [7].

3. DIFFUSION AND ADVECTION [1]

Diffusion in water bodies has been presented in many formulas, a few of which are given here (neglecting vertical diffusion).

The general diffusion formula is

$$\frac{\partial^2 S}{\partial x^2} + \frac{\partial^2 S}{\partial y^2} - \frac{1}{A}\frac{\partial S}{\partial t} = 0 ;$$

the basic dispersion formula is

$$\frac{\partial S}{\partial t} = Y - \frac{S}{n} - \frac{\partial}{\partial x}(U_x + pS_x) - \frac{\partial}{\partial y}(U_y + pS_y) ;$$

and the Fickian equation is

$$\frac{\partial S}{\partial t} = Y - \frac{S}{n} + K\nabla^2 S - \frac{\partial}{\partial x}(S_u U) - \frac{\partial}{\partial y}(S_v V);$$

where:

Y = addition (release)

n = decay

S = concentration

$pS_{x,y}$ = concentration velocity component

t = time

K (coefficient) = $\beta a v_r$ (a = depth; $v_r = u^2 + v^2$; β = 0.003)

S_u, S_v = concentration gradients in u and v direction

A = diffusion coefficient (Austausch coefficient)

The Lagrangian approach of diffusion in finite difference form was adopted by Wolff, Hansen and Joseph [8]:

$$S^{t+\tau}_{n,m} = S^t_{n,m}\left(1 - \frac{4\tau A}{\ell^2}\right) + \frac{A\tau}{\ell^2}\left(S^t_{n-1,m} + S^t_{n+1,m} + S^t_{n,m-1} + S^t_{n,m+1} - 4S^t_{n,m}\right)$$

where:

t = time

τ = time step

ℓ = grid size

S = concentration

A = diffusion coefficient

n,m = grid coordinates

The above finite equation deviates from the usual finite difference diffusion formula only in the addition of the last term (-4S), which makes the solution similar to the solution of the "Laplacian" ($K\nabla^2 S$). Also, the advection is computed linearly in finite difference form:

$$S_{n,m}^{t+\tau} = S_{n,m}^{t} - \tau \left| U_{n,m}^{t+\tau} \right| \frac{(S_{n,m}^{t} - S_{n,m\pm 1}^{t})}{\ell} -$$

$$- \tau \left| V_{n,m}^{t+\tau} \right| \frac{(S_{n,m}^{t} - S_{n\pm 1,m}^{t})}{\ell}$$

where Sn,m-1 or n,m+1 (respectively n-1, n+1) are used, depending on the direction (sign) of U and V.

The Lagrangian approach used by Wolff, Hansen and Joseph [8], though reproducing the diffusion process well, does not conserve absolutely the amount of the dispersing substance. The following modified formula, however, was found to be conservative, provided the proper A (Austausch coefficient) is chosen and corresponds to the chosen time step and grid size:

$$S_{n,m}^{t+\tau} = S_{n,m}^{t} - \frac{4\tau A}{\ell^2} S_{n,m}^{t} + \frac{\tau A}{\ell^2} (S_{n-1,m}^{t} + S_{n,m-1}^{t}$$

$$+ S_{n+1,m}^{t} + S_{n,m+1}^{t} - 4S_{n,m}^{t}) + \frac{\tau A}{\ell^2} (S_{n-1,m-1}^{t}$$

$$+ S_{n-1,m+1}^{t} + S_{(n+1,m-1)}^{t} + S_{(n+1,m+1)}^{t})$$

It should be mentioned that the transport equation used in NEPRF programs is very similar to the "upwind" difference scheme used in air pollution problems (Pandolfo et al. [9]). This scheme requires that $\frac{U\Delta t}{\Delta \ell} < 1$.

The Austausch coefficient (A) is a function of grid size and time step. In an experiment designed to investigate the conservation of diffusing substances, one of the main criteria was found to be a relationship between grid size and time step. This relation of A to grid size with a 1,000 sec time step is shown in Figure 2. The correct value of A is found from this graph and from the relation, $A = \frac{1,000}{\Delta t} A$ (graph). With a small time step, the value of A approaches that found empirically by Okubo and Ozmidov [10] and Kullenberg [11]. An idea of the proper A to be used in different grid sizes can be obtained also from the Joseph and Sendner [12] formulation. There is still some slight uncertainty about the dependence of the horizontal Austausch coefficient (K_h) on the length scale, $K_H = k_1 \times 10^{-3} \ell^{k2}$. Kullenberg [11] gives the values for the coefficients $k_1 = 1.3$ and $k_2 = 1.31$, whereas Okubo [13] gives the corresponding values as 1.03 and 1.15. Both lines are shown in Figure 2.

4. INPUTS AND RESULTS

Case 1 is a 48-hour, tides-only (no wind) run. Beginning at approximately high tide, hour 29 (104400 s), a continuous source of pollutants is input at row 12, column 47, approximately 56°50'N, 155°W (Figure 1). The amount of continuous source is 1000 units/day, input into the model as 0.463 units per 40-second time step. Case 1 is considered to be a summer case with the thickness of the first layer (mixed layer depth) as 20 m.

A time series of layer 1 surface currents (cm/s) and tidal heights (cm) at point 12,47 for Case 1 is given in Figure 6. The circled times on the x-axis are those at which layer 1 and 2 currents (cm/s) and height deviations (cm) are presented over the whole grid (Figures 7 through 15).

Case 2 is indentical to Case 1 except a constant wind of 10 m/s from 320° true is used to force the surface layer over the whole grid. The wind is started at hour 24 (86400 s) and is continued through the remainder of the run. Considering current flow during the no-winds condition, winds from 320° true were chosen as a worst case situation with respect to pollutant landfall originating from a source at point 12,47.

Figure 16 is a time series of layer 1 surface currents (cm/s) and tidal heights (cm) at point 12,47 for Case 2. Circled times on the x-axis are those for which layer 1 and 2 currents (cm/s) and height deviations (cm) are presented over the entire grid (Figures 17 through 25). Pollutant distribution at hours 42 and 48, after initializing the continuous source at hour 29, are shown in Figures 26 and 27 for Cases 1 and 2 respectively.

In Figures 7-15 and 17-27, contour intervals are as follows: layer 1 plots, 5 cm; layer 2 plots, 50 cm; and pollutant plots, 200 arbitrary units. Layer 1 and 2 currents are represented by current barbs at every-other grid point. Each flag on a current barb indicates 10 cm/s; thus a barb with two and one-half flags represents a current of 25 cm/s (approximately one-half knot).

Values of the various constants input into this particular Gulf of Alaska model are given in Table 2.

Table 2. Constant parameters for computations of flow in the western Gulf of Alaska.

Constants	Values
Number of Rows Number of Columns	21 60
Grid Step (cm) Rotation Angle* (deg)	1481600 39
Wind Drag Coefficient Mid-latitude of Grid (deg)	3.2×10^{-6} 55.5
Bottom Friction Coefficient Austausch Coefficient	0.003 5.25×10^{5}
Time Step (sec) Number of Layers	40 2
Layer 1 Smoothing Parameter Layer 2 Smoothing Parameter	0.99 0.98
Layer 1 Density (gr/cm^3) Layer 2 Density (gr/cm^3)	1.023 1.025

*Counterclockwise angle between north and positive Y axis of the computational grid

5. VERIFICATION AND DISCUSSION

The work of Favorite et al. [14] describes surface flow in the vicinity of Kodiak Island using dynamic methods to obtain geostrophic currents. These methods, however, do not intrinsically resolve the tidal currents and currents due to sea level fluctuations which dominate in coastal waters.

Until adequate current measurements are obtained so that proper tuning and verification of the western grid Gulf of Alaska model can be accomplished, previously used and less satisfactory verification methods must be employed [5].

A harmonic prediction of surface heights, based on tidal station data within the grid but not used to drive the model, is compared to computed model output (Case 1) for the given location. Figure 5 demonstrates the comparison of a harmonic prediction from King Cove (55°04'N, 162°19'W) and computed data from row 5, column 15; it indicates good agreement between the harmonic prediction and computed data.

Three features should be noted in the current and height fields of Figures 7-15 and 17-25: (1) the extremes in surface height deviation (layer 1) off the southwest edge (row 9, column 9) of Sanak Island; (2) the apparent convergence zone (except in Case 2, layer 1) in the Shelikof Strait off the western tip of Kodiak Island; and (3) the apparent incoherence of the second layer height deviations.

The first feature off Sanak Island is probably caused by the juxtaposition of steep bottom topography arising out of the Aleutian Trench (Figure 3) and the relatively shallow bank to the southwest of Sanak.

The second feature, which appears in all but the winds case layer 1, is probably also due to bottom topography. Off the western corner of Kodiak Island, the 200 m contour (Figure 3) indicates a narrow channel which originates from the Aleutian Trench to the south and into but not completely through the Shelikof Straits. Further support of this feature off Kodiak is found in drift bottle studies [15] which indicate this area as a convergence zone. Persistence of these features off Sanak and Kodiak Islands, using various boundary prescriptions of the tidal inputs, also indicates that these features are of topographic origin rather than simply interactive effects caused by the given boundary prescriptions.

The third feature, the irregularities of the second layer height deviations, are possibly caused by topographic effects, but they may just as likely be caused by insufficient tuning of the model by means of the second layer smoothing parameters

It would be of interest to attempt verification of the three features noted above to evaluate the extent of further tuning required.

Study of the actual numerical output of pollutant distributions is necessary for the best understanding of the dispersion of a continuous pollutant source in Cases 1 and 2 described previously. An indication of the numerical outputs is given in the pollutant contour plots for hours 42 and 48 for Case 1 (Figure 26) and Case 2 (Figure 27).

A southwestward trend of pollutant movement is observed in both Cases 1 and 2 with this tendency accentuated as expected in the case that includes winds from the northwest. Pollutant landfall in Cases 1 and 2 from a release at point 12,47 apparently occurs in the Trinity Islands to the southwest of Kodiak at least 22 hours after the start of continuous pollutant release.

The cause of the apparent slow dispersal from this particular release point is reasonable when the current velocities and grid step are compared. If one assumes the maximum current speed of 30 cm/s at point 12,47 is constant in the area, the grid step of 1481600 cm yields a simple advection speed of 13.7 hours per grid step. Diffusion hastens the spreading somewhat, but the speed is not a sustained 30 cm/s and the direction is also variable. The combination of these factors yields the apparent slow pollutant dispersal.

REFERENCES

1. Laevastu, T., 1974: A vertically integrated hydrodynamical-numerical model (W. Hansen type), model description and operating/running instructions. Part 1 of a series of four reports. ENVPREDRSCHFAC Tech. Note No. 1-74.

2. Laevastu, T., 1974: A multilayer hydrodynamical-numerical model (W. Hansen type), model description and operating/running instructions. Part 2 of a series of four reports. ENVPREDRSCHFAC Tech. Note No. 2-74.

3. Laevastu, T. with M. Clancy and A. Stroud, 1974: Computation of tides, currents and dispersal of pollutants in lower bay and approaches to New York with fine and medium grid size hydrodynamical-numerical models. Part 3 of a series of four reports. ENVPREDRSCHFAC Tech. Note No. 3-74.

4. Laevastu, T. and R. Callaway with A. Stroud and M. Clancy, 1974: Computation of tides, currents, and dispersal of pollutants in New York Bight from Block Island to Atlantic City with large grid size, single and two-layer hydrodynamical-numerical models. Part 4 in a series of four reports. ENVPREDRSCHFAC Tech. Note No. 4-74.

5. Laevastu, T. and G. D. Hamilton, 1974: Computations of of real-time currents off Southern California with multilayer hydrodynamical-numerical models with several open boundaries. ENVPREDRSCHFAC Tech. Paper No. 15-74.

6. Bauer, R. A., 1974: Description of the optimized EPRF multilayer hydrodynamical-numerical model. ENVPREDRSCHFAC Tech. Paper No. 15-74.

7. Kagan, B. A., 1970: Properties of certain difference schemes used in the numerical solution of the equations for tidal motion. Izv. Atmos. and Ocean Phys., 6, 7, 704-717.

8. Wolff, P. M., W. Hansen and J. Joseph, 1970: Investigation and prediction of dispersion of pollutants in the sea with hydrodynamical-numerical (HN) models. Marine and Sealife (Fishing News, Ltd., London), 146-150.

9. Pandolfo, T. P., M. A. Atwater and G. E. Anderson, 1971: Prediction by numerical models of transport and diffusion in an urban boundary layer. Cent. Env. and Man, Inc., Hartford, CO, Rept. No. 4082, 139 pp.

10. Okubo, A., and R. V. Ozmidov, 1970: Empirical dependence of the coefficient of horizontal turbulent diffusion in the ocean on the scale of the phenomenon in question. Izv. Atmos. and Ocean Phys. 6, 5, 534-536.

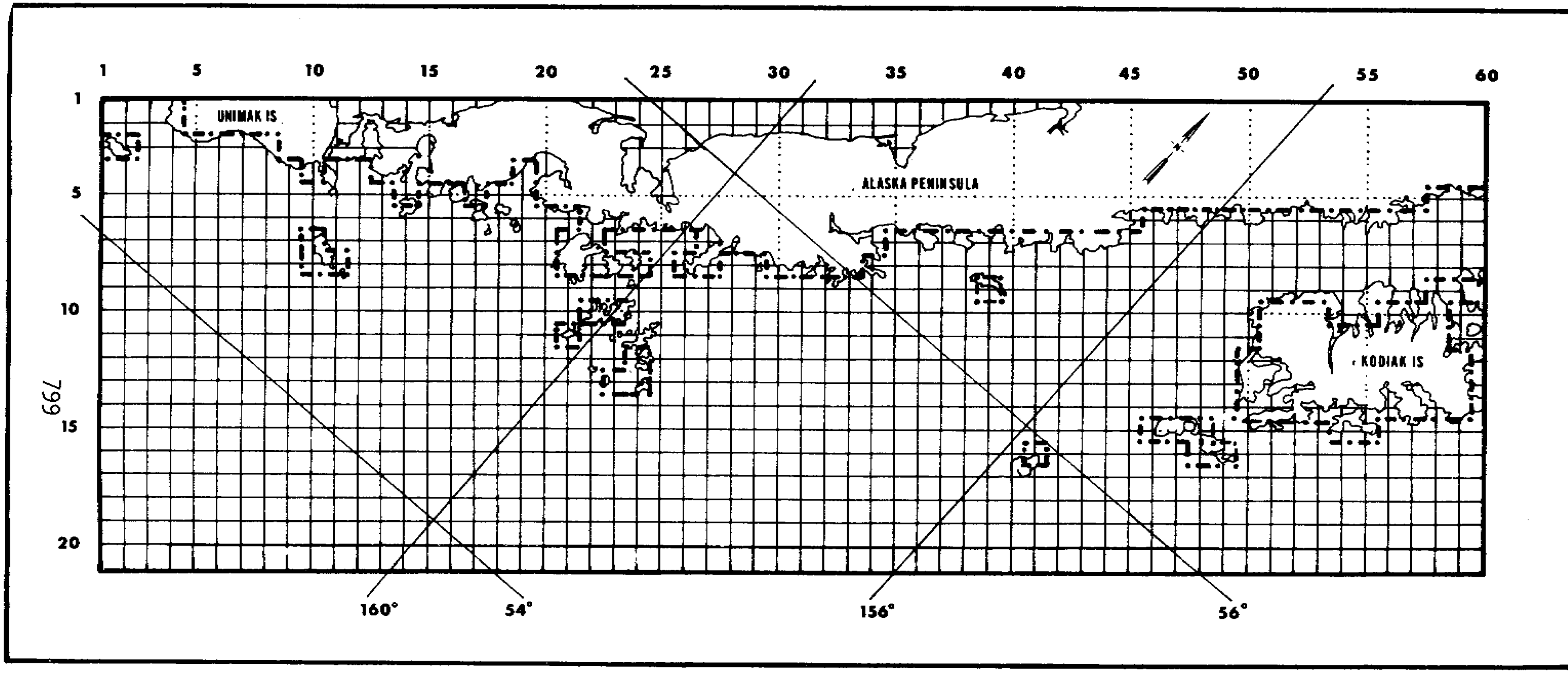
11. Kullenberg, G., 1972: Apparent horizontal diffusion in stratified vertical shear flow. Tellus, 24, 17-28.

12. Joseph, J., and H. Sendner, 1958: Uber die horizontale diffusion im meere, Dtsch. Hydrogr, Zeitschr., 11, 2, 49-77.

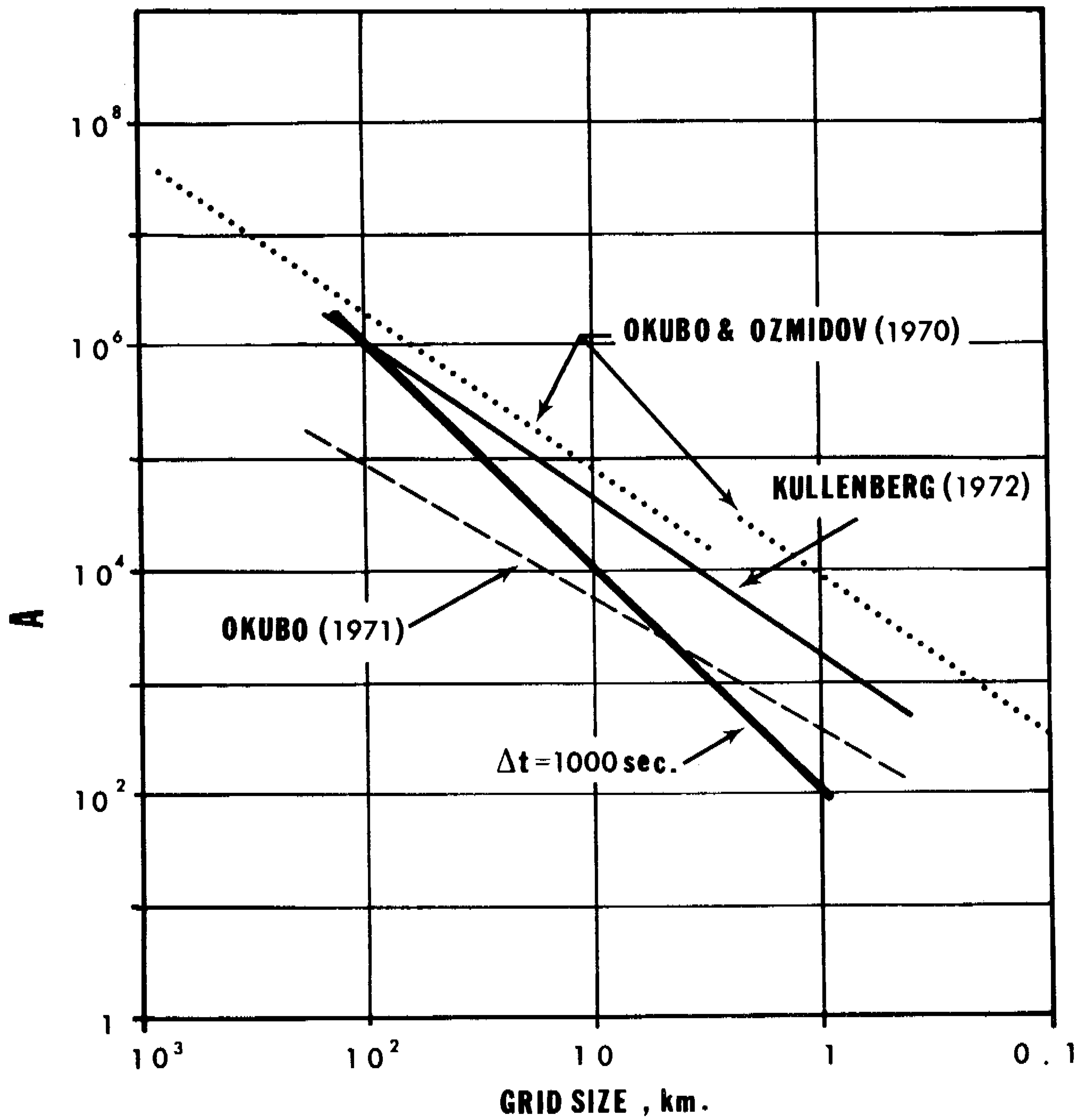
13. Okubo, A., 1971: Oceanic diffusion diagrams. Deep Sea Res., 18, 8, 789-802.

14. Favorite, F., W. J. Ingraham, and D. M. Fisk, 1975: Environmental conditions near Portlock and Albatross Banks (Gulf of Alaska), May 1972. Northwest Fisheries Center Processed Dept., May.

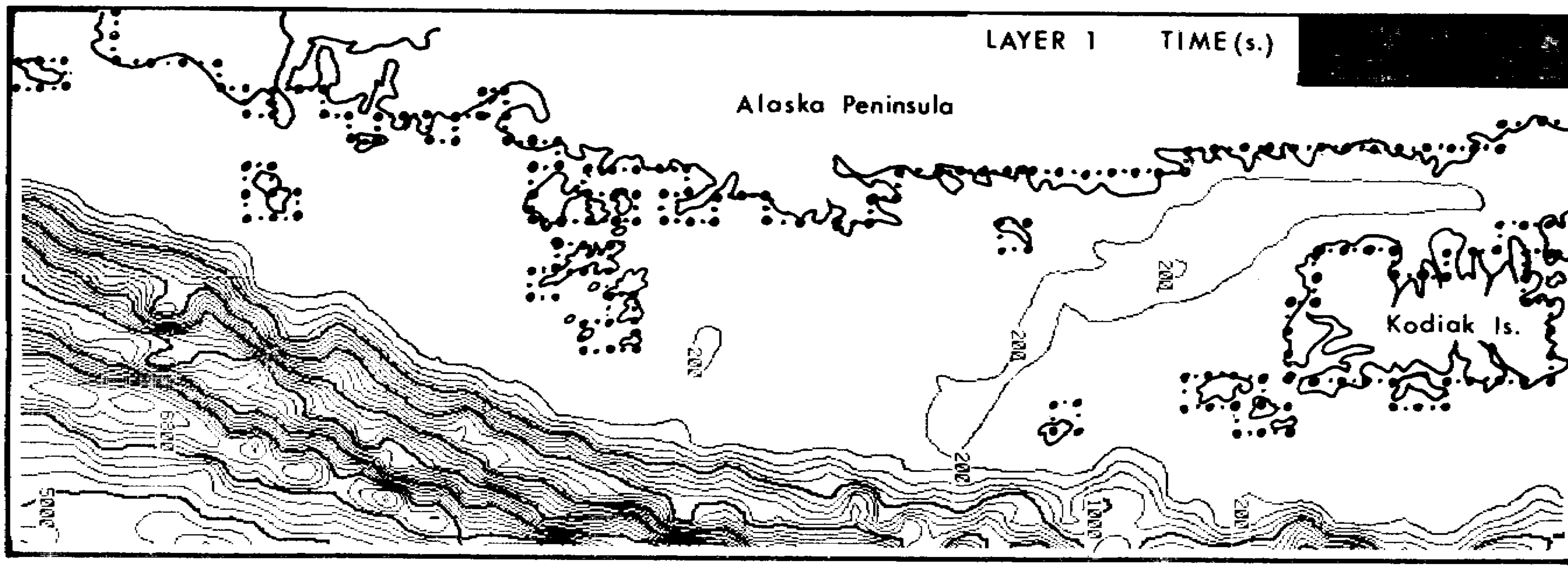
15. Ingraham, W. J., A. Bakun, and F. Favorite, 1976: Physical oceanography of the Gulf of Alaska. Northwest Fisheries Center Processed Dept., March.



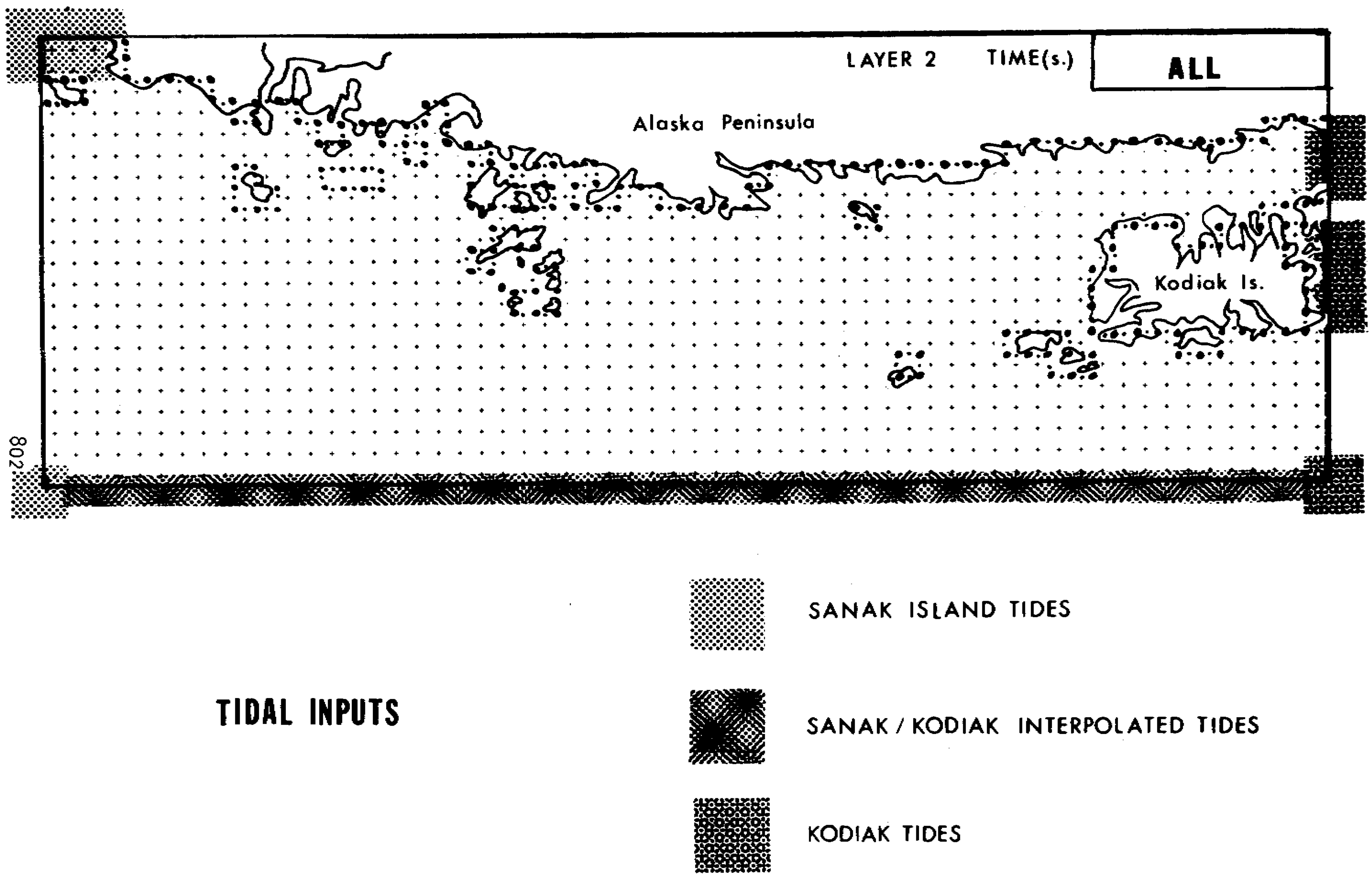
1. Gulf of Alaska, western grid.



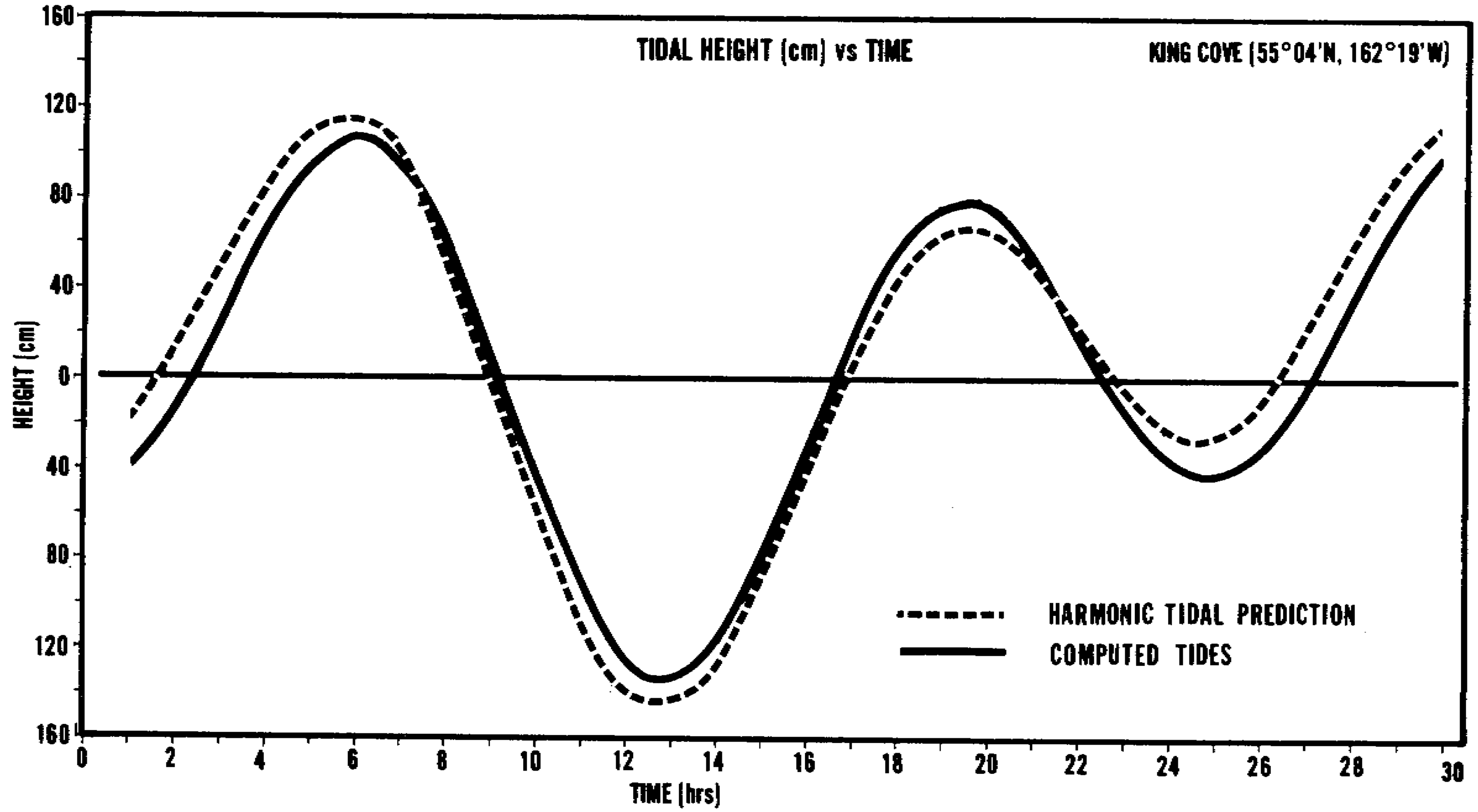
2. Austausch coefficient (A) vs. grid size (km) for t = 1000 s.



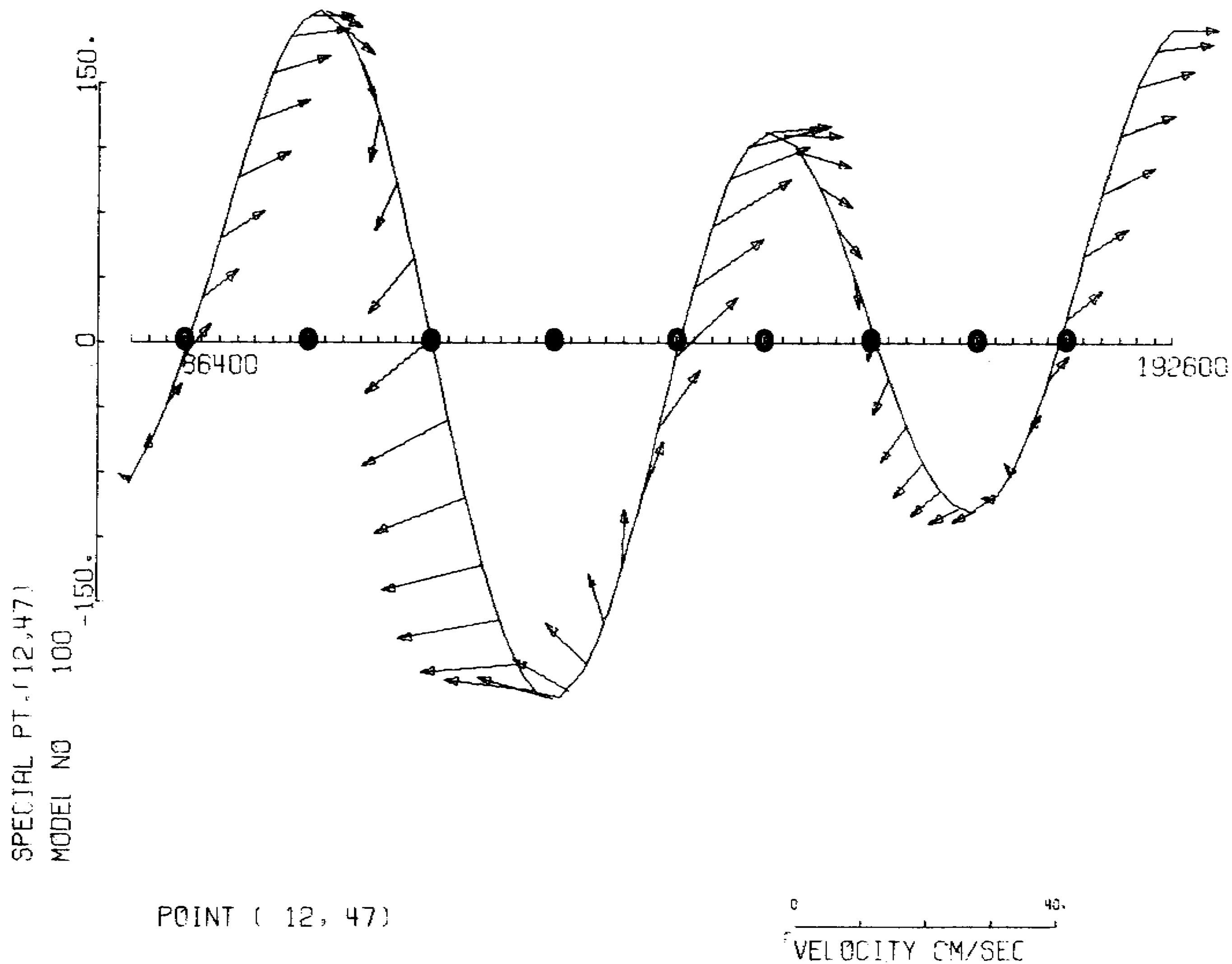
3. Bottom topography (m), Gulf of Alaska, western grid.



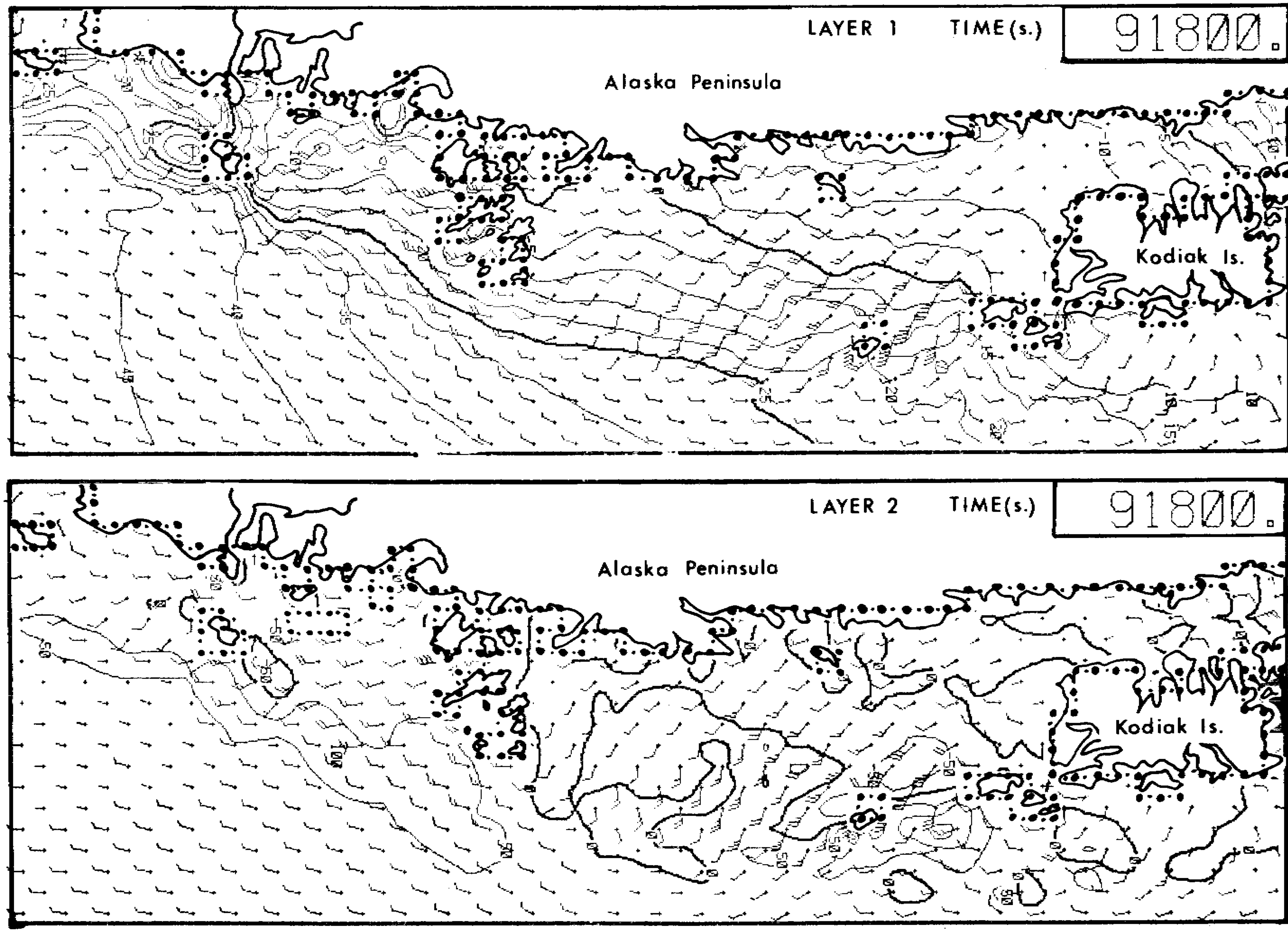
4. Tidal specifications at grid boundaries.



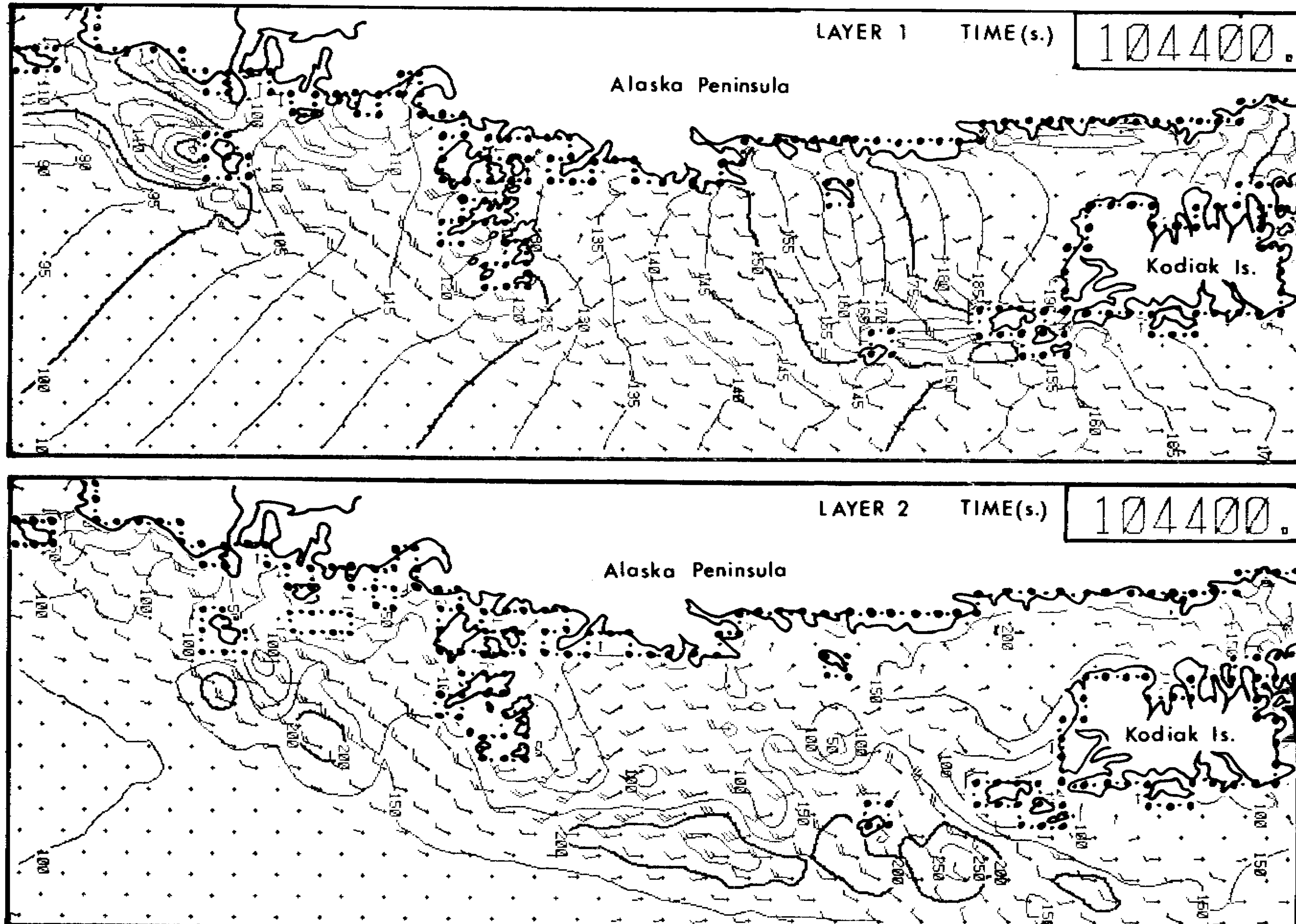
5. Harmonically predicted vs. computed tidal heights (cm) at King Cove (55°04'N, 162°19'N).



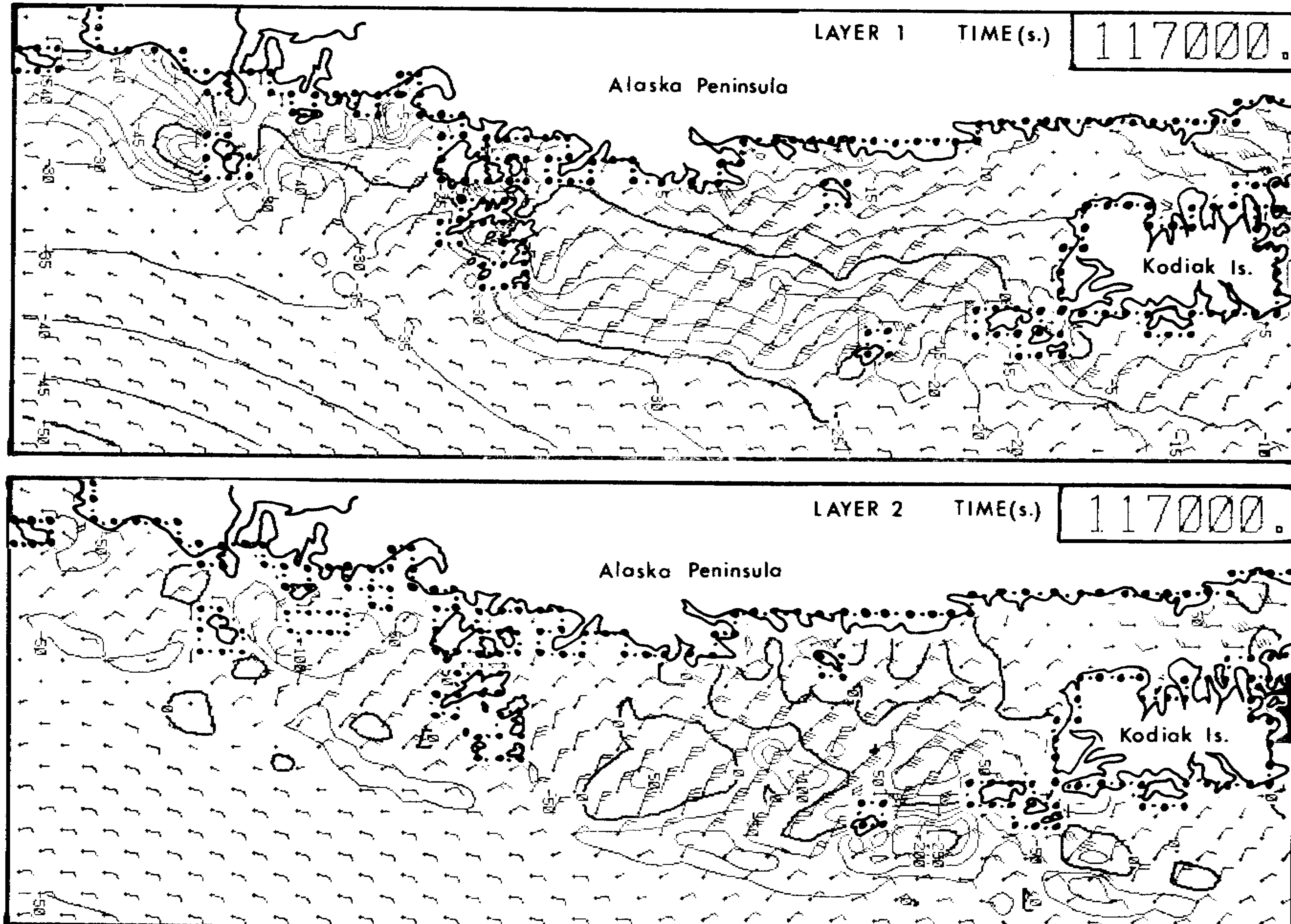
6. TIDAL HEIGHTS AND CURRENTS WITHOUT WINDS
LAYER3, OPTIMIZED H-N MODEL FOR B.L.M. GULF OF ALASKA, WESTERN GRID.



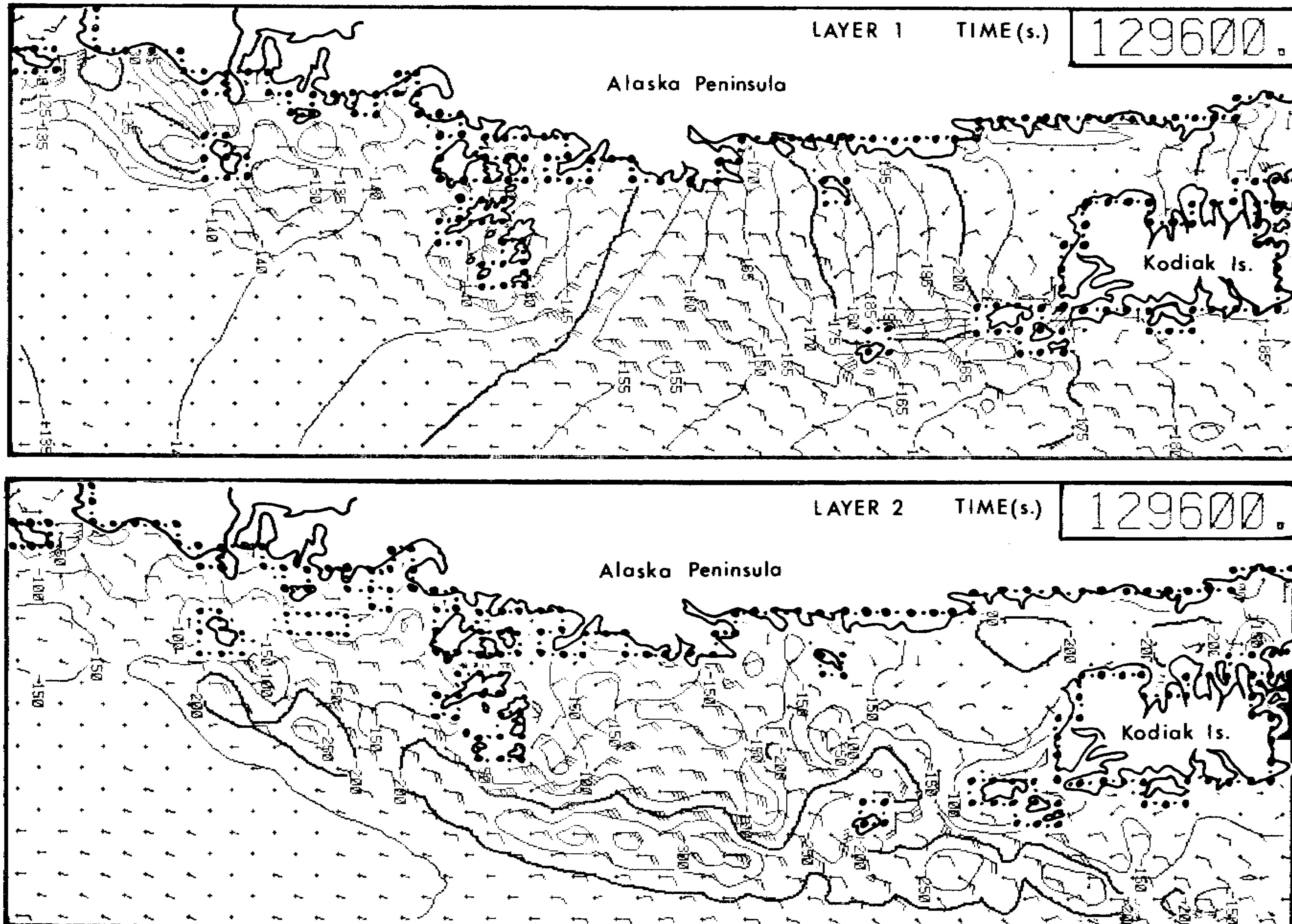
7. Case 1, currents (cm/s) and tidal heights (cm) for layers 1 and 2 at 25 1/2 hours (91800 s).



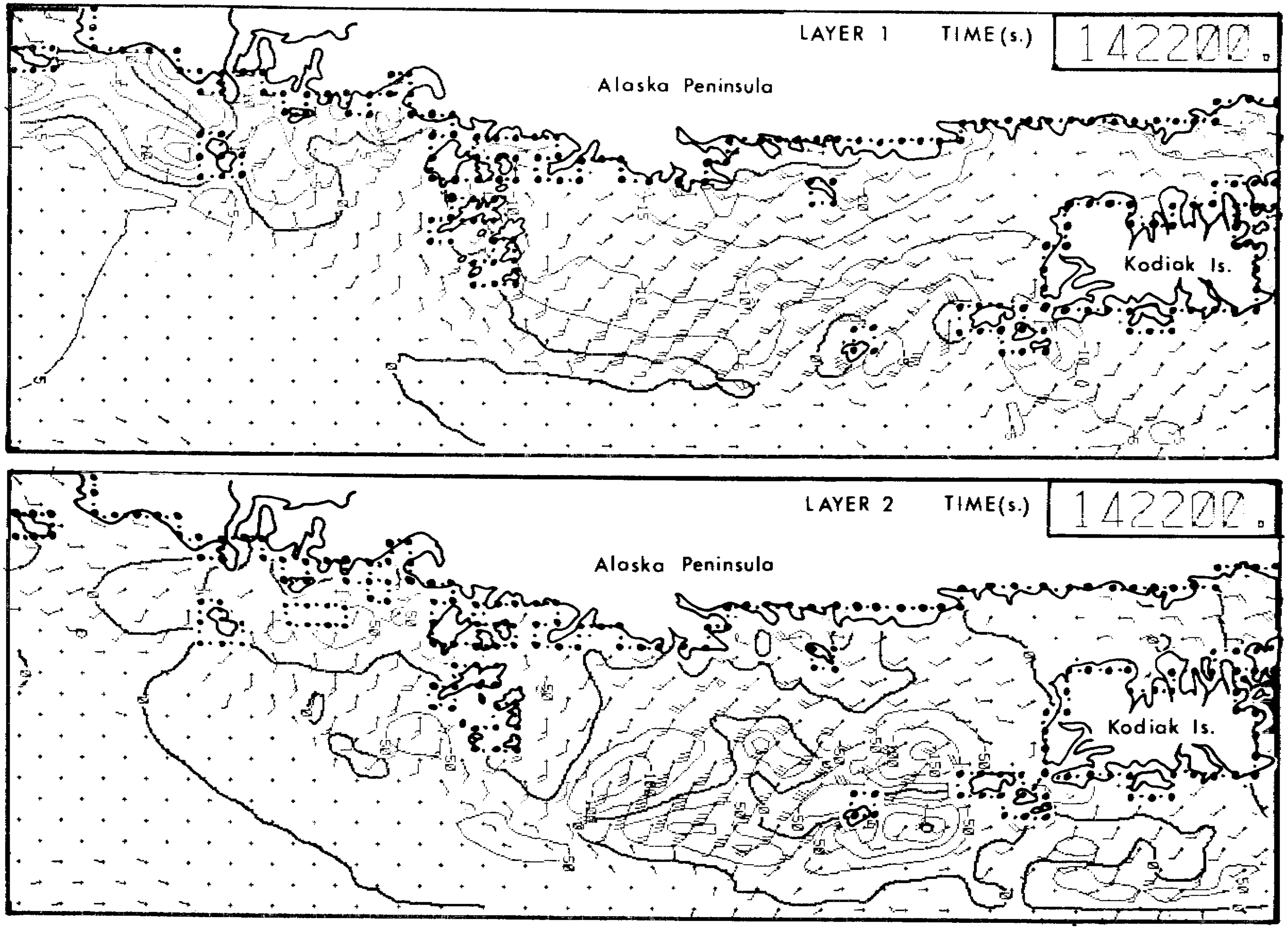
8. Case 1, currents (cm/s) and tidal heights (cm) for layers 1 and 2 at 29 hours (104400 s).



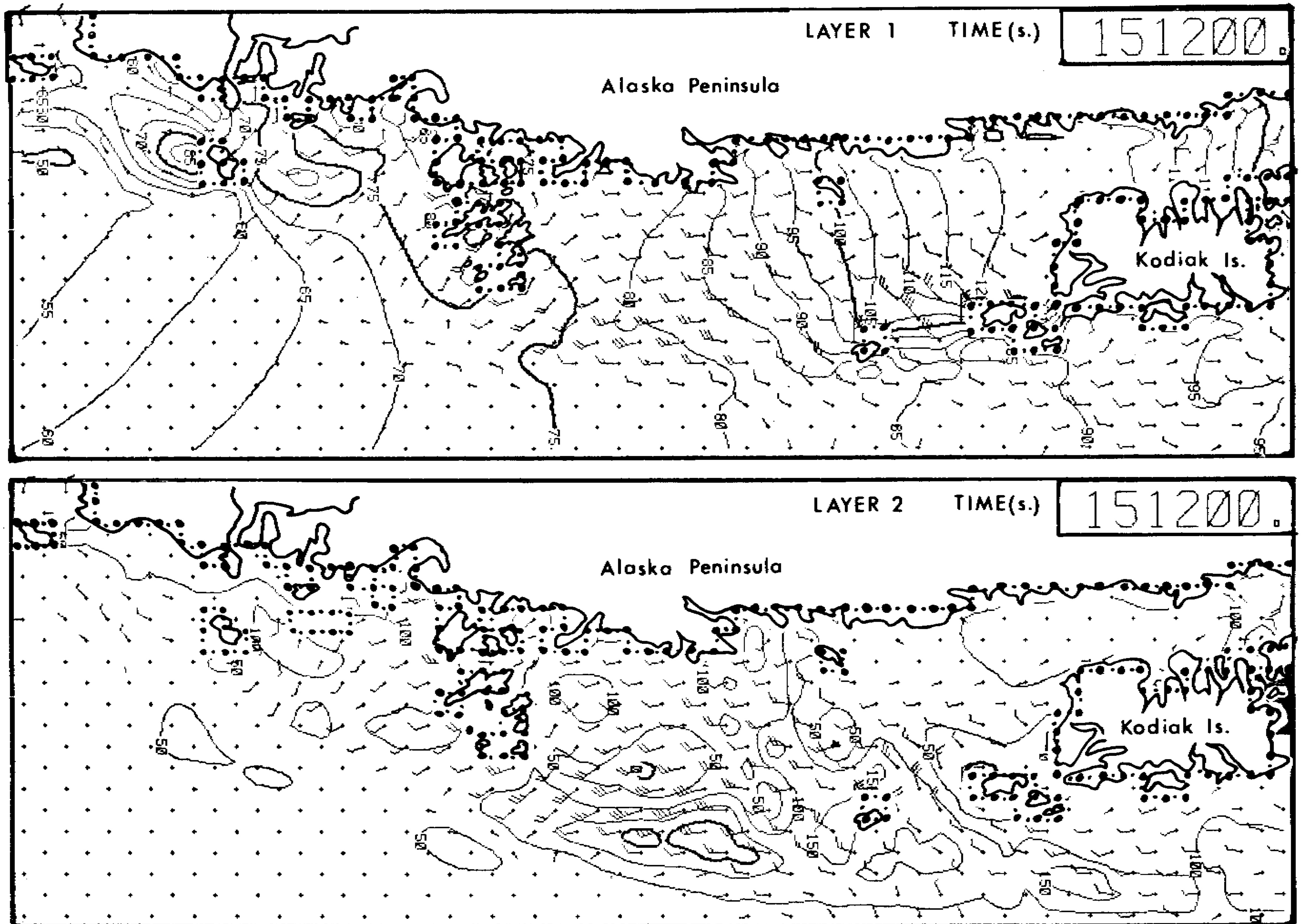
9. Case 1, currents (cm/s) and tidal heights (cm) for layers 1 and 2 at 32 1/2 hours (11700 s).



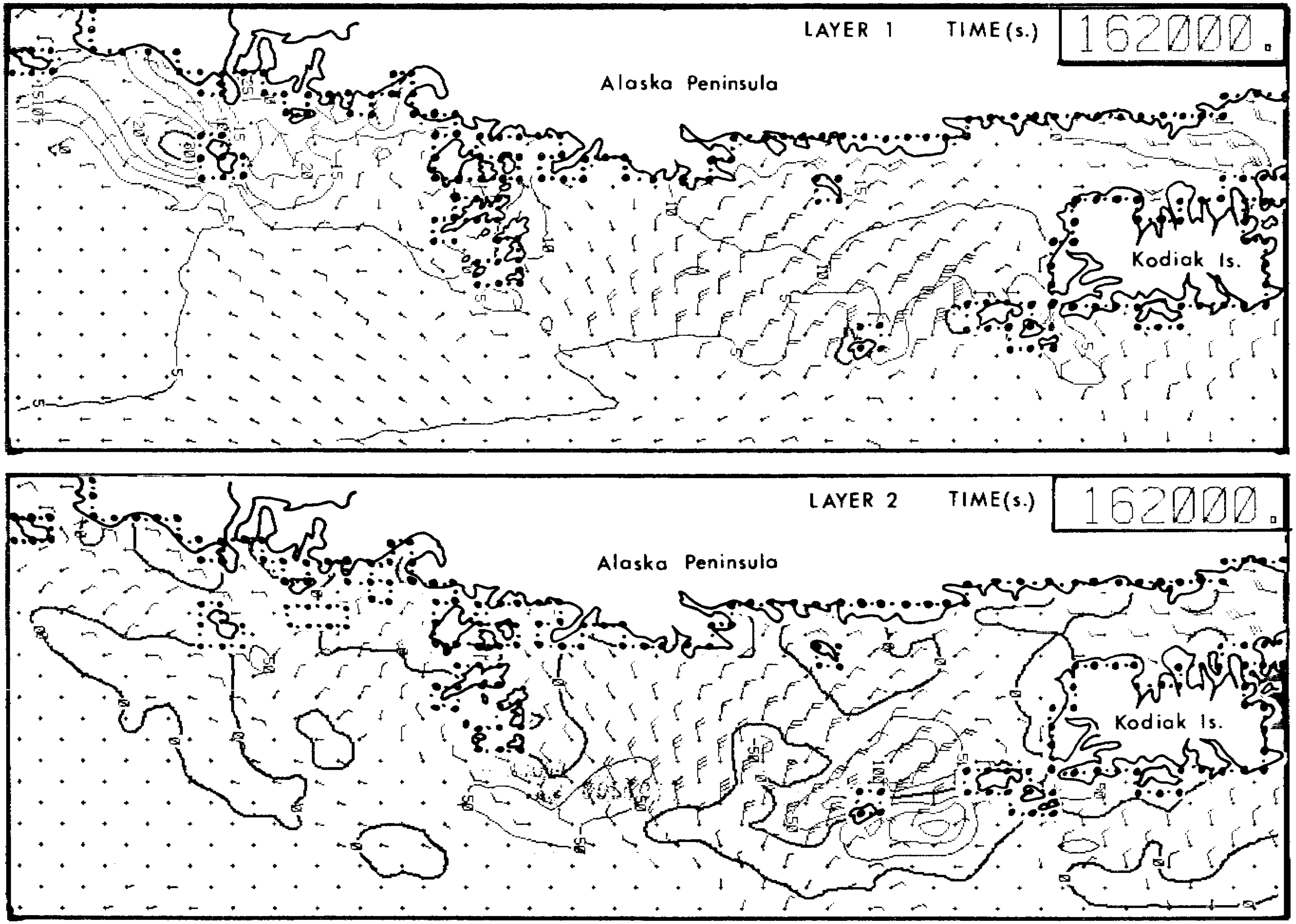
10. Case 1, currents (cm/s) and tidal heights (cm) for layers 1 and 2 at 36 hours (129600 s).



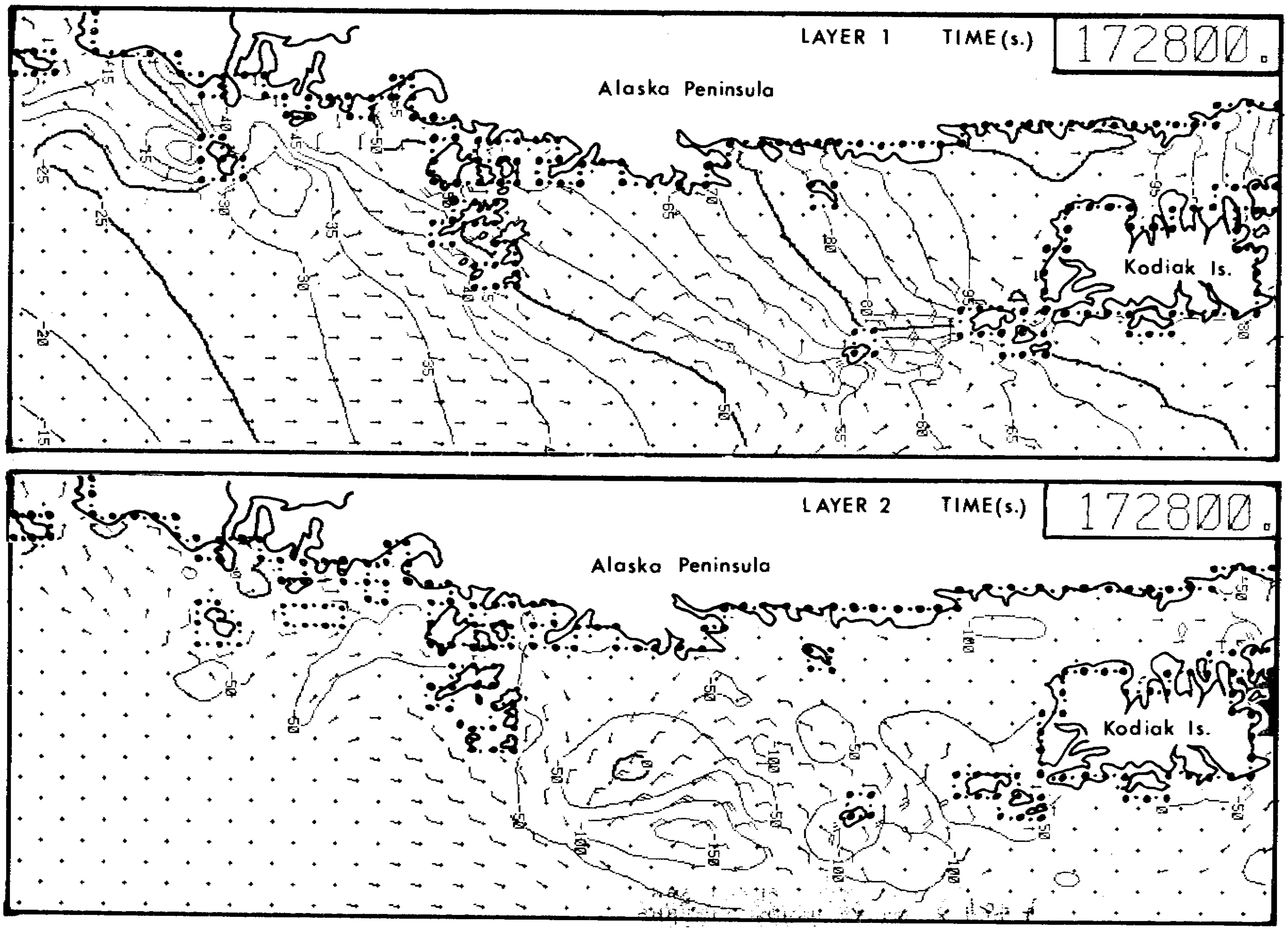
11. Case 1, currents (cm/s) and tidal heights (cm) for layers 1 and 2 at 39 1/2 hours (142200 s).



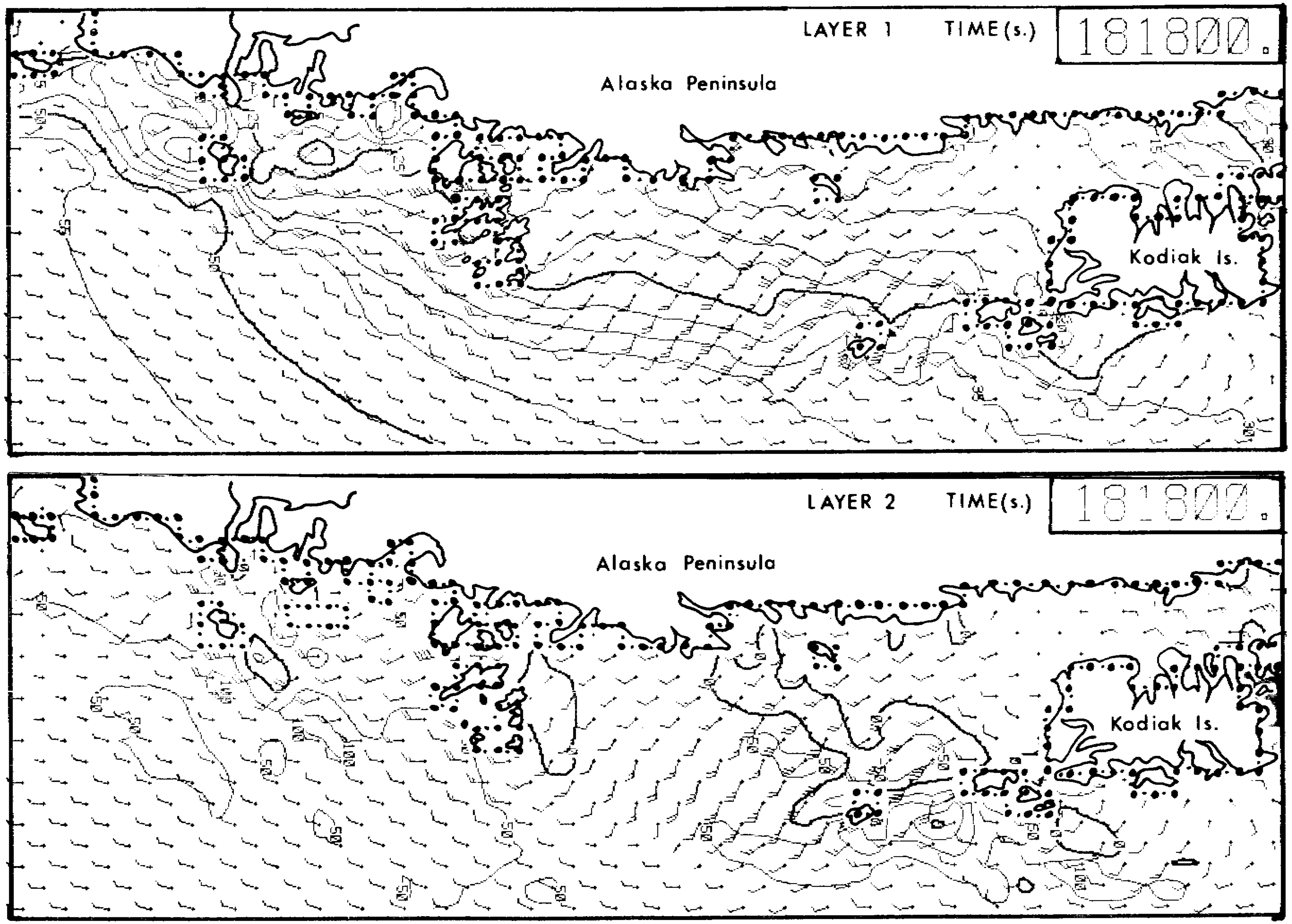
12. Case 1, currents (cm/s) and tidal heights (cm) for layers 1 and 2 at 42 hours (151200 s).



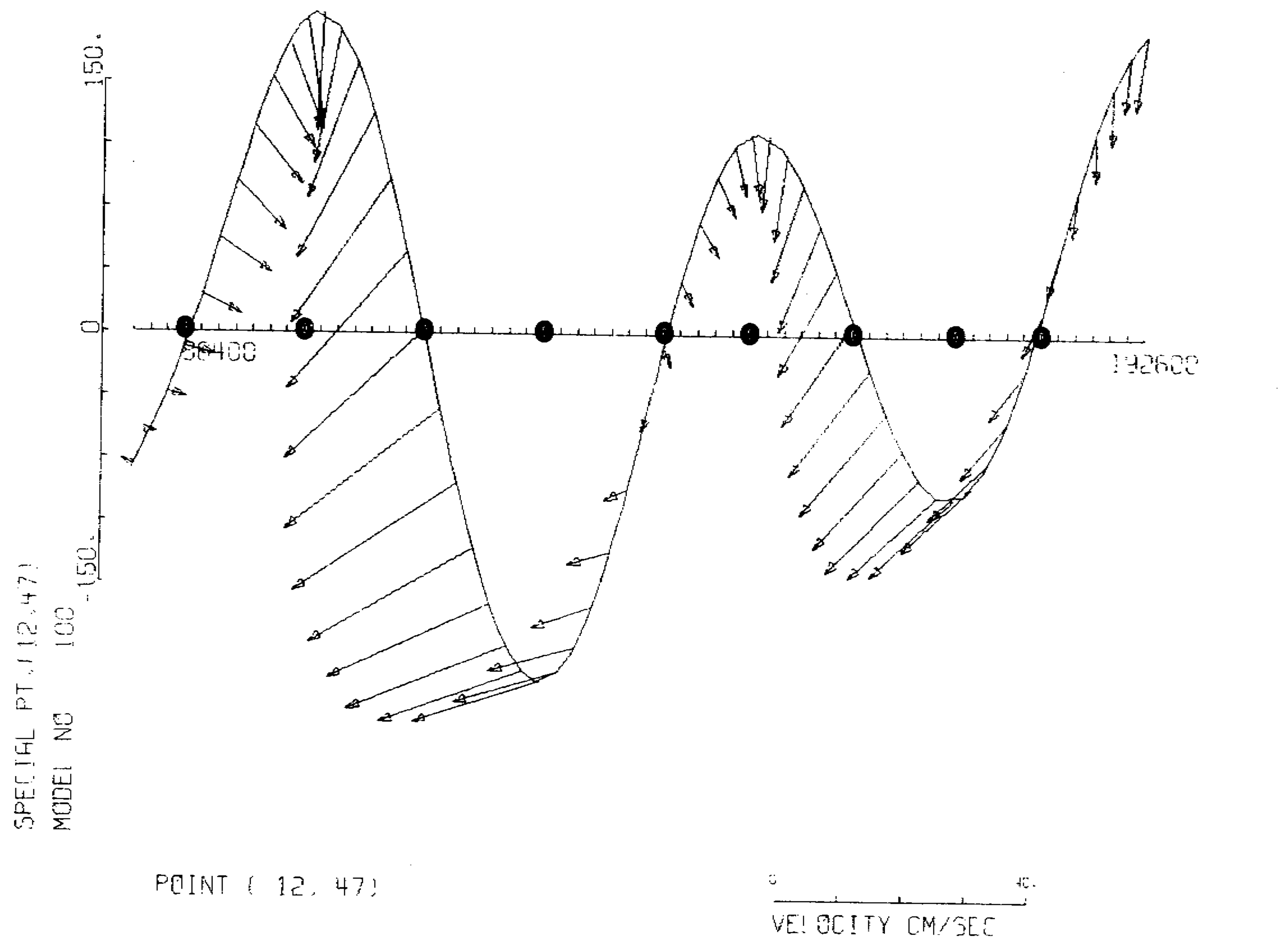
13. Case 1, currents (cm/s) and tidal heights (cm) for layers 1 and 2 at 45 hours (162000 s).



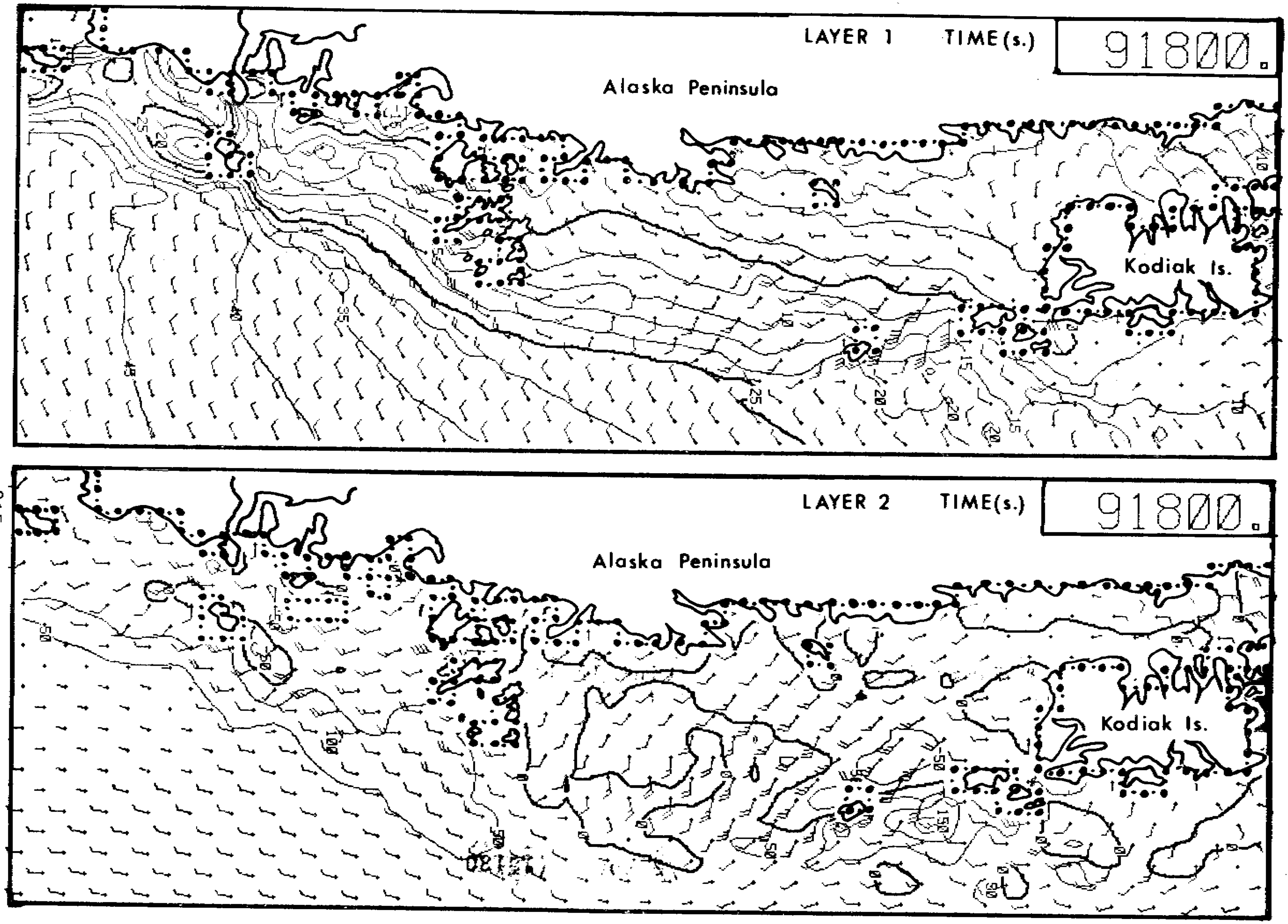
14. Case 1, currents (cm/s) and tidal heights (cm) for layers 1 and 2 at 48 hours (172800 s).



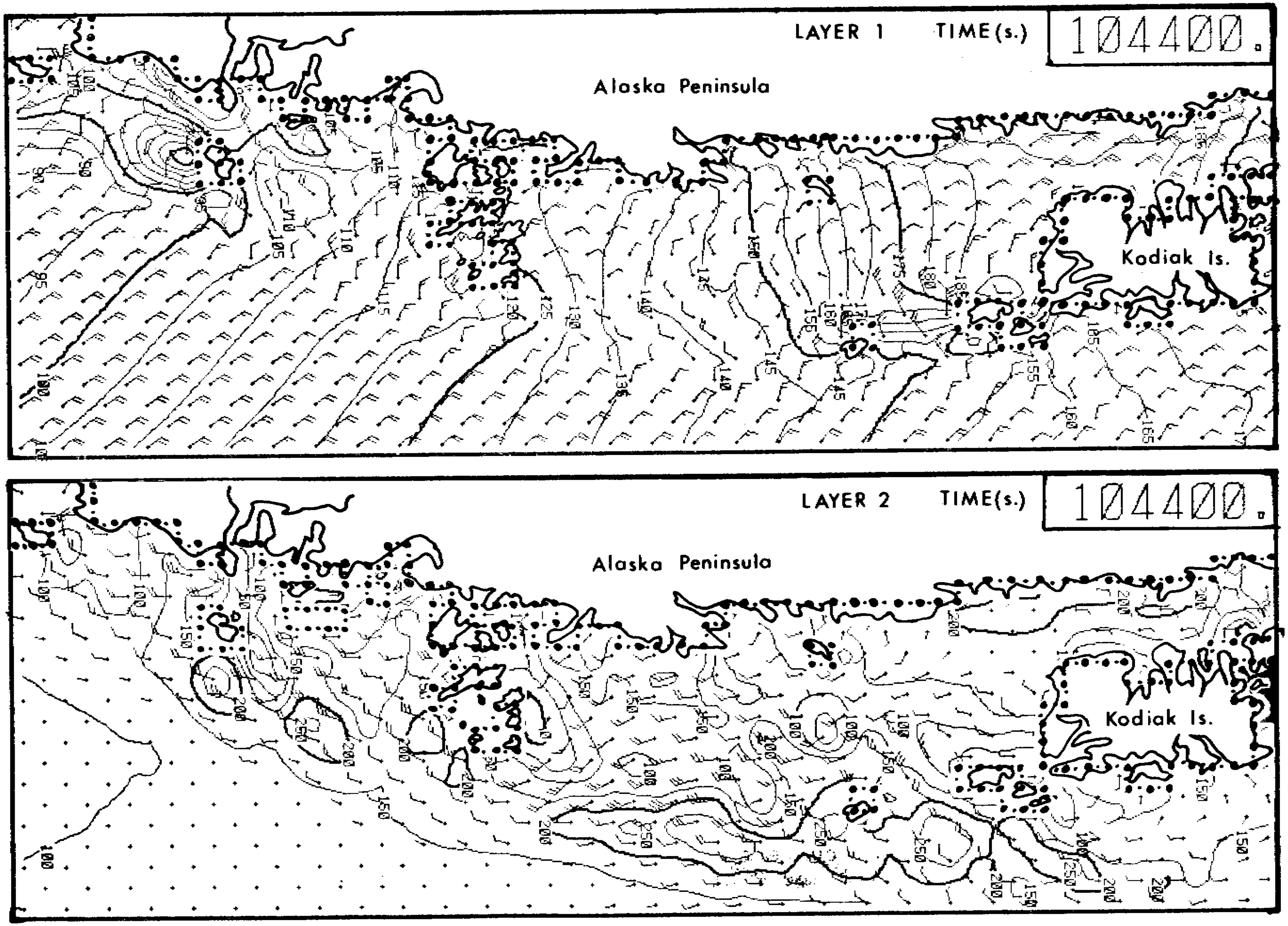
15. Case 1, currents (cm/s) and tidal heights (cm) for layers 1 and 2 at 50 1/2 hours (181800 s).



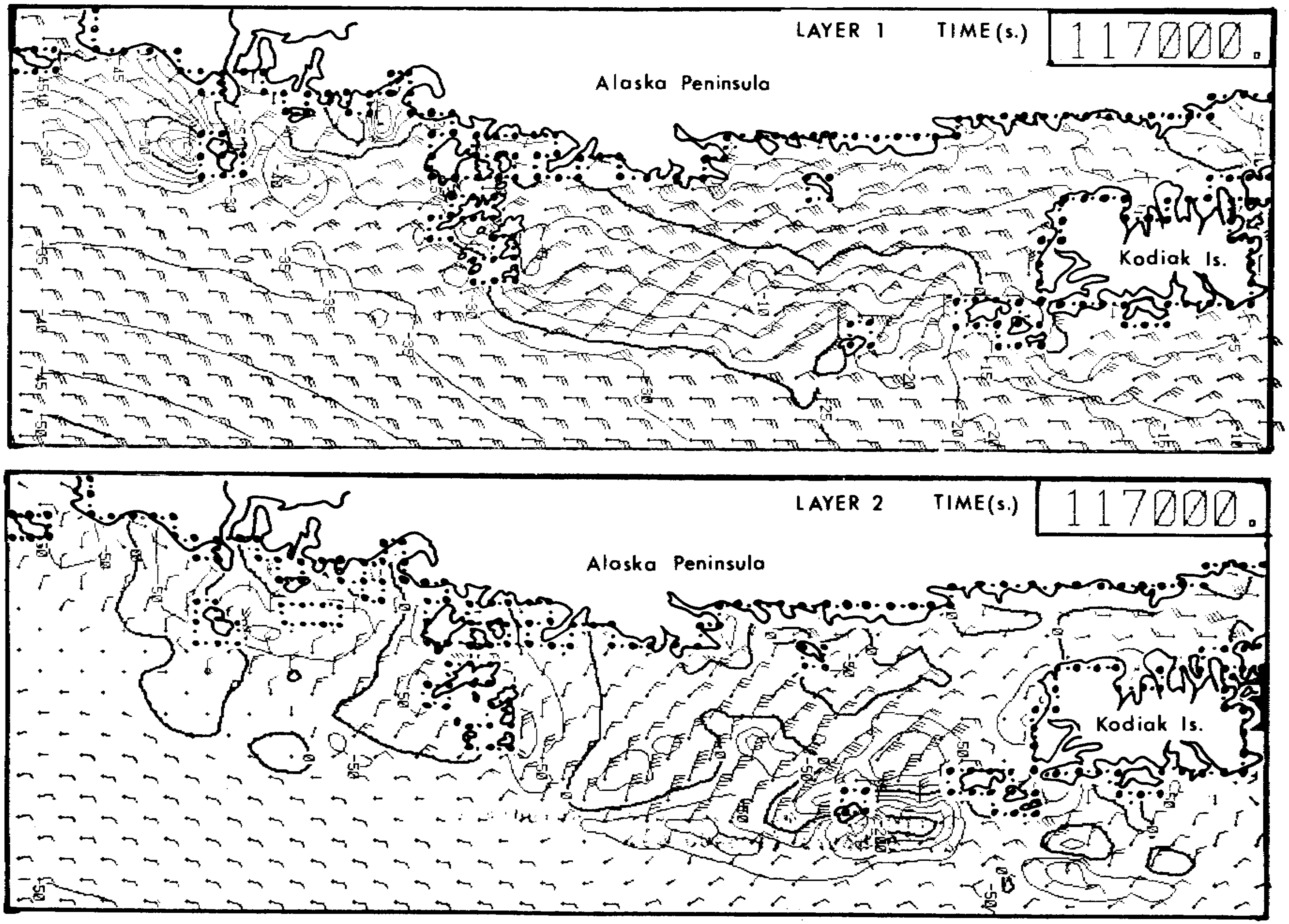
16. TIDAL HEIGHTS AND CURRENTS WITH NW WINDS
LAYER3, OPTIMIZED H-N MODEL FOR B.L.M. GULF OF ALASKA, WESTERN GRID.



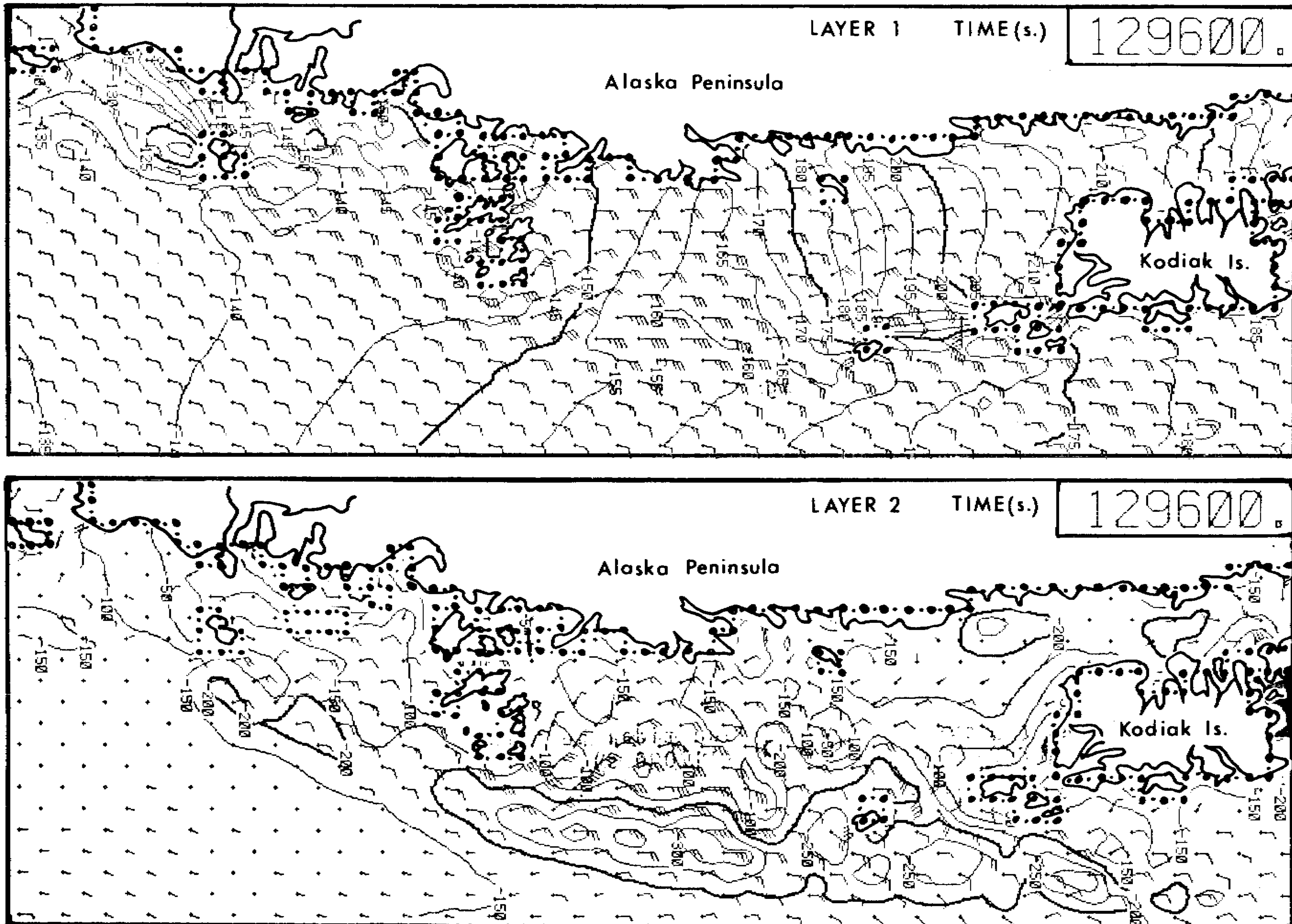
17. Case 2, currents (cm/s) and tidal heights (cm) for layers 1 and 2 at 25 1/2 hours (91800 s).



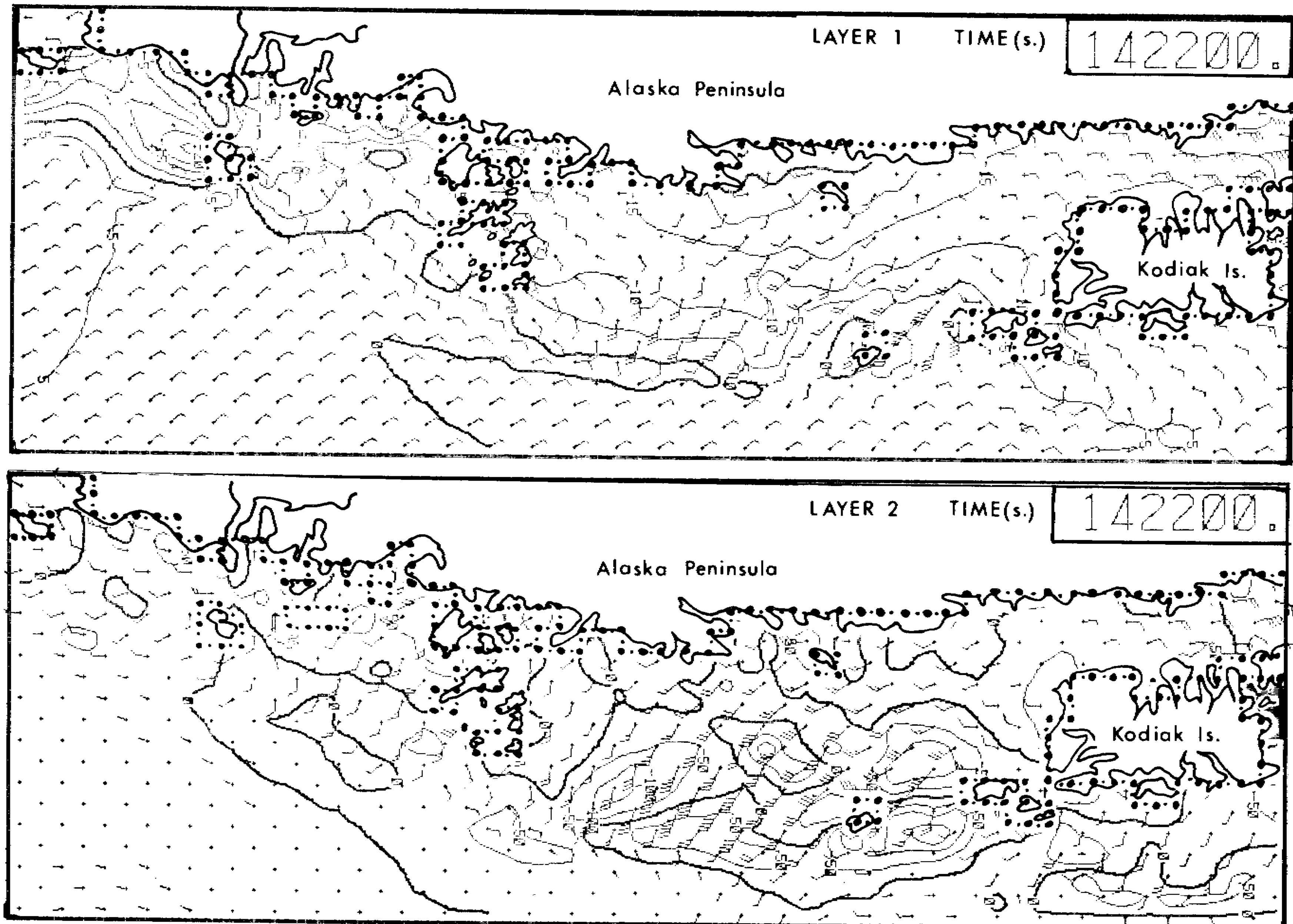
18. Case 2, currents (cm/s) and tidal heights (cm) for layers 1 and 2 at 29 hours (104400 s).



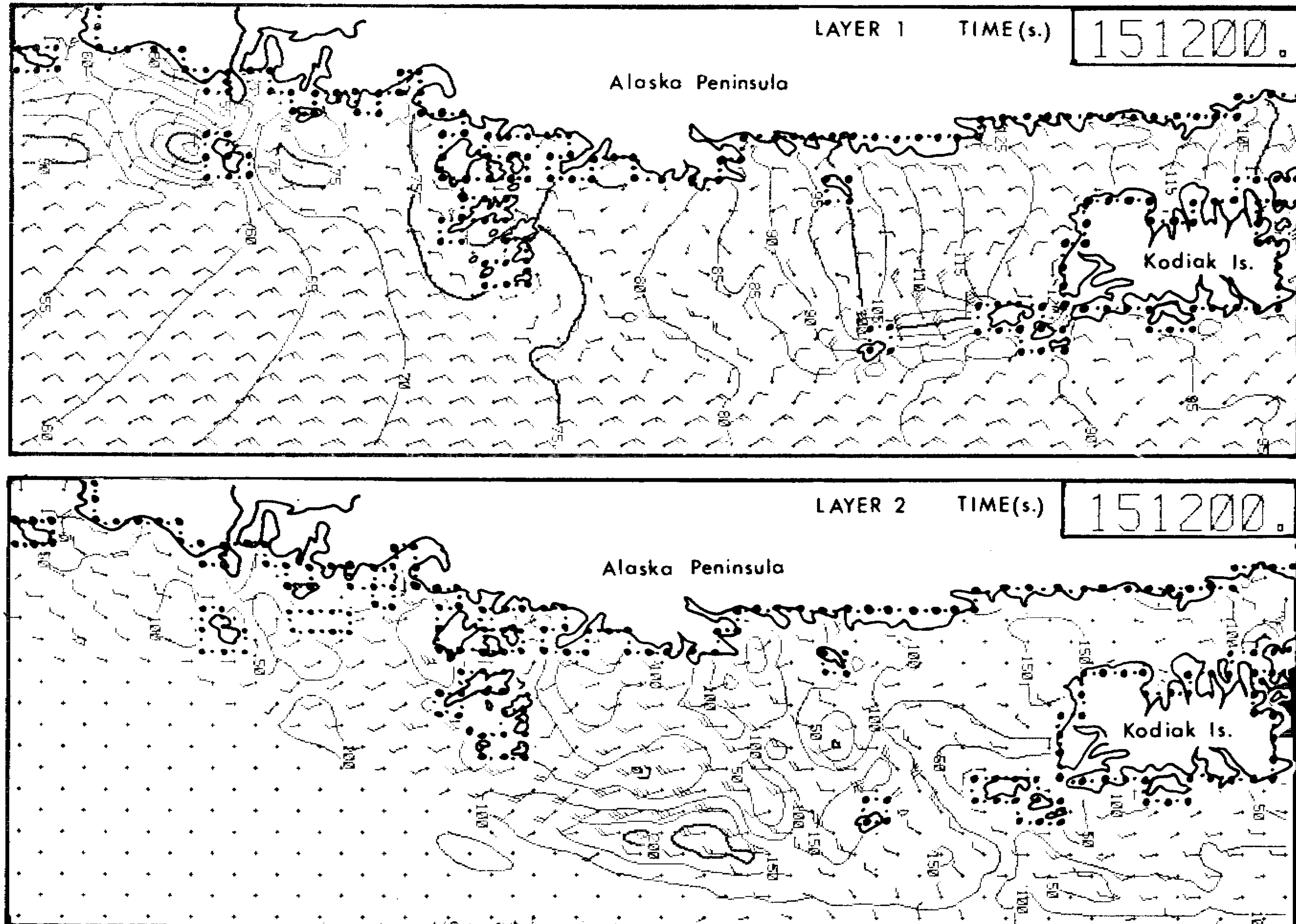
19. Case 2, currents (cm/s) and tidal heights (cm) for layers 1 and 2 at 32 1/2 hours (117000 s).



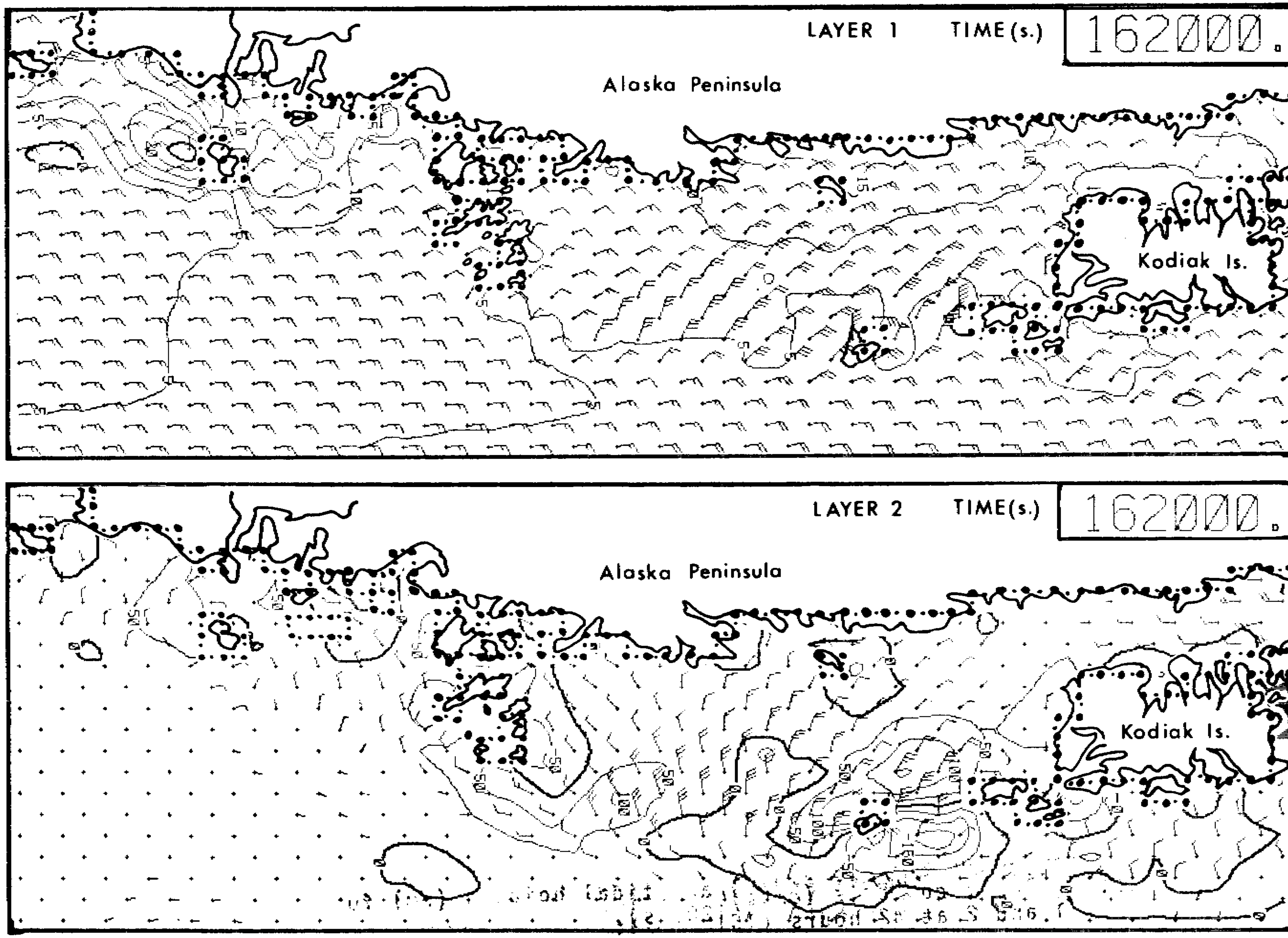
20. Case 2, currents (cm/s) and tidal heights (cm) for layers 1 and 2 at 36 hours (129600 s).



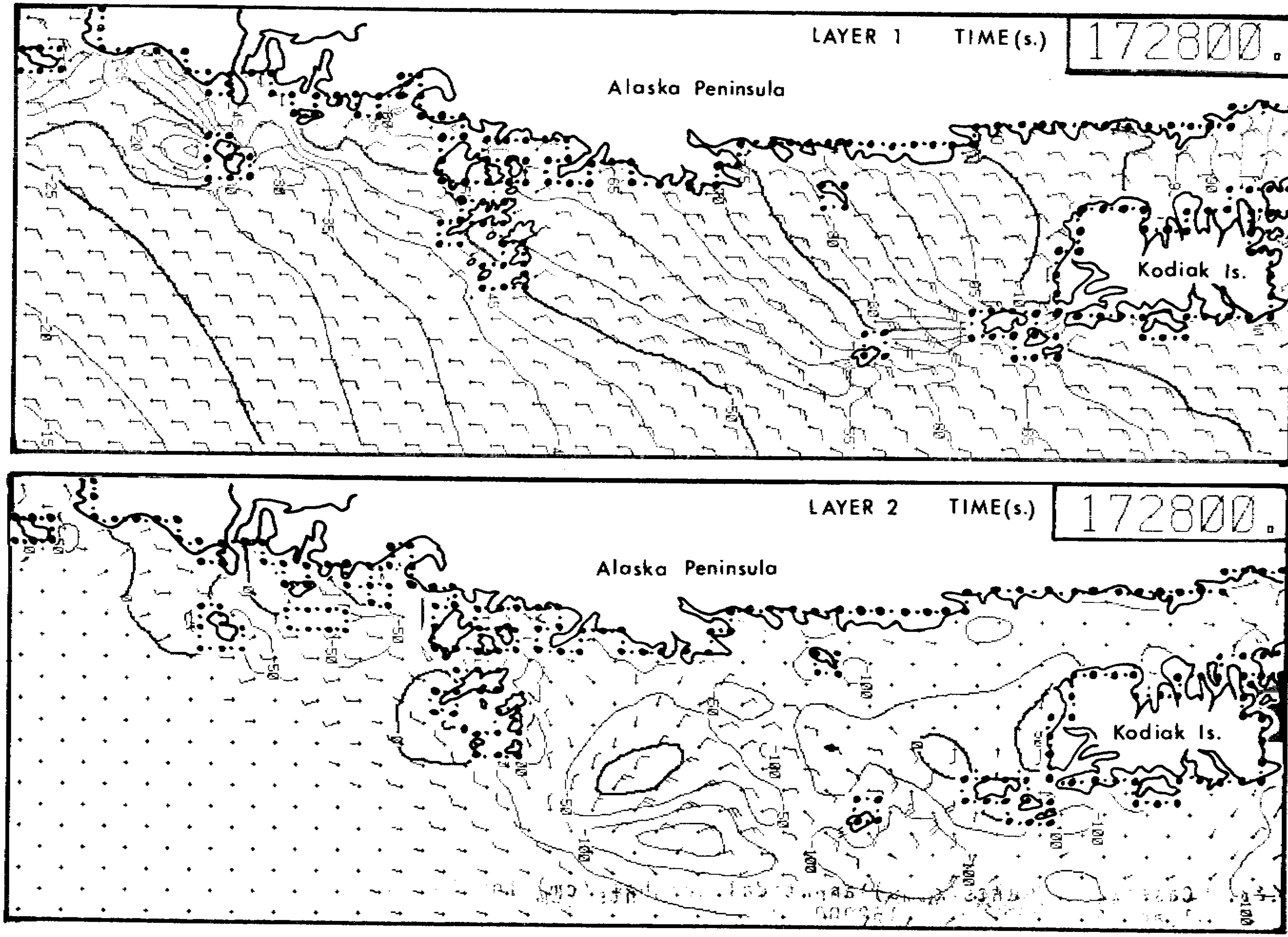
21. Case 2, currents (cm/s) and tidal heights (cm) for layers 1 and 2 at 39 1/2 hours (142200 s).



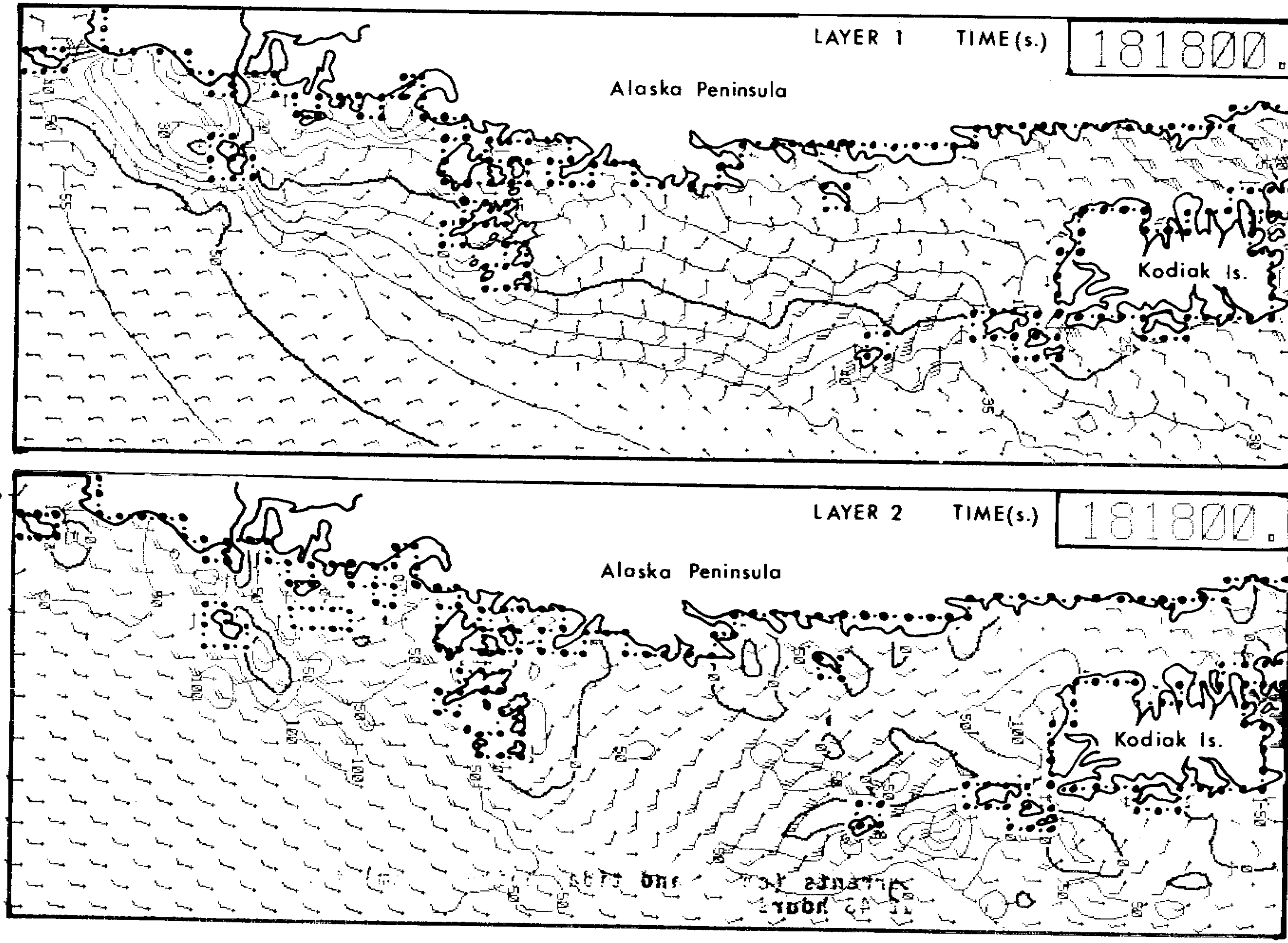
22. Case 2, currents (cm/s) and tidal heights (cm) for layers 1 and 2 at 42 hours (151200 s).



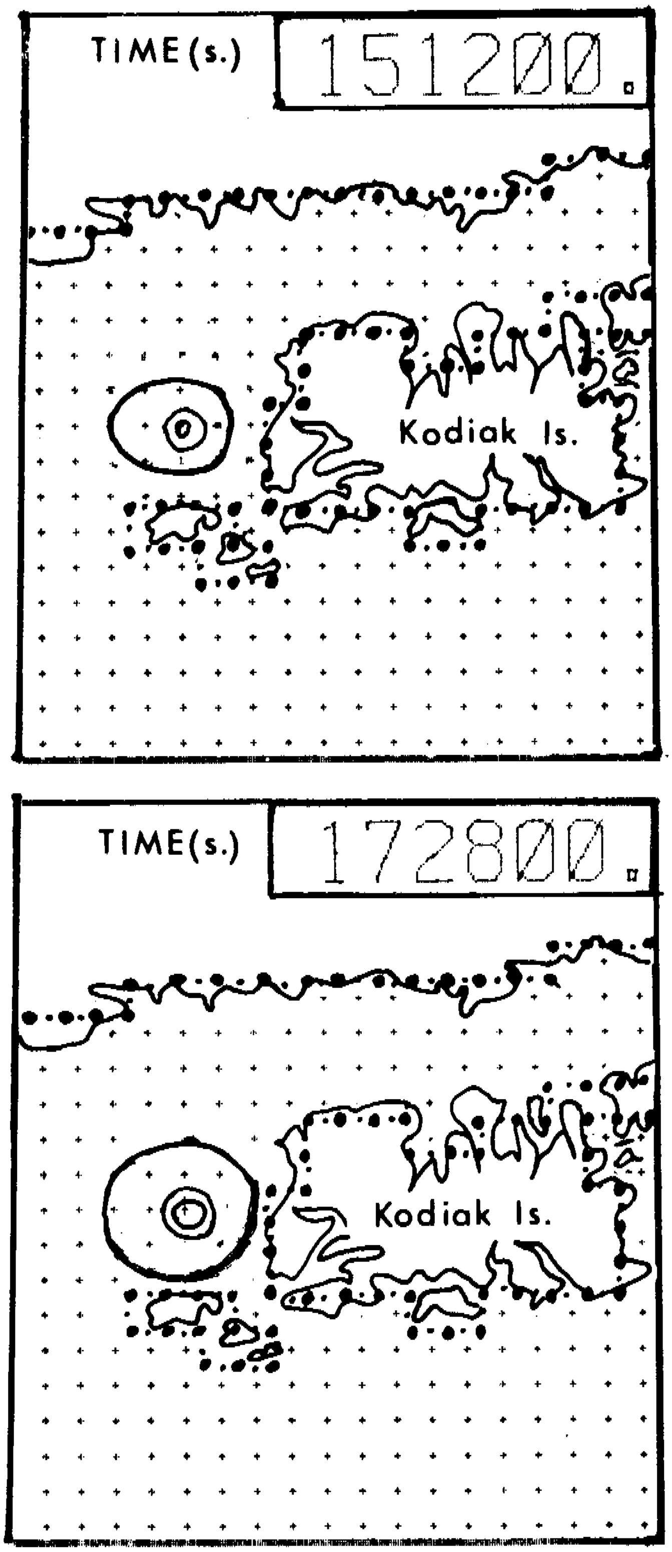
23. Case 2, currents (cm/s) and tidal heights (cm) for layers 1 and 2 at 45 hours (162000 s).



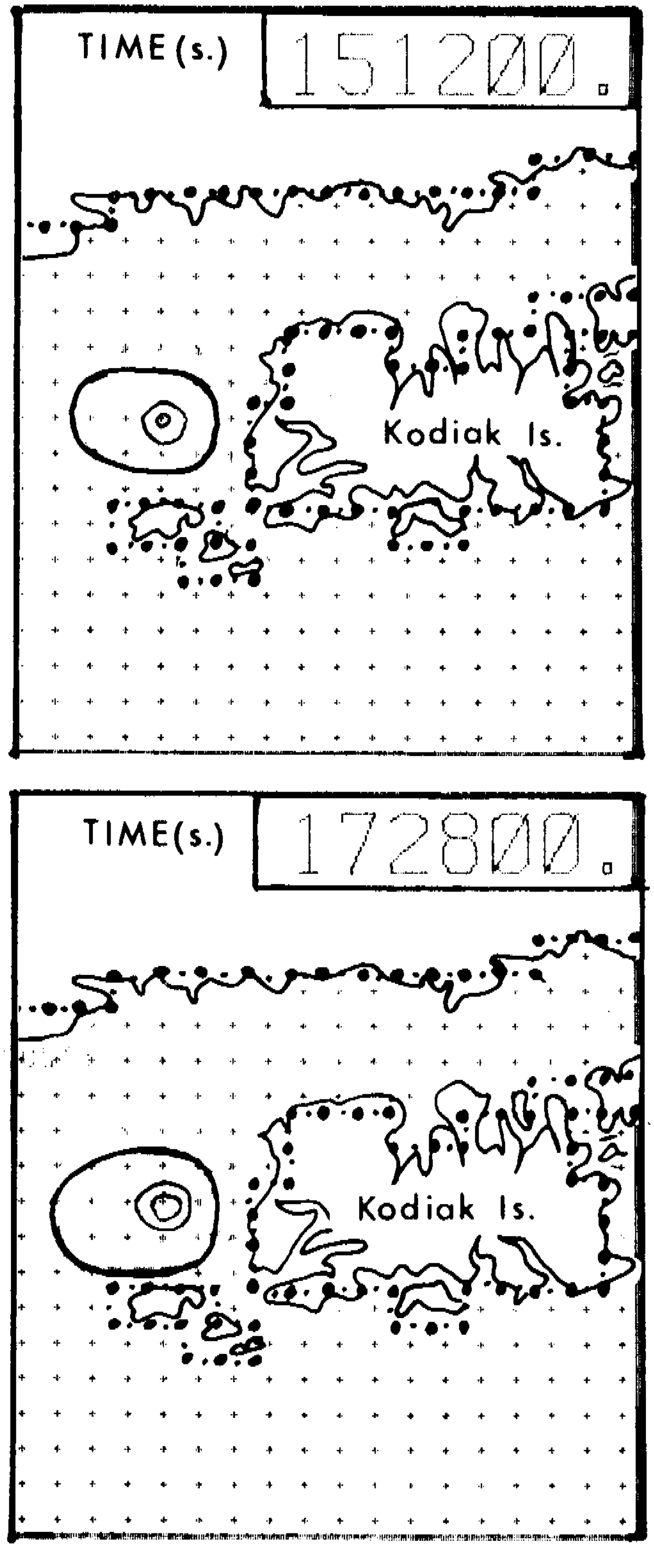
24. Case 2, currents (cm/s) and tidal heights (cm) for layers 1 and 2 at 48 hours (172800 s).



25. Case 2, currents (cm/s) and tidal heights (cm) for layers 1 and 2 at 50 1/2 hours (181800 s).



26. Case 1, pollutant distribution (arbitrary units) at 42 hours (151200 s) and 48 hours (172800 s) after starting continuous source at 29 hours (104400 s).



27. Case 2, pollutant distribution (arbitrary units) at 42 hours (151200 s) and 48 hours (172800 s) after starting continuous source at 29 hours (104400 s).

Quarterly Report

Contract #03-5-022-56
Research Unit #289
Reporting Period 7/1 - 9/30/76
Number of Pages 4

MESOSCALE CURRENTS AND WATER MASSES IN THE GULF OF ALASKA

Dr. Thomas C. Royer
Associate Professor of Marine Science
Institute of Marine Science
University of Alaska
Fairbanks, Alaska 99701

October 1, 1976

Quarterly Report

I. Task Objectives

To continue gathering hydrographic data over the continental shelf region of the Gulf of Alaska in the eastern portion (GASSE), western portion (GASSO) and the Kodiak Island region. To continue to monitor currents and sea level at a permanent station location in the Gulf of Alaska.

II. Field Activities

The station line out of Seward and the three eastern transects of the western grid were occupied from 21 July to 1 August aboard the *Moana Wave*. A total of 69 CTD stations were occupied. The current meter array at station nine (58° 41.1'N, 148° 19.6'W) with five meters and pressure gauge was recovered. Another array without a pressure gauge was redeployed at the same location. The eastern grid (GASSE) was occupied from 7-17 September using the NOAA ship *Surveyor*. A total of 65 CTD stations were occupied with four stations in Prince William Sound.

III. Results

We are continuing to receive the weather data from Middleton Island (now up to 6/76) and EB03 data (to April 1976). Additional data for the U. S. Coast Guard sections has been received. The recovered current meter data has been forwarded to PMEL for initial processing. The pressure guage tape was processed by Aanderaa Instruments Limited, in British Columbia. With the exception of three data points (two being when the array was aboard after recovery), all the pressure gauge records were good. The recovered array was in good condition except that the seven lowest floats were missing. We are awaiting the current meter data prior to completely analyzing the problem.

A paper entitled "On the ocean temperature distribution in the Gulf of Alaska, 1974-1975" by Royer and Muench was completed. The principal investigator attended a physical oceanography workshop in Seattle in July. He also met with BLM representatives in Anchorage on 8 September to discuss the work near Kodiak Island.

Preliminary analysis of the hydrographic data near Kodiak indicates that the fresh water, high temperature surface water observed near the shelf break off Kodiak in both the ship and satellite data sets has its origin in the nearshore region east of Kayak Island. It also appears that the anomalous conditions in July 1974 in the central gulf were due to the unusual wind stress patterns in May of that year as reported by Ingraham, Bakun and Favorite in their final report of RU-357 to BLM. Maximum current speeds of nearly 1.5 knots were determined from ship set computations southwest of Kodiak at the shelf break.

IV. Problems Encountered

Severe logistics problems occurred when personnel attempted to reach Kodiak to sail on the *Moana Wave*. After two days of waiting in Anchorage by cruise personnel, the ship was instructed to sail to Seward to receive personnel and gear. A shift of the departure date by one day in the last version of the draft project instructions partially compensated for this problem.

The running of the Kodiak Island grid by *Surveyor* personnel ran into problems due to use of the PMC CTD manual. There are numerous errors in the manual and until they are corrected by PMC it is recommended that prior instructions be used.

We are still in the process of converting computer programs to our new system and the data display aspects of this study have been hampered. It is expected that in the next quarter this problem will be solved and displays will be forthcoming.

OCS COORDINATION OFFICE

University of Alaska

ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: September 30, 1976

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 19 R.U. NUMBER: 289

PRINCIPAL INVESTIGATOR: Dr. T. C. Royer

Submission dates are estimated only and will be updated, if necessary, each quarter. Data batches refer to data as identified in the data management plan.

Cruise/Field Operation	Collection Dates		Estimated Submission Dates[1]		
	From	To	Batch 1	2	3
Acona #193	7/1/74	7/9/74	submitted	None	None
Acona #200	10/8/74	10/14/74	submitted	None	None
Acona #202	11/18/74	11/20/74	submitted	None	None
Acona #205	2/12/75	2/14/75	submitted	None	None
Acona #207	3/21/75	3/27/75	submitted	None	None
Acona #212	6/3/75	6/13/75	submitted		
Oceangrapher #805	2/1/75	2/13/75	submitted	None	None
Silas Bent #811	8/31/75	9/28/75	Submitted		
Discoverer #812	10/3/75	10/16/75	(a)		
Surveyor #814	10/28/75	11/17/75	submitted		
Discoverer #816	11/23/75	12/2/75	(b)	None	None
Station 60	6/2/74	9/10/74	None	Unknown	None
Station 64	4/28/75	5/20/75	None	Unknown	None
Station 9	Current meter, not available in field.				
Station 9	Pressure gauge, not available in field.				
Moana Wave MW 001	2/21/76	3/5/76	submitted		
Moana Wave MW 003/004	4/20/76	5/21/76	(c)		
Moana Wave MW005	9/22/76	8/1/76	(c)		
Surveyor SU 003	9/7/76	9/17/76	(c)		

Note: 1 Data Management Plan and Data Formats have been approved and are considered contractual.

(a) Parent tapes were coded in PODAS format, tapes were submitted to F. Cava as requested.

(b) Data useless due to malfunction of shipboard data logger.

(c) Data will be processed in FY '77 contingent upon approval of and funding for extension of this project for FY '77.

Quarterly Report

Contract #03-5-022-56
Research Unit #307
Reporting Period 7/1 - 9/30/76
Number of Pages 2

HISTORICAL AND STATISTICAL DATA ANALYSIS AND SHIP OF OPPORTUNITY PROGRAM

Dr. Robin D. Muench
Associate Professor of Marine Science
Institute of Marine Science
University of Alaska
Fairbanks, Alaska 99701

October 1, 1976

Quarterly Report

I. Task Objectives

To obtain temperature, salinity, dissolved oxygen, nutrient and meteorological data on an opportunity (not-to-interfere) basis from oceanographic vessels operating in the southeastern Bering Sea region, to analyze this data and to incorporate it into the ongoing analysis of historical data.

II. Field Activities

None.

III. Results

NODC computer printout oceanographic data for area of Bering Sea between Aleutians and 61°N and 165 to 176°W was processed. For eight selected years between 1920 and 1971 horizontal distributions of temperature and salinity were plotted and contoured for 10, 50, and 100 m.

The new reagent type oxygen bottles used on the *Surveyor* 001 and 002 cruises were calibrated and a comparison made between the dissolved oxygen values obtained by Winkler micropepette titration on board. For this purpose oxygen samples had been drawn in quadruplicate and processed in duplicate using regular fragile erlenmeyer flasks and sturdy reagent type bottles. The results showed the bottles can be used interchangeably with proper operator experience.

A paper entitled "On the ocean temperature distribution in the Gulf of Alaska, 1974-1975" by Royer and Muench was completed.

OCS COORDINATION OFFICE

University of Alaska

ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: September 30, 1976

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 14 R.U. NUMBER: 307

PRINCIPAL INVESTIGATOR: Dr. R. D. Muench

Submission dates are estimated only and will be updated, if necessary, each quarter. Data batches refer to data as identified in the data management plan.

Cruise/Field Operation	Collection Dates		Estimated Submission Dates[1]			
	From	To	Batch 1			
Acona #197	7/20/75	7/30/75	submitted			
Discoverer Leg I & II #808	5/15/75	6/19/75	submitted			
Discoverer Leg I #810	8/9/75	8/28/75	(a)			
Miller Freeman #815	11/19/75	11/26/75	submitted			
Surveyor 001/002	3/76	4/76	11/30/76			

NOTE: 1 Data Management Plan and Data Format have been approved and are considered contractual.

(a) Parent tapes were coded in PODAS format, tapes were submitted to F. Cava as requested.

RU# 335

NO REPORT WAS RECEIVED

A final report is expected next quarter

Quarterly Report

Contract No: N/A
Research Unit No: 347
Reporting Period: July 1, 1976; through September 30, 1976
Number of Pages: 3

"Marine Climatology of the Gulf of Alaska and the Bering and Beaufort Seas"
Climatic Atlases (3)

Principal Investigators

James L. Wise
Associate in Climatology
Arctic Environmental Information and Data Center
University of Alaska
707 'A' Street
Anchorage, AK 99501
Comm: (907) 279-4523

William A. Brower, Jr. (D5312)
Applied Climatology Branch
National Climatic Center
Federal Building, Room 401
Asheville, NC 28801
Comm: (704) 258-2850 x266
FTS : 672-0266

September 22, 1976

Quarterly Report

I. Task Objectives

To compile and publish a descriptive climatology of that portion of the Alaskan waters and coastal areas that are important to resource development of the outer continental shelf (OCS).

II. Field and Laboratory Activities

This project has no field or laboratory activities. It is a joint effort by the AEIDC and the NCC to produce a climatic atlas for each of three Alaskan marine and coastal areas: the Gulf of Alaska (50°-65°N, 130°-165°W); the Bering Sea (50°-65°N, 155°-180°W); and the Beaufort Sea (65°-75°N, 140°-180°W).

NCC is to provide monthly climatological analyses in the form of 360 isopleth charts and 9,540 statistical graphs. The analyses are to be based on 600,000 surface marine observations and two million (3-hourly) observations for 49 (selected) coastal stations contained in NCC's digital data base. AEIDC is to provide extremes of all weather elements and information on coastal damage resulting from wind generated weather elements, check analysis work done by NCC, and prepare all materials for publication. (AEIDC will provide an independent quarterly report).

III. Results

Computer processing of the digital data is complete. This includes the computer-to-microfilm production of 9,540 statistical graphs and the computer plotting of 360 charts. All graphs have been photo processed and forwarded to AEIDC to prepare for printing. The 360 isopleth charts have been analyzed and edited by staff meteorologists and are currently undergoing NCC's required technical review (audit); of these, 50% have been mailed to AEIDC to prepare for printing. (Microfilm copies of the charts and graphs and glossy prints of the charts are being held by NCC for reference during preparation of the materials for print by AEIDC and can be made available to OCSEAP PI's and others at cost for reproduction).

IV. Preliminary Interpretation of Results

The U.S. Navy Marine Climatic Atlas of the World, Vol.II, North Pacific Ocean (1959), one of eight volumes in a series of atlases of the world which is currently being updated by the Navy, has had wide acceptance as an authoritative reference for large scale operational planning and research.

2.

The present study will provide three atlases to represent the total of the Alaskan waters in greater detail and each will be based on more than 20 years of additional data. Also, as marine data are typically sparse in the near coastal zone, a zone of sharp gradients and complex climate, data for the 49 coastal stations were included. Such a combination should provide the best possible climatological picture for the coastal waters of Alaska.

V. Problems Encountered

A computer-visual inventory of the digital surface marine data file disclosed a sparcity of data north of 60° latitude. To permit a better climatic description of the Bering and Beaufort Seas, marine observations were digitized from manuscript forms archived at NCC for the period 7/73-12/74 and digital data for 22 additional coastal stations held in NCC's file were combined with data of the 27 stations originally selected. However, as there were little data available in NCC's digital file for the land and marine area east of Barter Island, the Beaufort Sea Atlas will contain only a limited climatic description of the Mackenzie Bay area.

VI. Estimate of Funds Expended

The $84.5K allotted for FY-76, 76T periods were expended as of 6/15/76; $15K of the $25K approved for FY-77 have been provided during 76T to permit continuation of the Project and will be expended by 9/30/76. Preparation of the three atlases are well underway and all are scheduled for completion in FY-77.

The $13K funded during FY-76T for use in the maintenance of the Alaskan OCSEAP Surface Marine and Coastal Station Data File have been expended to perform the following:

> Observations for 28 stations and for the marine area have been extracted from Global Weather Central's (GWC) telecommunications digital (unedited) data file to supplement and update the Atlas Project digital data file. This expands the file from 49 to 77 coastal stations and from 600K to 700K marine observations. Also produced for the GWC data is a computer inventory that lists the number of observations by month-year for each of the 28 stations and MSQ (10° square) marine areas.

3.

- An inventory of hourly and daily digital data is being prepared for all stations currently held in several tape files at NCC.

- Monthly persistence graphs are being produced for 25 coastal stations which are to provide the hours duration of and days interval between for winds $\geq$ 34 knots.

- Extreme value analyses are being performed for as many of the above 25 stations as possible. These analyses will provide tabular and graphical wind speed estimates for selected return periods (2, 5, 10, 50, 100, 500, 1000 years) and upper and lower limits of a 68 percent confidence band.

The last two products are to be included in the marine atlases.

Quarterly Report

Contract #03-5-022-56
Research Unit #347
Reporting Period 7/1 - 9/30/76
Number of Pages 2

MARINE CLIMATOLOGY OF THE GULF OF ALASKA AND THE BERING AND BEAUFORT SEAS

James L. Wise
Arctic Environmental Information and Data Center
University of Alaska
Anchorage, Alaska 99501

October 1, 1976

Quarterly Report

I. Task Objectives

To determine and publish the knowledge of the climatological conditions of that portion of Alaska that is important to OCS development.

II. Field and Laboratory Activities

This portion of the project has no field or laboratory activities. It is a joint project with the National Climatic Center (NCC) in Asheville, North Carolina. AEIDC responsibilities are to provide extremes of all weather elements, information on coastal damage resulting from wind generated storm flooding, check analysis work done at NCC, and through our graphics department, prepare materials for publication, including contracting for and supervising the publication, of the three marine atlases.

III. Results

To date 97 percent of the extremes data have been compiled and additional surge data, wave height data, and ocean current data are being sought. 100 percent of the data analysis has been received from NCC with some minor adjustments to be made to make the data presentations fit the formated pages and to correct some deficiencies of contrast to make them better for printing. All three base maps have been completed, graphics work is proceeding such that 50 percent of the analyzed data graphs have been pasted in proper locations on the three atlases. Four sets of the 17 isopleth analyses have been received from NCC and five percent of the analyzed pages have been completed. There has been no type setting of text or data tabulations done by the AEIDC. Text that has been written is being edited. Writing of text is about 50 percent complete.

IV. Preliminary Interpretation of Results

Not applicable.

V. Problems Encountered/Recommended Changes

Not applicable.

OCS COORDINATION OFFICE

University of Alaska

ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: September 30, 1976

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 25 R.U. NUMBER: 347

PRINCIPAL INVESTIGATOR: Mr. James Wise

No environmental data are to be taken by this task order as indicated in the Data Management Plan. A schedule of submission is therefore not applicable[1].

NOTE: [1] Data Management Plan has been approved and made contractual.

NORTHWEST FISHERIES CENTER

PROCESSED REPORT

JULY 1976

PHYSICAL OCEANOGRAPHY OF THE GULF OF ALASKA

by

W. J. Ingraham, Jr., A. Bakun and F. Favorite

FINAL REPORT

RU - 357

ENVIRONMENTAL ASSESSMENT of the ALASKAN CONTINENTAL SHELF

Sponsored by

UNITED STATES DEPARTMENT of INTERIOR

Bureau of Land Management

Prepared by:
Northwest Fisheries Center
National Marine Fisheries Service
2725 Montlake Boulevard E.
Seattle, Washington 98112

CONTENTS

PHYSICAL OCEANOGRAPHY OF THE GULF OF ALASKA

INTRODUCTION

Although extensive oceanographic investigations have been carried out in the Gulf of Alaska in the last two decades, our knowledge of actual conditions and processes and their cause and effect is still inadequate to permit any accurate short- or long-term forecasts of oceanic conditions. However, a fairly extensive data base exists, and the purpose of this report is to summarize the state of our knowledge concerning the physical environment of offshore areas of the Gulf of Alaska prior to the commencement of present OCSEAP[1/] investigations. The Gulf of Alaska is considered to extend southward from the coast to a line from Dixon Entrance to Unimak Pass, essentially 54°N.

It should be recognized at the outset that the ocean is a turbulent regime that can be characterized only by statistical techniques based on extensive time-series data on water properties and direct current measurements collected on appropriate space scales. Such data are not available for the Gulf of Alaska area. Physical oceanographic studies up to the present time have been limited to aperiodic, widely-spaced station data of an exploratory nature obtained primarily to provide background information on general flow and ranges of environmental conditions related to specific aspects of fisheries investigations (Favorite, 1975). The most recent and comprehensive are those of the International North Pacific Fisheries Commission (INPFC). General environmental conditions in the Subarctic Pacific Region for the years 1953 to 1971 have been summarized by Dodimead, Favorite and Hirano (1963), and Favorite, Dodimead and Nasu (1976); the latter provides an extensive bibliography that is not reproduced in this

1/ Outer Continental Shelf Environmental Assessment Program.

report. There is also extensive but fragmentary information available in reports of results of Soviet fishing activities (e.g. Moiseev,1963-70).[2/] Although the presently available station data are extensive, they are aperiodic, non-synoptic and lack the close grid spacing, wide area coverage, repetitive observations, and direct current measurements necessary to characterize the specific nature of flow.

A general assessment of oceanographic conditions can be made from knowledge of meteorology and bathymetry. With respect to water properties, we can expect seasonal changes in both temperature and salinity. Northward flow into the gulf brings unseasonably warm water into the gulf year round. Winter cooling will gradually erode the high temperatures in surface layer, but these will quickly be restored by seasonal warming in spring and summer. The vertical extent of winter cooling or convective overturn will depend on the stability of the water column, and this is affected primarily by the distribution of salinity with depth. Because there is an excess of precipitation over evaporation and extensive dilution in spring and summer from the extensive coastal watershed, a dilute surface layer can be expected to be underlain by a halocline. The readjustment of mass as a result of the general cyclonic flow around the gulf will result in a horizontal divergence and an upward vertical transfer in the center of the gulf. This is manifested in a doming or ridging of isolines of water properties in that area resulting in high salinities and low temperatures at the surface, particularly during winter when this process is most active.

There is a general eastward surface flow across the North Pacific Ocean composed of the northern sector of the anticyclonic flow in the central North Pacific gyre driven by winds associated with the Eastern Pacific high pressure system, and the southern sector of the general cyclonic flow of

2/ See also Bogdanov (1961), Plakhotnik (1962), and Filatova (1973).

the Subarctic Pacific gyre, driven by interactions of the Aleutian Low pressure system. This confluence and the subsequent eastward advection of meridional admixtures of subarctic and subtropic waters is subjected to various bathymetric conditions on reaching the eastern side of the ocean: first, a gradual shoaling, reducing the water column by half (from 6,000 - 3,000 m); second, the interference of numerous seamounts, (some extending to within 500 m of the surface); and, finally, an abrupt continental shelf. This results in marked changes in the fields of acceleration, vorticity and turbulence, as well as a predominant separation of flow into northward and southward components and associated disturbances of vertical strata. The northward branch, increasing in planetary vorticity, impinges on the head of the Gulf of Alaska where it is constrained by the land mass and is forced southwestward along the Alaska Peninsula. In order to accomplish this it must displace the northeastward flow into the gulf offshore, away from the continental slope. The vorticity balance of this southwestward flow is altered not only as a result of southward displacement, but also as a result of increasing depth (5,000 - 7,000 m) on encountering the eastern end of the Aleutian Trench. Further, we can anticipate that frictional and tidal effects on the shallow continental shelf will result in considerably reduced flow over the shelf compared to flow along and seaward of the continental slope, and that flow along the edge of the shelf will be complicated by internal waves and horizontal shelf waves.

The greatest fluctuations in flow conditions will be associated with the intensification of winds in winter. The center of the Aleutian Low travels in an anticyclonic pattern; present in late spring and summer in the northern Bering Sea, it occurs in the Gulf of Alaska in late fall, and in the western Aleutian area in winter. Thus, maximum cyclonic winds occur in the Gulf of Alaska from November to January. Maximum Ekman transport will occur at this time, piling up water along the coast and resulting in a seaward flow along the bottom. Maximum total transport also occurs at this time greatly increasing northward flow into the gulf. In summer, a northward displacement of the Eastern Pacific High results in anticyclonic winds resulting in an offshore component of Ekman transport at the surface and a compensatory onshore flow over the continental shelf. Minimum overall transport also occurs at this time.

Thus there is a potential for considerable complexity and great variability in actual conditions, and it is these time-dependent phenomena that we are most interested in. All data available will be used to define physical conditions in the gulf as accurately and completely as possible.

It is difficult to assess how representative the oceanographic data being collected or analyzed are in defining conditions in a particular area unless some measure of variability over extended time periods is available. About a century ago it was recognized that oceanic conditions in the gulf were considerably warmer than corresponding latitudes at the western side of the ocean (Dall, 1882) and this was attributed to the influence of the "Kuro Siwo" because of the known analogous effects of the Gulf Stream in the Atlantic Ocean on the climate of Europe. Although data from the "China steamers" between San Francisco, Yokohama and Hong Kong in the 1870's provided extensive data on conditions in the central Pacific Ocean, even the gold rushes and subsequent commercial traffic to Alaska failed to provide a data base documenting oceanographic conditions in the gulf. There are surface temperature data for the Gulf of Alaska from the 19th century, presumably from government and commercial vessels, but these are too fragmentary in time and space to establish climatic trends. Nevertheless, there are historical records of monthly mean air temperatures at Sitka that began when this location, called New Archangel, was controlled by the Russian-America Company (Dall, 1879) that are fairly complete to this date. Considering all years data are available since 1828 (Fig. 1), positive annual anomalies of greater than 1.5C° were recorded in 1829, 1869, 1915, 1926, 1940 and 1941; whereas, only in 1955 did a negative anomaly greater than 1.5C° occur. Cycles of 4-5 year duration are apparent in the data from 1850-71. The period from 1920 to 1947 was characterized by above normal conditions; however, there was a marked decline of over 3C° from 1940 to 1950. Below normal conditions have occurred from 1965 to the present. Perhaps the most significant aspect of these data is that the annual mean temperature for 1828-76 is precisely the same as the present day mean compiled and used by the National Weather Service, 6.3°C (43.3°F). Thus, both short-term fluctuations of 1-4 years and long-term trends, such as the cooling evident from 1940-55 have occurred. Although we have acquired sea level pressure data as far back as 1900, sea level data prior to 1930 are available only at Ketchikan, and oceanographic station data are generally available only since 1950. The longer records will be utilized where applicable, but most comparisons and interactions will of necessity be based on data from the 25-year period 1950-74.

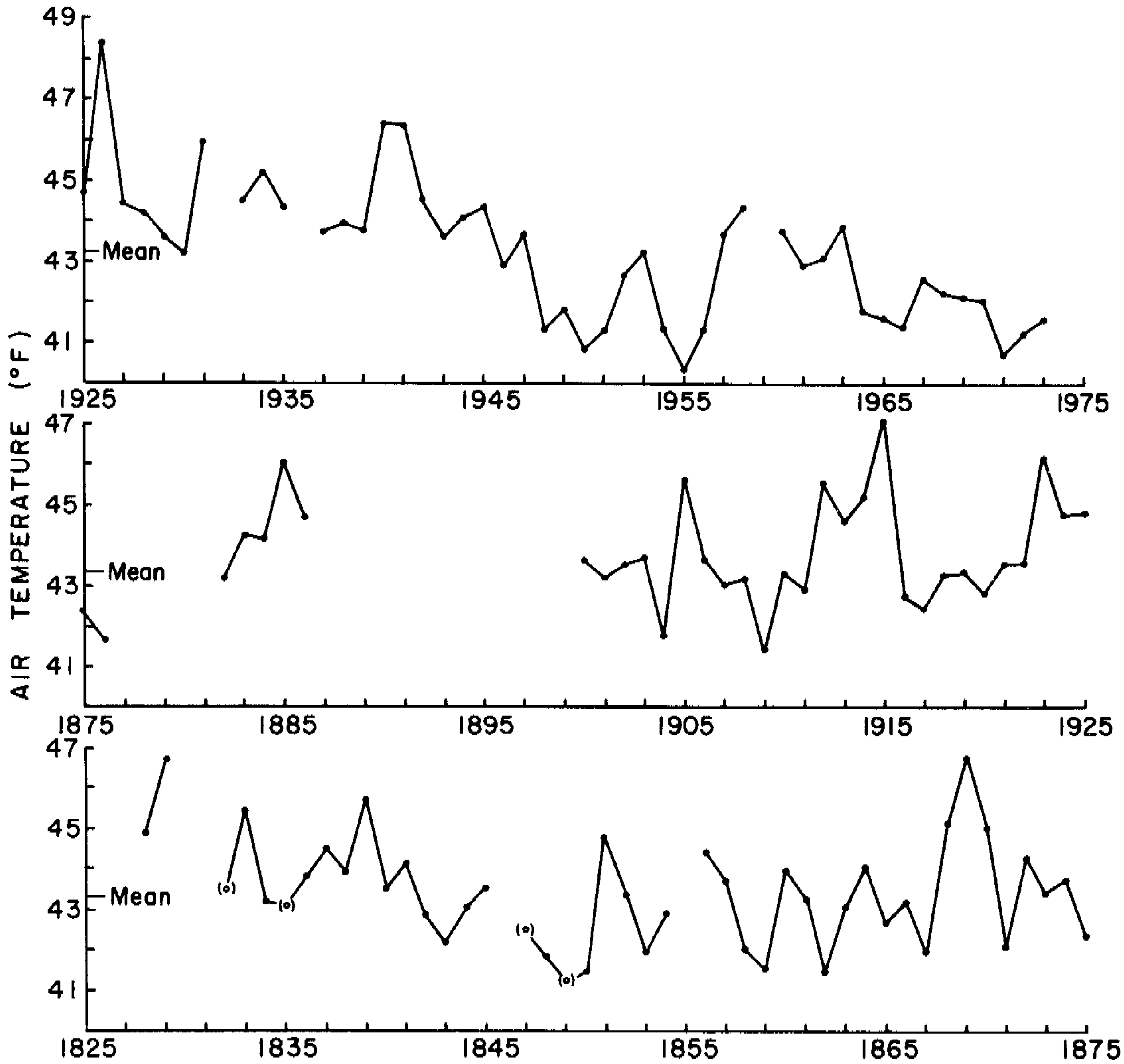


Figure 1. Air temperatures at Sitka (New Archangel) 1828-1974.

II. WATER PROPERTIES

Abrupt changes from normal conditions are usually quickly detected, but gradual changes over long periods often pass unnoticed; nevertheless, quantification of either requires an adequate data base. Reasonably complete time-series data in the gulf are available at shore stations, but none is available at specific locations in oceanic areas of the gulf[3/]. In the latter case, in order to obtain any semblance of time-series data, observations over extensive areas must be averaged over large intervals; such data provide an indication of trends but, obviously, numerous spacial and temporal phenomena are masked by the averaging process.

A. Temperature

Although observations at shore stations are the most complete source of temperature data, only surface values are obtained. Monthly mean values (referred to 1950-74 mean, where data are available) for Ketchikan, Sitka, Yakutat, Seward, Kodiak and Dutch Harbor indicate a progressively colder regime from southeastern Alaska around the gulf to the end of the Alaska Peninsula with one exception, that temperatures in winter at Dutch Harbor are about 2 or 3 C^{o} higher than at Kodiak (Fig. 2a). In southeastern Alaska the seasonal temperature range is about 9 C^{o} (from 5 - 14°C at Ketchikan and 3 - 12° at Seward), but the range increases to 11 C^{o} at Kodiak (1 - 12°) and decreases to 8 C^{o} at Dutch Harbor. Minima occur in January at Kodiak and in February at all other locations, maxima occur in July at Seward and in August at all other locations.

There are a number of oceanographic atlases of large areas of the Pacific Ocean that permit a general assessment of mean temperatures in the offshore waters of the Gulf of Alaska (e.g. LaViolette and Seim (1969)) present monthly mean, minimum and maximum sea surface temperatures based on a

3/ Extensive data are available at Ocean Station "P" southward of the gulf -50°N, 145°W (e.g. Tabata 1965 and Fofonoff and Tabata 1966).

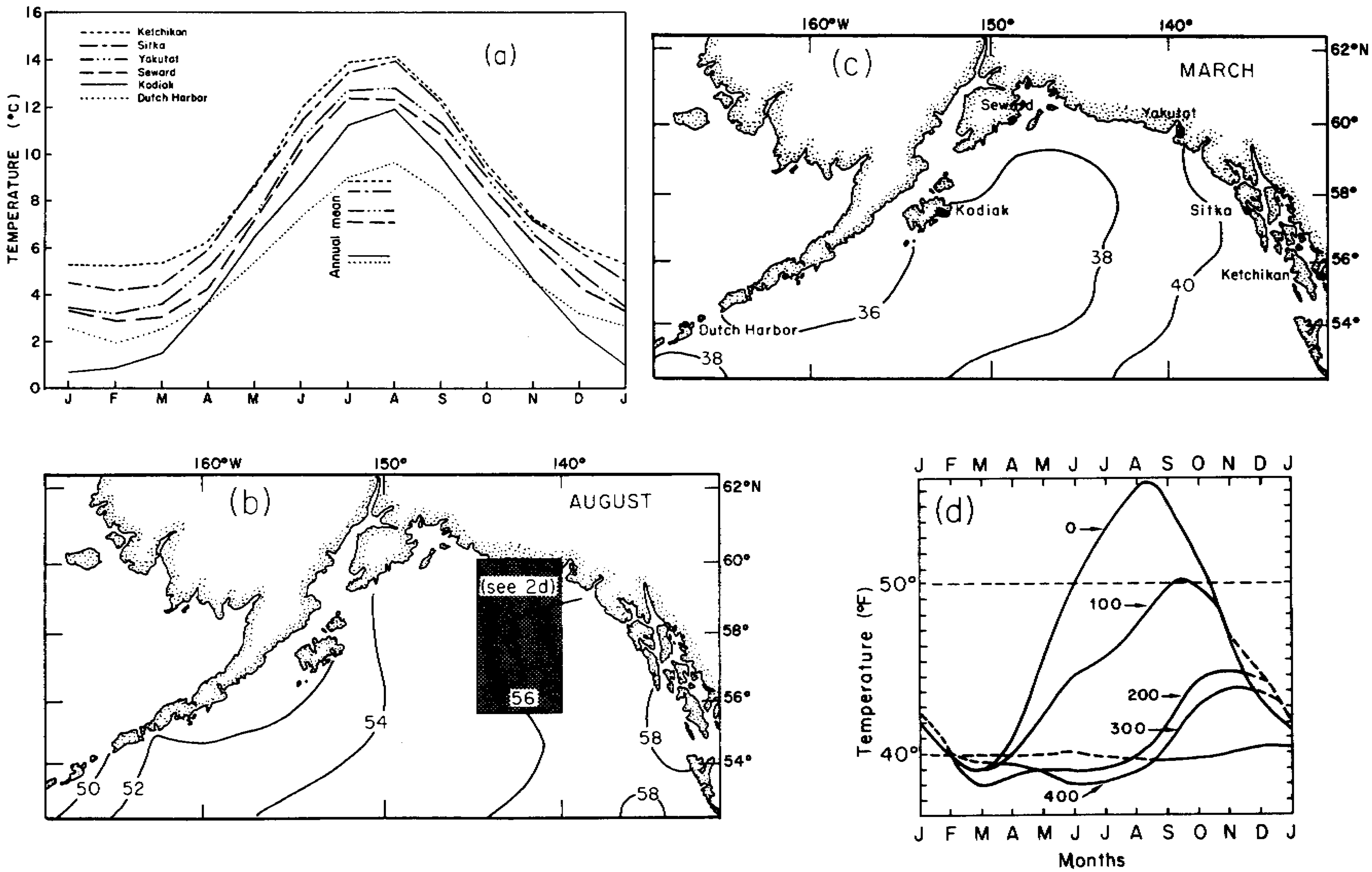


Figure 2. Sea temperature data: (a) monthly mean (1950-74) sea surface temperatures at the indicated coastal stations; (b and c) surface temperature distributions August and March (from Robinson and Bauer, 1971); and (d) monthly mean temperatures at 100 ft (30.5m) intervals to 400 ft (121.9m) in 5x5° Marsden quadrant 195-3, 55-60°N, 140-145°W (from Robinson, 1957).

1 x 1° grid), and there are also a few that are limited specifically to the gulf and adjacent area--e.g. Robinson (1957), Giovando and Robinson (1965) and Robinson and Baur (1971). These data are not only easily accessible, but adequately representative of mean conditions; thus, there is little need for an extensive summary here. It should be pointed out, however, that such atlases are representative only of offshore areas where mixing and stirring moderate the extreme conditions that occur in shallow inshore areas which are influenced by ice-melt in winter and spring, and runoff and warming over tidal shoals in spring and summer[4/]. Maximum surface temperature, 14°C, occurs in August, but conditions are sufficiently similar in September to consider either month as representative, and minimum surface temperature, 3.5°C, occurs in March (Fig. 2b and c) - temperatures of 0°C, or lower, can be found in Prince William Sound and Cook Inlet depending on the extent of ice cover.

A representative seasonal temperature cycle to a depth of 122 m (400 ft) is afforded by a compilation of station and bathythermograph (BT) data in the 5 x 5° quadrangle from 55-60°N, 140-145°W (Fig. 2d). Near isothermal conditions are present from the surface to approximately 100 m during January-March and represent the vertical extent of convective turnover during winter. This process not only determines the extent of the surface layer in winter, but results in the formation of a temperature-minimum stratum ($\sim$3°C) at depths of 75 to 150 m when surface waters are warmed in spring and summer. Wind mixing and stirring result in the formation of a warm surface layer in summer of 20-30 m thickness that is underlain by a sharp thermocline extending to the depth of winter overturn. Subsequent downward diffusion in spring, summer and autumn gradually erodes but

4/ See Muench and Schmidt (1975) for a discussion of conditions in Prince William Sound.

seldom eliminates the temperature-minimum stratum, particularly in the central part of the gulf. The effects of this process are evident until November. However, year round temperatures of 4.5 to 5.0°C occur near 122 m around the periphery of the gulf, over the continental shelf and slope. These temperatures, 1-2C° higher than those in the temperature-minimum stratum, appear as a mesothermal, or temperature-maximum, stratum, but are merely representative of conditions in the water column below the influence of local seasonal effects.

Further information on conditions at 122 m is provided by a plot of the geographical extent of selected isotherms (Fig. 3a): the zonal trends south of 50°N suggest an eastward flow toward the coast; the abrupt northward trend of the 4.4°C isotherm boundaries west of 140°W suggests a broad variable northward flow into the gulf east of 150°W; the westward continuation of this feature south of the Alaska peninsula suggests a westward return flow in that area; and, finally, the tongue-like area westward of 147°W between 51° and 54° suggests the presence of an eastward intrusion of cold water from the west or an area of upward vertical transfer of cold water from depth, or both. A vertical temperature profile along 145°W (Fig. 3b) based on long-term mean temperatures from all station data (2 x 2° grid) clearly exhibits a ridging of the 4 and 5° isotherms in the zone between 48-57°N; and the effects of temperature on geostrophic flow dictate an eastward, onshore flow to the south of this zone and a westward return flow north of the zone.

Mean temperature distributions below the range of the shallow bathythermograph (450' or 137 m) must be obtained from station data and are not

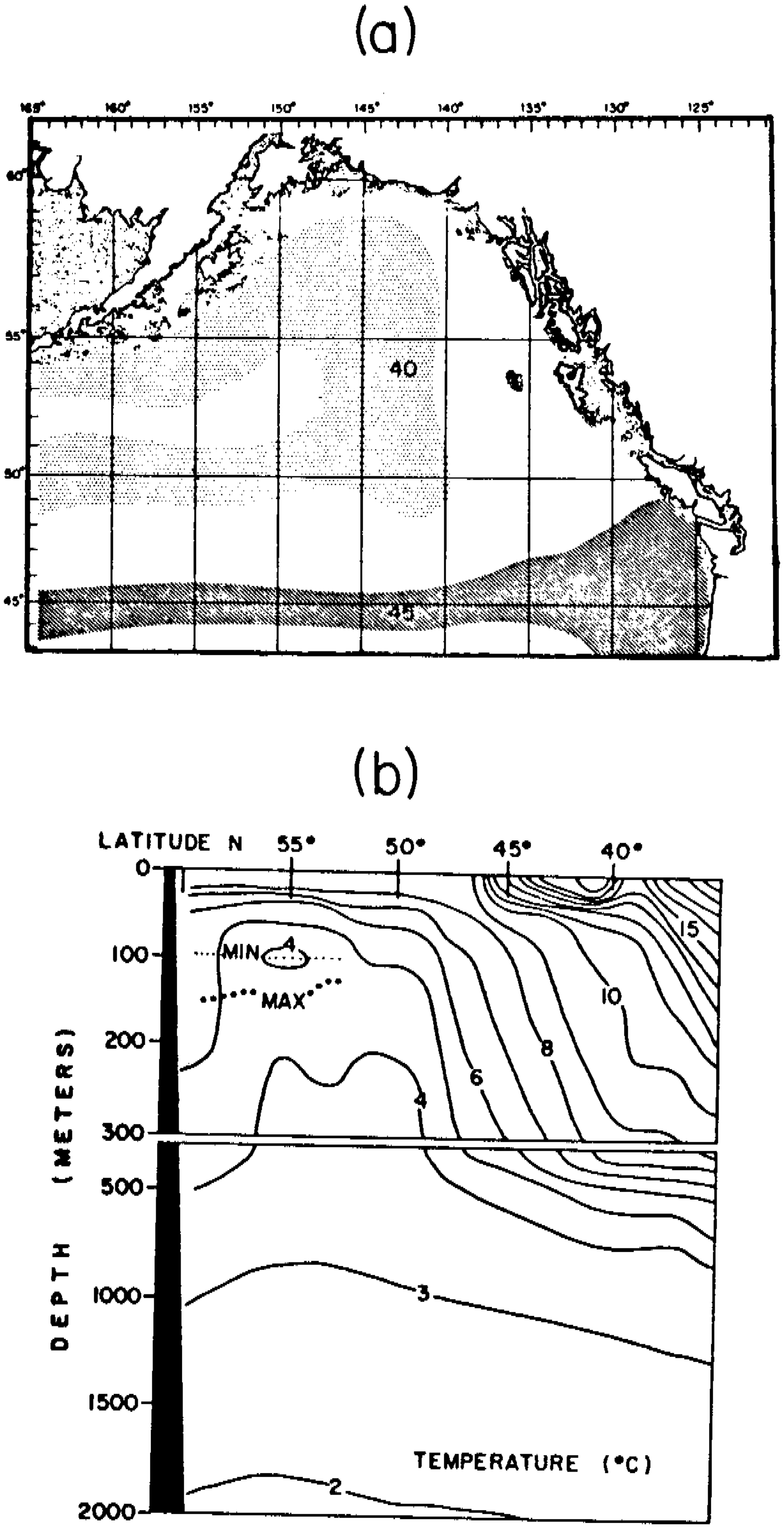


Figure 3. Geographic range of selected isotherms (°F) at 400 ft (121.9m) (from Robinson, 1957), and vertical section of long-term mean temperatures (based on 2x2° grid) along 145°W.

readily accessible. Plots based on long-term mean data (2 x 2° grid) at depths of 200, 500, 1000 and 2000 m (Fig. 4) clearly indicate the northward sweep of warm water into the gulf on the eastern side and the permanence of the cold intrusion isolated offshore on the western side; the two features exist at all levels. It should be noted that data averaged in this manner (2 x 2° grid) do not adequately represent temperature fields in the narrow boundary current at the western side of the gulf, particularly south of the Alaska Peninsula, but the gradual lowering of temperature from 5 - 4°C in an east-west direction around the gulf at 200 m, which is considered the seaward limit of the continental shelf, is fairly representative of actual conditions as far west as Kodiak Island. A grid of less than 1/2 x 1/2° would be required to show continuity of isotherms west of this area, and the paucity of data prevent this. Data obtained east of Kodiak Island in spring 1972 (Fig. 5) indicate characteristics of the distribution of 4-5°C water near 200 m in this area; and there are numerous examples of the continuity of this temperature-maximum stratum from the gulf westward out along the Aleutian Islands (e.g. Ingraham and Favorite, 1968) based on closely spaced station data from individual cruises.

At all levels from 200 to 2000 m the mean temperature distributions suggest a confluence of cold oceanic water entering the gulf in a northeasterly direction and warm water entering in a northwesterly direction. There is also a perturbation evident in isotherms in the eastern side of the gulf at 200, 500 and 1000 m that appears to suggest that flow related to the former has a blocking effect on flow related to the latter. These phenomena are discussed in later Sections on Water Properties and Currents.

Anomalies from monthly mean surface temperatures at shore stations around the gulf indicate that marked short-term deviations occur at indi-

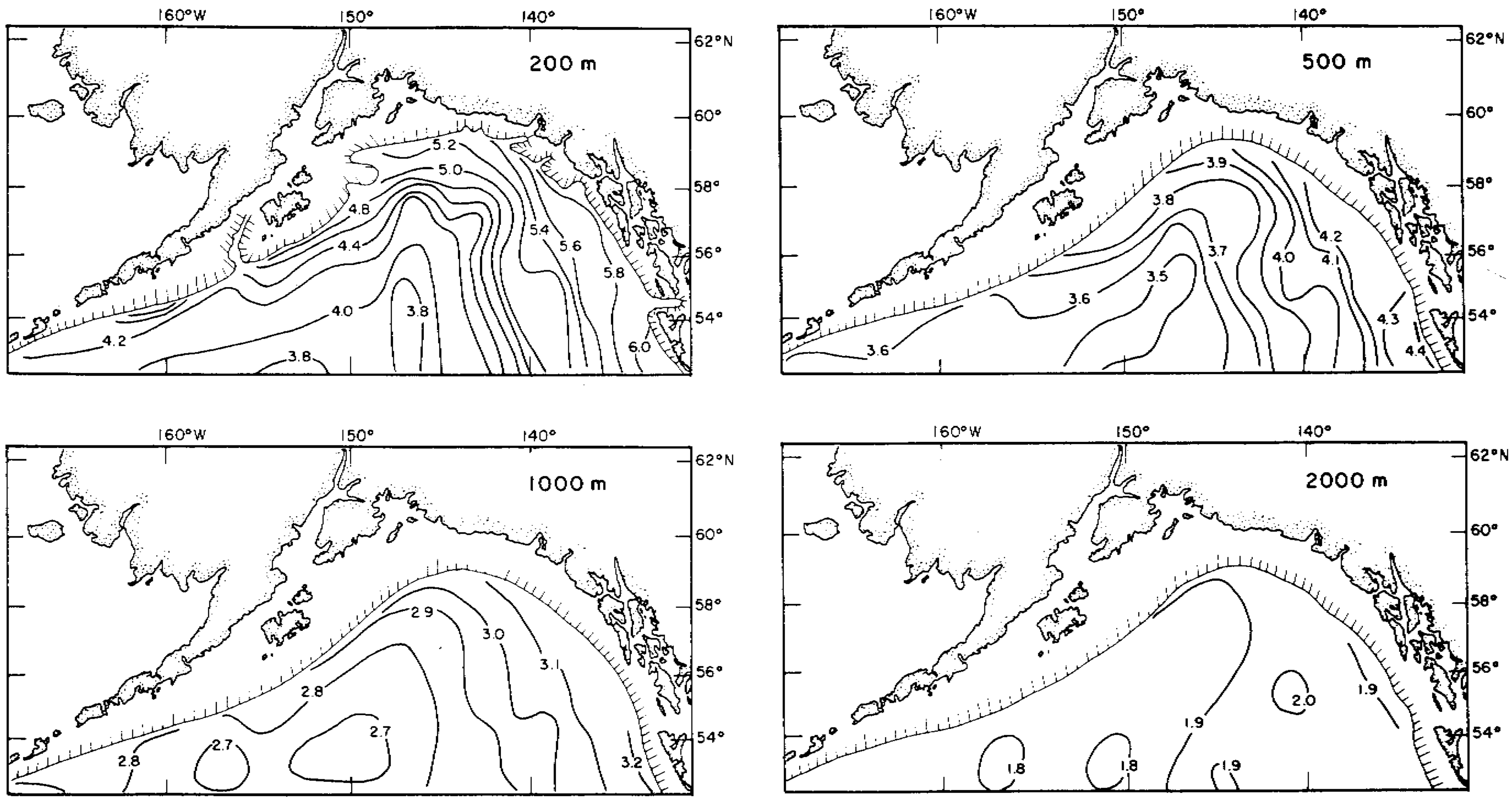


Figure 4. Long-term mean temperature distributions (based on 2x2° grid) at 200, 500, 1000 and 2000 m.

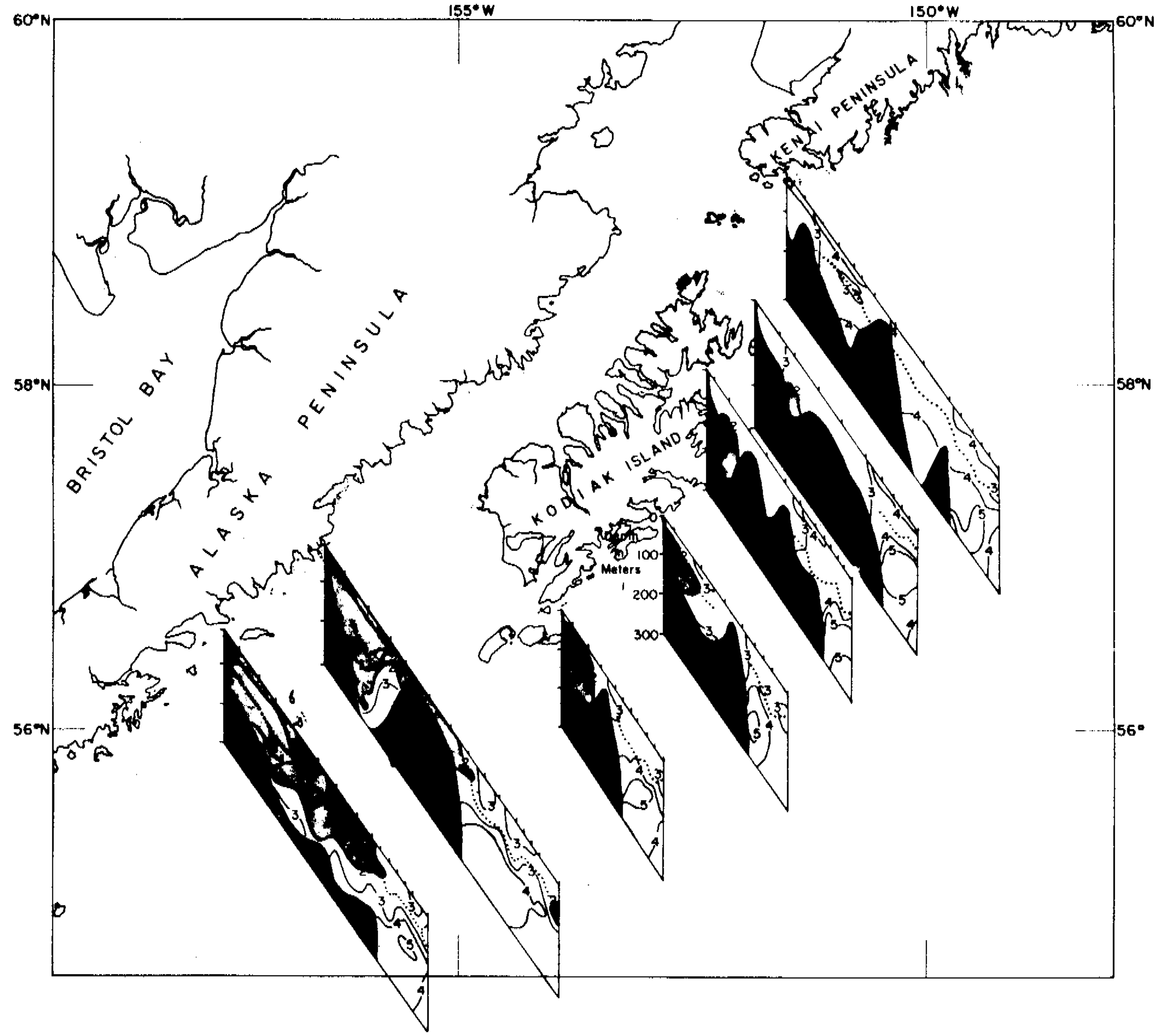


Figure 5. Vertical sections of temperature (°C) along lines of stations (RV George B. Kelez, April-May 1972 - Ticks indicate station locations) normal to the shelf edge indicating temperature-minimum stratum (dotted), and temperature-maximum (4-5°C) seaward of the shelf edge.

vidual stations that are not manifested at others. There is a similarity in the medium - term (1-3 years) trends, that is not apparent in the long-term trends (Fig. 6). For example, only at Dutch Harbor and Sitka is there evidence of a prolonged cooling period, 1958-73. The 12-month running mean clearly indicates cold periods centered around 1955 and 1972, and warm periods around 1958, 1963 and 1968. Similar trends in the oceanic area (5 x 5° Marsden quadrant 195-3; 55-60°N, 140-145°W) are evident (Fig. 7), and the transpacific occurrence of large areas of positive and negative anomalies at periods of 5-6 years has been pointed out by (Favorite and McLain, 1973). There are sufficient station data in offshore areas during the period 1955-1963 to indicate temperature changes that can occur at depth during cold and warm periods. Comparison of data in summer 1956 and 1958 indicates that values in the temperature-minimum stratum were over 1C° lower in 1956 over a wide area in the gulf (Fig. 8). Assuming winter convective overturn to 100 m, this represents a difference of 10,000 cal/cm^2 (of sea surface), a significant change in the heat content of the water column and the heat budget of the area.

Temperature anomalies in the water column are related also to advective processes. It is difficult to isolate the effects of winter turnover from advection in the upper 100 m or so, but at depths below seasonal influences there are secular changes that can be detected even with fragmentary data. Favorite (1975) has shown the apparent eastward intrusion of cold water from the west into the gulf indicated by the distribution of temperature on the salinity surface = 34.0 ^{0}/oo (which occurs at about 250 m) from 1955 to 1962. Any consideration of flow at depth in the gulf must take into

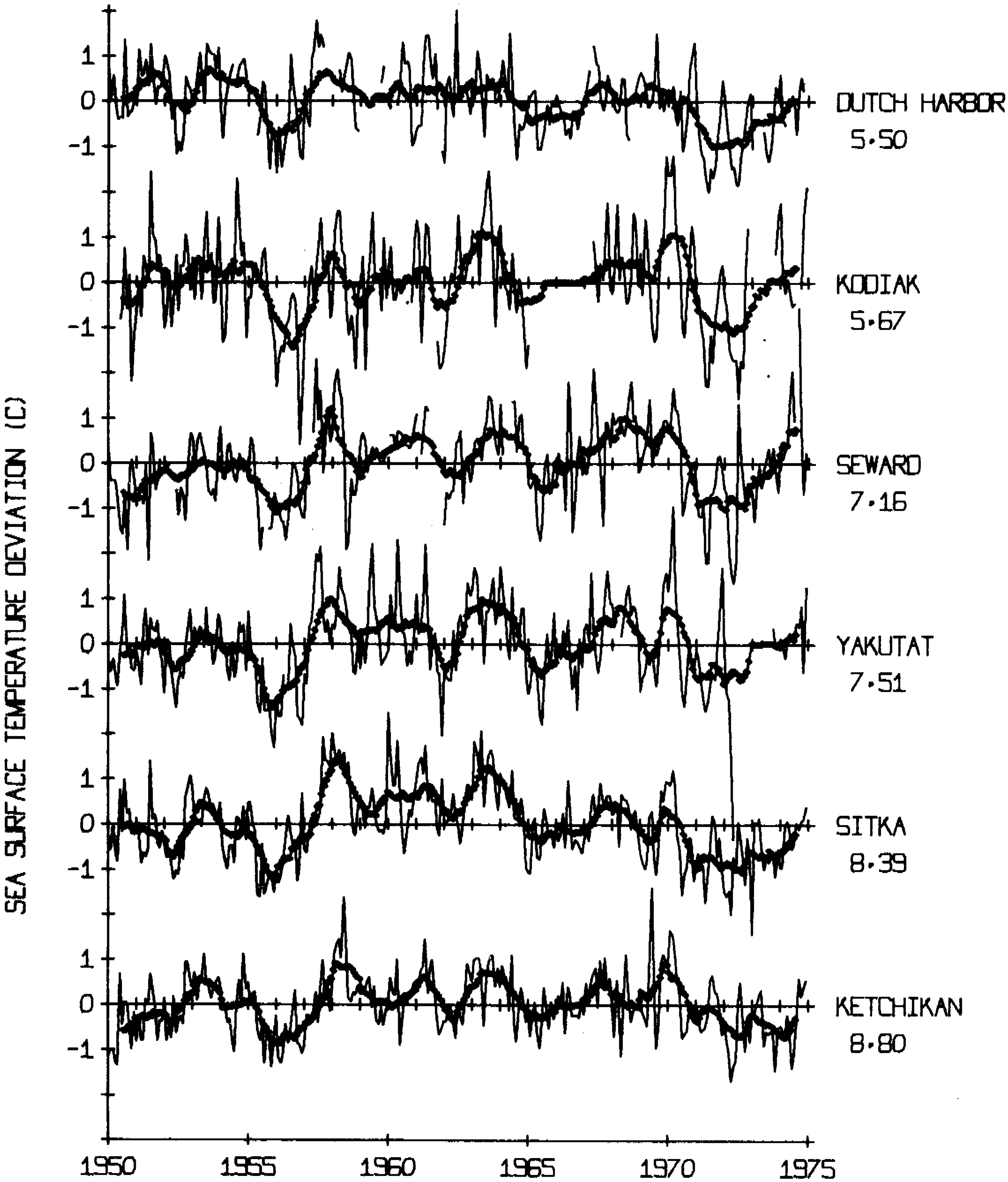


Figure 6. Deviations (C°) in sea surface temperature from monthly mean (1950-74) values at the indicated coastal stations; dotted segment indicates 12-month running mean.

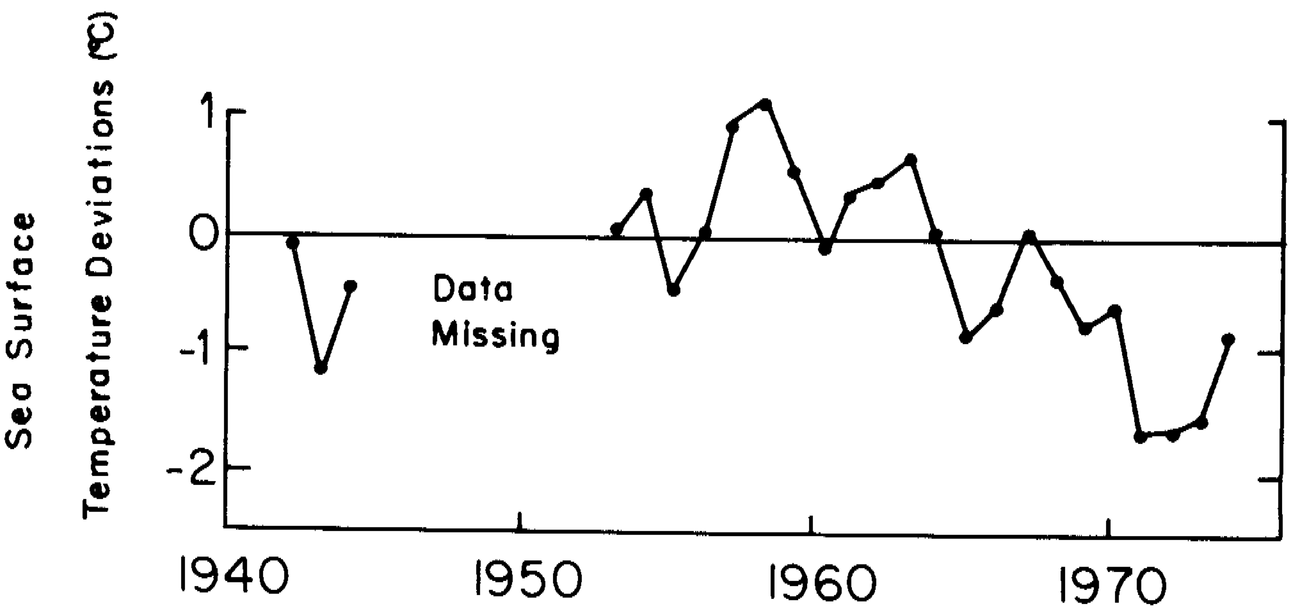


Figure 7. Deviations (C°) in sea surface temperature from annual mean (1948-67) values in 5x5° Marsden quadrant 195-3 (see Fig. 2) reflecting a cooling trend since 1958.

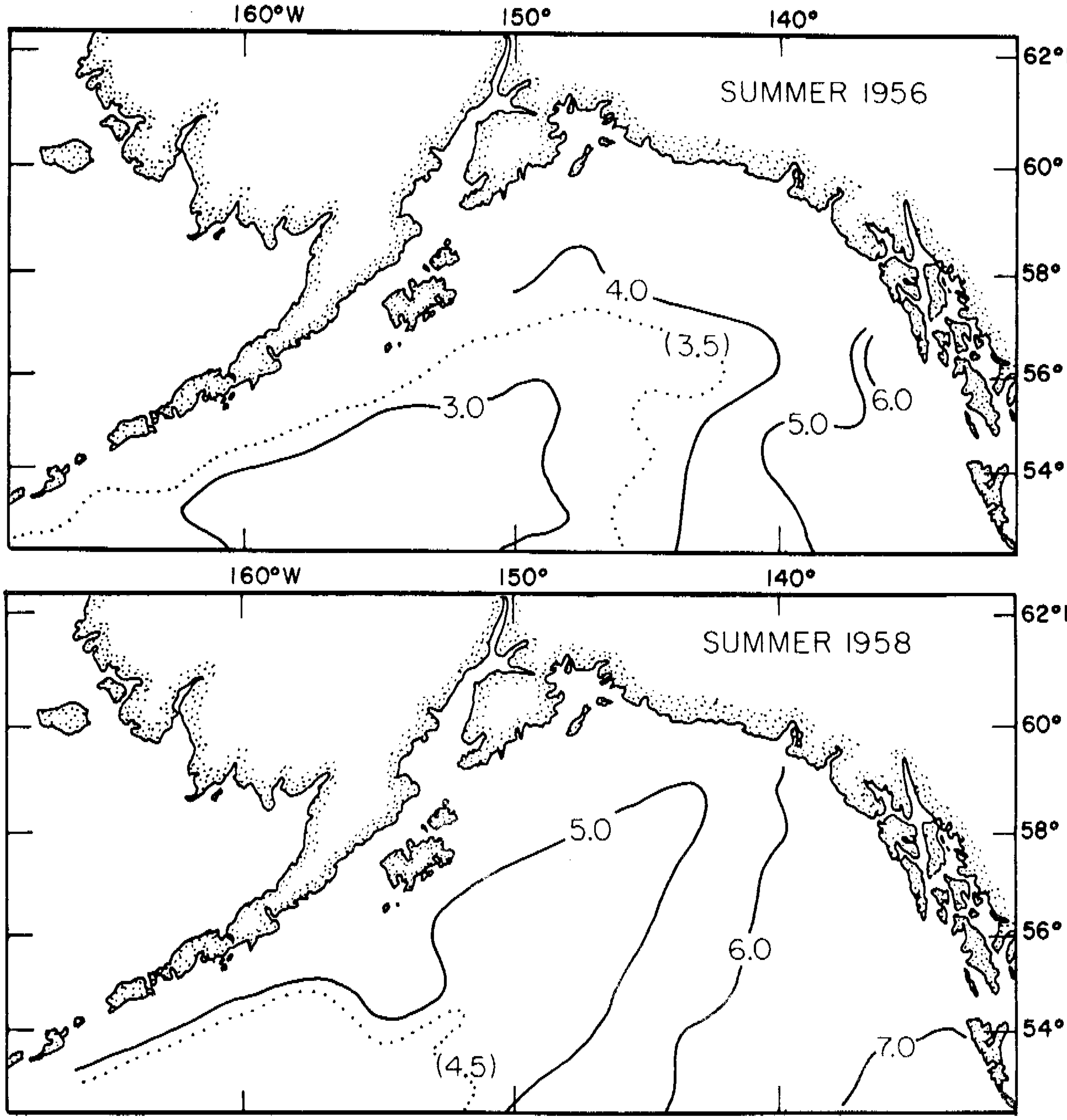


Figure 8. Temperatures (°C) in the subsurface temperature-minimum stratum (~75-125m) indicating much warmer conditions in summer 1958 compared to summer 1956 (from Dodimead et al, 1963).

consideration the fact that this anomalously cold water intruded nearly to the continental shelf in the eastern part of the gulf in 1961 (Fig. 9).

B. Salinity

Atlases depicting salinity distributions (e.g. Muromtsev, 1958; Barkley, 1968) provide limited information on actual conditions because of the paucity of these data. This is unfortunate because in many instances extensive salinity data, particularly near the surface, would provide more information concerning flow than temperature data. Because of a net excess of precipitation over evaporation (Jacobs, 1951) and extensive runoff, Tully and Barber (1960) have likened the oceanic regime to an estuarine system.

Although extensive runoff around the gulf in spring and summer dilutes coastal waters, this flow is difficult to quantify. Some clues as to the timing of this phenomenon are available from data on the monthly mean discharge from the Copper River, the dominant system in the area. Minimum discharge occurs from December to April; flow increases in May and reaches a maximum in July (Fig. 10). The effects of coastal runoff on offshore conditions is evident in station data averaged by season and 2 x 2° quadrangles (Fig. 11). Spring and summer data are the most complete but, although values as low as 16-18 $^{0}/oo$ occur in inshore areas, the 2 x 2° grid is too coarse to reflect precise inshore minima. Nevertheless, the seasonal offshore movement of coastal dilution is evident, specifically, the 32.0 $^{0}/oo$ isohaline, which moves offshore as much as 200 km in summer compared to its position in winter. Also evident is a region of high salinity in the southwestern part of the gulf reflecting vertical divergence.

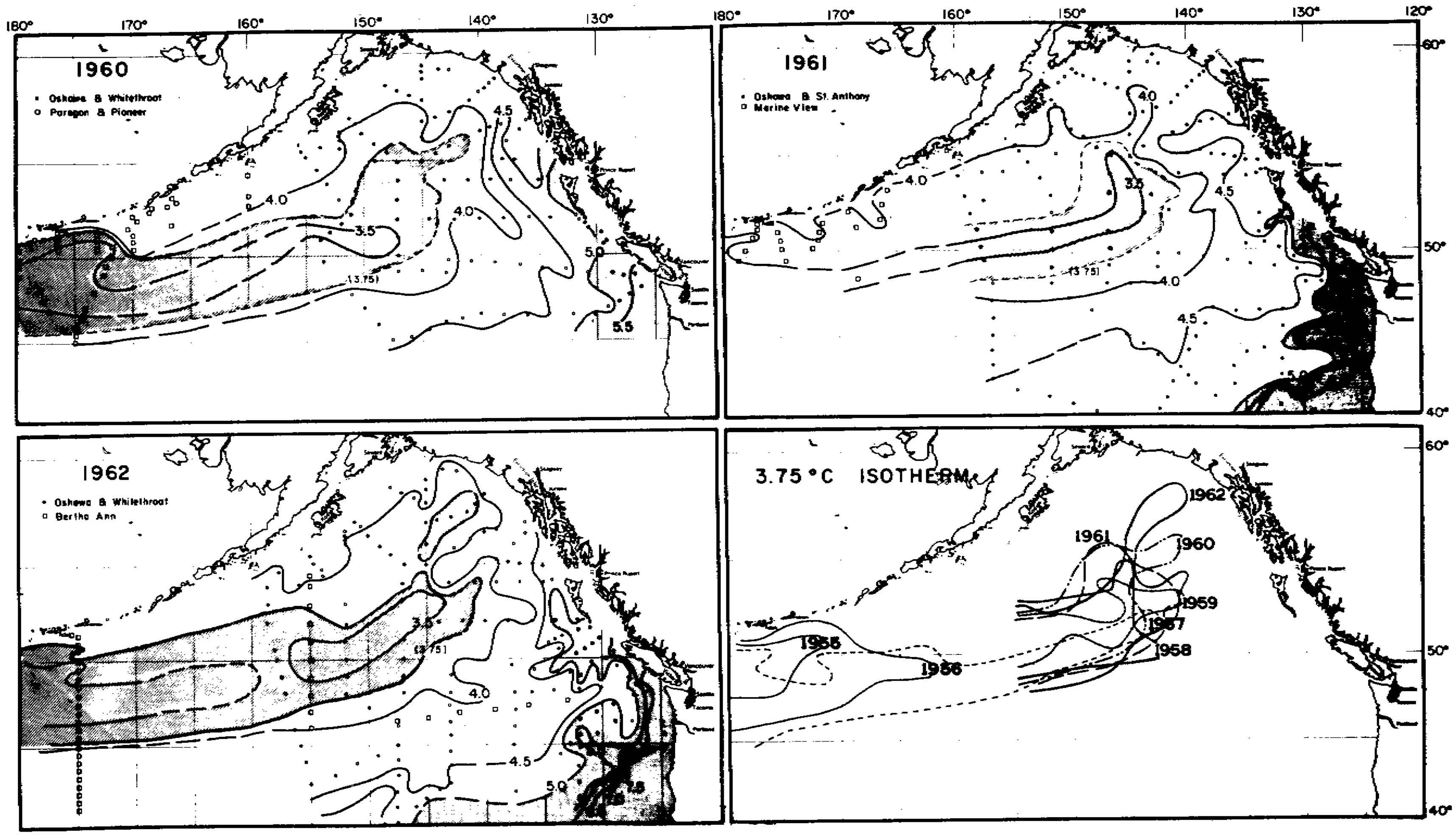


Figure 9. Temperatures (°C) on surface of salinity = 34.0 °/oo (~300m) in 1960, 61 and 62; and the configuration of the 3.75°C isotherm in 1955, 56, 57, 58, 59, 60, 61 and 1962.

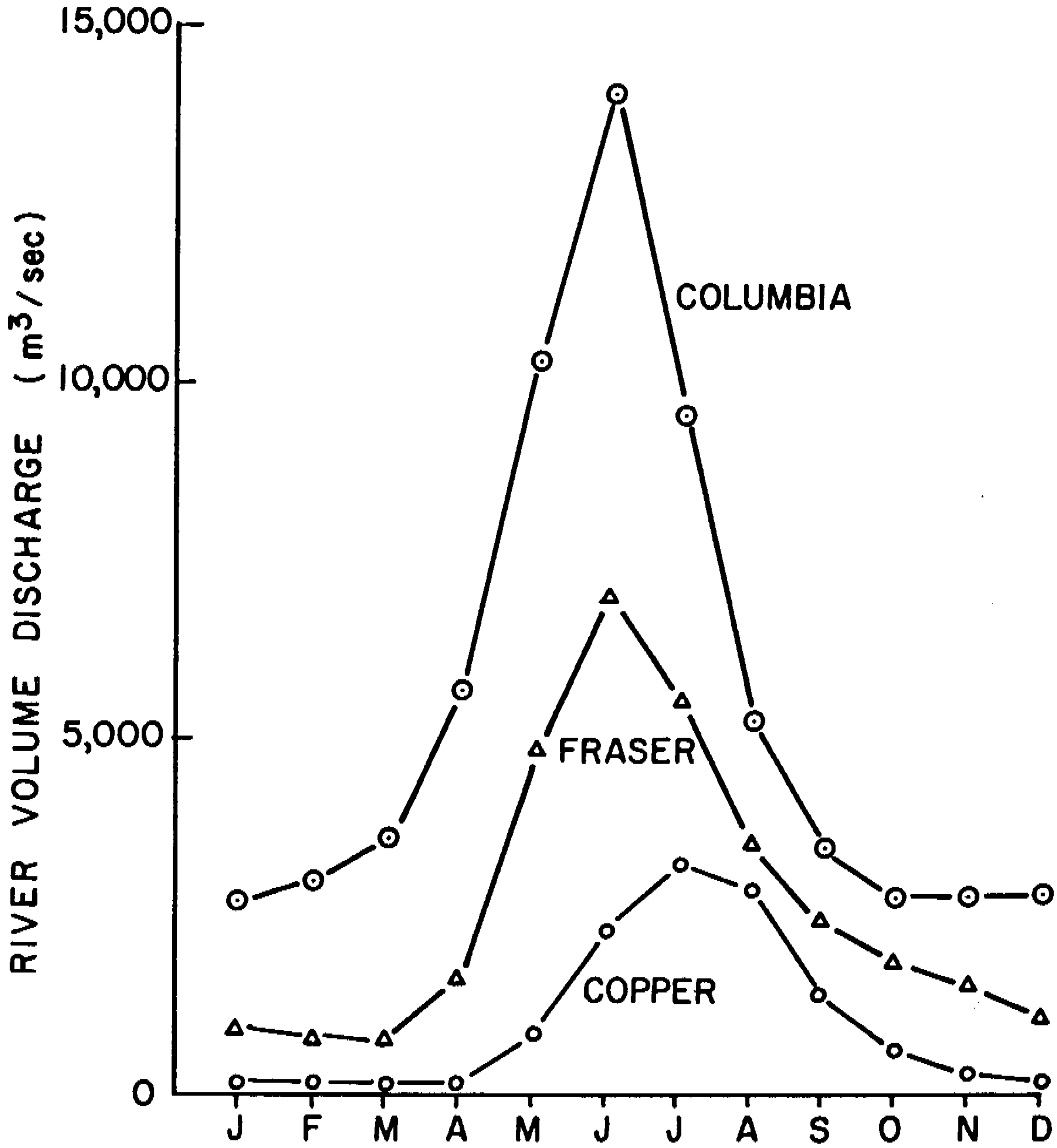


Figure 10. Monthly mean discharge (m^3/sec) from the Columbia, Fraser and Copper Rivers showing relative volume and month of peak runoff.

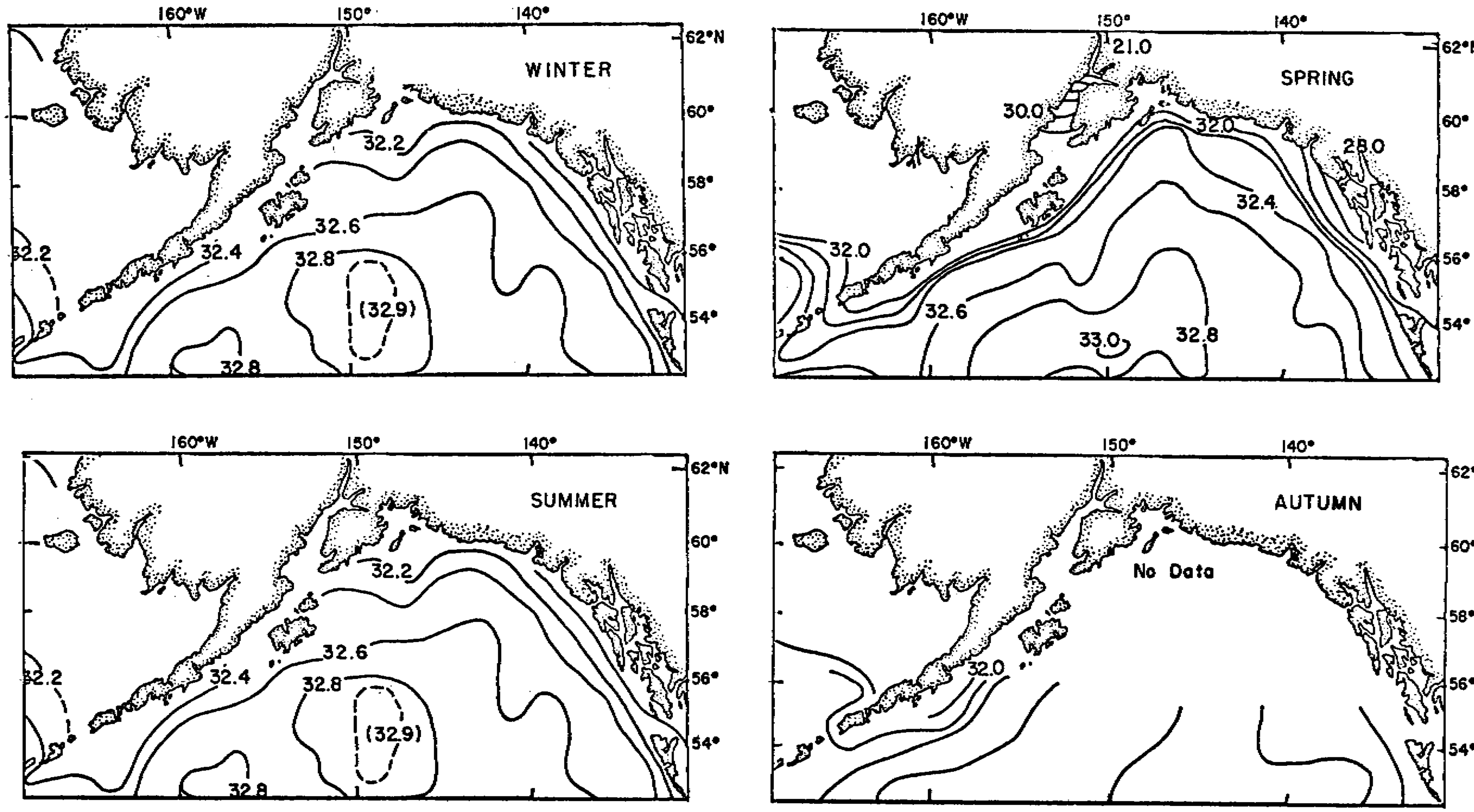


Figure 11. Long-term mean seasonal surface salinity distributions (based on a 2x2° grid) showing marked coastal dilution in summer and maximum values in southwest part of the gulf.

Maximum values (>33.0 ‰) in this area are evident in spring rather than as might be expected in winter, but this is believed due to limited data in the winter period.

Associated with the dilute surface layer is the marked halocline between 100-200 m (Fig. 12) evident in a vertical profile along 145°W. This feature gives a marked stability to the water column and greatly influences the vertical extent of winter convection and, thus, effects the vertical distribution of temperature and other water properties.

The salinity data are inadequate to show convincingly any anomalous salinity distributions in the gulf either in time or space. This does not mean that they do not occur. Considerable variability in the timing and volume discharge of coastal runoff takes place. An example of the variability possible is evident in the distributions of surface salinity off southeastern Alaska in summer 1957 and 1958 (Fig. 13). Considerable offshore dilution is evident in the 1958 distribution compared to that in 1957. However, the distributions represent mean fields over 3 month periods constructed from various data points, and it is difficult to ascertain which, if either, represents average or anomalous conditions.

There has always been speculation as to the existence of a frontal zone at the edge of the continental shelf indicating not only boundary processes such as shelf waves, but a simple separation of dilute coastal from saline oceanic water. Data from a continuously recording surface salinograph (Fig. 14) obtained during numerous transects of a short line of stations normal to the shelf edge eastward of Kodiak Island in spring 1972 (Favorite and Ingraham, 1976a) prove the existence of such a frontal

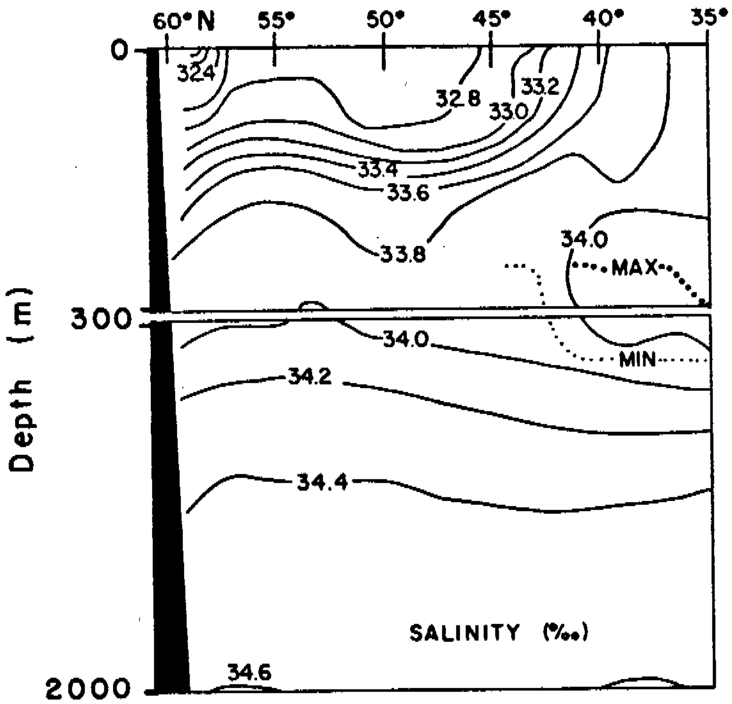


Figure 12. Vertical section of long-term mean salinities (based on 2x2° grid) along 145°W showing: the dilute surface layer north of 45°N, particularly near 60°N; the ridging or doming of isolines at 55°N; and, the halocline between 100-200 m.

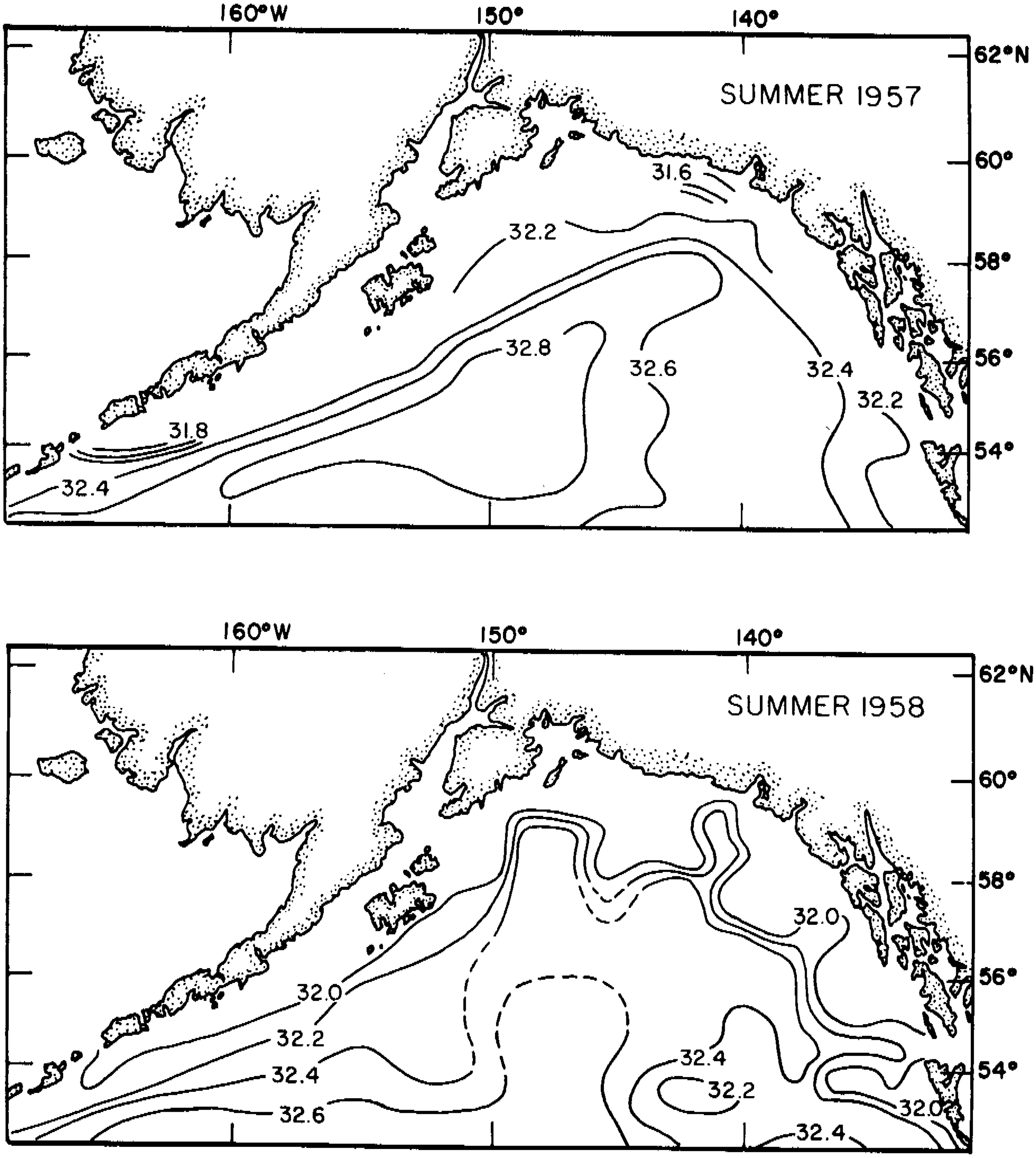


Figure 13. Surface salinity during summer 1957 and 1958 showing the extensive dilution off southeastern Alaska in the latter period reflecting the highly variable conditions that can occur in the surface layer (from Dodimead et al, 1963).

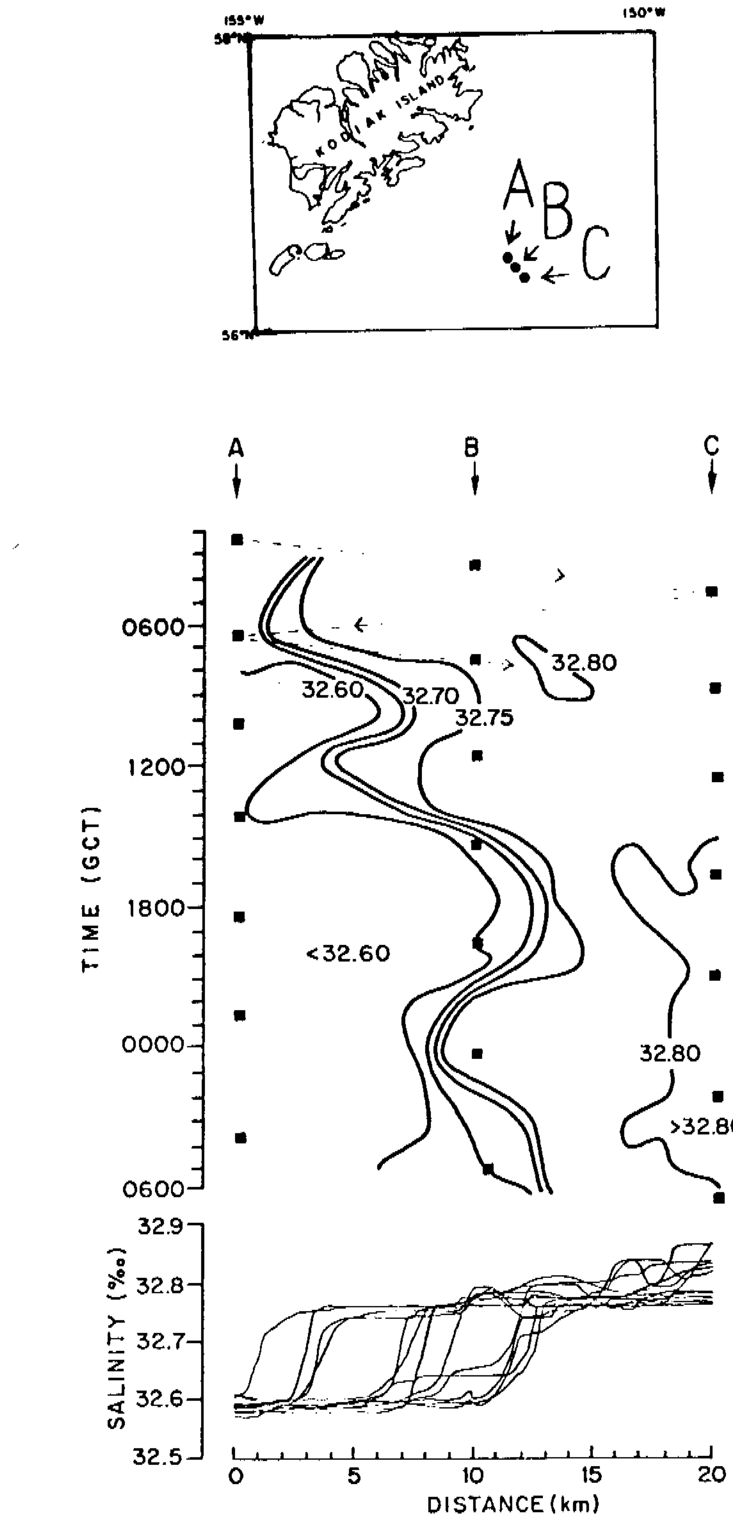


Figure 14. Surface salinity front detected seaward of Kodiak Island in the vicinity of the edge of the continental shelf (RV George B. Kelez, May 5-6, 1972) using constantly recording salinograph while occupying repetitive stations: A, B, C (dashed lines indicate vessel movement).

zone. Salinity distributions at 200, 500, 1000 and 2000 m (Fig. 15) reflect primarily the presence of the surface divergence in the offshore portion of the western gulf and the suggestion of cyclonic circulation found in the temperature distributions. There is also an obvious area of dilution off Cape Spencer in the 200 m temperature field.

C. Water Masses

All oceanic waters attain marked characteristics when they are in contact with the atmosphere and these characteristics are subsequently altered by lateral and vertical mixing. When discrete temperature and corresponding salinity values of a water parcel below the depth of seasonal influences are plotted against each other a well-defined temperature-salinity (T-S) curve results that is characteristic of a given area and defines a water mass (Sverdrup, Johnson and Fleming, 1942). Such a curve defines the Subarctic Water Mass, characteristic of the area lying generally north of 50°N in the eastern North Pacific Ocean.

The low temperatures and salinities that distinctly define this curve are due in part to the waters moving eastward at depth from the Okhotsk Sea, a general vertical movement of intermediate water due to the Ekman divergence at the surface, and an undetermined northward transport of deep water in the Pacific basin that is deflected upward in this area by the land boundaries in the gulf and the Aleutian-Commander island arc. Modifications to this basic T-S curve are caused by a northward flow of warm water on the eastern side of the gulf that originates not only from eastward flow south of 50°N, but also from northward flow in the California Undercurrent. The latter is manifested at the surface in winter, but is overridden at the surface in summer by a southward flow stemming from the southern branch of the easterly onshore flow.

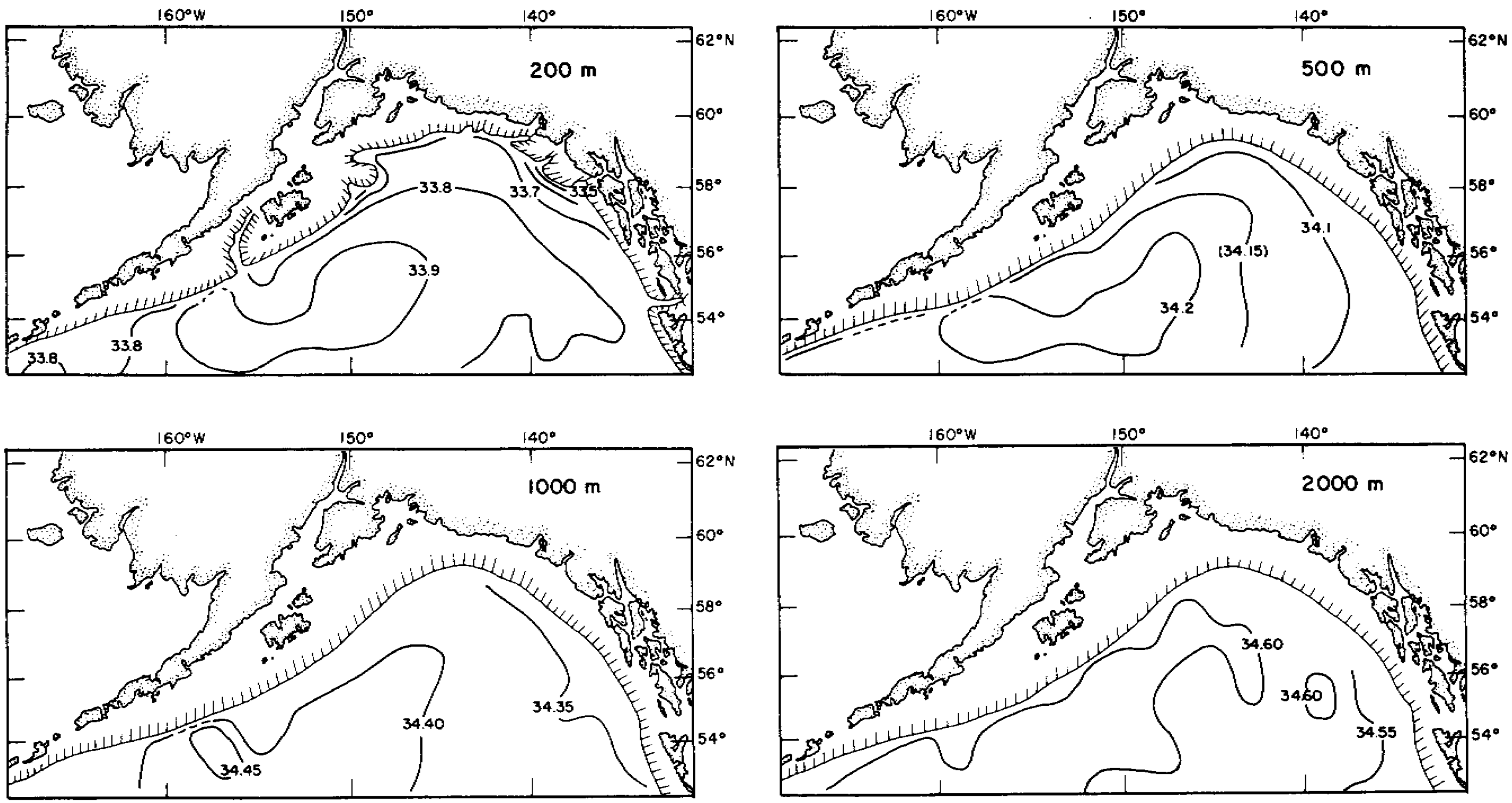


Figure 15. Long-term mean salinity distributions (based on 2x2° grid) at 200, 500, 1000 and 2000 m.

Monthly mean, as well as maximum and minimum, values of temperature and salinity at standard depths were computed from all station data by 2 x 2° quadrangles and are presented in the form of T-S curves at 4 selected locations at which winter and summer data were available (Figs. 16 and 17). Because of the paucity of data, in some instances only 3 stations, the curves and extreme values must be considered as only indicative of conditions rather than representing precise values and ranges. The water mass at the head of the gulf (area A) is formed from the merging of three major water masses moving northward into the gulf. In general, all have equivalent surface temperatures during the periods of maximum heating (summer, 13-14°C) and cooling (winter, 4-5°C), except in area B where winter temperatures of 3°C are evident, and there is a noticeable decrease in surface salinity shoreward from areas B to D, the greatest dilution occurring in area A. The elimination in winter of the temperature gradient, or thermocline, evident in the upper 50-75 m of the water column during summer is readily apparent in all areas. There are marked differences in temperatures from 100 and 300 m, about 3C°, between areas B and D; conditions at these depths in areas C and A reflect an admixture of the water masses in areas B and D, although the temperature maximum between 150 and 250 m is maintained. There is also a suggestion of a downward diffusion of summer heating below 125 m during winter. Below 300 m the T-S curves in areas A, B and C are similar and follow the trend of the general Subarctic Water Mass curve, however, there is a significant departure from this curve in area D attributed to northward flow along the coast. As might be expected, variability in temperature and salinity conditions is largely

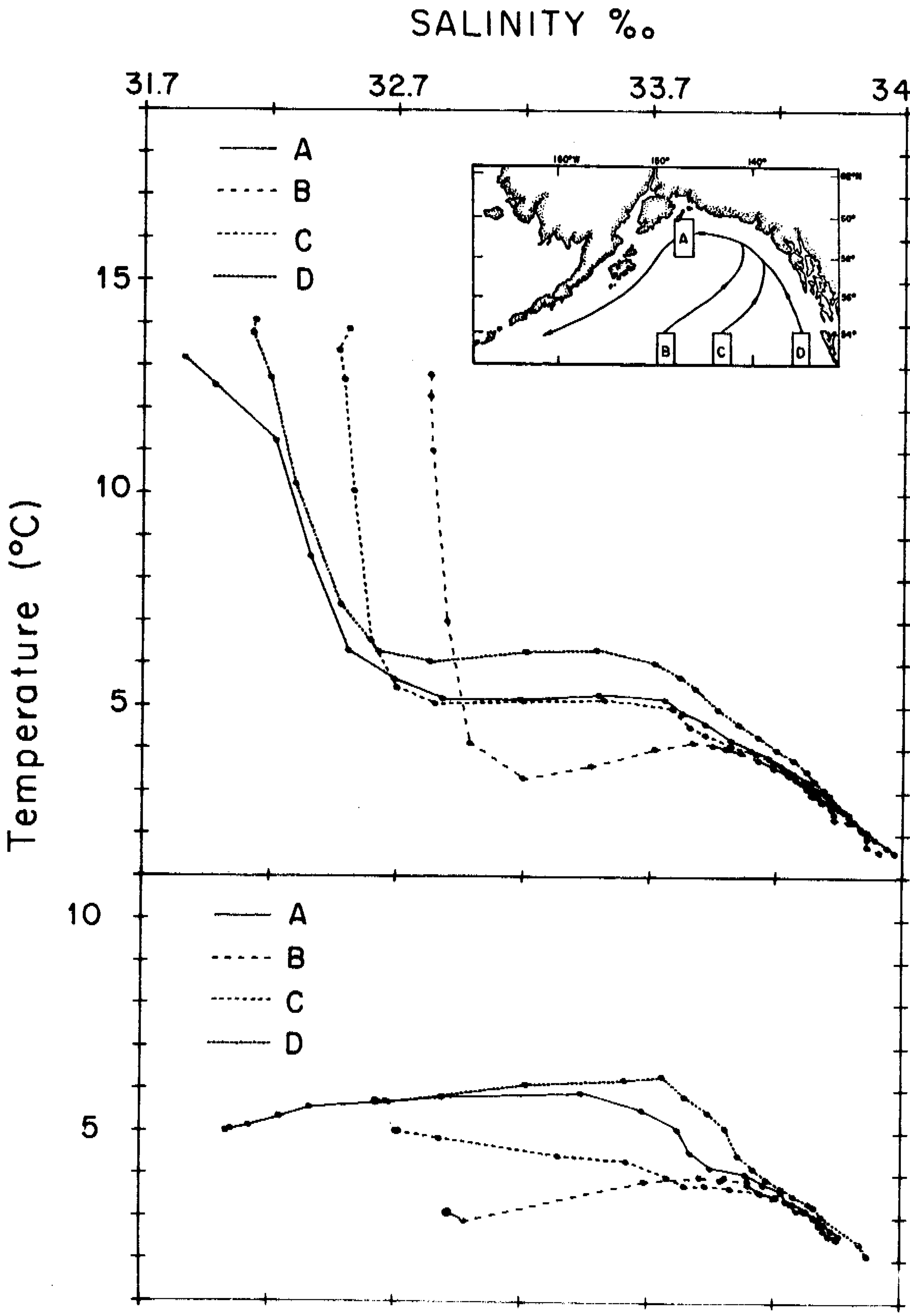


Figure 16. Long-term summer and winter mean temperature-salinity (T-S) relations at standard depths in the indicated 2x2° guadrangles showing characteristics of the various water masses funneling into the gulf.

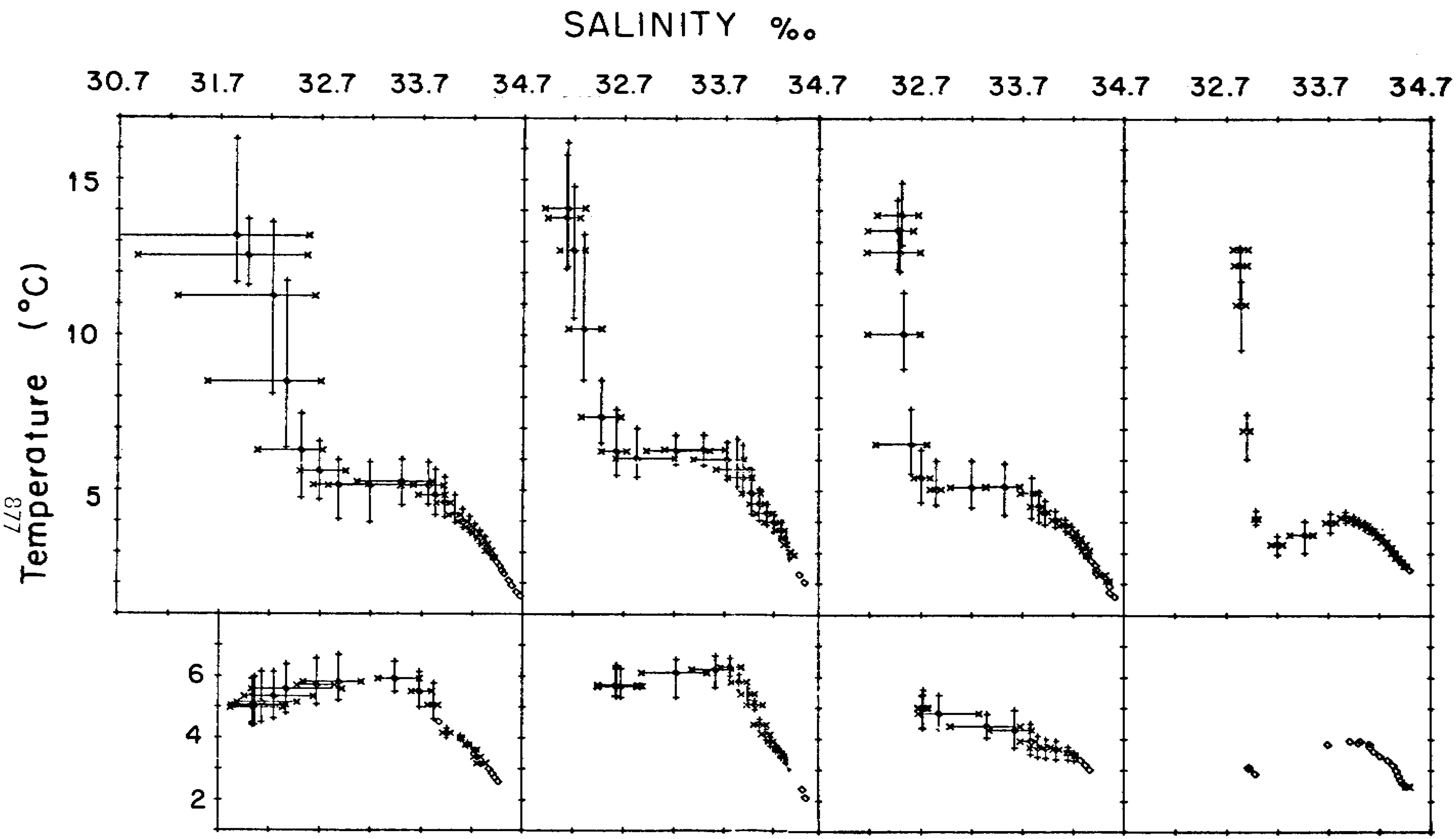


Figure 17. Maximum and minimum temperature-salinity (T-S) values at standard depths for the T-S curves shown in Figure 16.

limited to the upper 300 m of the water column and the greatest ranges occur in area A, primarily because that 2 x 2° quadrangle encompasses part of the continental shelf and is subjected to coastal runoff. Obviously conditions at the head of the gulf are dependent upon the relative components of flow in these three water masses.

III. CURRENTS

Bering, Chirikof, Cook, Clerke, Portlock, Dixon and countless other early explorers of the coastline around the gulf encountered the treacherous winds and coastal currents that exist in the area, and such information reported by mariners is constantly updated in the Alaska Coast Pilots. There are also early papers that synthesize this information. Wild (1877) presented a Current Chart of the Ocean that showed northward flow into the gulf stemming from a bifurcation of eastward onshore flow into northward and southward trending branches that occurred well seaward of Vancouver Island. Dall (1899) reported that the zone of separation was just seaward of Vancouver Island. Schultz (1911) indicated that only in summer did the separation occur at this latitude; during winter it occurred off the California coast near 41°N. Such schemes were largely based on sporadic reports and data from ship's logs, but the absence in the gulf of extensive commercial vessel traffic, whose daily observations of set and drift have provided an extensive historical data base on circulation in other areas, has resulted in a paucity of specific information concerning flow. Drift bottle studies provide information concerning gross circulation patterns, however, only the release and recovery points are known and actual trajectories are subject to various interpretations. The computation of geostrophic currents in which the relative field of currents is derived from the observed field of mass in the ocean, provides an indirect method of estimating oceanic flow. This method has several shortcomings and requires extensive synoptic observations at sea which are not possible to obtain from present platforms. Nevertheless, this method permits the calculation of relative currents and transports that provide considerable insight into oceanic flow throughout the area observations are made. No significant direct current measurements have been made in offshore waters of the gulf prior to OCSEAP studies. However, measurements off the west coast of Vancouver Island where a similar climate occurs reveals interesting patterns of onshore and offshore flow that are probably duplicated in gulf waters (Dodimead et al. 1963).

A. Drift Studies

Long before planned drift bottle or drift float programs were instigated, the presence of debris from Japanese fishing operations and remnants of California redwood trees on the southeast Alaskan coast signaled two widely differing sources of water flowing into the gulf. Although there have been a number of recoveries of bottles or floats from a variety of experiments, there are several studies that provide most of the basic information that can be deduced by such studies.

The first extensive study was conducted by the International Fisheries Commission, (IFC)--predecessor to the International Pacific Halibut Commission (Fig. 18); over 4,000 bottles were released from 1930-34 (Thompson and Van Cleve, 1936). Those released along an east-west line across the gulf from Baranof to Kodiak Island and at several locations inshore along the Alaska Peninsula in spring 1930 indicated a broad northward flow into the head of the gulf, with recoveries only at Cape St. Elias and Cook Inlet, and a southwestward drift along the Alaska peninsula and through Unimak Pass. Releases just east of Kodiak Island were recovered only along the southern coast of the island and on the Alaska peninsula to the west and north of the island; releases from three locations inshore along the Alaska Peninsula indicated a southwestward drift along the coast. Releases off the west coast of the

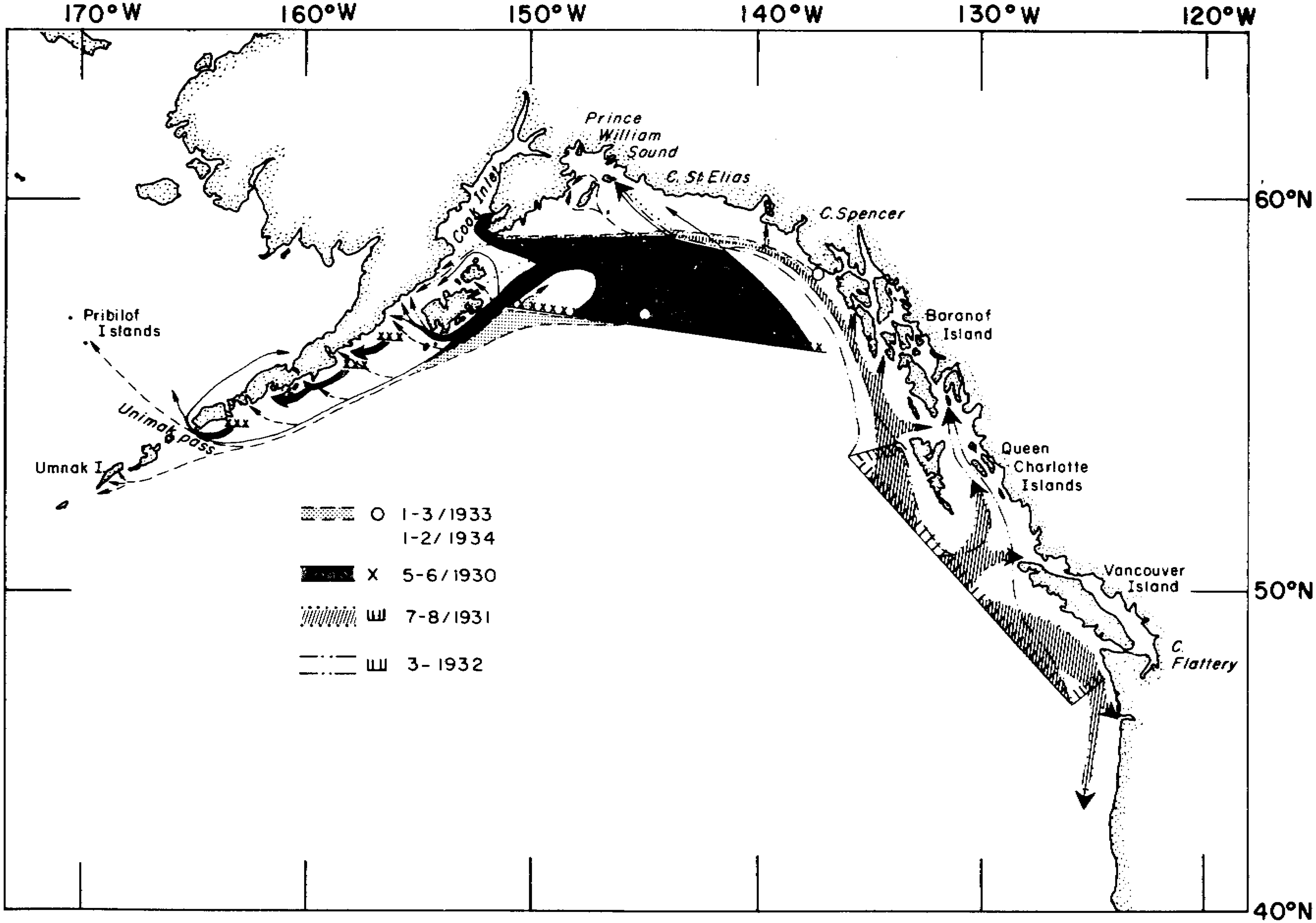


Figure 18. Schematic diagram of significant results of drift bottle studies conducted by the International Fisheries Commission (IFC) 1930-34 (adapted from Thompson and Van Cleve, 1936).

Queen Charlotte and Vancouver Islands in summer 1931 indicated a marked bifurcation of onshore flow at the northern end of Vancouver Island. Two bottles in the northern component of flow were recovered near Cape Spencer and one on Kodiak Island. In a similar experiment in spring 1932, except for one recovery at Cape Flattery (directly east of the release point), all recoveries were made northward of the release points, at various locations around the gulf. The western most recovery was made in Shelikof Strait and numerous recoveries were made in Prince William Sound where none was recovered in the 1930 and 1931 experiments. Releases north of 50°30'N and recovered north of 57°N were estimated to travel 9.4 miles per day. In winter 1933 and 1934, releases just north of Cape Spencer were recovered in Prince William Sound, along the west coast of the gulf, and on the Pribilof and Umnak Islands. These studies reflected a southward shift in winter of the zone of separation of the onshore flow off Vancouver Island that had been indicated earlier (Schutz, 1911). The northward branch, which moves cyclonically around the gulf, had a general drift of about 20 cm/sec and an inherent onshore component. Although a large cyclonic gyre encompassing the entire gulf at the latitude of Kodiak Island was inferred, there is no evidence other than delays between release and recovery to justify such a conclusion. The authors noted that, although westerly flow was predominant, at the head of the gulf, the currents were not regular or constant.

A subsequent experiment was conducted by the Pacific Oceanographic Group (POG), Nanaimo, from August 1956 to August 1959 (Dodimead and Hollister, 1962). Forty-two releases (33,869 bottles) were made from Ocean Station "P" (50°N, 145°W) and surrounding locations. Twenty-three of the releases were made at Ocean Station "P" at approximately 6-week intervals and these indicated a fairly complicated pattern in drift currents between the station and the North American coast. For example, of 998 bottles released on August 25, 1956 only one of the 114 recoveries was made north of Ketchikan and it was made on Middleton Island; whereas of 1,008 bottles released on August 24, 1957, all of the 39 recoveries were made at or west of Middleton Island. Of particular interest to the present study are the 5 releases north of Ocean Station "P", especially the 2 that were made north of 55°N. At the 3 locations south of 55°N between 155 and 160°W, an esterly set was indicated, recoveries being made throughout the head of the gulf. However, recoveries from the two releases north of 55°N (approx. 142°W) made on February 17, 1957 and August 17, 1957 were made only at the western side. Perhaps of more significance is that recoveries from the winter release (Fig. 19) were recovered as far north as the Pribilof Islands, as far west in the Aleutian area as Amchitka Island, as far east as the Washington-Oregon-California coast, and as far south as the Hawaiian Islands and Wake Islands--a tremendous dispersal that requires considerable thought when one contemplates possible oil pollution in the head of the gulf and the subsequent formation of floating tar balls.

Whereas the IFC studies were concerned with coastal drift [5/] and the POG studies largely with onshore drift from discrete offshore locations, the studies conducted by the National Marine Fisheries Service Northwest Fisheries Center (formerly Bureau of Commercial Fisheries Biological Laboratory) extended over a large area of the northern North Pacific Ocean.

5/ See Ingraham and Hastings (1974) for results of seabed drifter study off Kodiak Island in May 1972.

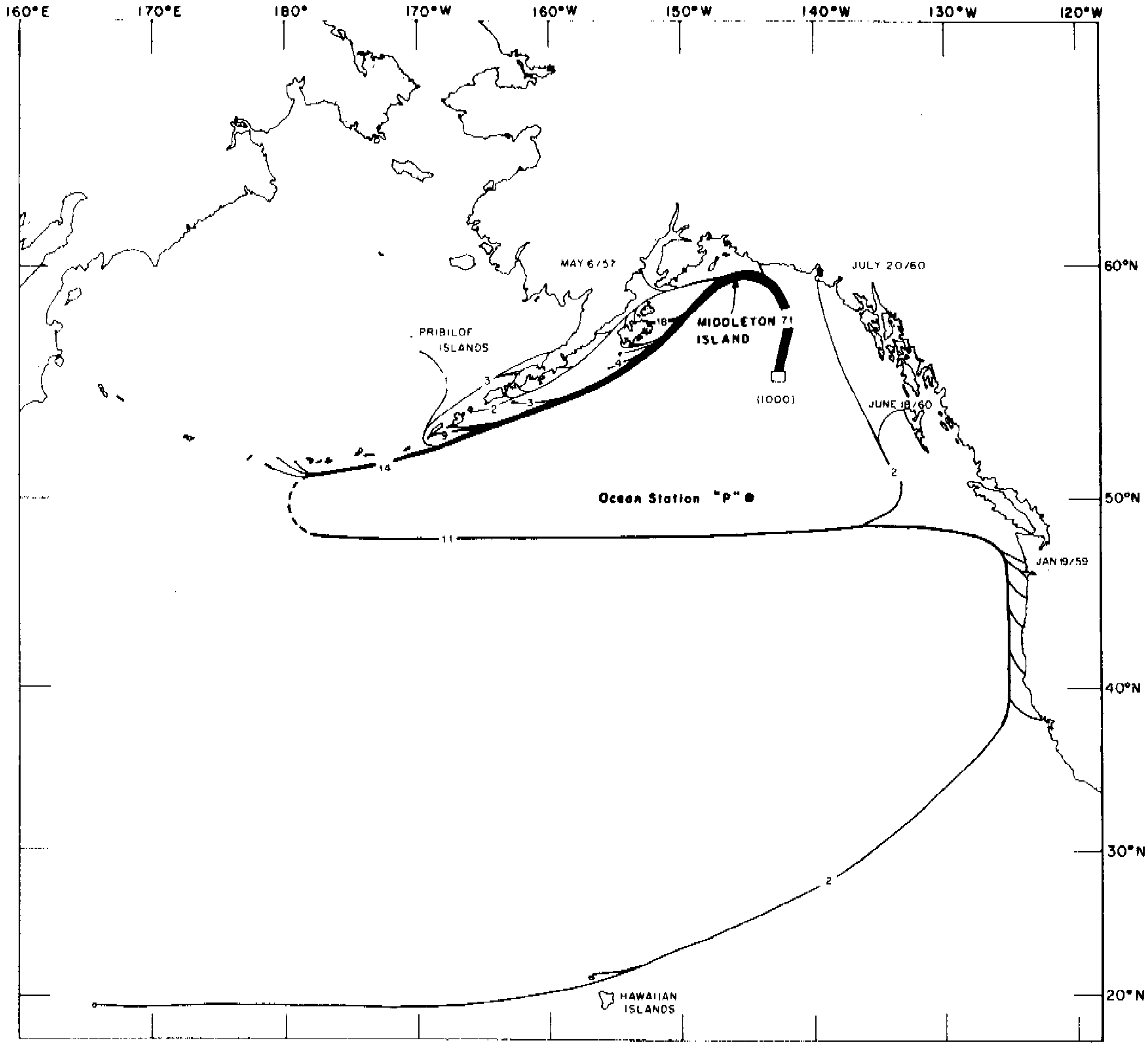


Figure 19. Release and recovery locations of drift bottles released by the Pacific Oceanographic Group (Nanaimo) in February 1957 showing the wide dispersal to the Bering Sea, the Aleutian Islands, Washington-Oregon-California coast, the Hawaiian Islands and Wake Island (from Dodimead and Hollister, 1962).

The two experiments that pertain to flow in the gulf were conducted in 1962 (Favorite, 1964) and in 1964 (Fisk, 1971); releases made along extended north-south and east-west cruise tracks (Fig. 20) indicated the broad north-south oceanic boundaries of eastward surface flow that moves directly into the gulf or toward the coasts of British Columbia, Washington, and Oregon where, in winter, a northward flow surfaces along the coast (Reid, Roden and Wyllie, 1958; Burt and Wyatt, 1964; and others).

B. Geostrophic Flow

The geostrophic (dynamic) method has been thoroughly described and evaluated (e.g. Fomin, 1964); basically, the method, which requires a balance between Coriolis and pressure gradient forces permits the computation of current relative to that at an arbitrary and perhaps fictional depth, selected in the belief that it is deep enough for isopleths of density and pressure to be parallel and thus a depth or level at which no motion exists (a zero reference level); no accelerations or physical boundaries are permitted. Fleming (1955) has presented a chart showing the locations in the northern North Pacific Ocean where the oceanographic station data required by his method had been obtained prior to 1955, and Dodimead et al (1963) showed station locations from 1955-59, as well as winter and summer fields of geopotential topography. McEwen, Thompson and Van Cleve (1930) and Thompson, McEwen and Van Cleve (1936) were the first to use this method in the Gulf of Alaska and found a westward flow in excess of 50 cm/sec at the edge of the continental shelf. The complexity of geostrophic flow in this area was evident in the closely spaced station data obtained by Doe (1955). Roden (1969) and Thomson (1972) have contributed to present knowledge of flow around the gulf.

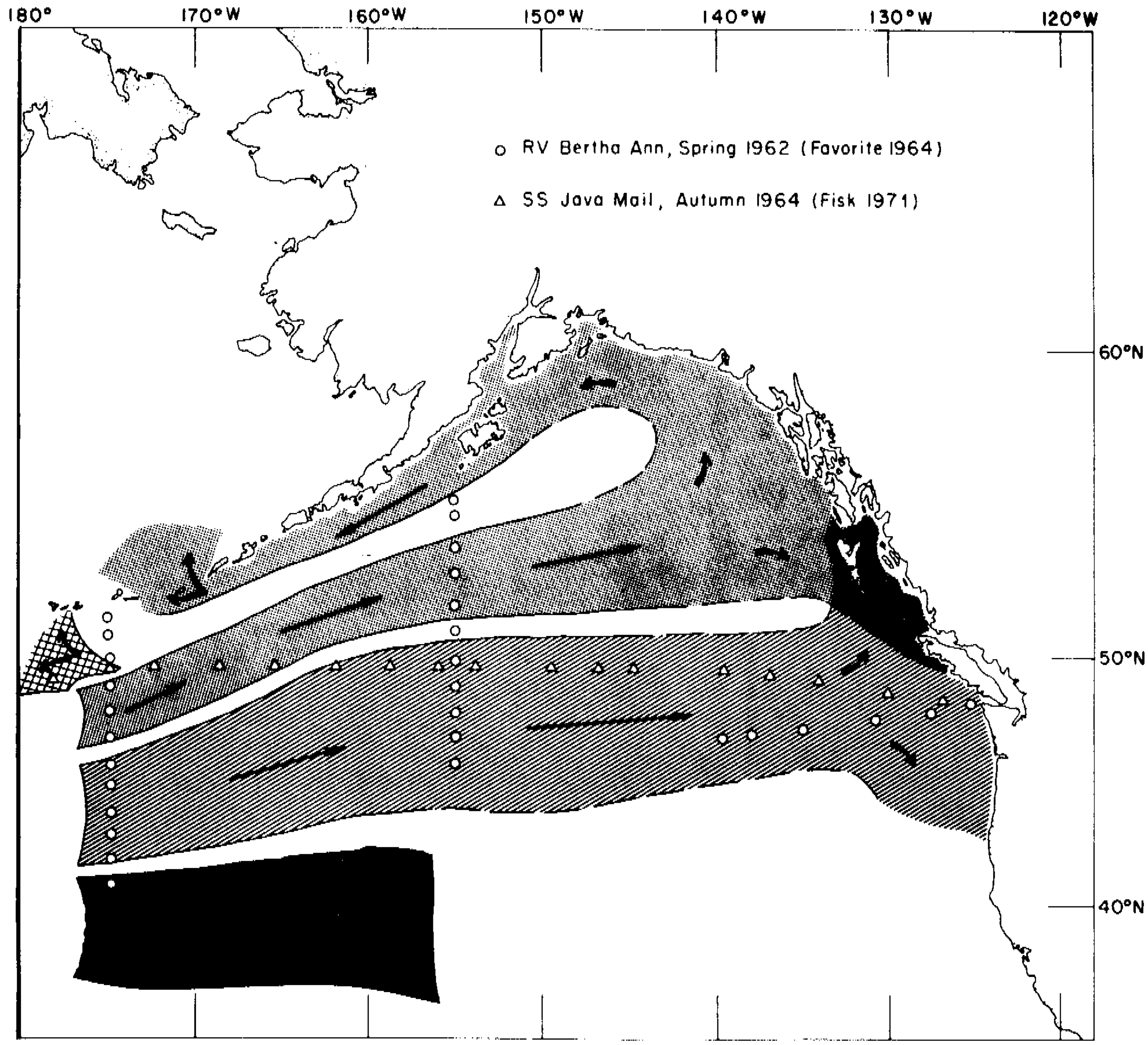


Figure 20. Schematic diagram of results of drift bottle studies by the Northwest Fisheries Center (Seattle) in 1962 and 1964 showing the general nature of easterly onshore drift.

The locations of all oceanographic station data on file at NODC (prior to OCSEAP studies) and used in this report are shown in Figure 21. Current speeds normal to a line between two oceanographic stations are obtained by the Sandstrom Helland-Hansen equation:

$$V = \frac{10}{f\Delta x} \left[\int_0^D \delta_1 \, dp - \int_0^D \delta_2 \, dp \right] \qquad (1)$$

where D is the accepted depth-of-no-motion expressed in decibars; δ, the geopotential anomaly; x, distance between stations; f, Coriolis acceleration; and, p, pressure.

Computations of geopotential anomalies at all stations were averaged by 2 x 2° quadrangles to obtain long-term means and seasonal (winter, spring, summer and autumn) means for the depth intervals 0/300 db, considered to be the layer of seasonal influence, and 0/2000 db, where 2000 db is considered to represent a level-of-no-motion. Mean values over such large areas (over 20,000 km) cannot be expected to reflect boundary currents over the narrow continental slope but general circulation patterns are evident. Data for winter, spring and summer are sparse, from 1 to 30 or more observations per quadrangle, with an average of about 10; data for autumn are only 20% available. At Ocean Station "P", observations are more numerous and provide at least a qualitative check on surrounding data. For example, in the mean summer data there are 112 observations at the quadrangle associated with Ocean Station "P"; mean value 0.53 dyn cm; although there are only 11 observations in the quadrangle to the west, and 10 in the quadrangle to the east, the mean values are 0.52 and 0.53 dyn cm respectively.

The seasonal mean fields of geopotential topography for the depth interval 0/300 db (Fig. 22) are quite similar. The longitude of the topographic low, 149°W is the same for all seasons but the latitude shifts

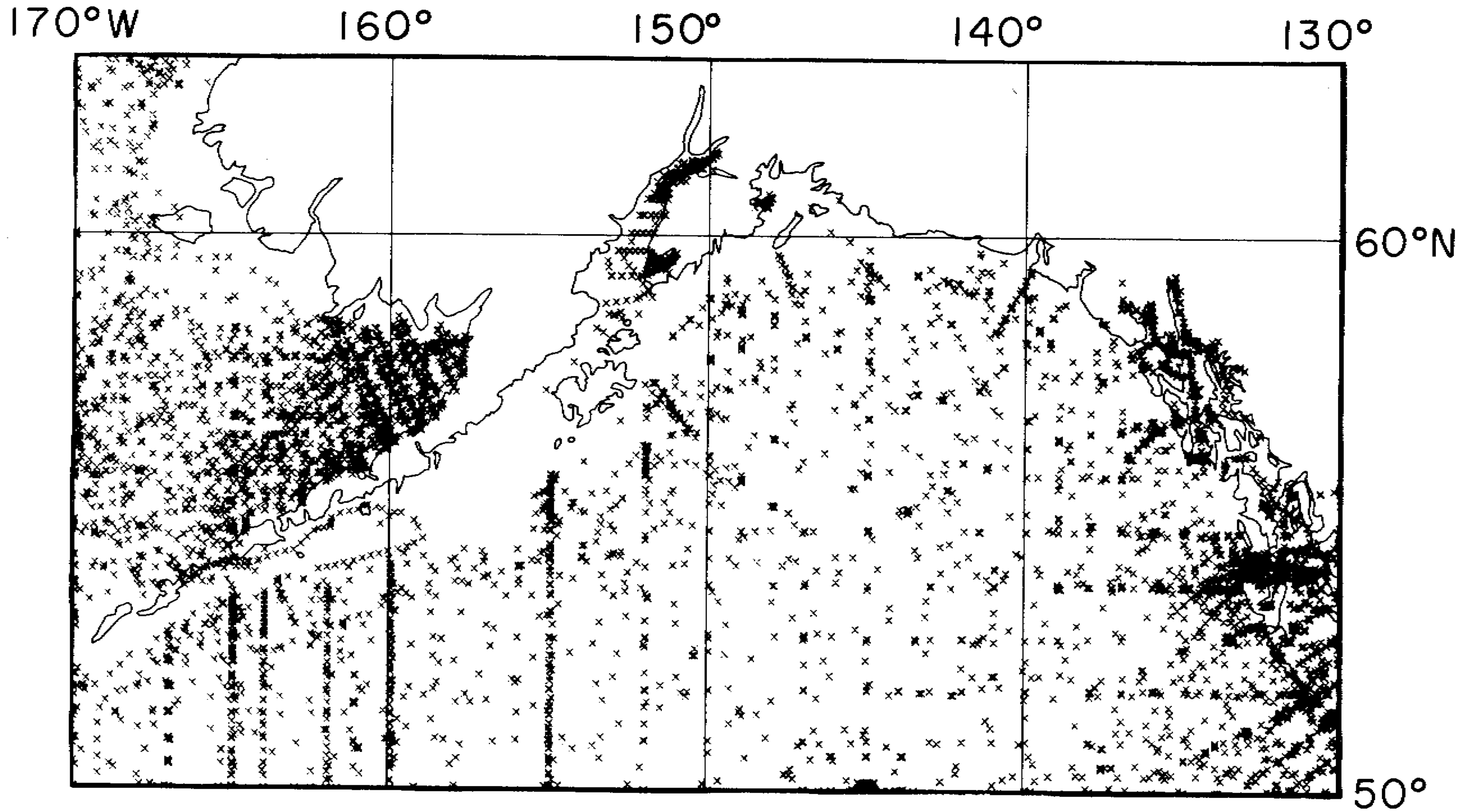


Figure 21. Locations of oceanographic stations in National Oceanographic Data Center geofile.

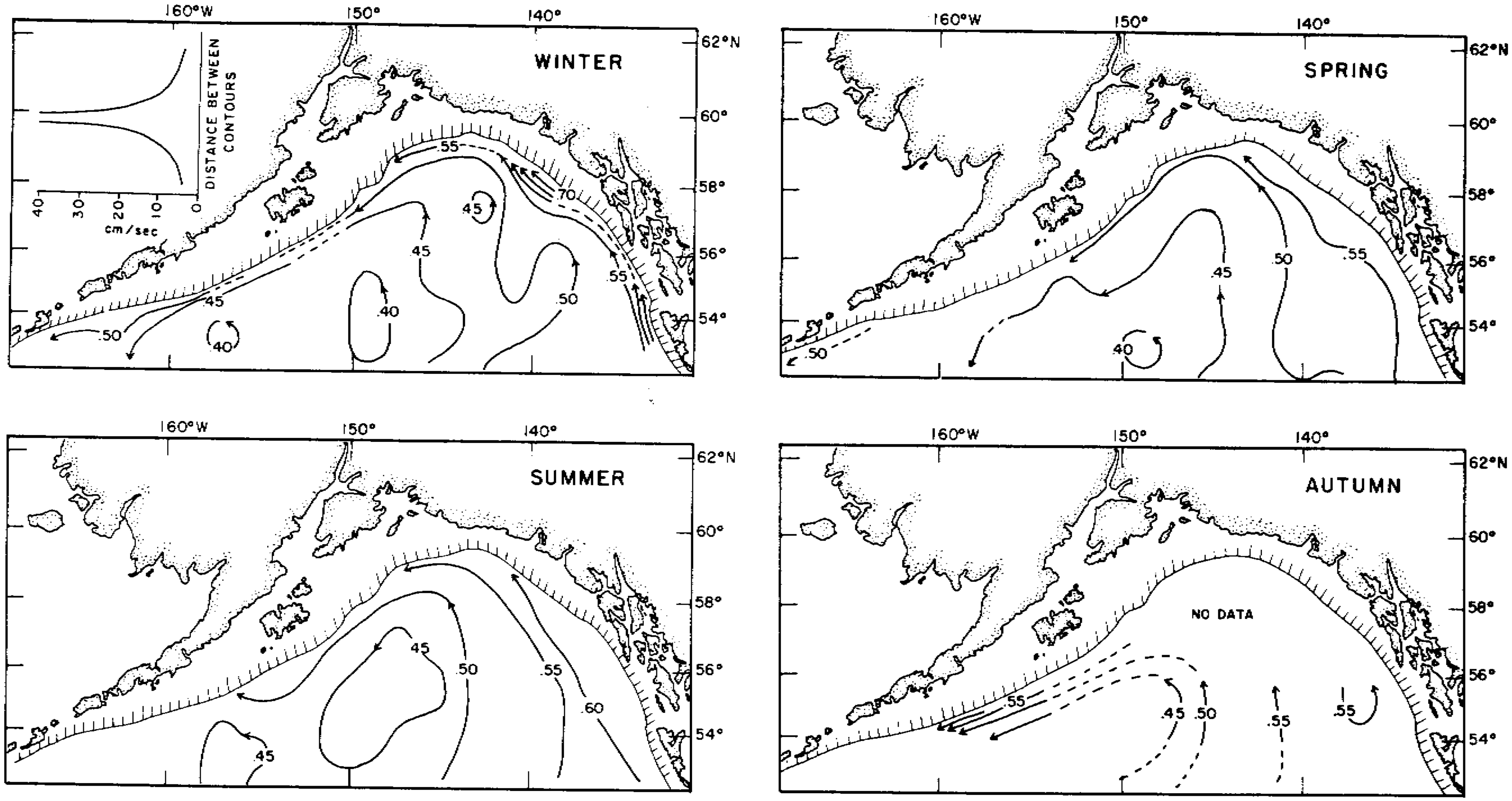


Figure 22. Long-term seasonal mean geopotential topographies, 0/300 db, (based on 2x2° grid) showing variability in geostrophic flow particularly the high velocities at the eastern side of the gulf (the broad grid spacing prevents showing the boundary current at the western side).

from 53°N in spring to 55°N in summer while winter is intermediate at 54°N (autumn data is lacking). Although numerous variations in the configurations of the respective isopleths occur, there is a difference of 15-20 dyn cm between the topographic low in the southwestern part of the gulf and the topographic high near the coast at the eastern edge of the gulf. Further, isopleths are not continuous around the gulf but, rather than representing a discontinuity in flow, as will be shown in the next section, this is primarily due to narrow width of the boundary current in the northern and western part of the gulf. Speeds of 3 - 5 miles per day and a northward transport, east of the topographic low, of 3 Sv are indicated.

The winter and summer mean fields of geopotential topography for 0/2000 db (Fig. 23) are generally similar to those for 0/300 db. The position of the topographic low remains near 55°N, 149°W. The difference in topography across the eastern side of the gulf changes from 35-40 dyn cm in summer to 50 dyn cm in winter indicating some winter acceleration; speeds are 20 and 25 cm/sec and transports are 12 and 15 Sv, respectively. Isopleths at northern and western sides of the gulf are discontinuous as before. As might be expected from the foregoing, the long-term mean field of geopotential topography for 0/2000 db is not much different from either of the above and the apparent conclusion one can draw is that in winter the baroclinic mode reflects an increase in flow of about 20 percent, and this increase stems largely from adjustment in the mass field below 300 m.

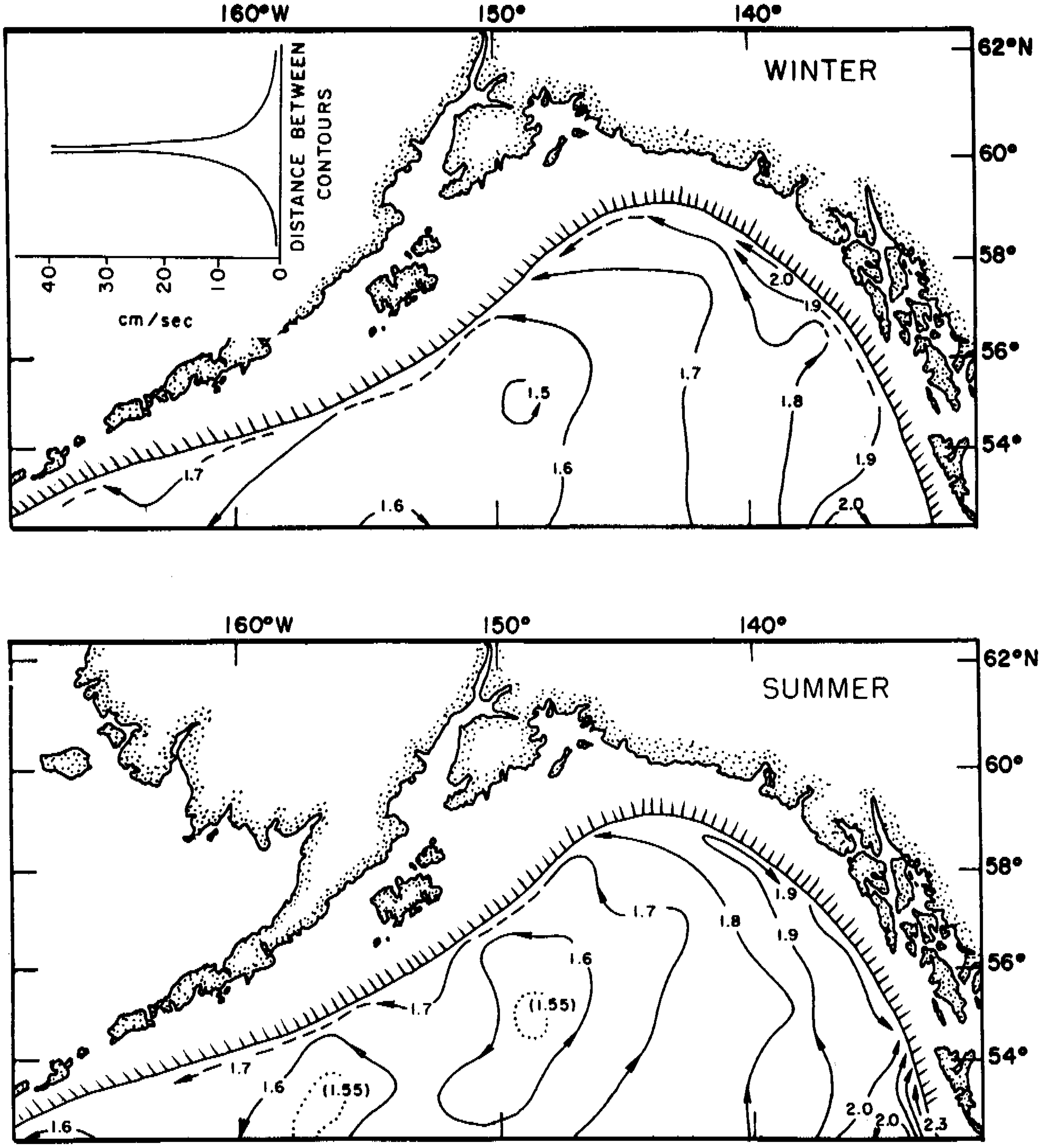


Figure 23. Long-term seasonal geopotential topographies 0/2000 db (based on 2x2° grid) showing generally similar features of cyclonic flow.

Because of the paucity and non-synoptic nature of the station data in the gulf, it is difficult to ascertain if irregularities in geopotential topographies are real or caused by the lack of synoptic data. However, there are three aspects that can be explored: are there patterns in individual years that are not obvious in the mean flow; what are the apparent fluctuations in transport, and do accelerations in the boundary current result in discontinuities in geostropic flow on the western side of the gulf? Because most of the data that permit answering these questions were obtained in the period 1955-63 and many of the observations were limited to 1000 m at that time (even though this was not considered a realistic level-of-no-motion), some comparisons must be made in reference to this level.

One pattern that is represented in one form or another is an extensive perturbation in the northward flow at the eastern side of the gulf. Examples of this are found in the geopotential topography (0/1000 db) for winter and summer 1957 (Fig. 24). The configuration of the isopleths suggests a possible blockage of westward flow at the head of the gulf resulting in a seaward plume that extends over 500 km in a southwesterly direction. The apparent effect of this phenomenon is a convergence of isopleths, and thus an acceleration of northward flow, at the eastern side of the gulf. Unfortunately neither closely spaced or repetitive stations have ever been made in this area so the actually physical nature or cause of this feature cannot be ascertained. This is also true of features at the western side of the gulf. At times there is an

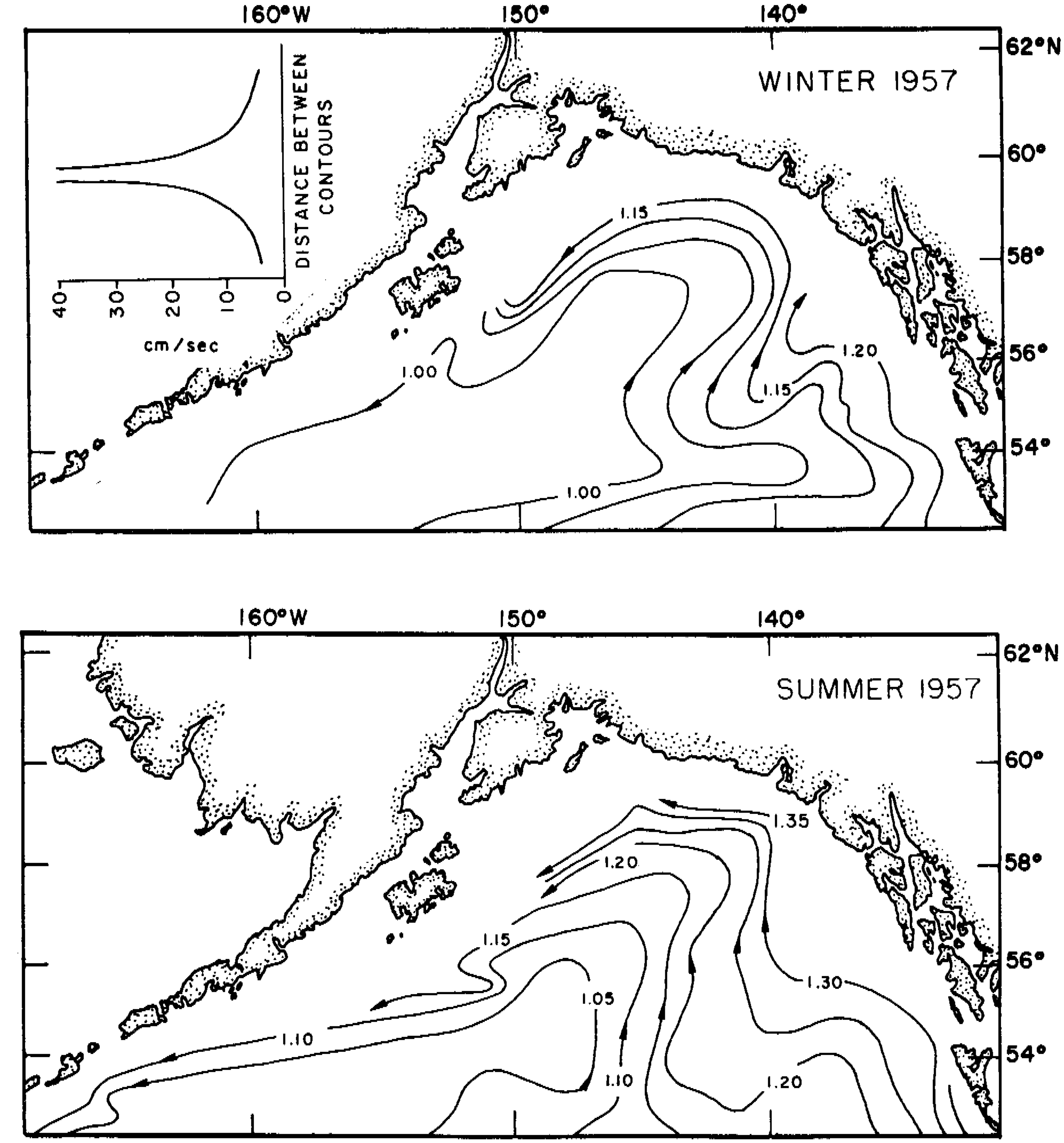


Figure 24. Geopotential topographies, 0/1000 db, winter and summer 1957 showing perturbation in flow at eastern side of the gulf.

indication of eddies breaking off to the east of the boundary current seaward of Kodiak Island (Dodimead et al, 1963), but there is also evidence that this is not a permanent feature of flow in this area.

The question as to whether or not there is continuity of geostrophic flow around the gulf would require extensive observations and extensive direct current measurements. However, some new insight into the boundary flow was obtained in 1972 when closely spaced observations were made on transects of the continental shelf and slope approximately 100 km apart east of Kodiak Island (Favorite and Ingraham, 1976a). It was discovered that approximately 70% of the westward flow out of the gulf occurred within 50 km of the shelf. Geostrophic velocities of 50 cm/sec (referred to 1000 db) occurred in a narrow band approximately 20 km wide and in one instance, velocities of 100 cm/sec (referred to 1500 db) were estimated within a 10 km band. Little evidence of any major perturbations were evident in the nearly 600 km stretch along the continental slope in this area. Thus, it would appear that when appropriate observations are made, fairly reasonable continuity may be obtained.

C. Volume Transports

Fluctuations in transport can be estimated by the difference in geopotential topography across the eastern part of the gulf. Data from 1954-62 (Table 1) indicates that the mean transport from 0 - 1000 m is approximately 8 Sv and individual values range from about 6 - 12 Sv, with no particular pattern to winter or summer values. Bennett (1958) reported that when observations are available to 2000 m the transport nearly doubles to approximately 15 Sv, with individual values ranging

Table 1. Northward volume transport (0 to 1000 m - to the nearest 0.5 Sv) into the gulf across 55°N, computed from geopotential topography (the lowest value in the Alaskan Gyre versus the inshore value at the location of the 1000-m isobath at the eastern side of the gulf).

Period	Transport (Sv)
1954 (summer)	9.0
1955 (summer)	9.0
1956 (summer)	7.5
1957 (winter)	6.5
1957 (summer)	7.0
1959 (winter)	8.5
1959 (summer)	9.0
1960 (winter)	12.0
1960 (summer)	8.0
1961 (spring)	6.5
1962 (spring)	6.5
Mean	8.1

from 13.5 - 16 Sv, and again no particular pattern to winter and summer values is evident. Thus, it would appear that the year to year seasonal fluctuations may be as great or greater than the within year seasonal ones.

IV. WIND STRESS-TRANSPORTS

Because of the paucity of data on actual winds, the wind-stress at the sea surface is obtained from distributions of sea level pressure. It should be noted at the outset that there is an unavoidable bias in long-term sea level pressure data because of not only the varying intensity and location of reports from shipping, but because of modern devices and techniques. The establishment of Ocean Station "P" in the mid-forties, the availability of satellite imagery showing cloud patterns in the mid-sixties, and the placement of ocean data buoys in the mid-seventies, all permit an increasingly better estimate of the sea level pressure fields and associated gradients. Several grid spacings are used in this report and each will be defined as encountered.

A. Pressure Fields

In order to obtain an initial assessment of variability of pressure, the historical sea level pressure data at 5 x 5^0 grid points were obtained from the National Center for Atmospheric Research (NCAR) and monthly mean fields (composed of 12 hourly and in some instances 24 hourly data) from 1899-1972 were plotted to ascertain the relative frequency at which the central pressure of the Aleutian low falls within the selected low pressure intervals (Fig. 25). In 6 instances the monthly mean pressure was less than 985 mb, these occurred in either December or January; in 32 instances it was less than 990 mb, all occurred from October to March; and in 91 instances it was less than 995 mb, all occurred from September to April. Although it appears that data from 1899-1950 are fairly representative of the period 1950-1972, we are concerned with the curl of the wind-stress and therefore details of the first and second derivative fields, and not

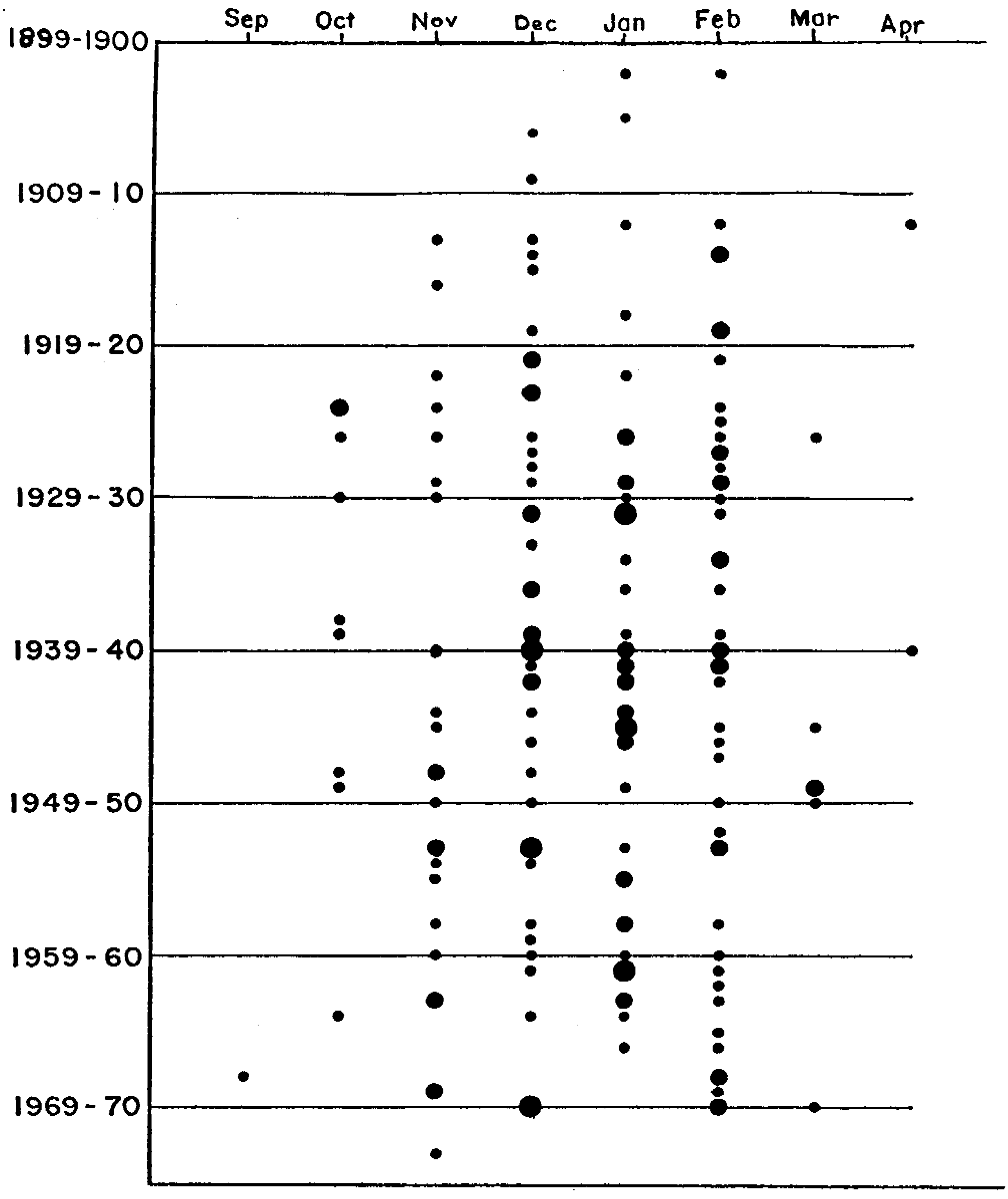


Figure 25. Frequency of monthly mean sea level pressure minima of the Aleutian low: <995 mb (●), <990 mb (●), and <985 mb (●).

merely the absolute value of pressure minima. If we choose 55°N, 155°W near the approximate center of the Alaskan Gyre, data at this grid point, deviations from monthly means, 12-month running means and power spectrum provide an indication of the general variability of sea level pressures. Deviations from monthly mean pressures do not exceed ± 5 mb and, except for the extended period, roughly 12 years, of positive deviations from 1901-1912 (which may be due to limited data), departures from normal are generally of 1-4 years duration. Particularly noticeable is the extended period of below normal pressures centered around 1940. The power spectrum (cycles less than 1.5 years not shown because of the obvious annual periodicity) based on annual mean values reflect cycles of 2.7, 6.7 and 13.3 years (Fig. 26). The 6.7 years is the approximate periodicity of oceanic temperature cycles (5.6 years) found by Favorite and McLain (1973). The 13.3 years suggests an influence of the sunspot cycle of 12.3 years. Favorite and Ingraham (1976b) have shown that if mean pressures from October to March for the three years centered around the period of sunspot maxima and minima from 1899 - 1972 are calcualted, with only one exception (1958), the center of the Aleutian low occurs in the central Aleutian area during periods of the sunspot maxima and in the Gulf of Alaska during periods of the sunspot minima; mean pressures are 2 mb lower during the latter period.

B. Transport Fields

Total integrated transports (wind-stress transports) are derived from the mean pressure fields by deriving a wind field that is transformed into a stress field. The nature of the coupling of energy between wind-stress and water transport is not precisely known and certainly varies under different conditions. When the water is warmer than the air, a

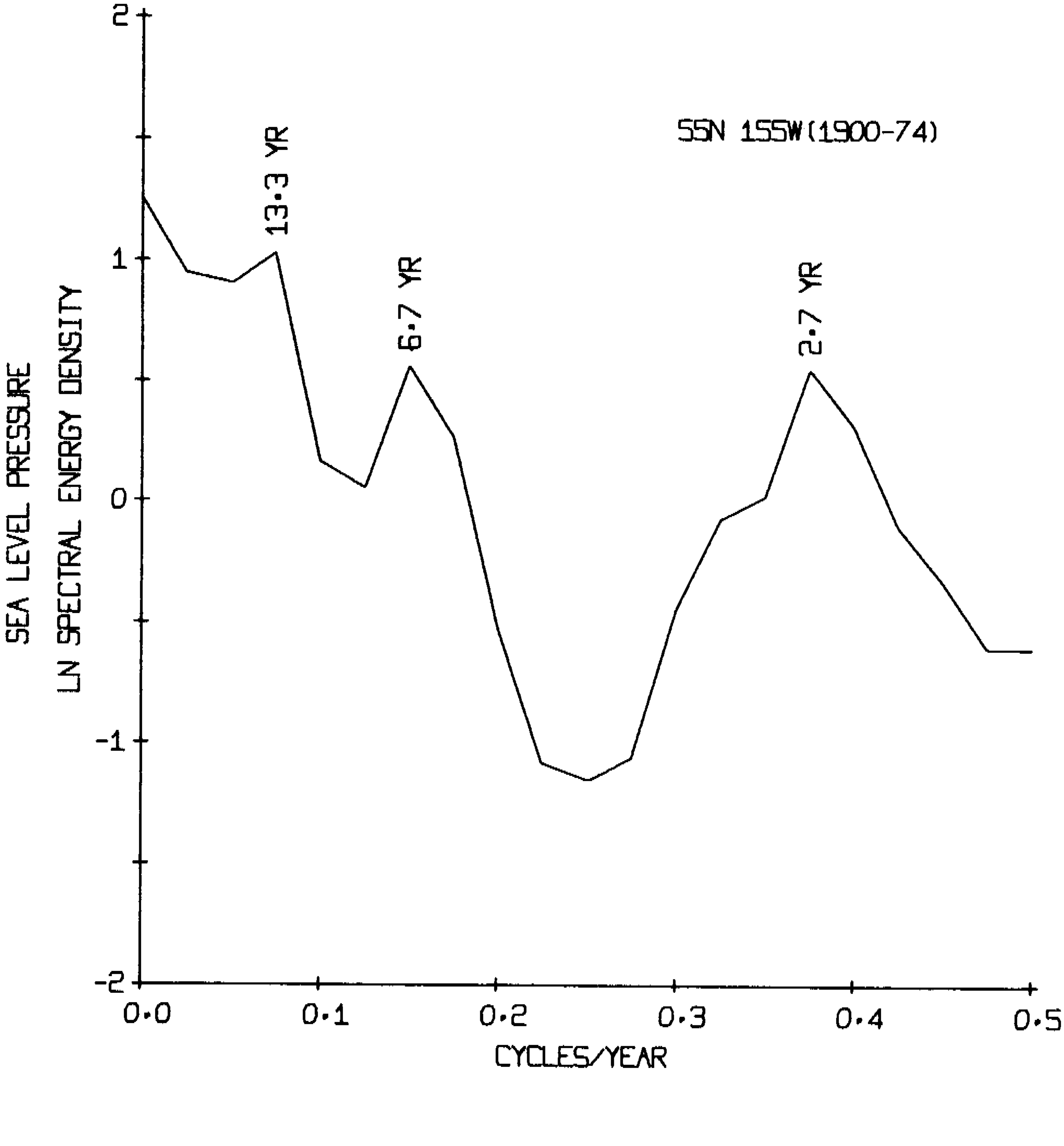


Figure 26. Spectral energy density, annual mean sea level pressure at 55°N, 155°W 1900-74 (20 lags) indicating cycles of 2.6, 6.7 and 13.3 years.

turbulent boundary layer exists and exchange of energy is more effective than when the water is colder than the air and a stable layer exists at the air-sea interface. Further, when interpolation and averaging processes are taken into account, caution must be exercised in interpreting results. However, a number of authors (e.g. Wyrtki, 1964) have indicated the usefulness of this technique in estimating flow.

Sverdrup (1947), by including the pressure gradient term in the Ekman transport equation, arrived at the following:

$$-f v = \frac{1}{\rho}\frac{\partial p}{\partial x} + \frac{\partial}{\partial z}\left(A_z \frac{\partial u}{\partial z}\right) \qquad (2)$$

$$f u = -\frac{1}{\rho}\frac{\partial p}{\partial y} + \frac{\partial}{\partial z}\left(A_z \frac{\partial v}{\partial z}\right) \qquad (3)$$

After cross differentiating and integrating from the surface to an unspecified depth-of-no-motion one obtains the transport equation:

$$M_y = \left(\frac{\partial \tau_y}{\partial x} - \frac{\partial \tau_x}{\partial y}\right) / \beta \qquad (4)$$

where τ is the wind stress and β the variation of the Coriolis parameter with latitude $\left(\frac{\partial f}{\partial y}\right)$. This shows for steady non-divergent flow the total meridional transport, M_y, is directly related to the curl of the wind stress and independent of the details of the mass distribution as long as the pressure gradient is baroclinically compensated at depth.

Using the technique devised by Fofonoff (1962) and the program constructed by Bakun (1973), geostrophic winds were computed from sea level pressure values (interpolated from the 5 x 5° field) computed on an equilateral triangular grid, 222 km on a side, centered at 47°N, 170°W. Pressure data archived on magnetic tape were arranged on the computation grid surrounding each selected location using Bessel's central difference formula. Finite difference first and second derivatives were formed and the geostrophic wind field was computed in spherical coordinates:

$$u_g = -\frac{1}{\rho R f} \frac{\partial p}{\partial \phi} \qquad (5)$$

$$\frac{\partial u_g}{\partial \phi} = -\frac{1}{\rho R f} \left(\frac{\partial^2 p}{\partial \phi^2} - \frac{\partial p}{\partial \phi} \cot \phi \right) \qquad (6)$$

$$\frac{\partial u_g}{\partial \lambda} = -\frac{1}{\rho R f} \frac{\partial^2 p}{\partial \lambda^2} \qquad (7)$$

$$v_g = \frac{1}{\rho R f \cos \phi} \frac{\partial p}{\partial \lambda} \qquad (8)$$

$$\frac{\partial v_g}{\partial \phi} = \frac{1}{\rho R f \cos \phi} \left(\frac{\partial^2 p}{\partial \phi \partial \lambda} + \frac{\partial p}{\partial \lambda} [\tan \phi - \cot \phi] \right) \qquad (9)$$

$$\frac{\partial v_g}{\partial \lambda} = \frac{1}{\rho R f \cos \phi} \frac{\partial^2 p}{\partial \lambda^2} \qquad (10)$$

where ϕ and λ are the latitude and longitude coordinates respectively, u_g and v_g are the eastward and northward components of geostrophic wind, p is the atmospheric pressure, ρ is the density of air (considered to be a constant equal to 0.00122 gm/cm), R is the mean radius of the earth and f is the Coriolis parameter.

These are transformed to estimates of the wind field near the sea surface by rotating the geostrophic wind 15 degrees to the left and contacting it by 30 percent to approximate, in a simplified manner, the effect of friction in the planetary boundary layer:

$$u = a_1 u_g + b_1 v_g \qquad (11)$$

$$\frac{\partial u}{\partial \phi} = a_1 \frac{\partial u_g}{\partial \phi} + b_1 \frac{\partial v_g}{\partial \phi} \qquad (12)$$

$$v = a_2 u_g + b_2 v_g \qquad (13)$$

$$\frac{\partial v}{\partial \lambda} = a_2 \frac{\partial u_g}{\partial \lambda} + b_2 \frac{\partial v_g}{\partial \lambda} \qquad (14)$$

where u and v are the eastward and northward components of surface wind, $\vec{V}$, and the transformation coefficients are: $a_1 = 0.7 \cos(15°)$,

$b_1 = 0.7 \sin(15°)$, $a_2 = -0.7 \sin(15°)$, $b_2 = 0.7 \cos(15°)$.

Derivatives of surface wind speed, $|\vec{V}| = \sqrt{u^2 + v^2}$ are computed according to:

$$\frac{\partial |\vec{V}|}{\partial \phi} = \left(u \frac{\partial u}{\partial \phi} + v \frac{\partial v}{\partial \phi} \right) \frac{1}{|\vec{V}|} \qquad (15)$$

$$\frac{\partial |\vec{V}|}{\partial \lambda} = \left(u \frac{\partial u}{\partial \lambda} + v \frac{\partial v}{\partial \lambda} \right) \frac{1}{|\vec{V}|} \qquad (16)$$

The stress on the sea surface, $\vec{\tau}$, was computed using a relatively high value, 0.0026, of the constant drag coefficient to partially offset the effect of using mean data:

$$\vec{\tau} = \rho\, C_D\, |\vec{V}|\, \vec{V} \qquad (17)$$

$$\frac{\partial \tau_\phi}{\partial \lambda} = \rho\, C_D \left(v \frac{\partial |\vec{V}|}{\partial \lambda} + |\vec{V}| \frac{\partial v}{\partial \lambda} \right) \qquad (18)$$

$$\frac{\partial \tau_\lambda}{\partial \phi} = \rho\, C_D \left(u \frac{\partial |\vec{V}|}{\partial \phi} + |\vec{V}| \frac{\partial u}{\partial \phi} \right) \qquad (19)$$

where τ_ϕ and τ_λ are the northward and eastward components of $\vec{\tau}$. The curl of the wind stress is then determined as

$$\nabla \times \vec{\tau} = \frac{1}{R} \left(\frac{1}{\cos\phi} \frac{\partial \tau_\phi}{\partial \lambda} - \frac{\partial \tau_\lambda}{\partial \phi} + \tau_\lambda \tan\phi \right) \qquad (20)$$

Integration of wind-stress curl along a parallel of latitude from an eastern boundary, in this case the west coast of North America, to successive grid points results in a total transport across that parallel of latitude; and eastward flow is obtained by satisfying continuity between grid points along two parallels of latitude. Welander (1959) has shown that wind-stress transport in a semi-enclosed basin (such as the Gulf of Alaska) must flow out in the form of a western boundary jet because eastern boundary currents are excluded, thus, northward transports across 55°N are considered to exit the gulf along the western shore.

When one considers the nature of the variability in location and frequency of ship reports that make up the bulk of these pressure data, the averaging processes involved, and the theory employed, there are severe limitations associated with this method of obtaining flow, but it provides an indication of the continuity of events that is unattainable from the fragmentary station data obtained only aboard research vessels. Mean (1950-74) seasonal integrated total transports (Fig. 27) indicate a maximum northward transport in excess of 19 Sv into the gulf in winter and an accompanying closed circulation in the gulf area. Northward transport drops to less than 5 Sv in spring and summer and is concentrated at the western side of the gulf, whereas there is a suggestion of southward flow ($<$ 1 Sv) at the eastern side. Intense northward transport greater than 15 Sv is reestablished in autumn, but the closed circulation evident in winter east of 155°W is not developed.

There are marked departures from mean conditions and these are most readily apparent in winter. Two winter periods, in 1963 and 1969, have been selected to reflect the range in values obtained in the period 1950-74 (Fig. 28). Computed northward transport in 1963 was less than 10 Sv, whereas, in 1969 it was nearly 3 times as great, in excess of 25 Sv. Thus, considerable variability in flow is indicated not only seasonally, but annually and marked deviations from the smoothed isopleths presented must occur. One can only conclude that, although a basic cyclonic flow

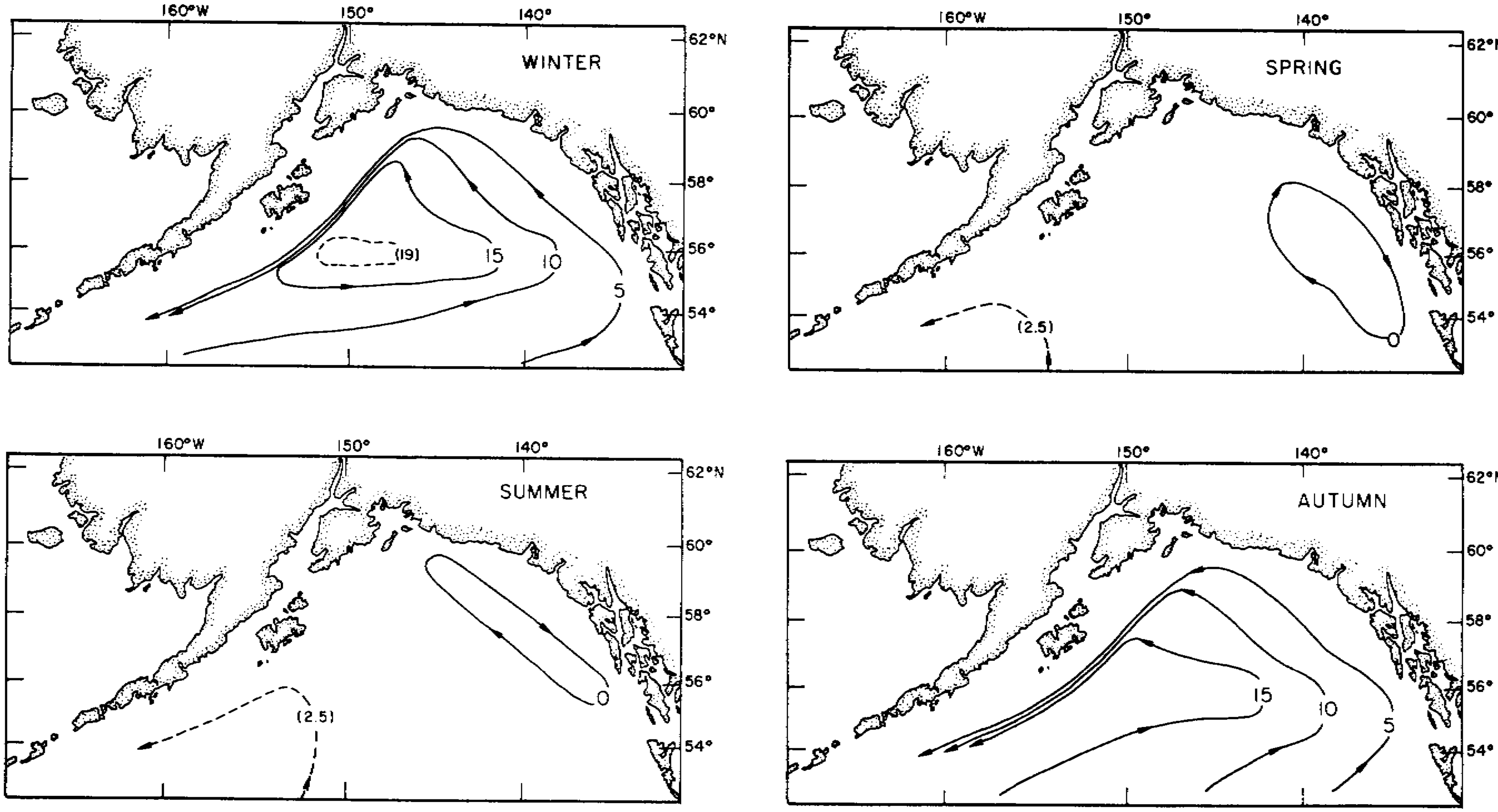


Figure 27. Seasonal mean (1950-74) integrated total transports (Sv) indicating general cyclonic flow with marked winter intensification of flow.

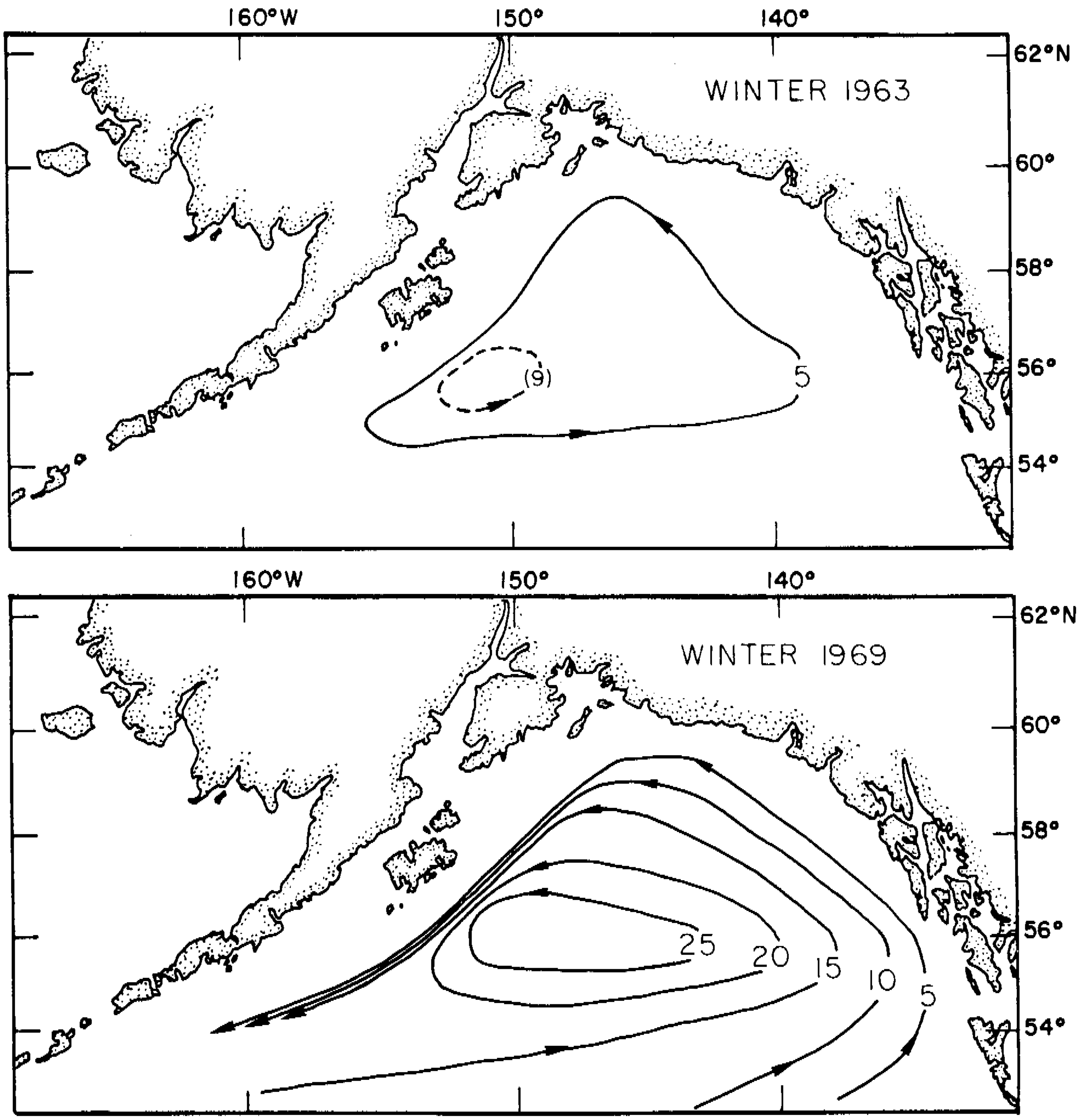


Figure 28. Total integrated transports (Sv) for winter (Jan. Feb. Mar.) 1963 and 1969 indicating variability in winter flow.

exists in the gulf, the variations and perturbations in flow due to variable wind-stresses result in a highly complex flow regime.

C. Numerical Model

Further refinements of estimates of water transport in the gulf, over those obtained by integrated total transport method, are obtained by expanding basic assumptions in the total integrated transport method to permit inclusion of variable bathymetry and to incorporate analyses in a numerical model first devised by Galt (1973) for an enclosed basin. This was configured to fit the North Pacific Ocean, Bering Sea, and Okhotsk Sea on the 222 km equilateral triangular grid mentioned in the previous section. Although limited to the barotropic flow assumption, the model provides an inital look at actual isopleths of flow considering the great increase in complexity of designing a baroclinic or multilayer model. Because of problems associated with specifying initial stream lines and vorticity on an arbitrary mid-ocean southern boundary for the Gulf of Alaska, the larger ocean area with a southern boundary far away from the area of interest was selected for the model. This exploratory version would show if a more detailed grid within the Gulf of Alaska as a subset of this large area model would be informative.

The basic model outputs are time dependent solutions of the transport stream function which, when presented in maps and contoured, give transport stream lines of flow. As before, the wind stress curl field is computed from sea level pressure; the bathymetry is scaled relative to the mean depth from flat bottom (0%) to actual bathymetry (100%) to simulate the effect of stratification; and coefficients may be selected which govern the character of the solution by scaling the importance of nonlinear advection (α), lateral friction (β), and bottom friction (γ). As the model spins up from zero initial stream function and vorticity, maps may be obtained at any time interval which is a multiple of the time step (6 hours or less) to show the development of flow which in most cases reaches near steady state after about 60 days or 240 time steps. Caution must be taken when interpreting the results because of the barotropic assumption which allows minor changes in deep bathymetry to affect flow. Further, short (one month or less) periods of unusually intense wind stress curl patterns give unrealistically high transports if run to a steady solution a considerable time beyond their actual duration.

The model is based on a nondimensionalized vorticity equation (1) which is obtained by cross differentiation and subtraction of the vertically integrated equations of motion:

$$\frac{\partial \xi}{\partial t} = (\nabla \times \psi \vec{k}) \cdot \left(\frac{\alpha \xi + f}{h}\right) + \beta \nabla^2 \xi - \frac{\gamma}{h}\left[\xi + \nabla \psi \cdot \nabla\left(\frac{1}{h}\right)\right] + \nabla \times \left(\frac{\tau}{h}\right), \quad (21)$$

where ξ is the vertical component of vorticity $\left(\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}\right)$; u and v are the horizontal components of velocity; h is the depth, f is the Coriolis parameter; α, β, and γ are constants that specify the effectiveness of the nonlinear advection, horizontal and vertical frictional forces respectively; τ is the wind stress; and ψ is the transport stream function defined by $-hu = \frac{\partial \psi}{\partial y}$ and $hv = \frac{\partial \psi}{\partial x}$. The continuity equation

$$\frac{\partial (hu)}{\partial x} + \frac{\partial}{\partial y}(hv) = 0 , \quad (22)$$

and finally a relationship between stream function and vorticity

$$\nabla\left(\frac{1}{h}\nabla\psi\right) = \xi \quad , \qquad (23)$$

complete the basic equations of the model. For further information on finite difference forms see Galt (1973).

A typical run of the model includes the following sequence of events throughout the 17 x 42 point array over the area from 33-61°N and 140°E-120°W. Initially the vorticity (ξ) and stream function (ψ) values are set to zero at each of the 714 grid points. Then the rate of change of vorticity ($\frac{\partial \xi}{\partial t}$) is computed at each grid point from equation (21) and integration of the rate of change over one time step interval (6 hours) gives a new vorticity value at each grid point. Using equation (23), new values for the transport stream function are computed from the new vorticity values by an over-relaxation technique, and streamfunction values at each grid point are contoured to indicate the new magnitude and direction of flow. This sequence is repeated. The model approaches steady conditions when the gradients are such that the terms on the right hand side of equation (21) approach zero indicating a balance between vorticity dissipation (by advection of potential vorticity, lateral friction, and bottom friction) and vorticity input at each grid point (the wind stress curl field).

Using the 25 year mean annual wind stress and a 10% bathymetry factor, the model after 60 days spin up shows the generally accepted features of flow around the Gulf of Alaska (Fig. 29). The cyclonic flow, western boundary intensification, and magnitude of transport (about 20 Sv) generally agree with the geostrophic calculations from field measurements

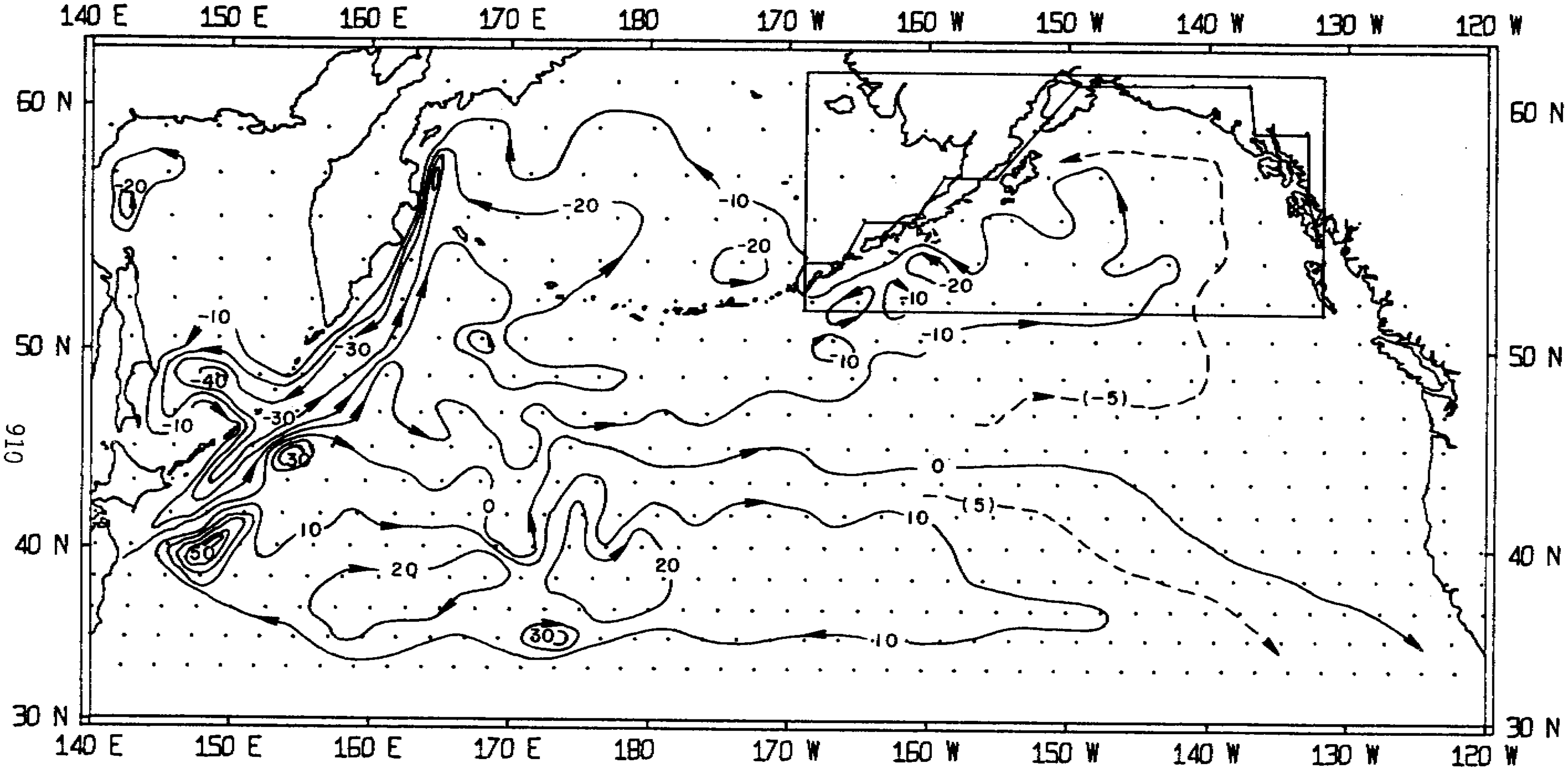


Figure 29. Numerical model of Transpacific ocean transports (Sv) using annual mean (1950-74) wind stress, 10% bathymetry factor, and α, β, γ coefficients.

of temperature and salinity if a reference level-of-no-motion of about 2000 db is used. Next the sea level pressure data were averaged by seasons to observe the effect of variable wind-stress. All factors except wind stress input were kept the same for each of the four runs which were driven by the seasonal mean (1950-74) wind-stresses, only the gulf portion of the model is presented (Fig. 30). As expected, the autumn and winter transport patterns are much more intense than the annual mean pattern, and the maximum transport of 63 Sv across 54°N (between 130° and 160°W) occurred for autumn conditions; the winter transport was 51 Sv followed by summer with 13 Sv and spring with 11 Sv. The general asymmetric cylonic features of flow were quite similar during both of the high transport seasons and both of the low transport seasons, but details were considerably different.

During autumn and winter an intense boundary current develops on the western side of the gulf, about 2 grid lengths offshore, over the continental slope. Eddy-like features form south of the boundary current. The lack of synopticity and closely spaced stations in historical oceanographic data has precluded detecting the existence of these eddies, other than perhaps isolated instances, which have been generally overlooked. At the eastern side of the gulf, the streamlines of easterly flow converge indicating higher velocities near Yakutat. The flow remains about the same magnitude zonally across the head of the gulf and intensifies as it is forced southwestward by the land boundary off Kodiak Island and the Alaska Peninsula.

During the spring and summer low wind stress period, flow is considerably reduced in magnitude, and the center of cyclonic flow shifts southward.

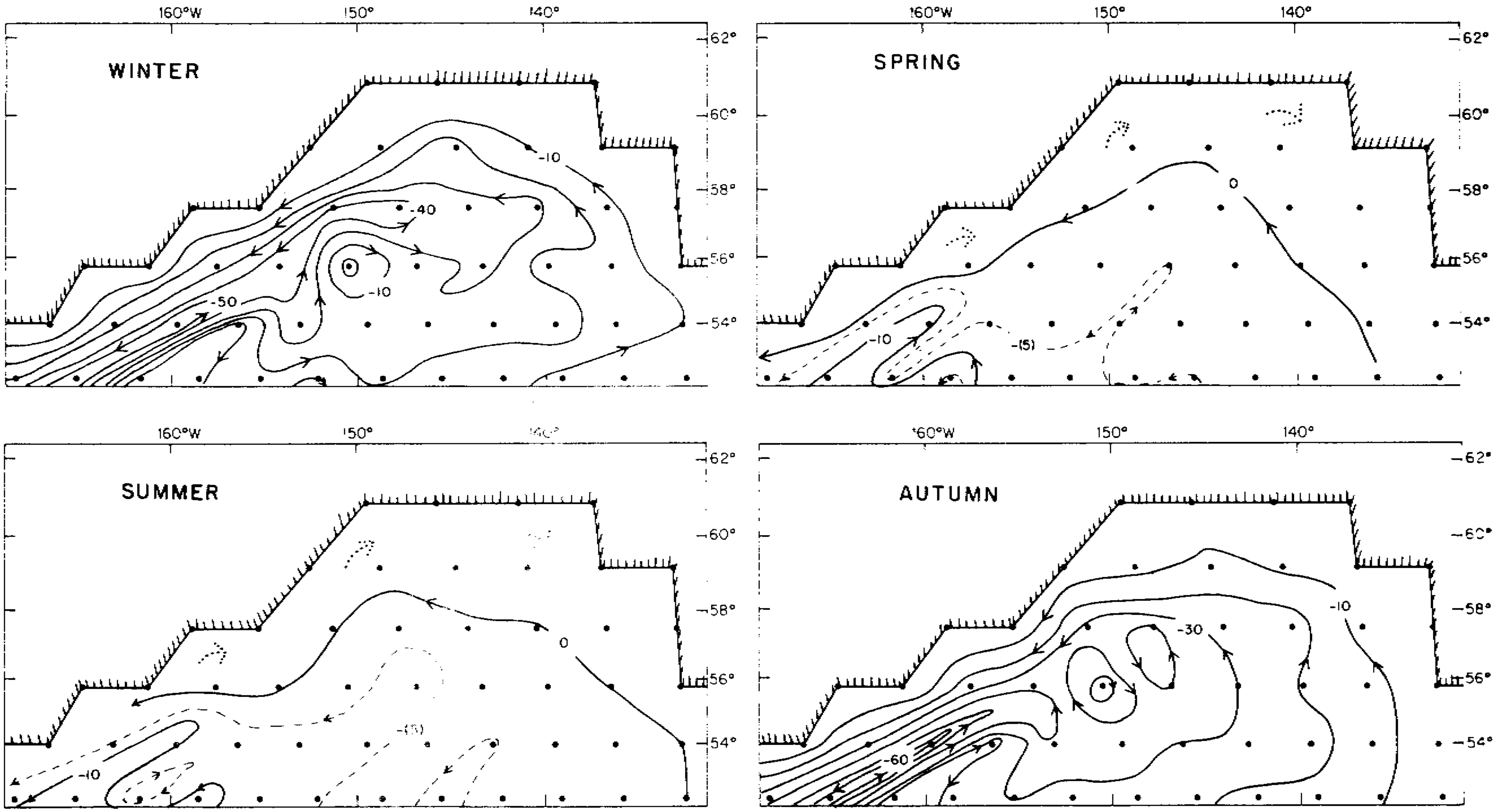


Figure 30. Seasonal mean transports (Sv) in the gulf obtained from numerical model studies suggesting a greater complexity in flow than evident in Fig. 27.

A new feature appears in the form of an inshore return flow of 1-3 Sv over the shelf that is not evident in the 10 (or 5) Sv contour interval shown. This is perhaps much more significant in terms of mean velocity considering that the transport in this area is confined to within a depth interval of 200m compared to the offshore depth interval of about 4000m. Other features of spring and summer transports include weak eddies or meanders, a broad northerly flow at the east side of the gulf, and a slight intensification of the southwesterly flow at the western side of the gulf.

Computed wind-stress fields for winter 1963 and 1969 (based upon extremes in the integrated total transport (wind-stress transport) time series) were selected to show the variability that may be expected during the high wind stress period (Fig. 31). The general features of the mean winter condition are clearly present, with 1969 having a high transport value of 83 Sv compared to only 22 Sv in 1963. The greatest departure in 1969 from mean conditions occurs in the eastern gulf where the easterly flow is contained about 400 farther south than normal, resulting in a more intense northwesterly flow along the coast. This was apparently associated with unusually strong positive wind-stress curl in the eastern gulf.

These numerical model studies suggest that flow in the gulf does not appear to be of a typically uniform cyclonic nature, but rather a funneling of northward flow into the head of the gulf that exists as a narrow boundary flow at the western side. Closure may well occur in nature (see Surface Salinity section) in the surface layer, which is generally isolated from the deeper flow by the halocline at 100-300m. Future studies should take into account the stratification or baroclinic effects.

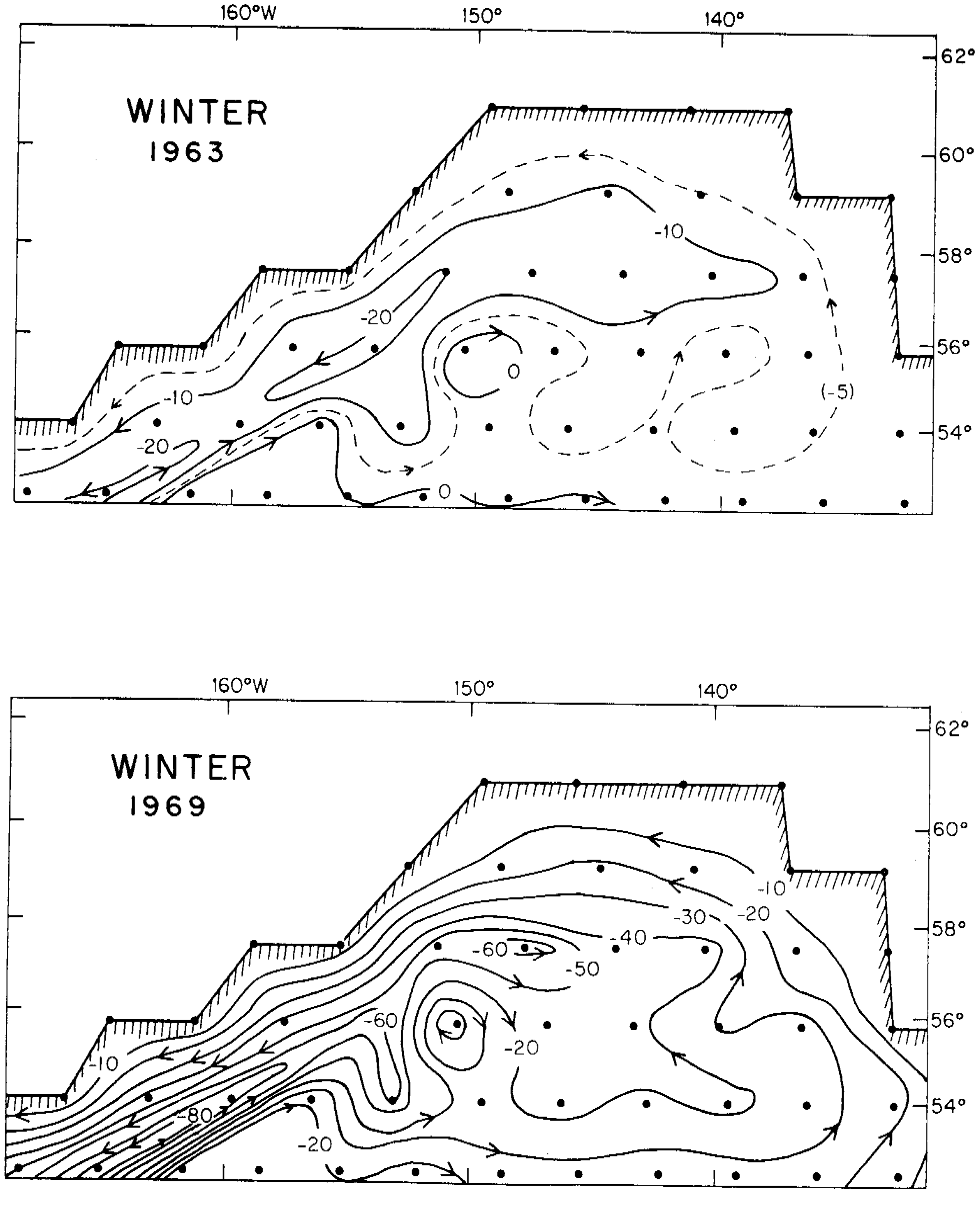


Figure 31. Numerical model transports (streamline interval 10 Sv) for winter (Jan. Feb. Mar.) 1963 and 1969 suggesting greater complexity in flow than evident in Fig. 28.

V. COASTAL SEA LEVELS

The geopotential topography computed from hydrographic data provides a relative indication of sea surface slopes but observations at shore stations are a direct measurement of actual sea level. Daily means of hourly heights referred to a local datum are recorded at selected coastal stations and the data are on file at NOAA Headquarters (Rockville). Although weekly and even daily departures from normal sea level have shown good correlations with coastal flow regimes in the Coastal Upwelling Experiments (CUE) off Oregon, monthly mean sea level data are appropriate for discussing the seasonal and longer-term variations which are the focus of this chapter. Distortions caused by changes in atmospheric pressure are corrected as follows:

$$\delta h = \frac{1}{\rho g} \delta p \qquad (24)$$

where h is the change in sea level, ρ the density of water, g the acceleration of gravity and p the atmospheric pressure. Steric effects which may result in seasonal differences as great as 6 cm are not compensated for because usually only departures from monthly means are considered.

LaFond (1939) showed that nearly all variations in sea level on the west coast of the United States could be accounted for by changes in the geopotential topography of the ocean off the coast and thus, were directly related to ocean currents. Jacobs (1939) reported that such relations were not due to changes in the density of surface water but actual slopes caused by atmospheric interactions. Pattullo et al (1955) found that in the northern North Pacific isostatic adjustments (steric and pressure effects) did not account for all seasonal departures from mean sea level, and Pattullo (1960) noted that in low latitudes sea level was high in summer but north of 40°N there was a distinct change of phase and sea levels around the Gulf of Alaska were highest in December. Local effects of river discharge on sea level at the mouth of the Columbia River were noted by Roden (1960) in a study of non-seasonal variations in sea level along the west coast of North America; only a moderate to poor coherence in relation to local sea surface temperatures were found. Sea level data south of Ketchikan were studied by Saur (1962) and deviations from isostacy were attributed to variability in ocean currents. Favorite (1974) showed that the anomalous increase in sea level at Yakutat during winter could be explained by an accompanying increase in northward wind-stress transports, and Reid and Mantyla (1975) have indicated that the winter increase in sea level along the entire coast of the northern North Pacific Ocean is due to increased flow in the overall subarctic cyclonic gyre.

A. Sea Level Pressures

A general gradual increase in monthly mean sea level pressure is evident at Ketchikan, Sitka, Yakutat, Seward, Kodiak and Dutch Harbor form February to July (Fig. 32) and this is followed by an abrupt decrease from July to October. Somewhat constant but low pressures prevail from November until January when an anomalous secondary maxima occurs that is probably caused in part by a westward shift in the center of the Aleutian low from the gulf to the central Aleutian Islands that occurs at this time.

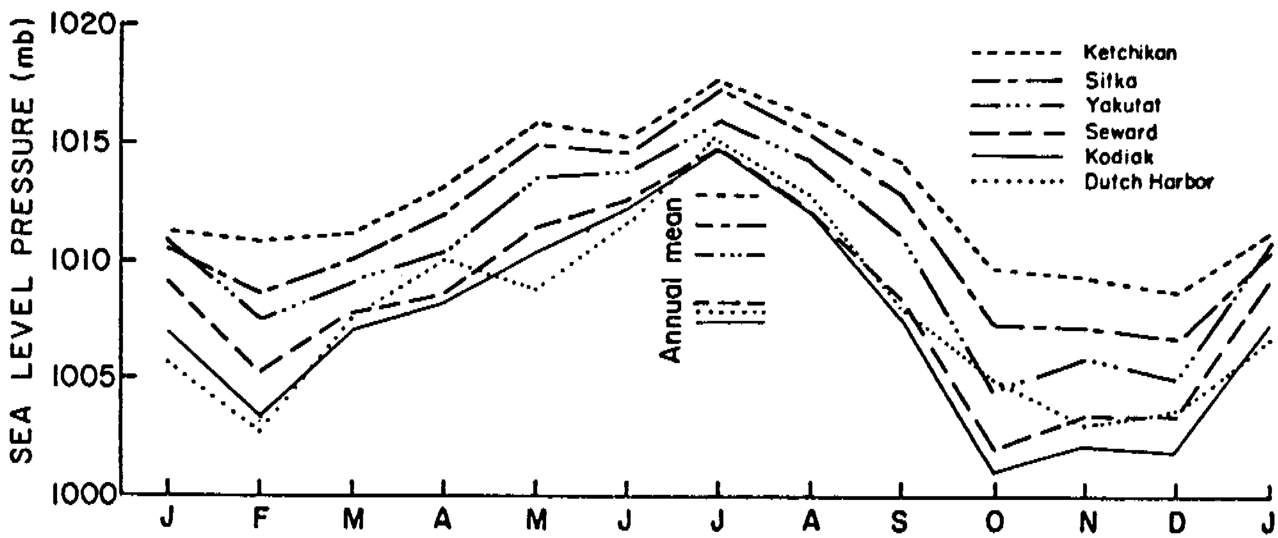


Figure 32. Monthly mean (1950-74) sea level pressure (mb) at the indicated coastal stations indicating maxima in July and minima in October.

Deviations from monthly means, and 12-month running means of sea level pressures for the 6 locations for 1950-74 (Fig. 33) indicate a marked similarity that is even reflected in abrupt anomalies of only a month or so duration. The abrupt increase in pressure in late 1950 at Dutch Harbor was evident at all stations, although decreasing in intensity to the south. In 1957 an abrupt increase and a subsequent decrease was evident at all locations and other examples are evident. Thus, there is a general response throughout the area to short or prolonged events but periods of positive or negative anomalies appear to be limited to from one month to about a year.

Spectral energy densities were computed for monthly mean values at each of the coastal stations over the period 1950-74 using a lag time of approximately 13 percent of the record length (40 lags over a continuous record of 300 data points). All locations exhibit maximum energy density at a frequency of approximately .085 cy/mo or 1 year (Fig. 34). Although the limited number of data points prohibits meaningful analysis of lower frequencies, there is an indication that the total energy distribution at these frequencies increases from Ketchikan to Dutch Harbor and a consistent indication of an energy peak at .025 cy/mo or 3.3 years. A coherency test using the coherence square technique shows a maximum coherence at a frequency of 1 year at all stations. Comparisons of data at all locations with those at Ketchikan indicates that there is also a good spatial coherence around the gulf (Fig. 35).

B. Mean Sea Levels

Monthly mean (1950-74) sea levels corrected for atmospheric pressure at Ketchikan, Sitka, Yakutat, Seward, Kodiak and Dutch Harbor (Fig. 36) reflect considerable coherence. Unfortunately there is no horizontal

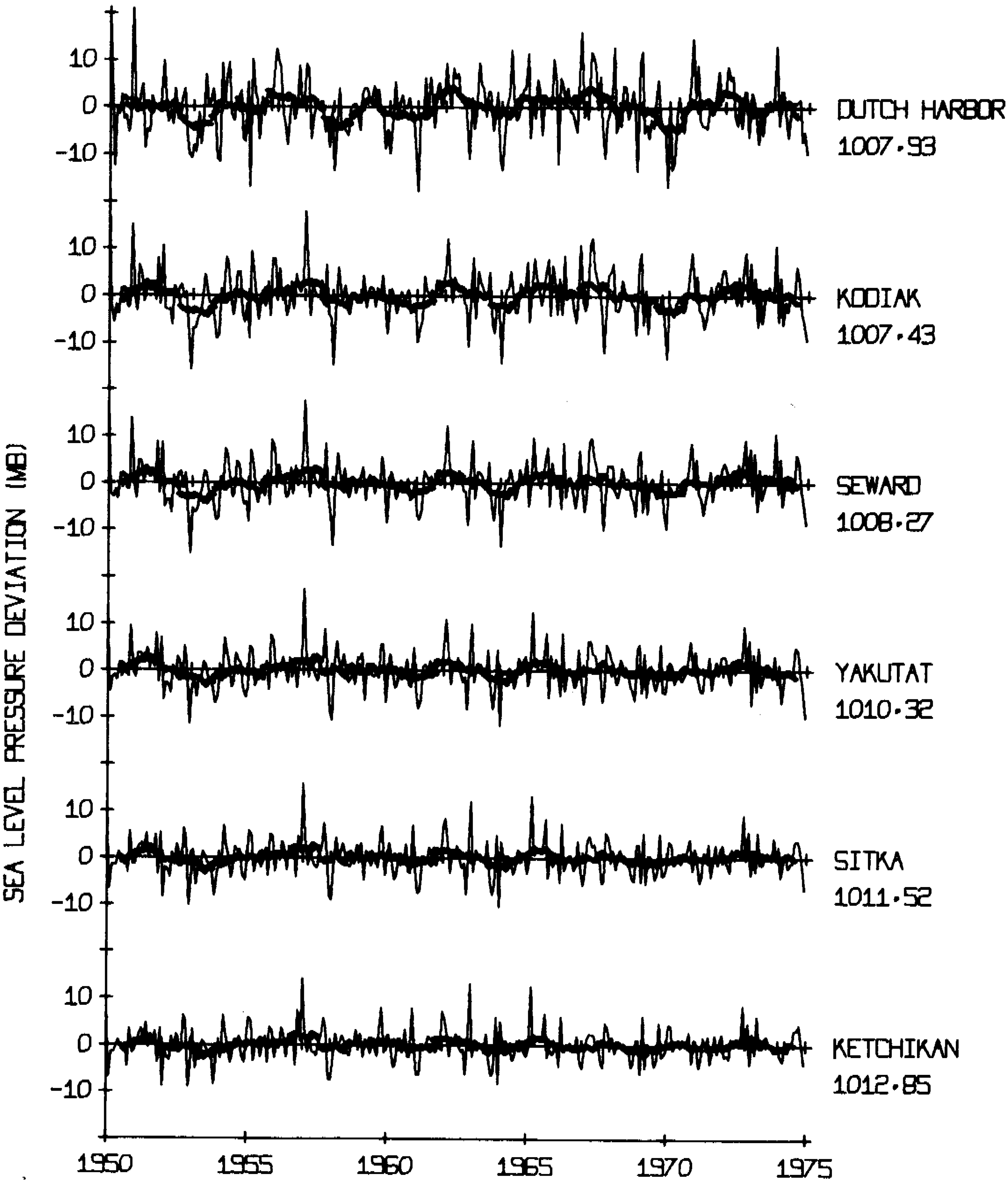


Figure 33. Deviations in sea level pressure (mb) from monthly mean (1950-74) values at the indicated coastal stations and 12-month running mean (dotted line).

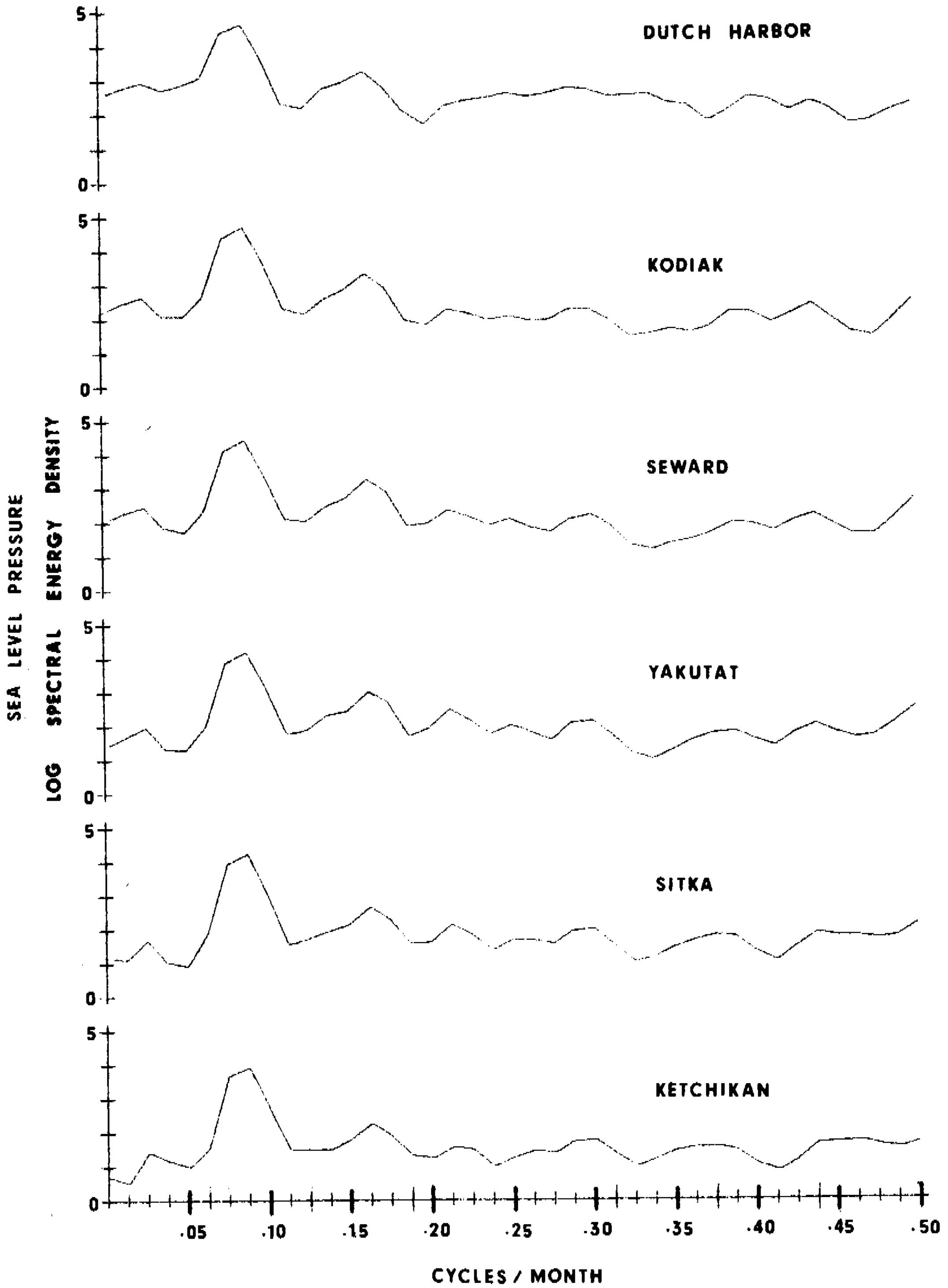


Figure 34. Spectral energy densities (40 lags) for sea level pressure at the indicated coastal stations indicating dominant annual cycle.

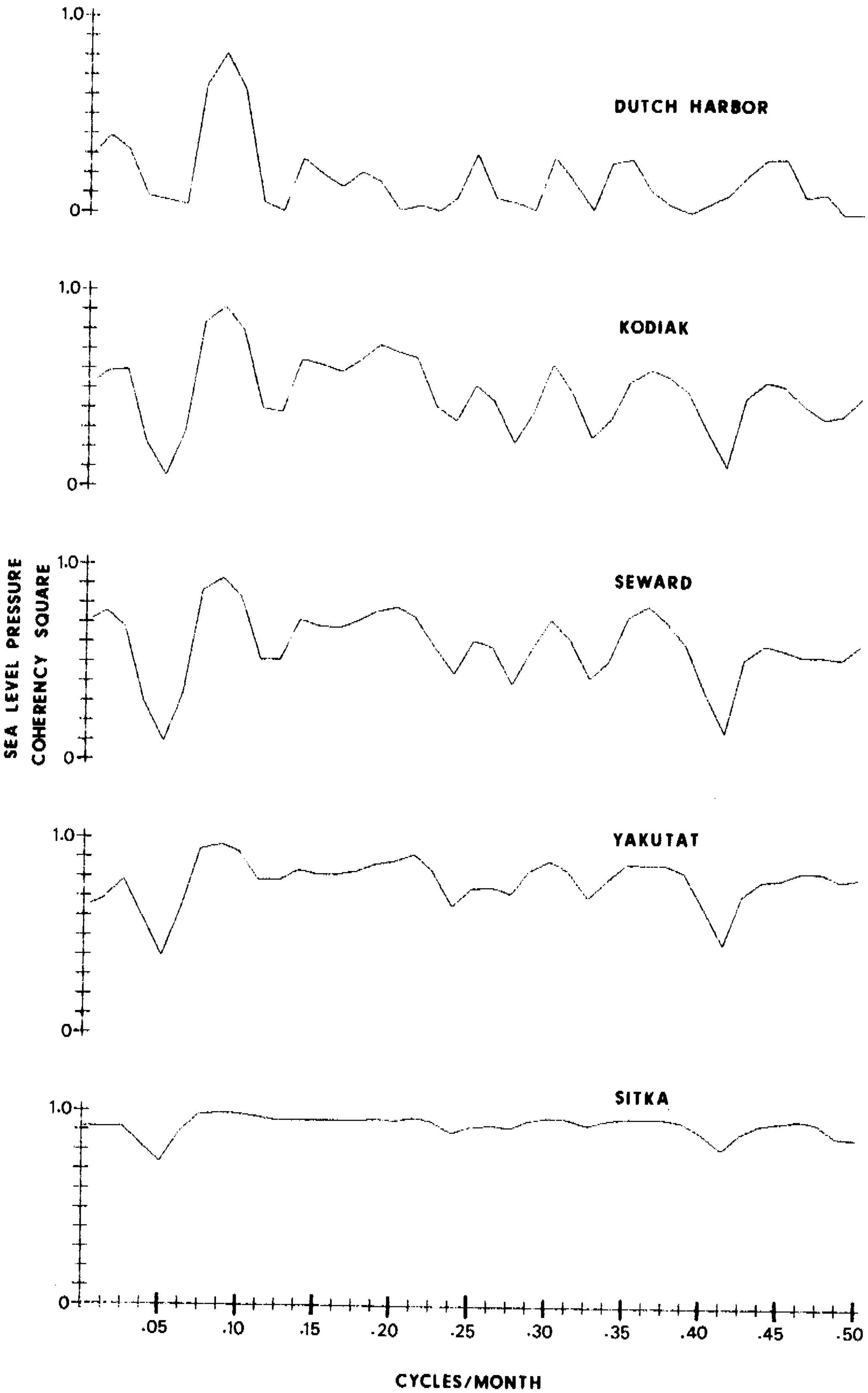


Figure 35. Coherence in sea level pressure at the indicated coastal stations, using Ketchikan as reference station, showing good coherence (>0.9) for annual cycle (.085 cy/mo).

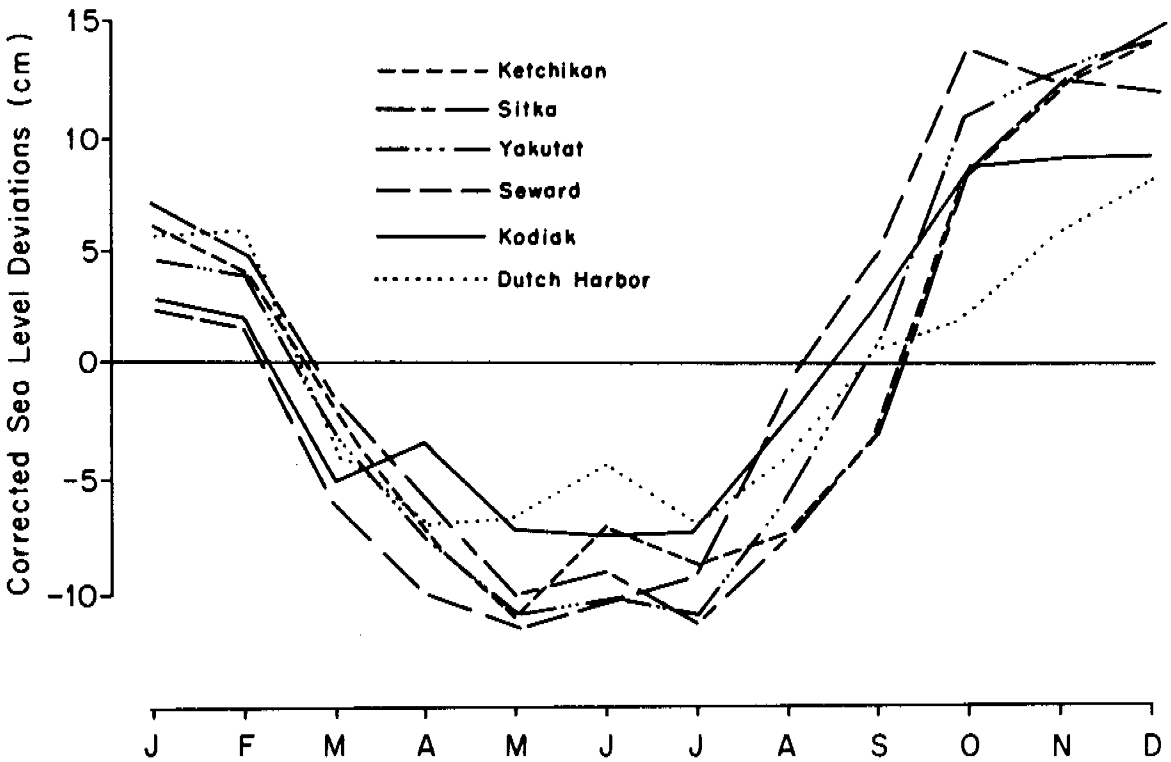


Figure 36. Deviations in monthly mean corrected (for atmospheric pressure) sea level (cm) from long term mean (1950-74) values at the indicated coastal stations showing increase in sea level in winter.

control between the various stations that would permit relating levels at the various sites to a common datum which would permit ascertaining relative levels. Deviations from monthly mean sea level for 1950-74 and 12-month running mean corrected sea level were compiled (Fig. 37). Here again there is continuity in short pulses (e.g. November 1952, January 1958, and others). However, positive and negative anomalies extend for longer periods up to 4 years. Well above normal sea level was evident at Dutch Harbor from 1957-61 and at Ketchikan from 1966-70. The apparent progressive lowering of sea level at Dutch Harbor from 1957 to 1974 is not evident at the other stations, but the below normal levels are evident from 1970 to 1974. These data can be grossly summarized for the area Sitka to Kodiak as follows: 1950-54 above normal, 1955-57 below normal, 1958-62 above normal, 1963 below normal, 1964-69 normal, 1970-74 below normal. As might be anticipated, power spectral analysis (40 lags) for corrected sea level at the coastal stations exhibits the 1 year frequency (Fig. 38). Data at Dutch Harbor, Seward, Yakutat and Ketchikan indicate significant energy densities at periods of less than one year and there is a high coherence ($>.9$) at this frequency at all stations compared to Ketchikan (Fig. 39). In contrast to sea level pressure, there is a marked coherence at 0.5 cy/mo. As before, the limited data points do not permit clear definition of periods greater than 1 year.

C. Relation to Transport

An increase in sea level normally signifies an increase in northward flow into the gulf. Such considerations can only be made when equivalent transport data are available. Obviously this cannot be obtained from

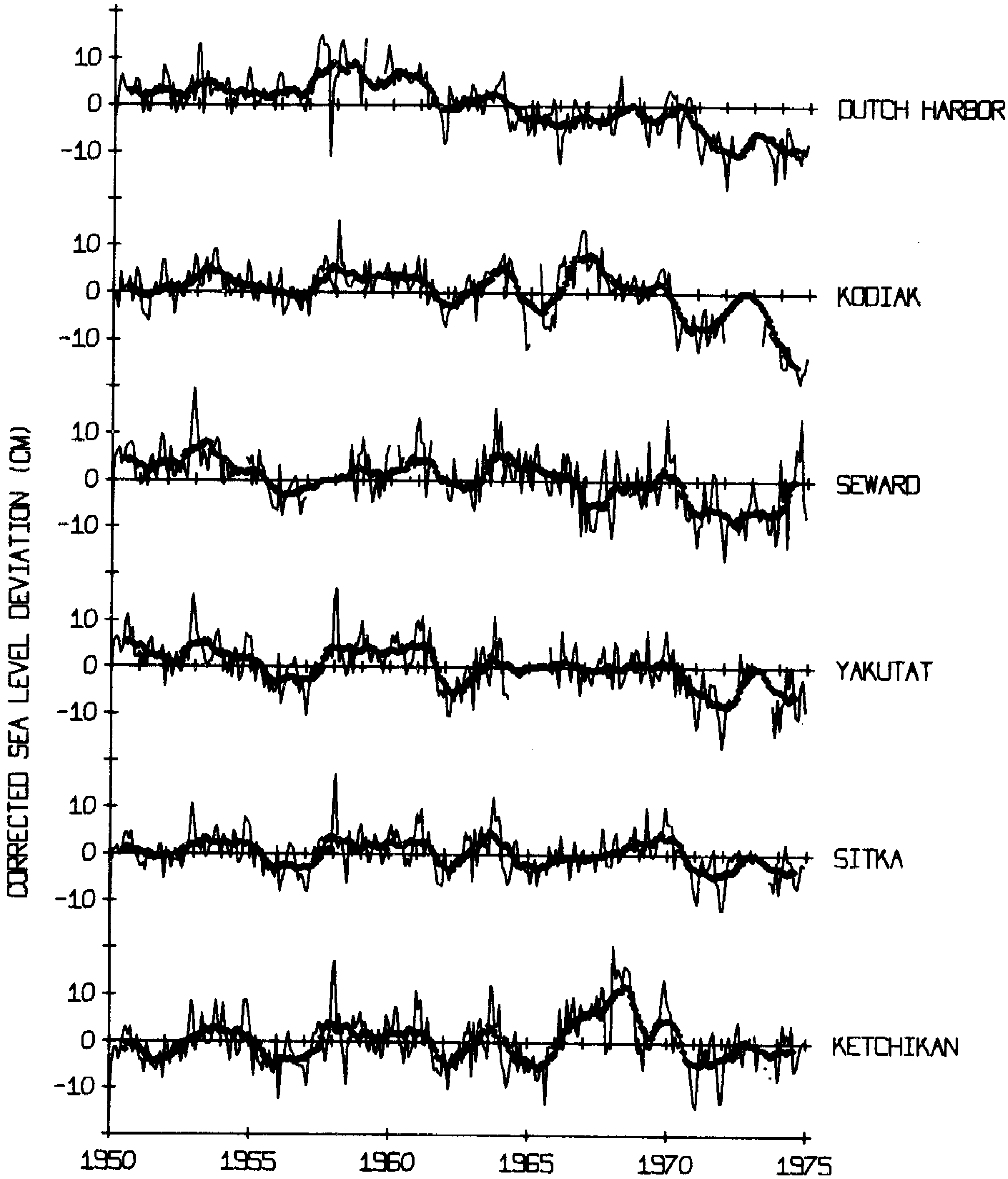


Figure 37. Deviations in corrected sea level (cm) from monthly mean (1950-74) values at the indicated coastal stations and 12-month running mean (dotted line).

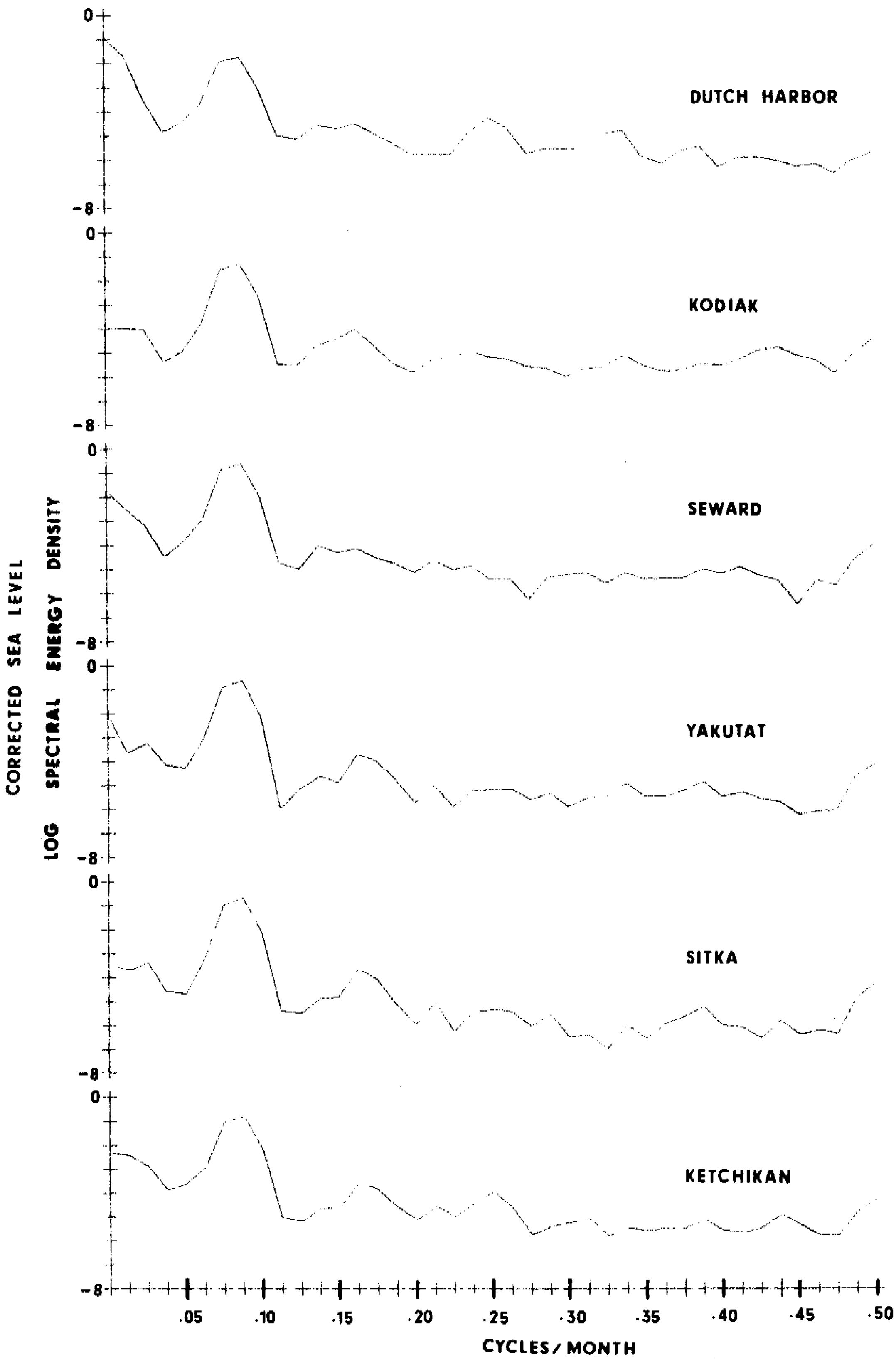


Figure 38. Spectral energy densities (40 lags) for corrected sea level at the indicated coastal stations showing the dominant 1 year cycle.

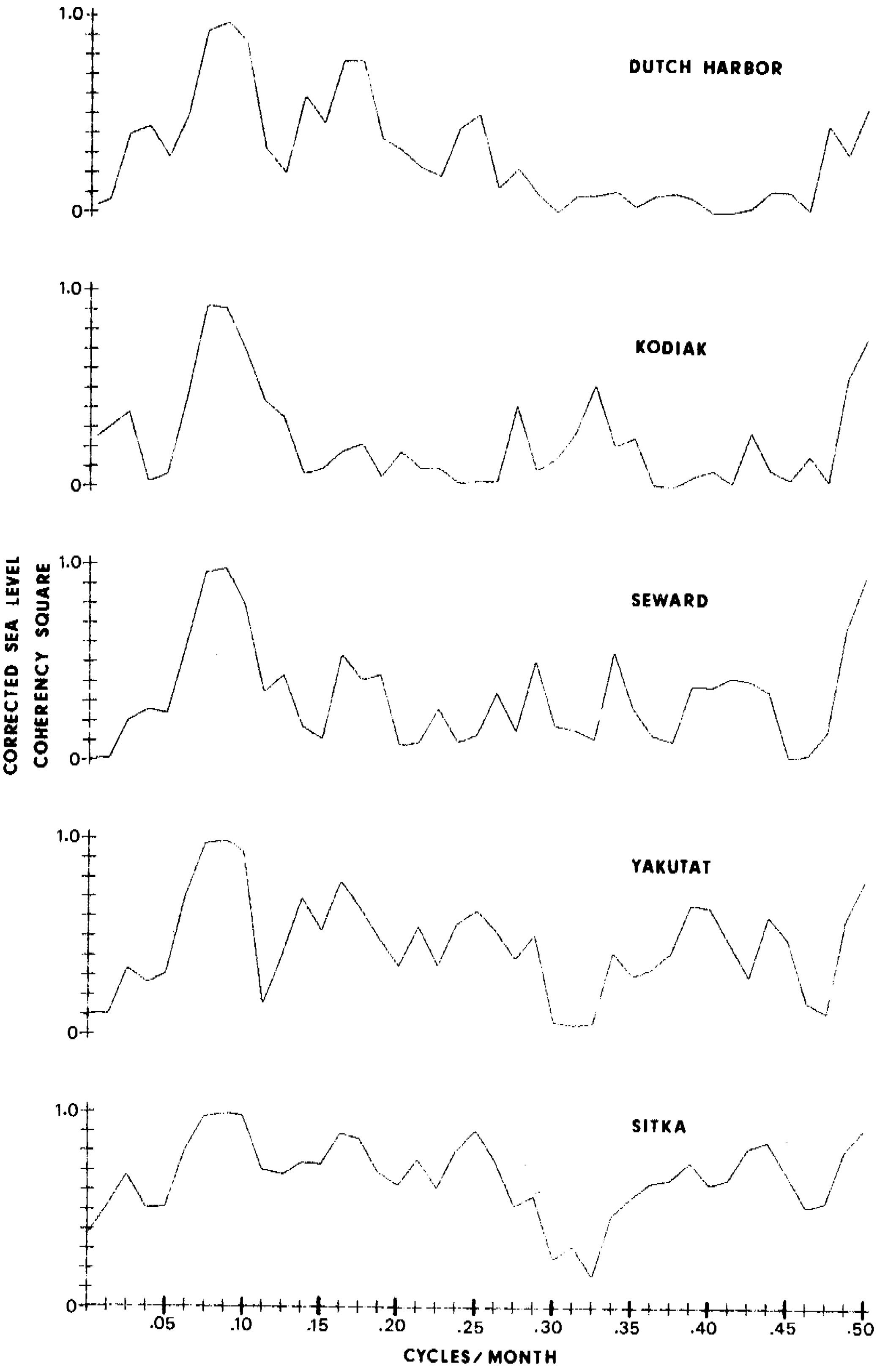


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Figure 39. Coherence in corrected sea level at the indicated coastal stations, using Ketchikan as a reference station, showing good coherence (>0.9) for annual cycle.

station data which are available only for one or two months in a limited number of years. However, comparisons can be made with wind-stress transports. Monthly mean wind-stress transports across 55°N (+northward; - southward) computed for the years 1900-74 indicate a mean transport of 11.22 Sv (Fig. 40). There is a progressive increase in the 25-year mean values from 8.39 to 10.90 to 14.35 Sv that is probably primarily, if not almost entirely, due to progressively better definition of sea level pressure fields; thus, limited comparisons between past and more recent data can be made. Further, the high monthly mean wind-stresses in winter are not of sufficient duration for the calculated transports to become established, but the presence of additional energy is indicated.

The individual monthly mean transports in 1950-74 have a greater range (∼ 80 Sv) than in the previous two 25-year periods (∼60 Sv). The following winters stand out as having high northward transport: 1908-09, 1949-50, 1955-56, 1958-59 and 1965-66. Anomalous southward transports are indicated in: fall 1900, winter 1920, winter 1929, fall 1930, summer 1936, summer 1958 and fall 1965.

Transport ranges reflected in the 12-month running means are quite similar (∼ 12 Sv) for the three 25-year periods. Except for the years 1950-1965 when there is evidence of an approximate 3-year cycle there is no immediately apparent suggestion of any other periodicities. The long data record (900 data points) provides the first substantial look at periods greater than one year and spectral analyses using 80 and 160 lags substantiate the peak near 3 years.

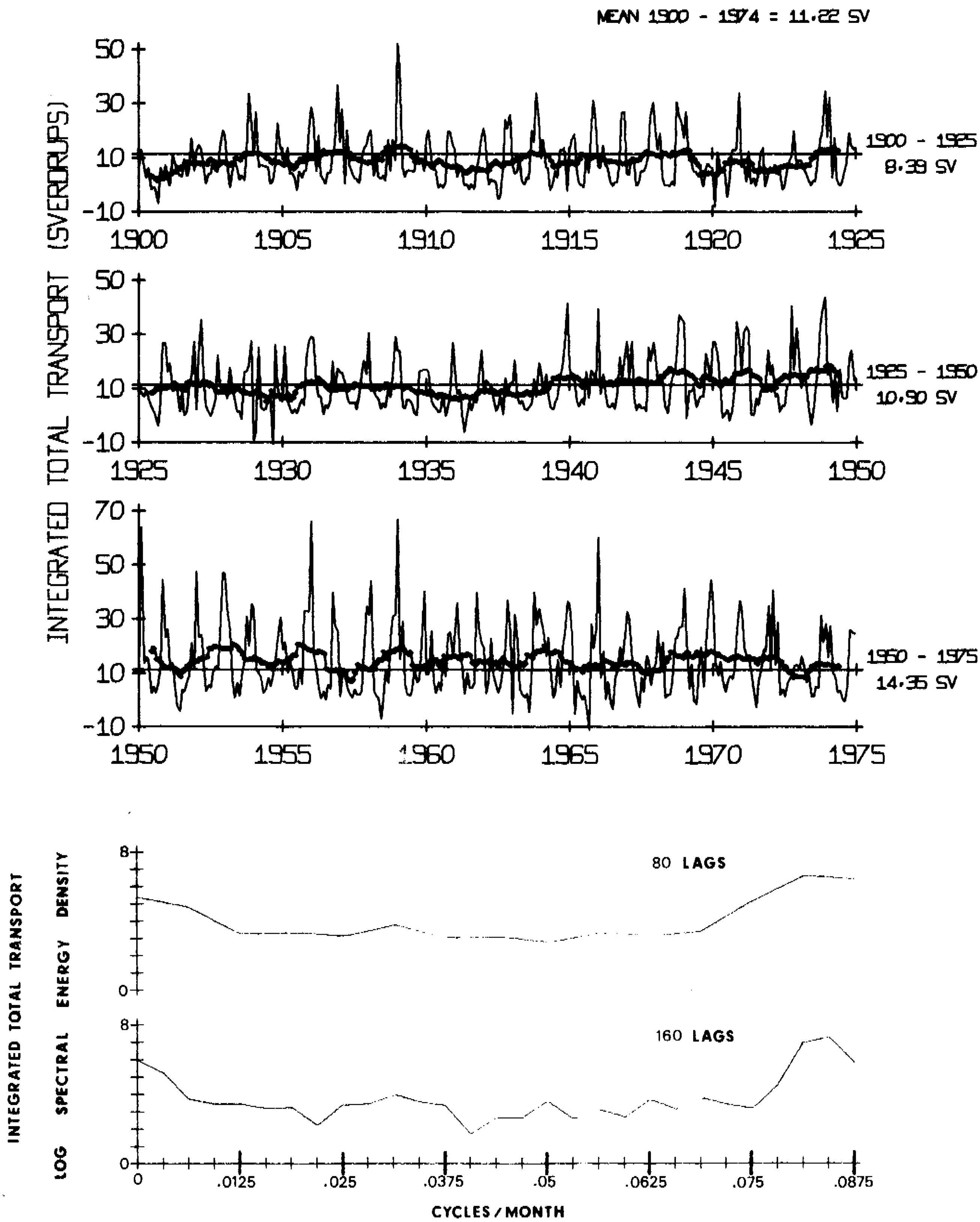

Figure 40. Monthly integrated total transports (Sv) across 55°N (+northward, -southward) 1900-74, 12-month running mean (dotted line), and spectral energy density (80 and 160 lags).

VI. SURFACE CONVERGENCE AND DIVERGENCE

The surface wind drift, i.e. the water carried along in the very surface layer of the ocean under the direct action of the wind, usually contributes only slightly to the surface velocity field, and because of its limited vertical extent is nearly always negligible in terms of total mass transport. However, the surface drift field can contain very large convergences and divergences, which may fluctuate rapidly, both in pattern and intensity. These convergences and divergences create pressure gradients and redistributions of mass which alter the underlying geostrophic currents. Because it is likely that these alterations are highly important on the scales of interest to OCSEAP field programs, a rather detailed study of the convergence-divergence pattern in the surface waters of the Gulf of Alaska has been made.

The energetic winter season dominates the annual cycle. Typically, positive wind stress curl associated with an atmospheric low pressure system induces divergent surface drift. Where the coastal boundary of the Gulf presents a barrier to this drift, convergence and intense downwelling result (Bakun, 1975). Such a situation would act to intensify the characteristic ridging of the density structure in the interior of the Gulf and to steepen the plunge of the isopycnals toward the coast. This "pumping" between the coastal and offshore areas would tend to build up baroclinicity through the winter season, which apparently would dissipate during the more relaxed portion of the year.

In order to investigate the coupled system, indices of divergence of wind-induced surface flow at 6-hourly intervals from January, 1967 through December 1975 were generated at 15 locations indicated in Figure 41. The surface flow field is approximated as Ekman Transport and an

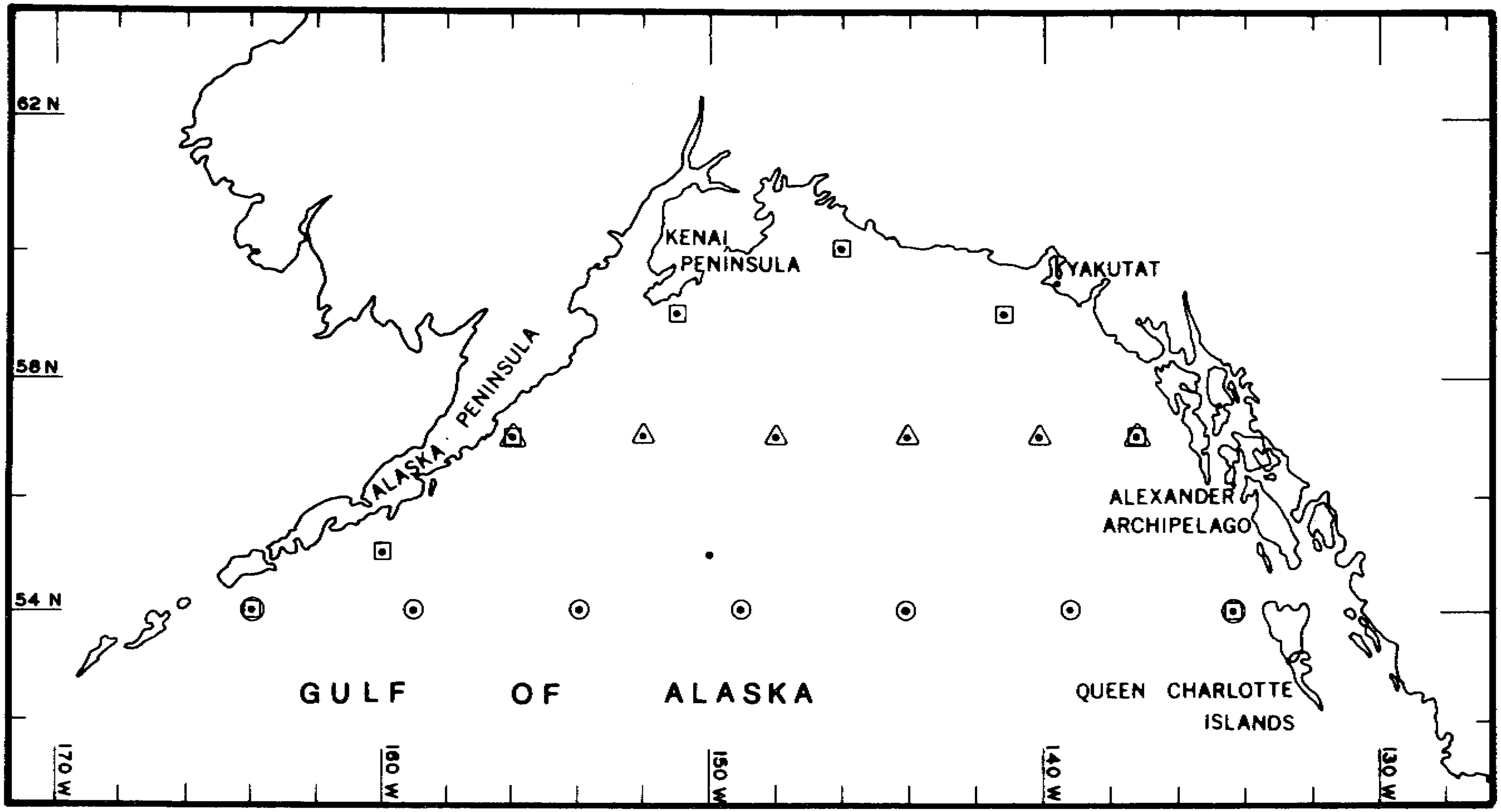

Figure 41 - Chart of the Gulf of Alaska region, showing locations at which time series of surface convergence-divergence indices were computed.

example segment of the time series at one location is shown (Fig. 42).

In the previous sections data fields averaged over a month or longer have been discussed. This is because attention has been focused on lower frequency, relatively slowly changing components of the variations, either because we are not equipped to deal with the shorter term variability or because sparsity of data requires that we collect observations over some time interval in order to get an adequate sample. Now an attempt will be made to deal with the synoptic scale. Such an approach is called for in this case because the extremely large variance of the surface divergence field on short time scales requires that proper interpretation of even the longer period variations be made within the framework of the process as it is actually occurring on the synoptic scale.

On this scale attention shifts from such mean pressure features as the Aleutian Low, or a Continental High, to individual traveling storm systems. Major winter storm tracks cut directly across the gulf from the southwest toward the northeast. Mean speeds of storm movement along these tracks are of the order of 25 knots (Klein, 1957). During the summer a larger proportion of storms turn northward through the Bering Sea and so are not felt with full intensity in the Gulf of Alaska. In addition, the summer storms are normally much less intense than the winter storms. The available reports of wind speed and direction for an area such as the gulf tend to be sparse and unevenly distributed. Example distributions of reports (Fig. 43) show that major fraction of available reports come from shore stations which, being subject to topographical influences, may not be completely representative of conditions offshore. The distribution of the observations taken at sea changes continually, and for any single observation, random errors in measurement or position may introduce

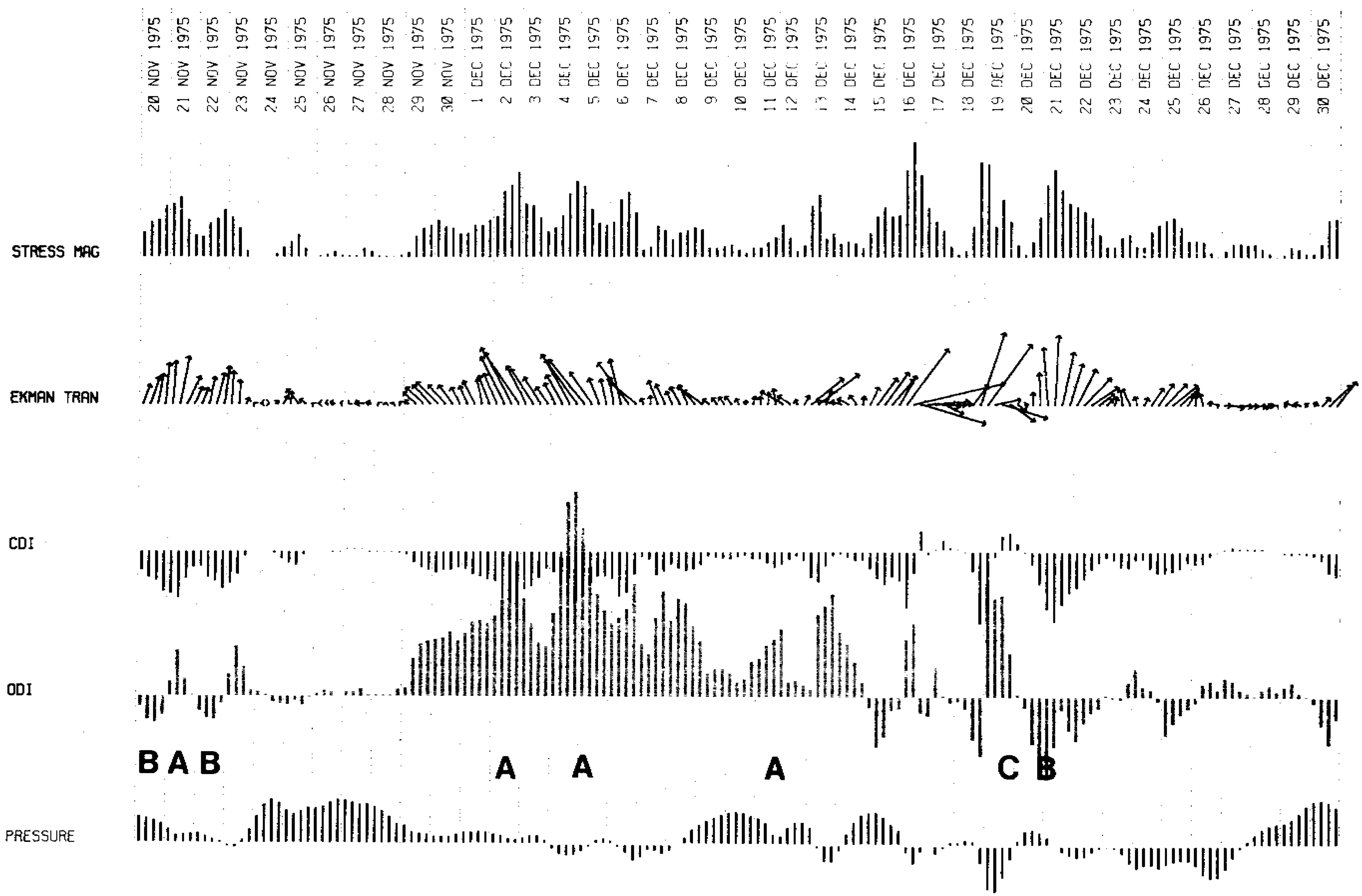

Figure 42 - Example time series segment (60°N, 146°W, Nov. 20, 1975 - Dec. 30, 1975). Upper graph indicates the stress magnitude at each 6-hourly synoptic sampling. Second graph indicates the magnitude and direction of Ekman transport; north is toward the top, etc. Third graph indicates the coastal divergence index (CDI). Fourth graph indicates the offshore divergence index (ODI). Large letters refer to type of event according to classification of Fig. 44.

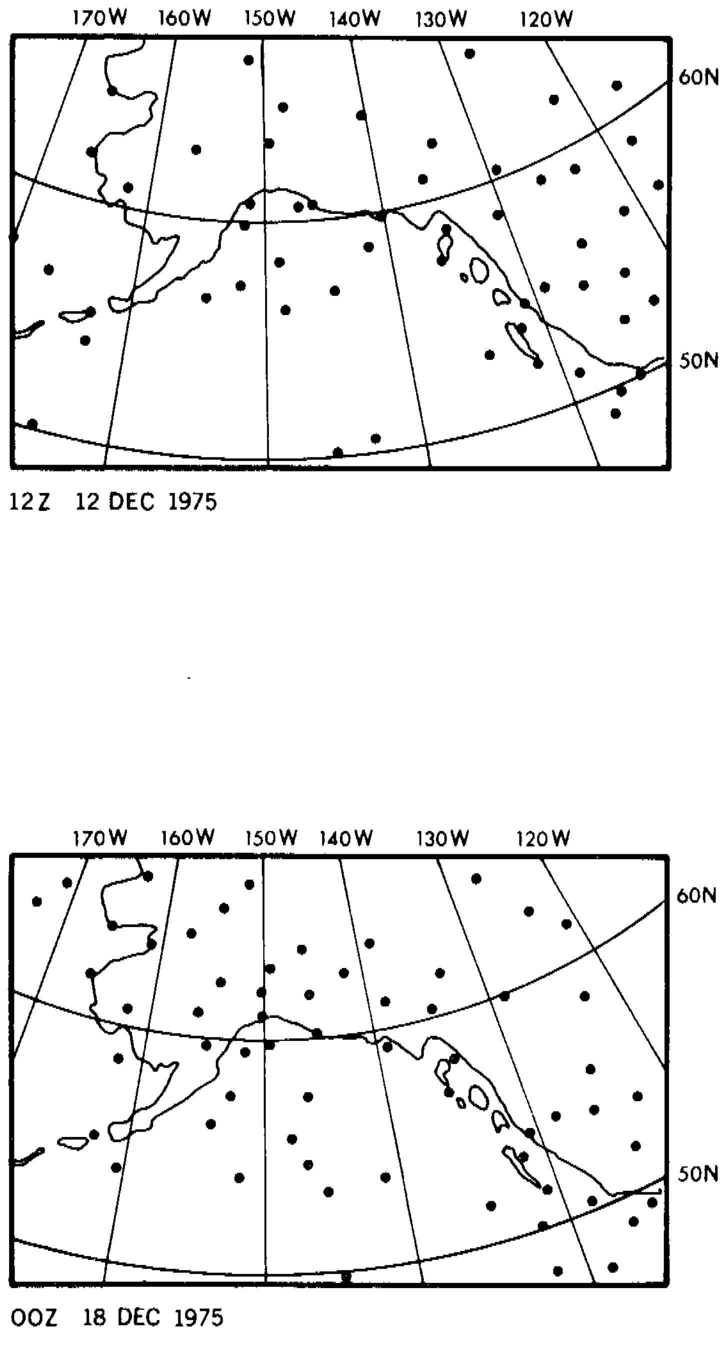

Figure 43 - Example distributions of synoptic reports which arrived at Fleet Numerical Weather Central in time for incorporation in the operational surface pressure analysis.

variability which is greater than the variability in the process itself (Nelson, 1974).

One way to arrive at a fairly consistent time series is to make use of analysed products produced by meteorological agencies. For this portion of the study 6-hourly synoptic surface atmospheric pressure analyses produced by Fleet Numerical Weather Central (FNWC) have been used. These analyses incorporate all available wind reports in the form of equivalent pressure gradients. The use of the pressure reports, which are linked to the wind field through well-known relationships, effectively increases the data base.

The method of atmospheric pressure analysis presently in use at FNWC is described by Holl and Mendenhall (1972). The basic steps in the analysis are as follows:

- Preparation of "first guess" field: The pressure analysis for the previous synoptic sampling, 6 hours earlier, is extropolated forward using a computation of 6-hour upper air movement and a 6-hour surface forecast using the FNWC primative equation computer forecast model.
- Assembly of new information: new reports are compared to the first guess field, subjected to a gross error check, and assigned a reliability value; surface wind reports are assembled in a gradient field.
- Blending for pressure: a blending equation of 61 terms which take into account the pressure, gradient, second-differences, cross differences, and Laplacians, plus the reliability value of each of these, is used to assemble a "best fit" pressure field.

- Computation of reliability field: depending on the amount and reliability of information available, each grid-point value is assigned a reliability.
- Reevaluation and lateral rejection: reports are again compared to blended pressure field and reliability field and assigned new reliability values; those failing to meet criteria are rejected.
- Recycling: a new assembly is made according to the new first guess field and assigned reliabilities. The whole process is then repeated a third time to gain further accuracy.

In order to produce the computed indices discussed in this section pressure data from FNWC fields archived on magnetic tape were arranged on a 3-degree computational grid and the curl of the wind stress, $\nabla \times \vec{\tau}$ derived as shown in equations 5-20, except that constant drag coefficient of 0.0013, appropriate for synoptic rather than mean data, was used. The Ekman transport, $\vec{E}$, is derived as

$$\vec{E} = \frac{1}{f} \vec{\tau} \times \vec{k} \qquad (25)$$

where $\vec{k}$ is a unit vector directed vertically upward.

The divergence of Ekman transport integrated over the width of the coastal upwelling-downwelling boundary zone, per unit length of coast, is given, to a high degree of approximation, by the offshore component. Bakun (1973) called this by the term upwelling index. In this report we refer to it as the coastal divergence index, abbreviated as CDI.

$$CDI = \vec{E} \cdot \vec{n} \qquad (26)$$

where $\vec{n}$ is a unit vector normal to the coast. Units used are metric tons per second per 100-meter length of coast.

Away from the boundary zone the divergence of Ekman transport is computed as

$$\text{ODI} = \nabla \cdot \vec{E} = \frac{1}{f} \nabla \times \vec{\tau} - \frac{\beta}{f} \vec{E} \cdot \vec{j} \qquad (27)$$

where β indicates the meridional derivative of f. ODI stands for <u>offshore divergence index</u>. The values presented in this report are in terms of vertical velocity (millimeters per day) through the bottom of the Ekman layer required to balance the computed divergence.

A. Vicinity of the coastal boundary

Various combinations of coastal and offshore convergence or divergence occur near the coastal boundary (Fig. 44). Both types A and B are characterized by coastal convergence (negative CDI) in the coastal boundary zone; surface water is piled up toward the coast with a resulting depression of the isopycnals, tending to intensify counter-clockwise flow along the border of the gulf. In the case of type A, divergence immediately offshore of the boundary zone (positive ODI) would favor confinement of the intensification to a narrow zone next to the coast. In the type B situation continued convergence offshore of the boundary zone (negative ODI) would spread the effect toward the interior of the Gulf.

Under situations C and D, coastal divergence (positive CDI) would favor clockwise circulation along the boundary of the Gulf (or deceleration of counter-clockwise flow, etc.). Correspondingly, type C (positive ODI) would tend to spread the effect, while type D (negative ODI) would tend to confine it to the immediate boundary zone.

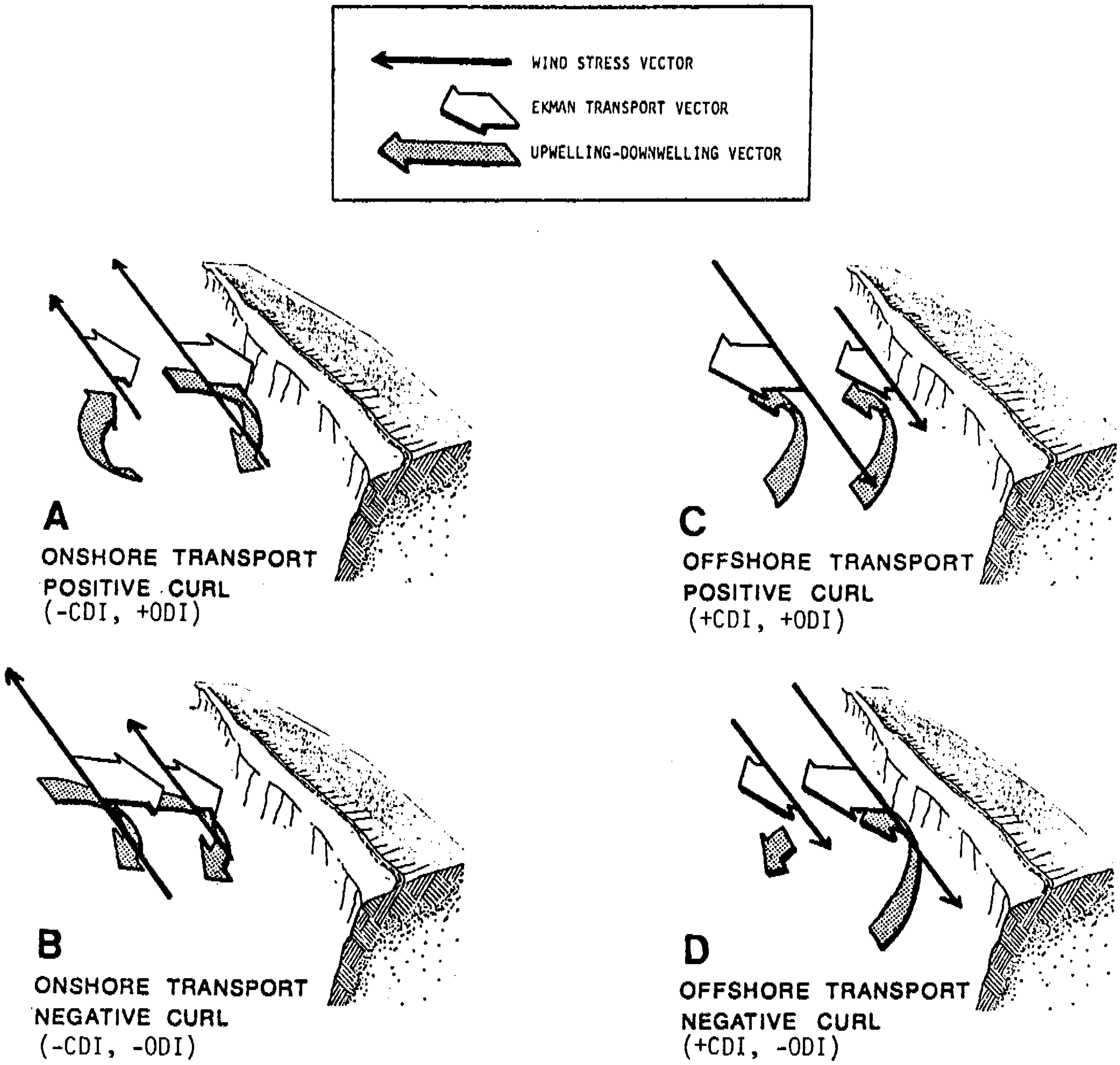

Figure 44 - Classification of indicated events according to combination of coastal and offshore convergence or divergence. A. Onshore Ekman transport and positive wind stress curl; convergence and downwelling at the coast, divergence and upwelling offshore. B. Onshore Ekman transport and negative wind stress curl; convergence and downwelling at the coast, continued convergence offshore. C. Offshore Ekman transport and positive wind stress curl; divergence and upwelling at the coast, continued divergence offshore. D. Offshore Ekman transport and negative wind stress curl; divergence and upwelling at the coast, convergence offshore.

The monthly frequency distributions of coastal divergence indices (CDI), at the near coastal locations (surrounded by squares in Fig. 41) show strongly negative mean values during the winter, indicating convergence and resulting downwelling at the coast (Fig. 45). The area of greatest intensity extends from the Kenai Peninsula (59°N, 151W) to the Alexander Archipelago (57N, 137W), reaching a maximum near Yakutat (59N, 141W). This situation relaxes during the remainder of the year; coastal divergence (positive CDI) is indicated on average over much of the gulf during summer. This "summer upwelling season" is longest in the southwest portion, extending from April to December near the extremity of the Alaska Peninsula and exhibiting three separate maxima (April, August, and November). The season of mean upwelling becomes progressively shorter and less intense with distance clockwise around the gulf, lasting three months off the Kenai Peninsual and essentially vanishing off the Alexander Archipelago.

The maximum variance corresponds in season and location to maximum absolute values of the mean. Standard deviations are larger than the means. Thus the winter season is characterized by highly energetic pulsations and relaxations of coastal convergence. In other seasons, the general trend is for the variance to decrease with the mean. The most stable situation appears to be the summer season in the northern gulf (59N, 151W; 60N, 146W; 59N, 141W). The three separate maxima exhibiting fairly similar mean positive CDI values off the lower Alaska Peninsula (54N, 164W; 55N, 160W) appear quite distinct in terms of variance. The August maximum in the mean shows the lowest variance, whereas, the November maximum exhibits standard deviations nearly three times those of August. Thus, the mean

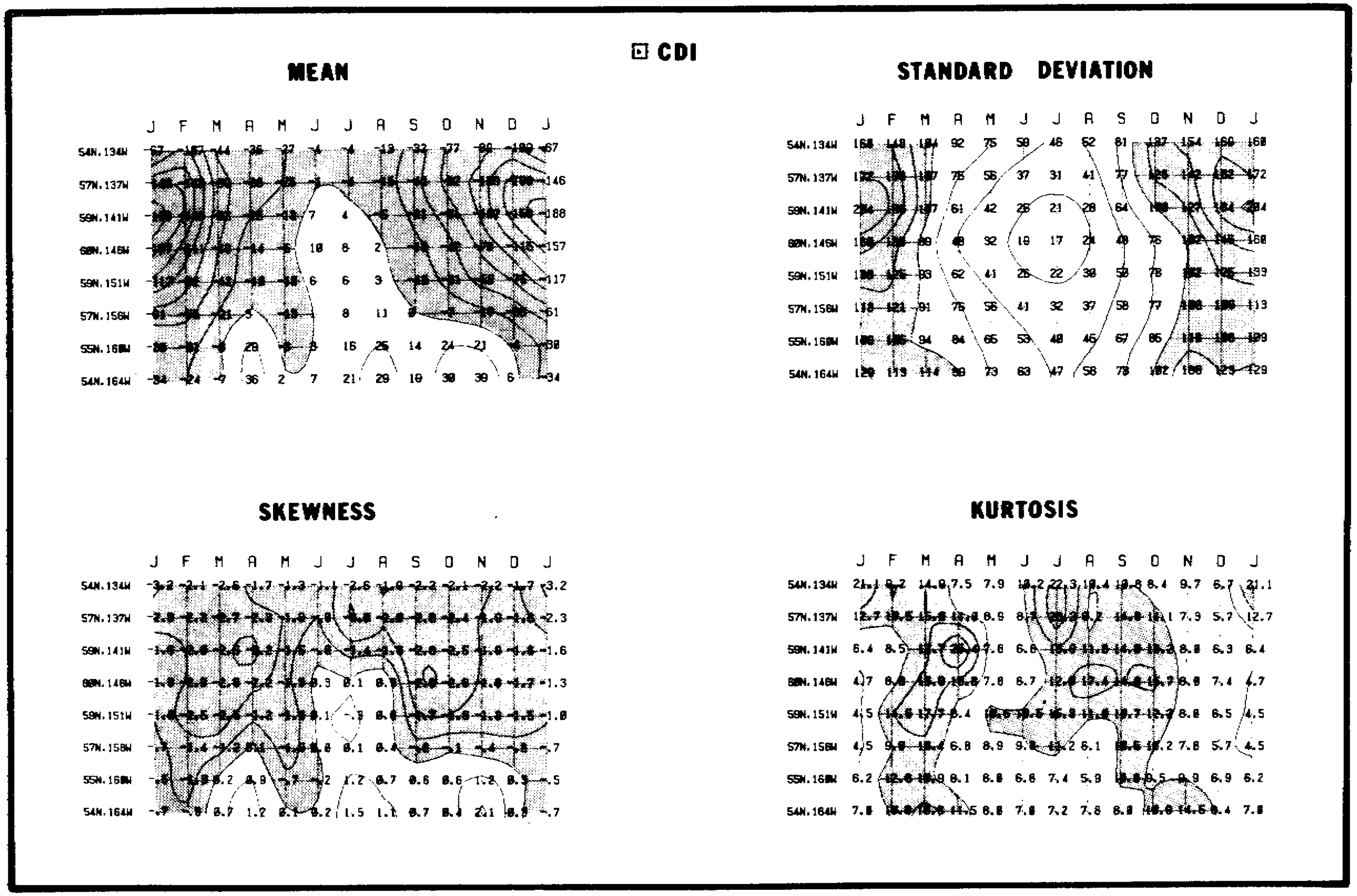

Figure 45 - Moments of the frequency distributions of coastal divergence indices (CDI) grouped by month at the near-coastal locations indicated by triangles in Fig. 41. Mean: units are cubic meters per second transported off each 100-meter width of coast; contour interval is 25. Standard Deviation: units and contour interval are the same as for the mean. Skewness: contour interval is one normalized unit. Kurtosis: contour interval is 5 normalized units.

upwelling indicated for November represents an energetic mix of upwelling and downwelling events, with the balance tipped slightly toward upwelling.

The skewness tends to have the same sign as the mean; i.e. extreme events during downwelling seasons tend to be downwelling events, and those during upwelling seasons to be upwelling events. Some modification of this general pattern appears in the northern gulf where the distribution of skewness shows a tendency to be more negative than the mean (i.e. a considerable contribution from relatively extreme downwelling events even during seasons of mean upwelling). Off the lower Alaska Peninsula an expansion of the period of positive skewness beyond that of positive mean value indicates relative importance of extreme upwelling events, most probably related to very intense storms centered north of the Alaska Peninsula.

In all months and locations the kurtosis is larger than 3.0 indicating that there appears to be a much larger contribution of extreme events than would be the case in a Gaussian process. The details of the distribution of kurtosis are controlled to some extent by the fact that the kurtosis is normalized against the variance; thus, the winter season exhibits relatively low kurtosis because the variance is high (i.e. events which would be "extreme" at other seasons are the norm during winter). When a winter-type storm appears in the spring, for example, it contributes to a higher kurtosis because the general level of activity is lower. The relatively high kurtosis during the summer season indicates that the generally stable situation is interrupted only infrequently. Large contributions to the variance from extreme events are indicated for the lower Alaska Peninsula area during the fall season.

The monthly frequency distributions of offshore divergence indices (ODI) at the near coastal locations (Fig. 46) have mean values which are positive, indicating divergence on the average offshore of the coastal upwelling-downwelling zone, except during January in the southwestern Gulf and during the summer from the Kenai Peninsual eastward. Strongest divergence on average occurs near Yakutat during winter, corresponding in season and location to the maximum negative CDI values.

The ODI variance is largest in winter, but rather than corresponding in location to the mean as was the case for the CDI values, there is a double maximum (59N, 151W; 57N, 137W) with a relative minimum in the area of the maximum mean values. In the southwestern Gulf the period of maximum variance shifts to the fall.

The skewness of the monthly ODI distributions tends to be positive; extreme events are characterized by divergent surface drift associated with cyclonic storms. Some of the monthly distributions in the northern and eastern gulf exhibit a slight negative skewness in the spring or summer. The kurtosis indicates major contributions to the variance from infrequent, extreme events.

Comparison of mean CDI and ODI values confirms that, in a mean sense, the preeminent situation along the coastal boundary of Gulf is type "A" (see Fig. 44). The extreme energy of the downwelling at the coast and divergence offshore associated with winter storm systems completely dominates the annual cycle. Table 2 lists the "types" corresponding to the monthly mean situation at the various locations. Type D is restricted to the extremely low-energy summer situation in the northern gulf. The

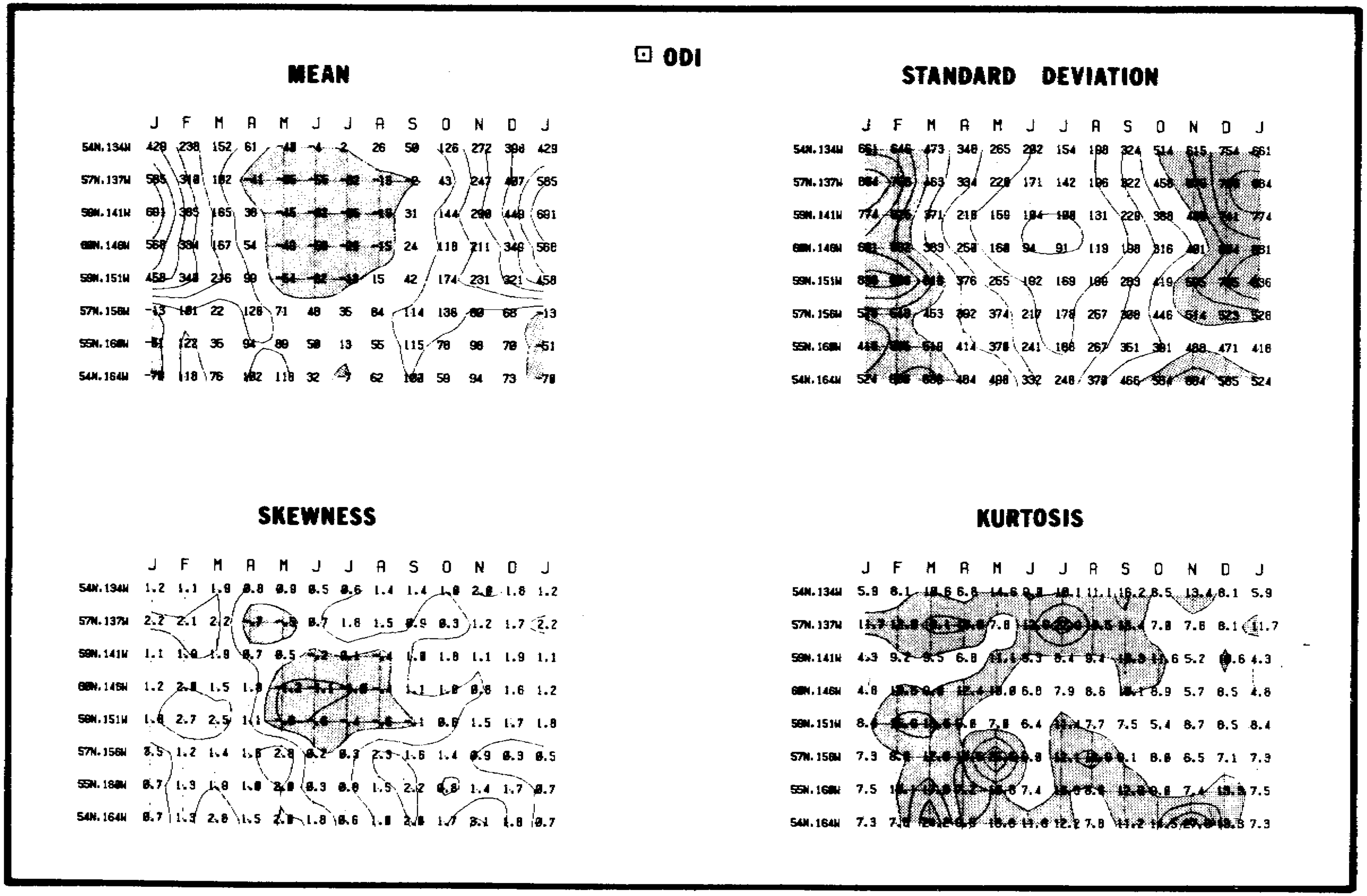

Figure 46 - Moments of the frequency distributions of offshore divergence indices (ODI) grouped by month at the near-coastal locations indicated by squares in Fig. 41. Mean: units are millimeters per day upward velocity through the bottom of the Ekman layer required to balance the indicated divergence; contour interval is 100. Standard deviation: units and contour interval is one normalized unit. Kurtosis: contour interval is 5 normalized units.

TABLE 2 - Monthly mean "types" of convergence-divergence couple, according to the classification of Figure 44, characterizing the near-coastal locations indicated by squares in Figure 41.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
54N, 164W	B	A	A	C	C	C	C	C	C	C	C	C
55N, 160W	B	A	A	C	A	C	C	C	C	C	C	A
57N, 156W	B	A	A	C	A	C	C	C	C	A	A	A
59N, 151W	A	A	A	A	B	D	D	C	A	A	A	A
60N, 140W	A	A	A	A	B	D	D	D	A	A	A	A
59N, 141W	A	A	A	A	B	D	D	B	A	A	A	A
57N, 137W	A	A	A	B	B	B	B	B	B	A	A	A
54N, 134W	A	A	A	A	B	B	A	A	A	A	A	A

coastal area of the lower Alaska Peninsula is, on average, under a type C situation over much of the year; considering this surface drift effect alone, the net tendency would seem to be to break down some of the baroclinicity built up in the type A situation further east.

The fraction of 6-hourly samplings during each month characterized by the various event types are summarized for several locations (Fig. 47). The seasonal shift from type A to type D at 59N, 141W is well illustrated. In this presentation, all periods, even where the index values were so small as to be negligibly different from zero, were included in calculating the percentages. When the weaker events are excluded the percentage of the dominant event type increases. By progressively increasing the required intensity the percentages of the less common types would eventually approach zero.

In order to perform spectral analysis on seasonal time series of substantial length, we have constructed composite winter and summer time series of the indices at each location. For example, winter time series were formed of all values within weeks of which the first day falls within the months of December, January, or February. Thus, the first week of December, 1974 follows directly after the last week in February, 1973. Summer series were similarly formed from values within weeks which begin in June, July, or August, etc. This procedure affects only the longer period spectral estimates which tend to be lost in the unresolvable seasonal and climatic scale energy. The results effectively summarize the features observed from analysis of the various short, properly continuous, seasonal segments of the time series.

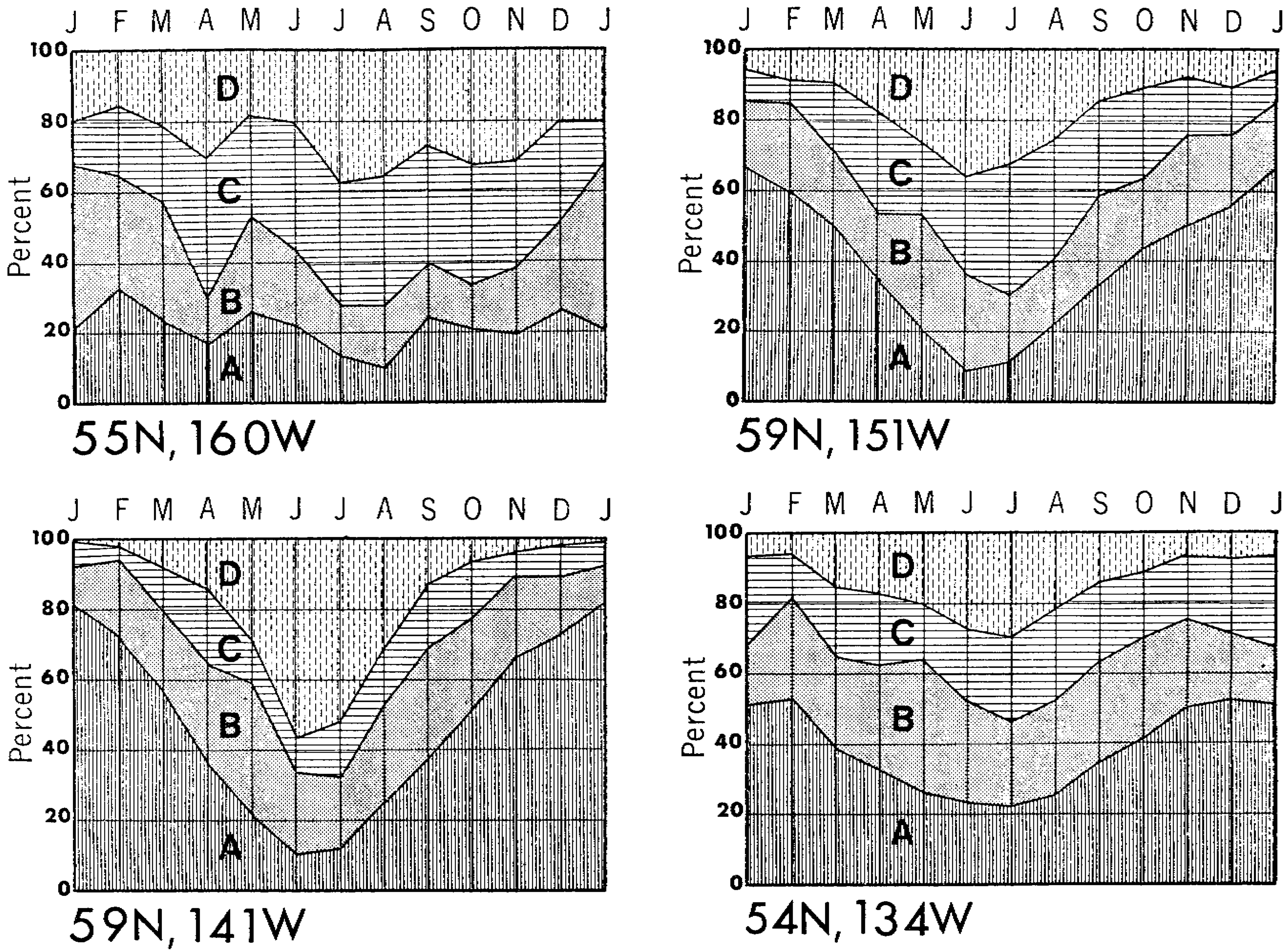

Figure 47 - Percentages, by month, of 6-hourly synoptic samplings characterized by each of the "event types" classified in Fig. 44.

Autocorrelation functions were computed from the CDI series (Fig. 48) and from the ODI series (Fig. 49). In all cases autocorrelation drops off rapidly within the first several days; time scales of individual events are characteristically short. A diurnal fluctuation, most marked in the CDI series, is apparent during summer (and less markedly in spring) at near-coastal locations in the northern and eastern Gulf. A somewhat lower frequency oscillation, indicating the "event" scale, is visible in many of the functions.

Examples of cross correlations between the CDI indices and ODI indices at the same location (Fig. 50) show that cross correlation tends to be negative for short lag periods, most markedly in the winter in the northeastern Gulf where the type A situation (negative CDI, positive ODI) predominates. Indications of negative cross correlations during summer in the same area are related to the predominance of Type D. Off the Alaska Peninsula cross correlation is low, indicating a rather complex mixture of event types and intensities.

Power spectra corresponding to the autocorrelation functions (see Figs. 48 and 49) have been constructed (Figs. 51 and 52) based on 100 lags of seasonal data series containing over 3000 data points each. This translates to about 66 degrees of freedom, representing considerable stability in the resulting spectral estimates. The spectra are similar in general form, resembling "red noise" spectra. Such spectra, which are characterized by a general decrease in energy from lower to higher frequencies, are indicative of temporal persistence within the series.

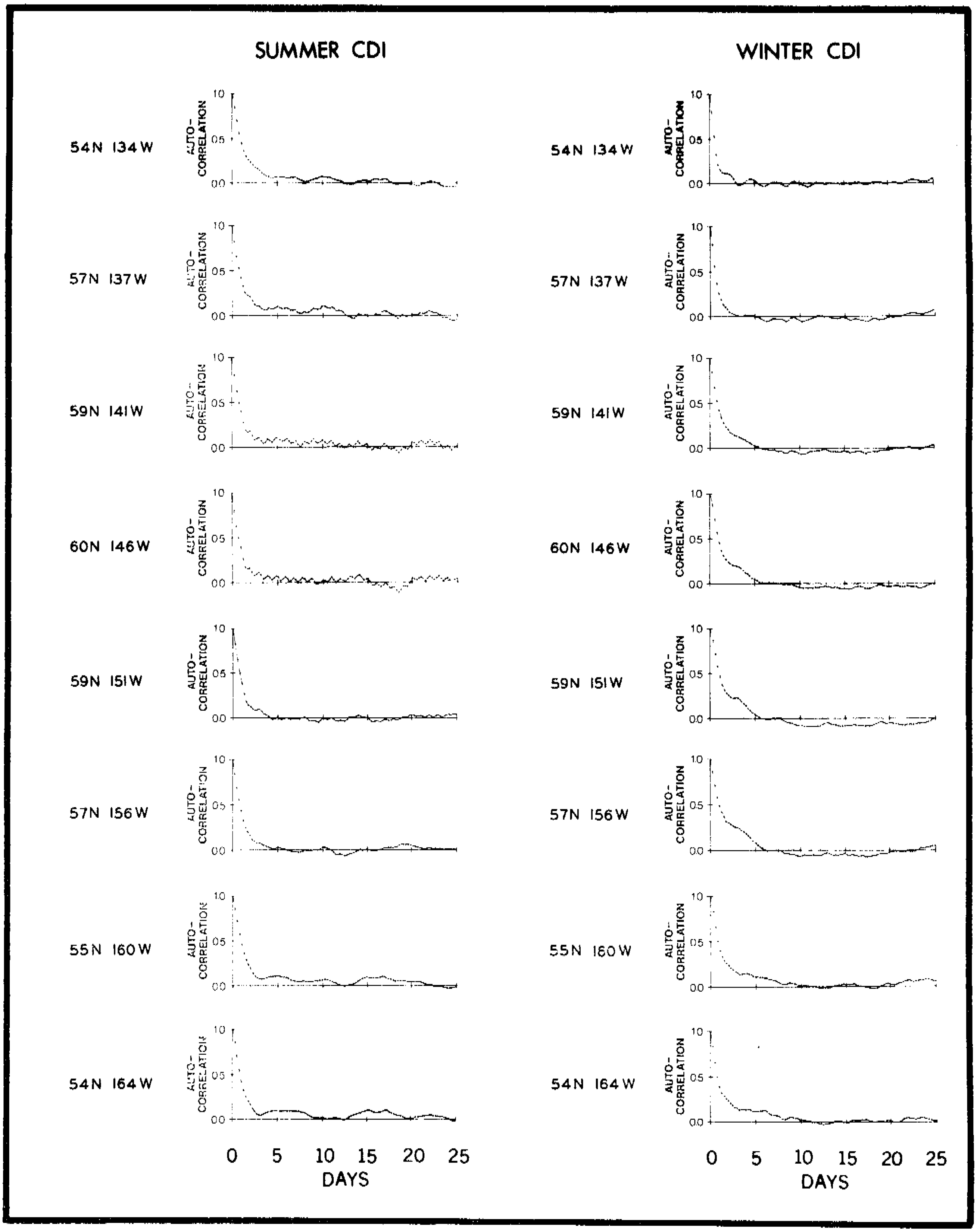

Figure 48 - Autocorrelation functions for coastal divergence indices (CDI) at the near-coastal locations.

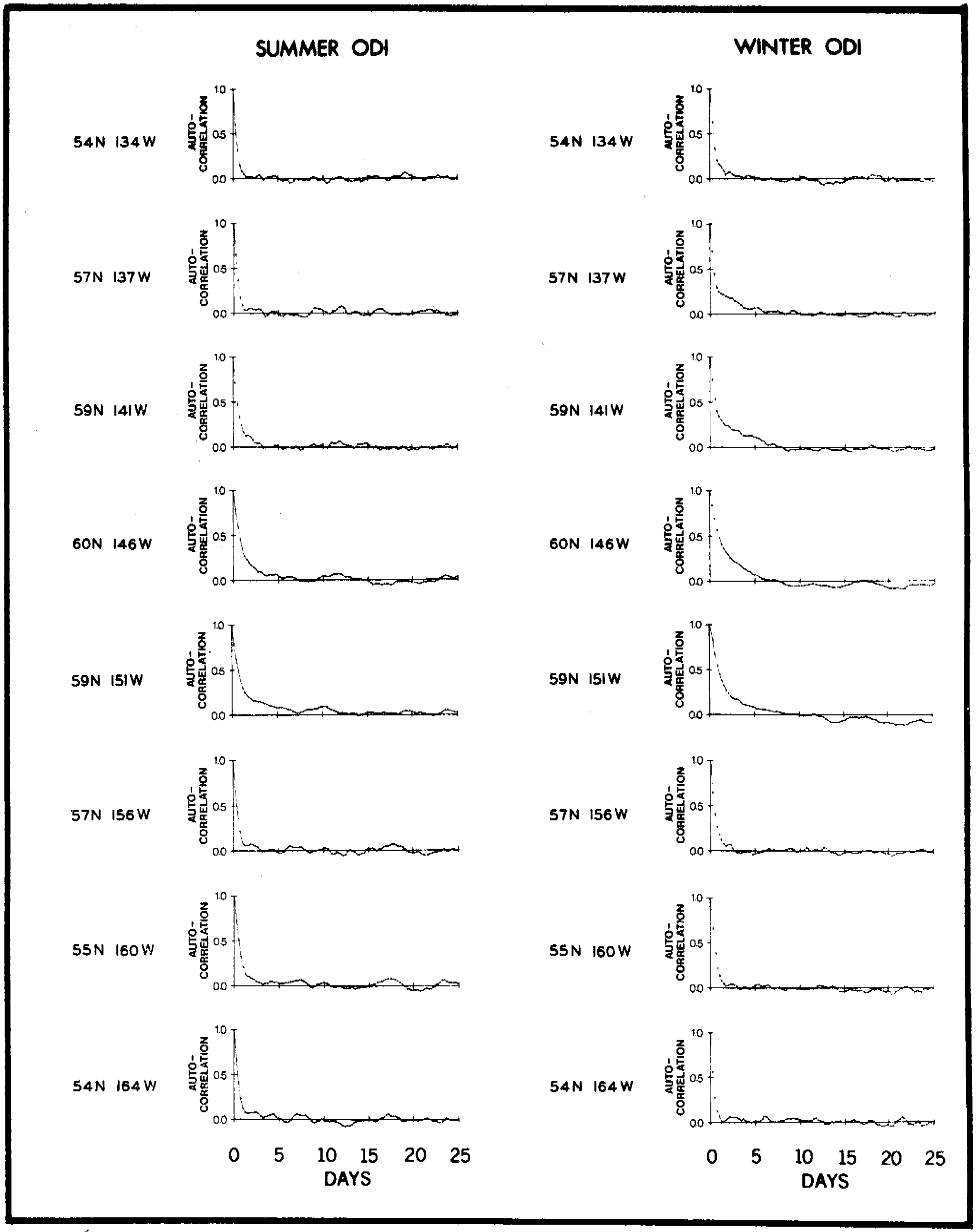

Figure 49 - Autocorrelation functions for offshore divergence indices (ODI) at the near-coastal locations.

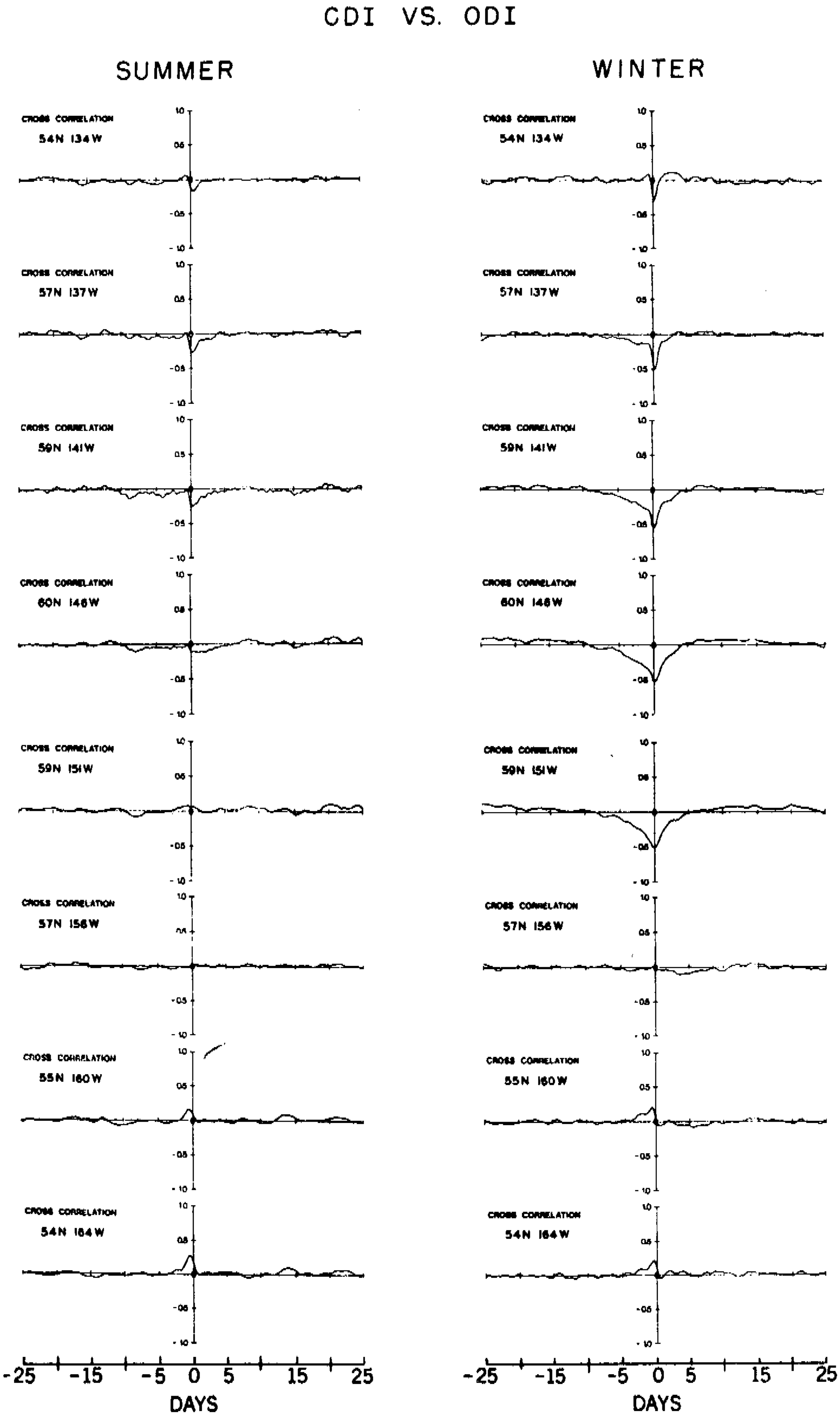

Figure 50 - Cross correlation functions for coastal divergence indices (CDI) v.s. offshore divergence indices at the near-coastal locations. Summer functions are on the left; winter functions on the right.

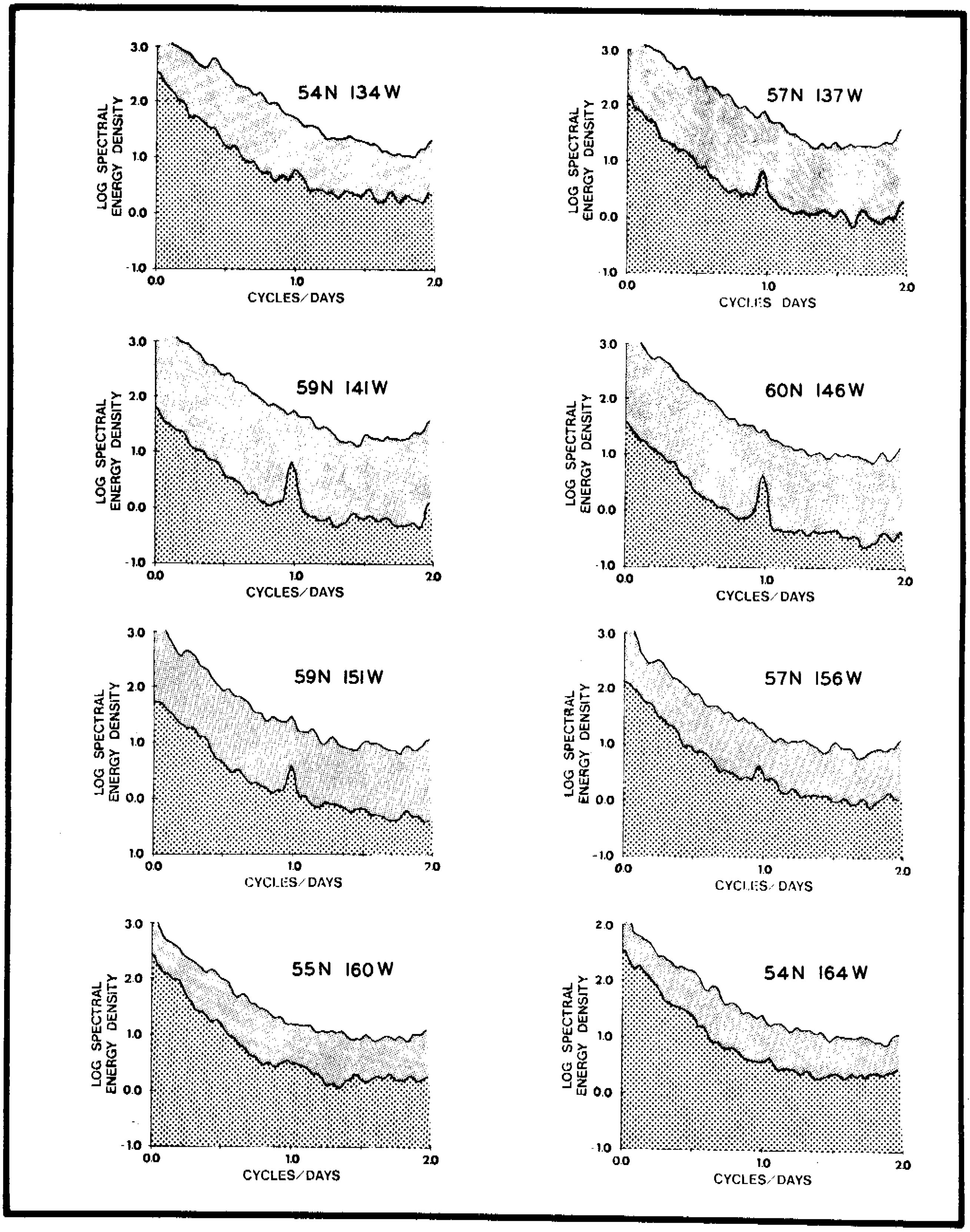

Figure 51 - Power spectra for coastal divergence indices (CDI). Winter and summer spectra at each location are superimposed. Higher energy (upper) trace plots the winter spectrum.

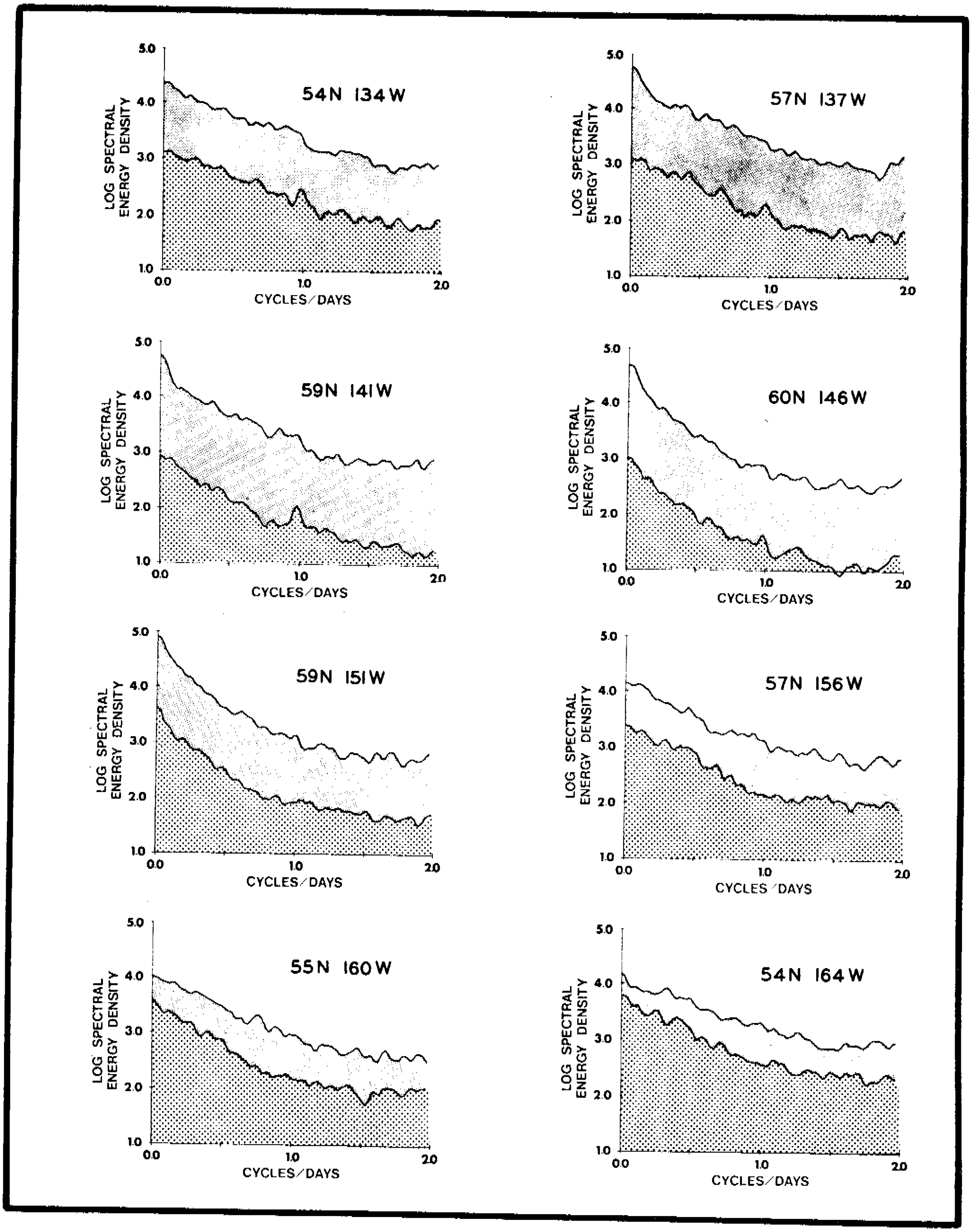

Figure 52 - Power spectra for offshore divergence indices (ODI) at near-coastal locations. Winter and summer spectra at each location are superimposed. Higher energy (upper) trace plots the winter spectrum.

Superimposed are several other features of interest. Considerable energy is spread over the "event scale" of periods of somewhat greater than a day to a week or more. In certain of the series this stands out as a broad hump representing a quasi-periodicity, that is a definite rhythm, albeit somewhat irregular. The only true periodicity is the diurnal fluctuation which stands out as a definite spike in the spring and summer spectra at locations in the northern and eastern gulf. The smaller spike at the semi-diurnal frequency appears merely because the diurnal variation is not perfectly sinusoidal, the morning to afternoon intensification being generally more rapid than the evening to morning relaxation.

Coherence functions for the CDI v.s. the ODI winter series (Fig. 53) indicate maximum coherence at the "event" and longer frequency bands in the "type A" area in the northern and eastern Gulf. Coherence is progressively less toward the southwest. During the summer coherence is minimal except at the diurnal frequency. In general, coherence between the CDI and ODI series at the same location is small compared to, for example, the coherence between series of the same type of index at adjacent locations (Fig. 54). The indication is that the CDI and ODI signals act as semi-independent variables, less so in the fairly well defined "type A" situation of cyclonic winter storms moving through the northern and eastern Gulf, and more so in the Alaska Peninsula area where the various combinations of angle of storm movement in relation to the coast, position of storm center north or south of the coastal boundary, etc., introduces a much larger degree of randomness.

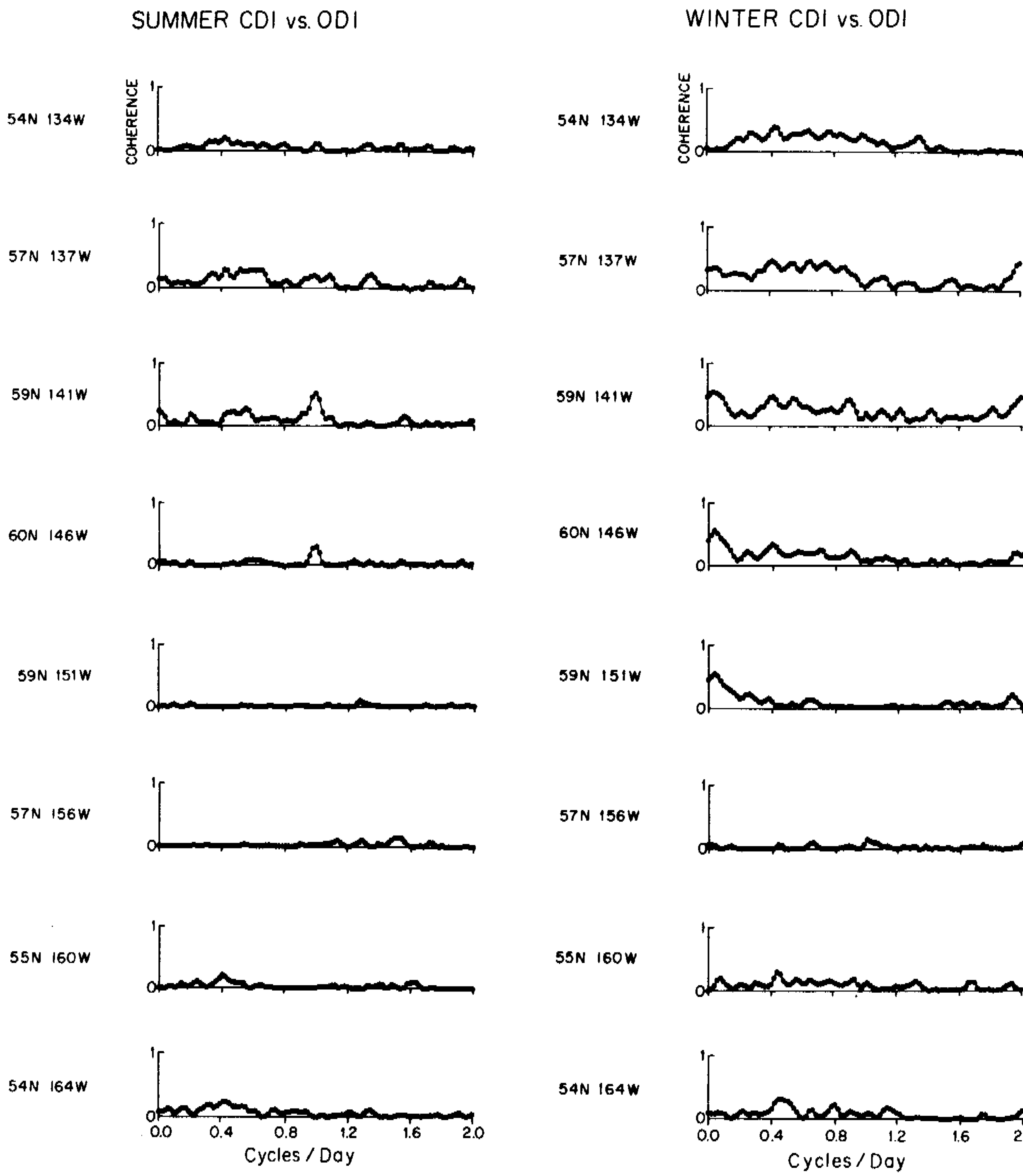

Figure 53 - Coherence functions for coastal divergence indices (CDI) v.s. offshore divergence indices (ODI).

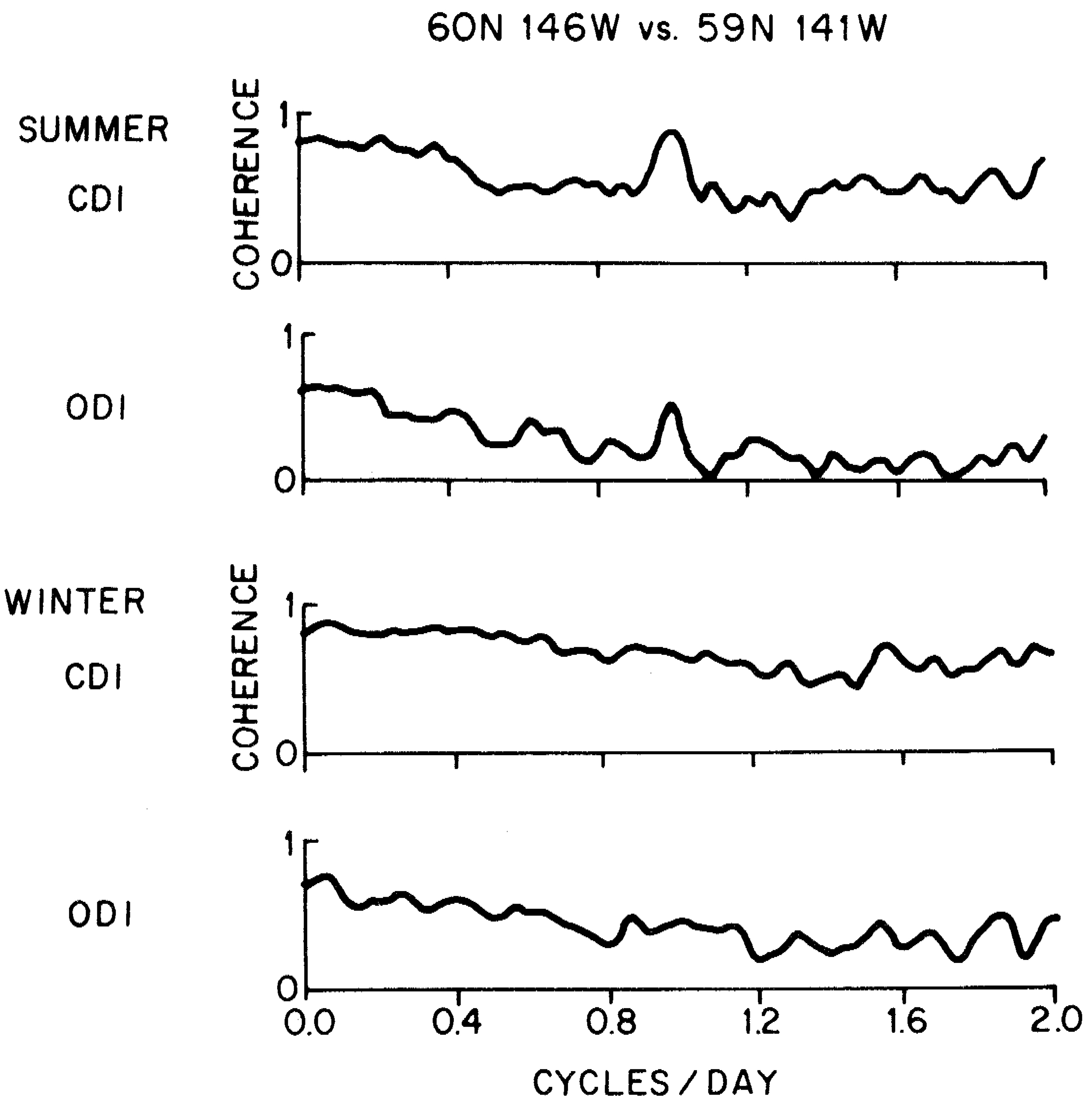

Figure 54 - Coherence functions between index series at adjacent locations: 60N, 146W v.s. 59N, 141W.

B. Interior of the Gulf

Away from the influence of the coastal boundary the CDI computations are, of course, not applicable; the distribution of surface divergence is indicated by the ODI series. The monthly frequency distributions of ODI series along 57°N (Fig. 55) and along 54°N (Fig. 56) show strongly positive mean ODI values during winter in the eastern portion of the gulf, reaching a maximum at 57N, 140W. This location thus appears as the point of maximum intensity of winter divergence. Intensity decreases from this location in all directions, but least rapidly to the north where the intersection of the lobe of intense divergence with the coast results in the maximum type A offshore divergence - coastal downwelling couple at 59N, 141W, described in the previous section. The mean intensities along 54N are much lower than at 57N.

The maximum mean negative values during the summer are likewise at 57N, 140W. The period of mean summer convergence (negative ODI values) which lasts from May through August along the coast in the northern and eastern Gulf (see Fig. 46) becomes progressively shorter westward along 57N, finally disappearing near 150W longitude. Along 57N mean convergence appears only during May and June at the near coastal location, 54N, 134W (Fig. 57).

The series at 57N, 140W also exhibits the greatest variance (see Fig. 56) during winter of any of the locations studied. Thus this location appears to mark a region of "maximum energy" in the surface divergence field of the Gulf of Alaska, both in the sense of amplitude of the seasonal mean signal and in the "spectral energy" sense of

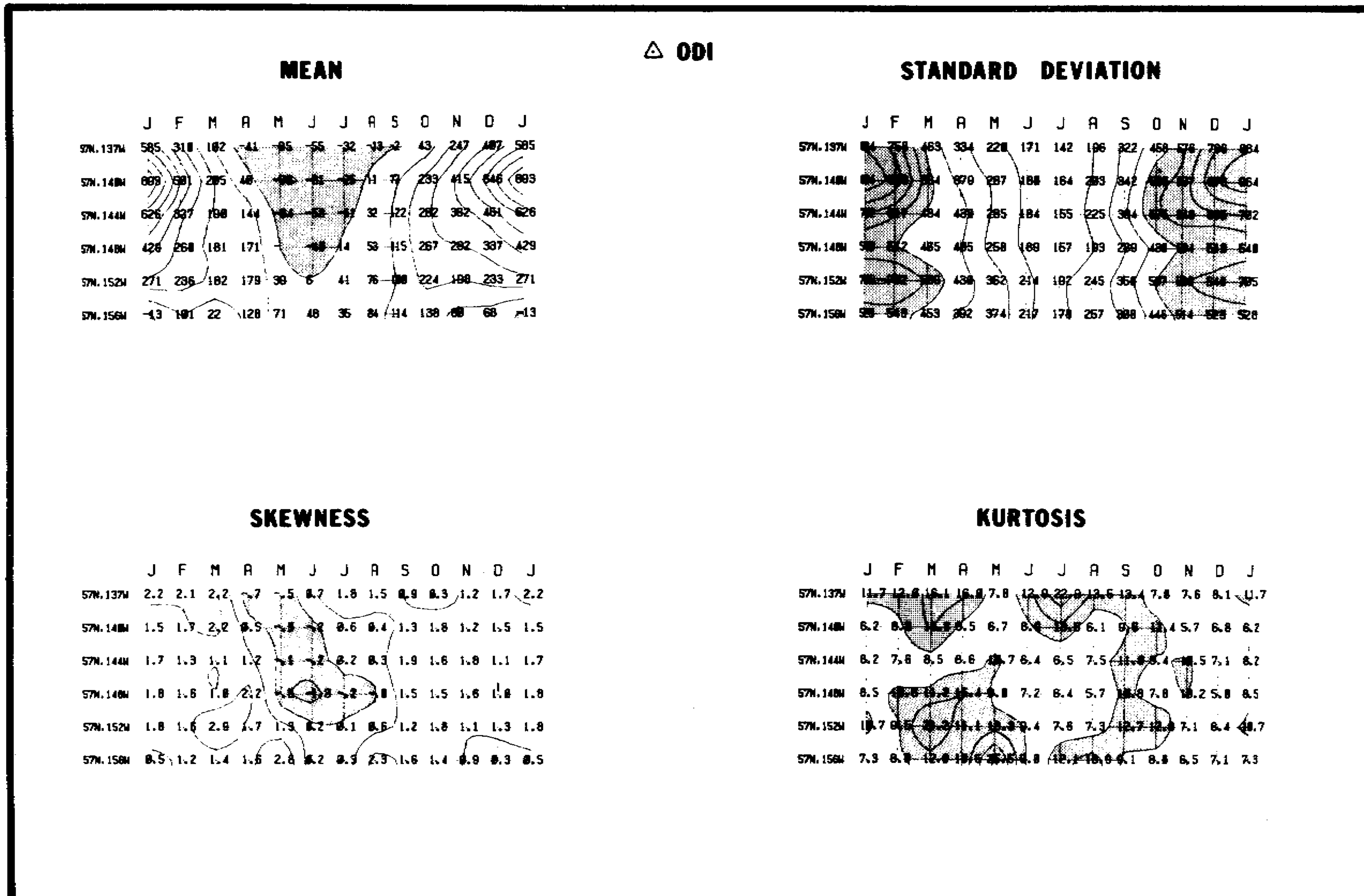

Figure 55 - Moments of the frequency distributions of offshore divergence indices (ODI) grouped by month at the locations along 57N indicated by triangle symbols in Fig. 41. Mean: units are millimeters per day upward velocity through the bottom of the Ekman layer required to balance the indicated divergence; contour interval is 100. Standard deviation: units and contour interval are as for the mean. Skewness: contour interval is one normalized unit. Kurtosis: contour interval is 5 normalized units.

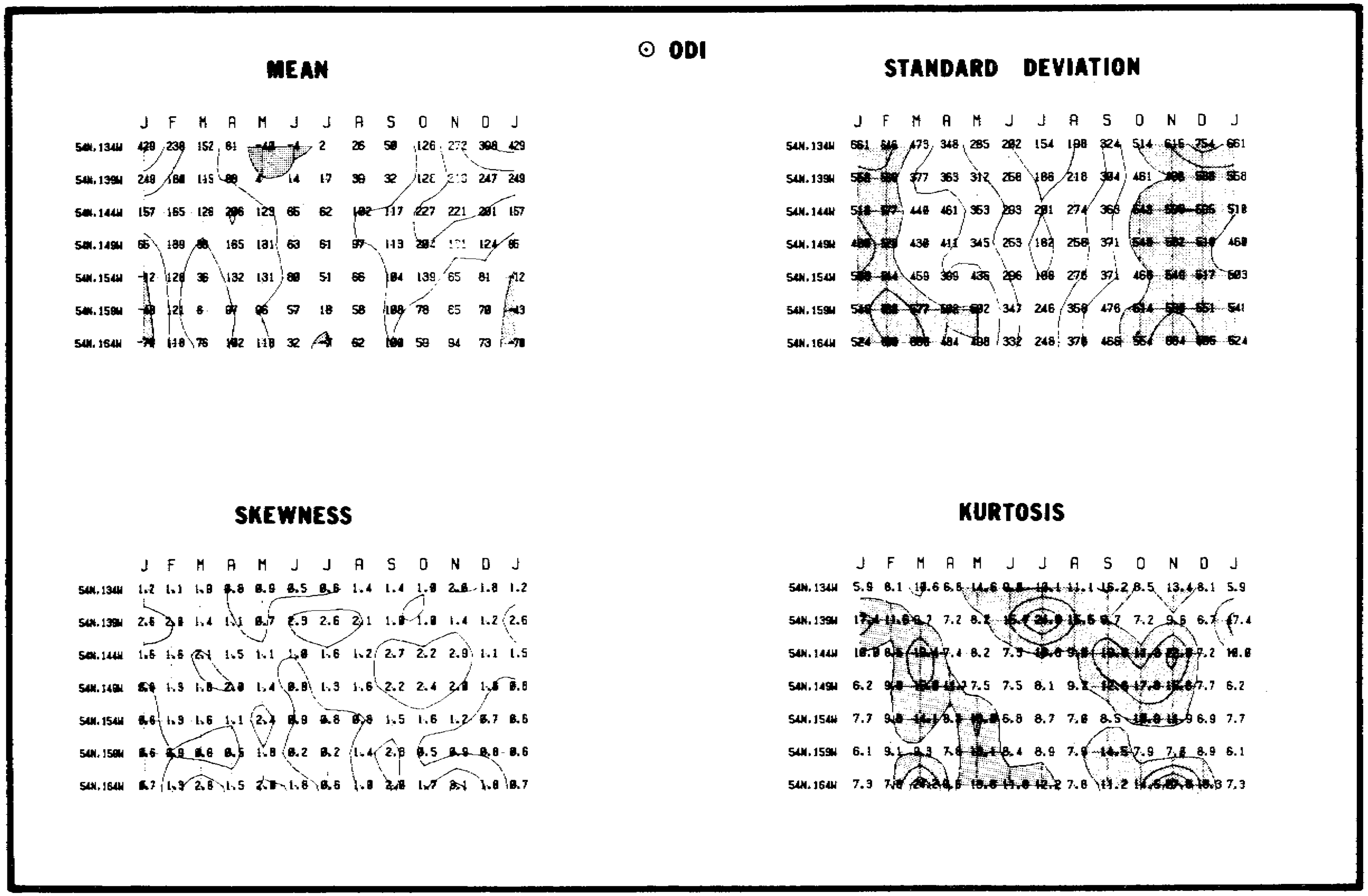

Figure 56 - Moments of the frequency distributions of offshore divergence indices (ODI) grouped by month at the locations along 54N indicated by circle synbols in Fig. 41. Mean: units are millimeters per day upward velocity through the bottom of the Ekman layer required to balance the indicated divergence; contour interval is 100. Standard deviation: units and contour interval are as for the mean. Skewness: contour interval is one normalized unit. Kurtosis: contour interval is 5 normalized units.

extremely rapid and strong pulsations. A lesser maxima in variance at 57N, 152W is apparently connected to the maxima along the coast at 59N, 151W (Fig. 46).

The skewness is negative along 54N latitude (Fig. 56) and, except for a limited period during the summer convergence season, along 57N latitude (see Fig. 55). Extreme events are usually divergent. The kurtosis as before, indicates major importance of rather infrequent, very intense events.

Power spectra for summer and winter ODI series at locations along 57N (Fig. 57) and at locations along 54N (Fig. 58) indicate that winter energy tends to be greatest to the north and east and summer energy is greatest to the south and west. The spike indicating the diurnal periodicity during summer is most prominent near the point of "maximum energy" at 57N, 140W. To the west and south the diurnal spike disappears.

Examples of cross correlations between the "maximum energy" locations at 57N, 140W and several surrounding locations (Fig. 59) indicate that correlation is highest at zero lag between 57N, 140W and the point of maximum winter "type A" coastal situation at 59N, 141W. A suggestion of higher correlation at positive lags between 57N, 140W and 57N, 137W and at negative lags between 57N, 140W and 57N, 144W illustrates the general eastward progression of the signal. Correlation with a location to the south, 54N, 139W, is considerably lower and is highest at a negative lag of one 6-hour period, even though the southern location is one degree further east. This indicates the northward progression of the signal which added to the eastward progression matches the general northeastward trend of the storm tracks. Correlation with the point at

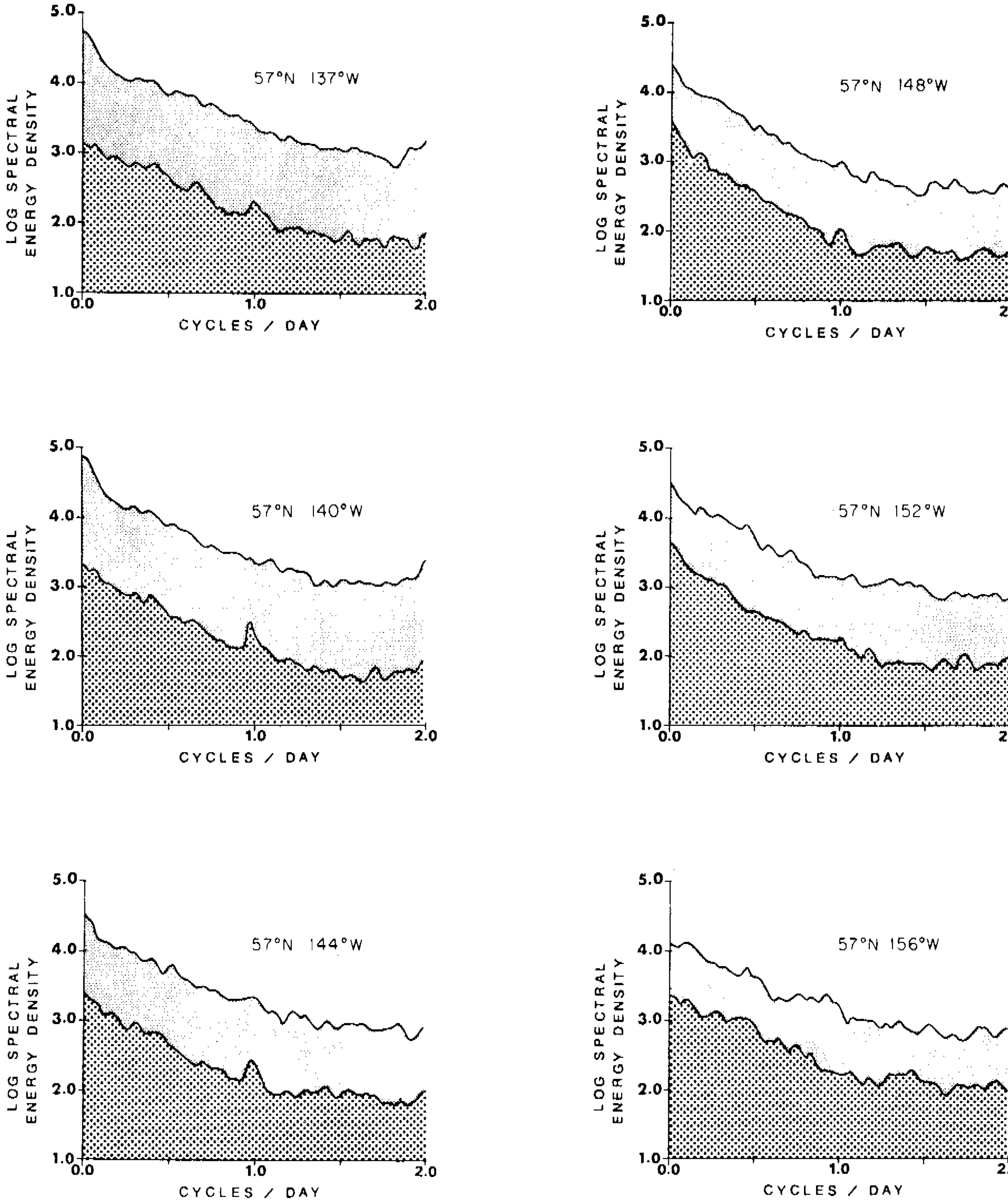

Figure 57 - Power spectra for offshore divergence indices (ODI) at locations along 57N latitude (locations indicated by squares in Fig. 41.) Winter and summer spectra at each location are superimposed. Higher energy (upper) trace plots the winter spectrum.

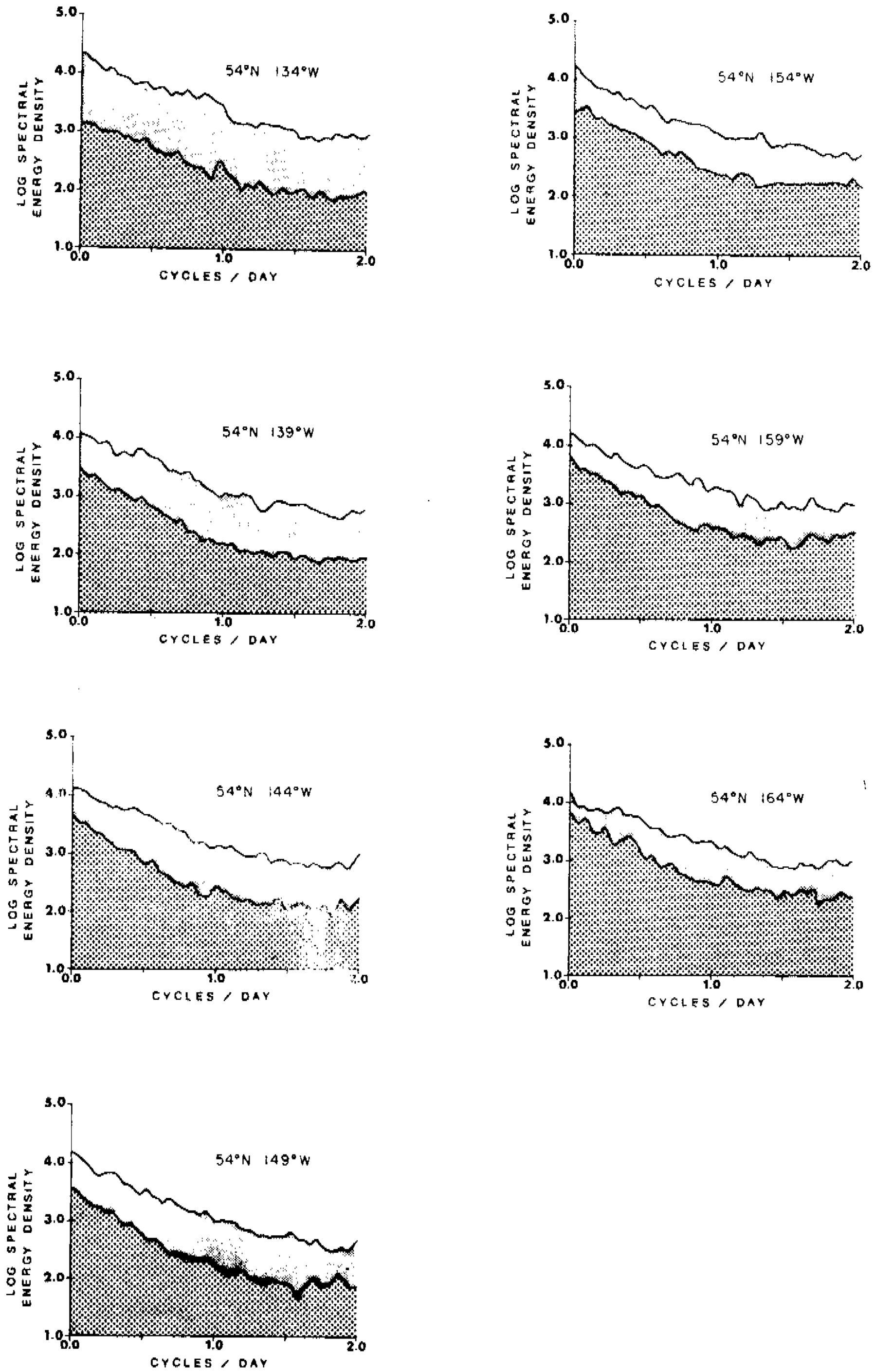

Figure 58 - Power spectra for offshore divergence indices (ODI) at locations along 54N latitude (locations indicated by circles in Fig. 41.) Winter and summer spectra at each location are superimposed. Higher energy (upper) trace plots the winter spectrum.

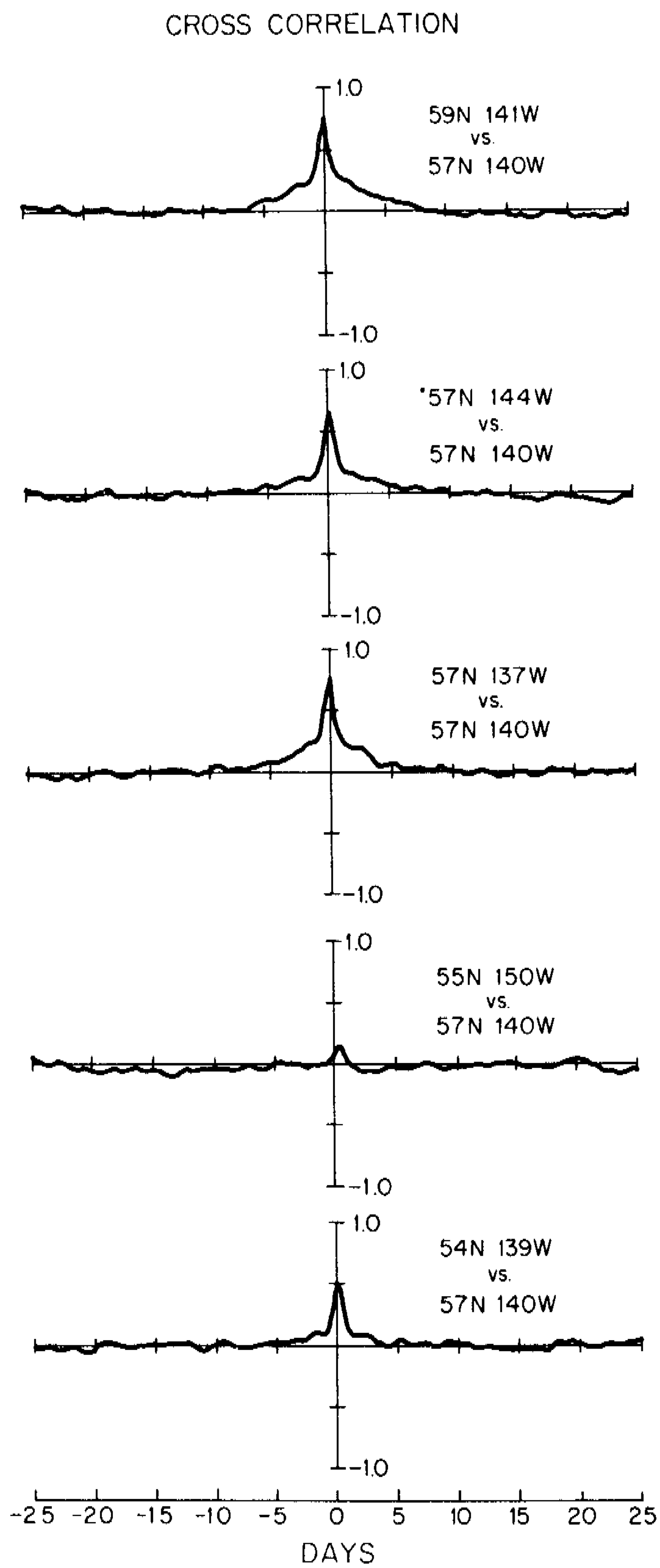

Figure 59 - Cross correlation functions for the winter ODI series at 57N, 140W v.s. winter ODI series at several surrounding locations.

55N, 150W is quite low, reaching its greatest value at negative lags of two 6-hour periods in the winter and three six hour periods in the summer; the progression is slower in the summer than in the winter.

Coherence functions corresponding to the cross-correlation functions of Fig. 59 indicate that the signal at 59N, 141W appears strongly related to that at 57N, 140W (Fig. 60). The adjacent points along 57N are likewise quite strongly related, particularly in the "event" frequency range. However, the coherence with the location to the south, 54N, 139W, is considerably less. Coherence with the signal at 55N, 150W, although on the line of general storm progression, is so low that it is not possible to prove statistically the signals are even related. This indicates considerable modification of the storm systems as they move across the gulf, consistent with its description as a region of strong atmospheric cyclogenisis.

C. Conditions - 1973, 1974 and 1975

The monthly mean CDI and ODI values at the near-coastal locations and the monthly mean ODI values at locations along 57N for the individual years 1973, 1974, and 1975 (Fig. 61) show distributions which are rather complicated in detail. However, it may be useful to delineate certain major features which may have had important effects on the ocean environment during these most recent years of increased field studies. In early 1973, maximum magnitudes of both the ODI and CDI indices appeared during January at 57N, 151W; apparently, the maximum strength of the winter "type A" couple was located in the northwestern Gulf, rather than in its "usual" position in the northeastern Gulf as indicated by the

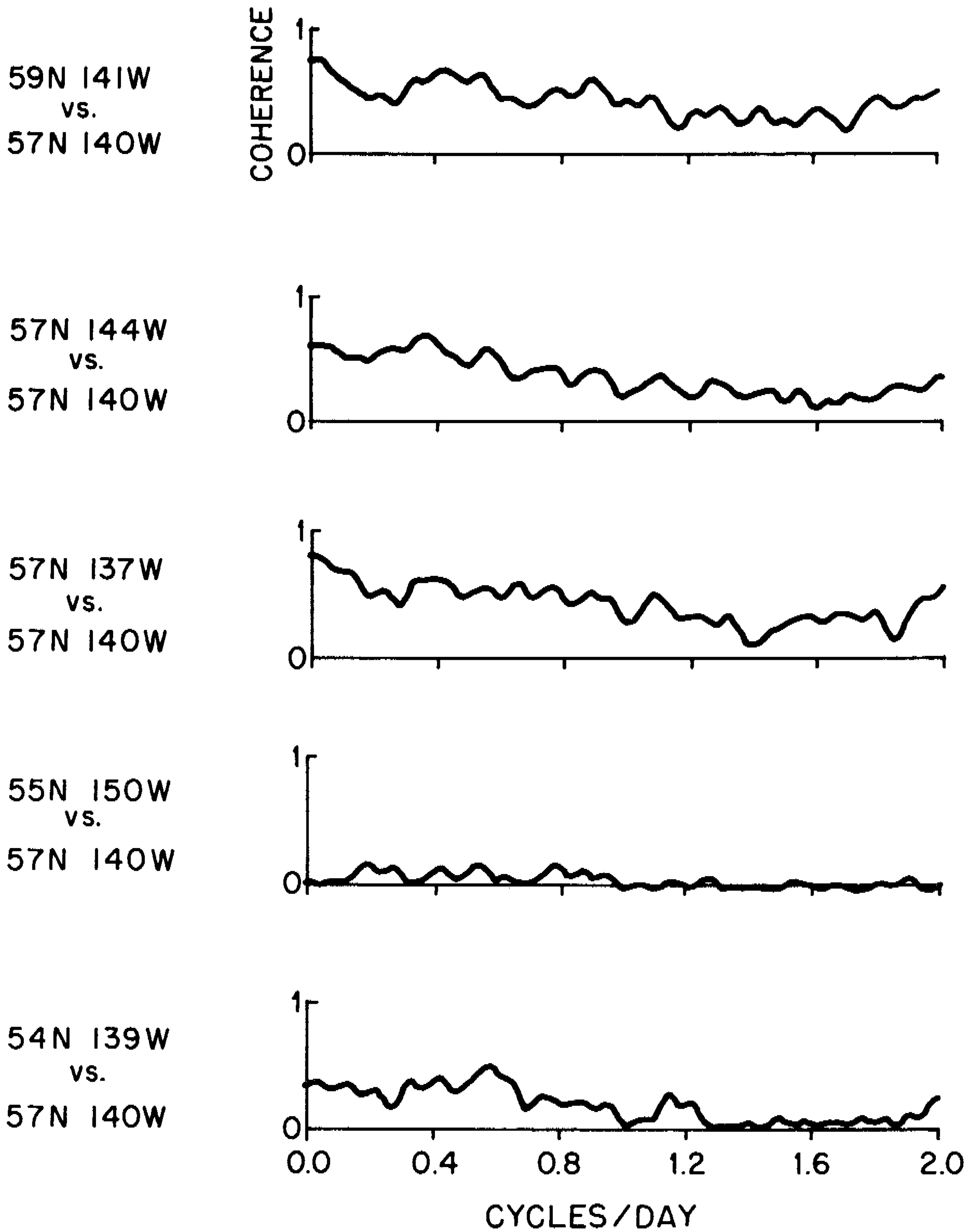

Figure 60 - Coherence functions for the winter ODI series at 57N, 140W v.s. winter ODI series at several surrounding locations.

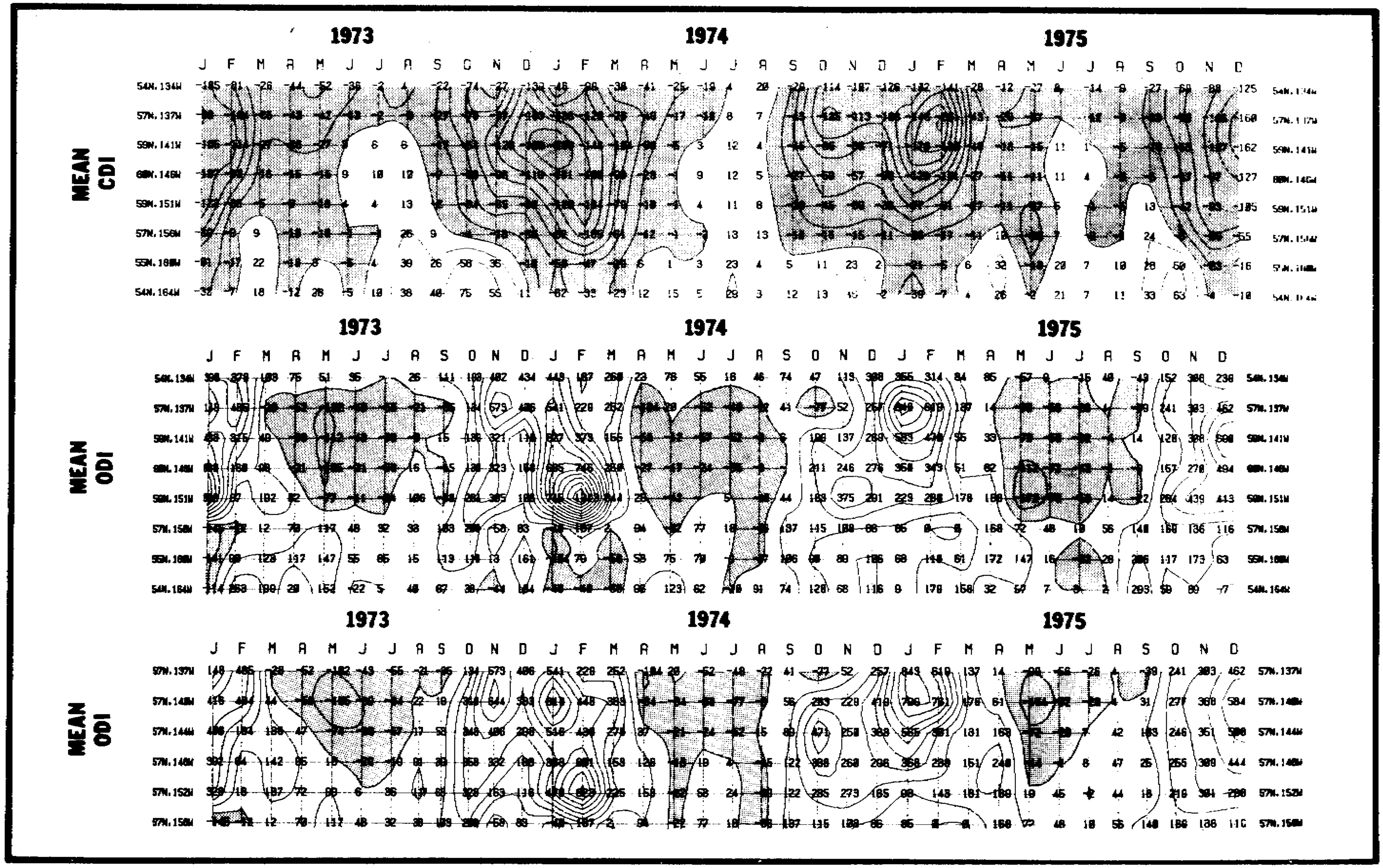

Figure 61 - Monthly means of index series for the years 1973, 1974, and 1975. Top figure: CDI series at near-coastal locations; units are cubic meters per second transported off each 100-meter width of coast. Middle figure: ODI series at near coastal locations; units are millimeters per day upward velocity through the bottom of the Ekman layer required to balance the indicated divergence. Bottom figure: ODI series at locations along 57N latitude; units, etc., are same as for middle figure.

nine-year composite mean monthly distributions (see Figs. 45 and 46). Lower than normal magnitudes of both types of indices during February and March throughout the northern Gulf point to an unusually rapid relaxation of the winter situation. For example, an early transition to a "type C" couple is indicated off the Alaskan Peninsula during March, where normally the transition occurs in April (Table 2). The trend toward less positive than normal ODI values in the northern Gulf continued through the spring to considerably stronger than normal negative values in May, representing quite energetic downward pumping in the offshore area, particularly in the northeastern Gulf. The last quarter of 1973 featured a strong predominance of coastal upwelling along the outer Alaskan Peninsula.

During the first quarter of 1974, stronger than normal convergence (negative CDI values) is indicated along the coast of the Gulf of Alaska, except in the extreme east. Maximum offshore divergence (positive ODI values) appeared, as in the previous year, in the northwestern Gulf. An extremely large mean ODI value was computed for February at 59N, 151W. Actually, anomalously large values appeared during all of the first three months of 1974 at both 59N, 151W, and 60N, 146W. The values at 59N, 141W, the normal maximum along the coast, although much smaller than those further east, were near the 9-year mean values for that location. The result is an extremely strong "type A" couple for the northern Gulf during early 1974. The implication is that dramatically increased baroclinicity in the ocean structure may have had an important effect on the dynamics of the area for some period to follow.

During the spring and summer of 1974, the indices tended to have values near the seasonal means, but by fall a situation of weaker than normal coastal convergence (smaller negative CDI values) seems to have set in. This situation generally persisted through the whole winter over much of the Gulf and was coupled with generally weaker than normal divergence offshore during December and January. An exception was the eastern Gulf where a reasonably strong "type A" couple is indicated for January and February. In total, the winter of 1974-75 appears to have been one of less energetic "type A" pumping than seems to be normal. Certainly the situation contrasts highly with the very energetic situation of the previous winter.

VII. SUMMARY AND CONCLUSIONS

Our knowledge of the physical oceanography of the Gulf of Alaska is quite inadequate to forecast flow. This stems largely from the lack of a persistent, challenging oceanographic program that permits progressive advances based on acquired knowledge. The focus of attention has been not only limited, but intermittent, however, this has not been due to a lack of interest on the part of the oceanographer, rather because of lack of funds, equipment, and adequate theory. Thus, a normal advance from the descriptive phases of presenting observed and steady-state conditions to the analytical phases of understanding processes and forecasting various time-dependent phenomena has not taken place.

There have been several periods of rather extensive research activity: in the late 19th century by the U.S. Bureau of Fisheries, the late 1920's and early 1930's by the International Fish Commission, the mid 1950's to the early 1970's by the International North Pacific Fisheries Commission, and in recent years by the Institute of Marine Science of the University of Alaska.[6/] The interval between periods of activity has gradually decreased from about 50 years to the order of 5 years or less, and hopefully the instigation of the OCSEAP studies will result in the continuing research effort required to obtain adequate knowledge concerning flow.

The dominant physical phenomena in the Gulf of Alaska is the Aleutian low pressure system whose center moves anti-cyclonically out of the northern Bering Sea in early autumn, crosses the Alaska Peninsula and attains a mean position of about 55°N, 155°W in the gulf in late fall and early winter. During winter it moves southwestward to about

6/ See Rosenberg (1972).

50°N, 175°E before returning northward into the western Bering Sea in late winter and early spring. The cyclogenesis and cold air advection in the gulf associated with the mean position of the low pressure center in fall and winter determines the extent and intensity of winter overturn and vertical divergence, as well as, the containment of precipitation, in the form of ice and snow along the coast and in the snowshed ringing the gulf which determines to a great extent the amount of dilution in coastal waters in spring and summer. Station data are marginally adequate in period 1955-62 to show considerable differences between the upper layer temperature distributions in 1956 and 1958, and between the surface salinity distributions in 1957 and 1958, but these are certainly not extreme conditions. Approximate ranges for temperatures in coastal waters are -1.8 - 18°C, and in the central part of the gulf, 1 - 14°C; approximate ranges of salinity in coastal waters are several parts per thousand to 32.6 $^{0}/oo$ and in the central part of the gulf, 32.2 - 33.0 $^{0}/oo$. At depth, below the effects of seasonal influences, conditions are somewhat in a steady-state condition, this makes it difficult to trace anomalous intrusions, or percentage of flow attributed to various sources without extensive data, but there is evidence in the temperature fields that significant changes can occur over periods of several years and certainly longer trends must also exist. Temperature data in the gulf are considered too fragmentary to show the rather consistent 2-3 year variations of ± 1-2°C detected in the central and western parts of the Pacific Ocean by Favorite and McLain (1973).

In regard to surface flow, drift bottle studies have shown that the source of surface flow into the gulf is not from the Kuroshio but largely from the Oyashio and its extension the Subarctic Current, and there is a well documented coastal flow northward along the west coasts of the United States and Canada that also extends into the gulf. Studies have shown that the nature of the separation of the Subarctic Current off the coast is quite variable and complex and, thus, the effect of the northern branch of this flow, which penetrates into the gulf, is equally variable and complex. There is an indisputable onshore component of surface flow around the gulf. But it is not known whether the drifting objects are transported around the gulf largely seaward of the continental shelf and only when they are carried out of the oceanic flow and over the shelf are they trapped in a coastal regime and carried directly ashore, or whether, in spite of tidal currents and increased frictional effects, there is continuity in northward flow in offshore and onshore areas that results in a gradual dispersal of floating objects on the coast as the flow sweeps around the gulf. Nevertheless, it is apparent that floating objects released over the continental shelf at the eastern part of the gulf drift into coastal embayments such as Prince William Sound and Cook Inlet, and move southwestward on either side of Kodiak Island. Further, there is evidence that floating objects in the northern part of the gulf have a potential for wide dispersal: northward into Bering Sea, westward out along the Aleutian Islands, eastward in the Subarctic Current to the coast of Southeastern Alaska, the west coasts of British Columbia, Washington, Oregon and California, and westward again to the central Pacific Islands and the Asian coast.

Geostrophic currents are somewhat of a dilemma. First, closely spaced data suggest that the broad sweep of cyclonic flow around the gulf, generally shown in atlases or summaries of widely spaced data, is actually a highly turbulent regime composed of eddies of various dimensions. There is a frequent suggestion of a large perturbation at the eastern side of the gulf whose dimensions and configuration do not suggest a shelf wave phenomenon, but rather the possibility that at times some of the northward flow funneling into the eastern side of the gulf is unable to move westward across the head of the gulf and is found to turn back on itself. Second, although geostrophic currents clearly reflect the area of divergence, the Ridge Domain, a dominant oceanographic feature in the gulf, there are no direct measurements that permit ascertaining to what extent this feature is governed by (1) Ekman transport (2) a normal internal readjustment of mass between two opposing flows, and (3) a vertical movement of northward flowing deep water, caused by the effect of the land barrier imposed by the gulf. Third, the high velocity cyclonic flow at the edge of the continental shelf is also a dominant feature and an inshore countercurrent is usually detected in geostrophic computations. At this time it is not clear whether this is an aspirative phenomenon not uncommon under such circumstances, whether it is merely an error caused by inadequacies in this method in the presence of physical boundaries, or whether it is largely the effect of eddies or shelf waves along the edge of the continental shelf. Finally, there is the large variability in transport computed from the sporadic cruise data in one instance (1960) a 50% increase in mean flow, and a 100% increase over low flows, but there is no consistent evidence of winter intensification in flow expected as a result of increased wind-stress during that period. However, increases in sea levels at coastal stations in winter suggest that there is at least a barotropic response. Thus, it would appear that winter intensification of flow does occur but the pulses of winter wind-stress are of too short a duration for the distribution of mass to adjust to the actual flow regime; however, over decades and centuries the calculated geostrophic regime appears to have adjusted to an integrated, quasi-steady state between the effects of winter intensification and summer relaxation. Thus, there may be an inherent under-estimation of actual flow in summer when using the wind-stress transport method. The long data record of sea level pressures provides a qualitative indication of transport variability. Spectral energy densities indicate a dominant annual period and a suggestion of an approximate 3-year period. The latter is evident primarily in the decade 1950-59 and does not appear to be a dependable forecasting index. Although monthly transports occasionally show totally unrealistic values, quarterly means and 12-month running means indicate a relatively ordered system (within limits) with no apparent indices to forecast anomalous events.

Of course, wind-stress estimates are merely that, estimates, and so are the outputs of model studies whose results are largely dependent on wind-stress inputs. It should also be obvious that fluctuations in conditions in the gulf are also influenced by various external and internal forces throughout the Pacific Ocean. Nevertheless, considerable advances in our knowledge of the physical oceanography of the gulf will come from short-period monitoring of actual conditions and extensive direct current measurements, not only across the shelf, but also across the slope and in the Ridge Domain. OCSEAP studies are beginning to provide such data.

Studies of surface divergence indices show the extreme variability in direction and intensity of wind-stress in time and space around the gulf, as well as insight into mechanisms that essentially pump water in contact with the shelf shoreward in summer and seaward in winter. The eastern side of the gulf has been shown to be the most energetic in regard to these processes and considerable variability is apparent. An attractive feature of the ODI and CDI computations is their basis in data fields that are routinely prepared and made available in real-time by meteorological agencies; in fact the fields are forecast over periods up to 72 hours or more. Thus, there is a potential for a very inexpensive, real-time monitoring of conditions affecting the flow field in the gulf. Hopefully the OCSEAP studies now underway will help to establish the quantitative linkages required to translate such information into a practical tool for marine environmental management.

VIII. ACKNOWLEDGMENTS

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LITERATURE CITED

Bakun, Andrew
1973. Coastal upwelling indices, west coast of North America. U.S. Dep. Commer. Natl. Oceanic Atmos. Admin., Tech. Rep. NMFS SSRF-671. 103 p.

Bakun, Andrew
1975. Daily and weekly upwelling indices, west coast of North America, 1967-73. U.S. Dep. Commer., Natl. Oceanic Atmos. Admin., Tech. Rep. NMFS SSRF-693. 114 p.

Barkley, Richard A.
1968. Oceanographic atlas of the Pacific Ocean. Univ. Hawaii Press, Honolulu. 20 p., 156 figs.

Bennett, E. B.
1959. Some oceanographic features of the northeast Pacific Ocean during August 1955. J. Fish. Res. Bd. Canada 16(5):565-633.

Bogdanov, K.
1961. (Water circulation in the Gulf of Alaska and its seasonal variability). Okeanologiya 1(5):815-824. In Russian. (Transl. in Deep-Sea Res., 1963, 10(4):479-487.)

Burt, Wayne V., and Bruce Wyatt.
1964. Drift bottle observations of the Davidson current off Oregon, p. 156-165. In: Kozo Yoshida (ed.), Studies on oceanography. Univ. Tokyo Press.

Dall, W. H.
1879. Meteorology, Appendix 1. In: Pacific Coast Pilot, coasts and island of Alaska, 2nd ser. 375 p. Gov. Print. Off., Washington, D.C.

Dall, W. H.
1882. Report on the currents and temperatures of Bering Sea and the adjacent waters. U.S. Coast and Geodetic Survey, Report 1880, app. 16:297-340, pl. 80.

Dall, W. H.
1899. The mollusk fauna of the Pribilof Islands. In: U.S. Treasury Dept. Committee on Fur-seal Invest., The fur seals and sea-islands of the North Pacific Ocean, pt. 3, p. 539-545, chart. Washington, Govt. Print. Off.

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. Int. North Pac. Fish. Comm., Bull. 13. 195 p.

Dodimead, A. J., and H. J. Hollister.
1962. Canadian drift bottle releases in the North Pacific Ocean. Fish. Res. Board Can., Manuscr. Rep. Ser. (Oceanogr. Limnol.) 141. 64 p. + 44 figs. (Processed.)

Doe, L. A. E.
1955. Offshore waters of the Canadian Pacific coast. J. Fish. Res. Board Can. 12(1):1-34.

Favorite, Felix.
1964. Drift bottle experiments in the northern North Pacific Ocean, 1962-1964. J. Oceanogr. Soc. Japan 20(4):160-167.

Favorite, Felix.
1974. On flow into Bering Sea through Aleutian Islands passes p. 3-37. In: D. W. Hood and E. J. Kelley (eds.), Oceanography of the Bering Sea. Inst. Mar. Sci. Occas. Publ. No. 2, Univ. Alaska, Fairbanks.

Favorite, Felix.
1975. The physical environment of biological systems in the Gulf of Alaska. Proceedings, Arctic Institute of North America symposium on science and natural resources in the Gulf of Alaska. Oct. 16-17, 1975, Anchorage (In Press).

Favorite, F., A. J. Dodimead, and K. Nasu.
1976. Oceanography of the Subarctic Pacific Region 1960-72. Int. North Pac. Fish. Comm., Bull. 33 (In Press).

Favorite, F., and W. J. Ingraham, Jr.
(1976a).On flow in the northwestern Gulf of Alaska May 1972. J. Oceanogr. Soc. Japan.

Favorite, F., and W. J. Ingraham, Jr.
(1976b).Sunspot activity and oceanic conditions in the northeastern North Pacific Ocean. NMFS Status of the Environment Report, 1975 (in preparation).

Favorite, Felix, and Douglas R. McLain.
1973. Coherence in transpacific movements of positive and negative anomalies of sea surface temperature, 1953-60. Nature (London) 244(5412): 139-143.

Filatova, Z. A. (ed.).
1973. Kompleksnye issledovaniya materikovogo sklona v raione zaliva Alyaska (multidisciplinary investigations of the continental slope in the Gulf of Alaska area). IV. Inst. Okeanol. 91. 260 p. (Transl., Fish. Res. Board Can., 1974, Transl. Ser. 3204.)

Fisk, Donald M.
1971. Recoveries from 1964 through 1968 of drift bottles released from a merchant vessel, S. S. Java Mail, en route Seattle to Yokohama, October 1964. Pac. Sci. 25(2):171-177

Fofonoff, N. P.
1962. Machine computations of mass transport in the North Pacific Ocean. J. Fish. Res. Board Can. 19(6): 1121-1141.

Fofonoff, N. P., and S. Tabata.
1966. Variability of oceanographic conditions between Ocean Station "P" and Swiftsure Bank off the Pacific coast of Canada. J. Fish. Res. Board Can. 23(6): 825-868.

Fleming, R. H.
1955. Review of oceanography of the northern Pacific. Int. North Pac. Fish. Comm., Bull. 2. 43 p.

Fomin, L. M.
1964. The dynamic method in oceanography. Elsevier Publ. Co., New York. 212 p.

Galt, J. A.
1973. A numerical investigation of Arctic Ocean dynamics. J. Phys. Oceanog. 3(4): 379-396.

Giovando, L. F., and Margaret K. Robinson.
1965. Characteristics of the surface layer in the northeast Pacific Ocean. Fish. Res. Board Can., Manuscr. Rep. Ser. (Oceanogr. Limnol.) 205. 13 p., 2 tables, 28 figs.

Holl, M. M. and B. R. Mendenhall.
1972. Fields by information blending, sea-level pressure version. (U.S.) Fleet Numer. Weather Central, Monterey, Calif., FNWC Tech. Note 72-2. 66 p.

Ingraham, W. James, Jr., and F. Favorite.
1968. The Alaskan Stream south of Adak Island. Deep-Sea Res. 15(4): 493-496.

Ingraham, W. James, Jr., and James R. Hastings.
1974. Seabed drifters used to study bottom currents off Kodiak Island. Mar. Fish. Rev. 36(8): 39-41.

Jacobs, Woodrow C.
1939. Sea level departures on the California coast as related to the dynamics of the atmosphere over the North Pacific Ocean. J. Mar. Res. 2: 181-193.

Jacobs, Woodrow C.
1951. The energy exchange between sea and atmosphere and some of its consequences. Bull. Scripps Inst. Oceanogr. 6: 27-122.

Klein, W. H.
1957. Principal tracks and mean frequencies of cyclones and anticyclones in the northern hemisphere. U.S. Dep. Commer., Weather Bur. Res. Paper 40. 60 p.

LaViolette, Paul E., and Sandra E. Seim.
1969. Monthly charts mean minimum and maximum sea surface temperature of the North Pacific Ocean. (U.S.) Naval Oceanogr. Office, Spec. Publ. 123. 58 p.

McEwen, George F., Thomas G. Thompson, and Richard Van Cleve.
1930. Hydrographic sections and calculated currents in the Gulf of Alaska, 1927 to 1928. Rep. Int. Fish. Comm. 4. 36 p.

Moiseev, P. A. (ed.)
1963-1970. Sovetskie rybokhozyaistvennye issledovaniya v severo-vostochnoi chasti Tikhogo okeana (Soviet fisheries investigations in the Northeastern Pacific). In 5 parts. Pt. 1 - Tr. Vses, Naucho-issled. Inst. Morsk. Rybn. Khoz. Okeanogr. (VNIRO) 48 (also Isv. Tikhookean. Nauchnoissled. Inst. Morsk. Rybn. Khoz. Okeanogr. (TINRO)50), 1963, 316 p.; Ot. 2 - Tr. VNIRO 49 (Izv. TINRO 51), 1964, 272 p; Pt. 3-Tr. VNIRO 53 (Izv. TINRO 52), 1964, 341 p.; Pt. 4-Tr. VNIRO 58 (Izv. TINRO 53), 1965, 345 p.; Pt. 5-Tr. VNIRO 70 (Izv. TINRO 72), 1970, 454 p. (Complete transls. of all 5 parts avail. Natl. Tech. Inf. Serv., Springfield, Va.--Pt. 1, 1968, 333 p., TT 67-51203; Pt. 2, 1968, 289 p., TT 67-51204; Pt. 3, 1968, 338 p., TT 67-51205; Pt. 4, 1968, 375 p., TT 67-51206; Pt. 5, 1972, 462 p., TT 71-50127.)

Muench, Robin D. and C. Michael Schmidt.
1975. Variations in the hydrographic structure of Prince William Sound. Inst. Mar. Sci. Rep. R75-1. Univ. Alaska, Anchorage. 135 p.

Muromtsev, A. M.
1958. Osnovnye cherty gidrologii Tikhogo okeana (Principal hydrological features of the Pacific Ocean). Gidrometerol. Izd., Leningrad. 631 p.; App. 2, Atlas of vertical profiles and maps indicating temperature, salinity, density and oxygen content. 124 p. (Transl. 1963, Natl. Tech. Inf. Serv., Springfield, Va., TT 63-11065.)

Nelson, C. S.
1974. Wind stress climatology off the west coast of North America (abst) (0-2). AGU Fall Annu. Meet. EOS, Trans. Am. Geophys. Union 56(12): 1132.

Pattullo, June G.
1960. Seasonal variation in sea level in the Pacific Ocean during the International Geophysical Year, 1957-1958. J. Mar. Res. 18: 168-184.

Pattullo, June, Walter Munk, Roger Revelle and Elizabeth Strong.
1955. The seasonal oscillation in sea level. J. Mar. Res. 14: 88-156.

Plakhotnik, A. F.
1962. Gidrologiya severo-vostochnoi chasti Tikhogo Okeana (obzor literaturnykh istochnikov). (Hydrology of the northeastern Pacific Ocean - review of literature sources). Tr. Vses. Nauch.-issled. Inst. Morsk. Rybn. Khoz. Okeanogr. 46: 190-201.

Reid, J. L., and A. W. Mantyla.
1976. On the seasonal variation of sea elevations along the coast of the northern North Pacific Ocean. AGU Fall Annu. Meet., Trans. Am. Geophys. Union 56(12): 1009.

Reid, Joseph L., Jr., Gunnar I. Roden, and John G. Wyllie.
1958. Studies of the California Current system. Prog. Rep. Calif. Coop. Oceanic Fish. Invest., 1 July 1956 - 1 Jan. 1958: 28-56.

Robinson, Margaret K.
1957. Sea temperature in the Gulf of Alaska and in the northeast Pacific Ocean, 1941-1952. Bull. Scripps Inst. Oceanogr. 7(1): 1-98, 61 figs.

Robinson, Margaret K., and Roger A. Bauer.
1971. Atlas of monthly mean surface and subsurface temperature and depth of the top of the thermocline, North Pacific Ocean. (U.S.) Fleet Numer. Weather Central, Monterey, Calif. 24 p. + 72 figs. (Processed.)

Roden, Gunnar I.
1960. On the nonseasonal variations in sea level along west coast of North America. J. Geophys. Res. 65: 2809-2826.

Roden, Gunnar I.
1969. Winter circulation in the Gulf of Alaska. J. Geophys. Res. 74(18): 4523-4534.

Rosenberg, Donald H. (ed.)
1972. A review of the oceanography and renewable resources of the northern Gulf of Alaska. Univ. Alaska, Fairbanks, Inst. Mar. Sci., IMS Rep. R72-23. 690 p.

Saur, J. F. T.
1962. The variability of monthly mean sea level at six stations in the eastern North Pacific Ocean. J. Geophys. Res. 67: 2781-2790.

Schulz, Bruno.
1911. Die stromungen und die temperaturverhaltnisse des Stillen Ozeans nordlich von 40° N-Br. einschliesslich des Bering-meeres. Ann. Hydrogr. Marit. Meteorol. 39: 177-190, 242-264.

Sverdrup, H. U.
1947. Wind-driven currents in a baroclinic ocean; with applications to the equatorial currents of the Eastern Pacific. Proc. Natl. Acad. Sci. 33: 318-326.