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CHARIOT PROJECT, PHASE II, 4/60

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INTERIM FINAL REPORT

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Laboratory of Radiation Biology
University of Washington
Seattle, Washington

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CHARIOT PROJECT, PHASE II

INTERIM FINAL REPORT

Introduction

The participation of the Laboratory of Radiation Biology in Phase II of the Chariot Project included the organization and coordination of the marine program, the radiological analyses of marine samples, the preparation of a list of the fishes and the marine invertebrates of the eastern Chukchi Sea, and a survey of salmon streams in the vicinity of the Chariot Site.

A discussion of the results of this program follows.

Organization of Marine Program

The objectives of the program were to evaluate the biological cost in the marine environment of the Chariot experiment and to determine the water movement in the eastern Chukchi Sea. To obtain these objectives staff from the Department of Oceanography, University of Washington, and their research vessel, the Brown Bear, and staff from the North Pacific Fisheries Exploration and Gear Research Branch of the Bureau of Commercial

Fisheries and their research vessel, the John N. Cobb, were engaged. As knowledge of the oceanography and biology of the area was scant, there was little foundation upon which to build the research programs. For this reason the programs were more extensive than they might otherwise have been.

A proposal for the oceanographic program was submitted to the A.E.C. by Dr. Richard H. Fleming, executive officer, Department of Oceanography, and was accepted. In addition to the study of water movements for the purpose of predicting the probable fate of radioactive materials introduced into the Chukchi Sea, the other major phases of this program included temperature and salinity observations, submarine geological studies, tidal observations, investigation of lagoons and biological studies related to the qualitative and quantitative ecology of the plankton. The Department of Oceanography has operated under their own contract and has prepared and submitted their own reports.

Most of the marine biological field program, other than the plankton studies by the Department of Oceanography was conducted aboard the John Cobb. By contract between

the A.E.C. and the Bureau of Commercial Fisheries the cost of the John Cobb operation was shared. In addition to supporting the A.E.C. program, the John Cobb operation provided the Bureau of Commercial Fisheries with information from which the potential of the area for commercial fishing could be evaluated. Samples were collected by means of otter trawl, biological dredge, midwater trawl, gill net, trap and beach seine. From the list of organisms in the collections a biological inventory was prepared for the purpose of documenting the flora and fauna of the area prior to the Chariot experiment. The quantity of fish in the collections was surprisingly small, but the collection of invertebrates was extremely rich. Neither bottom fish nor shellfish were present in commercial quantities during August 1959 at the 74 stations where collections were made.

Reports of the John Cobb cruise have been prepared by Dayton L. Alverson, ~~Chief~~, North Pacific Fisheries Exploration and Gear Research Branch.

The Brown Bear and the John Cobb worked in the eastern Chukchi Sea between the Bering Straits and Cape Lisburne during August. In this remote area mutual assistance of the scientific groups and crews aboard the two vessels was important in the operational and scientific

phases of the field program.

In addition to the radiological studies specialists were employed by the Laboratory of Radiation Biology for the purpose of identifying the fishes and marine invertebrates in the collections. Also, because of the importance of salmon to the people of Alaska, a fisheries biologist experienced in Alaskan salmon stream surveys was employed, although it was realized that salmon runs in the vicinity of the Chariot Site are not large.

List of Fishes

The identification of the fishes, which has been the responsibility of Dr. Norman J. Wilimovsky, Chief, Marine Fisheries Investigations, Bureau of Commercial Fisheries, Juneau, Alaska, is virtually complete. One or two genera require additional systematic judgment, and the proper nomenclatorial designation for three others must be determined on the grounds of nomenclatural priority. A report prepared by Dr. Wilimovsky on the fishes collected in the Chariot area is attached as Appendix 1.

List of Marine Invertebrates

The identification of the marine invertebrates

is being supervised by Dr. Albert K. Sparks, Associate Professor, College of Fisheries, University of Washington. His assistants are Mr. Walter Pereyra and Mr. Ian Ellis, graduate students. Dr. Dora P. Henry of the Department of Oceanography has identified the barnacles.

The collection of marine invertebrates is probably the best collection of all time in the eastern Chukchi Sea and is large both in respect to number of specimens and to number of species. Because of the size of the collection and the lack of prior information about the marine invertebrates of the Chukchi Sea, classification has not been completed. Although identification of the invertebrates will continue into next year, further collections in the Chukchi Sea during the summer of 1960 are not planned or needed.

A report by Sparks and Pereyra on the invertebrates collected in the eastern Chukchi Sea by the John Cobb during August 1959 is attached as Appendix 2.

Salmon Stream Surveys

Mr. Howard D. Smith of the Fisheries Research Institute, College of Fisheries, University of Washington, conducted surveys of the streams in the vicinity of the

Chariot Site for the purpose of evaluating the salmon resource. He was in the field between August 5 and 20, 1959. A report of his work is attached as Appendix 3.

Radiological Analysis of Samples

Additional analyses made since the December report was written confirmed the previous conclusion that fallout radioisotopes were either absent, or present in only scarcely detectable amounts in the marine samples. Potassium-40 was present in biological samples and Ra^{226} in mud; however, these are naturally occurring radioisotopes. The results of gamma and beta analyses are presented in Table 1, and the scientific names of the specimens used are listed in Table 2. The results of radiochemical analyses for Sr^{90} in herring bone, crab skeleton and snail shell were essentially zero.

The general lack of fallout isotopes in marine samples and their presence in terrestrial samples raised the question of whether or not the difference was due to analytical techniques. Samples were exchanged with the Hanford Laboratories, and, although the results of the analyses of our Laboratory's samples are not yet

available, the analyses of the Hanford samples by our Laboratory gave results that were similar to the Hanford results, suggesting that the difference was not in technique. Because the amount of fallout was low and dilution in the ocean is great, the absence of fallout isotopes in the marine samples is not unexpected.

Table 1. Average values for K⁴⁰, as determined by gamma spectrum analyses, and for gross beta activity of marine samples collected in the vicinity of the Chariot Site during August 1959. Values in micro microcuries per gram of wet tissue at time of counting.

Organism	Tissue	No. of samples	Gross beta			Gamma spectrometry*	
			Date counted	Anton	Low level	Date counted	K ⁴⁰
Pacific herring	muscle	5	Sept. 59	5.4 [±] .44		Apr. 60	3 [±] .5
		4	Nov. 59		5.78 [±] .089	May 60	4 [±] .6
		4	May 60	5.7 [±] .51			
		4	June 60	5.7 [±] .51			
	bone	5	Sept. 59	4.0 [±] 1.9			
		1	May 60	2.6 [±] 3.5	3.18 [±] .221		
		1	June 60	5.7 [±] 3.5			
	liver	5	Sept. 59	3.2 [±] .78			
Capelin	muscle	5	Sept. 59	4.2 [±] .51			
	bone	5	Sept. 59	2.2 [±] 2.2			
	liver	5	Sept. 59	3.5 [±] .67			
Saffron cod	muscle	1	Sept. 59	5.4 [±] .98			
	bone	1	Sept. 59	3.6 [±] 3.3			
	liver	1	Sept. 59	1.6 [±] .91			
Arctic cod	muscle	5	Sept. 59	3.2 [±] .45		June 60	0 [±] 6
		5	Sept. 59	2.9 [±] 1.4			
	bone	1	May 60	3.2 [±] 3.0	3.01 [±] .486		
		1	June 60	4.2 [±] 3.0			
	liver	5	Sept. 59	1.6 [±] .49		May 60	0 [±] 12

*For gamma spectrometry, 1 sample, but a composite of several specimens

Table 1. (continued)

Organism	Tissue	No. of samples	Gross beta			Gamma spectrometry*	
			Date counted	Anton	Low level	Date counted	K ⁴⁰
Sculpin	muscle	3	Oct. 59	3.8 $\pm$.53			
	liver	3	Oct. 59	2.7 $\pm$.54			
Bering flounder	muscle	1	Sept. 59	2.6 $\pm$.91			
	bone	1	Sept. 59	2.7 $\pm$ 2.7			
	liver	1	Sept. 59	2.0 $\pm$ 1.0			
Yellowfin sole	muscle	1	Sept. 59	3.7 $\pm$.81			
	bone	1	Sept. 59	3.3 $\pm$ 2.1			
	liver	1	Sept. 59	4.8 $\pm$ 1.2			
Hermit crab	muscle	2	Sept. 59	4.3 $\pm$ 1.7			
	skeleton	2	Sept. 59	5.0 $\pm$ 7.6			
		1	May 60	16 $\pm$ 12	5.20 $\pm$ 1.50		
		1	June 60	-3.8 $\pm$ 11			
	digestive gland	2	Sept. 59	4.8 $\pm$ 1.5			
Tanner crab	muscle	3	Sept. 59	2.3 $\pm$.53			
	skeleton	3	Sept. 59	1.1 $\pm$ 4.3			
	digestive gland	3	Sept. 59	2.9 $\pm$.68		June 60	-9 $\pm$ 5
King crab	muscle	1	Sept. 59	2.7 $\pm$.81		June 60	3 $\pm$ 2
	skeleton	1	Sept. 59	2.0 $\pm$ 5.9		June 60	0 $\pm$ 3
	digestive gland	1	Sept. 59	3.8 $\pm$ 1.1		June 60	5 $\pm$ 3
Crab (<u>Telmessus</u>)	muscle	2	Sept. 59	3.7 $\pm$.8			
	skeleton	2	Sept. 59	1.9 $\pm$ 4.3			
	digestive gland	2	Sept. 59	6.9 $\pm$ 1.4			

Table 1. (continued)

Organism	Tissue	No. of samples	Gross beta			Gamma spectrometry*	
			Date counted	Anton	Low level	Date counted	K ⁴⁰
Shrimp	muscle	10	Sept. 59	3.2 $\pm$.36		May 60	2 $\pm$.4
	viscera	10	Sept. 59	3.7 $\pm$ 1.2			
Barnacle	viscera	2	Sept. 59	13 $\pm$ 1.7		Nov. 59	30 $\pm$ 20
		2	Dec. 59		7.45 $\pm$.610	May 60	0 $\pm$ 20
		1	May 60		11.1 $\pm$.702		
	gonad	2	May 60	7.9 $\pm$ 1.5			
		2	June 60	6.9 $\pm$ 1.5			
		2	Sept. 59	2.2 $\pm$ 1.5			
Clam (<u>Macoma</u>)	muscle	7	Sept. 59	3.4 $\pm$ 1.3			
	soft parts	7	Sept. 59	3.7 $\pm$ 1.2		May 60	2 $\pm$.8
Clam (<u>Yoldia</u>)	muscle	3	Sept. 59	4.5 $\pm$ 1.4			
	soft parts	3	Sept. 59	4.0 $\pm$.78			
Scallop	muscle	5	Sept. 59	4.0 $\pm$.41		Apr. 60	2 $\pm$.4
		3	Nov. 59		3.29 $\pm$.221	May 60	2 $\pm$.5
		3	May 60	4.2 $\pm$.50			
	visceral mass	3	June 60	3.8 $\pm$.49			
		5	Sept. 59	7.6 $\pm$.97		Apr. 60	0 $\pm$ 1
		1	May 60	8.3 $\pm$ 2.3	6.84 $\pm$.516		
Snail	muscle	10	Sept. 59	2.7 $\pm$.48			
	digestive gland	10	Sept. 59	3.3 $\pm$.79		May 60	0 $\pm$ 2
Sea urchin	shell	4	Sept. 59	.72 $\pm$ 2.7			
	gonad	4	Sept. 59	1.7 $\pm$.87			
	intestine	4	Sept. 59	20 $\pm$ 1.6		May 60	10 $\pm$ 5
	and content	4	Nov. 59		14.2 $\pm$.632	June 60	0 $\pm$ 20

Table 1. (continued)

Organism	Tissue	No. of samples	Gross beta			Gamma spectrometry*	
			Date counted	Anton	Low level	Date counted	K ⁴⁰
Sea urchin	intestine and content	1	May 60				
		4	May 60	13 ±1.4			
		4	June 60	12 ±1.3			
Basket star	viscera, gonads, etc. portion of arm	1	Sept. 59	4.4± .96			
		1	Sept. 59	1.4±1.6			
<u>Brown Bear</u> plankton (235-2)	entire	2	June 60	2.6± .33			
<u>Brown Bear</u> plankton 236-10, 235-7 236-32, 236-33 236-70	entire	2	June 60	.97±.28			

*For gamma spectrometry, 1 sample, but a composite of several specimens

Table 2. Scientific names of specimens listed in Table 1

Group	Common name	Scientific name
Fish	Pacific herring	<u>Clupea harengus pallas</u>
	Capelin	<u>Mallotus villosus</u>
	Saffron cod	<u>Eleginus gracilis</u>
	Arctic cod	<u>Boreogadus saida</u>
	Sculpin	<u>Artediellus scaber</u>
		<u>beringianus</u>
	Sculpin	<u>Enophrys lucasi</u>
	Bering flounder	<u>Hippoglossoides robustus</u>
	Yellow fin sole	<u>Limanda aspera</u>
Invertebrates	Hermit crab	<u>Pagurus sp.</u>
	Tanner crab	<u>Chionoecetes opilio</u>
	King crab	<u>Paralithodes platypus</u>
	Crab	<u>Telmessus cheiragonus</u>
	Shrimp	<u>Crago dalli</u>
	Shrimp	<u>Sclerocrangon boreas</u>
	Clam	<u>Macoma sp.</u>
	Clam	<u>Yoldia sp.</u>
	Barnacle	<u>Balanus sp.</u>
	Scallop	<u>Chlamys islandica</u>
	Snail (welk)	<u>Buccinum sp.</u>
	Snail (welk)	<u>Neptunea sp.</u>
	Sea urchin	<u>Strongylocentrotus</u>
		<u>dröbachiensis</u>
	Basket star	<u>Gorgonocephalus stimpsoni</u>

APPENDIX NO. 1

A LIST OF FISHES FROM THE VICINITY OF PROJECT CHARIOT*

Norman J. Wilimovsky**

Task Order: To conduct field investigations and make collections necessary to prepare a list of marine and freshwater fishes in the Project Chariot area.

Field efforts toward this objective were carried out from July 27 through August 20, 1959. The field work involved (1) collecting in river and lakes in the Cape Thompson region, (2) test fishing in all lagoons in the immediate Project Chariot area, and (3) obtaining samples of fishes collected by the John N. Cobb during its survey activities in the Chukchi Sea. More than 106 separate collecting stations were occupied, though the resulting coverage was not divided evenly among the three habitat categories.

Fishing effort in the freshwater and brackish lagoons varied. However, all 10 of the lagoons from north of Cape Thompson to Cape Seppings were examined, and reasonably good knowledge of their fish fauna is available. The lagoons are generally closed to the sea during much of the open water

* A composite of Dr. Wilimovsky's Preliminary Progress Report of September 24, 1959 and his Preliminary Evaluation Report of November 25, 1959.

** Chief, Marine Fisheries Investigations, Bureau of Commercial Fisheries, Juneau, Alaska.

period, and inlet streams are small. This limits extensive population of such areas by a varied fish fauna.

Of the three habitats examined, the least effort, and consequently smallest coverage, was given to the river systems. The Cobb collections appear to be adequately representative of the fish fauna in the Chukchi Sea area. Our investigations covered in some detail all of the rivers and streams in the region from Cape Seppings to Point Hope. Some 30 stations were occupied. This survey included study of the Kukpuk River. Generally the rivers in this circumscribed area are of low productivity and do not support any fish runs of major size. Dolly Varden, char, grayling, stickleback, and sculpin dominate the fish fauna. The primary reason for this reduced productivity is that summer storms close off the mouths of these slowly flowing streams, limiting movement of migrating fish. The only evidence of migrating forms was a small pink salmon run on the Kukpuk River. Outside of the immediate study area, salmon occurred in the Kivalina River. Salmon are also known to occur north of the Point Hope area.

There are few lakes in the region; the lakes in the immediate Chariot vicinity have been very carefully surveyed --usually with negative results.

Identification of 2576 specimens collected in the Chariot area has been substantially completed. One or two

genera require additional systematic judgement, and the proper nomenclatorial designation for three others must be determined on the grounds of nomenclatural priority. The 52 taxa recognized are as follows:

MARINE FORMS

<i>Clupea harengus pallasii</i>	<i>Myoxocephalus axillaris</i>
<i>Oncorhynchus gorbuscha</i>	<i>Myoxocephalus jack</i>
<i>Oncorhynchus keta</i>	<i>Myoxocephalus stelleri</i>
<i>Salvelinus alpinus</i>	<i>Myoxocephalus quadricornis</i>
<i>Salvelinus malma</i>	<i>Microcottus sellaris</i>
<i>Osmerus dentex</i>	<i>Gymnocanthus tricuspis</i>
<i>Mallotus villosus</i>	<i>orientalis</i>
<i>Eleginus gracilis</i>	<i>Enophrys lucasi</i>
<i>Boreogadus saida</i>	<i>Nautichthys pribilovius</i>
<i>Atheresthes stomias</i>	<i>Aspidophoroides olrikii</i>
<i>Hippoglossoides robustus</i>	<i>Podothecus acipenserinus</i>
<i>Limanda aspera</i>	<i>Liparis herschelini</i>
<i>Pleuronectes quadrituberculatus</i>	<i>Liparis</i> sp.
<i>Liopsetta glacialis</i>	<i>Ammodytes hexapterus</i>
<i>Platichthys stellatus</i>	<i>Stichaeus punctatus</i>
<i>Hexagrammos</i> sp.	<i>Eumesogrammus praecisus</i>
<i>Hemilepidotus</i> sp.	<i>Lumpenus fabricii</i>
<i>Icelux</i> s. <i>spatula</i>	<i>Lumpenus medius</i>
<i>Triglops pingeli</i>	<i>Lycodes palearis arcticus</i>
<i>Arteidiellus scaber beringianus</i>	<i>Lycodes raridens</i>
<i>Megalocottus platycephalus</i>	<i>Lycodes</i> sp.
<i>Myoxocephalus scorpius</i>	<i>Gymnelis viridis</i>

FRESHWATER FORMS

<i>Salvelinus malma</i>	<i>Thymallus arcticus</i>
<i>Salvelinus alpinus</i>	<i>signifer</i>
<i>Coregonus autumnalis</i>	<i>Cottus cognatus</i>
<i>Coregonus sardinella</i>	<i>Gasterosteus aculeatus</i>
<i>Coregonus lavaretus pidschian</i>	<i>Pungitius pungitius</i>

The species list, as might be expected, is dominated by far-northern types. However, the Chariot collection is unique

in that it contains at least a dozen forms which heretofore have not been known to occur north of Bering Straits. As parts of the Chukchi Sea were studied by Russian expeditions in 1932 and 1933, the presence of these forms may represent either a general warming of the area, or a temporal extension of the range of Bering Sea fishes, owing to local oceanographic phenomena.

The catch records of 7,000 plus fish captured during the field operations give some evidence of order of abundance of the different species. Numerically, the ten dominant marine forms within the area of our exploration of the Chukchi Sea were:

Boreogadus saida	Hippoglossoides robustus
Clupea harengus pallasii	Osmerus dentex
Gymnocanthus tricuspid	Myoxocephalus scorpius
Artediellus scaber	Triglops pingeli
Mallotus villosus	Eleginus gracilis

By frequency of occurrence within the station pattern, the ten dominant marine forms are:

Boreogadus saida	Podothecus acipenserinus
Gymnocanthus tricuspid	Lumpenus fabricii
Hippoglossoides robustus	Artediellus scaber
Myoxocephalus scorpius	Osmerus dentex
Triglops pingeli	Lycodes spp.

Preliminary analysis does not indicate any definite pattern of abundance within the marine area studied. However, several of the species show distinctive ecological trends, and their occurrence is presently being analyzed with reference to substrate,

temperature, and depth range. Also, decided interspecific relations between species were evident. To analyze these relationships objectively, the data are being subjected to Cole's test of association. Because of the number of tabulations required, this material has been entered on punch cards and will be analyzed with the aid of an electronic computer. Processing of the cards is awaiting the installation of an IBM 709 computer on the University of Washington campus. Upon completion of these analyses, a final formal report will be prepared.

APPENDIX NO. 2

ANNUAL REPORT ON BENTHIC MARINE INVERTEBRATES
OF THE CHUKCHI SEA, PROJECT CHARLOT, JUNE 1, 1960

by Albert K. Sparks and Walter T. Pereyra

Introduction

Responsibility for the study of the benthic marine invertebrates for Project Charlot, a part of Operation Plowshare, was accepted by the Invertebrate Fisheries Section of the College of Fisheries. Plans for sampling the area were made in collaboration with Mr. Dayton L. Alverson, Chief, North Pacific Fisheries Exploration and Gear Research, U. S. Fish and Wildlife Service, and Dr. Norman Wilimovsky, Ichthyologist, Bureau of Commercial Fisheries, Juneau, Alaska, who were in charge of the cruise and the collection and identification of the fish, respectively. The objectives of this work were to sample the benthic invertebrates of the eastern Chukchi Sea and intertidal zone and lagoons in the area adjacent to the project site; to determine the general abundance of various invertebrate groups at each sampling location; to preserve for later identification in the laboratory representative specimens of each species at each location; and, finally, to prepare, after more complete identification, a list of the marine

invertebrates of the eastern Chukchi Sea.

The survey was carried out in the eastern Chukchi Sea from Bering Strait to just north of Cape Lisburne and west to longitude 169°W. This area has a bottom of varied types gradually sloping from the steep gravel beaches to approximately 30 fathoms depth. Small tides of up to nine inches in amplitude and a strong northerly-flowing current off Cape Thompson further characterize this area.

Due to the extent of the spring ice build-up and onshore storms, lagoons of various sizes and salinities have been formed behind the high beaches. As these lagoons are open for only part of the year, their salinities range from fresh to brackish.

The junior author arrived at Cape Thompson on July 28, 1959, where he met Dr. Wilimovsky and collaborated with him in sampling the lagoons, beaches, and the area just offshore from Cape Seppings to Point Hope. The senior author flew to Nome on August 5 and joined the Motor Vessel John N. Cobb. The John Cobb departed Nome on August 5, and, taking samples en route, proceeded to Kotzebue, Alaska, where Dr. Wilimovsky and the junior author joined the party. The senior author left the area on August 20, 1959, and returned to Seattle; the junior author remained on the vessel until September 11th

when the John N. Cobb arrived in Seattle.

Invertebrates collected and preserved in the survey area were brought back to the College of Fisheries for identification. Certain groups are being identified by the authors and personnel in the Invertebrate Fisheries Section of the College of Fisheries. Other groups have been sent out to specialists on the particular groups for identification. An extremely rich invertebrate fauna was observed during the investigation, although no economically valuable species were found in commercial quantities.

Materials and Methods

The survey of the lagoons and inshore areas in the vicinity of Cape Thompson was made with a six-foot hand seine, a beach seine, and a small hand dredge approximately 1' x 2', operated from a sixteen-foot boat. At times of strong offshore winds the dredge was floated out on a small wooden float and hauled back using a weasel. This method was also employed in sampling the lagoons. A total of eight stations were occupied from Cape Seppings to Point Hope.

Sampling of the remainder of the offshore areas was done from the 93-foot research vessel M/V John N. Cobb. At each of the stations listed in the cruise plan (See Fig. 1) a

Figure 1. Station pattern and types of gear used at each station by the John N. Cobb.

Legend

- Otter trawl
- Otter trawl and biological dredge
- Midwater trawl
- △ Shrimp traps
- ▲ Gill nets
- ▼ Beach seine

thirty-minute trawl was made using a standard commercial 4-1/2 inch stretch mesh eastern 400 mesh otter trawl with a 1-1/2 inch stretch mesh liner. Although a fine mesh liner was used, this gear was relatively inefficient in sampling many of the smaller forms. Invertebrates from each trawl were field identified, enumerated and representative samples preserved in ten per cent formalin neutralized with Hexamine for transport back to the College of Fisheries. The smaller material was stored in 16-ounce cans capped with a hand canner, while the larger animals were placed in cloth bags and kept in kegs of 10 per cent formalin.

At each station, when weather permitted, a very short drag was made using a toothed biological dredge, 2' x 4' at the mouth with a 1-1/2 inch stretch mesh nylon bag four feet in length. Contents of each haul were washed through a series of three graded screens, 3", 1", and 1/4", arranged in a washing box, and those invertebrates left on each screen were field identified, enumerated and representatives of each species preserved.

In the area off Chariot Site, midwater trawls were made using a Canadian-type midwater trawl, 70 square feet at the mouth opening, with 5" stretch mesh wings and a 1-1/4" stretch mesh cod end.

During the cruise a total of 59 otter trawls, 36 dredges, and 12 midwater trawls were made in addition to sampling with gill nets, shrimp pots, and beach seines.

Results

Sorting of the invertebrates to phylum and, in most cases, class and family has been completed. A study of the distribution of major groups in each phylum in relation to location, depth, bottom type and temperature has been made. These will be discussed. Additionally, a study has been made on the length and weight relationships of some of the caridean crustaceans collected.

General Considerations

The type and consistency of the bottom determines, to a very large extent, the distribution and abundance of benthic invertebrates. Based on a bottom sample taken at each station, bottom types were plotted as shown in Figure 2. It will be noted from the figure that in the area immediately off Chariot Site, within a radius of about thirty miles, is found a wide variety of bottom types including gravel, sand-gravel, silt, sand-silt, sand-silt-gravel, etc., whereas in some of the other areas shown, for example between Bering Strait and Kotzebue Sound, there are extensive areas of a

Figure 2. Bottom types of the eastern Chukchi Sea.

Legend

Silt

Shell

Sand

Gravel

Rock

single bottom type. This wide variety of benthic ecological situations in the area of Chariot Site probably accounts for the wide variety of fauna found in that particular area. Also, the temperature in this area shows a rapid decrease moving from shore outward as shown in Figure 3, and would probably encourage extensive variation in the fauna.

It is believed that a sufficient coverage of the area, from a survey point of view, was obtained in the present study. It is obvious, however, that an area this large could not be extensively studied within this period of time. It is known that some forms are present in the area which were not collected in the sampling program. This is particularly true of the deeper burrowing forms which were not taken in the dredge and those animals inhabiting the shallow areas near shore that were inaccessible to the John N. Cobb. Also, many small animals undoubtedly passed through the relatively large meshes of the sampling gear. Shells of Siliqua alta, Tellina lutea, and Mytilus edulis were collected on the beach but were never taken during the biological sampling. Large numbers of Mytilus were found in windrows on the beach near Kivalina, but were never collected offshore, suggesting that a sizeable population of this mollusc exists immediately offshore in this area.

Scouring of the inshore areas by ice greatly reduces the likelihood of any significant invertebrate populations

Figure 3. Bottom temperatures of the eastern Chukchi Sea in degrees Fahrenheit.

Figure 4. Depth contours of the eastern Chukchi Sea at five fathom intervals.

becoming established in the area from the beach out to a depth of approximately twenty feet. Because of the gradual slope in this area, this leaves relatively large areas of the littoral zone sparsely populated by small populations of hardy forms which can withstand the rigors of the spring ice-out and highly motile forms which can move in and out with the seasons.

Brackish-water lagoons behind the barrier beach, located in such places as Cape Seppings, do not support large invertebrate populations. These, too, are limited to forms that can be washed in from the sea during the spring onshore storms. In the investigations of the fresh-water and brackish-water lagoons at Cape Seppings, a few mysids, numerous Lepidurus and one nemertine worm were found, along with dying Mytilus which had been washed in by a recent storm. The junior author sampled the immediate offshore area intensively for about two miles out, and found mysids, Cumaceans (Diastylis goodsiri), small sponges, an Alcyonarian (Eunephthya rubiformis), brown algae, cragonid shrimp, starfish, a few amphipods, a few bryozoans, some hydrozoans, and a few tunicates to be typical of the fauna of the area. These were never found in large numbers and, of course, animals adapted to life in the large gravel predominated. An occasional barnacle was found in these areas, but they were never large.

Distribution of Major Groups

Rank abundance of individual groups has been plotted by station with the hope that some knowledge could be gained of the ecological factors determining the distribution of the various groups within the area. These data are shown in Appendices 1 and 2. For groups containing relatively few species, no breakdown within the phylum was necessary, but for large groups such as the echinoderms, in which a large number of species and widely diversified groups of animals were present within the phylum, the distribution of the classes was considered. Such a study has proved to be of some value in understanding the distribution of benthic invertebrates in the eastern Chukchi Sea, but due to the independent fluctuations of the dominant species within the groups, relative abundance data is quite weak. These groups will be considered below:

Phylum Porifera

In the present survey, sponges were restricted to depths of less than 20 fathoms in an area stretching from Bering Strait to Cape Lisburne. This contrasts with the distribution of poriferans reported by MacGinitie from Point Barrow, which were largely from depths greater than 20 fathoms. Most specimens, however, were collected

in the gravel zone between Cape Kruzenstern and Point Hope. No specimens were taken from areas of mud bottom. Species probably present in the area are listed in the faunal list. An amorphous sponge, probably Myxilla sp. or Topsentia sp., was found surrounding clusters of a barnacle, Balanus rostratus apertus, particularly off Cape Thompson.

Phylum Coelenterata -

Class Hydrozoa

This group of animals was not subjected to the same amount of search as were most of the other major groups, primarily due to the difficulty of recognizing these small, inconspicuous forms among the larger animals. As a result, only obvious clusters were seen and, therefore, there is considerable doubt that our sampling was representative. Large numbers of gastropod shells were partially or completely covered by an encrusting hydrozoan, Hydractinia. This was a very common sight but was not recorded during much of the cruise because of lack of knowledge concerning identification of this form at the time of the survey. Other forms were found in areas of hard substrate such as gravel. Distribution of the class as brought out in the present survey was rather general

throughout the eastern Chukchi Sea, with no definite relationship to bottom type, depth, or geographical location.

Class Scyphozoa

There is some doubt as to whether this group should be considered in this report since all the forms collected were pelagic rather than benthic. Medusae of the genus Cyanea were collected rather generally throughout the area, particularly in the midwater trawl samples.

Class Anthozoa

A complicating factor arose in studying the distribution of the Class Anthozoa because of the presence of two groups of animals of approximately equal size, but quite different in ecological requirements. These are a soft coral (Eunephthya rubiformis), and a species of sea anemone (Stomphia coccinea). These two organisms varied independently in abundance so that changes in one species may be overshadowed by changes in the other. It may be necessary to plot each species separately in order to find the true distributional picture. In general, the Class Anthozoa was found to be distributed over the entire area with the exception of the Kotzebue Sound silt bottom and the silty areas between Kotzebue Sound and Bering Strait. Specimens were taken from the gravel just

off the beach to the deepest waters sampled with a few small collections made in the gravelly areas of Bering Strait and the hard-bottom areas just north of Cape Lisburne. Occasional specimens, largely on mollusc shells, were taken in the silty area between Bering Strait and Kotzebue Sound.

Phylum Nemertea

Nemerteans were found in areas of silt bottom from just outside Kotzebue Sound to Station 57, the most northern station, and west to 169°W. longitude. It is of considerable interest that nemertine worms were found only in regions of silty bottom with the exception of three collections in which silt and shell or silt and sand bottoms were recorded. The greatest concentration of these forms was about twenty miles off Chariot Site in silt areas surrounded by areas of shell, sand, and gravel. One wonders, however, why more specimens were not collected in the silt areas between Bering Strait and Kotzebue Sound. Of some interest is a single specimen collected from a brackish-water lagoon behind the barrier beach just north of Cape Seppings. Nemertines were collected in ten of the thirty-six dredges taken on the entire cruise and in four of the otter trawls. Since the nemertines are burrowing forms, they were

taken more frequently in the dredge than in the otter trawl.

Phylum Bryozoa

The bryozoans, like the hydrozoans, were not adequately sampled, thus presenting the same problems in analysis of the data as were presented by the hydrozoans. Although encrusting Bryozoa were probably present at almost all stations, they were not specifically searched for and were recorded only if they happened to be noticed. Upright forms were likewise quite numerous but were not always recorded. MacGinitie collected 99 species of bryozoans in the Point Barrow area, indicating that the group should be widely represented in the eastern Chukchi Sea. Since the bryozoans are restricted to a habitat where they can attach, it is not surprising that the bulk of the observed bryozoans was found in regions where gravel or rocks are the predominant bottom type. Some species such as Costazia nordenskjoeldi were often observed encrusting the holdfast of the tunicates and other sessile invertebrates.

Phylum Brachiopoda

Brachiopods were collected on three occasions, all near the beach between Kivalina and Point Hope. All specimens were taken within five miles of shore in waters of less

than twenty fathoms depth with a gravel bottom. Since these forms require a solid substrate for attachment, it is not strange that they were not collected in areas with a silt bottom. It seems a little peculiar, however, that none were taken in the rocky or gravel areas north of Cape Lisburne or at a greater distance offshore where bottoms apparently suitable for brachiopods were found. Two species of this phylum were reported from Point Barrow.

Phylum Sipunculoidea

All specimens of this group have been tentatively identified as Golfingia margaritacea. Sipunculoids were collected from Bering Strait to the farthest station north of Cape Lisburne and out to 168° W. longitude. They were collected on 15 occasions, 13 times by dredge and twice by otter trawl. It is evident that their burrowing habits made them unavailable to the trawl. In contrast to the nemertines, the habitat requirement for sipunculoids appears to be less rigid. With few exceptions, sipunculoids were taken where sand was the principal component of the bottom sediment. These observations indicate that sipunculoids prefer areas devoid of silt. On several occasions collections were made quite

near shore in gravel zones between Chariot Site and Kivalina.

Phylum Priapulidea

A number of specimens of Priapulus caudatus were taken at four locations (Stations 17, 45, 36 and 57), all north of Cape Seppings. All specimens were collected in regions with either a silt or a mixed silt-gravel bottom. Due to the burrowing habits of these worms, all specimens were taken in the dredge. The priapuloids collected in this survey are presently being studied by Mr. William Shapiro as one part of an M. S. Thesis on the histology of Priapulus.

Phylum Echiuroidea

Echiuroids were collected from three locations; one at station 57, northwest of Cape Lisburne, the other two at adjacent stations 40 and 42, just southwest of Kivalina.

Phylum Mollusca

The molluscan fauna of the survey area is extremely rich and varied with a large number of species represented in most of the major groups with the exception of the class Cephalopoda.

Class Amphineura

Chitons were found only in the region from just off Chariot Site north. These forms were restricted to

areas of hard substrate with concentrations observed off Point Hope and north of Cape Lisburne. No amphineurans were collected south of the 68th parallel although some suitable bottom types occurred in this region. There appeared to be only two species of chitons present in the area, Trachydermon albus and Symmetrogephyrus vestitus.

Class Pelecypoda

Because of the extremely rich and varied bivalve fauna, consideration of the distribution of the class as a whole failed to produce a clear picture of the distribution of pelecypods relative to ecological relationships in the survey area. When consideration of the smaller groups or species is made, variation in abundance according to bottom types and other ecological conditions will no doubt develop. The most common species of pelecypod appears to be a tellenid bivalve, Macoma calcaria. This is a mud-inhabiting species, being generally distributed over most of the eastern Chukchi Sea in silty areas. Concentrations of Macoma and also of Chlamys were located off the Point Hope-Cape Thompson area. Pelecypods were collected in 39 dredge and 27 otter trawl samples, but were not taken in the area intermediate between Kotzebue Sound and Kivalina. It should be pointed out, however,

that because of inclement weather, much of that area was not sampled by dredge.

Class Gastropoda

Orders Aspidobranchia and Ctenobranchia

These groups, like the pelecypods, were found to be widespread throughout the eastern Chukchi Sea and were an extremely rich part of the fauna. Large whelks of the genus Neptunea, often five inches or more in height, were particularly numerous and conspicuous. These forms are predaceous, largely on bivalve molluscs, consequently their distribution tends to follow that of the bivalves. Geographically we find that these gastropods were collected over the entire survey area, except that they were not taken at the inshore stations between Chariot Site and Point Hope and at several of the stations in the gravel zone between Chariot Site and Kotzebue Sound. Most of these gastropods have been identified as to genus and many of them to species.

Order Opisthobranchia

The distribution of this group of gastropods is quite interesting. Aside from one collection between Bering Strait and Kotzebue Sound, they were not found in the entire southeastern Chukchi Sea. Nudibranchs were

collected regularly but never in extreme abundance, occurring most frequently in the Point Hope-Chariot area and extending out some 80 miles. They were generally taken in the gravel and sandy-gravel areas but were not excluded from areas of silt. Two of the most northern collections were made in areas of silty bottom as were the three in the Chariot-Point Hope area.

Class Cephalopoda

Two octopods were collected in the present survey. These were taken at stations 24 and 35 on the sandy-gravel bottom 40 to 50 miles due west of Chariot Site. Both these forms were quite small and probably belong to the genus Benthoctopus.

Phylum Annelida

The annelids have not yet been broken down into major subdivisions and, therefore, cannot be considered relative to their distributions. An attempt is being made to arrange for Dr. Olga Hartman of the Allen Hancock Foundation, University of Southern California, to work up the annelids collected on the survey. Generally, annelids were taken throughout the survey area with the greatest numbers being collected on the silt bottom areas southwest of Chariot Site and very

few or none taken from the gravel and sandy areas.

Although most of the worms were taken from areas with a silt bottom, a number of scale worms and tubeworms were collected with the otter trawl from other areas.

Phylum Arthropoda

Class Crustacea

Subclass Cirripedia

All barnacles collected in this study were submitted to Dr. Dora Henry for identification. She has now completed her identification and all species collected in the Chukchi Sea will be found in the species list.

Dr. Henry (verbal communication) has observed no relationships between bottom types and the distribution of the various species, due, no doubt, to the presence of barnacles on shells in the silty areas.

However, in examining the distribution of the barnacles collected in the survey, we find that once again there is a concentration on the gravel bottom just off Chariot Site and Point Hope. In the southern part of the survey area from Bering Strait to Kotzebue Sound, rather small numbers of barnacles were taken in the areas of sand bottom, presumably on shell, while to the north of Cape Lisburne barnacles were regularly collected, mostly on the hard bottom. As one would suspect, barnacles appear

to be better able to withstand the more rigorous conditions near the beach than any other animals collected.

Subclass Malacostraca

Order Peracarida

Suborder Mysidacea

Several mysidaceans were collected on the silty bottom just off Cape Seppings and Cape Kruzenstern. These were the only areas where this group was found except along the beach from Kivalina to Point Hope.

Suborder Cumacea

A few cumaceans (Diastylis goodsiri), were taken at stations 24 and 61 and just offshore from Kivalina to Chariot Site. Due to the small size of the members of this group, sampling was inadequate making further analysis invalid.

Suborder Isopoda

Isopods were cosmopolitan in distribution, being found over the entire eastern Chukchi Sea at practically all depths, temperatures and bottom types. A very large valviferan species was encountered just off the beach from Chariot Site to Point Hope and at some other areas offshore. Probably the most abundant free-living species was Idothaega entomon, while a parasitic form,

probably Phryxus abdominalis, was found parasitizing many of the shrimp, particularly of the family Hippolytidae. Isopods were taken only in the otter trawl, except for the beach collections, and there seems to be no relationship between the bottom type and distribution of the sub-order.

Suborder Amphipoda

Amphipods were quite generally distributed throughout the area except for the region between the mouth of Kotzebue Sound and off Cape Kruzenstern. Again, abundance was quite general with large numbers taken west and southwest of Chariot Site. The benthic amphipods in this area were quite large and conspicuous, one species in particular, a stegocephalid, was extremely large and apparently more numerous in the eastern Chukchi Sea than MacGinite found it to be at Point Barrow. Many of the species present in our study were quite colorful and easy to recognize aboard ship, but upon preservation were rendered more difficult to identify. Because of the large variety of species present, no relationship could be established with bottom type, depth or temperature.

Order Eucarida

Suborder Decapoda

Decapod crustaceans were quite numerous and widespread in the eastern Chukchi Sea, being collected at all but one station during the entire survey. Greatest abundance appears to be in the deeper waters off Chariot Site. Large numbers of cragonid shrimp, hippolytid shrimp and hermit crabs made up a major portion of the decapods collected. This is another group which is so extensive in its speciation that the distribution of the group as a whole is of no particular significance. The distribution of the genus Telmessus was quite interesting in that it was abundant north of Kivalina but was never taken to the south. Only a very few specimens of the king crab, Paralithodes platypus, were taken in this study.

Class Arachnida

Order Pantapoda

The pycnogonids were taken just off Chariot Site, at Kivalina, and at Station 39. Because of their small size and delicate bodies it is quite likely that the real abundance of this group is inadequately demonstrated.

Phylum Echinodermata

The Echinodermata was unquestionably one of the dominant phyla of invertebrates present in the eastern Chukchi Sea, forming a large, conspicuous part of each collection. Basket stars commonly covered the wings of the trawl and were a conspicuous sight as the trawl was being hauled aboard.

Class Asteroidea

Asteroids were extremely widespread and abundant at all stations, with the exception of two locations in the sandy silt area between Bering Strait and Kotzebue Sound. Because of the large number of species present it is possible that differences in the distribution of various species within the class are masked when considering the class as a whole. This, of course, will be brought out when identification of the species in the class has been completed. Distribution of the asteroids probably is controlled by the distribution of their food, largely molluscs, rather than directly by bottom type. The major focus of abundance seems to be in the area to the west of Point Hope, the same area in which numerous pelecypods and dead shell were recorded. Other foci of abundance were found off Cape Kruzenstern to the south and northeast of Cape Lisburne in the north.

Class Ophiuroidea

Ophiuroids collected in the Chukchi Sea consisted of two major types, the basket stars made up of only a single species, Gorgonocephalus stimpsoni, and a number of species of brittle stars. Basket stars were taken primarily in the otter trawl while brittle stars were confined to dredge hauls. Distribution of the class covered the entire survey area from Bering Strait to south of Cape Lisburne, except for a line of stations in the sand and silt zones between Kotzebue Sound and Kivalina and one station, Number 28, northwest of Point Hope. It is interesting to note that no ophiuroids were found north of Cape Lisburne although six otter trawls and six dredge samples were taken in this area. Brittle stars appear to be concentrated on the silt bottom in a band offshore from Chariot Site to a point southwest of Kivalina. Basket stars, on the other hand, were located farther offshore and in colder water, with the largest numbers being found at Station 30, the most westerly station off Point Hope.

Class Echinoidea

The Echinoids also consisted of two major types, sand dollars and sea urchins. A tremendous concentration of sand dollars was found on the sandy bottom at Station 58

just north of Cape Lisburne with a small collection taken at the adjacent Station 59. Sea urchins, however, were much more widely distributed and were often taken in the otter trawl. They appear to prefer a gravel area, as large numbers were taken in Bering Strait and extremely large numbers were found directly off Chariot Site where gravel and mixed sand and gravel predominated. Only occasional specimens were collected in the silt areas between Kotzebue Sound and Bering Strait north to Cape Krusenstern or, for that matter, north to Kivalina.

Class Holothuroidea

Holothuroids were taken primarily in the silt areas some distance offshore, particularly in the area between Kivalina and Point Hope. However, large numbers of psolids (Psolus fabricii) were taken in the gravel areas just off Chariot Site and in various other gravel areas.

Phylum Chordata

Sub-phylum Tunicata

Tunicates were one of the dominant invertebrate groups encountered in the eastern Chukchi Sea, being quite numerous and widespread in the survey area with the bulk occurring north of Cape Krusenstern. The greatest

numbers were encountered at the stations off Point Hope, Chariot Site, and Kivalina. Apparently gravel or other suitable hard substrate seems necessary for the attachment of these animals. Two species of Boltenia were the most numerous tunicates found in the area, although a total of probably a dozen other species were taken. Clusters of tunicates were found to afford attachment for other animals such as bryozoans and hydrozoans, and quite commonly a small clam, Hiatella arctica, nestled among them.

PARTIAL LIST OF INVERTEBRATES IDENTIFIED FROM
THE EASTERN CHUKCHI SEA

Phylum Porifera

Echinoclathria beringensis (Hentschel)

Halichondria lambei Brønsted ?

Myxilla incrustans (Johnston) ?

Topsentia disparilis (Lambe) ?

Phylum Coelenterata

Class Hydrozoa

Hydractinia sp.

Class Scyphozoa

Aurelia aurita (Linnaeus)

Cyanea capillata (Linnaeus)

Class Anthozoa

Sub-class Alcyonaria

Eunephthya rubiformis (Pallas)

Sub-class Zoantharia

Order Actiniaria

Stomphia coccinea (O. F. Müller)

Order Ceriantharia

Cerianthus borealis (Verrill) ?

Phylum Ctenophora

Bolinopsis infundibulum (O. F. Müller) ?

Mertensia ovum (Fabricius) ?

Phylum Sipunculoidea

Golfingia margaritacea (Sars)

Phylum Priapulidea

Priapulus caudatus Lamarck

Phylum Echiuroidea

Echiurus echiurus alaskanus (Fisher)

Phylum Bryozoa

Pachyegis sp.

Alcyonidium sp.

Costazia nordenskjoldi (Kluge) ?

Phylum Annelida

Order Polychaeta

Pista maculata (Dalyell) ?

Harmothaë imbricata (Linnaeus) ?

Myxicola sp.

Spirorbis sp.

Nereis sp.

Arenicola sp.

Phylum Echinodermata

Class Asteroidea

Crossaster papposus (Linnaeus)

Henricia sanguinolenta (O. F. Müller)

Leptasterias spp.

Ctenasterias sp.

Solaster sp. (probably S. endeca (Linnaeus)).

Pteraster obscurus (Perrier) ?

Class Ophiuroidea

Gorgonocephalus stimpsoni (Verrill)

Several species of unidentified brittle stars

Class Echinoidea

Strongylocentrotus dröbachiensis (O. F. Müller)

One species of unidentified sand dollar

Class Holothuroidea

Myriotrochus rinki Steenstrup

Psolus fabricii (Düben and Koren)

Another unidentified sea cucumber

Phylum Arthropoda

Class Crustacea

Subclass Cirripedia

Chthamalus sp. nov.

Balanus crenatus Bruguiere

B. hesperius Pilsbry

B. balanus balanus (Linnaeus)

B. rostratus apertus Pilsbry

Subclass Malacostraca

Order Peracarida

Suborder Mysidacea

Mysis oculata (Fabricius) ?

Suborder Cumacea

Diastylis goodsiri (Bell)

Suborder Isopoda

Superfamily Valvifera

Idotaega entomon (Linnaeus) ?

Mesidotea entomon

Superfamily Bopyroidea

Phryxus abdominalis (Kröyer) ?

Suborder Amphipoda

Superfamily Caprellidea

One species, no identification

Superfamily Gammaridea

Hyperoche medusarum (Kröyer) ?

Byblis gaimardii (Kröyer) ?

Paramphithoe polyacantha (Murdoch) ?

Erichthonius hunteri (Bate) ?

E. tolli Brüggen

Order Eucarida

Suborder Decapoda

Superfamily Macrura

Family Cragónidae

Crago dalli Rathbun

Sclerocrangon boreas (Phipps)

Argis lar (Owen) = Nectocrangon lar

Family Hippolytidae

Spirontocaris gaimardii Rathbun

S. phippsii (Kröyer)

S. stoneyi

S. spina (Sowerby)

S. arcuata Rathbun

Family Pandalidae

Pandalus goniurus Stimpson

P. jordani Rathbun ?

P. borealis Kröyer ?

Superfamily Anomura

Family Paguridae

Pagurus splendescens (Owens)

P. trigonocheirus (Stimpson)

Family Lithodidae

Paralithodes platypus Brandt

Chionoecetes opilio (O. Fabricius)

Family Atelicyclidae

Telmessus cheiragonus (Tilesius)

Class Arachnida

Order Pantapoda

One species, no identification

Phylum Mollusca

Class Amphineura

Family Lepidochitonidae

Trachydermon albus (Linnaeus)

Family Cryptochitonidae

Symmetrogephyrus vestitus (Broderip and Sowerby)

Class Pelecypoda

Order Prionodesmacea

Family Nuculidae

Nucula tenuis (Montagu)

Family Nuculanidae

Nuculana radiata (Krause)

Nuculana sp.

Yoldia myalis (Couthouy)

Y. scissirata Dall

Yoldia sp.

Family Pectinidae

Chlamys islandica (Müller)

Family Anomiidae

One unidentified species

Family Mytilidae

Musculus niger (Gray)

M. discors (Linnaeus)

Mytilus edulis Linnaeus

Order Anomalodesmacea

Family Thraciidae

Thracia sp.*

Order Teleodesmacea

Family Astartidae

Astarte borealis Schumacher

Astarte montagui (Dillwyn)

Family Carditidae

Cardita crassidens (Broderip and Sowerby)

Family Myacidae

Mya sp.

Family Pandoridae

Pandora grandis Dall

Family Cardiidae

Clinocardium ciliatum (Fabricius)

Serripes grönlandicus (Bruguiere)

*dead shell only

Family Tapetidae

Liocyma fluctuosa (Gould)

Family Tellinidae

Tellina lutea Wood (ex Gray, MS.)*

Macoma calcarea (Gmelin)

Macoma sp.

Family Solenidae

Siliqua alta (Broderip and Sowerby)*

Family Hiatellidae

Panomya ampla Dall

Hiatella arctica (Linnaeus)

Class Gastropoda

Order Aspidobranchia

Family Trochidae

Margarites costalis (Gould ex Loven MS.)

Margarites spp.

Order Ctenobranchia

Family Turritellidae

Tachyrhynchus reticulatum (Mighels) ?

Family Crepidulidae

Crepidula grandis (Middendorff)

Family Trichotropidae

Trichotropis bicarinata (Sowerby)

Trichotropis sp.

*dead shell only

Natica clausa Broderip and Sowerby

Polinices spp.

Family Lamellariidae

Velutina spp.

Family Muricidae

Boreotrophon beringi (Dall)

Boreotrophon spp.

Family Buccinidae

Buccinum glaciale Linnaeus

Buccinum tenue Gray

Buccinum polare Gray

Buccinum spp.

Beringius beringi (Middendorff)

Colus spitzbergensis (Reeve)

Neptunea ventricosa (Gmelin)

Neptunea heros (Gray)

Neptunea spp.

Plicifusus kroyeri (Möller)

Volutopsius sp.

Family Cancellariidae

Admete couthouyi (Jay)

Order Opisthobranchia

Suborder Tectibranchiata

Family Acteocinidae

Retusa umbilicata (Montagu)

Suborder Pteropoda

Family Clionidae

Clione limacina (Phipps)

Suborder Nudibranchia

Family Dendronotidae

Dendronotus sp.

Two unidentified species

Class Cephalopoda

Order Decapoda

Benthoctopus sp. ?

Phylum Tunicata

Class Ascidiacea

Didemnum albidum (Verrill) ?

Dendrodoa grossularia (van Beneden) ?

Boltenia echinata (Linnaeus)

Boltenia ovifera (Linnaeus)

Halocynthia aurantium (Pallas)

Rhizomolgula globularis (Pallas)

Molgula spp.

Styela sp.

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Appendix 1. Rank Abundance of the Invertebrate Groups Collected By Otter Trawl.

Rank Abundance Key

Rank No.	Verbal description	Numerical description
1	few	1 - 5
2	several	6 - 25
3	many	26 - 100
4	numerous	101 - 200
5	very numerous	200+

Otter Trawl Stations

	1	2	3	4	5	6	7	8	9	10	11
Phylum Porifera	0	2	2	0	0	0	0	0	2	*	0
Phylum Coelenterata											
Class Hydrozoa	0	0	0	0	0	0	1	0	0	0	0
Class Scyphozoa	0	0	0	3	3	3	3	3	0	0	0
Class Anthozoa	0	0	1	0	0	0	0	0	0	0	0
Phylum Nemertea	0	0	0	0	0	0	0	0	0	0	0
Phylum Bryozoa	0	0	0	0	0	1	1	0	0	0	0
Phylum Brachiopoda	0	0	0	0	0	0	0	0	0	0	0
Phylum Sipunculoidea	0	*	0	0	0	0	0	0	0	0	0
Phylum Priapuloida	0	0	0	0	0	0	0	0	0	0	0

*animal present but abundance not known

Appendix 1. (continued)

Otter Trawl Stations											
	1	2	3	4	5	6	7	8	9	10	11
Phylum Echiuroidea	0	0	0	0	0	0	0	0	0	0	0
Phylum Echinodermata											
Class Asteroidea	3	2	5	2	0	0	1	0	1	*	1
Class Ophiuroidea	2	1	0	0	0	0	0	0	1	4	4
Class Echinoidea	1	1	1	0	0	0	0	0	1	0	3
Class Holothuroidea	0	0	0	0	0	0	0	0	*	0	1
Phylum Mollusca											
Class Amphineura	0	0	0	0	0	0	0	0	0	0	0
Class Pelecypoda	0	0	0	0	0	0	0	0	0	2	0
Class Gastropoda											
Orders Aspidobranchia											
and Ctenobranchia	1	1	0	0	0	0	2	0	1	1	0
Order Opisthobranchia	0	0	0	0	0	1	0	0	0	0	0
Class Cephalopoda	0	0	0	0	0	0	0	0	0	0	0
Phylum Annelida	0	0	0	0	0	0	0	0	0	0	0
Phylum Arthropoda											
Cirripedia	0	1	0	0	0	0	0	0	0	4	0
Mysidacea	0	0	0	1	0	0	1	1	0	0	0
Cumacea	0	0	0	0	0	0	0	0	0	0	0
Isopoda	0	0	0	1	0	0	0	0	0	1	0
Amphipoda	1	1	0	0	0	1	0	0	0	1	4
Decapoda	3	4	5	2	0	2	0	1	3	5	0
Pantopoda	0	0	0	0	0	0	0	0	0	0	0
Phylum Tunicata	1	0	0	0	0	0	0	1	4	5	4

Appendix 1. (continued)

Otter Trawl Stations											
	12	13	14	15	16	17	18	19	20	21	22
Phylum Porifera	0	0	0	0	0	2	1	1	0	0	0
Phylum Coelenterata											
Class Hydrozoa	0	0	0	0	0	0	0	0	0	1	3
Class Scyphozoa	0	0	0	0	0	0	2	1	0	0	0
Class Anthozoa	0	0	2	0	1	3	3	3	2	2	2
Phylum Nemertea	0	0	0	0	0	0	0	0	1	0	0
Phylum Bryozoa	0	0	0	0	0	*	0	2	0	0	0
Phylum Brachiopoda	0	0	0	0	0	1	0	0	0	0	0
Phylum Sipunculoidea	0	0	0	0	0	0	0	0	0	0	0
Phylum Priapulidea	0	0	0	0	0	0	0	0	0	0	0
Phylum Echiuroidea	0	0	0	0	0	0	0	0	0	0	0
Phylum Echinodermata											
Class Asteroidea	2	1	1	2	2	2	1	3	2	3	3
Class Ophiuroidea	3	1	0	2	2	2	1	2	5	4	2
Class Echinoidea	0	1	0	0	0	1	2	4	2	1	0
Class Holothuroidea	0	1	5	0	*	0	0	1	0	4	0
Phylum Mollusca											
Class Amphineura	0	0	0	0	0	0	0	0	0	0	0
Class Pelecypoda	0	0	0	0	0	2	1	2	0	0	0

Appendix 1. (continued)

Otter Trawl Stations											
	12	13	14	15	16	17	18	19	20	21	22
Class Gastropoda											
Orders Aspidobranchia											
and Ctenobranchia	*	1	1	1	2	0	0	0	3	1	1
Order Opisthobranchia	0	0	0	0	0	0	0	0	1	0	0
Class Cephalopoda	0	0	0	0	0	0	0	0	0	0	0
Phylum Annelida	0	0	0	0	*	2	0	0	1	1	1
Phylum Arthropoda											
Cirripedia	0	0	0	0	0	1	2	2	1	0	0
Mysidacea	0	0	0	0	0	0	0	0	0	0	0
Cumacea	0	0	0	0	0	0	0	0	0	0	0
Isopoda	*	0	0	0	0	1	0	0	0	0	0
Amphipoda	1	1	2	4	1	1	0	1	1	1	2
Decapoda	3	3	2	5	3	5	2	3	3	3	3
Pantapoda	0	0	0	0	0	0	0	0	0	0	0
Phylum Tunicata	1	1	0	0	1	4	2	3	1	4	0

Appendix 1. (continued)

Otter Trawl Stations											
	23	24	25	26	27	28	29	30	31	32	33
Phylum Porifera	0	0	2	0	0	0	0	0	0	0	4
Phylum Coelenterata											
Class Hydrozoa	2	0	0	0	0	0	0	0	0	0	0
Class Scyphozoa	0	0	0	0	1	1	0	0	0	0	0
Class Anthozoa	1	2	4	*	2	1	2	5	1	1	3
Phylum Nemertea	1	0	0	0	0	0	0	1	0	0	0
Phylum Bryozoa	0	2	2	0	0	0	0	0	0	0	0
Phylum Brachiopoda	0	0	0	0	0	0	0	0	0	0	0
Phylum Sipunculoidea	0	0	0	0	0	0	0	0	0	0	0
Phylum Priapulidea	0	0	0	0	0	0	0	0	0	0	0
Phylum Echiuroidea	0	0	0	0	0	0	0	0	0	0	0
Phylum Echinodermata											
Class Asteroidea	2	2	2	2	2	2	4	5	4	3	2
Class Ophiuroidea	0	2	1	3	2	0	3	4	3	3	3
Class Echinoidea	0	0	0	0	0	0	0	0	0	1	*
Class Holothuroidea	3	1	*	0	0	0	1	4	5	0	1
Phylum Mollusca											
Class Amphineura	0	1	2	0	0	0	0	0	0	0	1
Class Pelecypoda	0	1	3	1	1	*	1	2	1	*	3

Appendix 1. (continued)

	Otter Trawl Stations										
	23	24	25	26	27	28	29	30	31	32	33
Class Gastropoda											
Orders Aspidobranchia											
and Ctenobranchia	1	0	3	2	0	2	2	3	1	3	2
Order Opisthobranchia	0	0	2	0	0	1	0	0	0	1	1
Class Cephalopoda	0	1	0	0	0	0	0	0	0	0	0
Phylum Annelida	0	2	*	0	0	1	0	1	1	2	1
Phylum Arthropoda											
Cirripedia	0	0	4	0	0	0	0	0	0	0	2
Mysidacea	0	0	0	0	0	0	0	0	0	0	0
Cumacea	0	1	0	0	0	0	0	0	0	0	0
Isopoda	0	1	0	0	0	0	0	1	0	0	0
Amphipoda	3	2	*	1	0	0	1	3	1	1	1
Decapoda	3	2	4	3	3	3	3	5	5	3	4
Pantapoda	0	0	0	0	0	0	0	0	0	0	0
Phylum Tunicata	1	2	5	4	1	1	0	0	0	0	4

Appendix 1. (continued)

	Otter Trawl Stations										
	34	35	36	37	39	40	41	42	43	44	45
Phylum Porifera	2	0	2	0	4	2	1	0	0	0	0
Phylum Coelenterata											
Class Hydrozoa	0	2	0	0	2	0	0	0	1	0	0
Class Scyphozoa	2	0	1	*	0	1	2	3	2	0	1
Class Anthozoa	1	1	0	2	4	0	0	0	0	0	2
Phylum Nemertea	0	0	0	0	0	0	0	0	0	0	0
Phylum Bryozoa	0	0	1	0	2	0	0	2	0	0	0
Phylum Brachiopoda	0	0	0	0	0	0	0	0	0	0	0
Phylum Sipunculoidea	0	0	0	0	0	0	0	0	0	0	0
Phylum Priapulidea	0	0	0	0	0	0	0	0	0	0	0
Phylum Echiuroidea	0	0	0	0	0	0	0	0	0	0	0
Phylum Echinodermata											
Class Asteroidea	2	1	1	1	2	3	1	0	2	1	2
Class Ophiuroidea	3	2	2	4	3	2	2	1	0	2	1
Class Echinoidea	0	1	1	2	2	0	0	0	1	0	1
Class Holothuroidea	1	1	0	0	1	0	0	0	0	0	4
Phylum Mollusca											
Class Amphineura	0	0	0	0	0	0	0	0	0	0	0
Class Pelecypoda	2	1	2	1	1	0	1	0	0	1	0

Appendix 1. (continued)

	Otter Trawl Stations										
	34	35	36	37	39	40	41	42	43	44	45
Class Gastropoda											
Orders Aspidobranchia											
and Ctenobranchia	2	2	2	*	0	0	0	1	0	2	1
Order Opisthobranchia	0	1	1	0	1	0	0	0	0	0	0
Class Cephalopoda	0	0	0	0	0	0	0	0	0	0	0
Phylum Annelida	1	1	1	1	1	0	1	1	0	0	1
Phylum Arthropoda											
Cirripedia	0	0	2	0	2	1	0	0	2	0	0
Mysidacea	0	0	0	0	0	0	0	0	0	0	0
Cumacea	0	0	0	0	0	0	0	0	0	0	0
Isopoda	0	0	1	0	0	0	0	0	0	0	0
Amphipoda	1	1	2	0	3	2	1	1	2	3	2
Decapoda	4	3	3	3	4	3	3	3	2	3	2
Pantapoda	0	0	0	0	1	0	0	0	0	0	0
Phylum Tunicata	3	2	3	*	5	4	2	1	1	0	0

Appendix 1. (continued)

Otter Trawl Stations

	46	47	48	49	50	51	52	56	57	58	59
Phylum Porifera	0	0	0	0	0	0	3	0	0	0	0
Phylum Coelenterata											
Class Hydrozoa	0	3	0	0	0	0	2	1	0	0	0
Class Scyphozoa	0	1	0	0	1	0	0	2	0	1	0
Class Anthozoa	3	3	3	2	1	2	3	1	1	0	1
Phylum Nemertea	0	0	0	0	0	1	0	0	0	0	0
Phylum Bryozoa	0	0	0	0	0	0	2	0	2	2	0
Phylum Brachiopoda	0	0	0	0	0	0	0	0	0	0	0
Phylum Sipunculoidea	0	0	0	0	0	0	0	0	0	0	0
Phylum Priapulidea	0	0	0	0	0	0	0	0	0	0	0
Phylum Echiuroidea	0	0	0	0	0	0	0	0	0	0	0
Phylum Echinodermata											
Class Asteroidea	2	1	4	*	4	3	3	1	4	2	2
Class Ophiuroidea	2	2	4	3	2	1	5	0	0	0	0
Class Echinoidea	0	0	0	0	0	0	5	1	0	2	0
Class Holothuroidea	3	*	3	*	5	3	3	1	0	0	0
Phylum Mollusca											
Class Amphineura	0	0	0	0	0	0	0	0	1	0	0
Class Pelecypoda	0	0	2	3	1	1	3	0	1	0	0

Appendix 1. (continued)

Otter Trawl Stations											
	46	47	48	49	50	51	52	56	57	58	59
Class Gastropoda											
Orders Aspidobranchia											
and Ctenobranchia	1	2	3	1	1	1	2	1	3	1	2
Order Opisthobranchia	1	*	0	0	1	1	0	0	1	0	0
Class Cephalopoda	0	0	0	0	0	0	0	0	0	0	0
Phylum Annelida	0	*	1	*	1	1	2	0	0	0	1
Phylum Arthropoda											
Cirripedia	0	0	0	0	0	0	2	1	3	0	2
Mysidacea	0	0	0	0	0	0	0	0	0	0	0
Cumacea	0	0	0	0	0	0	0	0	0	0	0
Isopoda	0	0	0	0	0	1	0	0	0	0	1
Amphipoda	2	2	4	*	2	2	0	0	2	1	1
Decapoda	3	5	4	5	5	3	4	3	4	3	5
Pantapoda	0	0	0	0	0	0	0	0	0	0	0
Phylum Tunicata	0	1	0	0	1	4	4	0	3	1	1

Appendix 1. (continued)

Otter Trawl Stations

	60	61	73	74
Phylum Porifera	0	0	0	4
Phylum Coelenterata				
Class Hydrozoa	2	0	0	2
Class Scyphozoa	2	0	0	0
Class Anthozoa	0	1	1	2
Phylum Nemertea	0	0	0	0
Phylum Bryozoa	2	0	0	2
Phylum Brachiopoda	0	0	0	0
Phylum Sipunculoidea	0	0	0	1
Phylum Priapuloida	0	0	0	0
Phylum Echiuroidea	0	0	0	0
Phylum Echinodermata				
Class Asteroidea	1	5	1	1
Class Ophiuroidea	0	0	2	3
Class Echinoidea	2	1	0	5
Class Holothuroidea	0	2	0	0
Phylum Mollusca				
Class Amphineura	0	2	0	0
Class Pelecypoda	0	0	1	2

Appendix 1. (continued)

Otter Trawl Stations

	60	61	73	74
Class Gastropoda				
Orders Aspidobranchia				
and Ctenobranchia	1	2	2	2
Order Opisthobranchia	0	0	0	0
Class Cephalopoda	0	0	0	0
Phylum Annelida	0	0	1	1
Phylum Arthropoda				
Cirripedia	1	2	1	3
Mysidacea	0	0	0	0
Cumacea	0	1	0	0
Isopoda	0	1	0	0
Amphipoda	1	1	1	1
Decapoda	4	5	3	3
Pantopoda	0	0	0	0
Phylum Tunicata	2	2	1	0

*animal present but abundance not known.

Appendix 2. Rank Abundance of the Invertebrate Groups Collected by Biological Dredge.

Rank Abundance Key

Rank No.	Verbal description	Numerical description
1	few	1 - 5
2	several	6 - 25
3	many	26 - 100
4	numerous	101 - 200
5	very numerous	200+

	Dredge Stations														
	1	2	4	5	12	13	14	17	18	19	20	21	22	23	24
Phylum Porifera	0	0	0	0	0	0	0	0	*	2	0	0	0	0	0
Phylum Coelenterata															
Class Hydrozoa	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
Class Scyphozoa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Class Anthozoa	0	0	0	0	0	1	2	0	2	2	1	0	0	1	2
Phylum Nemertea	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0
Phylum Bryozoa	0	0	2	0	0	0	0	0	*	2	0	0	0	0	2
Phylum Brachiopoda	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Phylum Sipunculoidea	0	0	1	1	0	0	0	1	0	0	0	0	0	0	1

*animal present but abundance not known

Appendix 2. (continued)

Dredge Stations

	1	2	4	5	12	13	14	17	18	19	20	21	22	23	24
Phylum Priapulioidea	0	0	0	0	0	0	0	*	0	0	0	0	0	0	0
Phylum Echiuroidea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phylum Echinodermata															
Class Asteroidea	0	0	0	2	*	0	0	1	1	2	1	1	1	2	1
Class Ophiuroidea	0	0	1	2	5	4	0	1	1	1	5	1	3	1	0
Class Echinoidea	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1
Class Holothuroidea	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0
Phylum Mollusca															
Class Amphineura	0	0	0	0	0	0	0	0	*	0	0	0	0	0	2
Class Pelecypoda	0	0	2	2	2	5	1	2	2	1	2	2	3	4	2
Class Gastropoda															
Orders Aspi- branchia and															
Ctenobranchia	0	0	1	0	2	2	0	0	1	0	2	0	1	1	3
Order Opistho- branchia	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1
Class Cephalopoda	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phylum Annelida	0	0	2	4	2	4	4	1	2	2	2	3	4	4	*

Appendix 2. (continued)

Dredge Stations

	1	2	4	5	12	13	14	17	18	19	20	21	22	23	24
Phylum Arthropoda															
Cirripedia	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Mysidacea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cumacea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Isopoda	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Amphipoda	0	0	0	5	1	0	0	0	0	0	1	2	2	3	2
Decapoda	0	0	1	2	1	1	1	0	1	2	2	0	0	1	2
Pantopoda	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phylum Tunicata	0	0	0	2	1	0	0	3	1	1	0	0	0	2	3

Appendix 2. (continued)

[illegible]

Appendix 2. (continued)

	Dredge Stations														
	25	33	35	36	37	39	40	41	42	43	44	45	46	51	56
Phylum Mollusca															
Class Amphineura	1	1	0	*	0	0	0	0	0	0	0	0	0	0	0
Class Pelecypoda	2	2	1	3	1	2	2	2	3	3	2	5	2	2	1
Class Gastropoda															
Orders Aspi- branchia and Ctenobranchia	1	2	0	4	0	1	2	0	2	2	0	2	2	0	0
Order Opistho- branchia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Class Cephalopoda	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Phylum Annelida	1	1	4	1	0	2	0	4	3	3	4	4	2	2	3
Phylum Arthropoda															
Cirripedia	1	1	0	1	0	0	2	0	2	1	0	0	0	1	0
Mysidacea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cumacea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Isopoda	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Amphipoda	1	1	1	0	0	2	2	0	2	4	4	0	4	0	1
Decapoda	1	2	1	2	1	2	3	2	2	2	0	0	2	1	0
Pantopoda	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phylum Tunicata	*	3	1	*	2	4	2	1	2	0	0	0	0	0	0

Appendix 2. (continued)

	Dredge Stations					
	57	58	59	60	61	73
Phylum Porifera	0	0	0	0	1	0
Phylum Coelenterata						
Class Hydrozoa	*	0	0	1	2	0
Class Scyphozoa	0	0	0	0	0	0
Class Anthozoa	0	0	1	0	0	0
Phylum Nemertea	1	0	0	0	0	0
Phylum Bryozoa	*	0	0	1	2	0
Phylum Brachiopoda	0	0	0	0	0	0
Phylum Sipunculoidea	2	0	0	0	0	0
Phylum Priapulidea	1	0	0	0	0	0
Phylum Echiuroidea	0	0	0	0	0	0
Phylum Echinodermata						
Class Asteroidea	0	0	1	1	1	0
Class Ophiuroidea	0	0	0	0	0	3
Class Echinoidea	0	5	0	2	0	0
Class Holothuroidea	1	0	0	1	1	1

Appendix 2. (continued)

	Dredge Stations					
	57	58	59	60	61	73
Phylum Mollusca						
Class Amphineura	0	0	0	1	2	0
Class Pelecypoda	2	0	1	1	2	2
Class Gastropoda						
Orders Aspidobranchia and Ctenobranchia	2	1	1	1	3	2
Order Opisthobranchia	0	0	0	0	0	0
Class Cephalopoda	0	0	0	0	0	0
Phylum Annelida	4	0	1	0	0	0
Phylum Arthropoda						
Cirripedia	2	1	2	1	0	1
Mysidacea	0	0	0	0	0	0
Cumacea	0	0	0	0	0	0
Isopoda	0	0	0	0	0	0
Amphipoda	1	0	0	0	0	0
Decapoda	1	1	2	0	1	1
Pantopoda	0	0	0	0	0	0
Phylum Tunicata	0	1	1	4	1	0

APPENDIX NO. 3

THE SALMON RESOURCE IN THE
VICINITY OF THE CHARIOT PROJECT*

Howard D. Smith**

A survey of the streams in the vicinity of the Chariot site was undertaken between August 5 and August 20, 1959, for the purpose of evaluating the salmon resource. The area surveyed is indicated in Figure 1.

METHODS OF EVALUATION

It is not possible to provide a comprehensive evaluation of the salmon resources of an area on the basis of one short period of study. Four of the five species of Pacific salmon manifest inconsistent ages at maturity and pink salmon (the 5th species) may appear in odd years to the virtual exclusion of the even --or vice versa-- and the cyclic nature of the salmon production curves in areas long under study warn against conclusions based upon a single year's data.

* A compilation from Mr. Smith's report, "An Evaluation of Salmon Resources in the Region of the United States Atomic Energy Commission's Project Chariot at Cape Thompson, Alaska." September 21, 1959.

** Senior Fisheries Biologist, Fisheries Research Institute, College of Fisheries, University of Washington.

Figure 1

Location of Cape Thompson Study Area

It is possible to assess the 1959 production by reference to several available sources of information, including "on the site" observations. For purposes of this paper the Cape Thompson study area is that region which lies between Kivalina and Point Hope and extends inland to encompass the lower part of the Kukpuk River drainage. Thus all waters within 30 miles of the project base at Ogotoruk Creek are under consideration here (Figure 1).

A. Literature

Information pertaining to the anadromous fishes in the vicinity of the project is to be found in Raleigh (1957), Willimovsky (1956) and Townsend (1885).

B. Interrogation

Salmon production may be evaluated in general terms from talks with native fishermen and informed residents. However, there is a likelihood of reaching erroneous conclusions as to abundance and distribution when one relies upon this source of information alone. The local names for salmon, and the failure of many of the natives to differentiate between salmon, trout, whitefish and others species pose special problems when reports are interpreted in the light of local terminology. Nevertheless talks with native fishermen at Kotzebue, Kivalina and Tigara have been valuable.

C. Aerial Survey

Valuable information on the distribution of salmon is available by means of aerial surveys.

On August 12 the streams from Ogotoruk Creek to and including the Kukpuk River were observed (Figure 2). The Kukpuk was flown eastward from its mouth to the confluence of the Ipewik, and then southward for a distance of 10 to 15 miles east of the Ogotoruk Creek drainage. Ogotoruk Creek was flown on the return from that trip.

On August 17 the Kukpuk was resurveyed from the forks to a point about $2/3$ of the way to the mouth, and the Ipewik was surveyed for an estimated 10 miles upstream.

D. Ground Reconnaissance

Coastwise trips by foot or weasel along the beach were not possible to the northwest because of cliffs, but were possible in a southeasterly direction. Six weasel trips and "on foot" inspection of streams southeast of the project site as far as Cape Seppings plus a survey of Ogotoruk Creek were made during the period of August 10 to 18. Inspections of smaller streams were limited to their mouths for they generally discharged into lagoons which in turn seeped into the sea through gravel bars. On August 13 and 18 surveys included the Singoalik River, largest stream between Cape Seppings and Point Hope. On the

Figure 2

Location of Kukpuk River showing section surveyed.

later visit the stream was surveyed from the mouth upstream for four miles via weasel.

E. Water Reconnaissance

The southernmost of three principal lagoons between Ogotoruk Creek and Tigara were visited on August 15. On August 17 three miles of the Kukpuk River about half way between the mouth and the confluence of the Ipewik River were surveyed from a rubber raft. The number and species of salmon and the nature of the stream and its spawning facilities were determined at first hand.

RESULTS OF EVALUATIONS

The several means of evaluating salmon production in the Cape Thompson area produced the following information:

A. From literature

Raleigh (1957--page 11, Table 1) estimates the average salmon catches from the villages of Kivalina and Tigara:

Village	Estimated Recent Annual Salmon Catch		
	Chums	Pink	Total
Kivalina	500	none	500
Point Hope	2520	70	2590
Combined	3020	70	3090

Raleigh lists as "low" the dependency of these two villages on the salmon resources of the area.

Townsend (1887--page 95) states that on his trip up the Kobuk River about 100 miles southeast of Cape Thompson during July and August, 1885, only a few pink salmon were seen but that great numbers of dog salmon were dried by the people.

Willimovsky (1952--page) states that the people of the region from Point Hope to Point Barrow utilize the sea fisheries only slightly. It is significant to note that the region around Cape Thompson is on the geographical and cultural edge of the Arctic where Willimovsky asserts that fishing in general was never a highly important or significant occupation.

B. From interrogation

At Kotzebue only chum salmon appeared important though natives said that small numbers of pinks and kings were taken on occasion. Over 40 chums constituted the catch of one gill net during the night of August 7-8, and the owner said it had been a good night. He reported that the chum run would last about a month -- roughly throughout August. The natives claim that most of the chums will ascend the Kobuk and Noatak Rivers, and say some fish are taken from the Kobuk by Kotzebue fishermen in years when the local catches are inadequate to meet the winter needs. It was also reported that salmon catches in 1958

were very light but that 1959 had been a good year. (Vague reports from a variety of sources later in the season affirmed 1959 as a year of outstanding chum production on the Kobuk.)

Hunting parties from Kivalina reported no salmon in the small streams between their village and Point Hope. They said "sometimes a few" and "just about none" when asked about the abundance of salmon in local streams. However, there is a small run to the Wulik River at Kivalina reported and these salmon, probably chums for the most part, are fished locally.

At Tigara residents showed a polite disinterest in matters of salmon utilization. No salmon were observed on any of the drying racks although scraps of meat were in evidence. Facilities for drying large quantities of fish were conspicuously absent -- in marked contrast with the rows of fish racks one encounters farther south. Although fish may be placed in pits in the permafrost and thus frozen indefinitely no such instances were encountered. On the beach at Point Hope local fishermen hauled small seines in which they were seen to capture half a dozen dolly varden during a fishing interval of some 30 minutes. The inefficiency of the small seines as compared with a short gill net appears obvious, and one must conclude that salmon are not in serious demand or gill nets would be in use.

Discussions with the native workmen at the project base, and with local white men, notably Mr. John Crosse, station

manager and veteran pilot with Wein Alaska Airlines at Kotzebue, confirmed the impressions gained in direct interrogation of the fishing and hunting population.

C. From aerial survey

The streams between Cape Thompson and Point Hope all appeared small and incapable of supporting salmon runs. Furthermore the larger of these empty into lagoons which at the time of the survey were closed to the sea.

The Kukpuk River enters Maryatt Lagoon through a series of channels which dominate the lower four or five miles of stream. Immediately above this region of multiple channels, and throughout a distance of some 15 miles, approximately 5000 pink salmon were observed on August 12. Less than 50 dead salmon were seen during this flight and inasmuch as conditions for surveying were excellent, i.e., good light, little wind, and clear water, both live and dead estimates are believed reasonable.

On August 17 the Kukpuk was resurveyed in part. At that time many hundreds of salmon were dead, but otherwise there was no apparent change in the numbers and distribution of the population. About 50 salmon were seen in the Ipewik River just above the mouth. No others were observed though visibility was excellent.

Ogotoruk Creek demands attention as the stream which flows through the excavation site. It has a moderate gradient, and useful gravel sizes but its spawning facilities are not extensive.

No salmon were seen in the stream this year, though the water level in common with all the streams in the area was reported to have been extraordinarily low*(about 2 cubic feet per second). During the period of observation, August 10-18 the stream reached the ocean only by seepage through the gravel bar at its mouth. The flow in the stream was quite inadequate for salmon.

The small streams southeast of the project as far as Cape Seppings are very small. Only two, the first in the "control" valley eight miles away, and the second draining into the second lagoon southeast of the base are significant in terms of potential salmon production. However no salmon were seen in them and it is doubtful that fish could ascend either of them this year on account of the low water level.

The Singoalik River empties into a large lagoon which is probably open to the sea only during higher water stages. It has a moderate gradient and on August 13 at a point one and one-half miles from the lagoon its width was 12 feet, its depth one foot and its surface flow was at a rate of approximately one foot per second. Nineteen pink salmon were observed in a single pool one mile above the lagoon. These were the only salmon observed in the river though Dr. Willimovsky captured two pink salmon in a gill net in the lagoon on August 4. No live salmon

* R. Kachedorian, U.S.C.G.S., and John Crosse, Wein Alaska Airlines -- personal communications.

and only 5 dead were observed in the river during the survey of August 18 though it was established that spawning facilities are good throughout the four miles surveyed, and there are numerous pools affording good protection for schooled fish.

D. From water reconnaissance

It was apparent that like the streams southeast of the project, those to the northwest are generally not accessible to anadromous fishes except possibly during periods of very high water or when wind-induced tides may provide temporary flow in to the lagoons from the sea.

The Kukpuk River appears to have excellent spawning facilities throughout the section surveyed from the air. Average dimensions were about 130 feet in width, 18 inches in depth and the surface flow was at about two feet per second. The river appears susceptible to high water but probably seldom suffers from severe gravel scouring. Salmon were spawning at the heads of most of the riffles, and by August 17 virtually all were actively spawning or spent. A few bear kills were observed. A total of 75 fish were measured to establish the approximate size range of this population, and a sex ratio was established from a total of 122 fish observed over a distance of about two miles. These were 75% males. No salmon, other than pinks were observed in the Kukpuk River.

CONCLUSIONS

The return of salmon to the Cape Thompson area in 1959 probably amounted to 6000-7000 fish, chiefly, if not all, pinks. It is not possible to relate this numerical return to that of other years but it appears likely that this was a "normal" year. Significant chum runs may well occur from time to time, however, and it is possible that in years of higher water than that observed in 1959, small numbers of salmon may enter a few of the smaller streams in the area.

It seems quite certain that salmon contribute very little to the economy of the region. The villagers of both Kivalina and Tigara are primarily hunters rather than fishermen, and though the meagre stocks of salmon are easily within reach they appear virtually unexploited. On the basis of present knowledge only two streams in the study area appear important. They are the Kukpuk and Singoalik Rivers which both produce pinks, and probably some chums occasionally, during the month of August. The possibility of salmon utilizing the streams of the area either before or after the 1959 survey period is slight. Thompson (1951) pointed out that as one proceeds northward along the Pacific coast the races of salmon concentrate their spawning periods into a progressively shorter period in order that they take advantage of the progressively shorter periods of environ-

mental optima. It is therefore probable that in order to adapt within the stringent environmental limitations of the Arctic, the salmon must enter the streams, spawn, and die in a very short period and virtually together.

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