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Environment Canada
Enviromental Protection Service
Pacific Region
Yukon Branch

WATER QUALITY AND BIOLOGICAL SURVEY OF THE COASTAL WATERS NEAR STOKES POINT YUKON - BEAUFORT SEA COAST

Regional Program Report No. 84-06

by

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ABSTRACT

A baseline water quality and biological survey of the Beaufort Sea coast in the vicinity of Stokes Point, Yukon was undertaken by Environmental Protection Service in August, 1983. The water quality, sediment, and bottom fauna characteristics in the nearshore marine and lagoon habitats were surveyed and compared to data collected in August, 1982 (Allan and Mackenzie-Grieve, 1983).

The nearshore marine stations exemplified the fluctuating water chemistry conditions typical of coastal waters. Sediment metal levels and oils and grease levels were comparable to data obtained in the previous year's study and similiar to other Beaufort Sea studies. The benthic community was different from that reported in the 1982 study. The population diversity was similiar in terms of the number of species per station and the Shannon-Weaver diversity index, but the species composition had changed as well as having a higher density. Thirty-four species were collected compared to fourteen found in the previous year. Six species not previously recognized in other Beaufort Sea literature were identified in the samples. Three new species of amphipods were collected.

The lagoon exhibited a structured water column with the noticeable presence of a halocline. The high oils and grease content as reported in the 1982 study was further investigated and determined to be of non-hydrocarbon origin and most probably, an artifact of elemental sulphur. The benthic community was similiar to that reported in the 1982 study. The two stations sampled showed 60.91 and 39.56% similarity to the respective stations in the previous year.

RÉSUMÉ

Le service de Protection de l'Environnement a effectué, au mois d'août 1983, une étude de base de la qualité de l'eau et des conditions biologique sur la côte de la mer de Beaufort près de Stokes Point, Yukon. La qualité de l'eau, sédiments et les caractéristiques de la faune benthique des lagunes et habitats marins furent analysées et comparées aux données recueillies en août 1982 (Allan et Mackenzie-Grieve, 1983).

Les stations marines réflètent les fluctuations des conditions chimiques de l'eau typiques aux eaux cotières. Les taux de métaux, huiles et graisses des sédiments sont comparables aux données obtenues dans l'étude précédente et similaires aux autres études de la mer de Beaufort. La communauté benthique fut différente de l'étude telle que rapportée en 1982. La diversité de population fut similaire en terme de nombre d'espèces par station et d'index de diversité Shannon-Weaver, mais la composition spécifique a changé aussi bien qu' ayant augmente de densité. Trente-quatre espèces furent échantillonnées comparativement a quatorze trouvées l'année précédente. Six expèces jamais rencontrées dans d'autres études de la mer de Beaufort furent identifiées dans les échantillons. Trois nouvelles espèces de amphipodes furent trouvées.

La lagune présente une halocline dans la structure de la colonne d'eau. Les hautes concentrations d'huiles et graisses comme rapportées dans l'étude de 1982 furent plus amplement analysées et ne proviendraient pas d'une source d'hydrocarbone mais elles semblent plus probablement être un artefact, dû au soufre élémental. La communauté benthique fut similaire a celle rapportée en 1982. Les deux stations échantillonnées démontrent un pourcentage de similarité de 60.91 et 39.56 pour les stations respectives de l'année précédente.

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1 INTRODUCTION

In recent years, the development of Yukon's north coast has been a major concern to governments, private industry, native peoples, and conservation organizations. The most controversial proposals have been a deepwater port and shorebase facility by Gulf Canada Resources Inc. at Stokes Point, and a quarry with port facility by Kiewit and Sons Ltd. at King Point. Due to the scarcity of biological information at these specific locations, the Environmental Protection Service undertook a baseline inventory study in 1982 at both Stokes Point and King Point (Allan and Mackenzie-Grieve, 1983). This study yielded some interesting results, especially with respect to the benthic invertebrate community at Stokes Point. In order to broaden and increase this data, a follow up survey was conducted in August, 1983.

This study surveyed nearshore marine and lagoon habitats in the vicinity of Stokes Point (Figure 1). Measurements of water quality (salinity, temperature, dissolved oxygen, non-filterable residue) and sediment characteristics (particle size, extractable metals, oils and grease) were made. The benthic invertebrate community was examined and compared to the previous year's data.

The 1983 expedition to Yukon's north coast also included an examination of five streams in the Stokes Point region. The results are presented in a companion report (Allan and Mackenzie-Grieve, 1984).

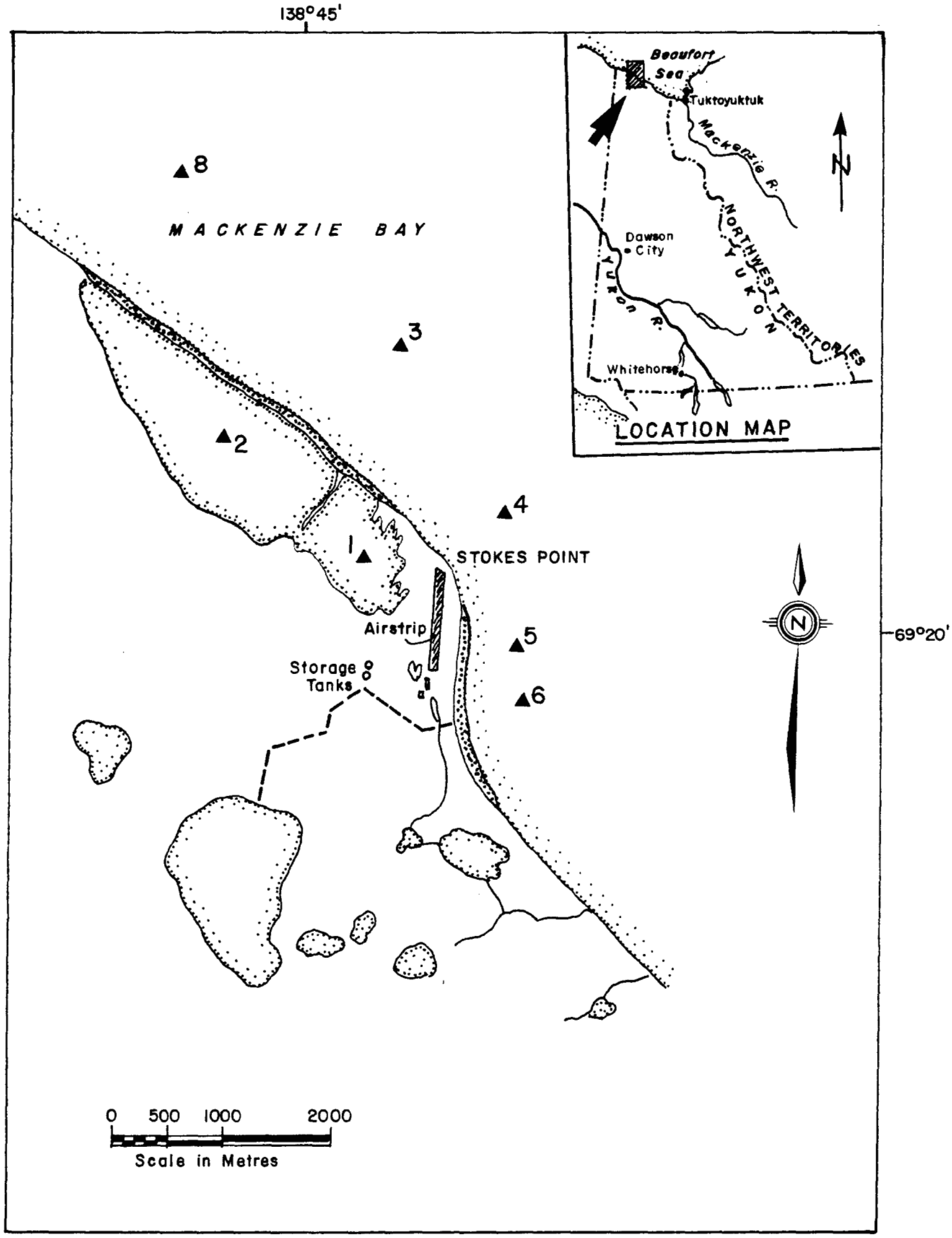

FIGURE 1 LOCATION OF SAMPLING STATIONS NEAR STOKES POINT

2 STUDY AREA

The study area is located near Stokes Point (69°20'N, 138°43'W) along the Beaufort Sea coastline of the Yukon Territory (Figure 1).

Data was collected at seven sampling stations, representing nearshore marine and lagoon habitats. Sample station location and numbering sequence followed those used in Allan and Mackenzie-Grieve, (1983) (Figure 1).

FIGURE 2 Aerial photograph of the Stokes Point Area. View is to the north with the eastern portion of the lagoon in foreground. The location of Station 1 is indicated.

3 METHODS

Field work on the marine portion of this year's survey was conducted from August 2-4, 1983. Sampling was completed in the following sequence: Stations 4 to 6 on August 2 and Stations 1 to 3 and 8 on August 4. Station numbers and approximate locations correspond to the 1982 sampling program (Allan and Mackenzie-Grieve, 1983).

Weather during the sampling period was variable, but generally cool and windy. Sampling was discontinuous on August 2 and postponed on August 3 due to rough water conditions. Tides during the survey fluctuated between 0.24 and 0.88 meters above chart datum (F.E. Stephenson, 1983).

An inflatable boat was used to access all stations. The nearshore marine stations were located along the five meter isobath (which was determined to be well below the extent of bottom freezing) and established by using a sounding line from the surface. An anchor was used to remain stationary while data was collected in the following order: water chemistry, sediment samples, and bottom fauna.

The following sections explain in more detail, the methods employed.

3.1 Water Quality

The water quality data collection and preparation methods are summarized in Appendix I, Table 1.

Water chemistry data was collected at two depths, surface and 0.5 meters above bottom. The parameters measured in the field included depth, dissolved oxygen, temperature, conductivity, and salinity. The latter three parameters were measured using the YSI Model 33 conductivity meter.

Dissolved oxygen levels were determined using the YSI Model 57 dissolved oxygen meter. The meter was calibrated using the water saturated air method and readings were corrected for *in situ* salinity before recording. Percent saturation was calculated from oxygen saturation tables derived from APHA et al (1981).

One litre water samples were collected for non-filterable residue analysis. The surface water samples were collected directly into a polyethylene container while the lower level sample was obtained using a Kahlsisco Model 135 water sampler. Containers were rinsed at least three times with sample water before filling. The samples were filtered through a preweighed Whatman GF/C 1.5 um glass fibre filter in the field. The filters were folded, then sealed in tin foil, placed on dry ice, and transported to the Environmental Protection Service laboratory in Whitehorse for analysis.

3.2 Sediment

The sediment sample collection and analysis methods are summarized in Appendix I, Table 2.

Three sediment samples were collected at each station using an Ekman dredge. Sediment samples were placed into geochemical sample bags and then inside plastic Whirlpack™ bags. Samples were immediately frozen on dry ice and maintained at a cool temperature throughout transportation.

Sediment samples were analyzed for particle size, extractable oils and grease, and extractable metals at the Environmental Protection Service Laboratory in West Vancouver.

3.3 Bottom Fauna

Bottom fauna samples were collected using an Ekman dredge ($0.023m^2$). Five replicate grabs ($0.115m^2$ sample area) were collected at each station. Samples were sieved using a Wildco wash bucket with a mesh opening size of 0.500 mm.

Bottom fauna samples were initially preserved in a 10% formalin solution and later transferred into a 70% methanol solution after debris segregation. Samples were identified and enumerated by Dr. Charles J. Low, a consulting invertebrate biologist, in Nanaimo,

British Columbia. Dr. Low conferred with Ed Bousfield of the National Museums of Canada in Ottawa, Ontario for identification of several amphipods.

To numerically compare the invertebrate data, diversity indices were calculated using the following formula as described by Pielou (1975):

$$\text{Species Diversity } (H') = -\sum_{i=1}^{g} (P_i \log_{10} P_i)$$

where $P_i = n_i/N$

n_i = total number of individuals in the ith genus in one sample

N = total number of individuals identified to genus and/or species taxonomic level in one sample

g = total number of genera in one sample

To evaluate the similarity of two sampling stations, the following index as described by Brock (1977) was used:

$$\text{Percent similiarity (Psc)} = 100 - 0.5 \sum_{i=1}^{k} |a_i - b_i|$$

where a_i and b_i are, for a given species, percentages of the total samples A and B which that species represents. The absolute value of their difference is summed over all species, k.

4 RESULTS AND DISCUSSION

4.1 Water Quality

The water chemistry data collected at Stokes Point are presented in Appendix II, Table 1.

4.1.1 Nearshore Marine. Due to fluctuating weather conditions, the water chemistry data was collected over a 3 day period and the results reflect the changing environmental conditions experienced during that time period.

Stations 6, 5, and 4 were sampled successively over an eleven hour period on August 2, 1983. Station 6 was sampled at 1015 hours and showed a structured water column in the sense that a wide gradient in water temperature was present. Stations 5 and 4 which were sampled at 1935 and 2040 hours respectively, indicated a trend of decreased surface temperature and increased near bottom temperature with a general increase in salinity and conductivity levels throughout the water column. This change coincided with the noticeable presence of a strong southeasterly, longshore current which was suspected to be responsible for the breakdown of stratification and perhaps the trend of increasing salinity.

The remaining nearshore marine stations could not be sampled until August 4, 1983, due to adverse sea conditions. The first station to be sampled after the storm, Station 3, indicated a thoroughly mixed water column with only marginal differences in surface and near bottom temperature with slightly higher salinity and conductivity values recorded in the surface water. Station 8 showed slightly different conditions with an increased temperature gradient and marginally higher salinity and conductivity values.

Dissolved oxygen levels were high with all samples being greater than 85% saturation. The high saturation level observed for the near bottom sample at Station 6 is not unreasonable when considering the very low water temperature present at the time of sampling.

The non-filterable residue readings varied between 1.3 to 20.4 mg/l. No trends in the data were noticeable. The low non-filterable residue readings suggest that the Mackenzie River plume was not present in the area.

In summary, the water chemistry data reflects the widely fluctuating environmental conditions experienced by the nearshore marine zone at Stokes Point. The salinity values, which fluctuated widely from 14.8 to 31.0^{o}/oo, were considerably lower than those observed in August, 1982 by Allan and Mackenzie-Grieve (1983) which ranged from 29.0 and 35.3^{o}/oo. Clearly the nearshore marine zone at Stokes Point is subjected to wide variations in water chemistry parameters. This will strongly influence the distribution, abundance, and diversity of bottom fauna organisms.

4.1.2 Lagoons. Water chemistry data at Stations 1 and 2 were consistent in detecting a halocline in the water column. Salinity values at Station 1 range from 12.9^{o}/oo at the surface to >40°/oo at the near bottom level. Conductivity readings varied from 14,100 to 43,200 umhos/cm at the surface and near bottom levels respectively. By moving the conductivity meter probe vertically, the very saline component was noted to be 1.0 m above bottom. The presence of a halocline in the Stokes Point lagoon was also reported in the summer of 1975 by Kendel et al (1975). Allan and Mackenzie-Grieve (1983), observed a well mixed water column with salinity values ranging from 19.0 to 21.6^{o}/oo in August, 1982.

Water temperatures in the lagoons were higher than the adjacent nearshore marine region. This is consistent with data collected in August, 1982 by Allan and Mackenzie-Grieve (1983).

Both stations showed a small temperature difference between surface and near bottom levels. Non-filterable residue levels were less than 10 mg/l and showed higher values in the near bottom samples. Dissolved oxygen levels were greater than 80% saturation in all samples.

4.2 Sediment

Three sediment samples were collected at each station. The results of the particle sizing are shown in Appendix III, Table 1. The less than 0.15 mm size fraction was analysed for extractable metals and oils and grease. This data is presented in Appendix III, Table 2.

4.2.1 Nearshore Marine. The results of the particle sizing (Appendix III, Table 1) show good correlation among subsamples representing a station. The sediment samples at Station 5 and 6 indicated a very fine sand substrate. Station 4 was a very fine to fine sand while Station 3 was a mixture of fine to medium sand. All stations except Station 8 showed a low percentage of silt and gravel sized particles. The low representation of gravel is partially due to the limitations of the Ekman dredge. Sediment samples which encountered a gravel lens were frequently lost because the jaws of the Ekman dredge would not close properly. This occurred approximately four times throughout the sampling.

The mean percent composition of particle size fractions less than 0.15 mm ranged from 13.7% at Station 3 to 87.5% at Station 5.

The oils and grease concentrations, as determined through the petroleum ether extraction analysis, are presented in Appendix III, Table 2. This analytical procedure has been modified to reflect a consistent minimum detection limit of 300 mg/kg which is considerably higher than the detection limits reported in Allan and Mackenzie-Grieve (1983).

The results for Stations 3 to 6 inclusive, ranged from <300 to 500 mg/kg. This fits within the range of <56 to 563 mg/kg reported in Allan and Mackenzie-Grieve (1983), but the mean values of the present study could be slightly higher since only two samples exceeded 300 mg/kg in the cited study. However, this cannot be properly evaluated due to the differing detection limits in the two studies. The results for Station 8 varied widely in the three replicates done with values of <300, 700, and 1100 mg/kg. The wide discrepancy amongst replicates makes it difficult to draw any firm conclusions.

The results of sediment extractable metal analysis are shown in Appendix III, Table 2. In addition, the mean concentrations of eleven selected extractable metals are compared with data from Allan and Mackenzie-Grieve (1983) in Table 1. The results for arsenic, cadmium, chromium, copper, iron, manganese, nickel, lead, and zinc were similar. The levels of silver could not be satisfactorily compared due to the differing detection limits in the two studies. There was a considerable difference noted in the concentrations of mercury. The 1983 report identified 0.24 mg/kg of mercury compared to 0.04 mg/kg in the current study. Reasons for this difference are unknown, however, the current data more closely aligns with data presented in Dome, Esso, and Gulf (1982) which showed mean concentrations of mercury up to 0.1 mg/kg in whole sediment samples.

4.2.2 Lagoons. The substrate at the two lagoons was noted in the field to be a silt-clay texture. However, the laboratory experienced difficulty in sieving the sediment samples, and therefore, the particle size results do not accurately reflect the nature of the substrate. The high proportion of gravel sized particles is due to clumping and the presence of woody debris in the substrate.

The results for oils and grease analysis (Appendix III Table 2) were similar to those reported in Allan and Mackenzie-Grieve (1983). Station 1 had a mean oils and grease content of 4300 mg/kg (range 3600 to 5200) compared to a mean value of 1890 mg/kg (range 1190 to 2340 mg/kg) in the cited study. Station 2 had a mean concentration of 600 mg/kg (range 300 to 800 mg/kg) compared to 425 mg/kg (range 421 to 430 mg/kg) reported in the cited study. Because of the unknown source of these high levels of oils and grease, the lagoon samples were also analysed for hydrocarbons by gas chromatography. The results of this test showed that there were no hydrocarbons present and that the high oils and grease results were suspected to be sulphur due to the particular melting point and the crystal formation of the residue upon evaporation of the solvent (D. Tupper, pers. comm.).

TABLE 1 MEAN CONCENTRATIONS OF SELECTED EXTRACTABLE METALS IN SEDIMENT SAMPLES COLLECTED FROM STOKES POINT

SAMPLE YEAR	NO. OF SAMPLES	EXTRACTABLE METALS (mg/kg)										
		Ag	As	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
1982 Nearshore Marine[1]	12	<5	10.2	<0.3	19.3	9.4	20200	0.24	327	18	7.3	63.1
1983 Nearshore Marine	15	<.016	9.9	<0.3	17.1	7.7	20100	0.04	304	18	5	58.2
1982 Lagoon[1]	6	<5	14.7	<0.3	34.0	29.0	30900	0.32	377	30	12	114
1983 Lagoon	6	.11	13.4	0.3	36.6	34.3	32300	0.13	370	36	15	131

1. Data extracted from Allan and Mackenzie-Grieve, 1983.

The extractable metal concentrations in sediment samples from the lagoon compare closely to the results in Allan and Mackenzie-Grieve (1983) for all selected elements except silver and mercury (Table 1). This relationship was also observed with the nearshore marine samples and discussed in that section of the report. The sediment samples from the lagoon had slightly higher concentrations of extractable metals compared to the nearshore marine samples. The most notable difference between the lagoon and nearshore marine sediments was in the concentrations of silver. Silver concentrations were an order of magnitude greater in the lagoon sediment samples.

4.3 Bottom Fauna

A taxonomic list outlining the organisms collected is presented in Appendix IV, Table 1. Organisms in which identification is uncertain are shown in parentheses. The results of the bottom fauna survey are provided in Appendix IV, Table 2.

Five grab samples (0.115 m^2 sample area) were collected at each of the seven stations. Grab samples were combined to represent each station rather than keeping each grab sample separate.

4.3.1 Nearshore Marine. Thirty-four species were identified in the nearshore marine samples. The most abundant groups, as represented by number of individuals collected, were polychaete worms (60%), copepods (15%), amphipods (9%), molluscs (5%), and cumaceans (5%). This is a considerably different benthic community than sampled in August, 1982 (Allan and Mackenzie-Grieve, 1983) which found molluscs and polychaetes representing 54% and 36%, respectively. Other studies, such as Kendel et al (1975) and Broad et al (1979) also found a much higher proportion of molluscs in their nearshore marine samples.

Fourteen species of polychaete worms were identified. Previous information from the same area (Allan and Mackenzie-Grieve, 1983), indicated only six species of polychaetes in the Stokes Point nearshore marine samples. Species most frequently represented were,

Scoloplos sp., Scololepis foliosa, Chaetozone setosa, and Samytha californiensis. Species not previously recognized in other Beaufort Sea literature (Carey, 1976; Kendel et al, 1975; Wacasey, 1975), were the polychaete worms, Protoarciella oligobranchia, Aonides sp., and Oriopsis gracilis; and the amphipods, Monoculopsis (micros) sp., Mecocheirus sp. and Pontoporeia monospinosa. Dr. Low (1983 pers. comm.) mentioned that the Aonides sp. may actually be an undescribed species as it did not key in any North American, Russian, and Arctic references. The three amphipods were identified by Mr. E.L. Bousfield (1983 pers. comm.) to be new species (n. sp.) and have been added into the National Collection of Crustacea at the National Museum of Canada, Ottawa.

The copepod, Limnocalanus macrurus, is a freshwater species, but was present at all nearshore marine stations. Its presence was also recognized by Allan and Mackenzie-Grieve (1983) in samples from the lagoons at Stokes Point and King Point. The only reasonable explanation for its occurrence in the present study would be immigration from regional freshwater sources.

The average number of species per station was 16 with a range from 13 to 20 species per station (Table 2). Previous sampling (Allan and Mackenzie-Grieve, 1983), found 14 species per station in the Stokes Point nearshore zone. The mean Shannon-Weaver diversity index was 0.86 (range 0.74 to 0.99) compared to 0.90 (range 0.83 to 1.04) found in the previous year's sampling. The population density ranged from 610 to 1900 individuals per meter squared with a mean value of $1240/m^2$. This is higher than density values observed in the 1982 data which had a mean of $880/m^2$ (range 380 to $1300/m^2$). Other studies, such as Kendel et al (1975) also found lower densities ($439/m^2$ at 12.5 m depth).

The benthic community, as represented in the current sampling, shows similar diversity in terms of species per station and diversity index, but higher densities compared to the previous year's study even though sampling times were similar in each year. The community structure has changed from primarily pelecypods and polychaetes (Allan and Mackenzie-Grieve, 1983) to a more diverse

TABLE 2 COMPARISON OF THE BOTTOM FAUNA DATA COLLECTED AT STOKES POINT

YEAR-STATION[1]	NO. OF SPECIES PRESENT	DIVERSITY (H')	DENSITY (no./m^2)
83-1	5	0.25	3500
82-1	7	0.38	4200
83-2	9	0.44	6300
82-2	9	0.41	4000
83-3	13	0.74	610
82-3	--	----	----
83-4	16	0.87	1000
82-4	--	----	----
83-5	16	0.78	1900
82-5	13	0.83	1300
83-6	20	0.99	1700
82-6	17	0.83	950
83-8	13	0.92	970
82-8	13	1.04	380

[1] 1982 data was extracted from Allan and Mackenzie-Grieve (1983)

community, but with a predominance of polychaetes. These changes reflect the fluctuating environmental conditions in the nearshore marine habitats and the relative ability of these organisms to tolerate these changes or recolinize the area as conditions become more favourable.

4.3.2 Lagoons. Nine species of bottom fauna were identified in the lagoon samples. Polychaete worms were the most abundant groups in terms of both total number of individuals collected (96%) and total number of species represented (6). The remaining organisms collected included members of the priapulid, pelecypod, and amphipod groups.

The species most abundantly represented were the polychaetes, *Nephtys cornuta* and *Polydora socialis*. In the previous sampling program (Allan and Mackenzie-Grieve, 1983), *Nephtys brachycephala* was the most abundant organism. Because of the conspicuous presence of the two species of *Nephtys*, we asked Dr. Low to reconfirm the identification. Dr. Low found that indeed they were the same organism (*N. cornuta*) and the incorrect identification occured on the 1982 samples because the taxonomic feature, bifurcate posterior antennae, had been damaged in most specimens.

All organisms collected, except *Peisidice aspera*, have been recognized in other Beaufort Sea literature (Carey, 1976; Kendel et al, 1975; Wacasey, 1975). Only one individual of *P. aspera* was collected.

The average number of species per station was seven compared to eight found in the previous year (Table 2). Diversity index values were 0.25 at station 1 and 0.44 at Station 2. This compares to 0.38 and 0.41 at Stations 1 and 2, respectively, from the 1982 data. Population densities varied from 3500 to 6300 individuals per meter squared at Stations 1 and 2 respectively. The previous year's study reported densities of $4200/m^2$ at Station 1 and $4000/m^2$ at Station 2.

The bottom fauna data appear to be quite similar to the results reported by Allan and Mackenzie-Grieve (1983). The data from the two studies was compared using an index of similarity (Table 3).

The bottom fauna community at Station 1 was 61% similar to the previous year and Station 2 was 40% similar.

Table 3 PERCENT SIMILARITY OF THE BOTTOM FAUNA COMMUNITY IN THE LAGOON AT STOKES POINT

Sample Year Station	1983 1	1983 2	1982 1	1982 2
1983 Sta. 1	X	49.49	60.91	39.56
1983 Sta. 2	X	X	49.45	39.56
1982 Sta. 1	X	X	X	42.84
1982 Sta. 1	X	X	X	X

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APPENDICES

APPENDIX I

COLLECTION, PREPERATION, ANALYSIS METHODS OF WATER AND SEDIMENT SAMPLES

APPENDIX I TABLE 1 WATER SAMPLE COLLECTION, PREPARATION AND ANALYSIS METHODS

PARAMETER	DETECTION LIMIT	COLLECTION AND PREPARATION PROCEDURE[1]	ANALYTICAL PROCEDURE	METHOD SECTION[2]
Depth		*In situ* using a graduated handline.		
Temperature	±.1°C	*In situ* measurement by lowering the receptor to the station depth.	YSI Model 33 Conductivity Meter	
Conductivity	0.2 umhos/cm	*In situ* measurement.	YSI Model 33 Conductivity Meter	
Salinity	1.0°/oo	*In situ* measurement.	YSI Model 33 Conductivity Meter	
Dissolved Oxygen	1.0 mg/l	In situ measurement. The instrument was calibrated in the field following the air calibration procedures. Measurements were compensated for salinity before recording.	YSI Model 57 Dissolved Oxygen Meter	
Non-Filterable Residue (NFR)	1.0 mg/l	In the field, a 1 litre water sample was filtered through a pre-weighed glass fibre filter with a 1.5 um pore size. The filter and residue was returned to the Lab for drying and weighing.	Filtration, drying and weighing of residue on filter	104

1 As described in Environment Canada (1976).
2 As described in Department of Environment (1979).

APPENDIX I TABLE 2 SEDIMENT COLLECTION, PREPARATION AND ANALYSIS METHODS

PARAMETER	COLLECTION/PREPARATION	ANALYSIS	METHOD CODE[1]
All Parameters	Samples were collected and placed in geochemical sampling bags within Whirlpack™ bags. Samples were frozen and kept cool through transportation. No preservatives were required.		
Extractable Metals Al, As, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, Mg, Mn, Mo, Na, Ni, P, Pb, Si, Sn, Sr, Ti, V, Zn	A sediment sample was dried in a low temperature oven then screened through a 100 mesh (0.15 mm) sieve. The material passing through the sieve was then leached with HCl and HNO_3.	Inductively Coupled Argon Plasma (ICAP) combined with Optical Emission Sepctrometer (OES)	320
Ag	Same sample as metals.	Graphite Furnace Atomic Absorption Spectrophotometry	330
K	Same sample as metals.	Flame Atomic Absorption Spectrophotometry	340
As	Same sample as metals.	Hydride Generation - ICAP	350
Hg	The sample was seived as described for metals and was completely oxidized by digestion with sulfuric acid peroxide.	Mercury Monitory	370

APPENDIX I TABLE 2 SEDIMENT COLLECTION, PREPARATION AND ANALYSIS METHODS (continued)

PARAMETER	COLLECTION/PREPARATION	ANALYSIS	METHOD CODE[1]
Particle Sizing	A dry, pre-weighed sample was passed through seives of the following mesh size: 2.0 mm, 1.0 mm, .5 mm, .25 mm .15 mm, and .063 mm.	Dry sieve	078
Oils and grease	A sample of air dried sediment was placed in the Soxhlet apparatus with petroleum ether solvent. The solvent dissolves the oils and grease which is then evaporated and the residue weighed.	Petroleum Ether Soxhlet Extraction	725
Hydrocarbons	The sediment sample is dissolved in cyclo-hexane and the solution is analysed using the gas chromatograph and compared to the spectrum from known petroleum products.	Gas Chromatographic	700

[1] As described in Department of Environment (1979).

APPENDIX II

WATER CHEMISTRY DATA

APPENDIX II TABLE 1 WATER CHEMISTRY DATA COLLECTED AT STOKES POINT, AUGUST 2 and 4, 1983.

STOKES POINT STATION	DESCRIPTION	DATE	LOCAL TIME	SAMPLE DEPTH (m)	TEMPERA-TURE (°C)	OXYGEN (mg/l)	O_2 SATURATION (%)	CONDUCTIVITY (100umhos/cm)	SALINITY (°/oo)	NON-FILTER-ABLE RESIDUE (mg/l)
1	lagoon	83-08-04	1200	0	11.0	9.8	89	131	12.9	3.8
				2.5	10.6	9.1	82	432	>40.0	5.8
2	lagoon	83-08-04	1050	0	11.0	9.6	87	141	14.0	1.9
				3.0	10.0	12.6	112	349	37.0	7.0
3	sea	83-08-04	0745	0	9.0	9.9	86	188	16.0	12.7
				4.5	8.8	11.3	97	147	14.8	3.2
4	sea	83-08-02	2040	0	6.9	10.4	86	211	22.5	1.3
				4.5	3.0	12.6	94	255	31.0	5.7
5	sea	83-08-02	1935	0	7.0	10.8	89	208	22.5	5.7
				4.5	2.8	13.8	102	251	27.1	20.4
6	sea	83-08-02	1015	0	8.0	11.8	100	188	19.6	10.6
				4.5	1.9	17.2	124	242	26.0	18.1
8	sea	83-08-04	0900	0	9.0	10.4	90	160	16.0	9.3
				4.5	6.5	11.0	90	207	20.8	6.6

APPENDIX III

SEDIMENT DATA

APPENDIX III TABLE 1 PERCENT COMPOSITION OF PARTICLE SIZE FRACTIONS IN THE SEDIMENT SAMPLES COLLECTED AT STOKES POINT, AUGUST 2 and 4, 1983.

SAMPLE NUMBER	PARTICLE SIZE					
	<.063 mm	.063-.15 mm	.15-.25 mm	.25-.5 mm	.5-1.0 mm	>1.0 mm
	SILT	V. FINE SAND	FINE SAND	MEDIUM SAND	COARSE SAND	GRAVEL
1-1*	23.0	10.3	5.1	9.7	11.2	40.7
1-2*	18.0	8.1	4.7	7.9	9.8	51.5
1-3*	20.9	12.8	5.5	10.5	12.5	37.8
2-1*	18.8	10.3	7.0	11.4	13.1	39.4
2-2*	9.6	23.7	6.8	11.8	13.3	34.8
2-3*	12.8	7.4	5.4	9.2	11.4	53.8
3-1	0.3	14.4	20.9	53.2	9.9	1.3
3-2	0.2	13.2	23.0	51.7	11.0	0.9
3-3	0.1	13.0	19.4	53.5	12.7	1.3
4-1	1.2	61.9	35.6	0.7	0.3	0.3
4-2	0.9	60.9	37.0	0.9	0.2	0.1
4-3	1.0	54.8	43.2	0.7	0.2	0.1
5-1	8.2	85.2	3.6	1.2	0.6	1.2
5-2	10.9	77.1	4.7	3.1	1.2	3.0
5-3	8.7	72.4	4.2	3.3	3.3	8.1
6-1	8.3	71.2	14.8	4.5	0.6	0.6
6-2	5.3	74.2	13.8	5.2	0.7	0.8
6-3	9.1	73.2	13.5	3.3	0.4	0.5
8-1	4.9	57.2	10.1	6.3	3.1	18.4
8-2	10.0	33.3	8.2	6.2	4.9	37.4
8-3	4.4	28.8	5.4	3.6	4.2	53.6

* These samples would not separate properly for particle sizing and also contained large amounts of organic debris.

APPENDIX III TABLE 2 CONCENTRATIONS OF OILS AND GREASE AND EXTRACTABLE METALS IN THE SEDIMENT SAMPLES COLLECTED AT STOKES POINT, AUGUST 2 AND 4, 1983.

SAMPLE NUMBER	Oils & Grease (mg/kg)	EXTRACTABLE METALS (mg/kg)												
		Ag	Al	As	Ba	Be	Ca	Cd	Co	Cr	Cu	Fe	Hg	K
1-1	5200	.11	19800	14	191	.7	14200	<.3	9.9	34.1	30.5	29900	.12	4660
1-2	3600	.1	18700	13.2	186	.7	14100	.5	13.7	32.3	29.3	25900	.12	4460
1-3	4100	.079	20700	13	198	.8	11400	.3	12.2	35.6	31.5	29300	.12	4970
2-1	600	.14	22100	9	204	.9	13600	<.3	13	37.5	37.8	36000	.13	5260
2-2	800	.13	22600	18	207	.9	13600	<.3	13.6	38.9	38.3	36000	.14	5300
2-3	300	.11	25100	13	226	.9	13200	<.3	9.7	41.2	38.2	36400	.14	5850
3-1	<300	<.016	8430	9.7	133*	.2	38600	<.3	7.4*	15.5	5.2	18400	.05	2120*
3-2	<300	<.016	8510	10.7	133	.2	39400	<.3	2.8	16.3	14.9	19300	.03	2080
3-3	<300	<.016	7890	8*	123*	.3	38800	<.3	7	15.1	5.3	18900	.03	1900*
4-1	<300	<.016	7970	10	287	.2	35900	<.3	10.7	17.1	6.9	24200	.03	1800
4-2	<300	<.016	8550	12	435	.2	37600	<.3	8.5	19.5	6.8	27400	.05*	1910
4-3	300	<.016	8910	15	378	.3	38000	<.3	12.3	20.7	7.5	27400	.04	2050
5-1	<300	<.016	8880	9.1	128	.3	41800	<.3	7.2*	15.9	5.9	17200	.03	2280
5-2	<300	<.016	8350	9	112	.2	40500	<.3	6.2	15	5.9	16700	.03	2070
5-3	500	<.016	8780	9.1	117	.3	41200	<.3	3.5*	15.8	6.9	17700	.04*	2190
6-1	<300	<.016	9380	10	149	.3	41900	<.3	5.6	16.6	7	17400	.03	2420
6-2	400	<.016	9140	8	148	.3	42400	<.3	7	16.7	6.7	17600	.03	2390
6-3	500	<.016	9340	9.4	160	.2	44000	<.3	6.5	17	7.1	17900	.03	2340
8-1	<300	<.016	8290	8	251	.2	43900	<.3	4.6*	16.6	7.1*	19600	.03	1940*
8-2	700	<.016	9630	8	249	.3	41700	<.3	5.1	18.7	11.5	21200	.05	2340
8-3	1100	<.016	10300	11.8	252	.3*	40400	.7*	6.3*	19.4	10.9	20900	.05	2490*

* This is the mean value of 2 replicates inwhich the range exceeded ± 10% of the mean.

APPENDIX III TABLE 2 CONCENTRATIONS OF OILS AND GREASE AND EXTRACTABLE METALS IN THE SEDIMENT SAMPLES COLLECTED AT STOKES POINT, AUGUST 2 AND 4, 1983. (continued)

SAMPLE NUMBER	Extractable Metals (mg/kg)												
	Mg	Mn	Mo	Na	Ni	P	Pb	Si	Sn	Sr	Ti	V	Zn
1-1	9730	337	2.9	7470	34	1080	14	5020	<2	72.4	126	61	122
1-2	8930	285	2.5	5450	35	1020	14	5560	<2	65.3	132	58	116
1-3	9570	300	2.7	7670	35	1070	12*	5830	<2	63.1	131	64	128
2-1	9760	425	2.0	4880	37	1080	15	6020	<2	68.0	131	69	140
2-2	9850	414	1.7*	5650	37	1070	17	6050	2*	69.8	131	70	139
2-3	10200	438	2.9	5900	35	1090	15	6120	<2	71.2	153	78	141
3-1	6060	261	<.8	580	16	1070	3*	4160	<2	106	173	28	52.4
3-2	6340	257	<.8	490	20	1140	3	4370	<2	108	187	28	54.5
3-3	6290	280	<.8	590	18	1140	6	3800	<2	105	172	26	53.8
4-1	6930	294	<.8	730	20	1490	5	4180	<2	98.3	255	33	66.3
4-2	7470	365	<.8	850	20	1660	7	4080	<2	106	339	42	71.3
4-3	7540	363	<.8	760	23	1770	9	4540	<2	107	350	41	71.5
5-1	6950	293	<.8	1160	18 *	995	4*	3970*	<2	111	157	26	51.7
5-2	6680	290	<.8	880	17	940	4	3760	<2	106	141	25	50.7
5-3	6840	295	<.8	940	16	977	4	4200	<2	111	133	28	54.5
6-1	6910	285	<.8	850	17	1010	6	4680	<2	111	173	28	52.7
6-2	7100	281	<.8	1070	18	1020	5	4480	<2	113	168	28	54.0
6-3	7360	314	<.8	890	17	1080	5	4520	<2	119	179	29	55.0
8-1	7340	303	<.8	730	16	1190	6*	3800*	<2	115	187	30	56.0
8-2	8000	342	<.8	1190	17	1220	6	4580	<2	111	190	35	64.5
8-3	7880	337	<.8	1320	20 *	1190	6*	4950	<2	111	178	35	64.1

* This is the mean value of 2 replicates inwhich the range exceeded ± 10% of the mean.

APPENDIX IV

BOTTOM FAUNA DATA

APPENDIX IV TABLE 1 A TAXONOMIC LIST OF THE BENTHIC ORGANISMS COLLECTED AT STOKES POINT, AUGUST 2 AND 4, 1983 (the numbers correspond to the organism referenced in Appendix IV, Table 2)

	Phylum / Class / Order / Family / Genus species
	Protozoa
	Rhizopodea
	Foraminifera
	Nonionidae
1.	*Elphidiella* sp.
	Rhynchocoela
	Anopla
2.	Heteronemertea
	Aschelminthes
3.	Nematoda
	Priapulida
	Priapulidae
4.	*Priapulus* sp.
5.	Bryozoa
	Mollusca
	Pelecypoda
	Protobranchia
	Nuculanidae
6.	*Portlandia arctica*
	Heterodontida
	Montacutidae
7.	*Montacuta dawsoni*
	Tellinidae
8.	*Macoma balthica*
	Annelida
	Polychaeta
	Subclass: Errantia

APPENDIX IV TABLE 1 A TAXONOMIC LIST OF THE BENTHIC ORGANISMS COLLECTED AT STOKES POINT, AUGUST 2 AND 4, 1983 (the numbers correspond to the organism referenced in Appendix IV, Table 2) (continued)

		Phyllodocida	
		Phyllodocidae	
9.			*Eteone longa*
		Nephtydidae	
10.			*Nephtys cornuta*
		Sphaerodoropsis	
11.			*Sphaerodoropsis minuta*
		Polyodontidae	
12.			*Peisidice aspera*
	Subclass:	Sedentaria	
		Ariciida	
		Orbiniidae	
13.			*Scoloplos* sp.
14.			*Protoarciella oligobranchia*
		Spionida	
		Spionidae	
15.			*Aonides* sp.
16.			*Pygospio elegans*
17.			*Scololepis foliosa*
18.			*Prionospio cirrifera*
		Polydoridae	
19.			*Polydora socialis*
		Cirratulida	
20.		Cirratulidae	
21.			*Chaetozone setosa*
		Terebellida	
		Terebellidae	
22.			*Terebellides stroemi*
		Ampharetidae	
23.			*Lysipe* sp.
24.			*Samytha californiensis*
		Capitellida	

APPENDIX IV TABLE 1 A TAXONOMIC LIST OF THE BENTHIC ORGANISMS COLLECTED AT STOKES POINT, AUGUST 2 AND 4, 1983 (the numbers correspond to the organism referenced in Appendix IV, Table 2) (continued)

	Capitellidae
25.	*Capitella* sp.
	Opheliidae
26.	*Travisea* sp. (*carnea* or *forbesii*)
	Sabellida
	Sabillidae
27.	*Oriopsis gracilis*
	Oligochaeta
	Haplotaxida
28.	Tubificidae
	Arthropoda
	Crustacea
	Subclass: Copepoda
	Eucopepoda
	Suborder: Callanoida
	Calanidae
29.	*Calanus* sp.
	Centropagidae
30.	*Limnocalanus macrurus*
	Subclass: Malacostraca
	Mysidacea
	Mysidae
31.	*Mysis* sp. (*occulata* or *mixta*)
	Cumacea
	Diastylidae
32.	*Diastylis* sp.
33.	*Leptostylis* sp.
	Tanaidacea
	Paratanaidae
34.	*Leptognatha gracilis*
	Isopoda
	Idoteidae
35.	*Saduria entomon*

APPENDIX IV TABLE 1 A TAXONOMIC LIST OF THE BENTHIC ORGANISMS COLLECTED AT STOKES POINT, AUGUST 2 AND 4, 1983 (the numbers correspond to the organism referenced in Appendix IV, Table 2) (continued)

		Amphipoda	
36.	Suborder:	Gammaridea	
		Lysianassidae	
37.			*Onismimus glacialis**
		Haustoriidae	
38.			*Pontoporeia monospinosa* n.sp.*
		Oedicerotidae	
39.			*Paroediceros lynceus**
40.			*Monoculopsis (micros)* n.sp.*
41.			*Mecocheirus* sp., n.sp.*
	Chordata		
42.	Ascidiacea		

* Taxonomic identification by E. Bousfield, National Museums of Canada, Ottawa.

APPENDIX IV TABLE 2 BOTTOM FAUNA COLLECTED AT STOKES POINT, AUGUST 2 AND 4, 1983.

STOKES POINT ORGANISM	STATION 1	2	3	4	5	6	8
1. *Elphidiella* sp.					1		
2. Heteronemertea			2	4		1	
3. Nematoda					2	1	
4. *Priapulus* sp.	23	3		3		1	
5. Bryozoa					1		
6. *Portlandia arctica*					5		1
7. *Montacuta dawsoni*			32				
8. *Macoma balthica*	3	1					
9. *Eteone longa*			1		1	10	1
10. *Nephtys cornuta*	339	352					
11. *Sphaerodoropsis minuta*						1	
12. *Peisidice aspera*		1					
13. *Scoloplos* sp.					14	40	
14. *Protoarciella oligobranchia*						1	
15. *Aonides* sp.	34		2	2		1	
16. *Pygospio elegans*		18				20	
17 *Scololepis foliosa*			10	4	2	37	5
18. *Prionospio cirrifera*				4	4	7	2
19. *Polydora socialis*		316					
20. Cirratulidae		4	3	5	38	21	20
21. *Chaetozone setosa*			2	4	60	5	
22. *Terebellides stroemi*		17					
23. *Lysipe* sp.			1	1	1	4	10
24. *Samytha californiensis*			2	32	11	14	14
25. *Capitella* sp.						5	1
26. *Travisea* sp.			1	1			
27. *Oriopsis gracilis*				4			

APPENDIX IV TABLE 2 BOTTOM FAUNA COLLECTED AT STOKES POINT, AUGUST 2 AND 4, 1983. (continued)

STOKES POINT ORGANISM	STATION 1	2	3	4	5	6	8
28. Tubificidae				1			
29. *Calanus* sp.				3		2	
30. *Limnocalanus macrurus*			1	26	51	7	15
31. *Mysis* sp.			8	5	2	1	
32. *Diastylis* sp.						1	19
33. *Leptostylis* sp.					3		13
34. *Leptognatha gracilis*			4				
35. *Saduria entomon*							2
38. Gammaridea				1			
37. *Onismimus glacialis*	1	15					
38. 39. 40. 41. Amphipods*			1	16	19	19	8
42. Ascidiacea				1	1		
Total Organisms (T)	400	727	70	117	216	199	111
Total at general level (N)	400	723	65	105	174	176	91
Diversity Index (H')	0.25	0.44	0.74	0.87	0.78	0.99	0.92

* These amphipods were identified to genus level by Ed Bousfield (Nat. Museums of Canada, Ottawa), but could not be separated for purposes of Diversity Index calculations.