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BASELINE CHARACTERISTICS OF COME BY CHANCE BAY NEWFOUNDLAND

Surveillance Report EPS-5-AR-76-9
Atlantic Region

BASELINE CHARACTERISTICS OF COME BY CHANCE BAY, NEWFOUNDLAND

by

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ENVIRONMENTAL PROTECTION SERVICE
St. John's, Newfoundland

SURVEILLANCE REPORT

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ABSTRACT

Benthic macroinvertebrate and water quality surveys were conducted in Come By Chance Bay, Newfoundland, to assess the pre-operational or baseline conditions before development of a 100,000 bbl/day petroleum refinery. Values were established for various water quality parameters including compounds specifically indicative of contamination by refinery effluent. Benthic macroinvertebrate community structure and delineation were analyzed through use of a number of species diversity indices and cluster analyses techniques.

Based on the above analyses, pre-operational conditions in the Bay were established. Water quality data indicated that the Bay was in a relatively pristine state (data to December, 1973). Also established were: values for species diversity, community delineation, and community structure. These data should provide useful baselines for evaluation of future post-operational conditions.

Résumé

Des études de macro-invertébrés du fond et de la qualité des eaux ont été conduites dans la baie Come-by-Chance en Terre-Neuve. Ces études ont au pour but l'évaluation des conditions biologiques et chimiques qui existaient avant la construction d'une raffinerie de pétrole utilisant 100,000 barils par jour. Des valeurs ont éte établies pour des paramètres variés sur la qualité des eaux, en particulier, des composés chimiques qui sont indicatifs de la contamination petrolière. La structure et la description des communautés macro-invertébrés du fond ont été analysés avec l'aide des indices de la diversité des espéces et des techniques d'analyse "cluster".

Les conditions ecologiques existant avant la construction de la raffinerie on été basées sur ces données. Les données sur la qualité des eaux indiquaient que la baie était presque naturelle (jusqu'au mois des décembre, 1973). On a établi aussi, des valeurs pour la diversité espèces, la description des communautés et la structure de communautés ces données devraient simplifier la comparaison de conditions aprés la construction de la reffinerie de pétrole avec ceux qui existaient auparauant.

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SUMMARY

1. Analysis of water quality data indicates that until December 1973 (refinery start-up) the waters of Come By Chance Bay were in a pristine condition relatively unaffected by the activities of man.
2. Quantitative species diversity indices applied to benthic macroinvertebrate collections yielded values for all stations and depths sampled. Relationships were established between depth and diversity and between distance from refinery and diversity.
3. Cluster analysis of stations indicated that most stations displayed a high level of similarity (in terms of numbers and types of organisms). This data indicates that all stations sampled display a similar type of benthic community.
4. Cluster analysis of species indicated that both intertidal and benthic communities can be represented by approximately 20 "common" species. These "common" or "indicator" organisms occur most frequently in any sample and are usually found in close association with one another.

5. Future refinery induced changes should be detectable through spatial and/or temporal alteration of species diversities, community delineation, community structure and water quality parameters. Comparison of future sampling with values presented here should indicate any significant alteration in the environs of Come by Chance Bay.

1.0 INTRODUCTION

With the establishment of the Provincial Refining Company's 100,000 barrel per day refinery at Come by Chance Newfoundland, a variety of chemicals (Appendix I) were introduced, for the first time, into the waters of Come by Chance Bay. Although most of these components are toxic to aquatic organisms at relatively low concentrations (McKee and Wolf, 1963; Fletcher, 1971; Wells, 1972; Kuhnhold, 1972; Moore and Dwyer, 1974) it is hoped that the requirements of the Federal Petroleum Refinery Liquid Effluent Regulations and Guidelines[a], and the dilution provided by the waters of Placentia Bay will mitigate any acutely toxic effects to the biota of these waters.

The protection provided by these regulations may not, however, guard against sublethal effects induced in organisms exposed to low concentrations of these chemicals. Changes in such biological functions as growth, respiration, reproduction and behavior in addition to possible accumulation in food webs and disruption of habitat, could indirectly affect the productivity of Come by Chance and possibly Upper Placentia Bays. Other reports describing the effects of refinery effluent on aquatic communities have dealt primarily with fresh-water habitats (Ewing, 1964; Wilhm and Dorris, 1968; Gregory and Lock, 1973a, b; and Lock and Gregory, 1973) and relatively little work has been done to describe similar effects in

[a] These regulations and guidelines were promulgated on November 1, 1975. Under these regulations the refinery is classified as a "new" refinery and is still the only new refinery in Canada.

previously unaffected coastal marine ecosystems.

It was the purpose of this study, therefore, to determine the pre-operational or base-line conditions of both benthic and intertidal macro-invertebrate communities as well as the existing water quality of Come by Chance Bay. Evaluation of these parameters should provide a sound basis for determination of future post-operational effects induced by refinery operation. In addition, future comparison studies should provide insight into the effectiveness of existing regulations protecting the marine environment.

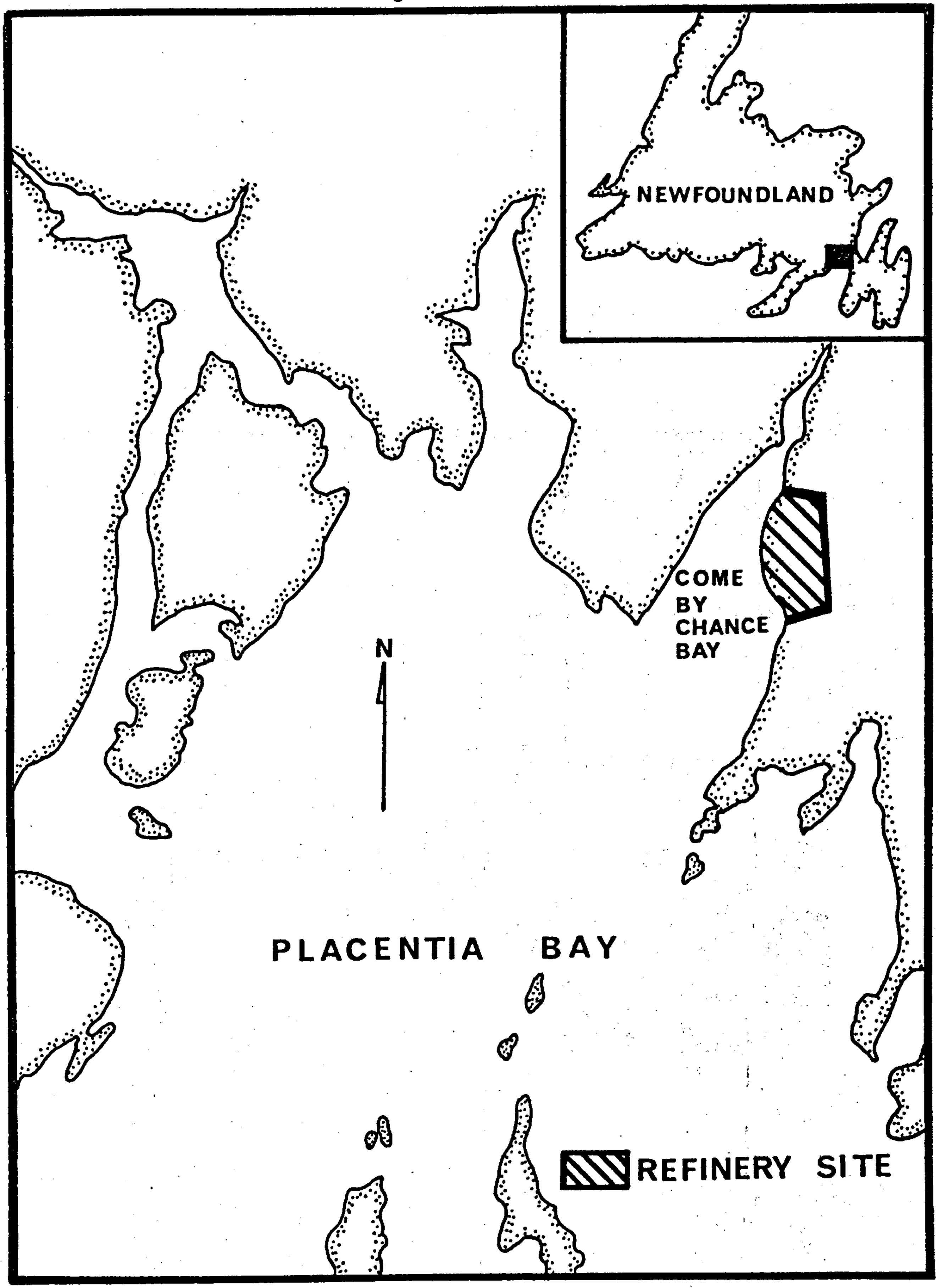


FIGURE 1 MAP OF UPPER PLACENTIA AND COME BY CHANCE BAYS

2.0 REFINERY OPERATION

2.1 Crude delivery and processing

The Provincial Refining Company, located on a 350 acre site on the eastern shore of Come by Chance Bay (Fig. 1), began production in December of 1973. This refinery has a total production capacity of 105,000 barrels per day (bbl/day) of crude and produces a wide range of products including: propane, isopentane, gasoline, jet fuel, kerosine, No. 4 oil, diesel oil, gas oil, and bunker C. Because yields vary widely with market requirements, however, it is not possible to quote specific percentages of these various products.

Crude oil is supplied to the refinery by very large crude carriers (VLCC) ranging in size from 216,000 to 276,000 dead-weight tons (DWT). These ships, capable of carrying up to 2,000,000 barrels of crude, arrive at the rate of 20 per year carrying Kuwaitan and Iranian oil loaded in the Persian Gulf. The trip to the refinery site takes approximately 30 days, and once on site, the crude is stored in six 600,000 barrel tanks to await processing.

Processing begins, after electrical desalting, in a 100,000 barrel per day atmospheric pipe still which takes gas and naptha overhead and sidestreams of kerosine and diesel (White, 1973). From this point, a variety of other units are employed to produce the final products. These include: (1) a vacuum distillation unit which separates light ends from the residual heavier gas oils; (2) an isomax unit which converts hydrocarbon distillates into gasoline or high quality middle distallates; (3) a hydrofiner unit which removes sulfur, nitrogen, and other contaminants from straight-run or cracked petroleum fractions; (4) a platforming unit which produces premium motor fuels, high yields of aromatic hydrocarbons, and aviation fuel; (5) a vis breaker unit which yields gas oil as well as some naptha; and (6) a merox unit which treats gasoline and lower boiling fractions for removal of mercaptans or sweetens heavier stocks by converting mercaptens to disulfides.

Final and intermediate products are stored on site in tanks providing up to 3.6 million barrels of storage capacity. 'Clean' products are shipped from the site in two 31,000 DWT 'product' tankers owned by the refinery. These deliver to markets in both Eastern Canada and the Eastern United States. Black oils, which include fuel oils and asphalts, are shipped in vessles fixed under time or voyage charters (White, 1972).

2.2 Waste treatment

In order to meet the requirements of the Federal Petroleum Refinery Liquid Effluent Regulations and Guidelines, the numerous wastewaters produced by the refinery are collected in segregated systems by degree of contamination and treated separately (Newfoundland Refining Company, 1973). The four types of wastewater encountered are collected and treated as follows:

1. Uncontaminated rain water from around the refinery is diverted to the sea without treatment.

2. Surface runoff water from within the refinery and non-oily blowdown streams from the make-up water treatment plant are subjected to gravitational separation, held overnight in a holding basin, and released to sea through a hay filter.

3. Sanitary waste water is treated in a conventional Imhoff tank, chlorinated, and released.

4. Oily process water and ballast water from product ships are treated in a three stage wastewater treatment plant consisting of gravitational settling, dissolved air flotation, and biological oxidation. The treated water is held in a 24 hr. retention basin, and released to the Bay.

In addition to the above treatment a 690,000 barrel impounding basin has been constructed to receive all emergency diversions of oily water.

Once treated, effluent is released into Come by Chance Bay at the rate of approximately 1800 U.S.G.P.M. Although these wastes include a wide variety of chemical constituents (Appendix I) only six are prescribed as deleterious by federal regulations and these must be regulated to specified levels before discharge. These are: oils and grease (10.0 ppm); phenols (1.0 ppm); sulfides (0.35 ppm); ammonia (12.5 ppm); suspended solids (25.0 ppm) and any substance capable of altering the pH of liquid effluent. These concentrations are based on allowable discharges in pounds/1000 barrels processed, and an assumed discharge rate of 20 IGPM/1000 barrels processed. In addition, federal guidelines also indicate that the effluent must be 'non-toxic' (ie. does not kill more than 50% of the fish in a 96 hr. flow-through bioassay).

3.0 METHODS

3.1 Benthic and intertidal macro-invertebrates

Collections of intertidal and benthic organisms were made during six week periods (July to August) in 1972 and 1973. Stations were positioned at increasing distance from the refinery site throughout Come by Chance and upper Placentia Bays (Fig. 2 & 3). Eight subtidal transects were sampled at 3, 6, and 9 fathoms (f) by SCUBA divers employing a 0.5 m by 0.5 m aluminum square. At each depth, the grid was dropped randomly six times, yielding a total of 18 samples per station transect. Intertidal samples were collected in a similar manner, the grid being deployed six times between mean low and high tide marks at each of 12 stations. All materials enclosed by each grid were scooped out, placed in plastic bags, preserved in 10% formalin, and returned to the laboratory for identification.

All specimens retained by an 80 mesh (.317 square mm/division) screen were identified to species, where possible, using a variety of keys (Gosner, 1971; Bousfield, 1963, 1973; Pettibone, 1963; Miner, 1960). Most identifications were confirmed by the National Museum (appendix II) and type specimens of each species were kept as reference for future identifications. The numbers of individuals of each species at each station and depth were recorded.

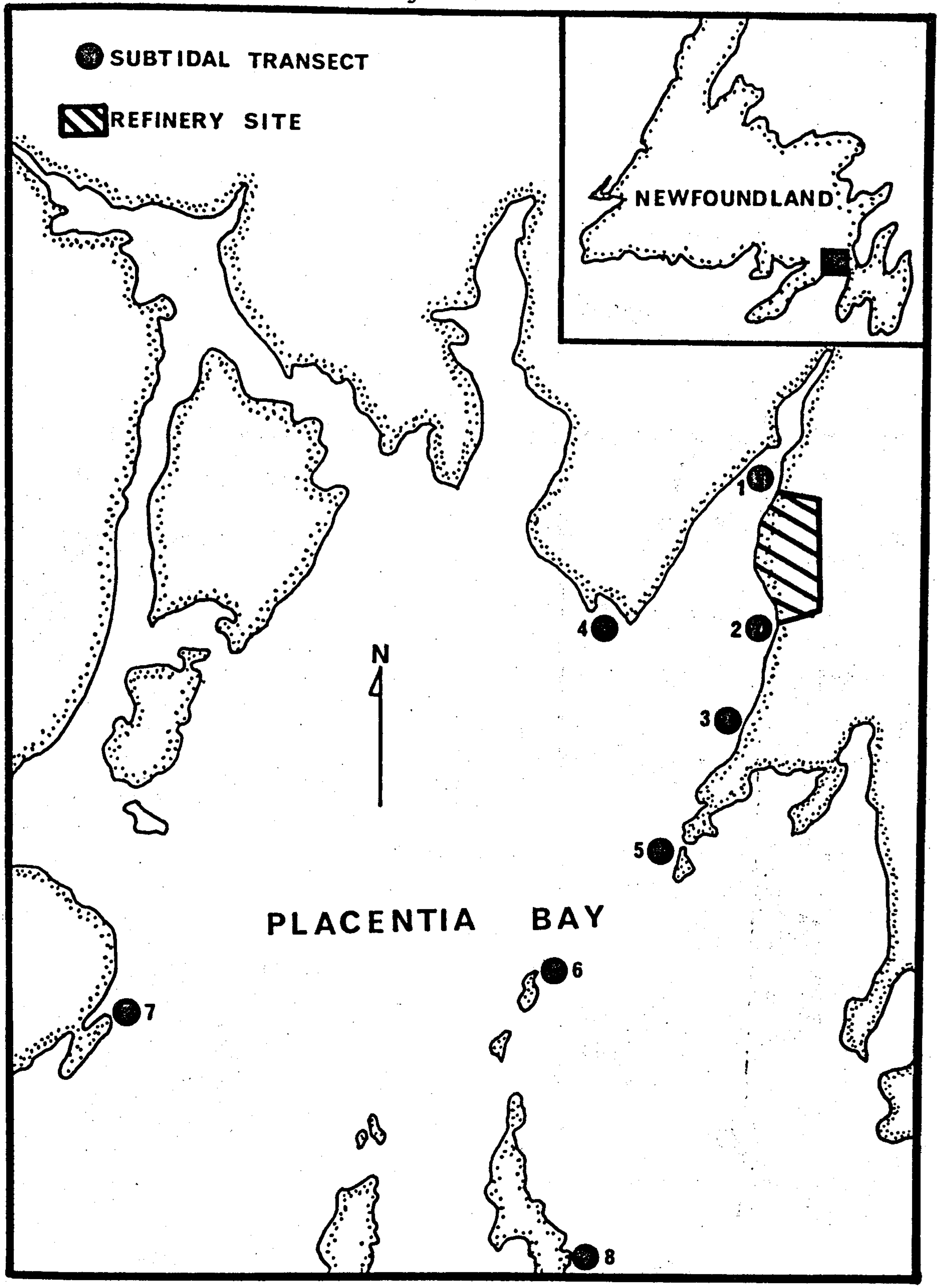


FIGURE 2 LOCATIONS OF SUBTIDAL TRANSECTS
(Each transect sampled at 3, 6 and 9 Fathoms)

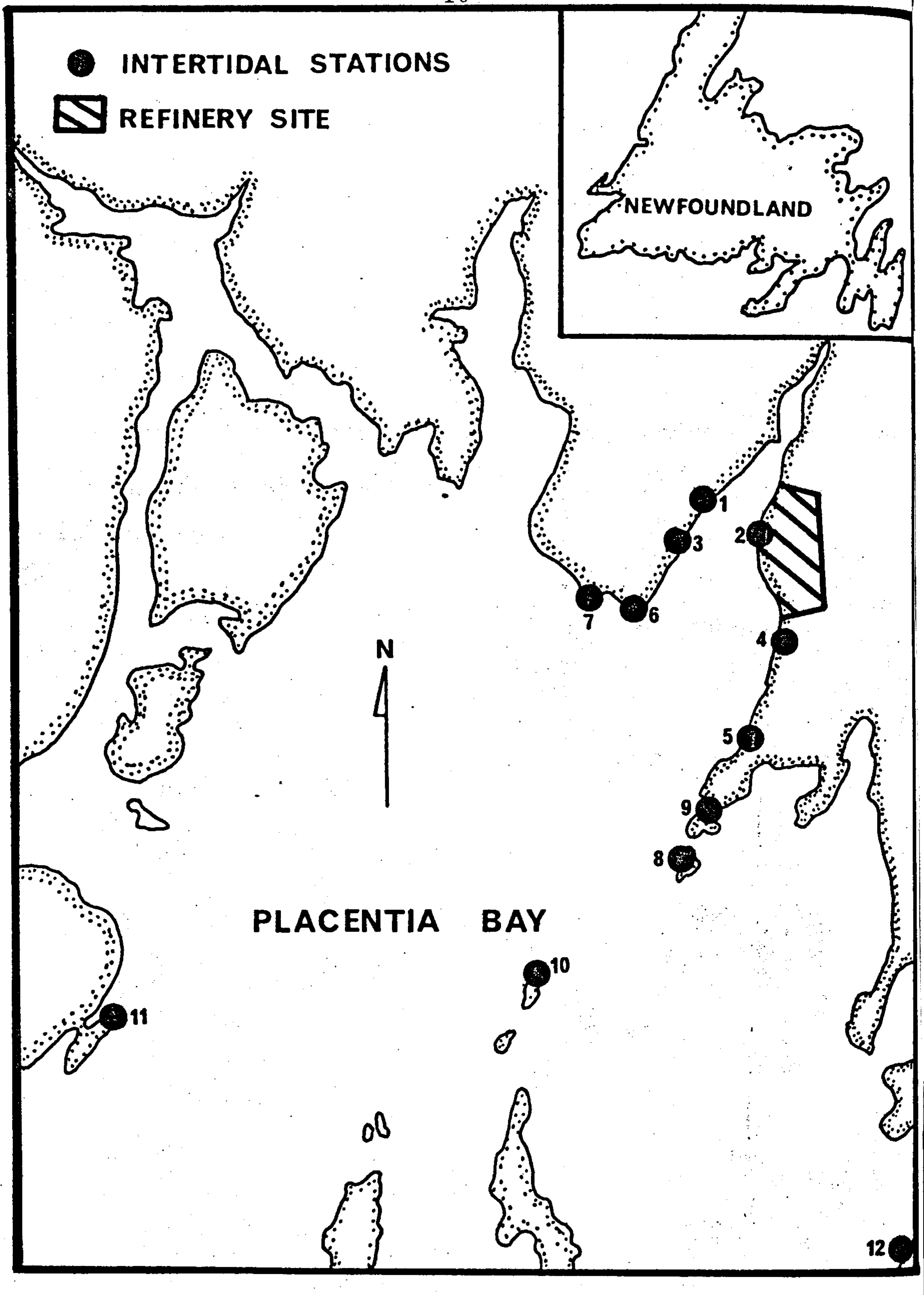


FIGURE 3 LOCATIONS OF INTERTIDAL STATIONS

Evaluation of benthic and intertidal macro-invertebrate communities was accomplished using a clustering technique to delineate communities (Field and McFarlane, 1968) and several diversity indices to determine community structure.

The diversity indices were:

McIntosh's Index $$M = \frac{N_{ij} - \sqrt{\varepsilon n^2}}{N_{ij} - \sqrt{N_{ij}}}$$ (McIntosh, 1967)

Margalef's Index $$R = \frac{S_j - 1}{\ell n\ N_{ij}}$$ (Margalef, 1957)

Shannon's Index $$S = -\sum_{i=1}^{s} \left(\frac{n_{ij}}{N_{ij}} \ln \frac{n_{ij}}{N_{ij}}\right)$$ (Pielou, 1966)

Simpson's Index $$P = \sum_{i=1}^{s} \left(\frac{n_{ij}}{N_{ij}}\right)^2$$ (Simpson, 1949)

where: N_{ij} = number of individuals in the j^{th} sample;

n_{ij} = number of individuals of the i^{th} species of the j^{th} sample;

S_{ij} = number of species in the j^{th} sample.

Margalef's index is a measure of variety or richness and is more sensitive to changes in the number of species than in numbers of individuals. Shannon's index measures both equitability and variety and as such varies with both the number of species and with the relative abundance of each species. McIntosh's and Simpson's indices are algebraic complements measuring equitability and dominance respectively and are therefore indicators of the evenness with which individuals are spread among the various species.

The similarity analysis technique used to delineate communities and determine community structure first calculates similarity coefficients from raw data giving a matrix of similarity coefficients comparing each component (stations or species) with every other component in the analysis. From this matrix, a clustering technique (Sokal and Sneath, 1963) groups together components more closely related, gradually increasing the size of the groups by lowering the criteria of admission. Once all individuals are grouped, the final clusters or aggregations are represented in graphical form by means of a dendogram.

The similarity coefficient used in this study was the coefficient of Czekanowski:

$$Cz = \frac{2W}{A+B}$$ (Bray and Curtis, 1957)

where: A = the sum of measures of all species in one sample;

B = the sum of measures of all species in another sample;

W = the sum of the lesser measures of each species for the two samples being compared. (ie. lowest value at each station).

This coefficient ranges from 0 (indicating no similarity) to 1 (indicating complete similarity), and can be done for values of numbers of specimens per station or weights of specimens per station; or logarithms of these values; or presence-absence data when used for measuring affinity between species.

In this study, when station grouping was done, logarithms of individual numbers were used since this method tends to de-emphasize the weighting given to species with high individual abundance (Field, 1970).

An important characteristic of this coefficient is that it excludes negative matches. This is necessary, because the fact that a species is absent at a number of stations does not necessarily indicate that these stations are environmentally similar. The species could be excluded at each station because of totally different environmental conditions.

Another important characteristic of this index is the fact that it used abundance values rather than presence-absence data. This is significant because there is obviously a great ecological difference between a sample in which only one individual of a species is present, and one in which the species is completely dominant in number (Field and McFarlane, 1968).

For the species or R analysis, presence-absence date was used such that:

W represented the joint occurrance of two species;

A represented the occurrance of species one;

B represented the occurrance of species two.

Again, a coefficient of zero represented no relationship between species while a value of 1 (or 100%) indicated complete association. In this case, the use of presence-absence data is justified because two species may be closely related biologically and yet one may be much more abundant than the other (Field, 1970).

The clustering technique was similar to the group-average method of Sokal and Sneath (1963), and the reader is referred to these authors for a more complete description of this anlaysis. All computations were performed on an IBM System/360 OS (TSO) Code and G Fortran processor.

3.2 Water quality sampling

Water quality sampling in Come by Chance Bay was initiated in June of 1971, and has continued (weather permitting) on a monthly basis since that time. Samples were collected at four stations (Fig. 4) at specified depths (0, 2, 5, 10 and 20 metres plus 1 metre from the bottom) throughout the water column. The parameters selected were those which would most accurately reflect the general water quality of the Bay as well as those indicative of contamination due to refinery operation. The parameters measured were: temperature, salinity, dissolved oxygen, biochemical oxygen demand (BOD), chemical oxygen demand (COD), turbidity, total suspended solids (TSS), chlorophyll (A, B, C, and Carotenoids), particulate organics, hydrocarbons, phenols, cyanide and ammonia nitrogen. All collections were made from Fisheries and Marine Service patrol boats (Porella or Pistolet Bay) using an 8 *l* Niskin (PVC) water sampling bottle, preserved where necessary, and returned to St. John's for analysis. All procedures and determinations except hydrocarbons (Gordon and Kaiser, 1974), chlorophyll (Strickland and Parsons, 1965), particulate organics (dry combustion and titration), temperature (reversing thermometer), cyanide (specific ion electrode and ammonia nitrogen (specific ion electrode) were those specified by A.P.H.A. Standard Methods (1971).

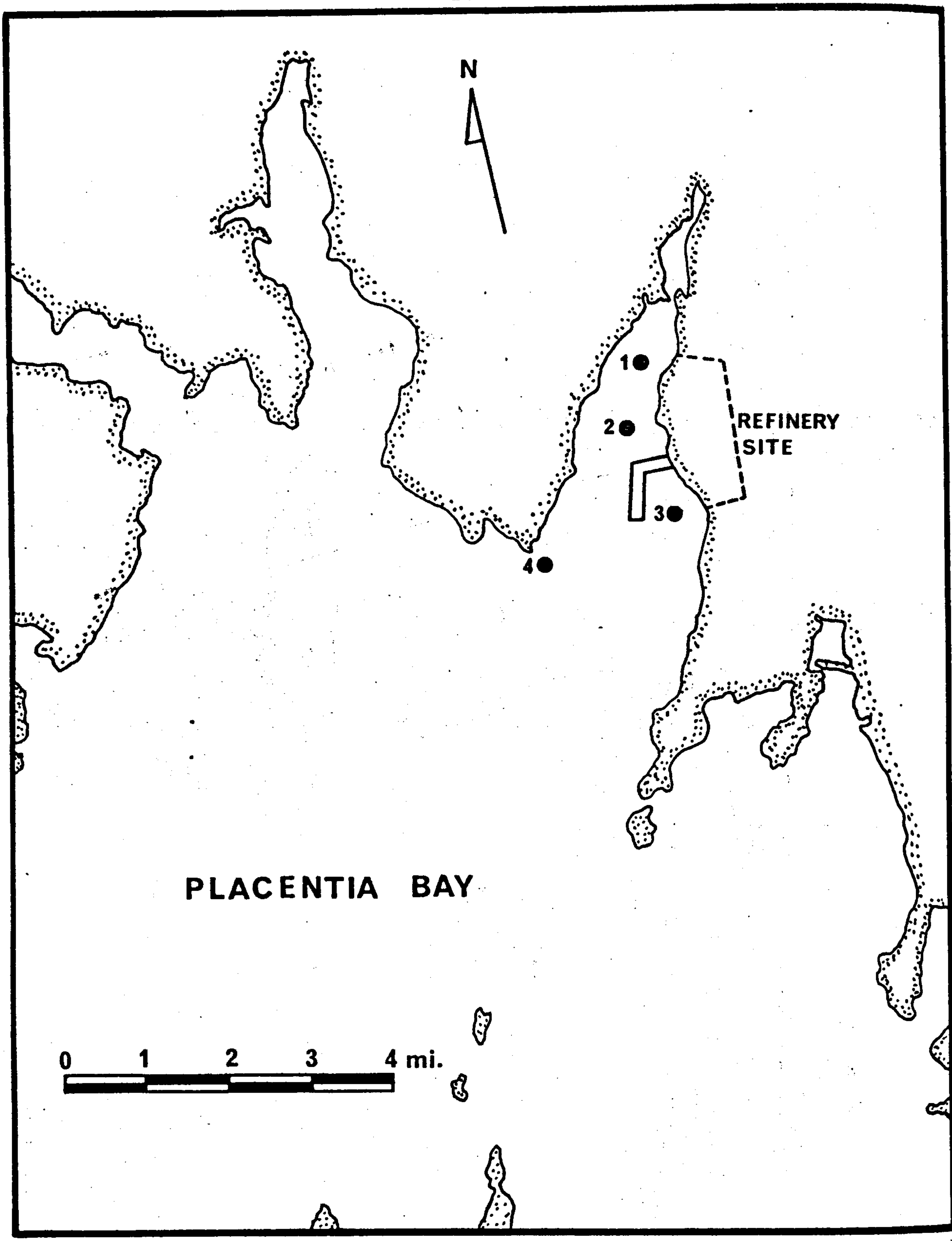


FIGURE 4 WATER QUALITY STATIONS IN COME BY CHANCE BAY

4.0 RESULTS

4.1 General

Organisms representing eleven phyla were collected from intertidal and subtidal sampling in Come by Chance and Upper Placentia Bays (Appendix II). Subtidal collections yielded totals of 113 and 108 species in 1972 and 1973 respectively. These accounted for totals of 26,269 and 17,100 individuals in the two years. The resultant average densities were 729.7 and 475.0 individuals per metre square. Intertidal sampling yielded totals of 46 and 52 species accounting for 96,803 and 97,914 individuals in 1972 and 1973 respectively. The average densities of these organisms per metre square were 5866.8 and 5934.2.

In both years, the dominant subtidal organisms were polychaete worms. The most numerous individuals, however, were the bivalve mollusc *Hiatella arctica* in 1972 and the amphipod *Corophium bonelli* in 1973. The densities of these organisms plus others which ranked highly in terms of number are shown in Table 1. This table indicates that there was a general decrease in total numbers of individuals in 1973 sampling. All subtidal stations were characterized by the presence of various amounts of the coralline alga *Lithothamnion* sp. (Appendix III). The cavities and spaces in this material undoubtedly provide habitat for many of the organisms listed above. In fact, most of the Mollusca and Annelida collected

Table 1

Abundances of common subtidal benthic animals in Come by Chance Bay

Group	Species	Mean Number per m^2	
		1973	1972
Platyhelminthes	polyclad sp. 4	-	380.6
Gastropod	*Ischnochiton ruber* and *alba*	37.8	388.6
Bivalves	*Volsella modiolus*	7.5	16.9
	Hiatella arctica	35.2	549.4
Polychaetes	*Harmothoe imbricata*	18.6	78.5
	Fabricia sabella		
	Nereis pelagica	23.06	35.6
Oligochaete			
Arachnid			
Insect			
Copepod	Tisbe sp.	72.6	197.5
Isopod			
Echinoderm	*Stronglyocentrotus* sp.	38.58	33.8
	Ophiopholis aculeata	43.4	59.6
Tunicate	unknown colonial #1	-	54.8
Crustacea			
Amphipods	*Corophium bonelli*	109.22	83.1
	Lepidonotus squamata	22.08	-

in subtidal sampling were found in close association with this alga and in most cases the calcified material had to be broken away in order to release organisms occupying these spaces.

In the intertidal collections, *Volsella modiolus* (Mollusca: Bivalvia) occurred most frequently in both years. Again the density of this plus other numerically important intertidal species are shown in Table 2. Not surprisingly, the intertidal community is quite unlike the subtidal one even though the major groups of organisms are represented in both habitats (Penrose *et al.*, 1974).

4.2 Diversity indices

Diversity indices for all sampling locations as well as mean values for all stations and depths are shown in Appendix IV. Average values for each depth and for the bay as a whole were not significantly different from year to year ($P < .05$) and the data for both years were therefore grouped to provide one set of mean values for both years (Table 3). Mean values for intertidal stations were generally lower than those calculated for subtidal stations. The exception, Simpson's index, was higher in intertidal locations.

The effect of depth of sampling was examined for the four indices. McIntosh's, Shannon's and Margalef's were all positively correlated with depth, while Simpson's index displayed a negative correlation over the same range (Fig. 4). All correlations were significant at $P < .05$.

Table 2

Abundances of common intertidal benthic animals in Come by Chance Bay

Group	Species	Mean Number per m^2	
		Intertidal'72	Intertidal'73
Platyhelminthes	triclad sp. 1	44.2	82.6
	polyclad sp. 4	26.2	38.7
Gastropod	*Lacuna vincta*	18.0	.11
	Littorina littorea	15.0	26.2
	L. obtusata	317.8	308.5
	Skena planorbis	49.7	196.6
	Thais lapillus	45.1	37.9
Bivalves	*Mytilus edulis*	1567.6	588.0
	Volsella modiolus	2192.7	1942.7
	Hiatella arctica	11.9	.78
Polychaetes	*Fabricia sabella*	20.6	184.9
Oligochaete	sp. 2	361.9	333.3
Arachnid	mite sp.	64.8	105.8
Insect	*Chironomid* larvae	131.1	702.8
Copepod	Tisbe sp.	36.4	121.8
Isopod	*Jaera marina*	28.3	234.72
Crustacea	*Balanus balanoides*	11.0	19.0
Amphipods	*Caliopius laeviusculus*	18.6	1.33
	Corophium bonelli	.9	.06
	Hyale nilssoni	55.2	239.7
	Amphitoe robusta	16.3	4.5
	Gammarus occidentalis	22.3	68.7
	Thais lapillus	49.2	37.9
Nemertine	*Lineus bicolor*	1.33	16.3

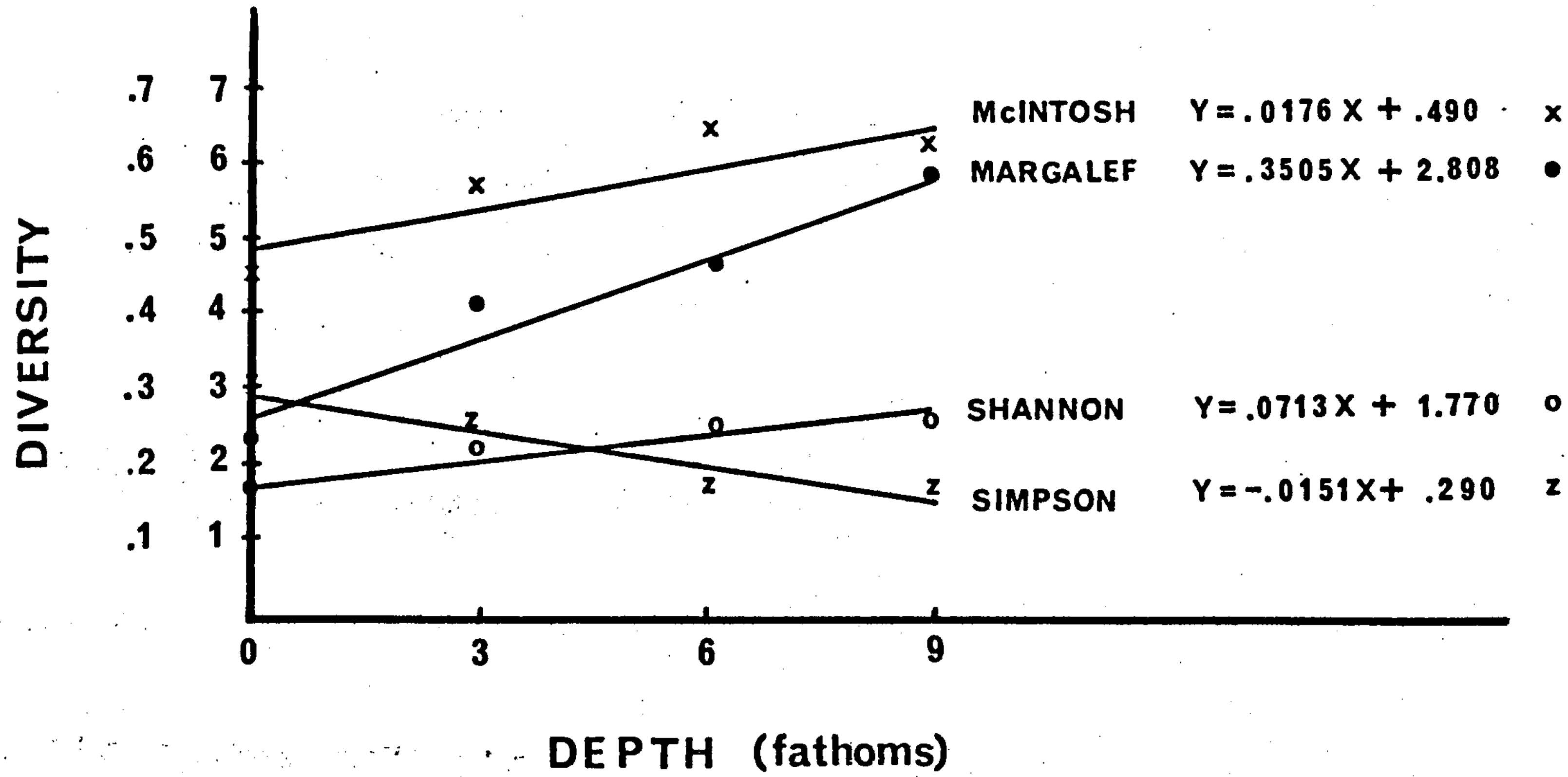
Table 3

Combined mean value of diversity for years 1972 and 1973

	McIntosh Index	Margalef Index	Shannon Index	Simpson Index
Intertidal	.4691[a] ± .1407[b] n = 24[c]	2.3941 ± .5515 n = 24	1.7157 ± .4548 n = 24	.3051 ± .4646 n = 24
3 Fathoms	.5695 ± .1643 n = 18	4.0204 ± 1.3741 n = 18	2.0670 ± .5503 n = 18	.2416 ± .1767 n = 18
6 Fathoms	.6344 ± .4004 n = 14	4.6808 ± 1.2984 n = 14	2.3037 ± .4400 n = 14	.1651 ± .1243 n = 14
9 Fathoms	.6117 ± .3812 n = 14	5.6284 ± 1.2771 n = 14	2.3210 ± .4400 n = 14	.1779 ± .0978 n = 14
All Subtidal Stations	.6021 ± .1350 n = 46	5.0394 ± 1.4589 n = 46	2.2166 ± .4786 n = 46	.1989 ± .1362 n = 14

a = mean value (2 years data);
b = plus or minus one standard deviation;
c = sample size.

FIGURE 5 RELATIONSHIP BETWEEN DEPTH OF SAMPLING AND SPECIES DIVERSITY
(Come by Chance 1972 & 1973)
0 Fathoms Represents Intertidal Stations



When the relationship between distance from the refinery site and diversity was examined, only Margalef's and Shannon's indices displayed significant correlations ($P < .05$) (Fig. 6). All other correlations, both benthic (Fig. 6) and intertidal (Fig. 7) were not significant ($P < .05$). In fact, the slopes of the lines obtained for intertidal stations were close to zero.

4.3 Cluster analysis of stations

Results of the cluster analysis technique for stations are shown in Fig. 8 to 13. These were prepared by the unweighted pair-group method (Sokol and Sneath, 1963) with arithmetic averages from matrices of Czekanowski coefficients (Field and McFarlane, 1970) relating stations on the basis of the logarithms of the numbers of the various species present at each site.

There are generally two sets of results: (1) Analysis of intertidal stations and (2) Analysis of benthic stations. Fig. 8 and 9 indicate that for both 1972 and 1973 all intertidal stations were grouped into single aggregations at similarity values of 58.2 and 69.6 per cent respectively (Fig. 8&9). When both years data were combined into the same analysis, all stations had formed a single aggregation at a similarity measure of 53.5 per cent (Fig. 10). In this analysis, stations tended to cluster more closely with other stations sampled in the same year than with themselves sampled in successive years.

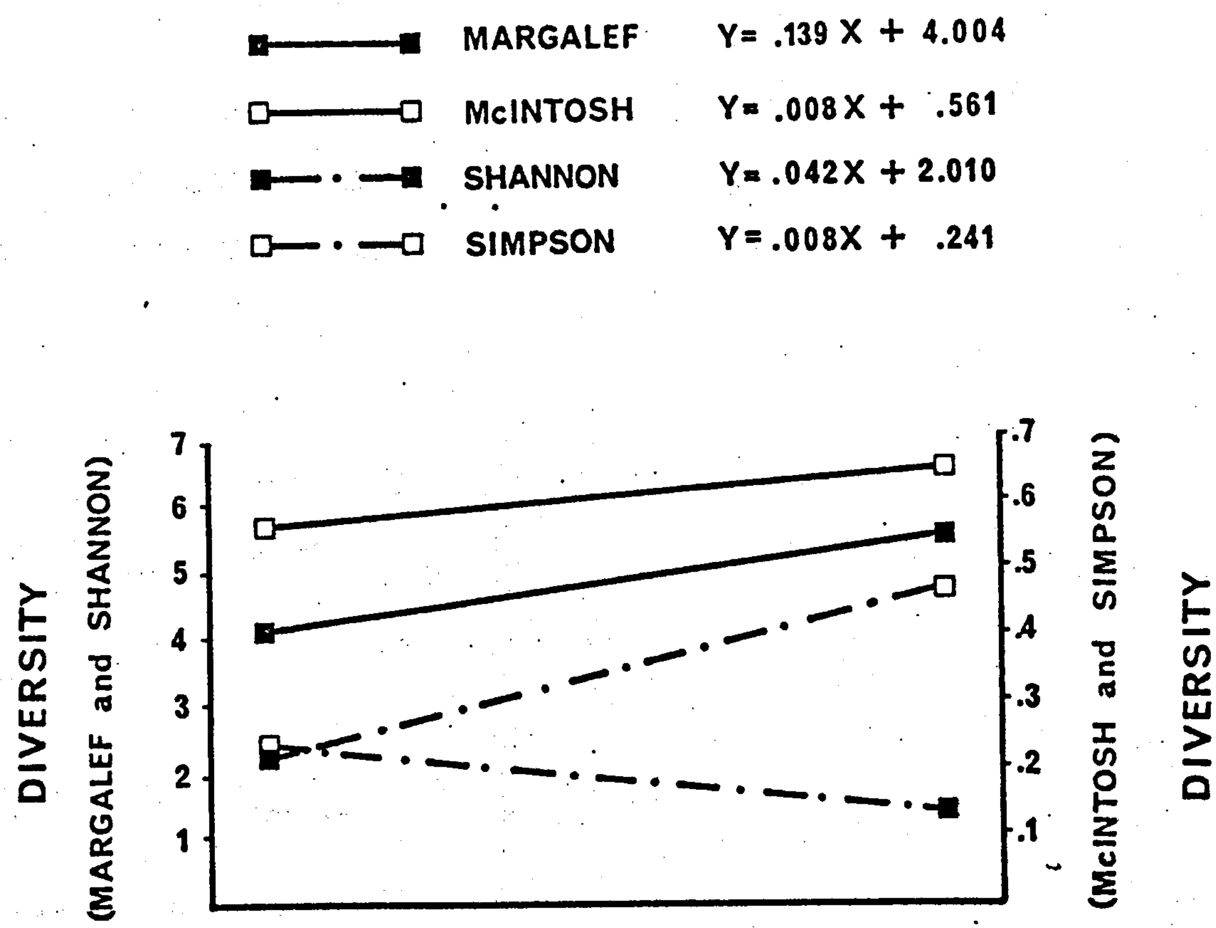


FIGURE 6. SPECIES DIVERSITY vs DISTANCE FROM REFINERY SITE (BENTHIC SAMPLING 1972 and 1973)

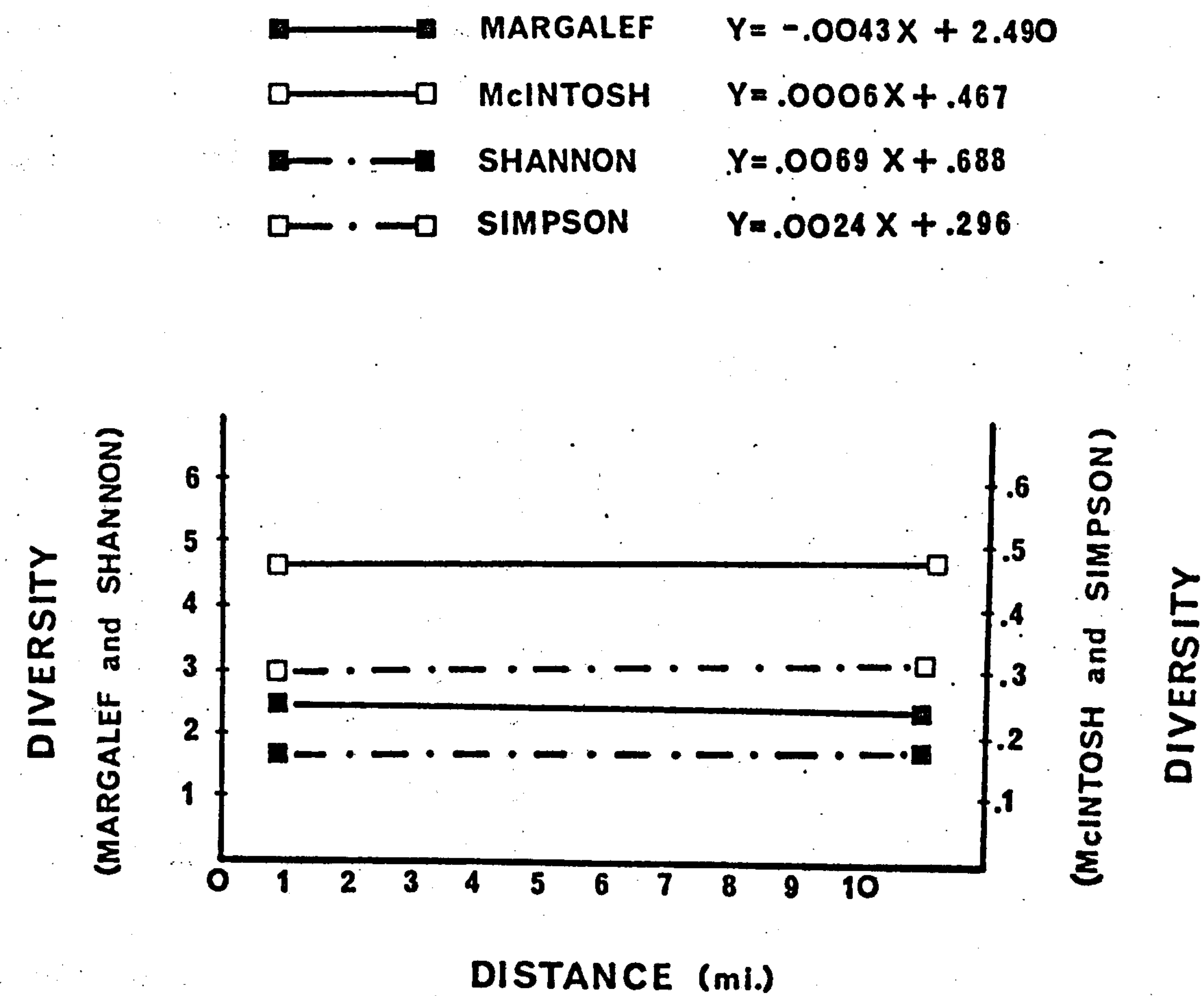


FIGURE 7. SPECIES DIVERSITY vs DISTANCE FROM REFINERY SITE (INTERTIDAL SAMPLING 1972 and 1973)

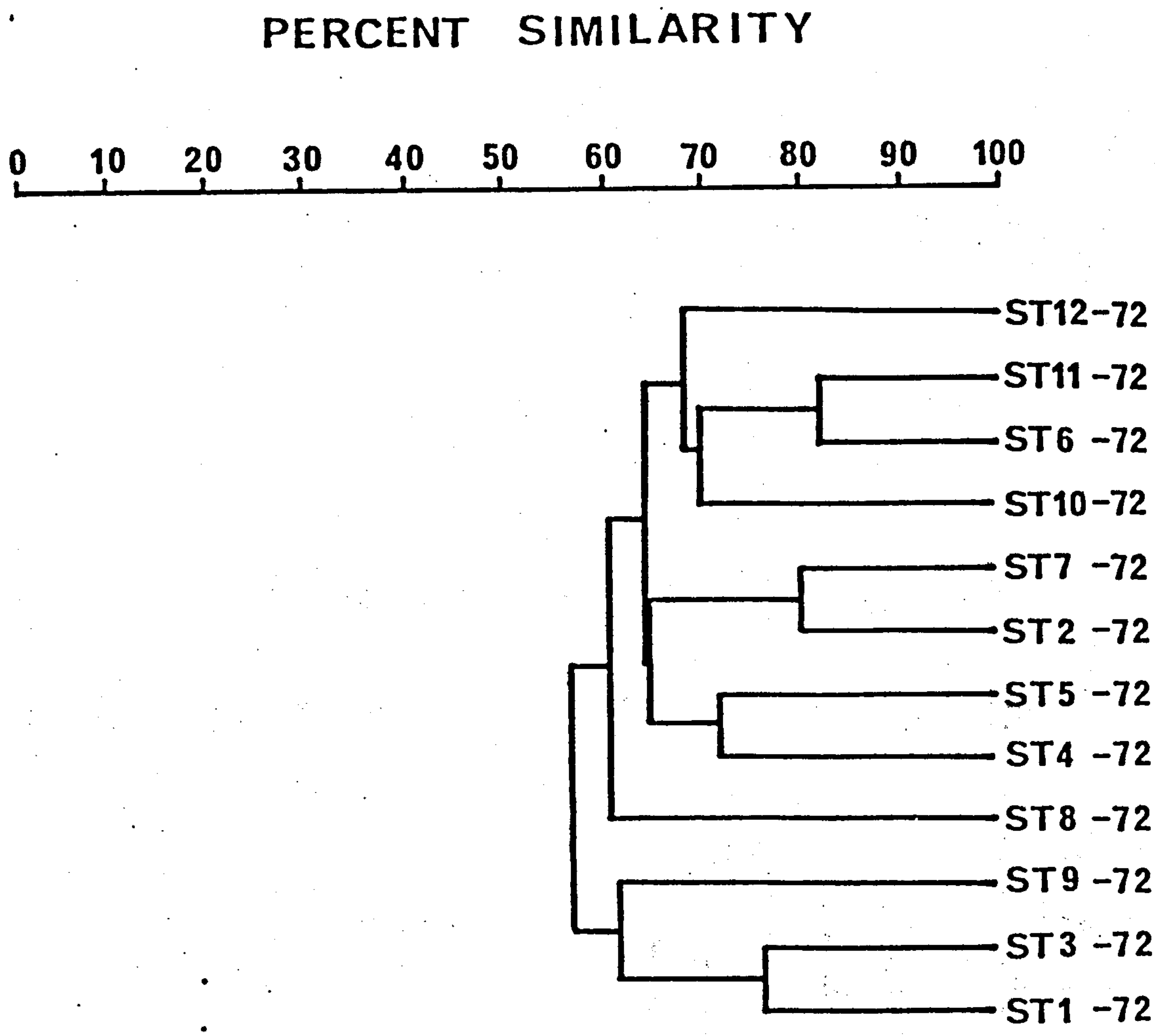


FIGURE 8

DENDOGRAM SHOWING THE RESULTS OF ANALYSIS OF 1972 INTERTIDAL SAMPLES BY THE CZEKANOWSKI COEFFICIENT AND GROUP AVERAGE SORTING. THE SCALE SHOWS PERCENTAGE SIMILARITY BETWEEN STATIONS OR GROUPS OF STATIONS.

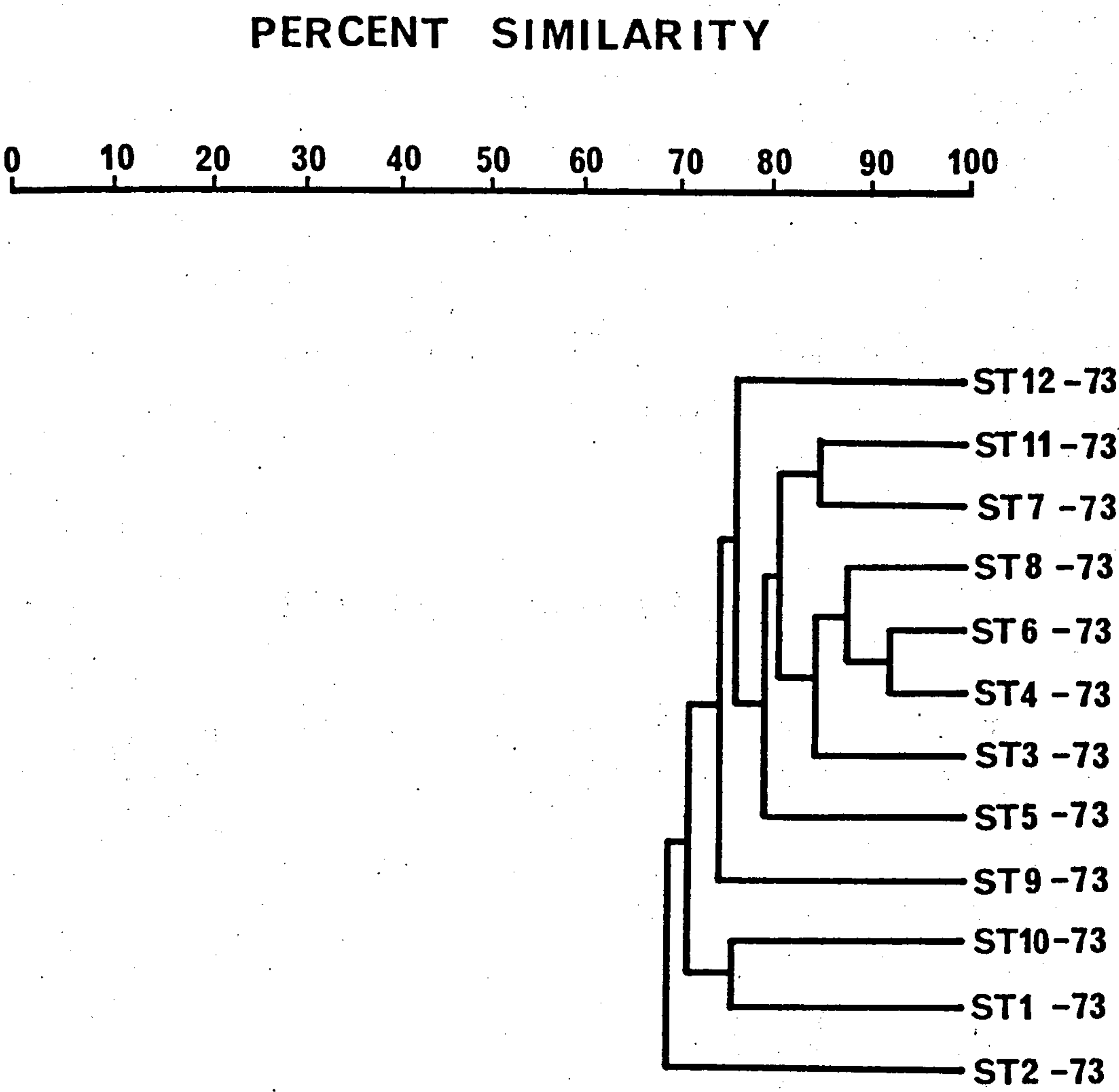


FIGURE 9

DENDOGRAM SHOWING THE RESULTS OF ANALYSIS OF 1973 INTERTIDAL SAMPLES BY THE CZEKANOWSKI COEFFICIENT AND GROUP AVERAGE SORTING. THE SCALE SHOWS PERCENTAGE SIMILARITY BETWEEN STATIONS OR GROUPS OF STATIONS.

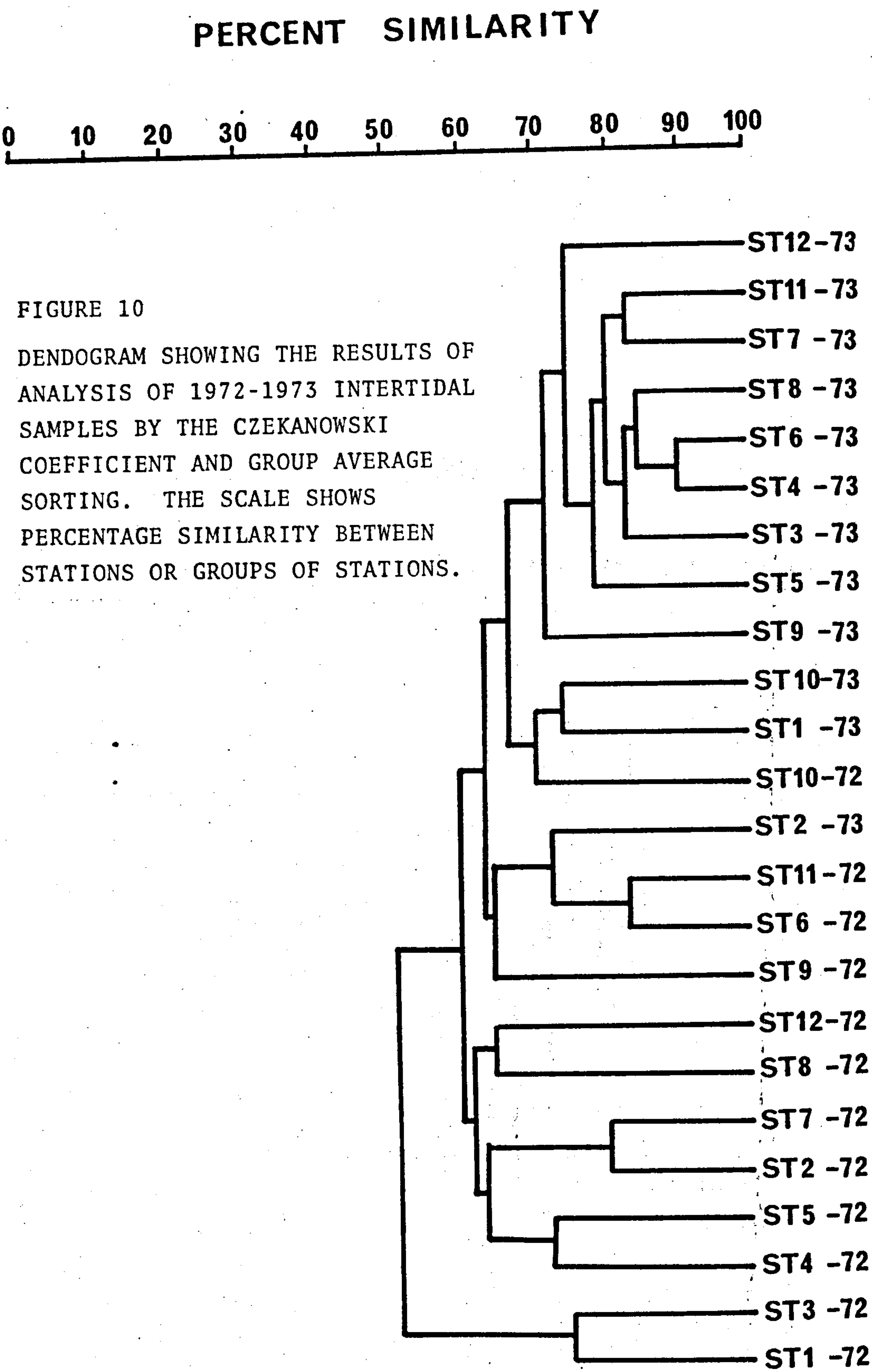


FIGURE 10

DENDOGRAM SHOWING THE RESULTS OF ANALYSIS OF 1972-1973 INTERTIDAL SAMPLES BY THE CZEKANOWSKI COEFFICIENT AND GROUP AVERAGE SORTING. THE SCALE SHOWS PERCENTAGE SIMILARITY BETWEEN STATIONS OR GROUPS OF STATIONS.

Analysis of benthic samples revealed that all stations had joined into single aggregations or clusters at similarity values of 38.4 and 15.3 per cent in 1972 and 1973 respectively (Fig. 11 and 12). This relatively low value for 1973 is caused by Station 1 East which had a more than average reduction of organisms in the second year of sampling. Whether this reduction was due to variations in sampling or identification techniques, damage during storage, or a real change in the number of organisms present caused by increased sedimentation during wharf construction is not known. By excluding this station, however, the final grouping occurs at a similarity measure of 37.4 per cent, a value much closer to that recorded for the previous year.

When data from both years were analysed simultaneously, all 46 stations were grouped as a single aggregation at a similarity value of 14.5% (Fig. 13). Again, Station 1 East is responsible for this low value and by excluding this location, the level of similarity at which all stations are grouped rises to 33.1 per cent.

It is interesting to note that the dendogram produced for sub-tidal stations revealed some partitioning of shallow-water (3 Fathom) stations. In both 1972 and 1973 these stations tended to form separate aggregations until relatively low values of similarity were attained. In 1972, 66 per cent of these stations did not join the main aggregation until a similarity value of 51.3 per cent had been reached (Fig. 11). In 1973,

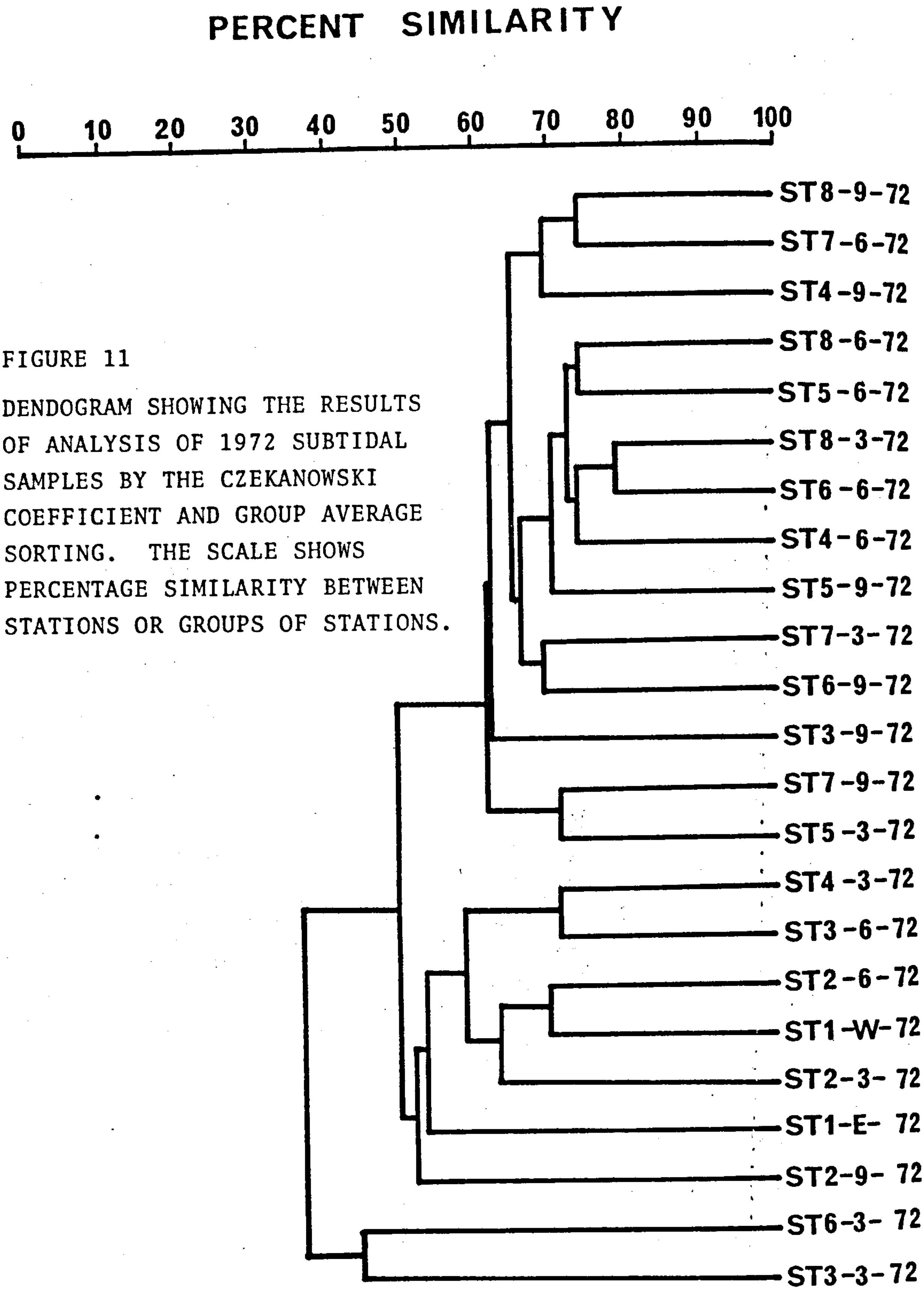


FIGURE 11

DENDOGRAM SHOWING THE RESULTS OF ANALYSIS OF 1972 SUBTIDAL SAMPLES BY THE CZEKANOWSKI COEFFICIENT AND GROUP AVERAGE SORTING. THE SCALE SHOWS PERCENTAGE SIMILARITY BETWEEN STATIONS OR GROUPS OF STATIONS.

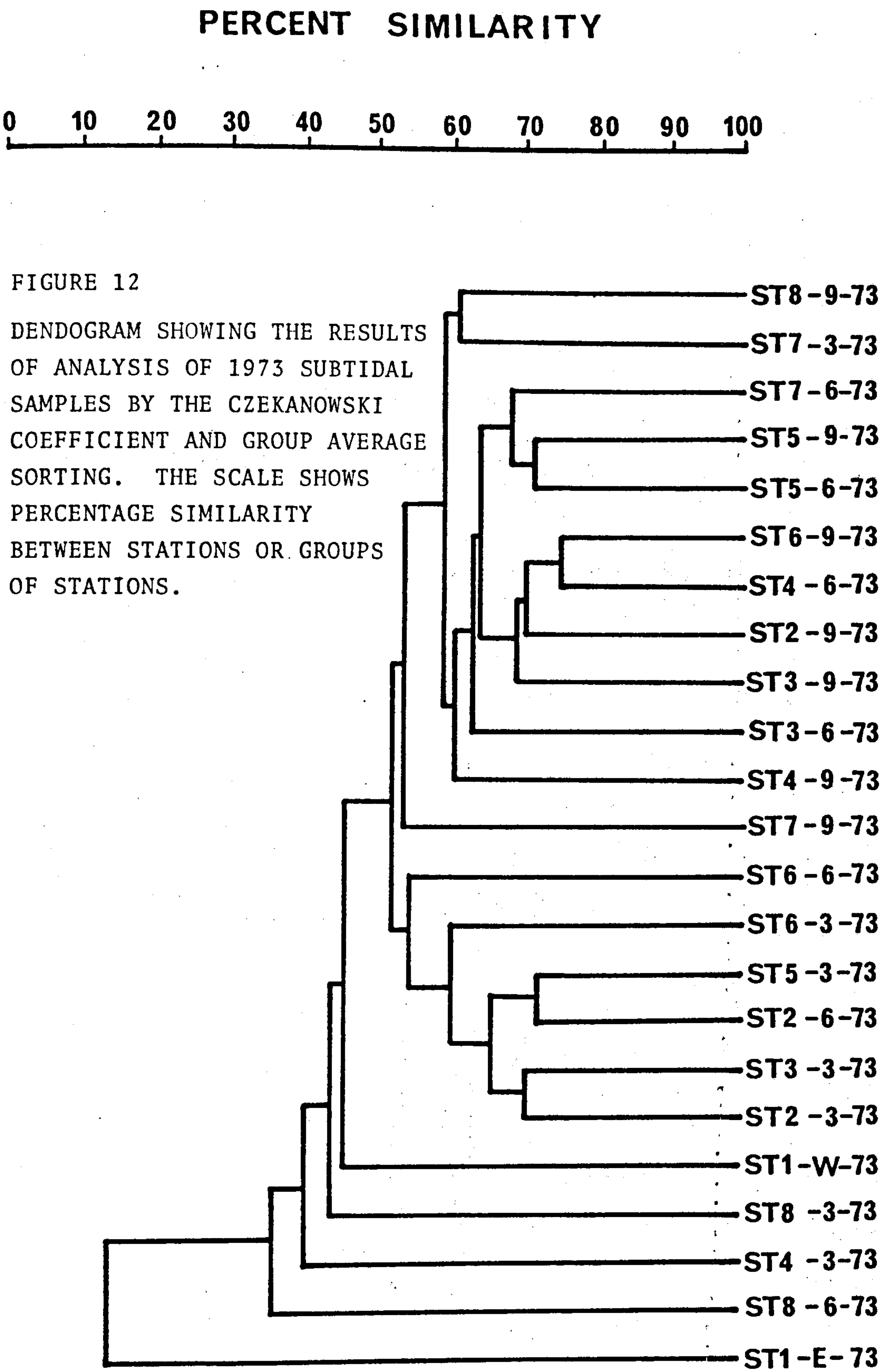


FIGURE 12

DENDOGRAM SHOWING THE RESULTS OF ANALYSIS OF 1973 SUBTIDAL SAMPLES BY THE CZEKANOWSKI COEFFICIENT AND GROUP AVERAGE SORTING. THE SCALE SHOWS PERCENTAGE SIMILARITY BETWEEN STATIONS OR GROUPS OF STATIONS.

88 per cent of the shallow-water stations were not included in the main aggregation until the similarity value had dropped to 53.3 per cent (Fig.12). When data from both years were analyzed, 78 per cent of the three fathom stations clustered separately until a similarity measure of 50.5 per cent had been achieved (Fig. 13).

Another feature of the combined analyses for the subtidal data is the fact that stations tended to group more closely with other stations sampled in the same year than with the same station sampled in successive years (Fig. 13). In this analysis, two distinct clusters were formed by deep-water (6 and 9 F) stations from 1972 and 1973, and these did not combine into a single aggregation until a similarity value of 53.0 per cent had been attained.

4.4 Cluster analysis of species

Analysis of intertidal and subtidal species association, through cluster analysis, revealed that the organisms representative of these communities are generally the same from year to year. The clusters formed during this analysis are shown in Fig. 14 to 17. In each case, selection of an arbitrary cut-off value of similarity at 70% yielded a definite set of organisms representative of the environment sampled. These organisms are listed in tables 4 and 5.

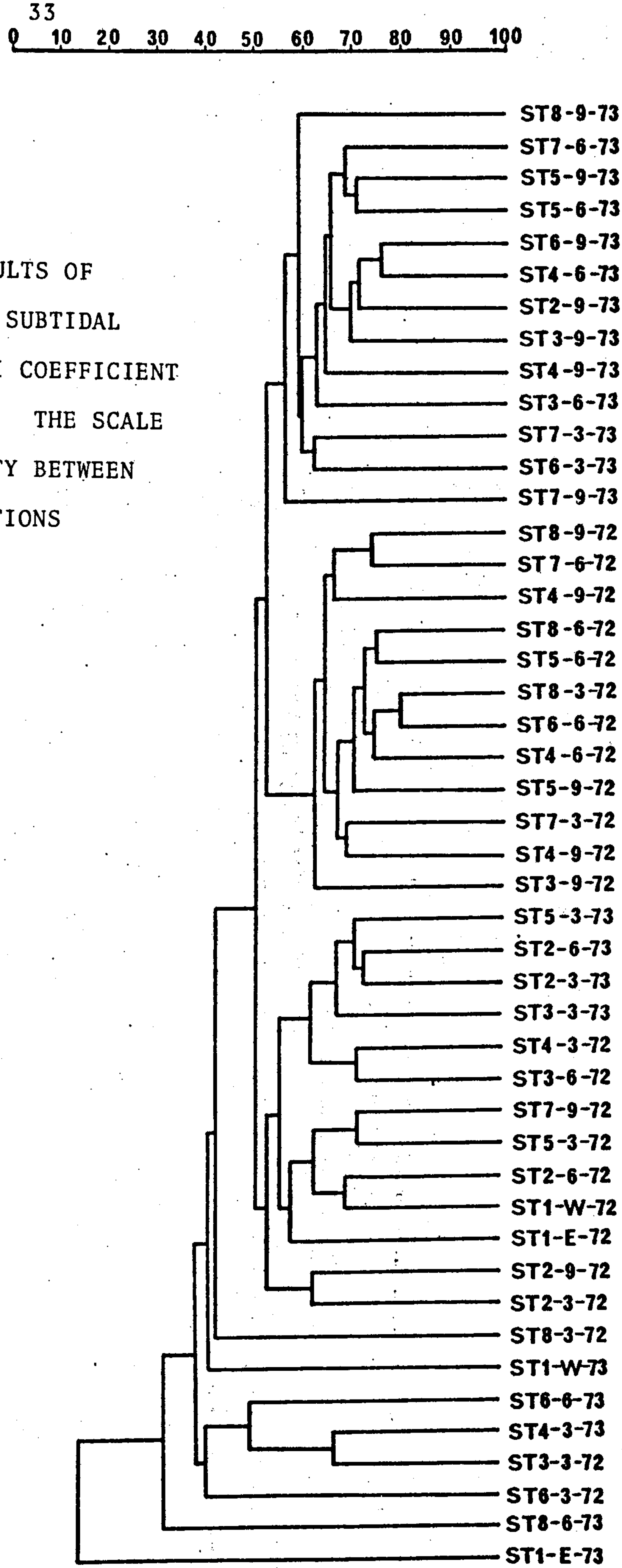
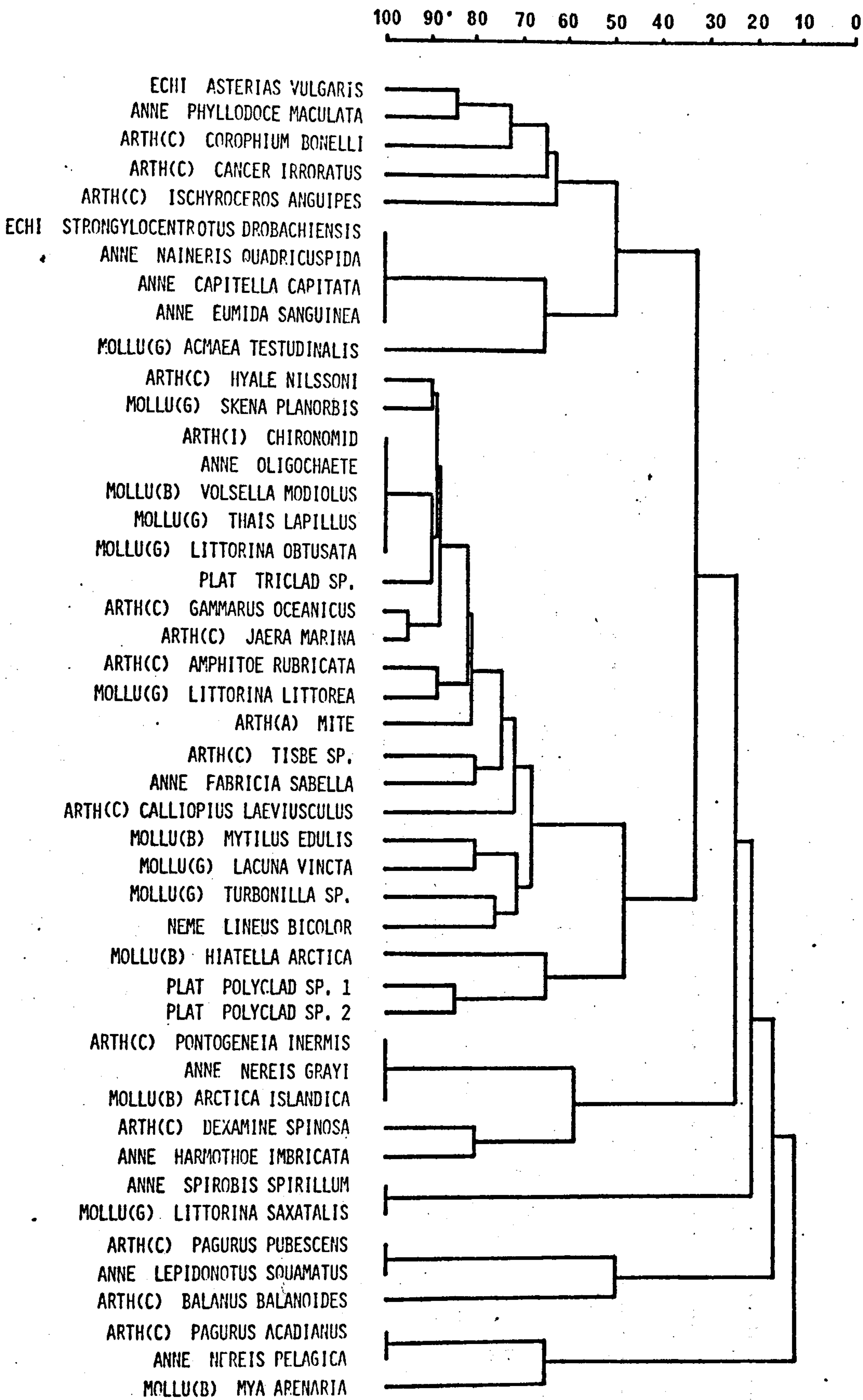


FIGURE 13

DENDOGRAM SHOWING THE RESULTS OF ANALYSIS OF 1972 AND 1973 SUBTIDAL SAMPLES BY THE CZEKANOWSKI COEFFICIENT AND GROUP AVERAGE SORTING. THE SCALE SHOWS PERCENTAGE SIMILARITY BETWEEN STATIONS OR GROUPS OF STATIONS

FIGURE 14. DENDOGRAM SHOWING THE RESULTS OF ANALYSIS OF 1972 INTERTIDAL SAMPLES BY THE CZEKANOWSKI COEFFICIENT AND GROUP AVERAGE SORTING. THE SCALE SHOWS PERCENTAGE SIMILARITY BETWEEN SPECIES OR GROUPS OF SPECIES.



100
90
80
70
60
50
40
30
20
10
0
ECHI ASTERIAS VULGARIS
ANNE PHYLLODOCE MACULATA
ARTH(C) COROPHIUM BONELLI
ARTH(C) CANCER IRRORATUS
ARTH(C) ISCHYROCEROS ANGUIPES
ECHI STRONGYLOCENTROTUS DROBACHIENSIS
ANNE NAINERIS QUADRICUSPIDA
ANNE CAPITELLA CAPITATA
ANNE EUMIDA SANGUINEA
MOLLU(G) ACMAEA TESTUDINALIS
ARTH(C) HYALE NILSSONI
MOLLU(G) SKENA PLANORBIS
ARTH(I) CHIRONOMID
ANNE OLIGOCHAETE
MOLLU(B) VOLSELLA MODIOLUS
MOLLU(G) THAIS LAPILLUS
MOLLU(G) LITTORINA OBTUSATA
PLAT TRICLAD SP.
ARTH(C) GAMMARUS OCEANICUS
ARTH(C) JAERA MARINA
ARTH(C) AMPHITOE RUBRICATA
MOLLU(G) LITTORINA LITTOREA
ARTH(A) MITE
ARTH(C) TISBE SP.
ANNE FABRICIA SABELLA
ARTH(C) CALLIOPIUS LAEVIUSCULUS
MOLLU(B) MYTILUS EDULIS
MOLLU(G) LACUNA VINCTA
MOLLU(G) TURBONILLA SP.
NEME LINEUS BICOLOR
MOLLU(B) HIATELLA ARCTICA
PLAT POLYCLAD SP. 1
PLAT POLYCLAD SP. 2
ARTH(C) PONTOGENEIA INERMIS
ANNE NEREIS GRAYI
MOLLU(B) ARCTICA ISLANDICA
ARTH(C) DEXAMINE SPINOSA
ANNE HARMOTHOE IMBRICATA
ANNE SPIROBIS SPIRILLUM
MOLLU(G) LITTORINA SAXATALIS
ARTH(C) PAGURUS PUBESCENS
ANNE LEPIDONOTUS SQUAMATUS
ARTH(C) BALANUS BALANOIDES
ARTH(C) PAGURUS ACADIANUS
ANNE NEREIS PELAGICA
MOLLU(B) MYA ARENARIA

FIGURE 15 DENDOGRAM SHOWING THE RESULTS OF ANALYSIS OF 1973 INTERTIDAL SAMPLES BY THE CZEKANOWSKI COEFFICIENT AND GROUP AVERAGE SORTING. THE SCALE SHOWS PERCENTAGE SIMILARITY BETWEEN SPECIES OR GROUPS OF SPECIES.

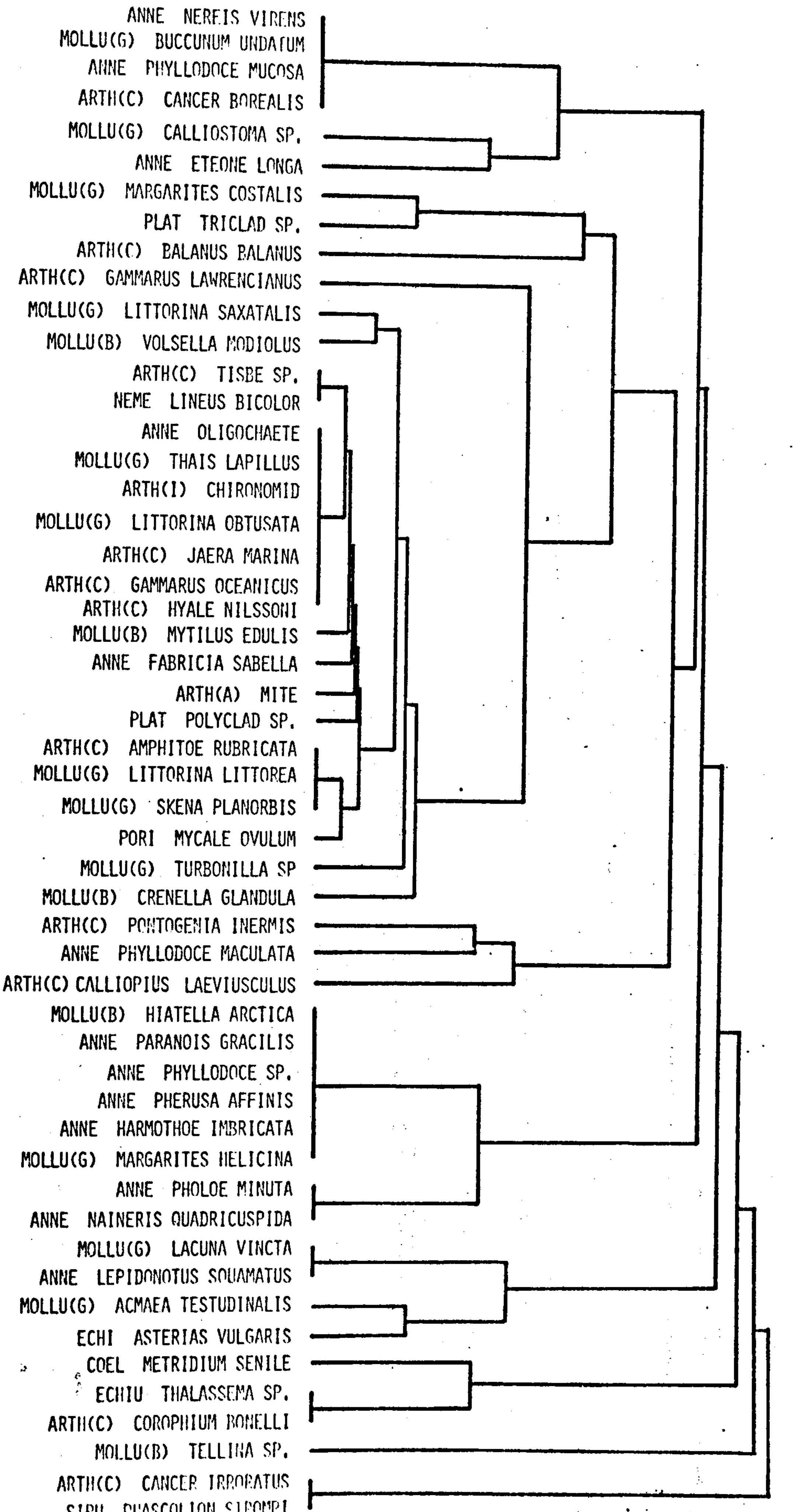

ANNE NEREIS VIRENS
MOLLU(G) BUCCUNUM UNDATUM
ANNE PHYLLODOCE MUCOSA
ARTH(C) CANCER BOREALIS
MOLLU(G) CALLIOSTOMA SP.
ANNE ETEONE LONGA
MOLLU(G) MARGARITES COSTALIS
PLAT TRICLAD SP.
ARTH(C) BALANUS BALANUS
ARTH(C) GAMMARUS LAWRENCIANUS
MOLLU(G) LITTORINA SAXATALIS
MOLLU(B) VOLSELLA MODIOLUS
ARTH(C) TISBE SP.
NEME LINEUS BICOLOR
ANNE OLIGOCHAETE
MOLLU(G) THAIS LAPILLUS
ARTH(I) CHIRONOMID
MOLLU(G) LITTORINA OBTUSATA
ARTH(C) JAERA MARINA
ARTH(C) GAMMARUS OCEANICUS
ARTH(C) HYALE NILSSONI
MOLLU(B) MYTILUS EDULIS
ANNE FABRICIA SABELLA
ARTH(A) MITE
PLAT POLYCLAD SP.
ARTH(C) AMPHITOE RUBRICATA
MOLLU(G) LITTORINA LITTOREA
MOLLU(G) SKENA PLANORBIS
PORI MYCALE OVULUM
MOLLU(G) TURBONILLA SP
MOLLU(B) CRENELLA GLANDULA
ARTH(C) PONTOGENIA INERMIS
ANNE PHYLLODOCE MACULATA
ARTH(C) CALLIOPIUS LAEVIUSCULUS
MOLLU(B) HIATELLA ARCTICA
ANNE PARANOIS GRACILIS
ANNE PHYLLODOCE SP.
ANNE PHERUSA AFFINIS
ANNE HARMOTHOE IMBRICATA
MOLLU(G) MARGARITES HELICINA
ANNE PHOLOE MINUTA
ANNE NAINERIS QUADRICUSPIDA
MOLLU(G) LACUNA VINCTA
ANNE LEPIDONOTUS SQUAMATUS
MOLLU(G) ACMAEA TESTUDINALIS
ECHI ASTERIAS VULGARIS
COEL METRIDIUM SENILE
ECHIU THALASSEMA SP.
ARTH(C) COROPHIUM BONELLI
MOLLU(B) TELLINA SP.
ARTH(C) CANCER IRRORATUS

FIGURE 16 DENDOGRAM SHOWING THE RESULTS OF ANALYSIS OF 1972 SUBTIDAL SAMPLING BY THE CZEKANOWSKI COEFFICIENT AND GROUP AVERAGE SORTING. THE SCALE SHOWS PERCENTAGE SIMILARITY BETWEEN SPECIES OR GROUPS OF SPECIES.

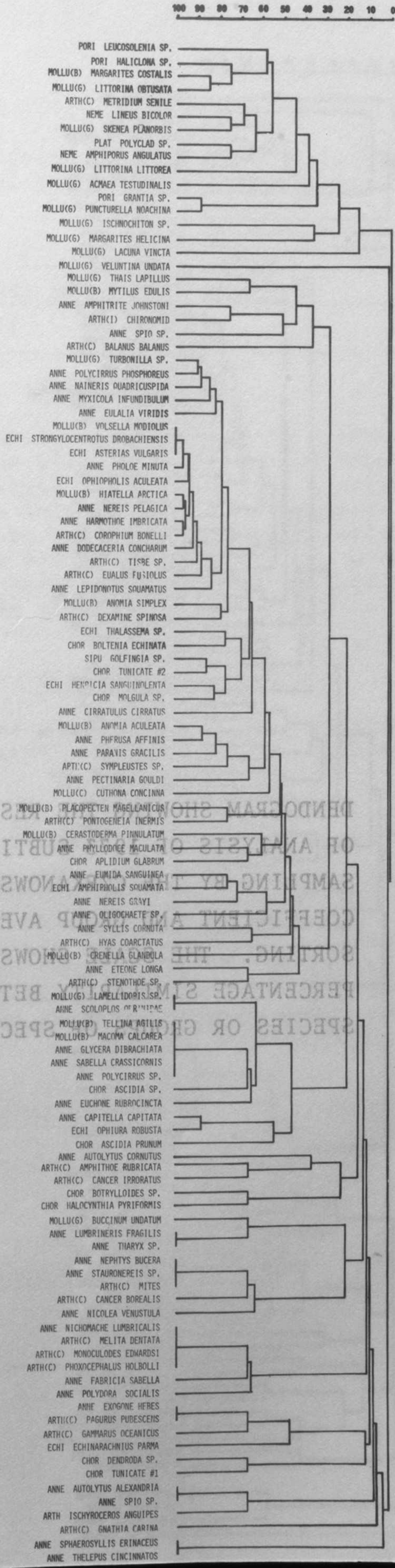
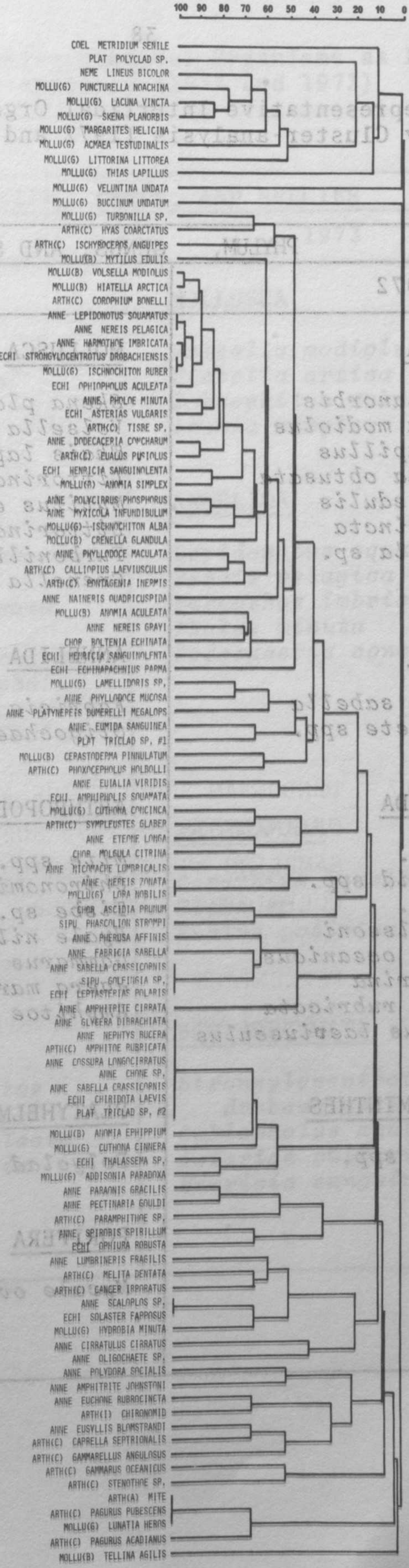

100 90 80 70 60 50 40 30 20 10 0
PORI LEUCOSOLENIA SP.
PORI HALICLONA SP.
MOLLU(B) MARGARITES COSTALIS
MOLLU(G) LITTORINA OBTUSATA
ARTH(C) METRIDIUM SENILE
NEME LINEUS BICOLOR
MOLLU(G) SKENEA PLANORBIS
PLAT POLYCLAD SP.
NEME AMPHIPORUS ANGULATUS
MOLLU(G) LITTORINA LITTOREA
MOLLU(G) ACMAEA TESTUDINALIS
PORI GRANTIA SP.
MOLLU(G) PUNCTURELLA NOACHINA
MOLLU(G) ISCHNOCHITON SP.
MOLLU(G) MARGARITES HELICINA
MOLLU(G) LACUNA VINCTA
MOLLU(G) VELUNTINA UNDATA
MOLLU(G) THAIS LAPILLUS
MOLLU(B) MYTILUS EDULIS
ANNE AMPHITRITE JOHNSTONI
ARTH(I) CHIRONOMID
ANNE SPIO SP.
ARTH(C) BALANUS BALANUS
MOLLU(G) TURBONILLA SP.
ANNE POLYCIRRUS PHOSPHOREUS
ANNE NAINERIS QUADRICUSPIDA
ANNE MYXICOLA INFUNDIBULUM
ANNE EULALIA VIRIDIS
MOLLU(B) VOLSELLA MODIOLUS
ECHI STRONGYLOCENTROTUS DROBACHIENSIS
ECHI ASTERIAS VULGARIS
ANNE PHOLOE MINUTA
ECHI OPHIOPHOLIS ACULEATA
MOLLU(B) HIATELLA ARCTICA
ANNE NEREIS PELAGICA
ANNE HARMOTHOE IMBRICATA
ARTH(C) COROPHIUM BONELLI
ANNE DODECACERIA CONCHARUM
ARTH(C) TISBE SP.
ARTH(C) EUALUS FUSIOLUS
ANNE LEPIDONOTUS SQUAMATUS
MOLLU(B) ANOMIA SIMPLEX
ARTH(C) DEXAMINE SPINOSA
ECHI THALASSEMA SP.
CHOR BOLTENIA ECHINATA
SIPU GOLFINGIA SP.
CHOR TUNICATE #2
ECHI HENRICIA SANGUINOLENTA
CHOR MOLGULA SP.
ANNE CIRRATULUS CIRRATUS
MOLLU(B) ANOMIA ACULEATA
ANNE PHERUSA AFFINIS
ANNE PARAONIS GRACILIS
ARTH(C) SYMPLEUSTES SP.
ANNE PECTINARIA GOULDI
MOLLU(C) CUTHONA CONCINNA
MOLLU(B) PLACOPECTEN MAGELLANICUS
ARTH(C) PONTOGENEIA INERMIS
MOLLU(B) CERASTODERMA PINNULATUM
ANNE PHYLLODOCE MACULATA
CHOR APLIDIUM GLABRUM
ANNE EUMIDA SANGUINEA
ECHI AMPHIPHOLIS SQUAMATA
ANNE NEREIS GRAYI
ANNE OLIGOCHAETE SP.
ANNE SYLLIS CORNUTA
ARTH(C) HYAS COARCTATUS
MOLLU(B) CRENELLA GLANDULA
ANNE ETEONE LONGA
ARTH(C) STENOTHOE SP.
MOLLU(G) LAMELLIDORIS SP.
ANNE SCOLOPLOS ARMIGER
MOLLU(B) TELLINA AGILIS
MOLLU(B) MACOMA CALCAREA
ANNE GLYCERA DIBRACHIATA
ANNE SABELLA CRASSICORNIS
ANNE POLYCIRRUS SP.
CHOR ASCIDIA SP.
ANNE EUCHONE RUBROCINCTA
ANNE CAPITELLA CAPITATA
ECHI OPHIURA ROBUSTA
CHOR ASCIDIA PRUNUM
ANNE AUTOLYTUS CORNUTUS
ARTH(C) AMPHITHOE RUBRICATA
ARTH(C) CANCER IRRORATUS
CHOR BOTRYLLOIDES SP.
CHOR HALOCYNTHIA PYRIFORMIS
MOLLU(G) BUCCINUM UNDATUM
ANNE LUMBRINERIS FRAGILIS
ANNE THARYX SP.
ANNE NEPHTYS BUCERA
ANNE STAURONEREIS SP.
ARTH(C) MITES
ARTH(C) CANCER BOREALIS
ANNE NICOLEA VENUSTULA
ANNE NICHOMACHE LUMBRICALIS
ARTH(C) MELITA DENTATA
ARTH(C) MONOCULODES EDWARDSI
ARTH(C) PHOXOCEPHALUS HOLBOLLI
ANNE FABRICIA SABELLA
ANNE POLYDORA SOCIALIS
ANNE EXOGONE HEBES
ARTH(C) PAGURUS PUBESCENS
ARTH(C) GAMMARUS OCEANICUS
ECHI ECHINARACHNIUS PARMA
CHOR DENDRODA SP.
CHOR TUNICATE #1
ANNE AUTOLYTUS ALEXANDRIA
ANNE SPIO SP.
ARTH ISCHYROCEROS ANGUIPES
ARTH(C) GNATHIA CARINA
ANNE SPHAEROSYLLIS ERINACEUS
ANNE THELEPUS CINCINNATOS

FIGURE 17 DENDOGRAM SHOWING THE RESULTS OF ANALYSIS OF 1973 SUBTIDAL SAMPLING BY THE CZEKANOWSKI COEFFICIENT AND GROUP AVERAGE SORTING. THE SCALE SHOWS PERCENTAGE SIMILARITY BETWEEN SPECIES OR GROUPS OF SPECIES.



100 90 80 70 60 50 40 30 20 10 0
COEL METRIDIUM SENILE
PLAT POLYCLAD SP.
NEME LINEUS BICOLOR
MOLLU(G) PUNCTURELLA NOACHINA
MOLLU(G) LACUNA VINCTA
MOLLU(G) SKENA PLANORBIS
MOLLU(G) MARGARITES HELICINA
MOLLU(G) ACMAEA TESTUDINALIS
MOLLU(G) LITTORINA LITTOREA
MOLLU(G) THIAS LAPILLUS
MOLLU(G) VELUNTINA UNDATA
MOLLU(G) BUCCINUM UNDATUM
MOLLU(G) TURBONILLA SP.
ARTH(C) HYAS COARCTATUS
ARTH(C) ISCHYROCEROS ANGUIPES
MOLLU(B) MYTILUS EDULIS
MOLLU(B) VOLSELLA MODIOLUS
MOLLU(B) HIATELLA ARCTICA
ARTH(C) COROPHIUM BONELLI
ANNE LEPIDONOTUS SQUAMATUS
ANNE NEREIS PELAGICA
ANNE HARMOTHOE IMBRICATA
ECHI STRONGYLOCENTROTUS DROBACHIENSIS
MOLLU(G) ISCHNOCHITON RUBER
ECHI OPHIOPHOLUS ACULEATA
ANNE PHOLOE MINUTA
ECHI ASTERIAS VULGARIS
ARTH(C) TISBE SP.
ANNE DODECACERIA CONCHARUM
ARTH(C) EUALUS PUSIOLUS
ECHI HENRICIA SANGUINOLENTA
MOLLU(B) ANOMIA SIMPLEX
ANNE POLYCIRRUS PHOSPHORUS
ANNE MYXICOLA INFUNDIBULUM
MOLLU(G) ISCHNOCHITON ALBA
MOLLU(B) CRENELLA GLANDULA
ANNE PHYLLODOCE MACULATA
ARTH(C) CALLIOPIUS LAEVIUSCULUS
ARTH(C) PONTAGENIA INERMIS
ANNE NAINERIS QUADRICUSPIDA
MOLLU(B) ANOMIA ACULEATA
ANNE NEREIS GRAYI
CHOR BOLTENIA ECHINATA
ECHI HENRICIA SANGUINOLENTA
ECHI ECHINAPACHNIUS PARMA
MOLLU(G) LAMELLIDORIS SP.
ANNE PHYLLODOCE MUCOSA
ANNE PLATYNEREIS DUMERELLI MEGALOPS
ANNE EUMIDA SANGUINEA
PLAT TRICLAD SP. #1
MOLLU(B) CERASTODERMA PINNULATUM
ARTH(C) PHOXOCEPHOLUS HOLBOLLI
ANNE EUIALIA VIRIDIS
ECHI AMPHIPHOLIS SQUAMATA
MOLLU(G) CUTHONA CONCINCA
ARTH(C) SYMPLEUSTES GLABER
ANNE ETEONE LONGA
CHOR MOLGULA CITRINA
ANNE NICOMACHE LUMBRICALIS
ANNE NEREIS ZONATA
MOLLU(G) LORA NOBILIS
CHOR ASCIDIA PRUNUM
SIPU PHASCOLION STROMPI
ANNE PHERUSA AFFINIS
ANNE FABRICIA SABELLA
ANNE SABELLA CRASSICORNIS
SIPU GOLFINGIA SP.
ECHI LEPTASTERIAS POLARIS
ANNE AMPHITRITE CIRRATA
ANNE GLYCERA DIBRACHIATA
ANNE NEPHTYS BUCERA
ARTH(C) AMPHITOE RUBRICATA
ANNE COSSURA LONGOCIRRATUS
ANNE CHONE SP.
ANNE SABELLA CRASSICORNIS
ECHI CHIRIDOTA LAEVIS
PLAT TRICLAD SP. #2
MOLLU(B) ANOMIA EPHIPPIUM
MOLLU(G) CUTHONA CINNERA
ECHI THALASSEMA SP.
MOLLU(G) ADDISONIA PARADOXA
ANNE PARAONIS GRACILIS
ANNE PECTINARIA GOULDI
ARTH(C) PARAMPHITHOE SP.
ANNE SPIROBIS SPIRILLUM
ECHI OPHIURA ROBUSTA
ANNE LUMBRINERIS FRAGILIS
ARTH(C) MELITA DENTATA
ARTH(C) CANCER IRRORATUS
ANNE SCALOPLOS SP.
ECHI SOLASTER FAPPOSUS
MOLLU(G) HYDROBIA MINUTA
ANNE CIRRATULUS CIRRATUS
ANNE OLIGOCHAETE SP.
ANNE POLYDORA SOCIALIS
ANNE AMPHITRITE JOHNSTONI
ANNE EUCHONE RUBROCINCTA
ARTH(I) CHIRONOMID
ANNE EUSYLLIS BLOMSTRANDI
ARTH(C) CAPRELLA SEPTRIONALIS
ARTH(C) GAMMARELLUS ANGULOSUS
ARTH(C) GAMMARUS OCEANICUS
ARTH(C) STENOTHOE SP.
ARTH(A) MITE
ARTH(C) PAGURUS PUBESCENS
MOLLU(G) LUNATIA HEROS
ARTH(C) PAGURUS ACADIANUS
MOLLU(B) TELLINA AGILIS

Table 4. Representative Intertidal Organisms as Determined by Cluster-analysis (1972 and 1973)

PHYLUM, GENUS, AND SPECIES	
1972	1973
MOLLUSCA	MOLLUSCA
Skena planorbis	*Skena planorbis*
Volsella modiolus	*Volsella modiolus*
Thais lapillus	*Thais lapillus*
Littorina obtusata	*Littorina obtusata*
Mytilus edulis	*Mytilus edulis*
Lacuna vincta	*Littorina saxatalis*
Turbonilla sp.	*Turbonilla sp.*
	Crenella glandula
ANNELIDA	ANNELIDA
Fabricia sabella	*Fabricia sabella*
Oligochaete spp.	*Oligochaete spp.*
ARTHROPODA	ARTHROPODA
Mite spp.	*Mite spp.*
Chironomid spp.	*Chironomid spp.*
Tisbe sp.	*Tisbe sp.*
Hyale nilssoni	*Hyale nilssoni*
Gammarus oceanicus	*Gammarus oceanicus*
Jaera marina	*Jaera marina*
Amphitoe rubricata	*Amphitoe rubricata*
Calliopius laeviusculus	
PLATYHELMINTHES	PLATYHELMINTHES
Triclad spp.	*Polyclad spp.*
	PORIFERA
	Mycale ovulum

Table 5. Representative Subtidal Organisms as Determined by Cluster-analysis (1972 and 1973)

PHYLUM, GENUS, AND SPECIES	
1972	1973
MOLLUSCA	MOLLUSCA
Volsella modiolus	*Volsella modiolus*
Hiatella arctica	*Hiatella artica*
Anomia simplex	*Ichnochiton ruber*
Turbonilla sp.	*Anomia simplex*
ANNELIDA	ANNELIDA
Lepidonotus squamatus	*Lepidonotus squamatus*
Nereis pelagica	*Nereis pelagica*
Harmothoe imbricata	*Harmothoe imbricata*
Pholoe minuta	*Pholoe minuta*
Dodecaceria concharum	*Dodecaceria concharum*
Polycirrus phosphorus	
Naineris quadricuspida	
Myxicola infundibulum	
Eulalia viridis	
ARTHROPODA	ARTHROPODA
Corophium bonelli	*Corophium bonelli*
Tisbe sp.	*Tisbe sp.*
Eualus posiolus	*Eualus posiolus*
Dexamine spinosa	
ECHINODERMATA	ECHINODERMATA
Strongylocentrotus drobachiensis	*Strongylocentrotus drobachiensis*
Ophiopholus aculeata	*Ophiopholus aculeata*
Asterias vulgaris	*Asterias vulgaris*
	Henricia sanguinolenta

Although several animals or groups of animals were associated at levels above 70% (often at 100%), each analysis yielded one large group of organisms which were linked above this value. For the purposes of this study, the large group will be referred to as the "indicator group" most representative of the communities sampled. These groups are formed around the most frequently occurring individuals, which are probably the species most familiar to biologists, but the species may be most frequent because they have wider tolerances than most (Field 1970).

The reproducability of this type of analysis is indicated by the high percentage of indicator organisms that are listed for both years in both intertidal and subtidal collections (Tables 4 and 5). In the intertidal analysis, 72 per cent (or 16 of 22) are repeated while 63.6 per cent (or 14 of 22) of the subtidal organisms are listed in both years. It is also interesting to note that the organisms listed in Tables 4 and 5 which were selected by cluster analysis, contain most of the species listed in tables 1 and 2 selected on the basis of their abundance in the samples collected.

4.5 Water quality

The average values for all water quality parameters from all sampling dates are shown in Table 4. Parameters which are specifically indicative of pollution by refinery wastes were very low or non-detectable. Phenol, cyanide and ammonia nitrogen were all below the level of detection while hydrocarbon concentrations ranged from 0.6 to 5.5 μg/ℓ (ppb) (Gordon *et al*, 1974). The method used in collecting hydrocarbon samples, however, is now in question.

Figures 18 to 21 indicate that for all stations the parameters measured reflect the same general pattern. There was relatively little seasonal variation within the data except for values of temperature, salinity and dissolved oxygen. Temperature and dissolved oxygen, of course, vary with the seasonal fluctuations of heat provided by radiant energy from the sun, and decreases in salinity during early summer may be attributable to surface run-off of fresh water from the land. Values ranging as low as 13.4 parts per thousand were encountered in surface waters in these months, and these values would tend to lower the average for the total water column.

When values for all stations were combined, the seasonal variations in the measured parameters were obtained for the Bay as a whole (Fig. 22). In this graph as in Fig. 18-21, each point represents the average of three years data for each month. The vertical bars represent the range of values encountered for that parameter over the depths sampled.

Table 6

Water quality data from surveys in Come by Chance Bay by the Environmental Protection Service June, 1971 - December, 1973

Parameter	Annual Average 1971 - 1973 Station				Mean of all stations 6/71 - 12/73	Range for all stations 6/71 - 12/73
	1	2	3	4		
Temperature (°C)	5.8	4.9	5.3	4.2	5.0	-2.0 - 19.0
Salinity (‰)	30.80	31.03	31.39	31.38	31.12	13.4 - 35.5
Dissolved Oxygen (ppm)	10.16	10.41	10.37	10.24	10.29	9.0 - 12.6
Biochemical Oxygen Demand (ppm)	0.8	0.7	0.8	0.7	0.8	0.0 - 4.9
Chemical Oxygen Demand (ppm)	6.38	6.24	7.06	6.57	6.56	0.0 - 23.00
Turbidity (JTU)	0.52	0.67	0.56	0.39	0.53	0.0 - 18.0
T.S.S. (mg/1)	0.96	1.27	0.85	0.91	0.99	0.0 - 29.00
Phenols (ppm)	N.D.	N.D.	N.D.	N.D.	N.D.	-
Cyanide (ppm)	N.D.	N.D.	N.D.	N.D.	N.D.	-
Ammonia Nitrogen (ppm)	N.D.	N.D.	N.D.	N.D.	N.D.	-
Hydrocarbons (ppb)	2.04	1.60	2.70	2.17	2.16	0.6 - 5.5

N.D. = not detectable.

cont'd ....

TABLE 6 (cont'd)

Parameter	Annual Average 1971 - 1973				Mean of all stations 6/71 - 12/73	Range for all stations 6/71 - 12/73
	Station					
	1	2	3	4		
Chlorophyll a (mg/m^3)	.583	.426	.415	.592	.504	0 - 6.16
Chlorophyll b (mg/m^3)	.243	.300	.247	.420	.302	0 - 5.52
Chlorophyll c (mg/m^3)	.580	1.25	.398	1.26	.872	0 -17.64
Carotene (SPU)	.503	.481	.442	.49	.479	0 -11.40

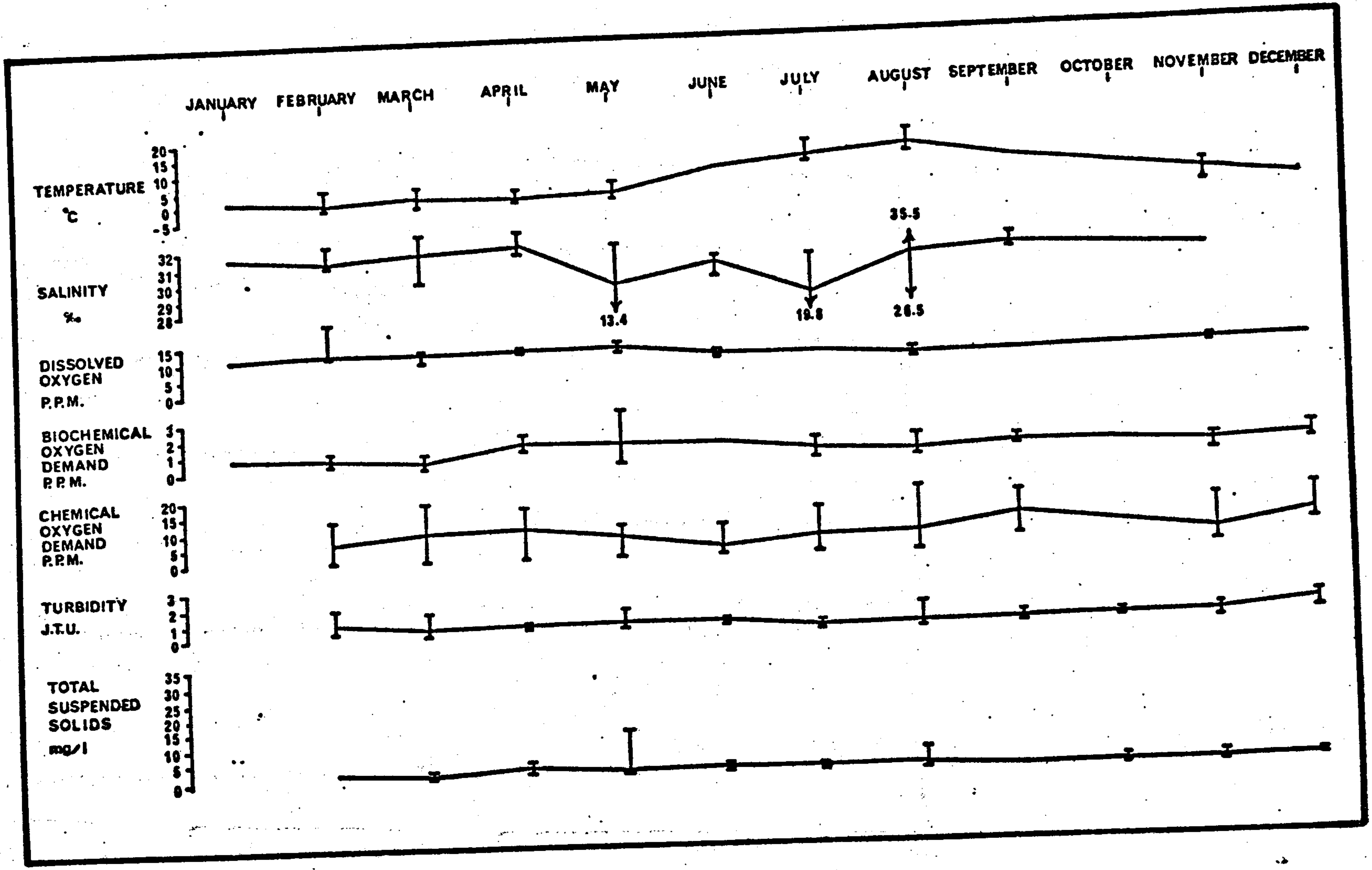


FIGURE 18 MONTHLY MEANS AND RANGES OF PARAMETERS MEASURED IN COME BY CHANCE BAY (JULY 1971 - DECEMBER 1973), STATION 1

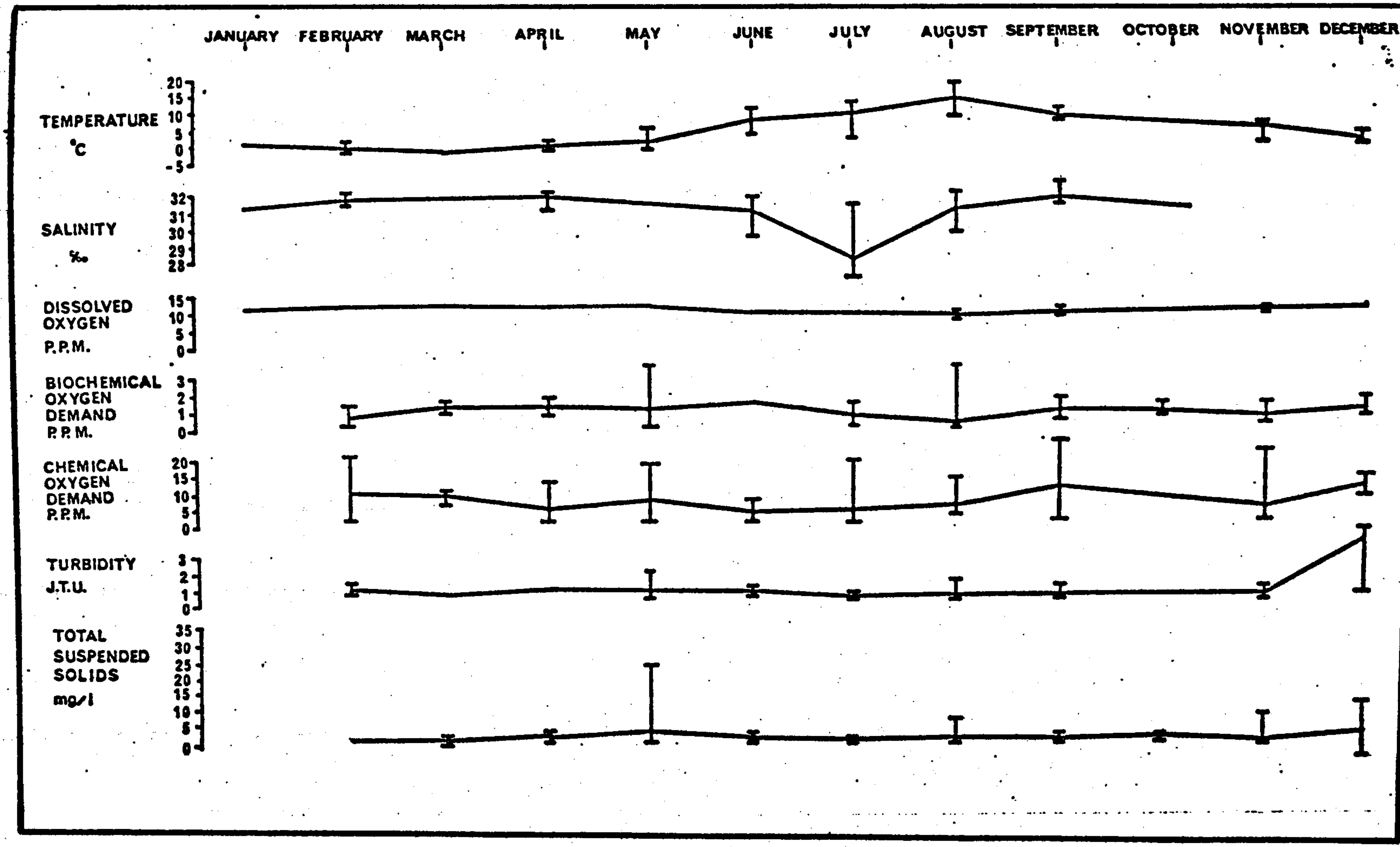


FIGURE 19 MONTHLY MEANS AND RANGES OF PARAMETERS MEASURED IN COME BY CHANCE BAY (JULY 1971 - DECEMBER 1973), STATION 2

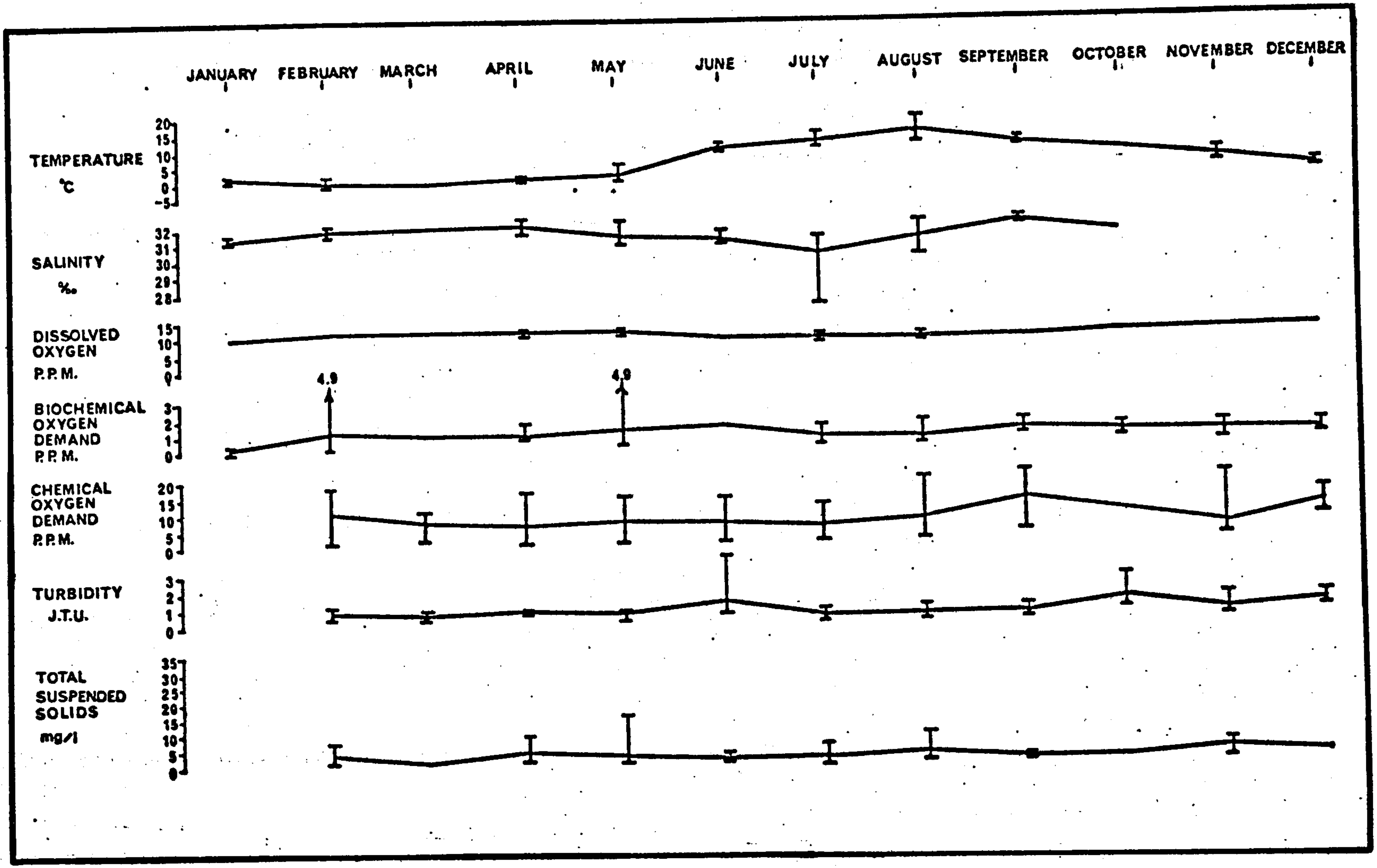


FIGURE 20 MONTHLY MEANS AND RANGES OF PARAMETERS MEASURED IN COME CHANCE BAY (JULY 1971 - DECEMBER 1973), STATION 3

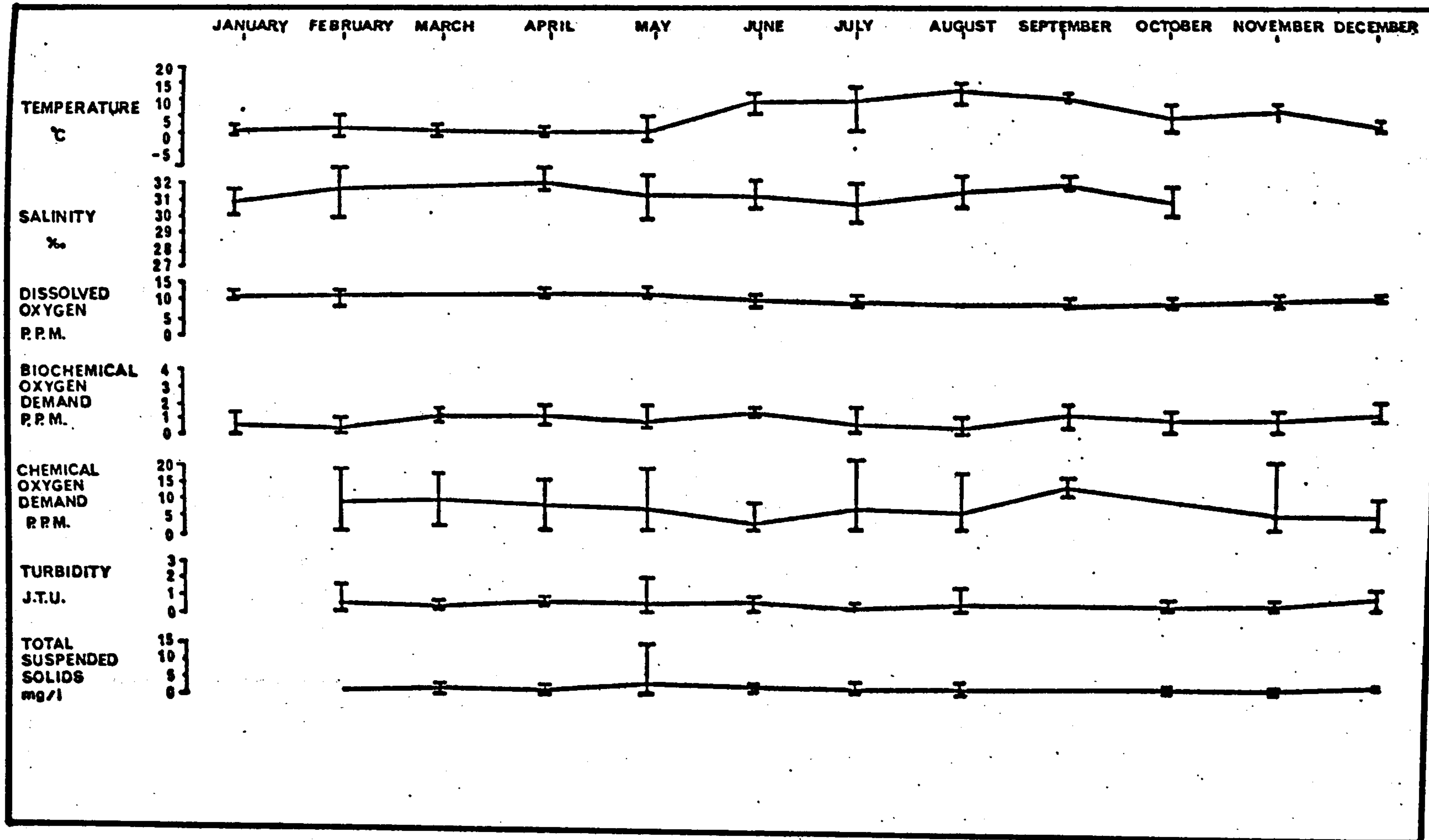


FIGURE 21 MONTHLY MEANS AND RANGES OF PARAMETERS MEASURED IN COME BY CHANCE BAY (JULY 1971 - DECEMBER 1973), STATION 4

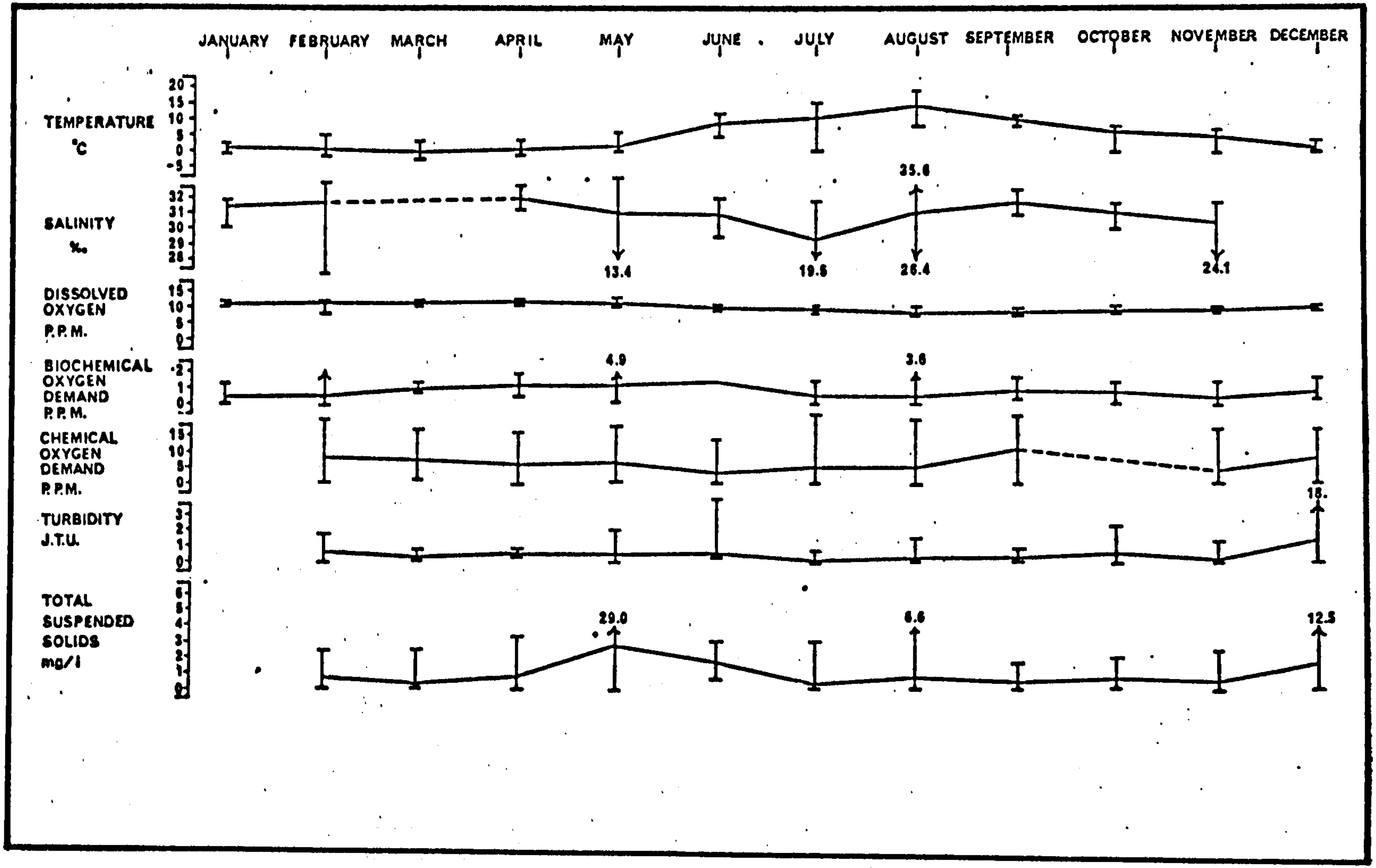


FIGURE 22 MONTHLY MEANS AND RANGES OF PARAMETERS MEASURED IN COME BY CHANCE BAY (JULY 1971 - DECEMBER 1973) ALL STATIONS

5.0 DISCUSSION

The information presented thusfar should provide a sound basis for determination of future changes induced by refinery operation. The biota selected for study (benthic and intertidal macro-invertebrates) are less mobile than fish or planktonic organisms, exhibit differential tolerances to various pollutants or changes and therefore meet many of the criteria of ideal indicators (McErlean *et al*, 1972). In addition, because these organisms have unusual respiratory, food gathering, and reproductive adaptations, they form characteristic assemblages or communities which are associated with particular water quality conditions (Olive and Dambach, 1973). Changes induced by refinery operation should therefore be reflected not only in altered water quality, but also in disruptions in the extent and structure of both intertidal and benthic invertebrate communities.

5.1 Diversity indices

The use of diversity indices to determine the "biological health" of a community of organisms is based on the theory that diversity is equated with the uncertainty that exists concerning the species of an individual specimen selected at random from a community (Cairns & Dickson, 1971). Water which is uninfluenced by the effects of pollution will usually have a greater number of taxa with a more or less even distribution of individuals among those taxa. Therefore, the uncertainty of randomly selecting an individual of a particular species, in such a case, is high and, by definition, the diversity of that assemblage of organisms is also high.

In contrast, ecosystems stressed by the effects of pollution often exhibit communities comprised of relatively fewer taxa with reduced species equitability. This leads to reduced uncertainty in selecting individuals of a particular species, and hence reduced diversity.

Diversity is generally expected to decrease following any recognizable alteration of an ecosystem and therefore should be a good biological indicator for most forms of water pollution (Cole, 1973). In addition to being a number which represents the pollutional state of a community, however, these indices also provide insight into the functional stability of an ecosystem. Community organization is the result of an intricate system of regulatory mechanisms such as predator-prey and host-parasite relationships which prevent extreme population fluctuations and such highly organized communities are therefore stable (Tenore, 1972). Changes in diversity indices, therefore, also indicate that a community which is becoming less diverse is also becoming less stable, and such a community is undoubtedly less able to cope with additional cultural or natural stresses introduced into its environment. Such influences as freshwater runoff, disturbance of sediments by storms, and radical temperature fluctuations could very severely alter an ecosystem which previously would have been only slightly affected.

The range of diversity indices used in the present study should provide an adequate basis for future comparisons once the refinery at Come by Chance has been in operation for a period of time. These values are representative of the present pristine environment at Come by Chance. Future changes in these parameters should be indicative of an influence induced by refinery operation.

The relationship between diversity and depth of sampling observed in this study is indicative of the unidirectional trend in diversity along a stability gradient described by Johnson (1970). As depth of sampling increases from zero (intertidal zone) to nine fathoms, environmental conditions become more stable and there is therefore an increase in diversity. Simpson's index is inversely related to depth, however, because it is a measure of dominance, and as such tends to decrease in more stable environments. In future, decreases in diversity caused by pollutional stress should be detected either by changes in the slopes of the lines representing this relationship, or by shifts in the position of these curves. For example, stress in the intertidal and shallow sub-tidal zones caused by frequent small or large scale oil spills could cause decreases in the diversity of communities at these depths. This would cause the slopes of the diversity-depth curves to change even though the deeper subtidal communities may not be affected. If, on the other hand, stress is induced by process effluent entering the Bay, it is possible that all depths will be detrimentally affected. Should this occur, the entire line could shift to a position lower on the scale of diversity. The degree of shift should be indicative of the severity of the stress that these chemicals are inducing.

The relationship between diversity and distance should also provide a means of evaluating future changes. At present, two indices (Margalef's and Shannon's) show a significant correlation with distance from the refinery site. This may be explained by variations in the amounts of the coralline alga *Lithothamnion* and various other macrophyte algal forms, or possibly by the fact that the closer stations are more "protected" and less open to influence from the open ocean. The presence or absence of these organisms would tend to alter the habitat available to benthic macro-fauna and thus a change in diversity at these stations would be expected. Should refinery operation adversely influence the biota at stations close to the refinery, a general decrease in diversity should be noticed. The slopes of these curves should therefore change such that the stations closer to the refinery display a lower value of diversity than those located at greater distance. Unless a catastrophic spill occurs, however, it is unlikely that the whole line would shift as was the case with the depth-diversity relationship.

In addition, direct statistical comparison between diversity indices determined at each station before refinery operation began and those calculated for post operation situations should provide insight into any influence the refinery may be exerting.

5.2 Cluster analysis of stations

The use of cluster anlaysis has recently become popular in delineating the extent of benthic macro-invertebrate communities. Several authors have used this technique to study problems ranging from the effects of hydro-electric development on a large river (Cairns *et al*, 1970) to determination of factors affecting the distribution of coastal marine benthos (Field, 1970). Studies by Environment Canada (Fisheries and Marine Service) have also employed this type of analysis to study the distribution of benthic macro-invertebrates in rivers receiving wastes from a variety of industrial complexes (Gregory and Lock, 1973a, b; Lock and Gregory, 1973). In the present study, this technique was used to develop base-line information on coastal marine benthic communities in a bay to receive refinery wastes.

Analysis of intertidal collections indicated that most stations contained species representative of the same community of organisms. Although there was no tendency for stations to aggregate spatially, there was some indication of temporal variation in cluster formation. This, however, is a common phenomenon noted in previous studies (Cairns *et al*, 1970; Kaesler and Cairns, 1972; Kaesler *et al*, 1971; and Cairns and Kaesler, 1971), occurred only at a high level of similarity, and is probably a function of variations in sampling technique rather than a true indication of changes in community structure.

Future changes in intertidal community structure caused by contact with oil or refinery process wastes should be reflected in spatial and/or temporal variations in dendogram pattern. Influences restricted to the immediate vicinity of the refinery site should cause spatial changes in community delineation. Stations exposed to such wastes may be expected to undergo shifts in species types such that these locations develop communities of organisms unlike those which presently exist. This type of change should be reflected by formation of clusters, by the affected stations, which do not join the main aggregations until relatively low levels of similarity are achieved. Should large-scale disruptions occur, such as massive oil spills or excessive influxes of process waste, temporal changes in cluster formation should develop to a greater extent than is now evident.

As in the analysis of intertidal stations, similarity analysis of subtidal sampling locations revealed that temporal variations in cluster formation existed, such that stations tended to aggregate more closely with other stations sampled in the same year. In addition, a third cluster was formed by shallow water stations (3 Fathoms). This is to be expected, however, for as depth of sampling increases, a stress or stability gradient is evident (Johnson, 1970) such that organisms exposed to shallow waters encounter a less stable more stressful environment. This would indicate, therefore, that organisms found at 3 fathoms are part of a micro-community within the confines of the larger community which includes organisms from all depths.

Once these three aggregations combine into a single cluster (at a similarity value of 50%), it is possible to assume that they define the limits of a single community of organisms. Field (1970), using the same technique, described stations grouping at levels as low as 30% to be members of the same community. It should be re-emphasized, however, that several stations (ST8-3-72, ST1-W-73, ST6-6-73, ST4-3-72, ST3-3-72, ST6-3-72, ST8-6-73 and ST1-E-73) remained separate until relatively low levels of similarity were attained. The reasons for this are not readily apparent. It is possible that variations in sampling technique or damage to stored samples occurred, although true variations in organisms present cannot be discounted. Examination of species diversity indices for these stations (Appendix IV) indicates that while some (ST3-3-72, and ST6-3-72) do indeed have low species diversity, others display values the same as or well above the mean values for both years. It is possible that these stations are separate for totally different reasons and it is important, therefore, to examine closely any deviations in future dendogram pattern.

If refinery operation does lead to disruption in benthic macro-invertebrate communities, the changes induced may be detected by comparing future dendogram patterns with those presented here. Should damage occur to shallow subtidal stations, a future dendogram should also show stations at these depths joining the main aggregation at levels lower than those determined in this study. Should damage extend into deeper water, stations at six and nine fathoms would also be separated during the clustering technique. Again, temporal and spatial shifts such as those described for the intertidal analysis may be expected to occur depending on the size and extent of future disruptions.

5.3 Cluster analysis of species

The results presented in section 4.3 should provide a basis for determining future changes in community organization. In the two environments sampled (intertidal and subtidal) lists of common or indicator organisms were established. These lists are representative of the type of community found in each environment, and should be the types of organisms found at future sampling dates. Although the number of organisms in each indicator group is small in comparison to the total number of animals collected (eg 20 vs 113), it is a change in these indicator groups that will reveal an altered community structure rather than the absence of one of the many less common organisms sampled.

Should refinery induced changes occur, it is reasonable to expect that future indicator groups will be different from those established here. Organisms now included in indicator groups, but which have low tolerance to either refinery effluent or crude or refined product, may be absent at future sampling dates. Absence of these animals will cause the production of dendogram patterns different from those established here and consequently different lists of indicator organisms should emerge. At present, the temporal variation in indicator lists is small. Should refinery induced changes occur, it may be expected that future indicator groups will be markedly different from those now established.

This type of analysis is important, therefore, because it is capable not only of indicating that community changes occur, but also precisely which organisms are 'lost' and hence why the community type has become altered. Such knowledge will be valuable in predicting future changes in energy flow through various organization levels, and thus possibly changes in interactions between various commercial and non-commercial species.

5.4 Water quality

In order for the changes discussed thusfar to occur, it is reasonable to expect that some degeneration in the present water quality must first take place. At present, most of the measured parameters fall well within the ranges observed for other coastal waters at similar lattitudes. (Siebert, 1972; Foote, 1973; Sverdrup *et al*, 1942). This fact, plus the low values recorded for the 'pollution' parameters in this study, indicates that Come by Chance Bay is presently in a pristine state relatively unaffected by the activities of man.

In order that this situation continue, however, it is important to stress that proper waste treatment practices be maintained. Failure to do so could lead to changes in the quality of these waters and subsequent damage to both the ecological and economic productivity of Come by Chance and upper Placentia Bays. Introduction of such toxic chemicals as phenols, ammonia, hydrocarbon, etc, in addition to causing direct harm to the biota present could conceivably cause changes in such parameters as dissolved oxygen, biochemical oxygen demand, chemical oxygen demand, etc, and these changes could in turn exert an influence on the existing subtidal and intertidal communities. Should waste treatment practices and handling of crude oil and refined products not be maintained at a high level of efficiency, further changes in water quality and community structure may soon be noted with a corresponding impact on the biological and economic productivity of Come by Chance and possibly Upper Placentia Bay.

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APPENDIX I

Expected composition of waste water leaving refinery site and entering Come by Chance Bay*

Constituent	Concentration p.p.m.
BOD	20
COD	-
Solids (Dissolved)	-
Solids (Suspended)	30
Oils (By Distillation)	15
Floating Debris, Oils, etc.	None visible
pH	6.0 - 9.0
Ammonia	10.0
Radioactive Substances (Picocuries/litre)	100
Arsenic	1.0
Barium	5.0
Cadmium	0.05
Chromium (Hexavalent)	0.05
(Trivalent)	1.0
Copper	0.1
Cyanide	0.025
Iron (Total)	10.0
Lead	0.1
Mercury	.005
Nickel	2.0
Nitrates	.15
Nitrogen (Ammoniacal)	10.
Phenol	0.1
Selenium	0.01
Silver	0.05
Phosphate (Total as P_2O_5)	1.0
Phosphorus (Elemental)	None detectable
Zinc	1.0
Sulphides	-
Cobalt	-
Sulphur (H_2S + Mercaptans)	-

*Procon (Great Britain) Ltd. 1971

APPENDIX II

Checklist of all species identified from sampling at Come by Chance 1972 and 1973

PHYLUM Genus and Species	Come by Chance	Confirmation by National Museum
PORIFERA		
Grantia sp.	X	
Leucosolenia sp.	X	
Haliclona sp.	X	
Mycale ovulum		
COELENTERATA		
Metridium senile	X	
MOLLUSCA		
Acmaea testudinalis	X	
Addisonia paradoxa	X	
Puncturella noachina	X	X
Veluntina undata	X	X
Ischnochiton ruber	X	X
Ischnochiton albus	X	X
Buccinium undatum	X	X
Calliostoma sp.	X	
Lacuna vincta	X	X
Littorina littorea	X	
Littorina obtusata	X	X
Littorina saxatilis	X	X
Lora nobilis	X	
Lunatia heros	X	
Margarites costalis	X	
Margarites helicina	X	
Skena planorbis	X	
Thais lapillus	X	
Tonicella marmorea		
Turbonilla interrupta	X	X

APPENDIX II (Continued)

PHYLUM Genus and Species	Come by Chance	Confirmation by National Museum
Turretella sp.	X	
Cuthona concinna	X	
Lamellidoris sp.	X	
Hydrobia minuta	X	
Anomia aculeata	X	X
Anomia simplex	X	
Anomia ephippum	X	
Arctica islandica		
Cerastoderma pinnulatum	X	
Crenella glandula	X	
Hiatella arctica	X	
Hiatella striata		
Macoma calcarea	X	X
Musculus corrugatus		
Mya arenaria	X	
Mytilus.edulis	X	
Serripes groenlandicus		
Placopecten megellanicus	X	
Tellina agilis	X	X
Volsella modiolus	X	
<u>ANNELIDA</u>		
Amphitrite cirrata	X	X
Amphitrite johnstoni	X	X
Autolytus alexandri	X	X
Autolytus cornutus	X	X
Capitella capitata	X	
Chone sp.	X	X
Cirratulus cirratus	X	
Cossura longicirrata	X	
Dodecaceria concharum	X	X

APPENDIX II (Continued)

PHYLUM Genus and Species	Come by Chance	Confirmation by National Museum
Euchone rubrocineta	X	X
Eulalia viridis	X	
Eumida fusigera	X	X
Eumida sanguinea	X	
Eusyllis blomstrandi	X	
Eteone longa	X	X
Exogone hebes	X	X
Exogonella sp.	X	X
Fabricia sabella	X	X
Flabelligera affinis		
Glycera dibrachiata	X	
Harmothoe imbricata	X	
Lepidonotus squamatus	X	X
Loimia medusa		X
Lumbrineris fragilis	X	X
Lumbrineris latreilli	X	X
Myxicola infundibulum	X	X
Naineris quadricuspida	X	X
Nephtys bucera	X	X
Nereis grayi	X	X
Nereis pelagica	X	X
Nereis virens	X	
Nereis zonata	X	X
Nichomache lumbricalis	X	X
Nicolea venustula	X	X
Nephtys incisa		
Paraonis gracilis	X	
Pectinaria gouldi	X	
Pheursa affinis	X	X
Pholoe minuta	X	X

APPENDIX II (Continued)

PHYLUM Genus and Species	Come by Chance	Confirmation by National Museum
Platyneris dumerilli magalops		
Phyllodoce maculata	X	X
Phylloduce mucosa	X	
Polycirrus phosphorus	X	X
Polydora socialis	X	X
Sabella crassicornis	X	X
Scopolos sp.	X	X
Sphaerosyllis erinaceus	X	X
Spio sp.	X	X
Spirobis spp.	X	
Sthenelais limicola		
Syllis cornuta	X	X
Stauronereis sp.	X	X
Tharyx sp.	X	X
Thelepus cincinnatus		
Oligochaeta spp.	X	X
NEMERTEA		
Amphiporus angulosus	X	X
Lineus bicolor	X	X
PLATYHELMINTHES		
Polyclad sp.	X	
Triclad sp.	X	
SIPUNCULA		
Golfingia sp.	X	
Phasicolon sp.	X	
ECHIVRIDA		
Thalassema	X	

APPENDIX II (Continued)

PHYLUM Genus and Species	Come by Chance	Confirmation by National Museum
ARTHROPODA		
Mite sp.	X	
Chironomid larvae	X	
Balanus balanus	X	X
Balanus balanoides	X	
Tisbe sp.	X	
Gnathia cerina	X	X
Idothea baltica		
Jaera marina	X	X
Jassa falcata		
Amphithoe rubricata	X	X
Calliopius laeviusculus	X	
Caprella septrionalis	X	X
Dexamine spinosa	X	
Gammarellus angulosus	X	
Gammarus lawrencianus	X	
Gammarus oceanicus	X	X
Hyale nilssoni	X	
Ischyrocerous anguipes	X	X
Leucothoe sp.		
Lysianopsis sp. (*alba*)		
Melita dentata	X	
Monoculodes tesselatus	X	X
Paramphithoe sp.	X	
Phoxocephalus holbolli	X	X
Pontogenia inermis	X	X
Pleusymtes glaber	X	X
Metopa sp.	X	X
Metopella sp.	X	X
Cancer borealis	X	X

APPENDIX II (Continued)

PHYLUM Genus and Species	Come by Chance	Confirmation by National Museum
Cancer irroratus	X	X
Hyas coarctatus	X	X
Pagurus acadianus	X	X
Pagurus pubescens	X	X
Homarus americanus	X	
Eualus pusiolus	X	X
Crangon septemspinosa		
<u>ECHINODERMATA</u>		
Echinarachnius parma	X	
Strongyloentrotus drobachiensis	X	
Asterias vulgaris	X	
Leptasterias vulgaris	X	
Henricia sanguinolenta	X	X
Solaster endeca		
Solaster papposus	X	
Amphipholis squamata	X	
Ophiopholis accleata	X	
Ophiura robusta	X	
Chiridata laevis	X	
<u>CHORDATA</u>		
Ascidia prunum	X	
Ascidia sp.	X	
Boltenia echinata	X	
Molgula citrina	X	
Molgula sp.	X	
Aplidium glabrum	X	
Dendrodoa sp.	X	
Botrylloides sp.	X	
Halocynthia pyriformis	X	

APPENDIX III

Wet weights of *Lithothamnion* spp. collected at subtidal sampling locations in 1972 and 1973

Station	Weight in Grams	
	1972	1973
1 - 3 F* East	1,070	602
1 - 3 F West	50	244
3 - 3 F	0	0
3 - 6 F	181	2,305
3 - 9 F	0	4,836
4 - 3 F	0	39
4 - 6 F	205	11,409
4 - 9 F	4,095	6,398
6 - 3 F	31	0
6 - 6 F	11,118	6,900
6 - 9 F	1,283	4,335
7 - 3 F	3,044	2,139
7 - 6 F	6,264	5,306
7 - 9 F	10,391	6,341
10 - 3 F	0	11
10 - 6 F	10,818	894
10 - 9 F	38,054	6,668
12 - 3 F	309	25
12 - 6 F	5,894	5,869
12 - 9 F	1,692	2,840
13 - 3 F	558	10
13 - 6 F	3,575	0
13 - 9 F	1,040	622

*F = Fathoms.

APPENDIX IV

Table 1

Species Diversity Indices for 1972 Sampling

Station		Depth	No. of species	Total individuals	McIntosh	Margalef	Shannon	Simpson
Intertidal	1	0	11	719	.4837	1.5203	1.5475	.2855
	2	0	24	2,573	.6594	2.9289	2.3899	.1250
	3	0	14	9,302	.1789	1.4226	.7691	.6772
	4	0	28	3,512	.5375	3.3075	2.007	.2222
	5	0	32	17,654	.3006	3.1701	1.2962	.4924
	6	0	20	1,479	.5013	2.6031	1.8595	.2619
	7	0	21	9,876	.2097	2.1744	.9461	.1279
	8	0	25	31,453	.3727	2.3174	1.1915	.3961
	9	0	12	472	.5699	1.8706	2.0258	.3441
	10	0	16	10,304	.3472	1.6233	1.0802	.4307
	11	0	16	4,318	.1852	1.7920	.8667	.6685
	12	0	24	5,142	.4677	2.6916	1.9414	.2903
Benthic	1	3 E East	31	483	.6785	4.1925	2.4305	.1241
	1	3 F West	16	139	.5194	3.0398	1.7462	.2753
Benthic	2	3 F	20	269	.6741	3.3961	2.2826	.1347
	2	6 F	24	295	.5880	3.8685	2.0570	.1991
	2	9 F	20	167	.5808	3.7124	2.0081	.2154
Benthic	3	3 F	12	151	.2027	2.1924	.8347	.6623
	3	6 F	26	1,339	.2423	3.4724	1.0476	.5842
	3	9 F	34	1,162	.6208	4.6756	2.1725	.1579
Benthic	4	3 F	28	264	.7387	4.8422	2.7237	.0941
	4	6 F	52	2,253	.6420	6.6062	2.3872	.1380
	4	9 F	36	876	.5856	5.1658	2.2242	.1885
Benthic	5	3 F	26	578	.6076	3.9311	2.2314	.1744
	5	6 F	45	3,675	.6174	5.3598	2.2778	.1543
	5	9 F	64	3,030	.6105	7.8590	2.3249	.1605

APPENDIX IV

Table 1 (Continued)

Station		Depth	No. of species	Total individuals	McIntosh	Margalef	Shannon	Simpson
Benthic	6	3 F	3	98	.3325	2.6172	1.2343	.4915
	6	6 F	59	1,917	.7154	7.6735	2.8469	.0905
	6	9 F	53	2,576	.5863	6.6208	2.2101	.1808
Benthic	7	3 F	44	1,145	.6275	6.1052	2.3622	.1529
	7	6 F	36	1,094	.6537	5.0017	2.4836	.1340
	7	9 F	36	587	.7245	5.4902	2.6936	.0933
Benthic	8	3 F	51	1,422	.5682	6.8892	2.2515	.1983
	8	6 F	46	2,149	.6775	5.8649	2.4949	.1137
	8	9 F	44	600	.7158	6.7220	2.7661	.0982

APPENDIX IV

Table 2

Species Diversity Indices for 1973 Sampling

Station	Depth	No. of species	Total individuals	McIntosh	Margalef	Shannon	Simpson
Intertidal 1		18	3,208	.4916	2.1057	1.8424	.0267
2		17	1,052	.5937	2.2994	1.9614	.1803
3		25	6,755	.2876	2.7217	1.2021	.5126
4		24	8,561	.5037	2.5400	1.8699	.2517
5		24	16,915	.3597	2.3623	1.5457	.4138
6		25	11,228	.5104	2.5738	1.9996	.2437
7		25	7,935	.5998	2.6729	2.1513	.1656
8		26	5,794	.6517	2.8853	2.3909	.1273
9		35	19,157	.6701	3.5895	1.9031	.0519
10		15	4,380	.5127	1.6697	1.7112	.2451
11		24	6,297	.6054	2.6292	2.2787	.1618
12		27	6,732	.6623	2.9496	2.3985	.1196
Benthic • 1	3 F East	11	38	.7070	2.7491	2.0125	.1662
• 1	3 F West	27	141	.8076	5.2691	2.9182	.0661
Benthic 2	3 F	25	493	.4031	3.8706	1.6711	.3783
2	6 F	19	364	.6285	3.0523	2.1875	.1635
2	9 F	34	1,352	.6447	4.5774	2.3186	.1390
Benthic 3	3 F	28	314	.5499	4.6961	2.1673	.2314
3	6 F	26	1,689	.6828	3.3639	2.3606	.1114
3	9 F	31	1,602	.4470	4.0656	1.7729	.3183
Benthic 4	3 F	12	241	.3273	2.0055	1.2236	.4814
4	6 F	43	1,468	.7162	5.7595	2.6825	.0916
4	9 F	53	1,274	.7027	7.2728	2.7592	.1005
Benthic 5	3 F	16	261	.7208	2.6957	2.3739	.1048
5	6 F	33	837	.6986	4.7550	2.5703	.1060
5	9 F	40	2,644	.3419	4.9492	1.4211	.4419

APPENDIX IV

Table 2 (Continued)

Station		Depth	No. of species	Total indi-viduals	McIntosh	Margalef	Shannon	Simpson
Benthic	6	3 F	27	264	.5743	4.6629	2.1284	.2126
	6	6 F	18	151	.6967	3.3883	2.3805	.1296
	6	9 F	41	945	.6016	5.8384	2.3208	.1747
Benthic	7	3 F	33	809	.5746	4.7073	2.3869	.2425
	7	6 F	32	858	.7031	4.5895	2.5105	.1030
	7	9 F	34	530	.7021	5.2607	2.6617	.1078
Benthic	8	3 F	25	397	.6367	4.0057	2.2282	.1585
	8	6 F	14	108	.6199	2.7765	1.9652	.1934
	8	9 F	39	320	.7001	6.5877	2.8401	.1149

APPENDIX IV

Table 3

Mean Values of McIntosh Index for 1972 Sampling Locations

Location	n*	Mean Diversity	Standard Deviation
All Intertidal Stations	12	.4011	.1599
Station 1 Benthic	2	.5989	.1125
" 2 "	3	.6143	.0519
" 3 "	3	.3552	.2308
" 4 "	3	.6554	.0774
" 5 "	3	.6118	.0050
" 6 "	3	.5447	.1948
" 7 "	3	.6685	.0501
" 8 "	3	.6538	.0765
All 3 Fathom Stations	9	.5499	.1753
All 6 Fathom Stations	7	.5909	.1590
All 9 Fathom Stations	7	.6320	.0619
All Benthic Stations	23	.5873	.1426

*n = number of individual values in sample.

APPENDIX IV

Table 4

Mean Values of Margalef's Index for 1972 Sampling Locations

Location	n*	Mean Diversity	Standard Deviation
All Intertidal Stations	12	2.2049	.6202
Station 1 Benthic	2	3.8661	1.1686
" 2 "	3	3.6590	.2406
" 3 "	3	3.4468	1.2417
" 4 "	3	5.5380	.9390
" 5 "	3	5.7166	1.9881
" 6 "	3	5.6371	2.6678
" 7 "	3	5.5323	.5529
" 8 "	3	6.4920	.5495
All 3 Fathom Stations	9	4.1895	1.5857
All 6 Fathom Stations	7	5.4067	1.4754
All 9 Fathom Stations	7	5.7494	1.4062
All Benthic Stations	23	5.0345	1.5956

n* = number of individual values in sample.

APPENDIX IV

Table 5

Mean Values of Shannon's Index for 1972 Sampling Locations

Location	n*	Mean Diversity	Standard Deviation
All Intertidal Stations	12	1.4934	.5399
Station 1 Benthic	2	2.0883	.4838
" 2 "	3	2.1159	.1464
" 3 "	3	1.3516	.7188
" 4 "	3	2.4450	.2547
" 5 "	3	2.2780	.0467
" 6 "	3	2.0971	.8122
" 7 "	3	2.5131	.1676
" 8 "	3	2.5041	.2574
All 3 Fathom Stations	9	2.0107	.6168
All 6 Fathom Stations	7	2.2278	.5730
All 9 Fathom Stations	7	2.3427	.2814
All Benthic Stations	23	2.1783	.5205

n* = number of individual values in sample.

APPENDIX IV

Table 6
Mean Values of Simpson's Index for 1972 Sampling Locations

Location	n*	Mean Diversity	Standard Deviation
All Intertidal Stations	12	.4018	.1821
Station 1 Benthic	2	.1997	.1069
" 2 "	3	.1830	.0426
" 3 "	3	.4681	.2714
" 4 "	3	.1402	.0472
" 5 "	3	.1630	.0102
" 6 "	3	.2542	.2103
" 7 "	3	.1267	.0304
" 8 "	3	.1367	.0538
All 3 Fathom Stations	9	.2564	.1936
All 6 Fathom Stations	7	.2019	.1719
All 9 Fathom Stations	7	.1563	.0456
All Benthic Stations	23	.2093	.1551

n* = number of individual values in sample.

APPENDIX IV

Table 7

Mean Values of McIntosh's Index for 1973 Sampling Locations

Location	n*	Mean Diversity	Standard Deviation
All Intertidal Stations	12	.5373	.1192
Station 1 Benthic	2	.7573	.0503
" 2 "	3	.5587	.1350
" 3 "	3	.5599	.1182
" 4 "	3	.5820	.2207
" 5 "	3	.5871	.2126
" 6 "	3	.6242	.0642
" 7 "	3	.6599	.0739
" 8 "	3	.6522	.0422
All 3 Fathom Stations	9	.5890	.1526
All 6 Fathom Stations	7	.6779	.0381
All 9 Fathom Stations	7	.5914	.1428
All Benthic Stations	23	.6168	.1270

n* = number of individual values in sample.

APPENDIX IV

Table 8

Mean Values of Margalef's Index for 1973 Sampling Locations

Location	n*	Mean Diversity	Standard Deviation
All Intertidal Stations	12	2.5832	.4730
Station 1 Benthic	2	4.0091	1.7819
" 2 "	3	3.8334	.7632
" 3 "	3	4.0418	.6664
" 4 "	3	5.0126	2.7119
" 5 "	3	3.4666	2.4016
" 6 "	3	4.6298	1.2253
" 7 "	3	4.8525	.3583
" 8 "	3	4.4566	1.9452
All 3 Fathom Stations	9	3.8513	1.1234
All 6 Fathom Stations	7	3.9550	1.0933
All 9 Fathom Stations	7	5.5074	1.1335
All Benthic Stations	23	4.3869	1.3082

n* = number of individual values in sample.

APPENDIX IV

Table 9

Mean Values of Shannon's Index for 1973 Sampling Locations

Location	n*	Mean Diversity	Standard Deviation
All Intertidal Stations	12	1.9379	.3496
Station 1 Benthic	2	2.4653	.6404
" 2 "	3	2.0590	.3423
" 3 "	3	2.1002	.2995
" 4 "	3	2.2217	.8652
" 5 "	3	2.1217	.6146
" 6 "	3	2.2765	.1317
" 7 "	3	2.5197	.1376
" 8 "	3	2.3445	.4488
All 3 Fathom Stations	9	2.1233	.4747
All 6 Fathom Stations	7	2.3795	.2429
All 9 Fathom Stations	7	2.2992	.5298
All Benthic Stations	23	2.2548	.4327

n* = number of individual values in sample.

APPENDIX IV

Table 10

Mean Values of Simpson's Index for 1973 Sampling Locations

Location	n*	Mean Diversity	Standard Deviation
All Intertidal Stations	12	.2083	.1401
Station 1 Benthic	2	.1161	.0707
" 2 "	3	.2269	.1316
" 3 "	3	.2203	.1038
" 4 "	3	.2245	.2225
" 5 "	3	.2175	.1942
" 6 "	3	.1723	.0415
" 7 "	3	.1511	.0791
" 8 "	3	.1556	.0393
All 3 Fathom Stations	9	.2268	.1310
All 6 Fathom Stations	7	.1283	.0370
All 9 Fathom Stations	7	.1995	.1307
All Benthic Stations	23	.1885	.1143

n* = number of individual values in sample.

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