

Changes in benthic communities along a presumed pollution gradient in Vancouver Harbour

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Objectives of this work during the MEQ Practical Workshop were to assess degree of pollution in Vancouver Harbour by analyzing macrobenthic community structure, and examine the potential usefulness of higher-level taxa of macrobenthos in detecting degree of pollution.

Samples for benthic community studies were collected with a Van Veen grab at 7 stations on a presumed pollution gradient from the head of Vancouver Harbour through to Howe Sound (see Section I, Fig. 1.2). 5 replicate grab samples were taken at each site. Sediments were immediately passed through a 0.5 mm sieve. Benthic organisms were removed from the sieve, and preliminary sorting of fauna was carried out in the West Vancouver Laboratory, Fisheries and Oceans Canada. Samples were preserved and transported to Russia and Korea for further analysis.

Detailed identification of polychaetes was completed at the Far Eastern Regional Hydrometeorological Institute (Vladivostok),

ophiuroids, nemertineans, crustaceans, sipunculans and others at the Institute of Marine Biology (Vladivostok), and molluscs at the Korean Ocean Research and Development Institute (Seoul). The data were then combined for community analyses using a station by species matrix.

The sediments were analyzed for grain size at KORDI using standard sieving and settling tube technique. It was shown that all stations are characterized by mud, except the Howe Sound station that is dominated by sand. 171 species were identified in the sorted 8 faunal groups. The stations were divided into 3 groups by species and abundance similarity: 2 stations in Port Moody Arm, 4 stations in the Inner and Outer Harbours, and 1 station in Howe Sound.

Some preliminary results on faunal composition (Fig. 1-3, Table 1), along with interpretation of changes relative to the data on contaminants in the sediments found by other researchers (Fig. 4) are presented in this report.

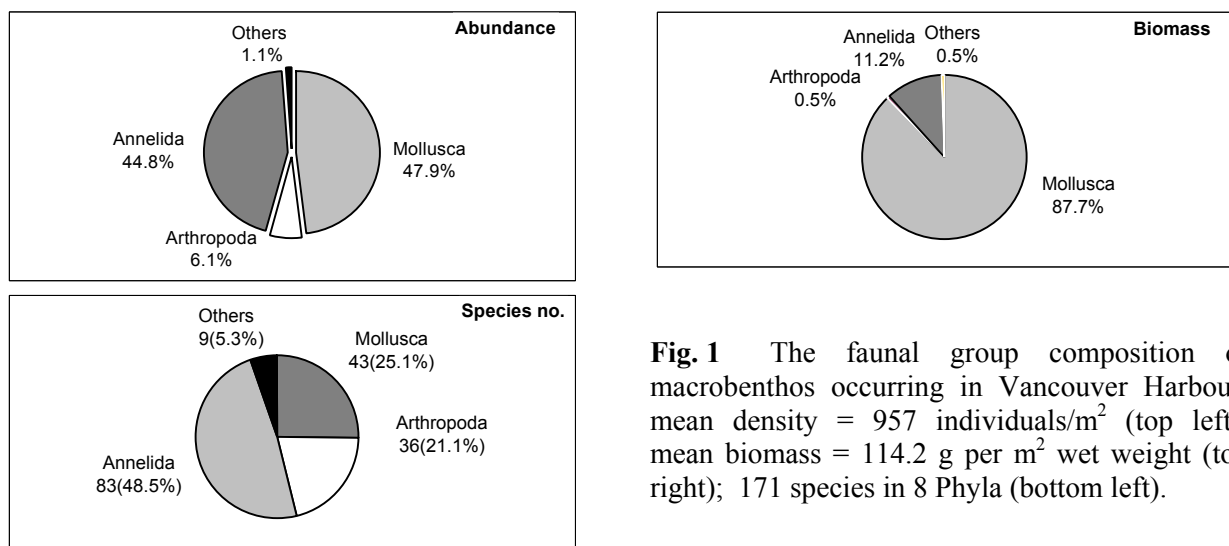


Fig. 1 The faunal group composition of macrobenthos occurring in Vancouver Harbour: mean density = 957 individuals/m² (top left); mean biomass = 114.2 g per m² wet weight (top right); 171 species in 8 Phyla (bottom left).

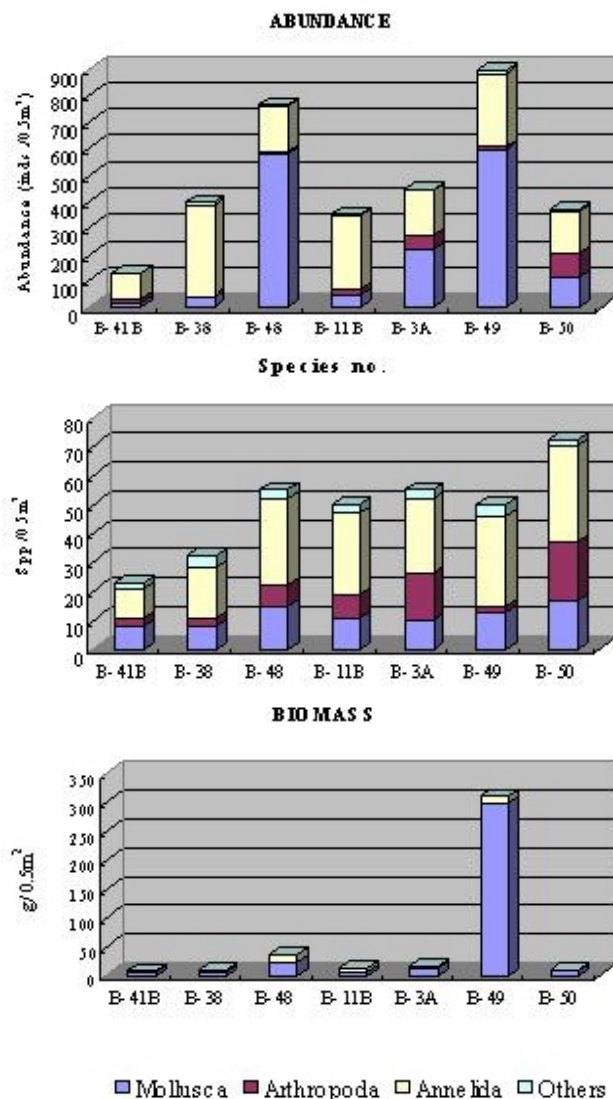


Fig. 2 The abundance (top left), biomass (top right) and species number (bottom left) of macrobenthos occurring in Vancouver Harbour.

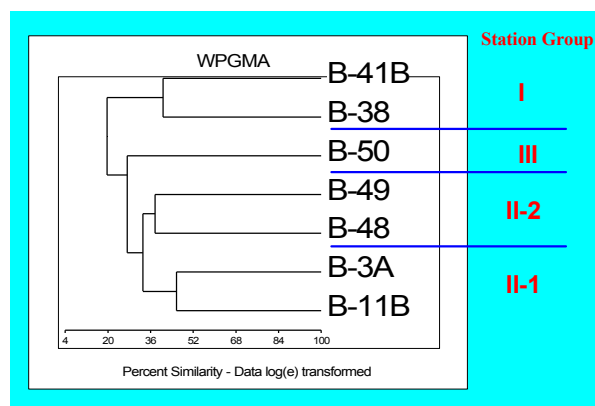


Fig. 3 A dendrogram from the cluster analysis using the abundance of macrobenthos occurring in study areas near Vancouver Harbour by percent similarity and weighted pair group average linkage.

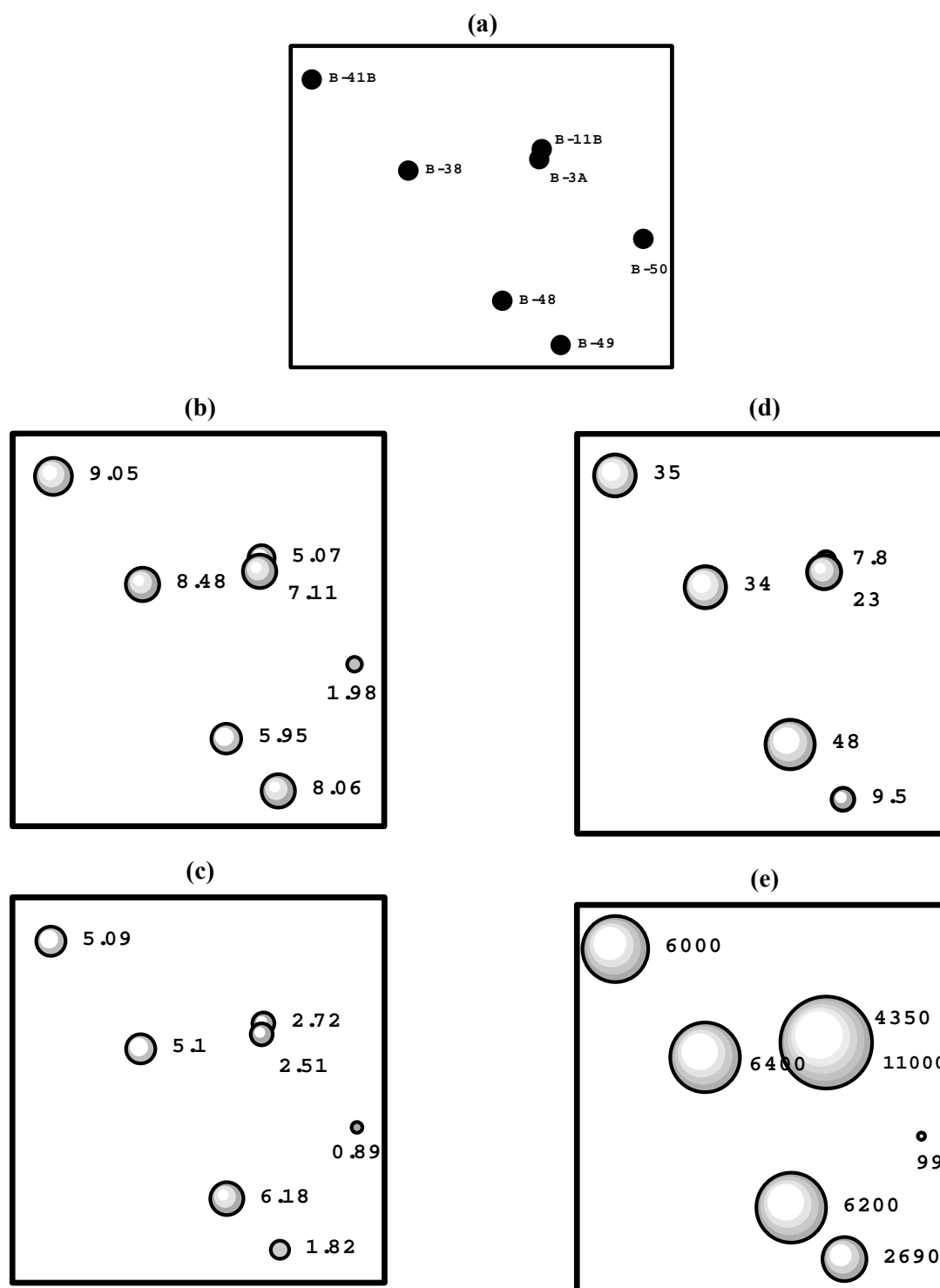


Fig. 4 MDS ordination of Bray-Curtis similarities from 4th-root transformed species abundance data at 7 stations (a); same MDS but with superimposed circles of increasing size with increasing concentration of Mz (b), organochlorine pesticides (c) polychlorinated biphenyls (d), and polycyclic aromatic hydrocarbons (e). Units for (c)-(e) are ng/g dry weight.

Table 1. Ecological parameters and dominant species in each station group.

	STATION GROUP			
PARAMETERS	I	II-1	II-2	III
Number of station (n)	2	2	2	1
Number of species	45	77	84	72
Mean no. of species (Spp./0.5m ²)	27.5	52.5	52.5	72
Mean density (Inds./m ²)	526.0	798.0	1658.0	732
ECOLOGICAL INDICES				
Species diversity (H')	2.06	2.87	2.28	3.51
Eveness (J)	0.63	0.73	0.58	0.82
DOMINANT SPECIES (INDS./M ²)				
<i>Tharyx multifilis</i> (P)	<u>235</u>	1	-	-
<i>Nephtys cornuta franciscanum</i> (P)	<u>81</u>	16	8	-
Spionidae indet.1 (P)	<u>45</u>	-	14	2
<i>Lumbrineris luti</i> (P)	<u>36</u>	<u>81</u>	57	<u>56</u>
<i>Axinopsida serricata</i> (M)	21	<u>104</u>	<u>717</u>	<u>96</u>
<i>Transenella tantilla</i> (M)	-	<u>89</u>	-	2
<i>Ophelina acuminata</i> (P)	-	<u>122</u>	13	-
Bivalvia indet.5 (M)	1	1	<u>161</u>	-
<i>Macoma calcarea</i> (M)	3	-	<u>143</u>	-
<i>Nucula tenuis</i> (M)	1	-	23	<u>52</u>
<i>Tellina capenteri</i> (M)	-	-	-	<u>26</u>
<i>Pinnixa rathbunae</i> (C)	5	-	-	<u>62</u>
Tanaidacea indet. (C)	-	-	-	<u>42</u>
<i>Chaetozone setosa</i> (P)	-	4	5	<u>30</u>
<i>Glycera</i> sp. (P)	1	-	6	<u>32</u>
<i>Nephtys firruginea</i> (P)	1	16	61	<u>30</u>
<i>Scoloplos armiger</i> (P)	-	3	1	<u>30</u>

- 1) Underline numbers are the mean density of dominant species in each station group;
2) P: polychaetes; M: molusks; C: crustaceans;
3) "-": not occurred.

Fish communities and life history attributes of English sole (*Pleuronectes vetulus*) in Vancouver Harbour

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Introduction

The species composition of fish communities has been proposed as a key variable to assess the biological integrity of estuarine ecosystems (Deegan *et al.* 1997), and is also used as a monitoring variable to detect changes in coastal water quality. In this paper, we report on the spatial changes and relative abundance of demersal or bottom dwelling fish in Vancouver Harbour, and evaluate the usefulness of the data for evaluation of environmental quality in the context of the PICES Practical Workshop. There are some data available on fish communities in Vancouver Harbour collected several decades or years ago (Levings 1973; Goyette and Thomas 1987, Goyette and Boyd 1989, Washington Dept of Fish and Wildlife 1995), enabling comparisons over the longer term. The English sole (*Pleuronectes vetulus*) was identified as a dominant demersal species in the earlier work. Because the physiological and health status of English sole was studied extensively by other investigators in the Workshop, basic data on length, weight, age and growth, and feeding were also obtained.

Methods

Field sampling

A small otter trawl (mesh size in body/wing 38 mm, 3.2 mm in codend, width of opening estimated 4.9 m) was towed by the NOAA vessel *Harold W. Streeter* at 5 stations, on a presumed pollution gradient from inner to outer Vancouver Harbour (see Section I, Fig 1.4; Table 1). Each station was sampled between 3 and 7 times. The net was towed between 5 and 10 minutes, and sampled an estimated area of between 1,643 to 8,570 m² in each trawl.

Table 1. Basic data on trawl stations in Vancouver Harbour* indicates one additional trawl completed but results discarded because of gear problems.

Site name	Station name	Number of trawls	Depth range (m)
Port Moody	T-38	3	11-14
Indian Arm	T-48	3	26-30
Lonsdale Quay	T-11B	4	24-26
West Vancouver Lab*	T-49	6	30-45
Gibsons-Howe Sound*	T-50	3	55-73

The catch from each trawl was sorted by species, then enumerated by species and weight. The larger invertebrates such as Dungeness crab (*Cancer magister*), tanner crab (*Chionocetes tanneri*), anemone (*Metridium* spp) and a few species of bivalve molluscs were also enumerated and weighed. The total length of each English sole in the catch was measured to the nearest millimetre. Data on weight, stomach content, and age were obtained for English sole specimens autopsied by Stehr et al. (this report) for physiological condition and histopathology. The minimum size for the latter studies was 25 cm, the approximate length of sexual maturity for this species. After autopsy, the stomach was removed from each fish and preserved in 3.7% formalin. For ageing, the right otolith was removed and placed in a glycerol-thymol mixture.

Laboratory methods

Stomach contents of a random sample of 10 English sole stomachs were examined in the laboratory. A Wild M-5 Stereomicroscope was used to enumerate organisms, which were identified to the major group level. Ages were

determined by the Fish Aging Unit, DFO Science Branch, Pacific Biological Station, Nanaimo. Condition factor was computed using Fulton's K where $K = wt/l^3 \times 10^5$.

Results

Fish community data

The mean number of fish species obtained in the trawls ranged from 11 (se 0.5) at station T-38 to 12.2 (se 0.2) at T-49. However based on the total number of species caught in the trawls at a particular site, the fish community at Station T-11B was most diverse (19 species), with the other stations as follows: T-38, 12 species; T-48, 16 species; T-49, 17 species; and T-50, 17 species. Mean biomass ranged from 0.65 kg·100 m⁻² (se 0.1) at T-38 to 0.15 kg·100 m⁻² (se 0.1) at T-11B,

and number of individuals from 350 100 m⁻² (se 50) to 100·100 m⁻² (102) at the latter 2 stations.

15 fish species accounted for at least 1% of the catch in the trawls at particular stations (Table 2). Flatfish (Pleuronectidae and Bothidae) were the dominant species, especially English sole (*Pleuronectes vetulus*), Starry flounder (*Platichthys stellatus*), Flathead sole (*Hippoglossoides elassodon*), Dover sole (*Microstomus pacificus*), Rex sole (*Errex zachirus*), slender sole (*Lyopsetta exilis*) and Rock sole (*Pleuronectes bilineatus*). Flatfish were the dominant taxa at the inner harbour station (T-38), accounting for more than 50% of the fish caught there. Other dominant species were the Pacific tomcod (*Microgadus proximus*) and the blackbelly eelpout (*Lycodopsis pacifica*). Species composition at the five sites differed significantly ($p < 0.05$) after testing with χ^2 .

Table 2. Percentage data for abundance of fish species accounting for at least 1% of catch (numerical data) at any of the five stations sampled in Vancouver Harbour. Percentages computed using only fish data.

Species/Station	T-38	T-48	T-11B	T-49	T-50
Longfin smelt	1.7	3.1	1.2	0.0	0.0
Herring	2.8	1.6	5.5	<1.0	0.0
Longnose skate	0.0	0.0	<1.0	0.0	0.0
Spiny dogfish	0.0	0.0	0.0	0.0	<1.0
Pacific hake	0.0	0.0	0.0	0.0	35.5
Walleye pollock	0.0	<1.0	0.0	0.0	0.0
Pacific tomcod	8.6	10.3	10.5	1.1	9.2
Shiner seaperch	4.1	1.0	1.0	<1.0	<1.0
Copper rockfish	0.0	0.0	0.0	0.0	<1.0
Tadpole sculpin	0.0	0.0	0.0	0.0	<1.0
Roughback sculpin	0.0	1.0	1.9	<1.0	0.0
Buffalo sculpin	0.0	0.0	<1.0	0.0	0.0
Staghorn sculpin	3.3	1.7	<1.0	<1.0	0.0
Sturgeon poacher	0.0	<1.0	1.0	<1.0	7.1
Midshipman	4.3	1.6	0.0	<1.0	<1.0
Whitespot greenling	0.0	<1.0	<1.0	0.0	0.0
Blackbelly eelpout	0.0	6.6	2.1	38.2	3.1
Flathead sole	1.0	14.7	1.0	14.1	1.6
Dover sole	13.1	0.0	0.0	1.3	<1.0
English sole	49.6	56.1	56.8	14.9	35.9
Rock sole	0.0	<1.0	6.2	1.5	<1.0
Slender sole	0.0	0.0	2.9	8.8	3.3
Starry flounder	9.6	1.0	4.5	5.7	0.0
Butter sole	0.0	0.0	<1.0	0.0	0.0
Rex sole	0.0	0.0	0.0	10.2	1.2
Sand sole	1.1	<1.0	2.6	1.3	0.0
Speckled sandab	0.0	0.0	0.0	0.0	<1.0
Pacific sandab	1.0	0.0	2.1	1.0	1.0

English sole life history features

Abundance

Mean abundance of English sole varied between the stations, ranging from about 6 fish·100 m⁻² (se 1) at station T-38 to <1·100 m⁻² (se 1) at station T-49. Biomass showed the same pattern, ranging from about 0.35 kg·100 m⁻² (se 0.05) at station T-38 to 0.05 kg·100 m⁻² (se 0.7) at station T-49. Abundance and biomass at station T-38 was significantly higher ($p<0.05$) compared to the other stations.

Length, sex ratio, and age

Mean English sole length was 291 mm (se 4.6) at Station T-38, 270 mm (se 4.7) at T-48, 242 mm (se 4.6) at T-11b, 254 mm (se 3.9) at T-49, and 240 mm (se 4.8) at T-50. As judged by ANOVA, lengths were significantly different between stations (Table 3, $p<0.05$), with the largest fish at Station T-38. Mean lengths at Station T-38 were statistically significant ($p<0.05$) when tested against all other stations. Comparisons among the other stations were variable.

Sex ratio

Female English sole were more common (chi - square, $P<0.05$) in the inner harbour stations (T-50, T-48, and T-11B) relative to the outer harbour stations (Table 4).

Age and growth

Age of the English sole ranged from 2 - 15 years (Fig. 2) and mean age over all stations and sexes was 7.3 y. Mean age at the various stations were 9.3 y at T-38, 7.4 y at T-48, 6.4 y at T-11B, 6.3 y at T-49, and 7.4 y at T-50. The percentage accounted for the various age groups was significantly ($p<0.05$) different over all the stations, as judged by chi-square. More older fish were found in the inner harbour stations. The only 14 and 15 y fish in the survey were caught at station T-38.

Table 3. Statistical comparisons of mean lengths of English sole at the five stations.

Station	T-50	T-48	T-11B	T-38	T-49
T-50	-	-	-		
T-48	<0.05	-	-		
T-11B	ns	<0.05	-		
T-38	<0.05	<0.05	<0.05	-	
T-49	ns	ns	ns	<0.05	-

Table 4. Percentage of male and female English sole at the five stations.

Site/sex	T-38	T-48	T-11B	T-49	T-50
Percent Female	75	86	76	45	44
Percent Male	25	14	24	55	56
Number of Fish	28	28	30	42	27

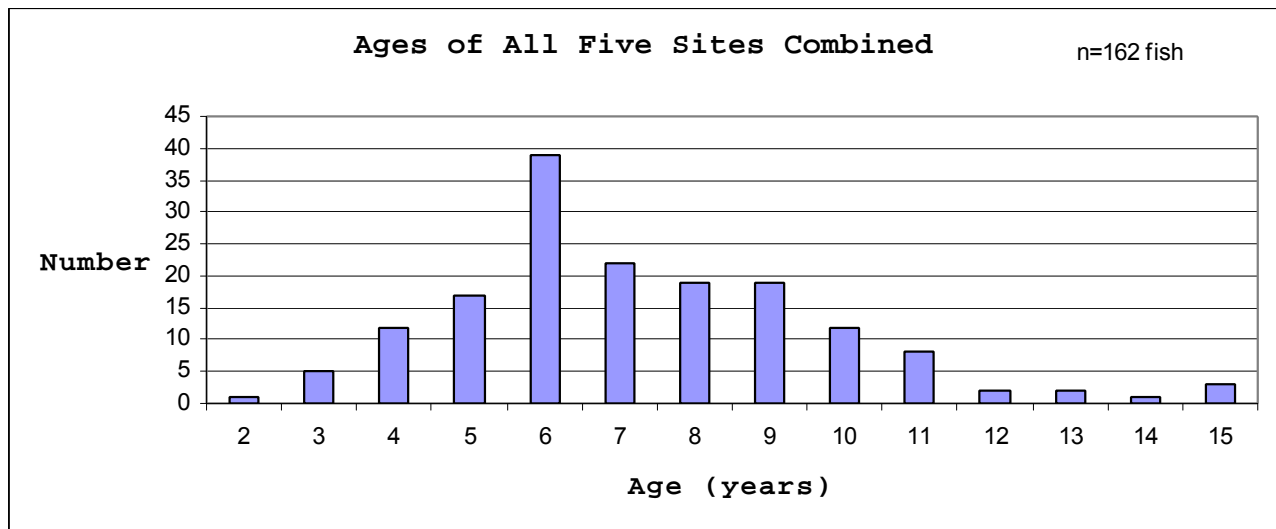


Fig. 2 Age distribution of English sole from all sample stations combined.

English sole growth was estimated by the slope of the regression line between age (x) and length (y). Using combined data for both males and females, English sole grew fastest at station T-11B ($y=9.35x + 182.25$), followed by T-38 ($y=3.31x + 265.77$), T-48 ($y=3.05x + 248.11$), T-50 ($y=1.92x + 225.92$), and T-49 ($y=1.69x + 243.30$).

Condition factor

Condition factor was lower for male and female English sole at Stations T-38 and T-50 ($K < 0.787$) relative to the other three stations ($K > 0.808$) (Table 5).

Table 5. Fulton's condition factor (K, se, and number of fish) for female and male English sole.

Station	Female English sole	Male English sole
T-38	0.787, 0.01, 21	0.726, 0.02, 7
T-48	0.821, 0.02, 24	0.808, 0.04, 4
T-11B	0.853, 0.01, 23	0.838, 0.02, 7
T-49	0.827, 0.02, 19	0.844, 0.01, 23
T-50	0.758, 0.02, 12	0.716, 0.02, 15

Feeding habits

In ranked order, annelid worms, bivalve molluscs, foraminifera, amphipods, and unidentified

crustaceans were the dominant organisms in English sole stomachs at all stations except T-38. At the latter station, annelid worms were the dominant taxa. The mean number of organisms per stomach ranged from about $48 \cdot \text{fish}^{-1}$ (se 10) at Station T-38 to $22 \cdot \text{fish}^{-1}$ (se 9) at Station 11-B.

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Marine environmental quality assessment using polychaete taxocene characteristics in Vancouver Harbour

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Introduction

An International Practical Workshop on biological effects of pollutants, organised by the Marine Quality Committee of PICES, took place from May 24 to June 7, 1999, in Vancouver, British Columbia, Canada. Specialists from all PICES member countries participated in the sampling and analysing of the data obtained to detect biological consequences of contaminants in the marine environment.

To evaluate marine environment quality, a set of chemical and biological properties was used. Biological properties included the characteristics of polychaete taxocene. Polychaetes are one of the most important groups of marine benthic animals. This group is characterised by high species richness and diversity as well as high biomass and density (up to 80% of total benthos abundance). In addition, polychaetes have a high level of tolerance to adverse effects – both to pollution and natural perturbation (Bryan and

Gibbs 1987; Burd and Brinkhurst 1990; Levings et al. 1985; Rygg 1985a, b). Thus, the state of polychaete taxocenes indicates the state of marine bottom communities as a whole. So, for marine environmental quality assessment we used characteristics of polychaete taxocene and sediment chemistry data.

Materials and methods

Sampling design

Benthic samples were collected in Vancouver Harbour in May-June of 1999 (see Section I, Fig. 1.2). 7 sites were sampled: one in Howe Sound (B-50), one in Outer Harbour (B-49), two in Inner Harbour (B-3A, B-11B), one in Indian Arm (B-48), two in Port Moody (B-38, B-41B). 5 replicate sediment samples were taken at each site with a Van-Veen grab (0.11 m²) to analyse a set of chemical and biological properties.

Sample processing

The sediments were washed by seawater through a 1-mm sieve, and residues including macrobenthos were preserved with a 4% buffered formaldehyde solution. In the laboratory, benthic organisms were sorted from the sediment to major taxa. All individuals were identified to species level, but some organisms could only be identified to higher taxa. Wet weight of macrofauna was determined: organisms were blotted and air-dried for approximately one minute prior to weighing (Bilyard and Becker 1987).

Data analysis

The software package PRIMER (Plymouth Routines In Multivariate Ecological Research), developed at the Plymouth Marine Laboratory was used for data analysis (Clarke and Green 1988, IOC 1983, UNEP 1995, UNESCO 1988). Univariate measures included Margalef richness index (R), Shannon-Wiener diversity index (H), Pielou evenness index (e), Simpson domination index (Si), total polychaetes biomass (B), abundance (N), and number of polychaetes species (S). Ecological indices were calculated as:

$$H = -\sum p_i \log_2 p_i,$$

$$e = H / \log_2 S$$

$$R = (S-1) / \log_2 N;$$

$$Si = \sum (p_i)^2$$

where p_i is the proportion of abundance i -th species from total abundance of polychaetes; S is total number of polychaetes species.

Multivariate techniques included ordination of benthic samples by Multi-Dimensional Scaling (MDS) and their classification by clustering. Clustering was done by a hierarchical agglomerative method which employs group-average linking of Bray-Curtis similarities, after the 4th root transformation. Species biomass data, excluding those with count less than 2% of total polychaete biomass, were used. Ordination of polychaete taxocene parameters and environment factors was by Principal Component Analysis (PCA).

Results and discussion

In total, 82 polychaete species were found. The biomass matrix consisted of 82 species at 7 sites, and was subjected to ordination and cluster-analysis. Results of ordination are shown in Figures 1. MDS technique detected 4 groups of stations according to dissimilarity of species composition. The reliability of this diagram was tested by value of stress coefficient. Low values

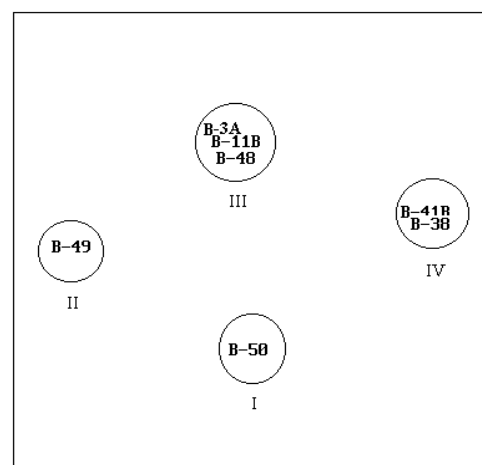
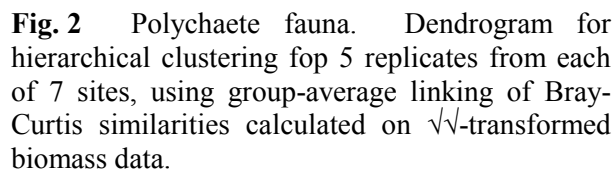


Fig. 1 Polychaete fauna. MDS ordination of Bray-Curtis similarities from vv-transformed species biomass data from 7 sites. MDS stress = 0.01.

Cluster-analysis confirmed the result of ordination, and detected the same 4 groups of stations as well, shown in Figures 2 and 3. The first diagram shows the results for 5 replicates, while the second diagram demonstrates the results of average biomass for 7 sites.



Species Group	Category	Bray-Curtis Similarity (approx.)
B-50	I	32
B-49	II	38
B-48	II	56
B-3a	III	47
B-11B	III	57
B-41B	IV	54
B-36	IV	54

Fig. 3 Polychaete fauna. Dendrogram for 7 sites.

Table 1. Pollutant concentrations adverse affects on marine benthic invertebrates.

Pollutants	ERL – Effect range-low¹	ERM –Effect range-medium²	Observed concentrations	Sites^{3,4}
Cd (ppm)	0.676–1.2	4.21–9.6	0.2–1.2	<u>B-3A</u>
Cr	52.3–81.0	160–370	25.0–68.3	<i>B-41B</i>
Cu	18.7–34.0	108–270	10.8–172.5	B-38
Pb	30.2–46.7	112–218	4.0–75.8	B-3A, B-41B, B-38
Ni	15.9–20.9	42.8–51.6	11.3–34.0	<i>B-49</i>
Zn (ppm)	124–150	271–410	35.0–406.7	B-3A
ΣDDTs (ppb)	1.58	46.10	0–2.50	<u>B-41B</u>
ΣLACs	552	3160	70–2200	B-3A
ΣHACs	1700	9600	29–8800	B-3A
ΣPCBs (ppb)	22.7	180	0–48	B-48

¹ ERL-results in initial, reversible changes in benthic community.

ERM-results in reduction of benthos abundance and species richness in bottom community, and 50% mortality in toxicology experiments (Boyd *et al.* 1998; Long *et al.* 1995).

³ Shaded fields indicate stations with pollutant content, corresponding to ERM concentrations.

⁴ Bold and italic show stations with pollutant content, corresponding to ERL concentrations.

Table 1 demonstrates the range of pollutant concentrations in bottom sediments that negatively affects marine benthos. These values were obtained by American and Canadian scientists (Boyd *et al.* 1998, Long *et al.* 1995). Pollution loads at the level of effects in initial reversible changes in benthic communities (range-low concentrations results), and at the level of effects in reduction of benthos abundance and species richness in communities, and 50% mortality in toxicological experiments (range-medium concentrations results). As shown in Table 2, these concentrations of trace metals, DDTs, PCBs, LACs and HACs were found at 5 stations.

The PCA of sediment chemistry data (concentrations of 22 pollutants in bottom sediments) detected 4 groups of stations, shown in Figure 4. Group II (sites B-38 and B-41B) is characterized by maximal and increasing concentrations of organic contaminant in bottom sediments. Site B-3A has maximal concentrations of trace metals. Low pollutant content was recorded at site B-50. Group III (sites B-11B, B-48, and B-49) is characterized by intermediate position. In this diagram Group II (sites B-38 and B-41B) disposes separately from the other sites, as it was shown in Figure 1. So we can propose that strong species dissimilarity of Sites B-38 and B-41B compared with other sites may be evidence of pollutant impact.

The PCA of polychaete taxocene characteristics, including number of species and ecological indices, has also indicated 4 groups (Fig. 5). Group I and II (sites B-38 and B-41B) have lowest values of number of species, as well as indices of diversity and richness. Site B-38 has maximal values of domination index. Domination of tolerant pollution species *Tharyx multifilis* and low density of sensitive-pollution species (*Scoloplos armiger*, *Laonice cirrata*) were detected at these stations. Sites of Group IV (B-50, B-49, B-48, and B-11B) are characterized by the highest values of the number of species, and maximal richness and diversity of polychaetes. Site B-3A is very close to Group IV.

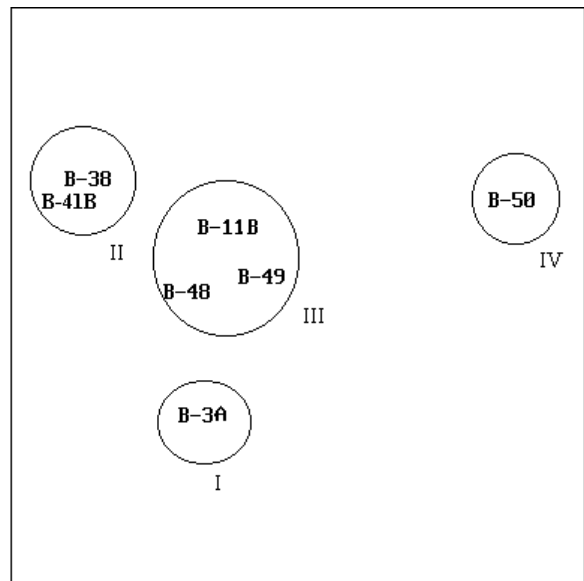


Fig. 4 PCA ordination of sediment chemistry data. Concentration of 22 pollutants in bottom sediments after transformation (\sqrt{x}) and normalization for 7 sites (% variance explained = 77%).

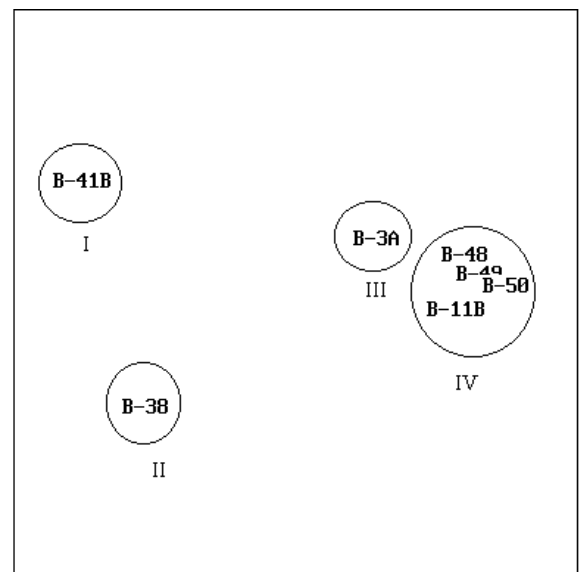


Fig. 5 PCA ordination of 5 characteristics of polychaete taxocene variables after transformation ($\log x$) and normalization for 7 sites (% variance explained = 99.6%).

Thus, sediment quality assessment indicates:

- Severe adverse effect at sites B-38 and B-41B;
- Sites B-48, B-49 and B-11B are characterized by low and moderate adverse effects;
- Site B-3A, judging by ecological indices and species structure has an intermediate position between severe and moderate adverse effects.

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