Softbottom Benthic Communities in Sydney Harbour, Nova Scotia. 2. 2000 survey. Distribution and Relation to Sediments and Contamination

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ABSTRACT

As part of a study of microbiology, contaminant dynamics, toxicology and geochemistry, of Sydney Harbour, an inlet and major port on the northern coast of Cape Breton Island, Nova Scotia, Canada, seabed organisms 0.5 mm and larger (macrofauna) were sampled in October 1999 and July 2000 to provide information on distribution of biological communities and the influence of contamination (PAHs, PCBs, and organic loading) on their distribution. Results from sampling in July 2000, and a synthesis of both years data are presented here.

Sediments in South Arm, Northwest Arm and the central channel of the outer harbour were comparable in composition and distribution to those found in 1999. Areas of high TOC in South Arm coincided with high levels of polycyclic aromatic hydrocarbons (PAHs), and polychlorinated biphenyls (PCBs), reflecting likely sources in discharges from the City of Sydney and Muggah Creek. Levels of TOC, PAHs and PCBs in silty sediments elsewhere in Sydney Harbour were much lower although still detectable, and PAH and PCB concentrations were negligible to undetectable in sandy sediments at the harbour mouth. Levels of TOC, TPAHs, and PCBs in sediments were similar in magnitude and geographic distribution to those observed in 1999 and did not differ statistically between years. Multiple regression analysis showed statistically significant linear and multiple linear regression relationships between contaminants and distance from Muggah Creek and some related parameters, confirming that the City of Sydney and Muggah Creek are probably the most important sources of these contaminants in South Arm.

Biological communities having composition and distribution similar to those found in October 1999, occurred in Sydney Harbour in July 2000. However, abundance, and in some cases diversity of communities, and abundance of individual species, were reduced over those observed in 1999. Low abundance and numbers of species occurred in areas showing highest concentrations of organic carbon, PAHs and PCBs in sediments (central and northeast South Arm) and which were dominated by the burrowing anemone *Cerianthus borealis;* the polychaetes *Nephtys incisa* and *Polydora quadrilobata;* and the nemertean worm *Cerebratulus* sp. Silt bottoms elsewhere were dominated by the capitellid polychaete *Mediomastus ambiseta*, the polychaetes *Ninoe nigripes,* and *Nephtys incisa*, the bubble shell *Acteocina canaliculata*, the burrowing anemone *Cerianthus borealis*, the nemertean *Cerebratulus* sp, and the opportunistic polychaete *Owenia fusiformis* (locally abundant in the other harbour). Other opportunists (*Polydora* spp and *Capitella capitata*) occurred locally on silt bottom in both contaminated and uncontaminated areas. Diverse communities occurred on silty sand bottom in the channel in the outer Harbour; and at the reference site at the harbour mouth.

RÉSUMÉ

Dans le cadre d'une étude portant sur la microbiologie, la dynamique des contaminants, la toxicologie et la géochimie du havre de Sydney, qui est un bras de mer et un port important du nord de l'île du Cap-Breton, en Nouvelle-Écosse (Canada), nous avons échantillonné en octobre 1999 et juillet 2000 les organismes benthiques de 0,5 mm et plus (macrofaune) pour recueillir de l'information concernant la distribution des communautés vivantes et l'influence de la contamination (HAP, PCB et charge organique) sur leur distribution. Nous présentons ici les résultats de l'échantillonnage de juillet 2000 et une synthèse des données recueillies pendant ces deux années.

La composition et la distribution des sédiments du bras sud, du bras nord-ouest et du chenal central de la portion aval du havre de Sydney étaient comparables à celles observées en 1999. Les zones de forte teneur en COT dans le bras sud coïncidaient avec de fortes concentrations d'hydrocarbures aromatiques polycycliques (HAP) et de polychlorobiphényles (PCB), pollution qui semble provenir des rejets de la ville de Sydney et du ruisseau Muggah. Les concentrations de COT, de HAP et de PCB dans les sédiments limoneux des autres portions du havre de Sydney étaient beaucoup plus basses, quoique encore détectables, et les concentrations de PAH et de PCB étaient négligeables à indétectables dans les sédiments sableux à l'entrée du havre. Les teneurs en COT, en HAP totaux et en PCB étaient semblables en termes de niveau et de répartition géographique à celles notées en 1999, et il n'y avait pas de différences statistiques d'une année à l'autre. Une analyse de régression multiple a montré des relations de régression linéaire et de régression linéaire multiple statistiquement significatives entre les contaminants et la distance du ruisseau Muggah et certains paramètres connexes, ce qui confirme que la ville de Sydney et le ruisseau Muggah sont probablement les sources les plus importantes de ces contaminants dans le bras sud.

Des communautés vivantes dont la composition et la distribution étaient semblables à celles qui avaient été observées en octobre 1999 étaient présentes en juillet 2000 dans le havre de Sydney. Toutefois, l'abondance et, dans certains cas, la diversité des communautés et l'abondance de certaines espèces étaient réduites par rapport à celles de 1999. La faible abondance et le petit nombre d'espèces correspondaient aux zones où les concentrations de carbone organique, de HAP et de PCB étaient les plus hautes dans les sédiments (centre et nord-est du bras sud) et qui étaient dominées par l'anémone fouisseuse *Cerianthus borealis*, les polychètes *Nephtys incisa* et *Polydora quadrilobata*, et le ver némertien *Cerebratulus* sp. Ailleurs, les fonds limoneux étaient dominés par le polychète capitellidé *Mediomastus ambiseta*, les polychètes *Ninoe nigripes* et *Nephtys incisa*, la bulle *Acteocina canaliculata*, l'anémone fouisseuse *Cerianthus borealis*, le némertien *Cerebratulus* sp., et le polychète opportuniste *Owenia fusiformis* (abondant localement dans l'autre havre). D'autres opportunistes (*Polydora* spp. et *Capitella capitata*) étaient présents localement sur des fonds limoneux dans les zones contaminées et non contaminées. Des communautés diverses se retrouvaient sur les fonds de sable limoneux dans le chenal de la portion aval du havre et à la station témoin de l'entrée du havre.

INTRODUCTION

Sydney Harbour, an inlet and major port on the northern coast of Cape Breton Island, has experienced more than a century of contamination from industrial and human activity centred on the Port of Sydney. In particular, the harbour has been exposed to high loadings of polynuclear aromatic hydrocarbons (PAHs) and other contaminants from releases from the Sydney Steel Plant located there, and sewage and other releases from the City of Sydney and associated port activity. Although the probable impact of industrial activities on the environment of the Harbour was known in the 1970s, recognition in the early 1980s of high levels of contamination in the environment and biota of the Harbour led to a shutdown of the coke ovens, the major source of aquatic releases from the Steel Plant, and resulted in a wide range of studies carried out through the 1980s to determine the extent of contamination and potential effects. In 1999, Fisheries and Oceans Canada and Environment Canada, with funding from Health Canada's Toxic Substance Research Initiative (TSRI), began a multi-year study of the waters and sediments of Sydney Harbour, to assess conditions more than a decade after activities at the Plant were discontinued, to provide a toxicological and oceanographic basis to determine status and potential for recovery of the seabed ecosystem in the Harbour. As part of that project, Envirosphere Consultants Limited, an environmental consulting firm based in Windsor, Nova Scotia, carried out sampling and analysis of seabed (benthic) invertebrate communities and sediments in Sydney Harbour in October 1999 and July 2000 to determine distribution and abundance of biological organisms and sediment characteristics. The results of the analysis of sediments and biological samples from the July 2000 cruise, and a comparison and assessment of the two years' biological data are presented in the current report.

METHODS

Background and Previous Studies

The waters of Sydney Harbour, a Y-shaped inlet on the northern coast of Cape Breton Island and one of Nova Scotia's major harbours, have been exposed to a wide range of industrial and human contamination for over a century. Although the Harbour has many of the contamination problems typical of other major industrial ports, including organic loading, BOD, metallic and organic contaminants, and bacterial contamination, it has been impacted more severely than most harbours by decades of uncontrolled release of contaminants from the Sydney Steel Plant, situated near its head. In particular, the Sydney Tar Ponds, the former watershed of Muggah Creek — used for industrial disposal by the Steel Plant and adjacent community and one of the most severely contaminated waste dump sites in Canada — has been responsible for exchanging large quantities of contaminants including PAHs and other toxic chemicals, with Sydney Harbour.

Suspected contamination of the Ponds, and the status of Sydney Steel as a major industrial site, as well as the discovery of high concentrations of PAHs in commercial catches of lobster in Sydney Harbour in the early 1980s, led to a suspension of critical activities of the steel plant. Through the 1980s and 1990s, a number of environmental studies were carried out which assessed the distribution, concentration, and character of contaminants in various environmental compartments in Sydney Harbour. Wendland (1979), in a study carried out for Environment Canada, assessed sediment contaminants and benthic communities at stations throughout South Arm and at a control station in Northwest Arm. Three subsequent studies by Environment Canada (Packman *et al.* unpublished; Matheson *et al.* 1983; and Kieley *et al.* 1986) examined contamination in sediments and biota in both arms of the harbour and in the outer harbour. P. Lane and Associates (1989, 1990) carried out contaminant and biota sampling, and physical oceanographic modelling in connection with assessment of the impact of effluents from the tar ponds. A 1995 resampling of sediment and biota was carried out for Environment Canada by Jacques Whitford Environment — International Technology Corporation Joint Venture (Ernst *et al* (1999)), and Environment Canada sampled sediments and biological communities at five stations along a contaminant gradient from Muggah Creek to the outer harbour in 1997 (including the current reference station) as part of a study to develop toxicological indicators of sediment contamination (Zajdlik *et al.* 2000).

Biological communities have been sampled in three earlier studies in connection with the assessment and monitoring of contamination problems (Wendland 1979; and P. Lane and Associates, 1988, 1989; Zajdlik *et al.* (2000)). Wendland (1979) focused on South Arm, and P. Lane and Associates (1988 and 1989), though covering all of Sydney Harbour, provided largely descriptive results with only cursory analysis and interpretation. Zajdlik *et al.* (2000) provided species lists and abundances for the biological community and several community measures. Communities in Sydney Harbour as a whole and relations to sediments and contaminant sources, following an analysis of the October 1999 data, as well as a discussion of the relations of present communities to earlier studies, were presented in Envirosphere Consultants Limited (2000a), and sediment grainsize and total organic carbon from the July 2000 survey were presented in Envirosphere Consultants Limited (2000b).

A standard set of sampling stations for sediments and biota were adopted by Environment Canada in Matheson *et al.* (1983); a subset of these were later sampled in a monitoring study (Kieley *et al.* 1986). A later study (P. Lane and Associates 1989) also used station locations from Matheson *et al.* (1983) but added a number of stations along the axes of the Harbour Arms. This sample grid was also used in the 1995 sampling (Ernst *et al* 1999).

The basic sampling grid for the present study used the Matheson *et al.* (1983) and P. Lane and Associates (1989) stations as a basis (and consequently represents stations in later studies), but added stations to meet particular sampling needs of the present program (Figures 1 & 2). The stations are logically arranged and are suitable for an oceanographic sampling program, covering the Harbour both laterally and longitudinally. The general sampling grid included a series of transects of South Arm, Northwest Arm and the outer Harbour, typically three stations across with one station in the approximate centre. One transect is situated off the mouth of Muggah Creek and would be expected to capture a contaminant gradient from severely contaminated to moderately contaminated. The sampling grid was augmented in 2000 by adding stations selected to fill in gaps between some of the major transects and to include some stations which had shown potential significance in terms of contamination and toxicological parameters.

Station Locations

Station locations for sediments and biota in July 2000 are presented in Figure 2. Station locations largely repeated stations sampled in 1999 but included additional locations for coring, to identify sources and sinks of contaminants; and to sample in the vicinity of sites having significance for a program component involving toxicology testing. Some of the shallower stations sampled in 1999 were missed in 2000 because the draught of the support vessel was too large to sample shallow sites.

Field Methods

Sampling was carried out from July 10-14, 2000 on the CCGS *Earl Grey*. Sampling for biological community and sediments was carried out using 0.1 m^2 and 0.12 m^2 Van Veen grab samplers. A given sampling event included taking several grab samples to supply adequate material for various program components[1]. Measurements of contaminants (PAH and PCB) and bulk water content were provided from another program component. For those analyses, the contents of 1-2 Van Veen grabs were emptied onto a plastic tray and transferred to a polyethylene-lined, 20L plastic bucket, where they were homogenized and subsampled. This sample represented the sediment column reaching to the depth of penetration of the grab, approximately 15-20 cm, which, in the soft sediments found in most areas, usually represented a full grab sample. For biological analysis, the surface of the grab sample was examined through the access door and subsampled (100-200 mL) from the surface 2-5 cm for grain size and Total Organic Carbon (TOC) content.The grab was then emptied onto a polyethylene tray, and the contents transferred to heavy plastic bags. Each sample was logged and allocated a serial station identification number. Samples for biological community analysis were not replicated at most stations but replicates were taken at stations representing horizontal and longitudinal gradients in South Arm;, sediment grainsize parameters and TOC were measured on the first grab sample taken for biological analysis.

Chemical Analysis

Grainsize and Total Organic Carbon

Grainsize and TOC analyses were carried out by Seatech Limited, Halifax. For determination of organic carbon, one gram of sediment was washed with diluted HCl in a water bath at 60°C to remove carbonates. The acid was diluted and the sample dried at 80°C. Total Organic Carbon (TOC) was analyzed on a LECO carbon analyzer (limit of detection, 0.01%).

Grainsize distribution was determined by pipette analysis and dry sieving (Krumbein and Pettijohn 1938). Samples were washed through a 230 mesh sieve, and the retained portion dried and sieved through U.S. mesh 4, 10, 18, 35, 60, 100, and 230. The eluent from the washing (wet sieving) was made up to 1 L with water, calgon deflocculant added, and pipette samples

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[1] Availability of a motorized barge with differential GPS allowed additional sampling to be carried out simultaneously to that on the CGCS *Earl Grey*.

withdrawn at appropriate time intervals. The results were reported using the Wentworth grade scale.

Measures of grainsize distribution included:

$$\text{Median grain size} = \phi_{50}$$

$$\text{Mean grain size} = \frac{\phi_{16} + \phi_{50} + \phi_{84}}{3}$$

$$\text{Inman Sorting} = \frac{\phi_{95} - \phi_{05}}{6.6} + \frac{\phi_{84} - \phi_{16}}{4}$$

ϕ as a measure of grain size is defined as $-\log_2$ (grain diameter in mm). A grain size of 1 mm corresponds to 0 ϕ. Measures were calculated by a software package (Community Analyses System, Version 4.2. Ecological Data Consultants, Gainesville, Florida) and were based on Folk (1966) and Folk and Ward (1957).

Biological Analysis

Biological samples were sieved at a dockside warehouse on a 0.5 mm sieve, and preserved in 10% formalin buffered with borax. Samples from selected stations, chiefly those which had replicate samples and were also sampled in 1999, were analyzed. Samples from Stations 2-6, 11, 12, 18, 27, 31, and 37-39 as well as some additional samples were analyzed by K. Querbach, Dalhousie University, as part of an MSc thesis project (Querbach 2002) (Figure 3). These included stations, typically having replicate grab samples, on a longitudinal (Stations 4, 5, 11, 12, 17, 18, 37, 40, 43) and cross-sectional gradient (Stations 6, 31, 37, 38 & 39) and a reference site (Station 27). These stations are not included in community analyses in the present study[2] but are presented in an appendix to this report and are used in interpreting distributions of species and in multiple regression analyses of contaminant effects. Samples from Stations 15, 19, 28, 29, 34, 36, 41 and 42 were not analyzed, and have been archived.

Animals were sorted by stereomicroscope at 8x magnification; 10% of samples were resorted to determine sorting efficiency, which was always >90%. Because of large sample volume or numbers of organisms, three samples were subsampled (see Table A3) (spread evenly in a circular tray before a divider with measured quadrants was inserted and partioned material placed in separate containers; enough quadrants were sorted to give >200 organisms. The method had been evaluated and proven to give satisfactory consistency among quadrants in a previous project. All organisms were blotted dry and weighed to determine standing crop (wet weight biomass); stored in 70% isopropanol; and identified to the lowest possible taxonomic level,

[2] Biological community information from Querbach (2002) was not used in community analyses such as cluster analysis because of differences in level of identification. Reference specimens from that study were compared with those in the present one to ensure that identifications were consistent.

typically to species. Authors identified the material, referring to current taxonomic literature, and to verified specimens from the 1999 sampling, and other reference specimens.

For each sample, number of species per 0.1 m^2 sample, number of individuals/m^2, standing crop (biomass, grams/m^2 wet weight), Shannon-Wiener index (H') (Pielou 1973) and Pielou's evenness index (J') (Pielou 1973) were determined. The Shannon-Wiener Diversity index is widely used in ecology and represents both the number of species and distribution among individuals, with higher numbers of species generally resulting in increased values and high values of single species resulting in low diversity measures. While the Shannon-Wiener index is not universally accepted as a measure of diversity *per se*, it is useful here as an information statistic that aids in describing and interpreting the structure of the species abundance data. Descriptions of the indices can be found in Pielou (1973), and Legendre and Legendre (1983).

Multivariate Analysis

Physical/chemical data were subjected to Principal Components Analysis (PCA) (Legendre and Legendre 1983). For biological data, cluster analysis and canonical correspondence analysis (CCA) were used to determine groupings of stations based on species composition, and to evaluate relationships of physical factors in determining groupings. Cluster analysis was conducted using the PRIMER multivariate computer package (Clarke and Warwick 1994), PCA in SYSTAT and canonical correspondence analysis using the CANOCO program (Ter Braak 1988; Jongman *et al.* 1995).

Principal Components Analysis (PCA) – Principal components analysis is a data analysis technique which identifies patterns of variation in a data set based on correlations or covariance between physical/chemical variables. It seeks to partition the variance of the dataset along to a number of independent or orthogonal axes. Axes typically represent one or a combination of environmental factors that are responsible for the variation. For PCA analysis, various transformations were applied to normalize the distributions: arcsine square root transformation for percentage grainsize fractions and Total Organic Carbon (TOC); log transformations for depth, distance from Muggah Creek, and contaminants; and median grainsize was not transformed. The datasets were standardized prior to analysis (Sokal and Rohlf 1981). Data from the PCA analyses were presented unrotated.

Cluster Analysis—Similarity of stations in terms of biological species composition was assessed by cluster analysis using a similarity index (Bray-Curtis, Czekanowski quantitative, or proportional similarity) (Legendre and Legendre 1983; Bloom 1981). The index compares the stations based on occurrence and numbers of each species. A matrix consisting of species that occurred at two or more stations was used in the analysis. The Bray-Curtis/Czekanowski index is defined as:

$$\frac{2W}{A + B}$$

where A and B are the total number of individuals of each species at the two stations respectively; and, W is the total of the lower of the two abundances when the two species co-occur. The index is calculated for all possible pairs of stations and the relationships (e.g. stations most and least similar in species composition) are organized into a cluster diagram (dendrogram) to illustrate relationships. Clustering used a group average sorting algorithm. The log (x + 1) transformation was applied to the biological abundance data to normalize the data. The data matrix was reduced in size by dropping species occurring at less than 0.05 % of total abundance. As a result, 32 species were used in the cluster analysis.

Canonical Correspondence Analysis—This multivariate technique is applied to species-station data and associated environmental information to allow interpretation and summary graphic display of species and station relationships as they plot on axes which account for the maximum dispersion of the environmental data and therefore represent gradients which could be at the root of species distributions. Species and stations, depending on their scores on axes corresponding to the direction of dispersion in the values of a small number of environmental variables, can be plotted on X-Y coordinates, providing a graphic display of relationships both of species, stations, and environmental variables. The data set used for similarity analysis, containing 28 species most abundant overall (see above) was used in this analysis. The environmental data set used to adjust the analysis for possible effects, included median grain size, as well as individual grain size categories, total organic carbon, TPAH, PCB, water content, distance from Muggah Creek and depth. Simple canonical correlation analysis without detrending, and with 'forward selection' of environmental variables was used (Ter Braak 1988). Separate analyses were conducted which included: 1) all stations; 2) only stations having silt/clay sediments; and 3) stations having fine sediments in South Arm, excluding the inner Arm at the mouth of Sydney River. Species data was transformed by log(x + 1) and sediment grainsize percentages and TOC were transformed by the arcsine square root transformation, while median grain size was used without transformation, and contaminant concentrations (PAHs and PCB contaminations) were log transformed.

Multiple Regression Analysis—Multiple regression analysis of sediment physical/chemical, contaminant and biological measures was carried out following Sokal and Rohlf (1981) using SYSTAT after appropriate transformations to normalize the data. Multiple regression is an extension of simple linear regression, which identifies combinations of linear relationships of variables of interest with other environmental parameters. Multiple regression was used to give an indication of the importance of physical/chemical variables in South Arm of Sydney Harbour in both years and on the combined data set, in influencing the distribution of the organic contaminants and Total Organic Carbon (TOC), as well as distribution of biological parameters, including community measures and abundance of species which are key community components.

Statistical Analysis—Differences in contaminant levels and biological parameters between sectors of Sydney Harbour and between years were assessed using parametric Analysis of Variance and non-parametric Kruskal-Wallace One-Way Analysis of Variance (Sokal and Rohlf 1981) on transformed data using the SYSTAT statistical package.

RESULTS

Sediments

As in 1999, the survey did not include areas shallower than about 8 metres, and thus largely softbottom (sand/silt/clay) environments were represented. Types and distribution of sediments were similar in July 2000 as observed in the 1999 survey (Figures 4-7). Sediments in South Arm, mouth of Sydney River, and Northwest Arm are predominately silty with a small proportion of clay, and occasionally coarser (gravel and sand) fractions (Table 1). In the central channel seaward of the junction of Northwest and South Arms, sandy silt occurs, and sediments at the reference station in the outer harbour are sandy to gravelly (Envirosphere Consultants Limited 2002).

In both 1999 and 2000, total organic carbon (TOC) content was highest in the silty sediments and lowest in sediments having significant coarse or sand fractions. In addition, total organic carbon content in silty sediments showed higher levels in South Arm than in Northwest Arm or the outer harbour, and a maximum in Central South Arm off Muggah Creek (Table 2; Figure 8) (Envirosphere Consultants Limited 2002). The combined distribution (1999 and 2000) for South Arm also showed the pattern of highest TOC levels off the mouth of Muggah Creek and elevated levels elsewhere (Figure 9). Sediment content of TOC was significantly different between five sub-areas of Sydney Harbour (Table 3 (Analysis of Variance, $p< 0.05$), for both the study area as a whole, and for 1999 stations repeated in 2000, but was not different between 1999 and 2000.

Water content of surface sediments was higher in silty samples than in sandy ones, and higher in Inner, Central and Northeast South Arm (62 – 69%) than in Northwest Arm and northwestern parts of South Arm (46 to 59%) (Table 2, Figures 10-11). Water content was lowest (25%) in sandy sediments at the harbour mouth and at intermediate levels in the sandy silt sediments of the central channel seaward of the junction of Northwest and South Arms (Stations 17 and 18) (36 & 43% respectively). Water content observed in 2000 was similar at a range of locations in Sydney Harbour to that observed in 1999 (Table 4). The regression for all stations (Figure 11) was significant (Anova, $p <0.001$), although the regressions of 2000 on 1999 values for silty sediments only (sediment water contents above 40%) were not significant (correlations of $r=0.06$ ($n=17$) and 0.433 ($n=4$) for South Arm and Northwest Arm respectively), either overall or for Northwest or South Arms separately. Water content at the reference station in this study (Station 14) was similar to that observed at the same location in 1999 (Figure 11). Water contents of the three subareas of South Arm (1999 and 2000 combined) were all significantly higher than in Northwest Arm (ANOVA, $p < 0.05$).

As in 1999, sediment grainsize parameters for all stations sampled in 2000 showed a positive correlation between silt and clay, and negative correlations between silt/clay and coarser (sand/gravel) fractions (Table 5a). Sand (medium coarse and very coarse sand) and coarser fractions (granule and pebble) were positively correlated. However, silt and clay were negatively correlated in the group of stations having fine sediment (Table 5b). Unlike 1999, none of the sediment grainsize parameters were significantly correlated with depth; the greater number of shallower stations (which also had coarser bottom (sand/gravel substrate)) sampled in 1999 probably accounts for the difference. Contaminants (Total PAH and PCBs) showed positive correlations with silt, clay and TOC. The highest correlations of organic contaminants were with TOC: (r =0.74 for TPAH; and r=0.59 for PCB, Table 5a). TPAH and PCB were highly positively correlated (r=0.91); similar elevated correlations were observed in 1999. TOC, TPAH and PCB were strongly negatively correlated with distance from the mouth of Muggah Creek, reflecting the high concentrations found in Central South Arm off Muggah Creek. The correlations for stations having predominantly silty sediment (largely those in South Arm and Northwest Arm) (Table 5b) were similar, although silt and clay were negatively correlated. TPAH and PCB were strongly positively correlated (r=0.91) with each other (as they were in the analysis of all the stations), and were also highly correlated with TOC; these three parameters were strongly negatively correlated with distance from the mouth of Muggah Creek (Table 5b).

Principal Components Analysis (PCA) of all stations using sediment grainsize parameters, contaminant concentrations, water content, TOC and depth, separated stations geographically (Figure 12), reflecting the grainsize gradient (coarser in the outer harbour) as well as different levels of contaminants between areas. Station 28 had a unique position, having a mixture of silty sediments and gravely to rocky ones (Figure 4a). Two factors accounted for the majority of variance in sediment composition, and contaminant levels for Sydney Harbour as a whole (Table 6a; Figure 12). The first factor, accounting for 46.9% of the variance is a grainsize gradient, representing hydrodynamic effects on sediment composition, which shows a sharp gradient from silt/clay sediments in the inner harbour (South Arm and Northwest Arm) and sandier sediments in the outer Harbour (Stations 14 and 17). Sands had strong positive loadings on Factor 1 while silts and clays, as well as Total PAH and PCBs, showed strong negative loadings (Table 6a). Factor 2, accounting for 19.7% of the variance, was important in strong positive loadings of coarse sediment fractions (coarse sand to pebble) as well as TOC and Total PAH; and a negative loading for distance from Muggah Creek. Factor 2 represents the influence of a contaminating coarse sediment component such as gravel, slag etc. which occasionally occurred particularly in South Arm. A gravel to cobble fraction was observed at Station 28, and many of the stations in Central South Arm had a coarse sand and granule component (Table 1) which would not be expected in the predominantly silt to clay bottom. The high loading of TOC and PAH on Axis 2 reflects that Central South Arm is the area most contaminated with TPAH and PCB, and has the highest levels of TOC.

Three factors accounted for the majority of the variance (69.8%) when the principal components analysis was restricted to predominantly silt/clay sediments (Table 6b; Figure 13). The first factor, accounting for 31.3% of the variance, represents local variation in sediment composition (similar to Axis 2 in the first analysis). Sand and coarser fractions showed high positive loadings on the axis, while silt had a high negative loading (Table 6b). Axis 2 showed high negative loadings of TOC and sediment contaminants (Total PAH and PCB) and explained 22.5% of the variance. Factor 2 likely represents the influence of contaminant sources, reflected in distance from Muggah Creek. Factor 3 explained 16% of the variance and showed strong positive loadings of the granule fraction and clay, and negative loadings of very fine sand and median grain size. TOC and clay were correlated (Table 5b) and the third factor may be TOC and its involvement in physical properties of sediments.

The first two factors in a principal components analysis which examined factors in variation of TOC, TPAH, PCB, silt and clay, for the South Arm stations seaward of Dobson's Point (the bend in South Arm above the Sydney downtown area), explained 74% of the variance in the data set (52% on the first and 22% on the second axis) (the full results or a plot of the axes in 7 of the PCA are not presented in this report). The first axis represents the distance from contaminant sources, with TOC, TPAH and PCB all loading strongly on it (loadings greater than 0.87). The second axis likely represents the effect of silt/clay content. Normally the silt/clay fraction influences organic and contaminant content of sediments (when contaminants are present, the finer the sediment, the higher the organic and contaminant content). PCB loaded in the same direction as clay on the second (silt/clay) axis (TOC loaded in an opposite manner and TPAH had a negligible loading) which suggests a different pattern affecting the distribution of TPAHs and PCBs.

Contaminant Distribution

Total PAH and PCBs in sediments were highest in Central South Arm in July 2000 (Table 2, Figures 14-17), reflecting local contaminant sources. Sediments having similar grainsize composition outside South Arm had much lower levels[3]. Levels in South Arm with the exception of Stations 28 and 37 in Outer South Arm, were higher than in adjacent areas.

Concentrations of both TPAH and PCB in silt/clay sediments were significantly different between five sub-areas of Sydney Harbour (Table 3) (Analysis of Variance, $p < 0.001$), for stations having silt/clay sediment as a whole, as well as for stations which were sampled in 1999 and repeated in 2000. Levels of TPAH and PCB did not differ between 1999 and 2000 within Central and Outer South Arm between Dobson's Point and Point Edward (an area of similar bottom type including the waterfront of the City of Sydney and areas seaward, including the mouth of Muggah Creek) (ANOVA, $p < 0.05$).

Total PAH and PCB showed highest concentrations off the City of Sydney waterfront and mouth of Muggah Creek, reflecting the importance of Muggah Creek as one of the sources in the vicinity. The localized distribution was shown by regression relationships of these parameters with distance from Muggah Creek, and both Total PAH and PCB had significant regression relationships with distance (Table A4). The main environmental parameters which showed significant partial regressions with both Total PAH and PCBs in fine sediments were total organic carbon (TOC) and silt (Table A4). The regressions of these added variables on depth were minor and offered little improvement in multiple regressions. TOC also showed a strong linear regression relationship with distance from Muggah Creek (Table A4), the equation for 1999 and 2000 combined explaining 62% of the variance in TOC compared to 69% in the best equation (using depth, distance and clay content). The multiple regression equation describing the relationship between PCB concentration and distance from Muggah Creek explained only 37% of the variance compared to a range of from 30 to 52% for various combinations of variables and different years (Table A4). In contrast, the regression of Total PAH on distance

[3] A discussion of contaminant levels and variation with location is presented in this report to aid in interpretation of the biological data. A more definitive presentation of contaminants will be the subject of final reports of other program components.

explained 70% of the variance (as high as 83% explained in 1999 dataset alone, Table A4). The dropoff of TOC, Total PAH and PCB was logarithmic with the distance from Muggah Creek (as all the regressions were determined using log-transformed contaminant levels and distance).

Regressions of TOC and TPAH on distance from Muggah Creek explained similar proportions of the variance in those variables respectively (58-69 versus 62-83% depending on the combination of variables and the dataset on which the analysis was conducted) (1999, 2000, or both combined)(Table A4). PCB level was explained less well by regressions on distance (37-38%) and TOC (30-50%) than Total PAH. This suggests different behaviour of PCBs and also may indicate a different input pattern than Total PAH and TOC.

Animal Communities

Abundance, number of species, Shannon-Wiener Diversity, and biomass of biological communities were low in Central and Northeast South Arm, and Inner South Arm at the mouth of Sydney River, as they were in 1999. Two stations in Northwest Arm (Station 24 & 26) were also low in these measures in 2000 (and thus lower than in 1999), while Stations 25 & 27 in Northwest Arm (the latter from Querbach (2002), Table A7) showed comparable measures to those observed in 1999. Stations in the Outer Harbour (Stations 14 and17) had higher abundance, biomass, and number of species, than the other stations, comparable to 1999, and moderate Shannon Wiener Diversity (Table 7; Figures 18-23).

Biological communities at stations off Dobson's Point in Inner South Arm (Station 9 & 33), and along the southwest shore opposite the Sydney waterfront, had higher abundance, number of species, and Shannon Wiener diversity than the adjacent areas of Central and Northeast South Arm, or Inner South Arm at the mouth of Sydney River. A similar pattern was observed in 1999 and represents the occurrence of a community found elsewhere in the Sydney Harbour system on silt/clay bottoms (in particular Northwest Arm in 1999), and which fringes the area of most TOC, TPAH and PCB contamination. This community typically has the polychaete *Mediomastus ambiseta*, as well as the polychaetes *Ninoe nigripes* and *Nephtys incisa*; the bubble shell gastropod *Acteocina canaliculata*; the nemertean *Cerebratulus* sp.; the burrowing anemone *Cerianthus borealis*; and the phoronid, *Phoronis architecta* which occurred occasionally. It occurred throughout Northwest Arm in 1999 but only at Station 25 and 27 in 2000, as well as in the parts of South Arm noted above. In South Arm off Muggah Creek, and in northeast portions of the Arm (the area having highest sediment content of TOC, TPAH and PCB), a subset of this group of species (*Cerianthus, Nephtys incisa,* and *Cerebratulus*) occurred, with numbers lower and frequently with not all the species occurring. In particular the gastropod *Acteocina*, and the polychaetes *Mediomastus* and *Ninoe* were absent from this area, while the nemertean *Cerebratulus*, the burrowing anemone *Cerianthus borealis,* and the polychaete *Nephtys incisa* occurred throughout.

The reference site at the Harbour mouth had moderate abundance, numbers of species, biomass and diversity. However, all measures were reduced at this site compared with 1999. One of the samples taken at the site had negligible organisms and was probably a bad sample, it was included in the cluster analysis but was omitted from the canonical correspondence analysis (CCA).

A community on sandy silty bottom in the central channel seaward of the junction of Northwest Arm and South Arm, having many of the species from the widespread community, but including the polychaete *Owenia fusiformis*, as a dominant, together with several other abundant species including *Mediomastus ambiseta,* occurred again in 2000 (Tables A1-A3). Abundances of 33,000-42,000 individuals/m^2 at Station 17 (*Owenia* abundance from 22,000-35,000 individuals/m^2) were comparable to those at the same location in 1999 (66,000) although the abundance of *Owenia* was greater in 2000. The species was also abundant at Station 18 (Figure 2) and a similar community to that which occurred at Station 17 was present (Querbach 2002) (Table A7).

The high abundances elsewhere in the Harbour found in 1999 (made up largely of the polychaete *Mediomastus ambiseta* but including moderate numbers of other species) were not observed in 2000, although in some cases the abundances of some of the other species were comparable. The phoronid *Phoronis architecta* also occurred in 2000 [4]. In 1999, this species had a distribution similar to that of *Cerianthus*, that is, occurring widely including Central and Northeast South Arm, but its distribution in 2000 was more restricted.

Total community abundance did not differ between 1999 and 2000 in the study area as a whole, but was significantly lower in Northwest Arm in 2000 (Kruskal Wallace One-Way Analysis of Variance, $p < 0.05$)(due to the lower numbers or absence of the polychaete *Mediomastus ambiseta* at several stations). Number of species differed between 1999 and 2000 at the outer harbour (Stations 14 and 17) (Kruskal Wallace One Way Analysis of Variance, $p < 0.01$), largely a result of Station 14 having many fewer species than in 1999 (Table 8).

Several groupings of stations having similar composition and abundance of seabed organisms were identified by cluster analysis (Figure 24 mapped in Figure 25 and summarized in Table 9). Species composition, abundance and relative abundance of biological organisms are presented in Appendix Tables A1 to A3.

Although there were overall similarities in patterns in biological communities observed in 2000, as compared to 1999, there were some notable differences. A community which in 2000 was found in northwestern Northwest Arm (Station 25, C1 in Figure 25 and Station 27 (Querbach 2002)) and also in the area between Central South Arm and the mouth of Sydney River, occupied all Northwest Arm and a similar area of South Arm in 1999.This group included the polychaetes *Mediomastus ambiseta, Ninoe nigripes, Nephtys incisa, Scolelepis squamatus,* and *Tharyx* sp; the burrowing anemone *Cerianthus borealis*; the nemertean *Cerebratulus* sp.; the gastropod *Acteocina canaliculata;* and the phoronid *Phoronis architecta*. These species were shown in the SIMPER analysis to be most responsible for the clustering of this group[5]. This appears to be the'natural' community in the Harbour on silt/clay bottoms. A subset of species from this

[4] Only one damaged specimen thought to be this species, was found in our analyses and Querbach (2002) found the species at several stations.
[5] This was assessed using the ANOSIM module of the PRIMER clustering software.

community, which is also reduced in number of species and abundance, occurred over the remainder of Northwest Arm and Outer South Arm in 2000, forming Group A1 (Figure 25). The polychaete *Nephtys incisa*, the burrowing anemone *Cerianthus borealis*, and the nemertean *Cerebratulus* sp. were most responsible for clustering this group. This grouping was similar in species composition and abundance to that found at several stations in Central and Outer South Arm (Groups A2 and B). *Nephtys* incisa and *Cerianthus borealis* were most responsible for clustering in Group A2, and species including the burrowing anemone *Cerianthus borealis,* the nemertean *Cerebratulus* sp., and the polychaetes *Polydora quadrilobata* and *Nephtys incisa* were most important in clustering Group B. Compared with Group A1, Groups A2 and B had reduced numbers of species. One sample at Station 10 in Central to Northeast South Arm (designated B* on Figure 25), had a unique occurrence of large numbers of the capitellid polychaete *Capitella capitata* (1090 individuals/m^2). Querbach (2002) found another occurrence of large numbers of this species in a sample at Station 38.

A cluster analysis of stations in 1999 & 2000 together, reflected this overall pattern of distribution of biological communities (Figure 26). South Arm and occasionally Northwest Arm stations containing the dominant species (*Cerianthus, Mediomastus, Ninoe, Nephtys incisa, Acteocina,* and *Cerebratulus*) formed Group 1 (Figure 26). All stations from Inner, Central, and Northeast South Arm, fell in this group, as did some Northwest Arm stations. Stations located between Inner and Central South Arm (Stations 1, 9, 22 & 33), as well as Northwest Arm stations in 1999 occurred in Group 2. The stations in South Arm in1999 at which the polychaete *Mediomastus ambiseta* and the gastropod *Acteocina canaliculata* occurred, grouped separately from those at which *Mediomastus* occurred in 2000 (Groups 2-2 and 2-1 respectively), largely because of the much higher abundance of *Mediomastus* in 1999. The repeated station in the central channel in Outer Sydney Harbour (Station 17 in 2000; Station 23 in 1999) grouped together (Group 2-3, Figure 26) and the sandy stations (including the reference station in both years) in Outer Sydney Harbour formed Group 3. Unlike 1999, a zone of significantly elevated abundance on the northwest side of South Arm and at Dobson's Point in inner South Arm (due to the presence of the polychaete *Mediomastus ambiseta* in the community) was not present.

Canonical Correspondence Analysis (CCA) was applied to the biological and physical data sets to show the relationship of groupings of species and stations to environmental parameters. CCA is a numerical procedure which identifies common patterns of distribution of chemical/physical variables, as well as in abundance of organisms, and the relationship between biological distributions and the physical/chemical environment. It is preferable to principal components analysis (PCA) for biological data, as it can identify non-linear relationships which are more common in biological communities living in and reacting to physical/chemical gradients. The relationships of species, stations and environmental variables in relation to axes in the analysis, can be summarized in terms of correlations of scores with the axes, and summaries of amount of dispersion accounted for by the axes, similar to PCA. Typically two axes account for the majority of the dispersion in the data, and correlations or scores of 1) physical/chemical parameters; 2) stations; and 3) species from the analysis on the first two axes can be used to generate two-dimensional representations of the relationships.

A first CCA analysis included all stations; a second analysis looked only at stations having silt/clay bottom (and thus mainly stations in the inner harbour, Northwest Arm and South Arm); and a third only the stations having silt/clay sediment in South Arm seaward of Dobson's Point. The first analysis was intended to reveal the more general pattern of communities expected to be strongly influenced by the sharp gradients between the presence of sandy, low contaminant communities in the outer harbour, and contaminated, silty communities in the inner harbour; while the second analysis was intended to look at more subtle patterns in factors when sediment type was more uniform and other parts of the system as a whole was included (including Northwest Arm). The third analysis focused on the South Arm and its uniform bottom type and well-defined distribution of contaminants. The results of the three CCA analyses are presented in Figures 27 to 29 and Tables 10 -12.

The influence of location on sediment content and contaminant levels and the effect of substrate type on sediment was represented by Axes 1 & 2 of the CCA which included all Sydney Harbour stations for July 2000 (Figure 27a). The success of the CCA in explaining the patterns in the data is expressed by the percentage of the variance in the data that the resolved axes explain. The CCA showed a comparatively low percentage of the variance accounted by the first two axes, indicating that weak relationships occur between biological communities and physical/chemical factors. Axis 1 accounted for 22 % of the variance in species data and Axis 2, 17 % (Table 12a). Even an analysis having low percentages explained, however, can provide meaningful interpretations of relationships and effects (Jongman *et al.* 1995). Station 10 in the upper right of Figure 27a is an outlier, occurring because it is the only station where the capitellid polychaete *Capitella capitata* predominates, and as the stations where *C. capitata* occurs are both at intermediate distance from Muggah Creek and on fine sediments. The variables related to fine sediments (silt, clay, organic contaminants, water content and TOC) had strong positive correlations with Axis 1 and negative ones with Axis 2, reflected in their grouping in the lower right of Figure 27b, and the variables reflecting coarse sediment (median grain size, sand content, distance from Muggah Creek) all correlated in an opposite fashion on those axes, plotting on the upper right. Depth correlated strongly with Axis 3, and TOC with Axis 4 (Table 11a). The stations in the outer harbour grouped in the upper left of Figure 27a and stations in South Arm and Northwest Arm in the lower right. The groupings of species show the variation in physical characteristics, showing the dominant species from South Arm (14=*Nephtys incisa*; 28=*Cerianthus borealis;* and 18=*Polydora quadrilobata*) (see Table 10 for other numbering) occurring in the lower right (Figure 27c) and species occurring at the outer stations (8=*Nucula delphinodonta*; 3=*Hydrobia totteni*; 26=*Echinarachnius parma*) at the upper left. *Owenia fusiformis*, the polychaete which was the dominant at Station 17, is not included because it occurred at that station only and inclusion requires occurrence at more than one station (the species also occurred at Station 18 in K. Querbach's analysis (Querbach 2002; Table A7) but it was not available to be included in the analysis).

Sediment grainsize variation among fine sediments, and distance from Muggah Creek, were responsible for groupings in the CCA of stations other than Station 14, which had sandy substrate. In that analysis, Axis 1 represents sediment grainsize variation and Axis 2 variation in organic contaminants (i.e. PAH, PCB). Station 17 had a unique community, and its elevated sand content, resulted in its positioning by itself to the left of Figure 28b. The position of Station 17 reflects both the difference in sediment type and distance from Muggah Creek (Station 17 was one of the furthest from Muggah Creek). In contrast, Station 25, which had a community containing many of the main species for Sydney Harbour, but supporting other species and greater abundance, placed at the top of Figure 28a. A group of stations around the periphery of Central and Northeast South Arm where high TOC occurred, placed at the origin of Figure 28a, and the stations having high TOC, PCB, TPAH and reduced communities dominated by *Cerianthus borealis* and *Nephtys incisa*, occurred in the lower right. Axis 1 explained a comparably low proportion (24%) and Axis 2, 13.5% of the variance in species abundance (Table 12b). Silt content, contaminants and depth had positive correlations with Axis 1 and median grainsize and fine sdand had strong negative correlations. TPAH and TOC had negative correlations with Axis 2, in particular TOC at a correlation of –0.73 (Table 11b) and distance from Muggah Creek had a positive correlation (0.41). The burrowing anemone *Cerianthus borealis* (28); and the polychaetes *Nephtys incisa* (14) and *Polydora quadrilobata* (18) showed associations with the reduced community at Stations 7, 8, 20 and 30, and the remaining species in the community showed a similar influence of factors on Stations 1, 9, 13, 22 and 33, by grouping around the origin in Figure 28c where the community with a full complement of dominant species occurred (Figure 28c). Species occurring uniquely with Station 25 were the gastropods *Hydrobia totteni* and *Diaphana minuta,* which plotted in the upper part of Figure 28c.

The CCA of Central and outer South Arm stations alone (Figures 29a-c) showed comparatively small influence of environmental variables on species (with depth and distance from Muggah Creek the largest). The predominant community on fine sediments, which occurred peripherally to the zone in Central and Northeast South Arm having high TOC, Total PAH and PCB (a group having the gastropod *Acteocina canaliculata* present, at Stations 1, 9, 22, and 33) separated from the community having reduced components (*Cerianthus borealis* and *Nephtys incisa* only). Axis 1 explained 33% and Axis 2, 20% of the variance. Depth was strongly correlated with Axis 1 in the analysis (Table 11c), and the leftmost grouping is clearly slightly deeper than the others, but depth probably only represents a small component of the difference, and the effects of the variables in this analysis are in general small. Axis 2 represented a grainsize gradient, with silt most highly correlated with the axis (r=0.63, Table 11c). The depth effect reflects the distribution of these stations in generally shallower waters peripheral to the zone of high TOC and contaminants in Central South Arm.

Some of the biological community measures and the distributions of dominant invertebrate species in South Arm showed statistically significant regression relationships with the concentration of Total Organic Carbon (and likely with TPAH and PCB, because of the high correlation of these parameters with TOC), and also distance from Muggah Creek (Table A5), indicating a response to contaminated conditions in Central South Arm. Some species showed decreased abundance in the Central South Arm compared with other areas, while others showed no apparent relationship. *Number of species per sample* was explained by a multiple regression of depth and distance from Muggah Creek, from 42 to 64% of the variance (depending on dataset or combination of variables in the regression) was explained by this relationship (Table A5). Number of species showed a significant regression on depth in July 2000, which explained 59% of the variance, which increased slightly when depth and TOC were added. The regression of number of species with TOC alone or distance from Muggah Creek explained only 23-38% and

20-44% of the variance in number of species respectively. Several parameters (TOC, distance from Muggah Creek, depth, silt and clay) frequently showed significant partial regression relationships or significant individual regressions with number of species. *Biomass* showed significant regressions principally with distance from Muggah Creek and TOC, but a comparatively small percentage of the variance (from 20-44% and 23-38% respectively) was explained by regressions (Table A5). *Abundance of organisms* showed significant multiple regression relationships with depth, TOC, silt, and clay (Table A5). *Shannon Wiener diversity* did not show significant regressions in either single or multiple regressions with the parameters of TOC, distance, depth or silt and clay.

Abundance of the bubble shell *Acteocina canaliculata*, and the polychaetes *Ninoe nigripes* and *Mediomastus ambiseta*, all showed significant linear regressions, frequently with depth (the most important) (negative rlationship) but also with distance from Muggah Creek (positive) and TOC (negative) (Table A5). These species were least abundant in the central harbour and occurred in greater abundance in the fringe (which often were shallower stations, accounting for the depth relations) (Figures 30-36). These regressions typically accounted for a high proportion of variance in the abundance of these species (from 39 to 78%), but the proportion of the abundance of *Mediomastus* explained was lower (12-45%) (Table A5).

The abundances of the nemertean *Cerebratulus* sp and the polychaete *Nephtys incisa* were more strongly influenced by distance from Muggah Creek and TOC in the regressions, which typically accounted for a smaller proportion of abundance in these species (22-49%).The abundance of the burrowing anemone *Cerianthus borealis* had no significant regressions with depth, distance from Muggah Creek, TOC or the others. *Cerianthus* is widely distributed in Sydney Inlet, particularly throughout South Arm and at the mouth of Muggah Creek, and its abundance does not appear to be influenced by conditions there. The species' tubes extending into the sediment isolates it from conditions which occur there.

Oxygen depletion in nearbottom waters through sediment oxygen consumption and other factors such high BOD effluent is a possible causative factor in the distribution of seabed biological communities in many coastal areas. With the exception of one station at the mouth of Sydney River, at no time during the current survey did oxygen levels in near bottom waters show reduced oxygen concentrations (Table 13). A survey in August 1987 (P. Lane and Associates 1988), however, documented oxygen depletion in South Arm, showing oxygen levels in near bottom waters as low as 3.4 mg/L (P. Lane and Associates 1988). Since many of our stations repeated stations in that study, we could use the oxygen depletion in 1987 to examine the relationship between factors leading to oxygen consumption (chiefly current sediment organic carbon content); and the observed oxygen depletion, further to determine whether the distributions of biological organisms in the current study can be related to the pattern of oxygen consumption likely to occur. Oxygen depletion (measured as the difference in the observed levels in 1987 subtracted from 7 mg/L) (Table 14) showed significant regressions with TOC and distance from Muggah Creek, but did not explain much (only 28-38% and 19%) of the variance in oxygen depletion respectively (Table A4). Regressions using TOC, silt and clay content explained the largest fraction of the variance (43 to 72%) in oxygen depletion. Distribution of oxygen deficit from P. Lane and Associates (1988) (Figure 37) was similar to that for TOC and the other contaminants, suggesting that there may be a linkage.

Biological community measures showed several significant regressions with oxygen deficit (Table A6). In particular, number of species, biomass, abundance as well as the abundance of the polychaete *Ninoe nigripes* and *Cerebratulus* sp., showed negative regressions on oxygen deficit (Table A6).

DISCUSSION

With a few exceptions the same animal communities occurred in the Sydney Harbour system in July 2000 as occurred in October 1999. A community consisting of the *Mediomastus ambiseta, Acteocina canaliculata*; the polychaetes *Nephtys incisa, Ninoe nigripes,* and *Polydora quadrilobata*; the nemertean *Cerebratulus* sp; and the burrowing anemone *Cerianthus borealis* occurred in the Northwest Arm and parts of South Arm, but most of its components (with the exception of the burrowing anemone *Cerianthus borealis*, the polychaeta *Nephtys incisa* and the nemertean *Cerebratulus*) were not present in the zone of the highest sediment TOC and contaminant (TPAH & PCB) levels in Central and Northeast South Arm. Mid-channel of the outer harbour (Station 17), supported a community, which also occurred in 1999, dominated by the polychaete *Owenia fusiformis* but including several other species. The reference site in sandy bottom in the outer harbour (Station 14), supported community which, although reduced in abundance and number of species over 1999, was comparable in terms of community composition.

The occurrence of two stations in Northwest Arm in 2000 (Stations 24 and 26) having reduced communities similar to those in the most contaminated areas of South Arm, differed from 1999. The reduced community is shown as group A1 on Figure 25. The difference could represent a seasonal change in community distribution (July versus October) or disturbance-related phenomenon.

Patches of the capitellid polyhaete *Capitella capitata* which occurred in South Arm in one of the two samples each at Stations 10 and 38, was not observed in 1999. *Capitella* is an opportunist species and characteristically colonizes disturbed sediments, achieving high abundances.

The communities at the mouth of Sydney River in Inner South Arm were more severely reduced than in Central and Northeast South Arm, the only recurring species being the polychaete *Nephtys incisa. Nephtys* was the only recurring species in this area in 1999, as well. All organisms were marine, indicating the influence of the marine system on this part of the harbour. Sediments in the inner harbour are similar physically to those in Central and Northeast South Arm but without the high TOC levels found in Central South Arm.

The occurrence of the bubble shell gastropod, *Acteocina canaliculata* as a dominant species, found widespread in Sydney Harbour but not in the most contaminated areas, is consistent with its occurrence in a community having high numbers of polychaetes (in particular *Mediomastus*), as the species feeds on polychaetes and small clams (Maurer *et al.* 1979). The species was often abundant and contributed to the high overall abundances at many of the stations.

The elevated concentration of TOC and the associated organic contaminants (TPAH and PCB) in sediments in Central South Arm in the vicinity of the Sydney waterfront and the mouth of Muggah Creek, demonstrates once again that these areas are the principal sources. Multiple regression analysis showed the relationship between physical and chemical factors (grainsize parameters, depth), and distance from Muggah Creek. For TOC, TPAH and PCB content, distance from Muggah Creek in most cases was the most important independent variable in the regressions. The analysis showed that concentration of PCBs was less well predicted than TOC and Total PAH by the regressions with distance from Muggah Creek, suggesting that Muggah Creek may be more significant as a source for TOC and Total PAH than for PCB. Depth was a minor factor in some multiple linear regression relationships for sediment physical characteristics, organic contaminant levels, and biological parameters. Depth did not emerge as clearly in the statistical analysis as expected, possibly reflecting a narrow depth range sampled and possible inaccuracies in depth measurements. The small-scale topography of the seabed in the South Arm was not known, although depth distribution on transects, and the distribution of TOC and contaminants, suggests that there may be a channel-like feature in South Arm. Better values of depth, as for example extracted from a digital depth model for the harbour, may show greater importance of depth in linear regression relationships, since the variation in many of the parameters in the study, both biological and physical, would be expected to have a depth component.

The pattern of localized elevated TOC with associated contaminants in the vicinity of sewage outfalls occurs in other heavily populated coastal areas (e.g. Halifax Inlet, Buckley & Hargrave 1989) and many other developed harbours in Nova Scotia have high levels of sediment organic carbon, comparable to those found here (Loring *et al.* 1996). Muggah Creek is one of the depositories for raw sewage, and a major source for South Arm. Although it hasn't been examined here, trace metal content is frequently elevated in sediments enriched in organic content by sewage inflows, and is expected to show a similar relationship to at least TOC and Total PAH, which showed the best relationship with distance from Muggah Creek.

A variety of factors related to the enriched organic loading as well as Total PAH and PCB content of sediments could operate to affect biological communities. Contaminant levels in the organic sediments could be toxic to the organisms; high oxygen demand of the organic rich sediment is probably an important factor, as well as associated possible periodic reductions in nearbottom oxygen; and the physical properties of the sediments (e.g. texture) can physically affect suitability for colonization by animals.

Distribution and character of benthic communities both in 1999 and 2000 showed the influence of the zone of highly organic sediments in Central and Northeast South Arm. The group of organisms living on the sediments most contaminated with TOC, TPAH, and PCBs were reduced in numbers, biomass and diversity compared to those in other parts of the harbour, although the predominant species in the group (*Cerianthus borealis; Nepthys incisa;* and *Cerebratulus)* occurred in both contaminated and relatively uncontaminated areas. The dominant species occurred consistently between years and also appears to have been present in the Arm in the late 1970s and 1980s (Stewart *et al.* 2002). *Cerianthus borealis* and *Nephtys incisa* have been associated with contaminated sediments in other studies, and *Nephtys incisa* is resistant to low oxygen conditions (Nilsson and Rosenberg 1994). *Phoronis architecta,* which occurred occasionally in contaminated areas of the harbour (found in 2000 by Querbach 2002), can also tolerate reducing sediments (Vandergon and Colacino 1989; 1991).

These patterns of distribution of communities in relation to sediment contamination in South Arm, were further shown by linear and multilinear regression relationships with a distance from Muggah Creek and TOC, although often depth was a significant variable (compared to contaminants), where TOC and distance from Muggah Creek was typically most important. The core species in the main community, however, showed fewer significant regression relationships (Table A5) and *Cerianthius borealis* showed no significant regression relationships with any variable, reflecting its consistent occurrence throughout the zone with highest TOC and organic contaminants as well as in other areas, and showing the presence of a community tolerant of the TOC, TPAH and PCB contamination in the area.

One linkage proposed here between the high organic and contaminant levels in sediments and biological communities, is the role of reduced oxygen conditions, both continuously through the presence of reducing sediments, and with periodic oxygen reductions in near bottom waters under particular oceanographic conditions. TOC was one of the important factors influencing the abundance of species in the regression analysis, affecting number of species, biomass and abundance, and is likely to be strongly correlated with oxygen demand of sediments and its potential for creating reduced oxygen conditions.

Based on the existing information, Sydney Harbour does not appear to be influenced particularly by oxygen reductions in nearbottom waters, although the available information is insufficient to describe conditions in the harbour in the long term. The present DFO study did not encounter near bottom oxygen depletion (October 1999 and 2000, July 2000), and the only record of occurrence is oxygen depletion event sampled in 1987 (P Lane and Associates 1988). However levels measured were at some distance above the seabed, and levels in the boundary layer could be expected to be much lower. The presence of organisms in the most of the contaminated areas suggests that long-term occurrences of extremely low oxygen does not occur, since no animals can survive under those conditions (Nilsson and Rosenberg 1994) and such areas have typical patterns of recolonization and reduced fauna which were not observed here. In addition, the biological community in South Arm included several size classes of individual species, possibly representing different year classes. Some of the *Nephtys incisa* captured in South Arm in the present study were at least one year old (established by measuring the width of the tenth segment and using size categories from Zajac and Whitlatch (1988)).The largest *Cerianthus borealis* observed had a body 5-6 cm long exclusive of tentacles, also indicating an advanced age. These species appear to be resistant to the various factors, including reducing conditions in sediments, as well as high levels of contaminants, in the Sydney Harbour system. Some of these species can apparently persist for prolonged periods (including apparently since the late 1970s).

Toxicity of the contaminants in Sydney Harbour sediments, in particular TPAHs (which occur at much higher levels than PCBs) to animals in sediments, both the juvenile and adult stages of species sampled here, as well as to sediment micro- and meiofauna, may be a potential cause of the reductions in and composition of communities in South Arm. Concentrations of TPAHs and PCBs in the most contaminated areas of South Arm are significantly above sediment quality guidelines for the protection of marine life and probable effects levels (CCME 1999). In the case of benzo(a)pyrene, typical levels in contaminated areas of 10-30 ug/g exceed the probable effects level of 763 ng/g by 1-2 orders of magnitude. Levels of total PCBs up to 3400 ng/g also significantly exceed probable effects levels of 189 ng/g (CCME 1999). Other contaminants as well (e.g. aliphatic hydrocarbons, metals) are also high in these areas and are responsible for toxicity to biological organisms. The prolonged presence of these levels of PAHs, PCBs and hydrocarbons, as well as other contaminants, could influence distribution of benthic communities by direct toxic effects, and by preventing larval settlement. With any contaminants, however, it is necessary to know the form and means of exposure, as well as showing probable exposure. The extremely high levels of PAHs and PCBs suggest that levels in environmental compartments likely to affect benthic organisms, are also high.

Sediment contaminants, as well as reduced oxygen conditions, are thus almost certainly important factors in the distribution of biological communities in Sydney Harbour, but the relative influence, as well as the specific effects on organisms, must still be determined.

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FIGURES

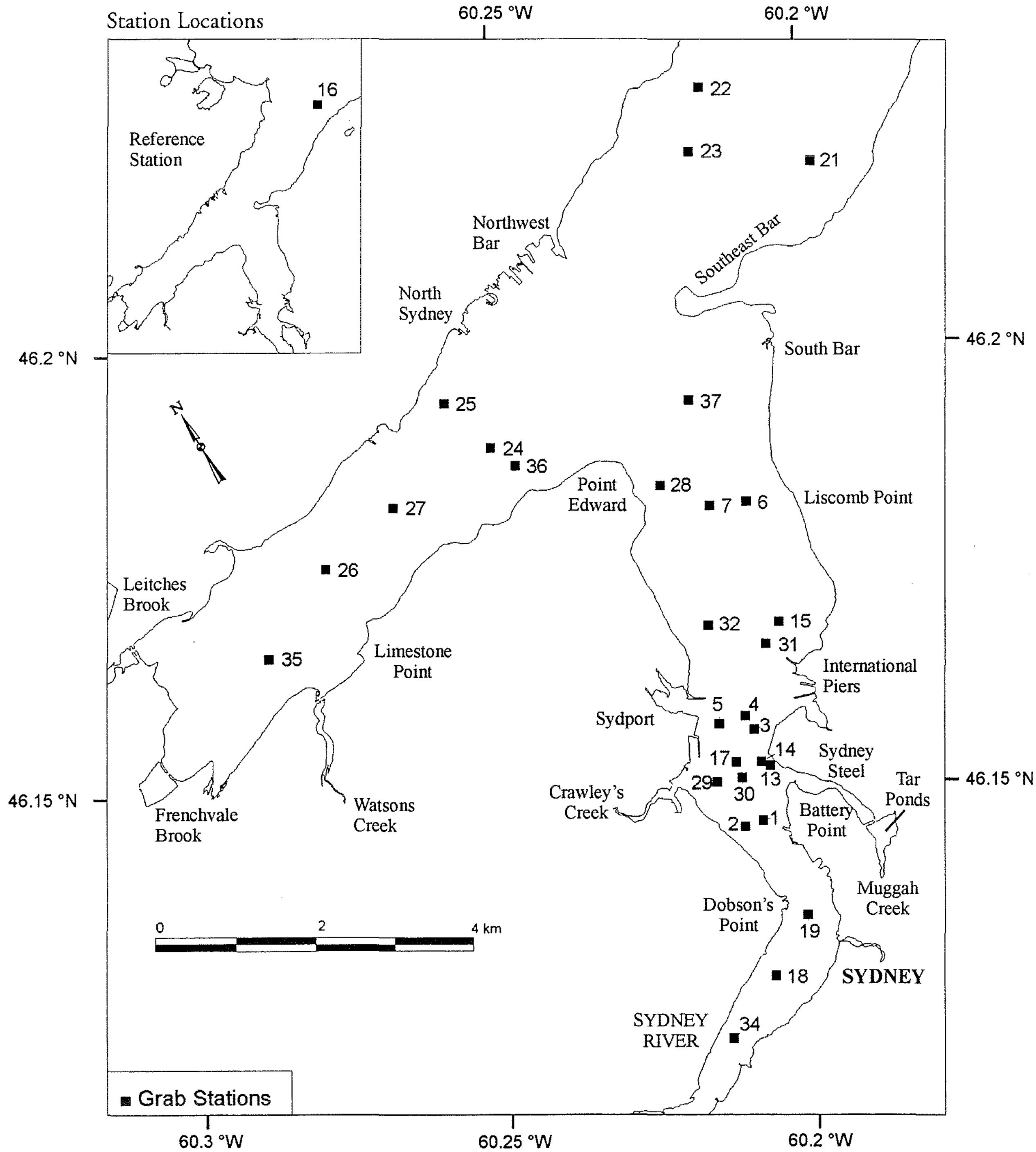

Figure 1. Station locations in Sydney Harbour, MV Navicula Cruise 99-072, October 1999.

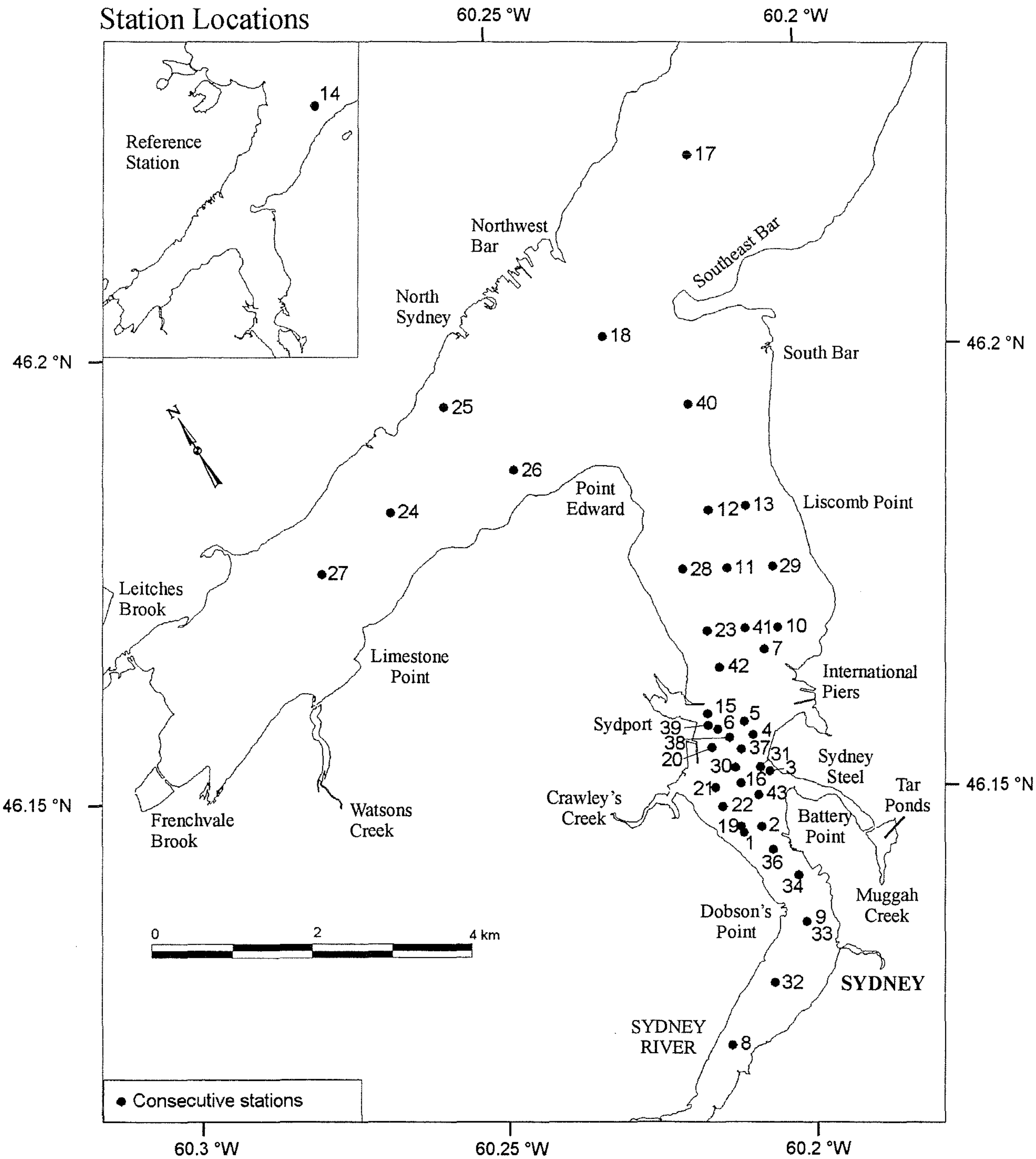

Figure 2. Consecutive stations for sediment sampling, CCGS Earl Grey Cruise 2000-073, Sydney Harbour, Nova Scotia, July 2000.

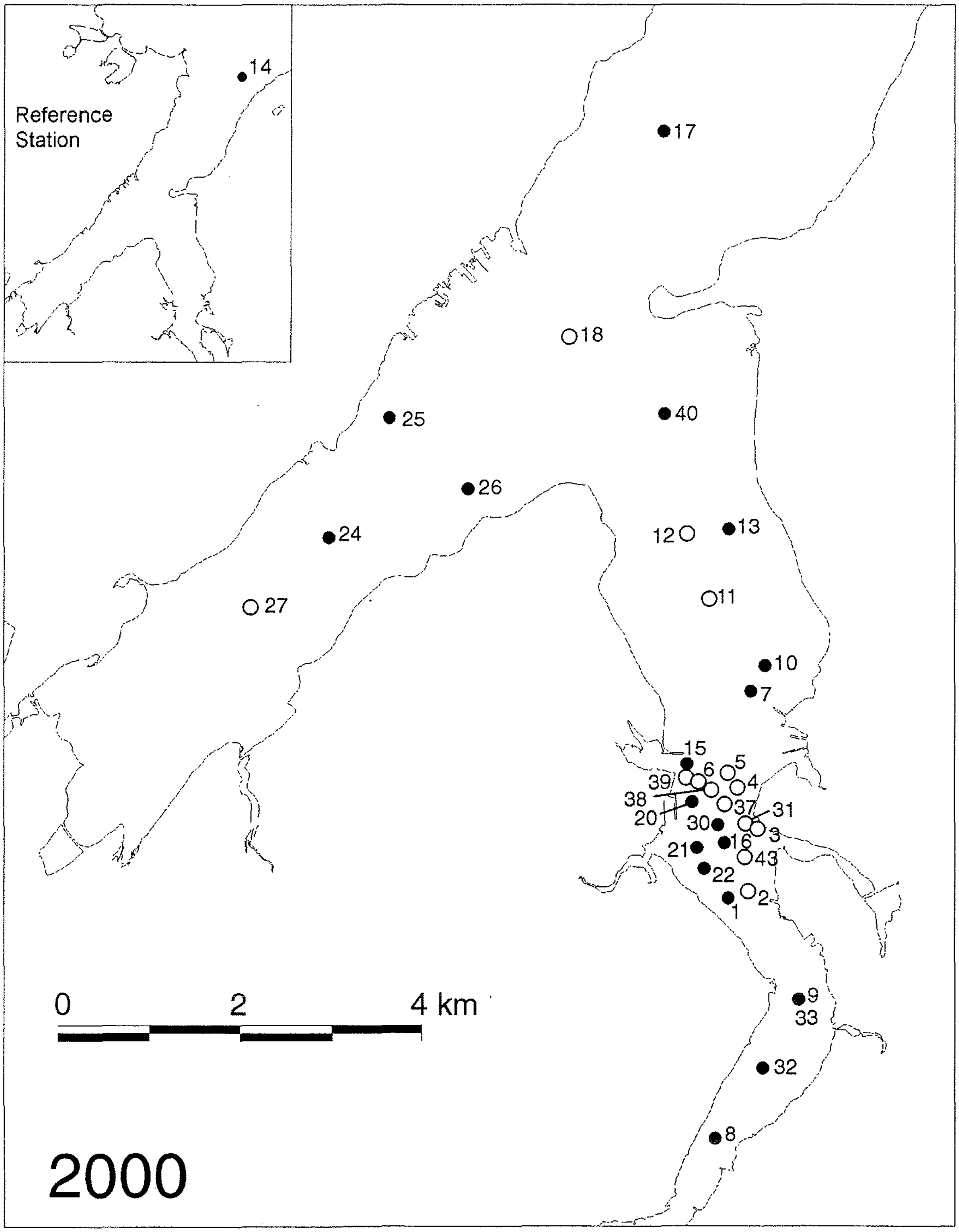

Figure 3. Stations for analysis of Biological Communities, Sydney Harbour, July 2000.

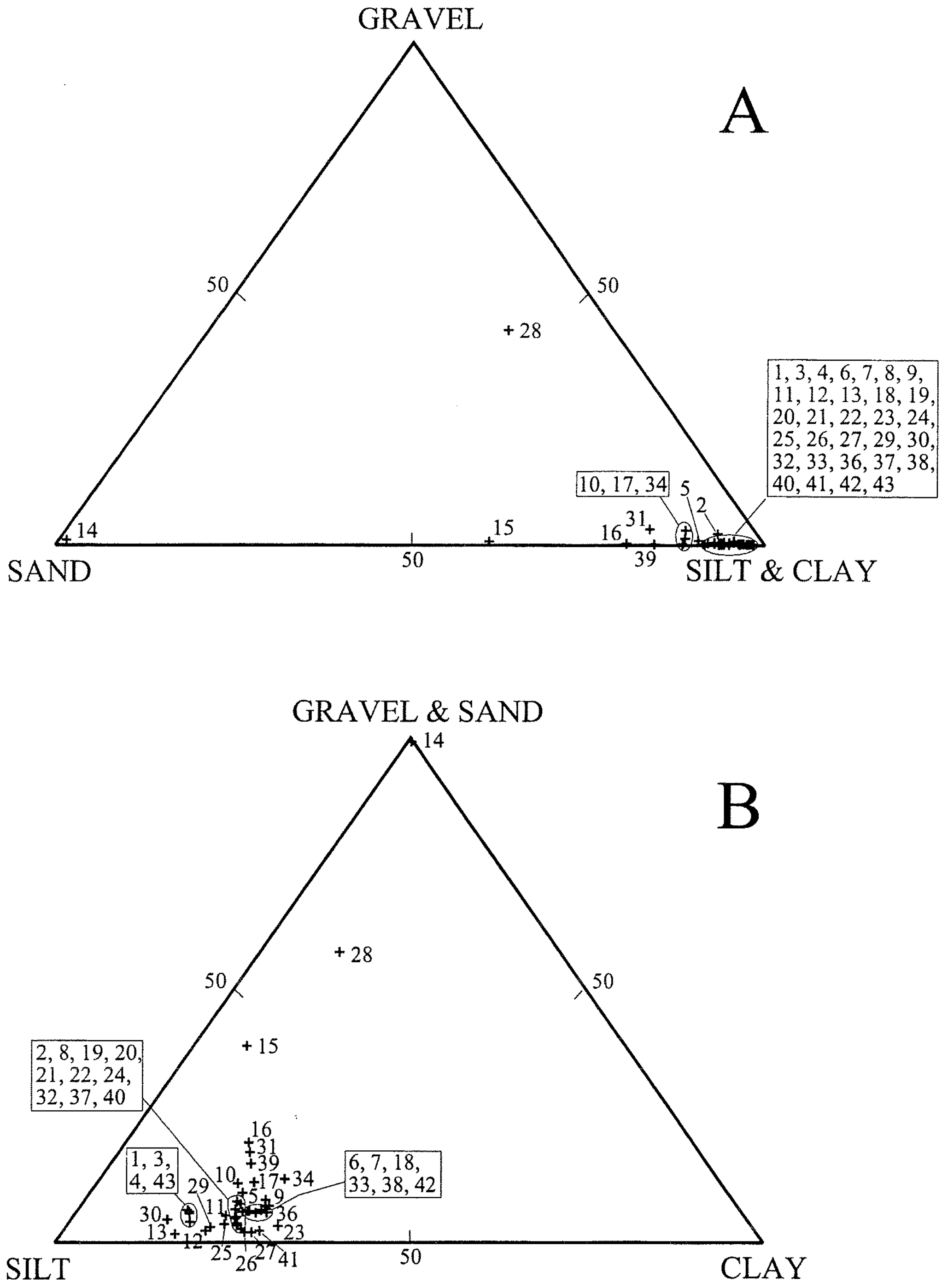

Figure 4. Ternary diagram of grainsize distribution for Sydney Harbour sediments, July 2000. Numbers represent consecutive stations. A. Based on gravel, sand, silt/clay. B. Based on sand/gravel, silt, clay.

Sand Content (%)

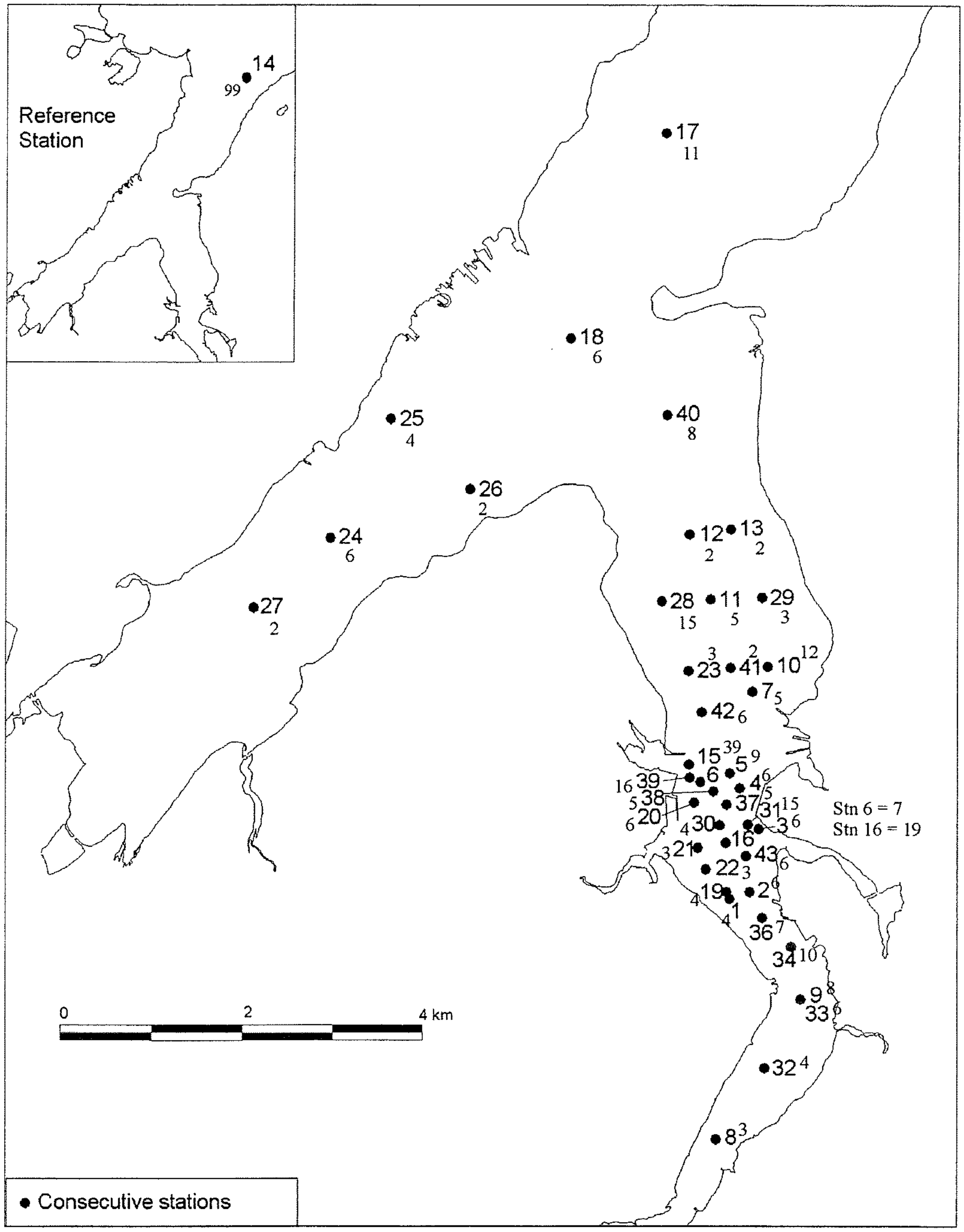

Figure 5. Sand content (%) in Sydney Harbour sediments, July 2000.

Silt Content (%)

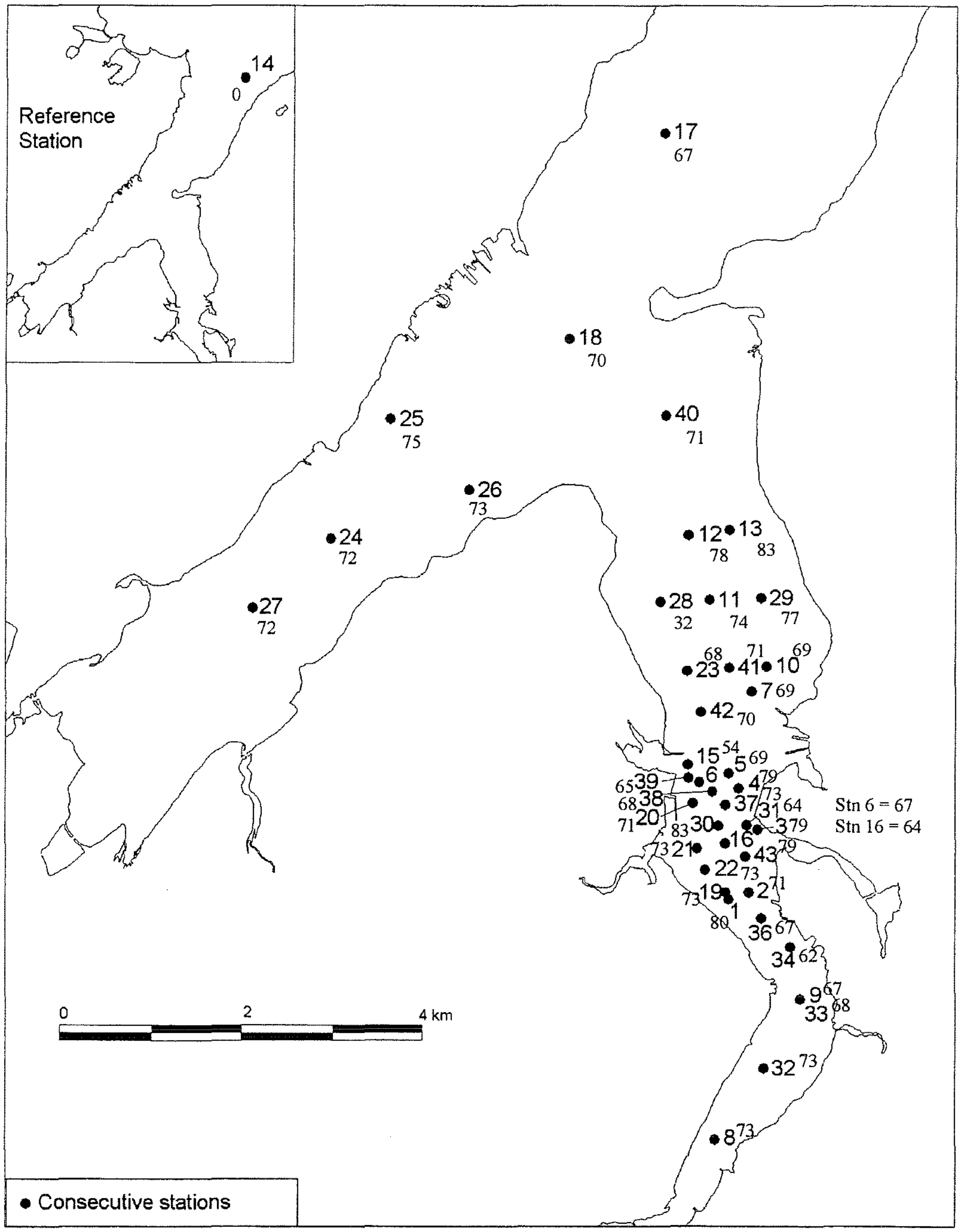

Figure 6. Silt content (%) in Sydney Harbour sediments, July 2000.

Clay Content (%)

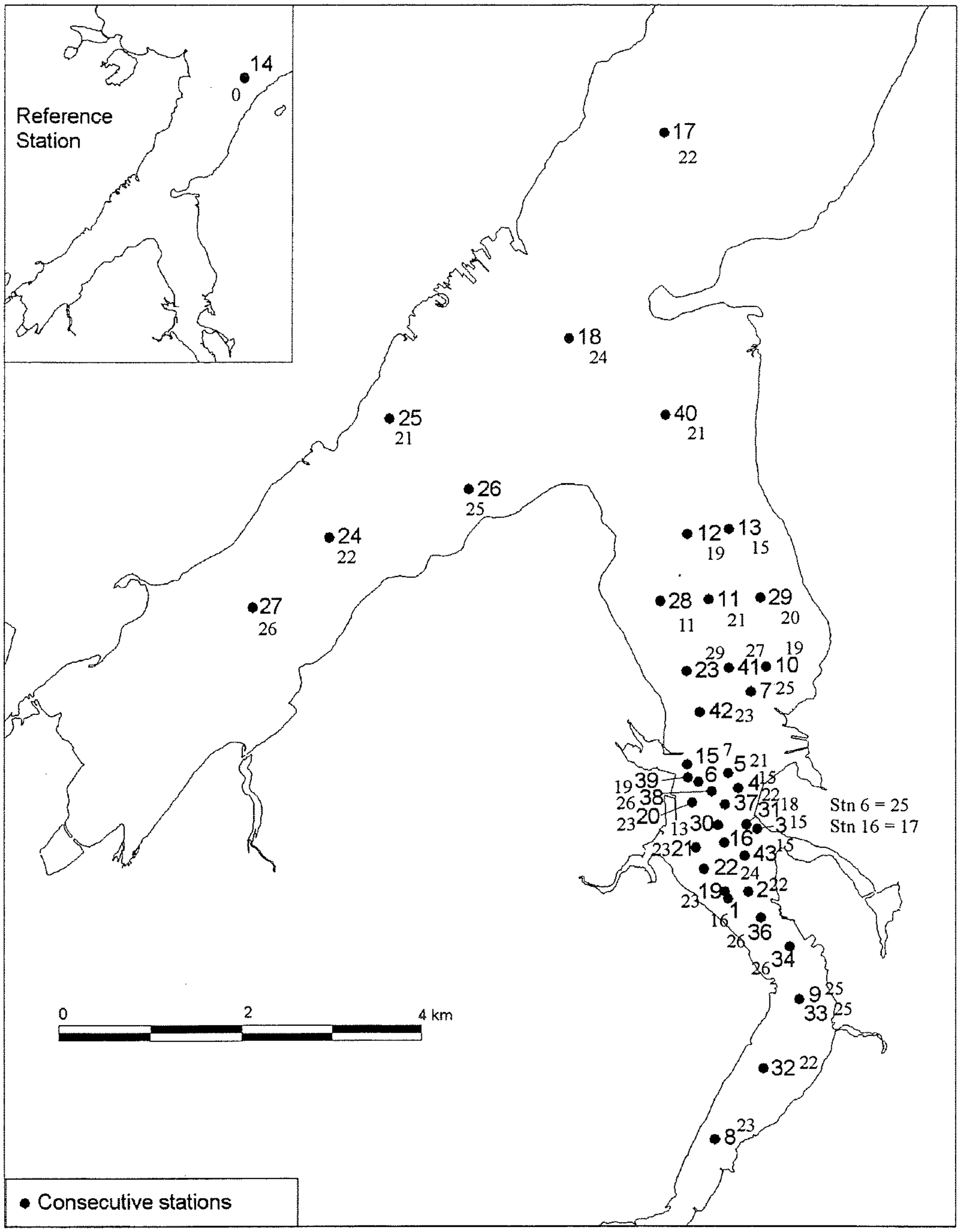

Figure 7. Clay content (%) in Sydney Harbour sediments, July 2000.

Total Organic Carbon (%)

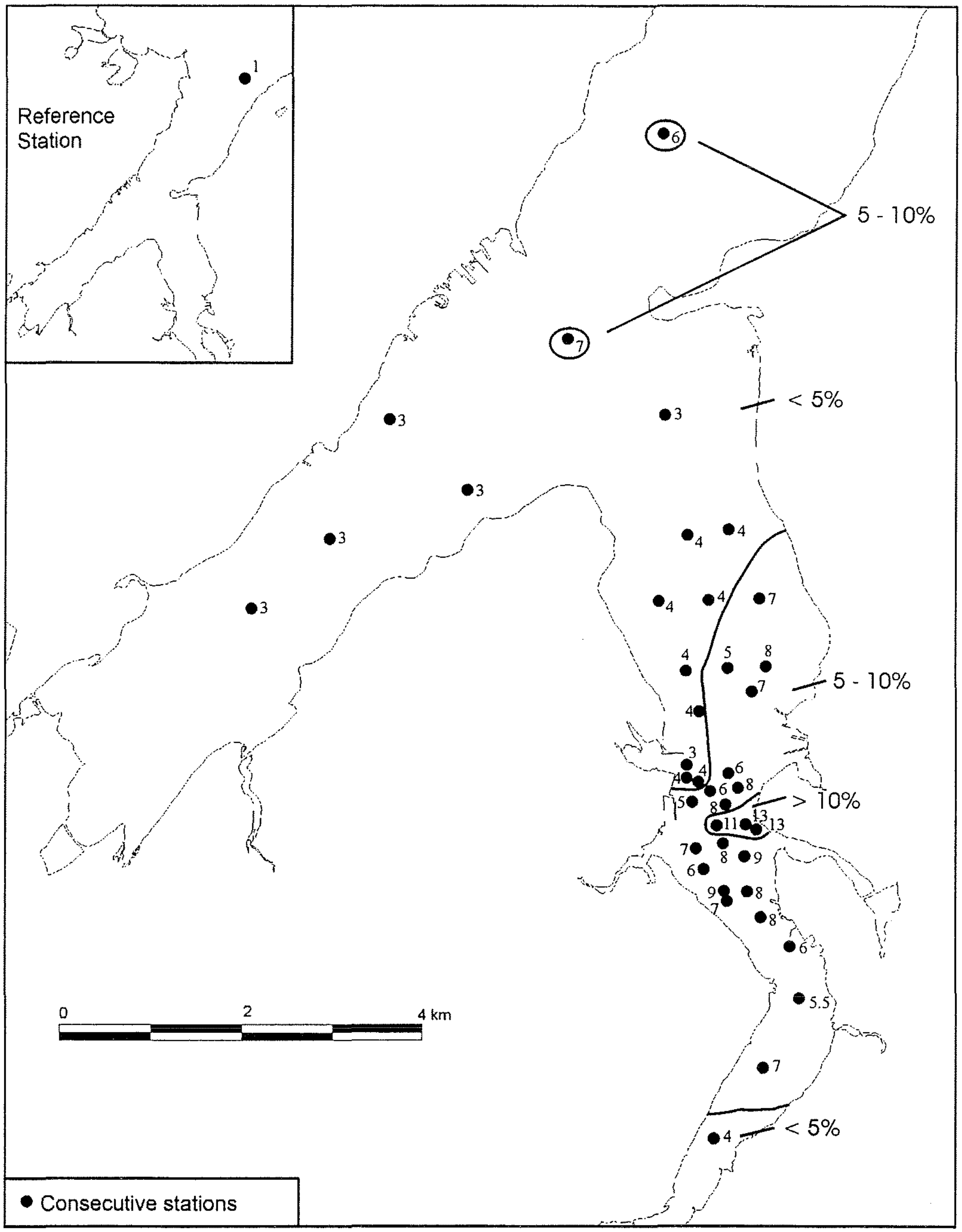

Figure 8. Concentration of Total Organic Carbon (%) in Sydney Harbour sediments, July 2000.

TOC (%)

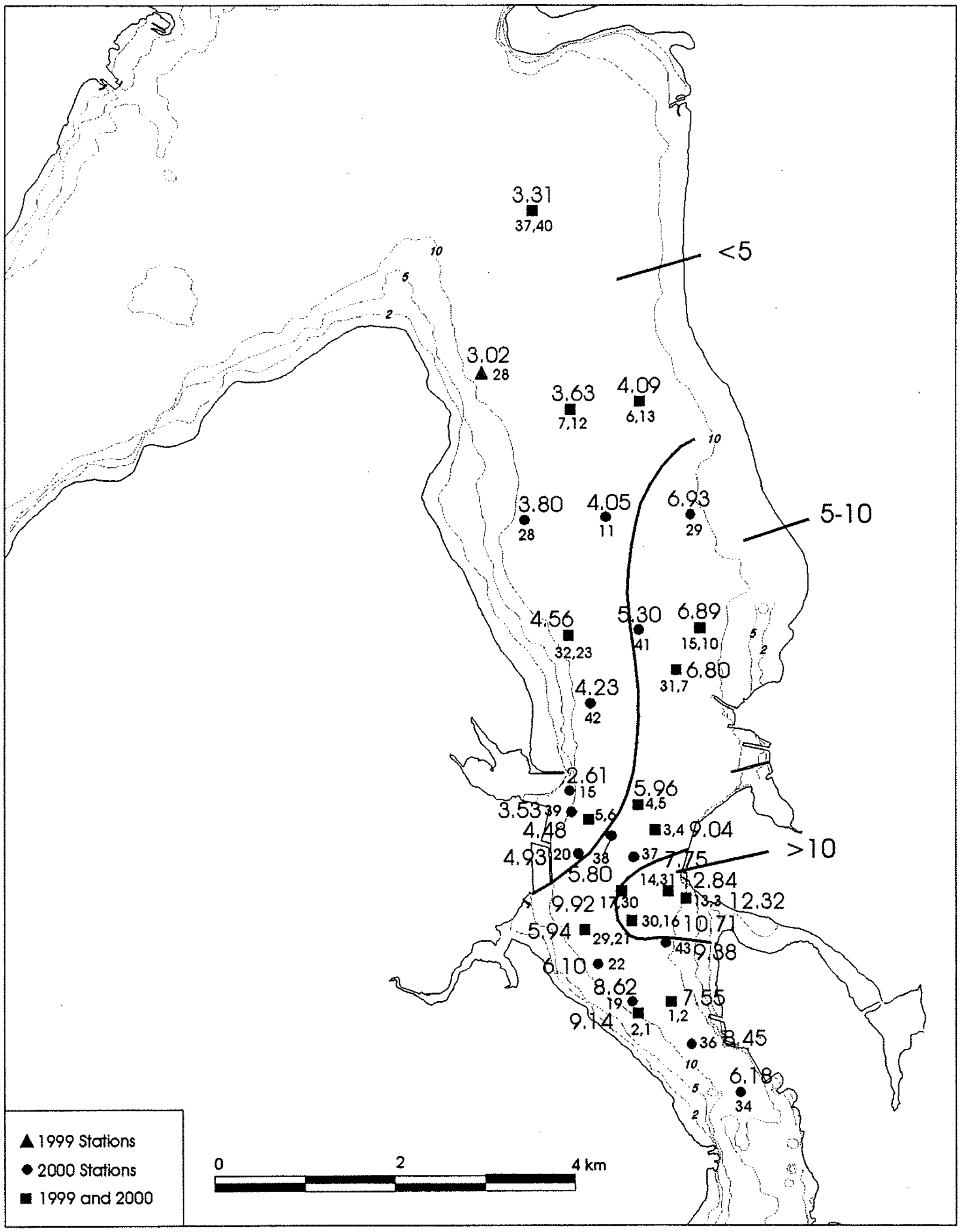

Figure 9. Concentration of Total Organic Carbon (%) in Sydney Harbour sediments, October 1999 and July 2000 combined.

Water Content (%)

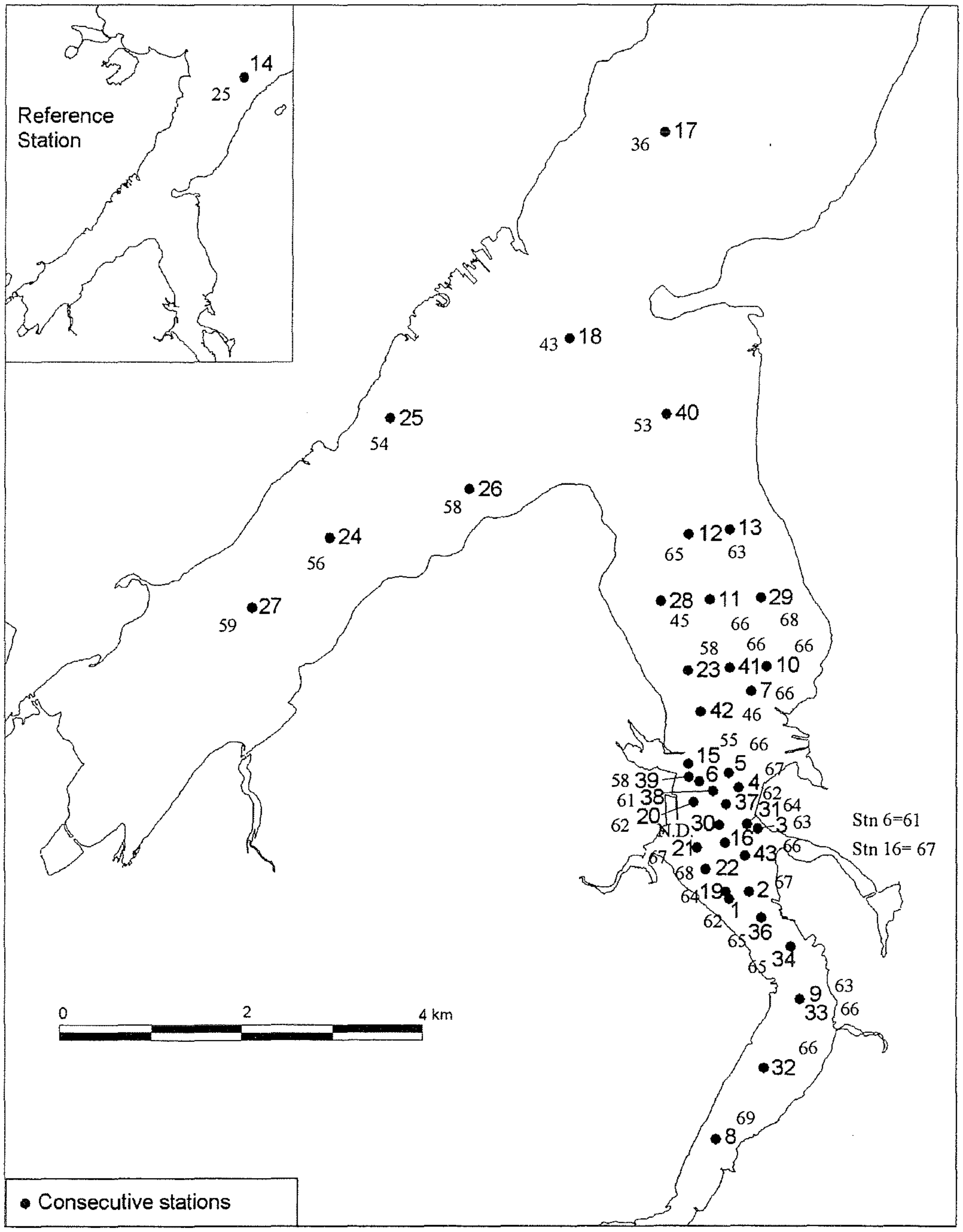

Figure 10. Water content (%) in bulk sediment samples, Sydney Harbour, July 2000.

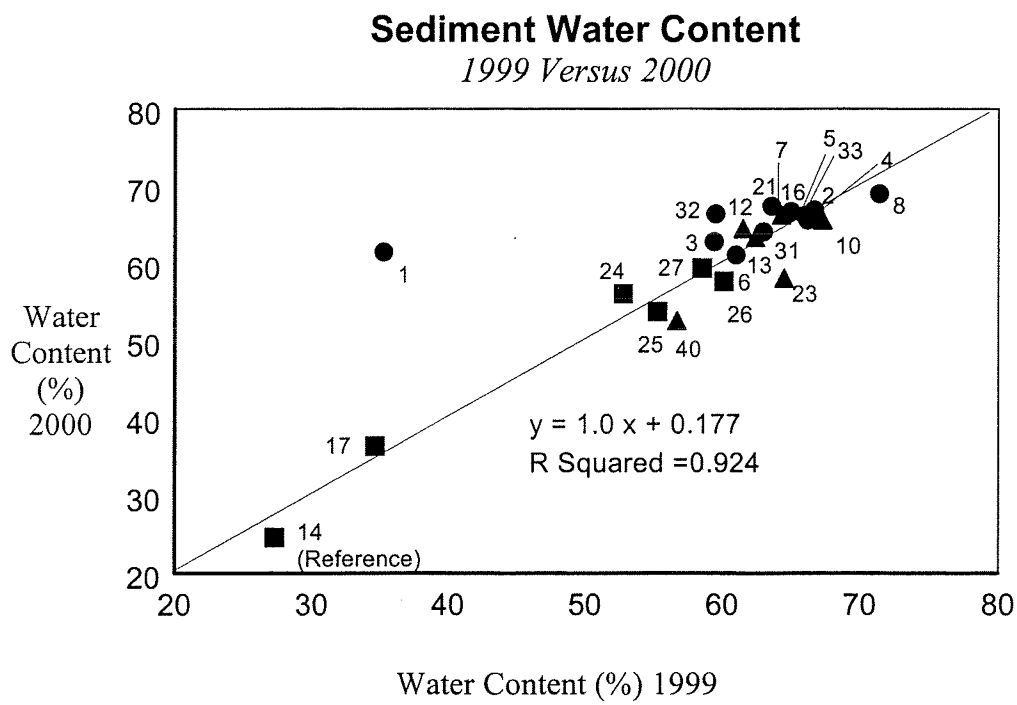

Figure 11. Regression of water content (%) in bulk sediment samples at stations in Sydney Harbour which were sampled both in 1999 and 2000. Northwest Arm and Outer Harbour stations (14, 17, 24-27) represented by squares; Outer South Arm stations (7, 10, 12, 13, 23 & 40) represented by triangles; Central and Inner South Arm stations (1, 2, 3, 4, 5, 6, 8, 16, 21, 31, 32, & 33) represented by circles. Station 1 is an outlier.

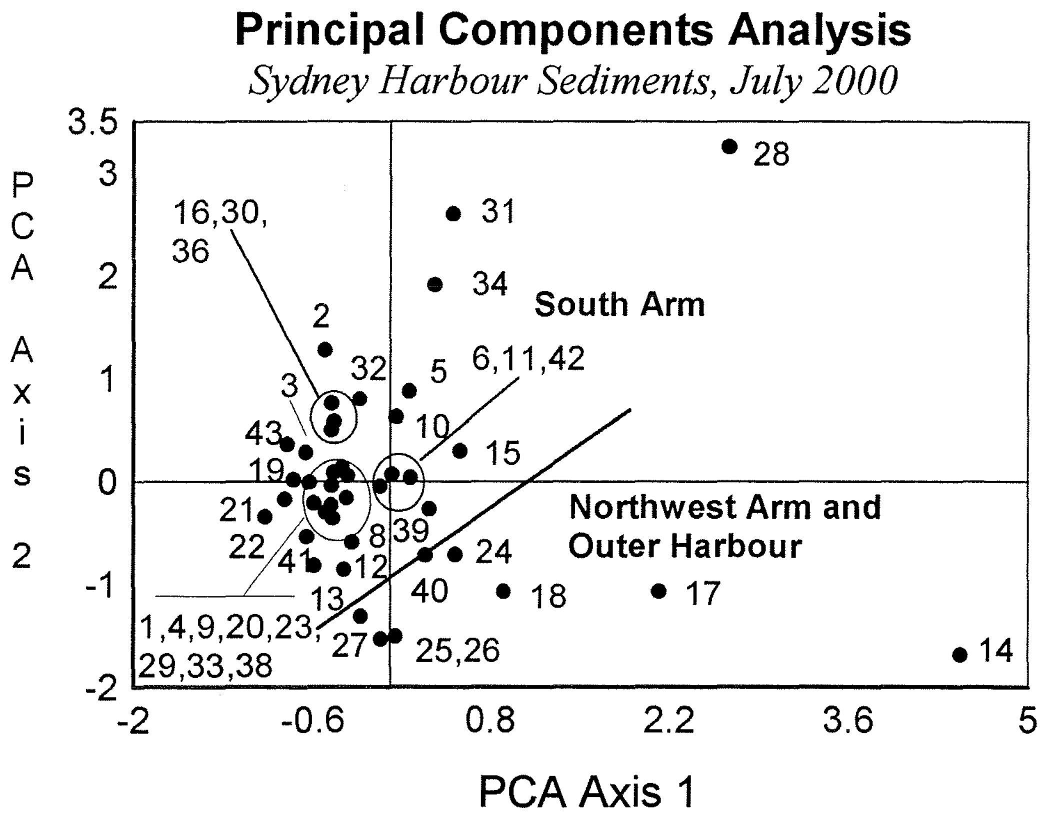

Figure 12. Plot of stations based on first two Principal Components from analysis of sediment grainsize parameters, TOC, water content, and organic contaminant content, Sydney Harbour, Nova Scotia, July 2000.

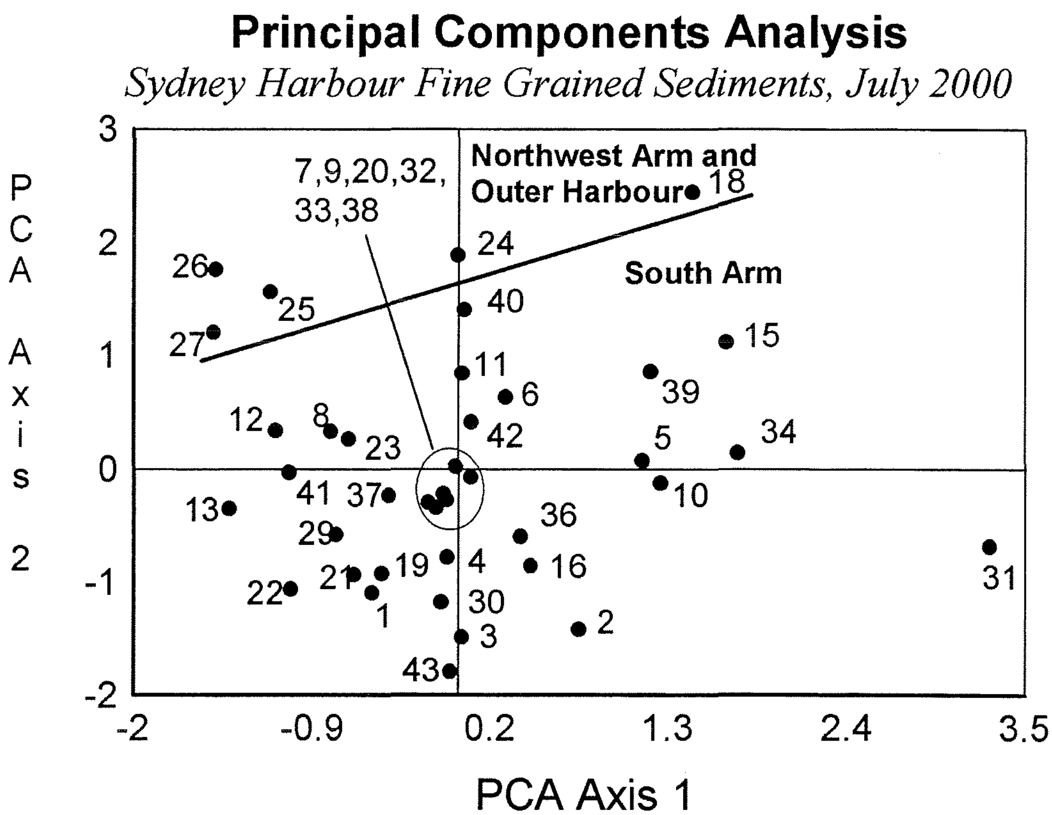

Figure 13. Plot of stations on fine-grained sediments based on first two Principal Components from analysis of sediment grainsize parameters, TOC, water content, and organic contaminant content, Sydney Harbour, Nova Scotia, July 2000.

TPAH (ug/g)

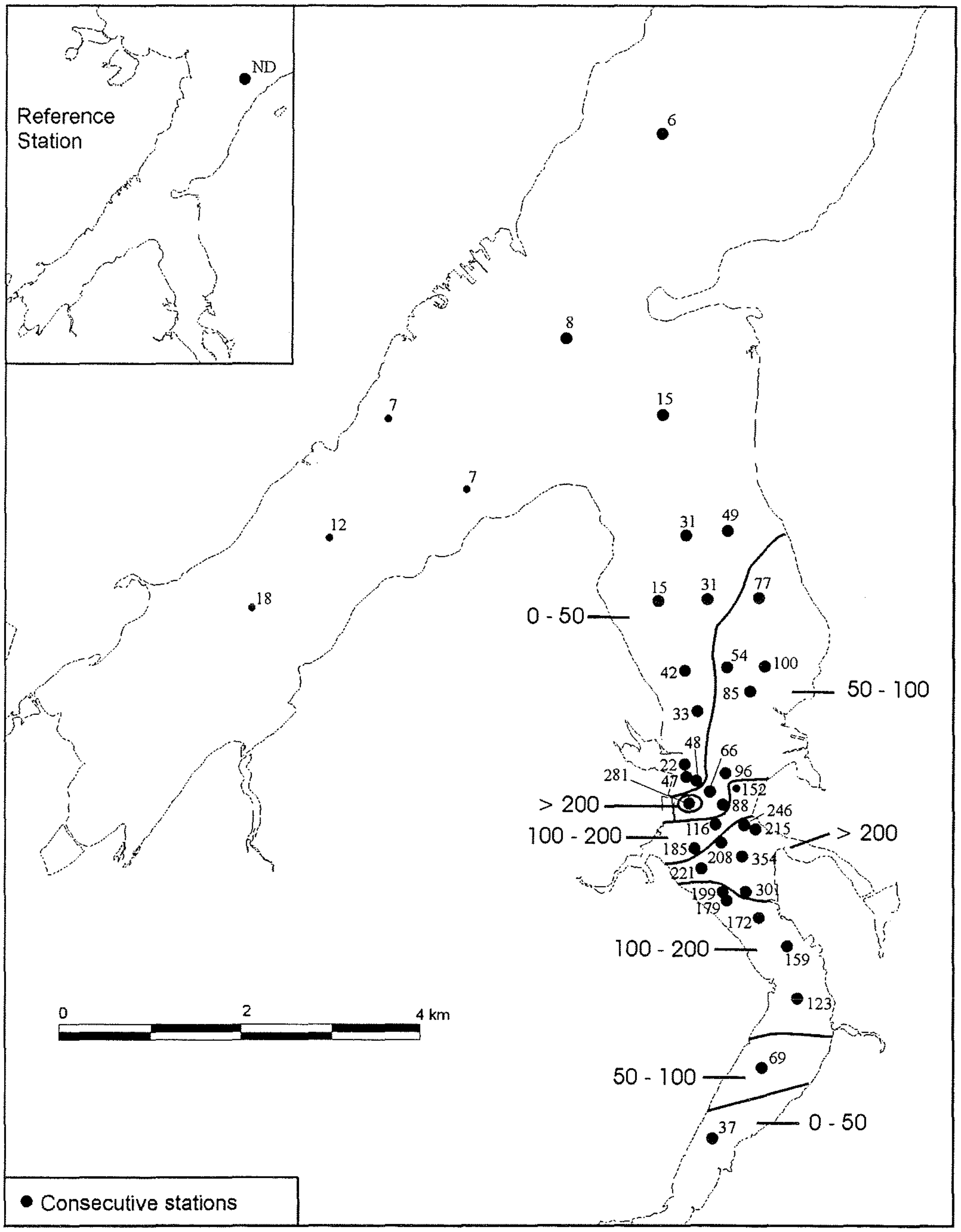

Figure 14. Concentations of total polycyclic aromatic hydrocarbons (TPAH) (µg/g) in Sydney Harbour sediments, July 2000.

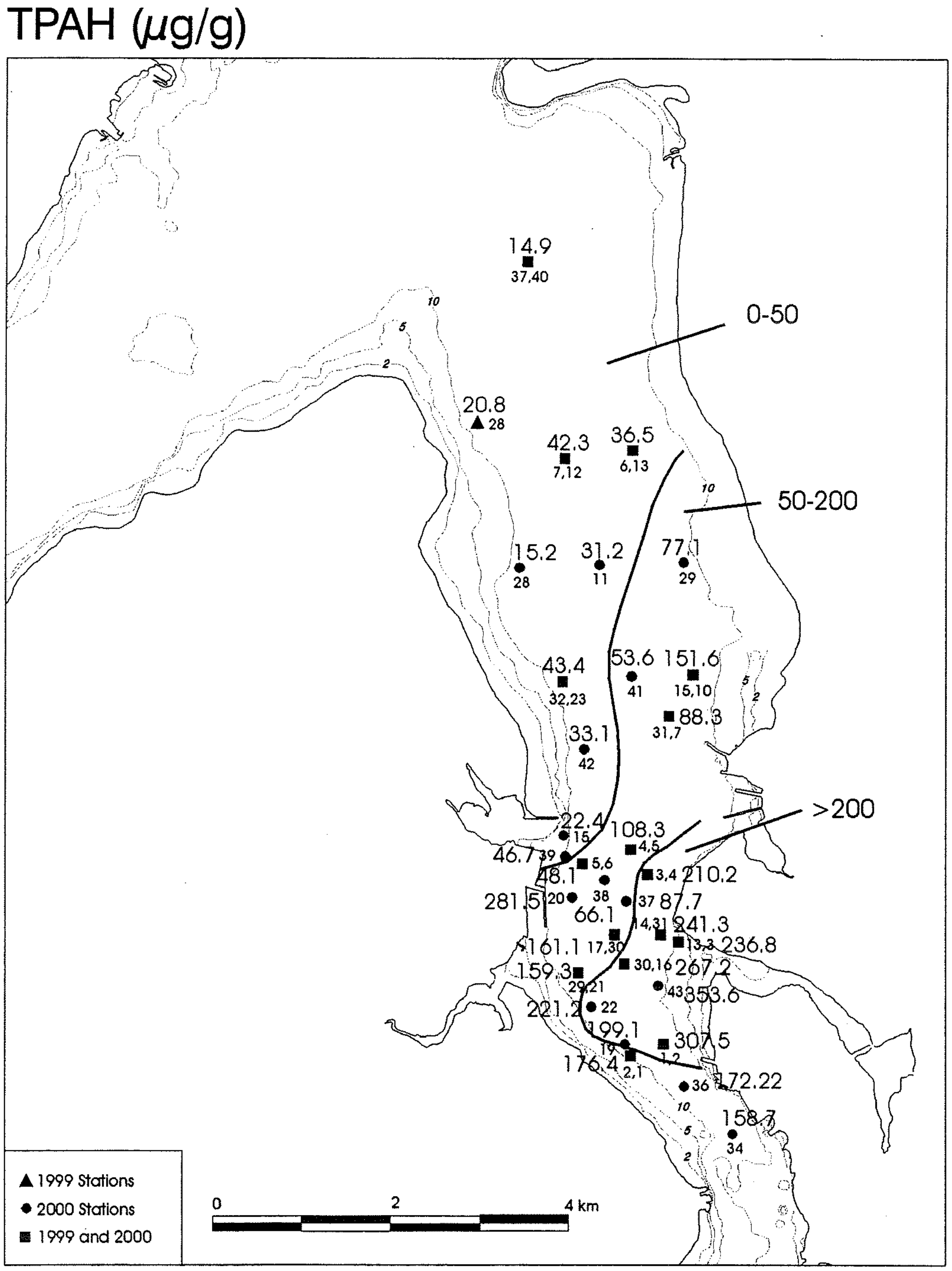

Figure 15. Concentations of total polycyclic aromatic hydrocarbons (TPAH) (µg/g) in Sydney Harbour sediments, October 1999 and July 2000 combined.

PCB's (ng/g)

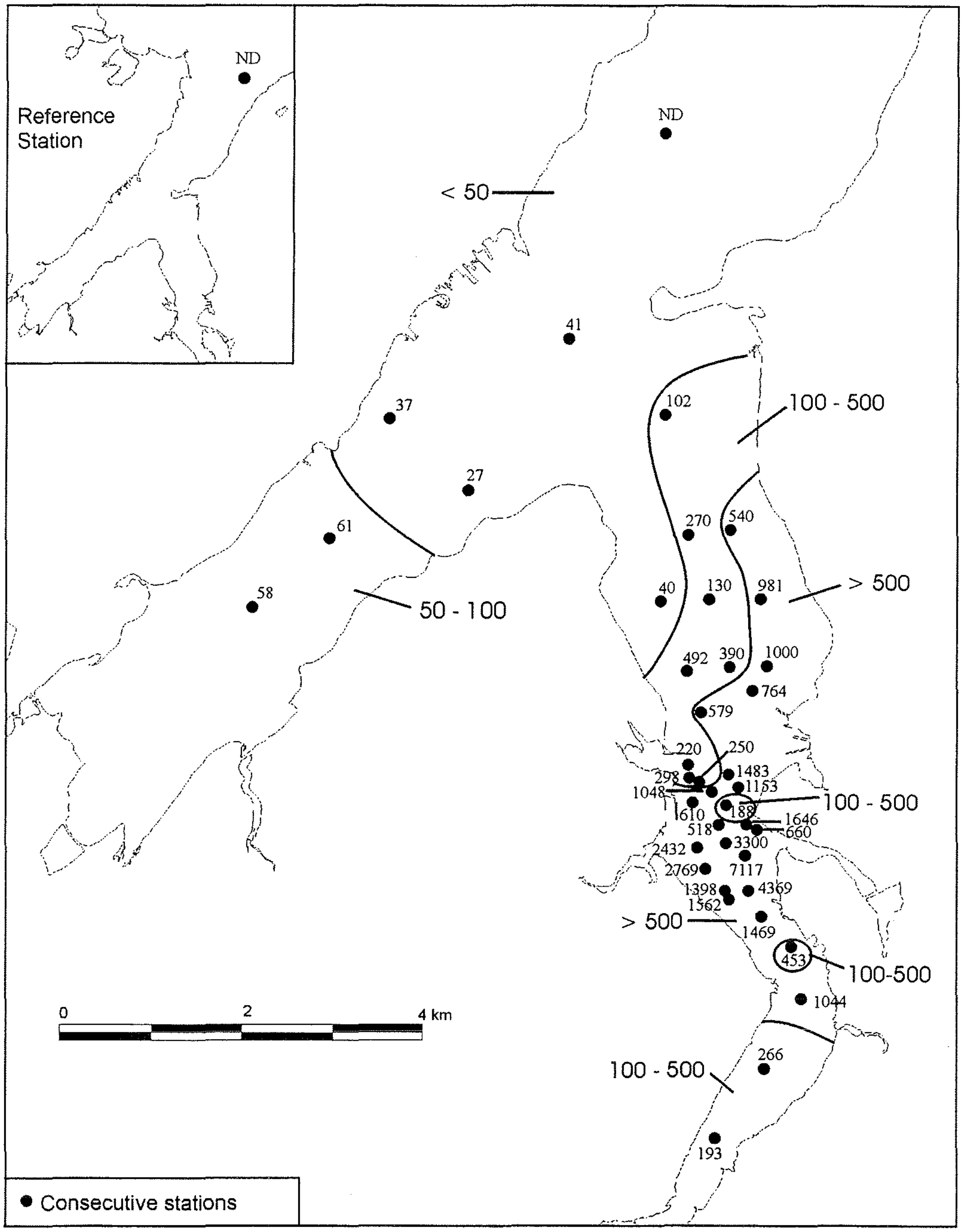

Figure 16. Concentration of polychlorinated biphenyls (PCBs) (ng/g) in Sydney Harbour sediments, July 2000.

PCBs (ng/g)

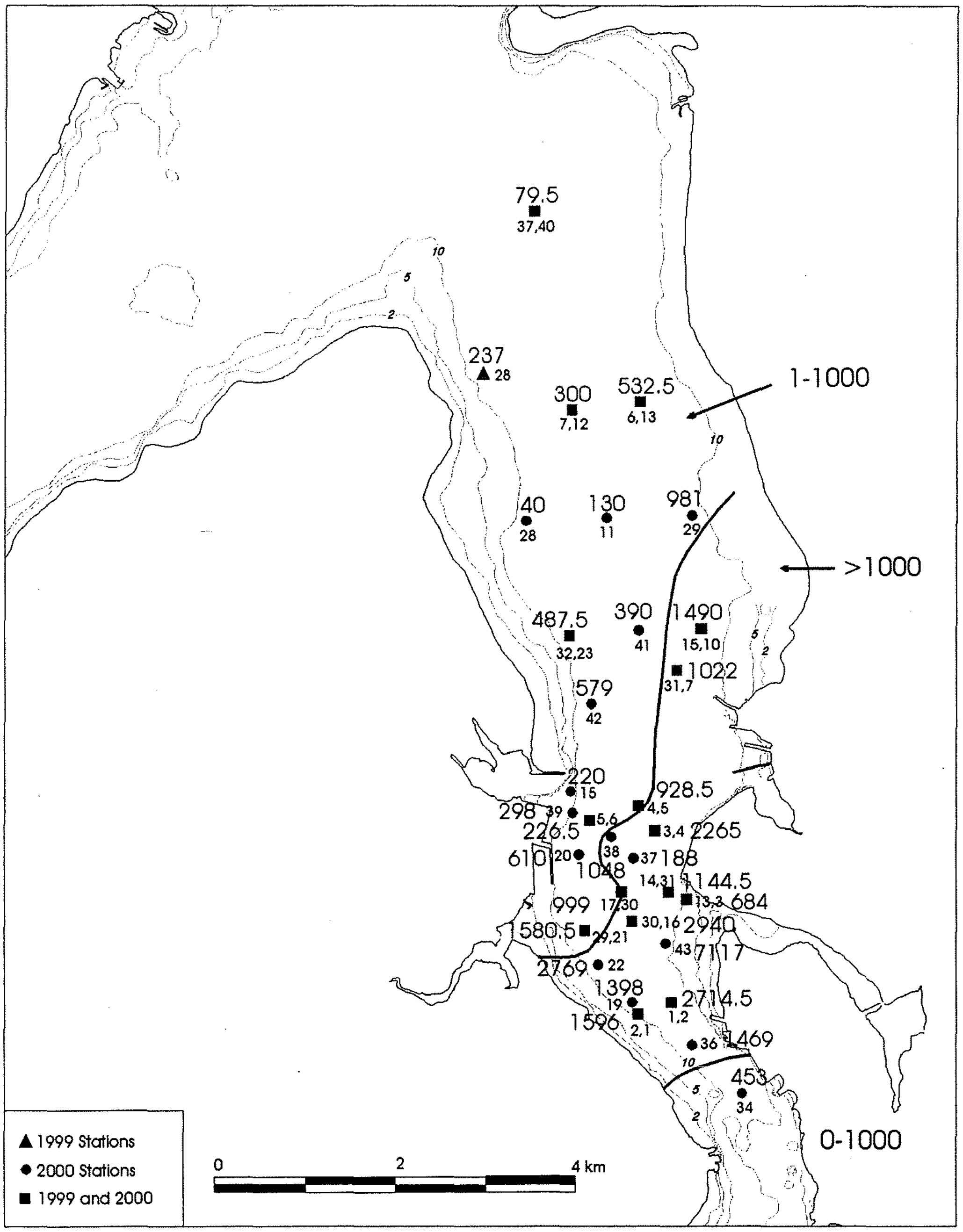

Figure 17. Concentration of polychlorinated biphenyls (PCBs) (ng/g) in Sydney Harbour sediments, October 1999 and July 2000 combined.

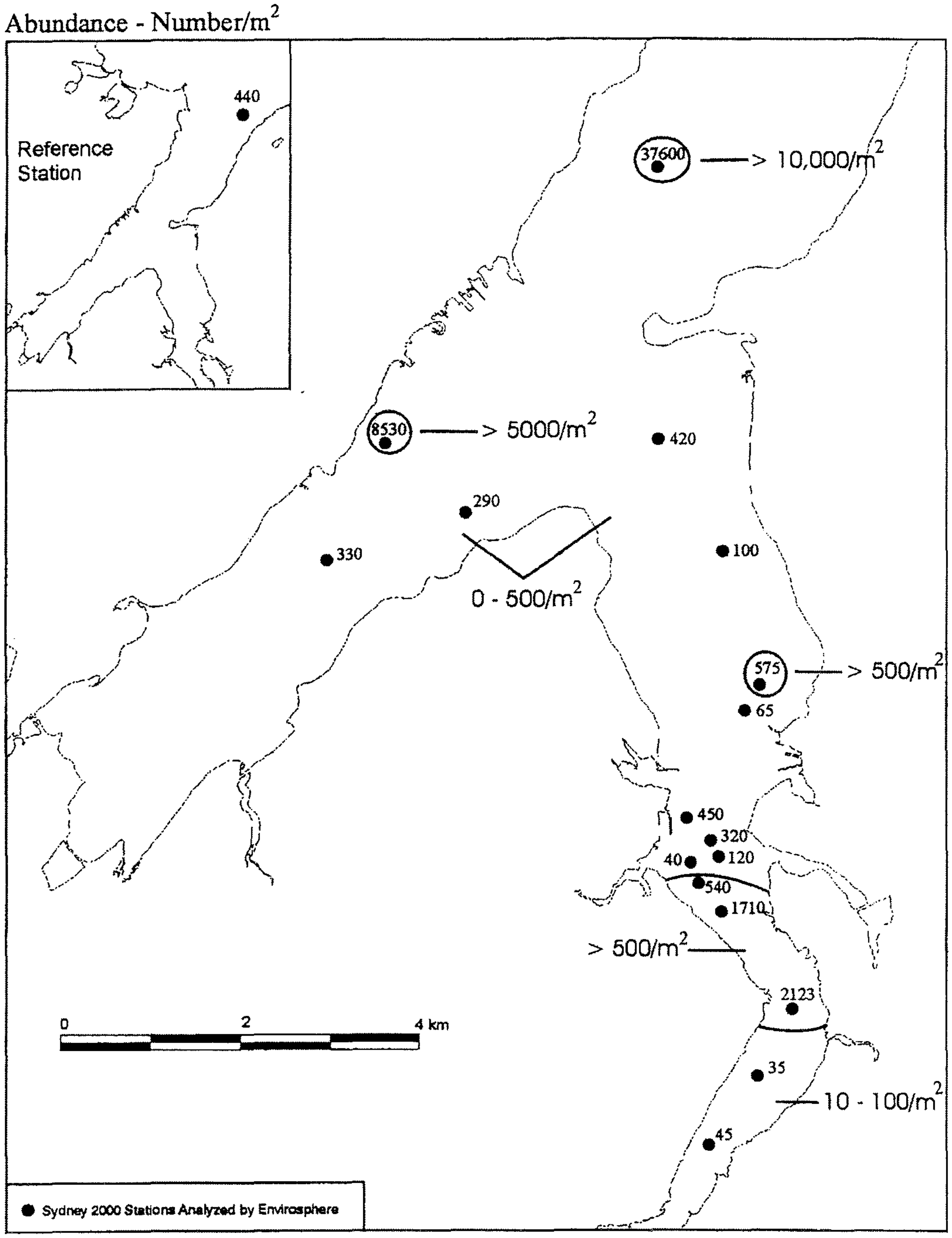

Figure 18. Abundance (number of organisms/m^2) of seabed biological communities in Sydney Harbour sediments, July 2000.

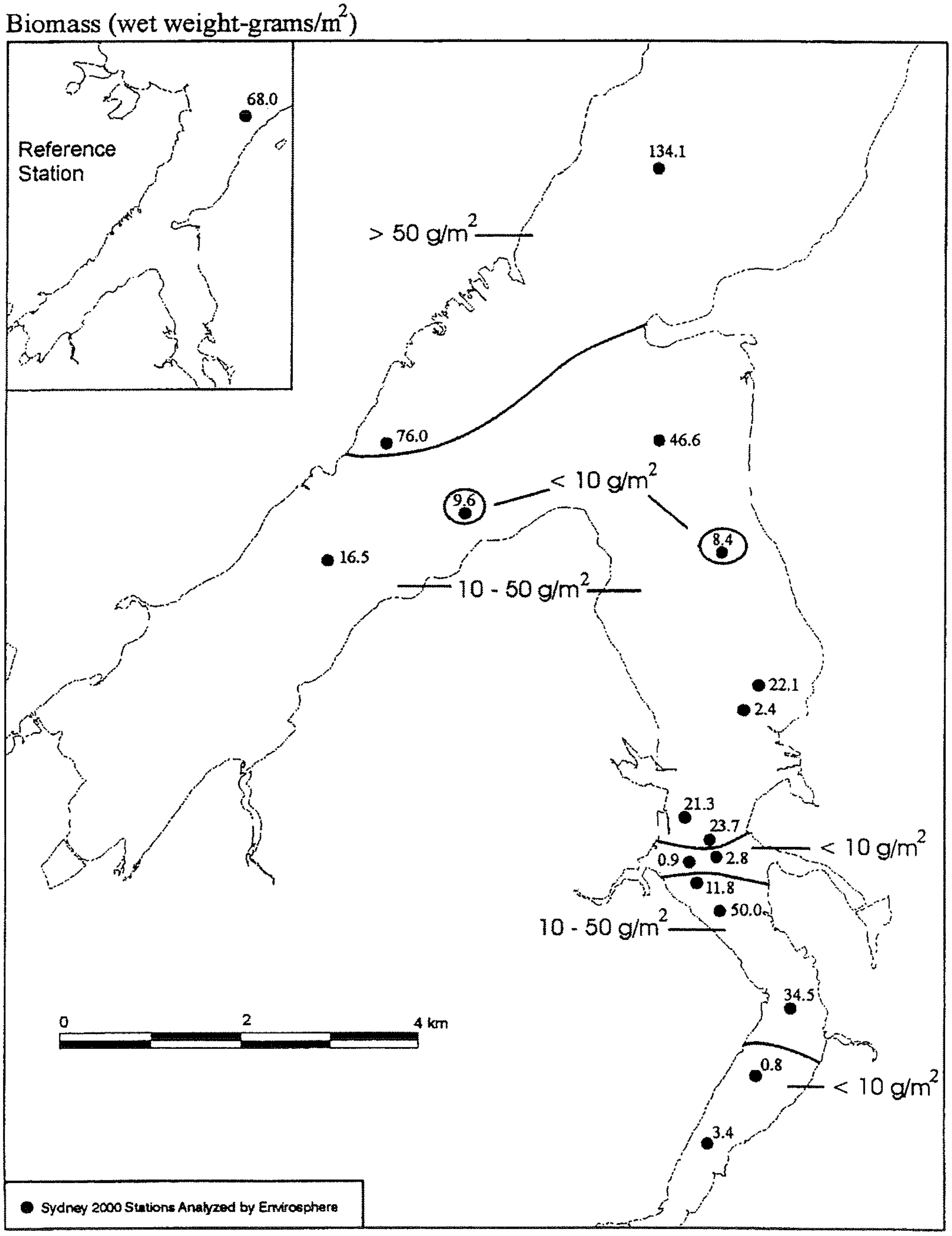

Figure 19. Biomass (g/m^2) of seabed biological communities in Sydney Harbour sediments, July 2000.

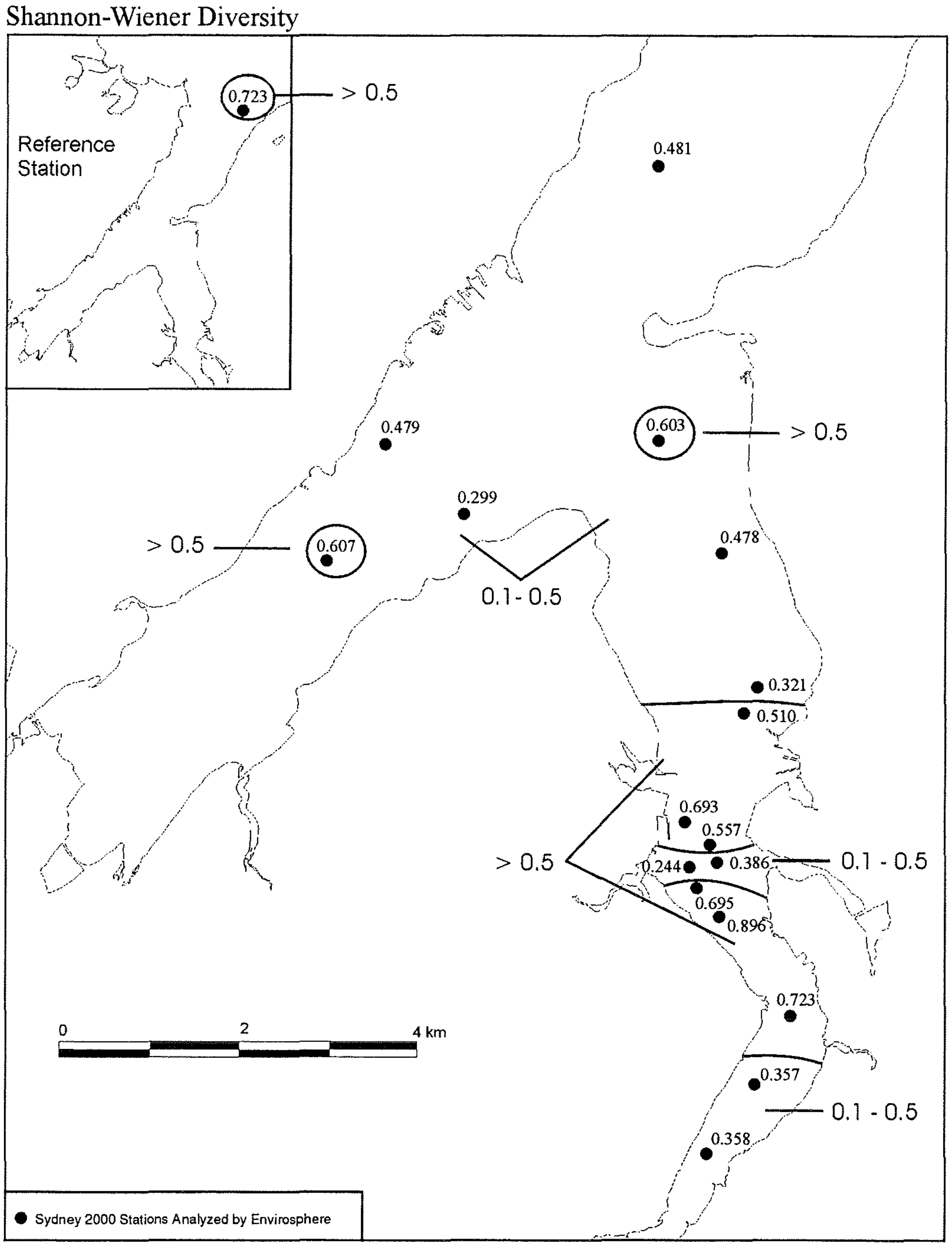

Figure 20. Shannon-Wiener Diversity ($\log_{10}$) of seabed biological communities in Sydney Harbour sediments, July 2000.

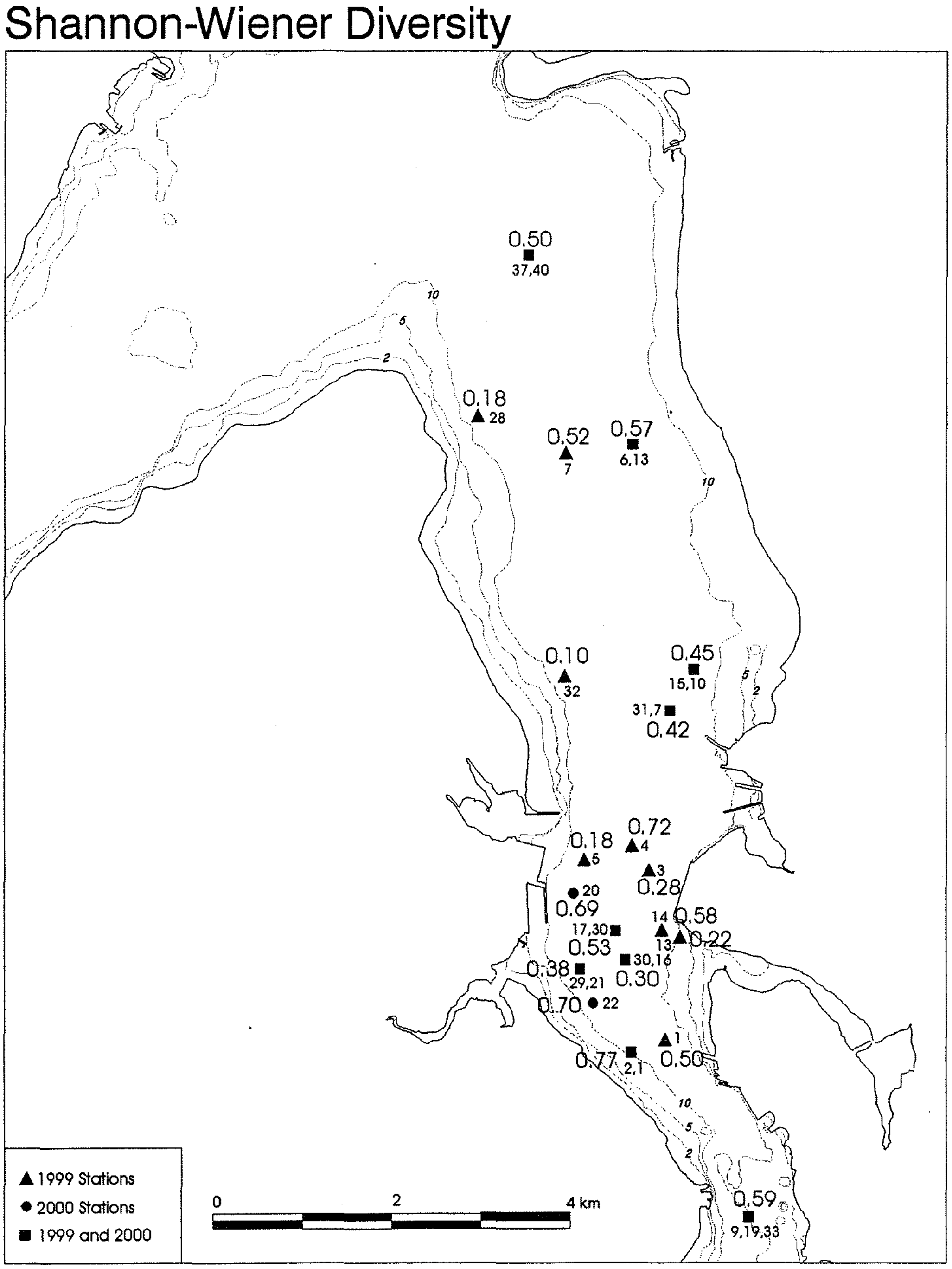

Figure 21. Shannon-Wiener Diversity ($\log_{10}$) of seabed biological communities in Central and Outer South Arm, Sydney Harbour, October 1999 and July 2000 combined.

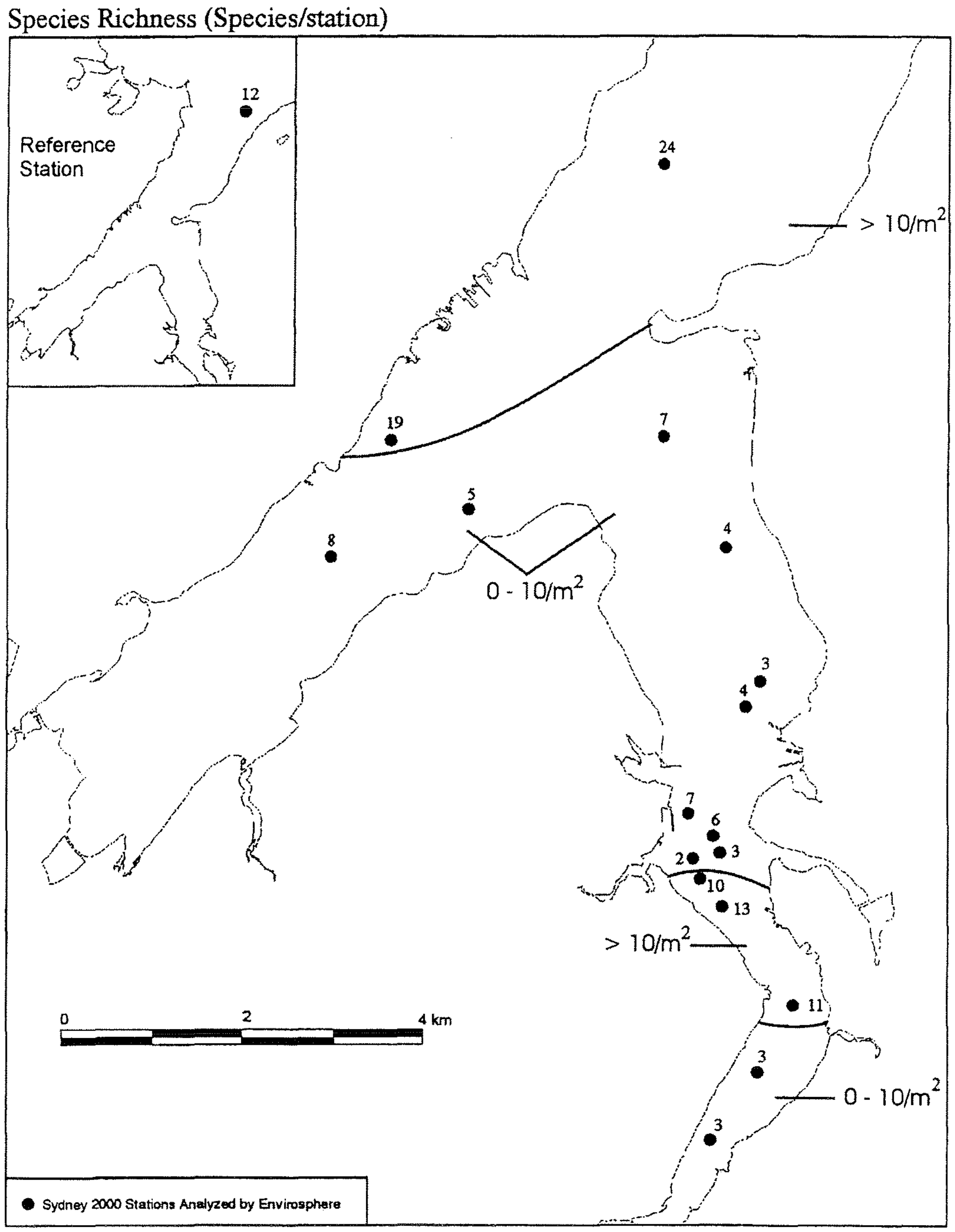

Figure 22. Species Richness (species/sample) of seabed biological communities in Sydney Harbour sediments, July 2000.

Species Richness (species/sample)

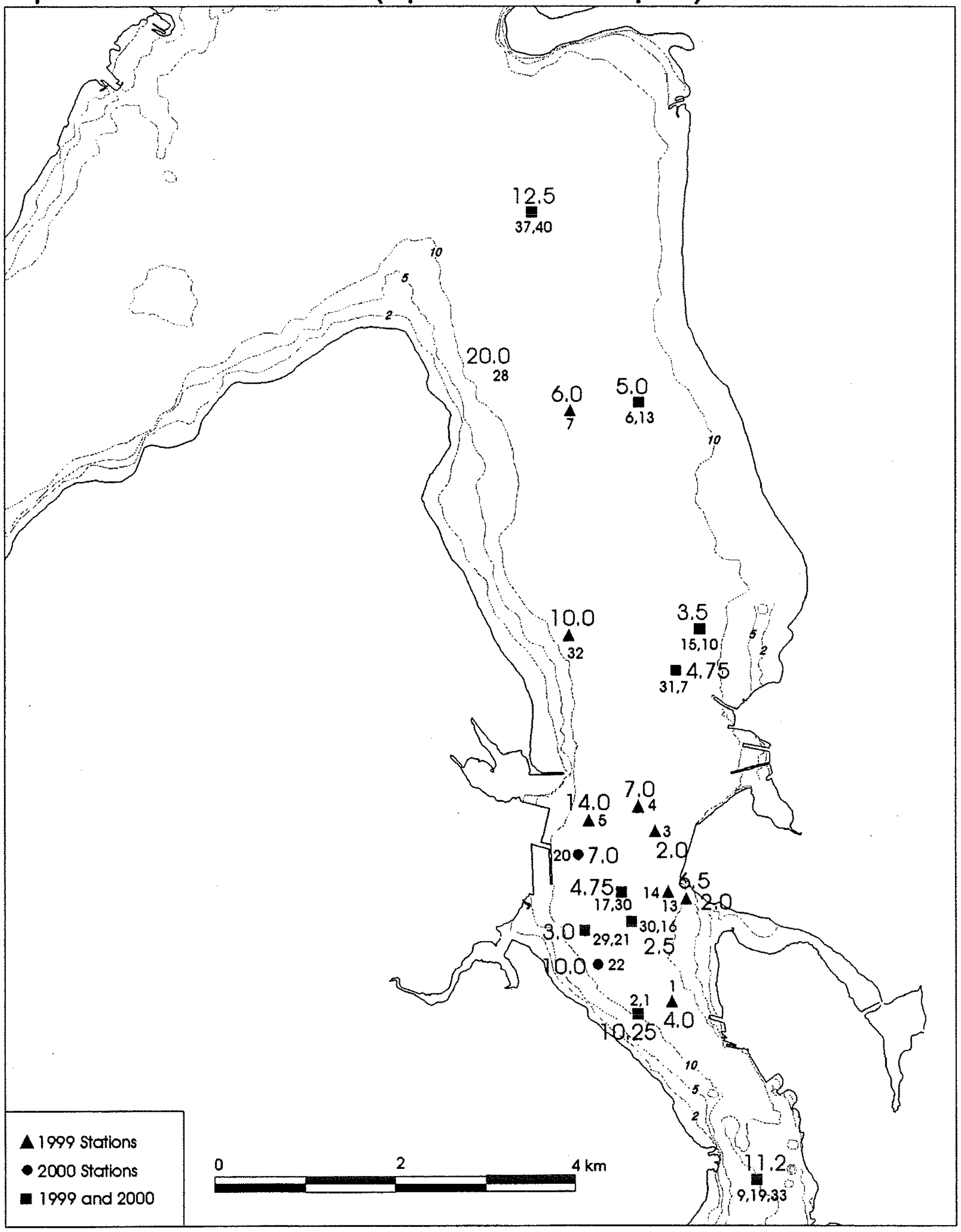

Figure 23. Species Richness (species/sample) of seabed biological communities in Central and South Arm, Sydney Harbour sediments, October 1999 and July 2000 combined.

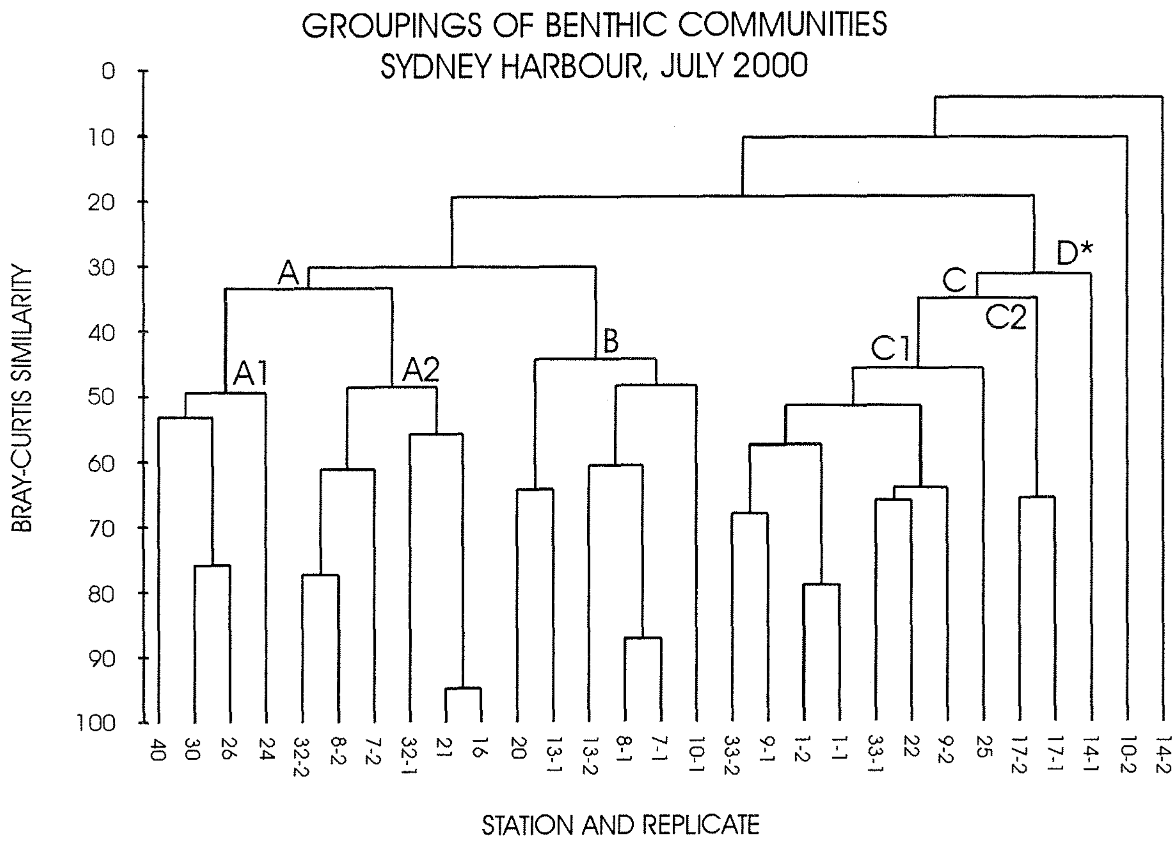

Figure 24. Groupings of seabed biological communities based on Bray-Curtis Index of Similarity, Sydney Harbour, July 2000.

Station Locations

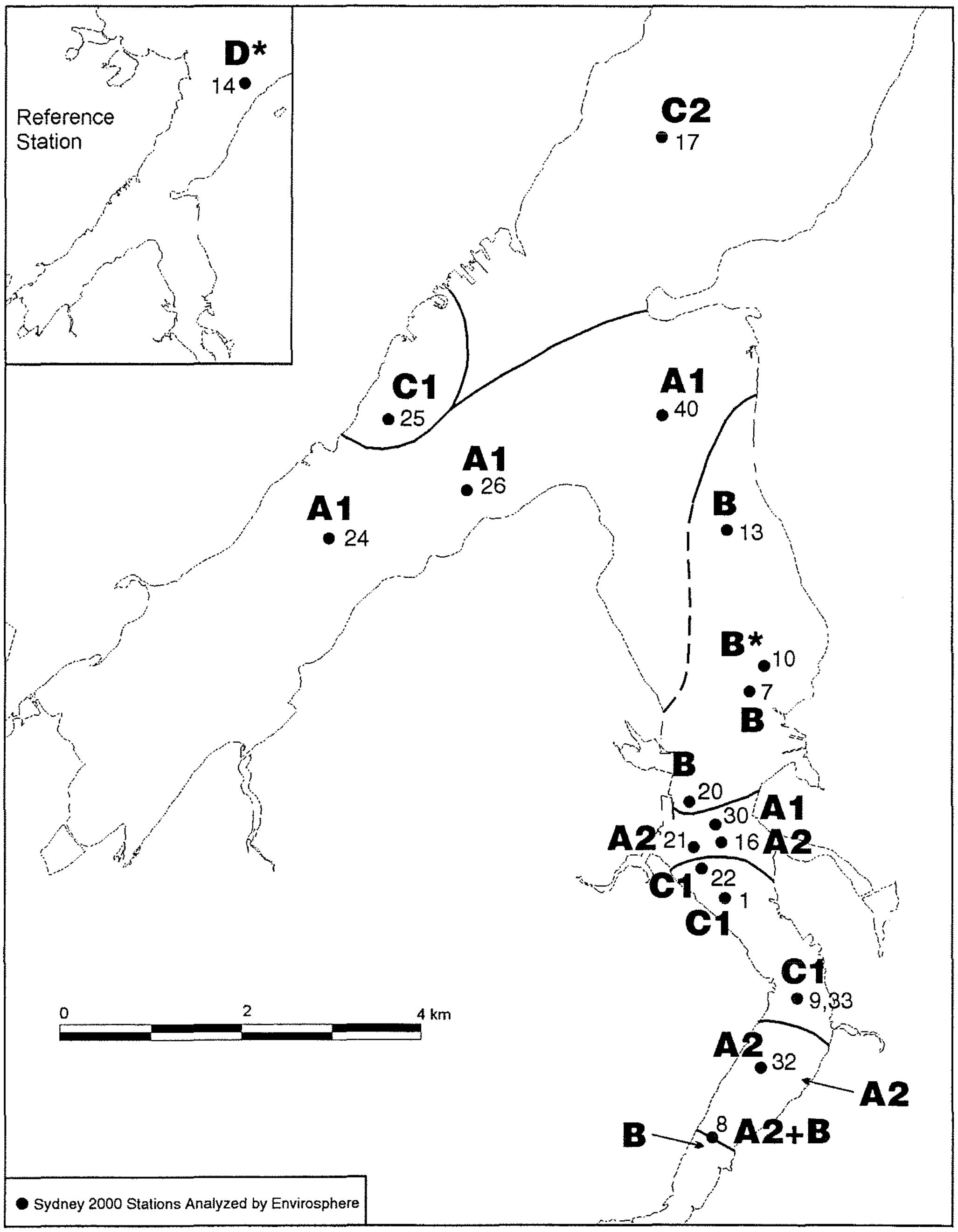

Figure 25. Distribution of seabed biological communities in Sydney Harbour, July 2000.

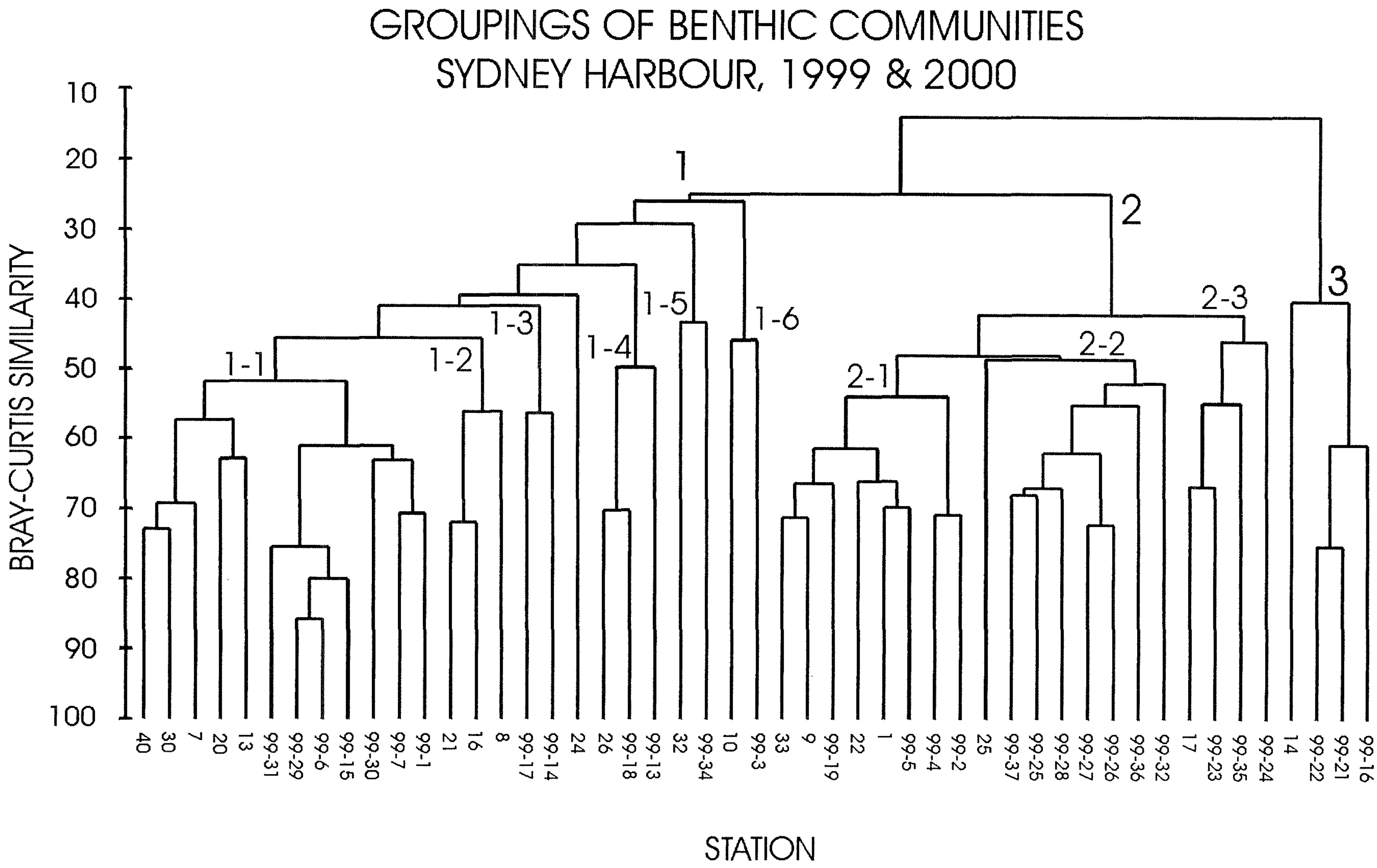

Figure 26. Groupings of seabed biological communities based on Bray-Curtis Index of Similarity, October 1999 and July 2000 combined, Sydney Harbour, NS.

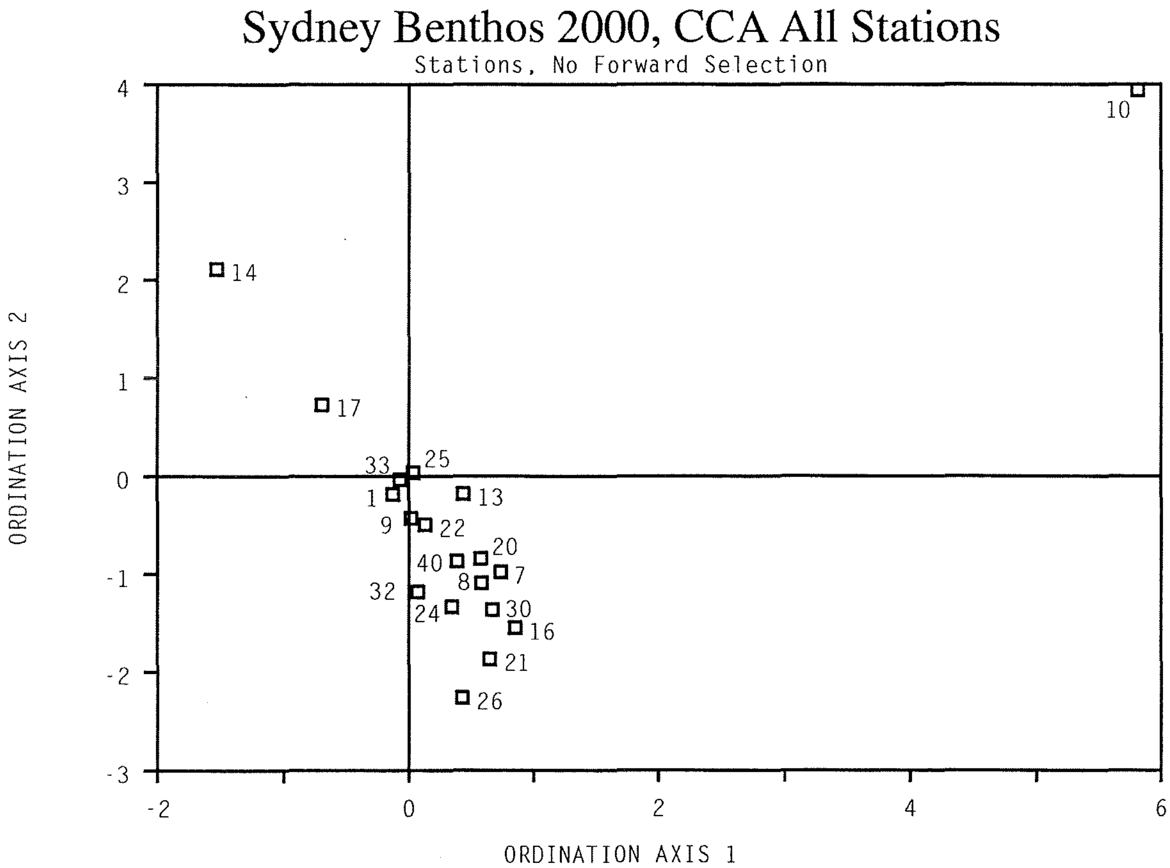

Figure 27a. Plot of stations on the first two axes of a canonical correspondence analysis (CCA), Sydney Harbour, Nova Scotia, July 2000.

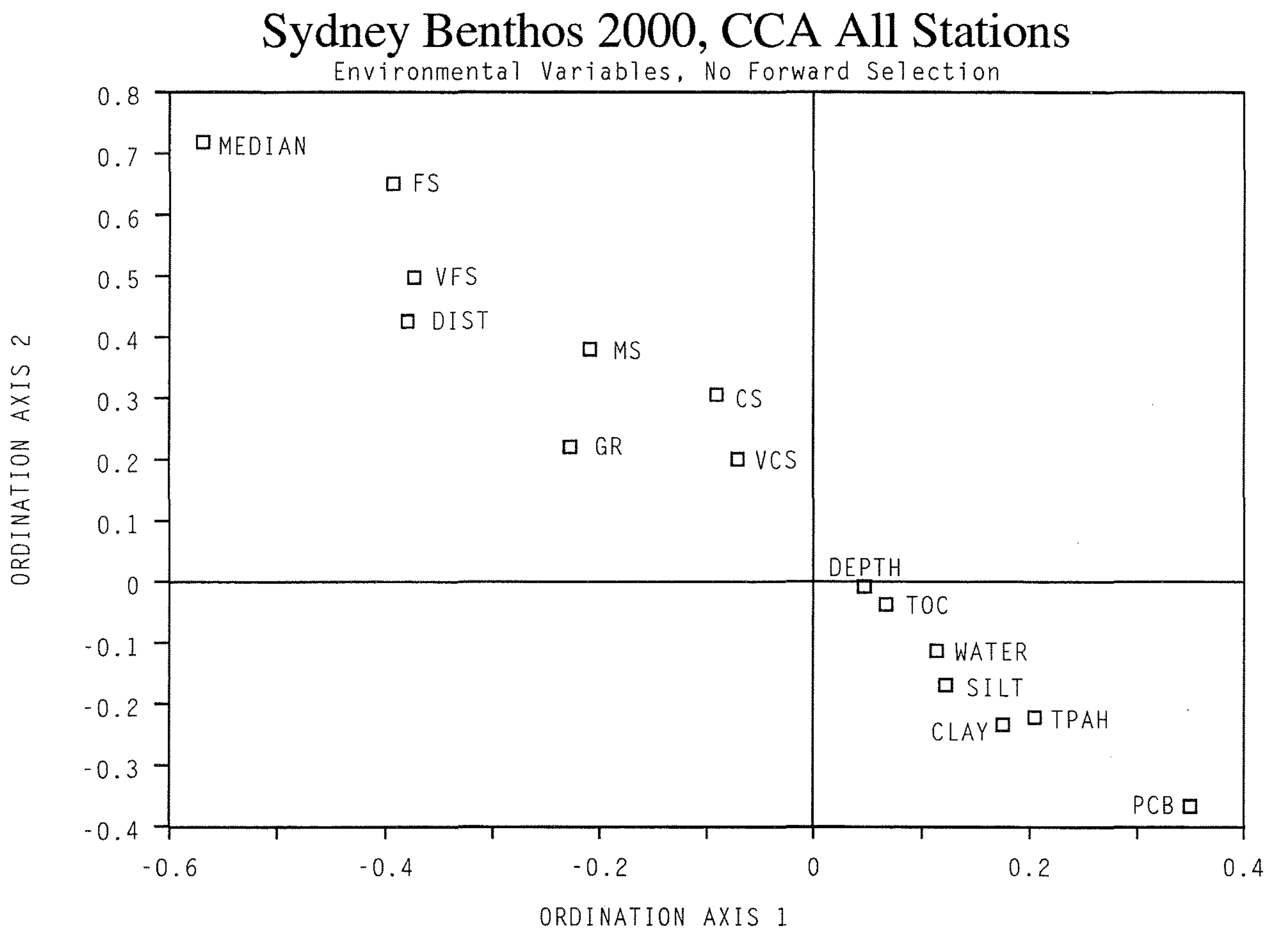

Figure 27b. Plot of environmental variables on the first two axes of a canonical correspondence analysis (CCA), Sydney Harbour, Nova Scotia, July 2000.

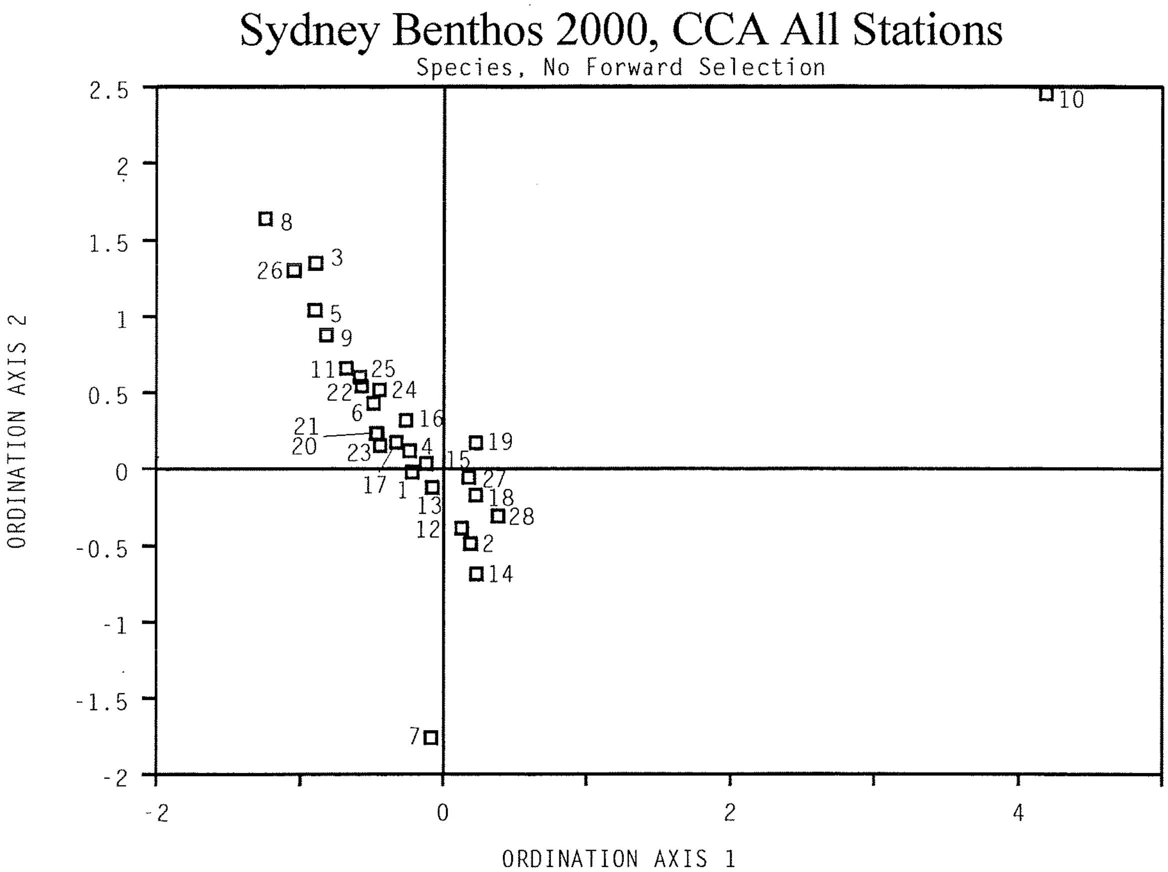

Figure 27c. Plot of species on the first two axes of a canonical correspondence analysis (CCA), Sydney Harbour, Nova Scotia, July 2000. Names of species corresponding to numbers are presented in Table 10.

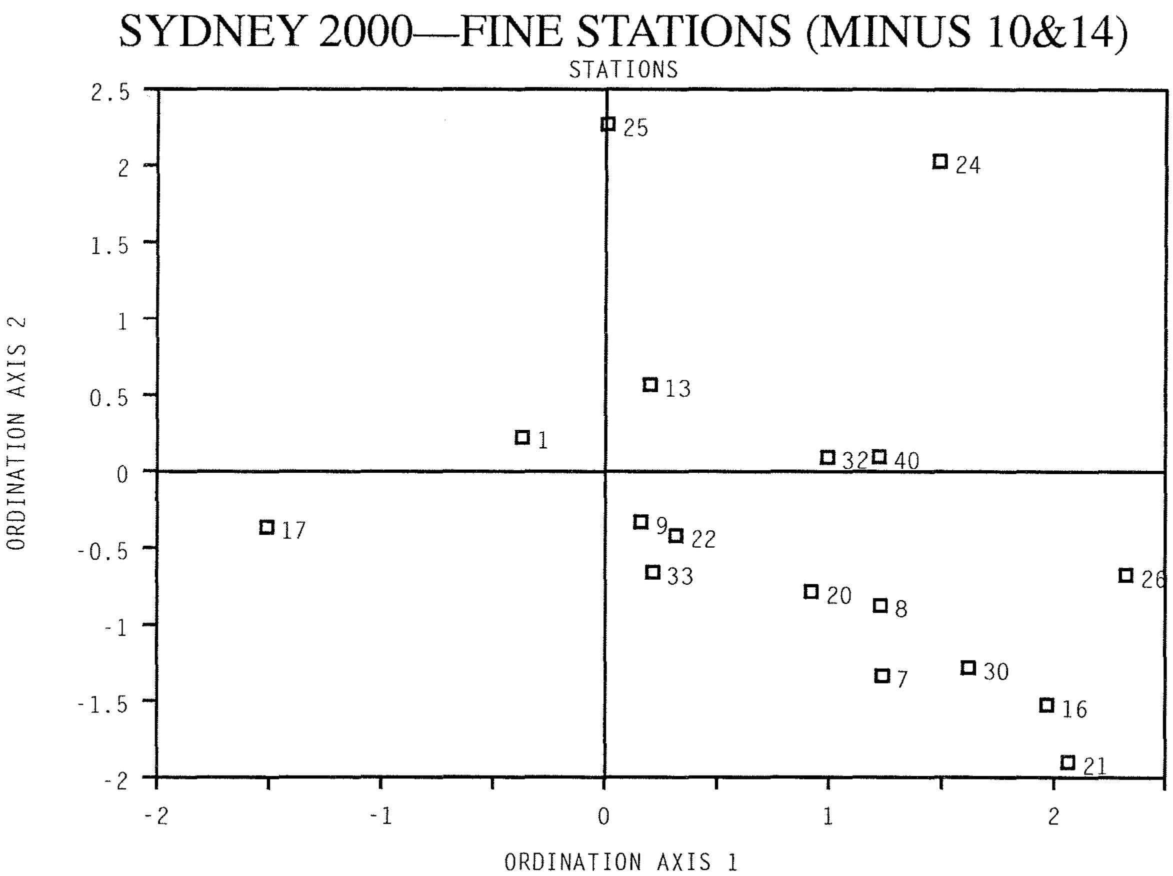

Figure 28a. Plot of stations on the first two axes of a canonical correspondence analysis (CCA), on stations having fine sediments (silt-clay and silty sand only), Sydney Harbour, Nova Scotia, July 2000. Stations 10 and 14 have been excluded.

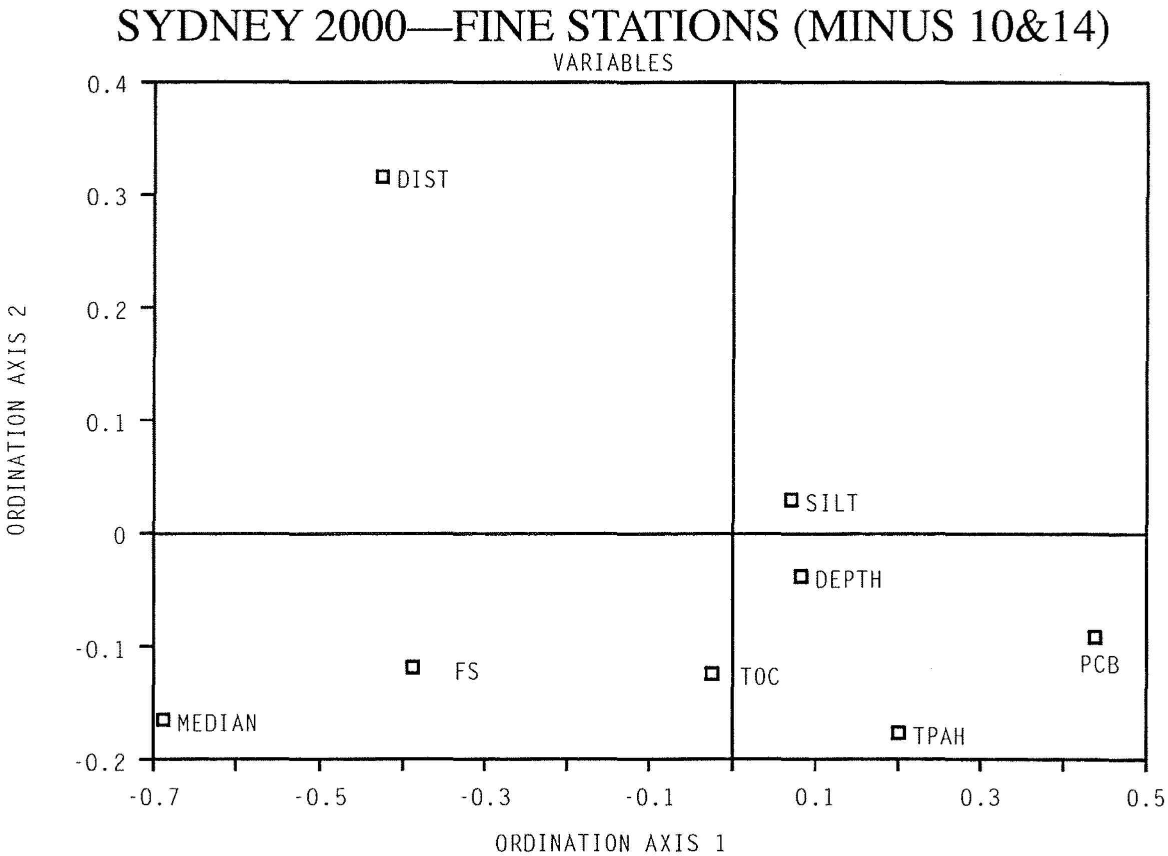

Figure 28b. Plot of environmental variables on the first two axes of a canonical correspondence analysis (CCA), on stations having fine sediments (silt-clay and silty sand only), Sydney Harbour, Nova Scotia, July 2000. Stations 10 and 14 have been excluded.

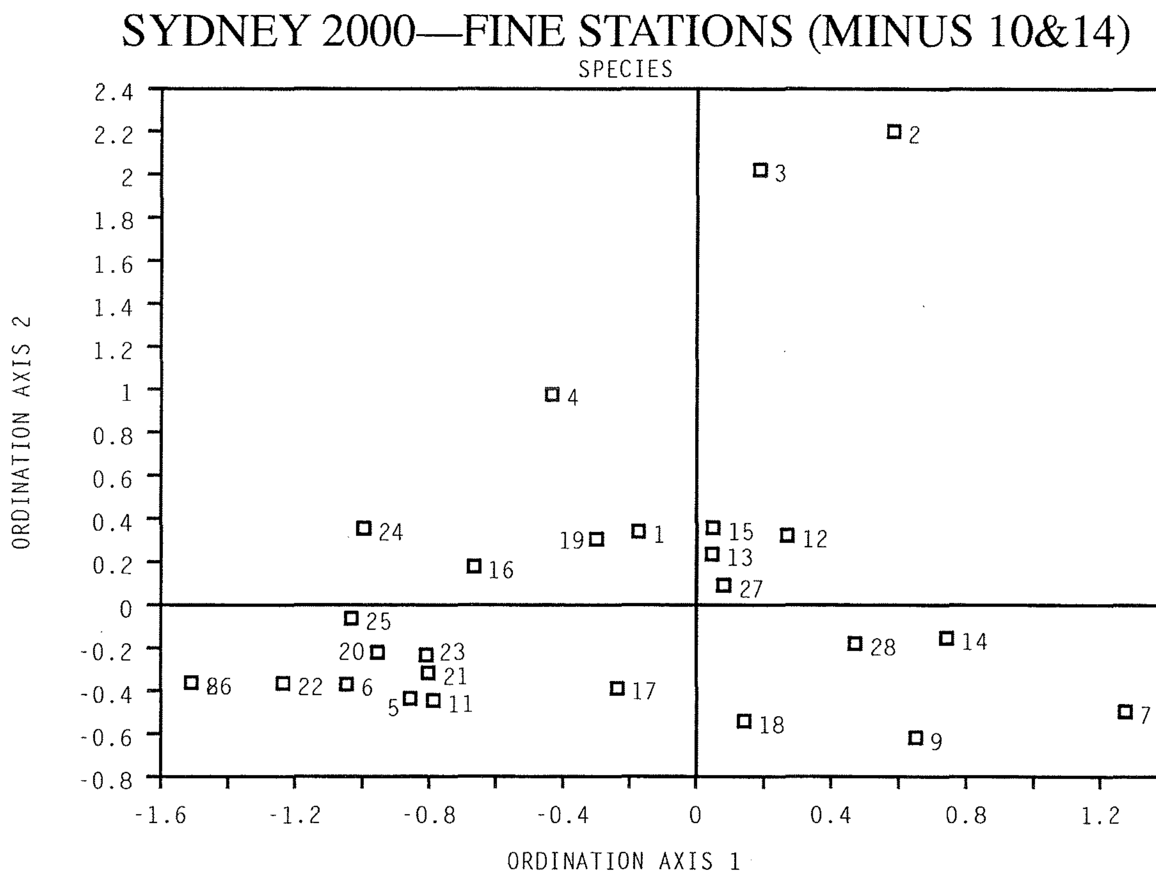

Figure 28c. Plot of species on the first two axes of a canonical correspondence analysis (CCA), on stations having fine sediments (silt-clay and silty sand only), Sydney Harbour, Nova Scotia, July 2000. Stations 10 and 14 have been excluded. Names of species corresponding to numbers are presented in Table 10.

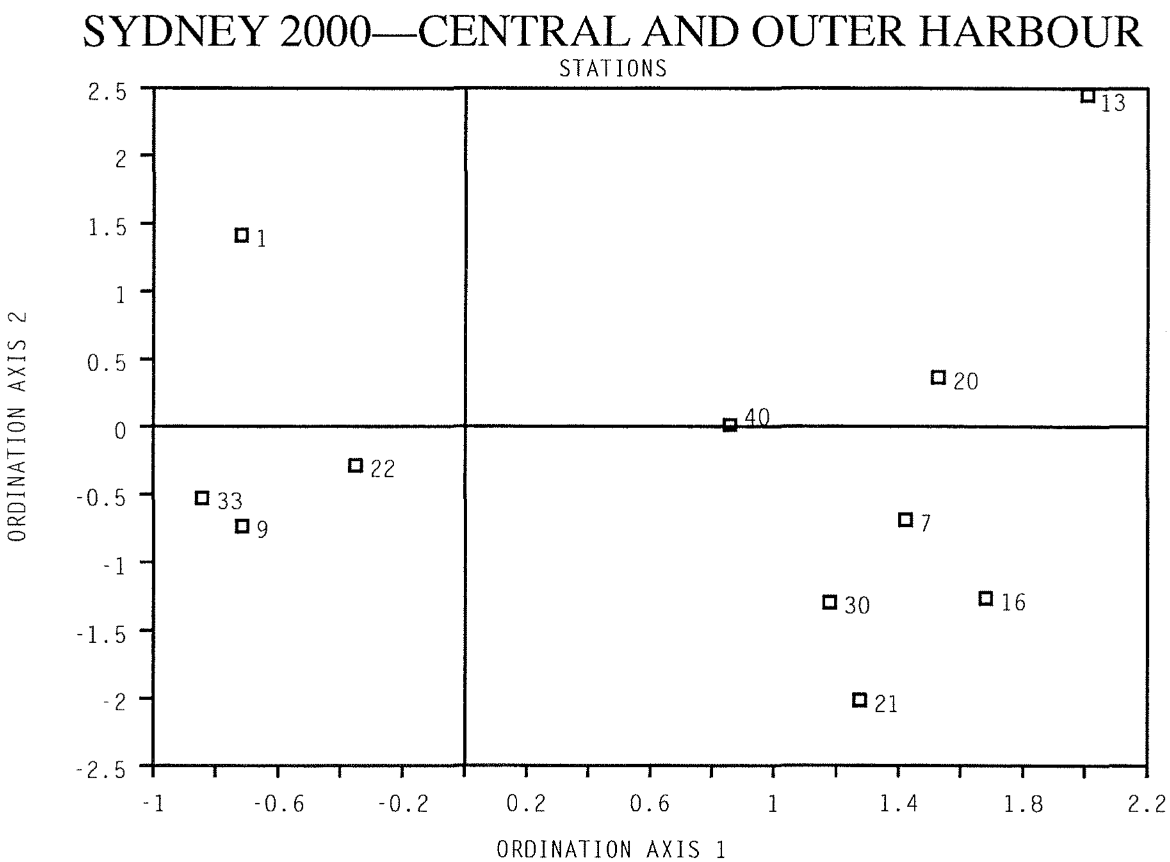

Figure 29a. Plot of stations on the first two axes of a canonical correspondence analysis (CCA), on stations having fine sediments (silt/clay), in the South Arm of Sydney Harbour, Nova Scotia, July 2000. Station10 and Inner Harbour stations 8 & 32 have been excluded.

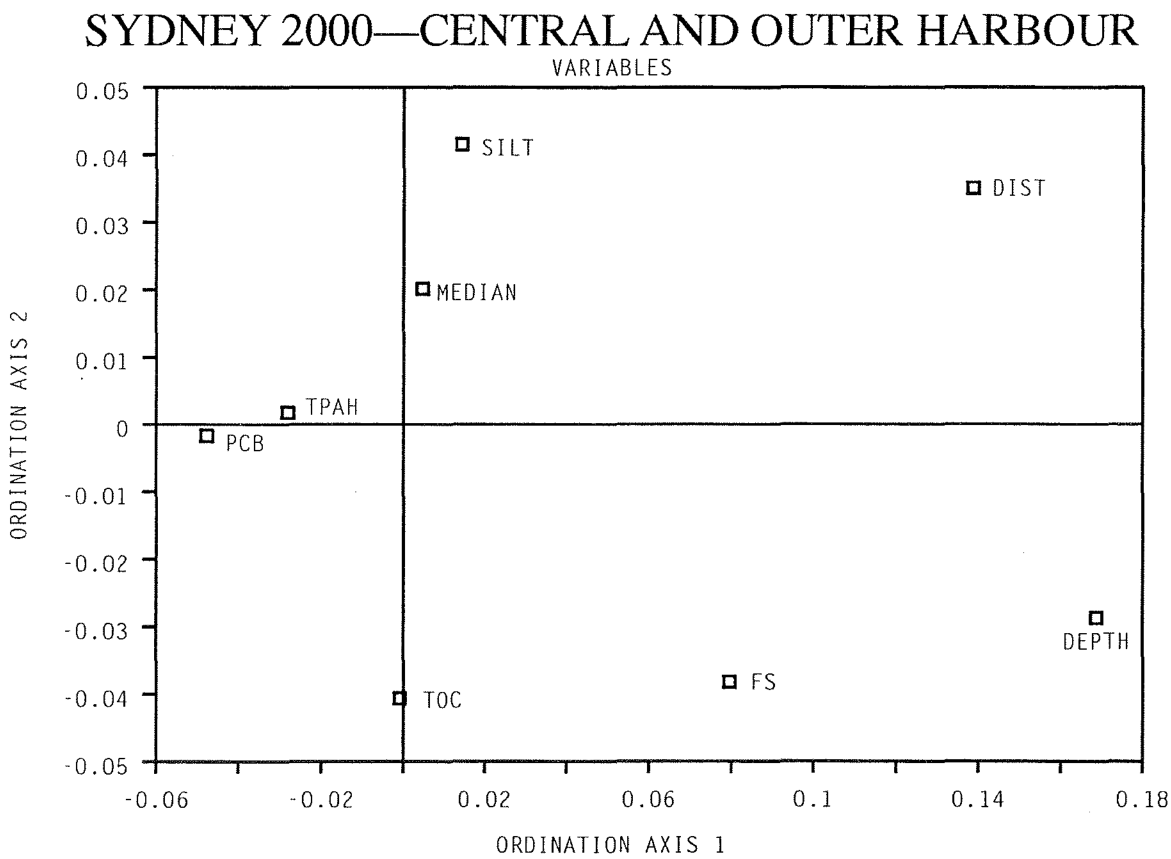

Figure 29b. Plot of environmental variables on the first two axes of a canonical correspondence analysis (CCA), on stations having fine sediments (silt/clay), in the South Arm of Sydney Harbour, Nova Scotia, July 2000. Station 10 and Inner Harbour stations 8 & 32 have been excluded.

SYDNEY 2000--CENTRAL AND OUTER HARBOUR

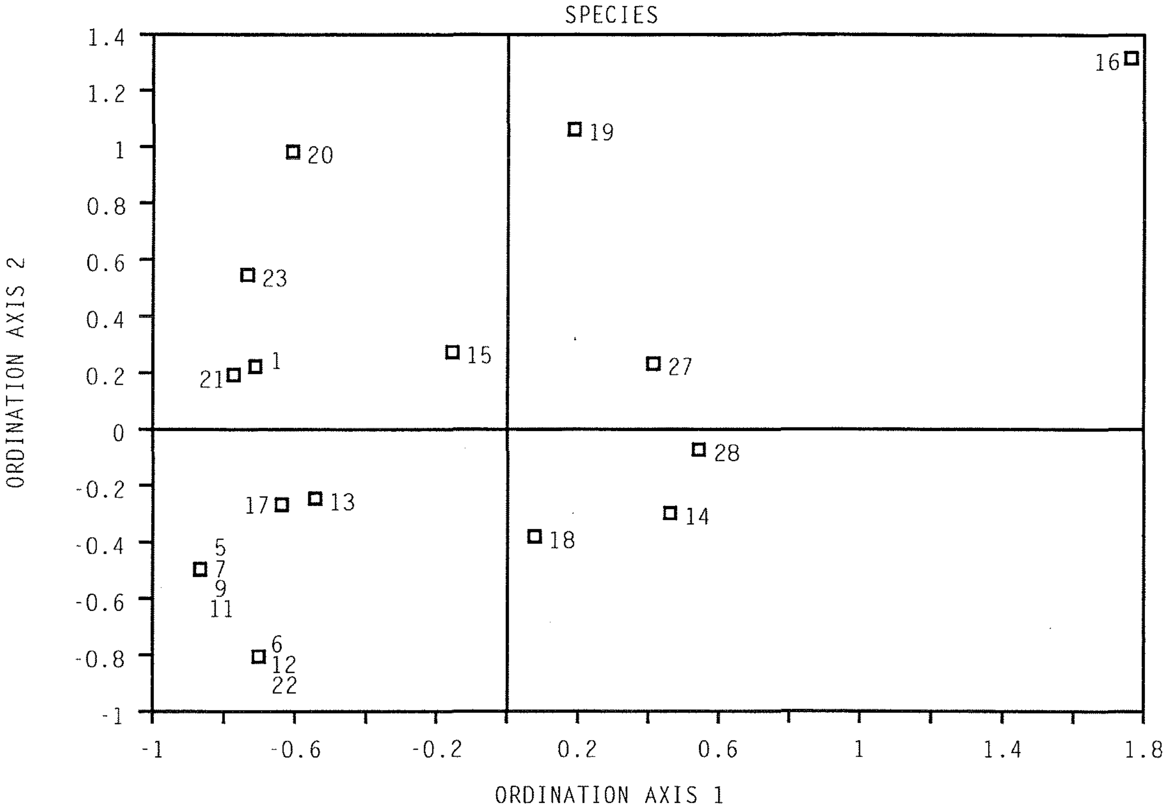

Figure 29c. Plot of species on the first two axes of a canonical correspondence analysis (CCA), on stations having fine sediments (silt/clay), in the South Arm of Sydney Harbour, Nova Scotia, July 2000. Station 10 and Inner Harbour stations 8 & 32 have been excluded. Names of species corresponding to numbers are presented in Table 10.

Acteocina canaliculata

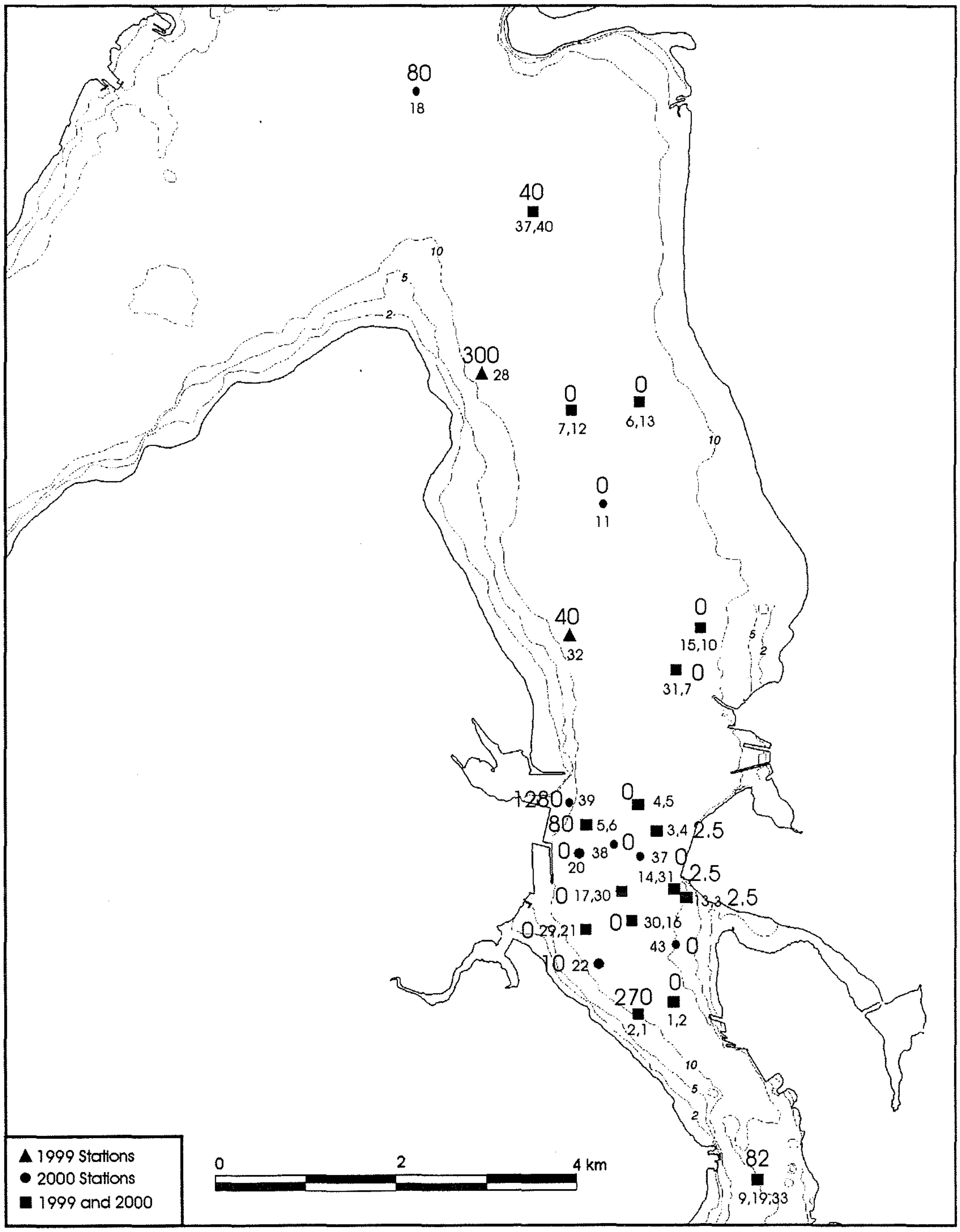

Figure 30. Distribution and abundance of *Acteocina canaliculata* in Central and Outer South Arm, October 1999 and July 2000 combined. Smaller number near symbol represents station number(s).

Cerebratulus sp

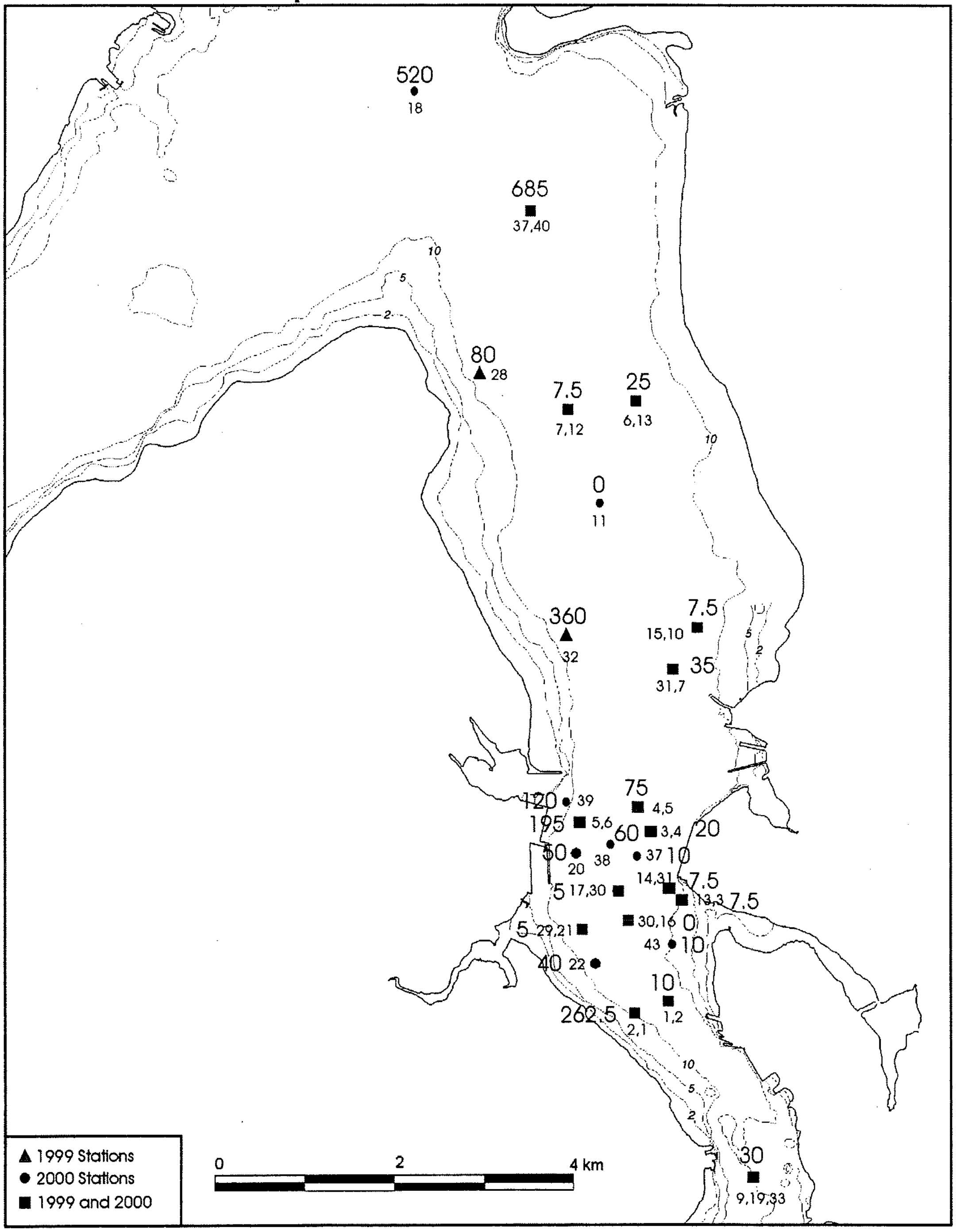

Figure 31. Distribution and abundance of *Cerebratulus* sp. in Central and Outer South Arm, October 1999 and July 2000 combined. Smaller number near symbol represents station number(s).

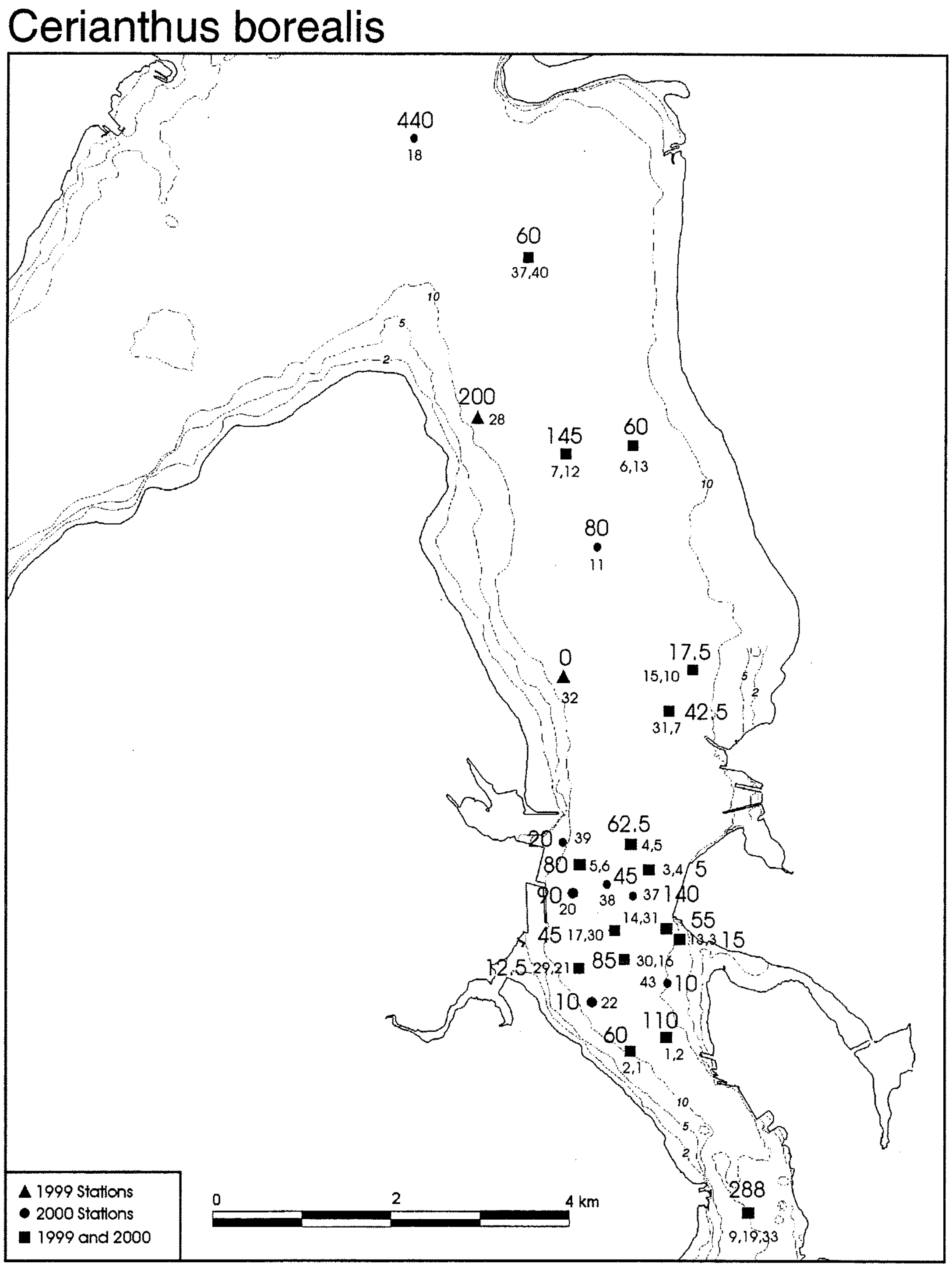

Figure 32. Distribution and abundance of *Cerianthus borealis* in Central and Outer South Arm, October 1999 and July 2000 combined. Smaller number near symbol represents station number(s).

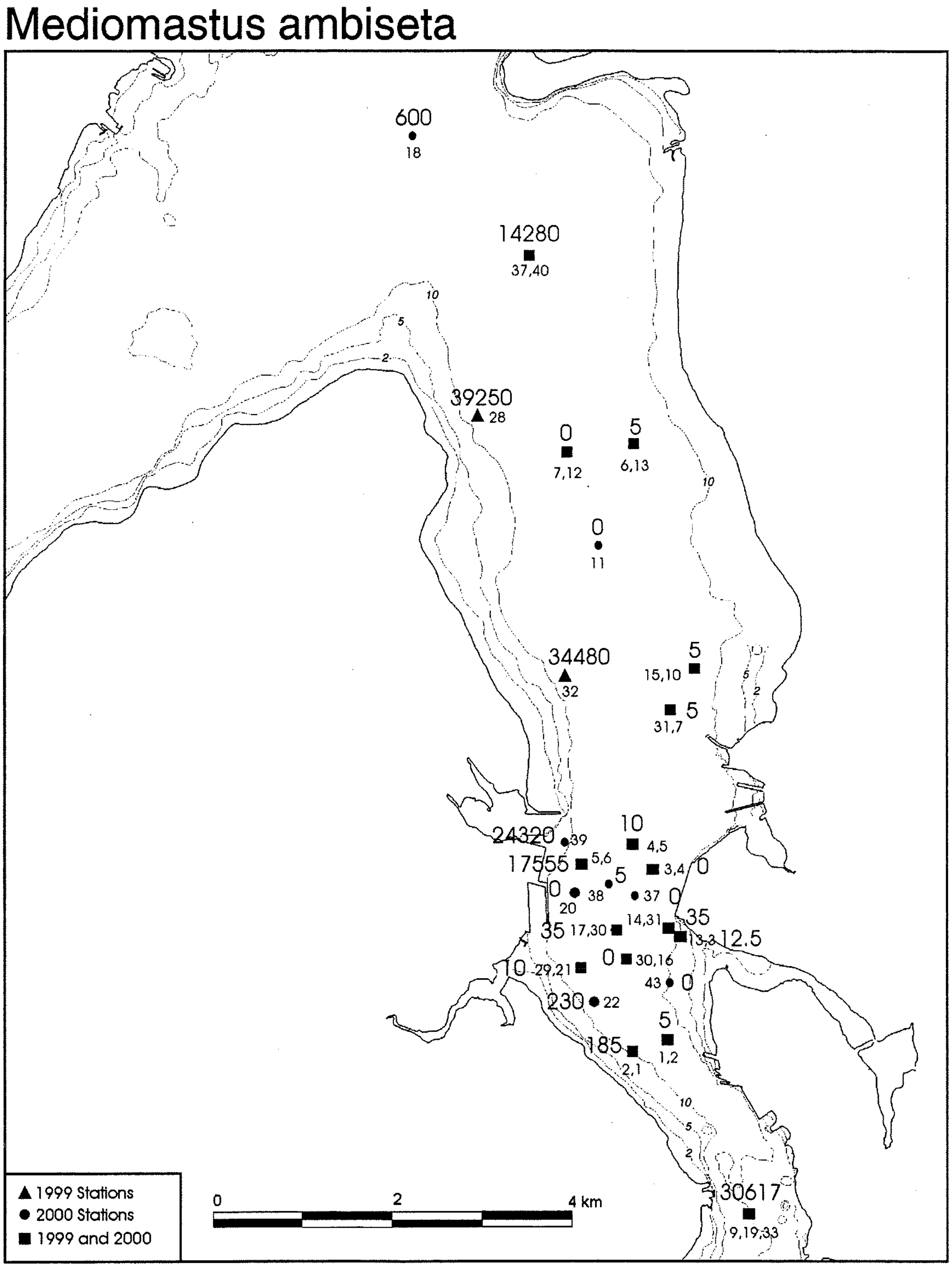

Figure 33. Distribution and abundance of *Mediomastus ambiseta* in Central and Outer South Arm, October 1999 and July 2000 combined. Smaller number near symbol represents station number(s).

Nephtys incisa

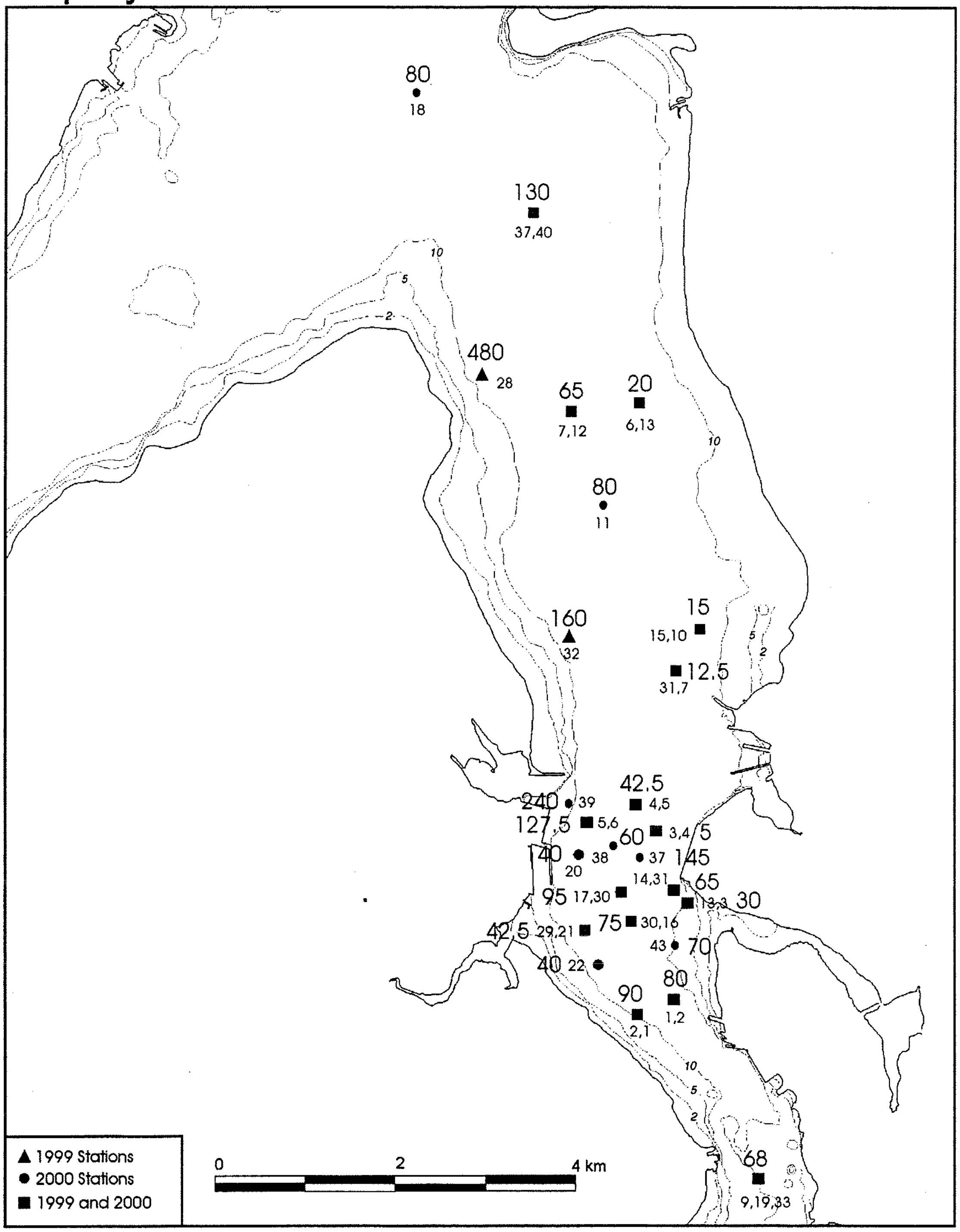

Figure 34. Distribution and abundance of *Nephtys incisa* in Central and Outer South Arm, October 1999 and July 2000 combined. Smaller number near symbol represents station number(s).

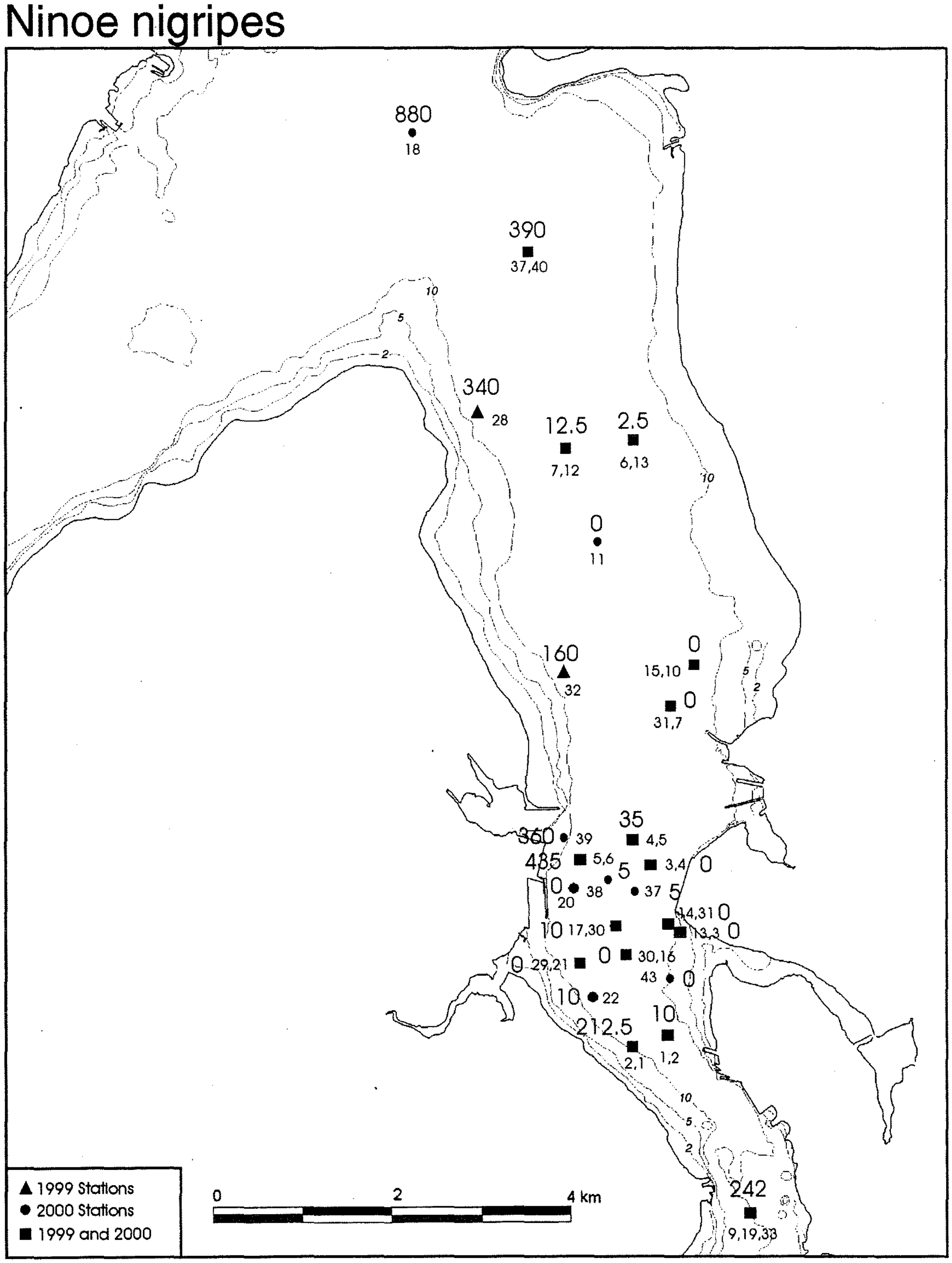

Figure 35. Distribution and abundance of *Ninoe nigripes* in Central and Outer South Arm, October 1999 and July 2000 combined. Smaller number near symbol represents station number(s).

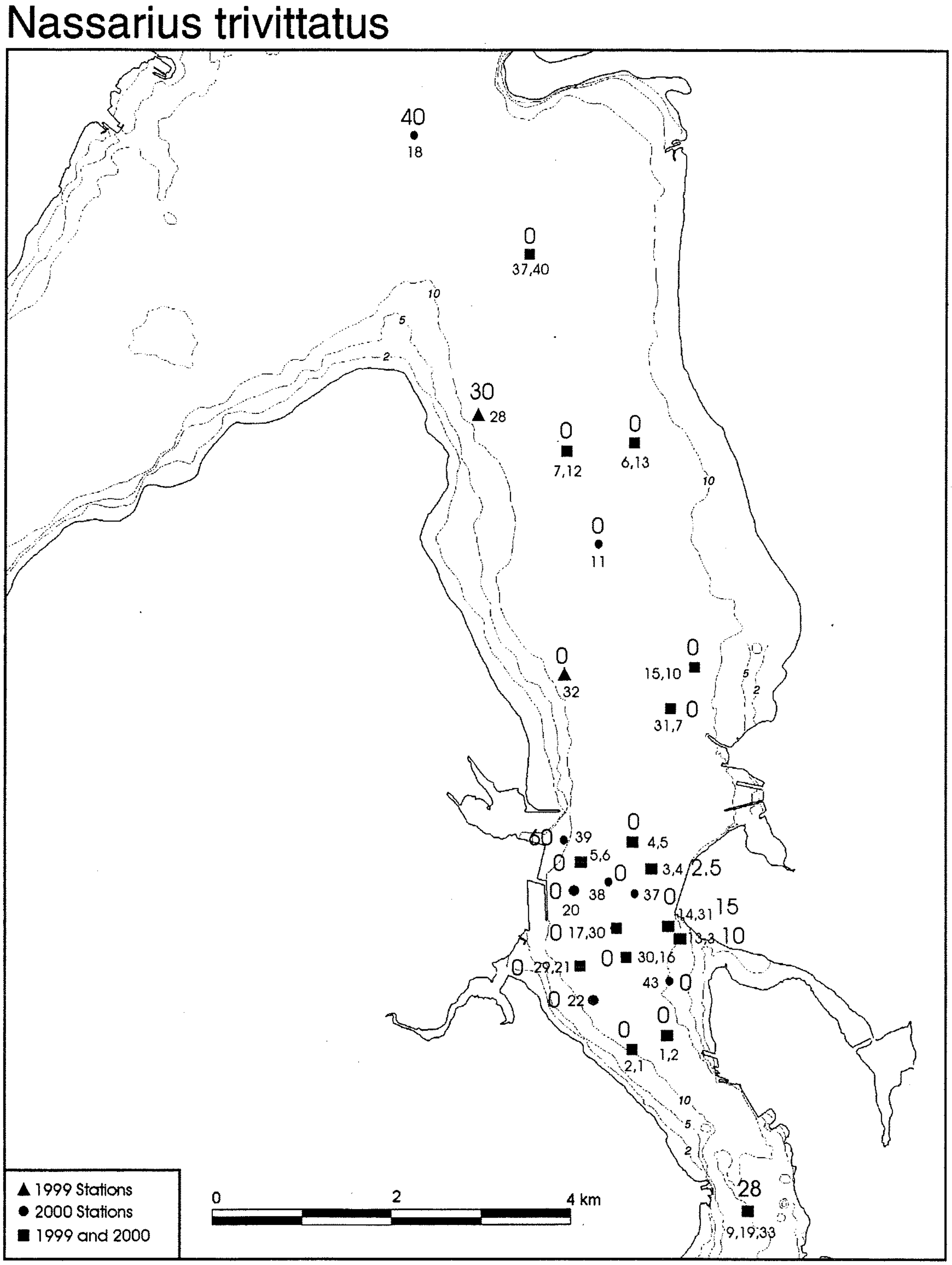

Figure 36. Distribution and abundance of *Nassarius trivittatus* in Central and Outer South Arm, October 1999 and July 2000 combined. Smaller number near symbol represents station number(s).

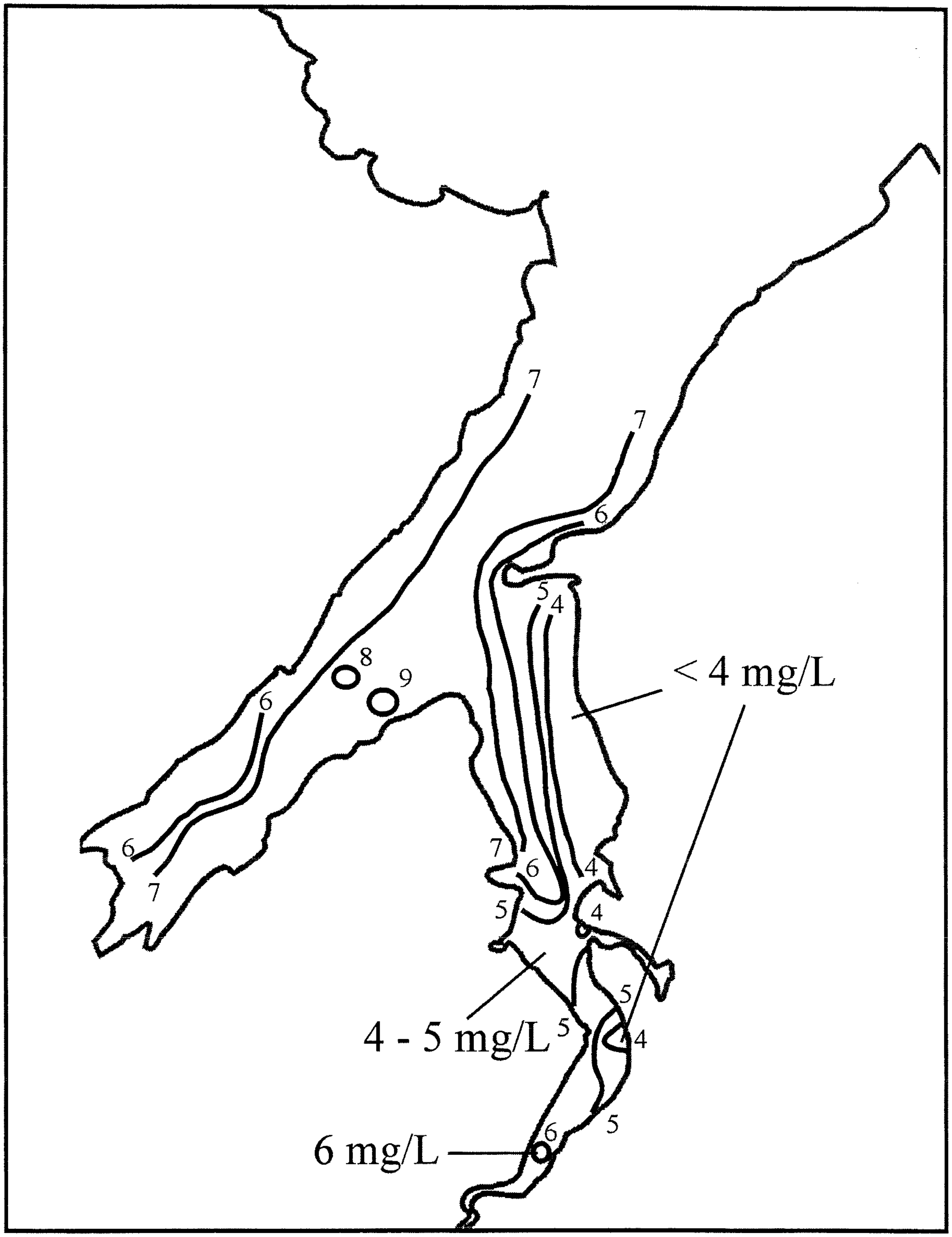

Figure 37. Distribution of nearbottom dissolved oxygen concentrations (mg/L) in August 1987 (drawn from data in P. Lane & Associates 1988).

TABLES

Table 1. Station Data and Sediment Grainsize Composition[1], Sydney Harbour, July 2000.

Station	Location		Sample Reference	Depth (m)	Composition (%)													
					Pebble	Granule	Sand					Silt				Clay	
	Latitude	Longitude					Very Coarse	Coarse	Medium	Fine	Very Fine	Coarse	Medium	Fine	Very Fine	Coarse	Medium
1	46 08.748	60 12.626	224401	10.8	0.00	0.10	0.15	0.15	0.25	0.55	2.75	7.55	24.69	39.68	8.00	5.25	10.89
2	46 08.787	60 12.449	224402	15.9	0.84	1.21	0.58	0.37	0.42	0.63	3.52	7.26	21.45	31.91	10.09	7.83	13.88
3	46 09.156	60 12.354	224403	10.0	0.00	0.00	0.11	0.26	0.63	1.00	4.32	5.01	34.05	33.16	6.69	4.48	10.28
4	46 09.405	60 12.504	224404	16.4	0.00	0.00	0.15	0.31	0.57	0.87	3.76	7.51	29.84	34.67	6.94	4.48	10.91
5	46 09.496	60 12.586	224405	16.8	0.00	0.72	0.72	1.07	1.28	1.28	4.65	5.57	18.18	33.71	11.90	7.97	12.97
6	46 09.452	60 12.842	224406	14.5	0.00	0.21	0.63	0.47	0.89	0.68	4.19	14.18	19.52	19.31	14.44	8.79	16.69
7	46 09.981	60 12.365	224407	18.1	0.00	0.31	0.21	0.21	0.46	1.19	3.41	5.52	16.99	31.44	15.49	8.42	16.37
8	46 07.320	60 12.810	224408	7.6	0.00	0.10	0.15	0.20	0.35	0.35	2.18	7.70	23.93	30.54	11.17	6.95	16.39
9	46 08.136	60 12.045	224409	11.2	0.00	0.05	0.21	0.26	0.47	0.73	6.71	11.63	22.32	22.63	10.11	7.60	17.29
10	46 10.130	60 12.233	224410	17.2	0.00	0.05	0.46	1.22	1.78	2.54	5.55	4.48	22.85	34.15	7.58	5.55	13.79
11	46 10.542	60 12.700	224411	18.8	0.00	0.35	1.01	0.61	0.71	0.61	1.82	6.17	18.55	38.93	10.36	6.67	14.21
12	46 10.934	60 12.862	224412	18.7	0.00	0.00	0.15	0.25	0.25	0.40	1.21	6.94	17.35	44.67	9.51	6.09	13.18
13	46 10.954	60 12.505	224413	19.0	0.00	0.00	0.10	0.10	0.26	0.36	0.72	2.72	30.64	44.98	4.76	2.61	12.76
14	46 14.986	60 10.609	224414	15.7	0.00	0.73	1.45	1.24	2.59	33.78	60.21	0.00	0.00	0.00	0.00	0.00	0.00
15	46 09.558	60 12.935	224417	14.0	1.00	0.15	0.55	0.90	3.06	2.61	3.52	7.89	21.04	23.15	14.52	8.34	13.26
16	46 09.082	60 12.641	224418	17.0	0.00	0.20	0.41	0.66	0.81	1.06	3.09	6.84	21.01	32.00	10.23	8.25	15.44
17	46 13.343	60 12.950	224415	13.5	0.00	0.15	0.21	1.13	4.52	3.96	29.03	30.42	13.51	7.09	3.08	2.67	4.21
18	46 12.130	60 13.830	224416	16.1	0.00	0.10	0.25	0.35	1.11	2.47	15.31	19.90	19.24	15.06	9.32	6.70	10.18
19	46 08.790	60 12.650	224419	14.6	0.00	0.10	0.05	0.10	0.36	0.62	2.48	6.68	19.15	36.44	10.82	8.13	15.06
20	46 09.330	60 12.900	224420	14.5	0.00	0.00	0.15	0.20	0.60	0.91	4.08	9.62	19.14	29.77	12.75	7.36	15.42
21	46 09.057	60 12.881	224421	14.7	0.00	0.00	0.05	0.10	0.45	0.60	2.14	0.00	28.65	32.67	11.97	8.14	15.24
22	46 08.930	60 12.820	224422	13.9	0.00	0.00	0.00	0.10	0.20	0.35	1.87	5.95	19.36	38.33	9.53	7.56	16.74
23	46 10.119	60 12.913	224423	16.1	0.00	0.10	0.15	0.25	0.40	0.50	1.71	5.94	23.22	20.40	18.04	12.90	16.37
24	46 10.987	60 15.950	224424	14.5	0.00	0.30	0.51	0.61	1.01	1.22	2.84	4.66	23.39	24.86	19.09	7.44	14.08
25	46 11.690	60 15.400	224425	12.6	0.00	0.00	0.11	0.21	0.37	0.42	2.42	5.30	26.42	26.89	16.44	9.03	12.39
26	46 11.249	60 14.737	224426	22.3	0.00	0.00	0.15	0.15	0.26	0.21	1.08	7.61	18.82	26.22	20.31	12.03	13.16
27	46 10.585	60 16.641	224427	13.6	0.00	0.00	0.15	0.15	0.40	0.25	0.90	6.94	21.98	23.38	19.68	11.69	14.49
28	46 10.540	60 13.120	224428	13.7	39.73	3.15	2.14	2.24	3.61	3.00	4.02	3.76	10.53	9.77	7.48	5.09	5.49
29	46 10.540	60 12.260	224429	18.2	0.00	0.05	0.15	0.20	0.35	0.51	1.67	8.04	17.90	41.96	9.45	6.42	13.30
30	46 09.190	60 12.690	224430	16.8	0.00	0.36	0.41	0.41	0.41	0.46	2.44	4.46	29.33	42.21	6.70	3.50	9.34

Table 1. Station Data and Sediment Grainsize Composition[1], Sydney Harbour, July 2000.

Station	Location		Sample Reference	Depth (m)	Composition (%)												
					Pebble	Granule	Sand					Silt				Clay	
	Latitude	Longitude					Very Coarse	Coarse	Medium	Fine	Very Fine	Coarse	Medium	Fine	Very Fine	Coarse	Medium
31	46 09.185	60 12.446	224431	16.1	1.18	1.79	1.64	2.35	2.97	2.40	5.37	6.65	20.30	26.23	11.09	6.19	11.86
32	46 07.730	60 12.373	224432	12.7	0.00	0.67	1.55	0.67	0.31	0.26	1.13	3.35	17.89	40.93	10.88	6.24	16.13
33	46 08.136	60 12.045	224433	12.6	0.00	0.30	0.30	0.30	0.40	0.50	4.53	10.51	17.68	24.35	15.84	11.01	14.29
34	46 08.450	60 12.110	224434	17.7	0.00	2.79	2.26	1.50	1.45	1.24	3.28	6.61	16.93	24.07	14.29	10.05	15.53
36	46 08.630	60 12.350	224436	16.5	0.00	0.41	0.15	0.36	0.76	1.37	4.17	8.49	18.92	22.13	17.19	10.33	15.72
37	46 09.310	60 12.620	224437	17.5	0.00	0.00	0.10	0.25	0.40	0.71	3.48	8.18	21.66	29.38	13.48	8.08	14.29
38	46 09.390	60 12.730	224438	16.9	0.00	0.41	0.15	0.31	0.51	0.71	3.78	9.70	18.02	25.63	14.50	10.36	15.93
39	46 09.480	60 12.930	224439	10.5	0.00	0.00	0.25	0.92	1.22	1.63	11.56	12.07	28.12	15.84	9.12	6.37	12.89
40	46 11.655	60 13.024	224440	17.0	0.00	0.25	0.30	0.35	0.81	1.41	4.95	9.44	21.41	24.85	15.20	8.54	12.47
41	46 10.130	60 12.550	224441	19.3	0.00	0.05	0.05	0.10	0.31	0.41	1.27	4.83	17.69	33.86	14.29	10.52	16.62
42	46 09.870	60 12.810	224442	14.8	0.00	0.26	0.36	0.46	0.77	0.97	3.27	10.41	19.96	23.23	16.85	8.52	14.96
43	46 09.000	60 12.470	224443	13.00	0.00	0.00	0.26	0.15	0.46	0.77	4.37	5.82	36.39	31.09	5.51	4.27	10.91

1. Wentworth Scale

Table 2. Total PAH, PCB Total Organic Carbon, Water Content, and grainsize parameters in sediments, Sydney Harbour, July 2000. Distance = distance from Muggah Creek (km). Bulk water content determined during organic contaminant analysis (supplied by G. Tremblay, DFO).

Station	Distance	Sample	TOC (%)	TPAH ug/g dry	PCB ng/g dry	Water Content (%)	Median Grain Size (mm)	Inman Sorting
1	0.83	224401	6.56	178.810	1562	61.5	0.012	1.53
2	0.62	224402	7.87	301.015	4369	66.9	0.012	1.88
3	0.24	224403	12.50	215.410	660	62.8	0.014	1.55
4	0.73	224404	7.89	152.332	1153	66.5	0.014	1.57
5	0.92	224405	6.46	95.915	1483	66.2	0.011	1.90
6	1.07	224406	4.33	48.470	250	61.1	0.011	2.04
7	1.78	224407	7.24	84.665	764	66.3	0.010	1.83
8	3.44	224408	4.33	36.566	193	69.0	0.011	1.78
9	1.81	224409	5.04	125.393	1285	62.8	0.012	2.05
10	2.06	224410	8.12	99.545	1000	65.6	0.012	1.97
11	2.84	224411	4.05	31.240	130	66.4	0.011	1.73
12	3.59	224412	3.53	30.827	270	64.5	0.011	1.58
13	3.58	224413	3.61	49.344	540	63.4	0.012	1.32
14	12.13	224414	1.18	0.751	ND	24.6	0.111	0.71
15	1.30	224417	2.61	22.365	220	54.9	0.012	2.22
16	0.57	224418	7.71	208.316	3300	66.7	0.011	1.87
17	8.10	224415	6.11	5.664	ND	36.4	0.049	1.79
18	6.06	224416	6.83	7.738	41	43.0	0.021	2.07
19	0.78	224419	8.62	199.088	1398	64.1	0.011	1.73
20	1.01	224420	4.93	281.452	610	61.7	0.011	1.87
21	0.87	224421	6.65	185.384	2432	67.4	0.011	1.57
22	0.84	224422	6.10	221.204	2769	68.4	0.010	1.71
23	2.15	224423	4.30	41.806	492	58.1	0.009	1.75
24	7.52	224424	3.14	12.198	61	56.1	0.010	1.82
25	6.85	224425	2.94	7.262	37	53.8	0.011	1.64
26	5.92	224426	3.05	6.610	27	57.7	0.009	1.64
27	8.58	224427	3.38	18.232	58	59.4	0.009	1.67
28	2.97	224428	3.80	15.244	40	45.3	0.295	4.28
29	2.82	224429	6.93	77.053	981	68.0	0.011	1.64
30	0.66	224430	11.40	115.715	518	—	0.013	1.38
31	0.37	224431	12.90	246.219	1646	64.1	0.014	2.59
32	2.54	224432	6.90	69.336	266	66.4	0.010	1.73
33	1.81	224433	6.11	121.239	803	65.6	0.010	1.88
34	1.22	224434	6.18	158.684	453	65.0	0.010	2.58
36	0.85	224436	8.45	172.220	1469	65.1	0.010	1.93
37	0.69	224437	7.75	87.729	188	62.3	0.011	1.77
38	0.90	224438	5.80	66.089	1048	61.4	0.010	1.89
39	1.19	224439	3.53	46.653	298	57.6	0.018	2.11
40	4.94	224440	3.35	14.577	102	52.6	0.011	1.88
41	2.05	224441	5.30	53.555	390	66.4	0.009	1.66
42	1.67	224442	4.23	33.088	579	45.9	0.010	1.89
43	0.38	224443	9.38	353.602	7117	66.3	0.015	1.56

ND = Not Detected
TPAH and PCB levels provided by S. Cobanli.

Table 3. Station groupings for comparisons of sediment contaminants and biological community measures, Sydney Harbour, Nova Scotia, October 1999 and July 2000. Station numbers are consecutive in each year and don't correspond to the other sampling period. For station locations, see Figures 1 & 2.

Inner South Arm		*Northwest Arm*		Central and NE South Arm	
1999	2000	1999	2000	1999	2000
18	8	24	24	1	1
19	9	25	25	2	7
34	32	26	26	3	10
	33	27		4	13
		35		6	16
		36		7	22
NW and Outer South Arm		*Outer Harbour*		13	30
5	20	16	14	14	
28	21	21	17	15	
29	40	22		17	
32		23		30	
37				31	

Table 4. Water content (%) on bulk sediment samples for organic contaminant analysis, measured at similar locations in Sydney Harbour in 1999 and 2000.

2000		1999	
Station Numbers	Water Content (%)	Station Numbers	Water Content (%)
1	61.5	2	35.2
2	66.9	1	66.7
3	62.8	13	59.4
4	66.5	3	66.5
5	66.2	4	66.0
6	61.1	5	61.0
7	66.3	31	64.3
8	69.0	34	71.4
10	65.6	15	67.3
12	64.5	7	61.5
13	63.4	6	62.4
14	24.6	16	27.3
16	66.7	30	65.0
17	36.4	23	34.6
21	67.4	29	63.6
23	58.1	32	64.5
24	56.1	27	52.8
25	53.8	25	55.3
26	57.7	36	60.1
27	59.4	26	58.5
30	ND	17	64.6
31	64.1	14	63.0
32	66.4	18	59.5
33	65.6	19	66.2
40	52.6	37	56.7

Table 5a. Pearson correlations between sediment characteristics, contaminants, and depth, Sydney Harbour, July 2000. All stations, N=42. Bold correlations are significant ($p<0.05$).

	DEPTH	PB	GR	VCS	CS	MS	FS	VFS	SILT	CLAY	TOC	TPAH	PCB	DISTKM	MEDIAN	WATER
DEPTH	1.000															
PB	-0.083	1.000														
GR	0.088	**0.559**	1.000													
VCS	0.057	**0.473**	**0.854**	1.000												
CS	-0.003	**0.503**	**0.741**	**0.844**	1.000											
MS	-0.071	**0.474**	**0.520**	**0.593**	**0.862**	1.000										
FS	-0.006	0.135	0.299	**0.418**	**0.504**	**0.620**	1.000									
VFS	-0.143	-0.010	0.170	0.265	**0.421**	**0.603**	**0.909**	1.000								
SILT	0.027	**-0.335**	**-0.438**	**-0.496**	**-0.527**	**-0.597**	**-0.927**	**-0.826**	1.000							
CLAY	0.088	-0.209	-0.168	**-0.321**	**-0.392**	**-0.520**	**-0.829**	**-0.802**	**0.706**	1.000						
TOC	-0.034	-0.087	0.084	-0.064	0.000	-0.098	-0.300	-0.209	**0.412**	0.139	1.000					
TPAH	-0.108	-0.124	-0.016	-0.158	-0.197	**-0.360**	**-0.482**	**-0.467**	**0.525**	**0.429**	**0.744**	1.000				
PCB	-0.020	-0.133	-0.073	-0.225	-0.290	**-0.477**	**-0.554**	**-0.595**	**0.592**	**0.558**	**0.590**	**0.913**	1.000			
DISTKM	0.047	-0.029	-0.041	0.100	0.097	0.260	**0.529**	**0.526**	**-0.538**	**-0.504**	**-0.635**	**-0.877**	**-0.865**	1.000		
MEDIAN	-0.098	**0.903**	**0.505**	**0.477**	**0.512**	**0.538**	**0.443**	**0.322**	**-0.621**	**-0.515**	-0.232	**-0.340**	**-0.392**	0.238	1.000	
WATER	0.067	-0.252	-0.140	-0.226	**-0.339**	**-0.610**	**-0.681**	**-0.778**	**0.750**	**0.635**	**0.441**	**0.509**	**0.389**	**-0.712**	**-0.503**	1.000

Grainsize parameters (Wentworth scale)
PB = pebble content; GR = granule; VCS = very coarse sand; CS = coarse sand; MS = medium sand, FS = fine sand; VFS = very fine sand
TOC = Total Organic Carbon
TPAH = Total Polycyclic Aromatic Hydrocarbons
PCB = Polychlorinated Biphenyls
DISTKM = Distance from Muggah Creek
WATER = Water Content

Table 5b. Pearson correlations between sediment characteristics, contaminants and depth for stations having predominately silty sediment, Sydney Harbour, July 2000, N=39.

	DEPTH	PB	GR	VCS	CS	MS	FS	VFS	SILT	CLAY	TOC	TPAH	PCB	DISTKM	MEDIAN	WATER
DEPTH	1.000															
PB	-0.001	1.000														
GR	0.149	**0.425**	1.000													
VCS	0.096	**0.380**	**0.820**	1.000												
CS	0.060	**0.470**	**0.681**	**0.834**	1.000											
MS	0.008	**0.578**	**0.453**	**0.591**	**0.853**	1.000										
FS	0.009	**0.410**	0.307	**0.359**	**0.676**	**0.884**	1.000									
VFS	-0.269	0.107	0.110	0.132	**0.375**	**0.509**	**0.733**	1.000								
SILT	0.004	-0.268	**-0.476**	**-0.384**	**-0.523**	**-0.577**	**-0.546**	**-0.522**	1.000							
CLAY	0.106	-0.091	0.159	-0.039	-0.093	-0.104	-0.205	-0.222	**-0.611**	1.000						
TOC	-0.040	0.156	0.269	0.132	0.188	0.090	0.206	0.214	0.124	**-0.400**	1.000					
TPAH	-0.173	0.142	0.199	0.048	0.067	-0.026	0.030	0.044	0.100	-0.145	**0.732**	1.000				
PCB	-0.110	0.175	0.167	-0.041	0.029	-0.020	0.064	0.042	0.090	-0.111	**0.613**	**0.905**	1.000			
DISTKM	0.092	-0.204	-0.220	-0.092	-0.183	-0.138	-0.171	-0.161	0.024	0.114	**-0.608**	**-0.834**	**-0.803**	1.000		
MEDIAN	-0.249	0.145	-0.120	0.041	0.204	**0.327**	**0.515**	**0.770**	-0.032	**-0.665**	0.290	0.024	0.017	-0.093	1.000	
WATER	0.030	-0.015	0.150	0.112	0.015	-0.211	**-0.354**	**-0.465**	0.272	0.052	**0.389**	**0.491**	**0.394**	**-0.481**	**-0.321**	1.000

Grainsize parameters (Wentworth scale)
PB = pebble content; GR = granule; VCS = very coarse sand; CS = coarse sand; MS = medium sand, FS = fine sand; VFS = very fine sand
TOC = Total Organic Carbon
TPAH = Total Polycyclic Aromatic Hydrocarbons
PCB = Polychlorinated Biphenyls
DISTKM = Distance from Muggah Creek
WATER = Water Content

Table 6a. Principal component loadings for sediment characteristics and physical environmental variables, Sydney Harbour, Nova Scotia, July 2000.

	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4	FACTOR 5
DEPTH	-0.028	-0.038	0.273	0.777	0.541
PB	0.426	0.601	0.459	-0.410	0.237
GR	0.470	0.734	0.140	0.241	-0.096
VCS	0.587	0.619	0.115	0.290	-0.226
CS	0.675	0.599	-0.033	0.203	-0.259
MS	0.776	0.348	-0.111	0.041	-0.198
FS	0.864	-0.092	-0.374	0.073	0.152
VFS	0.809	-0.209	-0.516	-0.002	0.023
SILT	-0.899	0.002	0.137	0.016	-0.154
CLAY	-0.776	0.099	0.373	0.134	-0.268
TOC	-0.448	0.506	-0.532	0.038	0.131
TPAH	-0.704	0.529	-0.396	-0.065	0.106
PCB	-0.780	0.453	-0.228	-0.023	0.130
DISTKM	0.659	-0.603	0.218	0.065	-0.085
MEDIAN	0.681	0.379	0.311	-0.421	0.325
WATER	-0.829	0.267	0.132	0.002	0.007
% OF VARIANCE	46.93	19.67	9.68	7.30	4.95

Table 6b. Principal component loadings for sediment characteristics and physical environmental variables, silt/clay sediments. Sydney Harbour, Nova Scotia, July 2000.

	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4	FACTOR 5
DEPTH	-0.048	0.139	0.351	0.318	0.814
PB	0.573	-0.089	0.216	0.223	-0.331
GR	0.647	-0.058	0.574	0.128	0.042
VCS	0.685	0.100	0.443	0.356	-0.083
CS	0.871	0.126	0.255	0.210	-0.047
MS	0.885	0.238	0.050	0.072	-0.081
FS	0.853	0.183	-0.227	-0.074	0.099
VFS	0.669	0.180	-0.570	-0.357	0.075
SILT	-0.607	-0.390	-0.316	0.582	-0.030
CLAY	-0.171	0.261	0.675	-0.654	0.020
TOC	0.373	-0.735	-0.171	0.104	0.199
TPAH	0.237	-0.925	0.032	-0.185	0.027
PCB	0.214	-0.882	0.029	-0.228	0.068
DISTKM	-0.365	0.780	-0.007	0.242	-0.133
MEDIAN	0.469	0.042	-0.814	0.101	-0.005
WATER	-0.285	-0.646	0.420	0.169	-0.279
% OF VARIANCE	31.31	22.50	16.03	8.99	5.92

Table 7. Biological community measures for Sydney Harbour stations, July 2000.

Station & Replicate	Abundance (No/m^2)	Biomass g/m^2	Species/Station	Shannon Wiener Diversity (log_{10})	Pielou's Evenness
1-1	1270	35.19	12	0.962	0.891
1-2	2150	64.79	13	0.830	0.745
7-1	90	0.55	4	0.569	0.946
7-2	40	4.28	3	0.452	0.946
8-1	60	5.75	3	0.439	0.921
8-2	30	1.01	2	0.276	0.918
9-1	780	34.31	14	0.898	0.783
9-2	6400	42.39	8	0.397	0.440
10-1	40	8.69	4	0.602	1.000
10-2	1110	35.48	2	0.039	0.130
13-1	120	8.52	6	0.669	0.859
13-2	80	8.35	2	0.287	0.954
14-1	1230	135.62	26	1.182	0.835
14-2	20	0.32	2	0.301	1.000
16	120	2.84	3	0.386	0.808
17-1	41880	137.82	23	0.345	0.254
17-2	33320	130.47	25	0.617	0.441
20	450	21.28	7	0.693	0.820
21	40	0.87	2	0.244	0.811
22	540	11.77	10	0.695	0.695
24	330	16.54	8	0.607	0.672
25	8530	76.04	19	0.479	0.374
26	290	9.64	5	0.299	0.428
30	320	23.71	6	0.557	0.716
32-1	50	1.18	3	0.413	0.865
32-2	20	0.5	2	0.301	1.000
33-1	700	11.3	12	0.813	0.753
33-2	610	49.97	10	0.783	0.783
40	420	46.64	7	0.603	0.713

Table 8. Summary of community measures including geometric means (log_{10}) of abundance and biomass for the softbottom benthic community of Sydney Harbour, Nova Scotia, in 1999 & 2000.

1999

	Number of Samples	Abundance (number/m^2)				Wet Weight Biomass (grams/m^2)				Number of Species		Shannon-Wiener Diversity (log_{10})	
		$\bar{x}$	SD	$\bar{x}$ (log_{10})	SD (log_{10})	$\bar{x}$	SD	$\bar{x}$ (log_{10})	SD (log_{10})	$\bar{x}$	SD	$\bar{x}$	SD
1. Inner South Arm	3	30520.0	52723.6	2.93	1.76	15.4	23.1	0.82	0.75	5.7	5.5	0.260	0.180
2. Central & NE South Arm	16	291.9	291.3	2.26	0.47	13.8	16.2	0.87	0.57	4.4	2.3	0.450	0.210
3. Outer & NW South Arm	6	25305.0	19652.1	3.70	1.38	38.7	28.3	1.42	0.54	11.7	6.9	0.310	0.180
4. Northwest Arm	6	38850.0	45388.0	4.39	0.43	50.6	26.3	1.66	0.23	17.5	6.2	0.360	0.150
5. Outer Harbour	5	24714.0	23749.4	4.26	0.38	92.0	54.9	1.91	0.26	33.0	6.7	0.830	0.140

Inner South Arm: Stations 18, 19, & 34.
Central and NE South Arm: Stations 1-4, 6-15, 17, 30 & 31.
Outer and NW South Arm: Stations 5, 28, 29, 32, & 37.
Northwest Arm: Stations 24-27, 35-36.
Outer Harbour: Stations 16, 21-23.

2000

	Number of Samples	Abundance (number/m2)				Wet Weight Biomass (grams/m^2)				Number of Species (per sample)		Shannon-Wiener Diversity (log_{10})	
		$\bar{x}$	SD	$\bar{x}$ (log_{10})	SD (log_{10})	$\bar{x}$	SD	$\bar{x}$ (log_{10})	SD (log_{10})	$\bar{x}$	SD	$\bar{x}$	SD
1. Inner South Arm	8	1081.3	1760.0	2.33	1.39	18.3	17.3	0.95	0.65	6.8	4.4	0.540	0.310
2. Central & NE South Arm	11	534.6	690.3	2.36	0.61	18.6	19.6	1.08	0.48	5.9	4.0	0.550	0.260
3. Outer & NW South Arm	3	303.3	228.6	2.30	0.59	22.9	22.9	1.10	0.74	5.3	2.9	0.510	0.240
4. Northwest Arm	3	3050.0	4745.9	2.97	0.83	34.1	36.5	1.39	0.45	10.7	7.4	0.460	0.150
5. Outer Harbour	4	19020.0	21739.8	3.35	1.56	101.1	67.2	1.63	1.01	18.0	10.7	0.600	0.390

Inner South Arm: Stations 8, 9, 32 & 33.
Central and NE South Arm: Stations 1, 7, 10, 13, 16, 22 & 30.
Outer and NW South Arm: Stations 20, 21 &40.
Northwest Arm: Stations 24-26.
Outer Harbour: Stations 14 & 17.

Table 9. Dominance (relative abundance) of seabed organisms in communities identified by cluster analysis, Sydney Harbour, Nova Scotia, July 2000. Distribution of communities is shown in Figure 19.

A1

Species	Abundance	%
Nephtys incisa	67	48.9
Ninoe nigripes	24	17.5
Cerianthus borealis	18	13.1
Nephtys sp.	7	5.1
Polydora quadrilobata	6	4.4
Cerebratulus sp.	3	2.2
Mediomastus ambiseta	2	1.5
Diaphana minuta	2	1.5
Yoldia limatula	2	1.5
Phoronis architecta?	1	0.7
Anemone unid.	1	0.7
Mya arenaria	1	0.7
Retusa obtusa	1	0.7
Acteocina canaliculata	1	0.7
Pitar morhuanus	1	0.7

A2

Species	Abundance	%
Nephtys incisa	14	46.7
Cerianthus borealis	9	30.0
Polydora quadrilobata	2	6.7
Aricidea catherinae	1	3.3
Bivalvia unid.	1	3.3
Cerebratulus sp.	1	3.3
Harmothoe imbricata	1	3.3
Eudorella truncatula	1	3.3

B

Species	Abundance	%
Cerianthus borealis	21	25.0
Cerebratulus sp.	20	23.8
Polydora quadrilobata	17	20.2
Nephtys incisa	16	19.0
Leptocheirus pingius	4	4.8
Nephtys sp.	2	2.4
Ninoe nigripes	2	2.4
Phloe minuta	2	2.4

C1

Species	Abundance	%
Mediomastus ambiseta	1062	50.6
Ninoe nigripes	377	18.0
Polydora quadrilobata	197	9.4
Acteocina canaliculata	130	6.2
Cerianthus borealis	86	4.1
Cerebratulus sp.	63	3.0
Nephtys incisa	45	2.1
Leptocheirus pingius	36	1.7
Edotea montosa	29	1.4
Phyllodoce sp.	11	0.5
Photis reinhardi	10	0.5
Orchomenella minuta	9	0.4
Polydora sp.	5	0.2
Harmothoe imbricata	3	0.1
Diaphana minuta	3	0.1
Arcteobia anticostiensis	3	0.1
Tellina agilis	3	0.1
Hydrobia totteni	2	<0.1
Eteone longa	2	<0.1
Capitella capitata	2	<0.1
Harmothoe sp.	2	<0.1
Phloe minuta	2	<0.1
Euchone elegans	2	<0.1
Retusa obtusa	2	<0.1

B*

Species	Abundance	%
Capitella capitata	109	98.2
Cerebratulus sp.	2	1.8

C2

Species	Abundance	%
Owenia fusiformis	5692	75.7
Polydora quadrilobata	364	4.8
Edotea montosa	272	3.6
Ninoe nigripes	240	3.2
Photis reinhardi	236	3.1
Eudorella truncatula	156	2.1
Cerebratulus sp.	136	1.8
Orchomenella minuta	88	1.2
Acteocina canaliculata	52	0.7
Phloe minuta	48	0.6
Mediomastus ambiseta	36	0.5
Echinarachnius parma	32	0.4
Phoxocephalus holbolli	24	0.3
Cerianthus borealis	16	0.2
Leptocheirus pingius	16	0.2
Crenella decussata	12	0.2
Diastylis sculpta	12	0.2
Munnidae sp 1	8	0.1
Euchone sp.	8	0.1
Nucula delphinodonta	8	0.1
Eteone longa	8	0.1
Diastylis sp.	4	< 0.1
Diastylis polita	4	< 0.1
Pseudoleptocuma minor	4	< 0.1
Philoscia vittata	4	< 0.1
Bivalvia unid.	4	< 0.1
Ampharetidae	4	< 0.1
Hiatella arctica	4	< 0.1
Retusa obtusa	4	< 0.1
Nassarius trivittatus	4	< 0.1
Phyllodoce sp.	4	< 0.1
Polychaete unid.	4	< 0.1
Corophium bonelli?	4	< 0.1
Euchone papillosa ?	4	< 0.1
Nephtys incisa	4	< 0.1

D*

Species	Abundance	%
Nucula delphinodonta	23	18.4
Protodrilidae sp 1	23	18.4
Echinarachnius parma	11	8.8
Spiophanes bombyx	8	6.4
Clymenella torquata	7	5.6
Ninoe nigripes	7	5.6
Nephtys incisa	6	4.8
Hydrobia totteni	5	4.0
Arctica islandica	3	2.4
Turbonilla interrupta	3	2.4
Phloe minuta	3	2.4
Nassarius trivittatus	3	2.4
Glycera capitata	3	2.4
Tellina agilis	3	2.4
Unicola irrorata	2	1.6
Scoloplos robustus	2	1.6
Phyllodoce sp.	2	1.6
Lamprops	1	0.8
Eudorella truncatula	1	0.8
Eteone longa	1	0.8
Acteocina canaliculata	1	0.8
Cerebratulus sp.	1	0.8
Eteone sp.	1	0.8
Nephtys caeca	1	0.8
Nephtys longosetosa	1	0.8
Mediomastus ambiseta	1	0.8
Monoculodes sp.	1	0.8
Anonyx sarsi	1	0.8

Table 10. Species identification number for canonical correspondence analysis (See Figures 27c, 28c and 29c).

Number	Species
1	Acteocina canaliculata
2	Diaphana minuta
3	Hydrobia totteni
4	Retusa obtusa
5	Nassarius trivittatus
6	Hiatella arctica
7	Mya arenaria
8	Nucula delphinodonta
9	Tellina agilis
10	Capitella capitata
11	Eteone longa
12	Harmothoe imbricata
13	Mediomastus ambiseta
14	Nephtys incisa
15	Ninoe nigripes
16	Phloe minuta
17	Phyllodoce sp.
18	Polydora quadrilobata
19	Leptocheirus pingius
20	Orchomenella minuta
21	Photis reinhardi
22	Phoxocephalus holbolli
23	Edotea montosa
24	Diastylis polita
25	Eudorella truncatula
26	Echinarachnius parma
27	Cerebratulus sp.
28	Cerianthus borealis

Table 11a. Correlations of environmental variables with axes in Canonical Correspondence Analysis (CCA), of all Sydney Harbour stations, July 2000. Omits Station 10.

Axis 1		Axis 2		Axis 3		Axis 4	
Variable	r	Variable	r	Variable	r	Variable	R
Water	0.59	VFS	0.68	VCS	0.70	TOC	0.63
Clay	0.51	CS	0.66	Depth	0.52	MS	0.46
PCB	0.50	Median	0.66	FS	0.52	CS	0.39
Silt	0.46	FS	0.66	GR	0.49	VFS	0.30
TPAH	0.44	MS	0.58	Median	0.35		⋮
TOC	0.32	DIST	0.52		⋮	Water	-0.29
	⋮	VCS	0.39	TOC	-0.44		
MS	-0.33		⋮	Silt	-0.56		
FS	-0.41	TPAH	-0.46				
DIST	-0.48	PCB	-0.51				
VFS	-0.53	Water	-0.56				
Median	-0.54	Silt	-0.61				
		Clay	-0.65				

FS = Fine Sand; VFS = Very Fine Sand; MS = Medium Sand; CS = Coarse Sand; VCS = Very Coarse Sand; Median = Median Grainsize; Inman = Inman sorting Coefficient; PB = Pebble; GR = Gravel; TOC = Total Organic Carbon; BAP = Benzo(*a*)pyrene; TPAH = Total PAH; LPAH = Low Molecular Weight PAH; HPAH = High Molecular Weight PAH.

Table 11b. Correlations of environmental variables with axes in Canonical Correspondence Analysis (CCA) of analysis of stations on silt/clay sediments, Sydney Harbour, July 2000. Omits Station 10.

Axis 1		Axis 2		Axis 3		Axis 4	
Variable	R	Variable	r	Variable	r	Variable	r
PCB	0.66	DIST	0.41	PCB	0.39	DIST	0.44
Silt	0.65	Silt	0.28	TPAH	0.33	Depth	0.32
TPAH	0.47		⋮		⋮		⋮
Depth	0.43	TPAH	-0.42	Median	-0.32	Silt	-0.38
	⋮	TOC	-0.73	DIST	-0.35	PCB	-0.44
DIST	-0.54			FS	-0.44	TPAH	-0.45
FS	-0.72			Depth	-0.55		
Median	-0.81						

FS = Fine Sand; VFS = Very Fine Sand; MS = Medium Sand; CS = Coarse Sand; VCS = Very Coarse Sand; Median = Median Grainsize; Inman = Inman sorting Coefficient; PB = Pebble; GR = Gravel; TOC = Total Organic Carbon; BAP = Benzo(*a*)pyrene; TPAH = Total PAH; LPAH = Low Molecular Weight PAH; HPAH = High Molecular Weight PAH.

Table 11c. Correlations of environmental variables with axes in Canonical Correspondence Analysis (CCA), of Sydney Harbour stations on silt/clay sediments in South Arm, July 2000 (omits Station 10 and Stations 8 and 32 in Inner South Arm).

Axis 1		Axis 2		Axis 3		Axis 4	
Variable	r	Variable	R	Variable	r	Variable	r
Depth	0.88	Silt	0.63	DIST	0.47	DIST	0.23
FS	0.39	Median	0.23	Depth	0.21		⋮
	⋮		⋮		⋮	FS	-0.28
TPAH	-0.20	FS	-0.19	Median	-0.44	Silt	-0.29
PCB	-0.41	TOC	-0.28	TPAH	-0.45	TOC	-0.50
				PCB	-0.55		

FS = Fine Sand; VFS = Very Fine Sand; MS = Medium Sand; CS = Coarse Sand; VCS = Very Coarse Sand; Median = Median Grainsize; Inman = Inman sorting Coefficient; PB = Pebble; GR = Gravel; TOC = Total Organic Carbon; BAP = Benzo(*a*)pyrene; TPAH = Total PAH; LPAH = Low Molecular Weight PAH; HPAH = High Molecular Weight PAH.

Table 12a. Partitioning of the variance in species data explained for CCA analysis of all Sydney Harbour stations, July 2000.

	Axis 1	Axis 2	Axis 3	Axis 4
Eigenvalue	0.354	0.274	0.230	0.149
Species – Environment Correlations	0.982	0.947	0.995	0.994
Cumulative % Variance				
- of species data	21.5	38.2	52.2	61.3
- of species environment relation	24.3	43.1	58.8	69.0
Total inertia	1.645			

Table 12b. Partitioning of the variance in species data explained for CCA analysis of stations on silt/clay sediments, Sydney Harbour, July 2000.

	Axis 1	Axis 2	Axis 3	Axis 4
Eigenvalue	0.263	0.148	0.117	0.080
Species – Environment Correlations	0.947	0.965	0.924	0.853
Cumulative % Variance				
- of species data	23.8	37.3	47.8	55.0
- of species environment relation	36.7	57.4	73.7	84.8
Total inertia	1.104			

Table 12c. Partitioning of the variance in species data explained for CCA analysis of stations on silt/clay sediments in South Arm, excluding Station 10 and Inner Harbour Stations 8 & 32, Sydney Harbour, July 2000.

	Axis 1	Axis 2	Axis 3	Axis 4
Eigenvalue	0.262	0.161	0.110	0.078
Species – Environment Correlations	0.994	0.970	0.993	0.916
Cumulative % Variance				
- of species data	32.9	53.2	67.0	76.8
- of species environment relation	36.3	58.7	73.9	84.7
Total inertia	0.796			

Table 13. Dissolved oxygen concentrations (mg/L) in nearbottom waters, Sydney Harbour, Nova Scotia, October 1999, and July and October 2000. (Bracketed values beside some station numbers are CTD reference numbers).						
Consecutive Station	Latitude	Longitude	Pressure (Db)	Depth (m)	Oxygen (mg/L)	Temperature (°C)
Whaler — October 19-20, 1999						
1	46 6.192	60 14.628	-	4.0	5.7	13.4
2	46 6.300	60 14.334	-	2.5	7.3	13.3
3	46 6.498	60 13.974	-	5.0	8.2	12.0
4	46 6.816	60 13.800	-	6.0	8.2	12.2
5	46 6.816	60 13.488	-	7.4	8.2	12.1
6	46 6.924	60 13.014	-	7.0	8.2	12.2
7	46 7.236	60 12.780	-	7.4	8.3	12.2
8	46 7.650	60 12.402	-	9.9	8.0	12.2
9	46 8.196	60 12.096	-	8.4	8.3	12.1
10	46 8.898	60 12.462	-	13.4	8.2	11.9
11	46 9.462	60 12.696	-	13.4	8.6	11.7
12	46 10.104	60 12.798	-	16.9	8.6	11.7
13	46 10.668	60 12.960	-	15.4	8.9	11.7
14	46 11.226	60 13.254	-	15.4	8.7	11.6
15	46 13.494	60 12.294	-	11.4	8.9	10.4
16	46 10.086	60 18.510	-	3.5	8.6	11.5
17	46 9.258	60 18.216	-	4.5	8.4	11.5
18	46 9.756	60 17.682	-	6.4	8.3	11.7
19	46 10.164	60 17.100	-	8.9	8.9	11.6
20	46 10.500	60 16.758	-	11.4	8.9	11.5
21	46 10.908	60 15.966	-	13.4	8.9	11.3
22	46 11.268	60 15.126	-	12.9	9.2	11.1
23	46 11.634	60 14.466	-	12.4	9.3	10.6
24	46 11.952	60 13.380	-	13.4	9.3	10.4
Navicula — October 18-22, 1999						
1 (25)	46 8.802	60 12.450	-	12.4	8.6	12.5
2 (26)	46 8.790	60 12.648	-	9.9	8.6	12.6
9 (27)	46 9.438	60 12.450	-	14.4	9.0	11.8
10 (28)	46 9.510	60 12.582	-	14.9	8.9	11.6
11 (29)	46 9.474	60 12.882	-	10.9	8.4	11.7
12 (30)	46 10.980	60 12.492	-	16.9	8.4	11.6
16 (31)	46 14.988	60 10.608	-	14.4	9.6	10.4
18 (32)	46 7.728	60 12.372	-	10.4	8.7	11.5
20 (33)	46 13.632	60 12.462	-	10.4	9.3	10.2
24 (34)	46 11.382	60 14.928	-	6.0	9.2	11.2
26 (35)	46 10.578	60 16.668	-	10.9	9.0	11.0
28 (36)	46 11.082	60 13.338	-	11.9	8.7	11.0
33 (37)	46 10.962	60 12.894	-	15.9	8.7	10.5
34 (38)	46 7.320	60 12.810	-	6.0	8.4	11.3
35 (39)	46 10.026	60 17.148	-	8.4	8.2	11.1
38 (40)	46 11.004	60 12.912	-	15.4	9.2	10.5

Table 13 (continued). Dissolved oxygen concentrations (mg/L) in nearbottom waters, Sydney Harbour, Nova Scotia, October 1999, and July and October 2000. (Bracketed values are CTD reference numbers).

Consecutive Station	Latitude	Longitude	Pressure (Db)	Depth (m)	Oxygen (mg/L)	Temperature (°C)
Earl Grey — July 10-14, 2000						
2	46 08.748	60 12.626	11.7	11.6	8.9	9.3
3	46 08.787	60 12.449	15.3	15.2	8.0	8.1
5	46 09.438	60 12.450	15.7	15.6	8.2	8.7
6	46 09.510	60 12.567	14.8	14.7	8.2	8.7
9	46 10.954	60 12.505	18.2	18.1	8.3	8.1
11	46 11.002	60 12.910	17.6	17.5	8.7	9.3
13	46 14.986	60 10.609	15.0	14.9	8.7	12.3
14	46 13.632	60 12.460	12.3	12.2	9.0	13.6
15	46 11.249	60 14.737	19.1	19.0	8.2	8.7
17	46 11.082	60 13.337	13.6	13.5	7.9	9.0
19	46 09.082	60 12.641	16.1	15.9	8.6	8.4
22	46 07.730	60 12.373	10.9	10.8	8.6	12.4
23	46 07.320	60 12.810	5.8	5.8	8.9	14.5
24	46 10.585	60 16.641	10.5	10.4	8.7	12.8
25	46 09.987	60 17.222	9.1	9.0	9.2	13.2
36	46 11.655	60 13.024	15.6	15.4	8.0	8.7
Navicula — October 2-6, 2000						
1	46 08.75	60 12.63	14.0	-	7.7	15.0
7	46 09.51	60 12.57	13.0	-	7.9	14.9
10	46 10.13	60 12.55	15.5	-	7.9	14.9
12	46 13.63	60 12.46	13.5	-	8.6	14.8
15	46 11.00	60 12.91	16.5	-	8.0	15.0
17	46 08.79	60 12.45	13.5	-	6.9	15.2
21	46 10.95	60 12.50	17.0	-	7.9	15.2
25	46 09.82	60 12.64	13.0	-	7.3	14.9
29	46 07.73	60 12.37	10.0	-	7.4	15.2
30	46 10.59	60 16.64	11.5	-	8.0	15.0
37	46 13.63	60 12.46	11.5	-	9.0	15.1
39	46 11.66	60 13.02	15.5	-	8.6	15.2
40	46 12.48	60 13.54	13.5	-	8.6	15.0
47	46 07.32	60 12.81	6.5	-	8.4	15.1

Table 14. Oxygen deficits from 7 mg/L from P. Lane and Associates (1988) stations corresponding to stations in current study.

1999		2000	
Station	Oxygen deficit	Station	Oxygen deficit
1	2.7	1	2.7
2	2.7	2	2.7
3	2.6	3	3
4	0.6	4	2.6
5	1.5	5	0.6
6	3.6	6	1.5
7	0.7	7	
13	3	8	1
15	3.3	10	3.3
17	2.5	12	0.7
18	1.7	13	3.6
19	3.2	14	
27		21	2.3
28	0.2	22	
29	2.3	23	0.3
32	0.3	26	
34	1	27	
37	1.4	30	2.5
		32	1.7
		33	3.2
		40	1.4

APPENDICES

Table A1. Dominance and occurrence of seabed organisms from Sydney Harbour, July 2000, based on total number of individuals at 19 stations (29 samples).

Species	Total Number of Individuals	Percent of total	Number of Samples
Owenia fusiformis	5692	56.54	2
Mediomastus ambiseta	1101	10.94	13
Ninoe nigripes	650	6.45	15
Polydora quadrilobata	586	5.82	15
Edotea montosa	301	2.99	6
Photis reinhardi	246	2.44	6
Protodrilidae sp 1	230	2.30	1
Cerebratulus sp.	226	2.24	22
Acteocina canaliculata	184	1.83	11
Eudorella truncatula	159	1.58	5
Nephtys incisa	152	1.50	22
Cerianthus borealis	150	1.49	19
Capitella capitata	111	1.10	3
Orchomenella minuta	97	0.96	3
Leptocheirus pingius	56	0.56	8
Phloe minuta	55	0.55	5
Echinarachnius parma	43	0.43	2
Nucula delphinodonta	31	0.31	3
Phoxocephalus holbolli	25	0.25	2
Phyllodoce sp.	17	0.17	7
Crenella decussata	12	0.12	1
Diastylis sculpta	12	0.12	2
Eteone longa	11	0.11	3
Nephtys sp.	9	0.09	5
Munnidae sp 1	8	0.08	2
Euchone sp.	8	0.08	1
Nassarius trivittatus	8	0.08	3
Hydrobia totteni	7	0.07	2
Retusa obtusa	7	0.07	3
Spiophanes bombyx	7	0.07	1
Clymenella torquata	7	0.07	1
Tellina agilis	6	0.06	2
Diaphana minuta	5	0.05	2
Hiatella arctica	5	0.05	2
Bivalvia unid.	5	0.05	2
Polydora sp.	5	0.05	2
Diastylis polita	5	0.05	2
Ampharetidae	4	0.04	1
Polychaete unid.	4	0.04	1
Harmothoe imbricata	4	0.04	3
Philoscia vittata	4	0.04	1
Corophium bonelli?	4	0.04	1
Diastylis sp.	4	0.04	1

Table A1 (continued). Dominance and occurrence of seabed organisms from Sydney Harbour, July 2000, based on total number of individuals at 19 stations (29 samples).

Species	Total Number of Individuals	Percent of total	Number of Samples
Pseudoleptocuma minor	4	0.04	1
Euchone papillosa ?	4	0.04	1
Arctica islandica	3	0.03	1
Arcteobia anticostiensis	3	0.03	1
Glycera capitata	3	0.03	1
Turbonilla interrupta	3	0.03	1
Euchone elegans	2	0.02	1
Unicola irrorata	2	0.02	1
Scoloplos robustus	2	0.02	1
Eteone sp.	2	0.02	2
Mya arenaria	2	0.02	2
Harmothoe sp.	2	0.02	1
Yoldia limatula	2	0.02	1
Lamprops quadriplicata	1	0.01	1
Aricidea catherinae	1	0.01	1
Nephtys longosetosa	1	0.01	1
Nephtys caeca	1	0.01	1
Anonyx sarsi	1	0.01	1
Thracia sp.	1	0.01	1
Pitar morhuanus	1	0.01	1
Monoculodes latimanus?	1	0.01	1
Gastropoda unid.	1	0.01	1
Phoronis architecta?	1	0.01	1
Spionidae sp A	1	0.01	1
Anemone unid.	1	0.01	1
Scolelepis squamata	1	0.01	1
Spionidae	1	0.01	1

Table A2. Relative abundance of benthic infauna at 30 stations in Sydney Harbour, Nova Scotia, July 2000.

Species	Total No. of Individuals	Percent of Total	Number of Stations
BIVALVIA			
Arctica islandica	3	0.03	1
Crenella decussata	12	0.12	1
Hiatella arctica	5	0.05	2
Mya arenaria	2	0.02	2
Nucula delphinodonta	28	0.28	3
Pitar morhuanus	1	0.01	1
Tellina agilis	6	0.06	2
Thracia sp.	1	0.01	1
Yoldia limatula	2	0.02	1
Bivalvia unid.	5	0.05	2
GASTROPODA			
Acteocina canaliculata	184	1.83	11
Diaphana minuta	5	0.05	2
Hydrobia totteni	7	0.07	2
Retusa obtusa	7	0.07	3
Nassarius trivittatus	8	0.08	3
Gastropoda unid.	1	0.01	1
POLYCHAETA			
Ampharetidae	4	0.04	1
Arcteobia anticostiensis	3	0.03	1
Aricidea catherinae	1	0.01	1
Capitella capitata	111	1.10	3
Clymenella torquata	7	0.07	1
Eteone longa	11	0.11	3
Eteone sp.	2	0.02	2
Euchone elegans	2	0.02	1
Euchone papillosa ?	4	0.04	1
Euchone sp.	8	0.08	1
Glycera capitata	3	0.03	1
Harmothoe imbricata	4	0.04	3
Harmothoe sp.	2	0.02	1
Mediomastus ambiseta	1101	10.94	13
Nephtys caeca	1	0.01	1
Nephtys incisa	151	1.50	22
Nephtys longosetosa	1	0.01	1
Nephtys sp.	9	0.09	5
Ninoe nigripes	649	6.45	15
Owenia fusiformis	5692	56.54	2
Phloe minuta	52	0.52	5

Table A2 (cont.). Relative abundance of benthic infauna at 30 stations in Sydney Harbour, Nova Scotia, July 2000.

Species	Total No. of Individuals	Percent of Total	Number of Stations
Phyllodoce sp.	16	0.16	7
Polydora quadrilobata	586	5.82	15
Polydora sp.	5	0.05	2
Scolelepis squamata	1	0.01	1
Scoloplos robustus	2	0.02	1
Spionidae	1	0.01	1
Spionidae sp A	1	0.01	1
Spiophanes bombyx	7	0.07	1
Polychaete unid.	4	0.04	1
AMPHIPODA			
Anonyx sarsi	1	0.01	1
Corophium bonelli?	4	0.04	1
Leptocheirus pingius	56	0.56	8
Monoculodes latimanus?	1	0.01	1
Orchomenella minuta	97	0.96	3
Photis reinhardi	246	2.44	6
Phoxocephalus holbolli	25	0.25	2
Unicola irrorata	2	0.02	1
ISOPODA			
Edotea montosa	301	2.99	6
Munnidae sp 1	8	0.08	2
Philoscia vittata	4	0.04	1
CUMACEA			
Diastylis polita	5	0.05	2
Diastylis sculpta	12	0.12	2
Diastylis sp.	4	0.04	1
Eudorella truncatula	159	1.58	5
Pseudoleptocuma minor	4	0.04	1
ECHINODERMATA			
Echinarachnius parma	43	0.43	2
NEMERTEA			
Cerebratulus sp.	226	2.24	22
ANTHOZOA			
Cerianthus borealis	150	1.49	19
Anemone unid.	1	0.01	1
MISCELLANEOUS			
Phoronis architecta?	1	0.01	1

Table A3. Abundance (number/m^2) of seabed organisms at Sydney Harbour stations, July 2000.

Station	1-1	1-2	7-1	7-2	8-1	8-2	9-1	9-2	10-1	10-2	13-1	13-2
Sub Sample Factor								4				
Species												
BIVALVIA												
Arctica islandica	0	0	0	0	0	0	0	0	0	0	0	0
Crenella decussata	0	0	0	0	0	0	0	0	0	0	0	0
Hiatella arctica	0	0	0	0	0	0	10	0	0	0	0	0
Mya arenaria	0	0	0	0	0	0	0	0	0	0	0	0
Nucula delphinodonta	0	0	0	0	0	0	0	0	0	0	0	0
Pitar morhuanus	0	0	0	0	0	0	0	0	0	0	0	0
Tellina agilis	0	0	0	0	0	0	0	0	0	0	0	0
Thracia sp.	10	0	0	0	0	0	0	0	0	0	0	0
Yoldia limatula	0	0	0	0	0	0	0	0	0	0	0	0
Bivalvia unid.	0	0	0	0	0	0	0	0	0	0	0	0
GASTROPODA												
Acteocina canaliculata	190	550	0	0	0	0	140	40	0	0	0	0
Diaphana minuta	0	0	0	0	0	0	0	0	0	0	0	0
Hydrobia totteni	0	0	0	0	0	0	0	0	0	0	0	0
Retusa obtusa	0	0	0	0	0	0	0	0	0	0	0	0
Nassarius trivittatus	0	0	0	0	0	0	0	0	0	0	0	0
Turbonilla interrupta	0	0	0	0	0	0	0	0	0	0	0	0
Gastropoda unid.	0	0	0	0	0	0	10	0	0	0	0	0
POLYCHAETA												
Ampharetidae	0	0	0	0	0	0	0	0	0	0	0	0
Arcteobia anticostiensis	0	0	0	0	0	0	0	0	0	0	0	0
Aricidea catherinae	0	0	0	0	0	10	0	0	0	0	0	0
Capitella capitata	0	0	0	0	0	0	0	0	0	1090	0	0
Clymenella torquata	0	0	0	0	0	0	0	0	0	0	0	0
Eteone longa	0	0	0	0	0	0	0	0	0	0	0	0
Eteone sp.	0	0	0	0	0	0	0	0	0	0	0	0
Euchone elegans	20	0	0	0	0	0	0	0	0	0	0	0
Euchone papillosa ?	0	0	0	0	0	0	0	0	0	0	0	0
Euchone sp.	0	0	0	0	0	0	0	0	0	0	0	0
Glycera capitata	0	0	0	0	0	0	0	0	0	0	0	0
Harmothoe imbricata	0	0	0	0	0	0	20	0	0	0	0	0
Harmothoe sp.	0	20	0	0	0	0	0	0	0	0	0	0
Mediomastus ambiseta	240	50	0	0	0	0	70	4400	0	0	0	0
Nephtys caeca	0	0	0	0	0	0	0	0	0	0	0	0
Nephtys incisa	60	80	0	10	20	20	40	40	0	0	0	0
Nephtys longosetosa	0	0	0	0	0	0	0	0	0	0	0	0
Nephtys sp.	0	0	10	0	0	0	0	0	0	0	10	0
Ninoe nigripes	240	750	0	0	0	0	230	80	0	0	10	0
Owenia fusiformis	0	0	0	0	0	0	0	0	0	0	0	0
Phloe minuta	0	0	0	0	0	0	0	0	0	0	10	0
Phyllodoce sp.	0	10	0	0	0	0	40	0	0	0	0	0
Polydora quadrilobata	70	30	20	0	10	0	0	1480	10	0	0	0

Table A3 (cont.). Abundance (number/m^2) of seabed organisms at Sydney Harbour stations, July 2000.

Station	1-1	1-2	7-1	7-2	8-1	8-2	9-1	9-2	10-1	10-2	13-1	13-2
Sub Sample Factor								4				
Species												
Polydora sp.	0	0	0	0	0	0	0	40	0	0	0	0
Scolelepis squamata	0	0	0	0	0	0	10	0	0	0	0	0
Scoloplos robustus	0	0	0	0	0	0	0	0	0	0	0	0
Spionidae	0	0	0	0	0	0	0	0	0	0	0	0
Spionidae sp A	0	0	0	0	0	0	0	0	0	0	0	0
Spiophanes bombyx	0	0	0	0	0	0	0	0	0	0	0	0
Polychaete unid.	0	0	0	0	0	0	0	0	0	0	0	0
AMPHIPODA												
Anonyx sarsi	0	0	0	0	0	0	0	0	0	0	0	0
Corophium bonelli?	0	0	0	0	0	0	0	0	0	0	0	0
Leptocheirus pingius	80	190	0	0	0	0	0	0	10	0	10	0
Monoculodes latimanus?	0	0	0	0	0	0	0	0	0	0	0	0
Orchomenella minuta	0	80	0	0	0	0	0	0	0	0	0	0
Photis reinhardi	30	30	0	0	0	0	10	0	0	0	0	0
Phoxocephalus holbolli	0	0	0	0	0	0	10	0	0	0	0	0
Unicola irrorata	0	0	0	0	0	0	0	0	0	0	0	0
ISOPODA												
Edotea montosa	80	180	0	0	0	0	20	0	0	0	0	0
Munnidae sp 1	0	0	0	0	0	0	0	0	0	0	0	0
Philoscia vittata	0	0	0	0	0	0	0	0	0	0	0	0
CUMACEA												
Diastylis polita	0	0	0	0	0	0	0	0	0	0	0	0
Diastylis sculpta	0	0	0	0	0	0	0	0	0	0	0	0
Diastylis sp.	0	0	0	0	0	0	0	0	0	0	0	0
Eudorella truncatula	0	0	0	0	0	0	0	0	0	0	0	0
Lamprops quadriplicata	0	0	0	0	0	0	0	0	0	0	0	0
Pseudoleptocuma minor	0	0	0	0	0	0	0	0	0	0	0	0
ECHINODERMATA												
Echinarachnius parma	0	0	0	0	0	0	0	0	0	0	0	0
NEMERTEA												
Cerebratulus sp.	120	40	30	10	30	0	20	40	10	20	50	30
ANTHOZOA												
Cerianthus borealis	130	140	30	20	0	0	150	280	10	0	30	50
Anemone unid.	0	0	0	0	0	0	0	0	0	0	0	0
MISCELLANEOUS												
Protodrilidae sp 1	0	0	0	0	0	0	0	0	0	0	0	0
Phoronis? architecta	0	0	0	0	0	0	0	0	0	0	0	0

Table A3 (cont.). Abundance (number/m^2) of seabed organisms at Sydney Harbour stations, July 2000.

Station	14-1	14-2	16	17-1	17-2	20	21	22	24	25	26	30
Sub Sample Factor				4	4							
Species												
BIVALVIA												
Arctica islandica	30	0	0	0	0	0	0	0	0	0	0	0
Crenella decussata	0	0	0	0	120	0	0	0	0	0	0	0
Hiatella arctica	0	0	0	40	0	0	0	0	0	0	0	0
Mya arenaria	0	0	0	0	0	0	0	0	0	0	10	0
Nucula delphinodonta	230	0	0	40	40	0	0	0	0	0	0	0
Pitar morhuanus	0	0	0	0	0	0	0	0	0	0	0	0
Tellina agilis	30	0	0	0	0	0	0	0	0	0	0	0
Thracia sp.	0	0	0	0	0	0	0	0	0	0	0	0
Yoldia limatula	0	0	0	0	0	0	0	0	0	0	20	0
Bivalvia unid.	0	0	0	0	40	0	0	0	0	0	0	0
GASTROPODA												
Acteocina canaliculata	10	0	0	40	480	0	0	10	10	300	0	0
Diaphana minuta	0	0	0	0	0	0	0	0	20	30	0	0
Hydrobia totteni	50	0	0	0	0	0	0	0	0	20	0	0
Retusa obtusa	0	0	0	0	40	0	0	0	10	20	0	0
Nassarius trivittatus	30	0	0	40	0	0	0	0	0	0	0	0
Turbonilla interrupta	30	0	0	0	0	0	0	0	0	0	0	0
Gastropoda unid.	0	0	0	0	0	0	0	0	0	0	0	0
POLYCHAETA												
Ampharetidae	0	0	0	0	40	0	0	0	0	0	0	0
Arcteobia anticostiensis	0	0	0	0	0	0	0	0	0	30	0	0
Aricidea catherinae	0	0	0	0	0	0	0	0	0	0	0	0
Capitella capitata	0	0	0	0	0	0	0	0	0	10	0	0
Clymenella torquata	70	0	0	0	0	0	0	0	0	0	0	0
Eteone longa	10	0	0	80	0	0	0	0	0	0	0	0
Eteone sp.	0	10	0	0	0	0	0	0	0	10	0	0
Euchone elegans	0	0	0	0	0	0	0	0	0	0	0	0
Euchone papillosa ?	0	0	0	40	0	0	0	0	0	0	0	0
Euchone sp.	0	0	0	0	80	0	0	0	0	0	0	0
Glycera capitata	30	0	0	0	0	0	0	0	0	0	0	0
Harmothoe imbricata	0	0	0	0	0	0	0	0	0	10	0	0
Harmothoe sp.	0	0	0	0	0	0	0	0	0	0	0	0
Mediomastus ambiseta	0	10	0	320	40	0	0	230	0	5440	10	10
Nephtys caeca	10	0	0	0	0	0	0	0	0	0	0	0
Nephtys incisa	60	0	40	0	40	140	30	40	200	20	240	170
Nephtys longosetosa	10	0	0	0	0	0	0	0	0	0	0	0
Nephtys sp.	0	0	0	0	0	0	0	0	30	0	0	10
Ninoe nigripes	70	0	0	1480	920	10	0	10	20	2120	0	0
Owenia fusiformis	0	0	0	34640	22280	0	0	0	0	0	0	0
Phloe minuta	30	0	0	240	240	10	0	0	0	20	0	0
Phyllodoce sp.	20	0	0	40	0	0	0	20	0	0	0	0
Polydora quadrilobata	0	0	10	3280	360	130	10	160	0	0	0	50

Table A3 (cont.). Abundance (number/m^2) of seabed organisms at Sydney Harbour stations, July 2000.

Station	14-1	14-2	16	17-1	17-2	20	21	22	24	25	26	30
Sub Sample Factor				4	4							
Species												
Polydora sp.	0	0	0	0	0	0	0	0	0	0	0	0
Scolelepis squamata	0	0	0	0	0	0	0	0	0	0	0	0
Scoloplos robustus	20	0	0	0	0	0	0	0	0	0	0	0
Spionidae	0	0	0	0	0	0	0	0	0	10	0	0
Spionidae sp A	0	0	0	0	0	0	0	0	0	10	0	0
Spiophanes bombyx	80	0	0	0	0	0	0	0	0	0	0	0
Polychaete unid.	0	0	0	40	0	0	0	0	0	0	0	0
AMPHIPODA												
Anonyx sarsi	10	0	0	0	0	0	0	0	0	0	0	0
Corophium bonelli?	0	0	0	0	40	0	0	0	0	0	0	0
Leptocheirus pingius	0	0	0	160	0	20	0	10	0	80	0	0
Monoculodes latimanus?	10	0	0	0	0	0	0	0	0	0	0	0
Orchomenella minuta	0	0	0	0	880	0	0	10	0	0	0	0
Photis reinhardi	0	0	0	320	2040	0	0	0	0	0	0	0
Phoxocephalus holbolli	0	0	0	0	240	0	0	0	0	0	0	0
Unicola irrorata	20	0	0	0	0	0	0	0	0	0	0	0
ISOPODA												
Edotea montosa	0	0	0	200	2520	0	0	0	0	0	0	0
Munnidae sp 1	0	0	0	40	40	0	0	0	0	0	0	0
Philoscia vittata	0	0	0	40	0	0	0	0	0	0	0	0
CUMACEA												
Diastylis polita	0	0	0	0	40	0	0	0	0	10	0	0
Diastylis sculpta	0	0	0	40	80	0	0	0	0	0	0	0
Diastylis sp.	0	0	0	40	0	0	0	0	0	0	0	0
Eudorella truncatula	10	0	0	80	1480	0	0	0	0	10	0	0
Lamprops quadriplicata	10	0	0	0	0	0	0	0	0	0	0	0
Pseudoleptocuma minor	0	0	0	0	40	0	0	0	0	0	0	0
ECHINODERMATA												
Echinarachnius parma	110	0	0	0	320	0	0	0	0	0	0	0
NEMERTEA												
Cerebratulus sp.	10	0	0	480	880	50	0	40	0	330	10	10
ANTHOZOA												
Cerianthus borealis	0	0	70	160	0	90	0	10	30	50	0	70
Anemone unid.	0	0	0	0	0	0	0	0	10	0	0	0
MISCELLANEOUS												
Protodrilidae sp 1	230	0	0	0	0	0	0	0	0	0	0	0
Phoronis? architecta	0	0	0	0	0	0	0	0	0	0	10	0

Table A3 (cont.). Abundance (number/m^2) of seabed organisms at Sydney Harbour stations, July 2000.					
Station	32-1	32-2	33-1	33-2	40
Sub Sample Factor					
Species					
BIVALVIA					
Arctica islandica	0	0	0	0	0
Crenella decussata	0	0	0	0	0
Hiatella arctica	0	0	0	0	0
Mya arenaria	0	0	0	10	0
Nucula delphinodonta	0	0	0	0	0
Pitar morhuanus	0	0	0	0	10
Tellina agilis	0	0	0	30	0
Thracia sp.	0	0	0	0	0
Yoldia limatula	0	0	0	0	0
Bivalvia unid.	0	10	0	0	0
GASTROPODA					
Acteocina canaliculata	0	0	0	70	0
Diaphana minuta	0	0	0	0	0
Hydrobia totteni	0	0	0	0	0
Retusa obtuse	0	0	0	0	0
Nassarius trivittatus	0	0	10	0	0
Turbonilla interrupta	0	0	0	0	0
Gastropoda unid.	0	0	0	0	0
POLYCHAETA					
Ampharetidae	0	0	0	0	0
Arcteobia anticostiensis	0	0	0	0	0
Aricidea catherinae	0	0	0	0	0
Capitella capitata	0	0	10	0	0
Clymenella torquata	0	0	0	0	0
Eteone longa	0	0	0	20	0
Eteone sp.	0	0	0	0	0
Euchone elegans	0	0	0	0	0
Euchone papillosa ?	0	0	0	0	0
Euchone sp.	0	0	0	0	0
Glycera capitata	0	0	0	0	0
Harmothoe imbricata	10	0	0	0	0
Harmothoe sp.	0	0	0	0	0
Mediomastus ambiseta	0	0	170	20	0
Nephtys caeca	0	0	0	0	0
Nephtys incisa	30	10	110	60	60
Nephtys longosetosa	0	0	0	0	0
Nephtys sp.	0	0	0	0	30
Ninoe nigripes	0	0	70	270	220
Owenia fusiformis	0	0	0	0	0
Phloe minuta	0	0	0	0	0
Phyllodoce sp.	0	0	10	30	0
Polydora quadrilobata	0	0	230	0	10

Table A3 (cont.). Abundance (number/m²) of seabed organisms at Sydney Harbour stations, July 2000.					
Station	32-1	32-2	33-1	33-2	40
Sub Sample Factor					
Species					
Polydora sp.	0	0	10	0	0
Scolelepis squamata	0	0	0	0	0
Scoloplos robustus	0	0	0	0	0
Spionidae	0	0	0	0	0
Spionidae sp A	0	0	0	0	0
Spiophanes bombyx	0	0	0	0	0
Polychaete unid.	0	0	0	0	0
AMPHIPODA					
Anonyx sarsi	0	0	0	0	0
Corophium bonelli?	0	0	0	0	0
Leptocheirus pingius	0	0	0	0	0
Monoculodes latimanus?	0	0	0	0	0
Orchomenella minuta	0	0	0	0	0
Photis reinhardi	0	0	30	0	0
Phoxocephalus holbolli	0	0	0	0	0
Unicola irrorata	0	0	0	0	0
ISOPODA					
Edotea montosa	0	0	10	0	0
Munnidae sp 1	0	0	0	0	0
Philoscia vittata	0	0	0	0	0
CUMACEA					
Diastylis polita	0	0	0	0	0
Diastylis sculpta	0	0	0	0	0
Diastylis sp.	0	0	0	0	0
Eudorella truncatula	10	0	0	0	0
Lamprops quadriplicata	0	0	0	0	0
Pseudoleptocuma minor	0	0	0	0	0
ECHINODERMATA					
Echinarachnius parma	0	0	0	0	0
NEMERTEA					
Cerebratulus sp.	0	0	20	20	10
ANTHOZOA					
Cerianthus borealis	0	0	20	80	80
Anemone unid.	0	0	0	0	0
MISCELLANEOUS					
Protodrilidae sp 1	0	0	0	0	0
Phoronis? architecta	0	0	0	0	0

Table A4. Parameters for statistically significant single and multiple linear regression equations for sediment contaminants, physical parameters, depth and distance for Muggah Creek, in central and outer South Arm, Sydney Harbour, October 1999 and July 2000. Bolded values indicate parameter having significant partial regression. Significance * $p<0.05$, ** $p<0.01$, *** $p<0.001$. Shading indicates predominant parameter. O_2Def is the oxygen depletion from 7mg/L observed in P. Lane and Associates (1988).

Year	Dependent Variable	N	Constant	Depth (m) (log_{10})	Distance (km) (log_{10})	Total Organic Carbon (%)[1]	Silt (%)[2]	Clay (%)[2]	R^2	Significance
1999	TOC	16	22.250	**2.166**	**-5.631**			-0.618	0.77	***
2000	TOC	31	-3.913	**14.832**	**-7.788**			**-0.249**	0.74	***
All	TOC	47	4.820	7.995	**-7.219**			**-0.257**	0.69	***
1999	TOC	16	7.800		**-7.678**				0.69	***
2000	TOC	31	6.933		**-6.381**				0.58	***
All	TOC	47	7.237		**-6.950**				0.62	***
1999	TOC	16	39.865					**-1.176**	0.55	***
All	TOC	47	17.580					**-0.395**	0.15	**
1999	Depth	16	1.162		0.092				0.23	NS
2000	Depth	31	1.185		**0.113**				0.24	**
All	Depth	47	1.177		**0.104**				0.23	***
1999	Clay	16	27.442		**3.633**				0.38	**
All	O_2Def	27	2.054		**-1.288**				0.19	*
1999	O_2Def	13	0.416			**0.222**			0.38	*
2000	O_2Def	14	0.607			**0.210**			0.28	*
All	O_2Def	27	0.513			0.062			0.33	**
1999	O_2Def	13	-20.012	1.761		**0.397**	0.110	**0.396**	0.72	*
All	O_2Def	27	-4.695	1.624		**0.211**	0.058	0.001	0.44	**
1999	O_2Def	13	-18.321			**0.378**	1.105	**0.424**	0.72	**
2000	O_2Def	14	-1.238			0.102	**0.076**	-0.073	0.51	*
All	O_2Def	27	-2.951			**0.186**	**0.063**	0.002	0.43	**
2000	PCB	31	-0.270	0.800	**-0.992**		**0.026**	0.026	0.52	***
All	PCB	47	-0.001	1.085	**-0.984**		0.017	0.024	0.46	**
1999	PCB	16	3.481		**-0.857**		-0.039	0.055	0.48	*
2000	PCB	31	0.435		**-0.901**		**0.028**	0.031	0.51	***
All	PCB	47	1.019		**-0.883**		0.018	0.031	0.44	***
1999	PCB	16	2.174			**0.087**			0.50	**
2000	PCB	31	2.178			**0.102**			0.30	**
All	PCB	47	2.204			**0.092**			0.34	***
1999	PCB	16	2.851		**-0.690**				0.37	**
2000	PCB	31	2.905		**-0.962**				0.38	***
All	PCB	47	2.885		**-0.844**				0.37	***
1999	TPAH	16	1.038	1.188	**-1.114**		-0.003	-0.007	0.86	***
2000	TPAH	31	0.161	0.818	**-1.017**		0.012	0.006	0.69	***
All	TPAH	47	0.402	0.970	**-1.090**		0.007	0.003	0.74	***
1999	TPAH	16	2.385		**-1.062**		-0.011	-0.010	0.84	***
2000	TPAH	31	0.882		**-0.924**		0.014	0.012	0.67	***
All	TPAH	47	1.313		-1.000		0.008	0.009	0.72	***

Table A4 (cont.). Parameters for statistically significant single and multiple linear regression equations for sediment contaminants, physical parameters, depth and distance for Muggah Creek, in central and outer South Arm, Sydney Harbour, October 1999 and July 2000. Bolded values indicate parameter having significant partial regression. Significance * $p<0.05$, ** $p<0.01$, *** $p<0.001$. Shading indicates predominant parameter. O_2Def is the oxygen depletion from 7mg/L observed in P. Lane and Associates (1988).

Year	Dependent Variable	N	Constant	Depth (m) (log_{10})	Distance (km) (log_{10})	Total Organic Carbon (%)[1]	Silt (%)[2]	Clay (%)[2]	R^2	Significance
1999	TPAH	16	1.254			**0.101**			0.68	***
2000	TPAH	31	1.267			**0.106**			0.54	***
All	TPAH	47	1.274			**0.103**			0.59	***
1999	TPAH	16	2.057		**-1.034**				0.83	***
2000	TPAH	31	2.022		**-0.959**				0.62	***
All	TPAH	47	2.034		**-0.992**				0.70	***

[1] Regressions with untransformed TOC (%).
[2] Regressions with arcsine-square-root transformed grainsize proportions.

Table A5. Parameters for statistically significant single and multiple linear regression equations for biological measures in central and outer South Arm, Sydney Harbour, October 1999 and July 2000. Bolded values indicate parameter having significant partial regression. Significance * p<0.05, ** p<0.01, *** p<0.001. Shading indicates predominant parameter. R^2 is proportion of variance of dependent variables explained by equation. Analysis includes stations used in Querbach (2002).

Year	Dependent Variable	N	Constant	Depth (m) ($\log_{10}$)	Distance (km) ($\log_{10}$)	Total Organic Carbon (%)[1]	Silt (%)[2]	Clay (%)[2]	R^2	Significance
1999	Species	16	100.053	**-31.047**	8.025	**-1.209**	-0.178	**-1.381**	0.81	**
2000	Species	22	153.396	-24.156	-6.050	**-1.759**	**-1.120**	**-1.474**	0.74	***
All	Species	38	112.610	**-34.930**	0.065	**-1.493**	**-0.529**	**-0.857**	0.61	***
1999	Species	16	86.370	**-27.749**	**8.832**	**-1.063**		**-1.421**	0.81	***
2000	Species	22	63.076	**-38.133**	-1.889	-1.022		-0.128	0.50	*
All	Species	38	67.727	**-39.228**	2.791	**-0.935**		-0.277	0.51	***
1999	Species	16	54.279	**-37.918**	**9.443**	-0.432			0.66	**
2000	Species	22	61.422	**-40.363**	-0.965	-0.891			0.49	**
All	Species	38	61.626	**-41.454**	3.398	**-0.774**			0.50	***
1999	Species	16	49.344	**-36.572**	**12.639**				0.64	***
2000	Species	22	65.668	**-49.163**	5.937				0.42	**
All	Species	38	59.314	**-44.291**	**9.116**				0.42	***
1999	Species	16	52.757	-31.207		**-1.214**			0.53	**
2000	Species	22	62.669	**-41.900**		**-0.808**			0.49	**
All	Species	38	58.923	**-37.408**		**-1.051**			0.48	***
1999	Species	16	14.227			**-0.927**			0.38	**
All	Species	38	12.704			**-0.752**			0.20	**
1999	Species	16	6.864		**9.290**				0.44	**
2000	Species	22	50.069	**-35.982**					0.31	**
All	Species	38	35.491	**-23.843**					0.13	*
2000	Biomass	22	4.927	**-3.990**	**1.671**	0.078			0.41	*
All	Biomass	38	3.839	**-2.692**	**1.286**	0.035			0.36	**
1999	Biomass	16	1.505	0.226		**-0.073**			0.36	*
1999	Biomass	16	1.784			-0.075			0.36	*
All	Biomass	38	1.382			-0.061			0.12	*
1999	Biomass	16	1.189		**0.764**				0.44	**
2000	Biomass	22	0.736		**0.659**				0.18	*
All	Biomass	38	0.927		**0.757**				0.24	**
1999	Abundance	16	26.501	-6.017		**-0.374**	**-0.132**	-0.236	0.68	**
2000	Abundance	22	17.662	-4.157		**-0.109**	**-0.110**	-0.108	0.60	**
All	Abundance	38	18.943	**-4.533**		**-0.218**	**-0.103**	**-0.127**	0.52	***
1999	Abundance	16	2.795		**1.614**				0.35	*
All	Abundance	38	2.714		**0.780**				0.11	*
1999	Abundance	16	4.077			**-0.161**			0.30	*
All	Abundance	38	3.509			**-0.109**			0.17	*
2000	Abundance	22	7.536	**-4.135**					0.289	**
2000	SWDIV	10	2.616	-1.737					0.41	*

Table A5 (cont.). Parameters for statistically significant single and multiple linear regression equations for biological measures in central and outer South Arm, Sydney Harbour, October 1999 and July 2000. Bolded values indicate parameter having significant partial regression. Significance * p<0.05, ** p<0.01, *** p<0.001. Shading indicates predominant parameter. R^2 is proportion of variance of dependent variables explained by equation. Analysis includes stations used in Querbach (2002).

Year	Dependent Variable	N	Constant	Depth (m) (log_{10})	Distance (km) (log_{10})	Total Organic Carbon (%)[1]	Silt (%)[2]	Clay (%)[2]	R^2	Significance
1999	Acteocina canaliculata	16	20.268	**-13.280**	**2.357**		-0.077		0.78	***
2000	Acteocina canaliculata	23	11.979	**-9.851**	**0.885**		0.001		0.64	***
All	Acteocina canaliculata	39	14.669	**-11.112**	**1.547**		-0.020		0.65	***
1999	Acteocina canaliculata	16	26.644	**-13.609**		**-0.259**	**-0.148**		0.70	**
2000	Acteocina canaliculata	23	10.454	**-8.521**		-0.090	0.011		0.63	***
All	Acteocina canaliculata	39	14.314	**-9.404**		**-0.136**	-0.031		0.57	***
1999	Acteocina canaliculata	16	14.788	**-12.200**	**2.191**				0.72	***
2000	Acteocina canaliculata	23	12.048	**-9.853**	**0.885**				0.64	***
All	Acteocina canaliculata	39	13.499	**-11.077**	**1.543**				0.65	***
1999	Acteocina canaliculata	16	14.381	**-10.607**		**-0.180**			0.53	**
2000	Acteocina canaliculata	23	11.090	**-8.528**		**-0.088**			0.63	***
All	Acteocina canaliculata	39	12.363	**-9.290**		**-0.130**			0.56	***
2000	Acteocina canaliculata	23	9.695	**-7.856**					0.55	***
All	Acteocina canaliculata	39	9.425	**-7.572**					0.39	***
1999	Ninoe nigripes	16	18.761	**-11.052**	**2.273**		-0.091		0.49	*
2000	Ninoe nigripes	23	9.953	**-7.402**	**1.663**		-0.009		0.40	*
All	Ninoe nigripes	39	12.615	**-8.517**	**1.884**		-0.032		0.43	***
1999	Ninoe nigripes	16	29.519	**-13.241**		**-0.323**	**-0.194**		0.65	**
2000	Ninoe nigripes	23	7.204	**-4.996**		**-0.182**	0.011		0.41	*
All	Ninoe nigripes	39	13.092	**-6.863**		**-0.197**	-0.049		0.43	***
1999	Ninoe nigripes	16	12.279	**-9.974**	**2.076**				0.43	*
2000	Ninoe nigripes	23	9.423	**-7.384**	**1.663**				0.40	**
All	Ninoe nigripes	39	10.720	**-8.459**	**1.877**				0.42	***
1999	Ninoe nigripes	16	13.475	**-9.314**		**-0.219**			0.42	*
2000	Ninoe nigripes	23	7.849	**-5.004**		**-0.179**			0.41	**
All	Ninoe nigripes	39	10.021	**-6.684**		**-0.189**			0.39	***
All	Ninoe nigrpes	39	0.777		**0.976**				0.11	*

Table A5 (cont.). Parameters for statistically significant single and multiple linear regression equations for biological measures in central and outer South Arm, Sydney Harbour, October 1999 and July 2000. Bolded values indicate parameter having significant partial regression. Significance * p<0.05, ** p<0.01, *** p<0.001. Shading indicates predominant parameter. R^2 is proportion of variance of dependent variables explained by equation. Analysis includes stations used in Querbach (2002).

Year	Dependent Variable	N	Constant	Depth (m) (log_{10})	Distance (km) (log_{10})	Total Organic Carbon (%)[1]	Silt (%)[2]	Clay (%)[2]	R^2	Significance
2000	Ninoe nigripes	23	1.694			**-0.149**			0.22	*
All	Ninoe nigripes	39	1.760			**-0.135**			0.17	**
2000	Mediomastus ambiseta	23	12.679	**-10.057**	0.536				0.41	**
All	Mediomastus ambiseta	39	13.994	**-10.979**	1.837				0.27	**
2000	Mediomastus ambiseta	23	12.740	**-9.563**		-0.094			0.45	**
All	Mediomastus ambiseta	39	13.982	**-9.635**		**-0.214**			0.30	**
2000	Mediomastus ambiseta	23	11.254	**-8.847**					0.39	***
All	Mediomastus ambiseta	39	9.143	**-6.806**					0.12	*
1999	Mediomastus ambiseta	16	3.486			**-0.250**			0.25	*
All	Cerebratulus sp.	39	5.605	**-4.095**	**1.112**		0.006		0.22	*
1999	Cerebratulus sp.	16	8.945		-3.592	**0.215**	-0.033		0.50	*
All	Cerebratulus sp.	39	5.931	-3.139		**-0.118**	-0.004		0.22	*
1999	Cerebratulus sp.	16	4.792	-3.021	**1.746**				0.43	*
All	Cerebratulus sp.	39	5.990	**-4.106**	**1.114**				0.22	*
1999	Cerebratulus sp.	16	6.244	-2.931		**-0.198**			0.49	**
All	Cerebratulus sp.	39	5.699	-3.126		**-0.117**			0.22	*
1999	Nephtys incisa	16	13.156	**-4.771**		**-0.148**	-0.087		0.50	*
1999	Nephtys incisa	16	5.694	-3.450	**1.049**				0.37	*

[1] Regressions with untransformed TOC (%).
[2] Regressions with arcsine-square-root transformed grainsize proportions.

Table A6. Parameters for statistically significant linear regression equations for biological measures versus oxygen deficit from 1987 study, in central and outer South Arm, Sydney Harbour, October 1999 and July 2000. Bolded values indicate parameter having significant partial regression. Significance of regression * $p<0.05$, ** $p<0.01$, *** $p<0.001$. R^2 is proportion of variance of dependent variables explained by equation. Oxygen deficit is the difference between 7 mg/L and the concentration observed in August 1987. Analysis includes community and abundance measures from stations used in Querbach (2002).

Year	Dependent Variable	N	Constant	O_2 Deficit	R^2	Significance
1999	Species	13	13.953	**-3.190**	0.37	*
All	Species	25	12.453	**-2.526**	0.31	**
1999	Biomass	13	1.762	**-0.291**	0.48	**
1999	Abundance	13	4.224	**-0.678**	0.42	**
All	Abundance	25	3.682	**-0.450**	0.27	**
1999	Ninoe nigripes	13	2.343	**-0.600**	0.30	*
1999	Cerebratulus sp.	13	2.414	**-0.494**	0.35	*

Table A7. Abundance (number/m^2) of seabed organisms, July 2000, at Sydney Harbour stations analyzed by Kirsten Querbach, Dalhousie University Department of Oceanography (Querbach 2002).

Station and Replicate	2-1	2-2	3-1	3-2	4-1	4-2	5-1	5-2	6-1	6-2	11-1	12-1
Species												
GASTROPODA												
Acteocina canaliculata	0	0	0	10	10	0	0	0	0	0	0	0
Diaphana minuta	0	0	0	0	0	0	0	0	0	0	0	0
Hydrobia totteni	0	0	0	0	0	0	0	10	0	0	0	0
Lunatia triseriata	0	0	0	0	0	0	0	0	0	0	10	0
Nassarius trivittatus	0	0	0	10	10	0	0	0	0	0	0	0
Retusa obtusa	0	0	0	0	0	0	0	0	0	0	0	0
Sayella sp.	0	0	0	0	0	0	0	0	0	0	0	0
Whelk sp. 2	0	0	0	0	0	0	0	0	0	0	0	0
BIVALVIA												
Cerastoderma pinnulatum	0	0	0	0	0	0	0	0	0	0	0	0
Nucula delphinodonta	0	0	0	0	0	0	0	0	0	0	0	0
Tellina sp.	0	0	0	0	0	0	10	10	0	0	0	10
Yoldia limatula	10	0	0	0	0	0	0	0	0	0	0	10
Bivalve Juv. Unid.	0	10	0	0	0	0	0	0	30	0	0	10
POLYCHAETA												
Capitella capitata	0	0	0	0	0	0	0	0	250	0	10	0
Cirratulidae	0	0	0	0	0	0	0	0	0	0	0	0
Eteone longa	10	0	10	0	0	0	0	10	10	0	0	0
Euchone sp.	10	0	0	0	0	0	0	0	30	30	0	0
Harmothoe sp.	0	10	0	0	0	0	10	0	0	20	0	0
Lumbrineris sp.	0	0	0	0	0	0	0	0	0	0	0	0
Mediomastus ambiseta	10	10	10	0	0	0	0	40	110	150	0	0
Nephtys sp.	80	100	60	10	20	0	10	60	0	270	80	40
Nereis diversicolor	0	0	0	0	0	0	0	0	10	0	0	0
Ninoe nigripes	0	40	0	0	0	0	10	10	0	0	0	50
Owenia fusiformis	0	0	0	0	0	0	0	0	0	0	0	0
Polychaete sp. 1	0	0	0	0	0	0	0	0	0	0	0	0
Pherusa affinis	0	0	0	0	0	0	0	0	0	0	0	0
Phloe minuta	0	0	10	0	0	0	20	10	0	0	0	0
Phoronis architecta	0	10	0	0	0	0	0	20	10	0	20	0
Phyllodoce sp.?	0	0	0	0	0	0	10	0	0	0	0	0

Table A7 (continued). Abundance (number/m^2) of seabed organisms, July 2000, at Sydney Harbour stations analyzed by Kirsten Querbach, Dalhousie University Department of Oceanography (Querbach 2002).

Station and Replicate	2-1	2-2	3-1	3-2	4-1	4-2	5-1	5-2	6-1	6-2	11-1	12-1
Species												
POLYCHAETA (cont).												
Polydora sp.	160	20	1300	0	10	40	40	360	630	500	180	10
Spiophanes bombyx	0	0	0	0	0	0	0	0	0	0	0	0
Spionidae Unid.	0	0	0	0	0	0	0	0	0	0	0	0
Spionid sp. A	0	0	0	0	0	0	0	0	0	0	0	0
Sphaerodoropsis minuta	0	0	0	0	0	0	0	0	0	0	0	0
Tharyx acutus	0	0	0	0	0	0	0	0	0	0	0	0
AMPHIPODA												
Ampelisca vadorum	0	0	0	0	0	0	0	0	0	0	0	0
Corophium crassicorne	0	0	0	0	0	0	0	0	0	0	0	0
Leptocheirus pinguis	0	0	0	0	0	180	20	0	0	0	0	0
Orchomenella minuta	0	0	0	0	0	0	0	0	0	0	0	0
Photis reinhardi	10	0	0	0	0	0	0	0	0	0	0	0
Phoxocephalus holbolli	0	0	0	0	0	0	0	0	0	0	0	0
ISOPODA												
Chiridotea tuftsi	0	0	0	0	0	0	0	0	0	0	0	0
Edotea montosa	20	0	0	0	0	0	0	10	0	0	0	0
ECHINODERMATA												
Cerebratulus sp.	0	0	20	10	40	0	10	70	10	10	0	0
Cerianthus borealis	130	90	60	0	0	0	180	10	90	50	80	150
Cumacea sp.	0	0	0	0	0	0	0	0	0	0	0	0

Table A7 (continued). Abundance (number/m^2) of seabed organisms, July 2000, at Sydney Harbour stations analyzed by Kirsten Querbach, Dalhousie University Department of Oceanography (Querbach 2002).

Station and Replicate	12-2	18	27-1	27-2	31-2	37-1	37-2	38-1	38-2	39-1	39-2	43-1
Species												
GASTROPODA												
Acteocina canaliculata	0	80	0	40	0	0	0	0	0	2040	520	0
Diaphana minuta	10	0	0	0	0	0	0	0	0	880	360	0
Hydrobia totteni	0	0	0	0	0	0	0	0	0	160	0	0
Lunatia triseriata	0	0	0	0	0	0	0	0	0	0	0	0
Nassarius trivittatus	0	40	0	0	10	0	0	0	0	40	80	0
Retusa obtusa	0	40	260	0	0	0	0	0	0	80	0	0
Sayella sp.	0	0	0	0	0	0	0	0	0	40	0	0
Whelk sp. 2	0	0	0	0	0	0	0	0	0	40	40	0
BIVALVIA												
Cerastoderma pinnulatum	0	0	0	0	0	0	0	0	0	240	80	0
Nucula delphinodonta	0	240	0	0	0	0	0	0	0	0	40	0
Tellina sp.	0	0	0	0	0	10	0	0	0	200	0	0
Yoldia limatula	0	0	0	0	10	0	0	0	0	40	0	0
Bivalve Juv. Unid.	10	200	180	40	10	20	0	0	0	0	160	0
POLYCHAETA												
Capitella capitata	10	0	0	0	0	0	0	6600	0	80	440	10
Cirratulidae	0	0	0	0	0	0	0	0	0	0	120	0
Eteone longa	0	40	80	0	0	0	0	60	30	400	320	0
Euchone sp.	0	400	0	0	0	0	0	0	10	1120	760	0
Harmothoe sp.	0	0	20	0	0	0	0	0	10	160	160	0
Lumbrineris sp.	0	40	0	0	0	0	0	0	0	0	0	0
Mediomastus ambiseta	0	600	1660	680	10	0	0	10	0	34080	14560	0
Nephtys sp.	0	80	160	160	110	160	130	20	100	320	160	70
Nereis diversicolor	0	0	0	0	0	0	0	0	0	0	0	0
Ninoe nigripes	0	880	360	200	0	0	10	0	10	560	160	0
Owenia fusiformis	0	12760	0	0	0	0	0	0	0	0	0	0
Polychaete sp. 1	0	0	0	0	0	0	0	0	0	0	120	0
Pherusa affinis	0	80	0	0	0	0	0	0	0	0	0	0
Phloe minuta	0	80	0	0	0	0	0	30	0	360	240	0
Phoronis architecta	0	40	0	0	0	0	0	0	0	0	0	20

Table A7 (continued). Abundance (number/m^2) of seabed organisms, July 2000, at Sydney Harbour stations analyzed by Kirsten Querbach, Dalhousie University Department of Oceanography (Querbach 2002).

Station and Replicate	12-2	18	27-1	27-2	31-2	37-1	37-2	38-1	38-2	39-1	39-2	43-1
Species												
POLYCHAETA (cont).												
Phyllodoce sp.?	0	0	0	0	0	0	0	0	0	0	40	0
Polydora sp.	170	4880	2020	840	0	90	10	30	10	2120	7000	60
Spiophanes bombyx	0	0	0	0	0	0	0	0	0	0	160	0
Spionidae Unid.	0	40	40	0	0	0	0	0	0	200	80	0
Spionid sp. A	0	0	0	0	0	0	0	0	0	0	280	0
Sphaerodoropsis minuta	0	0	0	0	0	0	0	0	0	80	120	0
Tharyx acutus	0	0	0	0	0	0	0	0	0	40	0	0
AMPHIPODA												
Ampelisca vadorum	0	0	0	0	0	0	0	0	0	0	40	0
Corophium crassicorne	0	40	0	0	0	0	0	0	0	0	0	0
Leptocheirus pinguis	0	80	40	40	0	0	0	0	0	2560	4840	0
Orchomenella minuta	0	0	0	0	0	0	0	0	0	1080	640	0
Photis reinhardi	0	80	0	0	0	0	0	0	0	0	0	0
Phoxocephalus holbolli	0	0	0	0	0	20	0	0	0	0	0	0
ISOPODA												
Chiridotea tuftsi	0	80	0	0	0	0	0	0	0	0	0	0
Edotea montosa	0	120	0	0	0	0	0	0	0	0	40	0
ECHINODERMATA												
Cerebratulus sp.	10	520	100	40	10	10	10	120	0	160	80	10
Cerianthus borealis	70	440	100	0	70	160	120	50	40	0	40	10
Cumacea sp.	0	40	20	0	0	0	0	0	0	80	0	0

Table A8. Abundance (number/m^2) and number of species (per sample) for seabed organisms, July 2000, at Sydney Harbour stations analyzed by Kirsten Querbach, Dalhousie University Department of Oceanography (Querbach 2002).

Station	Total Abundance (number/m^2)	Number of Species (per sample)
2	365	9
3	755	6
4	155	4
5	470	11
6	1105	9
11	380	6
12	280	7
17	37585	24
18	21920	25
27	3540	11
31	230	7
37	375	6
38	3565	7.5
39	39420	28
40	420	6
43	180	6