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The Distribution of Nutrients, Suspended Solids, Dissolved and Particulate Metals in Halifax Harbour

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THE DISTRIBUTION OF NUTRIENTS, SUSPENDED SOLIDS, DISSOLVED AND PARTICULATE METALS IN HALIFAX HARBOUR

by

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ABSTRACT

Dalziel, J.A., Amirault, B.P. and Rantala, R.T.T. 1991. The distribution of nutrients, suspended solids, dissolved and particulate metals in Halifax Harbour. Can. Tech. Rep. Fish. Aquat. Sci. 1826: iii+60 pp.

This report presents the chemical data from six surveys of Halifax Harbour conducted from January to September 1989. Samples collected from six sites were analyzed for salinity, nutrients, suspended solids, dissolved metals (Zn, Cu, Cd, Ni, Pb, Mn, Fe), reactive mercury, and total particulate metals (Zn, Cu, Cd, Ni, Pb, Mn, Fe, A1). The dissolved and particulate metal data are compared to levels from the harbour mouth and surface water on the Scotian Shelf. The dissolved metal concentrations from the harbour were typically about twice those found on the shelf, but only particulate metal concentrations (expressed in μg/L and μg/g) for Zn, Cu and Pb were significantly higher. A linear relationship between dissolved Ni, Cu and Mn and the surface water salinity was noted from the data. A tidal survey at Tufts Cove showed little variability in dissolved metals during one tidal cycle. The data from water profiles in Bedford Basin showed that the high levels of Mn and Fe observed in January were depleted by March but evident again in August. These variations appear to be related to redox cycles.

RÉSUMÉ

Dalziel, J.A., Amirault, B.P. and Rantala, R.T.T. 1991. The distribution of nutrients, suspended solids, dissolved and particulate metals in Halifax Harbour. Can. Tech. Rep. Fish. Aquat. Sci. 1826: iii+60 pp.

Le présent rapport expose les données chimiques de six levés réalisés dans le port de Halifax de janvier à septembre 1989. On a analysé les échantillons prélevés sur les six sites étudiés afin d'en déterminer la salinité ainsi que la teneur en nutriments, en matières en suspension, en métaux dissous (Zn, Cu, Cd, Ni, Pb, Mn, Fe), en mercure réactif et en métaux sous forme de particules (Zn, Cu, Cd, Ni, Pb, Mn, Fe, A1). On compare les teneurs en métaux dissous et particulaires à celles de l'entrée du port et des eaux de surface de la plate-forme néo-écossaise. Les concentrations de métaux dissous dans les eaux du port sont généralement deux fois supérieures à celles de la plate-forme néo-écossaise; seules les concentrations de particules de Zn, de Cu et de Pb (exprimées en μg/L en et μg/g) relevées dans le port sont très supérieures à celles de la plate-forme. Une relation linéaire entre le Ni, le Cu et le Mn dissous et la salinité de l'eau de surface s'est dégagée des données. Il ressort d'un levé marégraphique réalisé à l'anse Tufts que les concentrations de métaux dissous varient peu pendant un cycle de la marée. Les données des profils hydrographiques provenant du bassin de Bedford révèlent que les fortes concentrations de Mn et de Fe relevées en janvier avaient disparu en mars, pou réapparaître en août. Ces variations semblent reliées aux cycles Redox.

INTRODUCTION

A first dissolved and particulate metal survey of Halifax Harbour was conducted in response to recently observed metal anomalies in sediments documented by Buckley et al. (1989). The levels of dissolved Zn, Cd, Pb, Ni, Cu and Hg determined from this first survey (January 89) show metal concentrations not greatly elevated over those found in surface waters of the Scotian Shelf or at other coastal sites in Nova Scotia (Dalziel et al., 1989). There were, however, high levels of dissolved and particulate Fe and Mn in deep water samples from Bedford Basin that were attributed to natural redox reactions occurring in the water and sediment in this area.

We were concerned that the data from one survey would not reveal the extent of variability of dissolved and particulate metal distributions in the harbour. The levels of dissolved metals at any one sampling site are likely to be much more variable over all time scales than sediment data. Sediments will tend to accumulate metal inputs while the dissolved and particulate metal distributions in water will fluctuate in response to the influence of tides, wind mixing, variability in anthropogenic and natural inputs (rainfall and runoff). These influences are likely to cause wide shifts in dissolved and particulate metal concentrations over short time periods. In order to determine the natural variability of dissolved metals and to more fully explore the significance of the levels found in the initial survey, a more extensive sampling exercise was conducted during 1989. This project comprised of five additional surveys during the period March to September. The Harbour stations - Compass Buoy, Tufts Cove, Dartmouth Cove, Georges Island, North West Arm - were the same sites used in the January study and chosen because of their proximity to areas of contaminated sediments. A station at the harbour mouth off Sleepy Cove was included for comparative purposes. Two additional studies were conducted; a tidal survey at Tufts Cove, to monitor the variability during a tidal cycle, and at Compass Buoy to compare the level of dissolved oxygen in the deep water with levels of particulate/dissolved iron and manganese.

The water samples collected at all stations were analyzed for suspended solids (SPM), dissolved and particulate metals, salinity and nutrients. This report documents the data from the January, March, May, June, August and September surveys and discusses major trends observed.

Methods

The five surveys conducted after the initial January study were run from March to late September. An additional survey, planned for November, was canceled due to a strike of ships personnel. All surveys were conducted during a falling tide in order to increase detection of changes in the dissolved and particulate metals associated with inputs to the harbour and release from contaminated harbour sediments. The details of the sampling and analytical protocol used in the January survey have been described by Dalziel et al. (1989). The subsequent surveys were carried out using the BIO vessel Sigma-T and the locations of stations surveyed are shown in Figure 1. After the initial January study, each of the subsequent surveys involved collecting 12 samples - a five sample profile at Compass Buoy; a mid-depth sample from Tufts Cove, Dartmouth Cove and N.W. Arm; a surface and mid-depth sample off Georges Island and Sleepy Cove. At each station the water was collected with a precleaned 5 liter General Oceanics Go-Flo sampler deployed on a stainless-steel hydrowire. From each Go-Flo, unfiltered nutrients and salinity samples were collected first, then a 2 liter unfiltered sample for dissolved and particulate metal. Following each survey the unfiltered samples for the analysis of dissolved and particulate metal determinations were taken to a class 100 clean room where each sample was filtered through an acid cleaned and tared 0.4 μm Nuclepore filter. The filtrate (dissolved metal sample) was preserved with 2.5 ml per liter of high purity acid (HCl) and stored in precleaned polyethylene bottles for later analysis. The particulate material collected on the filter from each sample (particulate metal sample) was washed of residual salt, air dried in a clean bench and weighed for gravimetric determination of suspended solids (SPM) concentration.

The analysis of the filtrates was conducted using the methods of Danielsson et al. (1982), for Zn, Pb, Cd, Ni, Cu, Fe and Bewers et al. (1976) for Mn. The analysis of seawater reference material was used to evaluate the precision and accuracy of the extraction methods (see Table 1). The detection limits were determined according to the method of Strickland and Parsons (1960) as three times the analytical standard deviation of a sample close to the detection limit. The SPM samples were decomposed in LORRAN teflon-PTFE digestion bombs for 45 seconds with 1 ml of aqua regia and 1 ml of HF (Ultrex grade) in a microwave oven (Rantala and Loring, 1989; Loring and Rantala, 1990). The fluorides were dissolved using 0.5 g of boric acid crystals and the solutions were made up gravimetrically to the equivalent of 10 ml in polypropylene bottles. The metals were determined using either flame (Fe, Mn, Zn) or graphite furnace (Al, Cd, Cu, Pb) atomic absorption spectrophotometry methods (Rantala and Loring, 1977, 1985). The analysis of marine sediment reference material was used to evaluate the precision and accuracy of the particulate analysis method (see Table 2).

Unfiltered samples were also collected during the surveys in June, August and September for reactive mercury. These samples were collected in specially cleaned 500 ml teflon bottles and returned to the clean room at BIO for preservation with high purity HNO_3. The analysis for reactive Hg was completed within 48 hours of sample collection using the method of Dalziel and Yeats (1985).

The salinity samples from all surveys were analyzed using a Guildline Autocell Salinometer to determine practical salinity as defined by the 1980 Unesco/ICES/SCOR/IAPSO Joint Panel. The measurement errors of the salinometer are typically <0.003 (psu).

The nutrients were collected in duplicate from each survey and preserved at -4 °C. The samples were thawed and then analyzed with a Technicon Auto Analyzer II using modified Technicon procedures. The accuracy and precision of this analysis method are indicated in Table 3.

DISCUSSION

Dissolved Trace Metals :

The dissolved trace metal data have been compiled in three tables and one set of figures. In Table 4, the dissolved metal concentrations for Cd, Cu, Fe, Mn, Ni, Pb and Zn are listed for each station together with the corresponding salinities and sampling depths. The concentration range for each metal from all six surveys is given in Table 5. Table 6 presents the average concentration from three areas in the harbour; Bedford Basin (Compass Buoy), Inner Harbour (Tufts Cove, Dartmouth Cove, Georges Island and N.W. Arm) and Harbour Mouth (Sleepy Cove) for each survey. The average data from these three harbour areas for all the surveys was also compared to the average concentration in the surface waters of the Scotian Shelf (unpublished data from BIO Cruise 85-017) and depicted in Figures 2(A) to 2(G).

From this data compilation, the following observations can be made for each of the dissolved metals.

CADMIUM

The cadmium data from all surveys had a range of 0.014 to 0.072 µg/L with a mean of 0.036µg/L (standard deviation of ±0.012 µg/L). From all the surveys, 87% of the concentrations were ≤0.050 µg/L and there were no large anomalies observed at any of the stations sampled. The average concentration of cadmium was about 1.5 times that found in the surface water of the Scotian Shelf.

COPPER

The copper concentrations range from 0.17 to 0.91 µg/L with 90% of the data ≤0.60 µg/L. The overall average from all the harbour data was 0.42µg/L (standard deviation of ±0.15 µg/L) and this concentration was 1.5 times the level found on the Scotian Shelf. The data from Table 4 and the bar graphs in Figure 2(B) showed that the highest concentration of copper was found in the August samples from Dartmouth Cove and off Georges Island. The bar graphs also showed that the central harbour was generally higher in dissolved copper than the other areas. A relation between salinity and the concentration of dissolved copper was found in the harbour (Figure 3(A)). The copper - salinity relationship was significant ($p<0.005$) with a correlation coefficient of 0.521 and a Y intercept at 4.52 µg/L. This relationship indicates that fresh water sources to the harbour largely control the distribution of copper throughout the harbour.

IRON

The iron concentrations range from 1.0 to 6.7 µg/L with 80% of the data ≤3.0 µg/L. The overall average of 2.3µg/L (standard deviation of ±1.2 µg/L) was 4-5 times the concentration found on the shelf (Figure 2(C)). The levels in the harbour were primarily a reflection of the terrestrial source of iron. The deep samples from Compass Buoy were noticeably elevated in the survey data from March, May and August. This was attributed to the reduction of Fe in underlying anoxic sediments and mobilization into the adjacent bottom water at this deep water site.

MANGANESE

The survey data range from 0.44 to 23.5 µg/L with 89% of the data ≤4.0 µg/L. The average from all surveys was 3.14µg/L (standard deviation of ±4.69 µg/L) which was about four times the shelf concentration. The large deviation in the average manganese concentration was attributed to the high concentrations found in the deep water samples from Compass Buoy during the January, August and to a lesser extent the September surveys. These high manganese concentrations can be attributed to the geochemical process of reduction of Mn(IV) oxides to Mn(II) in anoxic bottom sediments and the subsequent migration of reduced manganese into the overlying waters. The appearance of excess manganese in bottom waters overlying anoxic sediments as a result of this process is a common feature of relatively slow-moving coastal bottom waters (Yeats et al., 1979). There was also a relationship of dissolved manganese to salinity in the surface water (≤25 m) that is evident from Figure 3(B). The manganese - salinity relationship was significant ($p<0.005$) with a correlation coefficient of 0.448 and a Y intercept of 25.4 µg/L. The salinity relationship in the surface waters and the redox conditions in the deep water of Bedford Basin indicate the manganese distribution in the harbour was controlled by two sources; the fresh water inputs and a bottom water source from the Basin.

NICKEL

Dissolved nickel concentrations from all surveys range from 0.26 to 1.14 µg/L with 87% of all data ≤0.60 µg/L. The average from the harbour surveys was 0.47µg/L (standard deviation of ±0.17 µg/L) which was 1.5 times the level found in the surface waters of the Scotian Shelf. High levels of nickel were found twice in the surface water at Compass Buoy (March and June) and once at Dartmouth Cove (June). The nickel data in the harbour water from all surveys show a relation to salinity (Figure 3(C)) The relation was significant ($p<0.005$) with a correlation coefficient of 0.622 and a Y intercept of 5.98 µg/L. This implied the fresh water sources control the nickel concentration in the harbour and extrapolation of the data to zero salinity show relatively little change in the dissolved nickel with source or time.

LEAD

Lead concentrations from the surveys range from 0.006 to 0.286 µg/L and average at 0.048µg/L (standard deviation of ±0.060 µg/L). The data from all surveys show that 84% of the dissolved lead was ≤0.060 µg/L. The bar graphs (Figure 2(F)) clearly showed the large variability between surveys in the same area of the harbour. This was most evident in the bar graphs from the Basin and Central harbour areas. These areas had very high values for lead during August in Tufts Cove, Dartmouth Cove and Compass Buoy; and, in September, at the Compass Buoy and Dartmouth Cove sites. Even with the high lead observed periodically in samples from the harbour, the average of all surveys (0.060 µg/L) was approximately twice the level found in the waters of the shelf.

ZINC

The concentration range for zinc was very large, 0.7 to 70 μg/L but 84% of the data was ≤5 μg/L. The overall average from the surveys was 4.4μg/L (standard deviation of ±8.7 μg/L) which was four to five times the concentration found in the surface waters of the shelf. The large deviation in the mean was mainly due to the anomalously high level found at Tufts Cove in the March survey (70 μg/L) and, the elevated values of 11.3 μg/L at Dartmouth Cove in January and 17.2 μg/L at Tufts Cove in June. The deep samples from Compass Buoy were elevated in the survey data from May, June and August indicating a possible remobilization of zinc from the contaminated sediments at this site (Buckley et al., 1989).

MERCURY

The samples collected from four surveys were analyzed for "reactive" mercury. This fraction has been operationally defined as the Hg available for reduction with $SnCl_2$ after acidification with nitric acid (pH approx. 1). This fraction of Hg is believed to be the most labile or available for biological or chemical interaction. The Hg data from the surveys given in Table 7 showed that concentrations range from detection limit (0.1 ng/L) to 2.4 ng/L with 80% of the data ≤1.5 ng/L. The Hg levels from the June and August surveys had the highest levels but no overall trend was evident from the data. An average of 1.0 ng/L from all the harbour data was similar to the levels found in the surface waters of the Scotian Shelf (Dalziel, 1991).

TIDAL SURVEY:

The tidal survey was conducted at the Tufts Cove survey site in mid July. The sampling at mid-depth (8 m) and near the bottom (14 m) was designed to observe the variability of dissolved metals and nutrients at a site where the bottom sediments are known to be heavily contaminated with metals - notably Zn, Cu and Pb (Buckley et al, 1989) and also at a site adjacent to a sewer outfall. The samples were collected about 2.5 hours before low tide, during the low tide and about 2.5 hours later during the incoming tide. The data from this study are listed in Table 8 and show the samples collected at 8 m were generally higher in dissolved metals than the more saline bottom water samples from 14 m. This indicates that the less saline surface water affected by harbour runoff was more laden with dissolved metals than the water closer to the contaminated sediments. The anomaly of 13.5 μg/L for Zn from the 8 m sample at 10:30 was a reflection of the variability found at this sampling site over a short time period.

The nutrient data from Table 8 show little variability over the time period of the experiment. The trend of higher nutrient levels in the deeper water was the reverse of that observed for dissolved metals and can be attributed to either remobilization from the bottom sediments or transport from the nutrient rich deep waters of Bedford Basin. A comparison of the nitrate to phosphate ratio in this data to coastal waters where this nutrient ratio was around 10:1 show the harbour waters have excess phosphate which is characteristic of nearshore water receiving sewage discharges.

COMPASS BUOY STUDY:

The initial harbour survey in January 1989 showed that the deep water in Bedford Basin had high concentrations of dissolved and particulate Mn. This anomaly was attributed to release of dissolved Mn from the anoxic bottom sediments to the overlying water. Additional sampling was conducted at this site as part of each harbour survey to monitor the extent of Mn remobilization over the time period of the harbour study. The concentration of dissolved oxygen from each sampling depth was measured to observe its relation to dissolved Mn and also as an indicator of deep water mixing or turnover. The oxygen and relevant metal data from this study (Table 9) show as the concentration of dissolved oxygen decreased from 10.3 to 2.4 ppm, the concentrations of particulate Mn and Fe increased (for Mn from about 4 µg/L in March to about 33 µg/L in September and for Fe from about 40 µg/L to 210 µg/L). These changes in metal concentrations were most evident in the deep samples 50 and 60 m for Mn and only at 60 m for Fe. The concentration of dissolved Mn was highest in the deep water (24 µg/L) in August and not in September when dissolved oxygen was at a minimum. The decrease in dissolved Mn observed in the September survey was probably due to increased oxidation between August and September resulting in the conversion of dissolved Mn to particulate Mn. The trend for dissolved Fe was not as dramatic as seen for dissolved Mn. There was also evidence for increase in dissolved Zn in the deep water of the basin (see page 5).

NUTRIENTS:

The nutrient data - silicate, phosphate and nitrate - from all six surveys are listed in Table 10. There were two features from the data that become apparent. The phosphate levels were high and indicative of water effected by sewage input. A modeling study of the harbour by Petrie and Yeats (1990) concluded that the major source of phosphate in the harbour could only be sewage discharge. The second apparent feature from the data was the high levels of all nutrients in the deep water of Bedford Basin (January, August and September). This nutrient pattern in a deep basin was the result from a combination of estuarine circulation, relatively stagnant conditions in the deep water of Bedford Basin and high productivity.

TRACE METALS IN SUSPENDED MATTER :

The results for total analysis of suspended particulate matter for Zn, Cu, Pb, Cd, Ni, Mn, Fe and Al are given with the gravimetric data in Table 11 and 12. The data in Table 11 are configured in units of mass per volume of water while the data in Table 12 are given in units of mass per gram of particulate material. Both sets of data were plotted in bar graphs in a format identical to the dissolved metal graphs, ie. the average values from three areas of the harbour and data from the Scotian Shelf were plotted for comparison. The graphs from the data expressed in units per liter are illustrated in Figures 4 (A) to (H) while the graphs for the data in units per gram of SPM are illustrated in Figures 5 (A) to (H). Configuring and plotting the data in these two ways enabled easier comparison to the dissolved metal data - expressed in units per liter, and the sediment data (Buckley et al, 1989) - expressed in units per gram of particulate. In the bar graphs for Al, Fe and Mn (Figure 4 and Figure 5) comparisons to values on the Scotian Shelf were not made because the nature of the offshore particulate was predominately biogenetic while the harbour particulate was mainly terrestrial.

The data from Table 11 and the related Figures 4 (A) to (H) were compared to the dissolved metal data to show the dominant phase - dissolved or particulate - of metals in the harbour waters. For Ni, Cd and Zn only about 10% of the total metal in the water was in the particulate phase, while for Cu the particulate fraction accounted for about 20%. The particulate analysis for Pb when compared to the dissolved fraction show about 80% of the total was in the particulate phase. For the detrital elements Fe and Mn, the particulate Fe fraction accounts for about 90% and the particulate Mn fraction accounts for about 60% of the total concentration for these elements in harbour water. In the case of Al, only the data for the particulate analysis were available but the dissolved Al in the harbour would be expected to be about 2-5 µg/L (Yeats, 1987). Using this value for dissolved aluminum, the particulate fraction would account for about 80% of the total aluminum.

The anomalies observed in the dissolved metal data (Zn, Pb and Mn) were generally apparent in the particulate data (Table 11) especially for Mn. The illustrated data in Figures 4(A) to (H) showed the levels of Pb, Zn and Cu were significantly higher than the average values for the Scotian Shelf, while the levels for Cd and Ni were 2-3 times average shelf concentrations. The graphs and data from Table 11 also showed the central harbour data (especially the data from Tufts Cove and Dartmouth Cove) to be generally the highest in concentration with these elevated levels extending to the harbour mouth.

The data from Table 12 and the related illustrations in Figure 5(A) to (H) have the particulate metal concentrations expressed in mass per gram of particulate material. The average levels of Zn, Cu and Pb from areas in the harbour (Figure 5(A, B and C) were significantly elevated compared to the levels on the shelf but were generally within a factor of two to levels found in other estuaries (Table 13). They also compare well with the data from a previous particulate sampling study (Yeats and Dalziel, 1987) in Halifax harbour. The data also show that the average concentration of Zn, Cu, Pb, Cd, Ni, Fe and Al from the various harbour areas was the highest for the March survey. In addition, except for Al, the levels from Bedford Basin were generally higher than the other sampling sites. The Al data from the harbour mouth was generally higher in concentration than samples from the other harbour stations. The data from the deep samples collected from Compass Buoy - Bedford Basin - have elevated levels of Mn and Fe in all but the May survey data. The reasoning for this anomaly has been already attributed to natural redox reactions. The January data from the initial survey indicated advection of particulate Mn into the rest of the harbour (Dalziel et al., 1989), a trend not as evident from the subsequent surveys. It should also be noted that the anomalies seen for Zn and Cd (January, Tufts Cove and March, Compass Buoy) may partially be attributed to the small sample mass (<0.5 mg) collected for these samples which limit the precision of chemical analysis.

CONCLUSIONS

The levels of most dissolved metals (Cd, Ni, Cu, Pb) analyzed during the six surveys of Halifax harbour had concentrations about twice the levels found on the Scotian Shelf. The Zn data had a few anomalies - especially the 70 µg/L found in Tufts Cove during the March survey - which contributed to the average concentration being four to five times the levels found on the Shelf. The relation between the concentration of dissolved Ni, Cu and Mn with salinity indicates that freshwater influxes play a major role as a source of these metals in the harbour. On three occasions, high levels of dissolved and particulate Fe and Mn were found in the deep water of Bedford Basin. There were attributed to remobilization from anoxic bottom sediments. The particulate metal data showed the concentrations of Zn, Cu and Pb from the harbour were much higher than levels found on the Shelf but similar to those in other coastal estuaries. The particulate data expressed in µg/L showed that Zn, Cd, Cu, and Ni exist predominately in the dissolved phase, while Fe, Al, Mn and Pb were largely particulate. The anomalies observed in the dissolved metal data, for elements such as for Zn and Pb, were not as evident in the particulate data.

The tidal survey from Tufts Cove showed little variability in the chemical data - metals and nutrients - measured around the low water period of the tide cycle.

The Compass Buoy data showed that as the deep water from Bedford Basin became less oxygenated, the concentrations of particulate Mn and Fe; and dissolved Mn generally increased. The chemical data from this study show a cyclic trend occurring in the deep water of the basin (i.e., from March to September); as oxygen becomes depleted the levels of dissolved and particulate Mn and Fe increase.

The nutrient data from all surveys show that the level of phosphate in harbour stations was high but characteristic of water influenced by untreated sewage discharges. The nutrient data from the deep water in the basin had high levels of all nutrients during the same period in which the anomalies in Mn and Fe were noted. This nutrient pattern was attributed to the estuarine circulation and stagnant conditions in the deep water of the basin.

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TABLE 1

STATISTICS FOR DISSOLVED METAL METHODS OF ANALYSIS

Elements	Conc. Units	CASS-2** BIO Analysis Conc.	(Std Dev)	n	Coefficient of Variation %	CASS-2 Certified Value Conc.	(Std Dev)	Detection Limit
Copper	ug/L	0.73	(0.04)	12	5	0.675	(0.039)	0.02
Nickel	ug/L	0.33	(0.04)	12	13	0.298	(0.036)	0.02
Lead	ug/L	0.021	(0.008)	12	38	0.019	(0.006)	0.005
Cadmium	ug/L	0.027	(0.007)	12	26	0.019	(0.004)	0.001
Iron	ug/L	1.24	(0.29)	12	23	1.20	(0.12)	0.05
Zinc	ug/L	2.69	(0.73)	12	27	1.97	(0.12)	0.03
Manganese	ug/L	1.49	(0.13)	5	9	1.99	(0.15)	0.01
Mercury *	ng/L							0.1

* A certified seawater reference material for mercury is not available. The detection limit was determined from the standard deviation of reagent blank analysis as defined in Dalziel and Yeats (1985).

** CASS-2 is a nearshore seawater reference material for trace metals purchased from the National Research Council of Canada.

TABLE 2

STATISTICS FOR PARTICULATE METAL METHOD OF ANALYSIS

Elements	Conc. Units	BCSS-1* BIO Analysis Conc.	BCSS-1* BIO Analysis (Std Dev)	n	Coefficient of Variation %	BCSS-1 Certified Value Conc.	BCSS-1 Certified Value (% Recovery)
Copper	ug/g	19	(0.57)	3	3.0	19	(100)
Nickel	ug/g	63	(3.47)	3	5.5	55	(115)
Lead	ug/g	24	(1.54)	3	6.4	23	(104)
Cadmium	ug/g	0.32	(0.02)	3	4.8	0.25	(128)
Zinc	ug/g	147	(0.59)	3	0.4	119	(124)
Manganese	ug/g	243	(18.2)	3	7.5	229	(106)
Iron	%	3.35	(0.11)	3	3.4	3.29	(102)
Aluminum	%	6.51	(0.07)	3	1.0	6.26	(104)

* This marine sediment reference material was analysed in triplicate (mean wt. 5.36mg). A suspended solids (SPM) certified reference material was not available.

TABLE 3

STATISTICS FOR THE NUTRIENT METHODS OF ANALYSIS

	Silicate	Phosphate	Nitrate
Detection Limit[(1)]	0.4μM	0.08μM	0.4μM
Precision[(2)]	1%	2%	1%
Accuracy	2%[(3)]	-[(4)]	2%[(3)]

Notes:

(1) -based on three times precision of blanks and calculated from a typical run of inshore samples

(2) -based on the long term performance of internal check standards at moderate concentrations

(3) -based on a secondary standard of intermediate concentration-no primary standards avialable

(4) -no primary or secondary standards available

TABLE 4

DISSOLVED METAL DATA

1989

JANUARY 18

Station Depth (m)	Sample Depth (m)	Salinity	Cd	Cu	Fe	Mn	Ni	Pb	Zn
			ug/L						
Compass B. (71m)	1	29.606	0.053	0.62		3.82	0.65	0.049	4.1
	5	30.010	0.029	0.40		2.93	0.48	0.023	3.8
	15	30.246	0.030	0.47		2.25	0.53	0.021	3.5
	25	30.496	0.030	0.43		2.74	0.51	0.016	6.5
	50	31.338	0.017	0.32		18.9	0.37	0.010	4.5
	60	31.404	0.014	0.40		14.0	0.35	0.018	3.5
Clearwater (20m)	12	30.187	0.036	0.36		2.87	0.54	0.020	5.9
Birch C. (28m)	20	30.431	0.038	0.40		1.30	0.47	0.024	7.3
Tufts C. (15m)	8	30.359	0.037	0.45		2.49	0.66	0.036	6.6
Dart. C. (11m)	5	29.744	0.048	0.81		6.49	0.59	0.055	11.3
Georges I. (20m)	3	30.623	0.029	0.49		2.55	0.48	0.030	4.4
	14	30.851	0.030	0.35		2.17	0.42	0.055	2.3
N.W.Arm (8m)	8	30.492	0.035	0.46		2.90	0.45	0.051	2.8
MARCH 17									
Compass	3	30.153	0.044	0.50	2.9	2.69	1.14	0.052	8.2
	10	30.598	0.034	0.45	1.2	2.52	0.42	0.023	5.0
	25	30.990	0.034	0.39	1.8	1.45	0.36	0.008	2.9
	50	31.096	0.034	0.36	2.8	1.59	0.36	0.016	2.6
	60	31.107	0.036	0.35	3.0	1.64	0.34	0.010	3.0
Tufts	10	30.770	0.027	0.48	6.5	2.86	0.60	0.064	70
Dartmouth	6	30.878	0.034	0.48	2.0	1.24	0.36	0.047	2.7
Georges	3	30.639	0.047	0.62	2.4	1.62	0.44	0.055	4.4
	14	31.019	0.033	0.42	1.5	1.20	0.34	0.046	3.2
N.W.Arm	8	30.899	0.052	0.54	2.0	1.12	0.38	0.111	2.4
Sleepy C. (30m)	3	30.952	0.031	0.46	1.5	1.62	0.42	0.019	2.2
	25	31.288	0.015	0.28	0.1	0.61	0.28	0.032	1.4

TABLE 4 (continued)

MAY 1

Station Depth (m)	Sample Depth (m)	Salinity	Cd	Cu	Fe	Mn	Ni	Pb	Zn
			ug/L						
Compass	3	30.330	0.044	0.54	1.1	1.12	0.52	0.019	2.0
	10	31.105	0.040	0.36	1.0	0.82	0.38	0.022	1.9
	25	31.353	0.026	0.28	2.3	2.03	0.30	0.010	1.6
	50	31.508	0.034	0.28	4.4	2.71	0.38	0.010	5.1
	60	31.546	0.034	0.31	4.2	3.23	0.39	0.033	4.7
Tufts	10	31.216	0.037	0.40	1.4	1.21	0.36	0.011	2.5
Dartmouth	6	31.117	0.052	0.58	3.7	2.13	0.39	0.101	3.0
Georges	3	30.623	0.038	0.57	1.6	1.10	0.56	0.040	2.4
	14	31.652	0.028	0.26	1.1	0.79	0.30	0.013	0.7
N.W.Arm	8	31.408	0.032	0.34	1.9	0.89	0.47	0.007	0.8
Sleepy	3	30.906	0.038	0.46	2.2	1.01	0.44	0.026	1.7
	25	31.832	0.035	0.24	2.0	0.89	0.31	0.052	1.0

JUNE 13

Station Depth (m)	Sample Depth (m)	Salinity	Cd	Cu	Fe	Mn	Ni	Pb	Zn
Compass	3	28.308	0.072	0.68	6.7	3.04	1.14	0.028	3.2
	10	30.328	0.036	0.48	1.7	1.98	0.44	0.018	1.9
	25	31.249	0.032	0.31	1.4	0.66	0.35	0.033	1.7
	50	31.406	0.041	0.30	1.1	1.64	0.32	0.008	3.1
	60	31.434	0.028	0.27	1.9	3.36	0.39	0.008	3.6
Tufts	10	30.523	0.052	0.42	2.5	1.28	0.43	0.012	17
Dartmouth	6	30.601	0.040	0.38	2.3	1.34	0.94	0.031	2.1
Georges	3	29.836	0.033	0.64	2.2	1.94	0.59	0.016	2.0
	14	30.921	0.022	0.25	1.8	1.44	0.60	0.013	1.1
N.W.Arm	8	30.700	0.028	0.29	1.5	1.56	0.62	0.031	1.8
Sleepy	3	29.425	0.042	0.53	1.5	1.53	0.56	0.013	1.8
	25	31.261	0.038	0.26	1.6	1.36	0.32	0.022	1.5

TABLE 4 (continued)

AUGUST 14

Station Depth (m)	Sample Depth (m)	Salinity	Cd	Cu	Fe	Mn	Ni	Pb	Zn
			ug/L						
Compass	3	30.681	0.052	0.60	1.9	1.27	0.54	0.148	4.5
	10	31.248	0.037	0.44	1.4	0.44	0.44	0.043	2.0
	25	31.429	0.064	0.37	1.9	1.16	0.45	0.021	2.0
	50	31.396	0.049	0.30	1.5	23.5	0.53	0.013	2.7
	60	31.407	0.031	0.36	3.1	23.5	0.46	0.018	2.6
Tufts	10	31.289	0.045	0.37	2.3	1.12	0.62	0.286	2.8
Dartmouth	6	30.877	0.038	0.91	3.8	1.61	0.49	0.165	2.1
Georges	3	30.734	0.028	0.87	2.3	1.36	0.52	0.080	1.4
	14	31.466	0.021	0.34	2.3	0.84	0.34	0.030	0.8
N.W.Arm	8	31.291	0.039	0.43	1.4	0.63	0.41	0.056	1.4
Sleepy	3	31.127	0.035	0.58	1.5	1.66	0.43	0.107	1.8
	25	31.528	0.033	0.23	1.2	1.61	0.36	0.054	0.7
SEPT. 25									
Compass	3	30.034	0.036	0.58	1.9	1.17	0.73	0.217	2.9
	10	30.044	0.024	0.43	1.2	0.96	0.38	0.030	2.5
	25	31.093	0.072	0.28	1.3	0.81	0.40	0.279	2.5
	50	31.386	0.024	0.20	1.0	7.99	0.38	0.006	3.0
	60	31.385	0.018	0.17	1.4	6.70	0.35	0.008	2.5
Tufts	10	30.798	0.027	0.29	2.6	1.80	0.29	0.058	1.2
Dartmouth	6	30.465	0.025	0.32	3.5	1.26	0.35	0.171	1.3
Georges	3	30.231	0.024	0.19	2.8	1.91	0.29	0.014	0.7
	14	31.242	0.023	0.43	4.1	1.11	0.39	0.025	2.0
N.W.Arm	8	30.800	0.020	0.23	1.7	1.05	0.26	0.054	1.4
Sleepy	3	30.194	0.026	0.46	2.9	1.22	0.39	0.051	1.2
	25	32.032	0.031	0.17	1.3	0.68	0.30	0.046	1.6

TABLE 5

HALIFAX HARBOUR METAL CONCENTRATION RANGES

Sampling Month	Cadmium	Copper	Iron	Manganese	Nickel	Lead	Zinc	Mercury
	ug/L							ng/L
January	0.014-0.053	0.32-0.81		1.30-18.9	0.35-0.66	0.010-0.055	2.3-11.3	d.l.-1.1
March	0.027-0.052	0.35-0.62	1.2-6.5	1.12-2.86	0.34-1.14	0.008-0.111	2.4-70	
May	0.026-0.052	0.26-0.58	1.0-4.4	0.79-3.23	0.30-0.56	0.007-0.101	0.7-5.1	
June	0.022-0.072	0.25-0.68	1.1-6.7	0.66-3.36	0.32-1.14	0.008-0.033	1.1-17	1.0-2.5
August	0.021-0.064	0.30-0.91	1.4-3.8	0.44-23.5	0.41-0.62	0.013-0.286	0.8-4.5	0.5-1.4
September	0.018-0.072	0.17-0.58	1.0-4.1	0.81-7.99	0.26-0.73	0.006-0.279	0.7-3.0	d.l.-2.3

Note: The data from the harbour mouth, Sleepy Cove was not used.

TABLE 6

AVERAGE VALUES for DISSOLVED METALS
(ug/L)

JANUARY 18		Cd	Cu	Fe	Mn	Ni	Pb	Zn
Bedford	Avg	0.029	0.44		7.44	0.48	0.023	4.3
Basin	SD	0.014	0.10		7.17	0.11	0.014	1.1
	n	6	6		6	6	6	6
Inner	Avg	0.036	0.51		3.32	0.52	0.045	5.5
Harbour	SD	0.008	0.17		1.79	0.10	0.012	3.7
	n	5	5		5	5	5	5
Harbour	Avg							
Mouth	SD		Samples Not Collected					
	n							

MARCH 17		Cd	Cu	Fe	Mn	Ni	Pb	Zn
Bedford	Avg	0.036	0.41	2.8	1.98	0.52	0.022	4.9
Basin	SD	0.004	0.06	0.6	0.52	0.31	0.016	1.8
	n	5	5	5	5	5	5	5
Inner	Avg	0.039	0.51	2.9	1.61	0.42	0.065	16.7
Harbour	SD	0.01	0.68	1.8	0.65	0.09	0.024	26.7
	n	5	5	5	5	5	5	5
Harbour	Avg	0.023	0.37	0.8	1.12	0.35	0.026	2.1
Mouth	SD	0.008	0.09	0.7	0.51	0.07	0.006	0.1
	n	2	2	2	2	2	2	2

TABLE 6 (continued)

MAY 1		Cd	Cu	Fe	Mn	Ni	Pb	Zn
Bedford Basin	Avg	0.037	0.35	2.6	1.98	0.39	0.019	3.4
	SD	0.006	0.10	1.5	0.92	0.07	0.009	1.7
	n	5	5	5	5	5	5	5
Inner Harbour	Avg	0.037	0.43	1.9	1.22	0.42	0.034	2.1
	SD	0.009	0.13	0.9	0.48	0.09	0.035	1.1
	n	5	5	5	5	5	5	5
Harbour Mouth	Avg	0.037	0.35	2.1	0.95	0.38	0.039	1.9
	SD	0.002	0.11	0.1	0.06	0.06	0.013	0.3
	n	2	2	2	2	2	2	2

JUNE 13		Cd	Cu	Fe	Mn	Ni	Pb	Zn
Bedford Basin	Avg	0.043	0.41	2.6	2.14	0.53	0.019	3.1
	SD	0.015	0.16	2.1	0.08	0.31	0.010	1.0
	n	5	5	5	5	5	5	5
Inner Harbour	Avg	0.035	0.40	2.1	1.51	0.64	0.021	5.0
	SD	0.010	0.14	0.4	0.23	0.17	0.010	6.1
	n	5	5	5	5	5	5	5
Harbour Mouth	Avg	0.040	0.40	1.6	1.44	0.44	0.018	1.6
	SD	0.002	0.14	0.1	0.09	0.12	0.005	0.2
	n	2	2	2	2	2	2	2

TABLE 6 (continued)

AUGUST 14		Cd	Cu	Fe	Mn	Ni	Pb	Zn
Bedford Basin	Avg	0.047	0.41	2.0	10.15	0.48	0.049	2.8
	SD	0.012	0.10	0.6	11.15	0.04	0.051	0.9
	n	5	5	5	5	5	5	5
Inner Harbour	Avg	0.034	0.58	2.4	1.22	0.48	0.123	2.3
	SD	0.008	0.25	0.8	0.35	0.10	0.093	0.6
	n	5	5	5	5	5	5	5
Harbour Mouth	Avg	0.034	0.40	1.3	1.69	0.40	0.080	2.3
	SD	0.001	0.18	0.2	0.07	0.04	0.026	0.6
	n	2	2	2	2	2	2	2

SEPTEMBER 25		Cd	Cu	Fe	Mn	Ni	Pb	Zn
Bedford Basin	Avg	0.035	0.33	1.4	3.59	0.45	0.128	2.7
	SD	0.019	0.15	0.3	3.26	0.14	0.140	0.2
	n	5	5	5	5	5	5	5
Inner Harbour	Avg	0.024	0.29	3.0	1.57	0.32	0.073	1.5
	SD	0.002	0.08	0.7	0.35	0.05	0.072	0.5
	n	5	5	5	5	5	5	5
Harbour Mouth	Avg	0.028	0.32	2.1	1.10	0.34	0.054	1.7
	SD	0.002	0.14	0.8	0.28	0.05	0.008	0.1
	n	2	2	2	2	2	2	2

TABLE 7

HALIFAX HARBOUR MERCURY DATA - 1989

Sample Location	Sample Depth (m)	January (ng/L)	June	August	September
Compass Buoy	3	0.4	1.0	0.5	d.l.
	10	0.5	1.7	0.8	d.l.
	25	0.3	1.2	1.0	0.3
	50	0.4	2.4	1.0	2.3
	60	d.l.	2.4	0.9	0.4
Tufts Cove	10	d.l.	1.8	1.2	d.l.
Dartmouth Cove	6	0.7	2.2	1.0	0.5
Georges Island	3	0.5	1.7	1.3	1.2
	14	0.3	2.5	1.3	0.7
N.W.Arm	8	1.1	1.2	1.4	0.6
Sleepy Cove	3			1.3	0.5
	25		2.2	1.1	1.1
	Avg	0.4	1.8	1.0	0.6
	S.D.	0.3	0.5	0.2	0.7

Note: stats. for all stations but Sleepy Cove

TABLE 8

JULY 17,1989 TIDAL SURVEY at TUFTS COVE -low tide @13:00

Sampling Time	Sample Depth (m)	Salinity	Cd	Cu	Fe	Mn	Ni	Pb	Zn	Silicate	Phosphate	Nitrate
			ug/L							umole/L		
10:30	8	30.754	0.032	0.50	3.1	1.96	0.35	0.073	13.5	1.58	0.76	0.59
	14	31.325	0.029	0.29	2.3	0.52	0.34	0.021	4.5	3.85	0.93	1.43
13:23	8	30.635	0.014	0.54	1.8	0.69	0.98	0.030	2.8	1.64	0.76	0.48
	14	31.208	0.012	0.33	3.8	0.72	0.33	0.023	2.1	4.10	0.85	1.34
16:00	8	30.445	0.048	0.56	2.1	0.64	0.42	0.040	2.5	1.54	0.82	0.44
	14	31.208	0.030	0.36	2.2	0.94	0.32	0.030	1.3	4.02	0.89	1.42

Bottom depth at Tufts Cove was 15 m.

TABLE 9

COMPASS BUOY STUDY

	Depth (m)	Oxygen (ppm)	Mn(D)	Mn(P)	Fe(D)	Fe(P)
			(ug/L)			
MARCH 17	3	9.2	2.69	5.74	2.85	40.3
	10	9.0	2.52	6.28	1.23	28.0
	25	8.3	1.45	5.99	1.75	23.4
	50	8.3	1.59	4.98	2.78	41.9
	60	8.4	1.64	3.95	2.99	50.3
MAY 1	3	12.4	1.12	8.22	1.05	30.4
	10	9.8	0.82	8.94	1.04	24.7
	25	9.8	2.03	7.16	2.26	40.4
	50	10.2	2.71	4.16	4.36	44.6
	60	10.3	3.23	3.36	4.18	39.0
JUNE 13	3	8.9	3.04	10.64	6.68	40.3
	10	8.1	1.98	4.64	1.67	38.0
	25	8.0	0.66	5.42	1.40	19.6
	50	7.1	1.64	11.66	1.13	39.6
	60	6.3	3.36	7.68	1.85	74.7
AUGUST 14	3	8.7	1.37		1.87	
	10	7.3	0.52	1.83	1.40	7.2
	25	6.9	1.24	5.70	1.90	24.5
	50	4.2	23.60	15.52	1.50	40.7
	60	3.3	24.00	12.21	3.14	141.7
SEPTEMBER 25	3	8.0	1.03	1.51	1.87	7.9
	10	7.7	0.82	1.66	1.24	5.8
	25	4.9	0.95	6.77	1.34	25.7
	50	3.2	7.95	32.81	1.04	44.1
	60	2.4	7.19	31.89	1.40	210.5

(D)- dissolved
(P)- particulate

TABLE 10

NUTRIENT DATA - 1989

JANUARY 18

Station Depth (m)	Sample Depth (m)	Silicate (umoles/L)	Phosphate (umoles/L)	Nitrate (umoles/L)
Compass Buoy (70)	1	11.9	1.24	8.0
	5	11.6	1.24	8.0
	15	10.0	1.12	7.3
	25	9.8	1.12	7.1
	50	28.5	2.18	14.9
	60	33.1	2.30	16.3
Clearwater (20m)	12	10.2	1.13	7.2
Birch Cove (28m)	20	10.9	1.19	8.0
Tufts Cove (15m)	8	9.5	1.08	6.9
Dartmouth C. (11m)	5	10.8	2.04	7.8
Georges I. (20m)	3	8.8	1.05	6.6
	14	8.2	0.94	6.3
N.W.Arm (8m)	8	8.4	1.16	6.1

MARCH 16

Station Depth (m)	Sample Depth (m)	Silicate (umoles/L)	Phosphate (umoles/L)	Nitrate (umoles/L)
Compass	3	10.5	1.02	7.8
	10	11.5	1.19	8.5
	25	11.5	1.26	8.6
	50	11.5	1.33	8.1
	60	11.4	1.38	7.6
Tufts	10	10.3	1.22	7.9
Dartmouth	6	8.6	1.04	6.6
Georges	3	9.4	1.24	7.2
	14	8.2	1.01	6.1
N.W.Arm	8	7.7	0.95	5.2
Sleepy Cove (30m)	3	8.2	0.97	6.0
	25	6.5	0.81	4.89

TABLE 10 (continued)

MAY 1

Station Depth (m)	Sample Depth (m)	Silicate	Phosphate umoles/L	Nitrate
Compass	3	1.34	0.55	d.l.
	10	5.6	1.08	5.3
	25	5.9	1.17	5.2
	50	4.08	1.05	4.11
	60	4.17	1.03	4.30
Tufts	10	5.9	1.07	5.2
Dartmouth	6	1.69	0.78	2.28
Georges	3	1.80	0.71	2.10
	14	1.84	0.66	2.34
N.W.Arm	8	0.71	0.54	0.48
Sleepy	3	1.21	0.45	d.l.
	25	3.38	0.80	3.87

JUNE 13

Station Depth (m)	Sample Depth (m)	Silicate	Phosphate umoles/L	Nitrate
Compass	3	d.l.	0.50	d.l.
	10	d.l.	0.84	0.62
	25	2.42	1.01	2.86
	50	7.4	1.45	5.5
	60	14.0	2.04	5.2
Tufts	10	0.65	0.80	0.89
Dartmouth	6	0.53	0.69	d.l.
Georges	3	d.l.	0.50	d.l.
	14	1.32	0.53	0.46
N.W.Arm	8	0.65	0.61	d.l.
Sleepy	3	d.l.	0.48	d.l.
	25	3.30	0.68	1.30

TABLE 10 (continued)

AUGUST 14

Station Depth (m)	Sample Depth (m)	Silicate	Phosphate umoles/L	Nitrate
Compass	3	d.l.	0.62	d.l.
	10	3.67	0.97	d.l.
	25	5.6	0.75	1.62
	50	19.8	1.98	9.2
	60	26.9	2.61	8.1
Tufts	10	3.70	0.84	0.53
Dartmouth	6	0.61	0.90	d.l.
Georges	3	d.l.	0.71	d.l.
	14	3.09	0.80	d.l.
N.W.Arm	8	0.66	0.79	d.l.
Sleepy	3	d.l.	0.50	d.l.
	25	3.83	0.76	0.75

SEPTEMBER 25

Station Depth (m)	Sample Depth (m)	Silicate	Phosphate umoles/L	Nitrate
Compass	3	1.06	0.62	d.l.
	10	4.62	0.59	d.l.
	25	7.2	1.04	1.66
	50	23.8	1.83	10.9
	60	31.6	2.73	9.6
Tufts	10	4.07	0.96	1.84
Dartmouth	6	4.47	1.09	1.12
Georges	3	4.59	0.81	2.96
	14	2.38	0.83	0.64
N.W.Arm	8	6.4	0.87	1.64
Sleepy	3	1.99	0.81	0.49
	25	6.6	0.86	5.6

TABLE 11

SPM METAL DATA
(expressed in units of mass per liter)

JANUARY 18

Station Depth (m)	Sample Depth	SPM (mg/L)	Zn ng/L	Cu ng/L	Pb ng/L	Cd ng/L	Ni ng/L	Mn ug/L	Fe ug/L	Al ug/L
Compass B. (70)	1	0.57	252	113	204	0.7		4.05	30.1	23.9
	5	0.68	250	102	141	0.8		5.50	29.0	23.4
	15	0.52	248	88	120	0.6		5.29	30.7	13.8
	25	0.36	224	60	103	0.5		4.87	17.0	9.9
	50	0.24	94	19	48	0.4		5.60	32.7	2.7
	60	0.54	183	25	39	0.5		6.71	55.9	2.4
Clearwater (20m)	12	0.51	381	85	102	0.6		5.40	22.8	13.0
Birch C. (28m)	20	0.39	263	65	119	0.7		6.10	17.7	9.6
Tufts C. (15m)	8	0.48	703	119	133	3.9		3.16	18.1	11.4
Dartmouth C. (11m)	5	1.32	800	484	315	3.7		2.01	49.2	33.7
Georges I. (20m)	3	0.66	206	116	114	0.9		1.41	21.9	29.8
	14	0.73	228	108	144	1.0		1.20	31.7	33.1
N.W.Arm (8m)	8	0.89	221	155	191	0.7		0.80	28.5	20.5
MARCH 16										
Compass	3	0.57	413	111	200	0.5		5.74	40.3	40.7
	10	0.47	327	93	147	0.4		6.28	28.0	22.5
	25	0.19	242	51	109	0.8	30	5.99	23.4	12.7
	50	0.23	192	56	98	0.7	30	4.98	41.9	12.8
	60	0.33	222	122	134	1.2	29	3.95	50.3	11.5
Tufts	10	1.99	1844	467	533	3.8		4.13	76.8	81.1
Dartmouth	6	0.62	344	177	206	0.6		2.13	35.2	32.5
Georges	3	1.39	573	275	366	0.4		2.33	46.7	44.7
	14	0.46	327	115	160	0.4		1.65	30.4	31.0
N.W.Arm	8	1.05	725	222	349	1.8		2.03	77.8	81.0
Sleepy Cove (30m)	3	0.30	240	85	151	0.6	30	1.49	26.6	27.3
	25	1.02	231	96	121	0.5		1.67	69.3	97.9

TABLE 11 (continued)

Station Depth (m)	Sample Depth	SPM (mg/L)	Zn (ng/L)	Cu (ng/L)	Pb (ng/L)	Cd (ng/L)	Ni (ng/L)	Mn (ug/L)	Fe (ug/L)	Al (ug/L)
MAY 1										
Compass	3	3.20	1357	74	141	0.6	163	8.22	30.4	12.8
	10	1.03	419	82	87	1.0	23	8.94	24.7	8.3
	25	0.41	313	37	81	0.9	18	7.16	40.4	8.2
	50	0.69	311	60	74	2.3	18	4.16	44.6	8.3
	60	1.05	254	48	63	1.5	22	3.36	39.0	9.4
Tufts	10	0.64	356	77	143	1.5	28	7.74	29.9	10.9
Dartmouth	6	6.75	938	290	439	3.4	61	4.23	87.8	87.8
Georges	3	2.40	785	139	77	1.4	62	6.47	26.9	7.2
	14	0.72	266	38	57	1.4	132	0.95	11.1	8.7
N.W.Arm	8	1.72	369	48	81	1.0	40	1.66	16.0	8.6
Sleepy	3	0.99	344	59	198	0.9	54	4.14	18.2	10.1
	25	0.24	126	25	58	0.8	21	0.31	9.4	10.4
JUNE 13										
Compass	3	4.29	1021	112	240	1.7	107	10.64	40.3	30.0
	10	1.15	570	98	230	2.1	73	4.64	38.0	34.5
	25	0.25	201	35	69	0.7	31	5.42	19.6	14.2
	50	0.24	196	29	58	0.6	21	11.66	39.6	5.0
	60	0.32	179	26	55	0.9	26	7.68	74.7	4.7
Tufts	10	1.01	450	86	151	1.7	44	4.68	31.5	29.0
Dartmouth	6	1.94	582	122	225	2.9	82	2.46	37.3	33.0
Georges	3	2.03	707	124	185	2.0	77	5.48	35.1	30.5
	14	0.72	322	92	141	1.5	76	1.52	25.8	24.5
N.W.Arm	8	1.92	415	73	148	2.3	56	1.82	29.4	28.8
Sleepy	3	3.31	655	132	139	2.6	63	7.54	34.7	26.5
	25	0.63	239	63	166	1.1	22	2.03	37.8	47.7

TABLE 11 (continued)

AUGUST 14

Station Depth (m)	Sample Depth	SPM (mg/L)	Zn	Cu	Pb	Cd	Ni	Mn	Fe	Al
			ng/L					ug/L		
Compass	3	torn								
	10	0.71	284	24	43	1.3	28	1.83	7.2	1.4
	25	0.59	268	56	211	1.3	47	5.70	24.5	13.5
	50	0.28	170	41	38	1.1	10	15.52	40.7	0.6
	60	0.36	190	26	35	0.6	9	12.21	141.7	1.4
Tufts	10	1.50	626	96	198	4.1	41	3.80	31.5	15.0
Dartmouth	6	4.98	911	224	393	5.0	100	3.96	36.3	10.0
Georges	3	2.35	809	139	141	1.9	80	3.44	23.8	4.7
	14	0.94	297	66	167	1.4	82	1.61	25.5	23.4
N.W.Arm	8	1.91	402	65	105	1.5	29	1.75	15.5	7.7
Sleepy	3									
	25									
SEPTEMBER 25										
Compass	3	3.31	503	179	122	2.6	175	1.51	7.9	1.7
	10	2.09	390	54	44	2.1	23	1.66	5.8	2.1
	25	0.57	319	56	161	2.2	41	6.77	25.7	7.4
	50	0.19	162	26	37	2.8	48	32.81	44.1	0.4
	60	0.84	290	38	81	1.6	13	31.89	210.5	1.7
Tufts	10	0.81	374	91	188	5.5	21	1.92	23.9	20.2
Dartmouth	6	1.22	398	77	113	1.7	21	3.11	21.3	11.0
Georges	3	0.32	189	51	97	1.1	23	1.13	22.0	21.9
	14	0.91	346	102	57	3.9	43	1.01	12.8	4.5
N.W.Arm	8	0.72	261	69	289	1.7	28	1.49	21.5	18.8
Sleepy	3	0.86	300	82	107	0.9	32	1.34	14.6	7.7
	25	0.34	174	43	66	1.1	26	0.73	21.7	32.2

TABLE 12

SPM METAL DATA
(expressed in units of mass per gram)

JANUARY 18

Station Depth (m)	Sample Depth	SPM (mg/L)	Zn	Cu	Pb	Cd	Ni	Mn	Fe	Al
			ug/g					mg/g	%	
Compass B. (70)	1	0.57	444	198	359	1.2		7.13	5.30	4.2
	5	0.68	370	151	209	1.2		8.15	4.30	3.5
	15	0.52	474	168	229	1.1		10.10	3.95	2.6
	25	0.36	617	165	282	1.4		13.40	4.67	2.7
	50	0.24	400	80	205	1.8		23.80	13.90	1.1
	60	0.54	340	46	72	1.0		12.50	10.40	0.4
Clearwater (20m)	12	0.51	741	165	198	1.2		10.50	4.43	2.5
Birch C. (28m)	20	0.39	667	165	302	1.9		15.50	4.49	2.4
Tufts C. (15m)	8	0.48	1570	266	298	8.7		7.06	4.04	2.6
Dartmouth C (11m)	5	1.32	606	367	239	2.8		1.52	3.73	2.6
Georges I. (20m)	3	0.66	312	176	172	1.3		2.13	3.32	4.5
	14	0.73	311	147	196	1.4		1.64	4.32	4.5
N.W.Arm (8m)	8	0.89	247	173	214	0.8		0.89	3.18	2.3
MARCH 16										
Compass	3	0.57	729	195	353	0.8		10.13	7.12	7.2
	10	0.47	690	197	310	0.8		13.27	5.92	4.8
	25	0.19	1243	262	559	4.2	154	30.78	12.03	6.5
	50	0.23	855	249	436	3.3	133	22.13	18.64	5.7
	60	0.33	672	369	405	3.5	89	11.97	15.25	3.5
Tufts	10	1.99	927	235	268	1.9		2.08	3.86	4.1
Dartmouth	6	0.62	553	284	331	0.9		3.43	5.65	5.2
Georges	3	1.39	413	198	264	0.3		1.68	3.37	3.2
	14	0.46	718	253	352	0.8		3.63	6.68	6.8
N.W.Arm	8	1.05	689	211	332	1.7		1.93	7.39	7.7
Sleepy Cove (30m)	3	0.30	800	283	503	1.9	100	4.97	8.87	9.1
	25	1.02	228	95	119	0.5		1.65	6.83	9.7

TABLE 12 (continued)

MAY 1

Station Depth (m)	Sample Depth	SPM (mg/L)	Zn	Cu	Pb ug/g	Cd	Ni	Mn mg/g	Fe %	Al
Compass	3	3.20	424	23	44	0.2	51	2.57	0.95	0.4
	10	1.03	405	79	84	1.0	22	8.65	2.39	0.8
	25	0.41	761	91	196	2.3	43	17.43	9.83	2.0
	50	0.69	452	87	108	3.3	26	6.03	6.48	1.2
	60	1.05	243	46	60	1.4	21	3.21	3.73	0.9
Tufts	10	0.64	554	119	223	2.4	43	12.03	4.64	1.7
Dartmouth	6	6.75	139	43	65	0.5	9	0.63	1.30	1.3
Georges	3	2.40	327	58	32	0.6	26	2.69	1.12	0.3
	14	0.72	368	53	79	1.9	182	1.32	1.54	1.2
N.W.Arm	8	1.72	214	28	47	0.6	23	0.96	0.93	0.5
Sleepy	3	0.99	348	60	200	0.9	55	4.19	1.84	1.0
	25	0.24	522	102	239	3.1	87	1.28	3.89	4.3

JUNE 13

Station Depth (m)	Sample Depth	SPM (mg/L)	Zn	Cu	Pb	Cd	Ni	Mn	Fe	Al
Compass	3	4.29	238	26	56	0.4	25	2.48	0.94	0.7
	10	1.15	496	85	200	1.8	63	4.03	3.30	3.0
	25	0.25	792	139	270	2.6	120	21.34	7.71	5.6
	50	0.24	828	123	244	2.5	90	49.23	16.72	2.1
	60	0.32	567	82	173	2.7	82	24.33	23.67	1.5
Tufts	10	1.01	450	86	151	1.7	44	4.68	3.15	2.9
Dartmouth	6	1.94	300	63	116	1.5	42	1.27	1.92	1.7
Georges	3	2.03	348	61	91	1.0	38	2.70	1.73	1.5
	14	0.72	446	128	195	2.1	105	2.11	3.58	3.4
N.W.Arm	8	1.92	216	38	77	1.2	29	0.94	1.53	1.5
Sleepy	3	3.31	198	40	42	0.8	19	2.28	1.05	0.8
	25	0.63	381	101	264	1.7	35	3.24	6.02	7.6

TABLE 12 (continued)

AUGUST 14

Station Depth (m)	Sample Depth	SPM (mg/L)	Zn	Cu	Pb (ug/g)	Cd	Ni	Mn (mg/g)	Fe (%)	Al
Compass	3	torn								
	10	0.71	402	34	61	1.9	39	2.59	1.02	0.2
	25	0.59	457	96	359	2.2	80	9.70	4.17	2.3
	50	0.28	609	148	135	4.1	35	55.65	14.61	0.2
	60	0.36	532	72	97	1.6	24	34.11	39.57	0.4
Tufts	10	1.50	417	64	132	2.7	27	2.53	2.10	1.0
Dartmouth	6	4.98	183	45	79	1.0	20	0.80	0.73	0.2
Georges	3	2.35	344	59	60	0.8	34	1.46	1.01	0.2
	14	0.94	317	70	179	1.5	88	1.72	2.72	2.5
N.W.Arm	8	1.91	210	34	55	0.8	15	0.91	0.81	0.4
Sleepy	3									
	25									
SEPT. 25										
Compass	3	3.31	152	54	37	0.8	53	0.46	0.24	0.1
	10	2.09	187	26	21	1.0	11	0.79	0.28	0.1
	25	0.57	562	98	283	3.9	72	11.91	4.52	1.3
	50	0.19	833	133	189	14.6	244	168.6	22.67	0.2
	60	0.84	346	45	97	1.9	15	38.11	25.16	0.2
Tufts	10	0.81	462	112	232	6.8	26	2.38	2.95	2.5
Dartmouth	6	1.22	325	63	92	1.4	17	2.54	1.74	0.9
Georges	3	0.32	596	162	306	3.6	72	3.55	6.92	6.9
	14	0.91	382	112	63	4.3	47	1.12	1.41	0.5
N.W.Arm	8	0.72	361	96	400	2.4	39	2.06	2.98	2.6
Sleepy	3	0.86	349	95	124	1.1	37	1.56	1.70	0.9
	25	0.34	508	125	194	3.2	77	2.12	6.34	9.4

TABLE 13

HARBOUR PARTICULATE METAL LEVELS COMPARED TO OTHER COASTAL AREAS

Location	Mn	Cu	Zn	Cd	Ni	Pb	Fe	Al
	ug/g						%	
Halifax Harbour	9930	106	422	1.9	46	164	5.32	2.1
Fergusons Cove (1)	1620	55	250	1.8	31	152	2.06	3.3
St. Lawrence estuary (2)	834	43	241	3.5		67	4.35	6.8
La Have estuary (3)	698	89	199			200	5.26	6.9
Bedford Basin (1)	8080	135	525	1.8	41	288	2.47	2.6

1 Yeats and Dalziel, 1987
2 Yeats and Loring, 1991
3 Cranston et al., 1975 - mean for stations 8,9 and 10

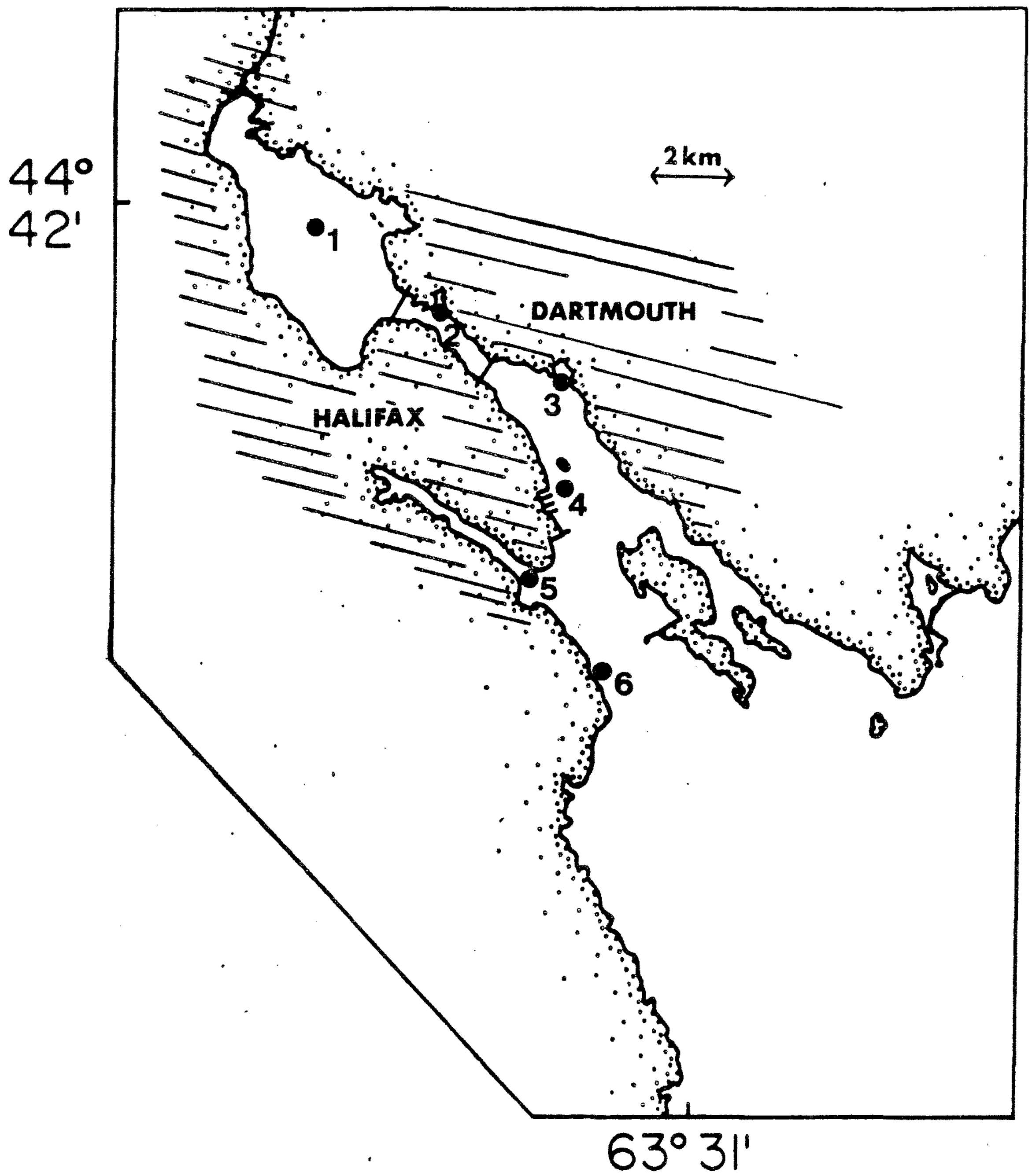
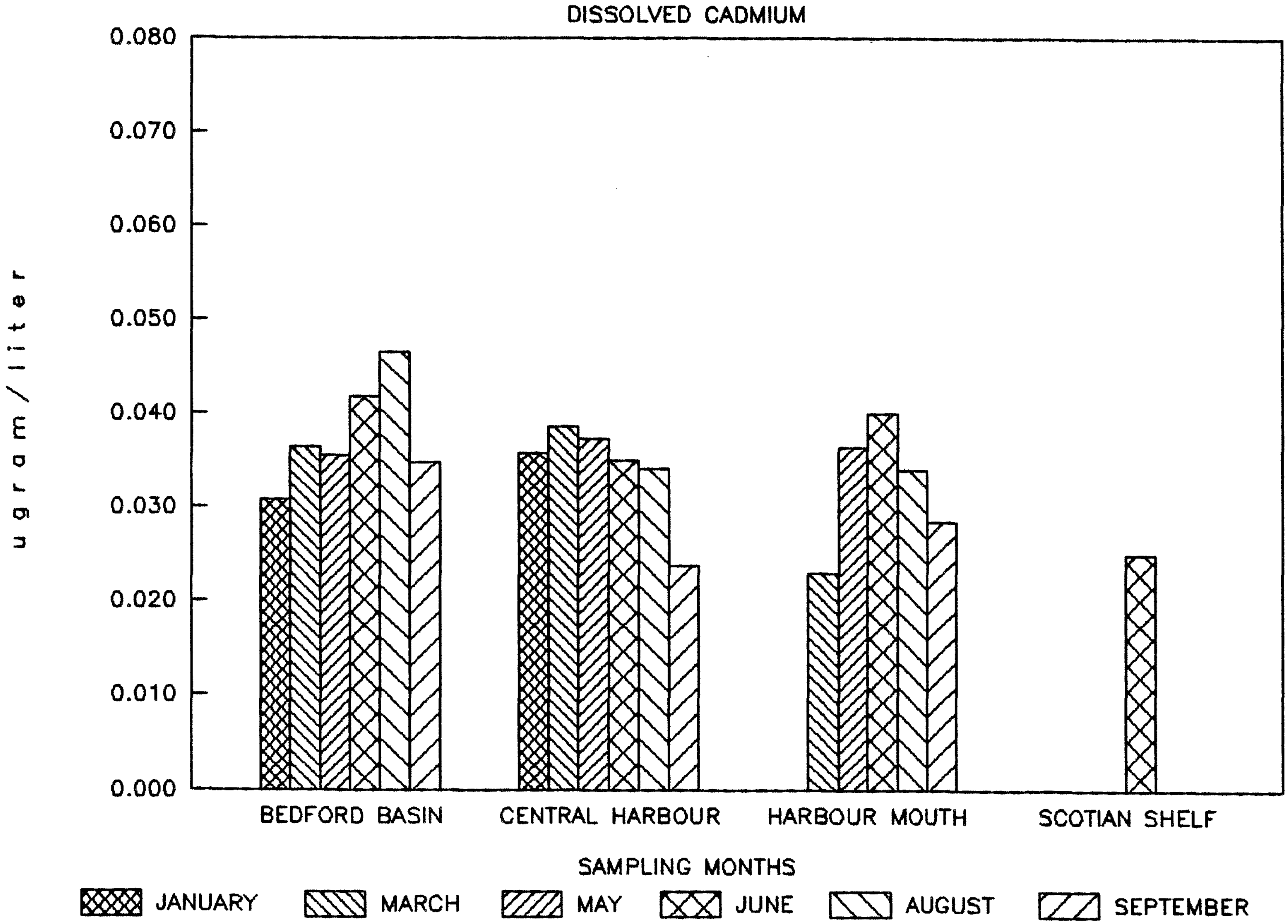


FIGURE : 1 Station locations of the harbour surveys

(1) COMPASS BUOY
(2) TUFTS COVE
(3) DARTMOUTH COVE
(4) GEORGES ISLAND
(5) NORTHWEST ARM
(6) SLEEPY COVE

FIGURE : 2 (A)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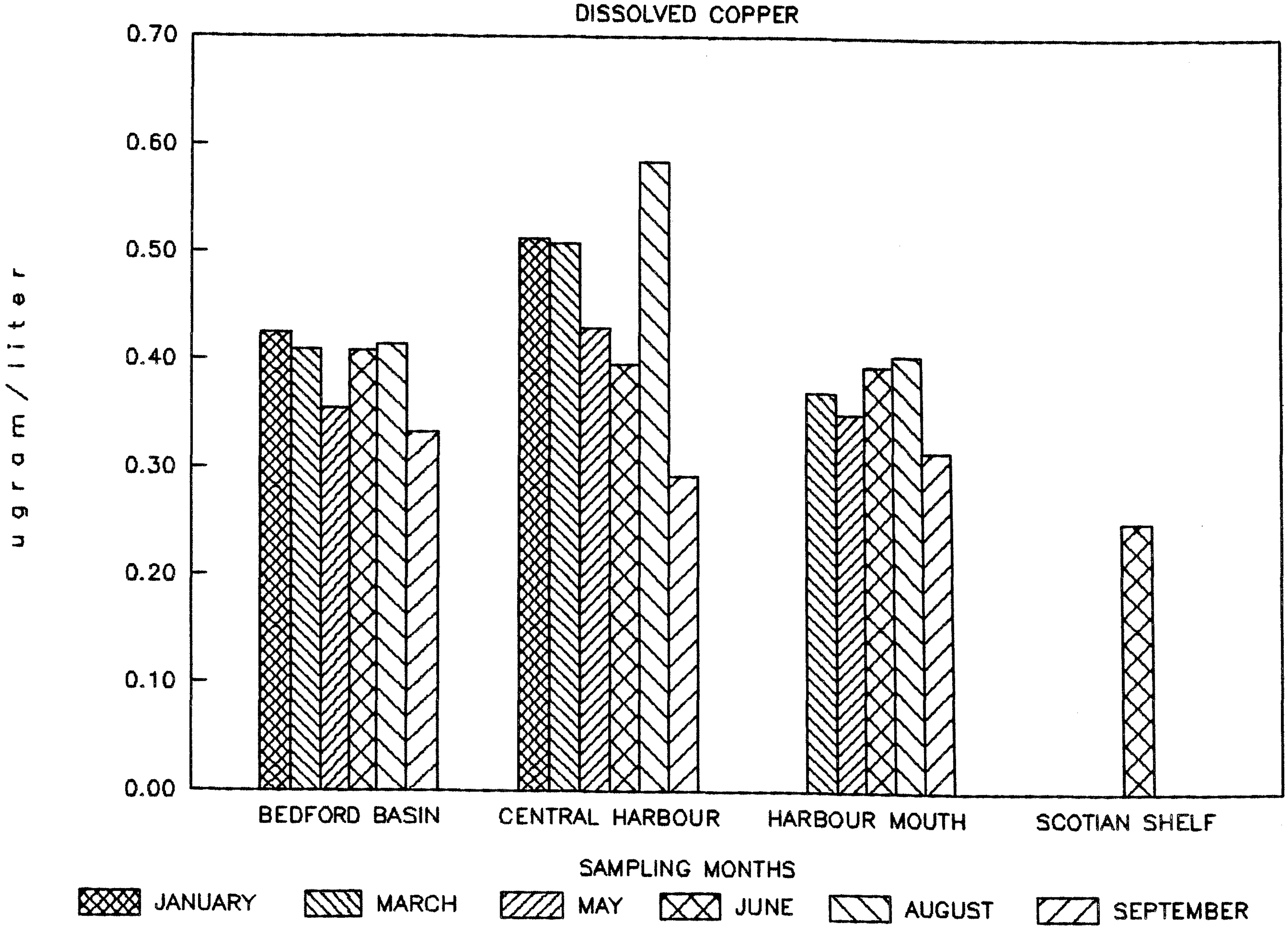
0.080
0.070
0.060
0.050
0.040
0.030
0.020
0.010
0.000
ugram/liter
BEDFORD BASIN
CENTRAL HARBOUR
HARBOUR MOUTH
SCOTIAN SHELF
SAMPLING MONTHS
JANUARY
MARCH
MAY
JUNE
AUGUST
SEPTEMBER

FIGURE : 2 (B)


DISSOLVED COPPER
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
ugram/liter
BEDFORD BASIN
CENTRAL HARBOUR
HARBOUR MOUTH
SCOTIAN SHELF
SAMPLING MONTHS
JANUARY
MARCH
MAY
JUNE
AUGUST
SEPTEMBER

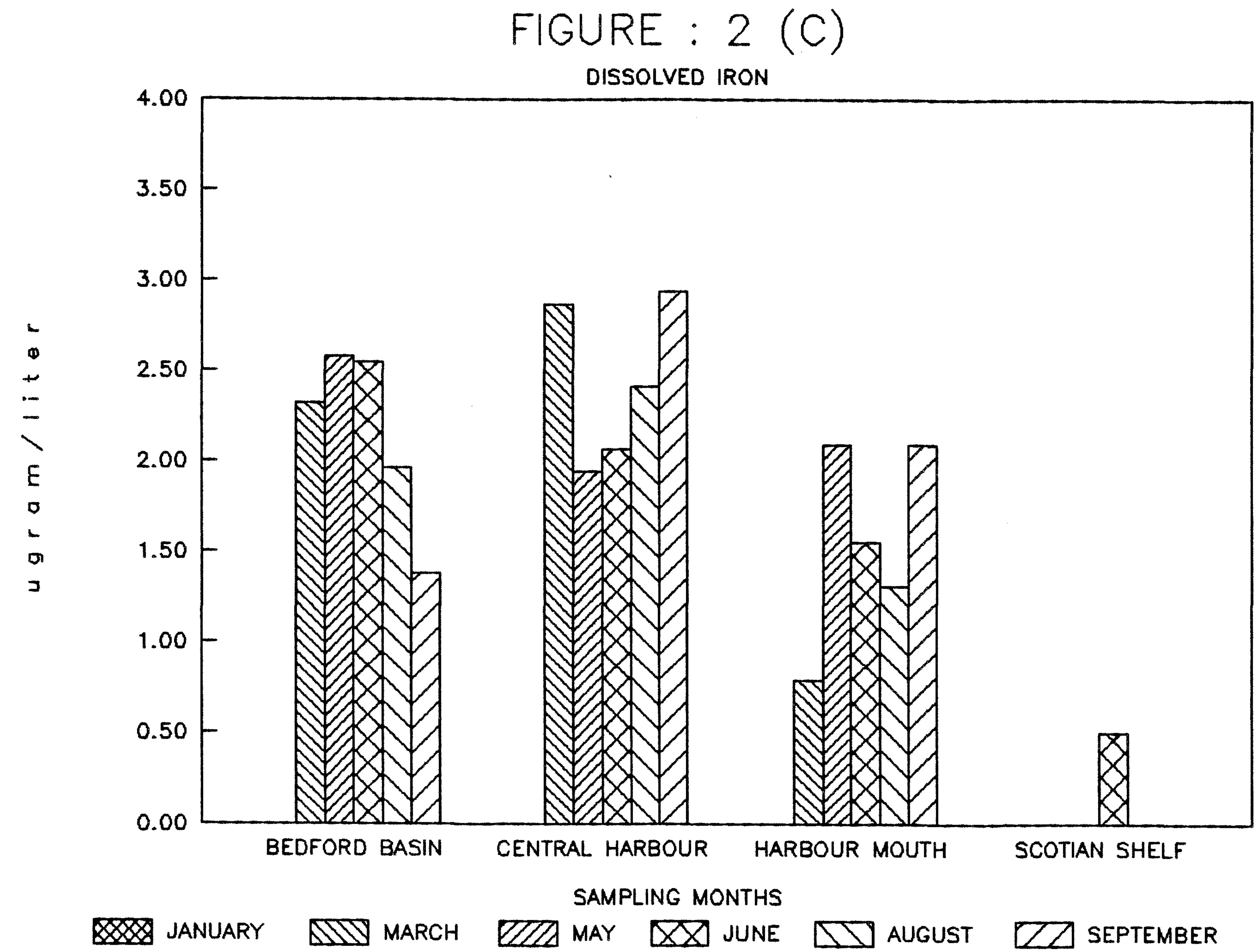
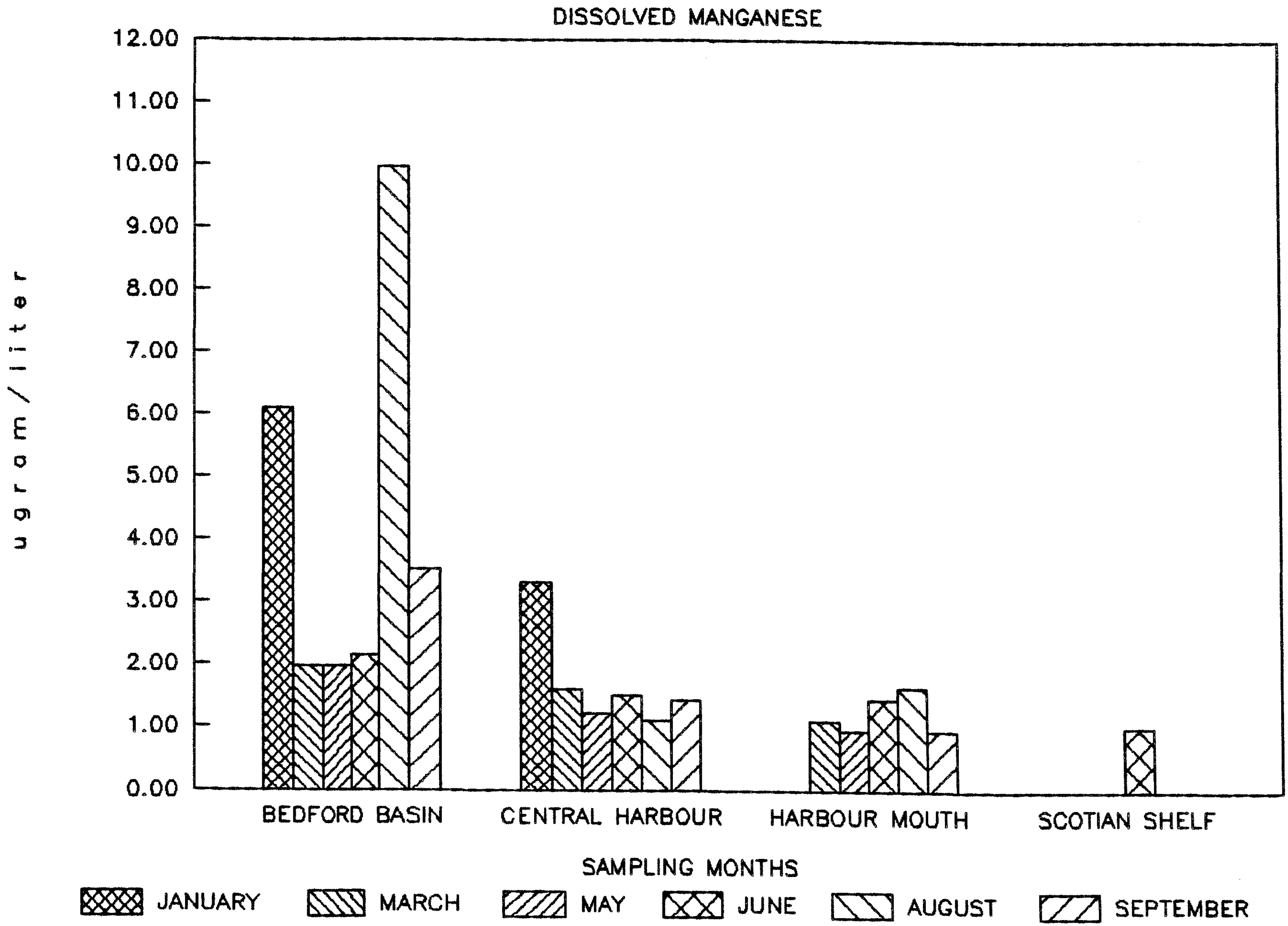


FIGURE : 2 (C)
DISSOLVED IRON
ugram / liter
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
BEDFORD BASIN
CENTRAL HARBOUR
HARBOUR MOUTH
SCOTIAN SHELF
SAMPLING MONTHS
JANUARY
MARCH
MAY
JUNE
AUGUST
SEPTEMBER

FIGURE : 2 (D)



DISSOLVED MANGANESE
ugram/liter
12.00
11.00
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
BEDFORD BASIN
CENTRAL HARBOUR
HARBOUR MOUTH
SCOTIAN SHELF
SAMPLING MONTHS
JANUARY
MARCH
MAY
JUNE
AUGUST
SEPTEMBER

FIGURE : 2 (E)

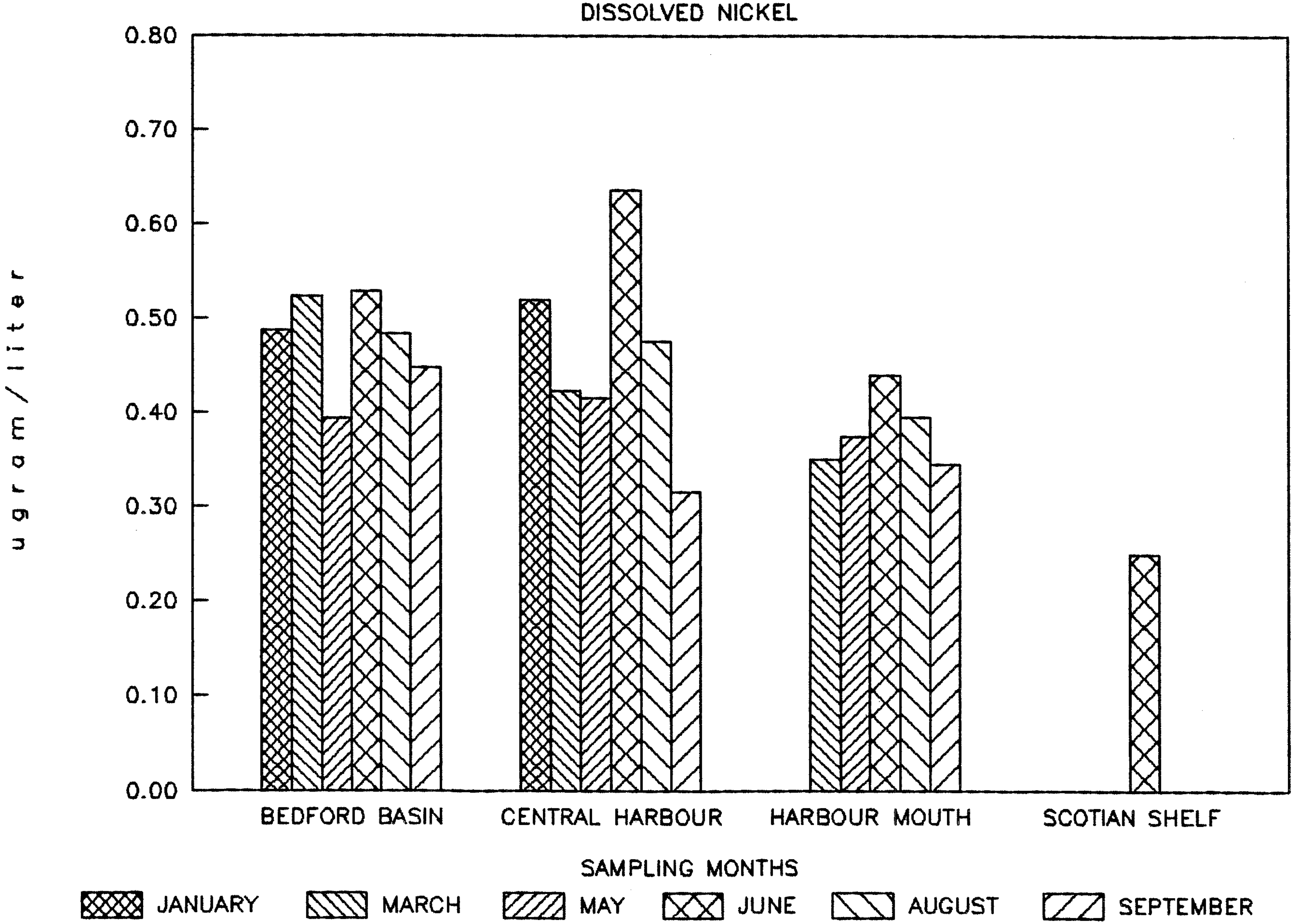
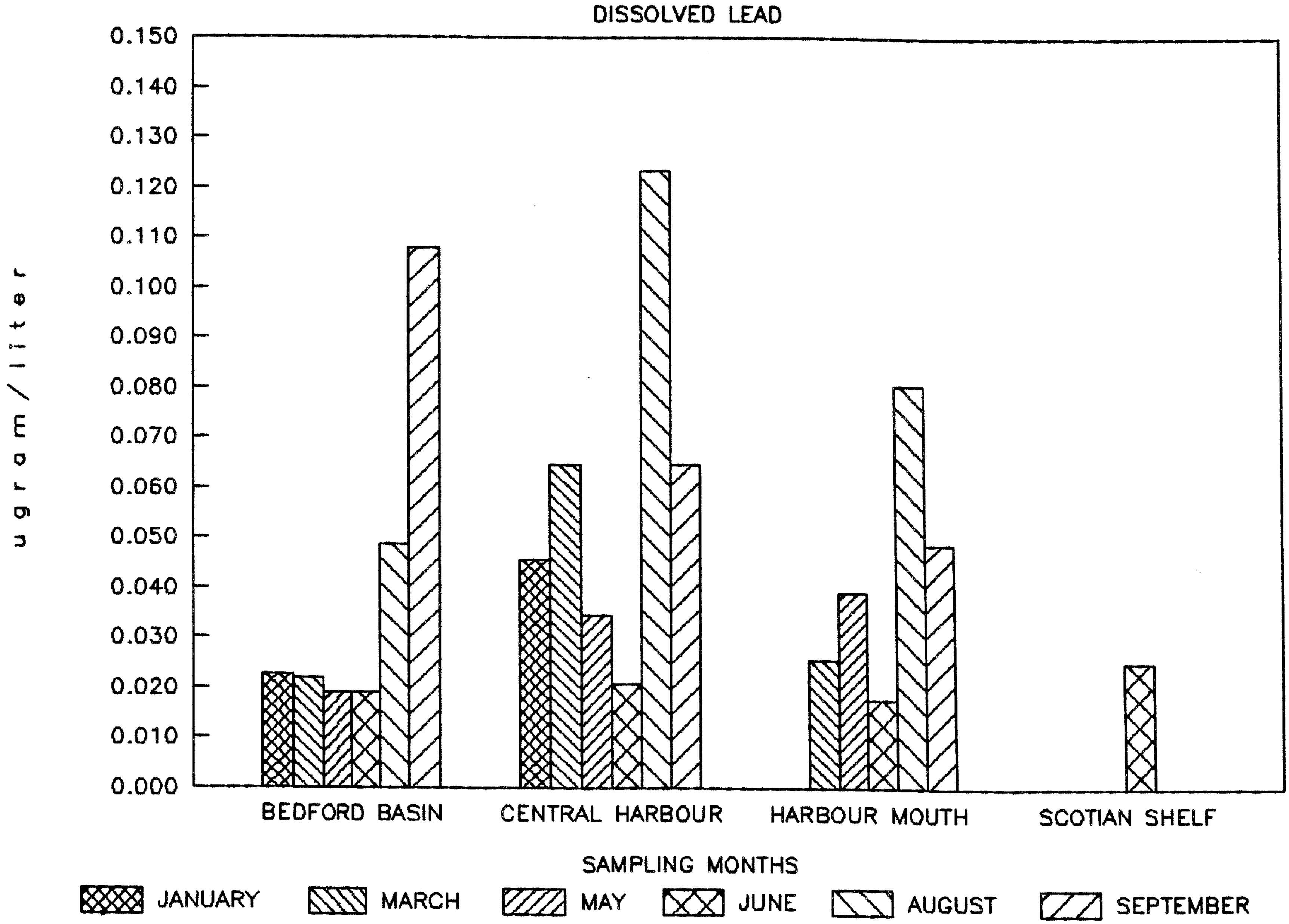

DISSOLVED NICKEL
ugram / liter
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
BEDFORD BASIN
CENTRAL HARBOUR
HARBOUR MOUTH
SCOTIAN SHELF
SAMPLING MONTHS
JANUARY
MARCH
MAY
JUNE
AUGUST
SEPTEMBER

FIGURE : 2 (F)



DISSOLVED LEAD
ugram/liter
0.150
0.140
0.130
0.120
0.110
0.100
0.090
0.080
0.070
0.060
0.050
0.040
0.030
0.020
0.010
0.000
BEDFORD BASIN
CENTRAL HARBOUR
HARBOUR MOUTH
SCOTIAN SHELF
SAMPLING MONTHS
JANUARY
MARCH
MAY
JUNE
AUGUST
SEPTEMBER

FIGURE : 2 (G)

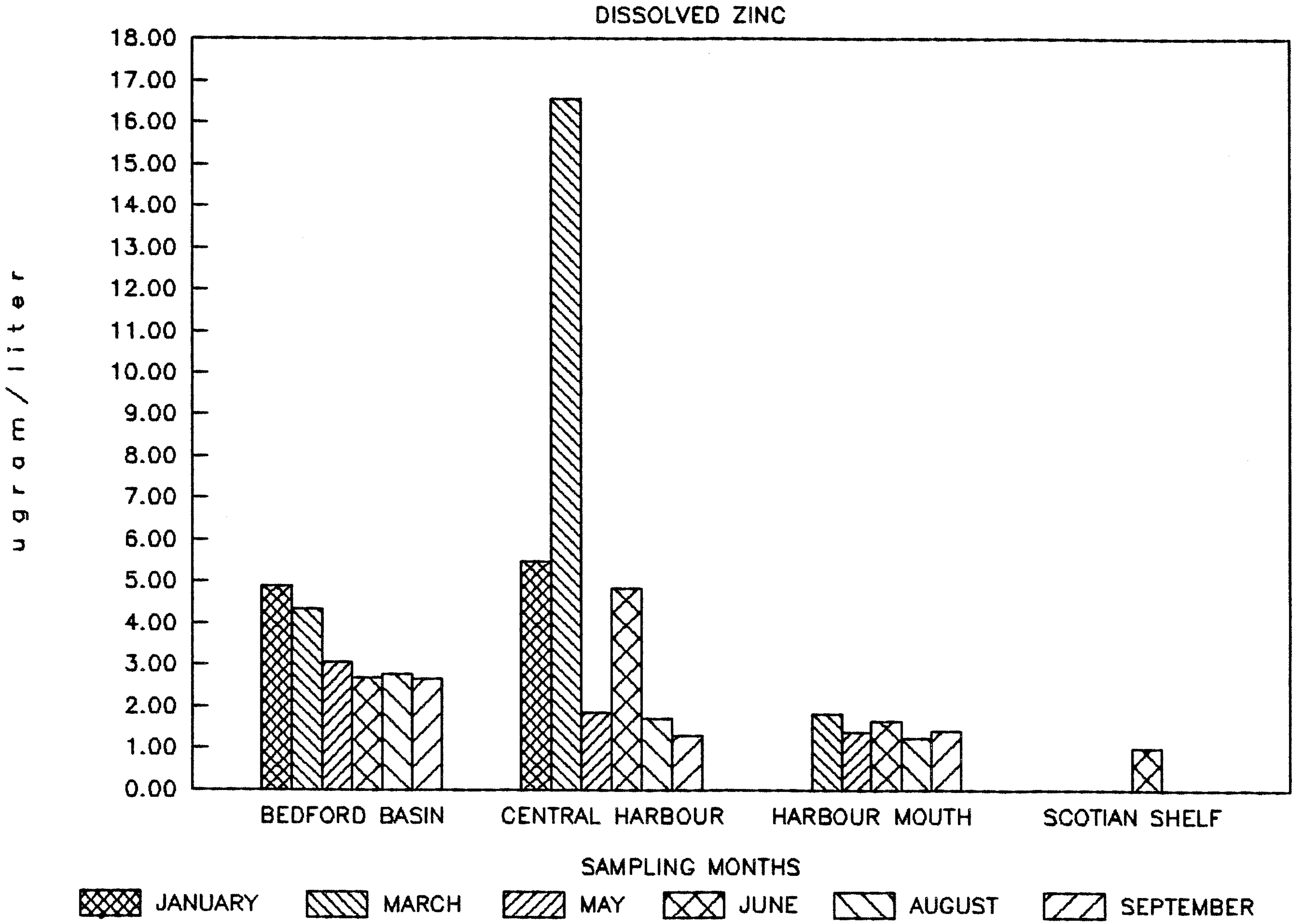

DISSOLVED ZINC
ugram / liter
18.00
17.00
16.00
15.00
14.00
13.00
12.00
11.00
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
BEDFORD BASIN
CENTRAL HARBOUR
HARBOUR MOUTH
SCOTIAN SHELF
SAMPLING MONTHS
JANUARY
MARCH
MAY
JUNE
AUGUST
SEPTEMBER

FIGURE : 3 (A)

COPPER VS SALINITY

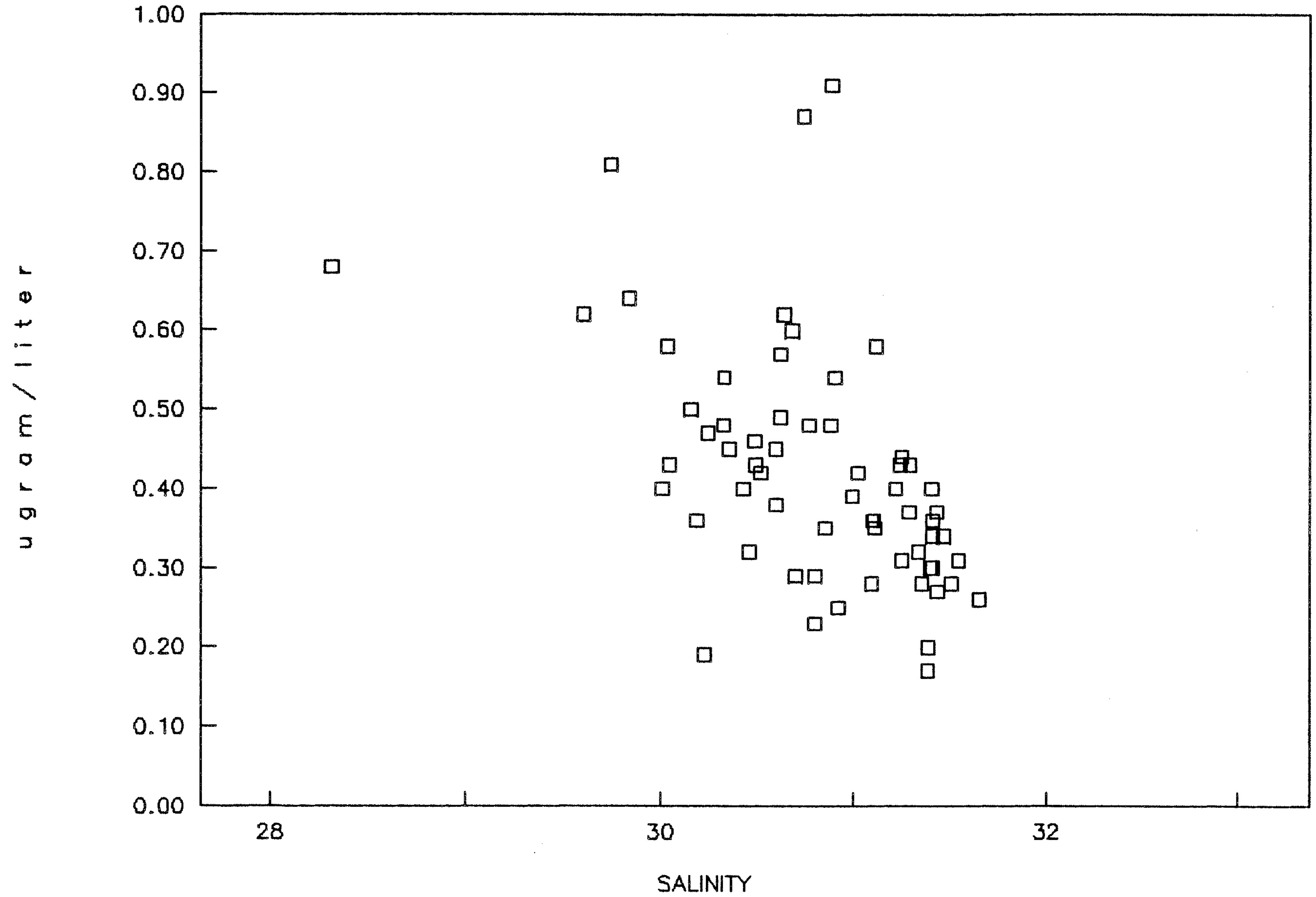


FIGURE : 3 (B)

MANGANESE VS SALINITY

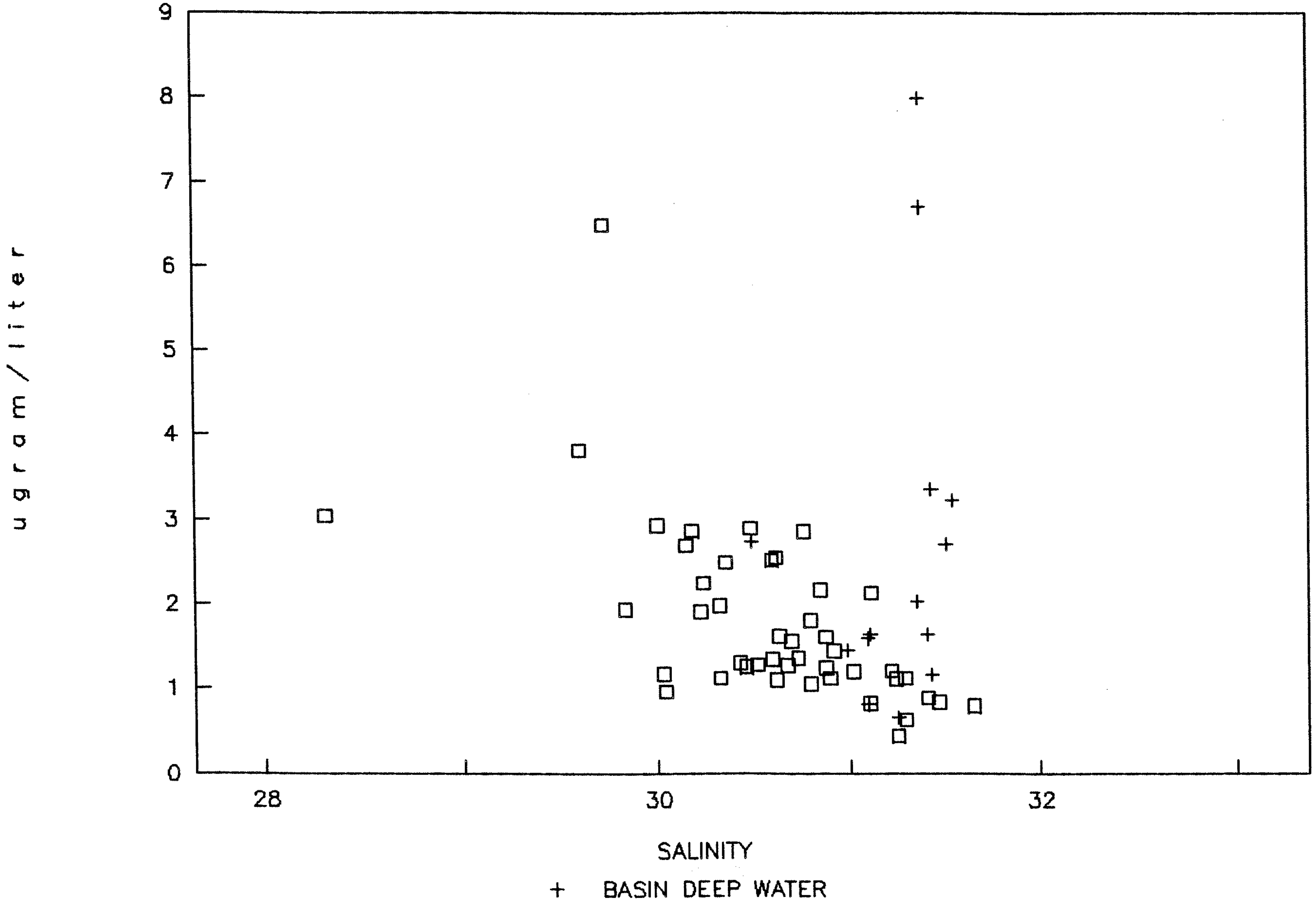


FIGURE : 3 (C)

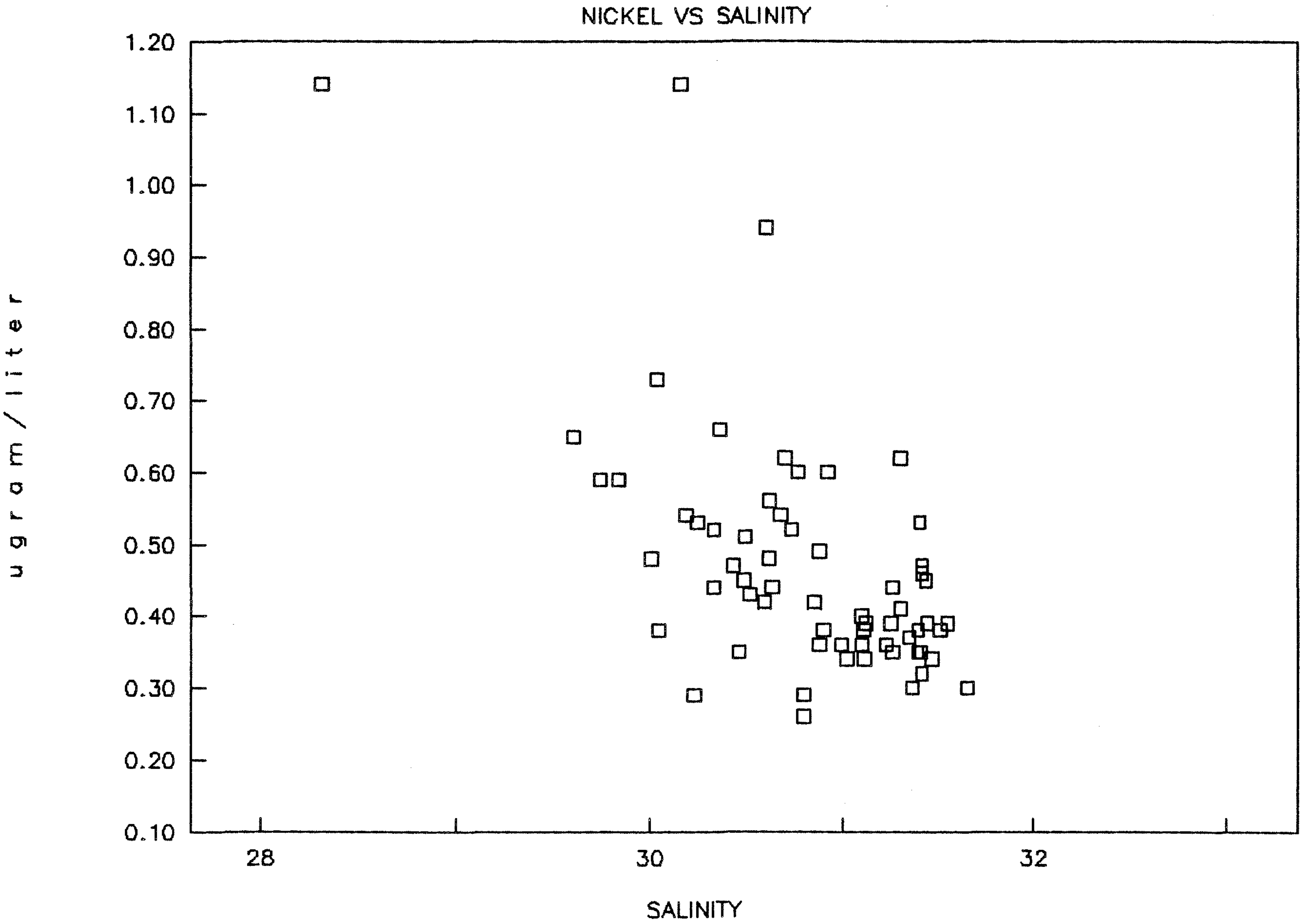

NICKEL VS SALINITY
1.20
1.10
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
ugram/liter
28
30
32
SALINITY

FIGURE : 4 (A)

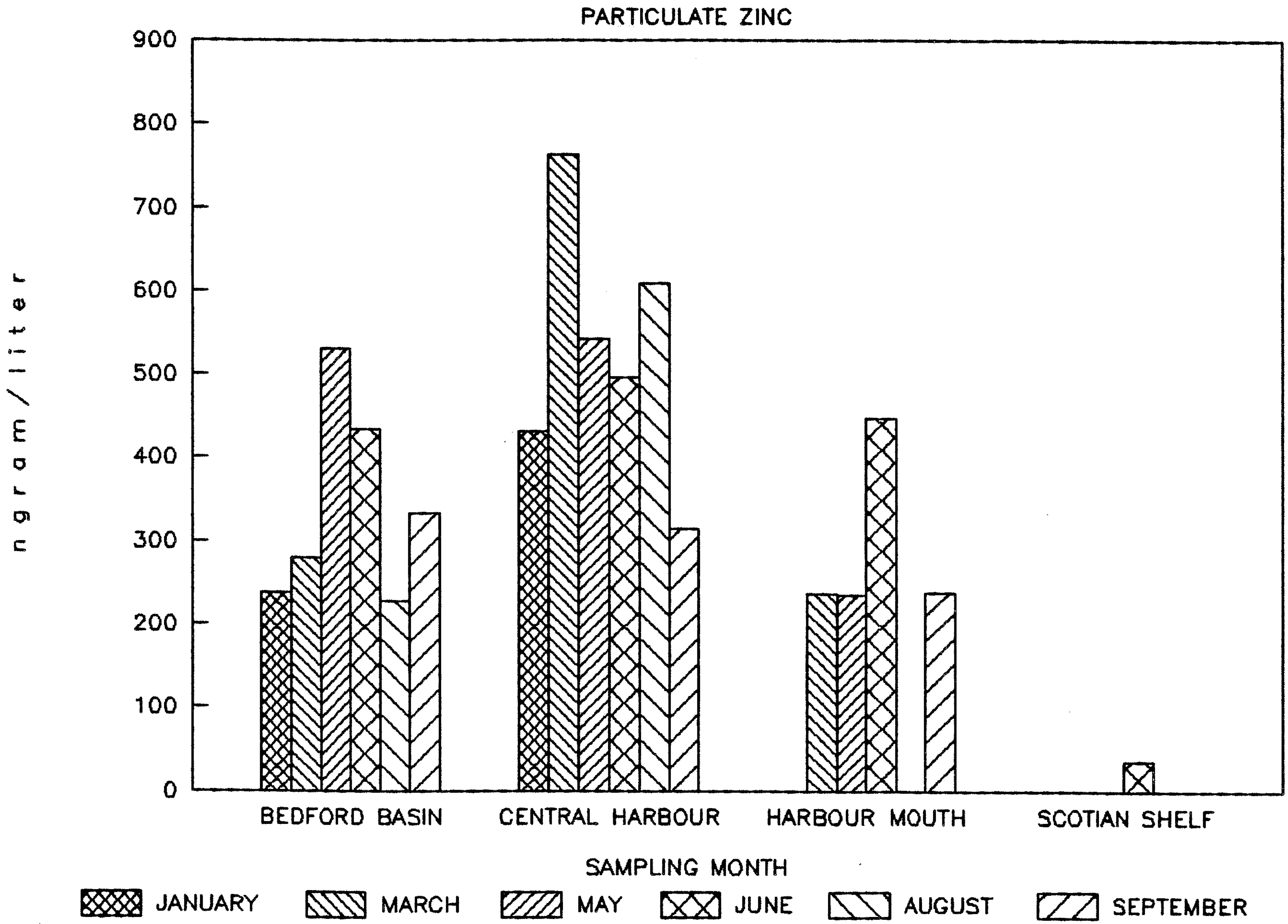

PARTICULATE ZINC
900
800
700
600
500
400
300
200
100
0
ngram / liter
BEDFORD BASIN
CENTRAL HARBOUR
HARBOUR MOUTH
SCOTIAN SHELF
SAMPLING MONTH
JANUARY
MARCH
MAY
JUNE
AUGUST
SEPTEMBER

FIGURE : 4 (B)

PARTICULATE COPPER

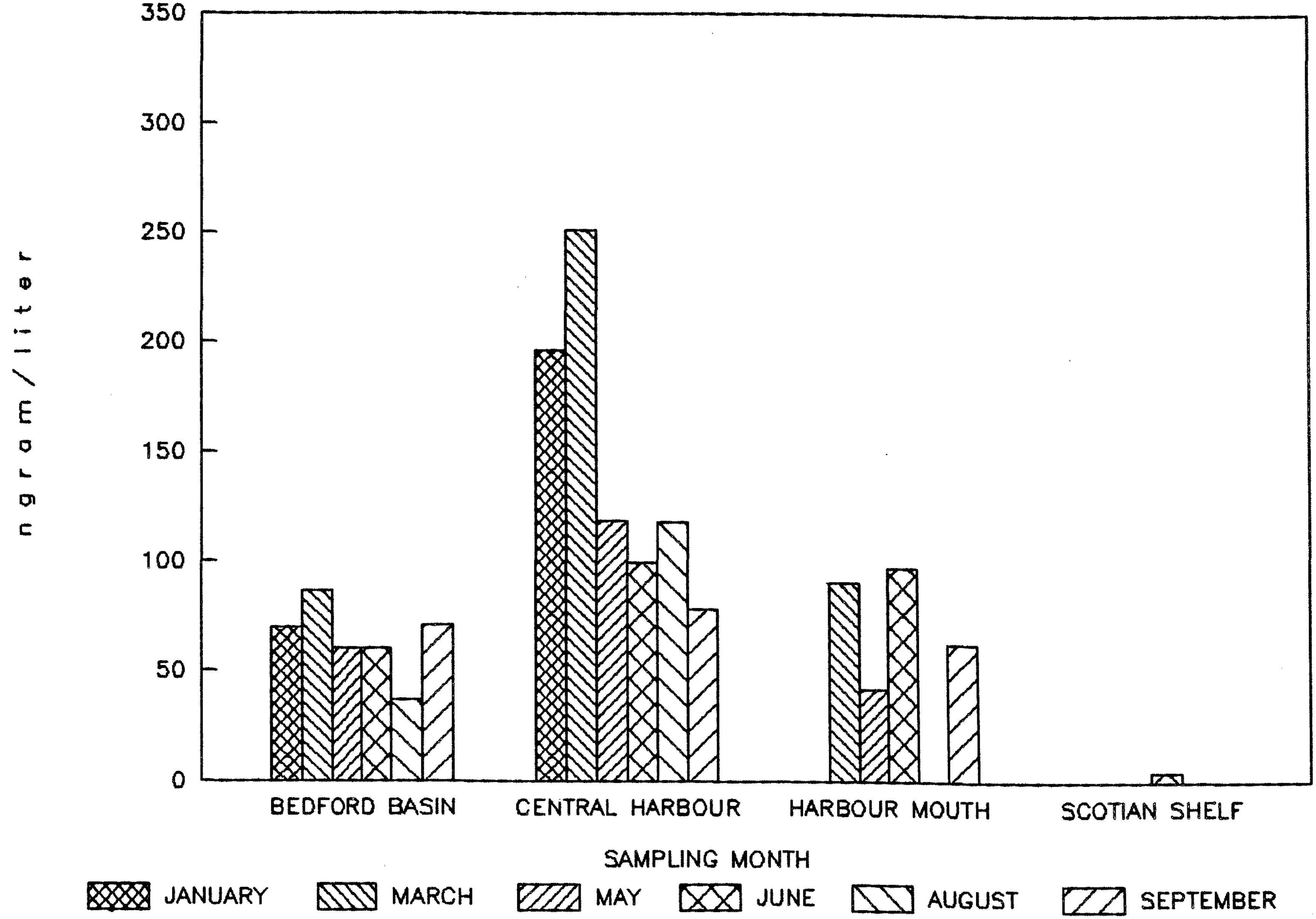


FIGURE : 4 (C)

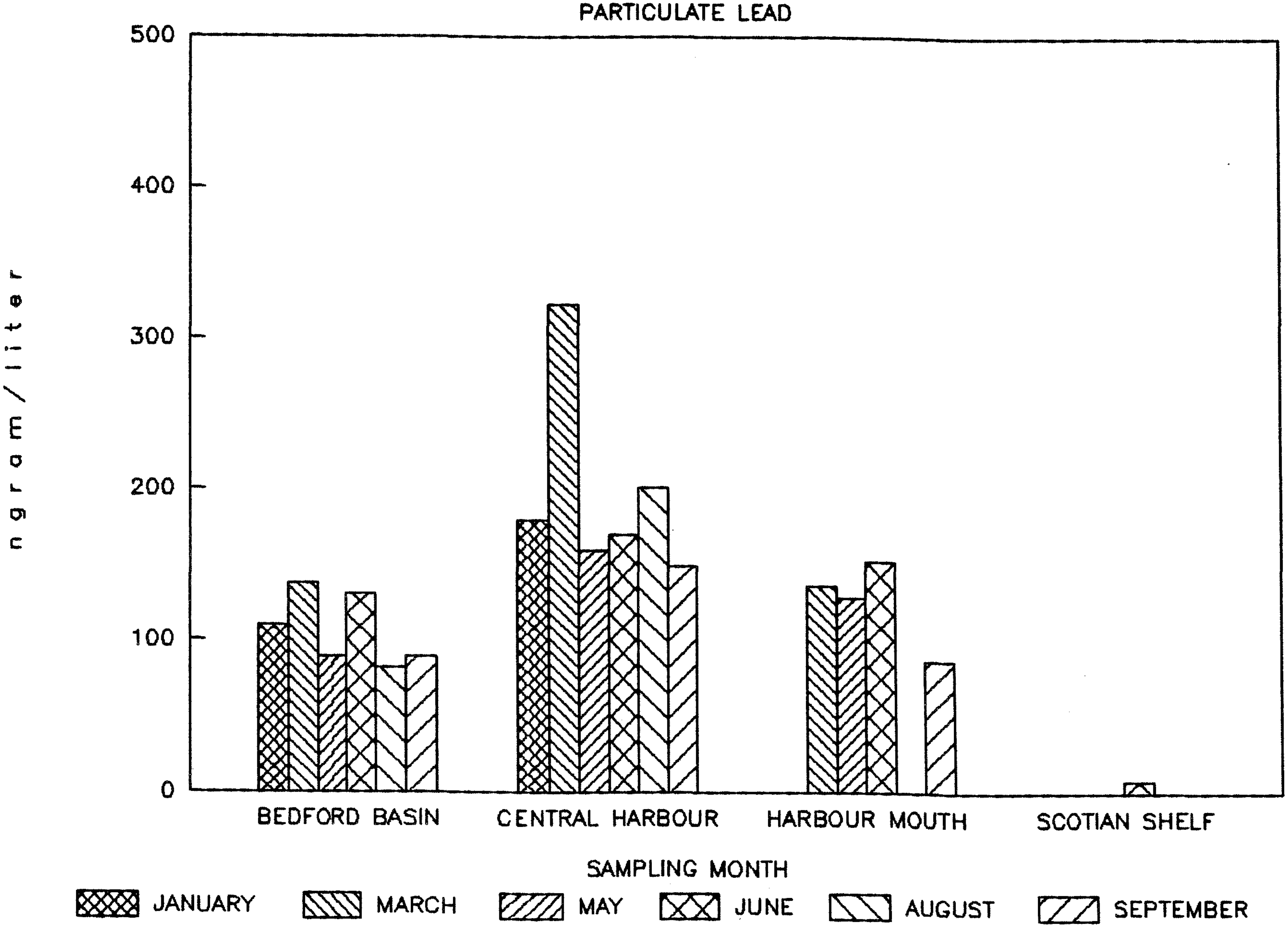

PARTICULATE LEAD
500
400
300
200
100
0
ngram / liter
BEDFORD BASIN
CENTRAL HARBOUR
HARBOUR MOUTH
SCOTIAN SHELF
SAMPLING MONTH
JANUARY
MARCH
MAY
JUNE
AUGUST
SEPTEMBER

FIGURE : 4 (D)

PARTICULATE CADMIUM

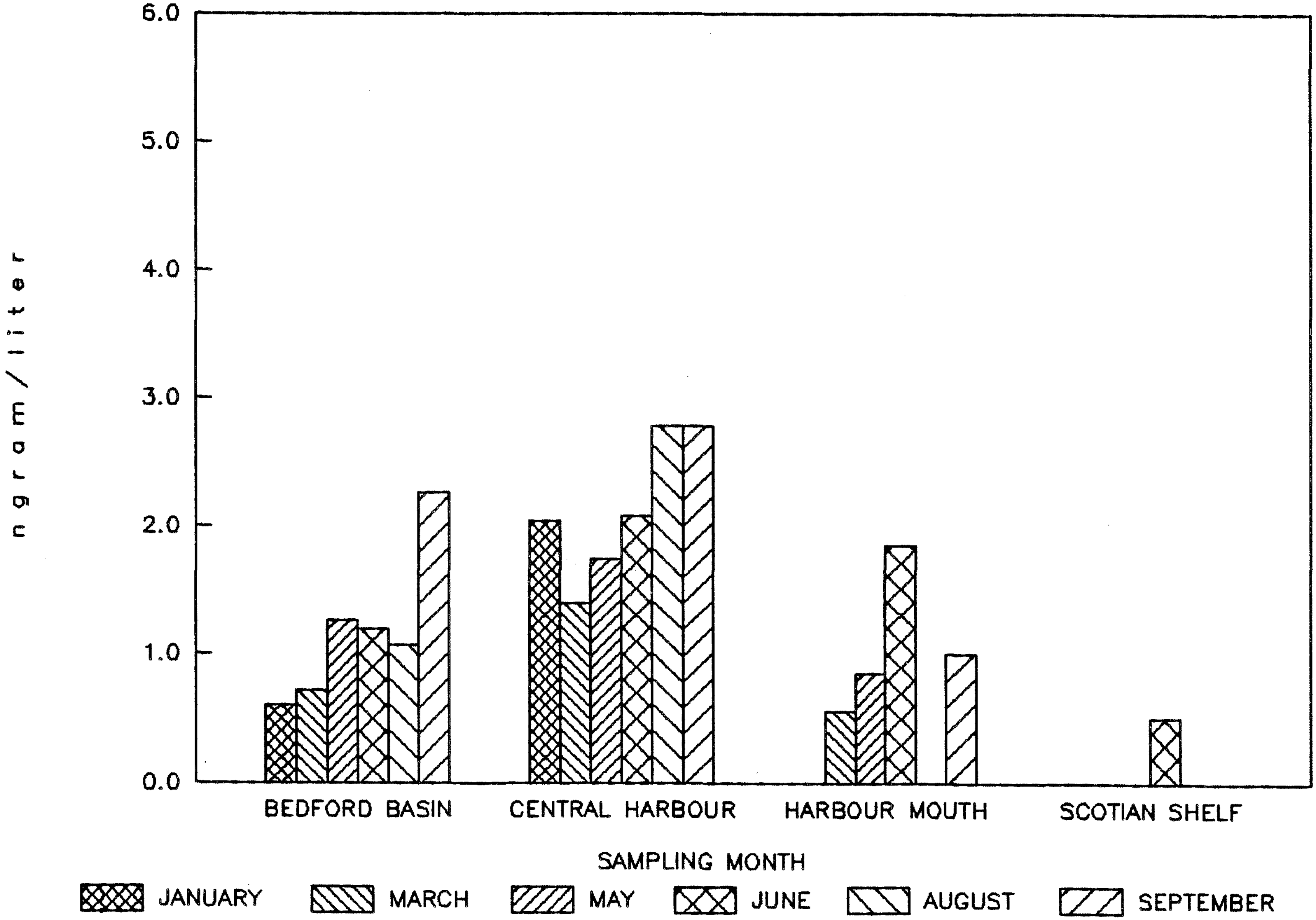


FIGURE : 4 (E)

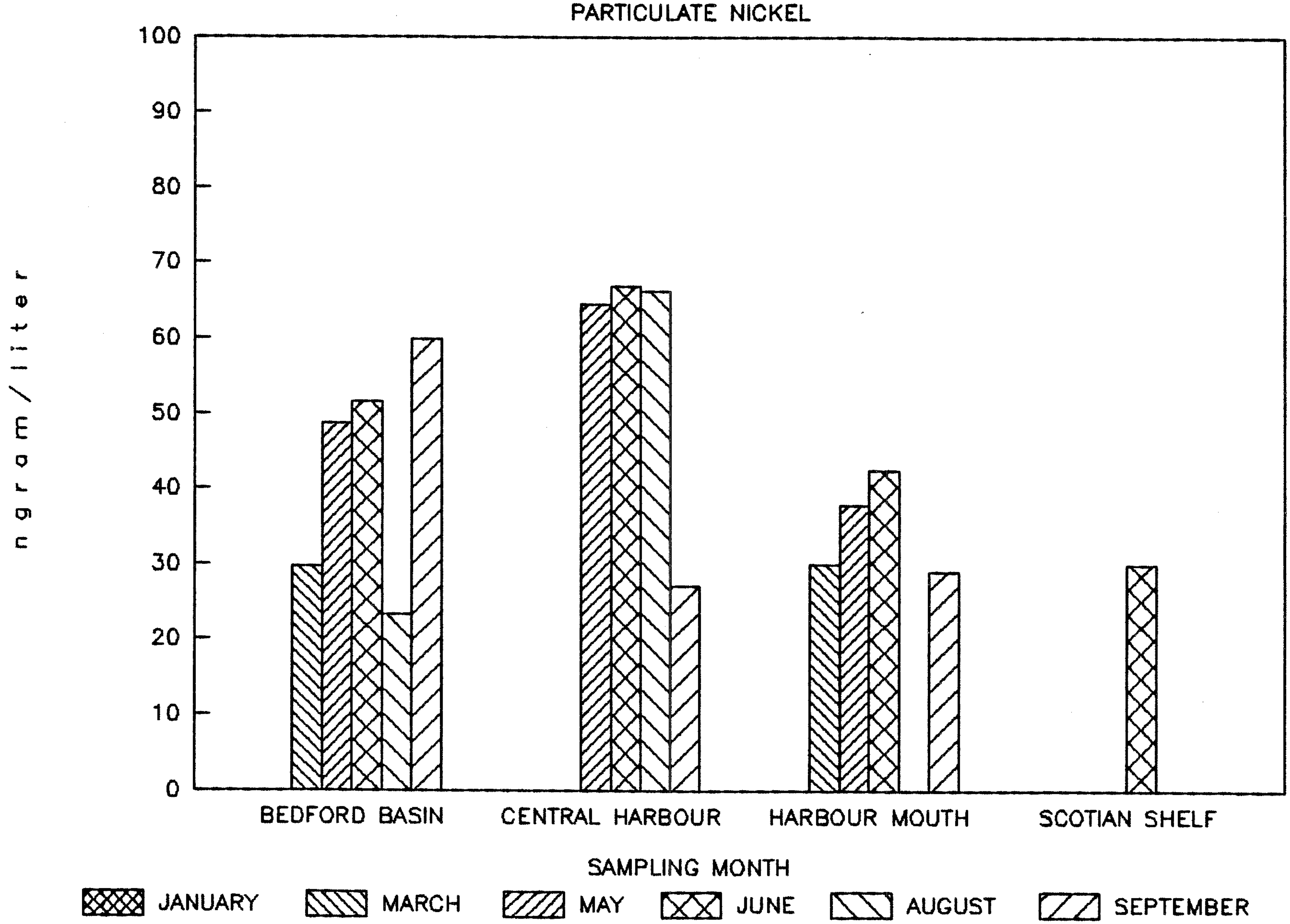

PARTICULATE NICKEL
100
90
80
70
60
50
40
30
20
10
0
ngram / liter
BEDFORD BASIN
CENTRAL HARBOUR
HARBOUR MOUTH
SCOTIAN SHELF
SAMPLING MONTH
JANUARY
MARCH
MAY
JUNE
AUGUST
SEPTEMBER

FIGURE : 4 (F)

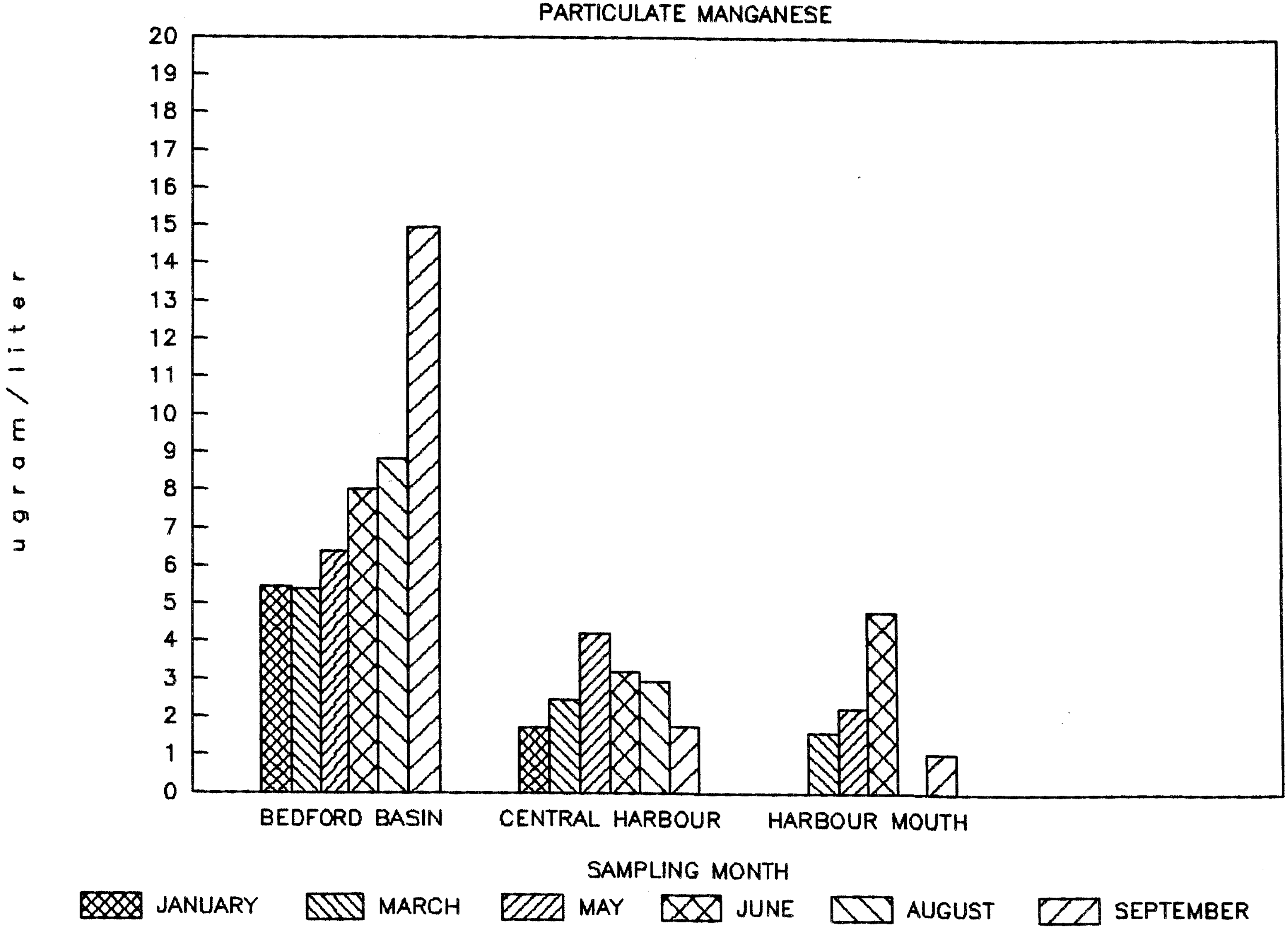

PARTICULATE MANGANESE
ugram/liter
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
BEDFORD BASIN
CENTRAL HARBOUR
HARBOUR MOUTH
SAMPLING MONTH
JANUARY
MARCH
MAY
JUNE
AUGUST
SEPTEMBER

FIGURE : 4 (G)

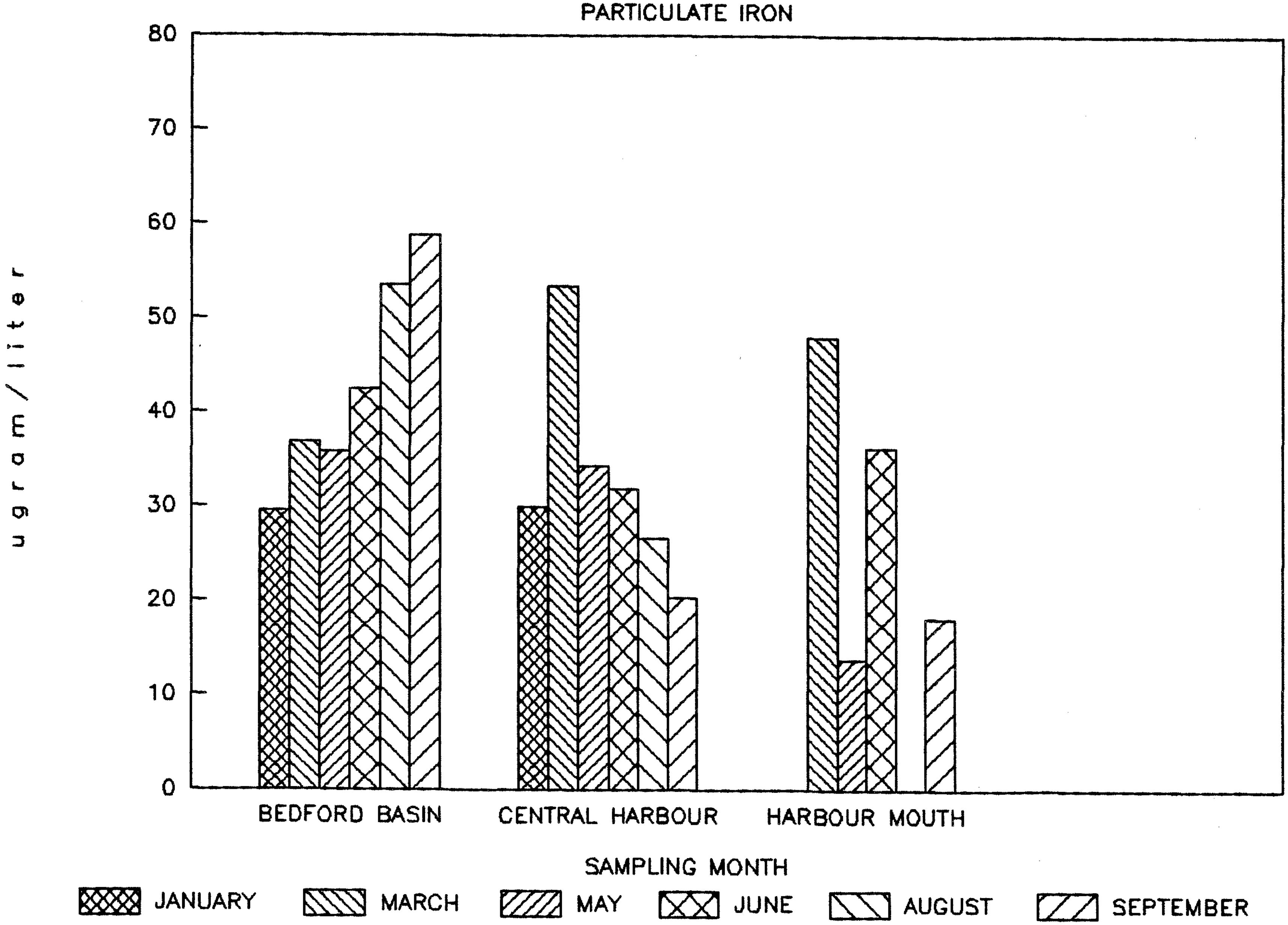
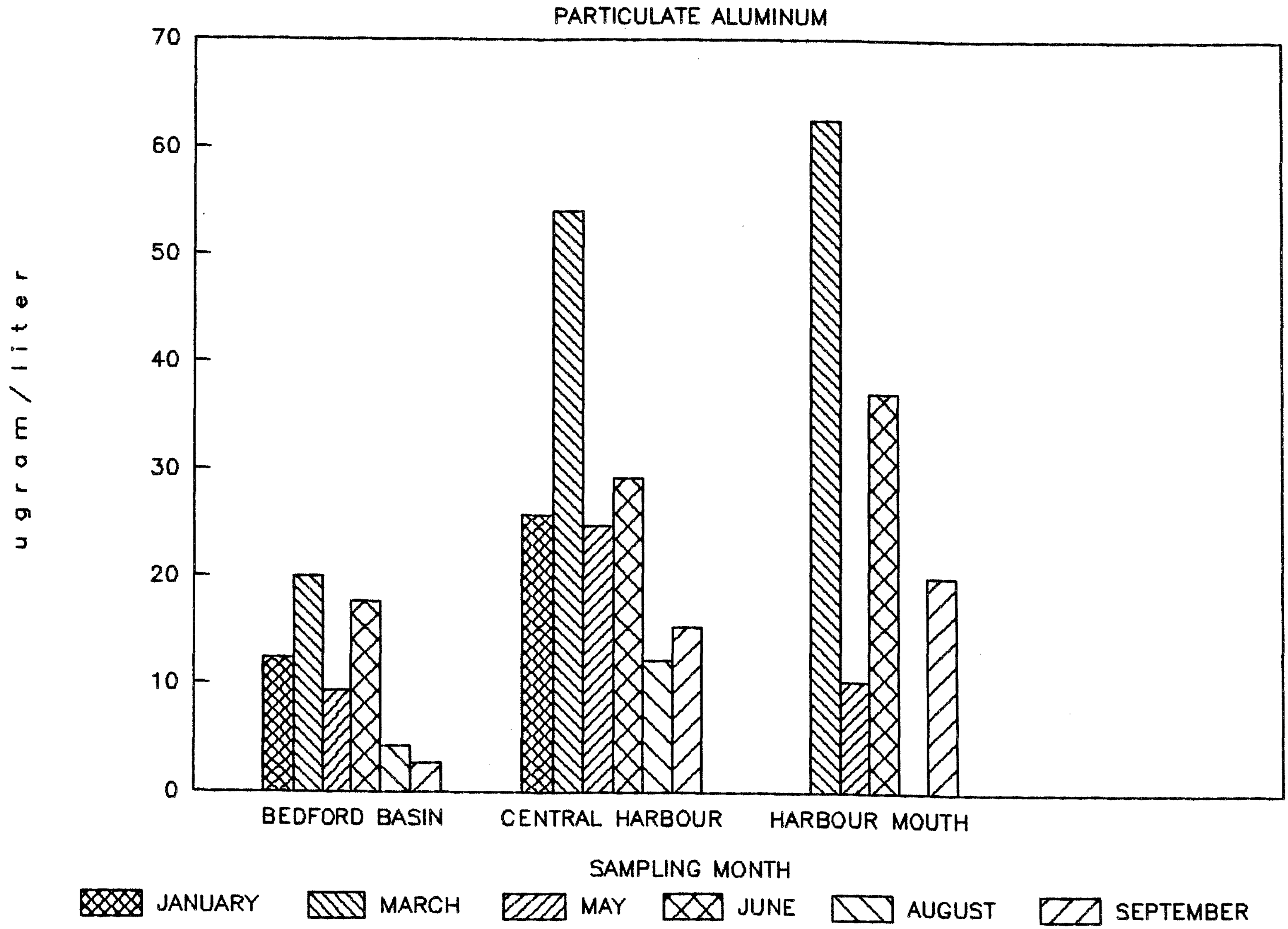

PARTICULATE IRON
ugram / liter
80
70
60
50
40
30
20
10
0
BEDFORD BASIN
CENTRAL HARBOUR
HARBOUR MOUTH
SAMPLING MONTH
JANUARY
MARCH
MAY
JUNE
AUGUST
SEPTEMBER

FIGURE : 4 (H)



PARTICULATE ALUMINUM
ugram / liter
0
10
20
30
40
50
60
70
BEDFORD BASIN
CENTRAL HARBOUR
HARBOUR MOUTH
SAMPLING MONTH
JANUARY
MARCH
MAY
JUNE
AUGUST
SEPTEMBER

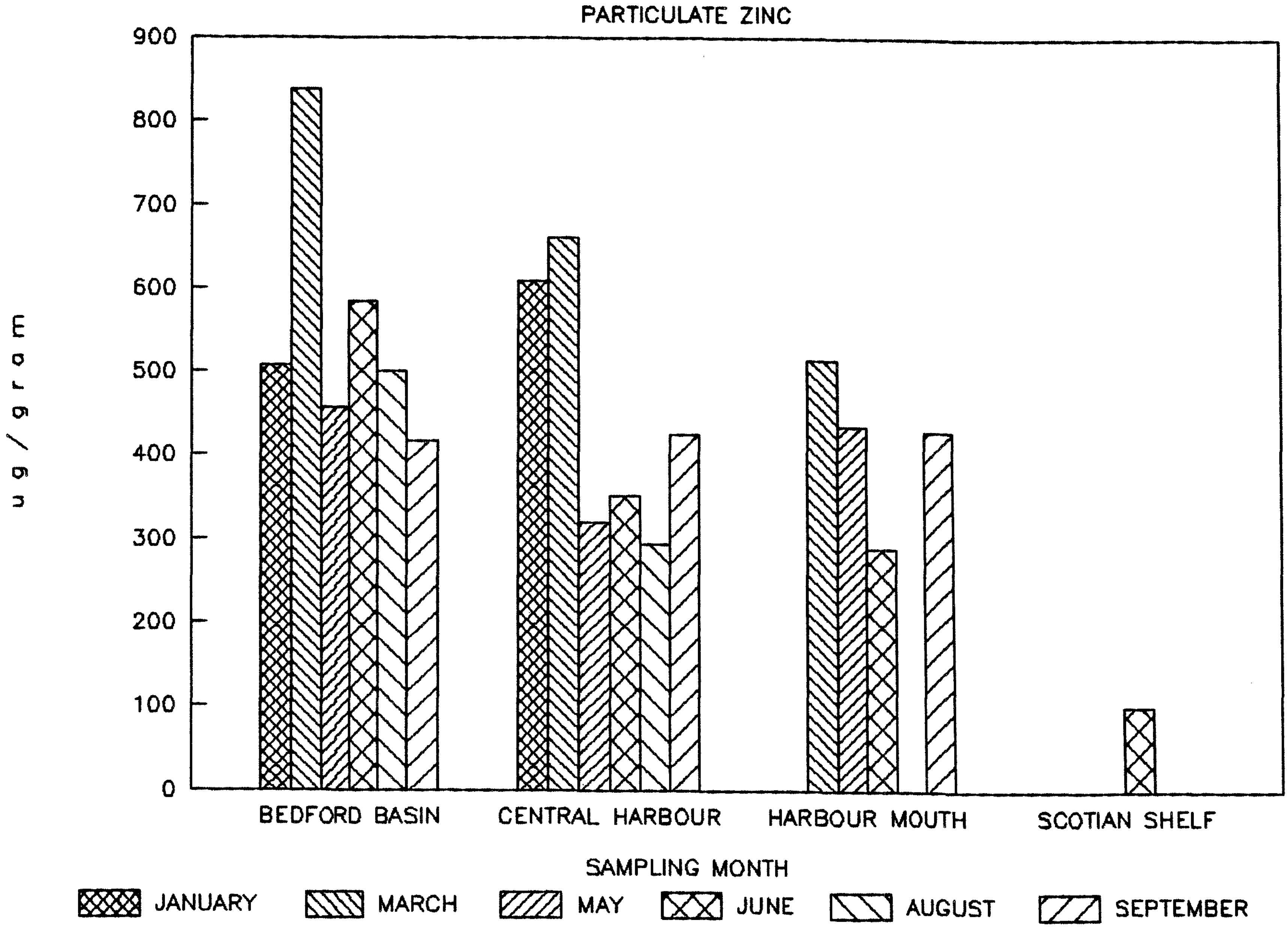
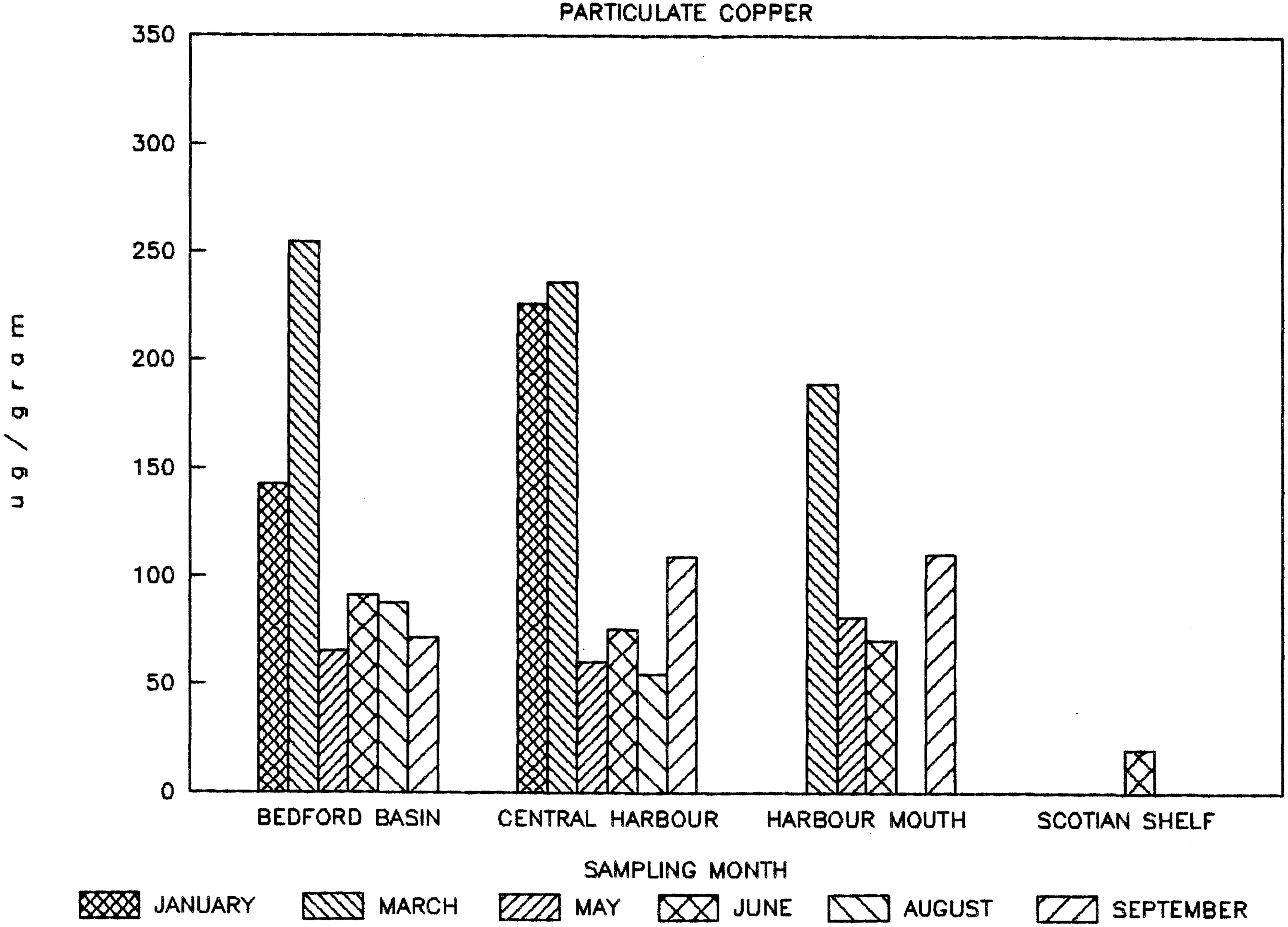

PARTICULATE ZINC
900
800
700
600
500
400
300
200
100
0
ug/gram
BEDFORD BASIN
CENTRAL HARBOUR
HARBOUR MOUTH
SCOTIAN SHELF
SAMPLING MONTH
JANUARY
MARCH
MAY
JUNE
AUGUST
SEPTEMBER

FIGURE : 5 (A)

FIGURE : 5 (B)



PARTICULATE COPPER
350
300
250
200
150
100
50
0
ug / gram
BEDFORD BASIN
CENTRAL HARBOUR
HARBOUR MOUTH
SCOTIAN SHELF
SAMPLING MONTH
JANUARY
MARCH
MAY
JUNE
AUGUST
SEPTEMBER

FIGURE : 5 (C)

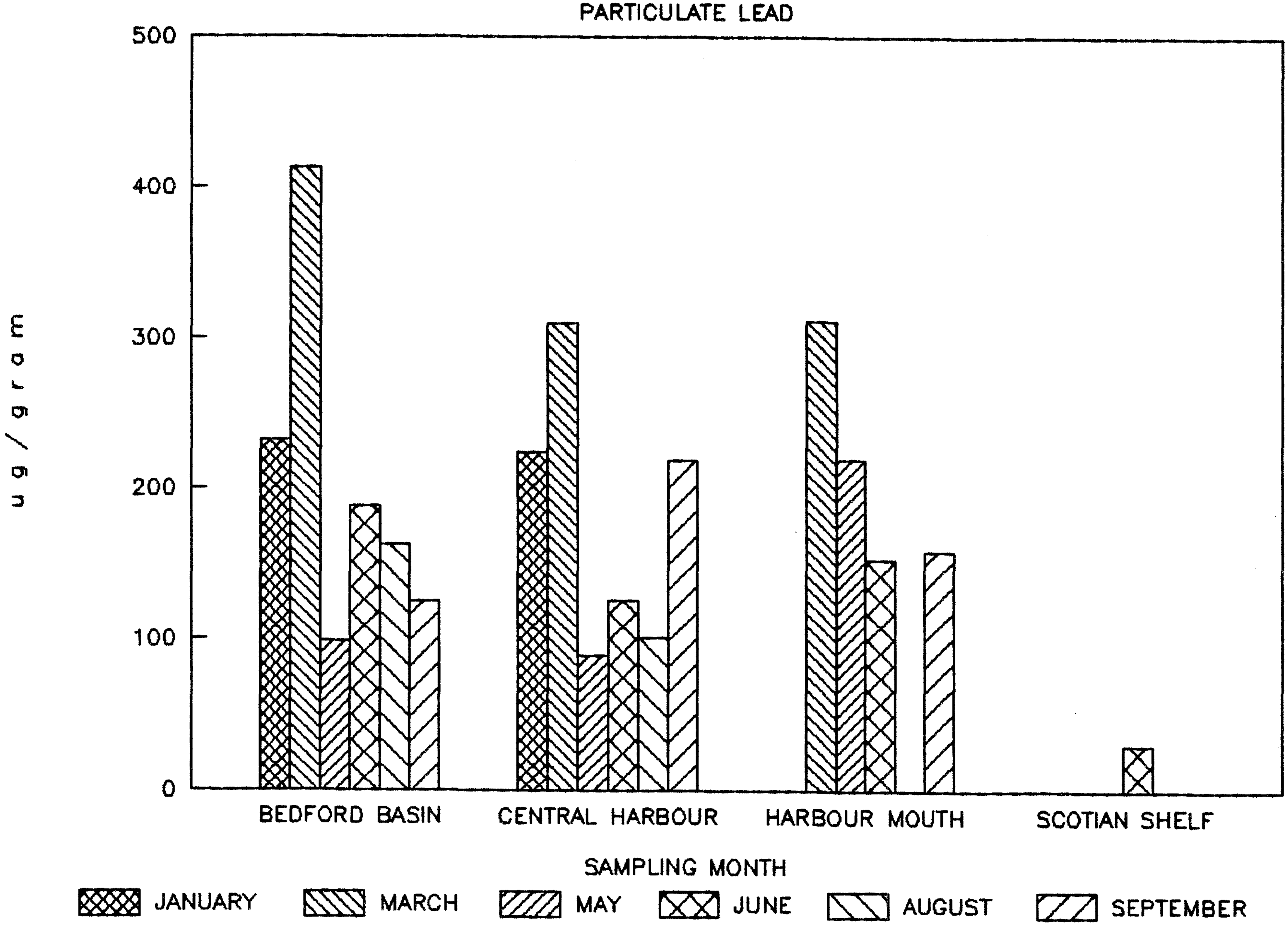

PARTICULATE LEAD
500
400
300
200
100
0
ug / gram
BEDFORD BASIN
CENTRAL HARBOUR
HARBOUR MOUTH
SCOTIAN SHELF
SAMPLING MONTH
JANUARY
MARCH
MAY
JUNE
AUGUST
SEPTEMBER

FIGURE : 5 (D)

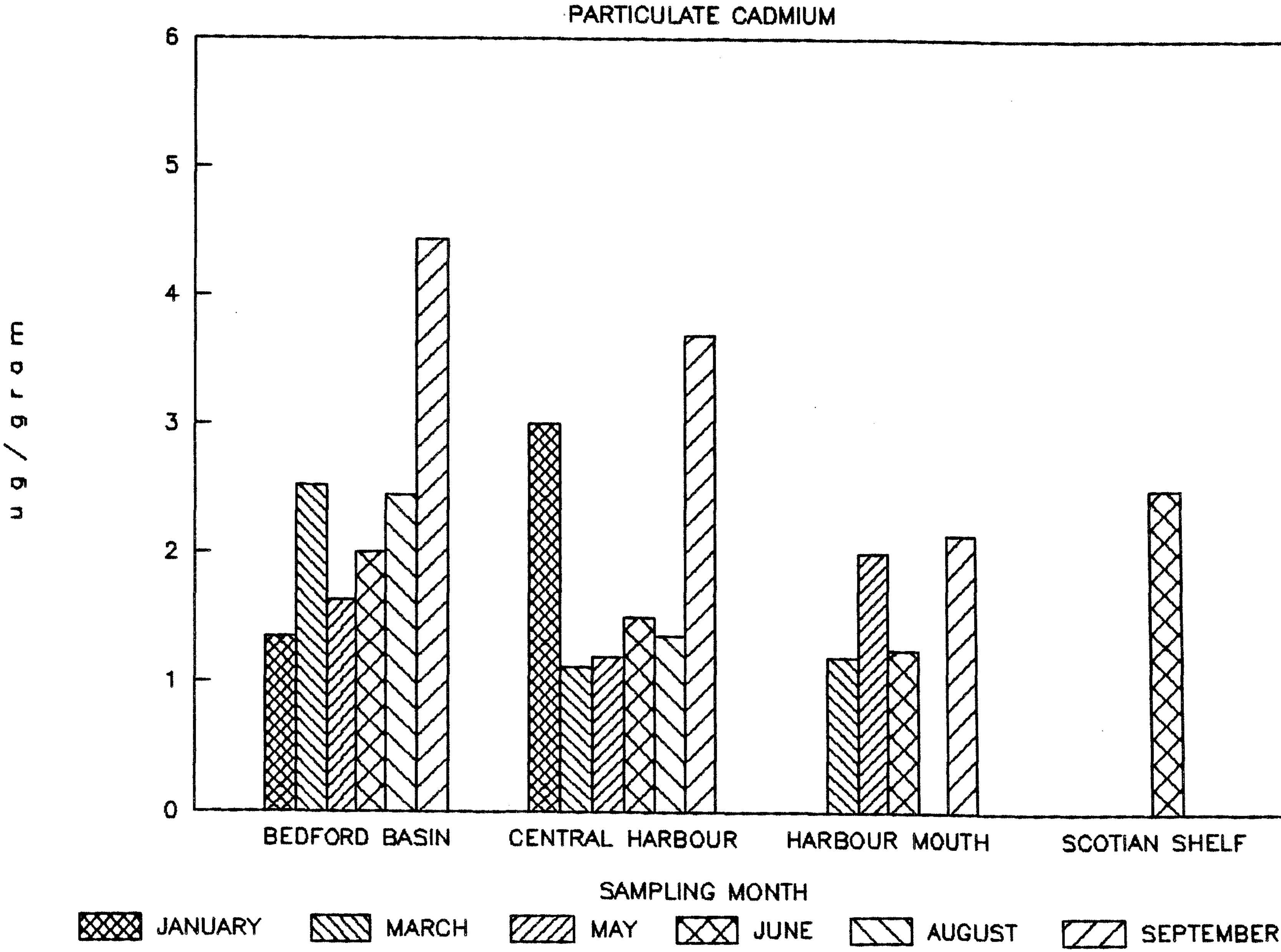
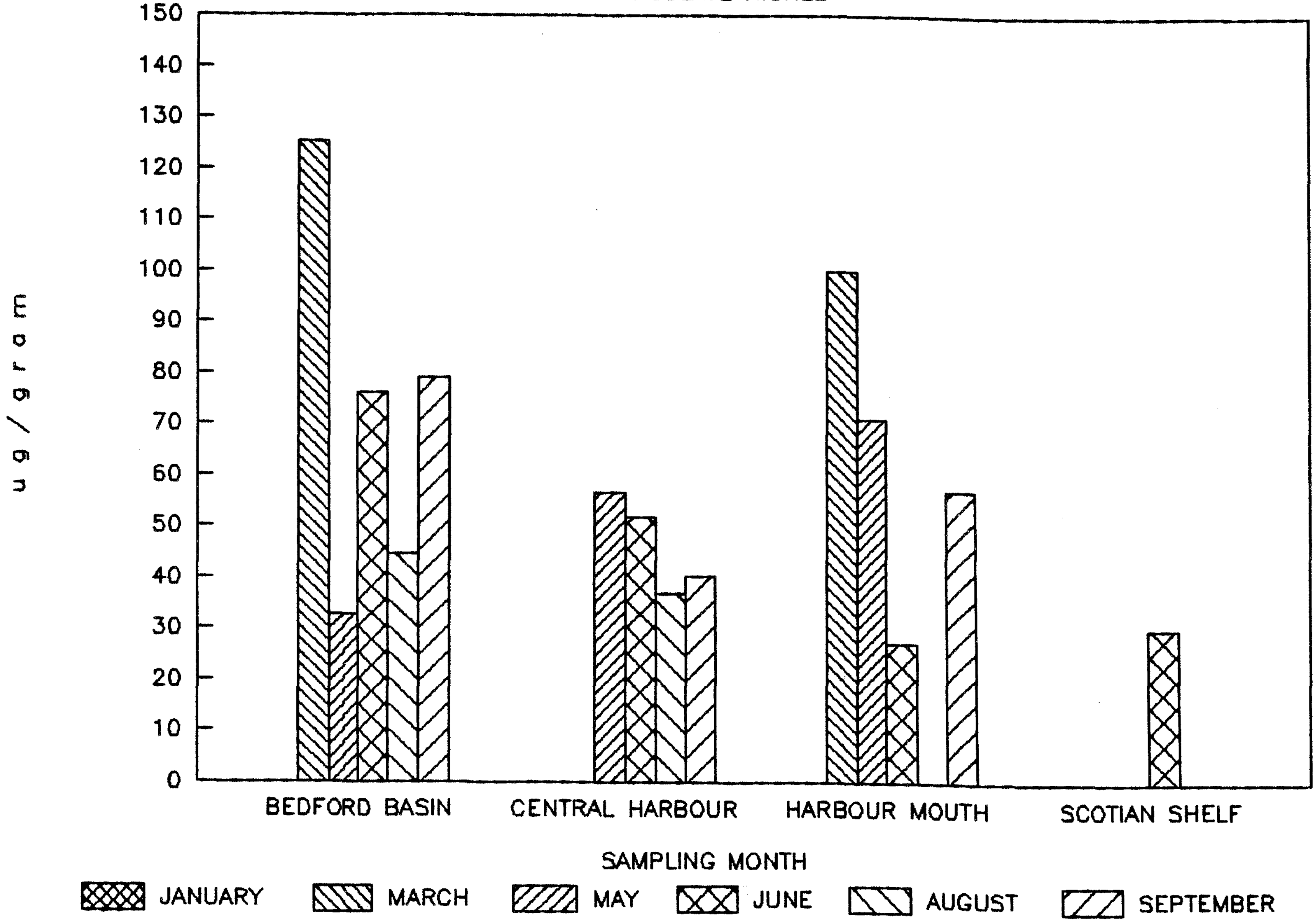

PARTICULATE CADMIUM
6
5
4
3
2
1
0
ug / gram
BEDFORD BASIN
CENTRAL HARBOUR
HARBOUR MOUTH
SCOTIAN SHELF
SAMPLING MONTH
JANUARY
MARCH
MAY
JUNE
AUGUST
SEPTEMBER

FIGURE : 5 (E)

PARTICULATE NICKEL



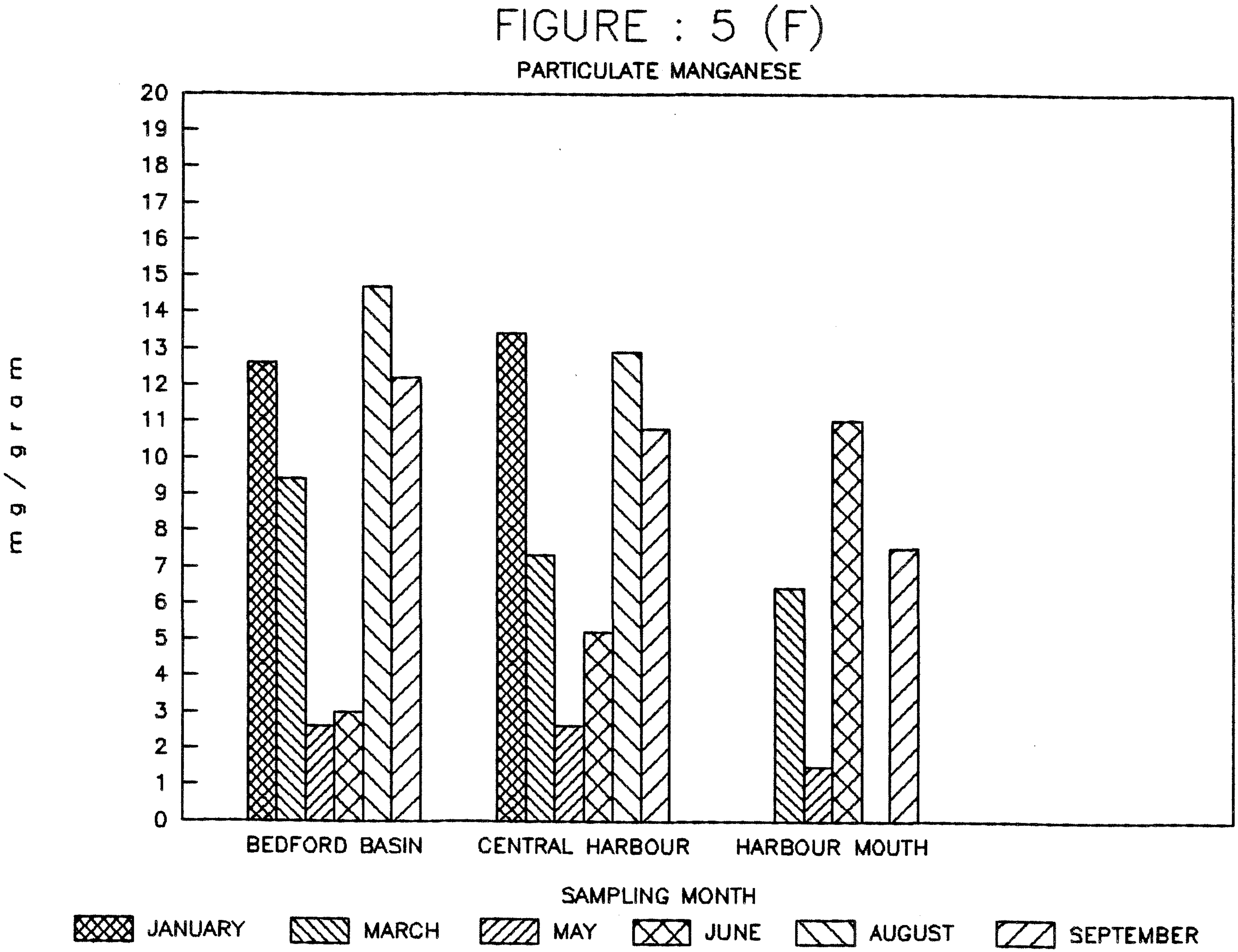


FIGURE : 5 (F)
PARTICULATE MANGANESE
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
mg/gram
BEDFORD BASIN
CENTRAL HARBOUR
HARBOUR MOUTH
SAMPLING MONTH
JANUARY
MARCH
MAY
JUNE
AUGUST
SEPTEMBER

FIGURE : 5 (G)

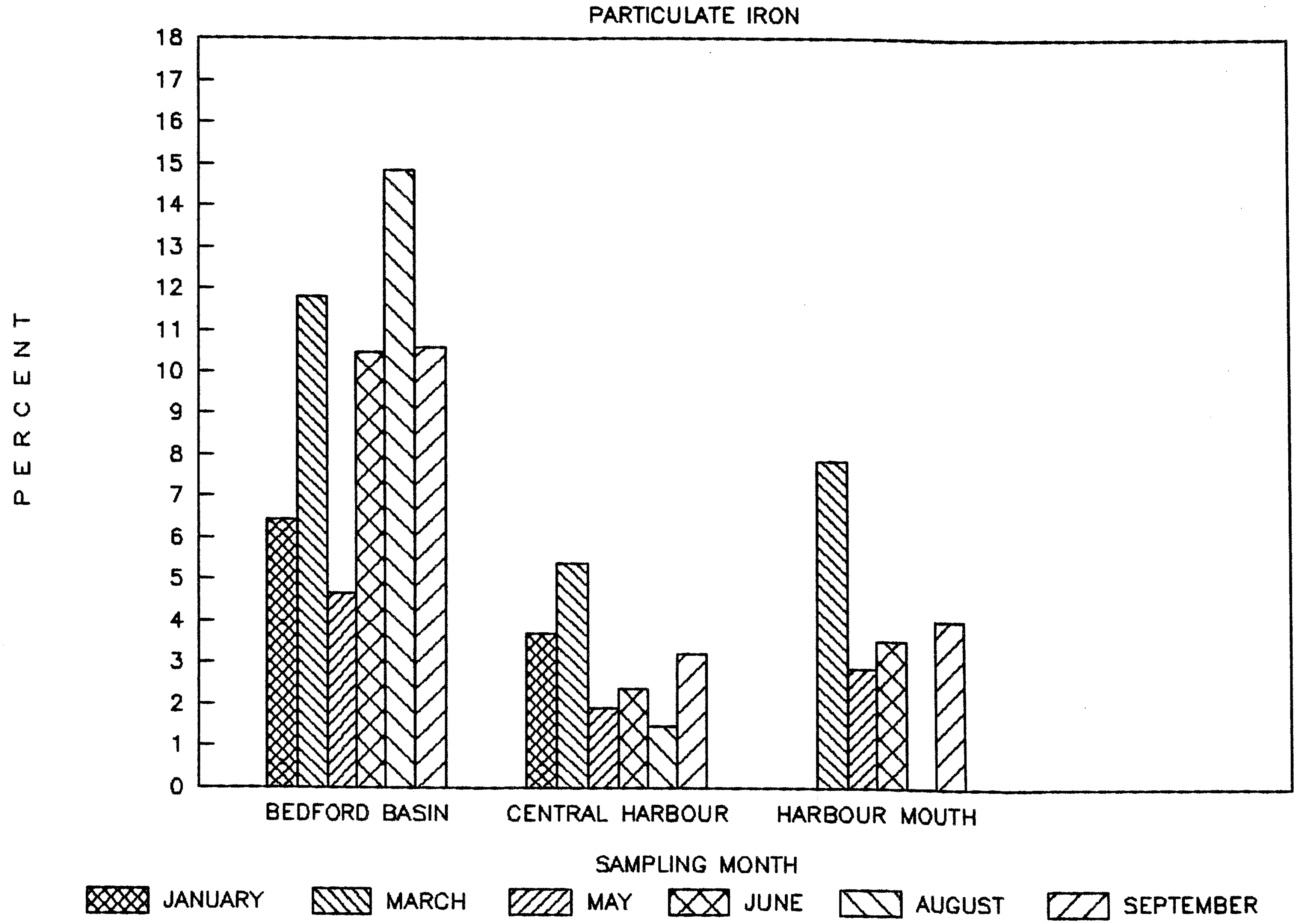

PARTICULATE IRON
PERCENT
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
BEDFORD BASIN
CENTRAL HARBOUR
HARBOUR MOUTH
SAMPLING MONTH
JANUARY
MARCH
MAY
JUNE
AUGUST
SEPTEMBER

FIGURE : 5 (H)

PARTICULATE ALUMINUM