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Surveillance Report EPS-5-AR-99-1
Atlantic Region

Canada

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February, 1999

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Keywords: TBT; butyltins; sediments; tributyltin; dibutyltin; monobutyltin

ABSTRACT

Due to the effects of butyltins on marine organisms which have been documented throughout the world, Canada implemented controls on the use of TBT as aquatic antifoulants in 1989. Samples of marine sediments obtained from large and small vessel harbours of Atlantic Canada in 1988 were compared with sediments obtained from those same areas in 1994. The results of the analysis of samples for tributyltin (TBT), dibutyltin (DBT) and monobutyltin (MBT) indicate that residue concentrations of total butyltin increased in half of the large vessel harbour locations and in approximately 90% of the small vessel areas. A determination of the percentage of TBT of the total butyltin content, in those samples, suggests greater fresh inputs in large vessel harbours than in pleasure craft marinas where the butyltin content was largely the result of older inputs. The risk to benthic organisms in large vessel harbours still remains high.

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CHANGEMENTS DANS LES CONCENTRATIONS DE RÉSIDUS DE BUTYLÉTAIN DANS LES SÉDIMENTS MARINS AU CANADA ATLANTIQUE ENTRE 1988 ET 1994

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Mots clés : TBT; butylétains; sédiments; tributylétain; dibutylétain; monobutylétain

RÉSUMÉ

Étant donné les effets des butylétains sur les organismes marins, effets qui ont été documentés dans le monde entier, le Canada a imposé en 1989 des restrictions sur l'emploi de TBT comme produits antisalissures. Nous avons comparé des échantillons de sédiments marins prélevés dans des ports pour gros et petits bateaux de la côte atlantique du Canada en 1988 à des sédiments recueillis dans les mêmes zones en 1994. Les résultats du dosage du tributylétain (TBT), du dibutylétain (DBT) et du monobutylétain (MBT) dans les échantillons indiquent que les concentrations de résidus de butylétain total ont augmenté dans la moitié des ports pour gros navires et dans environ 90 % des ports pour petites embarcations. La mesure du pourcentage de TBT dans la concentration de butylétain total, dans ces échantillons, permet de penser que les apports récents sont plus grands dans les ports pour gros navires que dans les ports de plaisance, où la présence de butylétain était en bonne partie attribuable aux apports plus anciens. Le risque pour les organismes benthiques demeure élevé dans les ports pour gros navires.

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INTRODUCTION

Organotin compounds are used extensively in Canada for a wide range of industrial purposes including: stabilization in polyvinyl chloride (67% of market); industrial catalysts (8% of market); as well as biocides such as antifouling agents, wood preservatives and slimicides (20% of market - Environment Canada 1993).

In the late 1970s and early 1980s evidence was collected that related organotin residues in the aquatic environment to a range of biological effects. Documented environmental effects have included reduced growth and shell deformation in bivalve molluscs (Waldock 1986) and the development of male sex organs by female gastropod molluscs (Smith 1981). Laboratory exposure induced effects include: acute lethality to marine animal larvae at environmentally relevant concentrations (Beaumont and Budd 1984, Roberts 1987); reproductive organ damage in starfish (Mercier et. al. 1994); neurotoxicity in rainbow trout, with accompanying behavioral changes (Triebskorn et. al. 1994a, Triebskorn et. al. 1994b) as well as growth inhibition and nitrification inhibition in bacteria (Miller and Cooney 1994).

Since the occurrence of environmental effects was correlated with use of organotins as antifouling agents and since that use represents the greatest source of organotin to the marine environment, many countries implemented controls on such uses (Waldock 1986). In 1989, Canada restricted the use of tributyltin antifoulant coatings under the authority of the Pest Control Products Act. The use of tributyltin paints was restricted to vessels over 25 metres in length, with the exception of aluminum hulled vessels or vessels with aluminum outboard marine fittings, and the leach rate for TBT from paints could be no greater than 4 $\mu g/cm^2/day$. Since the intent of those controls was to reduce the introduction of TBT to the marine environment, it was of interest to determine whether environmental burdens had changed with time after the controls were implemented. This study was undertaken to compare TBT concentrations in sediments obtained from various coastal locations in the Atlantic Region of Canada in 1994 with samples obtained from the same locations in 1988, one year prior to the implementation of controls.

METHODS

Locations

Sampling location selection (Figure 1) was based on the predominant source of TBT contamination. One group were those areas where the source of TBT would be primarily large ocean going vessels (commercial shipping and military) while the other group were areas where the source would be from small fishing and pleasure craft.

The large vessel locations included: Halifax Harbour; Liverpool Harbour and Port Mouton Harbour, all in Nova Scotia. Halifax Harbour has several ship repair facilities, a naval base and a number of docking areas for international shipping traffic. Liverpool Harbour is a major berthing area for offshore fishing vessels and also has a ship repair facility. Port Mouton is a berthing area for fishing vessels.

The small fishing vessel/pleasure craft sites consisted of: a marina at Chester, Nova Scotia; a mixed fishing vessel pleasure craft area at Lunenburg, Nova Scotia; a marina at Oak Island, Nova Scotia; a primarily small fishing vessel mooring area at Sambro, Nova Scotia and South Shore Marina, Nova Scotia which is primarily a pleasure craft area. Those areas moor a maximum of 300 boats.

Sediments were collected at one to four locations from each site in acid washed Teflon® core tubes by divers. Sediment samples were immediately frozen and maintained at -20°C. Prior to analysis sediment cores were extruded. For the 1988 samples the top 0-10 cm of each core was homogenized for analysis, however, in order to determine chronological differences, the 1994 cores were sectioned such that the 0-2 cm, 2-4 cm and 4-7 cm layers could be analyzed separately. For comparing the data between years, the concentrations in individual layers were combined in 1994.

- **Butyltin Analysis**

The chemical analysis of butyltin compounds in sediment samples was conducted by Environment Canada staff in their laboratory located at the Bedford Institute of Oceanography, Dartmouth, Nova Scotia. Procedures used for both the 1988 and 1994 surveys were very similar, however, minor modifications to the method were made in 1994 to enhance analytical quality control and reduce analysis time.

Air-dried sediment was ground to a fine consistency using a glass mortar and pestle. Ten to twenty grams of the dried material was refluxed for two hours with 75 mL of fresh 0.1% tropolone/benzene in a boiling flask coupled with a water-cooled condenser. The flask was centrifuged and the extract was dried by filtering through a glass column containing anhydrous sodium sulphate. The remaining solid material in the flask was shaken with an additional 25 mL volume of solvent and re-centrifuged. The resulting extract was passed through the sodium sulphate column and combined with the previous extract. The solvent was reduced to 1-2 mL and organotins in the concentrated extract were ethylated with 2 ml ethylmagnesium bromide in 2 N THF. After neutralization with HCL, and the solvent portion was separated from the aqueous phase and cleaned up on glass column (1.0 cm ID) containing 5% deactived silica gel (5 cm) sandwiched between 1-cm layers of sodium sulphate (1 cm). The organotins in extracts were eluted from the column with 60 mL hexane which was collected and concentrated to 1 mL prior to gas chromatographic analysis.

Butyltins in sample extracts were analyzed on an HP 5890 gas chromatograph coupled to an HP flame photometric detector (FPD) that was equipped with a 500 mm long-pass filter. Gas chromatographic separation of the moni, di, tri, and tetrabutyltin ethyl derivatives was accomplished by cool on column injection of extracts onto a 30 m x 0.25 mm DB-5 capillary column. Butyltin compounds in sample were identified and quantified by external standard technique using commercially purchased butyltin reference standards. Butyltin sediment concentrations are expressed as the corresponding cation.

The following modifications were made to the analytical method in 1994 in order to avoid the use of benzene, enhance analytical quality control and reduce analysis time:

1. A known amount of tripropyltin which served as a recovery surrogate was spiked into each sample prior to extraction.

2. In place of the solvent reflux extraction used in 1988, sediment samples were mixed with 8 g sodium chloride; 20 mL of distilled water, 20 mL hydrobromic acid and shaken with 30 mL of 0.1% tropolone/toluene (w/v) for one hour using a mechanical shaker. The procedure was repeated and the extracts were combined and dried over anhydrous sodium sulphate. The solvent was concentrated and exchanged with hexane prior to derivatization with ethylmagnesium bromide and column clean up.

3. Dipropyldipentyltin which served as an internal standard was added to each sample extract immediately before the gas chromatographic analysis.

Accuracy and precision of the method were verified by the requisite analysis of quality control samples with each batch of ten samples analyzed. The QC samples included a method blank, a duplicate, a matrix spike, and a certified reference material (1994). In 1994, each sample also was spiked with a tripropyltin recovery surrogate prior to extraction. A summary of the QC results obtained is given in Table 1. The detection limits for individual butyltins in sediment ranged from 0.001 µg/g to 0.01 µg/g dry weight.

RESULTS AND DISCUSSION

The results of analyses of sediments collected in 1988 and 1994 (Tables 2 and 3), expressed as total quantities of butyltin cation, indicate that in both years, the concentrations of butyltin were generally higher in the large vessel traffic areas than in the small vessel areas. In approximately 12% of the locations sampled in 1988, concentrations of TBT were above the 0.14 µg/g chronic toxicity threshold for benthic organisms proposed by Cardwell and Meadon (1989). In 1994, approximately 25% of the locations exceeded that threshold, and most of the exceeding locations (40%) were in the large vessel traffic areas. Matthiessen and Thain (1989) observed that concentrations of 0.041 µg Sn/g dry weight in sediments was sufficient to reduce populations of the polychaete *Scoloplos armiger* and the amiphod *Urothoe poseidonis*. In 1988 approximately 38% of our sample sites exceeded that value and in 1994, approximately 70% of sample locations were above that value. No butyltins were measured at the level of detection (<0.002 µg/g dry weight) at the control site in either year.

Other reports on the butyltin contamination of Halifax Harbour ranged from below the limit of detection in unspecified locations (Maguire et. al. 1986) up to 87 µg/g in sediments near a ship repair facility (Hennigar and Garron 1992). A recent study by Chau et. al. 1997 measured a concentration of 1.8 µg/g of total butyltin (reported as Sn dry weight) from an unspecified location in Halifax Harbour. Sediments obtained previously from adjacent to a ship repair facility in Liverpool Harbour had a TBT concentration of 420 µg/g (Hennigar and Garron 1986) which were much higher than the maximum of 14 µg/g which we measured near that same facility (the highest concentrations reported from this study). Concentrations in sediments reported here were variable as have been concentrations in sediments reported by others. Prior to regulation implementation Maguire et. al. (1986) reported TBT concentrations as high as 10.78 µg/g dry wt. in Vancouver Harbour sediments, and Stewart and de Mora (1992) reported concentrations as high as 38 µg/g dry wt. in the vicinity of ship repair facilities in Fiji.

Measured concentrations of tributyltin in sediments at various times after regulation implementation have been of the order 0.019 - 0.069 µg/g dry wt. in various river sediments of the U.K. (Dowson et. al. 1994); 0.014 - 0.717 µg/g dry wt. in freshwater sediments near marinas (Wong et. al. 1994); <0.005 µg/g dry wt to 0.161 µg/g dry wt. (Yonezawa et. al. 1994, Quevauviller et. al. 1994). The maximum concentrations reported here (14.0 µg/g dry wt.) in the large vessel traffic are well above those. They are also above those of Chau et. al. (1997) who sampled sediments, surface water and effluents from approximately 130 locations across Canada in 1994 and the highest butyltin concentrations they measured in marine sediments was 2.5 µg Sn/g dry weight. That was found close to a shipyard in Burrard Inlet, British Columbia.

Comparison of the two large vessel areas (Halifax Harbour and Liverpool) where samples were obtained from similar locations in both years (Figure 2) indicate that for three of the six sites, tributyltin concentrations were higher in 1994 than in 1988 and in locations where concentrations decreased, the reductions were small. A comparison of the small vessel sites for the two years (Figure 3) revealed that for four of the nine sample locations, tributyltin concentrations were greater in 1994 and those increases were generally substantial.

A comparison of the percentage of TBT of the total butyltin in sediments between 1988 and 1994 is presented in Table 4. Very different patterns are evident in the two site categories. Overall, Halifax Harbour had similar percentages of TBT in the two years and those percentages approximated those recorded in the U.K. which were thought to be indicative of fresh TBT sources (Chau et. al. 1997; Dowson et. al. 1994). Most of the source of TBT to Halifax Harbour would be from large shipping and military vessels while berthed or during repair of such vessels. The lack of change in the source strengths no doubt reflects a lack of change in TBT coating use patterns on large vessels - which are not required by regulation. The apparent increase in butyltin residues along with the apparent fresh inputs indicate that, as has been observed by others (Chau et. al. 1997; de Mora 1995), commercial shipping traffic and ship repair facilities now are probably the most important source of butyltins to the marine environment.

Liverpool Harbour, on the other hand, while demonstrating some of the highest concentrations, had a decrease in the amount of TBT contributing to the total quantity of butyltin between 1988 and 1994, indicating a probable reduction in TBT input. Since this harbour is primarily used by the offshore fishing fleet, that probable reduction in use would be for non-regulatory reasons since many of those vessels would be smaller than the 25 m minimum length restriction. The pleasure craft areas, on the other hand, all demonstrated reductions in the percentage of TBT in sediments. Those reductions were very similar to those reported by Dowson et. al. (1995) in boat traffic areas within three years of control implementation.

It would appear, that a reduction of TBT inputs has occurred in the pleasure craft areas and that the controls have been effective in those use areas. Such observations are consistent with previous reports where residue concentrations have declined in pleasure craft areas as a result of the implementation of controls (Chau et. al. 1997; Dowson et. al. 1994, Wong et. al. 1994), however, deposition may still be occurring in commercial vessel traffic and repair areas (Stuer-Lauridsen and Dahl 1994, Quevauviller et. al. 1994). It is not possible to determine, from the data reported here, whether TBT concentrations in large vessel traffic areas have peaked and are now starting to decline.

The changes in butyltin concentrations in various sediment layers are presented in Figures 4 and 5. When concentrations of each butyltin species were regressed separately against depth, no significant and consistent differences were obvious in either the large or small vessel traffic areas. In both the large and small vessel areas, locations were equally divided between those whose TBT concentrations increased with depth and those whose concentrations decreased with depth.

In summary, both 1988 and 1994, butyltin residues were higher in areas of large vessel traffic and repair, compared with small vessel marinas. Tributyltin residues in sediment from large vessel traffic and repair locations were higher in half of the sampling locations in 1994 compared with 1988, however, in those instances where TBT concentrations increased, that increase was substantial. Small vessel area sediments generally had lower concentrations of TBT in 1994 compared with those in 1988.

The observation that in small vessel locations TBT was a significantly higher percentage of total butyltin in all the 1988 samples compared with 1994 samples indicates a reduction in the inputs in the small vessel areas. The lack of a similar reduction of TBT as a percentage of the total butyltin in large vessel areas indicates that similar reductions in inputs may not be occurring in those harbours.

The 1989 controls on the use of TBT as an antifoulant appear to have been effective in reducing inputs to pleasure craft areas, however, that is not the case for large vessel areas. Up to 70% of the sediments obtained from the large vessel areas remain above those concentrations known to cause population effects in benthic invertebrates.

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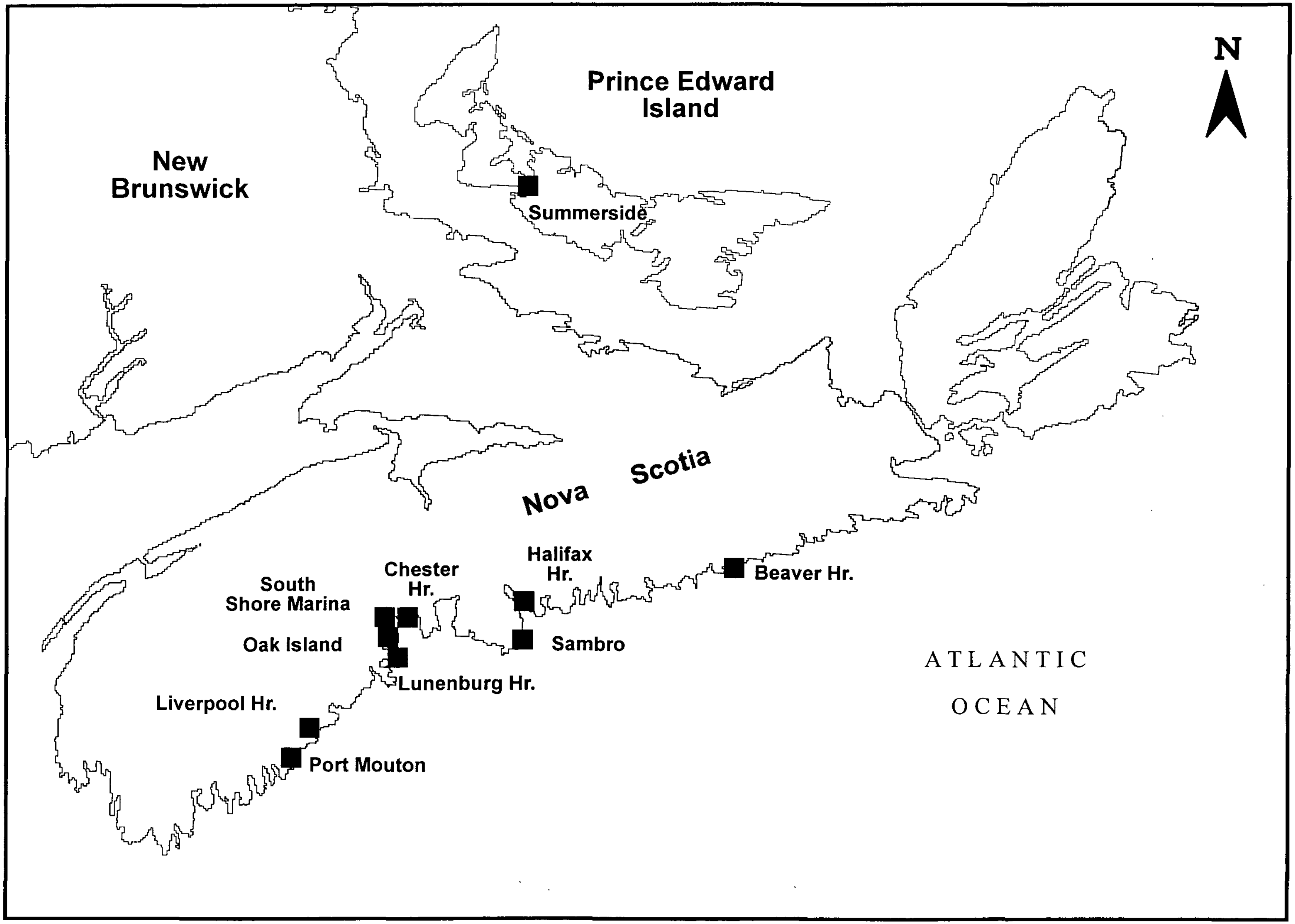


Figure 1: Sediment sampling locations

Figure 2. Tributyltin concentrations (ug/g dry wt.) from large vessel traffic areas.

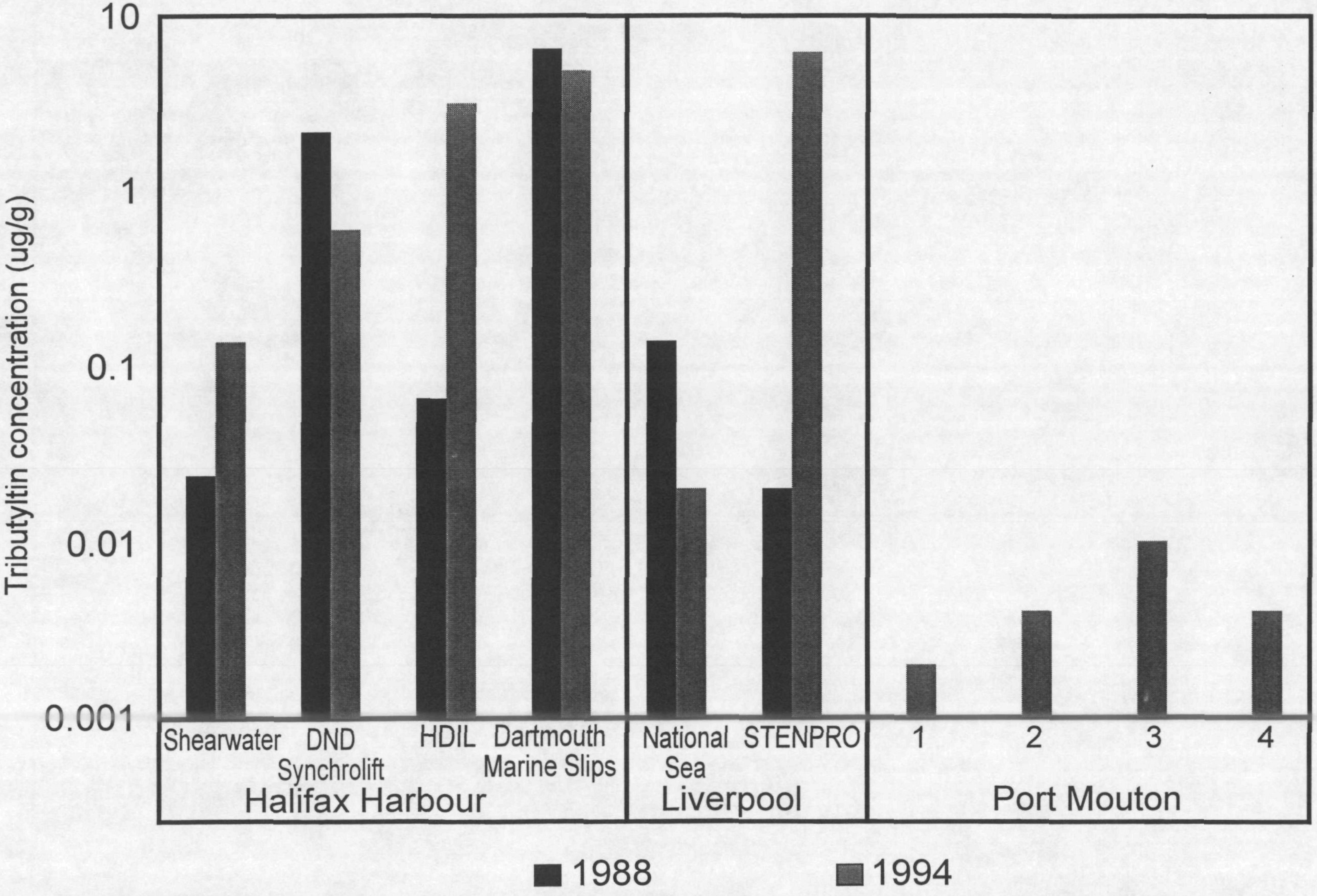


Figure 3. Tributyltin concentrations (ug/g dry wt.) from small vessel traffic areas.

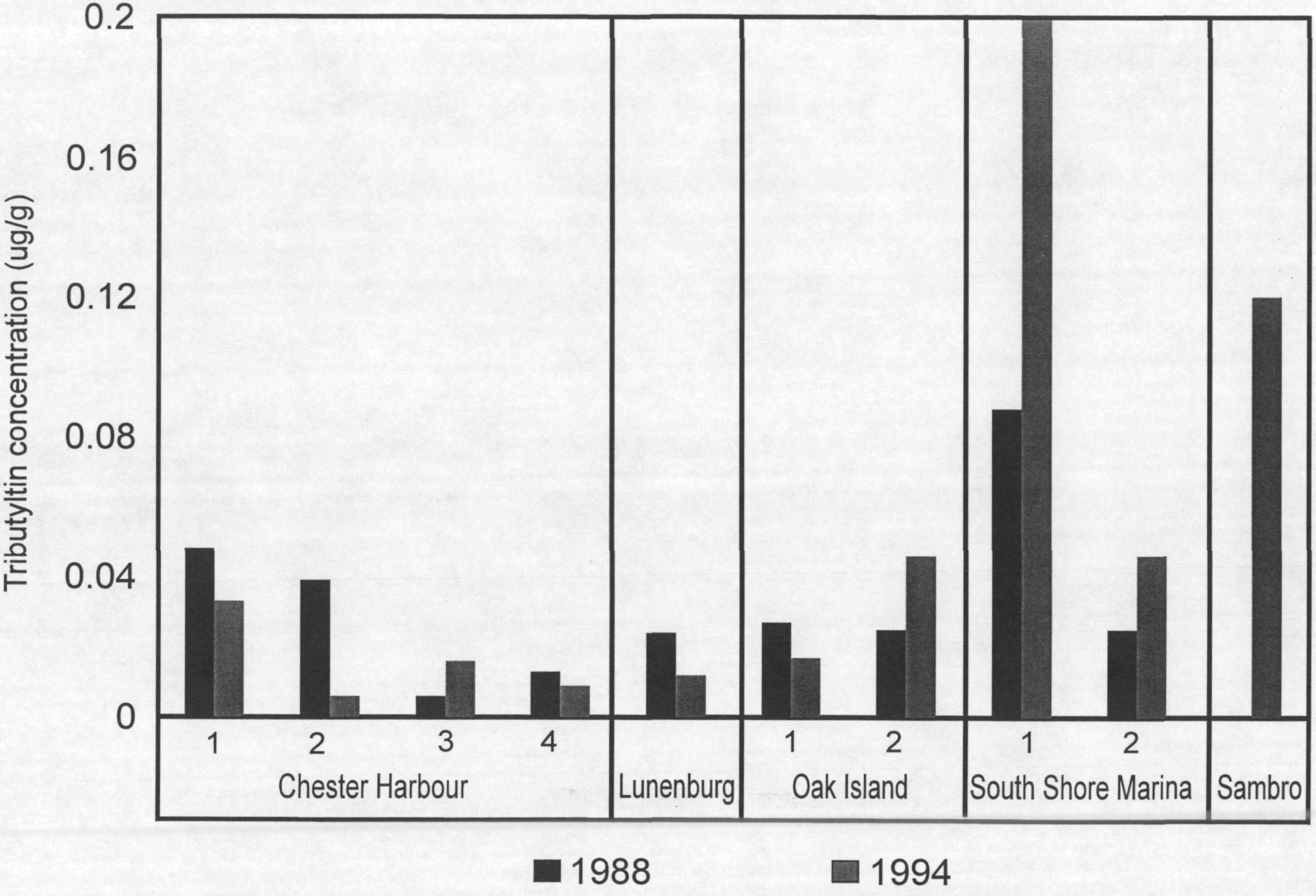
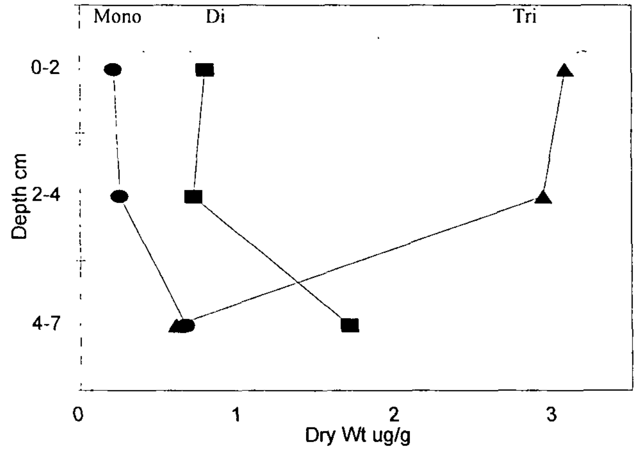
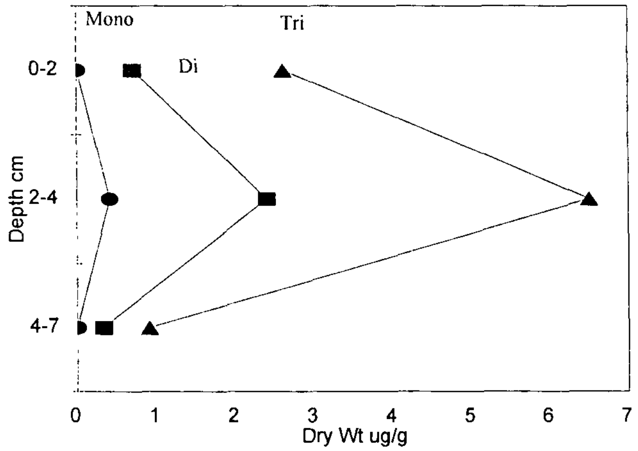


Figure 4. Depth profiles of butyltin concentrations in sediments from large vessel traffic areas in 1994.*

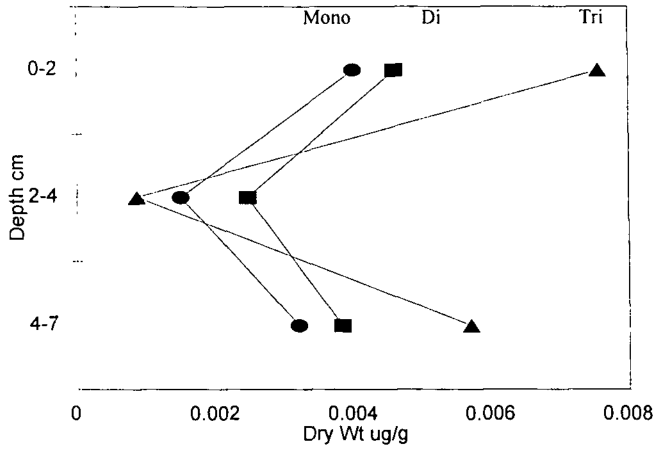
a. Halifax Harbour



b. Liverpool



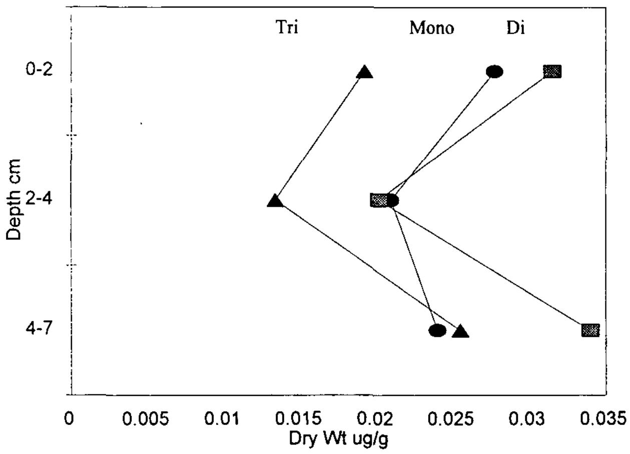
c. Port Mouton



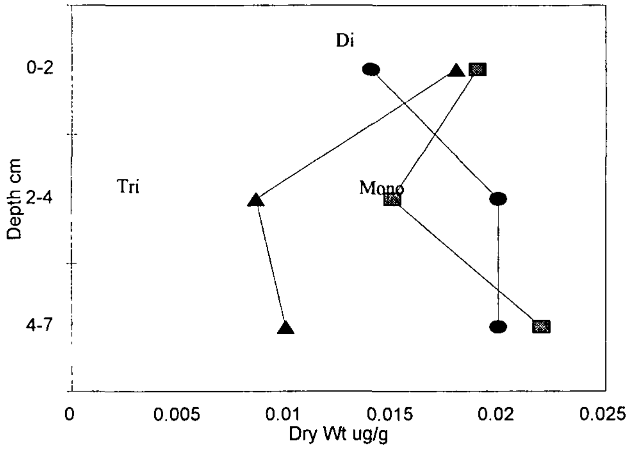
* presented as means of all sample sites

Figure 5. Depth profiles of butyltin concentrations in sediments from small vessel traffic areas in 1994.*

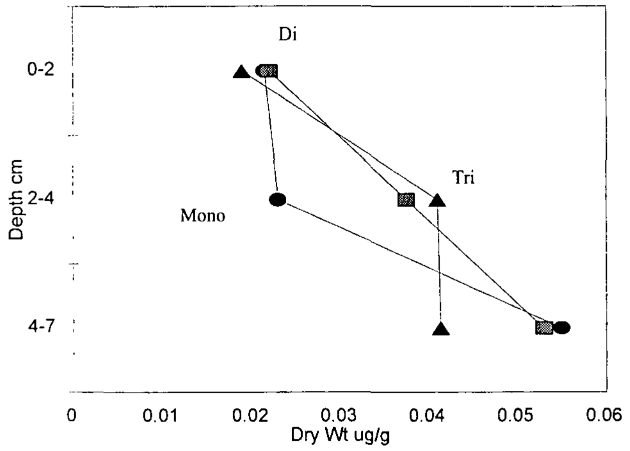
a. Chester



b. Lunenburg



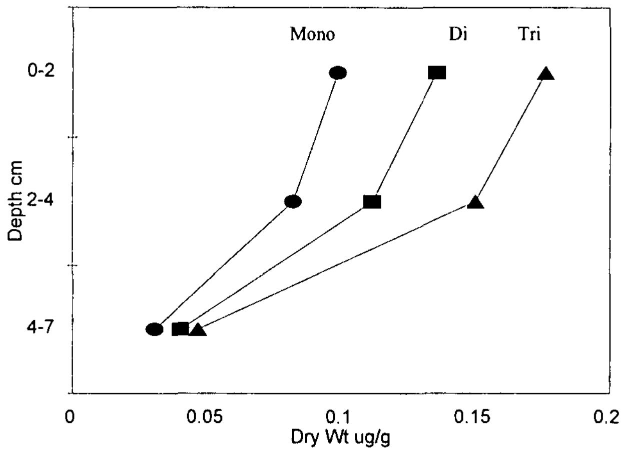
c. Oak Island



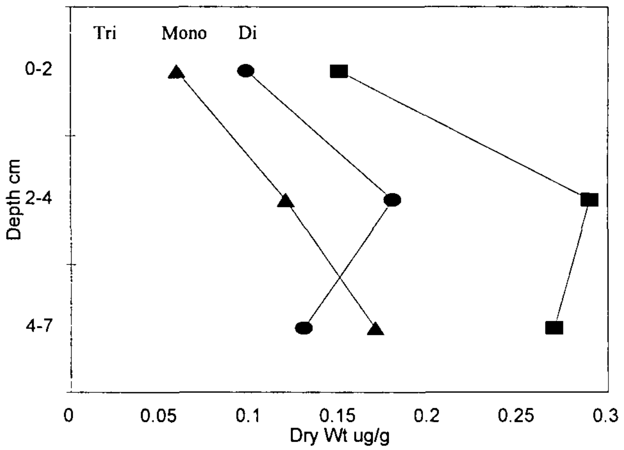
*presented as means of all sample sites

Figure 5. Depth profiles of butyltin concentrations in sediments from small vessel traffic areas in 1994.*

d. South Shore Marina



e. Sambro



*presented as means of all sample sites

TABLE 1 - ANALYTICAL QUALITY CONTROL RESULTS

Organotin	**Matrix**[1] **1989 (n=6)**	 **1994 (n=6)**	**CRM**[2] **1994 (n=6)**	**Surrogate Recoveries 1994 (n=73)**
Monobutyltin	100±9	60±18	-	-
Dibutyltin	75±20	76±5.6	86±10	-
Tributyltin	91±16	69±9.9	86±4.4	-
Tetrabutyltin	n/a[3]	77±9.4	n/i[4]	-
Tripropyltin[5]	n/a	66±16	66±16	60±14

[1] Matrix Spike % recovery: concentrations 0.06-0.07 μg/g (1988); 0.15 μg/g (1994).

[2] % recovery of NRC CRM PACS-1.

[3] Not analyzed.

[4] Not included in CRM.

[5] Sediment concentration of tripropyltin surrogate added to each sample in 1994: 0.15 μg/g.

TABLE 2 - 1988 SURFICIAL SEDIMENT (MEAN OF THREE SEDIMENT LEVELS) ANALYSES FOR BUTYLTINS

(μg/g of butyltin cation - dry wt.)

	Monobutyltin	Dibutyltin	Tributyltin	Total Butyltin
Large Vessel Areas				
Halifax Harbour				
Shearwater*	0.003	0.011	0.024	0.038
DND Syncrolift*	0.078	0.22	2.2	2.50
HDIL*	0.018	0.024	0.066	0.11
Dart Marine Slips*	0.9	1.9	6.5	9.30
Liverpool				
National Sea	0.006	0.029	0.14	0.18
STENPRO	<0.003	<0.003	0.02	0.02
Summerside	<0.01	0.010	0.069	0.079
Small Vessel Areas				
Chester Harbour				
1	<0.01	<0.01	0.048	0.048
2	<0.001	0.002	0.039	0.041
3	<0.001	0.002	0.006	0.008
4	<0.002	0.002	0.013	0.015
Lunenburg	<0.001	0.001	0.024	0.025
Oak Island				
1	<0.003	<0.003	0.027	0.027
2	<0.005	<0.005	0.025	0.025
South Shore Marina				
1	<0.01	<0.023	0.088	0.088
2	<0.005	0.005	0.025	0.03
Control Site				
Beaver Harbour				
1	<0.001	<0.001	<0.001	
2	<0.001	<0.001	<0.001	
3	<0.001	<0.001	<0.001	

* Mean of replicate core samples.

TABLE 3 - 1994 SURFICIAL SEDIMENT (MEAN OF THREE SEDIMENT LAYERS) ANALYSES FOR BUTYLTINS (µg/g - dry wt.)

Large Vessel Areas

	Monobutyltin	**Dibutyltin**	**Tributyltin**	**Total Butyltin**
Halifax Harbour				
Shearwater	0.12 *	0.92 *	0.14 *	1.18 *
DND Syncrolift	0.05	0.10	0.61	0.76
HDIL	0.38 *	0.63 *	3.2 *	4.21 *
Dartmouth Marine Slips	0.96 *	3.23 *	4.87	9.06
Liverpool				
National Sea	0.005	0.010	0.02	0.035
STENPRO	0.42 *	3.08 *	8.7 *	12.61 *
Port Mouton (No 1988 comparison data)				
Slipway	0.006	0.005	0.002	0.013
Mout + 20f	0.002	<0.002	0.003	0.005
Gov Whrf 1	0.001	0.006	0.010	0.017
Gov Whrf 2	0.002	0.003	0.004	0.009
Small Vessel Areas				
Chester Harbour				
1	0.036 *	0.053 *	0.035	0.124 *
2	0.007 *	0.008 *	0.006	0.021
3	0.021 *	0.024 *	0.016 *	0.061 *
4	0.028 *	0.012 *	0.009	0.049 *
Lunenburg				
Back Harbour	0.018 *	0.022 *	0.012	0.052 *
Oak Island				
1	0.020 *	0.021 *	0.017	0.058 *
2	0.049 *	0.054 *	0.048 *	0.151 *
South Shore Marina				
1	0.128 *	0.16 *	0.20 *	0.488 *
2	0.012 *	0.03 *	0.046 *	0.088 *
Sambro Harbour (No 1988 comparison data)				
Sambro	0.136	0.24	0.12	0.496
Control Site				
Beaver Harbour				
1	<0.002	<0.002	<0.002	
2	<0.002	<0.002	<0.002	
3	<0.002	<0.002	<0.002	
4	<0.002	<0.002	<0.002	

* Concentrations are elevated from 1988 sampling at equivalent sites.

TABLE 4 - TBT PERCENTAGE OF TOTAL BUTYLTINS

	% TBT*	
	1988	**1994**
LARGE VESSEL AREAS		
Halifax		
Shearwater	63.2	11.9
DND Syncrolift	88.0	80.3
HDIL	60.0	76.0
Dart Marine Slips	69.9	53.8
Liverpool		
National Sea	77.8	57.1
STENPRO	100	69.0
Summerside	87.3	
Port Mouton		
Slipway		15.4
Mout + 20f		60.0
Gov Whrf 1		58.8
Gov Whrf 2		44.4
SMALL VESSEL AREAS		
Chester Harbour		
1	100	28.2
2	95.1	28.6
3	75.0	26.2
4	86.7	18.4
Lunenburg	96.0	23.1
Oak Island		
1	100	29.3
2	100	31.8
South Shore Marina		
1	100	41.0
2	83.3	52.3
Sambro		24.2

* % TBT = Percentage of tributyltin, where totalbutyltin is sum of TBT, DBT and MBT concentrations.

TABLE 5 - 1994 SEDIMENT ANALYSES FOR BUTYLTINS
(µg/g of butyltin cation - dry wt.)
LARGE VESSEL AREAS

	Sediment Layer	Monobutyltin	Dibutyltin	Tributyltin
Halifax Harbour				
Shearwater	0-2 cm	0.025	0.084	0.11
	2-4 cm	0.044	0.091	0.094
	4-7 cm	0.29	0.75	0.23
DND Syncrolift	0-2 cm	0.097	0.21	1.1
	2-4 cm	0.039	0.072	0.56
	4-7 cm	0.021	0.023	0.17
HDIL	0-2 cm	0.19	0.36	3
	2-4 cm	0.48	0.99	4.7
	4-7 cm	0.46	0.54	1.9
Marine Slips	0-2 cm	0.54	2.5	8.1
	2-4 cm	0.44	1.7	6.4
	4-7 cm	1.9	5.5	0.12
Liverpool				
National Sea	0-2 cm	0.0052	0.0099	0.019
	2-4 cm	0.0065	0.01	0.019
	4-7 cm	0.004	0.0091	0.026
STENPRO	0-2 cm	---	1.4	5.2
	2-4 cm A	0.56	4	12
	2-4 cm B	1.1	5.6	14
	4-7 cm	---	1.3	3.6
Port Mouton				
Slipway	0-2 cm	0.0036	0.0026	<0.0020
	2-4 cm	0.0045	0.0045	<0.0020
	4-7 cm	0.01	0.0093	0.0065
Mout + 20f	0-2 cm	0.0029	<0.0020	<0.0020
	2-4 cm	<0.0020	<0.0020	<0.0020
	4-7 cm	0.0020	<0.0020	0.0091
Gov Whrf 1	0-2 cm	0.0036	0.0097	0.019
	2-4 cm	<0.0020	0.0029	0.0026
	4-7 cm	<0.0020	0.0045	0.0071
Gov Whrf 2	0-2 cm	0.0027	0.003	0.0038
	2-4 cm	<0.0020	0.0031	0.0041
	4-7 cm A	0.0043	0.0024	0.0029
	4-7 cm B	0.0024	0.0025	0.0059

TABLE 6 - 1994 SEDIMENT ANALYSES FOR BUTYLTINS
(µg/g of butyltin cation - dry wt.)
SMALL VESSEL AREAS

	Sediment Layer	Monobutyltin	Dibutyltin	Tributyltin
Chester Harbour				
Chester 1	0-2 cm	0.044	0.07	0.036
	2-4 cm	0.028	0.034	0.025
	4-7 cm A	0.033	0.054	0.037
	4-7 cm B	0.04	0.054	0.04
Chester 2	0-2 cm	0.019	0.019	0.015
	2-4 cm	0.0027	0.0035	0.0043
	4-7 cm	<0.0020	<0.0020	<0.0020
Chester 3	0-2 cm	0.017	0.018	0.0097
	2-4 cm	0.021	0.026	0.012
	4-7 cm	0.025	0.028	0.025
Chester 4	0-2 cm	0.031	0.019	0.016
	2-4 cm	0.032	0.017	0.012
	4-7 cm	0.022	---	---
Lunenburg				
Back Harbour	0-2 cm	0.014	0.019	0.018
	2-4 cm	0.02	0.025	0.0086
	4-7 cm	0.02	0.022	0.01
Oak Island				
Marina 1	0-2 cm	0.014	0.011	0.0088
	2-4 cm	0.029	0.033	0.029
	4-7 cm	0.016	0.019	0.014
Marina 2	0-2 cm	0.03	0.056	0.068
	2-4 cm	0.069	0.013	0.015
	4-7 cm A	0.04	0.062	0.046
	4-7 cm B	0.056	0.084	0.063
South Shore Marina				
Marina 1	0-2 cm	0.19	0.24	0.28
	2-4 cm	0.15	0.19	0.26
	4-7 cm	0.045	0.052	0.066
Marina 2	0-2 cm	0.0073	0.031	0.072
	2-4 cm	0.014	0.033	0.04
	4-7 cm	0.016	0.028	0.027
Sambro				
Sambro Harbour	0-2 cm	0.098	0.15	0.059
	2-4 cm	0.18	0.29	0.12
	4-7 cm	0.13	0.27	0.17