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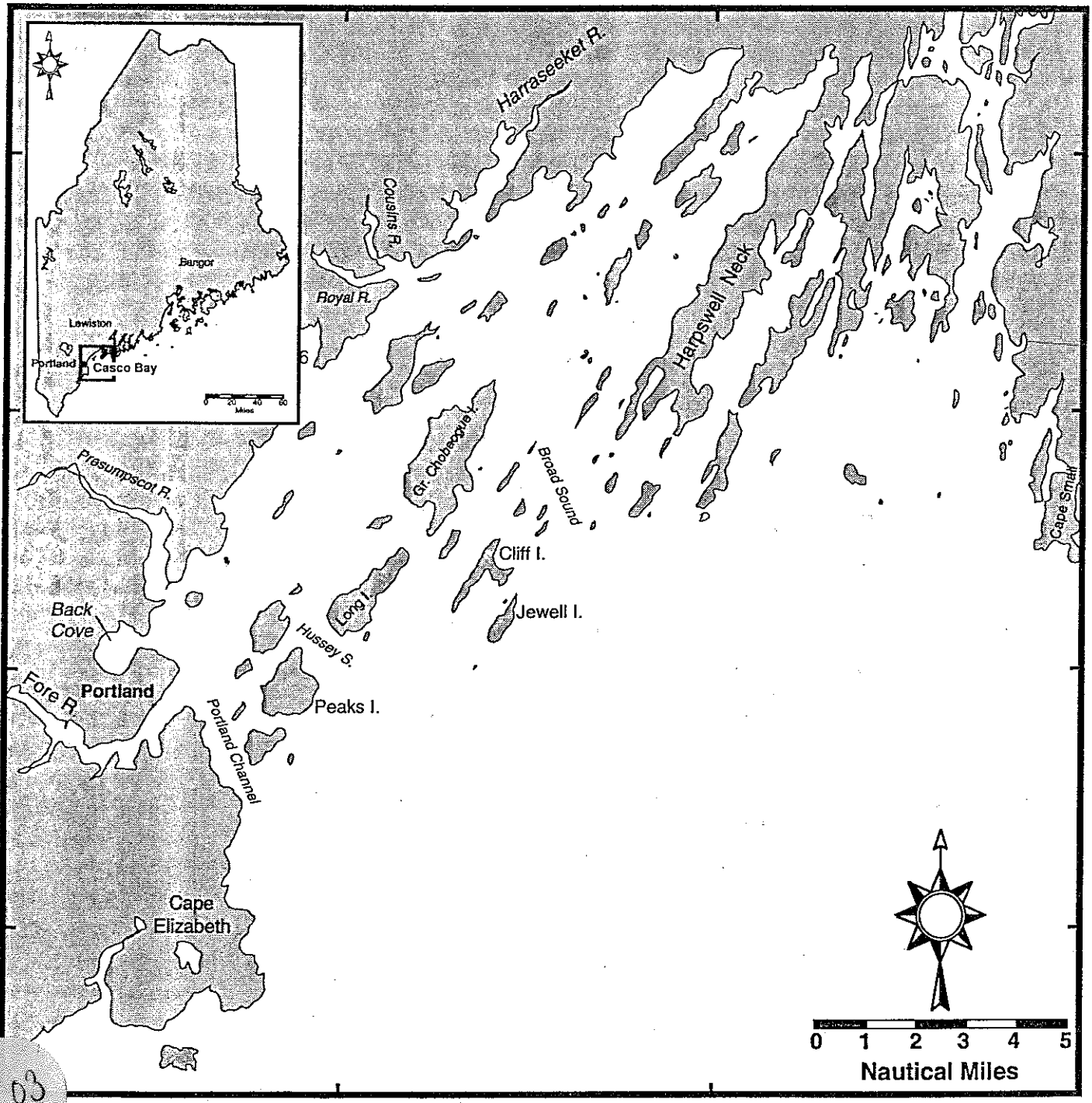
Assessment of Butyltins, PCDD/PCDF and Planar PCB Contaminants in Sediments from Casco Bay

GERG The Geochemical & Environmental Research Group



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November 1995

FINAL REPORT

ASSESSMENT OF BUTYLTINS, PCDD/PCDF AND PLANAR PCB CONTAMINANTS IN SEDIMENTS FROM CASCO BAY, MAINE, USA

prepared by the

GEOCHEMICAL AND ENVIRONMENTAL RESEARCH GROUP AND
THE DEPARTMENT OF OCEANOGRAPHY
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prepared for the

CASCO BAY ESTUARY PROJECT

November 1995

1. PROJECT NAME: Assessment of Contaminants in Sediments from Casco Bay

2. PROJECT REQUESTED BY: Casco Bay Estuary Project

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1.0 EXECUTIVE SUMMARY

This project was conducted for the Casco Bay Estuary Project and the U.S. Environmental Protection Agency Region 1. The purpose of this study was to extend a comprehensive evaluation of sediment quality in Casco Bay to include butyltins, 2,3,7,8- polychlorinated dibenzo-*p*-dioxins/polychlorinated dibenzofurans (PCDD/PCDF) and planar polychlorinated biphenyls (PCB). Butyltins, PCDD/PCDF and planar PCB were detected in sediments from all areas of Casco Bay. The concentrations were highest near potential input sources. For example, the butyltin concentrations are highest near marinas and boat anchorages while PCDD/PCDF and especially 2,3,7,8-tetrachloro-*p*-dioxin/tetrachloro dibenzofurans (TCDD/TCDF) had higher concentrations near the Presumpscot River sites, 10 miles down stream of a pulp and paper mill. There are also exceptions, for example the higher PCDD/PCDF concentrations in East Bay are not near known point sources, but may be the result of transport into the bay from sources in the Kennebec/Androscoggin River or localized combustion sources. The concentrations of butyltins, PCDD/PCDF and planar PCB found in Casco Bay sediments are in the range expected when compared to similar estuarine areas.

In spite of the low concentration in sediment, detection of 2,3,7,8-TCDD/TCDF in lobster tissue and tomalley indicate these compounds are bioavailable and have resulted in an advisory regarding consumption of lobster tomalley from Casco Bay (Mower 1994). The sediment contaminant studies document the presence of contaminants in Casco Bay. Additional studies are needed to determine if PCDD/PCDF isomers including 2,3,7,8-TCDD/TCDF, planar PCB, butyltins and other contaminants (metals, chlorinated pesticides, polycyclic aromatic hydrocarbons and PCB) are bioavailable to seafood and reach concentrations that pose a human health concern for seafood consumption from Casco Bay. This could be accomplished by the analyses of fish and shellfish from the areas where the sediments had the highest concentrations of toxic contaminants.

If the results from this study indicate a potential health risk, then additional studies of the relative importance of input sources to the affected areas could be under taken. These studies might include analyses of sediment further up-stream in the Presumpscot River, municipal waste, air

and precipitation samples. This would help to establish the relative importance of these sinks and sources of toxic contaminants.

A summary of the analytical results of this study are presented here. It should be noted that all of the concentrations cited in this report are on a dry weight bases (i.e., weight of contaminant per gram dry weight of sample). The complete analytical report for this project, including the quality assurance and quality control analytical results are provided in Appendix A. The analytical methods employed to produce the data discussed in this report are detailed in the Geochemical and Environmental Research Group's (GERG) Standard Operating Procedures provided in Appendix B.

2.0 INTRODUCTION AND BACKGROUND

2.1 Overview

Casco Bay is located on the coast of Maine in Cumberland County. The major city on the bay is Portland. The bay serves as a major docking facility and the principal fishing port of Maine (Larsen et al. 1983). The embayment is over 28 miles long and averages 8 miles in width. It is characterized by numerous islands that are highs between glacial scoured valleys. The rivers provide an average daily inflow to the bay of 60 m^3/sec of freshwater. The highest average flow rates (NOAA 1985) are in April (137 m^3/sec) and the lowest in September (23 m^3/sec). Cumberland County, with a surface area of 3000 km^2, accounts for most of the drainage basin for the Casco Bay estuary. The average tidal range for the bay is approximately, 2.7 m (NOAA 1985).

Casco Bay has a wealth of natural resources including marine habitats that support a rich and diverse ecology. Casco Bay's natural beauty, clean water, abundant fish and waterfowl, and its deep and protected waters have made it a sought-after location for residences, business, industry, and recreation. However, these same activities may add contaminants that pose a threat to the environmental integrity of the bay. Casco Bay has been designated an estuary of national significance and included in the U.S. EPA's National Estuary Program (NEP). The NEP goal is to protect and improve the water quality and enhance living resources by developing comprehensive conservation and management plans that work to ensure the ecological

integrity of designated estuaries. Casco Bay receives freshwater from rivers that discharge directly into the bay (Fore, Presumpscot, Cousins and Royal Rivers). It also appears that the Kennebec/Androscoggin River, which discharges just north of Casco Bay, may be a source of water and contaminants to the bay. The most densely populated portions of the Casco Bay watershed are Portland, the banks of the Fore and Presumpscot Rivers, and Back Cove. These areas may receive higher inputs of selected contaminants than other regions of Casco Bay.

Casco Bay can be sub-divided into five areas; Inner Bay, Outer Bay, West Bay, East Bay and Cape Small (Figure 1). The Inner Bay is bounded on the southwest by Portland harbor, the northwest by the shore, the northeast by Cousins Island and the southeast by the series of islands running in a line from Great Chebeague Island to Cushing Island. West Bay is the area to the north of Cousins Island and west of Highway 24, and includes Maquoit Bay, Merepoint Bay, Middle Bay and Harpswell Sound. East Bay is the area bounded to the east by Highway 24 and the western shore of New Meadows River. The Outer Bay is bounded on the northwest by the islands forming the southeast boundary of the Inner Bay and a line from the tip of Cape Elizabeth to Cape Small boundaries. Cape Small encompasses an area inside the bay within a four mile radius of the tip of Cape Small.

An assessment of sediment contamination for trace metals, hydrocarbons, chlorinated pesticides and PCB was recently reported for 65 sites throughout Casco Bay (Kennicutt et al. 1994). The objective of the present research was to extend the contaminants measured in that study to include butyltins, 2,3,7,8-polychlorinated dibenzo-*p*-dioxins (PCDD), and dibenzofurans (PCDF) and planar polychlorinated biphenyls (PCB). Butyltins, PCDD/PCDF and planar PCB have been detected in other near-shore ecosystems, and are known to be highly toxic. Addition of butyltin, PCDD/PCDF and planar PCB data makes the contaminant assessment of Casco Bay sediments more complete.

2.2 Historical Data

In the previous study, the Casco Bay sediments collected were generally characterized as fine-grained sediments with median total organic carbon (TOC) greater than or equal to 2%, except in the Cape Small area where sandy sediments with a median TOC concentration of 0.2% were

Casco Bay, Maine
CBNEP Sampling Sites (1994)

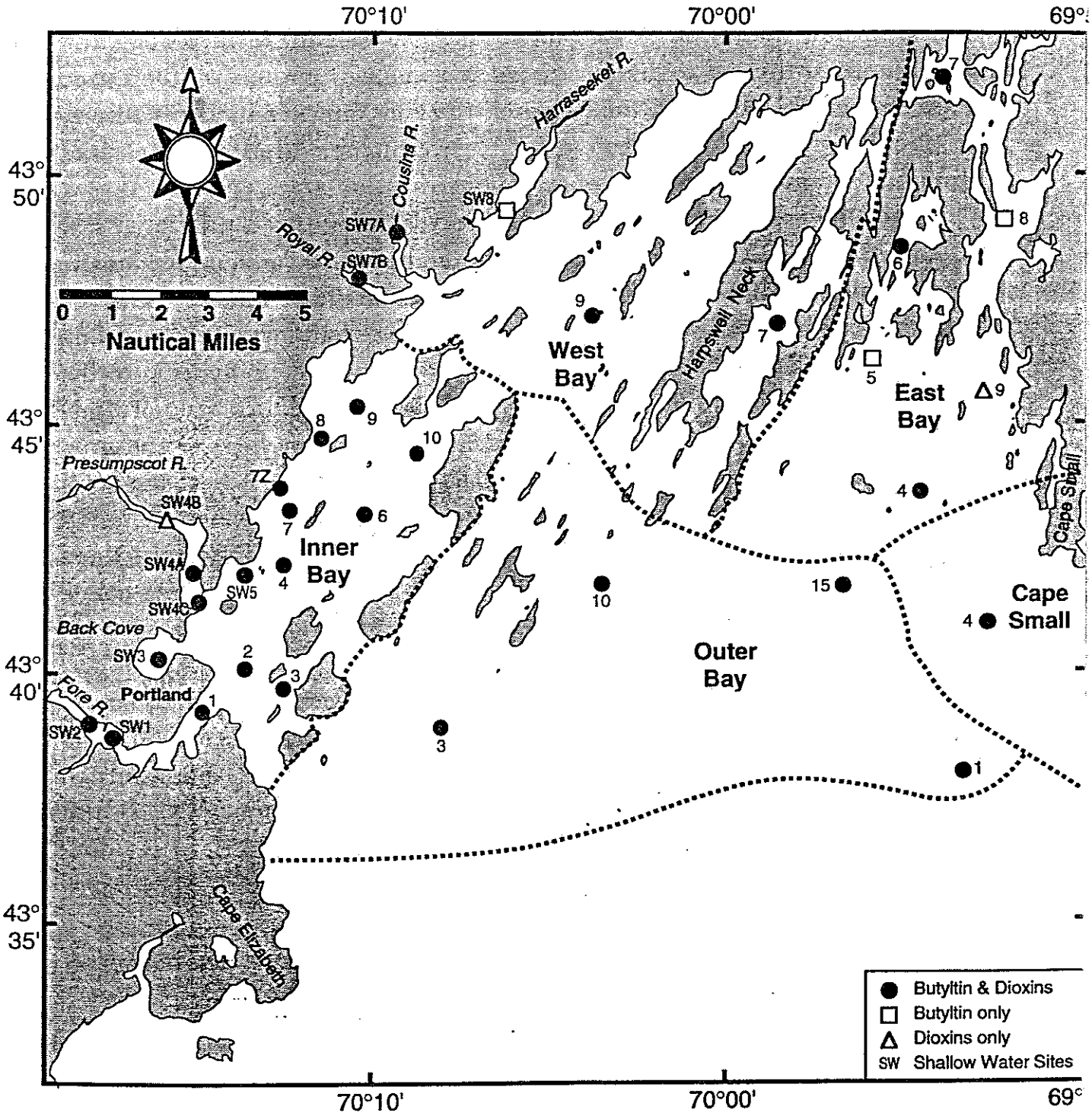

Figure 1. Sampling Sites for the 1994 Casco Bay sediment quality study.

found. The shallow water sediments are generally coarser grained and had a median TOC concentration of 1.5%. Coarser grained sediment in the shallow water is expected since tidal and wave activity can transport the finer material away from shore.

In 1991, 65 sites in Casco Bay were sampled and analyzed for organic contaminants. In 1994, 28 of the original sites were re-sampled for the analysis of butyltins, PCDD/PCDF and planar PCB, and 5 additional sites were added. Two of the new sites were analyzed for PCDD/PCDF and planar PCB, while the other three sites were analyzed for butyltins (Figure 1). The additional sites selected in 1994 were along the Presumpscot River, the Royal and Cousins Rivers and a marina at Falmouth Foreside. The other sites selected for re-sampling in 1994 were the sites containing the highest organic contaminant concentrations in 1991. The presence of high concentrations of contaminants in sediments indicate potential source of contaminants to organisms, which may lead to adverse environmental and/or human health effects. For example, the detection of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) and dibenzofuran (TCDF) in lobster tomalley has resulted in a human consumption advisory for Casco Bay (Mower 1994).

2.2.1 Butyltins

Butyltins include the sum of tetrabutyltin (4BT), tributyltin (TBT), dibutyltin (DBT) and monobutyltin (MBT). The only reports of detecting 4BT in sediment are in shipyards, probably from paint chips. TBT is the active ingredient used in marine paints to prevent fouling of marine vessel bottoms by the growth of barnacles and other organisms on solid surfaces immersed in sea water (Wade, et al. 1991). Fouling increases the roughness of the surface of the vessel and increases fuel consumption. Sediments near boating activities are the sites where tributyltin would be expected to be found in the highest concentrations. DBT and MBT are minor components of anti-fouling paints and are also degradation products of TBT. DBT is also used as a stabilizer in PVC and as a catalyst in the production of polyurethane foams (Muller et al. 1989). In 1990, sediments from the Fore River were sampled and analyzed for butyltins. The concentration of TBT ranged from 24 ng Sn/g to 693 ng Sn/g in the surficial sediments. DBT concentrations ranged from 15 ng Sn/g to 453 ng Sn/g. The highest concentration of

butyltins were observed in the sediments collected near shipyards (Ozbal 1992).

2.2.2 PCDD/PCDF

No historical PCDD/PCDF data is available for sediments from Casco Bay; however, there are data for the TCDD/TCDF for Androscoggin and Kennebec River sediments (Mower 1994). The Kennebec/Androscoggin River effluent join in Merrymeeting Bay and enters the Atlantic Ocean via the Kennebec estuary, which is just to the northeast of Cape Small. Since the average daily flow rate to the Kennebec estuary is more than eight times the flow rate into the Casco Bay estuary, it is possible that effluent from the Kennebec/Androscoggin River containing particulate materials could exit the Kennebec Estuary and enter Casco Bay where they may be deposited (NOAA 1985). Androscoggin River sediments had a median concentration of 2,3,7,8-TCDD of 23.1 and 5.3 pg/g for samples collected in 1985 and 1991, respectively. The median concentration of 2,3,7,8-TCDF in 1991 (the only year it was measured) was 168 pg/g. The analyses did not include the other 2,3,7,8-substituted polychlorinated-*p*-dioxins and furans (Mower 1994). Concentrations of 2,3,7,8-TCDD and 2,3,7,8-TCDF in bass, suckers, and lobster tissues from the Presumpscot River have been reported (Mower 1994). The muscle of the bass had no detectable TCDD, and TCDF concentrations were less than 1 pg/g. Suckers did contain TCDD and TCDF. The 2,3,7,8-TCDD toxicity equivalents (TEQ) were calculated based on the values reported by Safe (1994). Toxicity equivalents are based on the comparison of the relative toxicity of compounds to that of the most toxic known compound 2,3,7,8-TCDD. The toxicity equivalency factors (TEF) are multiplied by the analyte concentration to produce the TEQ for that compound (Safe 1994). The total TEQ is the sum of the TEQ for all compounds. This concept allows for the total TEQ and the relative toxicity that the various compounds contribute to the total TEQ to be determined. The TEQ concept is further discussed by Safe (1994). An average TEQ of 2.3 pg/g was calculated for the suckers. Lobster meat had an average TEQ of 0.8 pg/g, however the tomalley or hepatopancreas of the lobster had an average TEQ of 18.7 pg/g. TEQ at these levels resulted in the Maine Bureau of Health issuing an advisory in 1994 regarding human consumption of lobster tomalley (Mower 1994).

2.2.3 Planar PCB

There is no historical data on the concentrations of planar polychlorinated biphenyls (PCB) in Casco Bay sediments. There is heightened environmental concern regarding planar PCB due to their toxicity. The non-*ortho* chlorine substituted planar PCB (PCB77-3,3',4,4'-tetra, PCB126-3,3',4,4',5,-penta and PCB169-3,3',4,4',5,5'-hexa) are approximate isostereomers of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) and these planar PCB produce toxic responses typical of TCDD (Kannan et al. 1987). The planar PCB are minor components of commercial PCB mixtures (aroclors and kaneclors), with PCB77 being the most abundant planar PCB, and PCB126 and PCB169 present at lower concentrations. Brunstrom (1989) observed that the most toxic of the non-*ortho* chlorinated PCBs in chick embryos was PCB126. Toxic equivalency factors (TEF) have been proposed for each planar PCB relative to 2,3,7,8-TCDD (Safe 1992, 1994). The computed toxic equivalents (TEQ) from the concentration of the particular analyte and the appropriate toxic equivalency factor are useful in providing a single number evaluation of the relative toxicity of the sample for comparison. In summary, while the planar PCB are only minor components of PCB mixtures, they have the highest toxicity. Therefore, the planar PCB were measured so that the total TEQ and relative contribution from PCDD, PCDF and planar PCB in Casco Bay sediments could be assessed.

3.0 SAMPLING AND ANALYTICAL PROCEDURES

Sediment samples were collected by Dr. Dan Adkison of the Geochemical and Environmental Research Group (GERG) of Texas A&M University during November 15-17, 1994. Sediment samples were collected using the Maine University Research Vessel the *LEE*. Some shallow sites required sampling from shore and/or use of a smaller boat. Samples were collected with a Smith-McIntyre grab sampler and the top 2 cm were removed, placed in a clean glass jar, frozen and shipped to the laboratory for analysis. Known depositional areas were sampled in all regions of the bay, and efforts were made to sample fine-grained sediments (mud). The sampling included Cape Small in order to capture the plume of the Kennebec/Androscoggin Rivers. Each field sample (Table 1) was assigned a station number in the field. Selected field samples were

composited and each sample to be analyzed was assigned a unique file number upon arrival at GERG. The analysis for butyltins, PCDD/PCDF and planar PCB follow the Standard Operating Procedures (SOP) used by GERG. These analytical procedures are the methods utilized for the NOAA National Status and Trends Program, EPA's Environmental Monitoring and Assessment Program - Estuarine (EMAP-E) and the U.S. Fish and Wildlife Service trace organic analytical program. The method used for the PCDD/PCDF and planar PCB analyses is a modification of EPA method 8290 that employs high resolution GC/MS in order to obtain low parts per trillion detection limits (Gardinali et al. 1994). All methods have undergone extensive verification and intercalibration.

Quality assurance/quality control (QA/QC) procedures included analyses of matrix spikes, duplicates and laboratory blanks with each batch of samples. In addition a marine reference sediment, PACS-1 from the National Research Council of Canada was used for butyltins analyses, and SRM 1941a from the National Institute of Standards and Technology (NIST) was analyzed as a laboratory reference material for PCDD/PCDF and planar PCB. SRM 1941a does not currently have certified PCDD/PCDF or planar PCB concentrations. However, previous analyses of this SRM have proven its value as a homogeneous estuarine reference sediment (collected from Baltimore Harbor) that contains PCDD/PCDF (Chambers et al. 1994).

The concentrations of butyltins including tetrabutyltin (4BT), tributyltin (TBT), dibutyltin (DBT), and monobutyltin (MBT) were determined as described by Wade et al. (1990). Sediments were freeze-dried and a 10-15 gram aliquot of dry sediment was placed into a centrifuge tube and tripropyltin (TPT) was added as an internal standard. The sample was extracted with 0.2% tropolone in methylene chloride by vigorously shaking the capped tube with a wrist action shaker. The tube was centrifuged and the supernatant collected, and the procedure was repeated two more times. The extract was then concentrated on a rotary evaporator and solvent exchanged into hexane.

The sample was hexylated in a centrifuge tube by adding hexylmagnesium bromide under a nitrogen atmosphere and heating at 60°C in a water bath for six hours. The excess reagent was neutralized by adding 6M hydrochloric acid. The hexane phase was removed and saved, and the aqueous phase was extracted three more times with pentane. Sodium

Table 1. Collection Location of Sediment Samples from Casco Bay

File Number	Station Number	Field Sample Number	Depth (ft.)	Lat. (N) degrees	Lat. (N) minutes	Long. (W) degrees	Long. (W) minutes	Analytes
C17215	GREASE	5						DIOXIN
C17425	CS04	comp 68&69	122	43	41.015	69	53.875	BOTH
C17426	EB04	comp 70&71	92.2	43	43.688	69	54.442	BOTH
C17403	EB05	comp 8&9	44.7	43	46.304	69	55.899	TBT
C17404	EB06	comp 10&11	25.7	43	48.501	69	55.047	BOTH
C17400	EB07	1	7.6	43	52.012	69	54.023	BOTH
	EB07	2	8.3	43	52.049	69	53.993	
C17401	EB08	comp 3&4	50.2	43	48.799	69	52.194	TBT
C17402	EB09	comp 6&7	60.2	43	45.527	69	52.691	DIOXIN
C17418	IB01	comp 54&55	37.2	43	39.297	70	14.646	BOTH
C17419	IB02	comp 56&57	29	43	40.061	70	13.554	BOTH
C17420	IB03	comp 58&59	13.5	43	39.666	70	12.271	BOTH
C17413	IB04	comp 41&42	31.5	43	41.974	70	12.376	BOTH
C17245	IB06	35	55.2	43	43.052	70	10.206	BOTH
C17411	IB07	comp 30&31	40.2	43	43.299	70	11.972	BOTH
C17242	IB07-Z	32	17.7	43	43.671	70	12.484	BOTH
C17410	IB08	comp 28&29	34.5	43	44.632	70	11.228	BOTH
C17409	IB09	26	30.5	43	45.323	70	10.488	BOTH
	IB09	27	31.2	43	45.304	70	10.455	
C17408	IB10	comp 24&25	35	43	44.309	70	8.672	BOTH
C17424	OB01	comp 66&67	230	43	37.577	69	53.643	BOTH
C17421	OB03	comp 60&61	159	43	38.575	70	8.377	BOTH
C17422	OB10	comp 62&63	136	43	41.225	70	2.466	BOTH
C17423	OB15	comp 64&65	168	43	40.686	69	56.713	BOTH

Table 1. Cont.

File Number	Station Number	Field Sample Number	Depth (ft.)	Lat. (N) degrees	Lat. (N) minutes	Long. (W) degrees	Long. (W) minutes	Analytes
C17417	SW01	comp 52&53	8.3	43	38.681	70	17.084	BOTH
C17416	SW02	comp 49&50	7.6	43	38.853	70	17.575	BOTH
C17412	SW03	comp 36&37	7.2	43	40.207	70	15.761	BOTH
C17414	SW04-A	comp 43&44	6.3	43	42.034	70	14.762	BOTH
C17415	SW04-B	comp 45&46	8.8	43	42.857	70	15.038	DIOXIN
C17258	SW04-C	48	11.7	43	41.438	70	14.814	BOTH
C17250	SW05	40	10.1	43	41.938	70	13.545	BOTH
C17427	SW07-A	comp 72&73	6.1	43	48.396	70	9.188	BOTH
C17428	SW07-B	comp 74&75	7.1	43	47.641	70	10.114	BOTH
C17407	SW08	comp 16&17	13	43	49.304	70	6.159	TBT
C17405	WB07	comp 12&13	50.5	43	47.041	69	58.516	BOTH
C17406	WB09	comp 14&15	43.2	43	46.961	70	3.375	BOTH

comp = composite sample
DIOXIN = PCDD/PCDF and planar PCB
TBT = butyltins
both = PCDD/PCDF, planar PCB and butyltins

sulfate was added to the combined extracts to remove water, and the samples were then concentrated and transferred to a silica (13.5 g)/alumina (17.0 g) column and eluted with pentane. Samples were concentrated and tetrapropyltin (4PT), was added as a recovery standard. Samples were quantitatively analyzed by gas chromatography using a flame photometric detector equipped with a 610 nm filter. The sample concentrations are reported as ng of Sn per gram of dry sediment.

The method used for PCDD/PCDF and planar PCB sediment analyses has been reported (Chambers et al. 1994; Gardinali et al. 1994). The method determines the concentrations of 7 PCDD and 10 PCDF isomers having chlorine substitution in the 2,3,7,8 positions as well as planar PCB 77, 126, and 169. Sediments (10 to 25 g dry weight) were spiked with the

appropriate internal standards and were extracted for at least 24 hours with toluene in a Soxhlet extractor fitted with a Dean-Stark trap. PCDD/PCDF and planar PCB were separated from interfering compounds in sample extracts by mixed-bed silica, basic alumina, and AX-21 Super Activated Carbon column chromatography. The appropriate recovery standards were added and the extracts were reduced to a final volume of 20 µL.

Two µL of the concentrated extract were injected into an HRGC/HRMS system capable of performing selected ion monitoring at resolving powers of at least 10,000. The identification of the sixteen 2,3,7,8-substituted isomers and planar PCB 77, 126, 169 for which ^{13}C-labeled standards are available was based on their elution order from a DB-5MS analytical column with the corresponding retention time and the simultaneous detection of the two most abundant ions in the molecular ion region. The identification of OCDF was based on its retention time relative to ^{13}C-OCDD. Confirmation was based on a comparison of the ratios of the integrated ion abundance of the molecular ion species to their theoretical abundance ratios. Quantitation of the individual congeners was achieved with the establishment of a multipoint calibration curve for each analyte. Concentrations of 2,3,7,8-TCDF were confirmed on a DB-225 analytical column (Tondeur 1990).

4.0 CONTAMINANT CONCENTRATIONS

4.1 Butyltins

4.1.1 Casco Bay Data

Butyltins are the active ingredients of some anti-fouling paints. The fine-grained sediment samples were collected in areas (Figure 1) in close proximity to marinas, shipyards, docking facilities, anchoring areas (i.e., near Clapboard Island) and major shipping channels. A majority of the butyltin samples (16) were collected from the Inner Bay. One sample was collected from Cape Small to determine the geographic extent of the butyltin contamination. The geographic distribution of total butyltins (sum of 4BT, TBT, DBT and MBT) is shown in Figure 2. Total butyltin concentrations ranged from 7.3 to 72 ng Sn/g dry weight of sediment (Table 2). Highest concentrations were found near a marina (IB07-Z) and near Clapboard Island anchoring areas (IB06).

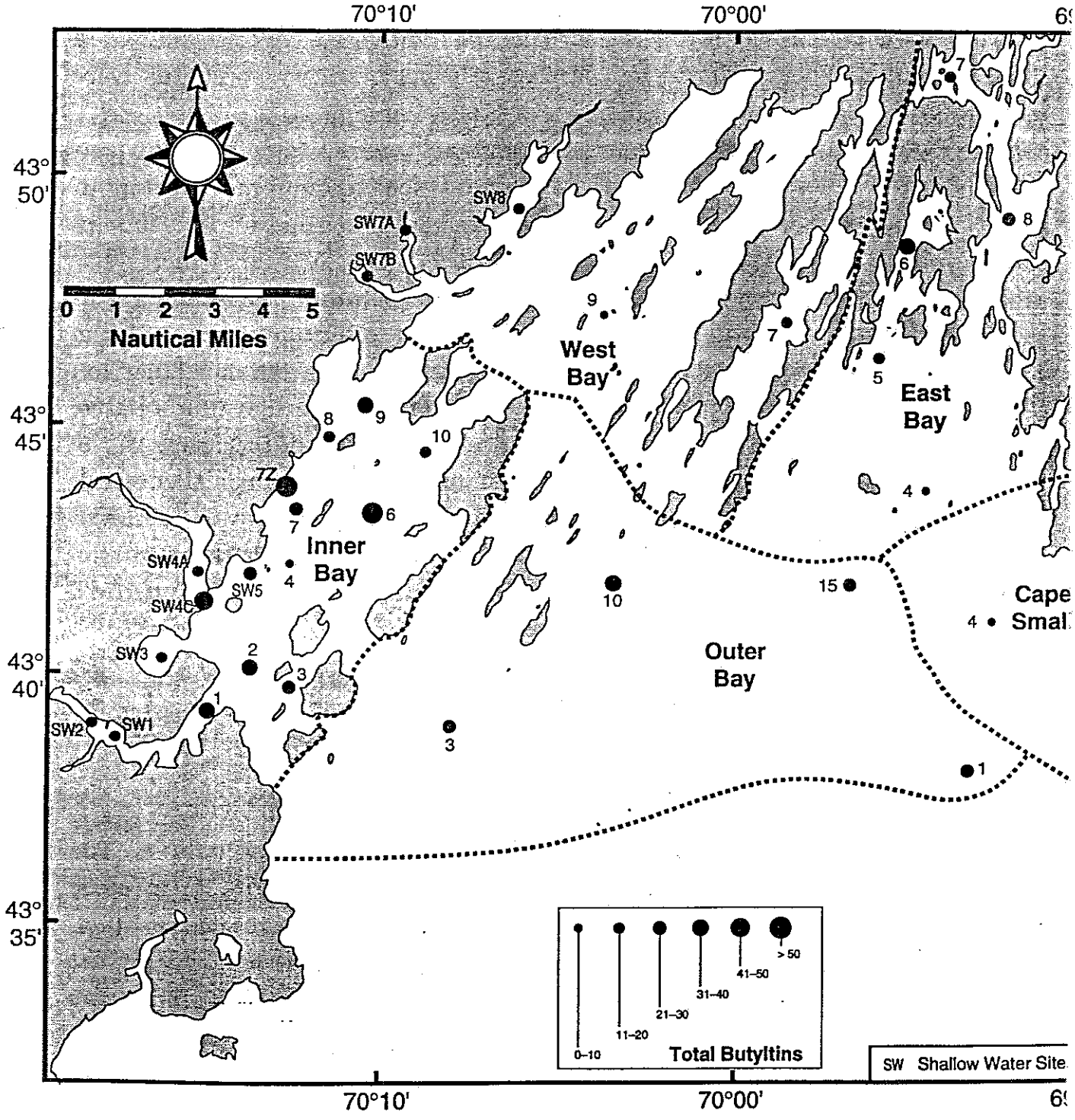

Figure 2. Total butyltin concentrations for the 1994 Casco Bay sediment quality study.

The geographic distribution of TBT (Figure 3) is nearly identical to that for total butyltin (Figure 2). TBT is the predominant and active ingredient of anti-fouling paints and TBT is, therefore, the major butyltin found in most sediments including those from Casco Bay reported here. The median TBT concentration by bay area were: Outer Bay (20 ng Sn/g), Inner Bay (19 ng Sn/g), East Bay (15 ng Sn/g), West Bay (11 ng Sn/g), and Cape Small (6.5 ng Sn/g). The highest concentration sites are the Inner Bay site (IB06, 59 ng Sn/g) and the marina at Falmouth Foreside (IB07Z, 52 ng Sn/g), and one of the sites on the Presumpscot River (SW04C, 36 ng Sn/g). In addition, the Inner Bay sites (SW05, 25 ng Sn/g, and IB09, 28 ng Sn/g), the Outer Bay site OB10 (28 ng Sn/g), and the East Bay site EB06 (28 ng Sn/g) are in the highest 25% of the concentrations measured in this study of Casco Bay. The sites with the highest concentration of tributyltins appear to be associated with boating activity.

The Inner Bay has the highest concentration of DBT (Figure 4) and MBT (Figure 5) which are degradation products of TBT. Degradation products are generally associated with samples containing high concentrations of TBT. The 4BT concentrations were at or near the method detection limit in all samples (Table 2). Paint chips are the expected source of 4BT and it is rarely found except in samples from shipyards or when TBT concentrations are high (greater than a few ppm).

4.1.2 Comparison with other Waterways

Sediments from Boothbay Harbor had tributyltin concentrations as high as 3900 ng Sn/g (Ozbal 1992). In twenty-five estuaries from Southern England and Wales the tributyltin concentration varied from 2 ng Sn/g to 1150 ng Sn/g. Sediment TBT concentrations found in a marina on the Bohemia River in Chesapeake Bay (McGee et al. 1994) were higher inside the marina (range 70 to 240 ng Sn/g) compared to outside the marina (range 6 to 15 ng Sn/g). A control site sediment from the Corsican River contained no detectable TBT. A survey of sediments from National Status and Trends "Mussel Watch" Program for the three coasts of the continental United States yielded TBT concentrations that ranged from the detection limit (5 ng Sn/g) to 187 ng Sn/g (Wade et al. 1990; Garcia-Romero 1988). The concentrations of TBT in 12 samples from Boston Harbor varied from the detection limit (0.4 ng Sn/g) to 520 ng Sn/g (Makkar et al. 1989). A

Table 2. Butyltins in Casco Bay Sediments

File No.	Description	4BT ng Sn/g	TBT ng Sn/g	DBT ng Sn/g	MBT ng Sn/g	Total Butyltins ng Sn/g
Cape Small						
	Median	ND	6.5	0.8	ND	7.3
C17425	CS04	ND	6.5	0.8	ND	7.3
East Bay						
	Median	ND	15	0.8	0.2	15
C17426	EB04	ND	8.8	0.8	0.2	9.8
C17403	EB05	0.1	15	0.7	0.1	15
C17404	EB06	0.7	29	2.1	0.9	32
C17400	EB07	ND	10	0.7	0.2	11
C17401	EB08	ND	20	1.5	0.4	22
Inner Bay						
	Median	ND	19	2.4	0.8	23
C17418	IB01	ND	22	6.2	5.9	34
C17419	IB02	ND	22	4.6	4.7	31
C17420	IB03	0.6	17	2.4	1.9	22
C17413	IB04	ND	5.9	1.3	1.2	8.4
C17245	IB06 #35	0.7	59	2.4	ND	62
C17411	IB07	ND	23	1.9	0.4	25
C17242	IB07-Z #32	0.2	52	18	2.1	72
C17410	IB08	ND	16	2.6	0.6	20
C17409	IB09	ND	28	2.2	0.2	30
C17408	IB10	ND	13	0.8	0.7	15
C17417	SW01	ND	9.4	1.8	0.7	12
C17416	SW02	ND	7.8	1.7	0.8	10
C17412	SW03	0.6	16	2.7	0.4	20
C17414	SW04-A	ND	8.5	1.2	1.0	11
C17258	SW04-C #48	ND	36	3.6	3.2	43
C17250	SW05 #40	ND	25	2.3	0.3	28
Outer Bay						
	Median	ND	20	1.5	0.9	22
C17424	OB01	ND	21	1.0	0.5	23
C17421	OB03	ND	19	1.7	1.0	22
C17422	OB10	ND	28	1.3	1.4	30
C17423	OB15	ND	18	2.2	0.7	21
West Bay						
	Median	ND	11	1.3	0.4	13
C17405	WB07	0.4	13	0.9	0.3	15
C17406	WB09	0.2	6.0	0.6	0.5	7.3
C17427	SW07-A	ND	11	1.3	0.4	13
C17428	SW07-B	ND	14	3.6	1.5	19
C17407	SW08	ND	9.7	1.3	0.3	11

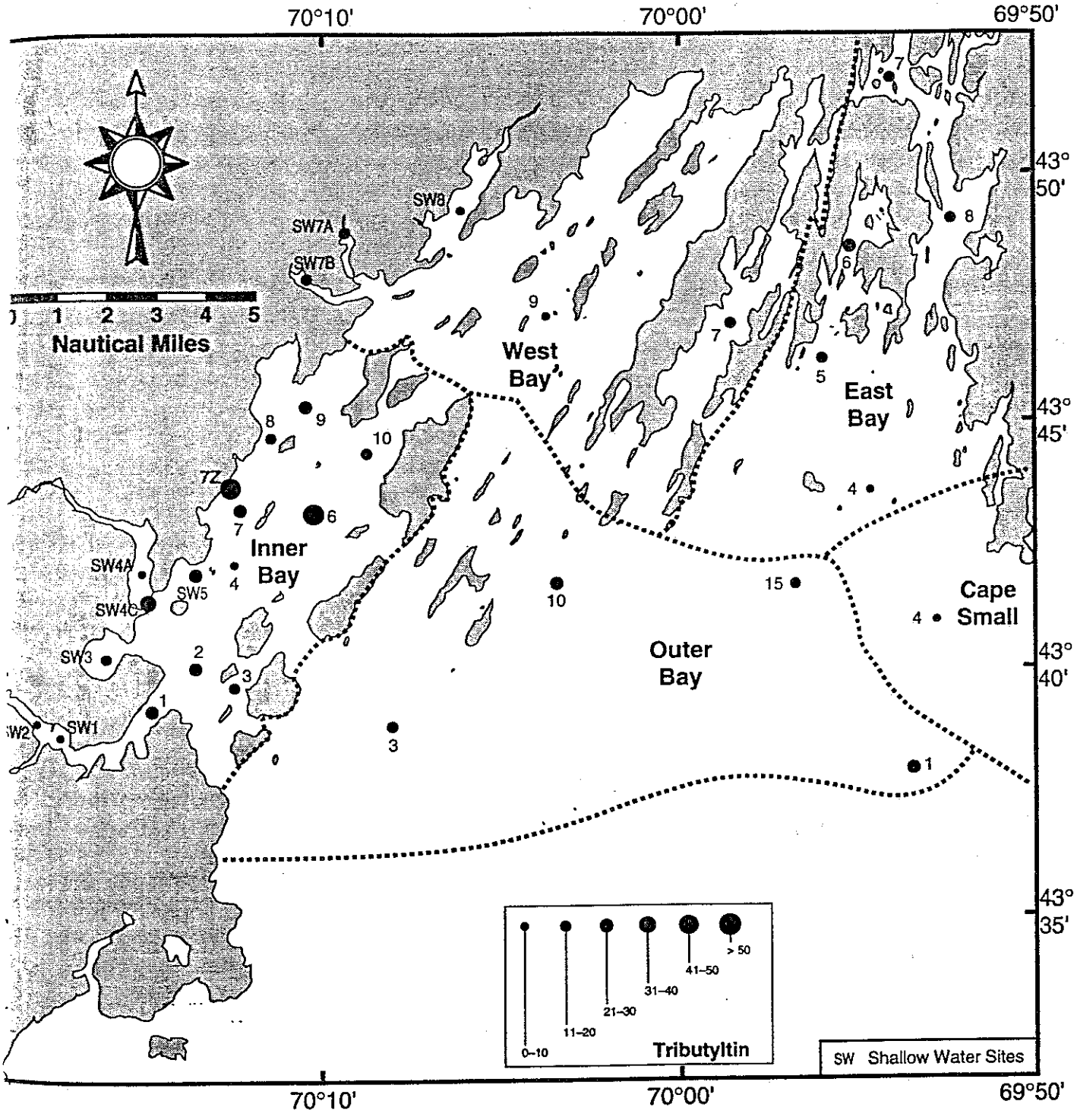

Figure 3. Tributyltin concentrations for the 1994 Casco Bay sediment quality study.

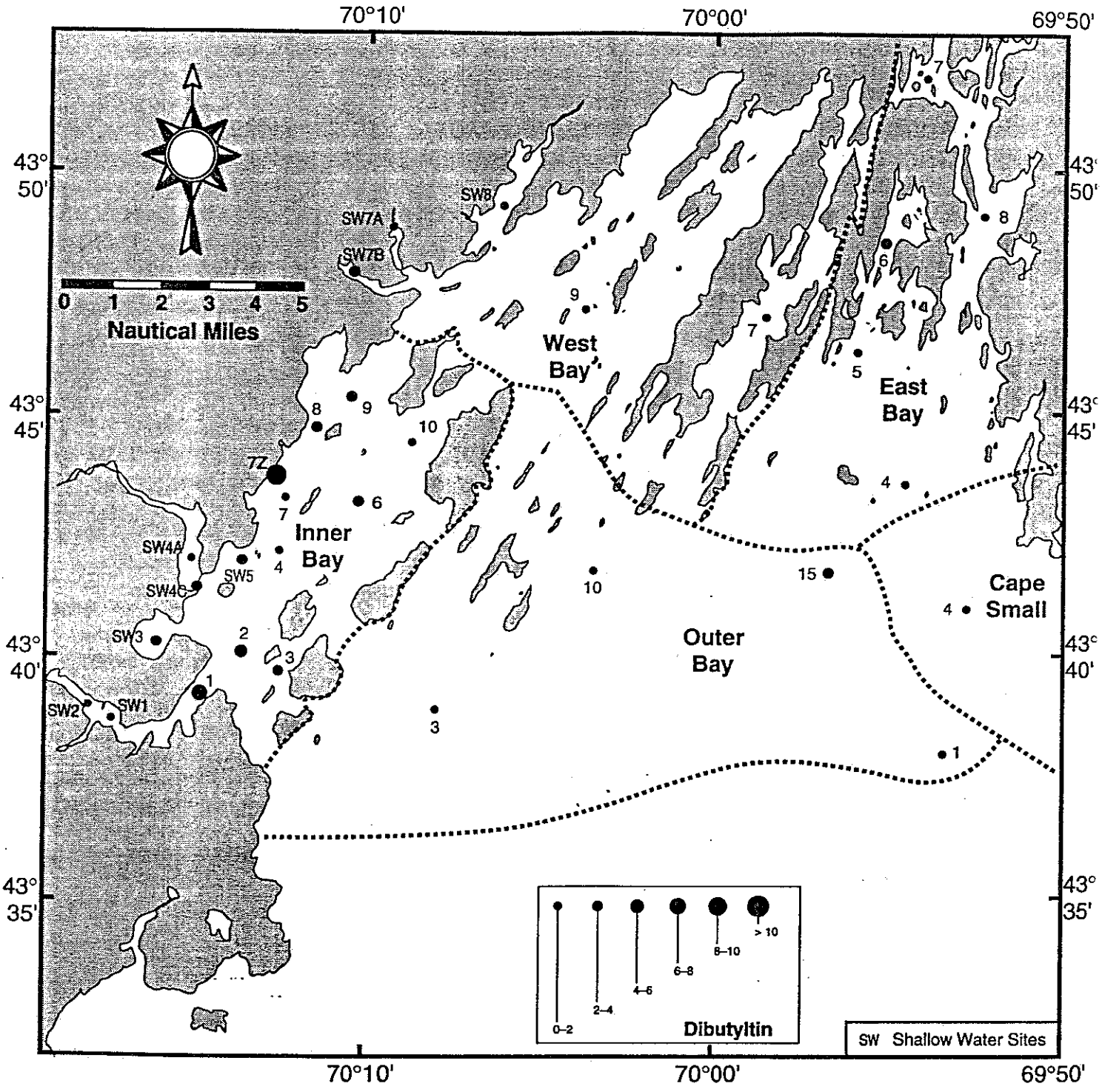

Figure 4. Dibutyltin concentrations for the 1994 Casco Bay sediment quality study.

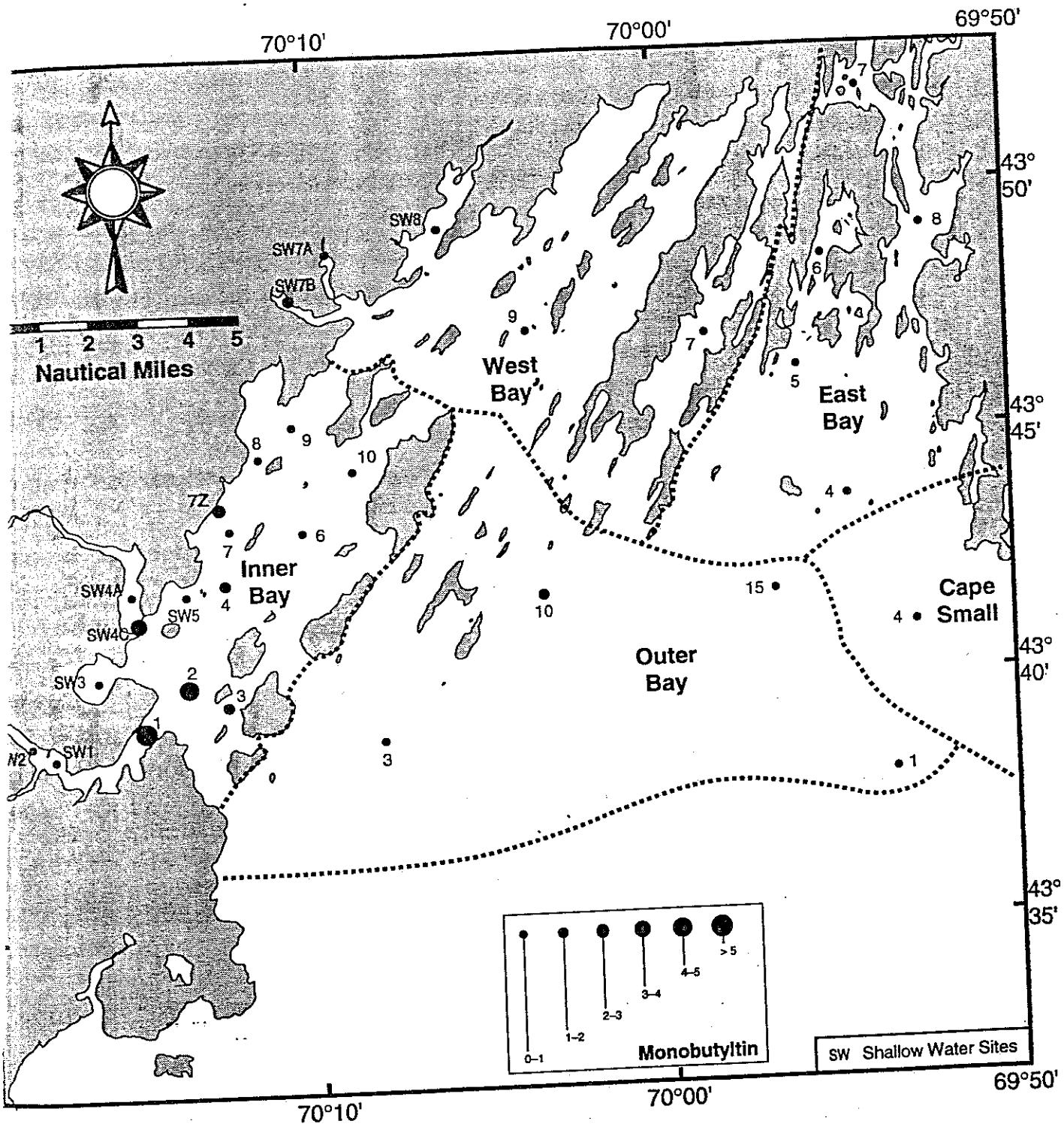

Figure 5. Monobutyltin concentrations for the 1994 Casco Bay sediment quality study.

recent review of sediment butyltin concentrations (Maguire 1991) reported a range from ND to over 10000 ng Sn/g. The concentrations found in this study for Casco Bay are in the lower end of this range. TBT affects shell generation in oysters and alters the reproductive dynamics of whelks (Weiss and Perlmutter 1987; Weiss 1988). Long-term test of TBT on fish and invertebrates suggests that the maximum acceptable concentration for TBT be set above 1 ppb (Laughlin et al. 1984). A recent report on the Louisianian Province that encompasses most Gulf Coast estuaries estimated that approximately 3% of the sediments had degraded conditions based on TBT concentrations that exceeded 5 ng Sn/g (Macauley et al. 1994). This estimate is based on limited studies of the toxicity of TBT to organisms living in the sediments. All sites for this study of Casco Bay had TBT concentrations that exceed 5 ng Sn/g and therefore would be categorized as having degraded conditions by this definition.

In 1989 the use of butyltin containing anti-fouling paints was limited to vessels larger than 25 m. Sediment concentrations found in Casco Bay should be maximums for most sites because the recent limitations of the use of TBT containing anti-fouling paints should reduce inputs (i.e., in small recreational boat harbors). Sites associated with larger vessels, for example, the Clapboard Island anchoring area that continues to be used by vessels larger than 25 m that may be painted with butyltin containing anti-fouling paints, may not have experienced any decrease in inputs of butyltins. The persistence of butyltins in sediments is not known. Therefore, the time scale for reducing the concentration of butyltins in the sediments in Casco Bay is not known.

4.2 PCDD/PCDF

4.2.1 Casco Bay Data

PCDD/PCDF are by-products of many processes that include chlorination steps. Paper mills, wood treatment facilities that use pentachlorophenol, steel mills, incinerators and other combustion processes (i.e., residential wood burning, vehicles, etc.) are some of the potential sources of PCDD/PCDF to the environment (Spiro and Thomas 1994; Fiedler 1994). Environmental loadings are also sometimes associated

with municipal and industrial waste and may be associated with high levels of other environmental contaminants, such as PCB (Wevers and Fré 1994).

The sum of the seventeen 2,3,7,8-PCDD/PCDF concentrations for Casco Bay ranged from 340 pg/g to 3400 pg/g (Table 3a,b,c). The spatial pattern observed for PCDD/PCDF concentrations (Figure 6) shows highest median concentrations in East Bay (2000 pg/g), Inner Bay (1600 pg/g) and Outer Bay (1400 pg/g). There were lower median concentrations in West Bay (740 pg/g) and Cape Small (340 pg/g). The spatial distribution of PCDD and PCDF has a similar pattern (Figures 7 and 8). The TEQ for all 2,3,7,8-substituted congeners of PCDD/PCDF (Safe 1994), also have a similar distribution (Figure 9). The median TEQ was highest in Inner Bay (15 pg/g), East Bay (13 pg/g) and Outer Bay (11 pg/g) and lower in West Bay (5.3 pg/g) and Cape Small (1.8 pg/g). The highest TEQs are associated with the Presumpscot River. Inner Bay sediments to the south of the river have higher TEQ indicating they may be influenced by the river discharge.

The percentage that 2,3,7,8-TCDF contributes to the total PCDF for most sites is 5% or less. The percentage of TCDF for sites on the Royal River (SW07B) and the Cousins River (SW07A) are 26.7% and 18.0%, respectively. This suggests a different source for the furans from these two sites (Figure 10). Inner Bay sites IB09 and IB08, to the south of the effluence of the Royal and Cousins Rivers also exhibit slightly elevated 2,3,7,8-TCDF percentages of 8.3% and 6.1%, respectively.

The geographic distribution of 2,3,7,8-TCDD (Figure 11) indicates higher concentrations in and near the Presumpscot River, lower concentrations in the Outer Bay, and no detectable 2,3,7,8-TCDD in East Bay, Cape Small or West Bay. This suggests a source of 2,3,7,8-TCDD in the drainage basin of the Presumpscot River. The source may be the bleached kraft pulp and paper mill near Westbrook and 10 miles from Casco Bay where 2,3,7,8-TCDD has been reported in the sludge from the paper mill waste water treatment plant (Mower 1994). The concentration of 2,3,7,8-TCDD has decreased in sludge samples from the paper mill between 1985 and 1992. However, previous discharges may be moving down the Presumpscot River as evidenced by the detections of 2,3,7,8-TCDD in sediments in this study and in lobster tomalley samples collected just south of the mouth of the Presumpscot River (Mower 1994).

Table 3a. Polychlorinated 2,3,7,8-dibenzofurans in Casco Bay Sediments

File Number	Description	TCDF pg/g	PCDF pg/g	HxCDF pg/g	HpCDF pg/g	OCDF pg/g
Cape Small						
	Median	1.7	ND	ND	9.2	21
C17425	CS04	1.7	ND	ND	9.2	21
East Bay						
	Median	5.5	1.4	9.5	57	74
C17426	EB04	2.5	ND	1.3	22	44
C17404	EB06	6.8	5.6	13	66	92
C17400	EB07	4.1	ND	5.9	48	56
C17402	EB09	7.9	2.8	14	79	141
Inner Bay						
	Median	5.9	4.8	12	50	67
C17418	IB01	7.3	5.9	15	83	150
C17419	IB02	7.6	4.9	13	84	190
C17420	IB03	6.1	4.8	12	63	92
C17413	IB04	5.7	4.9	11	51	61
C17245	IB06	4.1	2.8	3.4	35	52
C17411	IB07	5.1	5.4	13	50	68
C17242	IB07-Z	1.8	ND	2.1	29	64
C17410	IB08	2.9	2.4	1.9	17	24
C17409	IB09	9.4	3.2	10	39	51
C17408	IB10	5.9	5.0	13	50	67
C17417	SW01	3.4	2.6	7.2	34	64
C17416	SW02	2.9	2.7	6.4	29	55
C17412	SW03	7.1	4.4	16	71	120
C17414	SW04-A	7.7	6.1	13	62	100
C17415	SW04-B	11	5.8	15	100	210
C17258	SW04-C	12	6.8	20	98	150
C17250	SW05	2.4	2.0	6.5	23	30
Outer Bay						
	Median	4.2	3.4	7.4	41	65
C17424	OB01	2.6	2.2	4.7	25	41
C17421	OB03	6.4	5.5	13	70	100
C17422	OB10	4.9	4.2	9.0	51	76
C17423	OB15	3.5	2.6	5.7	30	54
West Bay						
	Median	6.6	2.8	3.6	13	25
C17405	WB07	0.9	1.3	2.3	8.3	11
C17406	WB09	4.3	4.1	5.4	41	35
C17427	SW07-A	8.8	1.4	1.4	11	26
C17428	SW07-B	18	5.9	4.8	15	23

TCDF = 2,3,7,8-TCDF
PCDF = 1,2,3,7,8-PCDF + 2,3,4,7,8-PCDF
HxCDF= 1,2,3,4,7,8-HxCDF + 1,2,3,6,7,8-HxCDF + 2,3,4,6,7,8-HxCDF + 1,2,3,7,8,9- HxCDF
HpCDF = 1,2,3,4,6,7,8-HpCDF + 1,2,3,4,7,8,9-HpCDF
OCDF = 1,2,3,4,6,7,8,9-OCDF

Table 3b. Polychlorinated 2,3,7,8-dibenzo-*p*-dioxins in Casco Bay Sediments

File Number	Description	TCDD pg/g	PCDD pg/g	HxCDD pg/g	HpCDD pg/g	OCDD pg/g
Cape Small						
	Median	ND	ND	1.5	21	290
C17425	CS04	ND	ND	1.5	21	290
East Bay						
	Median	ND	1.4	15	130	1800
C17426	EB04	ND	ND	3.7	49	600
C17404	EB06	ND	ND	17	150	2100
C17400	EB07	ND	2.7	12	110	1400
C17402	EB09	ND	2.8	18	210	2300
Inner Bay						
	Median	0.3	2.0	16	140	1400
C17418	IB01	1.0	2.6	24	250	2300
C17419	IB02	1.1	2.5	23	250	2100
C17420	IB03	0.9	2.3	19	190	1700
C17413	IB04	0.5	2.0	16	140	1300
C17245	IB06	ND	ND	14	100	820
C17411	IB07	ND	3.5	14	140	1300
C17242	IB07-Z	ND	ND	9.5	100	690
C17410	IB08	ND	ND	7.4	52	510
C17409	IB09	ND	ND	15	110	1300
C17408	IB10	ND	3.6	17	140	1500
C17417	SW01	0.3	1.2	10	97	880
C17416	SW02	0.3	1.1	9.8	98	960
C17412	SW03	0.9	3.1	21	210	1400
C17414	SW04-A	0.9	1.6	16	170	1400
C17415	SW04-B	1.2	2.3	25	290	2700
C17258	SW04-C	1.8	3.1	28.	290	2200
C17250	SW05	ND	ND	7.0	72	560
Outer Bay						
	Median	0.6	1.2	9.2	97	1100
C17424	OB01	0.2	0.8	5.1	56	660
C17421	OB03	0.7	2.0	17	170	1800
C17422	OB10	0.6	1.5	12	120	1300
C17423	OB15	0.5	0.7	6.4	73	950
West Bay						
	Median	ND	0.4	2.3	50	630
C17405	WB07	ND	0.7	0.9	21	340
C17406	WB09	ND	3.0	6.4	92	1100
C17427	SW07-A	ND	ND	3.7	51	540
C17428	SW07-B	ND	ND	ND	48	710

TCDD = 2,3,7,8-TCDD
PCDD = 1,2,3,7,8-PCDD
HxCDD= 1,2,3,4,7,8-HxCDD + 1,2,3,6,7,8-HxCDD + 1,2,3,7,8,9- HxCDD
HpCDFD= 1,2,3,4,6,7,8-HpCDD
OCDD = 1,2,3,4,6,7,8,9-OCDD

Table 3c. Sum of 2,3,7,8-Substituted PCDD/PCDF in Casco Bay Sediments

File Number	Description	Total PCDF pg/g	Total PCDD pg/g	Total PCDD/PCDF pg/g
Cape Small				
	Median	32	310	340
C17425	CS04	32	310	340
East Bay				
	Median	150	1900	2000
C17426	EB04	69	660	730
C17404	EB06	180	2200	2400
C17400	EB07	110	1500	1600
C17402	EB09	240	2500	2800
Inner Bay				
	Median	140	1500	1600
C17418	IB01	260	2600	2800
C17419	IB02	300	2300	2600
C17420	IB03	180	1900	2100
C17413	IB04	130	1400	1600
C17245	IB06	97	940	1000
C17411	IB07	140	1500	1600
C17242	IB07-Z	97	800	900
C17410	IB08	48	570	620
C17409	IB09	110	1500	1600
C17408	IB10	140	1600	1800
C17417	SW01	110	990	1100
C17416	SW02	96	1100	1200
C17412	SW03	210	1700	1900
C17414	SW04-A	190	1600	1800
C17415	SW04-B	340	3000	3400
C17258	SW04-C	290	2500	2800
C17250	SW05	64	640	710
Outer Bay				
	Median	120	1200	1400
C17424	OB01	75	720	790
C17421	OB03	200	1900	2100
C17422	OB10	150	1400	1600
C17423	OB15	96	1000	1100
West Bay				
	Median	58	680	740
C17405	WB07	23	360	390
C17406	WB09	90	1200	1300
C17427	SW07-A	49	600	650
C17428	SW07-B	66	760	820

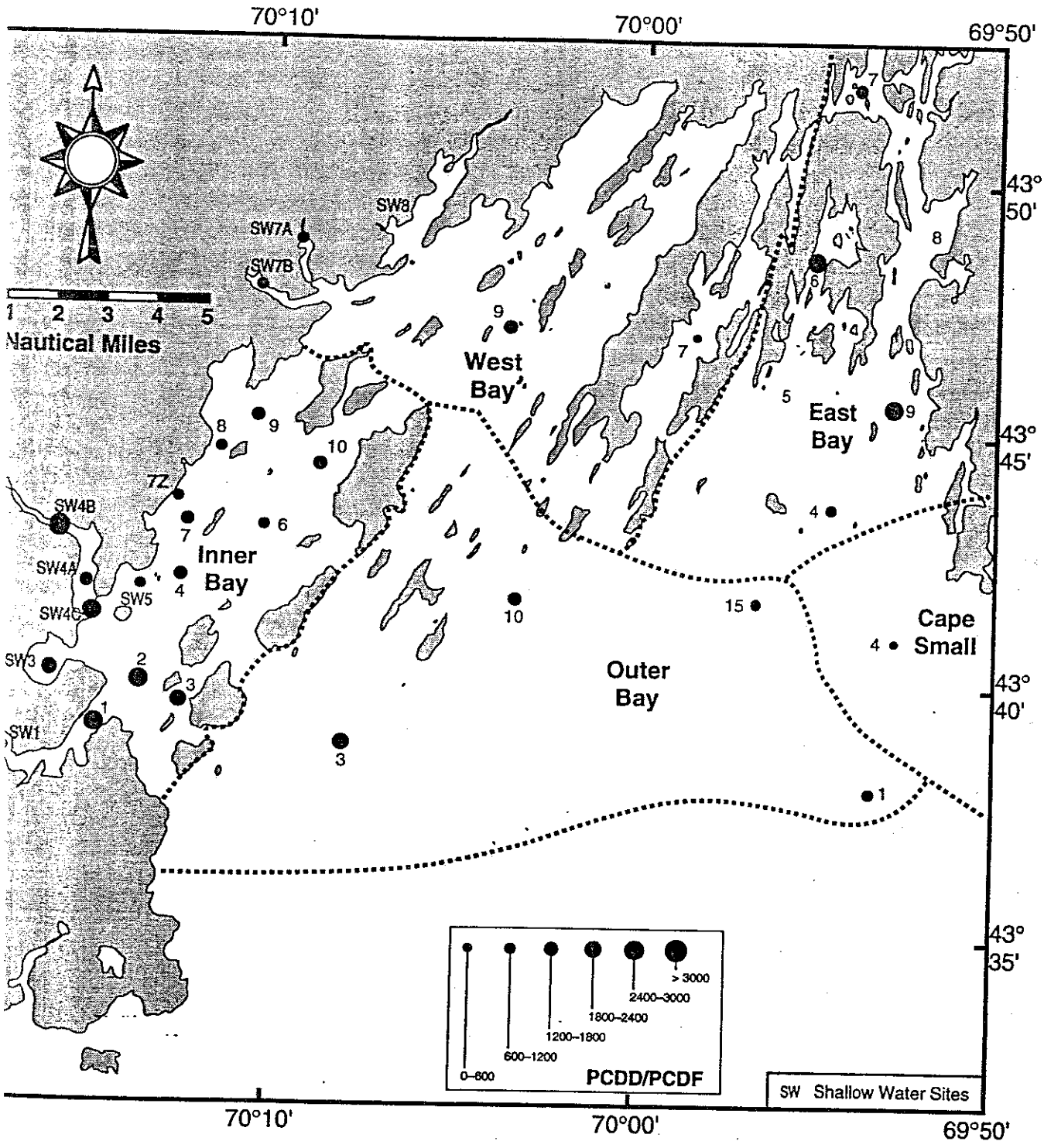

Figure 6. Sum of 2,3,7,8–substituted PCDD/PCDF concentrations for the 1994 Casco Bay sediment quality study.

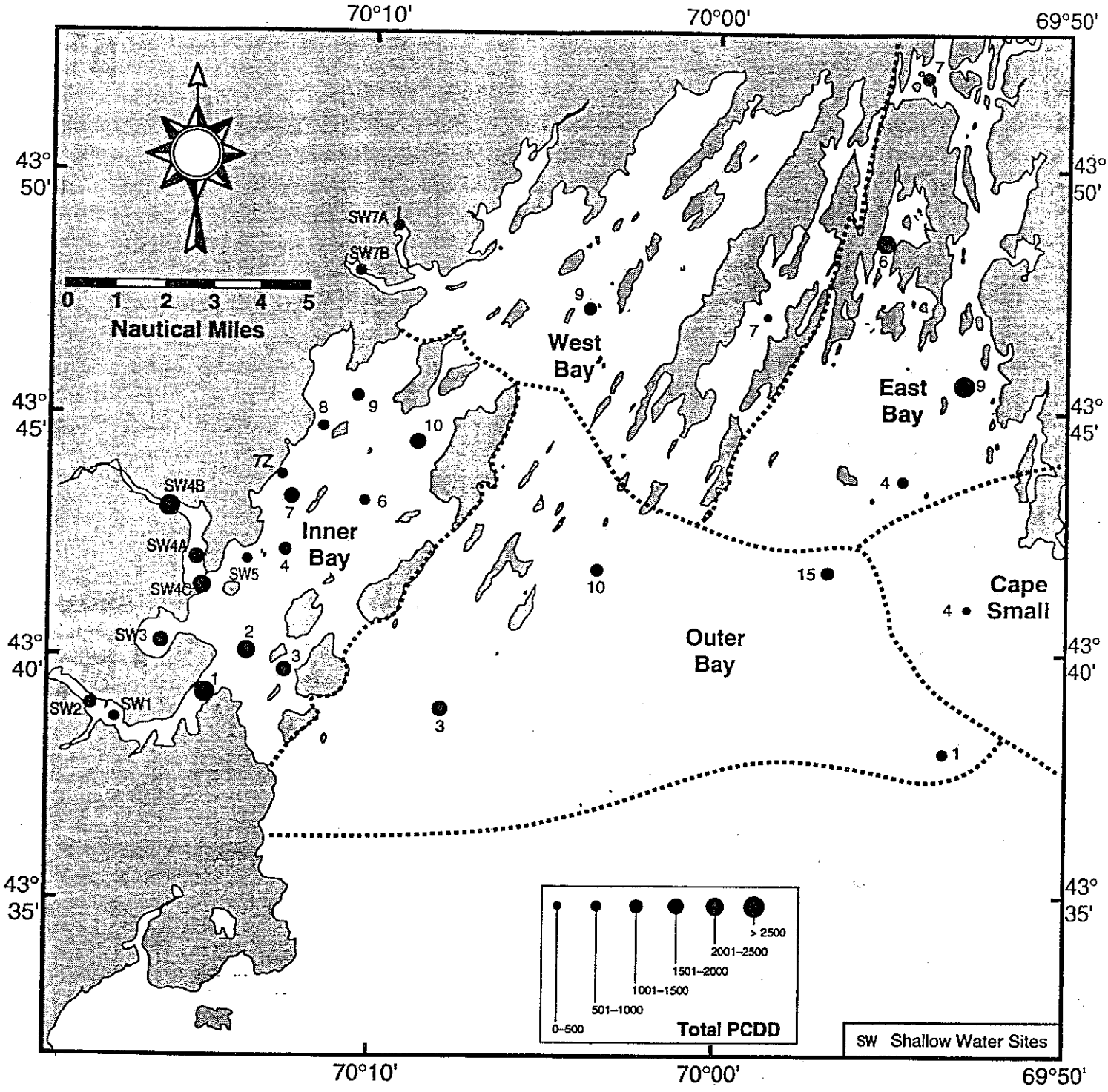

Figure 7. Sum of 2,3,7,8–substituted PCDD concentrations for the 1994 Casco Bay sediment quality study.

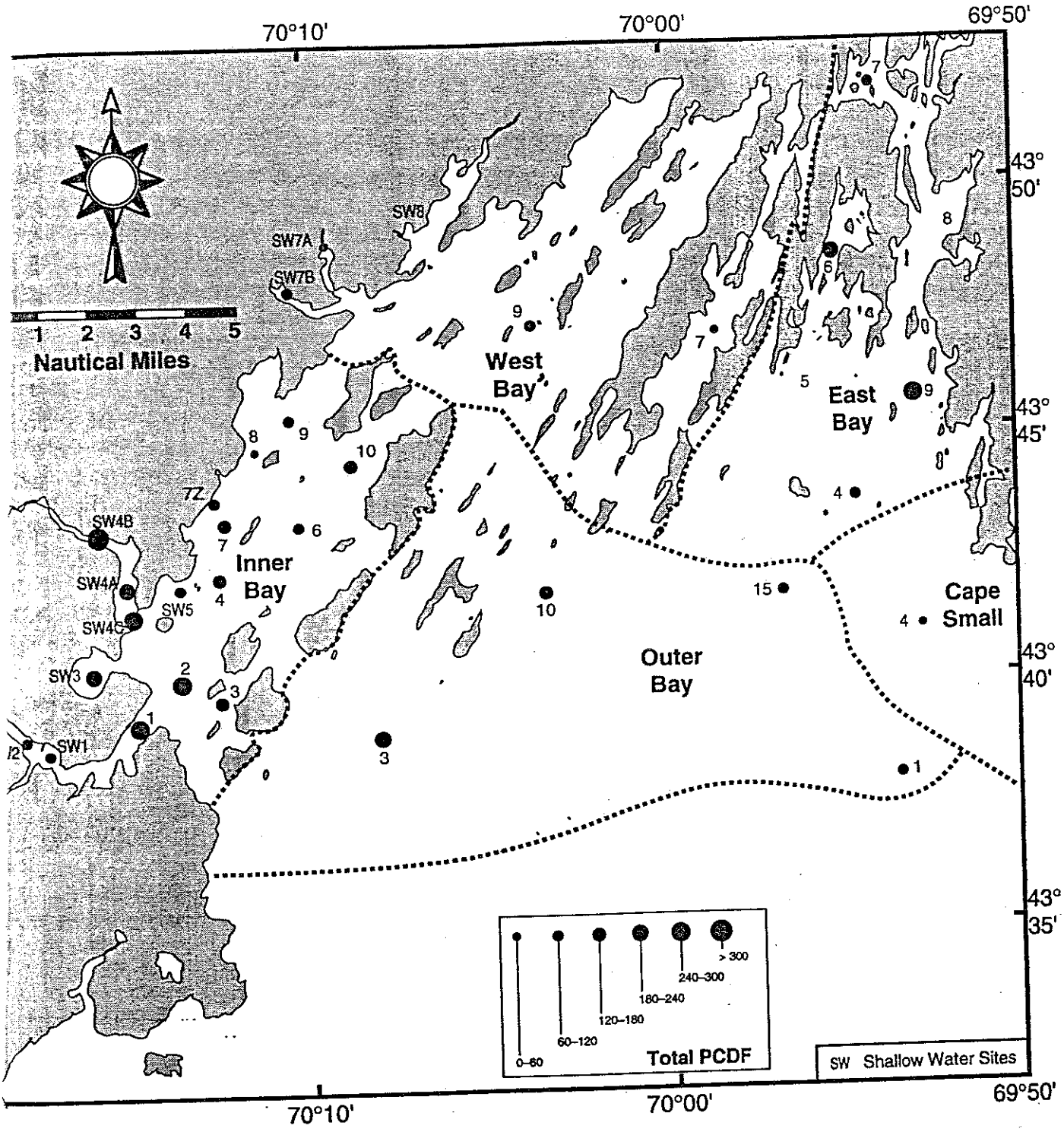

Figure 8. Sum of 2,3,7,8–substituted PCDF concentrations for the 1994 Casco Bay sediment quality study.

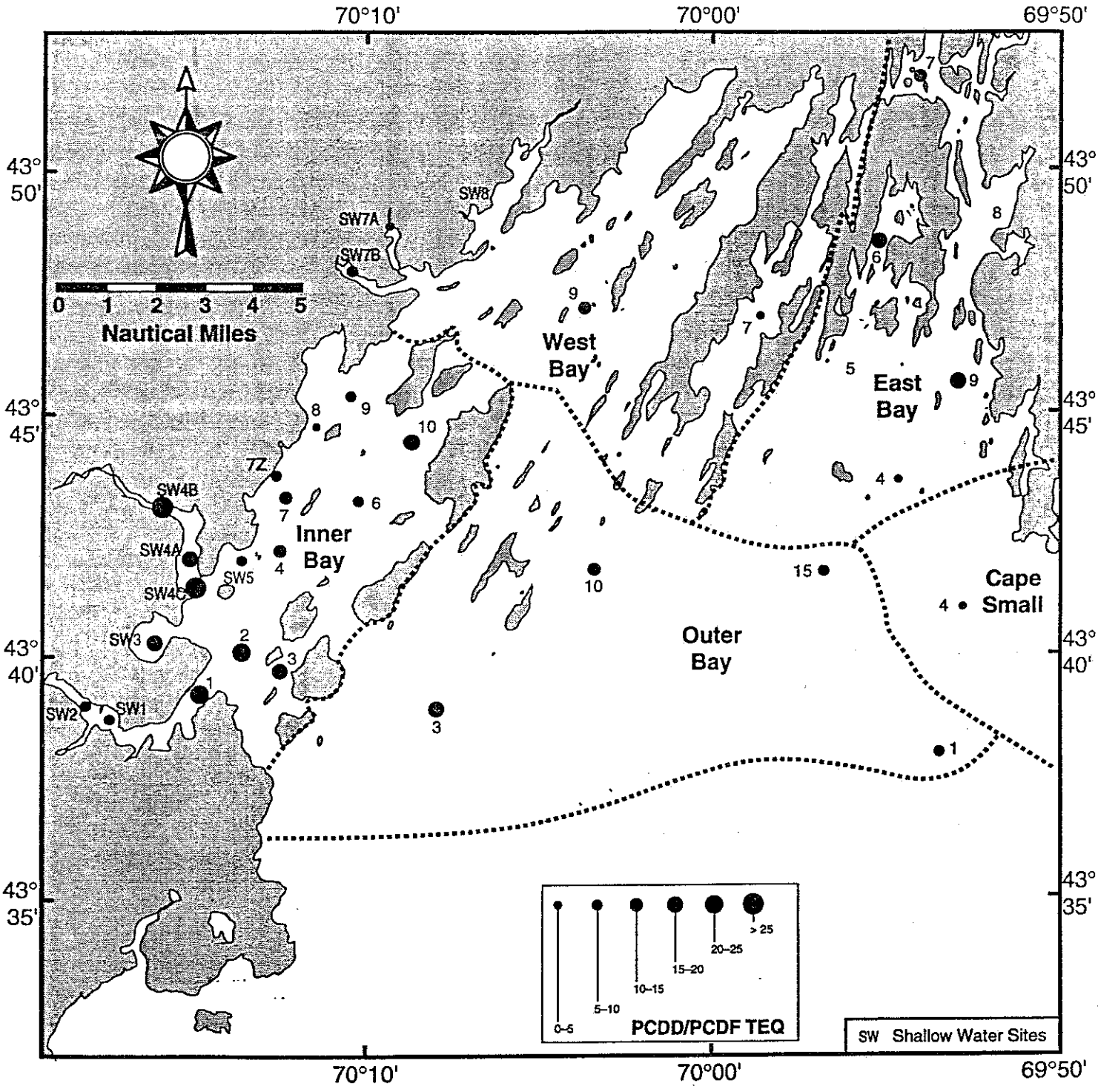

Figure 9. Total PCDD/PCDF TEQ for the 1994 Casco Bay sediment quality study.

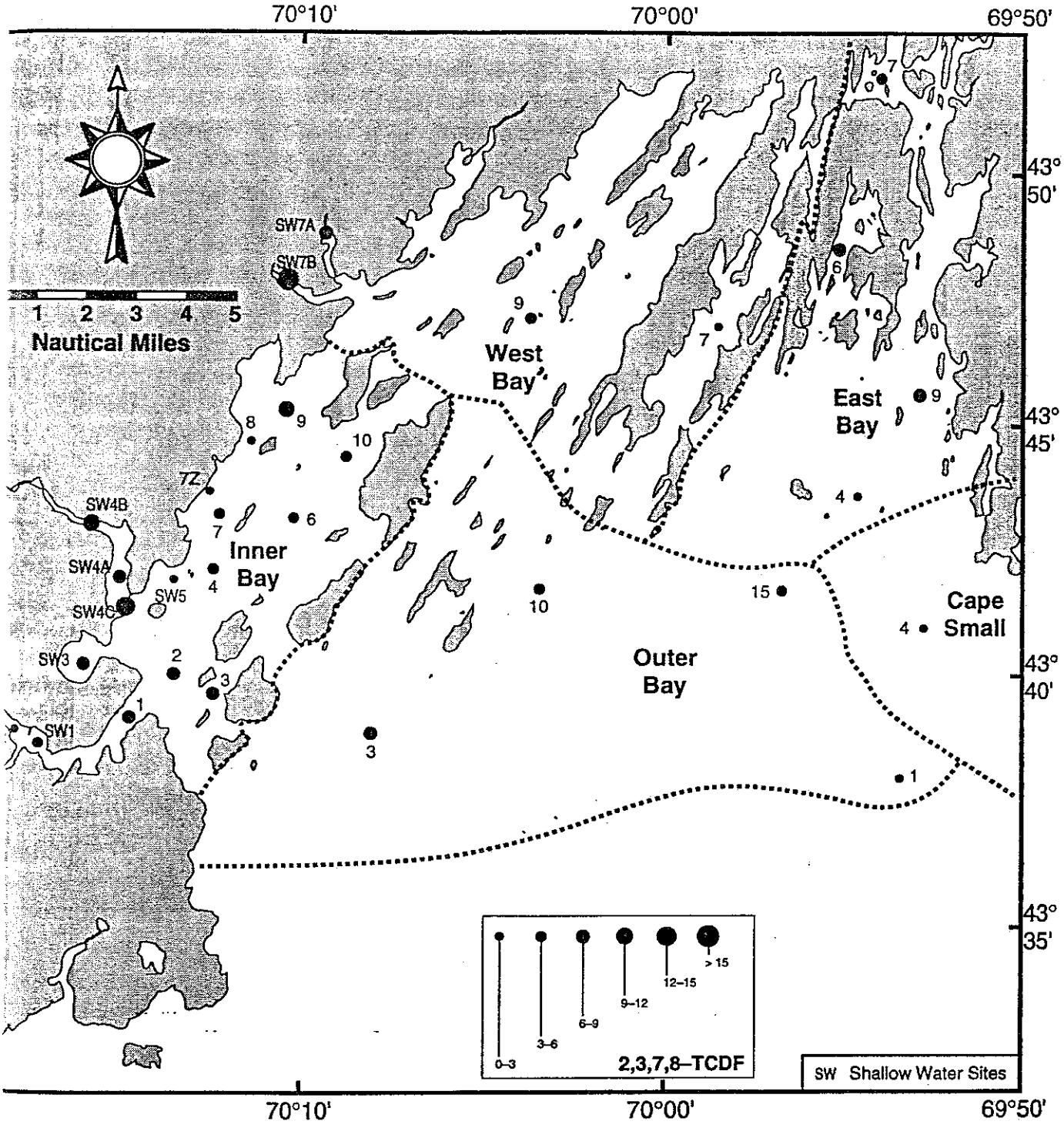

Figure 10. · 2,3,7,8–TCDF concentrations for the 1994 Casco Bay sediment quality study.

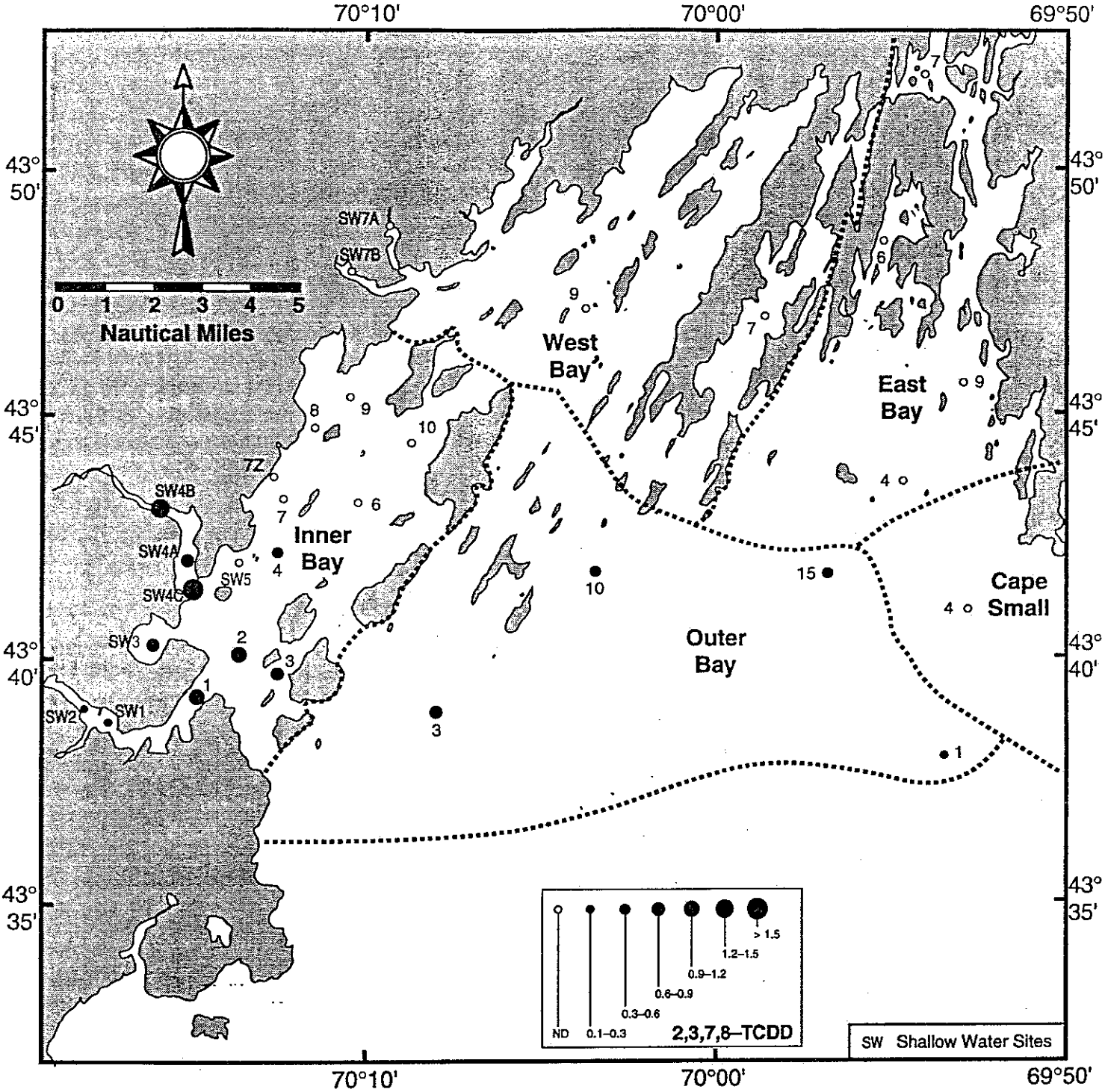

Figure 11. 2,3,7,8–TCDD concentrations for the 1994 Casco Bay sediment quality study.

The presence of higher concentrations of PCDD/PCDF (median 2000 pg/g) in East Bay site sediments is puzzling, but may be due to transport around Cape Small and deposition of fine-grained particulate matter from the Kennebec and Androscoggin Rivers. The East Bay has no major river input, only surface runoff from the surrounding shore area. Other possible sources of PCDD/PCDF responsible for the higher concentrations in East Bay are not apparent at this time but may be due to localized combustion processes (Spiro and Thomas 1994) including residential wood burning and incinerators (i.e., the one in Harpswell). Higher concentrations of PCDD/PCDF and TEQ are associated with sites near the Presumpscot River and Inner Bay. This may be a result of the influence of effluent from these rivers.

4.2.2 Comparison with other Waterways

Sediments from other coastal regions have a wide range of reported values for the concentration of 2,3,7,8-TCDD from not detected (ND) to 1500 pg/g. The TEQ for 2,3,7,8-TCDD/TCDF ranged from ND to 2300 pg/g (Clarke et al. 1994). The concentrations of 2,3,7,8-TCDD in Casco Bay (ND to 1.8 pg/g) are in the lower end of this range. However, sediments with low 2,3,7,8-TCDD concentrations may actually have TEQ values of concern resulting from the presence of other less toxic PCDD/PCDF isomers. For example, Inner Bay site SW04-C and East Bay site EB09 the TEQ for all the PCDD/PCDF measured was 27 and 18, respectively. The TEQ for these sites for only the TCDD/TCDF was 3.4 and 1.4, respectively. Therefore, the TCDD/TCDF TEQ may represent only 15% or less of the PCDD/PCDF TEQ. It is not known if all or some of these PCDD/PCDF found in the sediments are bioavailable.

4.3 Planar PCB

4.3.1 Casco Bay Data

In the initial 1991 study (Kennicutt et al. 1994), the spatial distribution of the median concentration of total PCB was; Inner Bay (33 ppb), East Bay (30 ppb), Outer Bay (20 ppb), West Bay (13 ppb) and Cape Small (2 ppb). A plot of the total PCB concentration from the samples obtained in 1991 versus the value of the planar PCB77 from the samples

obtained in 1994 yields a linear fit with an r^2 of 0.87, with four suspected outlier samples (one is not shown because it is off scale) excluded from the regression (Figure 12). These four points had lower total PCB concentrations than expected. The total PCB were determined on sediment samples collected in 1991 (Kennicutt et al. 1993) and the planar PCB determined on sediments collected in 1994. The Cape Small site likely had higher concentration of PCB when sampled in 1991. Total PCBs when sampled in 1994, based on the low value of PCB77 suggest that the total PCB concentration is probably near 6 ppb instead of 40 ppb. The depth and location of the sites for the two samplings were different. The other site that was excluded had similar problems.

For the planar PCB, the spatial distributions (Table 4; Figures 13 and 14) of the median concentration of PCB77 and PCB126 were similar to that for total PCB measured in the 1991 study (Kennicutt et al. 1994). For example, PCB 77 had higher median concentrations in Inner Bay (80 pg/g), East Bay (58 pg/g), Outer Bay (30 pg/g), West Bay (21 pg/g), and Cape Small (9.6 pg/g). In general the total planar PCB increase with increasing concentration of PCDD/PCDF (Figure 15). The Falmouth Foreside site (IB07-Z) has the highest concentration of planar PCB. The most toxic coplanar PCB, PCB126 sediment concentrations are highly correlated ($r^2 = 0.96$) with PCB77 concentrations (Figure 16). Planar PCB 169 was not detected in any of the sediment samples analyzed.

4.3.2 Comparison with other Waterways

In sediments from the Sacramento-San Joaquin River delta PCB77 varied from 9.5 pg/g to 27.8 pg/g. Bivalves associated with these sediments had at least a tenfold higher concentration of this planar PCB indicating possible biomagnification (Petreas et al. 1992). In Swedish sediments the concentration of PCB77 and PCB126 varies from not detected to 110,000 pg/g and not detected to 950 pg/g, respectively (Jarnberg et al. 1993). Thus PCB126 may pose as great a threat to the environment as the 2,3,7,8-TCDD and TCDF based on TEQ (Jarnberg et al. 1993). In sediments from Japan the average value for PCB77 was 150 pg/g for river sediments, while coastal sediments averaged 40 pg/g (Ohsaki et al. 1994). Concentrations of planar PCB found in Casco Bay sediments are within the expected range based on these other studies.

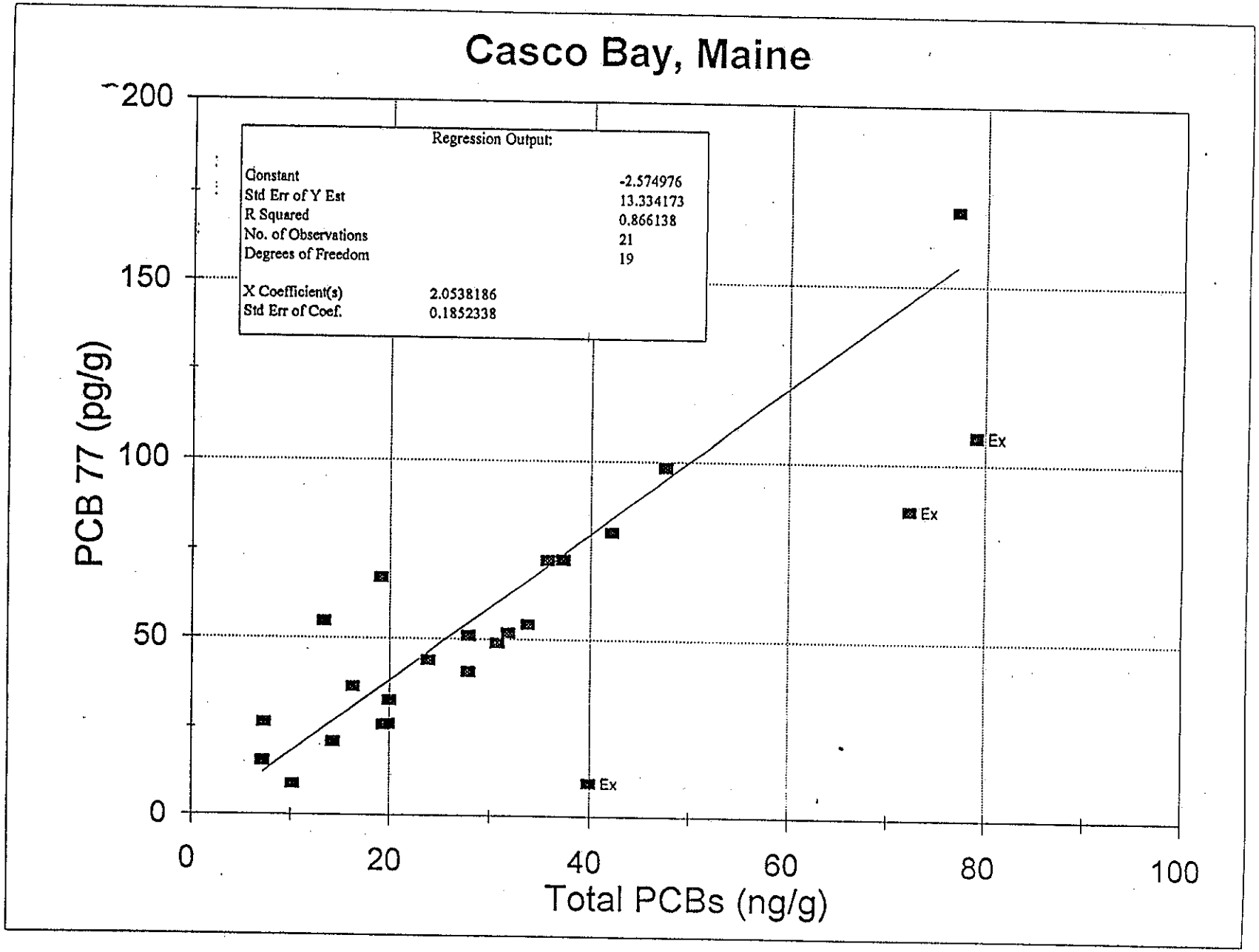

Figure 12. Relationship between total PCBs (from 1991) and PCB77 (from 1994).

Table 4. Planar polychlorinated biphenyls in Casco Bay Sediments

File Number	Description	PCB77 pg/g	PCB126 pg/g	PCB169 pg/g
Cape Small				
	Median	9.6	1.4	ND
C17425	CS04	9.6	1.4	ND
East Bay				
	Median	58	6.5	ND
C17426	EB04	21	2.3	ND
C17404	EB06	72	8.5	ND
C17400	EB07	44	5.6	ND
C17402	EB09	73	7.3	ND
Inner Bay				
	Median	80	8.5	ND
C17418	IB01	110	11	ND
C17419	IB02	98	10	ND
C17420	IB03	80	9.3	ND
C17413	IB04	52	ND	ND
C17245	IB06	42	5.6	ND
C17411	IB07	54	ND	ND
C17242	IB07-Z	210	23	ND
C17410	IB08	26	3.4	ND
C17409	IB09	55	5.4	ND
C17408	IB10	51	6.8	ND
C17417	SW01	87	9.9	ND
C17416	SW02	100	12	ND
C17412	SW03	170	15	ND
C17414	SW04-A	67	7.0	ND
C17415	SW04-B	95	8.5	ND
C17258	SW04-C	150	16	ND
C17250	SW05	26	3.2	ND
Outer Bay				
	Median	30	3.6	ND
C17424	OB01	15	ND	ND
C17421	OB03	49	6.9	ND
C17422	OB10	33	4.4	ND
C17423	OB15	26	2.7	ND
West Bay				
	Median	21	2.7	ND
C17405	WB07	8.8	1.5	ND
C17406	WB09	37	3.4	ND
C17427	SW07-A	13	1.9	ND
C17428	SW07-B	29	4.0	ND

ND = not detected

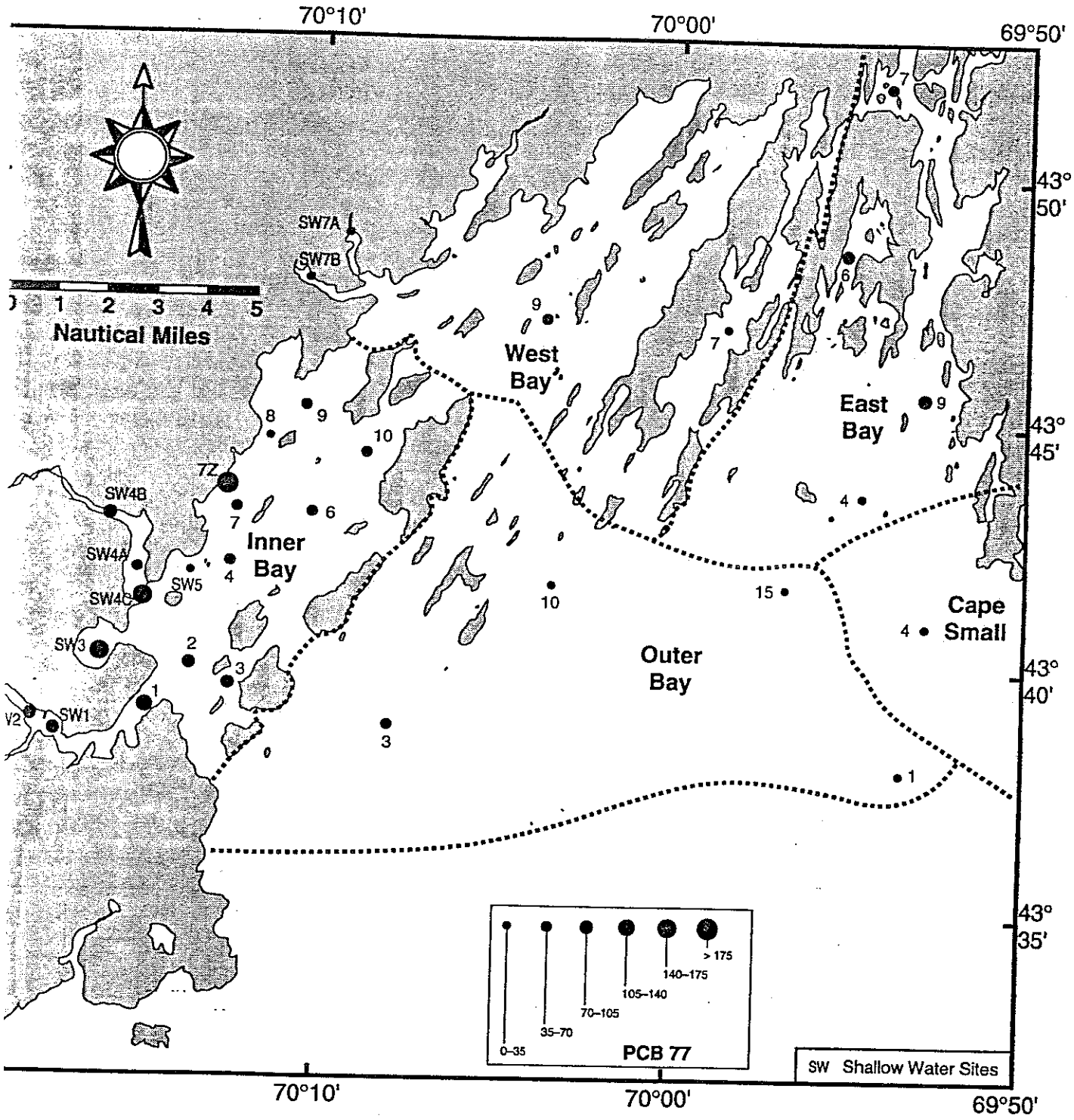

Figure 13. PCB 77 concentrations for the 1994 Casco Bay sediment quality study.

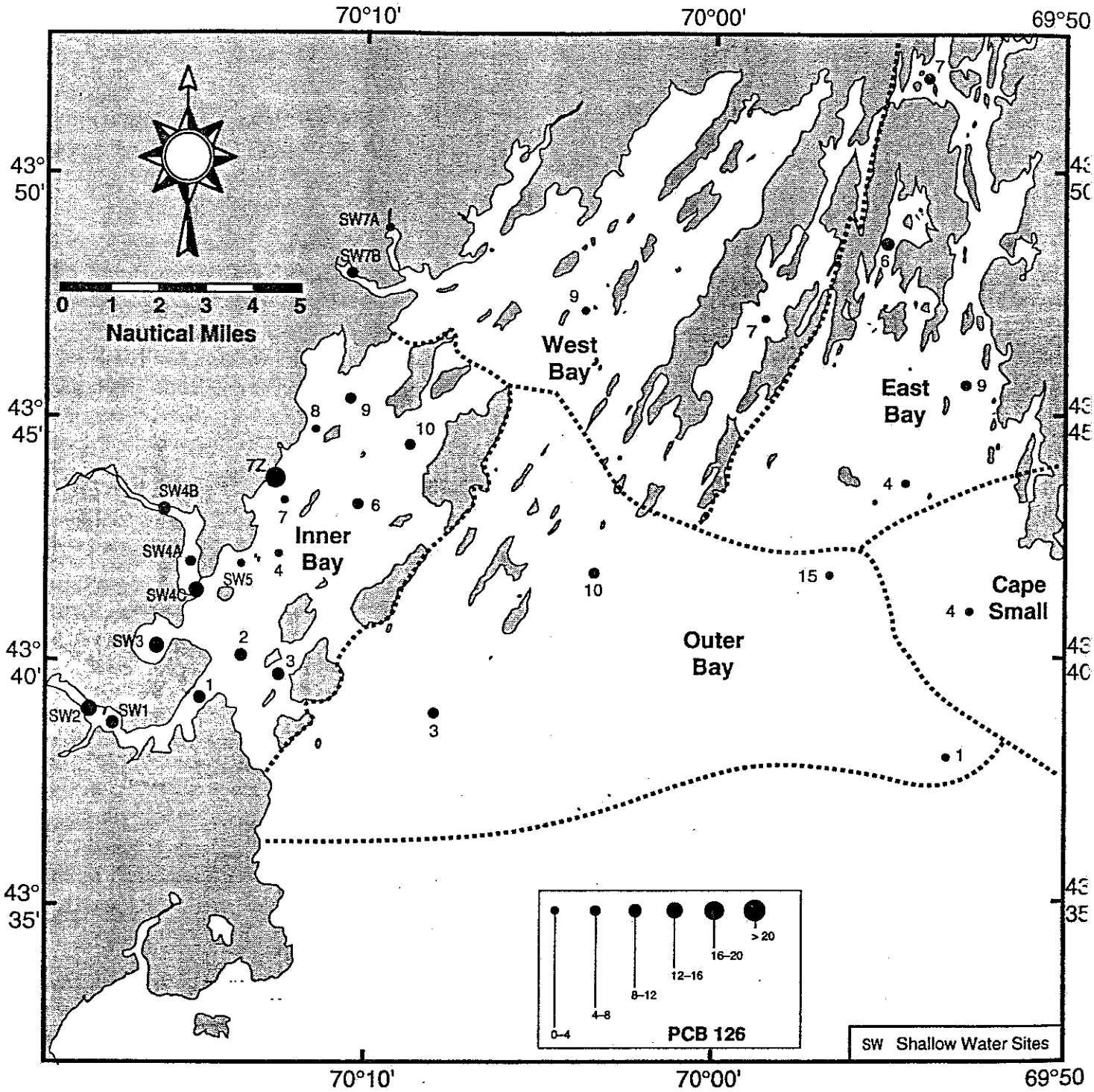

Figure 14. PCB 126 concentrations for the 1994 Casco Bay sediment quality study.

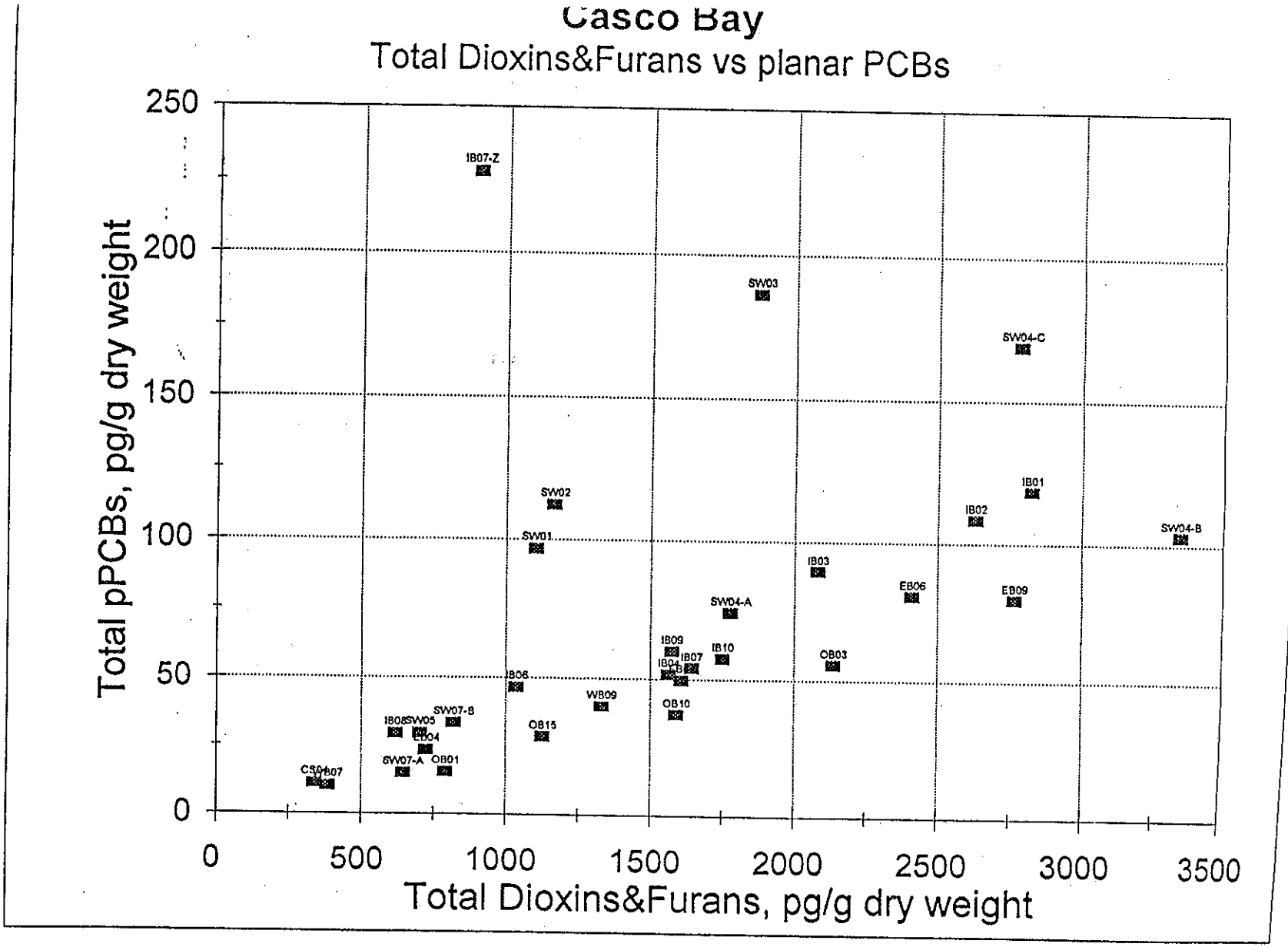

Figure 15. Relationship between total planar PCB and PCDD/PCDF.

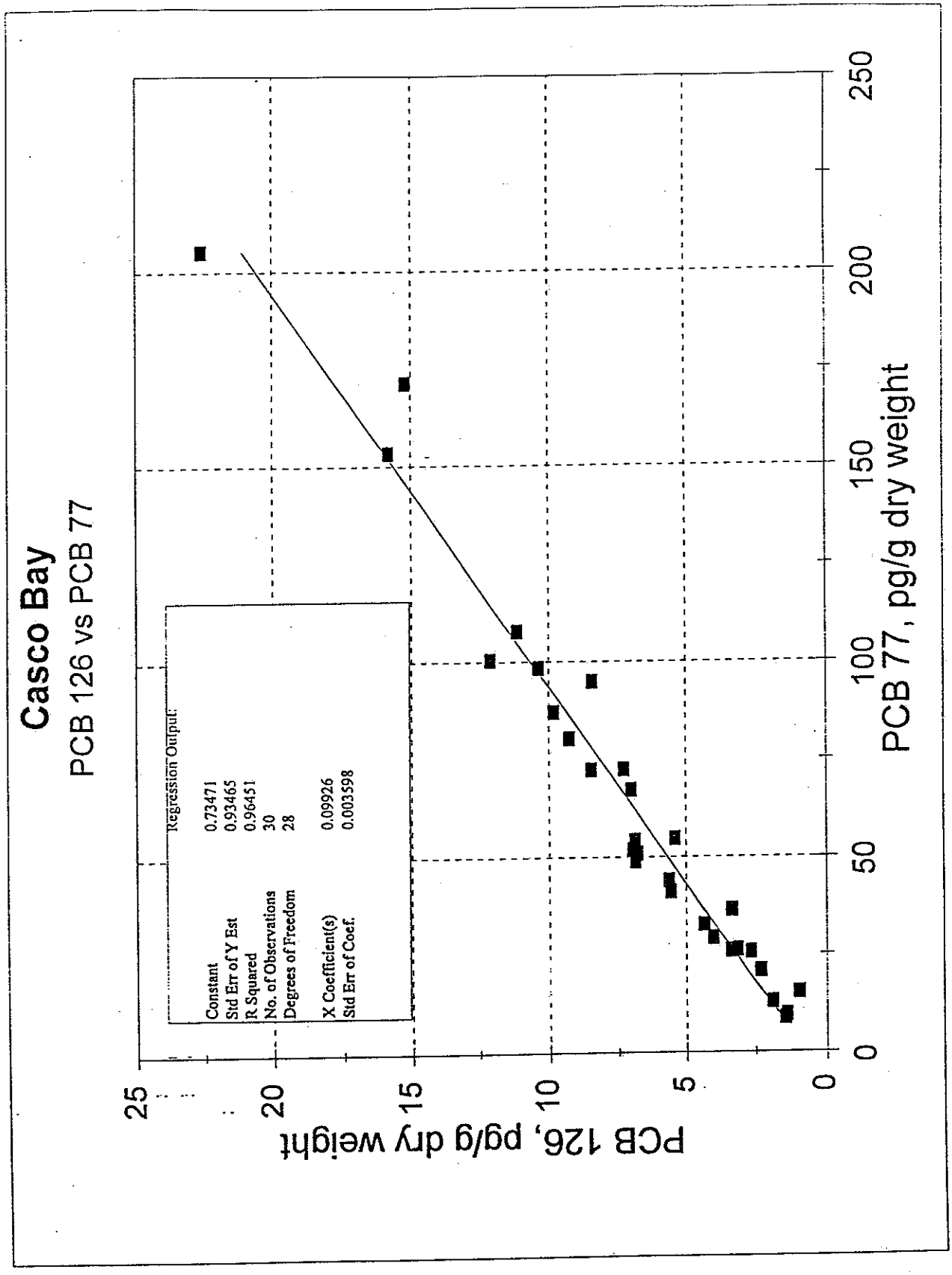

Figure 16. Relationship of PCB126 and PCB77.

4.4 TEQ

Sediment samples from Casco Bay were analyzed for planar PCB in order to determine the TEQ that can be attributed to these toxic compounds when compared to TEQ for PCDD/PCDF and TCDD/TCDF (Safe 1994). The consumption advisory for Casco Bay was based on the TEQ of 2,3,7,8-TCDD/TCDF. The TCDD/TCDF TEQ represents less than 15% of the total PCDD/PCDF TEQ (Figure 9) found in the Casco Bay sediments. The planar PCB also represent potentially available TEQ in the sediments. The TEQ distribution for planar PCB is similar to the TEQ for PCDD/PCDF (Figure 17). The addition of the planar PCB TEQ to the TEQ for PCDD/PCDF does not change the distribution substantially (Figure 18). However, TEQ for the planar PCB represent more TEQ to the sediment than the TCDD/TCDF TEQ (Table 5). Planar PCB have been demonstrated to be bioavailable (Sericano et al. 1994). In the future it would be prudent for regulators to determine not only the TEQ present from TCDD/TCDF but also planar PCB as well as other potential contributors to the total TEQ of fish and shellfish in order to adequately protect human health.

4.5 Summary

Butyltins, PCDD/PCDF and planar PCB were detected in sediments from all areas of Casco Bay. The concentrations observed were in the low end of the range reported for other similar estuaries. The concentrations were highest near potential input sources. For example, butyltins concentrations were higher in the vicinity of boating activities (i.e., docks, anchorages, shipyards). In spite of the low concentration in sediment, the TBT concentration may be responsible for degraded sediment conditions (Macauley et al. 1994).

The Inner Bay is the had the highest concentrations of PCDD/PCDF due to inputs from and upstream of the densely populated Fore and Presumpscot Rivers. For example, PCDD/PCDF and especially 2,3,7,8-TCDD had higher concentrations near the Presumpscot River where there is a pulp and paper mill 10 miles up stream. The effluent from the paper mill had detectable concentrations of 2,3,7,8-TCDD (Mower 1994) The Cape Small area is the least contaminated because it is furthest removed from most inputs and is not a major depositional area for sediments. The West

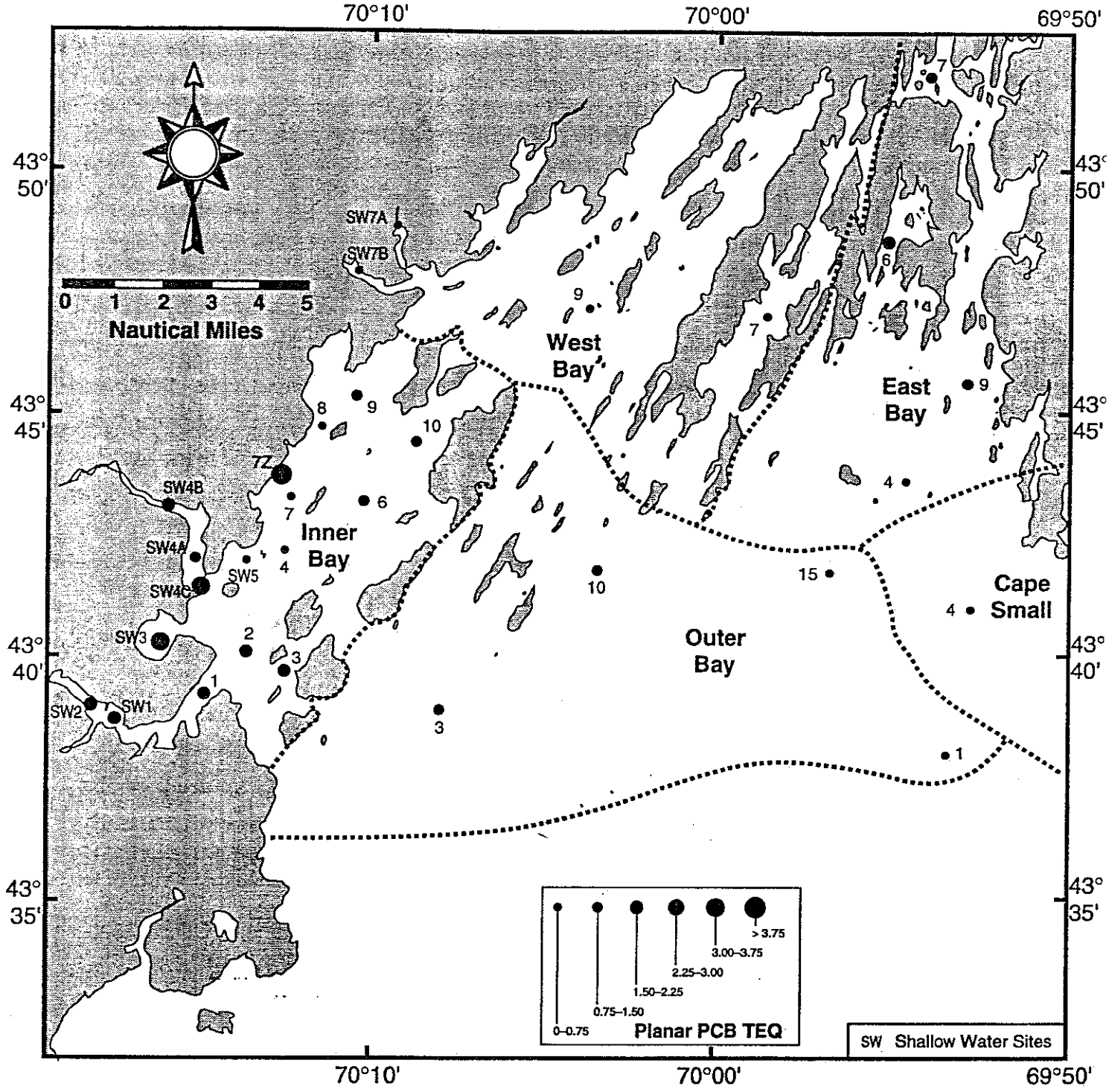

Figure 17. Planar PCB TEQ for the 1994 Casco Bay sediment quality study.

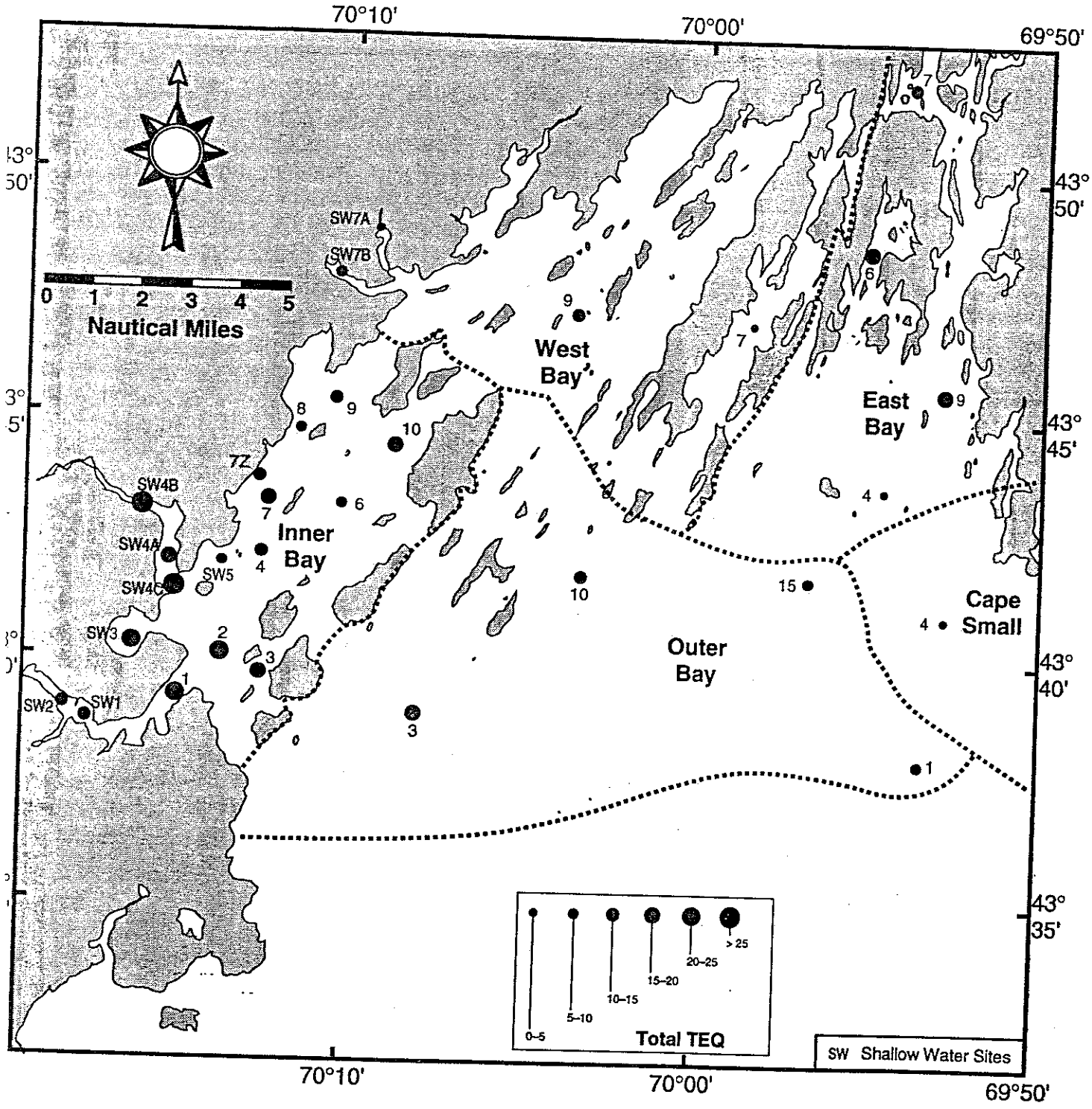

Figure 18. Total TEQ for the 1994 Casco Bay sediment quality study.

Table 5. Toxic equivalents (TEQ) for TCDD/TCDF, PCDD/PCDF, Planar PCB, and Total TEQ (sum of planar PCB plus PCDD/PCDF).

Lab Sample ID	Client Sample ID	TEQ (TCDD/TCDF)	TEQ (PCDD/PCDF)	TEQ (Planar PCB)	TEQ (Total)
Cape Small					
	Median	ND	1.8	0.2	2.0
C17425	CS04	ND	1.8	0.2	2.0
East Bay					
	Median	0.7	14	1.3	15
C17426	EB04	ND	4.1	0.4	4.5
C17404	EB06	ND	16	1.6	18
C17400	EB07	1.4	11	1.0	12
C17402	EB09	1.4	18	1.5	20
Inner Bay					
	Median	1.6	15	1.7	15
C17418	IB01	2.2	22	2.2	24
C17419	IB02	2.3	21	2.0	23
C17420	IB03	2.0	17	1.7	19
C17413	IB04	1.5	14	0.5	15
C17245	IB06	ND	8.9	1.0	9.9
C17411	IB07	1.8	15	0.5	16
C17242	IB07-Z	ND	6.0	4.3	10
C17410	IB08	ND	4.6	0.6	5.2
C17409	IB09	ND	9.8	1.1	11
C17408	IB10	1.8	15	1.2	16
C17417	SW01	0.9	9.2	1.9	11
C17416	SW02	0.8	8.5	2.2	11
C17412	SW03	2.4	19	3.2	22
C17414	SW04-A	1.6	16	1.4	17
C17415	SW04-B	2.3	25	1.8	27
C17258	SW04-C	3.4	27	3.1	30
C17250	SW05	ND	5.8	0.6	6.4
Outer Bay					
	Median	1.1	11	0.6	11
C17424	OB01	0.6	6.3	0.2	6.5
C17421	OB03	1.7	18	1.2	19
C17422	OB10	1.3	13	0.8	14
C17423	OB15	0.8	8.0	0.5	8.5
West Bay					
	Median	0.2	5.3	0.5	5.8
C17405	WB07	0.4	2.6	0.2	2.8
C17406	WB09	1.5	11	0.7	12
C17427	SW07-A	ND	4.2	0.3	4.5
C17428	SW07-B	ND	6.4	0.7	7.1

Bay is sheltered and receives inputs only from the Royal and Cousins Rivers and therefore is less contaminated. The higher contaminant concentrations in East Bay are not explained, but may be the result of transport into the bay from the Kennebec and Androscoggin Rivers or local combustion sources. The detection of 2,3,7,8-TCDD/TCDF in lobster tissue and tomalley indicates that these compounds are bioavailable. The concentrations of 2,3,7,8-TCDD/TCDF have resulted in an advisory regarding consumption of lobster tomalley (Mower 1994).

Additional studies are required to determine if PCDD/PCDF isomers, planar PCB, butyltins, and other contaminants are bioavailable to the fisheries resources of Casco Bay and pose human health concerns. The most likely source of concern based on this study are PCDD/PCDF and toxic PCB. These studies should focus on the Inner Bay where these contaminants are highest in the sediments which may be a potential source for bioaccumulation in the fisheries resources (i.e., lobster). It would also be informative to determine the relative importance of local combustion sources of PCDD/PCDF to Casco Bay by the analyses of air and precipitation samples.

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