Methods

- Mussel Watch sites were selected to represent coastal areas that can be used to construct a nationwide assessment.
- Approximately half the sites are visited each year.
- Sediment samples are collected from Mussel Watch sites approximately once every 10 years, when new sites are established, or during special sampling events such as oil spills.
- Bivalve collection includes blue mussels in the Northeast Atlantic, and West Coast; oysters in the Middle Atlantic, Southeast Atlantic, Gulf of Mexico, Hawaii, and Puerto Rico; and zebra mussels in the Great Lakes.

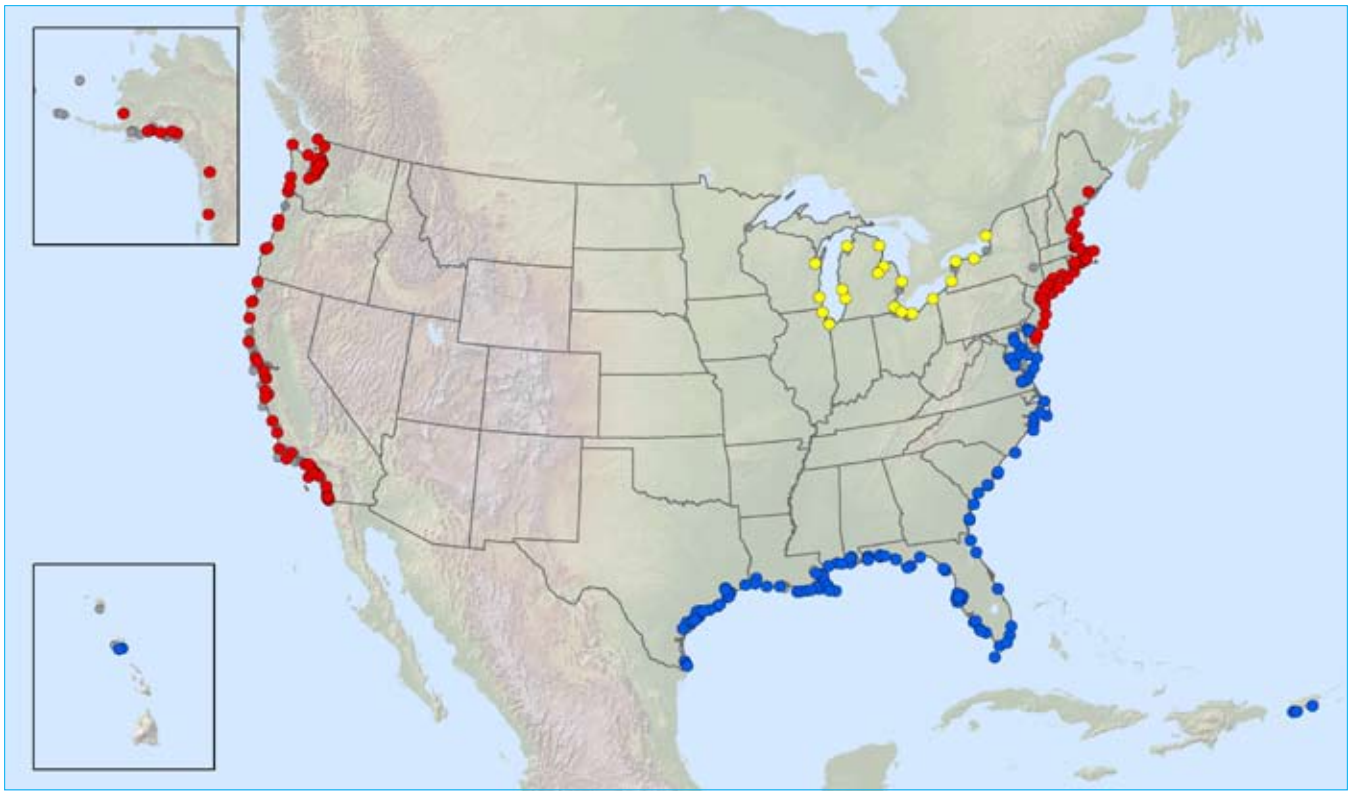

Figure 2. Distribution of ● zebra mussels, ● oysters, and ● mussels collected and measured as part of the Mussel Watch Program PBDE assessment. Mussel Watch Program sites not measured as part of this study (●).

Species and Sites

Mussels and oysters are widely distributed along the coasts. They are integrators of contaminants where they live, and their use as indicators minimizes the problems inherent in comparing data from markedly different species (Berner et al., 1976; Farrington et al., 1980; Farrington, 1983; Tripp and Farrington, 1984). They are good indicators of environmental quality because contaminant levels in their tissue respond to changes in the ambient environment and accumulate with little metabolic transformation (Roesijadi et al., 1984; Sericano, 1993).

Mussel Watch sites were selected to represent coastal areas that can be used to construct a nationwide assessment. Sites selected for monitoring are generally 10 to 100 km apart along the entire U.S. coastline, including the Great Lakes, Puerto Rico, and Hawaii. Where possible, sites were selected to coincide with historic mussel and oyster monitoring locations from other programs, such as the U.S. EPA's Mussel Watch sites that were sampled from 1976 to 1978 (Goldberg et al., 1983), and to complement sites sampled through state programs, such as the California Mussel Watch Program (Martin, 1985).

Because one single species of mussel or oyster is not common to all coastal regions, a variety of species are collected to gain a national perspective. A target species is identified for each site based on abundance and ease of collection. Mussels (*Mytilus*

Table 3. Bivalves species used to assess national coastal PBDE concentrations.

Target Species	Name used in this report
Mytilus edulis, Mytilus californianus, Mytilus galloprovincialis, and *Mytilus trossulus*	Mussels
Crassostrea virginica, Ostrea sandvicensis, Crassostrea rhizophorae, and *Chama sinuosa**	Oysters
Dreissena polymorpha and *Dreissena bugensis*	Zebra mussels

* smooth-edge jewelbox collected from one site in the Florida Keys

species) are collected from the North Atlantic (Maine to Delaware) and Pacific coasts. Oysters are collected from Delaware Bay southward and along the Gulf Coast (*Crassostrea virginica)*, Hawaii (*Ostrea sandvicensis)*, and Puerto Rico *(Crassostrea rhizophorae)*. *Chama sinuosa* is collected from the Florida Keys and is classified along with oysters for this report. Zebra and quagga mussels (*Dreissena species*) are invasive species collected from the Great Lakes (Table 3; Figure 2). Oysters and *Mytilus* species range in size from 7 to 10 cm and 5 to 8 cm, respectively. Zebra mussels are smaller, typically 2 to 4 cm. Previous comparisons of contaminant accumulation between mussels and oysters showed large differences for trace metals, particularly zinc and copper, but the differences in organic contaminants were determined to be minor and not likely to affect comparison between species (O'Connor, 1992).

Although the U.S. coastline is extensive, relatively few species are currently required to determine a national contaminant perspective. It is possible to make spatial comparisons of organic contaminant concentrations across all sites, because Mussel Watch species bioaccumulate organic contaminants similarly (O'Connor, 1992).

Oysters and mussels are collected by hand or dredged from intertidal to shallow subtidal zones, brushed clean, packed in iced containers, and shipped to analytical laboratories within two days of collection. Approximately 20 oysters or 30 mussels are composited for each site from three stations. The bivalves are shucked, soft tissue is homogenized, and approximately 15 grams of wet tissue is extracted. Sample collection, preparation, and extraction protocols are described in detail in McDonald et al., (2006); Lauenstein et al., (1997); Lauenstein and Cantillo, (1993a-d and 1998).

Mussel Watch sites are sampled biennially with approximately half the sites visited in any one year. Annual collections are spatially distributed to provide a national snapshot (Figure 2). To provide a historical perspective and a current assessment, Mussel Watch samples from 1996 and 2004-2007 were measured respectively. Samples collected between 2004 and 2007 were aggregated and called 200X (Figure 3). Hence, 200X is a designation for samples collected from 2004 through 2007.

Sediment Sites

Sediment samples are collected from Mussel Watch sites approximately once every 10 years, when new sites are established, or following extreme events such as oil spills. Bivalve and sediment sites are taken from areas in close proximity to one another. The top 3 cm of sediments, representing recent deposition, are used in this analysis. Three sediment grabs are collected from three

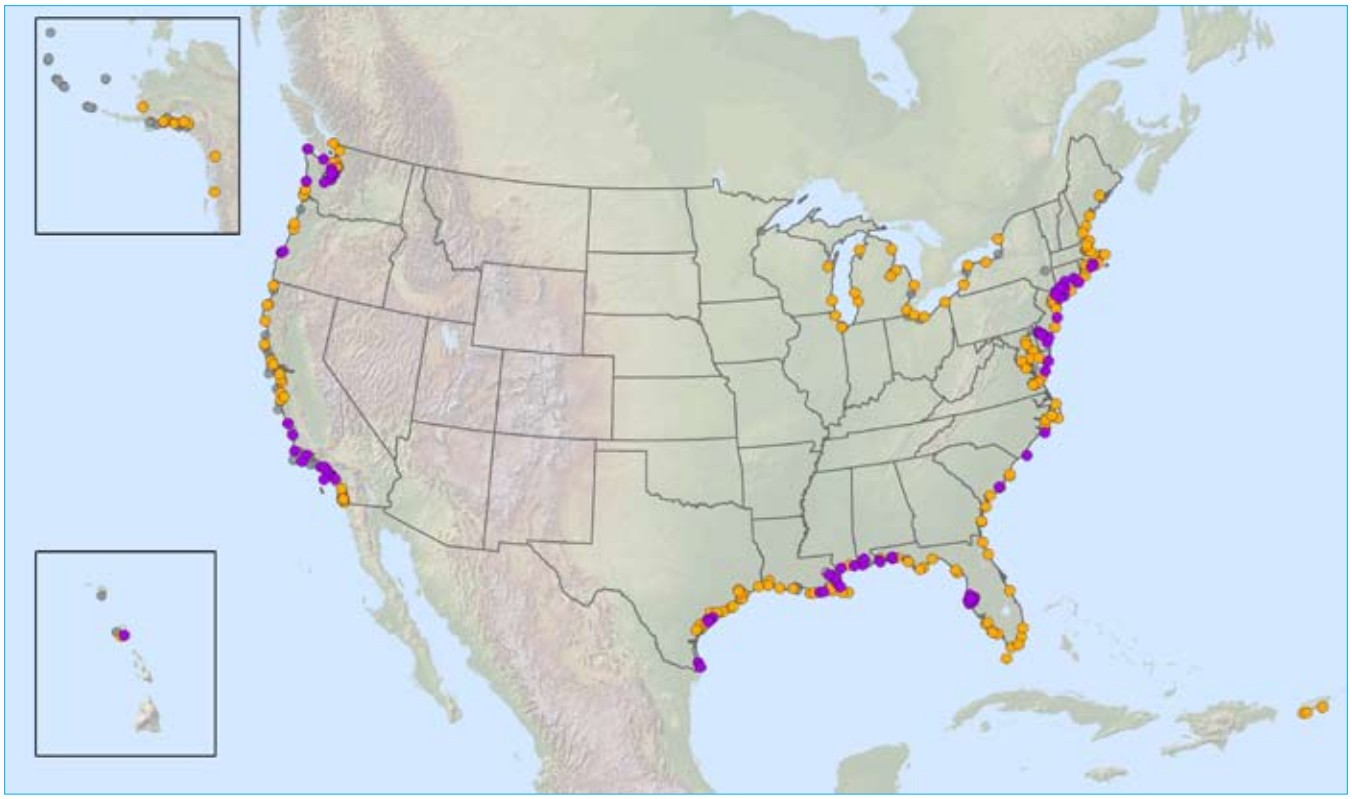

Figure 3. Number of biennial measurements taken at each of the 254 sites sampled in 1996 and 200X. Sites shown have one year (●) or two years (●) of data. Mussel Watch Program sites not measured as part of this study (●).

stations and composited. Sediment collection sites are located as near as possible to, but generally not more than, 2 km from the bivalve site, and located in low energy depositional areas.

Analytical Methods

Analytical methods used by the Mussel Watch Program are provided in Appendix 2 and available online at http://NSandT.noaa.gov. Of the 209 possible PBDE congeners, 38 were analyzed for this report (Table 2) as a result of available standards, methodology and predominant congeners (Appendix 2). The co-eluting congeners 49 and 71 are labeled in this document as 49.

Higher substituted PBDEs, such as the octa, nona, and deca homologues that were not measured in this study, appear to accumulate preferentially in sediment. Other homologues, those measured in this study, more frequently accumulate in tissue (Zhu and Hites, 2005). Hence, this presentation provides a partial picture of the sediment-tissue relationship.

While PBDE's occur at ten different bromination levels, it was standard in early analyses to quantify the concentration of the first seven homologues. The more highly brominated forms or homologues (octa-, nona-, and deca-) were not generally measured because a standardized procedure for doing so did not readily exist. As the use of Deca, the most highly brominated form became the industry standard, the need to measure its presence in the environment

became increasingly important. A procedure for measuring high molecular weight PBDE's was developed for use in the NS&T and was implemented as a part of our protocols in 2007. Archived Mussel Watch samples have not yet been reanalyzed for these heavier compounds but could be should the need arise.

Statistical Analysis

Results from a Shapiro-Wilk W test for tissue (W = 0.233, prob < W =0.001) and sediment (W = 0.257, prob < W = 0.001) show that Mussel Watch chemistry data were not normally distributed; thus, nonparametric tests were used for statistical analyses.

All measurements below detection limits were considered to be zero. Maps for each year show the sum of all 38 PBDE (Table 2) congeners measured for this study. Mussel Watch sites were classified into three groups. Sites below detection limit were categorized as low. Sites above the detection limit were categorized as either medium or high through cluster analysis. Clustering was performed using Ward's Minimum Variance technique. The concentration in each cluster group was then tested using Wilcoxon analysis to ensure that medium and high categories were significantly different at the $\alpha = 0.05$ level. Statistical outliers were reanalyzed to ensure measurements were correct and then combined within the high category. Here, clustering was used to partition site-specific PBDE concentrations into a fixed number of "closely related" subsets. For purposes of highlighting regions with elevated PBDEs, clustering was limited to 2 subsets: high and medium.

Spearman's nonparametric statistical test was used to test for correlation between PBDE concentrations and human population. Population was derived from 2000 census data and represents population within a radius of 20 km of each site. Tests were considered significant at the $\alpha = 0.05$ level.

To evaluate overall PBDE contamination levels in watersheds throughout the Nation, a 2-way clustering (statistical classification) procedure was performed using paired sediment and tissue concentrations simultaneously. This procedure provided a descriptive yet objective technique to consider PBDE contamination levels as a function of the two measurements. Sediment and tissue concentrations from all sites within each unique watershed were averaged to develop the 2-way classification.

The Wilcoxon analysis was used to compare sediment and tissue concentrations from the watershed comparison analysis, significance was achieved at the $\alpha = 0.05$ level. To ensure comparable dimensions the dry weight measurements for sediment and tissue were used.


Mussels

Results and Discussion

- The highest PBDE concentrations were measured at industrial and urban locations.
- Sediment and tissue PBDE concentrations were correlated with human population within 20 km of a site.

Tissue

The national distribution of PBDEs is presented as the sum of all 38 congeners. The majority of tissue measurements above detection limits had concentrations between 1 and 270 ppb lipid weight and were categorized as medium (Figure 4 - 6). Eight percent of tissue samples (1996 and 200X) had all 38 congener measurements below detection limits.

Anaheim Bay, CA, located in an industrialized area that includes a military base, had the highest measurement in the Nation (8202 pbb lipid weight). Elevated PBDE concentrations were also found in several other developed and industrialized areas; the most high measurements occurred in the Hudson-Raritan Estuary (Figures 5 and 6; Table 4).

The highest percentage of low and high measurements occur in oysters and mussels respectively (Figure 4). As discussed earlier, the species differences are not thought to reflect uptake rate variability, rather local contaminant conditions (O'Connor, 1992). Hence, species-based distributions of PBDE bivalve body burdens are not presented.

Using Spearman's nonparametric statistical test (Figure 7), human population within 20 km of a site was found to be positively correlated with tissue concentrations (Rho = 0.555, prob <0.001). However, sites located in the same region (e.g. Southern California) exhibited both increasing and decreasing decadal results (Figure 8). This is evidence that, like many contaminants, local sources are key in determining environmental concentrations.

Temporal changes were assessed using the following categories: increasing, decreasing, or no significant change (Figure 8). The highest increase occurred at Anaheim Bay, CA; the largest decrease occurred at a Buzzards Bay, MA location.

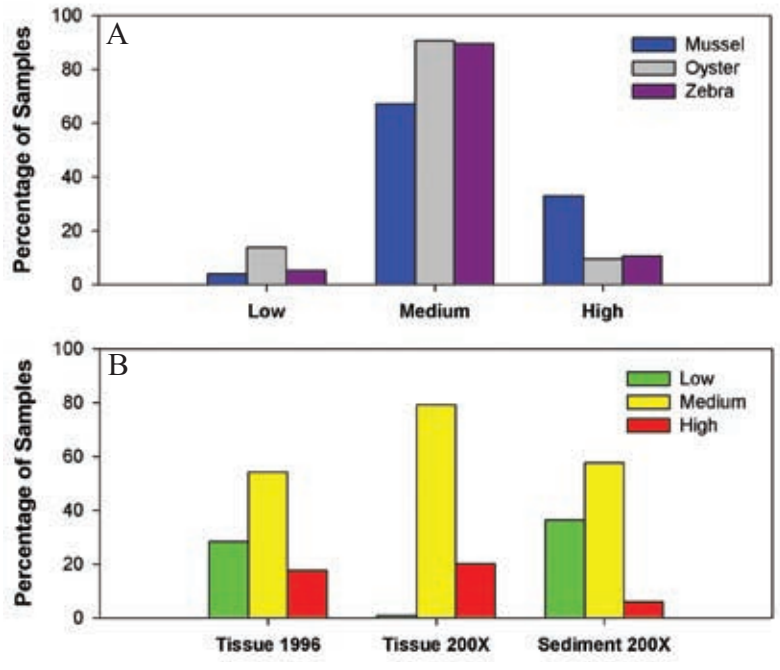

Figure 4. Percentage bar charts by species, tissue and sediment: (A) species mussel n = 161, oyster n = 158, and zebra n = 20; (B) tissue (1996 n = 85, 200X n = 254) and sediment (200X n = 122) measurements, where 200X = 2004 through 2007. Categories low (●), medium (●), and high (●) were determined by cluster analysis.

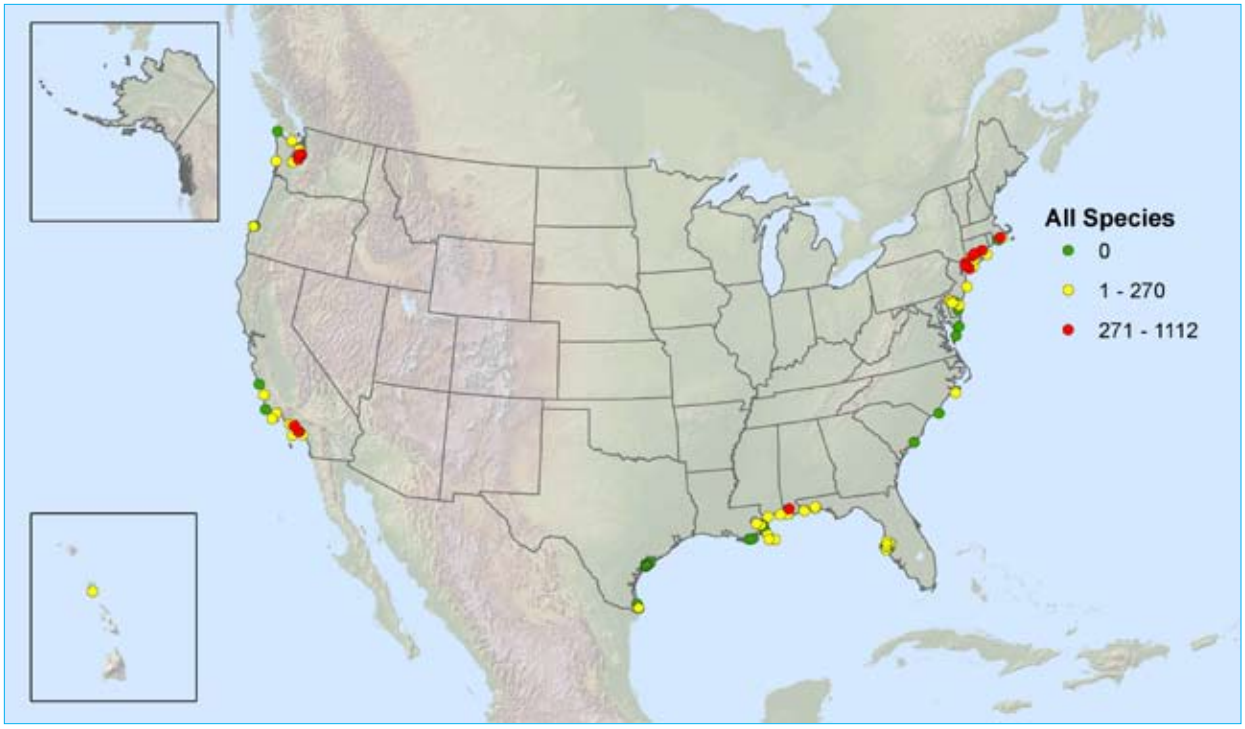

Figure 5. National distribution of 1996 PBDE tissue concentration in ppb lipid weight. Categories low (●), medium (●), and high (●) were determined by cluster analysis.

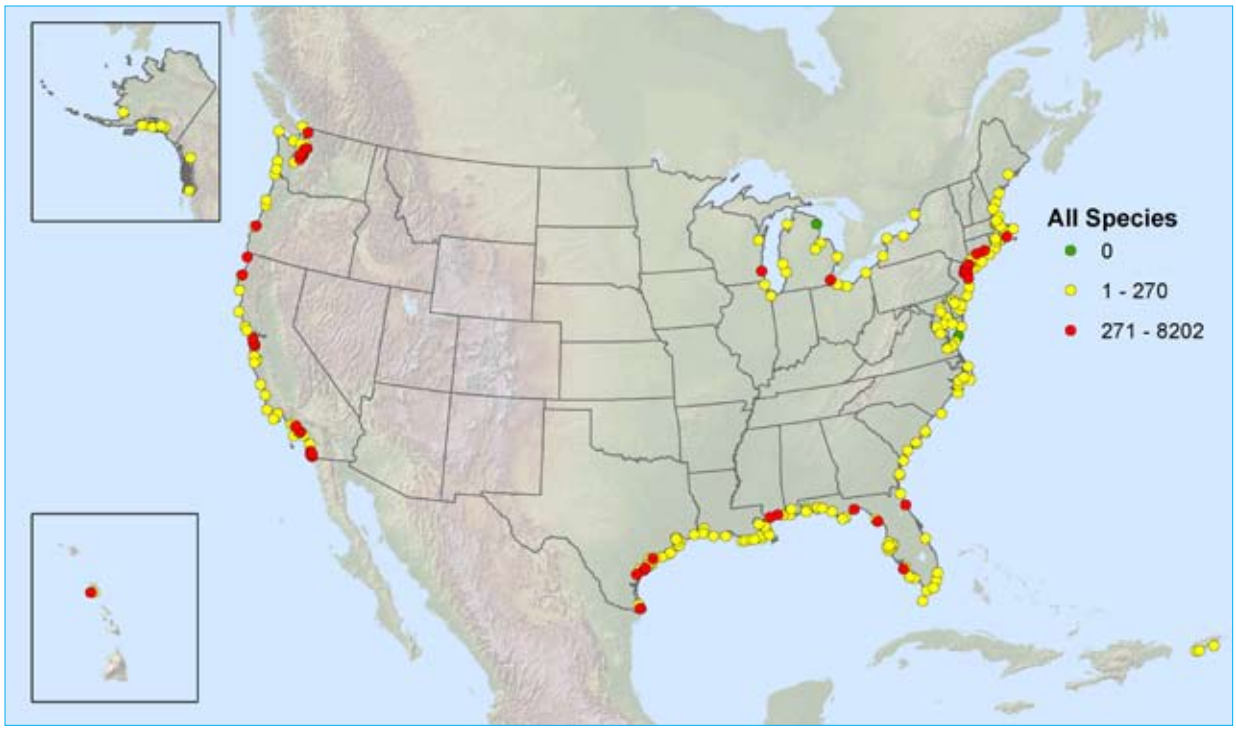

Figure 6. National distribution of 200X tissue concentration in ppb lipid weight (where 200X = 2004 through 2007). Categories low (●), medium (●), and high (●) were determined by cluster analysis.

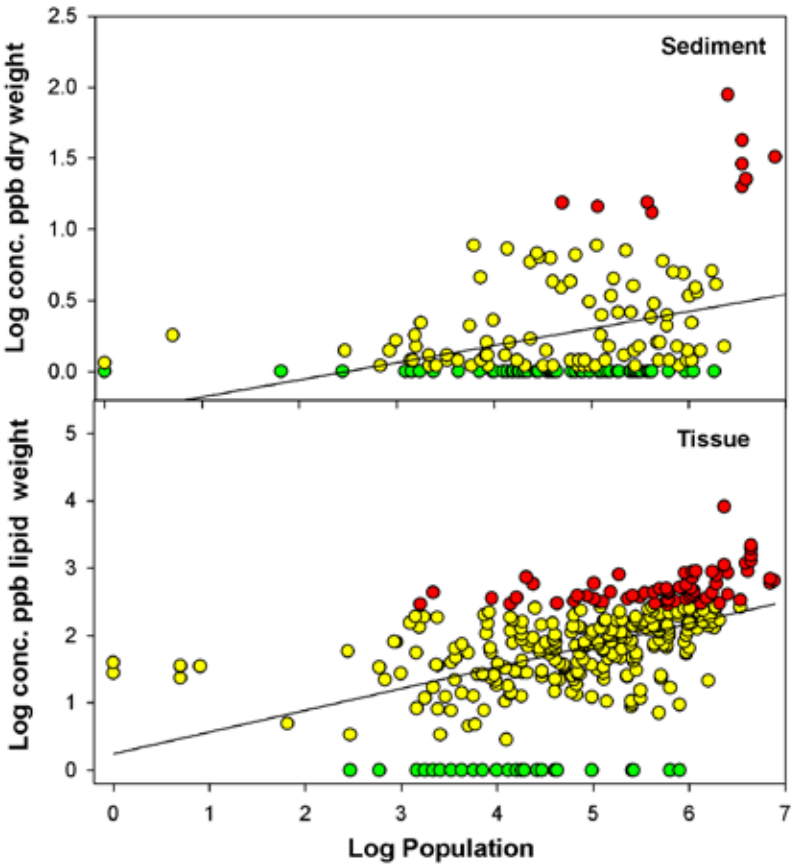

Figure 7. Tissue and sediment concentration vs population correlation analysis. Spearman's correlation tests for tissue (ρ = 0.555, prob <0.001) and sediment (ρ = 0.283, prob < 0.01) were both significant. Colors representing low (●), medium (●), and high (●) were determined by cluster analysis.

Figure 8. National change in tissue concentration in ppb lipid weight, where change = 1996 - 200X and where 200X = 2004 through 2007.

Table 4. Location of sites with elevated PBDE tissue concentrations (ppb lipid weight), where 200X = 2004 through 2007.

State	General Location	Specific Location	Tissue 1996	Tissue 200X
CA	Anaheim Bay	West Jetty	1112	8202
NY	Hudson River	Governor's Island		2189
NY	Hudson River	Battery Park		1946
NY	Hudson River	Shore Road		1550
NY	Hudson River	Fort Wadsworth		1287
NY	Hudson/Raritan Estuary	Lower Bay		1191
CA	San Francisco Bay	Dumbarton Bridge		900
NY	Hudson/Raritan Estuary	Jamaica Bay		899
CA	Marina Del Rey	South Jetty	404	855
CA	Imperial Beach	North Jetty		846
NJ	New York Bight	Sandy Hook		784
CA	San Francisco Bay	San Mateo Bridge		731
TX	Aransas Bay	Long Reef		728
MA	Waquoit Bay	Estuarine Reserve		720
NY	Long Island Sound	Throgs Neck	601	697
NY	Hudson/Raritan Estuary	Upper Bay		653
NY	Hudson/Raritan Estuary	Raritan Bay		594
WA	San Francisco Bay	Yerba Buena Island		585
CA	Crescent	Point St. George		581
WA	Puget Sound	Edmonds Ferry		567
CA	La Jolla	Point La Jolla		514
CA	Point Loma	Lighthouse		498
CT	Long Island Sound	New Haven	333	495
NJ	New York Bight	Shark River		439
MS	Mississippi Sound	Biloxi Bay		438
FL	Cedar Key	Black Point		436
CA	Long Beach	Breakwater	883	432
WA	Commencement Bay	Tahlequah Point	342	427
NJ	New York Bight	Long Branch		426
WA	Elliott Bay	Four-Mile Rock	895	405
MS	Mississippi Sound	Pass Christian		389

Table 4. Continued.

State	General Location	Specific Location	Tissue 1996	Tissue 200X
WA	Elliott Bay	Duwamish Head	453	389
TX	Corpus Christi	Nueces Bay		387
CA	Eureka	Samoa Bridge		383
WI	Lake Michigan	Milwaukee Bay		374
FL	Apalachee Bay	Spring Creek		361
TX	Matagorda Bay	Carancahua Bay		355
FL	Charlotte Harbor	Bird Island		352
CT	Long Island Sound	Connecticut River	590	350
WA	Puget Sound	Mukilteo		345
NY	Long Island Sound	Hempstead Harbor		334
FL	Matanzas River	Crescent Beach		322
HI	Honolulu Hrb.	Keehi Lagoon		319
WA	Bellingham Bay	Squalicum Marina Jet.		316
MI	Lake Erie	Stony Point		310
OR	Coos Bay	Russell Point		299
CA	San Diego Bay	Harbor Island		296
WA	Puget Sound	Everett Harbor		296
TX	Lower Laguna Madre	Port Isabel		293
TX	Mesquite Bay	Ayres Reef		292
WA	Sinclair Inlet	Waterman Point	456	287
AL	Mobile Bay	Dog River	374	
CT	Long Island Sound	Housatonic River	493	
MA	Buzzards Bay	Angelica Rock	804	
NY	Long Island	Jones Inlet	360	
NY	Long Island Sound	Mamaroneck	300	

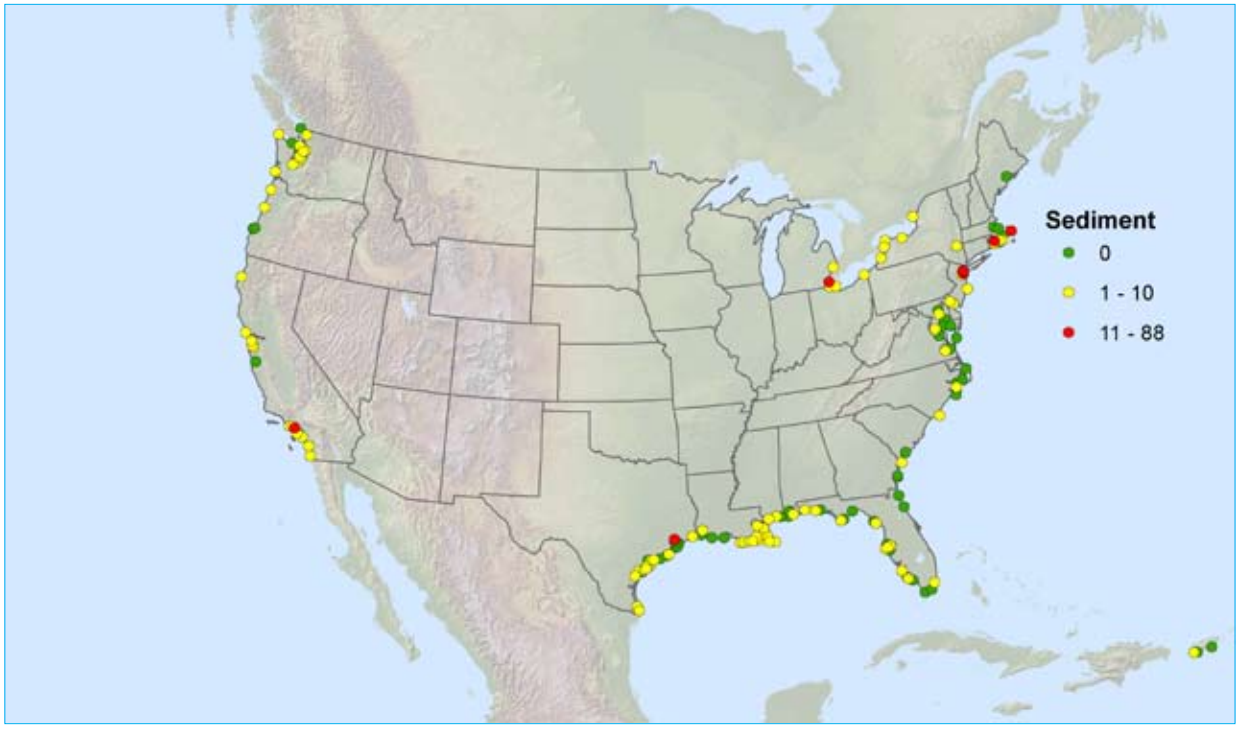

Figure 9. National distribution of 200X sediment concentration in ppb dry weight, where 200X = 2004 through 2007. Categories low (●), medium (●), and high (●) were determined by cluster analysis.

Sediment

Sediments were collected for PBDE quantification in 2004-2007. Sums ranged from below detection limit to 88 ppb dry weight (Figure 9). Thirty six percent of sediment samples had all 38 congener measurements below detection limits. As with tissue samples, cluster analysis was used to categorize like concentrations. A majority of sediment sites were categorized as medium with a small percentage of high measurements (Figure 4).

Elevated sediment concentrations (1 to 88 ppb dry weight) were found in urbanized or industrialized bays and estuaries (Figure 9; Table 5). However, a statistically significant correlation between sediment PBDE concentrations and population was weak in comparison to tissue (Figure 9). The relatively low correlation between population and sediment concentration may be caused by the large number of measurements that were below detection.

The highest sediment measurements observed were taken from an urbanized location, Marina del Rey, CA (88 ppb dry weight). Several high measurements were found in the Hudson-Raritan Estuary in addition to other areas (Figure 9; Table 5). Sediment PBDE concentrations were generally lower than concentrations found in tissues.

Location	State	Sediment	Tissue
Albemarle Sound	NC	0.00	26.92
Pensacola Bay	FL	0.10	29.60
Savannah River	GA	0.10	30.00
Atchafalaya/Vermilion Bays	LA	0.15	26.67
Sabine Lake	LA	0.10	26.02
Terrebonne/Timbalier Bays	LA	0.17	24.31
Big Cypress Swamp	FL	0.00	45.87
Mermentau	LA	0.00	47.83
Monie Bay	MD	0.00	37.37
St. Catherines/Sapelo Sounds	GA	0.00	37.14
Bogue Sound	NC	0.00	21.14
North Ten Thousand Islands	FL	0.00	20.17
Crystal-Pithlachascotee	FL	0.20	15.66
Pamlico Sound	NC	0.03	15.16
Rookery Bay	FL	0.20	9.50
Barataria Bay	LA	0.73	79.65
Choctawhatchee Bay	FL	0.75	76.00
Yaquina Bay	OR	0.70	91.67
San Antonio Bay	TX	0.46	64.72
Willapa Bay	WA	0.60	64.60
Tampa Bay	FL	0.24	62.99
Breton/Chandeleur Sound	LA	0.70	33.43
Buzzards Bay	MA	0.88	52.76
Puerto Rico	PR	1.47	42.10
Eastern Lower Delmarva	VA	0.00	0.00
Florida Bay	FL	0.00	2.90
Altamaha River	GA	0.00	64.29
Calcasieu Lake	LA	0.05	69.85
Dungeness-Elwha	WA	0.00	70.27
Mullica-Toms	NJ	0.10	74.89
East Mississippi Sound	MS	0.00	78.66
Mobile Bay	AL	0.00	87.97
Monterey Bay	CA	0.00	83.33
Austin-Oyster	TX	0.20	136.07
Los Angeles	CA	0.20	129.71
Bass Island	SC	0.00	103.75
Chesapeake Bay	VA/MD	0.10	104.25
Lower Laguna Madre	TX	0.20	105.63
Brazos River	TX	0.00	151.06
St. Johns River	FL	0.00	152.50
Massachusetts Bay	MA	0.00	159.38
Penobscot Bay	ME	0.00	143.33
Coos Bay	OR	0.00	170.78
Matagorda Bay	TX	0.06	206.00
Biscayne Bay	FL	0.60	136.25
Puget Sound	WA	0.74	224.53
Strait of Georgia	WA	0.40	185.39
Tomales Bay	CA	0.30	220.00
Apalachee Bay	FL	0.00	361.11
Daytona-St. Augustine	FL	0.00	322.00
Aransas Bay	TX	0.05	397.71
Humboldt Bay	CA	0.20	383.33
Suwannee River	FL	0.15	294.11
San Diego Bay	CA	0.40	296.30
Apalachicola Bay	FL	3.35	25.19
Chautauqua-Connaut	NY/OH	3.10	28.81
Cape Fear River	NC	5.40	28.77
Irondequoit-Ninemile	NY	5.00	72.66
Oak Orchard-Twelvemile	NY	5.80	56.83
Cape Cod	MA	14.40	31.82
St. Lawrence River	NY	3.60	6.73
Cedar-Portage	OH	6.30	184.76
Narragansett Bay	RI	4.87	135.83
Charlotte Harbor	FL	6.10	351.67
Corpus Christi Bay	TX	1.60	386.67
San Louis Rey-Escondido	CA	1.40	268.33
San Francisco Bay	CA	2.00	738.70
Delaware Bay	DE/NJ	1.95	135.02
Newport Bay	CA	2.60	126.20
Galveston Bay	TX	2.42	181.94
West Mississippi Sound	MS/LA	2.36	186.80
San Pedro Bay	CA	2.33	2961.90
Hudson River/Raritan Bay	NY	18.70	812.50
Ottawa-Stony	MI	13.50	310.24
Santa Monica Bay	CA	44.00	499.46

Cluster 1
Avg. Sed. = 0.29 (L)
Avg. Tis. = 37.5 (L)

Cluster 2
Avg. Sed. = 0.13 (L)
Avg. Tis. = 175.4 (H)

Cluster 3
Avg. Sed. = 5.9 (H)
Avg. Tis. = 35.8 (L)

Cluster 4
Ave. Sed. = 7.9 (H)
Ave. Tis. = 520.0 (H)

Figure 10. Cluster analysis of paired sediment (ppb dry weight) and tissue (ppb lipid weight) contamination measurements.

Table 5. Location of sites with elevated PBDE sediment concentrations (ppb dry weight), where 200X = 2004 through 2007.

State	General Location	Specific Location	Sediment 200X
CA	Marina del Rey	South Jetty	88
NY	Hudson-Raritan Estuary	World Trade Center	41
NY	Hudson-Raritan Estuary	Upper Bay	31
NY	Hudson-Raritan Estuary	Holland Tunnel	28
NY	Hudson-Raritan Estuary	Lower Bay	22
NY	Hudson-Raritan Estuary	Ellis Island	19
TX	Galveston Bay	Ship Channel	15
MA	Cape Cod	Nauset Harbor	14
OH	Lake Erie	Stony Point	14
RI	Narragansett Bay	Dyer Island	12

Regional and Local Analysis

Using the Wilcoxon statistical test, tissue PBDE concentrations were found to be significantly higher than sediment measurements taken at the same site (χ^2 = 211, prob < 0.001). To ensure comparable dimensions, the dry weight measurements for sediment and tissue were used during comparisons of the two matrices. No correlation was found between tissue and sediment measurements (prob = 0.135).

Two-way clustering of paired data provides a detailed view of paired concentration values, and groups of similar character (Figure 10). The cluster "map" is color-coded to represent concentration values, with dark red indicating elevated concentrations, light red and green indicating moderately elevated concentrations, and dark green indicating low concentrations. Cluster 4 stands out as a unique group with high concentrations of PBDEs in both tissue and sediment. These levels may also be reflected in humans. For example, the Hudson-Raritan Estuary is surrounded by the highest density population in the Nation, which probably contributes to the elevated PBDE levels observed there (Figure 5 and 6; Tables 4 and 5). A study by Johnston-Restrepo et al., (2005b) indicates that levels of PBDEs in adipose tissue of New Yorkers is orders of magnitude higher than levels found in Europeans.

Hoh and Hites, (2005) measured air samples from Lake Michigan through the Midwest to the Gulf of Mexico and detected residues of PBDE in remote areas. Their results suggest that concentrations in particles are 3 to 6 times higher in urban areas. While this finding corroborates the link between PBDE concentrations and human population density, it also highlights the potential of PBDEs to be transported through the atmosphere to remote locations. The highest concentrations occur in areas with high population; however, even in some densely populated areas, the median concentration was not always in the elevated range.

The distribution of congeners measured in this study is in the range of what has been reported globally for mussels and sediment

(Hoenicke et al., 2007; Oros et al., 2005; Hites, 2004; Christensen and Platz, 2001; de Wit, 2002). Sediment concentrations reported globally from highly polluted industrial locations had congener concentrations for 47, 99, and 153 on the order of 1000 ppb dry weight (Luo et al., 2007).

Industrial sources have also been identified in other studies as a source for the highest levels of PBDEs (Luo et al., 2007; de Wit, 2000). Studies have found that PBDE concentrations in urban areas are elevated but not to the level of industrial locations (Hoenicke et al., 2007; Oros et al., 2005; Hites, 2004; Christensen and Platz, 2001; de Wit, 2002). Mussel Watch sampling does not specifically collect industrial and point sources; as a result, mean sediment concentrations reported in this study were lower than what had been reported for industrial point sources.

Future assessments by the National Status and Trends Program will include higher brominated homologues, providing a more complete characterization of PBDEs in the U.S. coastal zone.

Societal Relevance

- In the environment major PBDE and PCB congeners have similar concentration ranges.
- Proper disposal of consumer goods is critical to limiting environmental releases of PBDEs.
- Societal benefits must be weighed against toxicity when determining the value of flame retardants.

Societal Relevance

PBDEs readily accumulate in organisms, including humans, and magnify upwards through marine food chains (Wan et al., 2008). Some of the highest PBDE levels measured in humans are from occupational exposures (Qu et al., 2007); however, PBDE levels in the general population result from exposure to contaminated indoor dust and food (Hites, 2004).

PBDEs have been called “the new PCBs,” and while there are some similarities, a major difference between them is the source of exposure. PCBs were primarily point source industrial contaminants, while PBDEs are primarily found in consumer goods.

A comparison of Mussel Watch PCB data (Kimbrough et al., 2008) and Mussel Watch PBDE data (this report) suggests environmental concentrations of major PBDE and PCB congeners have a similar concentration range. With the continued use of DecaBDE and the current pool of consummer goods that contain PBDEs, environmental concentrations of PBDEs could surpass that of PCBs in certain locations.

Chemical flame retardants clearly save lives and property, but the costs and benefits of using some of these compounds are hotly debated with respect to consumer health and safety, and the environment. The U.S. Consumer Product Safety Commission (CPSC, 2008) estimates losses from residential fire. They reported that the combined fire related deaths from upholstered furniture and mattress bedding fires (which exceeded all other categories) decreased from a high of 2,200 deaths in 1980 to 930 deaths in 1998 (CPSC, 2000) partly due to the use of flame retardants, including PBDEs.

Flame retardant manufacturers in the U.S. voluntarily stopped producing the PentaBDE and OctaBDE formulations in 2004. Thus, upholstered furniture and mattress manufactures had to seek alternative flame retardants to meet fire safety standards, some of these new retardants have already been measured in house dust samples (Stapleton et al., 2008). Unfortunately, alternative chemical flame retardants may be toxic while

others have very limited toxicity data. For example, chlorinated tris, a flame retardant, is a known carcinogen. Other brominated chemicals, such as tetrabrominated benzoate and tetrabrominated phthalate, have incomplete toxicity data (SFEI, 2008).

As with many persistent organic pollutants, PBDEs are distributed by atmospheric transport (Hoh and Hites, 2005). Even with a global reduction in PBDE use, the continued release of PBDEs into the environment is inevitable for years to come due to their persistant nature. Therefore, the proper disposal of consumer products such as furniture, mattresses, televisions, and computers is critical (Bogdal et al., 2008; Strandberg et al., 2001). Consumer products that contain PBDEs fill homes across the country. Hence, care must be taken to prevent further release of PBDEs into the environment when these products are discarded or recycled. Proper disposal methods must be developed and implemented.

Improper electronic waste recycling and disposal can cause significant environmental degradation (Luo et al., 2007) and may have negative occupational health ramifications (Qu et al., 2007). Proper disposal would curtail

local releases to the environment and limit atmospheric transport, thereby mitigating the threat to coastal areas, remote regions, and marine food chains. Elevated levels of PBDEs found in municipal sewage is evidence of an increased threat to the environment from land based sources (Song et al., 2006; de Wit, 2002).

The toxicity and ecosystem effects of PBDEs on marine biota have not been well studied. Laboratory toxicity studies show potential for adverse human health effects. Until such time as these questions are satisfactorily resolved, ongoing monitoring for these contaminants should continue.

This report clearly shows that PBDEs are ubiquitous in coastal sediments and bivalves. NOAA's NS&T Program will continue to monitor and report on PBDEs in sediment and tissue. In addition, NOAA staff are working with Federal and State agencies, and non-governmental organizations to identify other emerging contaminants of concern, including alternative flame retardants.