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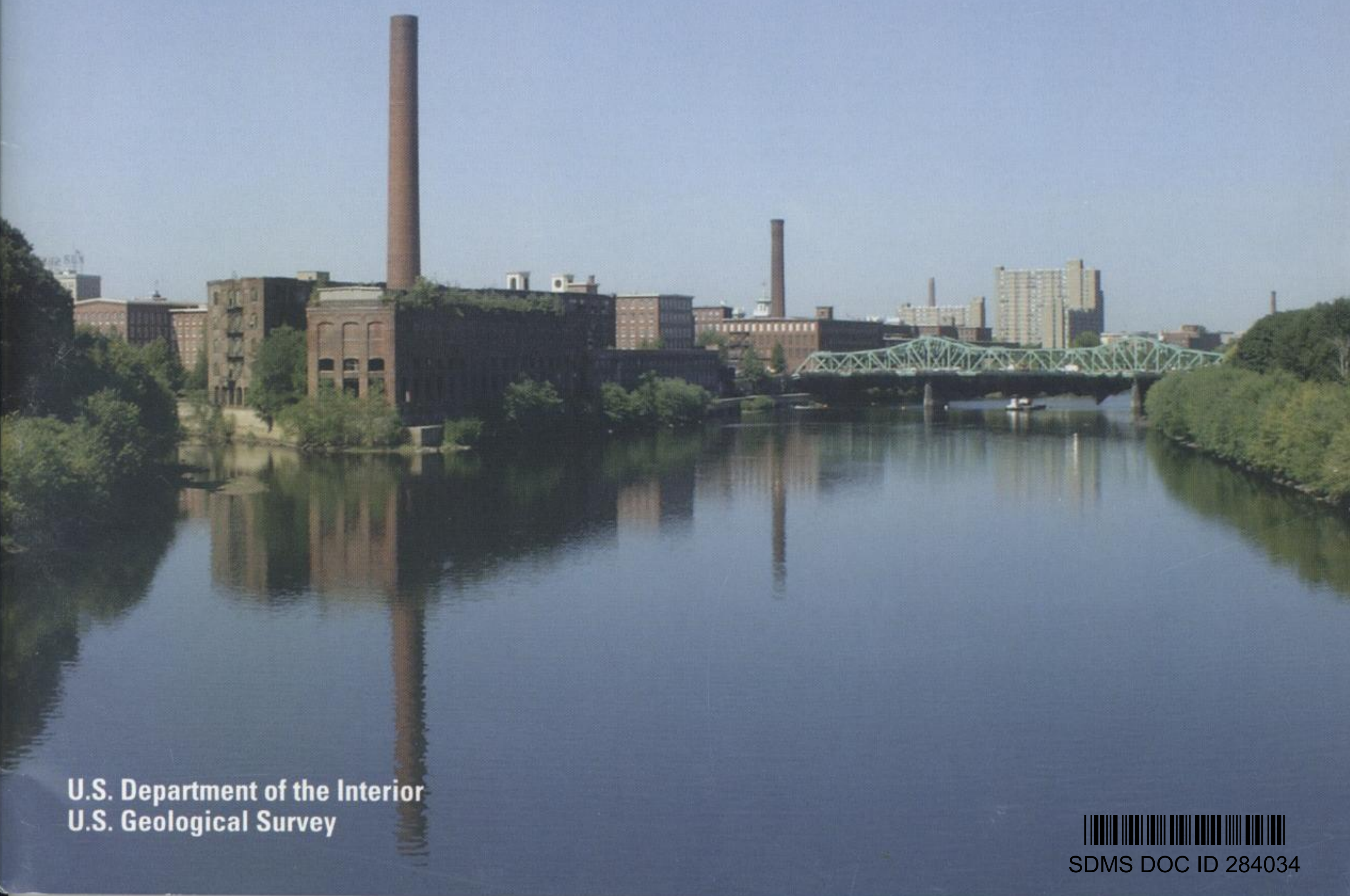
NATIONAL WATER-QUALITY ASSESSMENT PROGRAM

Trace Elements and Organic Compounds in Streambed Sediment and Fish Tissue of Coastal New England Streams, 1998-99

Water-Resources Investigations Report 02-4179



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Cover photograph shows the confluence of the Concord and Merrimack Rivers in Lowell, Massachusetts.

(Photograph by Britt Stock, U.S. Geological Survey)

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By Ann Chalmers

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Pembroke, New Hampshire
2002

U.S. DEPARTMENT OF THE INTERIOR
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FOREWORD

The mission of the U.S. Geological Survey (USGS) is to assess the quantity and quality of the earth resources of the Nation and to provide information that will assist resource managers and policymakers at Federal, State, and local levels in making sound decisions. Assessment of water-quality conditions and trends is an important part of this overall mission.

One of the greatest challenges faced by water-resources scientists is acquiring reliable information that will guide the use and protection of the Nation's water resources. That challenge is being addressed by Federal, State, interstate, and local water-resource agencies and by many academic institutions. These organizations are collecting water-quality data for a host of purposes that include: compliance with permits and water-supply standards; development of remediation plans for specific contamination problems; operational decisions on industrial, wastewater, or water-supply facilities; and research on factors that affect water quality. An additional need for water-quality information is to provide a basis on which regional- and national-level policy decisions can be based. Wise decisions must be based on sound information. As a society we need to know whether certain types of water-quality problems are isolated or ubiquitous, whether there are significant differences in conditions among regions, whether the conditions are changing over time, and why these conditions change from place to place and over time. The information can be used to help determine the efficacy of existing water-quality policies and to help analysts determine the need for and likely consequences of new policies.

To address these needs, the U.S. Congress appropriated funds in 1986 for the USGS to begin a pilot program in seven project areas to develop and refine the National Water-Quality Assessment (NAWQA) Program. In 1991, the USGS began full implementation of the program. The NAWQA Program builds upon an existing base of water-quality studies of the USGS, as well as those of other Federal, State, and local agencies. The objectives of the NAWQA Program are to:

- Describe current water-quality conditions for a large part of the Nation's freshwater streams, rivers, and aquifers.
- Describe how water quality is changing over time.
- Improve understanding of the primary natural and human factors that affect water-quality conditions.

This information will help support the development and evaluation of management, regulatory, and monitoring decisions by other Federal, State, and local agencies to protect, use, and enhance water resources.

The goals of the NAWQA Program are being achieved through ongoing and proposed investigations of 59 of the Nation's most important river basins and aquifer systems, which are referred to as study units. These study units are distributed throughout the Nation and cover a diversity of hydrogeologic settings. More than two-thirds of the Nation's freshwater use occurs within the 59 study units and more than two-thirds of the people served by public water-supply systems live within their boundaries.

National synthesis of data analysis, based on aggregation of comparable information obtained from the study units, is a major component of the program. This effort focuses on selected water-quality topics using nationally consistent information. Comparative studies will explain differences and similarities in observed water-quality conditions among study areas and will identify changes and trends and their causes. The first topics addressed by the national synthesis are pesticides, nutrients, volatile organic compounds, and aquatic biology. Discussions on these and other water-quality topics will be published in periodic summaries of the quality of the Nation's ground and surface water as the information becomes available.

This report is an element of the comprehensive body of information developed as part of the NAWQA Program. The program depends heavily on the advice, cooperation, and information from many Federal, State, interstate, Tribal, and local agencies and the public. The assistance and suggestions of all are greatly appreciated.

Robert M. Hirsch
Chief Hydrologist

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CONVERSION FACTORS AND ABBREVIATED WATER-QUALITY UNITS

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch	25.4	millimeter (mm)
inch	25380.7	micrometer (µm)
	Area	
acre	.405	hectare (ha)
square miles (mi^2)	2.59	square kilometer (km^2)
	Weight	
ounce (oz)	28.35	gram (g)
pound (lb)	0.454	kilogram (kg)
	Volume	
ounce (oz)	29.6	milliliter (mL)

ABBREVIATED WATER-QUALITY UNITS

µg/g microgram per gram

µg/kg microgram per kilogram

g/kg grams per kilogram

MISCELLANEOUS ABBREVIATIONS

DDD Dichloro diphenyl dichloroethane

DDE Dichloro diphenyl dichloroethylene

DDT Dichloro diphenyl trichloroethane

DDTM DDT and its major metabolites (DDD and DDE)

NAS/NAE National Academy of Sciences, National Academy of Engineering

NAWQA National Water-Quality Assessment

NECB New England Coastal Basins

NQWL National Water-Quality Laboratory

PAH Polycyclic aromatic hydrocarbon

PCB Polychlorinated biphenyl

PEL Probable effects level

SQG Consensus-based Sediment Quality Guidelines

Trace Elements and Organic Compounds in Streambed Sediment and Fish Tissue of Coastal New England Streams, 1998-99

By Ann Chalmers

Abstract

Streambed sediment and fish tissue were collected at 14 river sites in eastern New England during low-flow conditions in 1998 and 1999 as part of the New England Coastal Basins (NECB) study of the U.S. Geological Survey National Water-Quality Assessment (NAWQA) Program. Sampling sites were selected over a range of urban settings. Population densities at selected sites ranged from 26 to 3,585 people per square mile, and urban land use ranged from 1 to 68 percent. The streambed sediment samples were analyzed for a total of 141 contaminants, including 45 trace elements, 32 organochlorine compounds, and 64 semi-volatile organic compounds. The fish tissue samples were analyzed for 22 trace elements and 28 organochlorine compounds. Concentrations of selected contaminants in both streambed sediment and fish tissue correlated more strongly with population density than with other watershed characteristics. Cadmium, copper, lead, mercury, zinc, total polycyclic aromatic hydrocarbons (PAHs), total polychlorinated biphenyls (PCBs), dichloro diphenyl trichloroethane and metabolites (DDTM), and total chlordane in streambed sediment all showed strong positive correlations with population density (rho = 0.71 to 0.85, p value = 0.005 to <0.001). Correlations between population density and selected contaminants in fish tissue were less significant than with streambed sediment (rho = 0.62 to 0.72, p value = 0.03 to 0.008). Organic carbon concentrations were correlated with concentrations of arsenic, selenium, total PAHs, total PCBs, and DDTM in streambed sediment. The relation between concentrations of contaminants in streambed sediment and fish tissue was stronger for organochlorine compounds (rho = 0.75 to 0.55, p = 0.005 to 0.065) than for trace elements (rho = 0.63 to 0.53, p = 0.029 to 0.069). The NECB study area had the highest median concentrations of lead, mercury, total PAHs, total PCBs, and DDTM in streambed sediment and the highest median concentration of PCBs in fish tissue compared to 45 other NAWQA study units across the Nation. Concentrations of many of these constituents in streambed sediment also were frequently above the consensus-based Sediment-Quality Guidelines for the protection of wildlife, suggesting they are a threat to the health of aquatic biota in New England.

INTRODUCTION

Analyzing the levels of contaminants in streambed sediment and fish tissue is one component of an interdisciplinary approach used by the U.S. Geological Survey (USGS) National Water Quality Assessment (NAWQA) program to (1) describe water-quality conditions, (2) identify water-quality trends, and (3) to better understand the major factors that affect water-quality conditions and trends. In 1998-99, the USGS conducted an occurrence survey of trace elements and organic compounds in streambed sediment and fish tissue at 14 river sites in the New England Coastal Basins (NECB) study area (fig. 1). The NECB study is one of 59 individual NAWQA study units implemented to investigate water quality nationwide (Ayotte and Robinson, 1997).

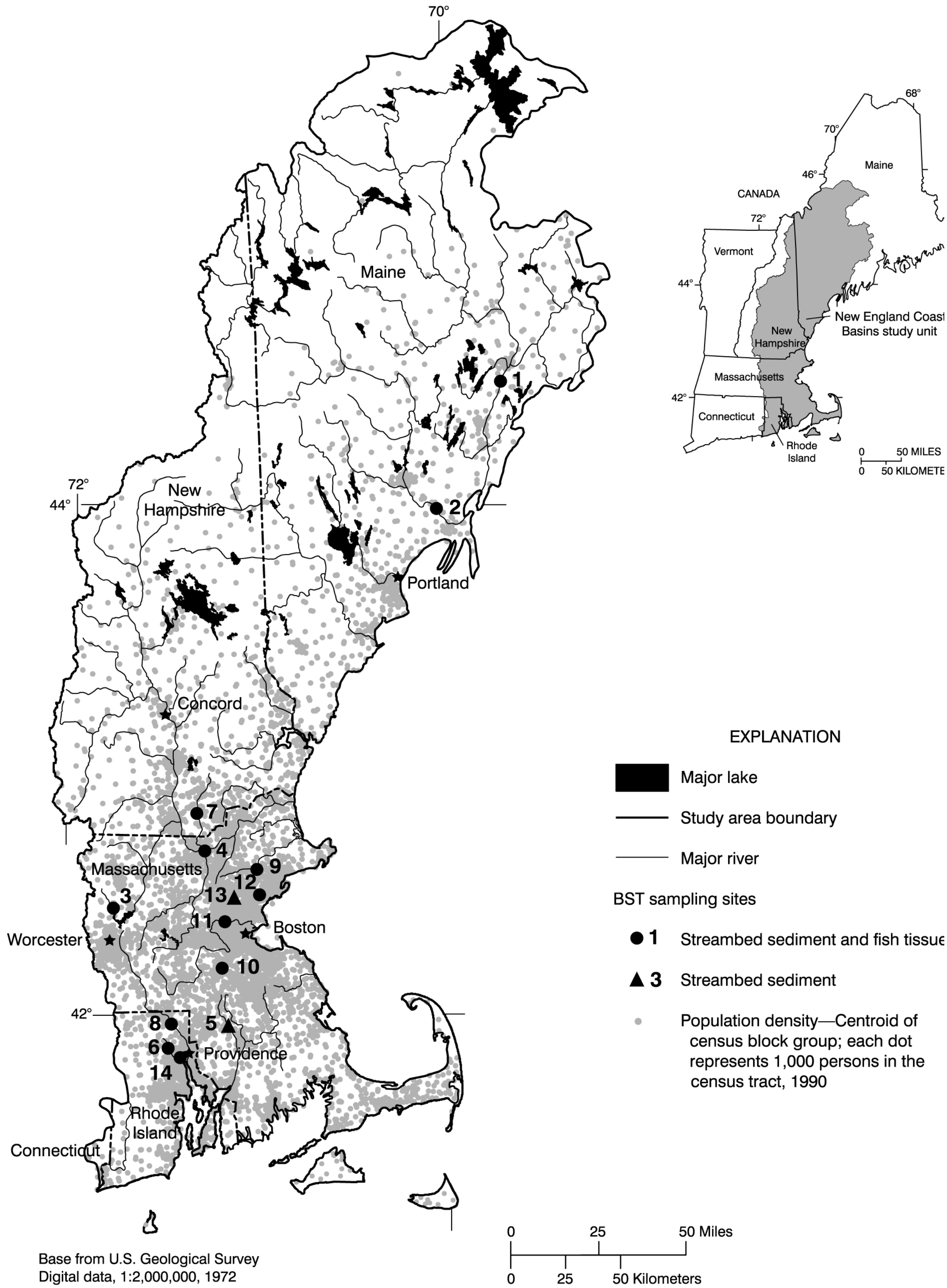


Figure 1. Location of streambed sediment and fish tissue (BST) sampling sites and population distribution in the New England Coastal Basins study area. Sites are listed in table 1. Population distribution data are from 1990 U.S. Census Bureau decennial files.

Trace elements and organochlorine compounds naturally tend to accumulate in sediment and fish tissue and provide time-integrated records of water-quality conditions. Trace elements originate from natural sources, but are redistributed and concentrated in anthroprogenic processes such as fossil-fuel combustion and waste incineration; in industrial emissions from plating, smelting, refining; and in wastewater and storm runoff discharges. The highest concentrations of trace elements in sediment are usually found in densely populated areas (Daskalakis and O'Connor, 1995; Breault and others, 2000), natural mineral deposits, or mines (Deacon and Stephens, 1998; Maret and Skinner, 2000). Mercury (Hg) is an exception; elevated concentrations of Hg can occur in highly urbanized areas and in remote areas with no direct source of pollution (Stafford and Haines, 1997; Mower and others, 1997; New Hampshire Fish and Game Department and New Hampshire Water and Pollution Control Commission, written commun., 1970; Pinski and others, 1993; Dreisig and Dupee, 1994; Massachusetts Department of Environmental Protection, 1997). Concentrations of Hg in sediments in New England have increased nearly four-fold over the past 150 years (Kamman and Engstrom, 2002). Reductions in Hg emissions in recent decades have resulted in declines in Hg concentrations in sediment cores in the region (Kamman and Engstrom, 2002; Engstrom and Swain, 1997). Concentrations of lead (Pb) in sediment cores and fish tissue have decreased since the early 1970s (Schmitt and Brumbaugh, 1990; Callender and Van Metre, 1997) with the passage of the Clean Air Act in 1970. Zinc (Zn) concentrations in sediment have remained elevated and have been correlated to increased automobile traffic (Callender and Rice, 2000). Zinc is an additive to rubber in automobile tires.

The occurrence and distribution of polycyclic aromatic hydrocarbons (PAHs) are a result of a mix of anthroprogenic and natural activities, primarily combustion of fossil fuels and wood. PAHs are a large group of compounds, including many suspected carcinogens. Abrupt increases in PAH concentrations in sediment cores from lakes and reservoirs in the United States have been linked with increased automobile use over the past 20 years (Van Metre and others, 2000).

Organochlorine compounds such as polychlorinated biphenyls (PCBs), chlordane, and dichloro diphenyl trichloroethane (DDT) do not occur naturally in the environment and are entirely a result of anthroprogenic activities. The organochlorine pesticides, chlordane and DDT, were used in agricultural, urban, and suburban settings for insect control. High concentrations of chlordane in sediment and fish tissue have mainly been found in urban areas (Arruda and others, 1987; Wong and others, 2000; Breault and others, 2000). Elevated concentrations of DDT and its major metabolites (DDTM) in the United States have been found both in agricultural areas of California, Washington, and the Southeast, and in urban areas in the Northeast (Nowell and others, 1999; Breault and others, 2000). Occurrence of PCBs is associated with industrial products including electrical transformers, capacitors, hydraulic fluids, and plasticizers. The highest levels of PCBs in streambed sediment and fish tissue in the United States have been detected in the industrial Mid-Atlantic region and New England (U.S. Environmental Protection Agency, 1992; Schmitt and others, 1990; Major and Carr, 1991; Phillips and others, 1997; Breault and others, 2000). Because of human health and environmental concerns, the commercial use of PCBs and organochlorine pesticides have been banned or restricted since the 1970s and 1980s. Residues of PCBs, chlordane, and DDTM still persist in many sediments and fish tissues at levels of concern, but concentrations have decreased over time (U.S. Environmental Protection Agency, 1992; Schmitt and others, 1990; Gilliom, 1985; Riva-Murray and others, 2002).

Purpose and Scope

This report describes the occurrence and distribution of selected trace elements and organic compounds in streambed sediment and fish-tissue samples collected from 14 river sites in the NECB study area. Results from these samples are used to (1) identify the predominant trace elements and organic compounds detected in streambed sediment and fish tissue, (2) compare concentrations of constituents found in this study with those from other studies and with suggested guidelines for the protection of aquatic life and wildlife, and (3) relate concentrations of selected constituents to watershed features such as land use and population density. This report focuses on the following trace elements and organic compounds frequently detected in streambed sediment and fish tissue in New England and known to be highly toxic to humans or wildlife: Arsenic (As), Cadmium (Cd), Chromium (Cr), Copper (Cu), Pb, Hg, Nickel (Ni), Selenium (Se), Zn, and organochlorine compounds PAHs, PCBs, chlordane, and DDTM.

Description of Study Area

The NECB study area covers 23,000 mi^2 in western Maine, eastern New Hampshire and Massachusetts, and nearly all of Rhode Island (fig. 1). Seventy-two percent of the study area is classified as forests, 8 percent as urban, industrial, or residential lands, 7 percent as agriculture, 6 percent as open water, 5 percent as wetlands, and 1 percent as barren lands (gravel pits or beaches) (Vogelmann and others, 2001). The population of the study area in 1990 was 7.78 million people, with the population density ranging from less than 5 people/mi^2 in the northern areas to 13,000 people/mi^2 in the Boston and Providence metropolitan areas in the southern part of the study area (Flanagan and others, 1999). About 1,600 dams (Flanagan and others, 1999) throughout the study area serve as traps for fine sediments and contaminants. The general bedrock geology of the study area is metamorphic rocks consisting of metasedimentary sandstones, shales, calcareous rocks, and volcanics intruded by crystalline igneous rocks. The study area is comprised of predominantly two U.S. Environmental Protection Agency (USEPA) Level III Ecoregions; the Northeastern Highlands (mountainous mixed conifer and deciduous forests), and the Northeastern Coastal Zone (a mix of rolling hills and plains with dominantly deciduous forests). The largest rivers in the study area, the Kennebec, Androscoggin, and Merrimack, are located in the northern two-thirds of the study area. The watersheds of these rivers are in parts of both the Northeastern Highlands and the Northeastern Coastal Zone ecoregions. The southern one-third of the study area is almost entirely in the Northeastern Coastal Zone, and has small, low-gradient coastal rivers that are influenced by the Boston and Providence metropolitan areas (Flanagan and others, 1999, figs. 15 and 16).

The Boston and Providence metropolitan areas are recognized as the birthplace of the American industrial revolution from the late 1700s to early 1900s. During this early industrial period, there were no water-quality regulations; all wastes, including industrial and sewage were discharged directly in the rivers. As a result, heavy contamination occurred in many streams from textile dyes, metal plating and machine operations (Shanahan, 1994), and chemical and leather industries (Spliethoff and Hemond, 1996). The effects of the early industrial period have been shown in sediment cores. High concentrations of As, Cd, Cu, Cr, Pb, and Zn were found by Spliethoff and Hemond (1996) in sediment cores at depths corresponding to intense industrial activity of the early 1900s. Also during this early industrial period, a large number of dams were built for operating cotton and wool mills. At its peak, the Blackstone River had an average of one dam every mile (Shanahan, 1994). Contaminates have accumulated in fine sediments behind impoundments in the study area and still remain in place today (Shanahan, 1994; Spliethoff and Hemond, 1996). Resuspension of these contaminated sediments during high flow events, dredging, or removal of dams remains a major water-quality concern for the area (Massachusetts Department of Environmental Protection and Office of Watershed Management, 1995; Rhode Island Department of Environmental Management, 1994).

The leading source of Hg contamination of freshwater streams and lakes in the study area is from atmospheric deposition (New Hampshire Department of Environmental Services, 1998; U.S. Environmental Protection Agency, 1999a). Fish consumption advisories for Hg have been issued for all lake and streams in Maine, New Hampshire, and Massachusetts, and in parts of Rhode Island, including any fish from the Woonasquatucket River below Smithfield (6 mi above Centerdale, R.I.), and for bass from Quidnick Reservoir (accessed December 13, 2000, at http://www.health.state.ri.us/environment/fish.html). PCBs remain a concern in the study area even 20 years after they were banned. Fish-consumption advisories for PCBs have been issued for freshwater rivers, reservoirs, and lakes in 10 water bodies in Maine, 20 water bodies in Massachusetts, and 2 water bodies in New Hampshire and Rhode Island (U.S. Environmental Protection Agency, 1999b). Massachusetts also has issued fish consumption advisory as a result of elevated PAH and chlordane levels in 2 water bodies (accessed December 13, 2000, at http://www.state.ma.us/dph/beha/fishlist.html).

Study Design

Streambed-sediment samples were collected at 14 river sites, and fish-tissue samples were collected at 12 of these 14 sites (table 1). The drainage areas of 9 wadeable sites ranged from 23 to 48 mi^2. The drainage areas of the five non-wadeable sites ranged from 268 to 5,403 mi^2. Sites were selected over a

Table 1. Characterization of streambed sediment and fish-tissue sampling sites, New England Coastal Basins

[mi^2, square miles; BS, streambed sediment; T, fish tissue; other land use is water, wetland, and barren land; population density data from U.S. Bureau of the Census, 1990 dicennial census files]

Site No. (fig. 1)	Site name	Latitude	Longitude	Sample type	Basin size (mi^2)	Land use (percent of total)				1990 Population density (people/mi^2)
						Urban	Agriculture	Forested	Other	
1	Kennebec River at North Sidney, Maine[1]	44°28′25″	069°41′08″	BS,T	5,403	1	6	83	10	26
2	Androscoggin River near Lisbon Falls, Maine[1]	43°59′00″	070°02′30″	BS,T	3,260	1	5	86	8	40
3	Stillwater River near Sterling, Mass.[2]	42°24′39″	071°47′30″	BS,T	32	4	10	77	9	152
4	Merrimack River below Concord River at Lowell, Mass.[1]	42°38′45″	071°17′56″	BS,T	4,635	9	8	74	9	278
5	Wading River near Norton, Mass.[2]	41°56′51″	071°10′38″	BS	43	18	7	64	11	498
6	Woonasquatucket River at Centerdale, R.I.[2]	41°51′32″	071°29′16″	BS,T	38	17	8	65	10	641
7	Beaver Brook at No. Pelham, N.H.[2]	42°46′59″	071°21′14″	BS,T	48	34	7	55	4	870
8	Blackstone River at Manville, R.I.[1]	41°58′16″	071°28′14″	BS,T	430	18	8	64	10	909
9	Ipswich River at South Middleton, Mass.[2]	42°34′10″	071°01′39″	BS,T	45	38	4	40	18	1,118
10	Neponset River at Norwood, Mass.[2]	42°10′39″	071°12′05″	BS,T	35	30	6	53	11	1,192
11	Charles River above Watertown Dam at Watertown, Mass.[1]	42°21′54″	071°11′26″	BS,T	268	30	7	53	10	1,320
12	Saugus River at Saugus Iron Works at Saugus, Mass.[2]	42°28′10″	071°00′28″	BS,T	23	56	4	27	13	2,409
13	Aberjona River at Winchester, Mass.[2]	42°26′50″	071°08′22″	BS	25	68	2	24	6	2,893
14	Moshassuck River at Providence, R.I.[2]	41°50′02″	071°24′42″	BS,T	23	44	9	40	7	3,585

[1] Non-wadeable.
[2] Wadeable.

range of population densities (table 1) to maximize our understanding of the effects of urbanization on water quality. The sites are not representative of the entire NECB study area, but focus on the more urbanized areas (fig. 1). Population densities within the selected watersheds ranged from 26 to 3,585 people/mi^2, based on 1990 U.S. Bureau of Census data (U.S. Bureau of the Census 1990 decennial census files); the amount of urban land use ranged from 1 to 68 percent (Vogelmann and others, 1998). Agricultural land within sampled watersheds sites ranged from 2 to 10 percent.

Acknowledgments

The author acknowledges James Coles, Karen Beaulieu, James Caldwell, and Britt Stock of the U.S. Geological Survey (USGS) and Peter Mitchell (Massachusetts Department of Environmental Protection) for the long hours they spent collecting and processing samples. Special thanks to James Coles for assistance with data interpretation and Verlin C. Stephens (USGS) for providing data from other study units. Reviews by James Coles, Stephen B. Smith, Keith Robinson, Jeffrey Deacon, Sarah Flanagan, and Debra Foster of the USGS, greatly improved the quality of the manuscript.

A special thanks is extended to Sarah Flanagan for help in preparing the text, figures, and tables for publication, and assisting with responses to reviewer comments. Her assistance was instrumental in the timely publication of this report.

METHODS OF SAMPLE COLLECTION AND ANALYSIS

Streambed sediment and fish-tissue samples were collected during low-flow conditions in September 1998, and June through July 1999. Streambed-sediment samples were collected according to NAWQA sampling protocols (Shelton and Capel, 1994). These protocols specify that the top 2 cm (0.8 in.) of streambed sediment are sampled to obtain only the most recently deposited material. Five to 10 representative subsamples were composited from depositional areas at each sampling site. Samples for trace elements were wet sieved through a 63-µm nylon mesh to obtain the silt and clay fraction. Streambed-sediment samples were analyzed at the USGS Branch of Geochemistry Laboratory in Lakewood, Colo., for 45 trace elements (Briggs and Meier, 1999; Arbogast, 1990). Streambed-sediment samples for organic compounds were wet sieved through a 2-mm (0.08 in.) stainless steel sieve to obtain the sand, silt, and clay fractions. Samples for organic compounds were analyzed at the USGS National Water-Quality Laboratory (NWQL) in Lakewood, Colo., for 32 chlorinated organic compounds (Foreman and others, 1995) and 64 semi-volatile organic compounds (including 27 PAHs) (Furlong and others, 1996).

Fish were collected by electrofishing with a backpack unit at seven of the wadeable sites, and with an electrofishing boat on the five non-wadeable sites (table 1). A national target taxa list was developed by the NAWQA program to keep the taxa among study units across the country as consistent as possible. In the NECB study area, white sucker (*Catostomus commersoni*) was the most commonly occurring fish among this list. White suckers were collected at 10 of the 12 sites. Smallmouth bass (*Micropterus dolomieu*) and largemouth bass (*Micropterus salmoides*) were collected at two sites where white suckers were not found (Merrimack River, site 4, and Kennebec River, site 1; fig. 1, table 1). No fish-tissue samples were collected at the Aberjona River (site 13) and the Wading River (site 5) because there were insufficient quantities of any target taxa at the time of sampling. Fish were processed in the field for laboratory analysis following NAWQA protocols (Crawford and Luoma, 1993). Fish tissue analyzed for trace elements consisted of a composite sample of seven to eight left dorsal fillets (scaled, skin on) placed in a precleaned glass jar. Fish-fillet samples were analyzed for 22 trace elements at the NWQL using methods described by Hoffman (1996). Fish tissue analyzed for organic compounds consisted of a composite sample of seven to eight whole individuals. Whole fish samples were analyzed at the NWQL for 28 individual organochlorine compounds using methods described by Leiker and others (1995).

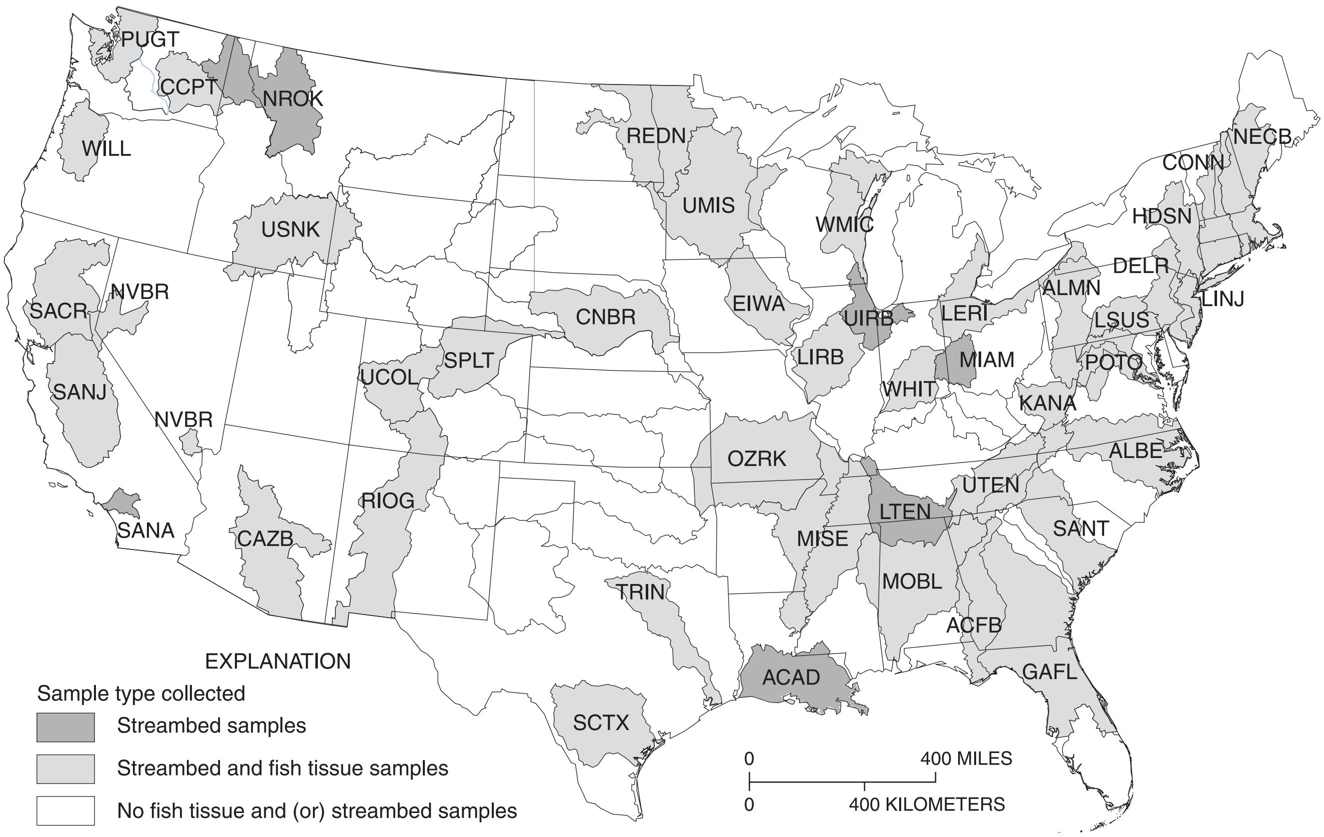
METHODS OF DATA ANALYSIS

Concentrations of As, Cd, Cu, Cr, Pb, Hg, Ni, Se, and Zn, total PAHs, total PCBs, total chlordane, and DDTM were compared to watershed characteristics, results from other NAWQA studies, and environmental guidelines. Total concentrations of PAHs, PCBs, chlordane, and DDTM were determined by summing the concentrations of all related compounds for each of these groups. The value of compounds below detection levels were set to zero. Total PAHs in streambed sediment were defined as the sum of all the 27 PAH compounds. Total PCBs consisted of Aroclors 1242, 1254, and 1260. Total chlordane was defined as the sum of *cis*- and *trans*-chlordane, *cis*- and *trans*-nonachlor, oxychlordane, and heptachlor epoxide. Total DDTM was defined as the sum of *o,p'* and *p,p'* homologs of dichloro diphenyl dichloroethane (DDD), dichloro diphenyl dichloroethylene (DDE), and DDT. Because PCB, chlordane, and DDTM tend to strongly partition in the lipid part of fish, these compounds were normalized to lipid content for all data correlations.

The S-Plus 2000 (Professional Release 2) (Mathsoft Inc., 1999) statistical software package was used for all statistical analysis. Normal probability plots were used to identify data distributions. Selected trace elements and organic data in streambed sediment and fish tissue were rank transformed and the degree of association between concentrations of trace elements and organic compounds and percentages of land use, population density, and concentrations of organic carbon were evaluated by Spearman's rho. Spearman's rho also was used to evaluate the relation between streambed sediment and fish tissue. A correlation was considered possible for rho equal to or greater than 0.50 and probability (p) less than 0.1. Significant correlations were defined as an absolute value of Spearmans rho greater than 0.60 and p less than 0.05. Highly significant correlations were defined as rho greater than or equal to 0.70 and p less than or equal to 0.005.

Streambed-sediment and fish-tissue data in the NECB study area were compared to results from monitoring sites in other NAWQA study units across the country (Gilliom and others, 1995) (fig. 2, tables 3, 6, and 7). Trace element and organic data were obtained from the NAWQA data warehouse (http://infotrek.er.usgs.gov/pls/nawqa/nawqa.home) in December 2000 and February 2001, respectively. Trace element and organic compounds in streambed sediment were compared to results from 46 study units, organochlorine compounds in fish tissue were compared to results from 39 study units, and population density data were compared to data from 44 study units. The number of bed sediment and fish tissue sites sampled in each study unit ranged from 6 to 56. Median values were used for comparison nationally and for individual study units for population density, and trace elements and organic compounds in streambed sediment and fish tissue. Trace-element data from fish tissue in the NECB study area were not comparable with other study units because the NECB collected fish-fillets samples, whereas other study units predominantly collected fish-liver samples.

Consensus-based Sediment Quality Guidelines (SQG) (MacDonald and others, 2000) were used to evaluate the potential effects of selected trace elements and organic compounds in streambed sediment on freshwater ecosystems. Consensus-based SQG were derived from published sediment guidelines taking into account possible interactions between contaminants. Trace-elements and organic-compound concentrations in sediment above the consensus-based SQG probable effect concentrations (PEC) (table 2) are expected to have frequent adverse effects to freshwater ecosystems. The consensus-based SQG were compared to the more commonly used Canadian Council of the Ministers of the Environment (CCME) sediment guidelines for probable effects levels (PEL) on freshwater aquatic biota (Canadian Council of Ministers of the Environment, 1999). Both the Consensus-based SQG and CCME were developed for bulk (unsieved) sediments; therefore, comparisons with the sieved samples in this study are expected to overestimate adverse effects because most contaminants are thought to be associated with the fine (silt and clay) sediment. Concentrations of selected contaminants in fish tissue were compared to National Academy of Science/National Academy of Engineering (NAS/NAE) (1973) recommended guidelines for protection of fish-eating wildlife, and the U.S. Food and Drug Administration (USFDA) 1984 action level guidelines for human consumption (table 2).



1991Study Units and Median Population Density
(people per square mile)

ACFB	Apalachicola-Chattahoochee-Flint River Basin, 147
ALBE	Albemarle-Pamlico Drainage, 64
CCPT	Central Columbia Plateau, 10
CNBR	Central Nebraska Basins, 12
CONN	Connecticut, Housatonic and Thames River Basins, 207
GAFL	Georgia-Florida Coastal Plain, 64
HDSN	Hudson River Basin, 133
LSUS	Lower Susquehanna River Basin, 154
NVBR	Nevada Basin and Range, 108
OZRK	Ozark Plateaus, 19
POTO	Potomac River Basin, 106
REDN	Red River of the North Basin, 7
RIOG	Rio Grande Valley, 5
SANJ	San Joaquin-Tulare Basins, 55
SPLT	South Platte River Basin, 102
TRIN	Trinity River Basin, 67
USNK	Upper Snake River Basin, 10
WHIT	White River Basin, 121
WILL	Willamette River Basin, 37
WMIC	Western Lake Michigan Drainage, 28

1994 Study Units and Median Population Density
(people per square mile)

ALMN	Allegheny& Monongahela River Basins, 55
CAZB	Central Arizona Basins, 24
EIWA	Eastern Iowas Basins, 34
KANA	Kanawha-New River Basin, 23
LERI	Lake Erie-Lake St. Clair Drainage, 126
LINJ	Long Island & New Jersey Coastal Drainages, 835
LIRB	Lower Illinois River Basin, 98
MISE	Mississippi Embayment, 32
PUGT	Puget Sound Basin, 348
SACR	Sacramento River Basin, 24
SANT	Santee Basin & Coastal Drainages, 92
SCTX	South Central Texas, 47
UCOL	Upper Colorado River Basin, 10
UMIS	Upper Mississippi River Basin, 54
UTEN	Upper Tennessee River Basin, 75

1997 Study Units and Median Population Density
(people per square mile)

ACAD	Acadian-Pontchartrain, 69
DELR	Delaware River Basin, 242
LTEN	Lower Tennessee River Basin, 49
MIAM	Great & Little Miami River Basins, 160
MOBL	Mobile River and Tributaries, 34
NECB	New England Coastal Basins, 890
NROK	Northern Rockies Intermontane Basins, 8
SANA	Santa Ana Basin, 921
UIRB	Upper Illinois River Basin, 144
COOK	Cook Inlet Basin, no population data
OAHU	Oahu, no population data

Figure 2. Location and population density of National Water-Quality Assessment Program (NAWQA) study units in the Nation, 1991-97. NAWQA study units in Hawaii (OAHU) and Alaska (COOK) not shown. Population density is the median value for basins monitored for streambed sediment and fish tissue.

Table 2. Guidelines for trace elements and organic compounds in bulk sediment and fish tissues

[Consensus-based Sediment Quality Guidelines (SQG), probable effect concentration (PEC), (MacDonald and others, 2000); and Canadian Council of Ministers of the Environment (CCME); probable effects levels (PEL) to freshwater ecosystems for unsieved sediment (Canadian Council of Ministers of the Environment, 1999); µg/g, microgram per gram; NECB, New England Coastal Basins study unit; PAH, polycyclic aromatic hydrocarbons; µg/kg, microgram per kilogram; --, no guideline; PCB, polychlorinated biphenyls; USFDA, U.S. Food and Drug Administration (1984) interstate commerce action level for concentrations in whole fish; NAS/NAE, National Academy of Sciences/National Academy of Engineering (1973) guideline for concentrations in fish fillets for the protection of fish-eating wildlife; DDTM, dichloro diphenyl trichloroethane and its metabolites]

Trace elements in streambed sediments (µg/g dry weight)	SQG PEC	No. NECB samples exceeding SQG PEC	CCME PEL	No. NECB samples exceeding CCME PEL
Arsenic	33	4	17	7
Cadmium	5	3	3.5	5
Chromium	111	6	90	9
Copper	149	4	197	3
Lead	128	8	91.3	9
Mercury	1.06	2	0.486	10
Nickel	48.6	6	35.9	8
Zinc	459	5	315	6
PAHs in streambed sediment (µg/kg dry weight)	**SQG PEC**	**No. NECB samples exceeding SQG PEC**	**CCME PEL**	**No. NECB samples exceeding CCME PEL**
Acenaphthylene	--	--	88.9	10
Acenaphthene	--	--	128	5
Anthracene	845	3	245	9
Benz[a]anthracene	1,050	8	385	10
Benzo[a]pyrene	1,450	7	782	9
Chrysene	1,290	8	862	9
Dibenz[ah]anthracene	--	--	135	8
Fluoranthene	2,230	8	2,355	8
9H-fluorene	536	1	144	7
Naphthalene	561	0	391	0
Phenanthrene	1,170	9	515	9
Pyrene	1,152	9	875	9
Total PAH	22,800	6	--	--
Organochlorine compounds in streambed sediment (µg/kg dry weight)	**SQG PEC**	**No. NECB samples exceeding SQG PEC**	**CCME PEL**	**No. NECB samples exceeding CCME PEL**
Total PCBs	676	2	277	5
Total chlordane	17.6	7	8.87	9
DDD[1]	28.0	5	8.51	8
DDE[1]	31.3	2	6.75	7
DDT[1]	62.9	1	4.77	7
DDTM	572	0	4,450	0
Organochlorine compounds in fish tissue (µg/kg wet weight)	**USFDA**	**No. NECB samples exceeding USFDA guidelines**	**NAS/NAE**	**No. NECB samples exceeding NAS/NAE guidelines**
Total PCBs	2,000	1	500	2
Total chlordane	300	0	100	1
DDTM	5,000	0	1,000	0
Trace elements in fish tissue (µg/g wet weight)	**USFDA**	**No. NECB samples exceeding USFDA guideline**	**NAS/NAE**	**No. NECB samples exceeding NAS/NAE guideline**
Mercury	1	0	.5	1

[1]Sum of *p,p′*- and *o,p′*- homologs.

TRACE ELEMENTS IN STREAMBED SEDIMENT AND FISH TISSUE

The concentrations of all trace elements analyzed in streambed sediment and fish tissue at NECB sampling sites are listed in appendixes 1A and 1B. Trace elements were the most frequently detected contaminants in streambed sediment in the NECB study area. Forty of the 45 trace elements analyzed in streambed sediment were detected at all sites. Gold and thallium were the only trace elements not detected in any streambed-sediment sample. Trace elements were detected much less frequently in fish tissue. Only 8 of the 22 trace elements analyzed in fish tissue (fillet) composites were detected at all sites. Of the 22 trace elements, 10 were not detected in any fish tissue (fillet) sample. Because of their toxic effects in the aquatic environment, the subsequent description of results focuses on As, Cd, Cu, Cr, Pb, Hg, Ni, Se, and Zn. These trace elements were detected in all streambed-sediment samples; however, only Hg and the trace elements essential to aquatic organisms (Cu, Se, Zn) were detected in all tissue samples; 7 of the 12 fish-tissue samples had detectable levels of As.

Comparisons with Other Studies and Guidelines

Median concentrations of selected trace elements and organic carbon in streambed sediment in the NECB study area were 1.5 to 8 times higher than the median concentrations of these constituents found in 46 NAWQA study units across the country (fig. 3 and table 3). Median concentrations of organic carbon, Pb, and Hg were the most elevated compared to other study units. Median concentrations of Cd and Cu in NECB streambed sediment were the second highest compared to other study units. Median concentrations of As and Zn were the third and fourth highest, respectively, compared to other study units.

Concentrations of Pb in NECB streambed sediments were most frequently above the consensus-based SQG for probable adverse effects to aquatic biota (fig. 3, appendix 1A). Eight of the 14 sites were above the SQG for Pb. Sampling sites near Boston, Providence, and Worcester (fig. 1) had trace element concentrations most frequently exceeding SQG guidelines. At the Aberjona River site (13), all but one of the selected trace elements were above the SQG. Seventy-five percent of the selected trace elements were above the SQG at the Blackstone River (site 8); and 62.5 percent were above the SQG at the Woonasquatucket River (site 6), Neponset River (site 10), and Moshassuck River (site 14) (fig. 3, appendix 1A). Similar percentages of the sites exceeded the CCME guidelines for all selected trace elements except Hg. Concentrations of Hg in NECB streambed sediments were above the CCME PEL of 0.49 µg/g at 10 out of 14 sites, but only two sites had Hg sediment concentrations above the SQG PEC of 1.06 µg/g (table 2).

Relations to Watershed Characteristics

The highly urban character of NECB sampling sites probably explains most of the elevated levels of trace elements in NECB streambed-sediment samples relative to the levels in most other NAWQA study units. Population density has been determined to be a good surrogate for urbanization or human activity (Rice, 1999). NECB sampling sites for streambed-sediment and fish tissue had the second highest median population density (890 people/mi^2) of the NAWQA study units (fig. 2). Population density was the watershed characteristic most strongly correlated with concentrations of trace elements in streambed sediments in the NECB study area. Concentrations of Cd, Cu, Pb, Hg, and Zn in streambed sediment samples all had highly significant positive correlations with population density (rho = 0.71 to 0.85, p = 0.005 to less than 0.001) (table 4). A weaker but still significant positive correlation was found between concentrations of Pb, Hg and Zn and urban land use (rho = 0.61 to 0.66, p = 0.021 to 0.011), and concentrations of Pb, Se, and Zn and commercial, industrial and transportation land use (rho = 0.61 to 0.65, p = 0.021 to 0.012) (table 4). Similar relations between Cd, Cu, Pb, Hg, and Zn concentrations in streambed sediment and urbanization were found in other NAWQA study units (Long and others, 2000; Scudder and others, 1997). Concentrations of As and Se in NECB streambed sediment samples were more strongly correlated to organic carbon concentrations (rho = 0.70, 0.77, p = 0.005, 0.001, respectively) than any other watershed characteristics (table 4). Arsenic concentrations in streambed sediment also appeared to be influenced by bedrock geology. Elevated concentrations of As at the Stillwater and Beaver River sites

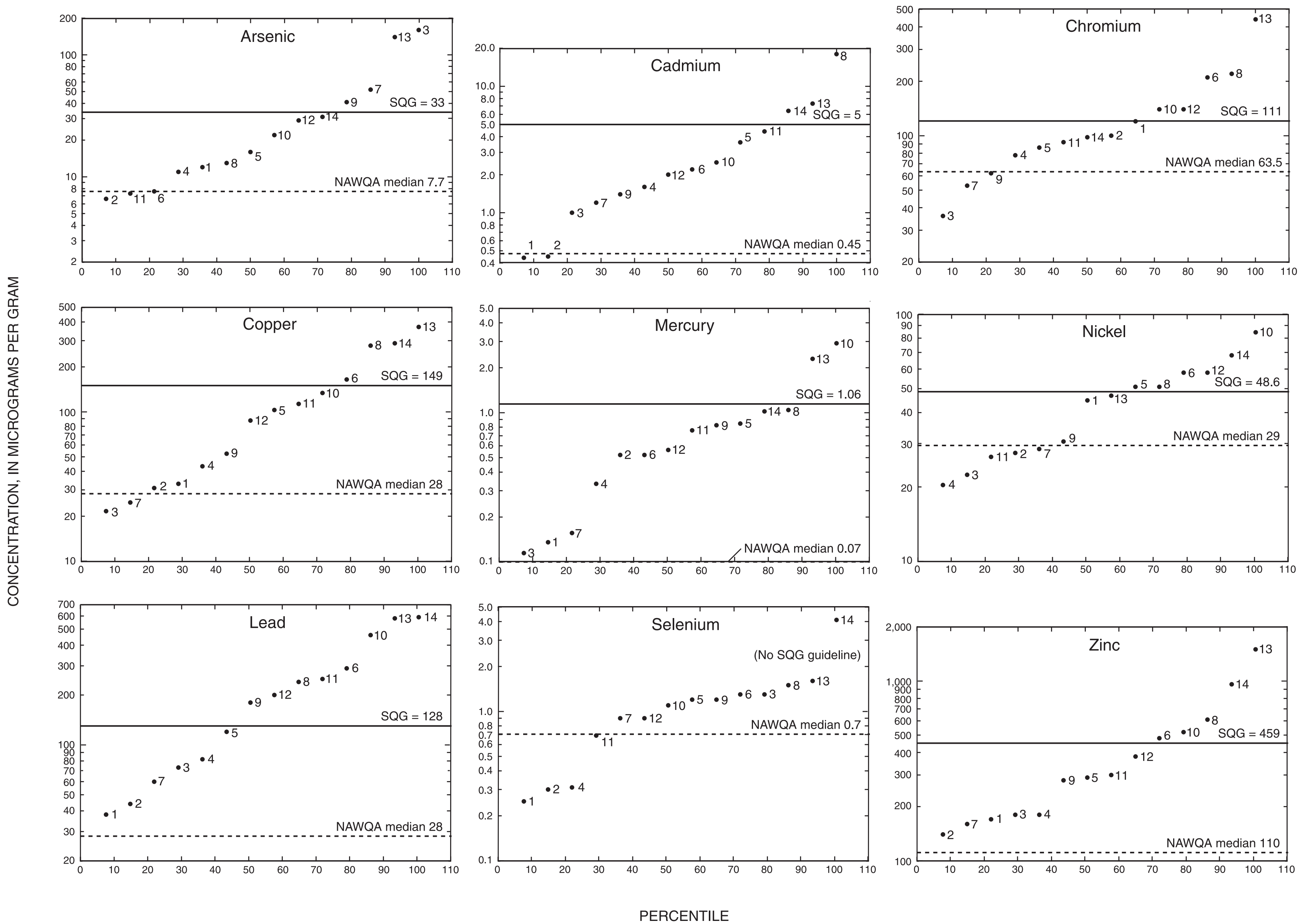


Figure 3. Concentrations of trace elements in streambed sediment, New England Coastal Basins. Site numbers are listed in table 1. Site locations are shown in figure 1. Solid lines represent consensus-based Sediment Quality Guidelines (SQG probable effect concentrations for freshwater ecosystems). Dashed lines represent National median concentrations from 46 NAWQA study sites.

Table 3. Median concentrations of selected trace elements and organic carbon in streambed sediment from 46 National Water-Quality Assessment Program (NAWQA) study units

[NAWQA, National Water-Quality Assessment Program; the number of monitoring sites ranged from 6 to 56; --, not available; All trace elements are median concentrations in microgram per gram, organic carbon is median concentration in percent; Values in **bold** are for the New England Coastal Basins study unit; Values underlined are highest among all study units. Locations of NAWQA study units are shown in figure 2.]

NAWQA study unit	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Selenium	Zinc	Organic carbon
ACAD	6.63	0.45	58.6	26.4	29.2	0.07	21.7	0.43	120	1.72
ACFB	5.6	.5	91	29	38	.08	31	.9	130	2.75
ALBE	4.4	.3	69.5	22.5	35	.08	20	.6	99	2.47
ALMN	13	.95	74.5	28	36.5	.07	45	.73	195	2.71
CAZB	22	.7	77	79	31	.08	42	1.3	160	2.51
CCPT	4.5	.2	53	26	12	.02	21	.2	82	2.15
CNBR	5.2	.3	45.5	14.5	17.5	.02	18.5	.72	69	1.31
CONN	5.9	1.1	91	55.5	80	.195	36.5	.9	200	5.3
COOK	11	.24	84	46	11	.17	40	.83	110	3.16
DELR	10.3	1.00	72	56.8	74	.16	34.3	1.35	290	4.9
EIWA	6.4	.4	46.5	13	15	.04	21	.8	72.5	2.5
GAFL	5.2	.5	75	17	38	.11	19	1	100	7.92
HDSN	7	.7	64	33	38	.1	33	.6	180	3.02
KANA	7.7	.5	75	26	38	.07	51	.82	200	--
LERI	13	.6	60	26	27	.07	31	.71	120	2.37
LINJ	7.3	.95	67.5	69	85.5	.17	29	.98	245	4.28
LIRB	6.8	.45	56	19.5	24.5	.03	24	.48	88	1.39
LSUS	7.5	.8	70	49	45	.12	48	1.3	300	3.82
LTEN	7.8	.27	50	21	26	.06	28	.49	84	1.89
MIAM	11	.38	63	30	25	.06	32	.56	130	2.14
MISE	10	.3	62	17.5	19	.035	28	.6	91.5	1.15
MOBL	11.3	.18	77.6	22.1	25.8	.05	29	.61	110	--
NECB	**19**	**2.1**	**99**	**92.5**	**190**	**.635**	**45**	**1.15**	**295**	**8.98**
NROK	10.05	.45	42.5	30	48.25	.06	18.05	.29	108	2.29
NVBR	19	.35	46	38	20.5	.205	22.5	.6	100	2.58
OAHU	8	.86	420	205	52.5	.175	235	1.75	375	7.19
OZRK	6.6	.5	47	18	25	.04	23	.6	90	2.36
POTO	10	.45	69	37	31	.07	36	.5	130	2.76
PUGT	12	.4	93	44	21	.1	54	.7	130	5.21
REDN	7.9	.6	65	23	13	.03	31	.9	95	2.15
RIOG	6.3	.25	48.5	23	21	.03	19.5	.4	82.5	1.6
SACR	9.6	.3	200	69.5	13	.09	120	.43	120	1.25
SANA	5.45	.48	57.5	54.5	32.5	.05	29	.41	160	3.59
SANJ	7.5	.1	100	45	20	.13	60	.4	110	2.23
SANT	5.4	.3	70	28	38	.08	24	.9	94	3.32
SCTX	3.7	.3	36	7	15	.02	14	.74	77	2.47
SPLT	6.05	.9	51	45	49	.08	19	1.65	180	2.37
TRIN	10	.3	58.5	17	20	.035	24.5	.4	77.5	1.22
UCOL	22.5	3.4	52.5	84	185	.1	26.5	1.3	940	2.8
UIRB	6.3	.3	57.5	45	21	.08	24.5	.43	110	2.37
UMIS	7.7	.6	69	26	23	.08	29	1.2	110	4.55
USNK	5.15	.4	55.5	15.5	14	.02	18	.6	81	1.96
UTEN	8.25	.4	61.5	27	38	.08	33	.7	140	2.72
WHIT	8	.55	57	25	24.5	.06	29	.52	100	1.92
WILL	8.6	.3	73	43	14	.06	29	.3	120	3.15
WMIC	6	.6	61	22	19.5	.1	21	.9	98	5.66
NATIONAL MEDIAN	7.7	.45	63.5	28	25.9	.0725	29	.7	110	2.50

Table 4. Summary of statistical analysis between selected trace elements and organic compounds in streambed sediment and fish tissue in relation to selected watershed characteristics and organic carbon, New England Coastal Basins

[Spearman's coefficients (rho) and probability values (p-values) are highly significant (in **bold** and underlined) when rho is greater than or equal to 0.7; and p-values are less than or equal to 0.005; they are significant (in **bold**) when rho is greater than 0.6, and p-values are less than 0.05; a weak correlation may exist when rho is between 0.5 and 0.6 and p-values are less than 0.1; a negative rho value indicates an inverse relation; <, less than; PAHs, polycyclic aromatic hydrocarbons; PCBs, polychlorinated biphenyls; DDTM, dichloro diphenyl trichloroethane and its metabolites; --, not applicable]

Trace element or organic compound	Population density		Urban land use		Commercial, industrial and transportation land use		Organic carbon	
	rho	p-value	rho	p-value	rho	p-value	rho	p-value
				Streambed sediment (14 samples)				
Arsenic	0.35	0.214	0.55	0.041	0.58	0.029	**0.77**	**0.001**
Cadmium	**.73**	**.003**	.55	.041	.55	.043	.22	.446
Chromium	.33	.246	.18	.532	.19	.512	-.23	.431
Copper	**.71**	**.004**	.52	.054	.56	.039	.21	.474
Lead	**.85**	**<.001**	**.66**	**.011**	**.65**	**.012**	.46	.098
Mercury	**.71**	**.005**	**.61**	**.021**	.59	.025	.37	.196
Nickel	.51	.062	.45	.107	.54	.046	.33	.252
Selenium	.54	.046	.48	.079	**.61**	**.021**	**.70**	**.005**
Zinc	**.78**	**<.001**	**.61**	**.021**	**.62**	**.018**	.38	.185
Total PAHs	**.85**	**<.001**	**.69**	**.006**	**.63**	**.016**	**.62**	**.017**
Total PCBs	**.76**	**.001**	**.61**	**.020**	**.60**	**.024**	**.76**	**.001**
Total chlordane	**.72**	**.003**	**.62**	**.017**	.50	.071	.58	.029
DDTM	**.76**	**.002**	**.63**	**.015**	.56	.038	**.63**	**.016**
				Fish tissue (12 samples)				
Arsenic	.10	.748	.22	.482	.10	.763	--	--
Copper	-.37	.241	-.49	.106	-.58	.049	--	--
Mercury	**-.72**	**.008**	-.52	.083	-.50	.101	--	--
Selenium	**.72**	**.008**	.47	.127	.40	.199	--	--
Zinc	.55	.061	.45	.140	.50	.101	--	--
Total PCBs	**.62**	**.033**	.36	.246	.35	.257	--	--
Total chlordane	**.66**	**.019**	.51	.087	.48	.113	--	--
DDTM	**.70**	**.011**	.56	.056	.45	.140	--	--

appendix 1A) may be attributed to direct bedrock sources of As. Stillwater River (site 3), and Beaver Brook (site 7) are in an area of calcareous and sulfide-bearing schist, granofels, and gneiss shown to be associated with high concentrations of As in ground water (Ayotte and others, 1999). Cr and Ni were the only trace elements in streambed sediment not significantly correlated with any watershed characteristic.

Population density was the only watershed characteristic significantly correlated with trace element concentrations in fish tissue (fillet) (table 4). Of the five trace elements (As, Cu, Hg, Se, and Zn) detected in fish tissue, only Hg and Se had a significant correlation with population density (rho = -0.72, p = 0.008; rho = 0.72, p = 0.008, respectively). The lower number of correlations between fish tissue and trace elements compared to streambed sediment probably reflects complications as a result of bioavailability, fish mobility, species differences, life stage, sex, diet, and physiological condition (Wong and others, 2000). The negative correlation between Hg concentrations in fish tissue and population density contrasts with the positive correlation found between Hg in streambed sediment and population density (rho = 0.71, p = 0.005) (table 4). This may reflect complications as a result of Hg bioavailability. Methyl mercury is the form of mercury that bioaccumulates in fish. Typically greater than 95 percent or more of Hg in fish tissue is methyl mercury (Porcella, 1994). Whereas elevated concentrations of total Hg in sediment are frequently correlated with population density (Daskalakis and O'Connor, 1995; Rice, 1999;

(Long and others, 2000), conditions in pristine areas favor high production of methyl mercury (Gilmour and others, 1998). As a result, elevated total Hg concentrations in sediment are frequently not coupled with methyl mercury accumulation in fish (Kelly and others, 1995).

Relations Between Trace Elements in Streambed Sediment and Fish Tissue

Hg and Se were the only selected trace elements that accumulated at higher concentrations in fish tissue than in streambed-sediment samples (appendix 1A and 1B). Both Hg and Se form bioavailable organometallic compounds in streambed sediment that can accumulate in muscle tissue (Wiener and Spry, 1996; Lemly, 1996). Se had a significant positive correlation between streambed sediment and fish tissue (rho = 0.63, p = 0.029) (table 5). Total Hg did not have a significant correlation between streambed sediment and fish tissue (rho = -0.54, p = 0.069) (table 5). Mercury must be methylated before it can efficiently be bioaccumulated in fish tissue. Therefore, concentrations of total Hg in sediment frequently are not a good predictor of mercury concentrations in fish tissue

Table 5. Summary of statistical analysis between selected trace elements and organic compounds in streambed sediment in relation to fish tissue, New England Coastal Basins

[Spearman's coefficients (rho) and probability values (p-values) are highly significant (in **bold** and underlined) when rho is greater than or equal to 0.7; and p-values are less than or equal to 0.005; they are significant (in **bold**) when rho is greater than 0.6, and p-values are less than 0.05; a weak correlation may exist when rho is between 0.5 and 0.6 and p-values are less than 0.1; a negative rho value indicates an inverse relation; PCBs, polychlorinated biphenyls; DDTM, dichloro diphenyl trichloroethane and its metabolites]

Trace element or organic compound	Streambed sediment in relation to fish tissue (12 samples)	
	rho	p-value
Arsenic	0.30	0.341
Copper	-.26	.418
Mercury	-.54	.069
Selenium	**.63**	**.029**
Zinc	.43	.158
Total PCBs	**.75**	**.005**
Total chlordane	.55	.065
DDTM	**.66**	**.018**

(Kelly and others, 1995). Cu and Zn, the other selected trace elements detected in all NECB fish-tissue (fillet) samples, did not show any correlation between streambed sediment and fish tissue (table 5). The uptake of Cu and Zn by fish may be homeostatically regulated (limited by cellular mechanisms), particularly in muscle tissue (Luoma, 1983). These results indicate total concentrations of trace elements in sediment may frequently be poor indicators of bioavailability. Not surprisingly, other studies also have shown little or no correlation between trace elements in streambed sediment and fish tissue (Long and others, 2000; Maret and Skinner, 2000; Scudder and others, 1997).

ORGANIC COMPOUNDS IN STREAMBED SEDIMENT AND FISH TISSUE

The concentrations of all organic compounds analyzed in streambed sediment and fish tissue at NECB sampling sites are contained in appendixes 2A, 2B, and 3. Detection frequencies for organic compounds were generally higher in fish tissue than in streambed sediment, although the number of organochlorine compounds detected was higher in streambed sediment than in fish tissue. PAHs were the most frequently detected group of organic compounds in streambed sediment samples in the NECB study area; 13 of the 27 PAH compounds were detected in all streambed sediment samples (appendix 3). PAHs were analyzed only in streambed sediment because PAHs are readily metabolized by fish and, therefore, do not accumulate as the parent compound in fish tissue (Crawford and Luoma, 1993). DDT metabolites accounted for most of the DDT detected in streambed sediment and fish tissue, suggesting DDT contamination was not recent (appendix 2A). One exception was the Blackstone River (site 8, fig. 1), where *p,p'*DDT in streambed sediment accounted for 73 percent of DDTM. *p,p'*DDE, the most persistent metabolite of DDT, was detected in 79 percent of streambed-sediment samples and in 92 percent of fish-tissue samples. Total PCBs were detected in 71 percent of streambed-sediment samples (appendix 2A) and 83 percent of whole fish tissue (appendix 2B). At least one component of chlordane was detected in 64 percent of streambed-sediment samples and 58 percent of the whole fish tissue. Dieldrin was detected in 50 percent of streambed-sediment samples (appendix 2A) and 17 percent of fish-tissue samples (appendix 2B). The following discussion will focus on the most commonly detected organic compounds—total PAHs, total PCBs, total chlordane, and DDTM.

Comparisons with Other Studies and Guidelines

Concentrations of organic carbon, total PAHs, total PCBs, and DDTM were higher in NECB streambed-sediment samples than in sediment samples in other NAWQA study units (table 6). The median organic carbon concentration in NECB sediment samples was 1.3 to 12 times higher than median concentrations in other NAWQA study units (table 6). The sum of the median values of the 27 PAH compounds in NECB sediment samples was 21,800 µg/kg, 4 times higher than the sum of medians in any other NAWQA study unit (table 6). Concentrations of individual PAH compounds above consensus-based SQGs occurred at more NECB sites (9) than any other organic compound (table 2). Total PAH concentrations in streambed sediment exceeded consensus-based SQC at six sites (table 2, fig. 4). Median concentrations of total PCBs and DDTM in streambed-sediment samples were 1.9 and 1.5 times higher, respectively, at NECB sites than medians at any other NAWQA study unit (table 6). Chlordane components in NECB streambed sediment had the second highest median concentration compared to other study units (table 6). Consensus-based SQGs for DDD, DDE, and DDT in streambed sediment were exceeded at 7 to 36 percent of NECB sites (table 2). DDTM concentrations in streambed sediment did not exceed SQG at any NECB sites (table 2, fig. 4). Total chlordane concentrations in streambed sediment exceeded the consensus-based SQG at 50 percent of NECB sites, and total PCB concentrations exceeded SQG at 14 percent of sites (fig. 4). Overall, organochlorine compounds in streambed sediment exceeded the CCME guidelines at more NECB sites than the consensus-based SQGs (table 2).

Total PCBs were the organic compounds most elevated in NECB fish tissue compared to other 38 NAWQA study units; median total PCB concentrations were 2.7 to 27 times higher than median concentrations in other NAWQA study units (table 7). The median total chlordane concentration in NECB fish tissue was in the upper 25 percent of sites nationally, and the median concentration of DDTM in NECB fish tissue was in the upper 50 percent of sites nationally (table 7). Fish tissue from the Charles River (site 11, fig. 1), exceeded the NAS/NAE guidelines for concentrations of total PCBs and total chlordane, and the U.S. Food and Drug Administration (USFDA) action level for concentrations of PCBs (National Academy of Sciences, National Academy of Engineering, 1973; U.S. Food and Drug Administration, 1984) (fig. 4). The Blackstone River (site 8, fig. 1), exceeded the NAS/NAE guideline for concentrations of total PCBs in fish tissue (National Academy of Sciences, National Academy of Engineering, 1973) (fig. 4).

Relations to Watershed Characteristics

High levels of organic compounds in streambed sediment in NECB relative to those in other study units are most likely a result of the high levels of urbanization at the selected NECB sites and the high organic carbon concentration in the NECB streambed-sediment samples. Population density was the watershed characteristic most strongly correlated with concentrations of organic compounds in streambed sediment. Total PAHs had the highest correlation with population density (rho = 0.85, $p < 0.001$) followed by total PCBs (rho = 0.76, $p = 0.001$), DDTM (rho = 0.76, $p = 0.002$), and total chlordane (rho = 0.72, $p = 0.003$) (table 4). Concentrations of total PAHs, total PCBs, DDTM, and total chlordane were all significantly correlated to urban land use (rho = 0.61 to 0.69, $p = 0.020$ to 0.006), whereas only PAHs and total PCBs were correlated to commercial, industrial and transportation land use (rho = 0.63, $p = 0.16$ and rho = 0.60, $p = 0.024$, respectively). The use of DDT and chlordane for insect control in residential areas may explain their low correlation with commercial, industrial and transportation land use. Concentrations of organic compounds in streambed sediment also were correlated to the organic carbon content of streambed sediment (table 4). Hydrophobic organic compounds (such as PAHs, PCBs, chlordane, and DDTM) are frequently associated with particulate organic carbon fraction of streambed sediment (Nowell and others, 1999). Total PCBs had the strongest correlation with sediment organic carbon (rho = 0.76, $p = 0.001$), followed by DDTM (rho = 0.63, $p = 0.016$), total PAHs (rho = 0.62, $p = 0.017$), and total chlordane (rho = 0.58, $p = 0.029$) (table 4).

Table 6. Median concentrations of selected organic compounds in streambed sediment from 46 National Water-Quality Assessment Program (NAWQA) study units

[NAWQA, National Water-Quality Assessment Program; the number of streambed monitoring sites ranged from 6 to 56; g/kg, grams per kilogram; All concentrations are in microgram per kilogram, unless noted otherwise; PCBs, polychlorinated byphenyls; DDTM, sum of DDT, dichloro diphenyl trichloroethane and its major metabolites; DDD, dichloro diphenyl dichloroethylene; DDE, dichloro diphenyl dichloroethane; PAHs, polycyclic aromatic hydrocarbons; <, less than minimum reporting level; --, not analyzed; Values that are **bold** are for the New England Coastal Basins study unit; Values that are underlined are highest among all study units. See figure 2 for location of study units]

NAWQA study unit	Organic carbon (g/kg)	Total PCBs	Total chlordane[1]	DDTM[2]	Total PAHs[3]
ACAD	17	<50	<1	1.05	858
ACFB	7	<100	<1	<2	<50
ALBE	8.2	<100	<1	1.2	<50
ALMN	17	<50	<1	<2	1,995
CAZB	14	<50	<1	1.1	485
CCPT	9.7	<100	<1	1.1	<50
CNBR	9.4	<100	<1	<2	98
CONN	19	<50	<1	3.7	4,813
COOK	8	<50	<1	<2	<50
DELR	35	<50	1.1	3.75	5,369
EIWA	16	<50	<1	<2	342
GAFL	32	<50	<1	<2	<50
HDSN	23	<50	<1	1.9	2,819
KANA	14.5	<50	<1	<2	870
LERI	11	<50	<1	2.5	816
LINJ	12	<50	4.6	1.5	4,454
LIRB	5	<50	<1	<2	182
LSUS	33	<100	<1	<2	1,766
LTEN	22	<50	<1	<2	170
MIAM	7	<50	<1	<2	1,414
MISE	9.9	<50	<1	3.7	328
MOBL	--	<50	<1	<2	--
NECB	**61.5**	**155**	**18**	**25.9**	**21,764**
NROK	13	<50	<1	<2	84
NVBR	14	<100	<1	<2	55
OAHU	48.7	80.9	70.9	17.5	4,036
OZRK	8.5	<50	<1	<2	<50
POTO	21.5	8.3	1.73	<5	945
PUGT	9.4	<50	<1	<2	283
REDN	16.5	<100	<1	<2	97
RIOG	15	<100	<1	<2	40
SACR	7.7	<50	<1	<2	152
SANA	26	<50	<1	6.3	1,011
SANJ	8.4	<100	<1	3.5	27
SANT	12	<50	<1	1.1	244
SCTX	21	<50	<1	<2	51
SPLT	14.5	<100	<1	1.5	584
TRIN	10	<50	<1	1.1	35
UCOL	7.3	<50	<1	<2	269
UIRB	15	<50	<1	1.75	867
UMIS	19	<50	<1	<2	472
USNK	14	<50	<1	<2	<50
UTEN	21.5	<50	<1	<2	783
WHIT	15	<100	<1	<2	94
WILL	19	<100	<1	1.6	<50
WMIC	39	<100	<1	1.1	96
NATIONAL MEDIAN	14.5	<50	<1	<2	267

[1]Sum of medians of *cis*-chlordane, *trans*-chlordane, heptachlor epoxide, oxychlordane, *cis*-nonachlor and *trans*-nonachlor.
[2]Sum of medians of *o,p'*- and *p,p'*- homologs of DDD, DDE and DDT.
[3]Sum of medians of 27 polycyclic aromatic hydrocarbon compounds.

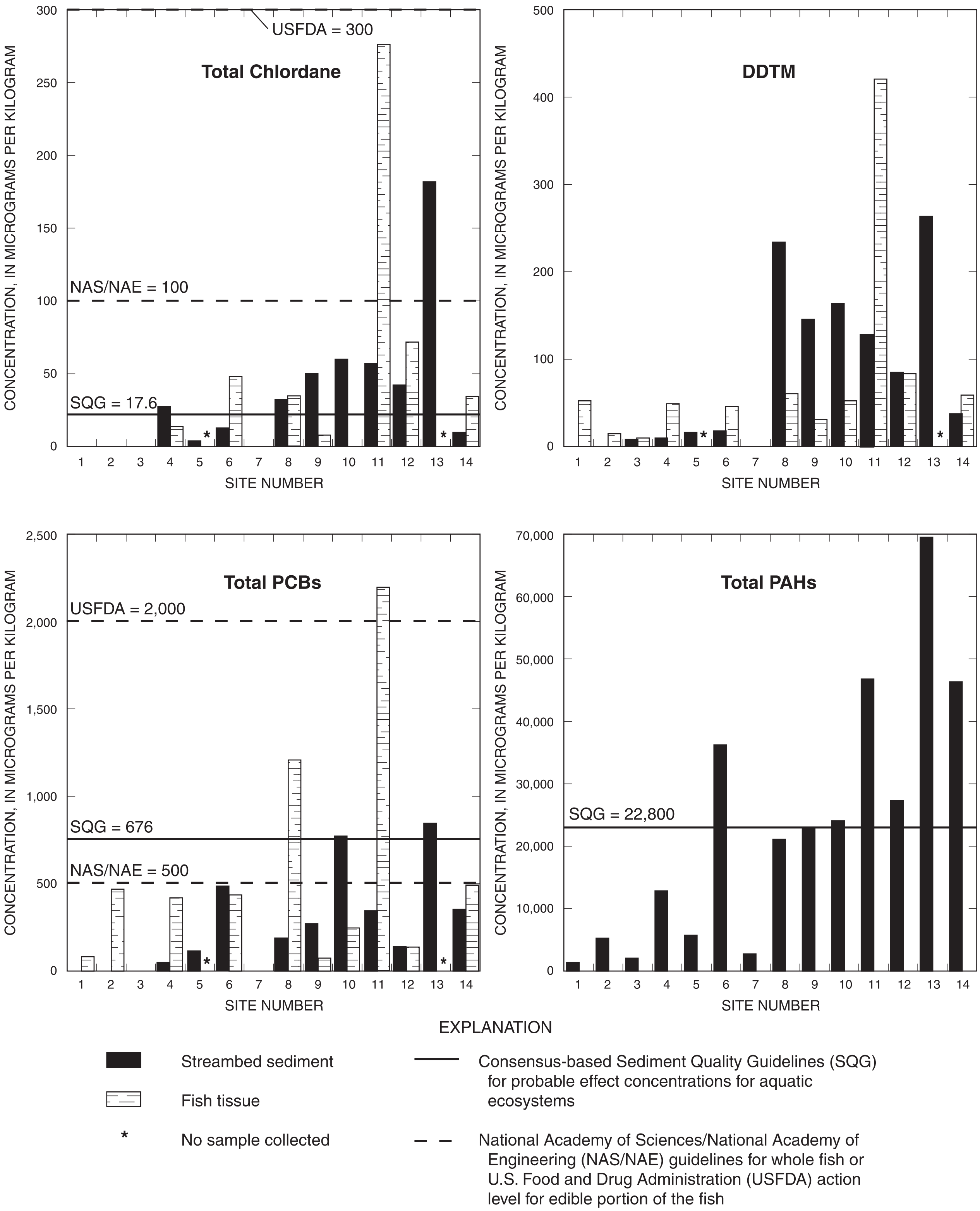


Figure 4. Concentrations of organic compounds in streambed sediment and fish tissue, New England Coastal Basins. Sites are ordered from low to high population density. Blanks indicate compounds in samples were below detection limits. DDTM is the sum of DDT and its metabolites. Site numbers are listed in table 1. Site locations are shown in figure 1.

Table 7. Median concentrations of selected organic compounds in fish tissue from 39 National Water-Quality Assessment Program (NAWQA) study units

[Concentrations in microgram per kilogram (µg/kg); NAWQA, National Water-Quality Assessment Program; PCBs, polychlorinated biphenyls; <, less than minimum reporting level; DDTM, sum of DDT, dichloro diphenyl trichloroethane and its metabolites; DDD, dichloro diphenyl dichloroethylene; DDE, dichloro diphenyl dichloroethane; Values in **bold** are for the New England Coastal Basins study unit; Values underlined are highest among all study units. See figure 2 for locations of study units.]

NAWQA study unit	Total PCBs	Total chlordane[1]	DDTM[2]
ACFB	<50	<5	<5
ALBE	<50	<5	7.5
ALMN	150	8.6	32
CAZB	<50	<5	18
CCPT	<50	<5	92.2
CNBR	<50	<5	11.5
CONN	250	23.4	76.8
COOK	128.5	<5	<5
DELR	159.5	19.6	57.8
EIWA	70	42.1	66
GAFL	<50.	<5	<5
HDSN	120	<5	68
KANA	70	<5	<5
LERI	210	6	49.2
LINJ	205	167.4	144.5
LIRB	160	114.7	55.4
LSUS	190	9.05	46.2
MISE	74.5	6.45	736
MOBL	65	<5	24
NECB	**325**	**9**	**44.3**
NVBR	<50	<5	<5
OZRK	<50	<5	<5
POTO	<50	<5	<5
PUGT	<50	<5	<5
REDN	<50	<5	43
RIOG	53.5	<5	59.5
SACR	<50	<5	20
SANJ	<50	<5	<5
SANT	<50	<5	<5
SCTX	<50	<5	12.5
SPLT	95.5	<5	83.5
TRIN	<50	16.4	24
UCOL	<50	<5	16
UMIS	70	6.6	38
USNK	<50	<5	74.3
UTEN	<50	<5	<5
WHIT	<50	<5	<5
WILL	<50	<5	9
WMIC	<50	<5	5.3
NATIONAL MEDIAN	<50	<5	20

[1]Sum of medians of *cis*-chlordane, *trans*-chlordane, heptachlor epoxide, oxychlordane, *cis*-nonachlor and *trans*-nonachlor.

[2]Sum of median concentrations of *o,p'*- and *p,p'*- homologs of DDD, DDE, and DDT.

Correlations between watershed features and organochlorine compounds in fish tissue were weaker than with streambed sediment (table 4). Population density was significantly correlated with DDTM (rho = 0.70, p = 0.011), total chlordane (rho = 0.66, p = 0.019), and total PCBs (rho = 0.62, p = 0.033) concentration in fish tissue. Correlations between concentrations of organic compounds in fish tissue and urban land use, and concentrations of organic compounds in fish tissue and commercial, industrial, and transportation land use, were not significant.

Relations Between Organic Compounds in Streambed Sediment and Fish Tissue

Correlations between streambed sediment and fish tissue were stronger with organic compounds than with trace elements (table 5). All organic compounds showed some degree of correlation between streambed sediment and fish tissue; a highly significant correlation was found with PCBs (rho = 0.75, p = 0.005), a significant correlation with DDTM (rho = 0.66, p = 0.018), and a weak correlation with total chlordane (rho = 0.55, p = 0.065). Wong and others (2000) and Breault and Harris (1997) also found correlations were stronger between fish tissue and streambed sediment with organic compounds than with trace elements.

SUMMARY AND CONCLUSIONS

Concentrations of selected trace elements and organic compounds in streambed sediment and organic compounds in fish tissue in the New England Coastal Basins (NECB) study area were elevated compared to concentrations in other NAWQA study units across the Nation. NECB had the highest median concentrations for Pb, Hg, total PAHs, total PCBs, and DDTM, and the second highest median concentrations for Cd, Cu, and chlordane components in streambed sediment when compared to median concentrations of 45 other NAWQA study units. NECB had the highest median concentration of total PCBs in fish tissue compared to 38 other NAWQA study units. PAHs and Pb were the contaminants in streambed sediments most frequently above the consensus-based SQGs for probable adverse effects to aquatic ecosystems. SQG guidelines for trace elements and organic compounds were exceeded most frequently at sites near large cities such as Boston, Providence and Worcester.

The high concentrations of trace elements and organic compounds in the NECB study area appear to be the result of urbanization or human activity in the watersheds sampled. Population density was more strongly correlated with concentrations of trace elements and organic compounds in NECB streambed sediment and fish tissue than other watershed characteristics. Population density had highly significant positive correlations with concentrations of Cd, Cu, Pb, Hg, Zn, total PAHs, total PCBs, total chlordane, and DDTM in streambed sediment. Significant positive correlations were found between population density and concentrations of Se, total PCBs, DDTM, and total chlordane in fish tissue.

Organic carbon concentrations may also be a factor contributing to the elevated concentrations of trace elements and organic compounds in NECB streambed sediment. Median concentrations of organic carbon in NECB streambed sediment were 1.3 to 12 times higher than median concentrations in other NAWQA study units. Organic carbon concentrations were correlated with concentrations of As, Se, total PAHs, total PCBs, and DDTM in NECB streambed sediment.

Concentrations of Se, total PCBs, and DDTM were significantly correlated between NECB streambed sediment and fish tissue. Correlations between streambed sediment and fish tissue were stronger with organic compounds than with trace elements, suggesting total trace element concentrations in streambed sediment may be poor indicators of trace element bioavailability to fish.

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APPENDIXES

Appendix 1A. Trace element concentrations in streambed sediment, New England Coastal Basins

[See figure 1 for location of sites and table 1 for description of sites. Samples were analyzed by the U.S. Geological Survey's Branch of Geochemistry Laboratory in Lakewood, Colo. All values in microgram per gram (µg/g), dry weight in less than 63 micrometer (µm) fraction, unless noted otherwise; Not detected (minimum reporting level <1 µg/g): gold, thallium; NECB, New England Coastal Basins study unit; %, percent of total; <, less than minimum reporting level given; Values underlined and **bold** exceed consensus-based Sediment Quality Guidelines listed in table 2.]

Trace elements	Minimum reporting level (MRL)	Concentration in streambed sediment of NECB rivers													
		Kennebec, site 1	Androscoggin, site 2	Stillwater, site 3	Merrimack, site 4	Wading, site 5	Woonasquatucket, site 6	Beaver, site 7	Blackstone, site 8	Ipswich, site 9	Neponset, site 10	Charles, site 11	Saugus, site 12	Aberjona, site 13	Moshassuck, site 14
Aluminum (Al) (%)	0.005	7.3	7.2	4.8	6.7	5	5.9	4.5	6	4.4	5.4	5.9	5.2	5.9	4.2
Antimony (Sb)	.1	0.64	0.5	1.3	1.2	2.1	3.3	0.28	3.4	2.7	4.6	3.2	1.2	3.4	10
Arsenic (As)	.1	12	6.6	**160**	11	16	7.6	**52**	13	**41**	22	7.3	29	**140**	31
Barium (Ba)	1	440	420	400	500	460	640	400	630	420	720	460	360	450	790
Beryllium (Be)	.1	2.3	3.4	3.6	3.9	2.3	5.7	3.1	2.6	2.8	2.4	2	2.8	3.2	1.9
Bismuth (Bi)	1	<1	<1	<1	<1	<1	1.4	<1	6.2	<1	<1	<1	<1	1.2	2
Cadmium (Cd)	.1	.44	.45	1	1.6	3.6	2.2	1.2	**18**	1.4	2.5	4.4	2	**7.3**	**6.4**
Calcium (Ca) (%)	.005	.96	1.4	1.1	1.8	1.1	1.2	1.2	1.4	1.4	1.3	1.5	1.4	1.6	1.4
Cerium (Ce)	1	79	97	100	140	54	120	85	84	68	62	62	72	90	67
Chromium (Cr)	1	**120**	100	36	78	86	**210**	53	**220**	62	**140**	92	**140**	**440**	98
Cobalt (Co)	1	18	13	19	8.6	30	14	18	14	28	21	12	18	27	37
Copper (Cu)	1	32	30	21	42	100	**160**	24	**270**	51	130	110	85	**360**	**280**
Europium (Eu)	1	1.5	1.5	1.6	1.9	1.2	2.3	1.2	1.6	1.1	1.4	1.3	1.3	1.5	1.2
Gallium (Ga)	1	16	16	12	14	11	14	13	14	13	13	12	14	18	11
Holmium (Ho)	1	<1.	1.1	1.2	1.5	1.2	3	1.1	1.5	1	1.2	1.1	1.2	1.4	1.4
Iron (Fe) (%)	.005	3.6	3.1	5.5	2.4	4.1	3.6	3.6	3.7	5.5	6.2	3	5.6	6	10
Lanthanum (La)	1	43	53	64	74	31	110	49	49	37	35	34	41	49	38
Lead (Pb)	1	38	44	73	82	120	**290**	60	**240**	**180**	**460**	**250**	**200**	**580**	**590**
Lithium (Li)	1	44	41	32	26	21	22	32	31	30	24	25	32	38	19
Magnesium (Mg) (%)	.005	1.1	.82	0.33	0.66	0.41	0.42	.44	0.82	0.52	1.1	0.75	0.91	0.88	0.6
Manganese (Mn)	4	960	950	2,100	750	4,800	1,600	6,800	860	8,000	5,500	750	1,500	2,400	12,000
Mercury (Hg)	.02	.13	.5	.11	.32	.81	.5	0.15	1.0	.79	**2.8**	.73	.54	**2.2**	.98
Molybdenum (Mo)	.5	.82	1.1	2.3	.98	2.6	34	1.3	2.8	3.2	2.6	1.6	3	4	7.6
Neodymium (Nd)	1	38	45	51	66	26	75	42	42	32	29	32	36	42	30
Nickel (Ni)	2	44	27	22	20	**50**	**57**	28	**50**	30	**83**	26	**57**	46	**67**
Niobium (Nb)	4	11	17	13	18	14	27	10	18	9.9	16	13	13	15	18
Phosphorus (P) (%)	.005	.13	.14	.21	.17	.17	.38	.16	.44	.23	0.23	.16	.24	.26	.36
Potassium (K) (%)	.005	1.8	1.9	1.3	1.8	1.2	1.7	1.1	1.6	1.1	1.4	1.6	1.4	1.4	1.2

Appendex 1A. Trace element concentrations in streambed sediment, New England Coastal Basins--Continued

Trace elements	Minimum reporting level (MRL)	Concentration in streambed sediment of NECB rivers													
		Ken-nebec, site 1	Andro-scoggin, site 2	Still-water, site 3	Merri-mack, site 4	Wading, site 5	Woon-asqua-tucket, site 6	Beaver, site 7	Black-stone, site 8	Ipswich, site 9	Nepon-set , site 10	Charles, site 11	Saugus, site 12	Aberjona, site 13	Moshas-suck, site 14
Scandium (Sc)	2	14	12	3.8	10	6.8	7.8	5.9	11	6.9	8.2	9.7	8.8	9.9	6
Selenium (Se)	0.1	0.25	0.3	1.3	0.31	1.2	1.3	0.9	1.5	1.2	1.1	0.69	0.9	1.6	4.1
Silver (Ag)	.1	1.1	1.7	0.54	1.7	10	2.4	.88	5.2	0.62	0.69	1.8	1.1	1.3	3.3
Sodium (Na) (%)	.005	1.2	1.6	1	2	1.1	1.5	1	1.4	.98	1.1	1.6	1.5	1.2	1
Strontium (Sr)	2	130	180	170	220	150	150	140	170	150	180	180	170	180	140
Sulfur (S) (%)	.05	.09	.14	.28	.11	0.38	0.53	.21	0.35	.41	.29	.36	.62	0.57	0.41
Tantalum (Ta)	1	<1	1.4	1	1.2	1.1	2	1.3	1.3	1.4	1.3	2.5	1.4	2.3	1.3
Thorium (Th)	1	12	17	12	22	6.5	11	12	12	9.6	8.3	9.5	9.4	11	7.6
Tin (Sn)	1	5.1	8.4	4.1	11	19	31	6.8	78	11	22	18	24	21	69
Titanium (Ti) (%)	.005	.52	.55	.34	.54	.32	.34	.27	.48	.3	.43	.47	.4	.45	.28
Uranium (U)	.1	3.4	6.2	4.9	6.2	1.8	4.2	7.9	4.1	5.4	2.2	3.6	3.6	6.5	2
Vanadium (V)	2	100	85	45	56	72	79	39	65	80	110	71	78	100	95
Yttrium (Y)	1	19	21	24	30	23	60	22	31	21	25	21	23	29	27
Ytterbium (Yb)	1	2	2.1	2.2	2.7	2.6	5.7	2	2.8	1.9	2.6	2	2.3	2.8	3
Zinc (Zn)	2	170	140	180	180	290	**480**	160	**610**	280	**520**	300	380	**1,500**	**960**
Organic carbon (%)	.01	3.03	3.87	9.91	3.21	8.98	8.48	9.15	6.66	12.6	9.59	5.3	7.22	9.44	11
Inorganic carbon (%)	.01	.01	.02	.09	.02	.07	.04	.1	.02	.12	.15	.02	.05	.08	.32
Organic plus inorganic carbon (%)	.01	3.04	3.89	10	3.23	9.05	8.52	9.25	6.68	12.7	9.74	5.32	7.27	9.52	11.3

Appendix 1B. Trace element concentrations in fish fillets, New England Coastal Basins

[See figure 1 for location of sites and table 1 for description of sites. Fish species were white suckers at all sites except Kennebec (smallmouth bass), and Merrimack (largemouth bass). Samples were analyzed by the U.S. Geological Survey's National Water Quality Laboratory in Lakewood, Colo. NECB, New England Coastal Basins study unit; All values in microgram per gram (µg/g) dry weight unless noted otherwise; Not detected (minimum reporting level <0.1 µg/g unless noted otherwise): aluminum (<1 µg/g), chromium (<0.5 µg/g), antimony, beryllium, cadmium, colbalt, lead, nickel, silver, uranium; <, less than minimum reporting level given; --, not applicable; Values **bold** exceed the National Academy of Sciences/National Academy of Engineering guideline (table 2) for the protection of fish-eating wildlife listed.]

Trace elements	Minimum reporting level (MRL)	Concentrations in fish fillets in NECB rivers											
		Ken-nebec, site 1	Andro-scoggin, site 2	Stillwater, site 3	Merrimack, site 4	Woon-asqua-tucket, site 6	Beaver, site 7	Black-stone, site 8	Ipswich, site 9	Nepon-set , site 10	Charles, site 11	Saugus, site 12	Moshas-suck, site 14
Arsenic (As)	0.1	0.48	<.24	0.39	<.26	<.25	0.29	0.36	0.49	<.27	0.41	0.53	<.26
Barium (Ba)	.1	<.1	0.50	.41	<.1	1.03	.64	.28	.45	0.76	.80	.59	1.14
Boron (B)	.2	1.15	.37	.33	0.89	0.58	.43	1.25	.34	.61	1.17	.66	0.54
Copper (Cu)	.5	1.61	1.19	1.09	1.34	.81	1.02	1.08	1.04	.88	1.20	1.03	1.11
Iron (Fe)	1	9.59	11.22	10.51	11.33	12.48	9.30	12.14	9.36	10.87	19.24	16.32	13.09
Manganese (Mn)	.1	.77	1.05	2.38	.57	.59	1.81	.68	1.96	1.84	.89	.77	.96
Mercury (Hg)	.1	**2.71**	1.43	1.19	1.88	.73	.77	.24	1.61	.93	.40	.66	.33
Molybdenum (Mo)	.1	<.24	.96	<.28	<.26	.35	<.27	<.24	<.27	<.27	<.22	<.25	<.26
Selenium (Se)	.1	1.08	.73	1.32	1.01	1.41	1.30	8.14	1.14	1.73	2.06	1.41	1.99
Strontium (Sr)	.1	.29	.49	1.75	.28	.28	.54	.54	.43	.76	.84	.53	.24
Vanadium (V)	.1	1.50	1.42	<.28	1.62	<.25	<.27	<.24	<.27	<.27	<.22	<.25	<.26
Zinc (Zn)	.5	47.47	52.10	38.31	55.15	132.53	56.07	54.71	49.35	47.88	72.85	66.72	93.05
Water, percent of total	--	80.08	80.01	80.67	80.54	79.92	81.44	78.75	80.82	81.38	78.38	80.22	80.49

Appendex 2A. Organochlorine compound concentrations in streambed sediment, New England Coastal Basins

[See figure 1 for location of sites and table 1 for description of sites. Samples were analyzed by the U.S. Geological Survey's National Water Quality Laboratory in Lakewood, Colo. All values are in concentrations of microgram per kilogram (µg/kg), dry weight in less than 2 millimeter (mm) fraction unless noted otherwise; Not detected (minimum reporting level <1 µg/kg unless noted otherwise): aldrin, chloroneb (<5 µg/kg), dacthal (<5 µg/kg), *alpha*-endrosulfan, endrin (<2 µg/kg), *alpha*-bhc, *beta*-bhc, heptachlor, isodrin, lindane, *p,p'*-methoxychlor (<5 µg/kg); o,p'-methoxychlor (<5 µg/kg), *cis*-permethrin (<5 µg/kg), toxaphane (<200 µg/kg), and pentachloroanisole; NECB, New England Coastal Basins study unit; <, less than minimum reporting level given; e, estimated concentration; DDD, dichloro diphenyl dichloroethylene; DDE, dichloro diphenyl dichloroethane; DDT, dichloro diphenyl trichloroethane; PCBs, polychlorinated biphenyls; g/kg, gram per kilogram; Values underlined and **bold** exceed consensus-based Sediment Quality Guidelines listed in table 2.]

Chlorinated organic compounds	Minimum reporting level (MRL)	Concentrations in streambed sediment in NECB rivers													
		Kennebec, site 1	Andro-scoggin, site 2	Stillwater, site 3	Merrimack, site 4	Wading, site 5	Woon-asqua-tucket, site 6	Beaver, site 7	Black-stone, site 8	Ipswich, site 9	Nepon-set, site 10	Charles, site 11	Saugus, site 12	Aberjona, site 13	Moshas-suck, site 14
cis-chlordane	1	<1	<1	<2	7.9	<2	5.7	<1	10	**19.4**	12.3	16	14	**65.2**	<1
cis-nonachlor	1	<1	<1	<2	2.4	<2	<1	<1	2.8	<3	5.8	4.8	4.2	7.5	2.2
Dieldrin	1	<1	<1	3.1	1.2	<2	<1	<1	1.5	<3	12.4	2.1	4.5	13.5	<1
Heptachlor epoxide	1	<1	<1	<2	<1	<2	<1	<1	<1	<3	<2	<1	<2	7.1	<2
Hexachlobenzene	1	<1	<1	<2	<1	<2	<1	4	<1	<3	<2	<1	<2	<2	6.7
Mirex	1	<1	<1	<2	<1	<2	<1	<1	1.1	<3	<2	<1	<2	<2	<1
o,p'-DDD	1	<1	<1	<2	<5	<2	<1	<1	12	<3	<2	22	11	9.6	<1
o,p'-DDE	1	<1	<1	<2	<1	<2	<1	<1	<1	8.9	<14.4	<1	<2	26.7	<12.1
o,p'-DDT	2	<2	<2	<4	<2	<4	<2	<2	<2	<6	<4	<2	<4	<4	<2
Oxychlordane	1	<1	<1	<2	3.2	<2	<1	<1	<3	<3	13.7	3.4	<2	<2	<9.6
p,p'-DDD	1	<1	<1	2.6	e 4.4	<2	11.2	<1	**44**	15.4	**75.3**	**67**	**39**	**81.8**	21.4
p,p'-DDE	1	<1	<1	3.4	2.4	12.7	5	<1	6.6	e **86.3**	29.1	27	21	**111**	7.6
p,p'-DDT	2	<2	<2	<4	e 2.2	2.6	<2	<2	**170**	34.2	57.6	10	13	33.7	6.9
PCBs	50	<50	<50	<100	e 45	111	474	<50	180	264	**766**	340	130	**833**	347
trans-chlordane	1	<1	<1	<2	7	3	<1	<1	**14**	**14.8**	**17**	**20**	**15**	**57.2**	<1
trans-nonachlor	1	<1	<1	<2	6.2	<2	6.1	<	5.2	15.3	10	12	8.5	**43.7**	7.1
trans-permethrin	5	<5	<5	<10	<5	<10	<5	<5	<5	<15	<10	12	<10	<10	<5
Inorganic carbon (g/kg)	0.1	<.2	<.2	0.2	<.2	0.2	<.2	<.2	<.2	0.3	3.2	<.2	0.2	<.2	0.8
Organic carbon (g/kg)	.2	11	15	60	18	64	74	44	27	110	97	60	63	77	79
Organic plus inorganic carbon (g/kg)	.1	11	15	60	18	64	74	44	27	110	100	60	63	77	80
Sample weight (grams)	.1	18.25	18.36	11.6	12.82	12.14	13	14.3	14.46	9.43	11.2	10.3	10.11	10.95	16.3

Appendex 2B. Organochlorine compound concentrations in whole fish tissue, New England Coastal Basins

[See figure 1 for location of sampling sites and table 1 for description of sites. Fish species were white suckers at all sites except smallmouth bass at Kennebec and Merrimack. Samples were analyzed by the U.S. Geological Survey's National Water Quality Laboratory in Lakewood, Colo. All values are in microgram per kilogram (µg/kg), wet weight unless noted otherwise; Not detected (minimum reporting level 5 µg/kg): aldrin, dacthal, endrin, *alpha*-bhc, *beta*-bhc, *delta*-bhc, heptachlor, lindane, *p,p'*-methoxychlor, *o,p'*-methoxychlor, pentachloroanisole oxychlordane, mirex, heptachlor epoxide, hexachlorobenzene, *o,p'*-DDE, *o,p'*-DDD, and *o,p'*-DDT; Toxaphane was not detected (minimum reporting level <200 µg/kg). NECB, New England Coastal Basins study unit; PCBs, polychlorinated biphenyls; <, less than minimum reporting level; e, estimated concentration; %, percent; Values underlined and **bold** exceed the U.S. Food and Drug Administration guideline for consumption of whole fish and values that are **bold** exceed the National Academy of Sciences/National Academy of Engineering guideline (table 2) for the protection of fish-eating wildlife listed.]

Organochlorine compounds	Minimum reporting level (MRL)	Concentrations in whole fish tissue in NECB rivers											
		Kennebec site 1	Andro-scoggin site 2	Stillwater site 3	Merrimack site 4	Woonasqua-tucket site 6	Beaver site 7	Blackstone site 8	Ipswich site 9	Neponset site 10	Charles site 11	Saugus site 12	Moshassuck site 14
Total PCBs	50	77	460	<50	410	430	<50	**1,200**	63	240	**<u>2,200</u>**	140	490
trans-nonachlor	5	<5	<5	<5	13	21	<5	11	7	<5	81	19	12
cis-nonachlor	5	<5	<5	<5	<5	<5	<5	e 4.7	<5	<5	24	8.3	<5
trans-chlordane	5	<5	<5	<5	<5	9.6	<5	6.2	<5	<5	40	15	6.4
cis-chlordane	5	<5	<5	<5	<5	17	<5	12	<5	<5	**130**	29	15
p,p'-DDE	5	51	14	8.9	40	28	<5	36	6	28	230	34	23
p,p'-DDD	5	<5	<5	<5	7.3	9.5	<5	23	12	17	160	38	22
p,p'-DDT	5	<5	<5	<5	<5	6.1	<5	<5	12	6.7	30	9.7	12
Dieldrin	5	<5	<5	<5	<5	<5	<5	24	<5	<5	29	<5	<5
Lipids (%)	0.5	3	8.1	2.4	3.6	2.7	1.8	4.3	1.7	1	15	0.8	2.3

Appendix 3. Semivolatile compound concentrations in streambed sediment, New England Coastal Basins

[See figure 1 for location of sampling sites and table 1 for description of sites. Samples were analyzed by the U.S. Geological Survey's National Water Quality Laboratory in Lakewood, Colo. All values in microgram per kilogram (µg/kg), dry weight in less than 2-millimeter fraction; Not detected (minimum reporting level <50 µg/kg): 2,4 dinitrotoluene, 2,6 dinitrotoluene, isophorone, methane 2 chloroethoxy, 2-chloronaphthalene, 4-chloro m-cresol, phenol c8-alkyl-, n nitrosodi propylamine, benzene nitro, benzene m dichloro, benzene pentachloronitro, 4 bromophenyl phenylether, 4 chlorophenyl phenyletherbis 2 chloroethyl ether, pentachloroanisole, phenol 2 chloro, and benzocinnoline; NECB, New England Coastal Basins study unit; <, less than minimum reporting level given; e, estimated concentration; --, no data; Values underlined and **bold** exceed consensus-based Sediment Quality Guidelines listed in table 2.]

Semivolatile compound name	Minimum reporting level (MRL)	Concentrations in streambed sediment in NECB rivers													
		Kennebec, site 1	Androscoggin, site 2	Stillwater, site 3	Merrimack, site 4	Wading, site 5	Woonasquatucket, site 6	Beaver, site 7	Blackstone, site 8	Ipswich, site 9	Neponset, site 10	Charles, site 11	Saugus, site 12	Aberjona, site 13	Moshassuck, site 14
Polycyclic aromatic hydrocarbons (PAHs)															
1,2 dimethylnaphthalene	50	<50	<50	<100	<100	<100	<100	<100	e 16.1	<100	<100	110	<100	<100	e 38.2
1,6 dimethylnaphthalene	50	68.8	50.7	<100	e 22.5	e 17.9	<100	e 10.2	e 35.7	e 26.9	e 40.6	132	<100	e 68.5	e 43.2
1 methyl-9H-fluorene	50	<50	<50	<100	<100	<100	<100	<100	e 20.1	<100	<100	e 93.2	<100	<100	<100
1 methyl phenanthrene	50	<50	e 44.	e 40.9	112	e 52.7	304	e 36.8	185	217	243	516	132	488	245
1 methylpyrene	50	<50	87.6	<100	e 66.1	e 22.6	202	e 20	156	142	175	330	164	428	183
2,3,6 trimethylnaphthalene	50	<50	e 39.7	<100	<100	e 1.9	<100	<100	e 8.4	e 11.2	<100	113	<100	e 42.7	e 25.7
2,6 dimethylnaphthalene	50	77	73	e 80.3	e 70	e 49.5	114	e 63.9	120	120	144	178	177	265	244
2-Ethyl naphthalene	50	<50	e 47.9	<100	e 25.7	<100	e 28.7	e 21.4	e 39.3	<100	e 40.5	103	<100	e 46.6	e 38.1
2-methyl anthracene	50	<50	e 38.3	<100	e 71.5	e 10.3	186	e 31.8	128	e 86.3	<100	383	312	279	142
4H-cyclopentaphenanthrene	50	<50.	e 44.1	<100	181	e 40.9	476	e 29.1	294	319	334	859	324	879	465
Acenaphthene	50	<50	<50	<100	e 54.9	<100	188	<100	130	104	e 86.6	417	e 84.	276	268
Acenaphthylene	50	e 43.7	200	e 57.7	142	e 84.5	380	e 68.4	227	272	294	688	212	820	213
Anthracene	50	e 9	106	e 45.7	280	108	734	e 56.3	538	510	446	**1,610**	402	**1,460**	**798**
Benz[a]anthracene	50	57.6	452	107	960	346	**2,640**	136	**1,530**	**1,740**	**1,630**	**3,930**	**1,670**	**4,660**	**2,990**
Benzo[a]pyrene	50	77.2	483	127	807	427	**2,600**	214	1,180	**1,880**	**1,600**	**3,670**	**2,340**	**5,670**	**3,270**
Benzo[b]fluoranthene	50	88.6	395	125	1,330	774	3,240	177	1,680	2,180	2,010	3,520	2,760	9,420	3,790
Benzo[ghi]perylene	50	56.9	279	e 72.6	e 366	345	e1,720	130	e487	1,160	e1,150	1,890	1,440	4,380	e1,920
Benzo[k]fluoranthene	50	84.2	400	136	e1,040	278	2,660	200	e1,790	1,330	1,650	3,050	2,090	3,070	3,680
Chrysene	50	133	539	148	1,230	542	**3,520**	190	**1,790**	**2,390**	**2,290**	**4,200**	**2,350**	**7,120**	**4,080**
Dibenz[a,h]anthracene	50	e 36.1	88.5	<100	e120.	102	337	e 49.3	e 186.	279	250	716	505	734	367
Dibenzothiophene	50	<50	e 20.4	<100	e 32.5	e 1.6	152	<100.	e 68.2	e 90.4	118	292	e 98.5	290	218
Fluoranthene	50	150	577	308	2,110	852	**6,070**	362	**4,010**	**3,480**	**4,310**	**6,400**	**4,680**	**12,300**	**8,920**
Fluorene	50	<50	e .61	<100	e 88	e 25.8	281	<100	163	174	152	**545**	101	428	336
Indeno[1,2,3-cd]pyrene	50	87.2	291	e 92.6	e 488	330	2,160	153	e 752	986	1,370	2,430	1,550	450	2,630
Naphthalene	50	<50	<50	<100	<100	e 19.5	167	<100	<100	e 67.1	125	<100	e 14.8	267	222
Phenanthrene	50	65.4	281	135	**1,180**	327	**2,820**	192	**1,540**	**2,330**	**2,090**	**4,790**	**1,850**	**5,380**	**4,470**
Pyrene	50	166	598	313	**1,780**	728	**5,000**	352	**3,730**	**2,830**	**3,410**	**5,580**	**3,760**	**10,100**	**6,480**

Appendix 3. Semivolatile compound concentrations in streambed sediment, New England Coastal Basins--Continued

Semivolatile compound name	Minimum reporting level (MRL)	Concentrations in streambed sediment in NECB rivers													
		Kennebec, site 1	Androscoggin, site 2	Stillwater, site 3	Merrimack, site 4	Wading, site 5	Woonasquatucket, site 6	Beaver, site 7	Blackstone, site 8	Ipswich, site 9	Neponset, site 10	Charles, site 11	Saugus, site 12	Aberjona, site 13	Moshassuck, site 14
Phthalates															
bis (2-ethylhexyl) phthalate	50	145	178	e 87.8	1,700	172	e 1,540.	e 74.3	1,240	1,200	e 1,400.	4,220	1,580	10,900	e 3,940
Butylbenzyl phthalate	50	e 10.9	e 46.6	<100	175	<100.	336	<100	127	149	403	152	156	322	463
Di-n-butyl phthalate	50	82.3	57.2	e 41.8	e 47.6	e 56.6	e 90.1	<100	e 24.9	119	e 97.9	110	112	116	e 99.3
Di-n-octyl phthalate	50	<50	<50	<100	e 118	<100	<100	<100	e 40.2	<100	153	e 118	168	693	605
Diethyl phthalate	50	<50	e 12	<100	<100	e 15.6	<100	<100	e 10.2	<100	<100	e 29.2	<100	e 9.9	<100
Dimethyl phthalate	50	<50	<50	<100	<100	e 7.3	<100	<100	e 23.6	e 1.2	<100	<100	<100	<100	<100
Phenols															
3,5-dimethyl phenol	50	<50	<50	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	e 31.6	<100
4-nitrophenol	--	--	--	--	--	--	--	--	--	--	--	--	--	e 535	--
p-cresol	50	77.8	560	5,050	e 76.5	686	886	2,010	e 66.6	3,260	1,130	208	3,730	6,030	372
Phenol	50	e 10.9	e 35.5	e 76.6	<100	e 56.7	e 77.5	e 59.1	e 13.8	184	72.2	e 66.5	123	343	124
Other semi-volatiles															
1,2,4-Trichlorobenzene	50	<50	<50	<100	<100	<100	<100	<100	e 16.5	<100	<100	<100	<100	<100	<100
1,2-Dichlorobenzene	50	<50	<50	<100	<100	<100	<100	<100	e 10.5	<100	<100	e 8.5	<100	<100	<100
1,4-Dichlorobenzene	50	<50	<50	<100	<100	<100	<100	<100	e 15.6	<100	<100	e 23.3	<100	<100	<100
2,2-biquinoline	50	<50	<50	<100	<100	<100	<100	<100	<100	e 33.2	<100	<100	<100	142	<100
Acridine	50	<50	<50	e 12.8	e 82.3	e 16.8	256	<100	e 99.8	e 99.9	145	149	161	345	341
Anthraquinone	50	e 43.7	114	<100	284	166	878	e 86.4	377	745	604	692	805	1850	1130
Azobenzene	50	<50	<50	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	402	<100
Carbazole	50	<50	e 15.2	<100	156	e 47.6	431	e 27.6	198	311	240	496	339	826	753
Isoquinoline	50	<50	<50	<100	<100	<100	<100	<100	e 8.8	<100	<100	e 75.3	<100	<100	<100
N-nitrosodi-phenylamine	50	<50	<50	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	e 94.6	<100
Phenanthridine	50	<50	<50	<100	e 47.2	<100	e 97.6	<100	e 91	102	e 57.7	134	e 44.7	191	123
Quinoline	50	<50	<50	<100	<100	<100	<100	<100	<100	<100	<100	e 37.8	<100	<100	e 23.6

TRACE ELEMENTS AND ORGANIC COMPOUNDS IN STREAMBED SEDIMENT AND FISH TISSUE OF COASTAL NEW ENGLAND STREAMS, 1998-99
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