# Contaminant Concentrations in Merrimack River Fish

Prepared By
A.R. Major
and
Kenneth C. Carr

U.S. Fish and Wildlife Service
New England Field Offices
Concord, New Hampshire 03301

May, 1991

# PREFACE

Information presented in this report is final documentation of the 1985 environmental contaminants evaluation of fish from the Merrimack River under Regional ID Number R5-85-013. Study design, implimentation, data analysis, and reporting were completed by Environmental Contaminants personnel in the New England Field Offices, U.S. Fish and Wildlife Service, Department of the Interior. Funding for the project was provided by the division of Enviromemtal Contaminants.

Questions, comments, and suggestions related to this report are encouraged. Written enquiries should refer to Report Number RY91-NEFO-1-EC and be directed to the Service at the following address:

U.S. Fish and Wildlife Service
New England Field Offices
22 Bridge Street
Concord, New Hampshire 03301

The Fish and Wildlife Service requests that no part of this report be taken out of context, and if reproduced, the document should appear in its entirety.

The use of trade names in this report is solely for identification purposes and does not constitute an endorsement by the Fish and Wildlife Service or the Department of the Interior.

# INTRODUCTION

The Merrimack River is a major anadromous fish resource in New England, that has benefitted from significant state, federal, and private assistance directed toward the restoration and enhancement of Atlantic Salmon and other anadromous fish species. The lower basin of the river, in particular, is significantly urbanized, with numerous point sources of contamination, including landfills, and industrial and municipal discharges. The Merrimack and its tributaries are also affected by non-point sources of pollution in the form of paved area runoff, and the use and mobilization of pesticides in agricultural and suburban areas.

In 1982, the U.S. Fish and Wildlife Service conducted a screening-level survey for selected USEPA priority pollutants to determine the state of contamination of fish in particular reaches of the river (Carr 1984). That survey showed that Merrimack River wholebody fish tissue levels of polychlorinated biphenyls (PCBs), lead, mercury, copper and cadmium were generally above mean national levels. At one station, PCB levels in *wholebody* white sucker and yellow perch exceeded the Food and Drug Administration's (FDA) action level of 2.0 ppm established for edible portion of fish.

In 1985, the U.S. Fish and Wildlife Service expanded the 1982 survey of the lower Merrimack River to determine contaminant trends and to determine finer resolution of contaminant hotspots. In addition to resampling most of the 1982 sampling stations, the 1985 survey was expanded to include new sample locations.

## METHODS

Sampling locations were selected based primarily on their relationship to industrial and municipal discharges, and urban areas in general, including the selection of reference sites. Twelve stations were sampled: eight of these were located either in, or immediately down river of municipalities; three were located upstream of major urban areas (reference stations); and one was located down river of a major tributary having numerous, significant dischargers (Figure 1). Sampling allowed near field assessment of impacts emanating from Concord, Hooksett, Manchester and Nashua, New Hampshire, and Lawrence, Lowell, and Haverhill, Massachusetts.

As in the 1982 survey, resident fish species were selected for analyses. However, anadromous fish species were also taken opportunistically in the 1985 survey. White sucker, brown bullhead and/or channel catfish were sampled as representatives of bottom feeding species; yellow perch, and smallmouth bass were sampled as representatives of open water predators. A typical fish sample for a given location consisted of a composite of five individuals of the same species. Wholebody composite samples were analyzed for organochlorine pesticides, PCBs, and polynuclear aromatic hydrocarbons (PAHs) by Mississippi State Chemical Laboratory, and metals analyses were conducted by the Environmental Trace Substances Laboratory. Contaminant residues in fish tissue are reported as ppm, wet weight.

Contaminant residue data reported for Station 6 were collected and analyzed as part of the 1984 National Contaminant Biomonitoring Program (NCBP). Samples from the NCBP and this survey were collected and preserved using the same protocol, and were analyzed using the same analyses methods.

## RESULTS

A total of 141 fish were collected and composited into 35 samples. Mean length, mean weight, and the number of fish used in each composite are summarized in Appendix 1. A total of seven species were collected; white sucker and smallmouth bass were the most common species, comprising 68.1% of the composite samples.

METALS

**Mercury** - There was little difference in mercury tissue levels among stations. The mean mercury concentration for all species was 0.20 ppm and ranged from 0.08 ppm (Station 4, YP) to 0.37 ppm (Station 5, SB). American shad had the lowest mean mercury level (0.12 ppm), and brown bullhead had the highest (0.31 ppm - Appendix 2). Location-specific mercury levels in 1985 (as compared in white suckers) were not significantly different from the levels recorded in 1982 (Table 1).

**Lead** - Predatory fish showed relatively elevated levels of lead at Stations 9 (in Manchester) and 12 (below Concord - Figure 2), and bottom-feeding fish had generally higher levels of lead at Stations 3 (below Lawrence), 5 (below Lowell), 6 (in Lowell) and 8 (above Nashua - Figure 3). The mean lead concentration for all species was 0.28 ppm and ranged from 0.05 ppm (Station 5, SB) to 0.97 (Station 4, AS). The single striped bass taken in our sampling effort had the lowest lead level (<0.01 ppm), while white catfish had the highest (0.51 ppm - Appendix 2). Location-specific levels of lead (as compared in white suckers) were lower ($P = 0.15$) in 1985 than the levels found in 1982, while levels of lead in yellow perch appear to have increased at Station 12 between 1982 and 1985 (Table 1).

**Cadmium** - The mean cadmium concentration for all species was 0.04 ppm and ranged from <0.01 ppm (Station 13, YP) to 0.09 ppm (Station 11, WS and Station 12, YP). Striped bass had the lowest mean cadmium level (0.03 ppm), and American shad had the highest (0.06 ppm - Appendix 2).

ORGANOCHLORINE PESTICIDES

**Chlordane** - Tissue residues of chlordane increased on a gradient from relatively low, up-river values to higher, down-river values. Although predatory fish showed relatively low chlordane levels, white suckers showed *whole body* chlordane levels above the FDA Action level of 0.3 ppm *edible portion* at Stations 3 and 5. The mean concentration for all species was 0.12 ppm, and ranged from <0.01 ppm (Station 8, BB) to 0.32 ppm (Station 3, WS - Appendix 3). Location-specific chlordane levels (as compared in white suckers) appear to have been higher ($P = 0.22$) in 1985 than they were in 1982 (Table 1).

Table 1. Change in contaminant concentrations (ppm – wet weight) between 1982 and 1985 in white suckers and yellow perch collected from the Merrimack River.

White Suckers

| YEAR | STATION | Hg | Pb | CHLOR-DANE | DDT | PCB |
|---|---|---|---|---|---|---|
| 82 | 2 | 0.16 | 0.38 | 0.17 | 0.31 | 2.63 |
| 85 | 2 | 0.14 | 0.19 | 0.18 | 0.14 | 2.40 |
| 82 | 4 | 0.22 | 1.30 | 0.10 | 0.33 | 1.47 |
| 85 | 4 | 0.16 | 0.31 | 0.24 | 0.22 | 1.56 |
| 82 | 8 | 0.21 | 0.71 | 0.07 | 0.21 | 0.20 |
| 85 | 8 | 0.27 | 0.50 | 0.19 | 0.33 | 1.94 |
| 82 | 12 | 0.26 | 0.37 | 0.01 | 0.06 | 0.89 |
| 85 | 12 | 0.24 | 0.10 | 0.04 | 0.14 | 0.86 |
| 82 Mean | | 0.21 | 0.69 | 0.09 | 0.23 | 1.30 |
| S.D. | | 0.04 | 0.43 | 0.07 | 0.12 | 1.02 |
| 85 Mean | | 0.20 | 0.28 | 0.16 | 0.21 | 1.69 |
| S.D. | | 0.06 | 0.17 | 0.09 | 0.09 | 0.65 |
| P value | | 0.799 | 0.153 | 0.219 | 0.803 | 0.547 |

Yellow Perch

| | | | | | | |
|---|---|---|---|---|---|---|
| 82 | 12 | 0.38 | 0.51 | 0.03 | 0.17 | 1.11 |
| 85 | 12 | 0.35 | 0.66 | 0.03 | 0.14 | 1.39 |

**DDT** - As with chlordane, concentrations of total DDT generally increased from up-river to down-river locations (Figures 6 and 7). However, overall DDT concentrations are generally low throughout the 13 sampling locations. Predatory fish taken at Stations 4 and 9, and bottom-feeding fish from Stations 3 and 8, showed slightly elevated levels of total DDT. The mean concentration for all species was 0.16 ppm, and ranged from 0.04 ppm (Station 13, YP) to 0.35 ppm (Station 3, WS - Appendix 3). Location-specific DDT levels (as compared in white suckers) in 1985 were not significantly different from the levels recorded in 1982 (Table 1).

POLYCHLORINATED BIPHENYLS

PCB levels also increased markedly from up-river to down-river locations. The mean concentration for all species was 1.38 ppm, and ranged from 0.40 ppm (Station 7, YP) to 4.10 ppm (Station 3, WP). Twenty three percent (n = 8) of *wholebody* composite samples had PCB levels in excess of the FDA Action Level of 2.0 ppm (*edible portion*). Predatory fish PCB concentrations exceeded 2.0 ppm at Stations 1, 2, and 4, and bottom-feeding fish exceeded 2.0 ppm at Stations 2 (both WS and WC), 3, 5, and 6 (Appendix 3). Location-specific PCB levels (as compared in white suckers) were not significantly different from the levels recorded in 1982 although they appear to have increased in yellow perch at Station 12 (Table 1).

POLYNUCLEAR AROMATIC HYDROCARBONS

PAH concentrations peaked at Station 7, declining both up and down-river from this point. The mean concentration for all species was 0.12 ppm, and ranged from <0.01 ppm (Station 4, SB) to 0.83 ppm (Station 7, WS - Appendix 4). The 1982 samples were not analyzed for PAHs. Therefore, location-specific changes in PAH residues could not be assessed.

# DISCUSSION

METALS

**Mercury**- Mercury levels in fish flesh in excess of 1.1 ppm fresh weight, are considered to be presumptive evidence of an environmental mercury problem (Eisler, 1987a). Mean levels of mercury in Merrimack River fish (0.20 ppm) fall well below this level, although they appear higher that the 1984 national average of 0.10 ppm (Schmitt and Brumbaugh, 1989). Of the six New England rivers (excluding the Merrimack) sampled in the 1984 phase of the National Contaminant Biomonitoring Program, fish in the Penobscot (0.22 ppm) and St. Lawrence (0.92 ppm) Rivers had higher mean levels of mercury (Table 2). Based on results reported in the scientific literature, the wholebody mercury levels found in our survey are not likely to be harmful to fish. McKim et al., (1979), exposed three successive generations of brook trout over 144 weeks to water column mercury concentrations of 0.0 - 0.29 ppb. Wholebody tissue concentrations of mercury from these fish ranged from none-detected to 3.4 ppm, and resulted in no apparent effects on survival or reproduction. However, Snarski and Olson (1982) documented the complete inhibition of spawning in fathead minnows when wholebody tissue mercury levels reached 4.5 ppm.

**Lead**- Mean lead levels in Merrimack River fish (0.28 ppm) fall well below the Canadian Ministry of the Environment's fish consumption advisory level of greater than 1.0 ppm of lead, but they are higher than the 1984 national average in whole fish of 0.11 ppm (Schmitt and Brumbaugh 1989) and the New England average of 0.17 ppm (Table 2). However, the wholebody lead levels found in our survey are not likely to be harmful to fish. Holcombe et al. (1976) found that lead water column exposure levels of 0.0 - 58.0 ppb for 144 weeks did not appear to affect reproduction in brook trout (tissue concentrations ranged from 4 - 12 ppm in livers, gills, and kidneys). It is encouraging to note that location-specific lead levels (as compared in white suckers) appear to have decreased since the 1982 survey (Table 1).

**Cadmium**- The mean cadmium level of all Merrimack River fish sampled in our 1985 survey was 0.04 ppm, which is not significantly higher than the 1984 national average of 0.03 ppm, and is equal to the New England average (Table 2). Benoit et al. (1976) found that exposure levels of 0.0 - 3.4 ppb for 156 weeks had no effect on the percent of brook trout eggs hatched (tissue concentrations ranged from 0 - 10 ppm in livers, gills, and kidneys). Adverse effects on fish and wildlife are probable when cadmium concentrations exceed 0.10 ppm in the diet (Eisler 1985).

Table 2. A comparison of mean contaminant levels (all species) in fish from seven rivers in the northeast US.

| River | Hg | Pb | Cd | [+] Chl DDT | PCB | |
|---|---|---|---|---|---|---|
| MA[a] | | | | | | |
| Androscoggin | 0.12 | 0.24 | 0.02 | 0.01 | 0.05 | 0.37 |
| Kennebec | 0.14 | 0.05 | 0.02 | 0.00 | 0.03 | 0.10 |
| Penobscot | 0.22 | 0.09 | 0.02 | 0.01 | 0.03 | 0.17 |
| CT[a] | | | | | | |
| Connecticut | 0.11 | 0.34 | 0.10 | 0.14 | 0.22 | 1.33 |
| NY[a] | | | | | | |
| Hudson | – | – | – | 0.09 | 0.24 | 6.45 |
| St. Lawrence | 0.92 | 0.14 | 0.02 | 0.03 | 0.10 | 0.55 |
| Mean | 0.30 | 0.17 | 0.04 | 0.05 | 0.11 [*] | 0.50 |
| NH[b] | | | | | | |
| Merrimack | 0.20 | 0.28 | 0.04 | 0.12 | 0.16 | 1.38 |

[a]Data compiled from Schmitt and Brumbaugh (1989).
[b]Data from this study.
[+]Chlordanes.
[*]Excludes the value from the Hudson river.

**Total Chlordane** - The mean total chlordane concentration of Merrimack River fish (0.12 ppm) was not significantly higher than the 1984 national average of 0.11 ppm, although this value is somewhat deceptive. The relatively low total chlordane levels at Stations 6 - 13 mask a potential problem area of the river (Stations 2 - 5) between Lowell and Haverhill, MA (Figure 1). Chlordane levels (*wholebody*) were high in white suckers at stations 3 and 5 (0.32 and 0.31 ppm respectively), exceeding the FDA Action Level of 0.30 ppm for *edible* portion. Although the chlordane levels reported here for Merrimack River fish are not directly comparable to the FDA Action Level due to the consideration of different media (fillet vs whole fish), the results are of concern. Of additional concern is the fact that total chlordane levels in fish appear to have increased since 1982 (Table 1). Of the six New England rivers sampled in 1984, only Connecticut River fish had higher mean chlordane concentrations (0.14 ppm - Table 2). Based on comparisons to national averages and with wholebody effect levels reported in the scientific literature, mean chlordane levels for the River are probably not harmful to fish or their non-human consumers. However, site-specific total chlordane residues exceed criteria for the protection of fish-eating birds. The National Research Council of Canada (1975) determined that an avian diet containing up to 0.3 ppm of chlordane is acceptable. Presumably, dietary levels in excess of this criterion are unacceptable for birds. Similarly, a joint committee of the National Academy of Sciences and National Academy of Engineering (1973) established a criterion of 0.1 ppm of chlordane in prey items as being protective of the well-being of predators. Chlordane's remaining legal use for underground termite control may explain its presence in the Merrimack's more urbanized area.

**Total DDT** - Merrimack River fish have fairly low levels of DDT contamination. The mean for all fish species (0.16 ppm) was below the 1984 national average of 0.26 ppm (Schmitt *et al.* 1989) and is well below the FDA Action Level of 5.0 ppm. Within the New England region, fish in the Hudson (0.24 ppm) and Connecticut (0.22 ppm) rivers have higher mean DDT levels (Table 2). Location-specific total DDT levels (as measured in white suckers) have not increased since 1982 (Table 1).

**Total PCBs** - The mean total PCB level for all Merrimack River fish sampled in this survey (1.38 ppm) was nearly four times the 1984 national level (0.38 ppm), and more than twice the 1984 New England level (0.50 ppm - Table 2). Although Hudson river fish had higher mean PCB concentrations (6.45 ppm), the Hudson is considered among the most heavily PCB-contaminated rivers in the country. Merrimack River PCB levels appear more similar to those found in the industrialized states of the Mid-Atlantic region (Schmitt *et al.* 1989). The extent and relative degree of the PCB contamination is greater for PCBs than for chlordanes. *Wholebody* PCB levels exceeding the FDA Action Level (2.0 ppm - *edible* portion) occurred in most species sampled, at every station down-river from Station 7 (NH - MA state line - Figures 8 and 9). These PCB levels have been shown to have negative impacts on various species of sensitive fish. Rainbow trout with 0.4 ppm Aroclor 1254 levels (wholebody) produced eggs with low survival (EPA 1980). Coho salmon injected with 50 to 100 micrograms of Aroclor 1254/kg body weight prior to smoltification contained elevated levels (0.50 to 1.2 ppm in liver tissue) two weeks after injection and experienced difficulty in adapting to seawater once they smoltified (Folmar *et al.* 1982). If similar levels of PCBs exist in Merrimack River anadromous fish, there could be an adverse impact on the river's anadromous fish restoration program. These levels also have potential detrimental effects on fish eating birds such as herons (*Ardea herodias*, *Butorides striatus*, and *Nycticorax nycticorax*) and wintering bald eagles (*Haliaeetus leucocephalus*) due to the effects of

biomagnification. Black-crowned night herons experienced reduced hatching success and decreased survival of hatchlings when geometric mean PCB concentrations in eggs were 4.1 ppm (Heinz et al. 1986). Mean PCB residues in eggs of bald eagles were significantly lower in eggs from successful nests (1.3 ppm) than unsuccessful (7.2 ppm - Wiemeyer et al. 1984).

**Total PAHs** - At present, no standards have been set for PAH's by any regulatory agency for the protection of sensitive species of aquatic organisms (Eisler, 1987b). PAH levels in fish are usually low because this group rapidly metabolizes PAHs (Lawrence and Weber, 1984). PAH levels in Merrimack River fish are generally low in relation to levels found in other studies with the exception of Stations 12 (0.38 ppm), 9 (0.50 ppm), and 7 (0.83 ppm - Figure 10). The 0.83 ppm level found in white suckers at Station 7 is higher than levels found in brown bullhead (0.66 ppm) in a contaminated area of the Black River in Ohio (Wetstal., 1984). An ongoing creosote spill at Nashua, NH most likely explains the elevated PAH levels in Merrimack river fish at station 7.

## LITERATURE CITED


Benoit, D.A., E.N. Leonard, G.M. Christensen, and J.T. Fiandt. 1976. Toxic effects of cadmium on three generations of brook trout (Salvelinus fontinalis). Trans. Amer. Fish. Soc. 105:550-560.

Carr, K.C. 1984. A survey of priority pollutants in Merrimack and Connecticut river fish. U.S. Fish Wildl. Serv., Concord, NH. 15 pp.

Eisler, R. 1985. Cadmium hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Fish Wildl. Serv. Biol. Rep. 85(1.2). 46 pp.

-------. 1987a. Mercury hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Fish Wildl. Serv. Biol. Rep. 85(1.10). 90 pp.

-------. 1987b - Polycyclic aromatic hydrocarbon hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Fish Wildl. Serv. Biol. Rep. 85(1.11). 81 pp.

-------. 1990. Chlordane hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Fish Wildl. Serv. Biol. Rep. 85(1.21). 49 pp.

EPA. 1980. Ambient water quality criteria for polychlorinated biphenyls. U.S. Environ. Protection Agency Rep. 400/5-80-068. 211 pp.

Folmer, L.C., W.W. Dickhoff, W.S. Zaugg, and H.O. Hodgkins. 1982. The effects of Aroclor 1254 and No. 2 fuel oil on smoltification and sea-water adaptation of coho salmon (Oncorhynchus kisutch). Aquat. Toxicol. 2:291-299.

Hoffman, D.J., B.A. Rattner, C.M. Bunck, H.M. Ohlendorf, and R.W. Lowe. 1986. Association between PCBs and lower embryonic weight in black-crowned night herons in San Francisco bay. J. Toxicol. Environ. Health 19:386-391.

Holcombe, G.W., N.A. Benoit, E.N. Leonard, and J.M. McKim. 1976. Long-term effects of lead exposure on three generations of brook trout (Salvelinus fontinalis). J. Fish. Res. Bd. Can. 33:1731-1741.

Lawrence, J.F., and D.F. Weber. 1984. Determination of polycyclic aromatic hydrocarbons in some Canadian commercial fish, shellfish, and meat products by liquid chromatography with confirmation by capillary gas chromatography-mass spectrometry. J. Agric. Food Chem. 32:794-797.

McKim, J.M., G.F. Olson, G.W. Holcombe, and E.P. Hunt. 1976. Long-term effects of methylmercuric chloride on three generations of brook trout (Salvelinus fontinalis): Toxicity, accumulation, distribution, and elimination. J. Fish. Res. Bd. Can. 33:2726-2739.

NAS/NAE. 1973. National Academy of Science - National Academy of Engineering Water Quality Criteria 1972. A Report of the Committee on Water Quality Criteria. EPA-R-73-033. USEPA, Wash. D.C.

National Research Council of Canada. 1975. Chlordane: itseffects on Canadian

ecosystems and its chemistry. NRCC publ. 14094. 189pp.

Schmitt, C.J., and W.G. Brumbaugh. 1989. National contaminant biomonitoring program: concentrations of arsenic, cadmium, copper, lead, mercury, selenium, and zinc in U.S. freshwater fish. Arch. Environ. Contam. Toxicol. (in press).

Schmitt, C.J., J.L. Zajicek, and P.H. Peterman. 1990. National contaminant biomonitoring program: residues of organochlorine chemicals in U.S. freshwater fish. Arch. Environ. Contam. Toxicol. 19:748-781.

Snarski, V.M. and G.F. Olson. 1982. Chronic Toxicity and bioaccumulation of mercuric chloride in the fathead minnow. Aquatic Toxicol. 2:143-156.

Weimeyer, S.N., T.G. Lamont, C.M. Bunck, C.R. Sindelar, F.J. Gramlich, J.D. Fraser, and M.A. Byrd. 1984. Organochlorine pesticide, polychlorobiphenyl, and mercury residues in bald eagle eggs-1969-79-and their relationships to shell thinning and reproduction. Arch. Environ. Contam. Toxicol. 13:529-549.

West, W.R., P.A. Smith, P.W. Stoker, G.M. Booth, T. Smith-Oliver B.E. Butterworth, and M.L. Lee. 1984. Analysis and genotoxicity of a PAH-polluted river sediment. Pages 139-In M. Cooke and A.J. Dennis (eds.). Polynuclear aromatic hydrocarbons: mechanisms, methods, and metabolism. Battelle Press, Columbus, Ohio.

Appendix 1. Total length (cm) and weight (gm) of fish used for contaminant analysis of the Merrimack River, 1985.

| STATION NUMBER | SPECIES CODE[a] | N | LENGTH (cm) X ± S.D. | WEIGHT (gm) X ± S.D. |
|---|---|---|---|---|
| 1 | STB | 2 | 40.8 ± 3.3 | 658.0 ± 159.0 |
| 1 | YP | 5 | 28.1 ± 1.7 | 299.6 ± 56.5 |
| 2 | SB | 4 | 29.1 ± 1.4 | 402.6 ± 74.1 |
| 2 | WC | 5 | 39.0 ± 4.1 | 894.4 ± 250.1 |
| 2 | WS | 2 | 37.8 ± 1.3 | 635.5 ± 45.5 |
| 3 | SB | 5 | 28.6 ± 0.5 | 377.0 ± 23.1 |
| 3 | WS | 5 | 44.0 ± 4.3 | 989.8 ± 256.1 |
| 4 | AS | 2 | 46.3 ± 2.8 | 726.5 ± 68.5 |
| 4 | SB | 5 | 28.3 ± 4.0 | 295.2 ± 112.3 |
| 4 | WS | 5 | 39.9 ± 1.0 | 735.8 ± 65.2 |
| 4 | YP | 5 | 21.4 ± 1.6 | 127.2 ± 23.0 |
| 5 | AS | 1 | 45.0 | 604.0 |
| 5 | SB | 2 | 25.8 ± 3.3 | 215.0 ± 79.5 |
| 5 | WS | 5 | 42.5 ± 2.5 | 876.2 ± 137.5 |
| 5 | YP | 4 | 22.3 ± 3.6 | 173.8 ± 87.7 |
| 6[b] | SB | 5 | 31.4 | 400.0 |
| 6[b] | WS | 5 | 42.0 | 800.0 |
| 6[b] | WS | 5 | 39.6 | 800.0 |
| 7 | SB | 2 | 24.0 ± 2.5 | 204.0 ± 68.0 |
| 7 | WS | 5 | 40.0 ± 3.1 | 753.8 ± 158.9 |
| 7 | YP | 2 | 18.5 ± 1.0 | 79.5 ± 11.5 |
| 8 | BB | 4 | 27.4 ± 1.5 | 249.8 ± 53.5 |
| 8 | SB | 4 | 26.5 ± 3.9 | 317.8 ± 160.4 |
| 8 | WS | 4 | 38.1 ± 2.5 | 646.8 ± 112.8 |
| 9 | SB | 5 | 33.3 ± 2.6 | 503.6 ± 129.2 |
| 9 | WS | 4 | 39.5 ± 1.1 | 681.0 ± 45.0 |
| 10 | SB | 4 | 38.3 ± 1.5 | 817.0 ± 0.0 |
| 10 | WS | 5 | 43.5 ± 2.5 | 944.0 ± 160.5 |
| 10 | YP | 4 | 27.5 ± 1.1 | 295.3 ± 36.1 |
| 11 | WS | 5 | 40.7 ± 5.4 | 794.6 ± 260.1 |
| 11 | YP | 5 | 22.1 ± 1.4 | 145.0 ± 23.1 |
| 12 | WS | 5 | 42.2 ± 2.0 | 890.0 ± 82.7 |
| 12 | YP | 3 | 28.0 ± 1.5 | 257.3 ± 10.4 |
| 13 | WS | 5 | 45.2 ± 2.1 | 876.4 ± 84.4 |
| 13 | YP | 3 | 23.7 ± 0.2 | 177.3 ± 6.6 |
| TOTALS | | | | |
| | AS | 3 | 45.8 ± 2.3 | 685.7 ± 80.4 |
| | BB | 4 | 27.4 ± 1.5 | 249.8 ± 53.5 |
| | SB | 30 | 30.2 ± 4.8 | 427.9 ± 197.5 |
| | STB | 2 | 40.8 ± 3.3 | 658.0 ± 159.0 |
| | WC | 5 | 39.0 ± 4.1 | 894.4 ± 250.1 |
| | WS | 52 | 41.5 ± 3.6 | 817.1 ± 184.7 |
| | YP | 31 | 24.2 ± 3.6 | 199.9 ± 85.9 |

[a]AS-American Shad, BB-Brown Bullhead, SB-Smallmouth Bass, STB-Striped Bass, WC-White Catfish, WS-White Sucker, YP-Yellow Perch.

[b]Data from Schmitt and Brumbaugh (1989).

Appendix 2. Toxic metal concentrations (ppm – wet weight) from whole body analysis of fish collected from the Merrimack River, 1985.

| STATION NUMBER | SPECIES CODE[a] | PERCENT MOISTURE | PERCENT LIPID | METALS Hg | Pb | Cd | Cr | Cu | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | STB | 76.2 | 6.29 | 0.16 | <0.01 | 0.03 | – | 0.69 | |
| 1 | YP | 69.2 | 6.25 | 0.32 | 0.09 | 0.04 | – | 0.46 | |
| 2 | SB | 72.0 | 6.93 | 0.14 | 0.07 | – | – | – | |
| 2 | WC | 74.2 | 8.44 | 0.24 | 0.51 | – | – | – | |
| 2 | WS | 67.0 | 15.10 | 0.14 | 0.19 | – | – | – | |
| 3 | SB | 70.6 | 6.33 | 0.13 | 0.10 | – | – | – | |
| 3 | WS | 67.6 | 14.30 | 0.26 | 0.47 | – | – | – | |
| 4 | AS | 76.0 | 3.79 | 0.10 | 0.97 | 0.06 | – | 1.00 | |
| 4 | SB | 72.4 | 5.12 | 0.29 | 0.08 | – | – | – | |
| 4 | WS | 67.2 | 13.90 | 0.16 | 0.31 | – | – | – | |
| 4 | YP | 70.0 | 5.82 | 0.08 | 0.62 | – | – | – | |
| 5 | AS | 76.2 | 3.43 | 0.13 | <0.01 | 0.05 | – | 0.81 | |
| 5 | SB | 74.6 | 3.39 | 0.37 | 0.10 | – | – | – | |
| 5 | WS | 68.6 | 13.9 | | 0.26 | 0.42 | – | – | – |
| 5 | YP | 70.6 | 9.23 | 0.15 | 0.43 | – | – | – | |
| 6[b] | SB | 72.3 | 6.40 | 0.23 | 0.14 | 0.02 | – | 0.34 | |
| 6[b] | WS | 73.0 | 8.50 | 0.18 | 0.36 | 0.06 | – | 0.59 | |
| 6[b] | WS | 72.8 | 10.50 | 0.21 | 0.38 | 0.01 | – | 0.67 | |
| 7 | SB | 74.2 | 3.82 | 0.17 | 0.05 | – | – | – | |
| 7 | WS | 68.2 | 14.60 | 0.17 | 0.10 | – | – | – | |
| 7 | YP | 74.2 | 6.76 | 0.10 | 0.30 | – | – | – | |
| 8 | BB | 76.4 | 4.18 | 0.31 | 0.29 | – | – | – | |
| 8 | SB | 74.2 | 6.08 | 0.18 | 0.05 | – | – | – | |
| 8 | WS | 72.0 | 10.10 | 0.27 | 0.50 | – | – | – | |
| 9 | SB | 70.2 | 9.30 | 0.22 | 0.65 | 0.07 | 0.30 | – | |
| 9 | WS | 70.2 | 6.02 | 0.20 | 0.21 | 0.02 | 0.60 | – | |
| 10 | SB | 72.6 | 5.47 | – | – | – | – | – | |
| 10 | WS | 68.2 | 11.70 | – | – | – | – | – | |
| 10 | YP | 68.8 | 7.15 | – | – | – | – | – | |
| 11 | WS | 70.4 | 8.05 | 0.24 | 0.16 | 0.09 | 0.30 | – | |
| 11 | YP | 70.2 | 5.99 | 0.18 | 0.10 | 0.02 | 0.20 | – | |
| 12 | WS | 72.4 | 7.21 | 0.24 | 0.10 | 0.07 | 0.20 | – | |
| 12 | YP | 72.4 | 4.69 | 0.35 | 0.66 | 0.09 | 0.32 | – | |
| 13 | WS | 70.2 | 9.12 | 0.19 | 0.32 | 0.07 | 0.20 | – | |
| 13 | YP | 81.2 | 6.12 | 0.16 | 0.19 | <0.01 | 0.20 | – | |

Appendix 2 (continued). Toxic metal concentrations (ppm – wet weight) from whole body analysis of fish collected from the Merrimack River, 1985.

| STATION NUMBER | SPECIES CODE[a] | PERCENT MOISTURE | PERCENT LIPID | METALS Hg | Pb | Cd | Cr | Cu |
|---|---|---|---|---|---|---|---|---|
| **TOTALS** | | | | | | | | |
| | AS | 76.1 | 3.61 | 0.12 | 0.49 | 0.06 | – | 0.91 |
| | BB | 76.4 | 4.18 | 0.31 | 0.29 | – | – | – |
| | SB | 72.6 | 5.87 | 0.22 | 0.16 | 0.04 | 0.30 | 0.34 |
| | STB | 76.4 | 6.29 | 0.16 | <0.01 | 0.03 | – | – |
| | WC | 74.2 | 8.44 | 0.24 | 0.51 | – | – | – |
| | WS | 69.8 | 11.00 | 0.21 | 0.29 | 0.05 | 0.33 | 0.63 |
| | YP | 72.1 | 6.50 | 0.19 | 0.34 | 0.04 | 0.24 | 0.46 |
| | ALL FISH | 71.9 | 7.83 | 0.20 | 0.28 | 0.04 | 0.29 | 0.65 |

[a]AS–American Shad, BB–Brown Bullhead, SB–Smallmouth Bass, STB–Striped Bass, WC–White Catfish, WS–White Sucker, YP–Yellow Perch.
[b]Data from Schmitt and Brumbaugh (1989).

Appendix 3. Pesticide and PCB concentrations (ppm – wet weight) from whole body analysis of fish collected from the Merrimack River, 1985.

| STATION NUMBER | SPECIES CODE[a] | CHLOR-DANE | DDT | DIEL-DRIN | EN-DRIN | MIREX | PHENE | TOXA-PCB |
|---|---|---|---|---|---|---|---|---|
| 1 | STB | 0.12 | 0.23 | 0.01 | ND[b] | ND | ND | 1.55 |
| 1 | YP | 0.14 | 0.13 | 0.01 | ND | ND | ND | 2.05 |
| 2 | SB | 0.11 | 0.10 | 0.01 | ND | ND | ND | 2.27 |
| 2 | WC | 0.25 | 0.25 | 0.05 | ND | ND | ND | 2.90 |
| 2 | WS | 0.18 | 0.14 | 0.03 | ND | ND | ND | 2.40 |
| 3 | SB | 0.17 | 0.10 | ND | ND | ND | ND | 1.34 |
| 3 | WS | 0.32 | 0.36 | ND | ND | ND | ND | 4.10 |
| 4 | AS | 0.02 | 0.06 | 0.01 | ND | ND | ND | 0.99 |
| 4 | SB | 0.18 | 0.30 | 0.02 | ND | ND | ND | 2.80 |
| 4 | WS | 0.24 | 0.22 | ND | ND | ND | ND | 1.56 |
| 4 | YP | 0.08 | 0.09 | ND | ND | ND | ND | 0.68 |
| 5 | AS | 0.02 | 0.05 | 0.01 | ND | ND | ND | 0.75 |
| 5 | SB | 0.14 | 0.23 | ND | ND | ND | ND | 1.88 |
| 5 | WS | 0.31 | 0.27 | ND | ND | ND | ND | 2.03 |
| 5 | YP | 0.20 | 0.16 | 0.01 | ND | ND | ND | 1.13 |
| 6[c] | SB | 0.07 | 0.15 | ND | ND | ND | 0.10 | 1.30 |
| 6[c] | WS | 0.18 | 0.27 | 0.01 | 0.01 | ND | ND | 2.50 |
| 6[c] | WS | 0.12 | 0.16 | 0.01 | ND | ND | ND | 1.30 |
| 7 | SB | 0.08 | 0.10 | 0.01 | ND | ND | ND | 0.46 |
| 7 | WS | 0.18 | 0.18 | ND | ND | ND | ND | 1.07 |
| 7 | YP | 0.10 | 0.08 | ND | ND | ND | ND | 0.40 |
| 8 | BB | ND | 0.05 | ND | ND | ND | ND | 0.70 |
| 8 | SB | 0.08 | 0.10 | 0.01 | ND | ND | ND | 0.72 |
| 8 | WS | 0.19 | 0.33 | ND | ND | ND | ND | 1.94 |
| 9 | SB | 0.14 | 0.33 | ND | ND | ND | ND | 1.75 |
| 9 | WS | 0.10 | 0.15 | ND | ND | ND | ND | 0.76 |
| 10 | SB | 0.08 | 0.10 | ND | ND | ND | ND | 0.57 |
| 10 | WS | 0.13 | 0.22 | ND | ND | ND | ND | 1.25 |
| 10 | YP | 0.07 | 0.22 | ND | ND | ND | ND | 0.69 |
| 11 | WS | 0.04 | 0.07 | 0.01 | ND | ND | ND | 0.70 |
| 11 | YP | 0.04 | 0.05 | ND | ND | ND | ND | 0.53 |
| 12 | WS | 0.04 | 0.14 | 0.01 | ND | ND | ND | 0.86 |
| 12 | YP | 0.03 | 0.14 | 0.01 | ND | ND | ND | 1.39 |
| 13 | WS | 0.05 | 0.15 | ND | ND | ND | ND | 0.80 |
| 13 | YP | 0.02 | 0.04 | 0.01 | ND | ND | ND | 0.09 |

Appendix 3 (continued). Pesticide and PCB concentrations (ppm – wet weight) from whole body analysis of fish collected from the Merrimack River, 1985.

| STATION NUMBER | SPECIES CODE | CHLOR-DANE | DDT | DIEL-DRIN | EN-DRIN | MIREX | PHENE | TOXA-PCB |
|---|---|---|---|---|---|---|---|---|
| **SPECIES MEANS** | | | | | | | | |
| | AS | 0.02 | 0.06 | 0.01[d] | | | | 0.87 |
| | BB | ND | 0.05 | ND | | | | 0.70 |
| | SB | 0.12 | 0.17 | 0.01 | | | | 1.45 |
| | STB | 0.12 | 0.23 | 0.01 | | | | 1.55 |
| | WC | 0.25 | 0.25 | 0.05 | | | | 2.90 |
| | WS | 0.16 | 0.20 | 0.01 | | | | 1.64 |
| | YP | 0.09 | 0.11 | 0.01 | | | | 0.87 |
| | ALL FISH | 0.12 | 0.16 | 0.01 | | | | 1.38 |

[a]AS-American Shad, BB-Brown Bullhead, SB-Smallmouth Bass, STB-Striped Bass, WC-White Catfish, WS-White Sucker, YP-Yellow Perch.
[b]None detected (LLD = 0.01 ppm).
[c]Data from Schmitt and Brumbaugh (1989).
[d]ND values were considered missing in the calculation of this mean.

Appendix 4. Polynuclear aromatic hydrocarbon concentrations (ppm- wet weight) from whole body analysis of fish collected from the Merrimack River, 1985.

| STATION CODE | SPECIES[a] | TOTAL PAH | ADJUSTED PAH[b] | NUMBER |
|---|---|---|---|---|
| 1 | STB | 0.01 | 0.01 | |
| 1 | YP | 0.03 | 0.04 | |
| 2 | SB | 0.09 | 0.13 | |
| 2 | WC | 0.16 | 0.23 | |
| 2 | WS | 0.09 | 0.13 | |
| 3 | SB | 0.10 | 0.14 | |
| 3 | WS | 0.22 | 0.31 | |
| 4 | AS | 0.01 | 0.01 | |
| 4 | SB | ND[c] | ND | |
| 4 | WS | 0.30 | 0.42 | |
| 4 | YP | 0.22 | 0.31 | |
| 5 | AS | 0.07 | 0.10 | |
| 5 | SB | 0.10 | 0.14 | |
| 5 | WS | 0.14 | 0.20 | |
| 5 | YP | 0.08 | 0.11 | |
| 6[d] | SB | – | – | |
| 6[d] | WS | – | – | |
| 6[d] | WS | – | – | |
| 7 | SB | 0.23 | 0.33 | |
| 7 | WS | 0.83 | 1.17 | |
| 7 | YP | 0.58 | 0.82 | |
| 8 | BB | 0.07 | 0.10 | |
| 8 | SB | 0.18 | 0.26 | |
| 8 | WS | 0.26 | 0.37 | |
| 9 | SB | 0.50 | 0.71 | |
| 9 | WS | 0.24 | 0.34 | |
| 10 | SB | 0.02 | 0.03 | |
| 10 | WS | 0.08 | 0.11 | |
| 10 | YP | 0.02 | 0.03 | |
| 11 | WS | 0.06 | 0.09 | |
| 11 | YP | 0.05 | 0.07 | |
| 12 | WS | 0.38 | 0.54 | |
| 12 | YP | 0.13 | 0.18 | |
| 13 | WS | 0.02 | 0.03 | |
| 13 | YP | ND | ND | |
| **SPECIES MEANS** | | | | |
| AS | | 0.04 | 0.06 | |
| | BB | ND | ND | |
| | SB | 0.12 | 0.13 | |
| | STB | 0.12 | 0.12 | |
| | WC | 0.25 | 0.27 | |
| | WS | 0.16 | 0.17 | |
| | YP | 0.09 | 0.09 | |
| ALL FISH | | 0.12 | 0.13 | |

[a]AS-American Shad, BB-Brown Bullhead, SB-Smallmouth Bass, STB-Striped Bass, WC-White Catfish, WS-White Sucker, YP-Yellow Perch.
[b]Detected PAH level/percent recovery.
[c]None detected (LLD = 0.01 ppm).
[d]Data from Schmitt and Brumbaugh (1989).