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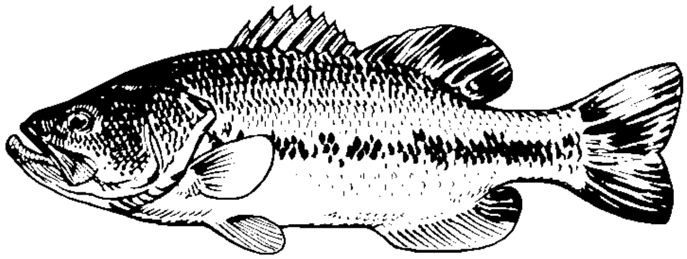

CONCENTRATIONS OF MERCURY AND OTHER ENVIRONMENTAL CONTAMINANTS IN FISH FROM GROVE POND

AYER, MASSACHUSETTS

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CONCENTRATIONS OF MERCURY AND OTHER ENVIRONMENTAL CONTAMINANTS IN FISH FROM GROVE POND

AYER, MASSACHUSETTS

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PREFACE

This report describes the results of a study to measure mercury, other trace elements, and organochlorine contaminant concentrations in fish collected from Grove Pond in Ayer, MA. Funding for this study was provided by Region 1 of the U.S. Environmental Protection Agency (EPA) within an Interagency Agreement between the U.S. Fish and Wildlife Service (USFWS) and EPA for technical assistance in the Superfund Program. The analytical work for this study was performed under Purchase Order 85830-3-0085.

Questions and comments to this report are encouraged. Written inquiries should be sent to:

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INTRODUCTION

During a remedial investigation of the Fort Devens Superfund Site in Ayer, Massachusetts, highly elevated concentrations of mercury (max. 130 mg/kg) were found in the sediments of Plow Shop Pond (Ecology and Environment, Inc. 1992). Isopleths of mercury concentrations in Plow Shop Pond sediments suggested that Grove Pond, a pond immediately upgradient and connected to Plow Shop Pond by a large culvert, could be the source of contamination. In response to the initial contaminant reports, US Army personnel of Fort Devens posted Plow Shop Pond cautioning anglers not to eat fish. Since Grove Pond was a suspected source of the Plow Shop Pond contamination and beyond the administrative control and responsibility of the US Army, EPA requested that the USFWS conduct a contaminant study of Grove Pond fish. Concurrent with the USFWS fish study; a contractor collected surface water, sediment, and benthic invertebrate samples for analyses by the Massachusetts Department of Environmental Protection (MaDEP).

STUDY PURPOSE

This study was undertaken to determine the concentrations of mercury, other trace elements, organochlorine pesticides, and polychlorinated biphenyls in Grove Pond fish.

STUDY AREA

Grove Pond is a shallow, eutrophic 18-acre pond within the Nashua River watershed. It is a popular site with local anglers and waterfowl hunters. The pond receives flow from Cold Spring Brook, Bowers Brook, an unnamed stream, Flannagan Pond, and Sandy Pond. Grove Pond empties into Plow Shop Pond through a large culvert. Plow Shop Pond drains into Nonacoicus Brook, which flows north into the Nashua River.

Aquatic vegetation in Grove Pond is abundant. Interior portions of the pond contain dense stands and mats of coontail (Ceratophyllum spp.) and purple bladderwort (Utricularia purpurea). Along the margins of the pond, pondweed (Potamogeton spp.), pickerel weed (Pontederia cordata), common buttonbush (Cephalanthus occidentalis), and purple loosestrife (Lythrum salicaria) can be found. The pond is used throughout the summer months by a number of avian species including mallard (Anas platyrhynchos), wood duck (Aix sponsa), Canada goose (Branta canadensis), great blue heron (Ardea herodias), and green-backed heron (Butorides striatus). During spring and fall migration, american wigeon (Anas americana), canvasback (Aythya valisineria), lesser scaup (Aythya affinis), and ring-necked duck (Aythya collaris) have been observed on the pond (Poole, T. 1993. Personal communication).

METHODS

Fish were collected by electrofishing in Grove Pond on September 25, 1992. Ten largemouth bass (Micropterus salmoides), 10 bluegill (Lepomis macrochirus), 4 yellow bullhead (Ictalurus natalis), and 4 brown bullhead (Ictalurus nebulosus) were collected.

Table 1. Mean lengths and weights of fish collected from Grove Pond.

Species	N	Length (cm)		Weight (g)	
		Mean	SD	Mean	SD
Lgmth Bass	10	39.3	6.37	966.7	752.0
Brn Bullhead	4	31	2.71	419	124.5
Yw Bullhead	4	20.8	2.14	112.5	43.2
Bluegill	10	19.1	1.00	133	15.5

The maximum total length in centimeters (± 0.5) and total weight to the nearest gram were measured for each fish (Table 2). Prior to processing, each fish was examined for external abnormalities. Scale samples were collected from all bass and aged by MaDFW personnel. Largemouth bass and bullhead were filleted in the field. Bass and bullhead fillet (skin-off) and partial body (the remainder of the fish including offal and the skin from fillets) samples were wrapped in aluminum foil (dull side toward sample), labelled, and placed in plastic freezer bags. Fillets were weighed to the nearest gram prior to packaging. Intact whole body bluegill samples were packaged similarly. Samples were immediately placed on ice in coolers and transported to freezers for storage at -20°C within 4 hours. Forty-six samples (10 whole body, 18 partial body, 18 fillet) were submitted for contaminant analysis.

RESULTS OF CHEMICAL ANALYSIS

All fish tissue samples were analyzed for mercury, other trace elements, organochlorine pesticides, and polychlorinated biphenyls (PCBs). Trace element analyses were performed by the Research Triangle Institute, Research Triangle Park, NC. Organochlorine pesticide and PCB analyses were conducted by the Mississippi State Chemical Laboratory, Mississippi State, MS. Analytical methods used by these laboratories are described in Appendix A.

Quality assurance was accomplished through the use of spike recoveries and the analysis of duplicate samples, reagent blanks, and reference materials (dogfish muscle, lobster hepatopancreas).

Analytical results are reported in ug/g (ppm), wet weight. Tables 3 (trace elements) and 4 (PCBs and DDT metabolites) summarize contaminant results by species. Tables 5 through 12 are condensed summaries of selected contaminant results for individual samples. The means reported in the results and discussion sections are geometric means ($\overline{x}_G$). When non-detects were incorporated into these calculations, one-half the sample detection limit (trace elements) or one-half the method detection limit (PCBs and OC pesticides) were used. If contaminants were found in only a few fillet samples for a species, ranges or individual sample results are provided.

Upper trophic level piscivores usually consume the entire fish. To evaluate hazards posed by Hg and other contaminants in Grove Pond for piscivorous wildlife, we combined fillet and partial body data. Whole fish of largemouth bass and bullhead were "reconstructed" from fillet and partial body samples using the following formula:

$$RWC = (FB+PBB)/TW$$

[RWC] The **Reconstructed Wholebody Concentration (ug/g)** = Fillet Burden (ug) + Partial Body Burden (ug)/Total Body Weight (g).

[FB] The **Fillet Burden (ug)** = Fillet Weight (g) x Fillet Concentration (ug/g).

The fillet weight (g) is found in Table 2.
The fillet concentration (ug/g) is found in the analytical reports, Appendices B and C.

[PBB] The **Partial Body Burden (ug)** = Partial Body Weight (g) x Partial Body Concentration (ug/g).

The partial body weight is the difference between the total body weight (g) and fillet weight (g), which are listed in Table 2.
The partial body concentration (ug/g) (erroneously listed as wholebody in the lab results) is found in the analytical reports, Appendices B and C.

[TW] The **Total Body Weight (g)** is found in Table 2.

Example: Reconstruction of **LmB1** wholebody Hg concentration.

Available Data	Source	LmB1
Fillet weight	Table 2	334 g
Fillet concentration	Appendix B	1.038 ug/g
Partial body weight	Derived from Table 2	2,513 g
Partial body concentration	Appendix B	1.144 ug/g
Total Body Weight	Table 2	2,847 g

Calculations

Fillet Burden (ug) = 334 g x 1.038 ug/g
= 346.7 ug

Partial Body Burden (ug) = 2513 g x 1.144 ug/g
= 2874.9 ug

Reconstructed Wholebody Concentration

= (346.7 ug + 2874.9 ug) / 2847 g
= 1.13 ug/g

Partial body concentrations were not significantly different ($p<0.001$) from reconstructed body concentrations.

We limited the reporting of results and discussion to contaminants with a potential to impact fish and wildlife resources in New England. Concentrations of all contaminants included in the analyses are reported in Appendices B (trace elements) and C (organochlorines).

Mercury (Hg) was found in all bass fillets ($\bar{x}_G$ 0.46 ug/g, range: 0.31 - 1.04 ug/g) and in six bullhead fillets ($\bar{x}_G$ 0.05 ug/g, range: nondetect - 0.20 ug/g). Mean concentrations in reconstructed wholebody samples were 0.32 ug/g (range: 0.10 -1.13 ug/g) for bass and 0.04 ug/g (range: nondetect - 0.14 ug/g) for bullhead. Wholebody bluegill Hg concentrations ranged from 0.08 to 0.24 ug/g with a mean of 0.16 ug/g.

Other Trace Elements

Arsenic (As) was not detected in any largemouth bass, brown bullhead or bluegill samples. Two yellow bullhead (YBH5, YBH8) body samples contained 0.13 ug/g of As, a level slightly above detection limits.

Cadmium (Cd) was detected in low concentrations (range: 0.03 - 0.15 ug/g) in 3 bass and 2 bullhead fillet samples. Reconstructed wholebody samples of bass and bullhead contained higher Cd concentrations with means of 0.05 ug/g (range: 0.01 - 0.885 ug/g) and 0.04 ug/g (range: 0.01 - 0.19 ug/g), respectively. Cadmium was detected in all bluegill wholebody samples at low levels ($\bar{x}_G$ 0.09 ug/g, range: 0.05 - 0.24 ug/g).

Chromium (Cr) was found in all fish samples, with the highest concentrations occurring in reconstructed wholebody and wholebody samples. Bass and bullhead fillet concentrations ranged from 0.12 to 0.49 ug/g ($\bar{x}_G$ 0.22) and from 0.10 to 0.41 ug/g ($\bar{x}_G$ 0.19), respectively. The mean Cr concentration in largemouth bass reconstructed wholebody body samples was 0.51 ug/g, slightly above the bullhead reconstructed wholebody mean of 0.49 ug/g. Bluegill wholebody Cr concentrations were higher ($\bar{x}_G$ 0.70 ug/g) with two samples (BG2, BG 8) exceeding 1 ug/g.

Copper (Cu) was also detected in all samples. Concentrations in fillets ranged from 0.11 to 0.43 ug/g in bass ($\bar{x}_G$ 0.27 ug/g) and from 0.15 to 0.60 ug/g in bullhead ($\bar{x}_G$ 0.32 ug/g). In bass reconstructed wholebody samples, Cu concentrations between 0.29 and 1.05 ug/g ($\bar{x}_G$ 0.46 ug/g) were found. Bullhead reconstructed wholebody sample concentrations ranged from 0.50 to 1.27 ug/g ($\bar{x}_G$ 0.68 ug/g). Wholebody bluegill Cu concentrations ran from a low of 0.37 ug/g to a high of 0.79 ug/g ($\bar{x}_G$ 0.58 ug/g).

Nickel (Ni) was detected in fewer than half of the fish samples. Less than half of the bass (range: nondetect - 0.91 ug/g) and half of the bullhead (range: nondetect - 0.22 ug/g) fillet samples contained detectable levels of Ni. Largemouth bass reconstructed wholebody samples exhibited a wide range of Ni concentrations with levels ranging from 0.06 to 4.15 ug/g (in LmB 7, the highest concentration detected in all fish samples). Nickel in bullhead reconstructed wholebody samples ranged from 0.06 to 0.87 ug/g ($\bar{x}_G$ 0.18 ug/g). In wholebody samples of bluegill, Ni concentrations were below the detection limit to 0.80 ug/g ($\bar{x}_G$ 0.16 ug/g).

Lead (Pb) was found in 5 bass (0.14 - 0.86 ug/g) and 3 bullhead (0.10 - 0.30 ug/g) fillet samples, and was below detection limits in the remainder of the fillets. Lead concentrations in reconstructed wholebody bass samples ranged from 0.14 ug/g to 4.32 ug/g ($\bar{x}_G$ 0.38 ug/g). The mean Pb concentration in reconstructed wholebody samples of bullhead ($\bar{x}_G$ 0.42 ug/g) was higher than the mean for bass. Lead was also found in all bluegill wholebody samples ($\bar{x}_G$ 0.48 ug/g, range: 0.16 - 1.38 ug/g).

Selenium (Se) was found in all largemouth bass fillets ($\overline{x}_G$ 0.16 ug/g, range: 0.14 - 0.18 ug/g) and in three of the eight bullhead fillet samples (range: 0.10 - 0.16 ug/g). Reconstructed wholebody samples of bass and bullhead contained mean Se concentrations of 0.32 ug/g (range: 0.22 - 0.51 ug/g) and 0.23 ug/g (range: 0.13 - 0.39 ug/g), respectively. Selenium concentrations in wholebody bluegill samples were between 0.27 ug/g and 0.38 ug/g ($\overline{x}_G$ 0.33 ug/g).

Zinc (Zn) concentrations in bass fillets were between 3.63 and 5.10 ug/g ($\overline{x}_G$ 4.40 ug/g). Bullhead fillets contained higher levels of Zn ($\overline{x}_G$ 4.52 ug/g, range: 3.72 - 7.95 ug/g) than bass.

Reconstructed wholebody samples of bass and bullhead followed the same pattern as fillets. Bass body samples had a mean concentration of 12.81 ug/g (range: 11.02 - 16.42 ug/g), while the bullhead mean Zn concentration was 13.17 ug/g (range: 10.02 - 20.50 ug/g). Bluegill wholebody Zn concentrations ran from a low of 17.66 ug/g to a high of 26.27 ug/g ($\overline{x}_G$ 21.38 ug/g).

Organochlorines

Polychlorinated biphenyls (PCBs) were not detected in any bullhead fillets and in half of the bass fillets (range: 0.07 - 0.15 ug/g). PCB concentrations in reconstructed wholebody largemouth bass ranged from 0.10 to 0.43 ug/g ($\overline{x}_G$ 0.22 ug/g). PCBs were detected in two yellow bullhead samples, and reconstructed wholebody concentrations were 0.12 ug/g (YBH 7) and 0.08 ug/g (YBH 8). Half of the bluegill wholebody samples contained PCBs. The mean PCB concentration for bluegill was 0.06 ug/g (range: nondetect - 0.21 ug/g).

DDT metabolites - p,p' DDD and p,p' DDE were detected in bass, bullhead, and bluegill. DDD occurred in 7 bass fillet samples at concentrations between 0.01 and 0.03 ug/g ($\overline{x}_G$ 0.01 ug/g). Reconstructed bass wholebody concentrations for DDD ranged from a low of 0.02 ug/g to a high of 0.11 ug/g ($\overline{x}_G$ 0.05 ug/g). DDD was found slightly above detection limits in two bullhead fillet samples (BBH 1 - 0.01, YBH 7 - 0.02 ug/g). In 7 bullhead reconstructed wholebody samples, DDD was found in concentrations ranging from 0.02 to 0.05 ug/g ($\overline{x}_G$ 0.02 ug/g). DDD was detected in all bluegill whole body samples from the detection limit of 0.01 to 0.07 ug/g ($\overline{x}_G$ 0.02 ug/g).

All bass samples contained residues of p,p' DDE. Bass fillet and reconstructed wholebody samples contained DDE concentrations ranging from 0.01 to 0.07 ($\overline{x}_G$ 0.02 ug/g) and 0.05 to 0.25 ug/g ($\overline{x}_G$ 0.12 ug/g), respectively. DDE was detected in 5 of 8 bullhead fillet samples ($\overline{x}_G$ 0.01 ug/g). Reconstructed wholebody samples of bullhead contained lesser amounts of DDE ($\bar{x}_G$ 0.04 ug/g, range: 0.01 - 0.10 ug/g) than bass. All bluegill samples contained DDE with a mean concentration of 0.05 ug/g (range: 0.02 - 0.13 ug/g).

No other organochlorines included in the analysis (Appendix C) were detected in tissue samples.

DISCUSSION

Elevated contaminant concentrations in fish tissues may be harmful to the fish or to their predators (other fish, wildlife, and humans). The discussion section of this report focuses on the potential hazards of fish contamination to **ecological receptors.** Brief notes regarding some contaminant concentrations in fillet samples (i.e., the edible portion) and FDA Action or Tolerance Levels are included in the discussion section to put the fish flesh concentrations in context. However, separate analysis of the human health implications and Grove Pond fish is required. Our use of FDA and State Action Levels for comparison purposes should not be considered an assessment of risk to human consumers of Grove Pond fish. This study will be provided to risk assessors of EPA and MaDEP, who can provide a more detailed evaluation of the human health risks associated with the consumption of Grove Pond fish.

Largemouth bass, bluegill, and bullhead are popular sportfish species often consumed by Massachusetts anglers. These species are also useful in assessing ecological risks. Bass, bullhead, and bluegill represent three different trophic positions in freshwater communities. Largemouth bass feed primarily on small fish, and represent upper trophic level piscivores. Mercury and other contaminants in Grove Pond biomagnify in food chains. Therefore, the highest levels of contaminants that biomagnify would be expected in bass, a piscivorous fish species, and probably the major predator within the Grove Pond fish community. Bluegill can be a major prey items of bass. They were analyzed to illustrate contaminant concentrations within the forage fish trophic level. Bluegill can be omnivorous, but as adults generally prey on small benthic organisms and larval and juvenile fish (Scott and Crossman 1973). Bullhead, known locally as horn pout, also have an omnivorous diet. They typically feed upon fish eggs, fish, insects (Scott and Crossman 1973), and other organisms and material that occur in close association with sediment. Bullhead were used to evaluate contaminant uptake in bottom feeders. These three fish species may occur in the diets of piscivorous migratory birds, which are trust resources of the USFWS.

Heavy macrophyte cover and mechanical problems greatly reduced electrofishing efficiency on the day of sampling. To obtain an adequate sample of bottom-feeding bullhead, two species, the yellow and brown bullhead were collected. Yellow and brown bullhead often coexist in ponds, and have similar foraging strategies and diet. We would not expect contaminant uptake to vary in significant amounts between these two bullhead species.

We attempted to collect similar-sized fish of each species, biasing the selection to larger size classes to illustrate the worst case bioaccumulation scenarios, and because consumptive anglers usually select larger fish. Because of electrofishing problems on the day of sampling, we were only partially successful in limiting the range of sizes of fish collected. Bluegill from a narrow range of size classes were collected. For bass and bullhead, there was greater variation in size classes (Table 1). No external abnormalities were observed in the fish we collected.

Largemouth bass and bullhead fillet concentrations were compared against US Food and Drug Administration Action or Tolerance Levels (FDA 1992, 21 CFR 109.30).

Wholebody bluegill and reconstructed bass and bullhead wholebody samples were compared to national levels reported in the US Fish and Wildlife Service's National Contaminant Biomonitoring Program (NCBP; Schmitt and Brumbaugh 1990, Schmitt et al 1990) for Cd, Cu, Hg, Pb, Se, Zn, PCBs, p,p' DDD, and p,p' DDE. The NCBP tracks temporal and geographic trends in trace element and organochlorine concentrations in composite samples of whole fish collected from 112 riverine stations throughout the United States. The latest results of the NCBP include fish collected in 1984. We used these results for comparative purposes and recognize the limitations of the NCBP data set. The geometric mean and 85th percentile concentrations reported in the NCBP have no regulatory significance or meaning with respect to potential hazards to fishery resources (May and McKinney 1981), but serve as reference points to distinguish elevated contaminant concentrations in fish.

Mercury (Hg) - Mercury is a mutagen, teratogen, and carcinogen, which bioconcentrates in organisms and biomagnifies through food chains (Eisler 1987). Methylmercury, an organic form of mercury, is a potent neurotoxin. Methylmercury accounts for over 95% of the total Hg in fish tissue (Grieb et al 1990). Mercury accumulates in axial muscle tissue (i.e., edible portion) of fish (Moore and Ramamoorthy 1984a).

In freshwater systems, the toxicity of Hg, rate of Hg biotic and abiotic methylation, and partitioning of Hg within biota can vary considerably depending on site-specific conditions (Zillioux et al 1993). This study only evaluated Hg in fish tissue. It is important to remember that other biota in Grove Pond, besides fish, may have accumulated Hg.

The FDA Action Level for methylmercury in fish tissue is 1 ug/g (FDA 1992). Only one Grove Pond bass fillet sample (LMB1, 1.04 ug/g) exceeded this level. Some states have adopted more conservative concentration limits than the FDA Action Level. Florida has a consumption standard of 0.5 ug Hg/g in edible tissue (Lange et al 1993). Minnesota developed the strictest advisory level in the US, with a standard of 0.16 ug Hg/g based on the frequency of consumption (Shubat 1991). Two additional Grove Pond bass fillets (LmB 2 and 9) had Hg concentrations above 0.5 ug/g, which would have exceeded the Florida criterion for Hg. Of the 18 fillets analyzed in this study, 11 (all bass, 1 bullhead) exceeded the Minnesota standard. According the to the Minnesota methodology, a person would have to consume one-half pound of these fish once per week for 3 months or more to be at risk. Figures 4 and 6 depict Hg concentrations in bass and bullhead fillets, respectively.

Figures 5, 7, and 8 depict Hg concentrations in Grove Pond bass and bullhead reconstructed wholebodies and wholebody bluegill compared to the NCBP geometric mean and 85th percentile concentrations.

Wholebody Hg concentrations in nineteen individual fish (10 bass, 1 bullhead, 8 bluegill) equal or exceed the geometric mean Hg concentration 0.10 ug/g measured in all fish sampled in the 1984 NCBP sampling event. Individual reconstructed wholebody Hg concentrations in 9 Grove Pond bass samples exceed the NCBP 85th percentile (0.17 ug/g) concentration. Seven of eight individual wholebody Hg concentrations in our Grove Pond bullhead samples are below the 1984 NCBP geometric mean concentration for whole fish. Individual wholebody Hg concentrations of 8 Grove Pond bluegill sampled equal or exceed the NCBP geometric mean value. Three bluegill exceeded the 85th percentile value.

Grove Pond fish tissue samples did not contain acutely toxic amounts of Hg. Although some species are more sensitive, Hg is toxic to fish when whole body concentrations reach a range of 10 to 30 ug/g (Spry and Wiener 1991). Younger life stages of Grove Pond fish, particularly eggs and larvae of fish spawning or nesting in the western portion of the pond with the most contaminated sediments, could be adversely impacted by Hg. In laboratory tests, McKim et al (1976) found that earlier life stages of brook trout were more sensitive to mercury formulations than older juvenile-adult trout.

Piscivorous birds and mammals foraging for extended periods of time in Grove Pond and Plow Shop Pond could be adversely affected by the consumption of mercury-contaminated prey. Mercury causes a variety of adverse effects in birds and mammals. Eisler (1987) lists a number of symptoms associated with Hg exposure in birds including muscular incoordination, withdrawal, hyporeactivity, hypoactivity, and changes in growth. Fimreite (1974) reported reduced hatching success and elevated liver concentrations in piscivorous birds inhabiting a Hg-contaminated freshwater lake. In the Fimreite study, adult common merganser (Mergus merganser) collected from two lakes downstream of a chlor-alkali plant and pulp mill contained mean liver Hg concentrations of 46.6 and 50.8 ug/g. Merganser collected from a lake upstream from the plant and mill contained liver Hg concentrations between 4.93 and 7.33 ug/g. Mercury can be lethal to birds with diets containing 4.0 to 40.0 ug Hg/g (Eisler 1987).

Mammals are particularly sensitive to Hg contamination, with some species accumulating toxic levels after short periods of exposure. Mercury can be lethal to mink (Mustela vison), one of the most sensitive mammalian species, at dietary concentrations of 1.1 ug/g (Kucera 1983) and otter at dietary concentrations of 2 ug/g (O'Connor and Nielsen 1980). Kucera (1983), studying 5 drainages in Manitoba, found that mink and otter accumulated 10 times more mercury than did predatory fish in the same drainages.

Eisler (1987) recommended that daily doses of Hg less than 640 ug/kg body weight and 250 ug/kg body weight should be protective of birds and mammals, respectively. For piscivorous birds and mammals with restricted home ranges that include Grove Pond and Plow Shop Pond, Hg concentrations in fish tissue could be potentially harmful.

Other Trace Elements

Arsenic (As) - Arsenic is a teratogen and carcinogen, which bioconcentrates in organisms, but does not biomagnify in food chains (Eisler 1988a). In unpolluted or mildly-contaminated waters, fish tissue may contain As residues ranging between < 0.1 and 0.4 ug/g (Moore and Ramamoorthy 1984a). Sensitive aquatic species with tissue residues greater than 1.3 ug/g may be damaged by As (Eisler 1988a). Bluegill with muscle tissue As residue concentrations greater than 1.3 ug/g (immatures) and 5 ug/g (adults) experienced reduced growth and survival (NRCC 1978).

Arsenic was not detected in most Grove Pond fish samples. When detected, As was within the range reported by Moore and Ramamoorthy (1984a), and well below the concentrations reported by Eisler (1988a) and the NRCC (1978) as harmful to fish. Arsenic was detected in only two body samples of bullhead, YBH5 and YBH8, both at 0.13 ug/g. The NCBP geometric mean for this element was slightly higher, 0.14 ug/g.

Because of the low concentrations detected in our samples of Grove Pond fish, we would not expect As in **fish tissue** to be a significant ecological contaminant of concern.

Cadmium (Cd) - Cadmium is a teratogen and carcinogen, and probable mutagen, that has been implicated as the cause for severe effects on fish and wildlife (Eisler 1985a). In humans, chronic exposure to Cd can lead to kidney dysfunction (FDA 1993a).

Vertebrate species with whole body concentrations of 2.0 ug/g likely indicate Cd contamination (Eisler 1985a). Animals with Cd tissue concentrations greater than 5 ug/g may be lethally affected by Cd, while higher tissue concentrations of 15.0 ug/g could be hazardous to the upper trophic level species that prey on these animals (Eisler 1985a).

In Grove Pond, higher Cd concentrations were detected in wholebody samples than in fillets. Edgren and Notter (1980) found higher Cd concentrations in yellow perch organ tissue, particularly the liver, rather than muscle tissue. Eisler (1985a) reported that Cd concentrated in the viscera of vertebrates, particularly the liver and kidneys.

In the 1984 NCBP samples, the national wholebody average for Cd in fish was 0.03 ug/g, and the 85th percentile concentration was 0.05 ug/g. The mean Cd concentration for reconstructed bass wholebody samples equalled the NCBP 85th percentile. One bass (LmB 7) contained 1.02 ug Cd/g. This particular fish, which was not the largest bass collected, also exhibited the highest concentrations of Cr, Cu, Ni and Pb. Mean bullhead ($\overline{x}_G$ 0.04 ug/g) Cd concentrations were slightly less than bass, while the mean bluegill ($\overline{x}_G$ 0.09 ug/g) concentration was higher than both species and above the NCBP national average and 85th percentile concentration.

Based on the tissue levels found in Grove Pond fish, Cd does not appear to pose a significant risk to piscivorous wildlife resources.

Chromium (Cr) - Trivalent Cr is an essential trace element to vertebrates. The hexavalent form of Cr may cause adverse effects in the liver and kidney, and could also be a carcinogen (FDA 1993b). In the laboratory, Cr is a mutagen, carcinogen, and teratogen to several organisms (Eisler 1986).

Average Cr concentrations in freshwater fish muscle may be less than 0.25 ug/g (Moore and Ramamoorthy 1984). Mean fillet concentrations in Grove Pond were 0.22 ug/g for bass and 0.19 ug/g for bullhead. There is no FDA Action Level for Cr in fish tissue.

Chromium was detected in all Grove Pond fish samples with the highest concentrations occurring in wholebody samples. Mean body concentrations were highest in bluegill ($\overline{x}_G$ 0.70 ug/g), followed by bass ($\overline{x}_G$ 0.51 ug/g), and then bullhead ($\overline{x}_G$ 0.48 ug/g). Chromium was not included in the NCBP and a national average for wholebody concentrations is not known. Eisler (1986) suggested that tissue concentrations in excess of 4.0 ug/g were indicative of Cr contamination. None of our Grove Pond fish samples approached the level presented by Eisler. Concentrations above 1 ug/g were detected in 1 bass (LmB7 1.16 ug/g) and 1 bullhead (BBH6 1.35 ug/g) reconstructed wholebody samples, and in 2 bluegill (BG2 1.05, BG8 1.23 ug/g) wholebody samples.

Copper (Cu) - Copper is an essential element for vertebrates, and commonly found in fish tissue. Freshwater fish can regulate Cu over a wide range of concentrations, but will accumulate Cu (particularly in the liver) in excess of nutritional requirements if continually exposed to the element (Leland and Kuwabara 1985). Moore and Ramamoorthy (1984a) suggested that even in polluted waters, fish muscle tissue concentrations seldom exceeded 1 ug Cu/g.

Copper was detected in all Grove Pond fish fillet samples at relatively low concentration. Mean fillet concentrations for bass ($\overline{x}_G$ 0.27 ug/g) and bullhead ($\overline{x}_G$ 0.32 ug/g) were lower than their mean wholebody concentrations. There is no FDA Action Level for Cu in fish tissue.

Reconstructed bullhead wholebody samples contained higher concentrations of Cu than bluegill wholebody samples and bass body samples. In comparison to the NCBP, wholebody sample means of the three Grove Pond species collected in this study were below the 85th percentile concentration (1.00 ug/g). Mean bass ($\overline{x}_G$ 0.46 ug/g) and bluegill ($\overline{x}_G$ 0.58 ug/g) wholebody samples were below the NCBP national average ($\overline{x}_G$ 0.65 ug/g), while bullhead ($\overline{x}_G$ 0.68 ug/g) were slightly higher.

Nickel (Ni) - Little information regarding the effects of elevated Ni body burdens on fish and wildlife is available. Nickel does not accumulate through the food chain (Moore and Ramamoorthy 1984a:173). In humans, toxic exposure to Ni can cause skin allergies, cancer, non-malignant respiratory disorders, and iatrogenic poisoning (i.e., poisoning associated with medical treatments that include nickel)(FDA 1993).

Nickel was detected in fillet and wholebody samples collected from Grove Pond, but with considerable variation in concentrations. Nickel was not included in the National Contaminant Biomonitoring Program. Preliminary estimates of Ni in freshwater fish tissue collected from areas believed to be uncontaminated, range from <0.2 to 2.0 ug/g WW (Jenkins 1980).

With the exception of one bass reconstructed wholebody sample (LmB 7 - 4.15 ug/g), Ni levels in Grove Pond fish tissue were within the range provided by Jenkins (1980).

Lead (Pb) - Lead is an ubiquitous environmental contaminant that is commonly found in fish and wildlife tissues, particularly in species with habitats proximal to roads and urban and industrial developments. Lead is bioconcentrated by organisms, but does not appear to magnify through food chains (Eisler 1988b). Exposure to Pb may cause neurological defects, kidney dysfunction, and anemia in vertebrates (Leland and Kuwabara 1985). In addition, adverse effects on aquatic biota can include reduced survival, impaired reproduction, and reduced growth (Eisler 1988b).

There is no FDA Action Level for Pb in fish tissue, but a concentration of 0.3 ug/g (wet weight) has been developed by the World Health Organization as an upper permissible limit for Pb in foods (Settle and Patterson 1980). Of the 18 fillet samples analyzed in this study, 4 bass fillet samples and one bullhead fillet contained Pb in excess of 0.3 ug/g.

Compared to Grove Pond fish fillet samples, Pb was detected more frequently, and in higher concentrations, in wholebody samples. Lead can accumulate in muscle tissue, but within an organism Pb accumulations can be higher in bony or "hard" tissues (Schmitt and Finger 1987, Eisler 1988b). Bass and bullhead reconstructed wholebody and bluegill wholebody mean concentrations were 0.38, 0.42, and 0.48 ug/g, respectively. These values were higher than the NCBP geometric mean (0.11 ug/g) and 85th percentile (0.22 ug/g) concentrations. Concentrations in excess of 1 ug Pb/g were detected in 5 Grove Pond (1 bass, 1 bullhead, 3 bluegill) wholebody samples.

Selenium (Se) - Selenium contamination in drainwater and surface water is a serious problem to fish and wildlife resources in the western United States, a region with seleniferous soils. In the eastern United States seleniferous soils are less common, but Se has been identified in the Northeast as an environmental contaminant in fish collected from rivers in industrialized areas.

Selenium is an essential trace element for vertebrates that can cause death in deficient amounts, but in excessive amounts can cause death, reproductive abnormalities, and growth retardation (Eisler 1985b). Although Se accumulates in axial muscle tissue of fish (Schmitt and Finger 1987), Grove Pond fillet concentrations of Se were considerably lower than wholebody samples. Bass fillets ($\overline{x}_G$ 0.16 ug/g) contained half the concentrations of Se than reconstructed wholebody samples.

Detectable levels of Se were found in only three of the eight bullhead fillet samples (BBH6 0.10, YBH4 0.16, YBH7 0.15 ug/g). These concentrations were approximately 60% less than reconstructed wholebody samples. There is no FDA Action Level for Se in fish tissue.

Fish consuming diets with 10 to 33 ug Se/g have experienced toxic effects (Besser et al 1993). Only low levels of Se were detected in Grove Pond fish. Bass ($\bar{x}_G$ 0.32 ug/g), bullhead ($\bar{x}_G$ 0.23 ug/g), and bluegill ($\bar{x}_G$ 0.33 ug/g) wholebody Se concentrations were below the NCBP national average of 0.42 ug/g. Therefore, Se does not appear to be an ecological contaminant of concern in Grove Pond fish tissue.

Zinc (Zn) - Zinc is an essential element for mammals (Moore and Ramamoorthy 1984a), fish (Spry et al 1988) and other organisms (Eisler 1993).

Mean fillet Zn concentrations in bass (4.4 ug/g) and bullhead (4.5 ug/g) were similar. There is no FDA Action Level for Zn in fish tissue. Diets containing Zn between 80 to 90 ug/g caused digestive problems and decreased serum cholesterol levels in humans (Eisler 1993).

Although it is an uncommon occurrence in aquatic systems, fish with diets deficient in Zn can experience reduced growth and increased mortality in fish (Spry et al 1988). Eisler (1993) reported that elevated concentrations of waterborne Zn has adverse effects on the growth, survival, behavior, and reproduction of sensitive fish, with early development stages being the most susceptible. Spry et al (1988), studying rainbow trout, found no toxic effects of exposure to high dietary and waterborne concentrations of Zn based on growth, mortality, major plasma ions, hematocrit, or plasma protein.

In the most recent NCBP fish survey (Schmitt and Brumbaugh 1990), the national average for Zn was 21.7 ug/g, and the 85th percentile concentration was 34.2 ug/g. Mean reconstructed wholebody concentrations of Grove Pond bass ($\bar{x}_G$ 12.8 ug/g) and bullhead ($\bar{x}_G$ 13.2 ug/g) were below the national average, while the mean bluegill ($\bar{x}_G$ 21.4 ug/g) wholebody concentration was close to the national average.

Organochlorines

Polychlorinated biphenyls (PCBs) - PCBs are lipophilic compounds that bioconcentrate in organisms (EPA 1980), and biomagnify in food chains (Eisler 1986). In fish, acute toxicity from PCBs is low, while chronic toxicity is relatively high (Murty 1986). PCB accumulations can adversely affect egg survival and fry development in fish (Hogan and Brauhn 1975).

The FDA promulgated a Tolerance Level for PCBs of 2 ug/g in fish sold commercially (21 CFR 109.30). Grove Pond fish fillet samples did not approach the FDA Tolerance Level. PCBs were detected in low concentrations in 5 bass fillets (range: nondetect - 0.15 ug/g, $\overline{x}_G$ 0.05 ug/g) and not detected in any of the bullhead fillets.

Since maximum PCB concentrations would be associated with fatty tissue and fat deposits (Moore and Ramamoorthy 1984b), reconstructed wholebody bass and bullhead and wholebody bluegill Grove Pond samples exhibited higher concentrations than skinless fillets. PCBs were detected in all bass ($\overline{x}_G$ 0.22 ug/g), two bullhead (0.08 and 0.12 ug/g) reconstructed wholebody samples, and in five bluegill wholebody samples (range: 0.09 - 0.21 ug/g). In the 1984 NCBP sampling event, the geometric mean for total PCBs in wholebody fish samples was 0.39 ug/g. In Grove Pond, only one of the reconstructed wholebody bass samples (LmB2 0.43 ug/g) exceeded the national average.

PCBs are common contaminants in the eggs and tissues of piscivorous birds. The implications of elevated egg and tissue PCB concentrations in piscivorous birds are not always clear. In some situations, total PCB concentrations may be elevated in wildlife tissues with no apparent adverse impacts. Poole (1989) studied a southeastern Massachusetts osprey (Pandion haliaetus) population and found high concentrations of PCBs in addled eggs (average 25 ug/g), but no decreases in productivity or increases in adult mortality. Recent research indicates that the estimation of total PCB concentrations may be less useful in assessing wildlife impacts than the determination of specific PCB congener concentrations (Colburn 1991). The total PCB concentrations and frequency of detection in Grove Pond fish do not indicate that a PCB contaminant source exists. Unless the PCBs that do exist are composed of the more toxic PCB congeners, piscivorous birds foraging in Grove Pond should not be at risk.

Some mammals foraging on Grove Pond fish may be adversely affected by PCB contamination. Mink are extremely sensitive to PCBs, and diets with PCB concentrations of 0.67 ug/g could lead to reproductive failure (Ringer 1983). Mean PCB concentrations in Grove Pond fish tissue did not reach the 0.67 ug/g threshold. However, if a particularly potent PCB congener comprises the bulk of the total PCB concentration, even the relatively low levels of PCBs detected in Grove Pond fish tissue could be hazardous to some species of piscivorous wildlife.

DDT Metabolites - DDT and its metabolites are persistent contaminants in the environment. Since the use of DDT in the United States was essentially discontinued in 1972 (Peterle

1991), the compound and its metabolites continue to be detected in fish and wildlife tissues. Two DDT metabolites - p,p' DDD and p,p' DDE - were detected in Grove Pond fish tissue.

The FDA Action Level for DDD and DDE in the edible portion of fish (i.e., fillets) is 5 ug/g (FDA 1992). No fillet samples from Grove Pond bass and bullhead approached the FDA Action Level. DDD concentrations in bass (detected in 7 fish, range: 0.01 - 0.03 ug/g) and bullhead (detected in 2 fish, 0.01 and 0.02 ug/g) fillets were low. Concentrations of DDE were also detected at low levels in all bass fillets ($\overline{x}_G$ 0.02 ug/g, range: 0.01 - 0.07 ug/g) and in 5 of 8 bullhead fillets (range: 0.01 - 0.04 ug/g).

Wholebody sample concentrations of DDD and DDE were higher than levels in fillets. DDT metabolites are lipophilic and accumulate in lipid deposits and other fatty tissues (Moore and Ramamoorthy 1984b). The NCBP national geometric means of DDD and DDE in whole body fish samples were 0.06 and 0.19 ug/g, respectively. In Grove Pond, the mean DDD concentration in reconstructed bass wholebody samples ($\overline{x}_G$ 0.05 ug/g) was slightly less than the NCBP national average, but five samples equaled or exceeded the national average. Bullhead reconstructed wholebody samples and bluegill wholebody samples ($\overline{x}_G$ 0.02 ug/g for both) contained less DDD than bass. All of our bullhead samples were below the NCBP average. One bluegill sample equalled the NCBP average for DDD and one sample was slightly higher (0.07 ug/g).

In bass, bullhead, and bluegill wholebody samples, DDE was found in higher concentrations than DDD. The mean DDE concentrations for all three species were lower than the NCBP average. The highest DDE concentrations were detected in bass, and two reconstructed wholebody samples (0.20 and 0.25 ug/g) exceeded the NCBP average.

While it was in use, DDT was implicated in fish kills following accidental spills and aerial sprays. Breakdown products (DDD and DDE) of DDT are extremely stable, and persist in the environmental today. Chronic exposure to sublethal concentrations of DDT metabolites and other pesticides can cause a number of adverse effects in fish including changes in morphology, behavior, biochemistry, hematology, histopathology, respiration, feeding and growth, reproduction, and development of early life stages (Murty 1986).

DDE exposure has been correlated to eggshell thinning in piscivorous birds (Wiemeyer et al 1993, Fitzner et al 1988). DDT metabolites in fish tissue have been associated with productivity changes in piscivorous birds populations. In one study (Ames 1966), total DDT levels in fish of 0.05 to 0.3 ug/g were associated with a stable osprey population, while fish with concentrations of 1.3 to 5.5 ug/g were related to a declining osprey population. Continued consumption of larger, older Grove Pond fish with the highest DDE and DDD concentrations could pose a risk for piscivorous birds.

SUMMARY

Elevated concentrations of Hg and Pb were detected in Grove Pond fish. One bass of ten had a Hg fillet concentration that exceeded the FDA Action Level for human consumption.

One bass, Lmb 7, reconstructed wholebody sample contained significantly higher concentrations of Cd, Cr, Cu, Ni, and Pb than the other nine bass samples. In contrast, this fish contained the lowest levels of Hg and Zn found in bass body samples.

Grossly elevated concentrations of PCBs and DDT metabolites were not detected in fish tissue. Concentrations that were found, however, could be potentially hazardous to some species of piscivorous wildlife that are particularly sensitive to these compounds.

Contaminated sediments in Grove Pond appear to be limited to the western edge of the pond. To prevent recontamination of Plow Shop Pond following restoration, remedial activities that are planned for that pond should also include the western edge of Grove Pond.

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FIGURES

Figure 1. Location Map

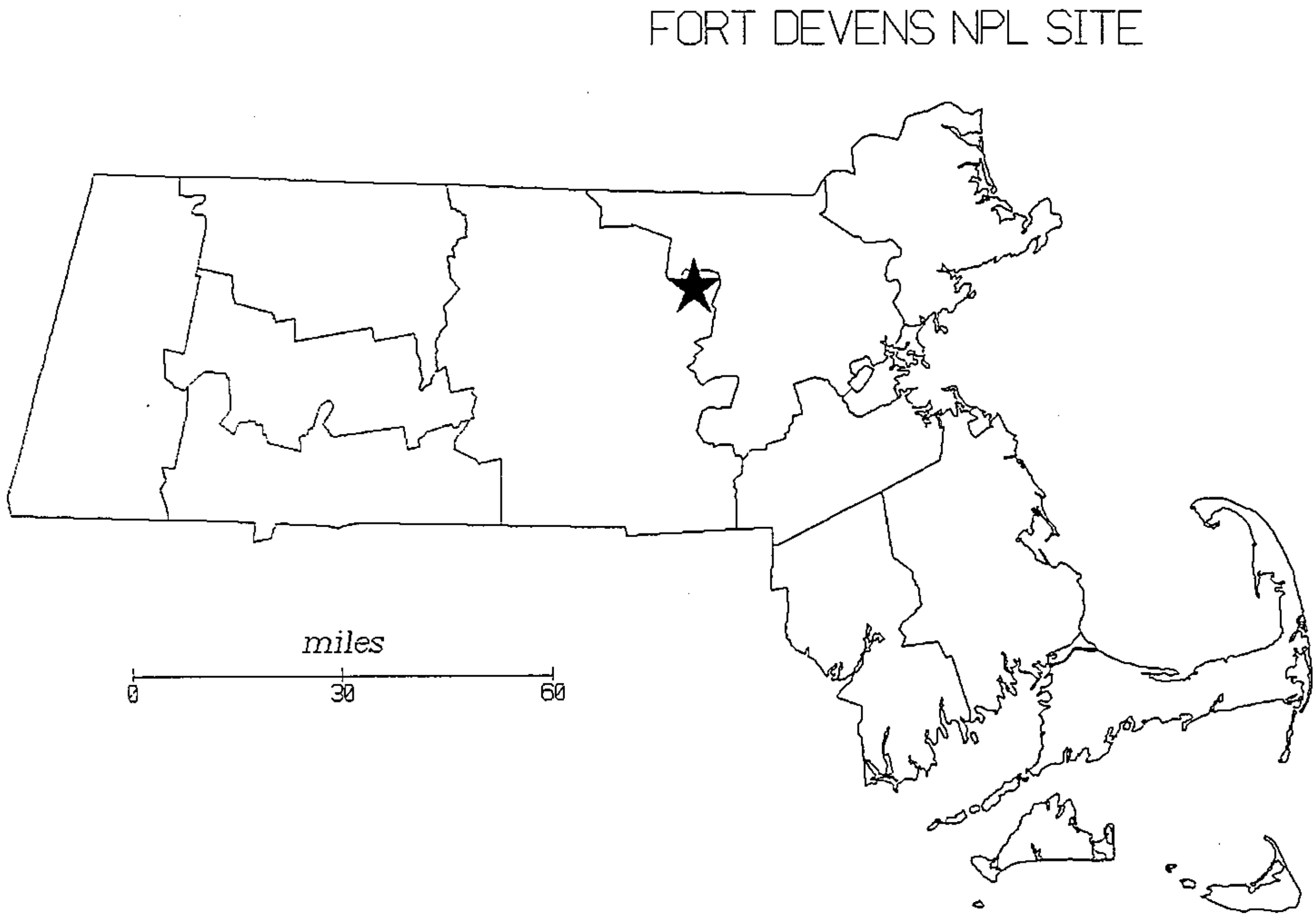


FIGURE 2. USGS QUADRANGLE, AYER, MASSACHUSETTS.
SCALE 1:25,000

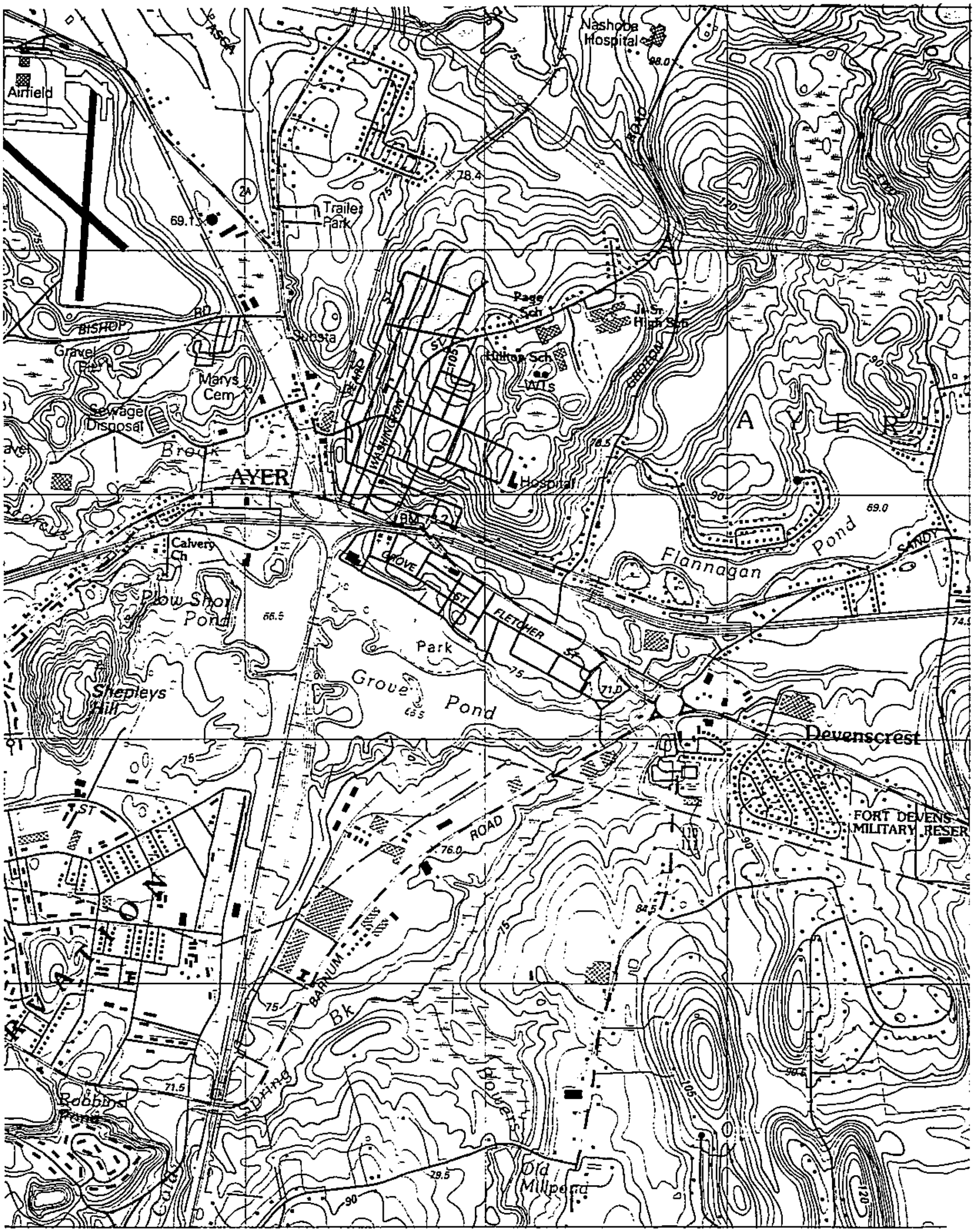
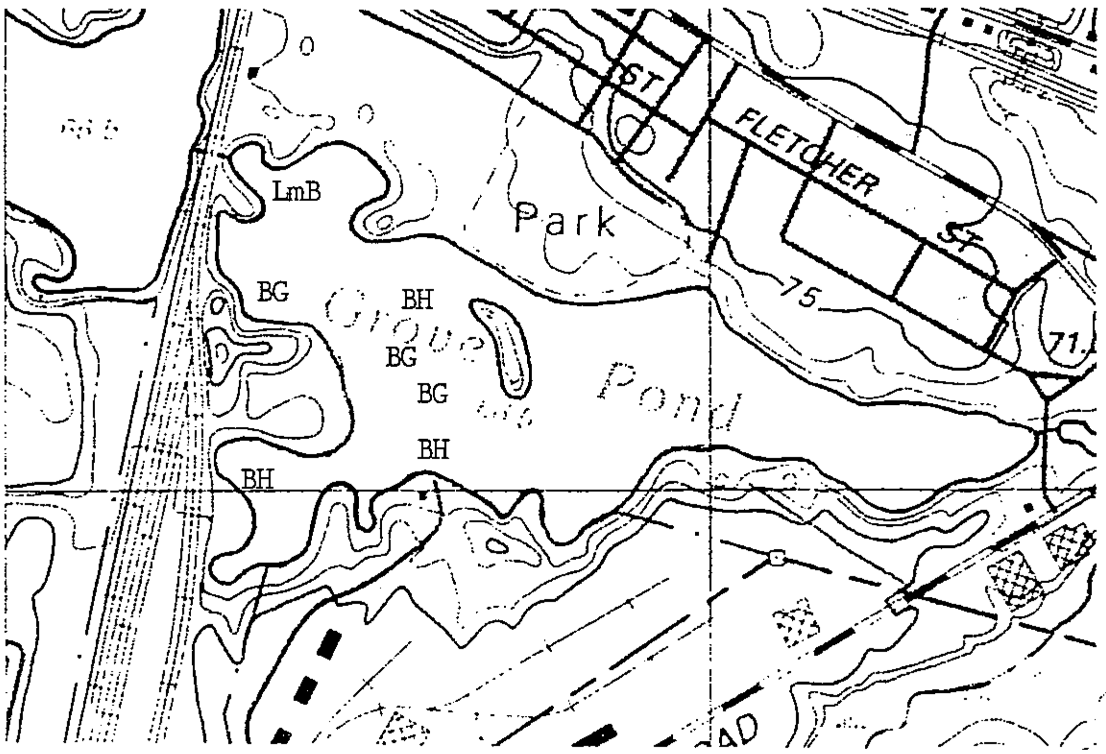


FIGURE 3. Approximate capture locations of fish in Grove Pond.



SPECIES CODE: LmB = Largemouth Bass
BH = Bullhead (Yellow or Brown)
BG = Bluegill

FIGURE 4

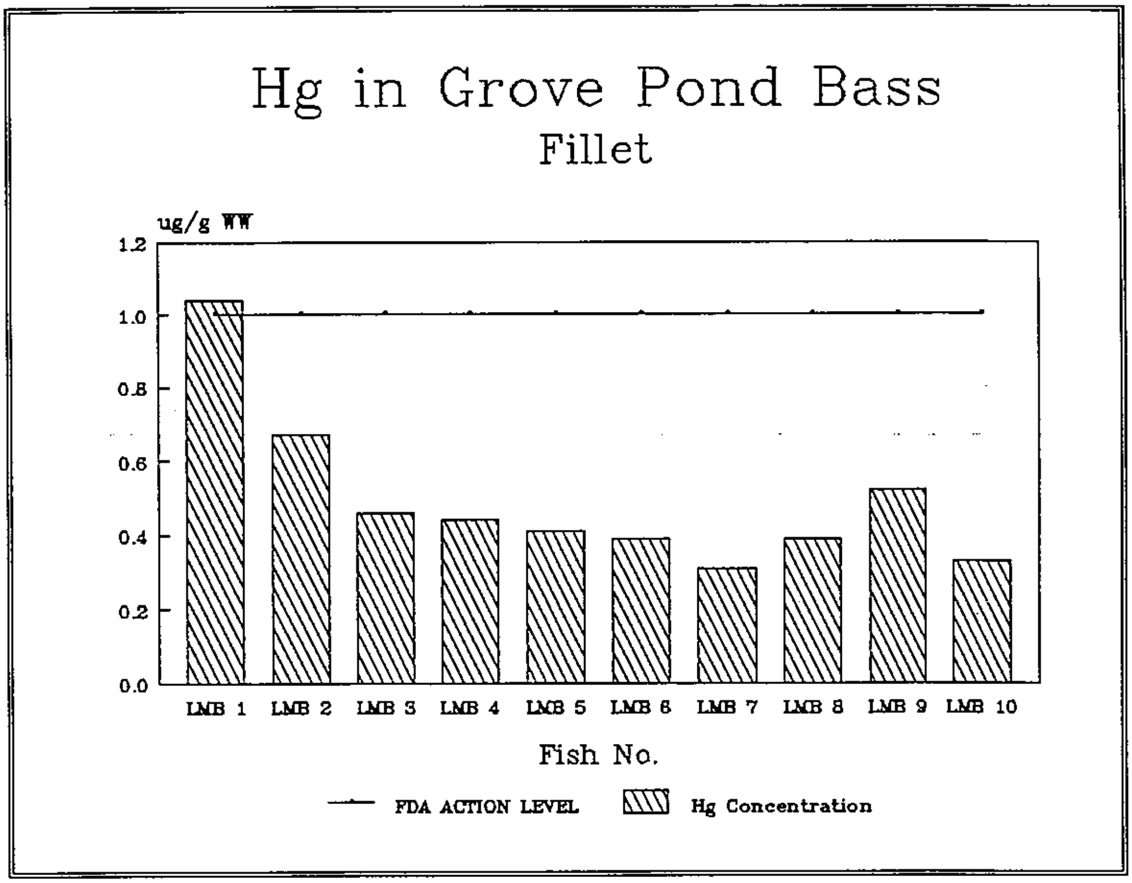


FIGURE 5

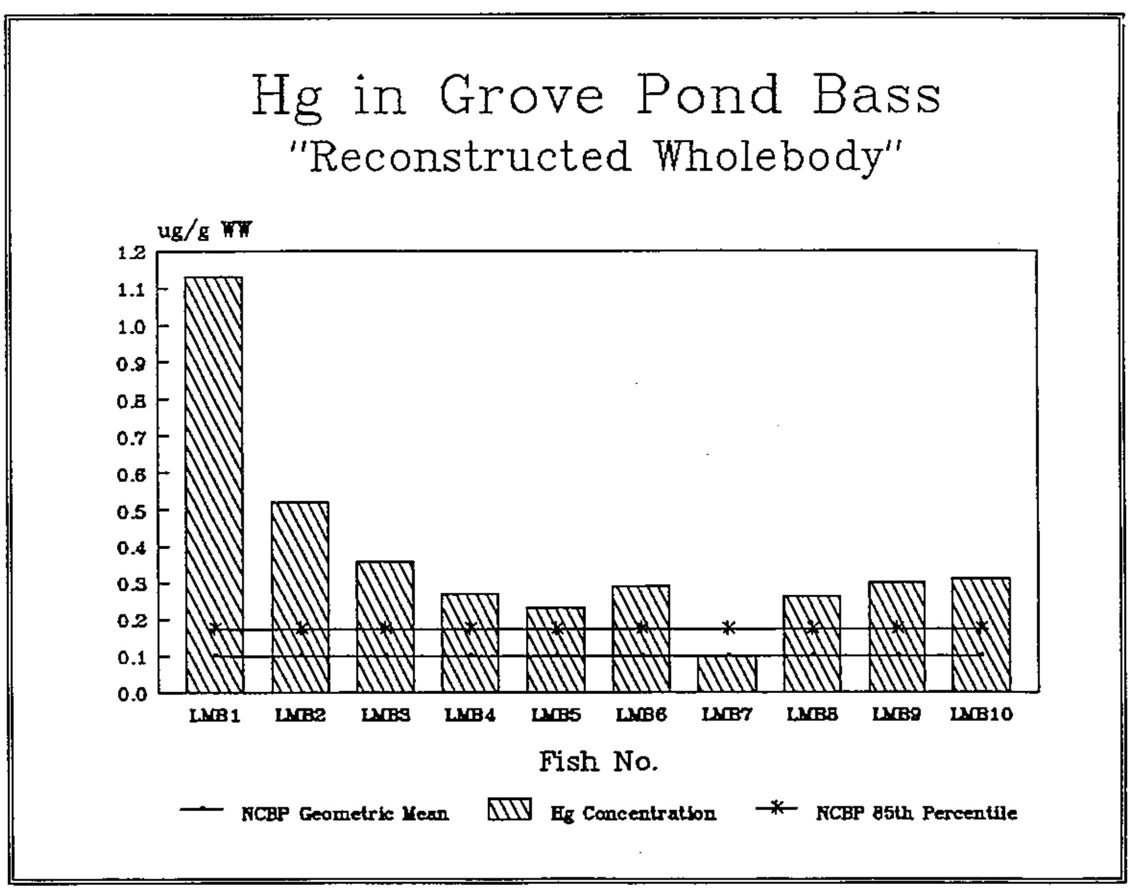


FIGURE 6

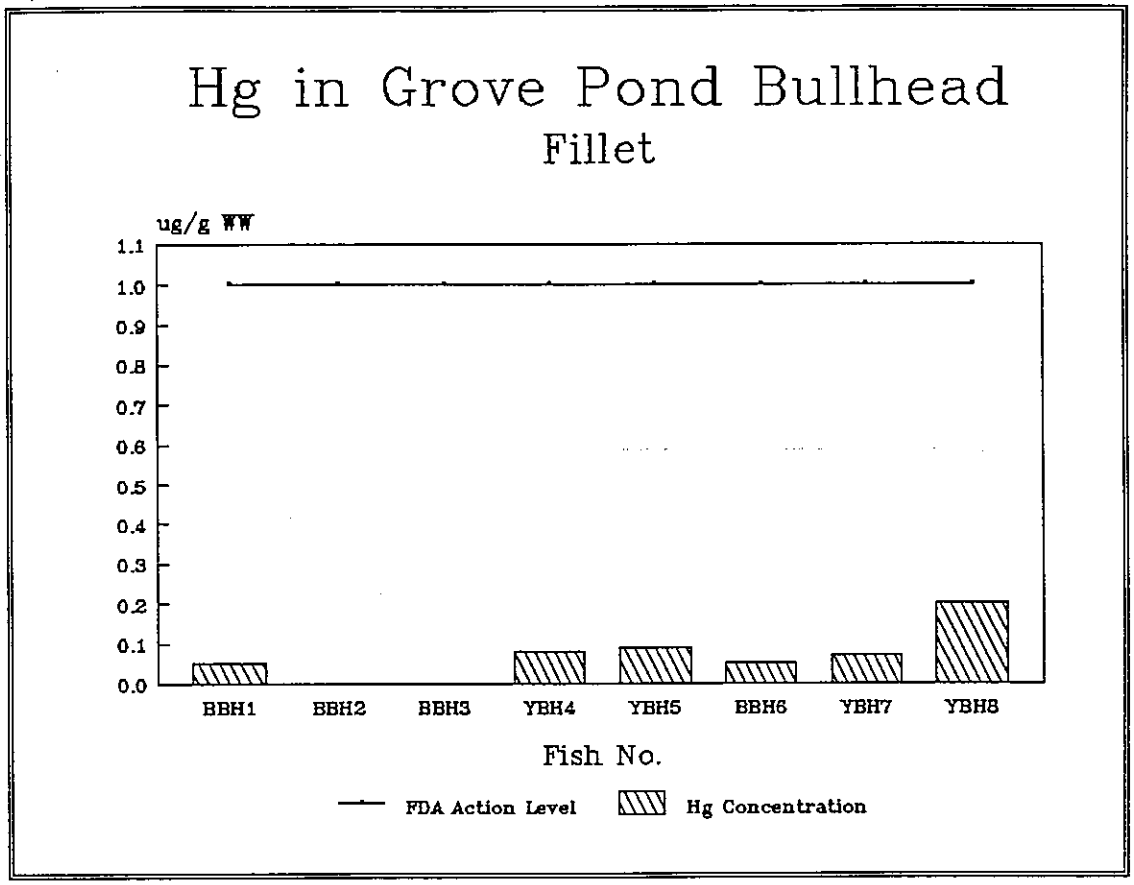


FIGURE 7

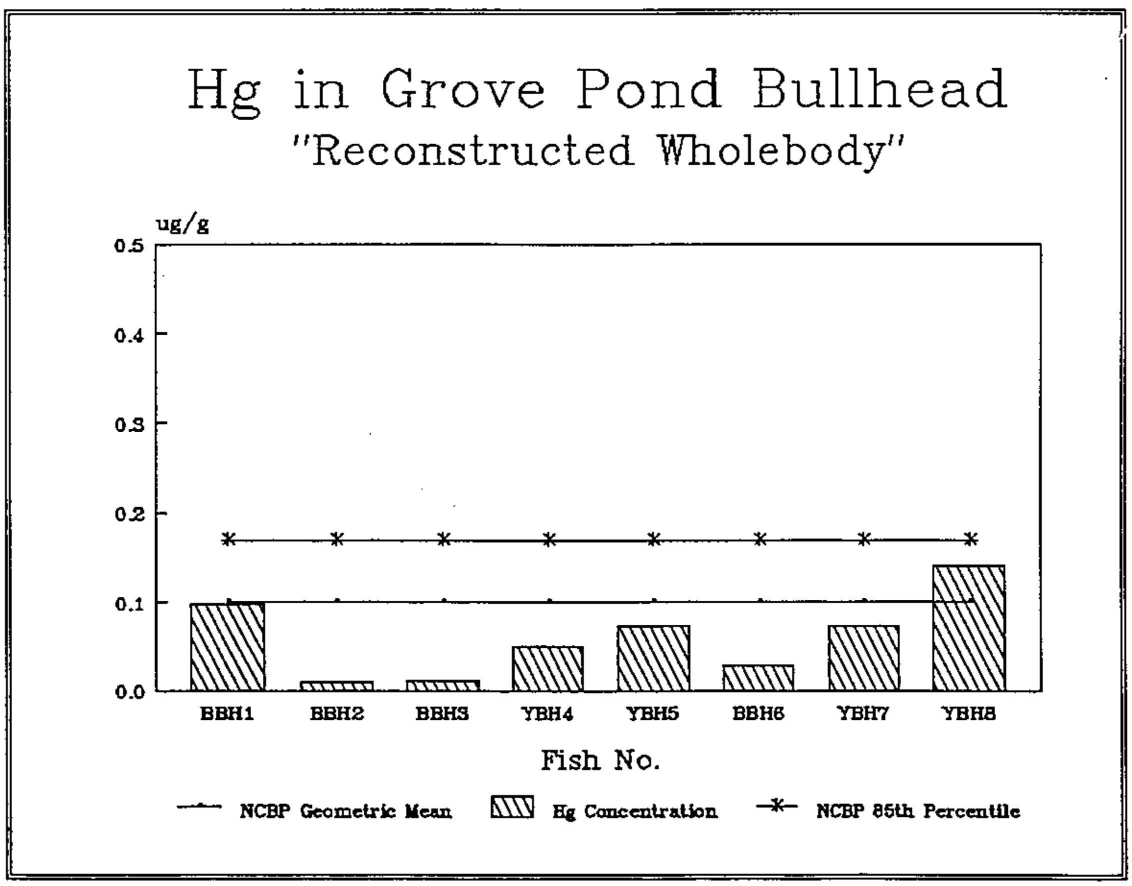
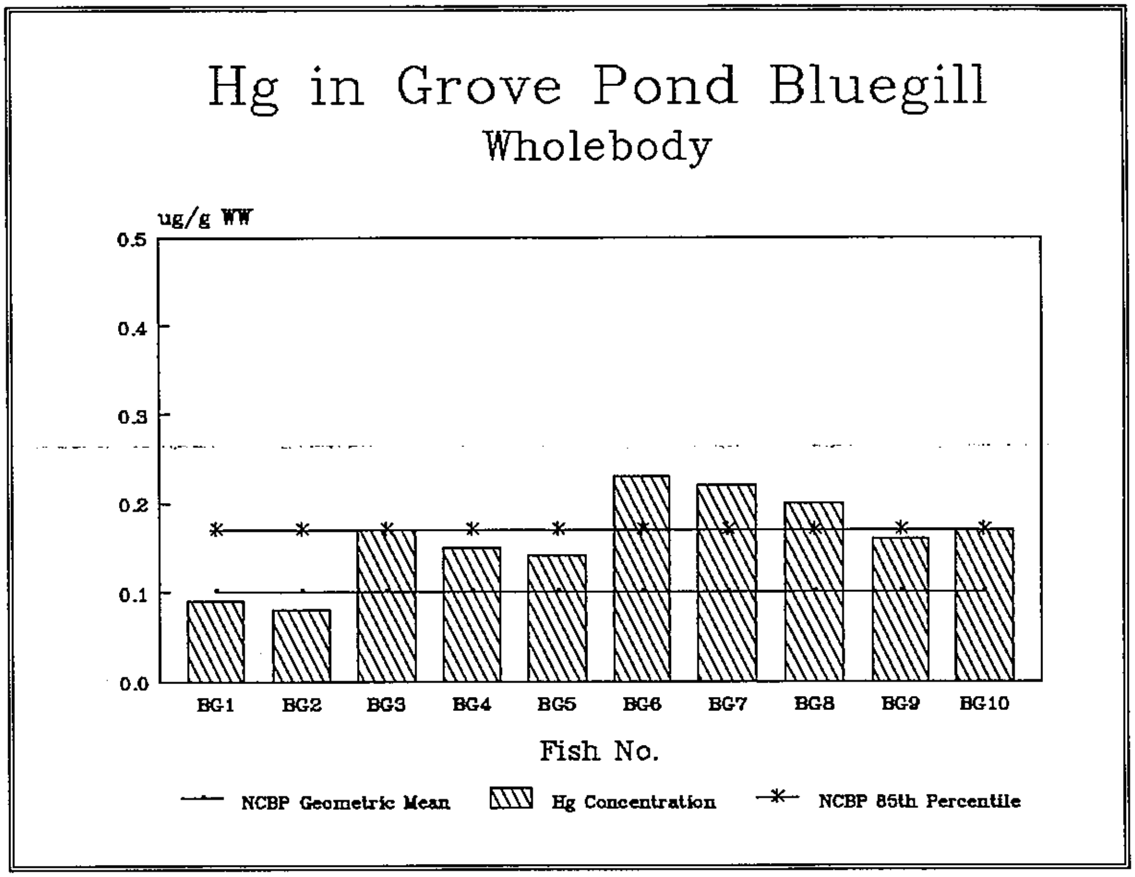


FIGURE 8



Hg in Grove Pond Bluegill
Wholebody
ug/g WW
0.5
0.4
0.3
0.2
0.1
0.0
BG1
BG2
BG3
BG4
BG5
BG6
BG7
BG8
BG9
BG10
Fish No.
NCBP Geometric Mean
Hg Concentration
NCBP 85th Percentile

TABLES

NOTES FOR TABLES 2-12

Species code: LmB - largemouth bass, BH - bullhead (brown and yellow combined), BBH - brown bullhead, YBH - yellow bullhead, BG - bluegill

nd = non detect

nc = not calculated

When non-detects were included in the determination of the geometric mean, one-half of the sample detection limit (trace elements) or one-half the method detection limit (PCBs and OCs) were used in the computation.

Table 2. Identification number, length, and weight by species of individual fish collected from Grove Pond, Ayer, Massachusetts, September 25, 1993.

Species	Sample ID No.	Total Lgth (cm)	Weight (g) Total	Weight (g) Fillet	Sex	Age
Largemouth Bass						
	LmB1	53.5	2847	334	F	X+
	LmB2	45	1550	180	M	IX+
	LmB3	42	1100	141	F	VI+
	LmB4	40	930	148	M	V+
	LmB5	34.5	640	99	M	IV+
	LmB6	37.5	650	101	F	IV+
	LmB7	38	690	101	F	V+
	LmB8	36.5	520	94	M	IV+
	LmB9	35	430	70	M	VI+
	LmB10	31	320	56	F	IV+
Brown Bullhead						
	BBH1	33	430	52		
	BBH2	32	463	47		
	BBH3	32	538	44		
	BBH6	27	245	22		
Yellow Bullhead						
	YBH4	20	85	14[1]		
	YBH5	19.5	93	13[1]		
	YBH7	24	177	22[1]		
	YBH8	19.7	95	14		
Bluegill						
	BG1	17	109			
	BG2	19	145			
	BG3	20.5	147			
	BG4	19	134			
	BG5	19	131			
	BG6	19.5	147			
	BG7	19.5	131			
	BG8	19	128			
	BG9	20.5	153			
	BG10	18.5	108			

[1] Includes both fillets

Table 3. Trace element geometric mean concentrations and ranges for Grove Pond largemouth bass and bullhead reconstructed wholebody samples and bluegill wholebody samples compared to the NCBP geometric mean and 85th percentile, ug/g WW.

Species	Element	Grove Pond		NCBP	
		$\bar{x}_G$	Range	$\bar{x}_G$	85th
LmB	Cd	0.05	0.03-0.88	0.03	0.05
	Cu	0.46	0.29-1.05	0.65	1.00
	Hg	0.32	0.10-1.13	0.10	0.17
	Pb	0.38	0.14-4.32	0.11	0.22
	Se	0.32	0.22-0.51	0.42	0.73
	Zn	12.81	11.0-16.4	21.7	34.2
BH	Cd	0.04	0.01-0.19	0.03	0.05
	Cu	0.68	0.50-1.27	0.65	1.00
	Hg	0.04	0.01-0.14	0.10	0.17
	Pb	0.42	0.18-1.12	0.11	0.22
	Se	0.23	0.13-0.39	0.42	0.73
	Zn	13.17	10.0-20.5	21.7	34.2
BG	Cd	0.09	0.05-0.24	0.03	0.05
	Cu	0.58	0.37-0.79	0.65	1.00
	Hg	0.16	0.08-0.24	0.10	0.17
	Pb	0.48	0.16-1.38	0.11	0.22
	Se	0.33	0.27-0.38	0.42	0.73
	Zn	21.3	16.7-26.3	21.7	34.2

Table 4. Total PCB and DDT metabolite geometric mean concentrations and ranges for Grove Pond largemouth bass and bullhead reconstructed wholebody samples and bluegill wholebody samples compared to the NCBP geometric mean, ug/g WW.

Species	Compound	Grove Pond		NCBP
		$\overline{x}_G$	Range	$\overline{x}_G$
LmB	PCBs	0.22	0.10-0.43	0.39
	p,p'DDD	0.05	0.02-0.11	0.06
	p,p'DDE	0.12	0.05-0.25	0.19
BH	PCBs	nc	nd-0.12	0.39
	p,p'DDD	0.02	nd-0.05	0.06
	p,p'DDE	0.04	0.01-0.10	0.19
BG	PCBs	0.06	nd-0.21	0.39
	p,p'DDD	0.02	0.01-0.07	0.06
	p,p'DDE	0.05	0.02-0.13	0.19

Table 5. Trace element concentrations and geometric means in fillet samples of largemouth bass from Grove Pond, ug/g WW.

Fish No.	Cadmium	Chromium	Copper	Mercury	Nickel	Lead	Selenium	Zinc
LmB1	0.0108*	0.221	0.290	1.038	0.0543*	0.138	0.180	4.765
LmB2	0.0108*	0.386	0.260	0.667	0.0538*	0.0538*	0.159	4.843
LmB3	0.151	0.316	0.365	0.465	0.907	0.822	0.144	3.819
LmB4	0.145	0.488	0.354	0.446	0.736	0.859	0.147	4.916
LmB5	0.0105*	0.147	0.195	0.408	0.0527*	0.0527*	0.172	4.110
LmB6	0.0105*	0.144	0.338	0.386	0.0527*	0.0527*	0.144	4.801
LmB7	0.0104*	0.124	0.256	0.310	0.0521*	0.226	0.175	3.724
LmB8	0.033	0.186	0.111	0.387	0.303	0.501	0.136	5.095
LmB9	0.0098*	0.156	0.230	0.517	0.0489*	0.0489*	0.167	3.633
LmB10	0.0095*	0.261	0.428	0.332	0.0473*	0.0473*	0.142	4.664
$\bar{x}_G$	0.020	0.220	0.266	0.464	0.107	0.144	0.156	4.405

* Non-detect. Table value is one-half the sample detection limit.

Table 6. Trace element concentrations and geometric means in reconstructed wholebody samples of largemouth bass from Grove Pond, ug/g WW.

Fish No.	Cadmium	Chromium	Copper	Mercury	Nickel	Lead	Selenium	Zinc
LmB1	0.067*	0.462	0.409	1.132	0.067*	0.176	0.510	12.780
LmB2	0.013*	0.516	0.529	0.518	0.067*	0.232*	0.316	11.019
LmB3	0.045	0.516	0.337	0.357	0.239	0.283	0.317	12.536
LmB4	0.049	0.593	0.382	0.267	0.269	0.562	0.323	11.534
LmB5	0.012*	0.348	0.287	0.235	0.062*	0.175*	0.304	11.319
LmB6	0.030*	0.406	0.353	0.296	0.215*	0.244*	0.310	16.425
LmB7	0.875*	1.162	1.049	0.103	4.146*	4.322	0.330	12.125
LmB8	0.016*	0.377	0.385	0.265	0.106*	0.141*	0.289	13.613
LmB9	0.109*	0.524	0.462	0.302	0.540*	0.860*	0.225	12.541
LmB10	0.091	0.495	0.856	0.311	0.057*	0.475*	0.289	15.188
$\bar{x}_G$	0.050	0.509	0.463	0.316	0.187	0.384	0.315	12.810

* Non-detects within fillet and/or partial body samples. The values used for non-detects in reconstruction calculations were one-half the sample detection limit.

Table 7. Trace element concentrations and geometric means in fillet samples of bullhead from Grove Pond, ug/g WW.

Fish No.	Cadmium	Chromium	Copper	Mercury	Nickel	Lead	Selenium	Zinc
BBH1	0.0096*	0.155	0.149	0.055	0.0479*	0.0479*	0.0487*	5.26
BBH2	0.028	0.194	0.368	0.0089*	0.167	0.305	0.0445*	4.41
BBH3	0.0094*	0.133	0.296	0.0094*	0.0471*	0.0471*	0.0470*	3.94
BBH6	0.0088*	0.289	0.391	0.052	0.0441*	0.098	0.099	3.72
YBH4	0.0088*	0.258	0.346	0.082	0.218	0.0443*	0.160	4.34
YBH5	0.0080*	0.099	0.275	0.089	0.0398*	0.0398*	0.0401*	3.80
YBH7	0.0082*	0.410	0.341	0.067	0.092	0.0408*	0.149	7.95
YBH8	0.025	0.128	0.597	0.199	0.162	0.170	0.0423*	3.88
$\bar{X}_G$	0.012	0.188	0.324	0.047	0.082	0.073	0.067	4.52

* Non-detect. Table value is one-half the sample detection limit.

Table 8. Trace element concentrations and geometric means in reconstructed wholebody samples of bullhead from Grove Pond, ug/g WW.

Fish No.	Cadmium	Chromium	Copper	Mercury	Nickel	Lead	Selenium	Zinc
BBH1	0.186*	0.770	0.847	0.037	0.866*	1.123*	0.131*	11.106
BBH2	0.088	0.422	0.544	0.010*	0.472	0.649	0.233*	10.017
BBH3	0.031*	0.412	0.548	0.010*	0.141*	0.392*	0.186*	12.764
BBH6	0.011*	1.351	1.266	0.028	0.057*	0.242	0.251	12.613
YBH4	0.011*	0.466	0.505	0.051	0.085*	0.364*	0.389	20.504
YBH5	0.033*	0.291	0.661	0.074	0.099*	0.184*	0.202*	12.454
YBH7	0.168*	0.364	0.751	0.072	0.496	0.757*	0.232	13.125
YBH8	0.030	0.306	0.549	0.139	0.075	0.252	0.328*	15.118
$\bar{X}_G$	0.042	0.478	0.677	0.038	0.178	0.415	0.232	13.174

* Non-detects within fillet and/or partial body samples. The values used for non-detects in reconstruction calculations were one-half the sample detection limit.

Table 9. Trace element concentrations and geometric means in wholebody samples of bluegill from Grove Pond, ug/g WW.

Fish No.	Cadmium	Chromium	Copper	Mercury	Nickel	Lead	Selenium	Zinc
BG1	0.079	0.386	0.769	0.092	0.146	0.227	0.289	17.655
BG2	0.051	1.053	0.544	0.085	0.071*	0.279	0.376	16.692
BG3	0.132	0.770	0.598	0.169	0.450	1.102	0.357	22.298
BG4	0.057	0.730	0.788	0.149	0.177	0.454	0.358	20.969
BG5	0.050	0.727	0.370	0.144	0.058*	0.216	0.268	19.720
BG6	0.058	0.489	0.529	0.235	0.063*	0.346	0.336	24.930
BG7	0.113	0.526	0.521	0.216	0.071*	0.163	0.371	23.199
BG8	0.235	1.229	0.690	0.204	0.786	1.384	0.379	26.271
BG9	0.083	0.659	0.457	0.162	0.060*	0.897	0.296	23.806
BG10	0.182	0.782	0.732	0.166	0.801	1.214	0.316	20.275
$\bar{X}_G$	0.090	0.697	0.584	0.155	0.155	0.475	0.332	21.377

* Non-detect. Table value is one-half the sample detection limit.

Table 10. Total PCB, DDT metabolite concentrations and geometric means in fillet and reconstructed wholebody samples of largemouth bass from Grove Pond, ug/g WW.

Fish No.	Fillet				Reconstructed Wholebody			
	Total PCB	p,p' DDD	p,p' DDE	p,p' DDT	Total PCB	p,p' DDD	p,p' DDE	p,p' DDT
LmB 1	0.10	0.02	0.05	nd	0.35	0.09	0.20	nd
LmB 2	0.15	0.03	0.07	nd	0.43	0.09	0.25	nd
LmB 3	0.11	0.02	0.03	nd	0.21	0.06	0.13	nd
LmB 4	0.09	0.03	0.06	nd	0.37	0.11	0.17	nd
LmB 5	0.025*	0.01	0.01	nd	0.21**	0.07	0.12	nd
LmB 6	0.025*	0.005*	0.01	nd	0.16**	0.04**	0.09	nd
LmB 7	0.07	0.01	0.03	nd	0.37	0.05	0.13	nd
LmB 8	0.025*	0.005*	0.01	nd	0.17**	0.03**	0.09	nd
LmB 9	0.025*	0.005*	0.01	nd	0.10**	0.02**	0.05	nd
LmB 10	0.025*	0.01	0.01	nd	0.13**	0.03	0.05	nd
$\overline{x}_G$	0.05	0.01	0.02		0.22	0.05	0.12	

* Non-detect. Table value is one-half the method detection limit

** Reconstruction calculations include non-detects in fillet.

Table 11. Total PCB, DDT metabolite concentations and geometric means in fillet and reconstructed wholebody samples of bullhead from Grove Pond, ug/g WW.

Fish No.	Fillet				Reconstructed Wholebody			
	Total PCB	p,p' DDD	p,p' DDE	p,p' DDT	Total PCB	p,p' DDD	p,p' DDE	p,p' DDT
BBH 1	nd	0.01	0.01	nd	nd	0.02	0.04	nd
BBH 2	nd	0.005*	0.005*	nd	nd	0.02**	0.02**	nd
BBH 3	nd	0.005*	0.01	nd	nd	0.02**	0.03	nd
BBH 6	nd	0.005*	0.01	nd	nd	0.03**	0.04	nd
YBH 4	nd	0.005*	0.005*	nd	nd	0.05**	0.05**	nd
YBH 5	nd	nd	0.01	nd	nd	nd	0.01	nd
YBH 7	0.025*	0.02	0.04	nd	0.12**	0.03	0.06	nd
YBH 8	0.025*	0.005*	0.005*	nd	0.08**	0.02**	0.10**	nd
$\bar{x}_G$			0.01			0.02[1]	0.04	

* Non-detect. Table value is one-half the method detection limit.
** Reconstruction calculations include non-detects in fillet.

Reconstruction was not performed if fillet and partial body samples were non-detects.

[1] YBH5 not included in calculation of geometric mean (i.e., n=7).

Table 12. Total PCB, DDT metabolite concentrations and geometric means in wholebody samples of bluegill from Grove Pond, ug/g WW.

Fish No.	Total PCB	p,p' DDD	p,p' DDE	p,p' DDT
BG 1	0.025*	0.03	0.05	nd
BG 2	0.21	0.07	0.13	nd
BG 3	0.15	0.01	0.07	nd
BG 4	0.16	0.03	0.11	nd
BG 5	0.025*	0.01	0.02	nd
BG 6	0.09	0.03	0.05	nd
BG 7	0.14	0.06	0.08	nd
BG 8	0.025*	0.01	0.02	nd
BG 9	0.025*	0.01	0.02	nd
BG 10	0.025*	0.02	0.03	nd
$\overline{x}_G$	0.06	0.02	0.05	nc

* Non-detect. Table value is one-half the method detection limit.

APPENDIX A

LABORATORY ANALYTICAL METHODS USED BY THE RESEARCH TRIANGLE INSTITUTE (TRACE ELEMENTS) AND THE MISSISSIPPI STATE CHEMICAL LABORATORY (ORGANOCHLORINES).

ANALYTICAL METHODS

Method Code	Method Description
001	LABORATORY: Research Triangle Institute
	I. Homogenization. Tissue samples are prehomogenized using a food processor. A portion of the tissue sample (or sediment) is then freeze dried for determination of moisture content and ground to 100 mesh with a mill.
002	LABORATORY: Research Triangle Institute
	II. Preconcentration Digestion for Inductively Coupled Plasma Emission (ICP) Measurement. Using a CEM microwave oven, 0.5 g of freeze dried tissue is heated in a capped 120 mL Teflon vessel in the presence of 5 mL of Baker Instra-Analyzed nitric acid for three minutes at 120 watts, three minutes at 300 watts, and 35 minutes at 450 watts. The vessel contents are then allowed to cool and the cap is removed and rinsed carefully with 3 ml of HNO_3 adding the rinsings to the vessels contents. The uncapped vessel is then returned to the microwave oven and heated until the vessel contents are less than 1 mL in volume. The contents are carefully rinsed with laboratory pure water into a 5 ml glass volumetric vessel and made to volume with additional laboratory pure water. The flask contents are then immediately transferred to a clean plastic centrigure or auto sampler tube and centrifuged for 1 minute to precipitate the suspended matter. The sample is now ready for ICP analysis.
004	LABORATORY: Research Triangle Institute
	IV. Digestion for Graphite Furnace and Cold Vapor Atomic Absorption (GFAA) Measurement. Using a CEM microwave oven, 0.25 to 0.5 g of freeze dried sample is heated in a capped 120 ml Teflon vessel in the presence of 5 ml of Baker Instra-Analyzed nitric acid for three minutes at 120 watts, three minutes at 300 watts, and fifteen minutes at 450 watts. The residue is then diluted to 50 ml with laboratory pure water.

ANALYTICAL METHODS (Cont.)

Method Code	Method Description
006	LABORATORY: Research Triangle Institute VI. ICP. ICP measurements are made using a Leeman Labs Plasma Spec I sequential or ES2000 simultaneous spectrometer.
007	LABORATORY: Research Triangle Institute VII. Graphite Furnace Atomic Absorption (GFAA). GFAA measurements are made using a Perkin-Elmer Zeeman 3030 or 4100ZL atomic absorption spectrometer.
008	LABORATORY: Research Triangle Institute VIII. Cold Vapor Atomic Absorption (CVAA). Hg measurements are conducted using SnCl4 as the reducing agent. A Leeman PS200 Hg Analyzer is employed.

Method 1. <u>Analysis For Organochlorine Pesticides and PCBs In Animal and Plant Tissue.</u>

Ten gram tissue samples are thoroughly mixed with anhydrous sodium sulfate and soxhlet extracted with hexane for seven hours. The extract is concentrated by rotary evaporation; transferred to a tared test tube, and further concentrated to dryness for lipid determination. The weighed lipid sample is dissolved in petroleum ether and extracted four times with acetonitrile saturated with petroleum ether. Residues are partitioned into petroleum ether which is washed, concentrated, and transferred to a glass chromatographic column containing 20 grams of Florisil. The column is eluted with 200 ml 6% diethyl ether/94% petroleum ether (Fraction I) followed by 200 ml 15% diethyl ether/85% petroleum ether (Fraction II). Fraction II is concentrated to appropriate volume for quantification of residues by packed or capillary column electron capture gas chromatography. Fraction I is concentrated and transferred to a Silicic acid chromatographic column for additional cleanup required for separation of PCBs from other organochlorines. Three fractions are eluted from the silicic acid column. Each is concentrated to appropriate volume for quantification of residues by packed or megabore column, electron capture gas chromatography. PCBs are found in Fraction II.

Elution Profiles for Florisil, Silica Gel and Silicic Acid Column Separations

A. Florisil Column:

1. <u>Fraction I</u> (6% ethyl ether containing 2% ethanol, 94% petroleum ether)
   HCB, alpha-BHC, beta-BHC, gamma-BHC, delta-BHC, oxychlordane, heptachlor epoxide, gamma-chlordane, trans-nonachlor, toxaphene, PCB's, o,p'-DDE, alpha-Chlordane, p,p'-DDE, p,p'-DDT, cis-nonachlor, o,p'-DDT, p,p'-DDD, p,p'-DDT, mirex, dicofol, endosulfan I (Split with FII).
2. <u>Fraction II</u> (15% ethyl ether containing 2% ethanol, 85% petroleum ether)
   dieldrin, endrin, dacthal, endosulfan I (split with FI), endosulfan II (split with FIII), endosulfan sulfate (split with FIII).
3. <u>Fraction III</u> (50% ethyl ether containing 2% ethanol, 50% petroleum ether)
   endosulfan II (split with FII), endosulfan sulfate (split with FII), malathion.

B. Florisil Mini-Column:

1. Fraction I (12 ml hexane followed by 12 ml 1% methanol in hexane)
   HCB, gamma-BHC (25%), alpha-BHC (splits with FII), trans-nonachlor, o,p'-DDE, p,p'-DDE, o,p'-DDD, p,p'-DDD (splits with FII), o,p'-DDT, p,p'-DDT, mirex, cis-nonachlor, cis-chlordane, trans-chlordane, PCB's, Photomirex and derivatives.

2. Fraction II (24 ml 1% methanol in hexane)
   gamma BHC (75%), beta-BHC, alpha-BHC (splits with FI), delta-BHC, oxychlordane, heptachlor epoxide, toxaphene, dicofol, dacthal, endosulfan I, endosulfan II, endosulfan sulfate, octachlorostyrene, Kepone (with additional 12mls 1% methanol in hexane).

C. Silica Gel:

1. SG Fraction I (100 ml petroleum ether)
   n-dodecane, n-tridecane, n-tetradecane, ocylcyclohexane, n-pentadecane, nonycyclohexane, n-hexadecane, n-heptadecane, pristane, n-octadecane, phytane, n-nonadecane, n-eicosane.

2. SG Fraction II (100 ml 40% methylene chloride in petroleum ether followed by 50 ml methylene chloride)
   napthalene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, 1,2-benzanthracene, chrysene, benzo [b] fluoranthene, benzo [k] fluoranthene, benzo [e] pyrene, benzo [a] pyrene, 1,2:5,6-dibenzanthracene, benzo [g,h,i] perylene.

D. Silicic Acid:

1. SA Fraction I (20 ml petroleum ether)

   HCB, mirex

2. SA Fraction II (100ml petroleum ether)

   PCB's, p,p'-DDE (splits with SA III)

3. SA Fraction III (20 ml mixed solvent: 1% acetonitrile, 80% methylene chloride, 19% hexane)

   alpha-BHC, beta-BHC, gamma-BHC, delta-BHC, oxychlordane, heptachlor epoxide, gamma-chlordane, trans-chlordane, toxaphene, o,p'-DDE, alpha-chlordane, p,p'-DDE (splits with SAII), o,p'-DDT, cis-nonachlor, o,p'-DDT, p,p'-DDD, p,p'-DDT, dicofol.

APPENDIX B

TRACE ELEMENT ANALYTICAL RESULTS
RESEARCH TRIANGLE INSTITUTE

NOTE: Wholebody samples listed for bass and bullhead, were actually partial body samples (i.e., minus one fillet for bass or minus one or two fillets for bullhead).

Laboratory data only provided to principal regulatory agencies. Laboratory data is available upon request from:

U.S. Fish and Wildlife Service
1033 South Main Street
Old Town, ME 04468
(207) 827-5938

APPENDIX C

ORGANOCHLORINE ANALYTICAL RESULTS
MISSISSIPPI STATE CHEMICAL LABORATORY

NOTE: Wholebody samples listed for bass and bullhead, were actually partial body samples (i.e., minus one fillet for bass or minus one or two fillets for bullhead).

Laboratory data only provided to principal regulatory agencies. Laboratory data is available upon request from:

U.S. Fish and Wildlife Service
1033 South Main Street
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