U.S. FISH AND WILDLIFE SERVICE
NEW ENGLAND FIELD OFFICE
SPECIAL PROJECT REPORT: FY97-MEFO-3-EC

ENVIRONMENTAL CONTAMINANTS IN FISH FROM MERE BROOK

U.S. NAVAL AIR STATION BRUNSWICK, MAINE

FEBRUARY 1997

MISSION

U.S. FISH AND WILDLIFE SERVICE

To conserve, protect, and enhance the nation's fish and wildlife and their habitats for the continuing benefit of the American people

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U.S. Naval Air Station Brunswick, Maine

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February 1997

EXECUTIVE SUMMARY

Mere Brook bisects three former landfills at the U.S. Naval Air Station in Brunswick, Maine (NASB). Leachate, soil, and sediment analyzed during Superfund remedial investigations at the sites contained elevated levels of mercury and other environmental contaminants. At the request of the U.S. Environmental Protection Agency and the U.S. Navy, the U.S. Fish and Wildlife Service conducted a contaminant study of Mere Brook fish. The purposes of this study were:

1) to determine the levels of trace element and organochlorine contaminants in Mere Brook fish and,

2) to compare these levels with national, regional, and State data.

Two size classes of brook trout (*Salvelinus fontinalis*) were collected by electrofishing - adults (average length 15 centimeters (cm) or approximately 6 inches (in.)) and juveniles (average length 7 cm, approx. 2.75 in.) at two Mere Brook locations. The focus location was a stream reach bisecting the former landfills and the reference area was a stream reach west of the NASB runway. Mere Brook did not contain large fish. Fillets were not removed and all fish were analyzed whole-body. Most fish were pooled, based on size, to meet minimum laboratory analytical requirements. Thirteen pooled samples (7 adult, 6 juvenile) were submitted for analysis.

Chemical analyses indicate that, with the exception of copper, trace element concentrations were not elevated in Mere Brook fish tissue. Although elevated, copper concentrations were not unique compared to regional data, and the levels in Mere Brook fish were not significantly different ($p > 0.05$) by size class or collection location. Site-specific differences ($p < 0.05$) by size class were found for three trace elements. Juvenile trout from the landfill site contained lower concentrations of chromium than juvenile trout from the reference area. Juveniles in the reference area, west of the NASB runway, contained higher levels of zinc than fish from the landfill location. Adult brook trout collected at the Mere Brook landfill location contained higher concentrations of mercury than adults from the reference area.

In a scan of 19 organochlorine compounds, six were detected in fish tissue: *trans*-chlordane, *cis*-chlordane, dieldrin, 4,4'-DDE, 4,4'-DDD, and 4,4'-DDT. These organochlorines were markedly higher at the landfill location than the reference area, and occur at concentrations that may pose a risk to piscivorous ecological receptors.

PREFACE

This report describes the results of a study to measure trace element and organochlorine contaminants in fish collected from Mere Brook in Brunswick, Maine. Funding for this study was provided by Region 1 of the U.S. Environmental Protection Agency (EPA) and the U.S. Naval Air Station, Brunswick (NASB). The analytical work for this study was performed under U.S. Navy Military Interdepartmental Purchase Request Number V0006095MIPR0013 and within an interagency agreement between the U.S. Fish and Wildlife Service (USFWS) and EPA for technical assistance in the Superfund Program (EPA/IAG #DW14934248-01-F).

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

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ACKNOWLEDGEMENTS

Access to Mere Brook was facilitated by Jim Caruthers and Chief Warrant Officer John Bond of the NASB Environmental Office. John Boland of the Maine Department of Inland Fisheries and Wildlife provided technical support and assistance with obtaining a scientific collection permit. Electrofishing support was provided by the USFWS Office of Fisheries Assistance in Laconia, New Hampshire. Joseph McKeon, Everett McLaughlin, Tim Cipriani, Beth Rhinehart, and Dave Griesche of the Laconia office provided valuable logistical and technical support during fish sampling. Susan Svirsky (EPA/Region 1) and Dave McDonald (Lockheed/Environmental Services Assistance Team) also provided field support during the study. Thomas May and Jesse Arms (U.S. Geological Survey, Biological Resources Division) provided analytical support for this project. Drew Major (USFWS/New England Field Office) provided assistance on SYSTAT and statistical procedures. Bob Lim (EPA/Region 1) and CWO Bond (NASB) arranged funding for the study and provided administrative assistance.

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* The National Biological Service became the Biological Resources Division of the U.S. Geological Survey in October 1996.

INTRODUCTION

During Superfund remedial investigations of Sites 1, 2, and 3 at the U.S. Naval Air Station in Brunswick, Maine, trace element and organochlorine contaminants were detected in leachate, sediment, and soil samples. Mere Brook, the major drainage of NASB, bisects the waste disposal areas with Sites 1 and 3 situated north of the brook and Site 2 to the south. Site 1 was a landfill from 1955 to 1975 that received refuse, waste oil and other petroleum products, solvents, pesticides, paint wastes, automobile and aircraft parts, and various chemicals. Site 3 was a disposal area from 1960 to 1973 that also received solvents, paint, and isopropyl alcohol. Site 2 was the NASB primary landfill from 1945-1955. Wastes in the Site 2 landfill included oils, paints, waste fuel, paint strippers and solvents. Seeps and surface runoff from these sites may have entered the stream and exposed Mere Brook biota to a variety of contaminants. The potential for contaminant uptake by Mere Brook fish has been a concern of the U.S. Navy, State and federal regulatory agencies and the natural resource trustees. In 1995, the U.S. Navy and U.S. Environmental Protection Agency provided funds to the U.S. Fish and Wildlife Service to conduct a contaminant study in Mere Brook.

STUDY PURPOSE

The purpose of the study was to determine the concentrations of mercury, other trace elements, and organochlorine contaminants in Mere Brook fish, and to put those concentrations into context with national, regional, and State data.

STUDY AREA

This study was conducted at the U.S. Naval Air Station in Brunswick (NASB), Cumberland County, Maine. NASB is in the village of Brunswick approximately 3.2 kilometers (2 mi.) east of the Town of Brunswick. Brunswick is located in southern Maine, approximately 42 kilometers (26 mi.) northeast of Portland, Maine's largest city (Figure 1). NASB is an active U.S. Navy installation supporting antisubmarine warfare operations.

Mere Brook is the major drainage of NASB. The brook bisects the installation, and traverses under the NASB runway through culverts for approximately 1 kilometer (0.6 mi.). The focus reach (length approx. 0.6 km (0.4 mi.)) was the portion of Mere Brook bisecting the NASB landfills. The NASB weapons compound is also adjacent to the focus reach. The reference area for this study was a similar length section of Mere Brook west of the NASB runway. Fish species in Mere Brook include brook trout (*Salvelinus fontinalis*), American eel (*Anguilla rostrata*), blacknose dace (*Rhinichthys atratulus*), and stickleback (Gasterosteidae). The stream channel near the landfills is generally shallow ($\leq$ 1 meter (3 ft.)) with widths of 1 to 2 meters (3 to 6.5 ft.). At the reference reach, the stream characteristics are similar, but the substrate is slightly firmer with more gravel. The maximum stream width is greater at the reference area than the landfill reach. Vegetative cover is similar at both sites, with generally more canopy cover at the reference location. The dominant canopy cover at both locations is comprised of white pine (*Pinus strobus*), hemlock (*Tsuga canadensis*), red oak (*Quercus rubra*), red

maple (*Acer rubrum*), and bigtooth aspen (*Populus grandidentata*). The stream banks supports skunk cabbage (*Symplocarpus foetidus*), moss (*Sphagnum* spp.), grasses (*Gramineae*), sedges (*Carex* spp.), goldenrod (*Solidago* spp.), broad-leaved cattail (*Typha latifolia*), wool grass (*Scirpus cyperinus*), nightshade (*Solanum dulcamara*), and jewelweed (*Impatiens capensis*).

An assumption in this study was that fish would not move through the culverts under the runway, and the population on the western edge of the runway would not be exposed to contaminants associated with the landfill on the eastern side of the runway. Water velocities and passage length are factors preventing passage through culverts. Belford and Gould (1989) found that spawning brook trout did not pass through 45-meter culverts with mean bottom velocities of 0.75 m/s. The length of the Mere Brook culverts (1000 m) between the focus location and reference area of this study likely precluded fish movement. However, complete separation of the populations is unlikely and downstream displacement of some fish to the eastern (landfill) reach may occur under flooding conditions.

METHODS

Fish were collected from Mere Brook with backpack electrofishing gear on July 24, 1995. Surface water temperature and conductivity were 21° C (70° F) and 106 µmhos/cm (uncompensated), respectively, at both locations during sampling. One hundred thirty eight brook trout were collected from two size classes - 18 fish averaging 15.3 cm (6 in.) and 120 fish averaging 7.1 cm (2.75 in.) in length. Several fingerling trout were collected because they were present in numbers and would represent the prey most likely consumed by piscivorous predators (e.g., green heron *Butorides striatus* or belted kingfisher *Ceryle alcyon*) at Mere Brook. Moreover, a minimum gram weight was required to obtain usable information in contaminant analyses.

The maximum total length in centimeters (± 0.5) was measured for each fish. Adult brook trout (15 cm) were weighed individually to the nearest gram. Composite samples of fingerling (7 cm) trout were weighed to the nearest gram, but juvenile fish were not weighed individually (Table 1). Prior to processing, each fish was examined for external abnormalities. Whole-body samples were wrapped in aluminum foil (dull side towards sample), labelled, and placed in plastic freezer bags. Samples were immediately placed on dry ice in coolers and transported to freezers for storage at 20° C within hours. Thirteen composite samples (7 of adult fish, 6 of juvenile fish) were submitted for contaminant analysis (Table 2). Growth rates of brook trout in Maine vary considerably due to habitat type, susceptibility to predation or angling, water quality, and genetics. Large (15 cm) and small (7 cm) fish are referred to as adults and juveniles, respectively, in portions of this report. Fish in this study were not aged, and we recognize the potential inaccuracies associated with our classification of adults and juveniles based on size class.

RESULTS OF CHEMICAL ANALYSES

All fish tissue samples (n=13) were analyzed for mercury, other trace elements, organochlorine pesticides, Aroclor-specific polychlorinated biphenyls (PCBs), percent moisture and percent lipid. Trace element analyses were performed by the U.S. Geological Survey Biological Resources Division's Midwest Science Center (MSC), in Columbia, Missouri (Appendix A). The trace element analytical results were reported by the MSC in µg/g, dry weight. Trace element data are presented throughout this report in µg/g (ppm), **wet weight**. The equation for conversion of dry weight to wet weight was $Conc_{WW} = Conc_{DW} * (1- (\%H_2O/100))$. Organochlorine pesticide and PCB (Aroclor-specific) analyses were conducted by ABC Laboratories (Appendix B) in Madera, California, and reported as µg/kg (ppb), wet weight. To facilitate comparisons with other data, and to maintain consistency in the report, the organochlorine data were converted from µg/kg (ppb) to **µg/g** (ppm), wet weight.

Quality Control

Quality control was accomplished through instrument calibration verification, replicate analyses, spike recoveries, and analysis of standard reference materials. Quality control results were considered within acceptable limits of the Midwest Science Center (Appendices A and B).

Statistical analyses

Statistical analyses were performed with SYSTAT 6.0 for Windows (SPSS 1996). Summary statistics include arithmetic mean, ranges, and standard error. For each contaminant, differences were tested with a two-sample t test grouped by size class or location. All statements of significance refer to $\alpha \leq 0.05$.

Trace Elements

The trace element analyses included arsenic, beryllium, cadmium, chromium, copper, mercury, nickel, lead, antimony, selenium, strontium, vanadium and zinc (Appendix A). Beryllium and antimony were not detected in fish tissue. Although, strontium and vanadium are included in the routine MSC trace element analyses, these two elements are rarely of ecological concern in New England and consequently are not discussed in this report.

Figures 2 and 3 illustrate trace element concentrations in adult and juvenile brook trout, respectively. Table 3 lists trace element detections in all fish (size classes combined) by location. Table 4 (adults) and Table 5 (juveniles) separate trace element detections by size class and location.

Arsenic (As) - Arsenic was detected in all samples. The mean As concentrations of all fish (size classes combined) from the landfill site and reference area were identical at 0.03 µg/g. The mean As concentration in adult brook trout from the landfill site was 0.02 µg/g, while the mean concentration in

adults at the reference area appeared slightly higher at 0.03 μg/g. The mean As concentration for juveniles was 0.04 μg/g at both locations. There was no significant difference in As concentrations by size class or location.

Cadmium (Cd) - Cadmium was detected in all samples. The mean Cd concentration of all fish (size classes combined) from the landfill site (0.03 μg/g) appeared slightly lower than the reference location (0.04 μg/g). Mean Cd concentrations in adult brook trout was 0.20 μg/g at the landfill site and 0.03 μg/g at the reference location. The mean Cd concentration in juveniles was 0.04 μg/g at the landfill and reference locations. There was no significant difference in Cd concentrations by size class or location.

Chromium (Cr) - Chromium was detected in all samples. The mean Cr concentration of all fish (size classes combined) from the landfill site was 0.24 μg/g, while at the reference location the mean concentration was 0.40 μg/g. The difference was not statistically significant. The mean Cr concentration in adult brook trout from the landfill (0.31 μg/g) was not significantly different from the reference location (0.28 μg/g). Mean chromium concentrations in juveniles were significantly higher in the reference area (0.57 μg/g) than the landfill site (0.18 μg/g).

Copper (Cu) - Copper was detected in all samples. The mean Cu concentration of all fish (size classes combined) from the landfill site was 1.79 μg/g and the mean at the reference location was 1.43 μg/g. The difference was not statistically significant. Although the mean Cu concentration in adults from the landfill location appears higher (2.14 μg/g) than the reference location (1.49 μg/g), the difference is not significant. Similarly, mean Cu concentrations in juveniles from the landfill (1.44 μg/g) and reference location (1.33 μg/g) are not significantly different.

Mercury (Hg) - Mercury was detected in all samples. The mean Hg concentration of all fish (size classes combined) from the landfill site (0.09 μg/g) was significantly higher than the mean from the reference location (0.05 μg/g). The mean Hg concentration in adults was significantly higher at the landfill site (0.12 μg/g) than the reference area (0.06 μg/g). The mean Hg concentration in juveniles from the landfill (0.06 μg/g) was not significantly different from the reference location (0.04 μg/g).

Nickel (Ni) - Nickel was detected in only four of the 13 samples; one adult and three samples of juveniles. The one Ni detection in adults was 0.10 μg/g, and the range in the three juvenile samples was 0.09 to 0.26 μg/g. The one detection in adults was from the landfill location sample. Nickel was not detected in the four reference area adult samples. The Ni concentration in one juvenile sample from the landfill site was the highest (0.26 μg/g) detected. The mean Ni concentration of the two juvenile samples from the reference area was 0.11 μg/g.

Lead (Pb) - Lead was detected in 11 of 13 samples. Lead was not detected in one adult and one juvenile sample from the landfill location. Since Pb was detected in more than half of the samples from the landfill location, one-half the method detection limit was used for non-detects to compute the mean. The mean Pb concentration of all fish (size classes combined) from the landfill site (0.05 µg/g) was significantly lower than the mean for all fish from the reference location (0.09 µg/g). When Pb was evaluated by size class (where n, or the sample size was smaller), location-specific significant differences were not found. In adults, the mean Pb concentration at the reference location was 0.10 µg/g and 0.05 µg/g at the landfill site. Juvenile concentrations were similar to adults. At the landfill the mean Pb concentration was 0.04 µg/g, while at the reference location juveniles contained 0.09 µg/g.

Selenium (Se) - Selenium was detected in all samples. The mean Se concentration of all fish (size classes combined) from the landfill site was 0.57 µg/g and appeared slightly lower than the mean Se concentration at the reference area (0.59 µg/g). The difference was not statistically significant. Mean Se concentrations in adults appeared higher at the reference location (0.57 µg/g) than the landfill site (0.48 µg/g), but the difference was also not significant. Mean Se concentrations in juveniles were similar at the landfill site (0.65 µg/g) and the reference location (0.61 µg/g).

Zinc (Zn) - Zinc was detected in all samples. The mean Zn concentration of all fish (size classes combined) from the landfill site was 24.05 µg/g. At the reference location, the mean Zn concentration for all fish was slightly higher at 24.48 µg/g. There was no significant difference between the means for all fish by location. Mean Zn concentrations in adults were similar at the landfill (22.58 µg/g) and reference locations (22.11 µg/g). However, mean Zn concentrations in juveniles were significantly higher at the reference area (27.65 µg/g) than the landfill location (25.52 µg/g).

Organochlorines

The organochlorine analysis included nineteen compounds (Appendix B). Six organochlorines were detected in Mere Brook fish: *trans*-chlordane (referred to as gamma-chlordane in the ABC Laboratories report), *cis*-chlordane (referred to as alpha-chlordane in the ABC Laboratories report), dieldrin, and 3 DDT metabolites (4,4'-DDE, 4,4'-DDD, 4,4'-DDT). Organochlorines not detected in Mere Brook fish were: alpha-BHC (hexachlorocyclohexane), gamma-BHC, beta-BHC, heptachlor, delta-BHC, aldrin, heptachlor epoxide, endosulfan I, endrin, endosulfan II, endrin aldehyde, endosulfan sulfate, methoxychlor, endrin ketone, and toxaphene. Polychlorinated biphenyls (PCBs, including the Aroclors 1016, 1221, 1232, 1242, 1248, 1254, and 1260) were also not detected.

When organochlorines were detected in Mere Brook fish, concentrations were higher in fish collected adjacent to the landfill than at the reference location. Figures 4 and 5 illustrate organochlorine concentrations in adult and juvenile brook trout, respectively. Table 6 lists the organochlorines detected in all fish (size classes combined) by location. Table 7 (adults) and Table 8 (juveniles) separate organochlorine detections by size class and location.

Chlordane (*cis*, *trans*, and Σ) - Chlordane was detected in six of the 13 samples, all from the landfill site. Chlordane was not detected at the reference area. Two chlordane compounds were detected - *trans* and *cis*. *Cis*-chlordane was detected in six samples, three adults (mean 0.166 µg/g) and three juveniles (0.032 µg/g), all from the landfill location. *Trans*-chlordane was detected in only three samples, all adults (mean 0.027 µg/g) and from the landfill location. *Trans*-chlordane was not detected in juvenile tissue samples from the reference location or landfill reach.

ΣChlordane is the sum of *cis*- and *trans*-chlordane. The ΣChlordane concentration of all fish from the landfill site was 0.112 µg/g. When separated by size class, the mean ΣChlordane concentrations were 0.193 µg/g in adults and 0.032 µg/g in juveniles.

Dieldrin - Dieldrin was detected in four of the 13 samples, all from the landfill location. Since dieldrin was detected in more than half of the samples from the landfill location, one-half the sample detection limit was used for non-detects to compute the mean for all fish (size classes combined). The mean dieldrin concentration for all fish from the landfill site was 0.042 µg/g. When separated by size class, the mean dieldrin concentration in adults, all from the landfill location, was 0.070 µg/g. In the single juvenile sample, also from the landfill site, the dieldrin concentration was 0.020 µg/g. Dieldrin was not detected in adult or juvenile brook trout samples from the reference location.

DDT metabolites - DDT metabolites detected in the organochlorine analyses included 4,4'-DDE, 4,4'-DDD, and 4,4'-DDT. DDE and DDD were detected in all samples, and DDT was detected in 11 samples.

The mean DDE concentrations for all fish (size classes combined) were 0.091 µg/g at the landfill location and 0.043 µg/g at the reference site. DDE was significantly higher in fish (size classes combined) from the landfill site than fish from the reference area. The mean DDE concentration was 0.092 µg/g in adults from the landfill site and 0.044 µg/g in adults from the reference area. Mean DDE concentrations in adults were not significantly different by location. In juveniles, the mean DDE concentrations were 0.091 µg/g (landfill) and 0.042 µg/g (reference). DDE was significantly higher in juveniles from the landfill location than juveniles from the reference area.

The mean DDD concentrations for all fish (size classes combined) were 0.059 µg/g at the landfill location and 0.049 µg/g at the reference location. There was no significant difference in DDD concentrations for all fish by location. In adults, DDD appears higher at the landfill location (0.077 µg/g) than the reference area (0.048 µg/g), but the difference was not statistically significant. The mean DDD concentration in juveniles from the reference area (0.051 µg/g) appeared higher than the landfill location (0.041 µg/g), but the difference was not significant.

DDT was detected in 11 samples - in all samples from the landfill and in five samples from the reference area. Since DDT was detected in more than half of the samples from the reference area, one-half the sample detection limit was used for non-detects to compute the mean for all fish (size classes combined). The mean DDT concentration for all fish from the landfill area was 0.122 μg/g and 0.026 μg/g from the reference area. For all fish (size classes combined), DDT was significantly higher at the landfill location than the reference area. The mean DDT concentration in adults was 0.177 μg/g at the landfill location. Since only half the adult samples from the reference area had detectable concentrations of DDT, a mean was not calculated. The concentrations in the two adult samples from the reference area were 0.029 μg/g and 0.027 μg/g. DDT was detected in all juvenile samples. At the landfill location the mean DDT concentration was 0.066 μg/g, while at the reference site the mean DDT concentration was 0.036 μg/g. DDT was significantly higher in juveniles from the landfill location than the reference site.

DDT metabolites were summed to determine ΣDDT. The mean ΣDDT for all fish (size classes combined) was 0.272 μg/g at the landfill site and 0.119 μg/g at the reference location. In this category, ΣDDT was significantly higher at the landfill site than the reference location. However, when ΣDDT was evaluated by size class (where n, or the sample size, was smaller), location-specific significant differences were not found. In adults, the mean ΣDDT concentration was 0.346 μg/g at the landfill site and 0.106 μg/g at the reference location, but the difference was not statistically significant. The mean ΣDDT concentrations for juveniles were 0.198 μg/g (landfill) and 0.129 μg/g (reference), and the difference was not significant.

DISCUSSION

In this section, brief notes on the characteristics of each contaminant are presented. Next, the concentrations of each contaminant detected in Mere Brook fish are placed in context with the reference area and with data from national, regional, or State sources, or levels reported in the scientific literature. In some instances, the potential effect of the contaminant burden to fish is also briefly discussed. Finally, the potential risk the tissue contaminant level may have on consumers (i.e., piscivores) of Mere Brook fish is *qualitatively* noted.

Mere Brook fish concentrations were compared against several data sources. National mean levels of trace elements and organochlorines were reported in the U.S. Fish and Wildlife Service's National Contaminant Biomonitoring Program (NCBP; Schmitt and Brumbaugh 1990, Schmitt *et al*. 1990). The NCBP tracks temporal and geographic trends in contaminant 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 the NCBP results extensively for comparative purposes and recognize the limitations associated with the data set.

Regional sources include data from Massachusetts, Connecticut, and New Hampshire (USFWS, unpublished data). State data sets include mercury results reported by Stafford (1994), studies reported in the scientific literature (Friant 1979, Haines 1983), and data compiled by the Maine Department of

Environmental Protection (DiFranco *et al*. 1995, Sowles *et al*. 1996). Contaminant concentrations in fish collected from highly contaminated sites were located in the scientific literature and were used to illustrate highly elevated values. Contaminant concentrations reported on a dry weight basis in any of these sources were converted to wet weight based on 75% moisture. The values reported in these various studies include many different species and sizes, fillet and whole-body concentrations, and fish collected from contaminated and uncontaminated sites. Some contaminants accumulate in axial muscle tissue (e.g., arsenic, selenium, mercury), while others accumulate in organ tissue (e.g., cadmium, chromium, organochlorines) or bone (e.g., lead). NASB fish were analyzed whole-body. Compared to fillet data, whole-body NASB fish would have lower levels for contaminants that preferentially accumulate in muscle tissue and higher concentrations for contaminants that preferentially accumulate in organ or bone. Overall, these different data sets are presented only for comparative purposes. The geometric mean and 85th percentile concentrations reported in the NCBP have no regulatory significance or meaning with respect to potential hazard to fishery resources (May and McKinney 1981), but serve as reference points to distinguish elevated contaminant concentrations in fish. Our compilation of concentrations from regional, State, and literature sources should be similarly viewed.

The discussion section deals primarily with contaminant exposure and the potential effects of fish contamination to ***ecological receptors***. Brief notes regarding some contaminant concentrations and FDA Action or Tolerance Levels or Maine health advisories are included for context. A separate assessment of our data would be necessary in order to determine the human health implications of contaminants in Mere Brook fish. Our use of FDA Action levels or State advisories for comparative purposes should not be considered an assessment of risk to humans. This study will be provided to risk assessors of EPA and the Maine Department of Environmental Protection, who may provide a more detailed evaluation of the potential human health risks associated with the consumption of Mere Brook fish.

Trace elements

Arsenic (As) - Arsenic is a teratogen and carcinogen which bioconcentrates in organisms, but does not biomagnify in food chains (Eisler 1994). In unpolluted or mildly-contaminated waters, fish tissue may contain As residues ranging between < 0.1 and 0.4 µg/g (Moore and Ramamoorthy 1984). Immature bluegills (*Lepomis macrochirus*) with tissue residues greater than 1.3 µg As/g experienced diminished growth and survival (Eisler 1994).

The NCBP (Schmitt and Brumbaugh 1990) geometric mean As concentration is 0.14 µg/g and the 85th percentile is 0.27 µg/g. At NASB, the mean concentrations in adult brook trout from the landfill location (0.02 µg/g) and reference area (0.03 µg/g) were well below the NCBP geometric mean. Arsenic concentrations in juvenile NASB brook trout were similarly low compared to the NCBP. The mean As concentration in juveniles was the same at both collection locations (0.04 µg/g), and appeared slightly higher than the mean adult brook trout concentrations. These As concentrations should not pose a risk to NASB brook trout or to piscivorous ecological receptors.

Cadmium (Cd) - Cadmium is a teratogen, possible carcinogen, and probable mutagen, that has been implicated as the cause for severe effects in 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 μg/g likely indicate Cd contamination (Eisler 1985a). Animals with Cd tissue concentrations greater than 5 μg/g may be lethally affected by Cd, while higher tissue concentrations of 15.0 μg/g could be hazardous to the upper trophic level species that prey on these animals (Eisler 1985a). Cadmium does not increase with fish age or size, and does not biomagnify in aquatic food chains (Spry and Wiener 1991). Cadmium primarily accumulates in gill, kidney, and liver tissue (Spry and Wiener 1991). Consequently, whole-body concentrations are useful bio-indicators of fish exposure to Cd (Cope *et al*. 1994).

The NCBP (Schmitt and Brumbaugh 1990) geometric mean Cd concentration is 0.03 μg/g and the 85th percentile is 0.05 μg/g. In highly contaminated areas, Cd in whole-body fish may be as high as 3 μg/g (Murphy *et al*. 1978). In a Maine fish tissue study (DiFranco *et al*. 1995), the geometric mean Cd concentration in 14 whole-body brook trout composite samples was 0.03 μg/g.

At NASB, adult brook trout Cd concentrations (0.02 μg/g) from the landfill location were lower than geometric mean NCBP concentration. The mean adult Cd concentration in the reference area was equal to the geometric mean NCBP concentration of 0.03 μg/g. Similar to arsenic, Cd appeared higher in NASB juvenile samples than adults. The mean Cd concentration for juveniles was 0.04 μg/g at both collection locations, and one sample at each location equaled the NCBP 85th percentile concentration of 0.05 μg/g. Based on these results, Cd levels in Mere Brook fish do not appear to be elevated or to pose a significant risk to piscivorous wildlife resources at NASB.

Chromium (Cr) -Trivalent Cr is an essential trace element for vertebrates. The hexavalent form of Cr may cause adverse effects in the liver and kidney, and could also be a carcinogen (FDA 1993b, Environment Canada and Health Canada 1994). In the laboratory, Cr is a mutagen, carcinogen, and teratogen to several organisms (Eisler 1986). In fish, Cr bioaccumulates in gills, liver, and kidneys (Holdway 1988). In heavily contaminated areas, biota may accumulate high levels of Cr. Freshwater snails from the Sebasticook River in central Maine contained 22 to 440 μg Cr/g, dry weight (Duval *et al*. 1980).

Chromium was not included in the NCBP and values reported in the scientific literature and field studies are presented for comparative purposes. Average Cr concentrations in freshwater fish muscle may be less than 0.25 μg/g (Moore and Ramamoorthy 1984). Levels of Cr in fish from 14 Ontario lakes averaged 0.23 μg/g, with a range of 0.19 to 0.27 μg/g (Johnson 1987). Brook trout fillets (n=6) analyzed by the Maine Department of Environmental Protection (Sowles *et al*. 1996) had a mean Cr concentration of 0.27 μg/g. Friant (1979) reported that smallmouth bass (*Micropterus dolomieui*)

muscle tissue from the Kennebec River contained 0.04 to 0.42 µg/g. Chromium concentrations in whole-body centrarchids and percids collected in field studies by the U.S. Fish and Wildlife Service unpublished data) in Massachusetts and Maine ranged from 0.26 to 11.89 µg/g (whole-body).

Adult brook trout from NASB contained mean Cr concentrations of 0.31 µg/g (landfill location) and 0.28 µg/g (reference location). Chromium was significantly higher in juvenile brook trout samples from the Mere Brook reference area (0.57 µg/g) than the landfill location (0.18 µg/g). Compared to the other data sets, NASB whole-body Cr concentrations do not appear highly elevated.

An unpublished study by S.D. Haseltine (cited by Eisler 1986) suggests that a diet containing 10 µg/g of Cr may reduce growth and survival in juvenile black ducks (*Anas rubripes*). The NASB data suggests that chromium does not appear to be a problem element in Mere Brook fish. Although invertebrates in the brook could have a higher Cr concentrations than fish, we would not expect the concentrations to reach the waterfowl dietary levels mentioned by Eisler (1986).

Copper (Cu) - Copper is an essential element for vertebrates, and commonly found in fish tissue. Early life stages of salmonids are susceptible to waterborne Cu and teratogenic effects including lordosis, soliosis, kyphosis, and rigid coiling of the vertebral column (Birge and Black 1979) may result from exposure.

Freshwater fish can regulate Cu over a wide range of concentrations, but will accumulate copper in excess of nutritional requirements if continually exposed to the element (Leland and Kuwabara 1985). Moore and Ramamoorthy (1984) suggested that even in polluted waters, fish muscle tissue concentrations seldom exceed 1 µg Cu/g. They also surmised that contaminated food is probably a more important source of copper than water. In New England, Cu concentrations above 1 µg/g are not unusual. In several USFWS field studies (unpublished data), Cu has been detected above 1 µg/g in several species and drainages.

The NCBP (Schmitt and Brumbaugh 1990) geometric mean Cu concentration is 0.65 µg/g, the 85th percentile is 1.0 µg/g, and the maximum is 23.1 µg/g. Copper concentrations in whole-body centrarchids and percids collected in field studies by the U.S. Fish and Wildlife Service (unpublished data) in Connecticut, Massachusetts, and Maine ranged from 0.3 to 55 µg/g (whole-body). Friant (1979) reported that muscle tissue of Kennebec River smallmouth bass contained 0.37 to 1.70 µg Cu/g. Six brook trout fillet samples analyzed by the Maine Department of Environmental Protection (Sowles *et al*. 1996) had a mean Cu concentration of 0.28 µg/g.

The mean Cu concentration in whole-body adult brook trout from NASB was 2.14 µg/g at the landfill and 1.49 µg/g at the reference location. Copper concentrations in juveniles appear lower than in adults. Juveniles from near the landfills contained 1.44 µg/g, while juvenile samples from the reference area contained 1.33 µg/g. Compared to the NCBP (Schmitt and Brumbaugh 1990) and Maine brook trout fillet data (Sowles *et al*. 1996), Mere Brook fish appear to contain elevated concentrations of Cu.

Regional data, however, indicate that elevated copper concentrations in fish are not highly unusual in New England. Moreover, compared to the upper ranges concentrations of the USFWS field studies and the NCBP, Cu concentrations at NASB are not highly elevated. The source of Cu in NASB fish is not known. We suspect that Cu is bioconcentrated by aquatic invertebrates that are the food source of Mere Brook 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 that accounts for over 95% of the total Hg in adult fish tissue (Grieb *et al*. 1990). Mercury accumulates in the axial muscle tissue (i.e., fillet) of fish (Schmitt and Finger 1987). Whole-body concentrations of 1-5 μg Hg/g may have chronic effects in trout, while concentrations of 10-20 μg/g could be lethal (Niimi and Kissoon 1994).

The NCBP (Schmitt and Brumbaugh 1990) geometric mean Hg concentration is 0.10 μg/g and the 85th percentile is 0.37 μg/g. In a survey of 19 Maine lakes, the mean Hg concentration in fillets of brook trout was 0.30 μg/g (Stafford 1994). In another Maine fish tissue study (DiFranco *et al*. 1995), the geometric mean Hg concentration in 28 whole-body brook trout composite samples was 0.35 μg/g. Brook trout from six riverine locations in Maine contained a mean Hg concentration of 0.13 μg/g in fillets (Sowles *et al*. 1996). Mercury levels in fish increase with age and size.

Brook trout collected for this study were not large fish, and the Hg levels were not elevated compared to the NCBP (Schmitt and Brumbaugh 1990) or State of Maine surveys (DiFranco *et al*. 1995, Stafford 1994, Sowles *et al*. 1996). NASB whole-body brook trout from the Mere Brook landfill location contained 0.12 μg Hg/g. Mercury in adult brook trout from the reference area was 50% lower (i.e., 0.06 μg/g). Juvenile brook trout samples from the landfill site had a mean Hg concentration of 0.06 μg/g and fish from the reference area contained a mean of 0.04 μg/g. Compared to these data, Hg was not highly elevated in Mere Brook fish and should not be a significant risk to piscivorous ecological receptors.

The FDA Action Level for methylmercury in fish tissue is 1 μg/g (FDA 1992). Several states have adopted lower levels to protect human health (EPA 1995). In 1994, the Maine Department of Health Services issued a health advisory cautioning pregnant women, nursing mothers, women who may become pregnant, and children less than 8 years old not to eat fish from lakes and ponds in the state. The Maine fish consumption advisory threshold for Hg is currently 0.43 μg/g.

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 1984:173). In humans, toxic exposure to Ni can cause skin allergies, cancer, non-malignant respiratory disorders, and iatrogenic poisoning (FDA 1993c).

Nickel was not included in the NCBP. Jenkins (1980) suggested that Ni in freshwater fish from uncontaminated areas should range from < 0.2 to 2.0 µg/g, but cautioned that more data are needed. At NASB, Ni was detected in one adult brook trout sample (0.10 µg/g) at the Mere Brook landfill location. Nickel was not detected in adult samples from the reference area. Half of the juvenile brook trout samples contained detectable levels of Ni; one sample near the landfill (0.26 µg/g) and two samples from the reference area (0.09 and 0.14 µg/g). Nickel concentrations, when detected, were not highly elevated compare to the range proposed by Jenkins (1980), and it is unlikely Ni poses a significant risk to fish and wildlife resources of Mere Brook.

Lead (Pb) - Lead is a ubiquitous environmental contaminant that is commonly found in fish and wildlife tissues, particularly in species with habitats proximal to roads and urban or industrial developments. Lead is bioconcentrated by organisms, but does not appear to magnify through food chains (Eisler 1988). Exposure to Pb may cause neurological effects, kidney dysfunction, and anemia in vertebrates (Leland and Kuwabara 1985). Adverse Pb effects on aquatic biota can include reduced survival, impaired reproduction, impaired function of the liver, kidney, and spleen, reduced growth, and spinal deformities (Holcombe *et al*. 1976, Eisler 1988).

Lead accumulation varies among fish species, and concentrations do not appear to be related to size (Czarnezki 1985). The NCBP (Schmitt and Brumbaugh 1990) geometric mean Pb concentration is 0.11 µg/g and the 85th percentile is 0.22 µg/g. In Maine, Kennebec River smallmouth bass muscle tissue contained 0.075 to 0.125 µg Pb/g (Friant 1979). In a Maine fish tissue study (DiFranco *et al*. 1995), the geometric mean Pb concentration in 28 whole-body brook trout composite samples was 0.03 µg/g. Three brook trout fillets analyzed by the Maine Department of Environmental Protection contained a mean Pb concentration of 0.36 µg/g (Sowles *et al*. 1996).

At NASB, Pb concentrations in Mere Brook fish (size classes combined) were significantly higher at the reference area (0.09 µg/g) than the landfill location (0.05 µg/g). The mean Pb concentrations in adult (0.10 µg/g) and juvenile (0.09 µg/g) brook trout samples from the reference location were less than the NCBP geometric mean of 0.11 µg/g. Lead concentrations in brook trout from NASB were not elevated, and adverse effects on biota using Mere Brook are not expected.

There is no FDA Action Level for Pb in fish tissue, but a concentration of 0.3 µg/g (wet weight) has been developed by the World Health Organization as an upper permissible limit for Pb in foods (Settle and Patterson 1980).

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. Nominal dietary intake of Se by rainbow trout (*Oncorhynchus mykiss*) is approximately 0.07 µg/g (Hilton *et al*. 1980). While Se may cause death in deficient amounts (Eisler 1985b), elevated intake of Se can also be harmful. Fish consuming diets with 10 to 33 µg Se/g have experienced toxic effects (Hilton *et al*. 1980, Besser *et al*. 1993). Excessive amounts may be lethal, cause reproductive abnormalities or failure, result in tissue damage, retard growth, or eliminate entire fish communities (Eisler 1985b, Lemly 1996).

The NCBP (Schmitt and Brumbaugh 1990) geometric mean Se concentration is 0.42 µg/g and the 85th percentile is 0.73 µg/g. Adult brook trout from NASB contained a mean concentration of 0.48 µg Se/g at the landfill location and 0.57 µg Se/g at the reference location. Selenium concentrations appeared higher in juvenile brook trout samples. The mean Se concentration in juveniles from near the landfills was 0.65 µg/g, and the mean at the reference area was 0.61 µg/g. In salmonids, growth is impaired at whole-body Se concentrations of 2 to 3 µg/g, and lethal to fish when concentrations exceed 5 µg/g (Lemly 1996). Compared to the NCBP and Lemly (1996), NASB Se concentrations were not highly elevated and the element should not be a problem for Mere Brook fish. Lemly (1996) also recommended a Se toxic threshold of 3 µg/g in aquatic food-chain organisms consumed by fish and wildlife. NASB brook trout Se concentrations were well below this threshold, and Se should not pose a significant risk to piscivorous receptors at Mere Brook.

Zinc (Zn) - Zinc is an essential element for vertebrates. Although it is an uncommon occurrence in aquatic systems, fish with diets deficient in Zn can experience reduced growth and increased mortality (Spry *et al*. 1988). Generally, Zn is efficiently regulated by wildlife, and tissue concentrations are not reliable indicators of exposure (Beyer and Storm 1995). Spry *et al*. (1988) found no toxic effects to rainbow trout (e.g., growth, mortality, major plasma ions, hematocrit, or plasma protein) resulting from exposure to high dietary and waterborne concentrations of Zn. However, Eisler (1993) reported that elevated concentrations of waterborne Zn has adverse effects on growth, survival, behavior, and reproduction of sensitive fish, with early life stages being the most sensitive.

The NCBP (Schmitt and Brumbaugh 1990) geometric mean Zn concentration is 21.7 µg/g and the 85th percentile is 34.2 µg/g. Murphy *et al*. (1978), studying Cd and Zn from an industrially contaminated lake, reported Zn tissue concentrations ranging from 34.7 to 56.2 µg/g and 19.7 to 29.7 µg/g for bluegill and largemouth bass (*Micropterus salmoides*), respectively. Citing several sources, Murphy *et al*. (1978) reported average Zn whole fish concentrations from uncontaminated areas ranging from 12 to 43 µg/g.

The Zn concentrations at NASB were similar to the NCBP. Adult brook trout samples contained 22.58 µg/g and 22.11 µg/g at the landfill and reference location, respectively. Zinc concentrations in juvenile trout appeared slightly higher, with a mean of 25.52 µg/g at the landfill location and 27.65 µg/g at the reference area. NASB Zn concentrations were not extraordinary, and should not pose a risk to Mere Brook fish or to piscivorous species.

Organochlorines

Organochlorines were detected in elevated concentrations in fish from the Mere Brook landfill site, but were not detected, or were found in low concentrations at the Mere Brook reference area west of the NASB runway. Three organochlorines were detected: chlordane, dieldrin, and DDT metabolites. Polychlorinated biphenyls were not detected in Mere Brook fish tissue.

Chlordane - Chlordane was widely used since the late 1940s as a broad spectrum insecticide. It was regularly used for subterranean termite control. All commercial uses of chlordane were cancelled in the United States in 1988 (Howard 1991). Chlordane persists for years in soil, sediment and biota. Although waste disposal ceased at NASB Site 3 in the 1970s, chlordane was detected in soils above 1 μg/g 15 years later (E.C. Jordon 1990). The immediate toxicity of chlordane varies depending on the species and life stage, but in general, can be considered moderately toxic to mammals, moderately to highly toxic to birds, and highly toxic to fish and aquatic insects (Briggs 1992, von Rumker *et al*. 1975).

Cis-Chlordane: The NCBP (Schmitt *et al*. 1990) geometric mean *cis*-chlordane concentration is 0.03 μg/g and the maximum is 0.66 μg/g. The mean *cis*-chlordane concentration in three adult and three juvenile NASB brook trout samples was 0.166 μg/g and 0.032 μg/g, respectively. Compared to the NCBP, three adult NASB brook trout samples contain elevated concentrations of *cis*-chlordane. These adults were collected adjacent to the Mere Brook landfills. *Cis*-chlordane was not detected in the three adult brook trout samples from the reference location. The landfill site was also the location were *cis*-chlordane was detected in juveniles (0.032 μg/g). The level of *cis*-chlordane in juveniles, however, was considerably lower than the concentration in adults and only slightly higher than the NCBP.

Trans-Chlordane: The geometric mean *trans*-chlordane concentration in the NCBP (Schmitt *et al*. 1990) is 0.02 μg/g and the maximum is 0.35 μg/g. *Trans*-chlordane was detected in concentrations slightly higher than the NCBP in three NASB adult brook trout samples (mean 0.027 μg/g), all from the landfill location. *Trans*-chlordane was not detected in juveniles at either sampling location. Murphy and Gooch (1995) and Eisler (1990) reported that *cis*-chlordane was preferentially stored and concentrated to a greater degree than *trans*-chlordane. The NASB results reflect the *cis*/*trans* storage relationship with *cis*-chlordane occurring more frequently and at higher concentrations.

ΣChlordane (*cis* + *trans*): In an EPA nationwide study of chemical residues in fish (EPA 1992), the average total chlordane tissue (fillet) concentration in brown trout (*Salmo trutta*) was 0.0073 μg/g. In the Surface Water Ambient Toxic Monitoring Program of Maine (Sowles *et al*. 1996), three brook trout fillet samples contained a mean chlordane concentrations of 0.0015 μg/g. The mean total chlordane concentrations in whole-body NASB brook trout were 0.193 μg/g for adults and 0.032 μg/g for juveniles. Compared to brown trout fillets analyzed by EPA (1992), NASB whole-body brook trout contain elevated concentrations of total chlordane.

The Food and Drug Administration Action Level for chlordane residues in fish muscle is 0.3 μg/g, wet weight (FDA 1992). NASB brook trout samples were below the FDA chlordane action level. However, chlordane muscle residues of 0.1 μg/g may endanger fish health in some species (Eisler 1990). New York State proposed a fish flesh chlordane concentration of 0.37 μg/g (cancer endpoint) and 0.500 μg/g (non-cancer endpoint) to protect piscivorous birds (Newell *et al*. 1987). Chlordane exists in elevated concentrations in Mere Brook adult trout adjacent to the NASB landfills (0.193 μg/g), and represents a potential risk to fish and fish-eating species.

Dieldrin - Dieldrin is a persistent insecticide that is insoluble in water and highly toxic to fish and aquatic insects (Briggs 1992). It is one of the most toxic organochlorines, and has been implicated in several cases of acute poisoning in wildlife (Blus 1995). Dieldrin contamination is generally associated with pesticide applications. However, atmospheric deposition is thought to have introduced dieldrin to remote ecosystems. In four remote lakes in Maine, Haines (1983) detected dieldrin in Age I brook trout ranging from 0.003 to 0.007 μg/g.

The NCBP (Schmitt *et al*. 1990) geometric mean dieldrin concentration is 0.04 μg/g and the maximum is 1.39 μg/g. Three NASB adult brook trout samples collected from the landfill reach contained a mean dieldrin concentration of 0.07 μg/g. Dieldrin was detected in only one juvenile trout sample, also from the landfill, at a concentration of 0.02 μg/g. New York State proposed a fish flesh dieldrin concentration of 0.022 μg/g (cancer endpoint) and 0.12 μg/g (non-cancer endpoint) to protect piscivorous birds (Newell *et al*. 1987). Compared to the NCBP and the NYS dieldrin criterion, dieldrin is elevated in fish inhabiting the reach adjacent to the NASB landfills.

A definitive effect value for dieldrin in piscivorous birds has not been established, but an egg concentration exceeding 1 μg/g may affect reproduction (Peakall 1996). Mammals and birds with brain dieldrin concentrations of 5 μg/g and 10 μg/g, respectively, could also be considered lethally poisoned by dieldrin (Peakall 1996). Based on brook trout concentrations, mammals and birds feeding on Mere Brook fish could be at risk from dieldrin contamination.

DDT and its 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 (EPA 1990), the compound and its metabolites continue to be detected in fish and wildlife tissues. DDT metabolites are lipophilic and accumulate in fatty tissues (Moore and Ramamoorthy 1984). 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). In raptors and piscivorous birds, DDT metabolites cause eggshell thinning (Hickey and Anderson 1968). Eggs of piscivorous birds with DDE residues of 1 μg/g have a 5 to 10% reduction in eggshell thickness; eggshells with 18% thinning are associated with declining populations (Blus 1996).

Waterfowl are also affected by DDT. DDE was found to thin eggshells and reduce reproductive success in captive black ducks (Longcore *et al*. 1971) and mallards (*Anas platyrhynchos*) (Heath *et al*. 1969).

DDE is a degradation product of DDT. The NCBP (Schmitt *et al*. 1990) geometric mean p,p'-DDE concentration is 0.19 µg/g and the maximum is 4.74 µg/g. DDE concentrations in Age I brook trout from four remote Maine lakes ranged from 0.011 to 0.034 µg/g (Haines 1983). DiFranco *et al*. (1995) found DDE ranging from 0.0002 to 0.382 µg/g in 234 whole fish samples from Maine lakes. DDE was detected at both NASB collection locations. Fish from the landfill site (size classes combined) had significantly higher DDE concentrations than fish from the reference area. NASB brook trout adults contained mean DDE concentration of 0.092 µg/g (landfill site) and 0.044 µg/g (reference location). Juvenile trout samples at the landfill and reference locations contained DDE concentrations of 0.091 µg/g and 0.042 µg/g, respectively. Compared to the NCBP, DDE concentrations in Mere Brook fish were not highly elevated.

The NCBP (Schmitt *et al*. 1990) geometric mean p,p'-DDD concentration is 0.06 µg/g. In 223 whole fish samples (different species) from Maine lakes, DDD concentrations ranged from 0.0001 to 0.4100 µg/g (DiFranco *et al*. 1995). DDD concentrations in whole-body adult brook trout from Mere Brook were 0.077 µg/g at the landfill and 0.048 µg/g at the reference location. For juveniles, DDD was lower at the landfill (0.041 µg/g) than at the reference area (0.051 µg/g). Compared to the NCBP, DDD concentrations in Mere Brook fish were not highly elevated.

The NCBP (Schmitt *et al*. 1990) geometric mean p,p'-DDT concentration is 0.03 µg/g. DiFranco *et al*. (1995) found DDT in 191 whole fish samples in Maine with a range of 0.0001 to 0.030 µg/g. At NASB, 4,4'-DDT was detected in all juvenile samples, in all adult brook trout from the landfill location, and in two of four adult brook trout samples from the reference area. All adult fish with detectable levels of 4,4'-DDT had concentrations that equaled (at the reference area) or exceeded (mean 0.177 µg/g at the landfill) the NCBP. Juvenile brook trout samples from the landfill location (mean 0.066 µg/g) exceeded the NCBP, while at the reference location the mean concentration was 0.036 µg/g. Compared to the NCBP, and considering the size of the fish analyzed in this study, 4,4'-DDT concentrations in Mere Brook fish were elevated.

The NCBP (Schmitt *et al*. 1990) geometric mean ΣDDT concentration is 0.26 µg/g. In Maine, four brook trout fillets analyzed by the Maine Department of Environmental Protection (Sowles *et al*. 1996) contained a mean ΣDDT concentration of 0.1486 µg/g. At NASB, the mean ΣDDT concentrations in adult brook trout from the landfill (0.346 µg/g) exceeded the NCBP. Adult brook trout from the reference area (mean 0.106 µg/g) had ΣDDT concentrations lower than the NCBP and similar to MEDEP data (Sowles *et al*. 1996). Juvenile brook trout from the landfill (mean 0.198 µg/g) and reference area (mean 0.129 µg/g) did not have elevated ΣDDT concentrations when compared to DDT levels found in adult fish in other studies.

The Food and Drug Administration Action Level for Fish for ΣDDT metabolites in fish is 5 μg/g (FDA 1992). The NASB results are considerably lower than the FDA action level. New York State proposed a fish flesh ΣDDT concentration of 0.2 μg/g to protect piscivorous birds (Newell *et al*. 1987). Adult brook trout and juveniles from the Mere Brook landfill area had concentration that equaled or exceeded the NYS criterion.

SUMMARY AND RECOMMENDATION

Trace elements

Brook trout from NASB did not contain highly elevated concentrations of trace elements. Copper concentrations were somewhat elevated, but compared to regional data sets, the concentrations in NASB fish were not unusual or highly elevated.

Organochlorines

Organochlorine concentrations were markedly higher in fish collected adjacent to the former NASB landfills than in the reference location. Chlordane, dieldrin, and DDT metabolites in Mere Brook fish are at concentrations potentially harmful to piscivorous receptors.

Recommendation

Remedial actions have been taken by the U.S. Navy to close and restore Sites 1 and 3 at NASB. A remedial plan is being proposed for Site 2. Monitoring to evaluate the success of remedial actions is a requirement of Superfund. Based on the results of this study, a resampling of surface water, sediments, and fish or other biota should be conducted following remedial actions to monitor environmental contaminants in Mere Brook, particularly mercury and organochlorines.

Cautionary Note: Mere Brook is a small stream that could rapidly be depleted of fish from oversampling. As stated earlier, juvenile trout were collected in this study because they were present in numbers and would represent the prey most likely consumed by piscivorous predators from higher trophic levels. Moreover, a minimum gram weight was required for contaminant analyses, and the removal of several small fish was necessary to obtain usable information. Our removal of 1.1 kg of brook trout from two unexploited or lightly angled area should not adversely affect the standing crop or genetic variability, if one exists, in Mere Brook. Repopulation of the sampled section of Mere Brook from unaffected (i.e., un-sampled downstream or upstream) areas should occur within one year (Phinney 1975). However, we recommend that collections in future investigations should be more limited and performed only to compared results with this study.

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FIGURES

Figure 1. Location Map - U.S. Naval Air Station, Brunswick, ME. 1:24,000.

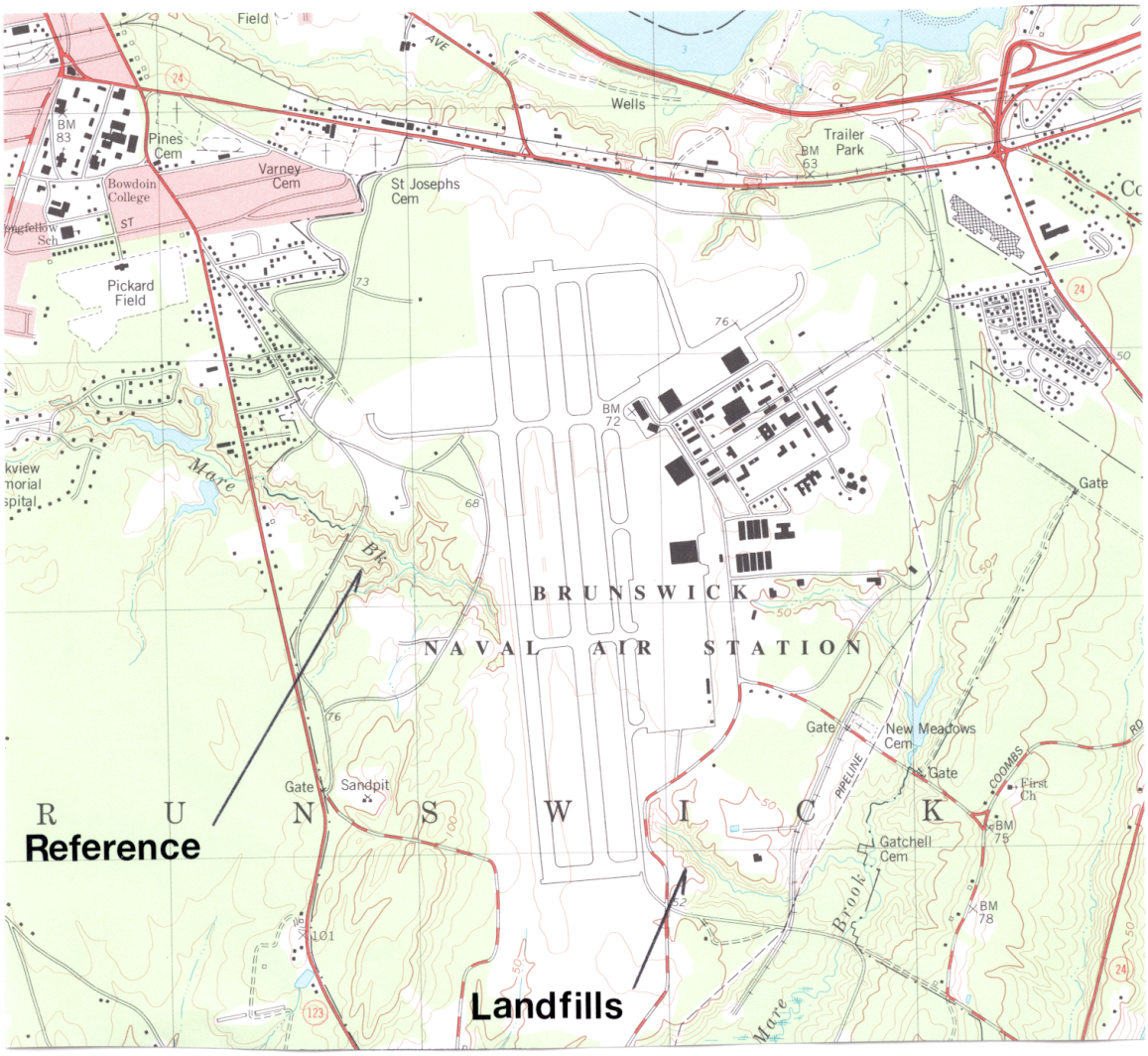


Figure 2. Trace elements in wholebody **ADULT** brook trout from Mere Brook by **LOCATION**.

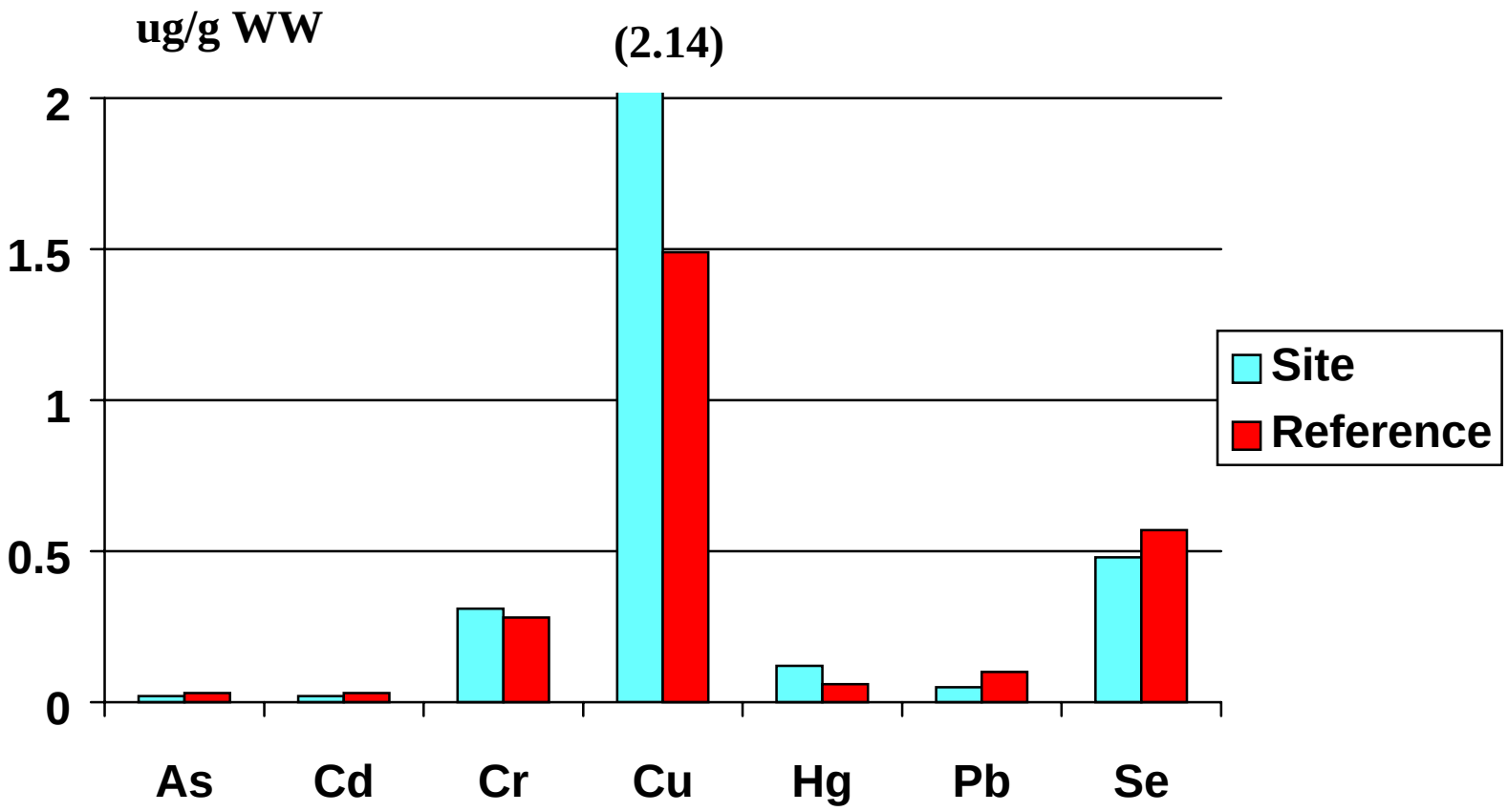


Figure 3. Trace elements in wholebody **JUVENILE** brook trout from Mere Brook by **LOCATION**.

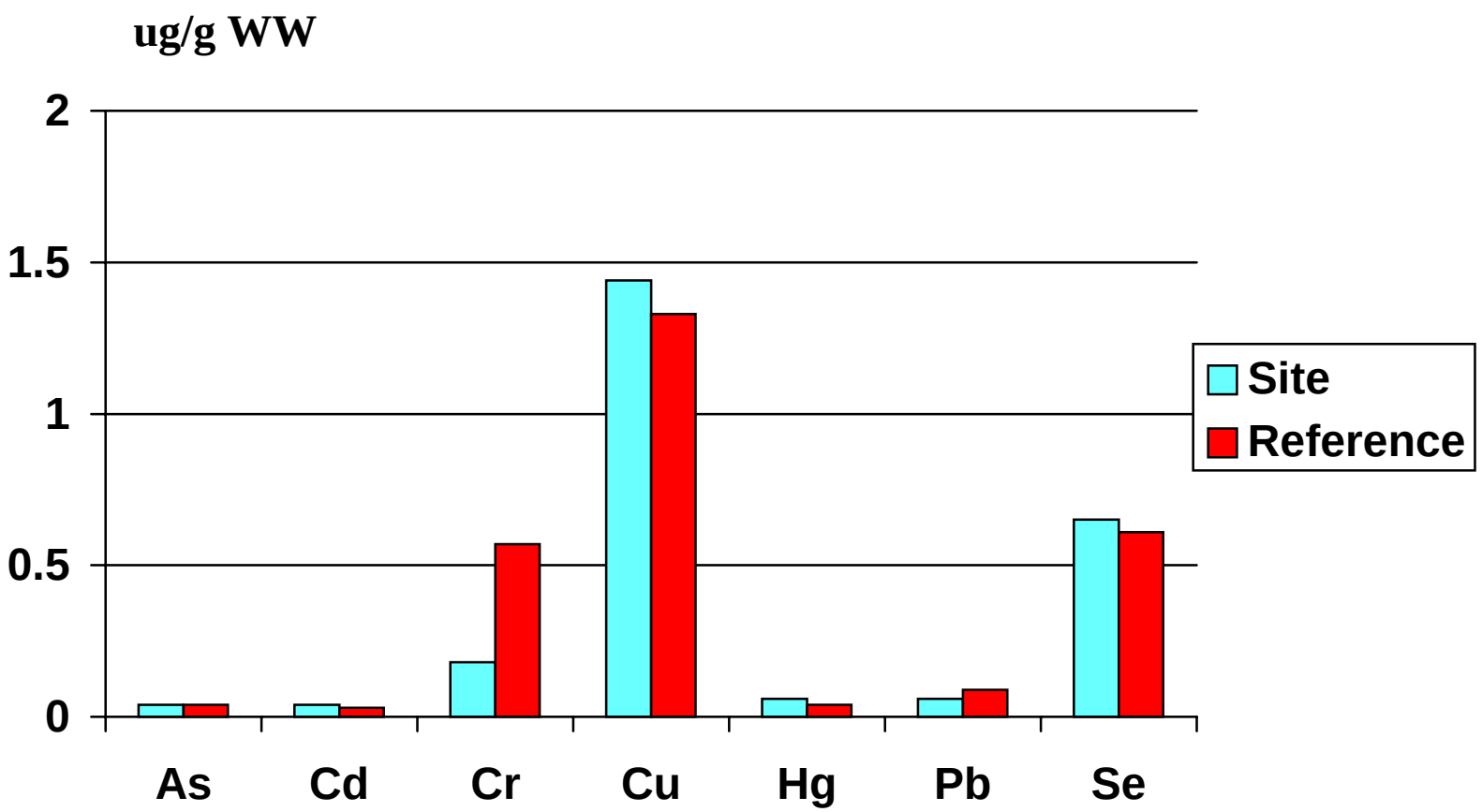
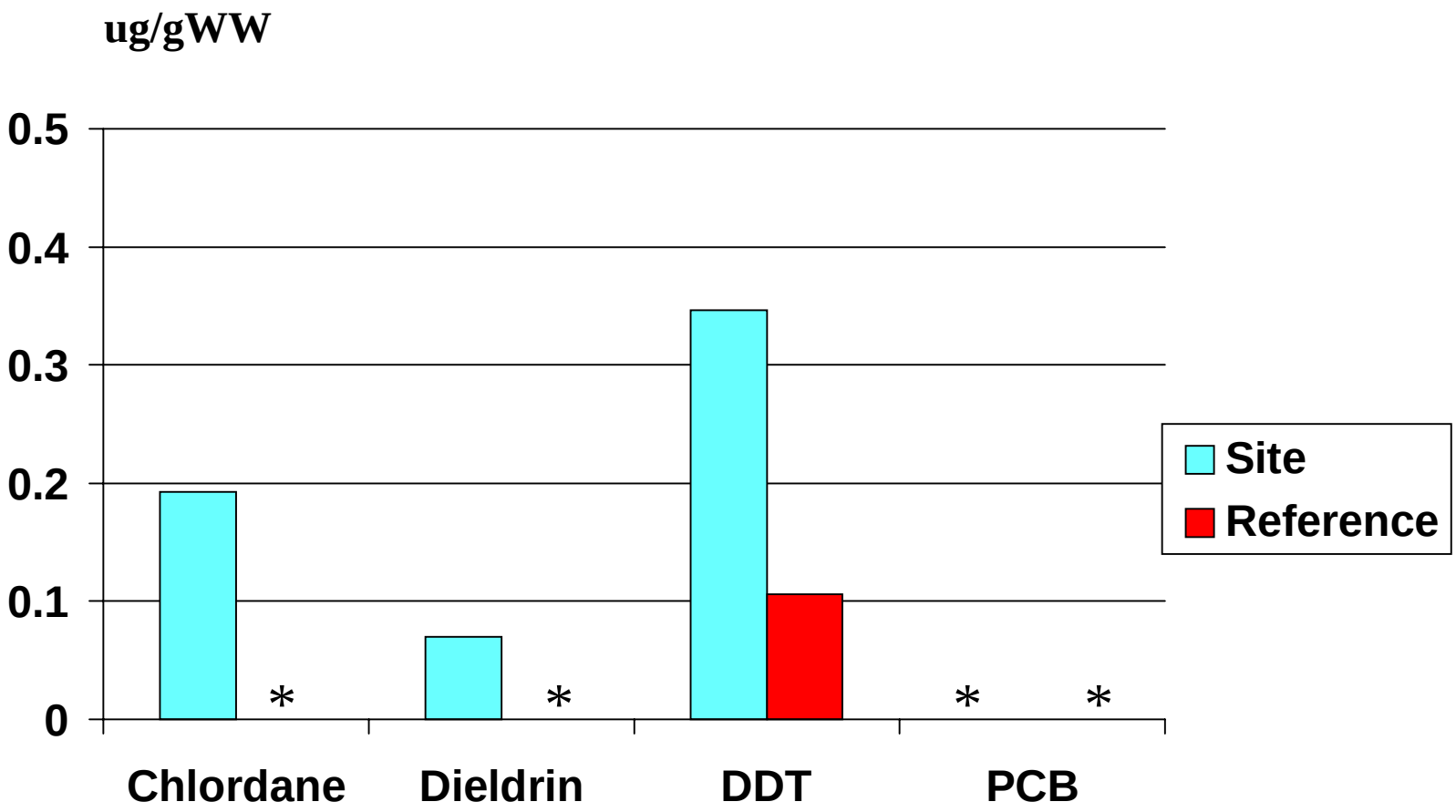
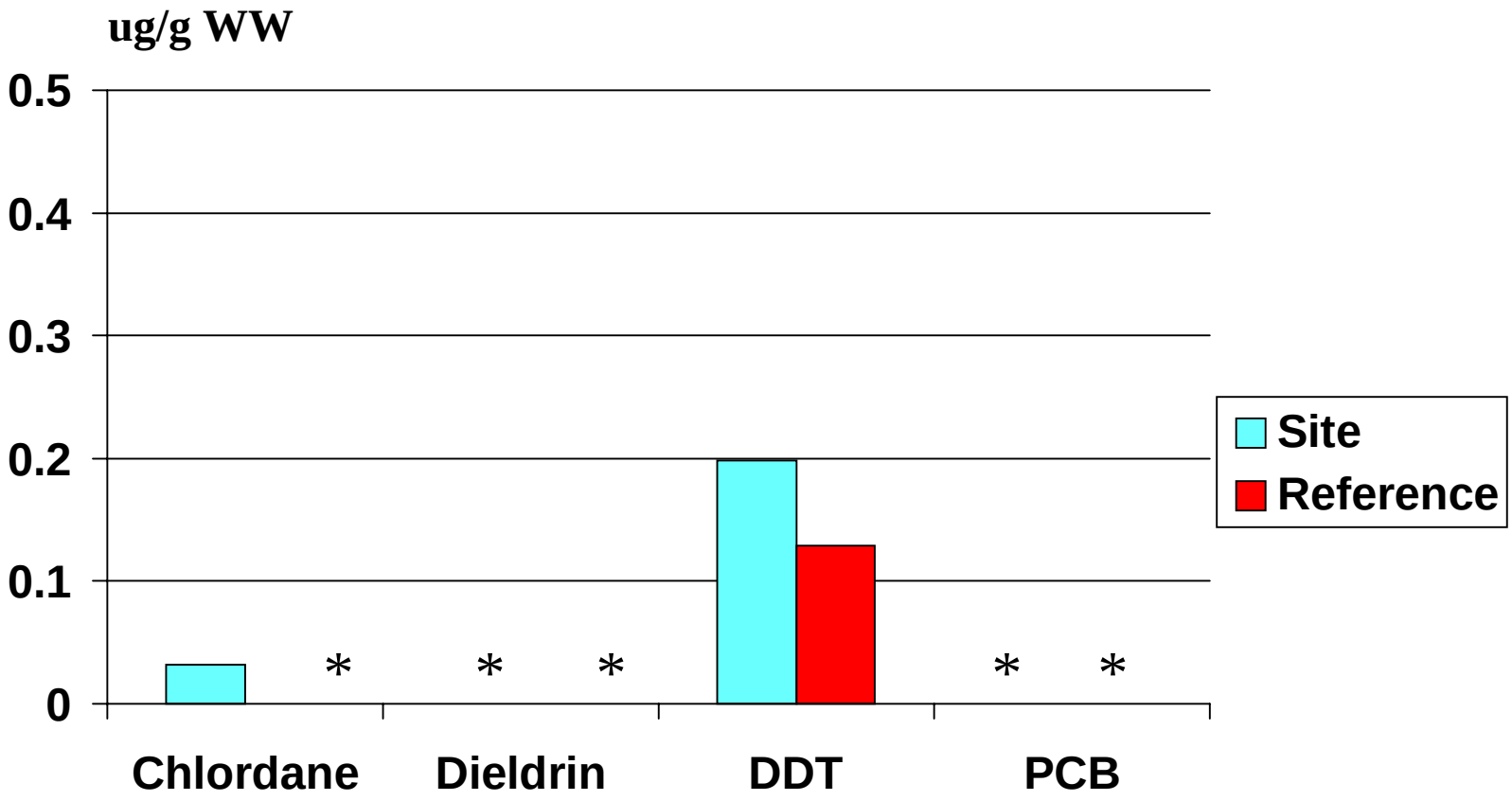


Figure 4. Organochorines in wholebody **ADULT** brook trout from Mere Brook by **LOCATION**.



* = not detected

Figure 5 Organochlorines in wholebody **JUVENILE** brook trout from Mere Brook by **LOCATION**.



TABLES

Table 1. Average length and weight of brook trout used in NASB samples.

Size Class	Length (cm)		Weight (g)		No. of
	Mean	Range	Mean	Range	Composite Samples
Adult (n=18)	15.3	12.6 - 20.4	36.7	19.9 - 80.1	7
Juvenile (n=120)	7.1	5.7 - 8.2	3.8		6

Table 2. Sample composites

FWS ID#	Samples Included in Composite	Location	No. of Fish in Sample	Total Sample Weight (g)
NASB-01	MB1-BKT-01	Adj to landfill	1	78.6
NASB-02	MB1-BKT-02, 04, 05, 06	Adj to landfill	4	139.6
NASB-03	MB1-BKT-03, 07, 08, 09	Adj to landfill	4	99.8
NASB-04	MB1-BKT-10	Adj to landfill	20	68.7
NASB-05	MB1-BKT-11	Adj to landfill	20	65.2
NASB-06	MB1-BKT-12	Adj to landfill	20	75.3
NASB-07	MB2-BKT-01	Reference area	1	80.1
NASB-08	MB2-BKT-02, 03	Reference area	2	104.3
NASB-09	MB2-BKT-04, 05, 07	Reference area	3	86
NASB-10	MB2-BKT-06, 08, 09	Reference area	3	71.9
NASB-11	MB2-BKT-10	Reference area	20	80.8
NASB-12	MB2-BKT-11	Reference area	20	81.1
NASB-13	MB2-BKT-12	Reference area	20	80

Table 3. Trace elements in wholebody brook trout (size classes combined) samples from Mere Brook by **LOCATION**, *u* g/g WW.

MSC#	FWS#	Sample	As	Cd	Cr	Cu	Hg	Ni	Pb	Se	Zn
Focus Location (adjacent to landfills)											
11862	NASB1	Adult	0.02	0.02	0.18	1.56	0.14	nd	0.04	0.52	20.28
11863	NASB2	Adult	0.01	0.02	0.21	1.63	0.12	nd	0.015	0.50	24.00
11864	NASB3	Adult	0.04	0.02	0.53	3.22	0.10	0.10	0.09	0.41	23.46
11865	NASB4	Juvenile	0.04	0.05	0.29	2.20	0.06	0.26	0.04	0.66	25.96
11866	NASB5	Juvenile	0.04	0.04	0.11	0.88	0.06	nd	0.015	0.64	24.42
11867	NASB6	Juvenile	0.04	0.03	0.14	1.25	0.07	nd	0.07	0.66	26.18
n=6											
Mean			0.03	0.03	0.24	1.79	0.09	nc	0.05	0.57	24.05
SE			0.005	0.005	0.063	0.337	0.014	nc	nc	0.042	0.873
Reference Location (west of runway)											
11868	NASB7	Adult	0.02	0.04	0.12	0.88	0.07	nd	0.10	0.55	21.06
11869	NASB8	Adult	0.04	0.03	0.36	2.16	0.07	nd	0.10	0.62	21.06
11870	NASB9	Adult	0.02	0.02	0.21	1.37	0.06	nd	0.08	0.53	22.80
11871	NASB10	Adult	0.03	0.05	0.41	1.56	0.06	nd	0.11	0.58	23.52
11872	NASB11	Juvenile	0.04	0.05	0.55	0.86	0.04	0.14	0.07	0.59	27.72
11873	NASB12	Juvenile	0.04	0.04	0.64	1.32	0.04	0.09	0.09	0.62	27.94
11874	NASB13	Juvenile	0.04	0.03	0.53	1.83	0.04	nd	0.11	0.62	27.28
n=7											
Mean			0.03	0.04	0.40	1.43	0.05	nc	0.09	0.59	24.48
SE			0.004	0.004	0.071	0.179	0.005	nc	0.006	0.014	1.170

nd=non-detect, nc=not calculated

Shaded cells were non-detects. Value listed is one-half the method detection limit.

Table 4. Trace elements in wholebody **ADULT** brook trout from Mere Brook by **LOCATION**, *u* g/g WW.

MSC#	FWS#	%H2O	As	Cd	Cr	Cu	Hg	Ni	Pb	Se	Zn
Focus Location (adjacent to landfills)											
11862	NASB1	74	0.02	0.02	0.18	1.56	0.14	nd	0.04	0.52	20.28
11863	NASB2	76	0.01	0.02	0.21	1.63	0.12	nd	0.015	0.50	24.00
11864	NASB3	77	0.04	0.02	0.53	3.22	0.10	0.10	0.09	0.41	23.46
n=3											
Mean			0.02	0.02	0.31	2.14	0.12	nc	0.05	0.48	22.58
SE			0.009	0.003	0.111	0.542	0.011	nc	nc	0.033	1.161
Reference Location (west of runway)											
11868	NASB7	74	0.02	0.04	0.12	0.88	0.07	nd	0.10	0.55	21.06
11869	NASB8	74	0.04	0.03	0.36	2.16	0.07	nd	0.10	0.62	21.06
11870	NASB9	76	0.02	0.02	0.21	1.37	0.06	nd	0.08	0.53	22.80
11871	NASB10	76	0.03	0.05	0.41	1.56	0.06	nd	0.11	0.58	23.52
n=4											
Mean			0.03	0.03	0.28	1.49	0.06	nd	0.10	0.57	22.11
SE			0.005	0.005	0.066	0.264	0.003		0.007	0.021	0.624

nd=non-detect, nc=not calculated

Shaded cells were non-detects. Value listed is one-half the method detection limit.

Table 5. Trace element concentrations in wholebody **JUVENILE** brook trout from Mere Brook by **LOCATION**, *u* g/g WW

MSC#	FWS#	%H2O	As	Cd	Cr	Cu	Hg	Ni	Pb	Se	Zn
Focus Location (adjacent to landfills)											
11865	NASB4	78	0.04	0.05	0.29	2.20	0.06	0.26	0.04	0.66	25.96
11866	NASB5	78	0.04	0.04	0.11	0.88	0.06	nd	0.015	0.64	24.42
11867	NASB6	78	0.04	0.03	0.14	1.25	0.07	nd	0.07	0.66	26.18
n=3											
Mean			0.04	0.04	0.18	1.44	0.06	nc	0.04	0.65	25.52
SE			0.002	0.005	0.054	0.392	0.003	nc	nc	0.007	0.554
Reference Location (west of runway)											
11872	NASB11	78	0.04	0.05	0.55	0.86	0.04	0.14	0.07	0.59	27.72
11873	NASB12	78	0.04	0.04	0.64	1.32	0.04	0.09	0.09	0.62	27.94
11874	NASB13	78	0.04	0.03	0.53	1.83	0.04	0.029	0.11	0.62	27.28
n=3											
Mean			0.04	0.04	0.57	1.33	0.04	0.09	0.09	0.61	27.65
SE			0.001	0.006	0.034	0.28	0.002	nc	0.012	0.007	0.194

nd=non-detect, nc=not calculated

Shaded cells were non-detects. Value listed is one-half the method detection limit.

Table 6. Organochlorines in wholebody brook trout (size classes combined) samples from Mere Brook by **LOCATION**, *u* g/g WW

MSC#	FWS#	Sample	*trans* Chlordane	*cis* Chlordane	Total Chlordane	Dieldrin	4,4' DDE	4,4' DDD	4,4' DDT	Total DDT
Focus Location (adjacent to landfills)										
11862	NASB1	Adult	0.053	0.300	0.353	0.120	0.130	0.120	0.290	0.540
11863	NASB2	Adult	0.016	0.110	0.126	0.052	0.086	0.069	0.120	0.275
11864	NASB3	Adult	0.012	0.088	0.100	0.039	0.060	0.043	0.120	0.223
11865	NASB4	Juvenile	nd	0.031	0.031	0.010	0.088	0.039	0.064	0.191
11866	NASB5	Juvenile	nd	0.034	0.034	0.020	0.096	0.046	0.078	0.220
11867	NASB6	Juvenile	nd	0.030	0.030	0.010	0.088	0.039	0.057	0.184
n=6										
Mean			nc	0.099	0.112	0.042	0.091	0.059	0.122	0.272
SE			nc	0.0425	0.0509	nc	0.0092	0.0130	0.0355	0.0551
Reference Location (west of runway)										
11868	NASB7	Adult	nd	nd	nd	nd	0.029	0.035	0.010	0.074
11869	NASB8	Adult	nd	nd	nd	nd	0.055	0.063	0.029	0.147
11870	NASB9	Adult	nd	nd	nd	nd	0.034	0.039	0.010	0.083
11871	NASB10	Adult	nd	nd	nd	nd	0.059	0.054	0.027	0.140
11872	NASB11	Juvenile	nd	nd	nd	nd	0.037	0.044	0.024	0.105
11873	NASB12	Juvenile	nd	nd	nd	nd	0.052	0.064	0.052	0.168
11874	NASB13	Juvenile	nd	nd	nd	nd	0.037	0.046	0.032	0.115
n=7										
Mean			nc	nc	nc	nc	0.043	0.049	0.026	0.119
SE			nc	nc	nc	nc	0.0044	0.0043	nc	0.0131

nd=non-detect, nc=not calculated
Total Chlordane= *trans* + *cis*
Total DDT=4,4'-DDE + 4,4'-DDD + 4,4'-DDT
Shaded cells were non-detects. Value listed is one-half the sample detection limit.

Table 7. Organochlorines in wholebody **ADULT** brook trout from Mere Brook by **LOCATION**, *u* g/g WW

MSC#	FWS#	% Lipid	*trans* Chlordane	*cis* Chlordane	Total Chlordane	Dieldrin	4,4' DDE	4,4' DDD	4,4' DDT	Total DDT
Focus Location (adjacent to landfills)										
11862	NASB1	2.44	0.053	0.300	0.353	0.120	0.130	0.120	0.290	0.540
11863	NASB2	0.92	0.016	0.110	0.126	0.052	0.086	0.069	0.120	0.275
11864	NASB3	1.36	0.012	0.088	0.100	0.039	0.060	0.043	0.120	0.223
n=3										
Mean			0.027	0.166	0.193	0.070	0.092	0.077	0.177	0.346
SE			0.0131	0.0673	0.0804	0.0251	0.0204	0.0226	0.0567	0.0982
Reference Location (west of runway)										
11868	NASB7	2.34	nd	nd	nd	nd	0.029	0.035	nd	0.064
11869	NASB8	1.93	nd	nd	nd	nd	0.055	0.063	0.029	0.147
11870	NASB9	1.40	nd	nd	nd	nd	0.034	0.039	nd	0.073
11871	NASB10	2.44	nd	nd	nd	nd	0.059	0.054	0.027	0.140
n=4										
Mean			nd	nd	nd	nd	0.044	0.048	nc	0.106
SE							0.0075	0.0065	nc	0.0218

nd = non-detect, nc=not calculated
Total Chlordane = *trans* + *cis*
Total DDT = 4,4'-DDE + 4,4'-DDD + 4,4'-DDT

Table 8. Organochlorines in wholebody **JUVENILE** brook trout from Mere Brook by **LOCATION**, *u* g/g WW.

MSC#	FWS#	% Lipid	*trans* Chlordane	*cis* Chlordane	Total Chlordane	Dieldrin	4,4' DDE	4,4' DDD	4,4' DDT	Total DDT
Focus Location (adjacent to landfills)										
11865	NASB4	1.41	nd	0.031	0.031	nd	0.088	0.039	0.064	0.191
11866	NASB5	2.32	nd	0.034	0.034	0.020	0.096	0.046	0.078	0.220
11867	NASB6	1.13	nd	0.030	0.030	nd	0.088	0.039	0.057	0.184
n=3										
Mean			nd	0.032	0.032	nc	0.091	0.041	0.066	0.198
SE				0.0012	0.0012	nc	0.0027	0.0023	0.0062	0.0110
Reference Location (west of runway)										
11872	NASB11	1.77	nd	nd	nd	nd	0.037	0.044	0.024	0.105
11873	NASB12	1.28	nd	nd	nd	nd	0.052	0.064	0.052	0.168
11874	NASB13	1.61	nd	nd	nd	nd	0.037	0.046	0.032	0.115
n=3										
Mean			nd	nd	nd	nd	0.042	0.051	0.036	0.129
SE							0.0050	0.0064	0.0083	0.0195

nd = non-detect, nc=not calculated
Total Chlordane = *trans* + *cis*
Total DDT = 4,4'-DDE + 4,4'-DDD + 4,4'-DDT

APPENDIX A

Trace Element Determinations - FR32102
US Department of the Interior
National Biological Service
Midwest Science Center
Columbia, MO

Available by request from:

US Fish and Wildlife Service
1033 South Main Street
Old Town, ME 04468

NOTE: The laboratory reports also contain information from another NASB fish tissue study (Picnic Pond). The Picnic Pond report is in preparation.

APPENDIX B

Organochlorine Determinations - 001250
ABC Laboratories California
Madera, California

Available by request from:

US Fish and Wildlife Service
1033 South Main Street
Old Town, ME 04468

NOTE: The laboratory reports also contain information from another NASB fish tissue study (Picnic Pond). The Picnic Pond report is in preparation.