Appendix C

Method for Selecting Biota-Sediment Accumulation Factors and Percent Lipids in Fish Tissue Used for Deriving Theoretical Bioaccumulation Potentials

Theoretical bioaccumulation potentials (TBPs) are empirically derived potential concentrations that might occur in the tissues of fish exposed to contaminated sediments. TBPs are computed for nonpolar organic chemicals as a function of sediment concentrations, fish tissue lipid contents, and sediment organic carbon contents. Four separate pieces of information are required to compute the TBP for nonpolar organic chemicals:

1. Concentration of nonpolar organic compound in sediment.
2. Organic carbon content of the sediment.
3. Biota-sediment accumulation factor (BSAF).
4. Lipid content in fish tissue.

The details of the TBP calculations and related assumptions are found in Appendix B of this report to Congress. This appendix describes the approach used to develop the BSAFs used in the NSI TBP evaluation and to evaluate fish tissue lipid content data from selected information sources for comparison to the values used in the NSI TBP evaluation. The BSAF values used for each chemical evaluated are presented in Appendix D.

Chemicals considered for fish tissue residue evaluation as part of the NSI data evaluation have at least one screening value available, and the sum of positive sediment results and positive tissue results is greater than 20 observations. BSAF values were assigned to all nonpolar organic chemicals in the NSI having available screening values. These screening values are risk-based concentrations (RBCs) developed either from carcinogenic potency slopes or from oral reference doses. Carcinogenic potency slopes and reference doses were obtained from IRIS (USEPA, 1995) and HEAST (USEPA, 1994b). Other screening values used for comparison to TBP values and tissue data are U.S. Food and Drug Administration (FDA) tolerance/action/guidance levels and EPA wildlife criteria. The BSAF values used in the analysis are presented in Appendix D along with the screening values discussed above.

Method for Selecting BSAFs

Biota-sediment accumulation factors (BSAFs) are transfer coefficients that relate concentrations in biota to concentrations in sediment. They are calculated as the ratio of the concentration of nonpolar organic chemical in fish tissue (normalized by lipid content) to the concentration of nonpolar organic chemical in sediment (normalized by organic carbon content). At equilibrium, BSAFs are in theory approximately 1.0. In practice, BSAFs can be greater than or less than 1.0 depending on the disequilibrium between fish and water, and that between water and sediment. Although based on partitioning theory, field measured BSAFs empirically account for factors such as metabolism and food chain biomagnificaiton. BSAFs can vary depending on the biota, dynamics of chemical loadings to the water body, food chain effects, and rate of sediment-water exchange. Thus, measured BSAF values will depend on many site-specific variables including hydraulic, biological, chemical, and ecological factors that affect bioavailability. The accuracy of a BASF, measured at one location at a point in time, when applied to another location at another point in time depends on two factors: (1) the degree to which variation from a theoretical BSAF of 1.0 is controlled by inherent properties of the chemical as opposed to environmental conditions of the locale, and (2) the degree of similarity between environmental conditions at the place of measurement and place of application.

BSAF values were assigned only to nonpolar chemicals in the NSI. This section describes how the BSAF values used for the TBP assessment were selected from recommended values for specific chemicals.

Sources of Recommended BSAFs

BSAFs used in the NSI TBP evaluation were obtained from the EPA Office of Research and Development (EPA/ORD) Environmental Research Laboratories at Duluth, Minnesota (Cook, 1995) and Narragansett, Rhode Island (Hansen, 1995). In some cases (i.e., EPA/ORD-Duluth), BSAFs were provided for specific chemicals; in other cases (i.e., EPA/ORD-Narragansett), BSAFs were provided by chemical class. Recommended BSAFs from each laboratory are described below.

EPA Environmental Research Laboratory, Duluth

BSAF recommendations obtained from EPA/ORD-Duluth included mainly chemical-specific values for:

- PCB congeners
- Pesticides
- Dioxins/Furans
- Chlorinated benzenes

The recommended values from EPA/ORD-Duluth were based on BSAF data compiled from various sites and studies. Data were selected based on the following criteria (Cook, 1995):

- The primary source of chemical exposure to food webs was through release of chemicals in sediments.
- The BSAF was derived for pelagic organisms (i.e., fish).
- Chemicals in sediments and biota were at roughly steady state with respect to environmental loadings of the chemical.

Pelagic BSAF data which predict relative bioaccumulation potentials of different chemicals are available for ecosystems in which sediments are a primary source of the chemicals to pelagic food webs through release of chemicals to the water. Little or no BSAF data exist for sites in which water and sediments are at steady-state with respect to external chemical loadings. The best BSAF data for fish are those measured for Lake Ontario and used to estimate BAFs in the Technical Support Document (TSD) for the Great Lakes Water Quality Initiative (GLWQI) (Cook, 1995; Cook et al., 1994; USEPA, 1994a). The lake Ontario BSAFs are based on a large set of sediment and fish samples collected in 1987 (USEPA, 1990). The BSAFs for PCDDs, PCDFs and co-planar PCB congeners are available from ORD-Duluth data. Additional BSAFs for PCBs and pesticides are available from the data of Oliver and Niimi (1988). These contemporary BSAFs are estimated to be approximately 20 to 25 percent of BSAFs when Lake Ontario surface sediments and water are at steady-state with chemical loading to the ecosystem; a condition which probably existed in the 1960s. EPA has measured BSAFs in the Fox River and Green Bay in Wisconsin and find similar values despite much different species and exposure conditions (Cook, 1995).

EPA Environmental Research Laboratory, Narragansett

EPA/ORD-Narragansett provided a second source of information for selecting BSAF values. Probability distribution curves for selecting BSAFs were presented by EPA/ORD-Narragansett for three chemical classes:

- PAHs
- PCBs
- Pesticides

EPA/ORD-Narragansett researchers developed cumulative probability curves for each chemical class from their database of BSAFs (Hansen, 1995). The database from which general BSAF recommendations were summarized included data from laboratory and field studies conducted with both freshwater and marine sediments. Data must be from species that directly contact sediments or feed on organisms that live in sediments, i.e., benthic invertebrates and benthically coupled fishes.

Overall the database contained more than 4,000 BSAF observations. Cumulative probability curves summarizing the BSAF data in the database were provided by Hansen (1995) for PAHs, PCBs, and pesticides. BSAF values were tabulated for several probability percentiles. These findings have been published in Tracey and Hansen, 1996.

Approach for Selecting BSAFs from Recommended Values

The general approach for selecting a BSAF for a chemical follows:

- Use a chemical-specific value for the BSAF, if available.
- If no chemical-specific value is available, use a BSAF derived for a chemical category.
- For chemicals having no specific information on the BSAF, use a default value of 1.

The EPA/ORD-Narragansett values for the BSAF were selected as the 50th percentile of the distribution of BSAFs by chemical class (Table C-1). The BSAF values from EPA/ORD-Duluth were averages of individual data points for specific chemicals. The preference for central tendency measures reflects risk management that imples an approximate 50 percent chance of bioaccumulation to a predicted level. Other components of the EPA risk levels for fish tissue chemical residues and FDA action/tolerance/guidance, such as toxic potency (cancer potency factor and oral reference doses) and exposure frequency, reflect more precautionary and protective risk management.

Because there was some overlap between the categories of chemicals for which BSAF values were recommended, the following approach was used to assign BSAFs to specific chemicals in the NSI (Table C-2). For dioxins and furans, chemical-specific values recommended by EPA/ORD-Duluth were applied; for PCBs, the value for total PCBs recommended by EPA/ORD-Duluth was used. When using BSAFs from USEPA (1994a), values from the study by Cook et al. (1994) were preferred over values reported by Oliver and Niimi (1988).

Pesticides received recommendations from both laboratories. The BSAFs developed by EPA/ORD-Narragansett were for benthic organisms and demersal (bottom-dwelling) fishes. The BSAFs developed by EPA/ORD-Duluth, on

Table C-1. EPA/ORD-Narragansett Data BSAF Distributions (kg sediment organic carbon/kg lipid)

	Chemical Class		
Probability Percentile	**PAHs**	**PCBs**	**Pesticides**
50	0.29	1.11	1.80
70	0.55	2.26	3.34
80	0.94	3.66	4.61
90	1.71	5.83	7.31
95	2.84	9.15	10.61
100	4.19	16.46	22.63

Table C-2. Conventions for Assigning BSAFs to Nonpolar Organic Compounds in NSI

Category of Chemical	Source of BSAF	BSAF Value Used in Evaluation
Dioxins	EPA/ORD-Duluth[a] "pelagic" chemical-specific BSAF	0.059
PCBs	EPA/ORD-Duluth[a] "pelagic" BSAF for total PCBs	1.85
Pesticides	log K_{ow} < 5.5 EPA/ORD-Narragansett[b] "benthic" class-specific BSAF for 50th percentile protection level	1.80
	log K_{ow} ³ 5.5 EPA/ORD-Duluth[a] "pelagic" chemical-specific BSAF if available; otherwise, use EPA/ORD-Narragansett[b] value	See chemical-specific BSAF given in Appendix D
PAHs	EPA/ORD-Narragansett[b] "benthic" class-specific BSAF for 50th percentile protection level	0.29
Halogenated and other compounds	Default value of 1 unless chemical-specific value available from EPA/ORD-Duluth[a]	1.0

[a]Cook, 1995.
[b]Hansen, 1995.

the other hand, were for benthically coupled pelagic (open-water) fishes. BSAFs from EPA/ORD-Narragansett were used for pesticides having log K_{ow} values less than 5.5. For pesticides having log K_{ow} values greater than or equal to 5.5, the BSAF values from EPA/ORD-Duluth were used. BSAF values selected by this approach are more appropriate because food web transfer to pelagic fishes is considered to be a more important process for chemicals having high log K_{ow} values. Exposure through environmental media, as in direct contact with sediments by benthic organisms, is a more important process for chemicals having low log K_{ow} values. Chemicals having no recommended BSAF values available were assigned a default BSAF of 1.

Evaluation of Tissue Lipid Content

Fish tissue lipid content enters the risk screening assessment as the normalizing factor in the numerator of the TBP equation. Normalizing by organic carbon content removes much of the site-to-site variation in the sorption of nonpolar organic chemicals by sediments (Karickhoff et al., 1979). In a similar manner, normalizing by lipid content can eliminate much site and species variation in the tendency of organisms to bioaccumulate nonpolar organic compounds (Esser, 1986). Lipid contents can vary naturally with species, site, season, age and size of fish, and trophic level. In addition, reported lipid contents can vary significantly depending on the analytical method (Randall et al., 1991).

The purpose of this section is to evaluate the percent fish lipid content data from various sources and compare these values to those selected for use in the NSI evaluation (i.e., 3.0 percent for fillets for human health TBP evaluations and 10.31 for whole body wildlife TBP evaluations).

The remainder of this section describes the lipid data sources evaluated and analysis of the lipid content data.

Sources of Lipid Data

Lipid data used for comparison with the percent lipid values selected for the NSI evaluation were obtained from three major sources:

- EPA's water monitoring database, STORET.
- *National Study of Chemical Residues in Fish*, or NSCRF (USEPA, 1992).
- U.S. Department of Agriculture's (USDA's) *Composition of Foods* (Dickey, 1990).

Additional sources included examples of whole fish and fillet lipid contents taken from the recent literature.

Each of the three major sources is described in the following paragraphs.

STORET

The STORET database was the single largest source of reported data on fish tissue lipid contents. Data stored under various parameter codes for lipid content in STORET were converted into units of percentage. Some screening of the data was performed as follows:

- Records were retrieved from January 1990 to March 1995.
- Reported lipid contents greater than 35 percent were eliminated because they were significantly greater than the 90th percentile.
- Only records having an anatomy code of “whole organism” or “fillet” were included. Records with a code of “fillet/skin” or “edible portion” were excluded.
- Data that appeared to be reversed (i.e., fillet percent lipid was greater than whole organism lipid) were also not considered.
- Also not considered were records in which the minimum and maximum were equal, or very nearly equal, when the number of observations was large.

There is less consistency in the data obtained from STORET relative to the NSCRF data because the analyses in STORET were conducted by numerous laboratories around the Nation. Data reported under different parameter codes (i.e., different methods for lipids) were grouped for the analysis. Moreover, the quality of the data in STORET is unknown. STORET data are compiled by species in Table C-3. The fishes are divided by trophic level and habitat into four subtables (Tables C-3a through C-3d) for the combinations of trophic levels 3 and 4 and epibenthic (bottom-dwelling) and pelagic (water column-dwelling) habitat.

National Study of Chemical Residues in Fish

The second largest database on fish tissue lipid content was available from the NSCRF (USEPA, 1992) (Table C-3). This set of lipid analysis data was taken in conjunction with analyses for dioxins/furans. An advantage of this database is that all of the lipid measurements were performed by the same laboratory using the same method. The data were screened to exclude data for fish species for which two or fewer observations were made.

USDA Report on Composition of Foods

A summary of a relatively small database on the composition of fish and shellfish foods and food products was available from USDA (Dickey, 1990). The section on fish and shellfish in the report coordinated by Dickey (1990) came from an earlier USDA report by Exler (1987). Data presented by Exler (1987) for various fish species were summarized from the USDA’s Nutrient Data Bank (NDB). Records in the NDB are based primarily on published scientific reports and technical journal articles. To a lesser extent, the NDB contains unpublished data from industrial, government, and academic institutions under contract with the Human Nutrition Information Service. Lipids data are given in percentage of edible portion, where “edible portion” is the part of food customarily considered edible in the United States. Records were available for 32 fishes.

Table C-3a. Lipid Contents of Trophic Level 3, Epibenthic Fishes

Species Name	Common Name	Whole Fish Lipid Content, Percent (size)	Fillet Lipid Content, Percent (size)	Reference, Comments
Aplodinotus grunniens	freshwater drum		mean = 1.9 (1.3 to 2.5, 3 obs)	EPA (1992)
Aplodinotus grunniens	freshwater drum		mean = 4.93, standard (error = 0.103, 905 obs)	Exler (1987)
Carpoides carpio	river carpsucker	mean = 5.8 (0.5 to 15.0, 3865 obs)	mean = 4.4 (1.8 to 9.2, 184 obs)	STORET
Carpoides cyprinus	quillback	mean = 5.1 (0.3 to 13.0, 780 obs)	mean = 3.2 (0.4 to 4.89, 78 obs)	STORET
Catostomus ardens	Utah sucker	mean = 3.5 (1.1 to 8.2, 356 obs)	mean = 1.6 (0.1 to 6.7, 695 obs)	STORET
Catostomus catostomus	longnose sucker (FW)		0.8 to 3.8 (not given)	Owens et al. (1994)
Catostomus catostomus	longnose sucker	mean = 3.9 (2.5 to 7.2, 298 obs)	mean = 7.05 (6.4 to 7.7, 32 obs)	STORET
Catostomus columbianus	bridgelip sucker	mean = 4.6 (0.7 to 10.4, 309 obs)		STORET
Catostomus commersoni	white sucker		5.41 ± 1.18 1.07 ± 0.23 1.36 ± 0.17 0.99 ± 0.22 2.25 ± 0.65 (not given)	Servos et al. (1994)
Catostomus commersoni	white sucker	mean = 6.1 (1.4 to 21.8, 39 obs)		USEPA (1992)
Catostomus commersoni	white sucker	mean = 4.3 (0.2 to 12.0, 4102 obs)	mean = 1.7 (0.2 to 9.1, 586 obs)	STORET
Catostomus commersoni	white sucker		mean = 2.32 (standard error = 0.069, 157 obs)	Exler (1987)
Catostomus macrocheilus	largescale sucker	mean = 6.7 (0.3 to 13.0, 752 obs)	mean = 1.6 (0.1 to 5.26, 482 obs)	STORET
Catostomus occidentalis	Sacramento sucker	mean = 9.8 (1.7 to 18.5, 3 obs)		USEPA (1992)
Cottus cognatus	sculpin (FW)	8 (5.4 g)		USEPA (1994a)
Cyprinus carpio	carp	9 (15 g)		Cook et al. (1991)
Cyprinus carpio	carp	18.7 (69.5 g) 15.7 (56.0 g) 13.0 (37.5 g) 16.6 (36.5 g) 17.5 (29.0 g)		Kuehl et al. (1987)

Table C-3a. (Continued)

Species Name	Common Name	Whole Fish Lipid Content, Percent (size)	Fillet Lipid Content, Percent (size)	Reference, Comments
Cyprinus carpio	carp	18.7 (69.5 g) 15.7 (56.0 g) 13.0 (37.5 g) 16.6 (36.5 g) 17.5 (29.0 g)		Kuehl et al. (1987)
Cyprinus carpio	carp	mean = 9.3 (0.5 to 25.1, 145 obs)	mean = 9.0 (2.0 to 19.6, 6 obs)	USEPA (1992)
Cyprinus carpio	carp	mean = 6.5 (0.3 to 17.0, 70002 obs)	mean = 4.3 (0.02 to 21.6, 16139 obs)	STORET
Cyprinus carpio	carp		mean = 5.60 (standard error = 0.207, 163 obs)	Exler (1987)
Ctenophyaryngodon idella	grass carp		mean = 5.2 (3 obs)	USEPA (1992)
Erimyzon oblongus	creek chubsucker	mean = 3.9 (3.9 to 4.0, 3 obs)		USEPA (1992)
Hypentelium nigricans	northern hogsucker	mean = 4.4 (0.8 to 8.98, 637 obs)	mean = 0.7 (0.5 to 0.99, 70 obs)	STORET
Ictalurus furcatus	blue catfish	mean = 7.3 (5.3 to 10.4, 5 obs)	mean = 2.7 (2.0 to 3.0, 4 obs)	USEPA (1992)
Ictalurus furcatus	blue catfish		mean = 6.0 (1.5 to 12.0, 56 obs)	STORET
Ictalurus melus (Ameiurus melas)	black bullhead	mean = 2.9 (0.9 to 6.2, 911 obs)	mean = 1.4 (0.15 to 5.1, 573 obs)	STORET
Ictalurus natalis (Ameiurus natalis)	yellow bullhead	mean = 2.8 (0.5 to 7.5, 235 obs)	mean = 0.96 (0.1 to 3.2, 294 obs)	STORET
Ictalurus nebulosus (Ameiurus nebulosus)	brown bullhead	mean = 2.2 (1.3 to 4.1, 133 obs)	mean = 1.5 (0.4 to 3.3, 107 obs)	STORET
Ictalurus punctatus	channel catfish	mean = 9.8 (3.4 to 23.0, 22 obs)	mean = 5.1 (1.1 to 11.5, 17 obs)	USEPA (1992)
Ictalurus punctatus	channel catfish	mean = 7.1 (0.3 to 15.0, 7512 obs)	mean = 5.1 (0.2 to 17.3, 20655 obs)	STORET
Ictalurus punctatus	channel catfish		mean = 4.26 (standard error = 0.417, 59 obs)	Exler (1987)
Ictiobus bubalus	smallmouth buffalo	mean = 5.7 (2.2 to 11.9, 6 obs)		USEPA (1992)

Table C-3a. (Continued)

Species Name	Common Name	Whole Fish Lipid Content, Percent (size)	Fillet Lipid Content, Percent (size)	Reference, Comments
Ictiobus bubalus	smallmouth buffalo	mean = 9.7 (2.8 to 17.3, 886 obs)	mean = 4.8 (0.2 to 14.5, 595 obs)	STORET
Ictiobus cyprinellus	bigmouth buffalo	mean = 15.1 (5.7 to 22.6, 3 obs)		USEPA (1992)
Ictiobus cyprinellus	bigmouth buffalo	mean = 5.8 (0.4 to 16.2, 675 obs)	mean = 4.1 (0.3 to 15, 1678 obs)	STORET
Ictiobus niger	black buffalo		mean = 3.5 (1.2 to 7.1, 42 obs)	STORET
Minytrema melanops	spotted sucker	mean = 4.5 (0.9 to 7.4, 9 obs)		USEPA (1992)
Minytrema melanops	spotted sucker	mean = 3.7 (0.7 to 5.9, 188 obs)	mean = 1.5 (0.9 to 3.2, 197 obs)	STORET
Moxostoma anisurum	silver redhorse	mean = 8.2 (6.2 to 8.5, 180 obs)	mean = 2.1 (1.3 to 2.7, 7 obs)	STORET
Moxostoma carinatum	river redhorse	mean = 5.1 (1.9 to 5.9, 193 obs)	mean = 1.3 (0.5 to 2.4, 170 obs)	STORET
Moxostoma duquesnei	black redhorse	mean = 5.0 (0.3 to 9.7, 1774 obs)	mean = 0.97 (0.7 to 1.8, 58 obs)	STORET
Moxostoma erythrurum	golden redhorse	mean = 6.0 (0.8 to 16.1, 2018 obs)	mean = 1.8 (0.6 to 2.8, 154 obs)	STORET
Moxostoma macrolepidotum	shorthead redhorse	mean = 19.8 (10.8 to 31.9, 4 obs)		USEPA (1992)
Moxostoma macrolepidotum	shorthead redhorse	mean = 6.5 (0.4 to 10.9, 683 obs)	mean = 3.0 (1.4 to 13.5, 342 obs)	STORET
Mugil cephalus	striped mullet		mean = 3.79 (standard error = 0.357, 43 obs)	Exler (1987)
Mylocheilus caurinus	peamouth	mean = 11.0 (9.36 to 12.91, 162 obs)		STORET
Ptychocheilus oregoni	northern squawfish	mean = 5.6 (0.8 to 12.0, 812 obs)	mean = 1.3 (0.7 to 3.0, 117 obs)	STORET
Ptychocheilus	squawfish		mean = 2.2 (0.5 to 3.0, 7 obs)	USEPA (1992)
Scaphirhynchus platorhynchus	shovelnose sturgeon		mean = 7.4 (1.1 to 20.3, 392 obs)	STORET

Table C-3b. Lipid Contents of Trophic Level 3, Pelagic Fishes

Species Name	Common Name	Whole Fish Lipid Content, Percent (size)	Fillet Lipid Content, Percent (size)	Reference, Comments
Acipenser sp.	sturgeon (unknown)		mean = 4.04 (7 obs)	Exler (1987)
Acrocheilus alutaceus	chiselmouth	mean = 5.0 (3.2 to 6.8, 47 obs)	mean = 0.55 (0.19 to 1.00, 91 obs)	STORET
Alosa pseudoharengus	alewife	7 (32 g)		USEPA (1994a)
Alosa pseudoharengus	alewife	mean = 8.9 (3.7 to 15.2, 128 obs)		STORET
Alosa sapidissima	American shad	mean = 6.55 (5.9 to 7.6, 270 obs)		STORET
Alosa sapidissima	American shad		mean = 13.77 (standard error = 1.00, 11 obs)	Exler (1987)
Anguilla rostrata	American eel		mean = 11.66 (standard error = 0.885, 14 obs)	Exler (1987)
Aplodinotus grunniens	freshwater drum	mean = 5.5 (1.0 to 19.7, 574 obs)	mean = 4.8 (0.3 to 21.2, 459 obs)	STORET
Archosargus probatocephalus	sheepshead		mean = 2.41 (standard error = 0.040, 5 obs)	Exler (1987)
Coregonus artedii	cisco (lake herring)		mean = 1.91 (standard error = 0.149, 69 obs)	Exler (1987)
Coregonus clupeaform	lake whitefish		mean = 5.86 (standard error = 0.451, 68 obs)	Exler (1987)
Coregonus hoyi	bloater	mean = 21.1 (16 to 25.5, 52 obs)	mean = 8.3 (3.2 to 17.0, 98 obs)	STORET
Dorosoma cepedianum	gizzard shad	mean = 7.4 (1.3 to 18.0, 189 obs)		STORET
Dorosoma petenense	threadfin shad	mean = 3.0 (0.5 to 18.0, 9 obs)		STORET
Gadus macrocephalus	true or Pacific cod		mean = 0.63 (standard error = 0.031, 18 obs)	Exler (1987)
Hiodon alosoides	goldeye	mean = 3.2 (3.5 to 2.8, 74 obs)		STORET

Table C-3b. (Continued)

Species Name	Common Name	Whole Fish Lipid Content, Percent (size)	Fillet Lipid Content, Percent (size)	Reference, Comments
Platygobia (*Hybopsis* in database) *gracilis*	flathead chub		mean = 3.3 (0.68 to 8.14, 75 obs)	STORET
Lepomis auritis	redbreast sunfish	mean = 3.6 (1.3 to 8.1, 550 obs)		STORET
Lepomis cyanellus	green sunfish	mean = 3.2 (2.2 to 7.8, 376 obs)		STORET
Lepomis gibbosus	pumpkinseed	mean = 3.9 (2.2 to 7.7, 126 obs)		STORET
Lepomis gibbosus	pumpkinseed		mean = 0.70 (standard error = 0.071, 8 obs)	Exler (1987)
Lepomis megalotis	longear sunfish	mean = 2.8 (1.0 to 7.2, 536 obs)		STORET
Osmerus mordax	rainbow smelt	4 (16 g)		USEPA (1994)
Osmerus mordax	rainbow smelt		mean = 2.42 (standard error = 0.107, 52 obs)	Exler (1987)
Pimephales promelas	fathead minnow	19 (1 g)		Cook et al. (1991)
Lepomis macrochirus	bluegill sunfish	mean = 3.5 (2.4 to 4.6, 4 obs)		USEPA (1992)
Lepomis macrochirus	bluegill sunfish	mean = 4.4 (0.1 to 8.7, 1034 obs)		STORET
Lota lota	burbot		0.35 to 0.7	Owens et al. (1994)
Lota lota	burbot		mean = 0.2 (0.1 to 0.3, 18 obs)	STORET
Lota lota	burbot		mean = 0.81 (standard error = 0.059, 13 obs)	Exler (1987)
Oryzias latipes	medaka	8 (0.175 g)		Schmieder et al. (1992)
Phoxinus erythrogaster	southern redbelly dace	mean = 5.6 (2.2 to 10.0, 762 obs)		STORET

Table C-3b. (Continued)

Species Name	Common Name	Whole Fish Lipid Content, Percent (size)	Fillet Lipid Content, Percent (size)	Reference, Comments
Pomoxis annularis	white crappie		mean = 1.0 (0.5 to 2.0, 7 obs)	USEPA (1992)
Pomoxis annularis	white crappie	mean = 2.1 (0.4 to 5.8, 622 obs)	mean = 0.4 (0.08 to 2.6, 936 obs)	STORET
Pomoxis nigromaculatus	black crappie		mean = 1.1 (0.5 to 1.5, 3 obs)	USEPA (1992)
Pomoxis nigromaculatus	black crappie	mean = 2.7 (0.7 to 8.4, 457 obs)	mean = 1.4 (0.13 to 5.3, 118 obs)	STORET
Prosopium williamsoni	mountain whitefish	mean = 8.5 (0.5 to 13.8, 327 obs)	mean = 1.6, (0.2 to 4.1, 532 obs)	STORET
Prosopium williamsoni	mountain whitefish		3.4 to 11.8 (not given)	Owens et al. (1994)
Richardsonius balteatus	redside shiner		mean = 0.9 (0.85 to 0.96, 50 obs)	STORET
Sebastes auriculatus	brown rockfish		mean = 1.57 (81 obs)	Exler (1987)
Sebastes marinus	redfish		mean = 1.63 (standard error = 0.092, 208 obs)	Exler (1987)
Semotilus atromacula	creek chub	mean = 3.9 (1.0 to 5.0, 815 obs)		STORET
Semotilus corporalis	fallfish	mean = 1.9 (0.25 to 3.9, 100 obs)		STORET

Table C-3c. Lipid Contents of Trophic Level 4, Epibenthic Fishes

Species Name	Common Name	Whole Fish Lipid Content, Percent (size)	Fillet Lipi Content, Per
Pylodictis olivaris	flathead catfish	mean = 3.1 (0.5 to 8.1, 829 obs)	mean = 3.0 (0.2 21.1, 1315 obs)
Pylodictis olivaris	flathead catfish	mean = 6.0 (1.6 to 8.7, 3 obs)	mean = 1.9 (0.6 to 3.1, 4 ob

Table C-3d. Lipid Contents of Trophic Level 4, Pelagic Fishes

Species Name	Common Name	Whole Fish Lipid Content, Percent (size)	Fillet Lipid Content, Percent (size)	Reference, Comments
Ambloplites rupestris	rock bass		mean = 1.0 (0.8 to 1.2, 3 obs)	USEPA (1992)
Ambloplites rupestris	rock bass	mean = 2.3 (0.6 to 4.4, 759 obs)	mean = 0.7 (0.4 to 0.98, 129 obs)	STORET
Amia calva	bowfin		mean = 0.5 (0.04 to 1.4, 230 obs)	STORET
Centropristis striata	black sea bass		mean = 2.00 (standard error = 0.221, 40 obs)	Exler (1987)
Esox lucius	northern pike		mean = 1.4 (0.6 to 2.6, 5 obs)	USEPA (1992)
Esox lucius	northern pike	mean = 1.9 (0.1 to 9.8, 810 obs)		STORET
Esox lucius	northern pike		mean = 0.69 (standard error = 0.005, 224 obs)	Exler (1987)
Esox niger	chain pickerel		mean = 1.3 (0.6 to 2.0, 5 obs)	USEPA (1992)
Leiostomus xanthurus	spot	mean = 5.2 (3.3 to 7.9, 300 obs)		STORET
Leiostomus xanthurus	spot		mean = 4.90 (standard error = 2.93, 10 obs)	Exler (1987)
Lutjanus campechanus	red snapper		1.34 (55 obs)	Exler (1987)
Micropogonias undulatus	Atlantic croaker		3.17 (standard error = 0.529, 8 obs)	Exler (1987)
Micropterus dolomieu	smallmouth bass		mean = 1.6 (0.8 to 4.4, 19 obs)	USEPA (1992)
Micropterus dolomieu	smallmouth bass	mean = 3.4 (0.3 to 8.8, 1166 obs)	mean = 0.6 (0.01 to 2.3, 848 obs)	STORET
Micropterus punctulatus	spotted bass		mean = 2.8 (0.9 to 4.5, 4 obs)	USEPA (1992)
Micropterus punctualtus	spotted bass	mean = 2.4 (0.6 to 4.9, 322 obs)	mean = 0.7 (0.1 to 1.8, 353 obs)	STORET

Table C-3d. (Continued)

Species Name	Common Name	Whole Fish Lipid Content, Percent (size)	Fillet Lipid Content, Percent (size)	Reference, Comments
Micropterus salmoides	largemouth bass		mean = 1.6 (0.4 to 7.6, 54 obs)	USEPA (1992)
Micropterus salmoides	largemouth bass	mean = 4.1 (0.3 to 10.6, 2924 obs)	mean = 0.7 (0.04 to 9.2, 4548 obs)	STORET
Morone americana	white perch	mean = 4.5 (2.6 to 7.1, 249 obs)		STORET
Morone chrysops	white bass		mean = 2.7 (0.7 to 4.8, 11 obs)	USEPA (1992)
Morone chrysops	white bass	mean = 4.6 (0.3 to 15.4, 615 obs)	mean = 3.9 (0.01 to 8.1, 847 obs)	STORET
Morone saxatilis	striped bass		mean = 2.33 (standard error = 0.381, 14 obs)	Exler (1987)
Oncorhynchus gorbuscha	pink salmon		mean = 3.45 (standard error = 0.141, 144 obs)	Exler (1987)
Oncorhynchus kisutch	coho salmon		mean = 2.7 (0.4 to 10.7, 383 obs)	STORET
Oncorhynchus kisutch	coho salmon		mean = 5.92 (standard error = 0.162, 217 obs)	Exler (1987)
Oncorhynchus mykiss	rainbow trout	11 (35 g)		Branson et al. (1985)
Oncorhynchus mykiss	rainbow trout		mean = 5.0 (4.1 to 5.6, 3 obs)	USEPA (1992)
Oncorhynchus nerka	sockeye salmon		mean = 8.56 (standard error = 0.392, 48 obs)	Exler (1987)
Oncorhynchus tshawytscha	chinook salmon	mean = 3.7 (2.4 to 5.1, 52 obs)	mean = 2.2 (0.04 to 17.7, 1957 obs)	STORET
Oncorhynchus tshawytscha	chinook salmon		mean = 10.44 (standard error = 1.692, 10 obs)	Exler (1987)
Perca flavescens	yellow perch	mean = 3.6 (1.2 to 9.1, 112 obs)	mean = 0.5 (0.1 to 4.6, 280 obs)	STORET
Pomatomus saltatrix	bluefish		mean = 4.27 (3 obs)	Exler (1987)

Table C-3d. (Continued)

Species Name	Common Name	Whole Fish Lipid Content, Percent (size)	Fillet Lipid Content, Percent (size)	Reference, Comments
Salmo clarki (Onchorhynchus clarki)	cutthroat trout		mean = 1.0 (0.2 to 1.7, 378 obs)	STORET
Salmo gairdneri (Onchorhynchus mykiss)	rainbow trout		mean = 3.36 (standard error = 0.256, 24 obs)	Exler (1987)
Salmo salar	Atlantic salmon		mean = 6.34 (standard error = 1.72, 7 obs)	Exler (1987)
Salmo trutta	brown trout		mean = 4.0 (1.6 to 8.1, 6 obs)	USEPA (1992)
Salmo trutta	brown trout	mean = 6.0 (1.5 to 8.9, 112 obs)	mean = 5.0 (0.14 to 14.8, 741 obs)	STORET
Salvelinus namaycush, Oncorhynchus mykiss, Oncorhynchus spp.	salmonids	11 (2410 g)		USEPA (1994a)
Salvelinus malma	Dolly Varden	mean = 7.1 (2.1 to 9.9, 3 obs)		USEPA (1992)
Salvelinus namaycush	lake trout	mean = 15.9 (12.6 to 18.3, 42 obs)	mean = 7.8 (2.5 to 20.0, 1883 obs)	STORET
Scomberomorus cavall	king mackerel		mean = 2.00 (standard error = 0.188, 6 obs)	Exler (1987)
Scomberomorus macula	Spanish mackerel		mean = 6.30 (standard error=3.810, 3 obs)	Exler (1987)
Stizostedion canadense	sauger	mean = 6.0 (0.8 to 16.3, 139 obs)	mean = 1.7 (0.3 to 10.0, 195 obs)	STORET
Stizostedion vitreum	walleye		0.6 to 0.7	Owens et al. (1994)
Stizostedion vitreum	walleye	mean = 6.2 (0.3 to 15, 1089 obs)	mean = 1.3 (0.3 to 6.0, 440 obs)	STORET
Stizostedion vitreum	walleye		mean = 1.22 (standard error = 0.162, 14 obs)	Exler (1987)
Stizostedion vitreum	walleye		mean = 1.6 (0.7 to 2.6, 13 obs)	USEPA (1992)

Analysis of Lipids Data

Lipids data were analyzed for comparison with the screening value selected for the NSI evaluation by computing averages. Eight averages of data for fishes of the following categories for data in STORET (Table C-4a) and the NSCRF (Table C-4b) were computed (and labeled A-H):

A. Trophic levels 3 and 4, whole body
B. Trophic levels 3 and 4, whole body, excluding migratory and saltwater fishes
C. Trophic level 4, pelagic, fillet
D. Trophic level 4, pelagic, fillet, excluding migratory and saltwater fishes
E. Resident, freshwater, demersal fishes, whole body
F. Resident, freshwater, pelagic fishes, whole body
G. Resident, freshwater, demersal fishes, fillet
H. Resident, freshwater, pelagic fishes, fillet.

Data for fillets and whole fish were evaluated separately. All analyses except “A” were of fishes in the NSI exclusively. Summary statistics reported include the mean, standard error, range, and number of observations. The matrices in Tables C-4a and C4-b indicate the categories of fishes averaged. The average of edible portions from USDA data was 4.1 percent lipid.

The mean fillet percent lipid content for various groups of fish species in the STORET database ranged from 0.753 to 4.49 percent; in the NSCRF, mean fillet values ranged from 1.6 to 4.9 percent. The mean whole-body percent lipid content for various groups of fish species in the STORET database ranged from 3.757 to 6.33 percent; in the NSCRF, mean whole-body values ranged from 4.6 to 8.8 percent.

Table C-4a. Lipid Analysis - STORET

	Matrix of Fishes Included in Average									Lipid Content, %			
	Trophic Level		Position in Water Column		Mobility		Habitat						
Analysis	3	4	Demersal	Pelagic	Resident	Migratory	Freshwater	Saltwater	Tissue/ Organ	Mean	Standard Error	Number of Observations	Range
A	●	●	●	●	●	●	●	●	whole	5.97		113,978	0.1-26.7
B	●	●	●	●	●		●		whole	5.97	0.010	110,998	0.1-26.7
C		●		●	●	●	●	●	fillet	2.5		13,293	0.01-20
D		●		●	●		●		fillet	0.753	0.010	6793	0.01-10
E	●	●	●		●		●		whole	6.33	0.011	91867	0.22-26.7
F	●	●		●	●		●		whole	3.757	0.020	13025	0.10-16.3
G	●	●	●		●		●		fillet	4.49	0.018	42687	0.02-24
H	●	●		●	●		●		fillet	1.06	0.021	9378	0.01-21.07

Table C-4b. Lipid Analysis - NSCRF

Analysis	Matrix of Fishes Included in Average								Tissue/ Organ	Lipid Content, %			
	Trophic Level		Position in Water Column		Mobility		Habitat						
	3	4	Demersal	Pelagic	Resident	Migratory	Freshwater	Saltwater		Mean	Standard Error	Number of Observations	Range
A	●	●	●	●	●	●	●	●	whole	8.5		249	0.5-31.9
B	●	●	●	●	●		●		whole	8.6	0.328	246	0.5-31.9
C		●		●	●	●	●	●	fillet	1.9		122	0.4-8.1
D		●		●	●		●		fillet	1.6	0.116	103	0.4-7.6
E	●	●	●		●		●		whole	8.8	0.338	233	0.5-31.9
F	●	●		●	●		●		whole	4.6	1.02	7	1.6-8.7
G	●	●	●		●		●		fillet	4.9	0.697	34	0.5-19.6
H	●	●		●	●		●		fillet	1.6	0.106	117	0.4-7.6

Data for fillets and whole fish were evaluated separately. All analyses except "A" were of fishes in the NSI exclusively. Summary statistics reported include the mean, standard error, range, and number of observations. The matrices in Tables C-4a and C-4b indicate the categories of fishes averaged. The average of edible portions from USDA data was 4.1 percent lipid.

The mean fillet percent lipid content for various groups of fish species in the STORET database ranged from 0.753 to 4.49 percent; in the NSCRF, mean fillet values ranged from 1.6 to 4.9 percent. The mean whole-body percent lipid content for various groups of fish species in the STORET database ranged from 3.757 to 6.33 percent; in the NSCRF, mean whole-body values ranged from 4.6 to 8.8 percent.

References

Branson, D.R., I.T. Takahashi, W.M. Parker, and G.E. Blau. 1985. Bioconcentration of 2, 3, 7, 8-tetrachlorodibenzo-p-dioxin in rainbow trout. *Environ. Toxicol. Chem.* 4:799-788.

Cook, P.M. 1995. Pelagic BSAFs for NSI methodology. Memorandum from P.M. Cook, ERL, Duluth, to C. Fox, USEPA Office of Water, March 29, 1995.

Cook, P.M., G.T. Ankley, R.J. Erickson, B.C. Butterworth, S.W. Kohlbry, P. Marquis, and H. Corcoran. 1994. *The biota-sediment accumulation factor (BSAF): Evaluation and application to assessment of organic chemical bioaccumulation in the Great Lakes.* In preparation. (cited in: USEPA, 1994a)

Dickey, L.E. 1990. *Composition of foods, raw, processed, prepared—1990 supplement.* Agriculture Handbook 8, 1990 Supplement. U.S. Department of Agriculture, Human Nutrition Information Service, Washington, DC.

Esser, H.O. 1986. A review of the correlation between physicochemical properties and bioaccumulation. *Pestic. Sci.* 17:265-276. (as cited by Randall et al., 1991).

Exler, J. 1987. *Composition of foods: Finfish and shellfish products.* Agriculture Handbook No. 8-15. U.S. Department of Agriculture, Human Nutrition and Information Service, Washington, DC.

Flint, R.W. 1986. Hypothesized carbon flow through the deep water Lake Ontario food web. *J. Great Lakes Res.* 12:344-354.

Hansen. 1995. Assessment tools that can be used for the National Sediment Inventory. Memorandum from D.J. Hansen, ERL, Narragansett, to C. Fox, USEPA Office of Water, February 28, 1995.

Karickhoff, S.W., D.S. Brown, and T.A. Scott. 1979. Sorption of hydrophobic pollutants on natural sediments. *Water Res.* 13: 241-248.

Kuehl, D.W., P.M. Cook, A.R. Batterman, D.B. Lothenbach, and B.C. Butterworth. 1987. Bioavailability of polychlorinated dibenzo-p-dioxins and dibenzofurans from contaminated Wisconsin River sediment to carp. *Chemosphere* 18:1997-2014.

Oliver, B.G., and A.J. Niimi. 1988. Trophodynamic analysis of polychlorinated biphenyl congeners and other chlorinated hydrocarbons in the Lake Ontario ecosystem. *Environ. Sci. Technol.* 22:388-397.

Owens, J.W., S.M. Swanson, and D.A. Birkholz. 1994. Bioaccumulation of 2, 3, 7, 8-tetrachlorodibenzo-p-dioxin, 2, 3, 7, 8-tetrachlorodibenzofuran and extractable organic chlorine at a bleached kraft mill site in a northern Canadian river system. *Environ. Toxicol. Chem.* 13:343-354

Randall, R.C., H. Lee II, R.J. Ozretich, J.L. Lake, and R.J. Pruell. 1991. Evaluation of selected lipid methods for normalizing pollutant bioaccumulation. *Environ. Toxicol. Chem.* 10:1431-1436.

Tracey, G.A. and D.J. Hansen. 1996. Use of biota-sediment accumulation factors to assess similarity of nonionic organic chemical exposure to benthically-coupled organisms of differing trophic mode. *Arch, Environ. Contam. Toxical.* 30:467-475.

Schmeider, P., D. Lothenbach, R. Johnson, R. Erickson, and J. Tietge. 1992. Uptake and elimination kinetics of ^{3}H-TCDD in medaka. *Toxicologist* 12:138.

Servos, M.R., S.Y. Huestis, D.M. Whittle, G. J. Van Der Kraak, and K.R. Munkittrick. 1994. Survey of receiving-water environmental impacts associated with discharges from pulp mills. 3. Polychorinated dioxins and furans in muscle and liver of white sucker (*Catostomus commersoni). Environ. Toxicol. Chem.* 13:1103-1115.

USEPA. 1990. *Lake Ontario TCDD bioaccumulation study—Final report.* U.S. Environmental Protection Agency, Region 2, New York, NY.

USEPA. 1992. *National study of chemical residues in fish.* 2 vols. EPA 823-R-92-008a,b. U.S. Environmental Protection Agency, Office of Science and Technology, Washington, DC.

USEPA. 1994a. *Great Lakes Water Quality Initiative technical support document for the procedure to determine bioaccumulation factors—July 1994.* EPA-822-R-94-002. U.S. Environmental Protection Agency, Office of Water, Office of Science and Technology, Washington, DC.

USEPA, 1994b. *Health effects assessment summary tables FY 1994. Supplement number 2.* EPA/540/R-94/114, NTIS PB94-921102. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, DC. November.

USEPA, 1995. *Integrated Risk Information System (IRIS).* Online. U.S. Environmental Protection Agency, Office of Health and Environmental Assessment, Environmental Criteria and Assessment Office, Cincinnati, OH.