DATA COLLECTION FOR THE HAZARDOUS WASTE IDENTIFICATION RULE

SECTION 11.0 AQUATIC FOOD WEB DATA

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Under Contract No. 68-W-98-085

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October 1999

ACKNOWLEDGMENTS

A number of individuals have been involved with the database development in support of the aquatic food web module. David Cozzie and Stephen Kroner of the U.S. Environmental Protection Agency (EPA), Office of Solid Waste, provided overall technical direction and review throughout this work.

Aimée Harmon and Andrea Thomas developed the methods and implemented the data collection effort in support of the aquatic food web module. Other Research Triangle Institute (RTI) staff members contributing to this report include Stephen Beaulieu, who provided the technical direction; Keith Little, who provided technical review; Jennifer Drake, who provided quality assurance (QA) support; Kathy Restivo, who performed the editorial review; and Sharon Pressley, who provided publication support.

DISCLAIMER

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11.0 Aquatic Food Web Data

Two primary databases were designed in support of the aquatic food web: the aquatic food web chemical properties database (referred to herein as the chemical properties database) and the fish attribute database.

The **chemical properties** database contains two types of parameters: (1) equation variables used in estimating the bioconcentration and bioaccumulation of nonionic organic compounds into aquatic organisms using chemical-specific properties (e.g., log K_{ow}, the octanol/water partition coefficient) and (2) experimentally derived bioconcentration and bioaccumulation factors (BCFs/BAFs) for ionic compounds, such as metals.[1]

The **fish attribute database** is composed of data characterizing the physiological traits and dietary preferences of aquatic biota. This database characterizes the life history attributes that influence the exposures of fish and other aquatic food web biota. Life history parameters such as fish body weight, tissue lipid fraction, tissue water fraction, and common prey items are identified. This database also supports the human health exposure analysis by identifying the types of fish that are likely to be consumed by humans.

11.1 Parameters

These two databases are discussed individually throughout this section. The parameters included in each database are outlined in Table 11-1 with a corresponding module parameter code and brief description. The final values used for each parameter are reported in Appendix 11A for the chemical properties database and Appendix 11B for the fish attribute database.

11.2 Data Sources

Various sources were investigated to compile the databases for the aquatic food web. Each database was constructed to reflect different degrees of variability. The chemical properties

[1] For clarity, bioconcentration factors (BCFs) are a measure of chemical accumulation into biota tissues associated with exposure to the surrounding media only (e.g., surface water) while bioaccumulation factors (BAFs) are associated primarily with the additive exposure from both contaminated prey and the surrounding media. For simplicity in this discussion, BCFs and BAFs are referred to jointly as bioaccumulation factors.

Table 11-1. Summary of Parameters Applied in Modeling the Aquatic Food Web

Chemical Properties Database	Fish Attribute Database
# Slopes (a and b) and error term (c) of the bioconcentration factor (BCF) regression equation for muscle tissue in fish (a_mus, b_mus, and c_mus, respectively)	# Fish body weight (BwFish)—Weight of whole fish in kg
# Slopes (a and b) and error term (c) of the BCF regression equation for whole body tissue in fish (a_fish, b_fish, and c_fish, respectively)	# Lipid fraction (LipFrac)—Fraction of lipid in the whole fish
# Aquatic macrophyte BCF (ChemaqmpBCFm)—Ratio of the measured concentration in the tissue of aquatic macrophytes to the concentration measured in the surrounding water	# Muscle lipid fraction (LipFracMus)—Fraction of lipid in the fish muscle (fillet)
# Benthic filter feeder bioaccumulation factor (BAF) (ChembenthffBAFm)—Ratio of the measured concentration in the tissue of the benthic filter feeder to the concentration measured in the surrounding water and/or prey	# Minimum prey preference (MinPreyPref)—Minimum fraction of diet for a given prey item
# Trophic level 3 (T3) and trophic level 4 (T4) fish BAF (ChemT3fishBAFm and ChemT4fishBAFm)—Ratio of the measured concentration in the tissue of the whole fish to the concentration measured in the surrounding water and prey	# Maximum prey preference (MaxPreyPref)—Maximum fraction of diet for a given prey item
# T3 and T4 muscle BAF (ChemT3musBAFm and ChemT4musBAFm)—Ratio of the measured concentration in the muscle of the fish to the concentration measured in the surrounding water and prey	# Fillet fraction (FilletFrac)—Fraction of fish that is fillet
	# Muscle water fraction (MusWaterFrac)—Water fraction in the muscle (fillet) of fish
	# Fish water fraction (FishWaterFrac)—Water fraction across all tissues of fish
	# T3 edible fish (T3EdibleFish)—Edible T3 fish for human consumption

database was compiled to reflect average constituent BCFs and BAFs for individual biota in the aquatic food web. In the case of the fish attribute database, the aim of the data collection effort was to represent the variability of parameters at the national level across different waterbody types (e.g., lakes and streams) and surface water temperatures (e.g., warm and cold). To accomplish these tasks, various government agencies, U.S. Environmental Protection Agency (EPA) offices, research laboratories, and primary literature sources were consulted to review publications, databases, and guidance documents to support the development of the aquatic food web databases. Key sources identified for each database are reviewed.

11.2.1 Chemical Properties Database

The chemical properties database characterized the chemical-specific bioaccumulation parameters in the aquatic food web. The sources identified for this database were limited. Bioconcentration factors (BCFs) and bioaccumulation factors (BAFs) were the primary metrics needed for this database to estimate measures of chemical bioaccumulation. Most measured BAFs were identified in the primary literature or in EPA's Aquatic Information and Retrieval (AQUIRE) database (U.S. EPA, 1999a). Because measured BAFs were missing for many constituents, accumulation was predicted for organic constituents using regression models based on chemical properties. The models proposed by Bertelsen et al. (1998) and Gobas (1993) were adopted for this analysis to predict the bioaccumulation of organic contaminants into fish. The following key sources were used in developing the chemical properties database:

- Bertelsen et al. 1998. Evaluation of log K_{ow} and tissue lipid content as predictors of chemical partitioning to fish tissues. *Environmental Toxicology and Chemistry* 17:1447-1455.

- Gobas, F.A.P.C. 1993. A model for predicting the bioaccumulation of hydrophobic organic chemicals in aquatic food webs: Application to Lake Ontario. *Ecological Modelling* 69:1-17.

- Primary literature (Barrows et al., 1980; Kumada et al., 1973; Lemly, 1985; Murphy et al., 1978; Stephan, 1993).

- U.S. EPA. 1999a. ECOTOXicology Database System. Office of Research and Development. National Health and Environmental Effects Research Laboratory. Duluth, MN.

11.2.2 Fish Attribute Database

The goal in developing the fish attribute database was to characterize the variability of the parameters in different aquatic habitats at the national scale. No single database was identified that classified the physical and behavioral attributes of fish at this level of resolution; therefore, this task required pooling multiple resources across different regions to represent the variability of parameters across a number of ecotypes and waterbodies. Although true national data distributions were preferred for this assessment, the data collection effort only reflects the initial stages of compiling such an extensive database. The key sources that were identified to characterize the module parameters of the fish attribute database are outlined in Table 11-2.

11.3 Methodology

The methods used to generate values for each parameter in the databases are detailed in this section, which is structured around the general databases developed for the aquatic food web: the chemical properties database and the fish attribute database. In each database discussion, methods of database compilation and processing and assumptions and uncertainties are addressed.

Table 11-2. Key Data Sources Identified to Evaluate for Fish Attribute Database

Government Agencies

U.S. Geological Survey. National Ambient Water Quality Assessment (NAWQA) Program. Available online at http://wwwrvares.er.usgs.gov/nawqa/nawqamap.html.

- South Platte River Basin (USGS, 1998a)
- Lake Erie-Lake St. Clair Drainage (USGS, 1998b)
- Albemarle Pamlico Drainage (USGS, 1998c)
- San Joaquin-Tulare (USGS, 1998d)
- Upper Snake River Basin (USGS, 1998e)

Lutz, C. 1999. The BSAF Database for Windows Version 1.0. Environmental Laboratory. Waterways Experiment Station.

EPA Documents

OEPA (Ohio Environmental Protection Agency). 1997, 1998a, b, c. Ecological Assessment Division of Surface Water.

- OEPA (Ohio Environmental Protection Agency). 1997. *Biological and Water Quality Study of Big Walnut Creek: D.E. Edwards Landfill.* October. Monitoring and Assessment Division. Division of Surface Water.

- OEPA (Ohio Environmental Protection Agency). 1998a. *Biological, Fish Tissue, and Sediment Study of the Ottawa River. Dura Avenue Landfill, 1996.* January. Monitoring and Assessment Division. Division of Surface Water.

- OEPA (Ohio Environmental Protection Agency). 1998b. *Biological and Water Quality Study of Lower Big Walnut Creek and Walnut Creek Tributaries, 1996: Rickenbacker Airport.* April. Ecological Assessment Unit. Division of Surface Water.

- OEPA (Ohio Environmental Protection Agency). 1998c. *Biological and Water Quality Study of Little Cuyahoga River and Tributaries.* April. Ecological Assessment Unit. Division of Surface Water.

U.S. EPA (Environmental Protection Agency). 1993b. *Interim Report on Data and Methods for Assessment of 2,3,7,8-Tetrachlorodibenzo*-p-*dioxin Risks to Aquatic Life and Associated Wildlife.* EPA-600/R-93/055. Office of Research and Development, Washington, DC.

U.S. EPA (Environmental Protection Agency). 1995a. *Great Lakes Water Quality Initiative Technical Support Document for the Procedure to Determine Bioaccumulation Factors.* EPA-820-B-95-005. Office of Water, Washington, DC.

U.S. EPA (Environmental Protection Agency). 1995b. *Trophic Level and Exposure Analyses for Selected Piscivorous Birds and Mammals. Volumes II and III. Analysis of Species in the Conterminous United States*. Office of Science and Technology, Office of Water, Washington, DC. Prepared by ICF Incorporated, Fairfax, VA, under EPA Contract No. 68-W3-0008 and No. 68-C3-0332.

(continued)

Table 11-2. (continued)

Primary Literature
Primary references (Clarke et al., 1988; Donald et al., 1998; Glassmeyer et al., 1997; Kuehl et al., 1987; Miskimmin et al., 1995).
General Reference
Cohen, J.E, F. Briand, and C.M. Newman. 1990. *Community Food Webs Data and Theory.* Springer-Verlag: Berlin.
FishBASE. 1998. *FishBASE '98: Concepts, Design and Data Sources*. Available online at http://www.fishbase.org/manual/contents.htm.
Gerking, S.D. 1994. *Feeding Ecology of Fish.* Academic Press: San Diego, CA.
Hackney, C.T, S.M. Adams, and W.H. Martin. 1992. *Biodiversity of the Southeastern United States Aquatic Communities.* John Wiley & Sons: New York, NY.
Lee, D.S., et al. 1980. *Atlas of North American Freshwater Fishes.* North Carolina State Museum of Natural History.
Page, L.M., and B.M. Burr. 1991. *A Field Guide to Freshwater Fishes.* Houghton Mifflin: Boston.
Simon, T.P. (ed). 1999. *Assessing the Sustainability and Biological Integrity of Water Resources Using Fish Communities.* CRC Press: Boca Raton, FL.
Smith, C.L. 1994. *Fish Watching: An Outdoor Guide to Freshwater Fishes*. Cornell University Press: Ithaca, NY.
Sternberg, D. 1987. *Freshwater Gamefish of North America.* Cowles Creative Publishing: Minnetonka, MN.

11.3.1 Chemical Properties Database

11.3.1.1 Database Compilation. The chemical properties database contains variables used in the module that are related to chemical accumulation in aquatic biota. Bioaccumulation in fish and other prey items in the aquatic food web is a critical link in estimating exposures of terrestrial organisms foraging primarily in aquatic food webs. Accumulation of chemicals into biota is a dynamic process, and it can be minimized, mediated, or magnified depending on chemical-specific properties, organism physiology and behavior, and other environmental conditions. The bioaccumulation of chemicals into aquatic biota can be estimated empirically using models or measured through laboratory exposure experiments. In this analysis, measured BAFs were gathered for metals and for other constituents (i.e., polynuclear aromatic hydrocarbons [PAHs], dioxin, and mercury compounds). For organic constituents, two different models were applied to estimate accumulation into fish tissues (i.e., Bertelsen et al., 1998, and

Gobas, 1993). This section discusses each method (i.e., estimated versus measured values) separately.

Estimated Bioaccumulation Factors. Chemical accumulation is sometimes quantified based on chemical properties (e.g., K_{ow}) and uptake rates using linear relationships. For this effort, accumulation of organic constituents into fish tissues was estimated using two chemical partitioning models: Bertelsen et al. (1998) and Gobas (1993). The Bertelsen et al. (1998) approach was applied when the chemical log K_{ow} values were less than 4.0. For chemicals with log K_{ow} values exceeding 4.0, the Gobas (1993) model was applied. Different methods were applied because the accumulation of chemicals is highly dependent on their hydrophobicity, which can be approximated based on the constituent-specific log K_{ow}. Low log K_{ow} constituents are less hydrophobic than high log K_{ow} constituents, by definition. For chemicals with log K_{ow} values less than 4.0, the bioaccumulation of dissolved chemicals from the water column is a good predictor of the bioconcentration in fish tissues. The Bertelsen et al. (1998) model primarily uses this relationship to estimate bioaccumulation in fish. For chemicals with K_{ow} values greater than 4.0, bioaccumulation from the water column is minimal compared to bioaccumulation from contaminated prey items. The Gobas (1993) model incorporates food web dynamics to estimate bioaccumulation in fish.

The equations proposed by Bertelsen et al. (1998) estimate the chemical residues in different fish tissues resulting from the chemical concentrations in surrounding surface water (i.e., estimated BCFs). This model was designed by the combination of two log-linear models to estimate the bioaccumulation of contaminants from the water column to the fish tissue (expressed on a lipid basis) (Bertelsen et al., 1998) (Equation 11-1).

$$\log\ (K_{tw}) = a\ (\log\ K_{ow}) + b\ (\log\ \text{fraction lipid}) + c \qquad (11\text{-}1)$$

where

K_{tw}	=	tissue/water equilibrium chemical partition coefficient
K_{ow}	=	chemical-specific octanol/water partition coefficient
fraction lipid	=	assumed or empirically derived tissue lipid fraction
a, b, c	=	see Table 11-3.

The K_{tw} value quantifies the ratio of the chemical in the tissue to the chemical in the water (i.e., the BCF). The coefficients a, b, and c are empirically derived for different tissue types (i.e., whole body and muscle). The coefficients correspond to module parameters a_mus, b_mus, and c_mus and a_fish, b_fish, and c_fish, which were used to derive BAFs for organic compounds in muscle and whole body, respectively. Both a and b are slope terms describing a three-dimensional data plane, and c is the error term. The variables a, b, and c are applied in Equation 11-1 as outlined in Table 11-3.

For chemicals with a log K_{ow} greater than 4.0, the Gobas (1993) model was applied. The Gobas model uses a steady-state model that estimates accumulation into various food web compartments of the aquatic ecosystem. It accounts for the toxicokinetics of uptake, elimination

Table 11-3. Constants for Different Tissue Types Applied to Equation 11-1

	Equation Variable		
Tissue Type (Parameter names)	**a**	**b**	**c**
Muscle (a_mus, b_mus, c_mus)	0.69	0.92	0.76
Whole body (a_fish, b_fish, c_fish)	0.74	1.00	0.72

rates, and multiple feeding interactions. For more information on the calculations applied in the Gobas method, see the module documentation (U.S. EPA, 1999b) for the aquatic food web.

Measured Bioaccumulation Factors. For other constituents not assigned as organic (e.g., metals and PAHs), bioaccumulation was approximated through experimental measurements in the laboratory or field as reported in the literature. The availability of measured BAFs for the following receptor categories was the focus of data collection efforts: aquatic macrophytes, benthic filter feeders, and trophic level 3 (T3) and 4 (T4) fish. The BAFs for T3 and T4 fish were further refined to estimate whole-body or fillet BAFs. For metals, BAFs identified for whole body were also applied as fillet BAFs. Measured BAFs were not available for many of the constituents. Primary literature searches and review of the AQUIRE (U.S. EPA, 1999a) database were conducted to fill data gaps, with limited success. Data selection criteria were used to identify measured BAFs from the sources in order to select values using analogous standards. The following criteria were used in reviewing data:

- In data searches, a BAF value was preferred over a BCF value because most organisms are usually more highly exposed through ingestion of contaminated matter than through direct contact. This is the preferred metric because it more accurately represents typical exposures observed in the environment. In spite of this, the primary literature more commonly reports BCFs rather than BAFs, creating data limitations for this analysis. For this method, BAFs were the first choice; when they were not available, BCFs were used.

- Exposures that reached steady-state conditions were preferred. To meet this requirement, exposures to aquatic biota had to exceed a certain duration depending on the receptor (e.g., algae >24 h, aquatic invertebrates >48 h, fish >96 h). For this analysis, however, the measured BCF/BAF value with the highest exposure duration was used. When a series of exposures at different concentrations were used to estimate BCFs, the occurrence of steady-state conditions (e.g., the plateau effect) was assessed. When this effect was observed, a geometric mean of the plateau values was taken to determine the BCF estimate.

- # Measured data were only used from studies exposing freshwater biota, as opposed to marine or estuarine species.

- # Metal BAFs were derived from studies reporting values based on total metal concentrations in tissue and media. This assumption introduces some uncertainty because not all metals occur in a bioavailable form. Typically, the total dissolved concentration is a better measure of what is actually bioavailable to fish.

The BAFs that were identified through data collection efforts were used to calculate chemical-specific geometric means for the aquatic prey items. Bioaccumulation data were assumed to be lognormally distributed; therefore, the geometric mean was the best central tendency estimate of the population mean. Sources used to calculate geometric means are provided in Appendix 11A, Table 11A-2. After initial literature searches, however, large data gaps were still apparent in the database, so additional data collection efforts focused on filling the data gaps. The results of these data collection efforts are presented here. Because fish BAFs were relatively available or could be readily calculated, additional data collection focused on benthic filter feeders and aquatic macrophytes.

Aquatic Macrophytes. Aquatic macrophytes are represented by species of macroalgae, mosses, ferns, and true angiosperms adapted to the aquatic environment. Aquatic macrophytes include a variety of aquatic primary producers that can be either floating, submerged, emergent, rooted, or unrooted. Obviously, this wide array of different plant types influences the variability in BAFs identified for this prey type. The goal of data collection efforts was to represent the range of differences in this prey item. The values identified to fill this data gap were gleaned from the primary literature. Data collection focused on constituent groups of metals, mercury, dioxin, and special chemicals. BAFs were identified for the specific constituents of cadmium, lead, zinc, and 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD). Most of the constituents were characterized by 1 data point; zinc was represented by 5 data points. The key findings are summarized in Table 11-4.

Table 11-4. Additional Bioaccumulation Factors Identified for Aquatic Macrophytes

Constituent	Species	Laboratory/Field	Bioaccumulation Factors	Source
Cadmium	Alligator weed	Field	17	Naqvi et al., 1993
Lead	Alligator weed	Field	42	Naqvi et al., 1993
Zinc	Duckweed	Laboratory	1,040, 690, 280, 500, 330	Dirilgen and Inel, 1994
2,3,7,8-TCDD	Duckweed	Not specified	4,300	U.S. EPA, 1993b

The BAFs reported for common species of aquatic macrophytes were considered appropriate to apply to the database if they were derived from studies reporting surface water concentrations and plant tissue concentrations. Most of the data identified in the primary literature, however, reported BAFs for aquatic macrophytes based on sediment exposures because many of the rooted macrophytes are exposed to contaminants primarily through root uptake. Studies have reported that, particularly for metals, uptake from sediments into the tissues of aquatic macrophytes is the principal pathway of exposure (Jackson, 1998). The literature review indicated a larger percentage of studies reporting BAFs for the sediment pathway compared to the surface water pathway. Using the biota-sediment accumulation factors (BSAFs) reported in the primary literature would expand the database significantly and more adequately represent all exposure pathways to this prey item. To use these values, the coding in the model would have to be altered to accept either a BAF or BSAF. In the future, the aquatic food web module should be modified to allow the module to select either sediment- or water-based BAFs, as appropriate.

Benthic Filter Feeders. Very little surface water exposure data were identified for benthic filter feeders. A limited number of values were found in the primary literature for pentachlorophenol (PCP) and 2,3,7,8-TCDD based on surface water exposures. The findings are summarized in Table 11-5.

Two databases were identified that derived BAFs for benthic filter feeders based on exposure to sediment: the National Oceanic and Atmospheric Administration's (NOAA's) National Status and Trends (NS&T) Program and the U.S. Army Engineers' BSAF database (Lutz, 1997a; O'Connor and Beliaeff, 1995). Since 1986, NOAA has assessed the spatial distribution of contaminants by measuring concentrations of trace metals and organic constituents in sediments and mussel tissue. These monitoring efforts have occurred at approximately 300 coastal sites. This program has been extended to measure similar concentrations in the Great Lakes. Similar sediment-derived accumulation factors have been collected by the U.S. Army Engineers and compiled into a BSAF database to reflect the accumulation in various benthic biota exposed to contaminated sediments. The NS&T database and the BSAF database are of limited application for the Hazardous Waste Identification Rule (HWIR) effort for the following reasons:

Table 11-5. Bioaccumulation Factors Identified for Benthic Filter Feeders

Constituent	Species	Laboratory/Field	Bioaccumulation Factors	Source
PCP	Duck mussel	Laboratory	110, 160, 160, 80, 310, 260, 460, 150	Makela et al., 1991
PCP	*Corbicula fluminea*	Laboratory	110, 107, 100, 100	Basack et al., 1997
2,3,7,8-TCDD	Snail	Field	380	U.S. EPA, 1993b

- # The values compiled in databases developed by NS&T and the U.S. Army Engineers are BSAFs calculated from the ratio of the concentration in the whole mussel divided by the concentration in the sediments. The HWIR database currently generates BAFs for mussels based on surface water concentrations resulting in values in units of L/kg tissue. As the model coding currently stands, this difference does not allow the inclusion of NOAA and U.S. Army Engineers databases.

- # The NOAA's and U.S. Army Engineers' databases report BSAF's for marine and estuarine mussel species. Because HWIR evaluates freshwater ecosystems, freshwater benthic filter feeders are the most appropriate receptors to estimate bioaccumulation. Given the fundamental differences in chemical equilibria in marine waters that may influence chemical bioavailability, species that occur in marine versus freshwater systems, and mechanisms of bioaccumulation between marine and freshwater filter feeders, researchers have proposed that the BAFs measured in marine species may be significantly different from those measured in freshwater benthic filter feeders. Hence, there is no strong evidence to suggest that using marine values for freshwater species is supportable (Metcalfe-Smith et al., 1996).

- # The Great Lakes data of the NS&T program are measured in freshwater species and, therefore, are more promising for deriving BAFs, provided that the HWIR model could be changed to accept BSAFs. One drawback to using the Great Lakes data is that they are very region-specific and may not completely represent all types of filter feeders found in waterbodies across the United States. Further, if species such as the zebra mussel are highly represented in NOAA's Great Lakes database, the data may not fully represent the variability in benthic filter feeder accumulation because these species have been documented to selectively bioaccumulate some compounds and not others (Klerks and Fraleigh, 1997). Given these uncertainties, incorporating these freshwater mussel data into HWIR data may not be appropriate.

The final values used to quantify bioaccumulation into aquatic prey items are presented in Tables 11A-1 and 11A-2 in Appendix 11A.

11.3.1.2 <u>Data Processing</u>. Estimated or measured BAFs were generated for prey items in the aquatic food web, including macrophytes, benthic filter feeders, and fish. Data permitting, fish BAFs were developed for both T3 and T4 fish based on both whole body and muscle tissue. Estimated BAFs generated by applying models were calculated internally by the model. For organics, BAFs used in the analysis were modeled for each prey item. The data presented in Appendix 11A do not reflect these internally calculated values. In the chemical properties database, these values are entered as the default value of 1. The default value acts as a placeholder and was required by the modeling system.

For other constituents, classified as dioxins, mercury, metals, and special (e.g., PAHs), measured BAFs were identified. The constituent-specific geometric mean of values was calculated for prey items. These values were manually compiled into the spreadsheet and are presented in Appendix 11A. When sufficient data were not identified through literature searches, a default value of 1 was entered.

11.3.1.3 <u>Assumptions and Uncertainties</u>. In developing the chemical properties database, several key assumptions and points of uncertainty were apparent. These uncertainties can be grouped into data gaps, default assumptions, and variability.

Data Gaps. Developing the chemical properties database was extremely limited by data availability. For constituents that required measured BAFs, data collection revealed that BAFs were either not available for a particular constituent and prey item combination or did not reflect the exposure assumptions of the module. In many cases, as pointed out in the methodology discussions, bioaccumulation was measured for aquatic macrophytes and benthic filter feeders based on sediment exposures rather than surface water exposures. The model is currently equipped to accept a BAF based on surface water exposures; however, this exposure pathway was frequently not identified in the primary literature. Because BAFs were not identified for many combinations of prey items and constituents, uncertainty is introduced into the assessment of food web exposures.

Default Values. When BAFs were not available, a default value of 1 was added to the database. Default values should not be construed as estimates of bioaccumulation; rather, they should be viewed only as placeholders until more representative data are identified. The risk results need to be considered within the limitations of the default values.

Variability. In the development of the chemical properties database, the BAFs reflected central tendency estimates. There is some uncertainty associated with how accurately the central tendency value was estimated given the variability of bioaccumulation parameters. In many cases, only a few BAFs were identified to characterize the distribution of values. Because distributions based on so few values are greatly influenced by extreme values (e.g., outliers) or clustered data, the central tendency value may not adequately reflect the variability in this parameter. As the model is refined, the variability in bioaccumulation may be better characterized through assumed distributions and Monte Carlo simulations. Bioaccumulation factors, in this context, could be specified at the regional level, increasing the resolution in the analysis.

11.3.2 Fish Attribute Database

11.3.2.1 <u>Database Compilation</u>. This database was used to reflect the variability in the parameters of fish body weight, lipid fraction (whole body and muscle), and prey preferences; the means for water fractions in whole body fish tissues and fillet fractions; and the fish categories (e.g., T3 large benthivores, T4 piscivores) in the aquatic food web likely to be consumed by humans. Because some of the parameters assessed in the fish attribute database can vary significantly across different waterbodies, water temperatures, and habitat structures, it was important to characterize some of the parameters across various aquatic ecosystems.

An additional step of preprocessing was conducted on the fish attribute database in an effort to capture the variability introduced into the body weights, lipid content (total body and muscle), and dietary preference parameters resulting from fish that are distributed across different environmental conditions. Species-specific data for these parameters were collated into groups based on trophic level (i.e., 3 or 4), relative fish size (i.e., small, medium, or large), water temperature preference (i.e., warm or cold), habitat preference (i.e., stream, pond, lake, or wetland), and dietary classification (i.e., benthivore, zooplanktivore, omnivore, or piscivore). These categories are not explicitly included in the list of parameters for the fish attribute database, but they were vital to the decision criteria used in compiling the database. Statistical metrics (e.g., mean, minimum and maximum) of body weight, fraction lipid, and dietary preference were derived for adult fish of specific trophic levels and habitat classifications. For example, a mean body weight was derived for small T3 benthivores in warmwater lakes. The following information outlines the important decision framework used in the preprocessing step of the fish attribute database:

Trophic Level–Trophic levels assigned to individual fish species in the fish attribute database were taken from the U.S. EPA (1995b), Goldstein and Simon (1999), and Halliwell et al. (1999). Trophic levels were assessed in these resources by evaluating the diet of individual fish species. Dietary preferences were reported in the form of quantitative dietary fractions and qualitative dietary descriptions. The data sources did not assess all the species identified in the fish attribute database. For fish species that did not have explicit trophic-level assignments, an approach was used to assign a probable trophic level based on several lines-of-evidence that seemed to suggest one trophic assignment over another (weight-of-evidence approach). When actual quantitative dietary fractions were not reported, descriptive qualitative diets were used to assess trophic levels. Four general rules in evaluating narrative dietary descriptions were applied, as follows:

- If the species primarily consumed fish, it was assigned as T4.

- If the fish ate mostly benthic invertebrates, phytoplankton, and zooplankton, it was assigned as T3.

- If the fish was closely related to another species that had an assigned trophic level, similar species were assigned to the same trophic level. For example, shiners were typically assigned to T3.

- For related species that could be assigned to either T3 and T4 (e.g., bass) depending on their life stage and habitat, no assumptions were made about trophic level, and the species was not included in the database.

Relative T3 Fish Size–Relative size was determined across T3 fish, so that reasonable assumptions about predation among T3 piscivorous fish could be made in module development (i.e., to avoid the uncommon phenomenon of small T3 fish preying on large T3 fish). The variability of size and morphology among T3

fish makes relative size categories somewhat difficult to define. Developing the relative size cutoffs for T3 fish (i.e., small, medium, or large) required professional judgment. Because exceptions to these general size classifications exist, they should only be considered reasonable guidelines in the majority of cases. Upon examination of the range of fish body weights and lengths in the fish attribute database, the following cutoffs were used to assigned T3 fish as either small, medium, or large (Table 11-6). Low and high cutoffs for fish body weight and fish length were determined by taking the 35th percentile and the 65th percentile of the data, respectively. If a fish met either of the cutoff values, fish length was used to assigned it to the larger or smaller classification group.

Water Temperature Preference. Water temperature preference was assigned to individual fish species as warmwater, coldwater, or both. For this task, warmwater fish species were species that tolerate surface water temperatures that annually exceed 25 °C. Warmwater fish typically inhabit surface water ranging from 10 to 30 °C. Coldwater species typically do not tolerate surface waters that exceed 25 °C, but they prefer surface waters ranging from 0 to 20 °C. Some fish, however, are capable of inhabiting the entire range of temperature extremes. These fish were assigned to the category of both. Water temperature preferences for individual fish species were reported by Halliwell et al. (1999). When water temperature preference designations could not be located for a particular fish species, a weight-of-evidence approach was used to predict the water temperature preference of a fish. The weight-of-evidence approach consisted of qualitatively examining the geographic distribution of a fish species, as follows:

– If the fish inhabited hydrologic regions where water temperatures annually exceeded 25 °C, the fish was assigned as warmwater.

– If the fish consistently inhabited regions where temperatures did not exceed 25 °C, it was categorized as coldwater.

– If the species inhabited regions without a clear trend in water temperature, the fish species was assumed to tolerate both high and low extremes in water temperatures and was categorized as both.

Habitat Preference. Habitat preferences (e.g., flowing versus standing water) were assessed for individual fish species using *Peterson's Field Guide: Freshwater Fish* (Page and Burr, 1991) and Lee et al. (1980). In these references, narrative descriptions of preferred habitats for individual fish species are recorded. Typically, fish are capable of inhabiting a variety of freshwater habitats, including streams, rivers, lakes, wetlands, and ponds. Habitat preferences, however, can be highly dependent on the life stage of the fish. Data collection efforts focused on characterizing habitat preferences for adult fish populations. The fish attribute database assigned fish to habitats that may include a number of potential waterbody types (e.g., flowing or standing). In the preprocessing step, this distinction helps to assign fish species to aquatic habitat types of the module.

Table 11-6. Fish Body Weight and Length Ranges Used in Relative Size Determinations

Size Classification	T3 Benthivores	T3 Zooplanktivores	T3 Omnivores
Fish Body Weight (g)			
Small	<2	<3	<9
Medium	2 to 27	3 to 11	9 to 61
Large	>27	>11	>61
Fish Length (mm)			
Small	<53	<61	<84
Medium	53 to 171	61 to 153	84 to 258
Large	>171	>153	>258

Dietary Classification. A dietary classification was assigned to each fish species based on the preferred prey items. Dietary preference data were derived primarily from U.S. EPA (1995b), Goldstein and Simon (1999), and Lee et al. (1980). Fish were designated as predominantly benthivores, zooplanktivores, omnivores, or piscivores (only T4 fish were classified as piscivores). Strict herbivores were not common among fish species; hence, this dietary classification was not used for this analysis (Gerking, 1994; Goldstein and Simon, 1999). The fish attribute database identified dietary fractions for the following prey items: plant material, detritus, zooplankton, benthos, terrestrial insects, and fish. Benthivores and zooplanktivores are species of fish that forage primarily on benthos and zooplankton/phytoplankton, respectively. Omnivores are species of fish that meet one of two criteria: (1) they forage on three or more different prey items or (2) they forage on fish as one prey item. If the species forage on fish, it was presumed likely to eat other categories of prey if fish were not available. Fish were assigned to a dietary classification on which the fish attribute database was sorted into the respective biota categories of the aquatic food web (e.g., small T3 benthivores).

Given these different classification levels in the preprocessing effort, parameters needed for the model (e.g., fish body weight, lipid fraction) could be compiled specific to trophic level, relative size, water temperature preference, habitat preference, and dietary classification. For example, lipids and body weights were compiled from the fish attribute database specifically for a small T3 omnivore in warmwater streams (i.e., this aquatic food web compartment uses all five of the preprocessing descriptors). When data were available, module parameters were estimated in each aquatic food web compartment across different habitats. A review of the methods used in database compilation of the model parameters (as opposed to the preprocessing parameters) is described for each variable in the fish attribute database: fish body weight, lipid fraction (whole body and muscle), water fraction (whole body and muscle), fillet fraction, and T3 edible fish.

11.3.2.1.1 ***Fish Body Weight.*** A species-specific mean of fish body weight was derived from data generated in the preprocessing effort. These species-specific means were collapsed into one value that represented an arithmetic mean body weight estimate for a fish category. For example, medium-sized T3 benthivores of coldwater lakes were composed of the mean body weights of the following species: longnose sucker, Sacramento sucker, splittail, and Utah sucker. The average of the species-specific means was used to characterized the variability of species within a food web compartment. The database reflected increasing body weights based on relative size (i.e., small, medium, or large) and trophic level (i.e., T3 or T4).

In compiling the fish body weight parameter, a few data decision criteria were used in identifying comparable and appropriate data. Fish body weight data were gathered that represented adult fish populations. There is some controversy about how to determine when fish have reached maturity. Maturity can be assessed by size, morphology, weight measurements, and, most commonly, sexual development. For many fish species, the transition across life stages is not well-defined. Explicit juvenile weights were not included in the database; however, in some cases, the fish age or life stage was not reported with the fish body weight. For NAWQA data, a review of the sample collection methods did not indicate the average age of the fish sampled. In most cases, fish weights were high enough to assume that the fish was an adult. As a gross check, these values were compared with reported general ranges, and, typically, fish body weights were within the range. Table 11B-3 in Appendix 11B provides the fish body weight results applied in this analysis.

11.3.2.1.2 ***Lipid Fraction (Whole Body).*** An analogous method, as that implemented for fish body weight, was implemented for fish lipid (whole body). When data were available, an average of species-specific means was used to estimate the lipid fraction in different aquatic biota. Overall, the availability of lipid values was limited in the primary literature, especially to estimate whole body fish lipid values. Given the lack of lipid data for some aquatic food web compartments, standard default lipid values were applied. These default values were adopted from the Great Lakes Water Quality Initiative (GLWQI): phytoplankton (0.05 percent), periphyton (0.05 percent), aquatic macrophytes (0.05 percent), zooplankton (5 percent), and benthos (3 percent) (U.S. EPA, 1995a). Default whole body lipid fractions for fish were calculated for T3 and T4 fish by pooling all identified data and calculating the mean. The default values calculated were 5.7 percent and 8.6 percent for T3 and T4 fish, respectively. Table 11B-3 in Appendix 11B provides the fish whole body lipid results applied in this analysis.

11.3.2.1.3 ***Lipid Muscle Fraction.*** This parameter quantified the fraction of lipid present in fish muscle (or fillet). Data for this parameter did not capture the same variability represented in the whole body lipid fraction values. Instead, values reported in the GLWQI that estimated the fraction of lipid in the muscle were used. Muscle lipid fractions were set at 1.82 percent for T3 fish and 3.10 percent for T4 fish (U.S. EPA, 1995a). Because the default values adopted from the GLWQI for T3 and T4 fish fillets were derived from a regional database, uncertainty is introduced into the analysis by applying these default values to a national analysis. Table 11B-2 in Appendix 11B provides the fish lipid muscle fraction results applied in this analysis.

11.3.2.1.4 ***Fillet Fraction.*** The fillet fraction is the conversion factor between the lipid fraction whole body and the lipid muscle fraction. It was derived from the default lipid values used for whole body and fillet in U.S. EPA (1995a). The GLWQI proposed a 6.46 percent lipid fraction (whole body) and a 1.82 percent lipid fraction (muscle) for T3 fish. For T4 fish, the GLWQI used a 10.31 percent lipid fraction (whole body) and a 3.10 percent lipid fraction (muscle). The parameter fillet fraction was derived by calculating the fraction of muscle lipid to whole body lipid. For example, to calculate the fillet fraction for T4 fish, the result of 3.10 divided by 10.31 generated a conversion factor of 0.29. The fillet fraction conversion factor was used to extrapolate lipid-normalized BAFs from whole body fish lipid-normalized values to muscle lipid-normalized values within a specified trophic level. A conversion factor (i.e., fillet fraction) of 0.29 was used for T4 fish and a conversion factor of 0.28 was used for T3 fish. Table 11B-2 in Appendix 11B provides the fillet fraction results applied in this analysis.

11.3.2.1.5 ***Fish Water Fraction and Muscle Water Fraction.*** The fish water fraction was an estimate of the fraction of water in the whole fish. This value was adopted from the *Wildlife Exposure Factors Handbook* (U.S. EPA, 1993a), which reports a percent water value of 75 percent for bony fish. The analogous variable that estimates water fraction in muscle tissue was found in Bertelsen et al. (1998). The muscle water fraction of 0.79 used in this analysis was a mean of three fish species (i.e., catfish, trout, and fathead minnow). Review of the *Exposure Factors Handbook* (U.S. EPA, 1997a) confirmed that the muscle water fraction used here was within the typical range for fillets. Table 11B-1 in Appendix 11B provides the fish water fraction and fish muscle water fraction results applied in this analysis.

11.3.2.1.6 ***T3 Edible Fish.*** Some relatively simple assessments were made of T3 fish species that humans typically consume. Generally most fish are edible; however, not all fish are eaten by humans. Preferences are usually a function of fish size. Sources that surveyed the kinds of fish people eat and catch were consulted to select fish categories that were likely to be consumed (U.S. DOI/U.S. DOC, 1997; U.S. EPA, 1997a). Across the fish categories assigned in this analysis, most of the fish that humans eat are T4 piscivores (e.g., salmon, trout, walleye, bass) and medium and large T3 omnivores (e.g., carp, smelt, perch, catfish, sucker, bullhead, sauger). Occasionally, large T3 benthivores (e.g., lake whitefish) and zooplanktivores (e.g., paddlefish) also are consumed. Professional judgment was required to assign edible fish categories across waterbodies. If a few examples of specific fish species could be found that were documented to be eaten by humans, then the fish category was included. There are exceptions to these general assignments; however, these assumptions are reasonable considering the general patterns of fish typically consumed by humans. Table 11B-3 in Appendix 11B provides the assignments of fish typically eaten by humans that were applied in this analysis.

11.3.2.1.7 ***Dietary Preferences.*** This parameter was developed to assess what prey items fish prefer (i.e., dietary preference) and how much of each prey item contributes to the total fish diet (i.e., dietary composition). Data were gathered that reported the percentage that different prey items contributed to the whole diet of a fish species. Using these data, a minimum and maximum dietary fraction for each prey item was quantified (U.S. EPA, 1995b). Two types of dietary fraction data were reported in the literature: (1) true minima and maxima or (2) single median values (i.e., values not necessarily reported in the same study). True minima and maxima were preferred; however, in the absence of these data, the minimum and maximum range of median values was used. When specific dietary fraction data could not be identified, narrative descriptions of fish diets were used. In these cases, dietary fractions were equally split across the prey items reported.

Data sources reported dietary fractions for the following prey items: plant material, zooplankton, benthos, terrestrial insects[2], detritus, and fish. The prey items in the aquatic food web were similar: periphyton, phytoplankton, macrophytes, zooplankton, benthic detritivores, benthic filter feeders, T3 benthivores (small, medium, and large), T3 zooplanktivores (small, medium, and large), and T3 omnivores (small, medium, and large). Because of the differences between the prey items used to construct the aquatic food web and the prey items for which data were identified, the data identified had to be translated into the aquatic food web prey items. The substitution scheme is presented in Table 11-7. Although detritus and benthic detritivores are not directly transferable as the same prey, by habitat proximity, it is likely that a diet made up of detritus also will be composed of benthic detritivores.

Table 11-7. Assignment of Prey Items in Fish Attribute Database to Prey Items in the Aquatic Food Web

Prey Items in Aquatic Food Web	Prey Items in Fish Attribute Database
Periphyton	Plant material
Phytoplankton	Plant material
Macrophytes	Plant material
Zooplankton	Zooplankton
Benthic detritivores/detritus	Detritus
Benthic filter feeders	Benthos
T3 benthivores (small, medium, and large)	Fish
T3 zooplanktivores (small, medium, and large)	Fish
T3 omnivores (small, medium, and large)	Fish
T4 piscivores	Fish

[2] The dietary fraction data identified for terrestrial insects did not translate into the food web compartments used in the aquatic food web module. There is some uncertainty associated with excluding this prey type because many fish consume these organisms in their diet.

Because of the limited data identified to characterize fish dietary preferences, professional judgment was required in determining an appropriate minimum and maximum range for fish dietary fractions. When a fish category was not represented in the database, the general trends in fish seen in other similar waterbodies were applied (e.g., comparing the same fish in warmwater wetlands to fish that occur in warmwater ponds). When limited data, some of which were derived from narrative descriptions of diets, were available, a weight-of-evidence approach was used to generate a reasonable dietary fraction estimate for a particular fish species.

To help clarify how data manipulations were conducted, Table 11-8 provides an example of the raw data conversion strategy for a small omnivore found in a warmwater pond. In many cases, as apparent in Table 11-8, the raw data translated into useful ranges; however, in some cases, the data had to be manipulated to meet the data requirements of the model. Note in the table how the plant material dietary fractions identified in the literature were converted to the prey categories of phytoplankton, aquatic macrophytes, and periphyton. Professional judgment was used to assess which prey item would be eaten more frequently than others in the pond ecosystem. Review of the literature indicated that in ponds macrophytes are likely to be the most abundant, followed by phytoplankton and periphyton. Because the composition of the algae and aquatic plant community in warmwater ponds varies over space and time, however, these assumptions only represent a snapshot of what may be occurring temporally in the pond. The ranges of minima and maxima were selected so that the additive fish consumption of plant material indicated in the raw data would not be exceeded (i.e., the sum of 0.10, 0.05, and 0.15 approximates the 0.31 indicated as the maximum in the raw data). An additional common assumption made in raw data conversions is represented in the example when the minimum/maximum range of 0.05 to 0.15 was derived for the prey item of fish. Obviously, insufficient data were available to characterize the minimum and maximum dietary fractions for this prey item; however, single median values were available to estimate a range. The low median value (0.05) was used as the minimum. The median value, assigned as the default, was taken from descriptive data in which two preferred prey items were noted (0.5 fish and 0.5 benthic invertebrates) for a particular fish species. Consideration that one of the median values was relatively low and that an additional narrative diet description noted that some species of small warmwater omnivores occurring in ponds do eat fish resulted in the reasonable estimation of 0.15 as a maximum value.

This example further illustrates that, in some cases, dietary fraction data were available, but the analogous prey item was not included in that particular waterbody. In the example, small omnivores that may occur in warmwater ponds do consume fish in their diet; however, in the aquatic food web, no other small fish has been assigned to this food web. Because the model requires that a small fish cannot eat a larger fish, it is presumed that in the warmwater pond food web the small omnivore will not eat fish.

This example emphasizes the amount of professional judgment that was required to derive some of the minimum and maximum prey preference data. Although a common weight-of-evidence approach was used in most cases, there is uncertainty in the development of these parameters based on the significant amount of professional judgment required for their derivation.

Table 11-8. Example of Dietary Fraction Raw Data Conversions to Meet Model and Food Web Requirements: Small Omnivores in Warmwater Ponds

	Raw Data [1]			Range Derived from Raw Data		Range Translation to Aquatic Food Web Compartments		
Prey Item	**Minimums**	**Maximums**	**Single Value**	**Min.**	**Max.**	**Prey Item**	**Min.**	**Max.**
Plant material	**0.04** 0.04 0.045	0.064 0.075 **0.308**	0.044 0.33 (default) 0.136	0.04	0.31	Phytoplankton Periphyton Aquatic macrophytes	0.01 0.01 0.01	0.10 0.05 0.15
Terrestrial insects	0.001 0.073	0.2 0.38	0.027 0.286 0.33 (default) 0.052	0	0.38	Terrestrial insects dropped as prey item because not included in aquatic food web.		
Zooplankton	0.166 0.199 0.577 0.324 **0.045**	0.3 0.47 **0.741** 0.353 0.049	ID	0.05	0.74	Zooplankton	0.05	0.74
Benthic invertebrates	0.57 0.243 **0.115** 0.483 0.591	**0.774** 0.599 0.75 0.676 0.678	0.5 (default) 0.33 (default)	0.12	0.77	Benthic filter feeders	Prey item not present in warmwater ponds.	
Detritus	0.042 **0.004**	0.09 **0.378**	0.022 0.037 0.052	0	0.38	Benthic detritivores	0	0.38
Fish	ID	ID	0.5 (default) **0.045**	0.05	0.15	Small benthivores Small zooplanktivores	These small fish do not inhabit small warmwater ponds.	

[1] Fish species represented by the raw data: banded killifish, brook silverside, golden shiner, brook stickleback, Eastern mosquitofish, pirate perch, and central mudminnow.
Bolded values indicate those minima and maxima selected as part of the range.

After data were compiled into a format that met the prey categories of the aquatic food web, several specific data requirements had to be met so that model errors would not occur. These requirements were considered important in setting the minimum and maximum prey preferences for fish. If the raw data contradicted these requirements, a weight-of-evidence approach had to be adopted that would conform data to meet these restrictions.

- Dietary preferences of fish had to correspond with the largest fraction of the diet (e.g., zooplanktivores eat primarily zooplankton). This information was not always reflected in the raw data when a fish category was not well-represented by an array of different species.

- The minimum fraction could not exceed the maximum value for a given prey item and fish category.

- Maximums could not equal 0.

- None of the maximums used across the various prey items could be equal for a fish category because the model ranks prey preferences in quantifying fish diets.

- Minimum dietary fractions, when added together across all prey items in a given fish category, could not exceed 1.

- Omnivorous fish could not consume fish that were larger than themselves.

Tables 11B-4 through 11B-19 in Appendix 11B provide the minimum and maximum prey preferences for fish categories applied in this analysis.

11.3.2.2 <u>Database Processing</u>. A significant amount of preprocessing was completed in the fish attribute database, and this preprocessing was described for each parameter in the database compilation section (Section 11.3.2.1). When deriving parameter metrics, the data were formatted so that they could be used by the modeling system. The data were individually dimensioned on different variables outlined in the module development. Two-dimensional variables such as fish body weight, fraction lipid (whole body), muscle lipid, and T3 edible fish were dimensioned on the biota type (e.g., T3 omnivore, T3 piscivore) and the aquatic food web (e.g., warmwater wetland, coldwater lake). Three-dimensional variables such as the minimum and maximum prey preferences were dimensioned on the biota type, the aquatic food web, and the prey type (i.e., synonymous with the biota type for the aquatic food web).

11.3.2.3 <u>Assumptions and Uncertainties</u>. Additional uncertainty discussions were briefly mentioned in the methodology section for specific parameters; however, the key assumptions and uncertainties associated with the development of the fish attribute database as a whole can be grouped into the following general categories: default values and data gaps, fish body weight uncertainty, and preprocessing assumptions. The critical issues within each category are reviewed here.

Default Values and Data Gaps

Default values were used for the parameters of lipid fraction (whole body and muscle) and dietary prey preference. To derive a default lipid value, all lipid fractions across T3 and T4 fish, respectively, were independently averaged. This included all the lipid values derived from the GLWQI (U.S. EPA, 1995a) document in addition to primary literature studies identified during data collection efforts. When lipid data were not available for a fish category in the aquatic food web, the default value for the lipid was applied. In the case of dietary fractions, the description of what food items typically comprise fish diet varied substantially across different sources. In some instances, no data were provided on the actual dietary fraction - only the general components were known (e.g., aquatic plants, zooplankton, and benthos). In these cases, the feeding guild to which the species was assigned (e.g., benthivore) was used to inform professional judgement in selecting appropriate prey preferences. Applying default values when data were not available to characterize the parameter introduces uncertainty into the analysis. Because data gaps were evident across aquatic food web parameters, a level of resolution in the analysis can be minimized or lost as more default values are applied. For instance, the lipid content in fish will typically vary from warm- to coldwater habitats for some fish. If default values are applied for medium benthivores in coldwater streams and medium benthivores in warmwater streams, the variability in this parameter is not characterized.

The data gaps in the analysis limited the ability to characterize aquatic food web parameters at the national scale. The parameters most limited by data gaps included fish body weight, whole body lipid, and minimum/maximum prey preferences for fish. Because real differences are noted in these parameters across different waterbodies and regions, the more data that are identified to assess parameter distributions increases the resolution of the analysis. Data limitations were probably the greatest uncertainty in the development of the aquatic food web database.

Fish Body Weight Uncertainty

Because a large portion of the fish body weight data was taken from the NAWQA studies, any uncertainties associated with this database influence the uncertainty in the fish attribute database. Some body weight data identified through the NAWQA appear to be low for some species. The lower body weights reported could be due to any number of reasons. The fish population sampled may have included juvenile fish. A review of the NAWQA biological sampling method did not explicitly define fish collection by age. Further, many of the NAWQA sample sites were located in streams, ponds, and swamps, which larger fish may not inhabit as frequently. These discrepancies may have resulted in a skewed body weight distribution toward lower values. Applying these body weight values introduces some uncertainty into how well the variability in body weights has been represented.

Preprocessing Uncertainty

Uncertainty in the preprocessing effort was generated by the assumptions made when data were insufficient to support a definitive decision. The decision criteria applied for each preprocessing variable were explicitly stated. For instance, the assumptions associated with fish water temperature preference were based on a weight-of-evidence approach when no water temperature preference was reported for a fish species. In these cases, temperature measurements taken at multiple sampling locations across different regions and drainage basins were assessed for the maximum average annual temperatures. If a fish species was found predominantly in regions where the temperature exceeded 25 ºC, then the fish was presumed to be warmwater. There is some uncertainty associated with these assignments because a fish assigned as warmwater could possibly tolerate both cold and warm surface water temperatures. Because this database was developed to delineate preferences if they exist (not absolutes), the weight-of-evidence approach was appropriate in spite of its limitations. Other assumptions and professional judgments used in the preprocessing effort were outlined within the preprocessing parameter discussions (Section 11.3.2.1). Assumptions also were made about trophic level, relative size, and habitat preferences. Each decision framework applied influenced how the data were categorized and manipulated. These assumptions cumulatively introduced uncertainty into the resulting fish attribute database.

11.4 Quality Assurance/Quality Control

11.4.1 Technical QA/QC

Data were compiled for the aquatic food web from extant databases developed by EPA and other government agencies and programs. The use of highly reviewed sources and scientifically accepted methods in the development of a database creates a high level of confidence in the technical quality assurance/quality control (QA/QC) of the database. Studies included in the chemical properties and fish attribute databases met specific criteria before they were incorporated into the respective databases. For instance, the AQUIRE database (U.S. EPA, 1999a) reports a confidence rank for each study included in the database. The confidence rank was based on the experimental methods that were used in the study. Studies assigned with a low confidence rank were not included in the chemical-specific database. Likewise, the NAWQA uses the same standard methodology in collection of data from different waterbodies; hence, the variability introduced from modified methods is reduced. Upon compiling the data, a QA/QC check of technical agreeability was performed by appropriate staff to judge whether the numbers were technically defensible and that the assumptions and selection of default values were reasonable.

11.4.2 Data Entry QA/QC

Data entry was performed by both hardcopy data entry and database downloading from Internet sites. When data were entered from hardcopy, manual review of the data input was conducted. When data were downloaded from the Internet, a review of column headers and a partial random QA/QC check of approximately 10 percent of the values were conducted. The databases downloaded from the Internet were manipulated both in form and report. Databases that were downloaded typically reported values over several years and had to be condensed into summary statistics. The conversion of these data was checked for proper statistical manipulation.

11.4.3 Data Formatting

Manual QA/QC checks were conducted to identify errors that may have occurred during data formatting efforts. Approximately 10 percent of the values were checked to ensure formatting for the modeling system did not change or shift values.

11.5 References

Barrows, M. E., S. R. Petrocelli, K. J. Macek, and J. J. Carroll. 1980. Chapter 24: Bioconcentration and elimination of selected water pollutants by bluegill sunfish (*Lepomis macrochirus*). In: *Dynamics, Exposure and Hazard Assessment of Toxic Chemicals,* R. Haque (ed.). Ann Arbor Science Publishers Inc., Ann Arbor, MI. pp. 379-392.

Basack, S. B., M. L. Oneto, N. R. Guerrero, V, and E. M. Kesten. 1997. Accumulation and elimination of pentacholophenol in the freshwater bivalve *Corbicula fluminea*. *Bulletin of Environmental Contamination and Toxicology,* 58:497-503.

Bertelsen, Sharon L., Alex D. Hoffman, Carol A. Gallinat, Colleen M. Elonen, and John W. Nichols. 1998. Evaluation of log KOW and tissue lipid content as predictors of chemical partitioning to fish tissues. *Environmental Toxicology and Chemistry,* 17(8):1447-1455.

Clarke, Joan U., Victor A. McFarland, and John Dorkin. 1988. Evaluating bioavailability of neutral organic chemicals in sediments -- a confined disposal facility case study. In: *Water Quality '88,* February 23-25, 1988, Charleston, SC. pp. 251-268, U.S. Army Corps of Engineers Committee on Water Quality, Washington, DC.

Cohen, Joel E., Frédéric Briand, and Charles M. Newman. 1990. Community food webs data and theory. Data and theory. In: *Biomathematics*. Volume 20. Springer-Verlag, New York, NY.

Dirilgen, N., and Y. Inel. 1994. Effects of zinc and copper on growth and metal accumulation in duckweed, *Lemna minor*. *Bulletin of Environmental Contamination and Toxicology,* 53:442-449.

Donald, David B., Gary A. Stern, Derek C. G. Muir, Brian R. Fowler, Brenda M. Miskimmin, and Renata Bailey. 1998. Chlorobornanes in water, sediment, and fish from toxaphene treated and untreated lakes in western Canada. *Environmental Science & Technology,* 32(10):1391-1397.

FishBASE. 1998. FishBASE '98: Concepts, Design and Data Sources. Website at http://www.fishbase.org/manual/contents.htm.

Gerking, Shelby D. 1994. *Feeding Ecology of Fish.* Academic Press, Inc., San Diego, CA.

Glassmeyer, Susan T., David S. De Vault, Tanya R. Myers, and Ronald A. Hites. 1997. Toxaphene in Great Lakes fish: a temporal, spatial, and trophic study. *Environmental Science and Technology,* 31:84-88.

Gobas, Frank A. P. C. 1993. A model for predicting the bioaccumulation of hydrophobic organic chemicals in aquatic food-webs: application to Lake Ontario. *Ecological Modelling,* 69:1-17.

Goldstein, Robert M., and Thomas P. Simon. 1999. Chapter 7: Toward a united definition of guild structure for feeding ecology of North American freshwater fishes. In: *Assessing the Sustainability and Biological Integrity of Water Resources Using Fish Communities,* Thomas P. Simon (ed.). CRC Press, Boca Raton, FL. pp. 123-138.

Hackney, C. T., S. M. Adams, and W. H. Martin (eds.). 1992. *Biodiversity of the Southeastern United States: Aquatic Communities.* John Wiley & Sons, Inc., New York, NY.

Halliwell, David B., Richard W. Langdon, Robert A. Daniels, James P. Kurtenbach, and Richard A. Jacobson. 1999. Chapter 12: Classification of freshwater fish species of the northeastern United States for use in the development of indices of biological integrity, with regional applications. In: *Assessing the Sustainability and Biological Integrity of Water Resources Using Fish Communities,* Thomas P. Simon (ed.). CRC Press, Boca Raton, FL. pp. 301-337.

Jackson, L. J. 1998. Paradigms of metal accumulation in rooted aquatic vascular plants. *The Science of the Total Environment,* 219:223-231.

Klerks, P. L., and P. C. Fraleigh. 1997. Uptake of nickel and zinc by the zebra mussel *Dreissena polymorpha*. *Archives of Environmental Contamination and Toxicology,* 32:191-197.

Kuehl, Douglas W., Philip M. Cook, Allan R. Batterman, Douglas Lothenbach, and Brian C. Butterworth. 1987. Bioavailability of polychlorinated dibenzo-p-dioxins and dibenzofurans from contaminated Wisconsin River sediment to carp. *Chemosphere,* 16(4):672.

Kumada, H., S. Kimura, M. Yokote, and Y. Matida. 1972. Acute and chronic toxicity, uptake, and retention of cadmium in freshwater organisms. *Bulletin of Freshwater Fisheries Research Laboratory,* 22(2):157-165. December 20.

Lee, David S., Carter R. Gilbert, Charles H. Hocutt, Robert E. Jenkins, Don E. McAllister, and Jay R. Stauffer, Jr. 1980. *Atlas of North American Freshwater Fishes, 1980- Et Seq.* North Carolina State Museum of Natural History, Raleigh, NC.

Lemly, A. D. 1985. Toxicology of selenium in a freshwater reservoir: implications for environmental hazard evaluation and safety. *Ecotoxicology and Environmental Safety,* 10:314-338.

Lutz, Charlie. 1999. The BSAF Database. Version 2.0 for Windows. Environmental Laboratory, The Aquatic Contaminants Team, Waterways Experiment Station, Vicksburg, MS. Website at http://www.wes.army.mil/el/dots/database.html. March 23.

Mäkelä, T. P., T. Petänen, J. Kukkonen, and A. O. J. Oikari. 1991. Accumulation and depuration of chlorinated phenolics in the freshwater mussel (*Anodonta anatina L.*). *Ecotoxicology and Environmental Safety*, 22:153-163.

Metcalfe-Smith, Janice L., Roger H. Green, and Lee C. Grapentine. 1996. Influence of biological factors on concentrations of metals in the tissues of freshwater mussels (*Elliptio complanata* and *Lampsilis radiata radiata*) from the St. Lawrence River. *Can.J.Fish.Aquat.Sci.*, 53:205-219.

Miskimmin, Brenda M., Derek C. G. Muir, David W. Schindler, and Norbert P. Grift. 1995. Chlorobornanes in sediments and fish 30 years after toxaphene treatment of lakes. *Environmental Science & Technology*, 29(10):2490-2495.

Murphy, B. R., G. J. Atchison, and A. W. McIntosh. 1978. Cadmium and zinc in muscle of bluegill (*Lepomis macrochirus*) and largemouth bass (*Micropterus salmoides*) from an industrially contaminated lake. *Environmental Pollution*, 17:253-257.

Naqvi, Syed M., Rosie D. Howell, and Maurice Sholas. 1993. Cadmium and lead residues in field-collected red swamp crayfish (*Procambarus clarkii*) and uptake by alligator weed, *Alternanthera philoxiroides*. *Journal of Envrionmental Science and Health*, 28(4):473-485.

O'Connor, Thomas P., and Benoit Beliaeff. 1995. *Recent Trends in Coastal Environmental Quality: Results From the Mussel Watch Project*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Office of Ocean Resources Conservation and Assessment, Coastal Monitoring and Bioeffects Assessment Division, Silver Spring, MD.

Ohio EPA (Environmental Protection Agency). 1997. *Biological and Water Quality Study of Big Walnut Creek. D.E. Edwards Landfill, 1996.* MAS/1997-10-2. State of Ohio Environmental Protection Agency, Division of Emergency and Remedial Response. State of Ohio Environmental Protection Agency, Monitoring and Assessment Section, Division of Surface Water, Columbus, OH. October 31.

Ohio EPA (Environmental Protection Agency). 1998a. *Biological, Fish Tissue, and Sediment Study of the Ottawa River. Dura Avenue Landfill, 1996, Lucas County, Ohio.* OEPA Technical Report MAS/1997-12-8. State of Ohio Environmental Protection Agency, Division of Emergency and Remedial Response. State of Ohio Environmental Protection Agency, Monitoring and Assessment Section, Division of Surface Water, Columbus, OH. January 30.

Ohio EPA (Environmental Protection Agency). 1998b. *Biological and Water Quality Study of Lower Big Walnut Creek and Walnut Creek Tributaries, 1996. Rickenbacker Airport, Franklin and Pickaway Counties, Ohio.* MAS/1997-12-10. State of Ohio Environmental Protection Agency Division of Emergency and Remedial Response. State of Ohio Environmental Protection Agency, Monitoring and Assessment Section, Division of Surface Water, Columbus, OH. April 3.

Ohio EPA (Environmental Protection Agency). 1998c. *Biological and Water Quality Study of the Little Cuyahoga River and Tributaries. Summit and Portage Counties.* MAS/1997-12-9. State of Ohio Environmental Protection Agency, Division of Surface Water (Ecological Assessment Unit) and Water Quality Section, Columbus, OH. Website at http://chagrin.epa.state.oh.us/document_index/psdindx.html http://chagrin.epa.state.oh.us/document_index/psdindx.html. April 14.

Page, Lawrence M., and Brooks M. Burr. 1991. A field guide to freshwater fishes. North America, north of Mexico. In: *The Peterson Field Guide Series*. R.T.Peterson (ed.). Houghton Mifflin Company, Boston, MA.

Sample, B. E., D. M. Opresko, and G. W. Suter II. 1996. *Toxicological Benchmarks for Wildlife: 1996 Revision*. ES/ER/TM-86/R3. Office of Environmental Management, U.S. Department of Energy. Health Sciences Research Division, Oak Ridge National Laboratory Risk Assessment Program, Oak Ridge, TN. June.

Simon, Thomas P. (ed.). 1999. *Assessing the Sustainability and Biological Integrity of Water Resources Using Fish Communities.* CRC Press, Boca Raton, FL.

Smith, C. Lavett. 1994. *Fish Watching: An Outdoor Guide to Freshwater Fishes.* Cornell University Press, Ithaca, NY.

Stephan, C. E. 1993. *Derivation of Proposed Human Health and Wildlife Bioaccumulation Factors for the Great Lakes Initiative*. Environmental Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Duluth, MN. March.

Sternberg, Dick. 1996. *Freshwater Gamefish of North America.* Cowles Creative Publishing, Inc., Minnetonka, Minnesota.

U.S. DOI, and U.S. DOC (Department of the Interior; Department of Commerce). 1997. *1996 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation.* FHW/96 NAT. U.S. Department of the Interior; U.S. Department of Commerce, Fish and Wildlife Service; Bureau of the Census, Washington, DC. Website at http://www.nctc.fws.gov/library/pubs3.html. November.

U.S. EPA (Environmental Protection Agency). 1993a. *Wildlife Exposure Factors Handbook. Volumes I and II.* EPA/600/R-93/187. U.S. Environmental Protection Agency, Office of Health and Environmental Assessment and Office of Research and Development, Washington, DC. December.

U.S. EPA (Environmental Protection Agency). 1993b. *Interim Report on Data and Methods for Assessment of 2,3,7,8-Tetrachlorodibenzo-p-dioxin Risks to Aquatic Life and Associated Wildlife.* EPA/600/R-93/055. U.S. Environmental Protection Agency, Office of Research and Development, Washington, DC. March.

U.S. EPA (Environmental Protection Agency). 1995a. *Great Lakes Water Quality Initiative Criteria Documents for the Protection of Wildlife: DDT, Mercury, 2,3,7,8-TCDD, and PCBs.* EPA-820-B-95-008. U.S. Environmental Protection Agency, Office of Water, Washington, DC. March.

U.S. EPA (Environmental Protection Agency). 1995b. *Trophic Level and Exposure Analyes for Selected Piscivorous Birds and Mammals. Volume I: Analyses of Species in the Great Lakes Basin; Volume II: Analyses of Species in the Conterminous United States; Volume III: Appendices.* U.S. Environmental Protection Agency, Office of Science and Technology, Office of Water, Washington, DC. March.

U.S. EPA (Environmental Protection Agency). 1995c. *Great Lakes Water Quality Initiative Technical Support Document for the Procedure to Determine Bioaccumulation Factors.* EPA-820-B-95-005. U.S. Environmental Protection Agency, Office of Water, Washington, DC. March.

U.S. EPA (Environmental Protection Agency). 1997a. *Exposure Factors Handbook.* EPA/600/P-95/002Fa. U.S. Environmental Protection Agency, Office of Research and Development, Washington, DC. August.

U.S. EPA (Environmental Protection Agency). 1997b. *Mercury Study Report to Congress. Volumes I - VIII.* EPA 452/R-97/003. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards and Office of Research and Development, Washington, DC. Website at http://www.epa.gov/ttn/uatw/112nmerc/mercury.html. December.

U.S. EPA (Environmental Protection Agency). 1999a. ECOTOX (ECOlogical TOXicity Database). National Health and Environmental Effects Research Laboratory, Mid-Continent Ecology Division and Western Ecology Division, Duluth, MN. Website at http://www.epa.gov/medecotx/. January 28.

U.S. EPA (Environmental Protection Agency). 1999b. *Aquatic Food Web Module. Background and Implementation for the Multimedia, Multipathway, and Multireceptor Risk Assessment (3MRA) for HWIR99.* (Draft Report). U.S. Environmental Protection Agency, October.

USGS (U.S. Geological Survey). 1998a. National Ambient Water Quality Assessment (NAWQA) Program: South Platte River Basin. Website at http://www/webserver.cr.usgs.gov/nawqa/splt/datarep/biosites/BIO.html.

USGS (U.S. Geological Survey). 1998b. National Ambient Water Quality Assessment (NAWQA) Program: Lake Erie-Lake St. Clair Drainage. Website at http://www-oh.er.usgs.gov/nawqa/activities.html.

USGS (U.S. Geological Survey). 1998c. National Ambient Water Quality Assessment (NAWQA) Program: Albemarle Pamlico Drainage. Website at http://sgi1dncrlg.er.usgs.gov/albe-html/ALBEdata.html.

USGS (U.S. Geological Survey). 1998d. National Ambient Water Quality Assessment (NAWQA) Program: San Joaquin-Tulare. Website at http://water.wr.usgs.gov/sanj_nawqa/data_ae.html.

USGS (U.S. Geological Survey). 1998e. National Ambient Water Quality Assessment (NAWQA) Program: Upper Snake River Basin. Website at http://wwwidaho.wr.usgs.gov/nawqa/data/archive.html.

Appendix 11A

Parameter Values Applied for the Aquatic Food Web Chemical Properties Database

Table 11A-1. Scalar Parameters Used in the Chemical Properties Database

Variable Name	Units	Central Tendency
a_mus	unitless	0.69
b_mus	unitless	0.92
c_mus	unitless	0.76
a_fish	unitless	0.74
b_fish	unitless	1
c_fish	unitless	0.72

Table 11A-2. Bioaccumulation Factors Identified for Aquatic Food Web Prey Items

Chemical Name	Chemical CAS ID Number	Aquatic Macrophytes (L/kg plant tissue)	Benthic Filter Feeders (L/kg benthos)	T3 Fish Whole Body (L/kg)	T4 Fish Whole Body (L/kg)	T3 Fish Muscle (L/kg)	T4 Fish Muscle (L/kg)	Reference
Acetonitrile	75-05-8	1	1	1	1	1	1	NA
Acrylonitrile	107-13-1	1	1	9.9	9.9	1	1	U.S. EPA, 1999a
Aniline	62-53-3	1	1	1	1	1	1	NA
Antimony	7440-36-0	1	1	1	1	1	1	NA
Arsenic	7440-38-2	1	1	3.5	3.5	3.5	3.5	Stephan, 1993
Barium	7440-39-3	1	1	1	1	1	1	NA
Benzene	71-43-2	10,000	1	77	77	1	1	U.S. EPA, 1999a
Benzo(a)pyrene	50-32-8	1	1	1	1	1	1	NA
Beryllium	7440-41-7	1	1	1	1	1	1	NA
Bis(2-ethylhexyl) phthalate	117-81-7	0.34[a]	1	3.6	15	1	1	Sample et al., 1996
Cadmium	7440-43-9	17[b]	1	265	265	265	265	Barrows et al., 1980
Carbon disulfide	75-15-0	1	1	1	1	1	1	NA
Chlorobenzene	108-90-7	1	1	1	1	1	1	NA
Chloroform	67-66-3	1	1	110	110	1	1	Sample et al., 1996
Chromium (total)	7440-47-3	1	1	87	87	87	87	U.S. EPA, 1999a
Chromium III (insoluble salts)	16065-83-1	1	1	1	1	1	1	NA
Chromium VI	18540-29-9	1	1	1	1	1	1	NA
Dibenz(a,h)anthracene	53-70-3	1	1	1	1	1	1	NA
Dichlorophenoxyacetic acid, 2,4- (2,4-D)	94-75-7	1	1	1	1	1	1	NA
Ethylene dibromide	106-93-4	1	1	1	1	1	1	NA

(continued)

Table 11A-2. (continued)

Chemical Name	Chemical CAS ID Number	Aquatic Macrophytes (L/kg plant tissue)	Benthic Filter Feeders (L/kg benthos)	T3 Fish Whole Body (L/kg)	T4 Fish Whole Body (L/kg)	T3 Fish Muscle (L/kg)	T4 Fish Muscle (L/kg)	Reference
Hexachloro-1,3-butadiene	87-68-3	1	1	1	1	1	1	NA
Lead	7439-92-1	42[b]	1	46	46	46	46	Stephan, 1993
Methyl mercury	7439-97-6m	1	1	1,600,000	6,800,000	1,600,000	6,800,000	U.S. EPA, 1997b
Mercury (elemental)	7439-97-6e	1	1	1	1	1	1	NA
Mercury (divalent)	7439-97-6	1	1	120,000	500,000	120,000	500,000	U.S. EPA, 1997b
Methoxychlor	72-43-5	4.2	0.94	8	8	1	1	U.S. EPA, 1999a
Methyl ethyl ketone	78-93-3	1	1	1	1	1	1	NA
Methyl methacrylate	80-62-6	1	1	1	1	1	1	NA
Methylene chloride	75-09-2	1	1	1	1	1	1	NA
Nickel	7440-02-0	1	1	0.8	0.8	0.8	0.8	Stephan, 1993
Nitrobenzene	98-95-3	1	1	1	1	1	1	NA
Pentachlorophenol	87-86-5	1	150	1	1	1	1	Makela et al., 1991 Basack et al., 1997
Phenol	108-95-2	1	1	33	33	1	1	U.S. EPA, 1999a
Pyridine	110-86-1	1	1	1	1	1	1	NA
Selenium	7782-49-2	1	1	485	1,690	485	1,690	Lemly, 1985
Silver	7440-22-4	1	1	0	0	0	0	Stephan, 1993
2,3,7,8 TCDD	1746-01-6	4,300[d]	380[d]	172,100	264,100	1	1	U.S. EPA, 1995c
Tetrachloroethylene	127-18-4	1	1	3.4	3.4	1	1	Sample et al., 1996
Thallium	7446-18-6	1	1	1	1	1	1	NA

(continued)

Table 11A-2. (continued)

Chemical Name	Chemical CAS ID Number	Aquatic Macrophytes (L/kg plant tissue)	Benthic Filter Feeders (L/kg benthos)	T3 Fish Whole Body (L/kg)	T4 Fish Whole Body (L/kg)	T3 Fish Muscle (L/kg)	T4 Fish Muscle (L/kg)	Reference
Thiram	137-26-8	1	1	1	1	1	1	NA
Toluene	108-88-3	10,000	1	1	1	1	1	U.S. EPA, 1999a
1,1,1-Trichloroethane	71-55-6	1	1	73	73	1	1	U.S. EPA, 1999a
Trichloroethylene	79-01-6	71	1	8.2	8.2	1	1	U.S. EPA, 1999a
Vanadium	7440-62-2	1	1	1	1	1	1	NA
Vinyl chloride	75-01-4	1	1	1	1	1	1	NA
Zinc	7440-66-6	510	1	4.4	4.4	4.4	4.4	Stephan, 1993

NA = Nonapplicable.

[a] Source: U.S. EPA, 1999a.
[b] Source: Naqvi et al., 1993.
[c] Source: Dirilgen and Inel, 1994.
[d] Source: U.S. EPA, 1993b.

Appendix 11B

Parameter Values Applied for the Aquatic Food Web Fish Attribute Database

Table 11B-1. Scalar Parameters Used in the Fish Attribute Database

Variable Name	Units	Central Tendency
MusWaterFrac	unitless	0.79
FishWaterFrac	unitless	0.75

Table 11B-2. Lipid Fraction in Fish Muscle and Fillet Fraction Conversion Factors Applied in the Fish Attribute Database

Biota Type	Biota Type Index	Lipid Fraction in Muscle	Fillet Fraction
Periphyton	1	0	0
Phytoplankton	2	0	0
Aquatic macrophytes	3	0	0
Zooplankton	4	0	0
Benthic detrivores	5	0	0
Benthic filter feeders	6	0	0
T3benth_sm	7	0.0182	0.28
T3benth_med	8	0.0182	0.28
T3benth_lg	9	0.0182	0.28
T3zoop_sm	10	0.0182	0.28
T3zoop_med	11	0.0182	0.28
T3zoop_lg	12	0.0182	0.28
T3omni_sm	13	0.0182	0.28
T3omni_med	14	0.0182	0.28
T3omni_lg	15	0.0182	0.28
T4pisc	16	0.031	0.29

Table 11B-3 Fish Body Weight, Whole Body Lipid Fractions, and Edible T3 Fish Values Applied in the Fish Attribute Database

Aquatic Food Web Index	Biota Type	Biota Type Index	Fish Body Weight (kg)	Fish Lipid Fraction (Whole Body)	T3 Edible Fish
1	periphyton	1	NA	0.01	0
1	phytoplankton	2	NA	0.01	0
1	aquatic macrophytes	3	NA	0.01	0
1	zooplankton	4	NA	0.05	0
1	benthic detrivores	5	NA	0.03	0
1	benthic filter feeders	6	NA	0.05	0
1	T3benth_sm	7	0.00	0.07	0
1	T3benth_med	8	0.01	0.07	0
1	T3benth_lg	9	0.15	0.07	0
1	T3zoop_sm	10	0.00	0.07	0
1	T3zoop_med	11	0.01	0.07	0
1	T3zoop_lg	12	0.04	0.07	0
1	T3omni_sm	13	0.01	0.07	0
1	T3omni_med	14	0.22	0.06	1
1	T3omni_lg	15	1.30	0.07	0
1	T4pisc	16	2.10	0.09	0
2	periphyton	1	NA	0.01	0
2	phytoplankton	2	NA	0.01	0
2	aquatic macrophytes	3	NA	0.01	0
2	zooplankton	4	NA	0.05	0
2	benthic detrivores	5	NA	0.03	0
2	benthic filter feeders	6	NA	0.05	0
2	T3benth_sm	7	0.00	0.07	0
2	T3benth_med	8	0.01	0.07	0
2	T3benth_lg	9	0.20	0.07	0

(continued)

Table 11B-3. (continued)

Aquatic Food Web Index	Biota Type	Biota Type Index	Fish Body Weight (kg)	Fish Lipid Fraction (Whole Body)	T3 Edible Fish
2	T3zoop_sm	10	0.00	0.07	0
2	T3zoop_med	11	0.01	0.06	0
2	T3zoop_lg	12	0.02	0.07	0
2	T3omni_sm	13	0.00	0.07	0
2	T3omni_med	14	0.32	0.04	1
2	T3omni_lg	15	0.66	0.08	0
2	T4pisc	16	2.30	0.07	0
3	periphyton	1	NA	0.01	0
3	phytoplankton	2	NA	0.01	0
3	aquatic macrophytes	3	NA	0.01	0
3	zooplankton	4	NA	0.05	0
3	benthic detrivores	5	NA	0.03	0
3	benthic filter feeders	6	NA	0.05	0
3	T3benth_sm	7	0.00	0.07	0
3	T3benth_med	8	0.01	0.07	0
3	T3benth_lg	9	0.20	0.07	0
3	T3zoop_sm	10	0.00	0.07	0
3	T3zoop_med	11	0.01	0.06	0
3	T3zoop_lg	12	0.02	0.07	0
3	T3omni_sm	13	0.00	0.07	0
3	T3omni_med	14	0.32	0.04	1
3	T3omni_lg	15	0.66	0.08	0
3	T4pisc	16	2.10	0.07	0
4	periphyton	1	NA	0.01	0
4	phytoplankton	2	NA	0.01	0
4	aquatic macrophytes	3	NA	0.01	0

(continued)

Table 11B-3. (continued)

Aquatic Food Web Index	Biota Type	Biota Type Index	Fish Body Weight (kg)	Fish Lipid Fraction (Whole Body)	T3 Edible Fish
4	zooplankton	4	NA	0.05	0
4	benthic detrivores	5	NA	0.03	0
4	benthic filter feeders	6	NA	0.05	0
4	T3benth_sm	7	0.00	0.07	0
4	T3benth_med	8	0.01	0.07	0
4	T3benth_lg	9	0.20	0.07	0
4	T3zoop_sm	10	0.00	0.07	0
4	T3zoop_med	11	0.01	0.06	0
4	T3zoop_lg	12	0.05	0.07	0
4	T3omni_sm	13	0.01	0.07	0
4	T3omni_med	14	0.22	0.06	0
4	T3omni_lg	15	1.30	0.07	1
4	T4pisc	16	3.00	0.10	0
5	periphyton	1	NA	0.01	0
5	phytoplankton	2	NA	0.01	0
5	aquatic macrophytes	3	NA	0.01	0
5	zooplankton	4	NA	0.05	0
5	benthic detrivores	5	NA	0.03	0
5	benthic filter feeders	6	NA	0.05	0
5	T3benth_sm	7	0.00	0.07	0
5	T3benth_med	8	0.02	0.07	0
5	T3benth_lg	9	0.31	0.07	0
5	T3zoop_sm	10	0.00	0.07	0
5	T3zoop_med	11	0.00	0.07	0
5	T3zoop_lg	12	0.03	0.06	0
5	T3omni_sm	13	0.01	0.07	0

(continued)

Table 11B-3. (continued)

Aquatic Food Web Index	Biota Type	Biota Type Index	Fish Body Weight (kg)	Fish Lipid Fraction (Whole Body)	T3 Edible Fish
5	T3omni_med	14	0.18	0.07	1
5	T3omni_lg	15	2.60	0.06	0
5	T4pisc	16	3.00	0.09	0
6	periphyton	1	NA	0.01	0
6	phytoplankton	2	NA	0.01	0
6	aquatic macrophytes	3	NA	0.01	0
6	zooplankton	4	NA	0.05	0
6	benthic detrivores	5	NA	0.03	0
6	benthic filter feeders	6	NA	0.05	0
6	T3benth_sm	7	0.00	0.07	0
6	T3benth_med	8	0.00	0.07	0
6	T3benth_lg	9	0.25	0.07	0
6	T3zoop_sm	10	0.00	0.07	0
6	T3zoop_med	11	0.01	0.06	0
6	T3zoop_lg	12	0.08	0.06	0
6	T3omni_sm	13	0.00	0.07	0
6	T3omni_med	14	0.23	0.05	1
6	T3omni_lg	15	0.89	0.06	0
6	T4pisc	16	1.80	0.08	0
7	periphyton	1	NA	0.01	0
7	phytoplankton	2	NA	0.01	0
7	aquatic macrophytes	3	NA	0.01	0
7	zooplankton	4	NA	0.05	0
7	benthic detrivores	5	NA	0.03	0
7	benthic filter feeders	6	NA	0.05	0
7	T3benth_sm	7	0.00	0.07	0

(continued)

Table 11B-3. (continued)

Aquatic Food Web Index	Biota Type	Biota Type Index	Fish Body Weight (kg)	Fish Lipid Fraction (Whole Body)	T3 Edible Fish
7	T3benth_med	8	0.00	0.07	0
7	T3benth_lg	9	0.25	0.07	0
7	T3zoop_sm	10	0.00	0.07	0
7	T3zoop_med	11	0.01	0.06	1
7	T3zoop_lg	12	0.08	0.06	0
7	T3omni_sm	13	0.00	0.07	0
7	T3omni_med	14	0.19	0.07	0
7	T3omni_lg	15	0.78	0.06	1
7	T4pisc	16	1.40	0.09	0
8	periphyton	1	NA	0.01	0
8	phytoplankton	2	NA	0.01	0
8	aquatic macrophytes	3	NA	0.01	0
8	zooplankton	4	NA	0.05	0
8	benthic detrivores	5	NA	0.03	0
8	benthic filter feeders	6	NA	0.05	0
8	T3benth_sm	7	0.00	0.06	0
8	T3benth_med	8	0.01	0.06	0
8	T3benth_lg	9	0.17	0.07	1
8	T3zoop_sm	10	0.00	0.07	0
8	T3zoop_med	11	0.01	0.06	0
8	T3zoop_lg	12	0.08	0.06	0
8	T3omni_sm	13	0.01	0.07	0
8	T3omni_med	14	0.21	0.07	1
8	T3omni_lg	15	0.96	0.06	1
8	T4pisc	16	3.20	0.09	0

NA = Not applicable.

Table 11B-4. Minimum Prey Preference Values Applied for Fish in Coldwater Streams

Biota Type	Peri-phyton	Phyto-plankton	Aquatic Macro-phytes	Zoo-plankton	Benthic Detrivores and Detritis	Benthic Filter Feeders	Small T3 Benthivore	Medium T3 Benthivore	Large T3 Benthivore	Small T3 Planktivore	Medium T3 Planktivore	Large T3 Planktivore	Small T3 Omnivore	Medium T3 Omnivore	Large T3 Omnivore	T4 Piscivore
	1	2	3	0	5	6	7	8	-999	-999	-999	-999	-999	14	-999	16
Periphyton	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Phytoplankton	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Aquatic macrophytes	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Zooplankton	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Benthic detrivores	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Benthic filter feeders	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3benth_sm	0.2	-999	0.1	-999	0.06	0.2	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3benth_med	0.2	-999	0.1	-999	0.06	0.2	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3benth_lg	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3zoop_sm	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3zoop_med	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3zoop_lg	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3omni_sm	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3omni_med	0.01	-999	0.01	-999	0	0.3	0.02	0.25	-999	-999	-999	-999	-999	-999	-999	-999
T3omni_lg	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T4pisc	0	-999	0	-999	0	0	0.02	0.3	-999	-999	-999	-999	-999	0.4	-999	-999

Table 11B-5. Maximum Prey Preference Values Applied for Fish in Coldwater Streams

Biota Type	Peri-phyton	Phyto-plankton	Aquatic Macro-phytes	Zoo-plankton	Benthic Detrivores and Detritis	Benthic Filter Feeders	Small T3 Benthivore	Medium T3 Benthivore	Large T3 Benthivore	Small T3 Planktivore	Medium T3 Planktivore	Large T3 Planktivore	Small T3 Omnivore	Medium T3 Omnivore	Large T3 Omnivore	T4 Piscivore
	1	2	3	0	5	6	7	8	-999	-999	-999	-999	-999	14	-999	16
Periphyton	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Phytoplankton	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Aquatic macrophytes	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Zooplankton	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Benthic detrivores	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Benthic filter feeders	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3benth_sm	0.5	-999	0.25	-999	0.2	1	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3benth_med	0.27	-999	0.4	-999	0.3	1	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3benth_lg	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3zoop_sm	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3zoop_med	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3zoop_lg	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3omni_sm	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3omni_med	0.2	-999	0.15	-999	0.17	1	0.16	0.7	-999	-999	-999	-999	-999	-999	-999	-999
T3omni_lg	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T4pisc	0.07	-999	0.08	-999	0.12	0.8	0.1	0.85	-999	-999	-999	-999	-999	1	-999	-999

Table 11B-6. Minimum Prey Preference Values Applied for Fish in Coldwater Wetlands

Biota Type	Peri-phyton	Phyto-plankton	Aquatic Macro-hytes	Zoo-plankton	Benthic Detrivores and Detritis	Benthic Filter Feeders	Small T3 Benthivore	Medium T3 Benthivore	Large T3 Benthivore	Small T3 Planktivore	Medium T3 Planktivore	Large T3 Planktivore	Small T3 Omnivore	Medium T3 Omnivore	Large T3 Omnivore	T4 Piscivore
	1	2	3	4	5	-999	-999	8	-999	-999	-999	-999	13	14	-999	16
Periphyton	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Phytoplankton	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Aquatic macrophytes	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Zooplankton	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Benthic detrivores	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Benthic filter feeders	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3benth_sm	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3benth_med	0	0	0	0.1	0.25	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3benth_lg	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3zoop_sm	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3zoop_med	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3zoop_lg	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3omni_sm	0.04	0.04	0.04	0.2	0.2	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3omni_med	0.01	0.01	0.01	0.2	0.1	-999	-999	0	-999	-999	-999	-999	0.02	-999	-999	-999
T3omni_lg	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T4pisc	0	0	0	0.2	0.1	-999	-999	0.1	-999	-999	-999	-999	0.1	0.02	-999	-999

Table 11B-7. Maximum Prey Preference Values Applied for Fish in Coldwater Wetlands

Biota Type	Peri-phyton	Phyto-plankton	Aquatic Macro-phytes	Zoo-plankton	Benthic Detrivores and Detritis	Benthic Filter Feeders	Small T3 Benthivore	Medium T3 Benthivore	Large T3 Benthivore	Small T3 Planktivore	Medium T3 Planktivore	Large T3 Planktivore	Small T3 Omnivore	Medium T3 Omnivore	Large T3 Omnivore	T4 Piscivore
	1	2	3	4	5	-999	-999	8	-999	-999	-999	-999	13	14	-999	16
Periphyton	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Phytoplankton	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Aquatic macrophytes	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Zooplankton	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Benthic detrivores	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Benthic filter feeders	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3benth_sm	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3benth_med	0.05	0.15	0.1	0.5	1	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3benth_lg	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3zoop_sm	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3zoop_med	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3zoop_lg	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3omni_sm	0.1	0.05	0.15	0.35	0.7	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3omni_med	0.12	0.1	0.13	0.9	0.8	-999	-999	0.05	-999	-999	-999	-999	0.2	-999	-999	-999
T3omni_lg	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T4pisc	0.01	0.04	0.03	0.8	0.85	-999	-999	0.95	-999	-999	-999	-999	0.3	0.9	-999	-999

Table 11B-8. Minimum Prey Preference Values Applied for Fish in Coldwater Ponds

Biota Type	Peri-phyton	Phyto-plankton	Aquatic Macro-phytes	Zoo-plankton	Benthic Detrivores and Detritis	Benthic Filter Feeders	Small T3 Benthivore	Medium T3 Benthivore	Large T3 Benthivore	Small T3 Planktivore	Medium T3 Planktivore	Large T3 Planktivore	Small T3 Omnivore	Medium T3 Omnivore	Large T3 Omnivore	T4 Piscivore
	1	2	3	4	5	-999	-999	8	-999	10	-999	-999	13	14	-999	16
Periphyton	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Phytoplankton	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Aquatic macrophytes	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Zooplankton	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Benthic detrivores	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Benthic filter feeders	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3benth_sm	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3benth_med	0	0	0	0.1	0	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3benth_lg	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3zoop_sm	0.05	0	0.1	0.3	0	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3zoop_med	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3zoop_lg	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3omni_sm	0.01	0.01	0.01	0.02	0.04	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3omni_med	0.01	0.01	0.01	0.2	0	-999	-999	0.05	-999	0.05	-999	-999	0.05	-999	-999	-999
T3omni_lg	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T4pisc	0	0	0	0.02	0	-999	-999	0.1	-999	0.1	-999	-999	0.1	0.2	-999	-999

Table 11B-9. Maximum Prey Preference Values Applied for Fish in Coldwater Ponds

Biota Type	Peri-phyton	Phyto-plankton	Aquatic Macro-phytes	Zoo-plankton	Benthic Detrivores and Detritis	Benthic Filter Feeders	Small T3 Benthivore	Medium T3 Benthivore	Large T3 Benthivore	Small T3 Planktivore	Medium T3 Planktivore	Large T3 Planktivore	Small T3 Omnivore	Medium T3 Omnivore	Large T3 Omnivore	T4 Piscivore
	1	2	3	4	5	-999	-999	8	-999	10	-999	-999	13	14	-999	16
Periphyton	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Phytoplankton	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Aquatic macrophytes	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Zooplankton	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Benthic detrivores	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Benthic filter feeders	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3benth_sm	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3benth_med	0.2	0.05	0.1	0.5	1	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3benth_lg	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3zoop_sm	0.15	0.05	0.3	0.9	0.6	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3zoop_med	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3zoop_lg	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3omni_sm	0.06	0.04	0.1	0.35	0.7	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3omni_med	0.12	0.1	0.13	0.9	0.8	-999	-999	0.11	-999	0.35	-999	-999	0.4	-999	-999	-999
T3omni_lg	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T4pisc	0.01	0.04	0.03	0.8	0.85	-999	-999	0.5	-999	0.86	-999	-999	0.9	1	-999	-999

Table 11B-10. Minimum Prey Preference Values Applied for Fish in Coldwater Lakes

Biota Type	Peri-phyton	Phyto-plankton	Aquatic Macro-phytes	Zoo-plankton	Benthic Detrivores and Detritis	Benthic Filter Feeders	Small T3 Benthivore	Medium T3 Benthivore	Large T3 Benthivore	Small T3 Planktivore	Medium T3 Planktivore	Large T3 Planktivore	Small T3 Omnivore	Medium T3 Omnivore	Large T3 Omnivore	T4 Piscivore
	1	2	3	4	5	6	-999	8	-999	-999	11	-999	13	-999	15	16
Periphyton	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Phytoplankton	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Aquatic macrophytes	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Zooplankton	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Benthic detrivores	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Benthic filter feeders	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3benth_sm	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3benth_med	0	0	0	0.1	0	0.25	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3benth_lg	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3zoop_sm	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3zoop_med	0	0	0	0.5	0	0	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3zoop_lg	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3omni_sm	0.04	0.04	0.04	0	0.02	0.48	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3omni_med	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3omni_lg	0.01	0.01	0.01	0.07	0.02	0	-999	0.03	-999	-999	0.03	-999	0.03	-999	-999	-999
T4pisc	0	0	0	0.1	0	0.15	-999	0.1	-999	-999	0.1	-999	0.1	-999	-999	-999

Table 11B-11. Maximum Prey Preference Values Applied for Fish in Coldwater Lakes

Biota Type	Peri-phyton	Phyto-plankton	Aquatic Macro-phytes	Zoo-plankton	Benthic Detrivores and Detritis	Benthic Filter Feeders	Small T3 Benthivore	Medium T3 Benthivore	Large T3 Benthivore	Small T3 Planktivore	Medium T3 Planktivore	Large T3 Planktivore	Small T3 Omnivore	Medium T3 Omnivore	Large T3 Omnivore	T4 Piscivore
	1	2	3	4	5	6	-999	8	-999	-999	11	-999	13	-999	15	16
Periphyton	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Phytoplankton	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Aquatic macrophytes	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Zooplankton	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Benthic detrivores	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Benthic filter feeders	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3benth_sm	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3benth_med	0.2	0.05	0.1	0.5	0.25	1	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3benth_lg	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3zoop_sm	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3zoop_med	0.03	0.2	0.1	1	0.01	0.11	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3zoop_lg	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3omni_sm	0.03	0.12	0.05	0.35	0.1	1	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3omni_med	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3omni_lg	0.06	0.2	0.1	0.9	0.92	0.75	-999	0.12	-999	-999	0.11	-999	0.09	-999	-999	-999
T4pisc	0.01	0.04	0.03	0.7	0.12	0.75	-999	0.85	-999	-999	0.9	-999	0.8	-999	-999	-999

Table 11B-12. Minimum Prey Preference Values Applied for Fish in Warmwater Streams

Biota Type	Peri-phyton	Phyto-plankton	Aquatic Macro-phytes	Zoo-plankton	Benthic Detrivores and Detritis	Benthic Filter Feeders	Small T3 Benthivore	Medium T3 Benthivore	Large T3 Benthivore	Small T3 Planktivore	Medium T3 Planktivore	Large T3 Planktivore	Small T3 Omnivore	Medium T3 Omnivore	Large T3 Omnivore	T4 Piscivore
	1	-999	3	-999	5	6	7	8	-999	-999	-999	-999	-999	14	-999	16
Periphyton	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Phytoplankton	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Aquatic macrophytes	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Zooplankton	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Benthic detrivores	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Benthic filter feeders	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3benth_sm	0.07	-999	0.07	-999	0.03	0.63	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3benth_med	0.015	-999	0.015	-999	0.01	0.2	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3benth_lg	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3zoop_sm	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3zoop_med	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3zoop_lg	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3omni_sm	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3omni_med	0.01	-999	0.01	-999	0.1	0.2	0	0.05	-999	-999	-999	-999	-999	-999	-999	-999
T3omni_lg	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T4pisc	0	-999	0	-999	0.05	0.05	0.01	0.1	-999	-999	-999	-999	-999	0.4	-999	-999

Table 11B-13. Maximum Prey Preference Values Applied for Fish in Warmwater Streams

Biota Type	Peri-phyton	Phyto-plankton	Aquatic Macro-phytes	Zoo-plankton	Benthic Detrivores and Detritis	Benthic Filter Feeders	Small T3 Benthivore	Medium T3 Benthivore	Large T3 Benthivore	Small T3 Planktivore	Medium T3 Planktivore	Large T3 Planktivore	Small T3 Omnivore	Medium T3 Omnivore	Large T3 Omnivore	T4 Piscivore
	1	-999	3	-999	5	6	7	8	-999	-999	-999	-999	-999	14	-999	16
Periphyton	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Phytoplankton	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Aquatic macrophytes	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Zooplankton	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Benthic detrivores	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Benthic filter feeders	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3benth_sm	0.25	-999	0.2	-999	0.24	1	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3benth_med	0.4	-999	0.3	-999	0.65	1	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3benth_lg	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3zoop_sm	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3zoop_med	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3zoop_lg	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3omni_sm	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3omni_med	0.45	-999	0.35	-999	0.87	1	0.11	0.8	-999	-999	-999	-999	-999	-999	-999	-999
T3omni_lg	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T4pisc	0.4	-999	0.3	-999	0.85	0.9	0.21	0.95	-999	-999	-999	-999	-999	1	-999	-999

Table 11B-14. Minimum Prey Preference Values Applied for Fish in Warmwater Wetlands

Biota Type	Peri-phyton	Phyto-plankton	Aquatic Macro-phytes	Zoo-plankton	Benthic Detrivores and Detritis	Benthic Filter Feeders	Small T3 Benthivore	Medium T3 Benthivore	Large T3 Benthivore	Small T3 Planktivore	Medium T3 Planktivore	Large T3 Planktivore	Small T3 Omnivore	Medium T3 Omnivore	Large T3 Omnivore	T4 Piscivore
	1	2	3	4	5	-999	-999	8	-999	-999	-999	-999	13	14	-999	16
Periphyton	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Phytoplankton	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Aquatic macrophytes	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Zooplankton	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Benthic detrivores	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Benthic filter feeders	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3benth_sm	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3benth_med	0.05	0.01	0.1	0.07	0.4	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3benth_lg	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3zoop_sm	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3zoop_med	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3zoop_lg	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3omni_sm	0.04	0.02	0.08	0.05	0.12	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3omni_med	0.01	0.01	0.01	0.04	0.14	-999	-999	0	-999	-999	-999	-999	0	-999	-999	-999
T3omni_lg	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T4pisc	0.01	0.01	0.01	0.1	0.2	-999	-999	0.22	-999	-999	-999	-999	0.08	0.2	-999	-999

Table 11B-15. Maximum Prey Preference Values Applied for Fish in Warmwater Wetlands

Biota Type	Peri-phyton	Phyto-plankton	Aquatic Macro-phytes	Zoo-plankton	Benthic Detrivores and Detritis	Benthic Filter Feeders	Small T3 Benthivore	Medium T3 Benthivore	Large T3 Benthivore	Small T3 Planktivore	Medium T3 Planktivore	Large T3 Planktivore	Small T3 Omnivore	Medium T3 Omnivore	Large T3 Omnivore	T4 Piscivore
	1	2	3	4	5	-999	-999	8	-999	-999	-999	-999	13	14	-999	16
Periphyton	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Phytoplankton	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Aquatic macrophytes	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Zooplankton	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Benthic detrivores	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Benthic filter feeders	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3benth_sm	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3benth_med	0.15	0.1	0.3	0.52	1	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3benth_lg	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3zoop_sm	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3zoop_med	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3zoop_lg	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3omni_sm	0.09	0.06	0.15	0.74	0.68	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3omni_med	0.2	0.1	0.5	0.9	1	-999	-999	0.07	-999	-999	-999	-999	0.02	-999	-999	-999
T3omni_lg	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T4pisc	0.06	0.03	0.09	0.8	0.68	-999	-999	0.9	-999	-999	-999	-999	0.5	1	-999	-999

Table 11B-16. Minimum Prey Preference Values Applied for Fish in Warmwater Ponds

Biota Type	Peri-phyton	Phyto-plankton	Aquatic Macro-phytes	Zoo-plankton	Benthic Detrivores and Detritis	Benthic Filter Feeders	Small T3 Benthivore	Medium T3 Benthivore	Large T3 Benthivore	Small T3 Planktivore	Medium T3 Planktivore	Large T3 Planktivore	Small T3 Omnivore	Medium T3 Omnivore	Large T3 Omnivore	T4 Piscivore
	1	2	3	4	5	-999	-999	8	-999	-999	11	-999	13	-999	15	-999
Periphyton	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Phytoplankton	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Aquatic macrophytes	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Zooplankton	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Benthic detrivores	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Benthic filter feeders	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3benth_sm	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3benth_med	0.08	0.08	0.08	0.07	0.06	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3benth_lg	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3zoop_sm	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3zoop_med	0	0	0	0.5	0.01	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3zoop_lg	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3omni_sm	0.01	0.01	0.01	0.05	0.12	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3omni_med	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3omni_lg	0.02	0.02	0.02	0.04	0.05	-999	-999	0.03	-999	-999	0.03	-999	0	-999	-999	-999
T4pisc	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999

Table 11B-17. Maximum Prey Preference Values Applied for Fish in Warmwater Ponds

Biota Type	Peri-phyton	Phyto-plankton	Aquatic Macro-phytes	Zoo-plankton	Benthic Detrivores and Detritis	Benthic Filter Feeders	Small T3 Benthivore	Medium T3 Benthivore	Large T3 Benthivore	Small T3 Planktivore	Medium T3 Planktivore	Large T3 Planktivore	Small T3 Omnivore	Medium T3 Omnivore	Large T3 Omnivore	T4 Piscivore
	1	2	3	4	5	-999	-999	8	-999	-999	11	-999	13	-999	15	-999
Periphyton	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Phytoplankton	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Aquatic macrophytes	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Zooplankton	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Benthic detrivores	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Benthic filter feeders	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3benth_sm	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3benth_med	0.21	0.2	0.22	0.52	1	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3benth_lg	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3zoop_sm	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3zoop_med	0.031	0.03	0.032	1	0.11	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3zoop_lg	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3omni_sm	0.1	0.05	0.15	0.74	0.77	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3omni_med	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3omni_lg	0.13	0.12	0.14	0.94	0.8	-999	-999	0.3	-999	-999	0.2	-999	0.07	-999	-999	-999
T4pisc	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999

Table 11B-18. Minimum Prey Preference Values Applied for Fish in Warmwater Lakes

Biota Type	Peri-phyton	Phyto-plankton	Aquatic Macro-phytes	Zoo-plankton	Benthic Detrivores and Detritis	Benthic Filter Feeders	Small T3 Benthivore	Medium T3 Benthivore	Large T3 Benthivore	Small T3 Planktivore	Medium T3 Planktivore	Large T3 Planktivore	Small T3 Omnivore	Medium T3 Omnivore	Large T3 Omnivore	T4 Piscivore
	1	2	3	4	5	6	7	-999	9	-999	-999	12	-999	14	15	16
Periphyton	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Phytoplankton	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Aquatic macrophytes	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Zooplankton	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Benthic detrivores	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Benthic filter feeders	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3benth_sm	0.01	0.05	0.02	0	0.03	0.63	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3benth_med	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3benth_lg	0	0	0	0.02	0.01	0	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3zoop_sm	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3zoop_med	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3zoop_lg	0.03	0.03	0.03	0	0.04	0.5	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3omni_sm	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3omni_med	0.01	0.01	0.01	0	0	0	0	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3omni_lg	0	0	0	0	0.02	0	0.01	-999	0.1	-999	-999	0.1	-999	0.05	-999	-999
T4pisc	0	0	0	0.05	0	0.1	0.05	-999	0.2	-999	-999	0.15	-999	0.05	-999	-999

Table 11B-19. Maximum Prey Preference Values Applied for Fish in Warmwater Lakes

Biota Type	Peri-phyton	Phyto-plankton	Aquatic Macro-phytes	Zoo-plankton	Benthic Detrivores and Detritis	Benthic Filter Feeders	Small T3 Benthivore	Medium T3 Benthivore	Large T3 Benthivore	Small T3 Planktivore	Medium T3 Planktivore	Large T3 Planktivore	Small T3 Omnivore	Medium T3 Omnivore	Large T3 Omnivore	T4 Piscivore
	1	2	3	4	5	6	7	-999	9	-999	-999	12	-999	14	15	16
Periphyton	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Phytoplankton	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Aquatic macrophytes	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Zooplankton	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Benthic detrivores	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Benthic filter feeders	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3benth_sm	0.05	0.12	0.1	0.58	0.24	1	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3benth_med	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3benth_lg	0.1	0.25	0.12	0.99	0.96	1	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3zoop_sm	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3zoop_med	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3zoop_lg	0.05	0.2	0.1	1	0.5	0.91	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3omni_sm	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3omni_med	0.2	0.3	0.25	0.95	0.87	1	0.4	-999	-999	-999	-999	-999	-999	-999	-999	-999
T3omni_lg	0.08	0.15	0.09	0.9	0.92	1	0.05	-999	0.5	-999	-999	0.45	-999	0.2	-999	-999
T4pisc	0.06	0.08	0.07	0.75	0.15	0.8	0.1	-999	1	-999	-999	0.95	-999	0.85	-999	-999