

RECOMMENDATIONS FOR A FISH TISSUE
MONITORING STRATEGY FOR
FRESHWATER LAKES, RIVERS, AND STREAMS

prepared by:

The Fish Tissue Advisory Committee

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SECTION 1

INTRODUCTION

1.1 Background

The subject of fish tissue contamination with toxic chemicals is one of utmost concern for the citizens of Georgia. Contamination of aquatic resources, including lakes, rivers, and streams, has occurred as a result of urbanization, industrialization, and the utilization of intensive agricultural practices. Pesticides, heavy metals, and complex organic compounds have entered waterways via point-source discharges, nonpoint source runoff, and atmospheric deposition.

Contamination of surface waters with even low environmental concentrations of toxic chemicals is problematic for several reasons. Many toxic chemicals are relatively resistant to natural degradation or break-down in the environment and are, therefore, extremely persistent. Fish accumulate toxic chemicals directly from the water and through their diet, and contaminant residues may ultimately reach concentrations hundreds or thousands of times above those measured in the water, sediment and food. For this reason, monitoring fish tissue contamination serves an important function as an early warning indicator of sediment contamination or related water quality problems. Monitoring fish tissue contamination also enables the State to detect concentrations of toxic chemicals in fish that may be harmful to consumers, and take appropriate action to protect public health and the environment.

The Environmental Protection Division (EPD) and the Game and Fish Division (GFD) of the Georgia Department of Natural Resources (DNR) have monitored contaminant concentrations in fish tissue in the past to serve these two functions. However, as a result of the growing public concern over toxic contamination of aquatic resources and the increasing amount of information available on toxicity of different chemicals and risk assessment, DNR formed the Fish Tissue Advisory Committee (FTAC) with the charge to provide guidelines for: 1) a comprehensive fish tissue sampling and analysis plan, and 2) the development and issuance of improved fish consumption advisories.

1.2 Objectives

The primary objective of the committee's work and this report are to provide guidance to DNR concerning the design and implementation of studies which will provide sufficient information for the issuance of specific fish consumption advisories for the State's waterways. The recommendations contained within this report describe what FTAC believes to be scientifically defensible methods for sample collection, data analyses, and issuance of fish consumption advisories in a timely, cost effective manner.

The specific aims of this report are to:

- a. Recommend a monitoring strategy designed to:
 - ▶ identify waterbodies where chemical contaminants are present in the edible flesh of fish in concentrations which may represent a health threat to consumers
 - ▶ collect sufficient data to issue specific consumption advice for at least two important target species of fish in each area monitored in a timely and cost effective manner.

- b. Recommend a standard sample collection procedure including:
 - ▶ site selection
 - ▶ time of sampling
 - ▶ target species and size to be sampled
 - ▶ type and number of samples per species
 - ▶ field handling procedures of samples.
- c. Recommend a standard laboratory procedure for preparing fish tissue for analysis.
- d. Identify target contaminants of concern and reasonable laboratory limits of detection.
- e. Recommend a standard method for analyzing data and preparing fish consumption advisories to provide reasonable, understandable information to protect consumers from carcinogenic and toxic effects of contaminants.

SECTION 2

PRIMARY STUDIES

Many agencies use a two-tiered approach for monitoring fish tissue contaminant concentrations. This strategy includes an initial screening program of limited, whole-body sampling of species known to be good bioaccumulators to identify worst-case areas where the potential for health risks to human and wildlife consumers might exist, followed by an intensive monitoring study to determine the geographic extent and magnitude of contamination in edible tissues in various fish species.

FTAC believes that this strategy may not be the most beneficial for a state agency for several reasons. Due to resource limitations, many agencies can only sample fish once per year, and there is normally significant lag time between sample collection and data analysis. With these constraints, the two-tiered strategy would place the state in the difficult position of having data from a given site which indicates health risks *may* exist as a result of fish tissue contamination. However, data sufficient for issuance of a fish consumption advisory would not be available (possibly for another year) until the more expensive, time consuming, intensive monitoring study is conducted. FTAC recommends an initial **primary** study of sufficient detail to provide adequate information on human health risks from consumption of contaminated fish for the issuance of consumption advisories.

2.1 Objective

The objective of the **primary** study is to identify waterbodies where chemical contaminants are present in the edible flesh of fish in concentrations which may represent a health threat to consumers, while providing sufficient data to issue specific consumption advice for at least two important target species of fish.

2.2 Target Species

Target species recommended by FTAC for the primary study are:

- 1 bottom-feeding species (catfish preferred, carp secondary choice), and
- 1 predator species (largemouth bass preferred).

Target species were chosen to meet several criteria. The target species are known to accumulate high concentrations of target contaminants in their tissues (i.e., a plausible worst-case exposure situation). They normally populate most of the freshwater systems in Georgia, and are routinely caught and consumed by anglers. Also the target species are nonmigratory, pollutant-tolerant, easily identified, abundant and easy to collect, and of sufficient size to provide adequate tissue samples for analyses of toxicants.

2.3 Target Contaminants

Several factors must be considered when a list of target contaminants is recommended. These include the contaminant's prevalence and persistence in the environment, its potential to bioaccumulate, its biochemical fate, toxicity, and availability/cost of analytical methods.

Currently, Georgia has fish consumption advisories in effect in four different areas of the state for three chemicals. The three chemicals which have been detected in sufficient quantity to trigger advisories are chlordane, PCBs, and mercury. A list of target contaminants and detection limits is given in Table 1. Included are 13 metals and 30 organic pesticides/PCBs. This list constitutes the "standard" laboratory scan which DNR currently has the capability to conduct. The list does not include the polyaromatic hydrocarbons (PAHs), chlorinated benzenes, or dioxins/dibenzofurans. There is limited data available on the occurrence of PAHs and chlorinated benzenes in fish tissue. Currently, only three states have issued fish consumption advisories as a result of PAH or chlorinated benzene contamination (RTI, 1991). Because of the significant cost of analysis for PAHs and the chlorinated benzenes and the limited evidence of their widespread occurrence, FTAC does not believe routine monitoring of all fish tissue for these contaminants is warranted at this time. However, if information becomes available which indicates PAHs or chlorinated benzenes may be significant environmental contaminants at a particular location, monitoring on a site-specific basis may be necessary.

There is great concern regarding the presence of dioxins/dibenzofurans in the environment and their bioaccumulation in fish tissue, but the cost of analysis is high (\approx \$1500/sample) for a routine monitoring program. Pulp and paper mills which use chlorine to bleach pulp are believed to be a major source of dioxins/dibenzofurans release into waterways (USEPA, 1990a). Currently, dioxins/dibenzofurans are monitored in fish tissue (whole fish and fillets) in the vicinity of five bleached kraft pulp mills in Georgia. The

studies are conducted yearly by a private consulting firm following a study protocol that was approved by DNR, and are required under the facilities NPDES permits. FTAC recommends that the data collected yearly via this program be evaluated in a manner consistent with the evaluation of the other data collected through the State's monitoring programs. The need for dioxins/dibenzofurans analysis at other sites should be reevaluated periodically taking into consideration possible sources of contamination, new scientific information regarding dioxins/dibenzofurans toxicity, and any improvements in technology which may lower the cost of analyses.

FTAC notes that new chemicals may be identified that need to be added to the list of contaminants monitored in fish tissue. The list of chemicals provided in Table 1 should be considered provisional. Similarly, advances are constantly being made in the analytical techniques available for contaminant analysis. Detection limits listed in Table 1 are considered reasonable with methods currently available. Because the detection limit is often the limiting factor in data analysis for risk assessment, every effort should be made to keep abreast of any changes or improvements in methods which will allow lowering of detection limits.

2.4 Sampling Sites, Locations and Numbers

One of the objectives of the primary study is to identify areas where fish tissue contamination may present a health or environmental risk. To satisfy this objective, sampling sites should target areas suspected of having high contamination. Selection criteria for sites with potential for high concentrations of target contaminants have been

recommended by U.S. EPA (U.S. EPA, 1986a). The criteria include the presence of municipal or industrial discharges and facilities, RCRA or CERCLA sites, the presence of intensive agricultural activities, and intensive urban land development. Species and numbers of fish present, and fishing pressure should also be considered when sampling locations are being chosen.

Within a given waterbody, numbers of sampling sites will depend on site specific circumstances. For example, determining the number of sites necessary to sufficiently estimate contamination of a river reach will depend on numerous factors including (but not limited to) urban centers, industrial facilities, and agricultural land use in the immediate vicinity in the drainage basin. Number and drainage characteristics of tributaries should also affect the selection of sampling sites. For river and stream systems, decisions on locations and numbers of sampling sites must be made on a case by case basis taking into account all available historical/geographical data.

FTAC reviewed a list of 27 lakes listed in the 1990 Lake Monitoring Project by EPD ranging in size from 69,776 to 598 acres in surface area. Committee members agreed that for the primary study, a minimum of three separate sites should be chosen to provide adequate coverage of the larger lakes. Particular attention should be given to choice of sampling locations in the larger lakes with more than one major tributary source and where contaminant concentration gradients may exist. More than three sites may be needed in larger lakes to adequately define geographic extent of contaminant problems.

2.5 Sampling Times

FTAC recommends that yearly sampling be conducted in late summer through fall. Collection of samples during this period allows one to avoid the spawning season of the target species, and ensures that lipid content of fish is relatively high and constant. Another factor which may facilitate fall sampling is that water levels are often lower which may make collection easier.

2.6 Sample Type

Compositing tissue from several individuals prior to analysis provides a means of collecting information on average contaminant concentrations from a large number of fish with a limited number of analyses. Composite samples of edible fillets from the target species (largemouth bass and catfish or carp) should be collected as a basis for estimating or predicting human health risks. The variability among contaminant concentrations (e.g., highest versus lowest values) in individual fish is lost by compositing. However, an accurate estimate of individual variation is not necessary to meet the objective of the primary study. Therefore, composite samples are recommended by FTAC to reduce cost of analysis for the primary study. An edible fillet is defined as the fillet portion of the fish including the bellyflap. For scaled fish, fillets should be scaled but left with the skin on. For fish without scales, the skin should be removed from the fillet. Composites should contain tissue from five individual fish for a given target species. Tissue from different species of fish should never be mixed to produce a composite.

In addition to the composite samples of fillet tissue, a single, whole fish analysis of one

of the bottom-feeder composites (catfish or carp) should also be conducted for each site as an indicator of an absolute worst case scenario and for long-term or trend analysis. The whole fish analysis can be a reconstructed analysis. After fillets are taken from bottom-feeders for the composite, the remainder of the carcasses are saved for compositing and analysis. The contaminant concentrations in both the fillet composite and the remainder-of-carcass composite are added to yield a whole body estimate.

2.7 Fish Size and Number

Discussions of committee members revealed two differing views regarding a strategy for limiting fish size. One view was that fish collected should be of the largest size available to serve as a worst case scenario. This method could bias the samples and lead to overly restrictive advisory information. Another view was that size ranges could be narrowly specified so that advisory information could be very specific relative to size. This procedure would require the collection and analysis of an unreasonably large number of composites, exceeding the scope of the primary study. As a compromise between these two extremes, FTAC recommends that fish collected from a given site be of a size that is representative of what fishermen could readily catch in the area. All fish collected should also be of a legally harvestable size. Once fifteen fish (enough for three composites of five fish) are collected from a given site for a species, they should be grouped by size. Ideally, the smallest fish in a composite should be at least 75% of the size of the largest fish. Composites would be prepared with five fish of a similar size and length representative of the three most prevalent size classes (i.e., small, medium, and large). This type of

sampling effort and grouping of fish based on size (length) will allow for the development of advisory information based on specific size classes of fish.

2.8 Composite Replication

Replication of sampling is required to permit statistical analysis of data to detect differences in mean concentrations between sites. FTAC generally agreed, that at a minimum, three values (providing at least 1 degree of freedom) are needed to conduct any comparisons or statistical manipulations of the data. In the narrowest sense, replication of composites would require the collection of more than one five fish composite of the same size and species of fish at each station within a lake or river reach. Because FTAC is recommending that fish collected at a sampling station be grouped into composites based on size (length), replication of composites at each site will not be achieved. However, in most instances multiple sites will be needed in waterbodies to adequately evaluate fish tissue contamination. Therefore, samples of the same size class from different stations within a waterbody can be treated as replicates, unless there are differences in contaminant concentrations related to sampling area.

2.9 Sample Analysis

All samples collected should be analyzed for the complete list of target contaminants (Table 1). The accuracy and precision of the analytical methods used should be adequate to allow reliable quantitation of contaminants at or below the recommended detection limits listed in Table 1. The composition of this list should be expected to change over time as

new chemicals of concern are identified and analytical methods made available.

Much discussion occurred among FTAC members regarding the need for lipid analysis. Many organic contaminants are lipophilic, and partition and accumulate to a greater degree in the fatty tissues of fish. Lipid normalization may provide insight into species differences in contaminant concentrations (Stober, 1991). However, data is available which suggests that the relationship between lipophilic contaminants and lipid content of fish is not clear cut or well understood (Appendix A). FTAC recommends that non-normalized wet weight data should be used for all calculations and analyses related to decision making for human health protection. Because lipid analyses are relatively inexpensive and simple to conduct, FTAC also recommends that lipid analyses be conducted on all samples. This data base over time may provide useful information for future modeling and trend analysis.

For a more thorough discussion of analysis of individual versus composite samples, sample replication, statistical analyses, and lipid analysis, see Appendix A.

SECTION 3

SECONDARY STUDIES

3.1 Objective

The objective of the **secondary study** is to provide information regarding additional fish species and/or geographic extent of contamination for waterbodies where the primary study indicated that contamination of the target species was of such a nature that restrictive fish consumption advisory information was issued.

3.2 Justification

Fish chosen as target species for the primary study were chosen because they are good indicator species which readily accumulated contaminants. Providing information on their contaminant concentrations and possible health risks from their consumption should greatly aid the public. However, FTAC acknowledges that there are popular, heavily fished waterbodies where the major fish collected for consumption may be a different species with a very different potential (lesser or occasionally, greater) for bioaccumulation of contaminants. Examples of these are: crappie; the bream (bluegill, redear, shellcracker); white, striped, and hybrid bass; and brook, brown, and rainbow trout. In situations where the primary study has resulted in restrictive consumption advisory information for the target species on waterbodies which are important fisheries, sampling in successive years of other fish species is recommended to broaden the consumption advisory information.

If data collected from the different sampling sites in the primary study indicate that there are dramatic site or size related differences in contaminant concentrations for either target species within a given waterbody, further studies may be warranted to more thoroughly define the geographic extent of contamination (increased sampling sites) and/or provide an improved database for rigorous statistical analyses (increased replication).

3.3 Target Species

Target species for the secondary study should be chosen based on site specific information related to fish populations and fishing preferences of the local anglers. Input from GFD fisheries biologists familiar with the given waterbody will be critical to ensure proper selection of appropriate species for sampling.

3.4 Other Study Parameters

Concerning the choice of other study parameters, FTAC recommends that the same general study design be used regarding sampling times, sample type, fish size, and sample analysis as was recommended for the primary study. Site specific information should be utilized in selection of sampling numbers and locations, and numbers of sample replicates per site to best meet the objective of the secondary study.

SECTION 4

FIELD AND LABORATORY PROCEDURES

4.1 Field Collection

Field collection procedures should be structured such that handling of fish and opportunities for contamination or loss of sample integrity are minimized. Fish may be held on wet ice for up to 24 hours before sample preparation, but fish from different sites and different species should be segregated. Fish should not be frozen prior to filleting (if at all possible) to ensure that internal organs do not rupture from the freezing process, and contaminate edible tissue.

4.2 Composite Preparation

Many contamination problems can be avoided if fillets are removed from fish in a clean laboratory environment. However, if transporting fish samples to a central laboratory is not possible, filleting can be conducted in the field, provided clean work surfaces and instruments are available. The following recommendations on processing and preparation of composite fillet samples are taken directly from Stober (1991).

To avoid cross-contamination, all equipment used in sample handling should be thoroughly cleaned before each sample is processed. All instruments must be of a material that can be easily cleaned (e.g., stainless steel, anodized aluminum, or borosilicate glass). Before the next sample is processed, instruments should be washed with a detergent solution, rinsed with tap water, soaked in isopropanol, and finally rinsed with organic free distilled water. Work surfaces should be cleaned with isopropanol, washed with distilled water and allowed to dry completely.

The removal of biological tissues should be carried out by or under the supervision of an experienced biologist. Tissue should be removed with clean stainless steel or quartz instruments (except for external surfaces)...Polypropylene and polyethylene (plastic) surfaces and implements are a potential source of contamination and should not be used. To control

contamination when resecting tissue, technicians should use separate sets of utensils for removing outer tissue and for resecting tissue for analysis.

For fish samples, special care must be taken to avoid contaminating targeted tissues (especially muscle) with slime and/or adhering sediment from the fish exterior (skin) during resection...To initiate processing, each fish is measured to the nearest tenth of a centimeter, weighed (nearest gram) and external condition noted...Fish are scaled (or skinned: catfish) and filleted carefully, removing bones, to get all of the edible portion of flesh.

A fillet includes the flesh tissue and skin from head to tail beginning at the mid-dorsal line from the left side of each fish and including the belly flap. The fillet should not be trimmed to remove fatty tissue along the lateral line or belly flap. A comparable fillet can be obtained from the right side of the fish and can be composited with the left fillet, kept separate for duplicate quality assurance analysis, analyzed for different compounds or archived. Each right and left fillet should be weighed individually, recorded and individually wrapped in clean aluminum foil...

Filleting should be conducted on cutting boards covered with heavy duty aluminum foil, which changed between composite samples. Knives, fish scalers, measurement boards, scales, etc. should be cleaned with reagent grade isopropanol, followed by a rinse with distilled water between each composite sample...Excess aluminum foil should be used to carefully fold and wrap the fillet samples. When filling out I.D. labels use pencil or waterproof marker and place the foil wrapped sample in a secured plastic bag.

Recommended holding times for frozen tissue samples have not been established by U.S. EPA, but a maximum 6-mo to 1-yr holding time is preferable...At a minimum, the samples should be kept frozen at -20°C until extraction...Liquid associated with the sample when thawed must be maintained as part of the sample because the lipid tends to separate from the tissue. Storage of samples should remain under the control of the sample collector until relinquished to the analytical laboratory.

Whole fish may be frozen and stored if no resection of internal organs or fillets will be conducted and the ultimate analysis is wholebody. However, if resection of fillets or organs is required these tissues should be removed prior to freezing and can be stored frozen in appropriate individual containers. The tissues may then be ground and homogenized at a later date and refrozen in sample packets for shipment to the analytical laboratory(s).

Organic contaminants are not evenly distributed throughout biological tissue, especially in fish. This is also true for fish fillets. Therefore, to obtain a homogenous sample, the whole fish or the whole fillet must be ground to a homogeneous consistency. This procedure should be carried out by the sample collector on partially thawed samples...The ground sample is divided into quarters, opposite quarters are mixed by hand with a clean stainless steel spatula and then the two halves are mixed back together. Repeat the mechanical grinding, quartering and hand mixing two more times. No chunks of tissue should be present at this point as they will not be efficiently extracted...

When compositing fillets or whole fish each individual fillet or fish should be ground separately following the above described procedure. Then take equal amounts from each fillet or fish sample to be composited to provide a total equal to that required for extraction or the total number of split and archived samples required by the study plan. If the ground fish is to be re-frozen prior to extraction and analysis, weigh out the exact amount for extraction into a small container...Tightly seal the container or foil packet. Repeat with additional containers for duplicates, splits, or archived samples. Lipid material tends to migrate during freezing,

therefore, storing a weighed portion ensures extraction of a representative portion of the tissue if the foil or container is completely rinsed with solvent by the analytical chemist.

Whenever a ground sample is to be split between two or more labs, the ground sample must also be mixed with reagent grade anhydrous sodium sulfate (previously heated to 400°C to drive off any phthalate esters acquired during storage) to ensure the homogeneity of the sample prior to splitting...

4.3 Records

Record keeping procedures are extremely important from the initial collection of fish through the final data analyses. Sample identification is critical to ensure that proper tracking of individual fish through composite preparation occurs. As fish are collected from a given station, each individual should be uniquely identified. A tag or label should contain the following information: date, species, location collected, and person in charge of sample preparation. As soon as fish are weighed and length measured, fish may be assigned to replicates from a particular site. This information should be added to the tag along with an identifying number (i th fish of j th replicate). The tag should stay with the fish through the filleting process and be packaged with the two fillets from an individual fish for laboratory processing. A field data sheet should be completed during the sample collection and field preparation process containing all of the above information and accompany fish tissues to the analytical laboratory with a chain of custody form.

SECTION 5

DATA ANALYSIS AND FISH CONSUMPTION ADVISORIES

5.1 Development of Fish Consumption Advisories

In the past, DNR has based fish consumption advisories on FDA action levels or tolerances (Table 2) which have been set for mercury, approximately 12 pesticides or related degradation products, and PCBs. Even though many states still use FDA's action levels as the basis for issuing fish consumption advisories, this method is increasingly criticized. Perhaps the most often heard criticism is that FDA's action levels were developed to protect consumers of commercial seafood in interstate commerce from fish contamination, and are not protective enough or appropriate for use for consumption advisories aimed at safe-guarding sport and subsistence fishermen. Additionally, action levels have been developed for only a few chemicals. With today's sophisticated analytical techniques, the states routinely have access to information on many contaminants in fish tissue for which action levels have not been developed.

In recent years, interest has increased in the use of risk assessment methods or techniques which allow one to arrive at an estimate of the risk resulting from consumption of contaminated fish. With these methods, one may actually calculate a quantitative value for risk from consumption of fish containing carcinogens (U.S. EPA, 1989a). It should be emphasized that any calculations of risk are only estimates, the actual risk can not be determined.

Currently, probability is not used to express the potential for noncarcinogenic toxicity.

Instead, the potential for noncarcinogenic toxic effects are evaluated by comparing an exposure level for a specified time period with a reference dose or RfD (i.e., a level of exposure below which it is unlikely that even sensitive populations will experience any adverse health effect). If this ratio, referred to as a hazard quotient, exceeds unity there may be concern for potential noncancer effects (U.S. EPA, 1989b).

The relationship of risk to the potency and intake of a carcinogen, and the hazard quotient to the reference dose (toxicity) and intake are shown below.

$$\text{Risk (unitless probability)} = \text{Cancer Potency Factor (mg/kg-day)}^{-1} \times \text{Intake (mg/kg-day)}$$

or,

$$\text{Hazard Quotient (unitless)} = \frac{\text{Intake (mg/kg-day)}}{\text{Reference Dose (mg/kg-day)}}$$

These formulas illustrate the need for accurate estimates of fish consumption (intake) in order to estimate potential toxicity or carcinogenicity of contaminated fish tissue. The generalized formula for calculating intake from fish consumption is as follows:

$$\text{Intake (mg/kg/day)} = \frac{\text{CF} \times \text{IR} \times \text{FI} \times \text{EF} \times \text{ED}}{\text{BW} \times \text{AT}}$$

where:

CF = contaminant concentration in fish (mg/kg)

IR = ingestion rate (kg/meal)

FI = fraction ingested from contaminated source (unitless)

EF = exposure frequency (meals/year)

ED = exposure duration (years)

BW = body weight (kg)

AT = averaging time (period over which exposure is averaged in days)

Utilizing this methodology, U.S. EPA has calculated "fish tissue concentrations" for numerous chemicals (U.S. EPA, 1991). The values are calculated using standard inputs of 6.5 g/day consumption, 365 day/year exposure frequency, 70 years exposure duration, 70 kg bw, and 70 years x 365 days/year averaging time. For chemicals which are carcinogenic, U.S. EPA utilizes a risk value of 1×10^{-6} in calculating the fish tissue concentration, and for chemicals which result in noncancer toxicity, U.S. EPA uses the RfD. These values indicate "how much of a given contaminant fish tissue may contain, without risk of excess lifetime cancer exceeding 1 in a million, or any likelihood of noncancer toxicity occurring, **as long as the exposure assumptions are appropriate.**

One way of using the risk assessment methodology in developing fish consumption advisories would be to simply use the fish tissue concentration values developed by U.S. EPA as "action levels", and issue advisories when fish tissue exceeded them. However, one significant problem with this approach is that the exposure assumptions used by U.S.EPA were taken from estimates of national averages, and are not suitable for estimating intake of sport or subsistence fishermen. Another major problem with this type of approach is that it continues to oversimplify the nature of the problem of fish tissue contamination (i.e., safe versus not safe) and limit the type of information one can develop for an advisory (i.e., eat versus don't eat).

Extensive discussions were held by FTAC concerning the complex nature of the relationship between chemical contamination of fish tissue, fish tissue consumption, and

toxicity and/or carcinogenicity of contaminants. An adequate monitoring plan will provide measured tissue concentrations of fish tissue contaminants from selected sites, which can be used with caution to provide reasonable estimates of fish tissue contamination for a given waterbody. Additionally, the data base on toxicity and carcinogenicity of contaminants is rapidly expanding. Therefore, the area where the greatest degree of uncertainty is introduced into the process of developing fish consumption advisories is arriving at a reasonable estimate of fish tissue consumption for different subpopulations.

FTAC believes it is extremely important for the State to develop a strategy whereby advisories not only convey information that is readily understandable, but also stress the importance of the relationship between consumption or exposure and the ultimate toxic or carcinogenic endpoints of concern.

5.2 Model Choice

Dourson and Clark (1990) proposed a method to improve the credibility of fish consumption advisories and make the information provided by them much more useful for the average fish consumer. The proposed model accounts for the amount of fish consumed by making fish consumption the dependent variable and recommends that, where consumption should be limited, advisory information be released as number of fish meals allowed per month or week. FTAC has reviewed this model and endorses its use.

The steps required for evaluation of data with the Dourson and Clark (1990) model include the calculation of fish intake from the appropriate RfDs for noncancer toxicity or potency factors for cancer. Equations for these calculations are shown in Appendix B.

The second step is to estimate the amount of fish consumed per meal. Dourson and Clark (1990) determined that a difference of approximately twofold (i.e., ¼ to ½ lb) exists in the sizes of individual fish meals (U.S. EPA, 1988). The authors concluded that this range of meal size and the frequency of fish meals eaten over a given period follows a logarithmic scale (Figure 1). That is, the consumption of 3 to 10 g of fish per day is in the range of eating one ¼- to ½-lb fish meal per month: the consumption of 10 to 30 g/day is in the range of eating one ¼- to ½-lb meal per week: the consumption of 30 to 100 g/day is in the range of eating three ¼- to ½-lb meals per week: the consumption of 100 to 300 g/day is in the range of eating one ¼- to ½-lb meal per day. The fish consumption advisory proposed by Dourson and Clark (1990) is developed from a direct comparison of calculated fish intake values to the estimated amount of fish consumed per meal and meal frequency (Table 3).

The advantages of this model are numerous. The most obvious is that it allows the release of a gradient of recommendations ranging from unlimited consumption to complete restriction with intermediate recommendations based on fish meals per week or month. This type of information should be easier for fish consumers to interpret and will stress the important principle that degree of health risk is based on **contaminant concentration and quantity consumed** (i.e., the dose makes the poison).

Another major advantage of this method is that it enables one to conduct risk assessments for mixtures (i.e., assessments when more than one chemical is present in fish tissue) for either toxics or carcinogens. The model treats toxic or carcinogenic effects as additive, which is the currently accepted practice in risk assessment (U.S. EPA, 1986b).

However, when fish tissue contains contaminants that cause both noncancer and cancer toxicity, separate fish intakes would need to be calculated for both endpoints because current theoretical methods do not exist to combine risks from both (U.S. EPA, 1986b).

A practical advantage resulting from the use of this method is that recommendations are based on how much fish people should be able to "safely" eat (a question that is frequently asked by consumers). No information need be generated for public release discussing theoretical risk calculations, cancer potency factors, RfDs, or toxic versus carcinogenic classification systems. All of these are technical, complex concepts that are difficult to explain and place in the proper perspective for the general public, and may only serve to confuse the issue of how much fish one should be able to consume.

5.3 Model Inputs

Management decisions must be made concerning appropriate inputs for some of the basic model parameters. For analyses of carcinogenic compounds, an appropriate risk level, a standard body weight, and an exposure duration must be chosen. For analyses of noncarcinogen toxicity, only body weight and exposure duration must be chosen.

FTAC recommends that a risk level of 10^{-4} be used in the model for analysis of carcinogens. In any risk assessment, managers must determine what level of risk is "acceptable" to both individuals and the regulatory agency. Even though an acceptable risk level has not been strictly defined by any regulatory agency, risk levels acceptable to different U.S. regulatory agencies have ranged as high as 10^{-3} to 10^{-2} in certain situations where the exposed population was small (Travis, *et al.*, 1987). However, for exposures

of the entire U.S. population, 10^{-6} has been the most widely accepted risk level (U.S. EPA, 1989a).

In choosing an appropriate risk level for use in fish consumption advisories, several points should be considered relative to the development of U.S. EPA's cancer potency factors. The cancer potency factor or slope factor is a plausible upper-bound (i.e., 95th confidence interval) estimate of the probability of a response per unit intake of a chemical, over a lifetime (U.S. EPA, 1989). The actual risk is likely to be lower than the predicted upper-bound risk and could even be zero in some cases. Because the response area that is important is below what can actually be quantitated in animal studies, the response curve is extrapolated into the low-dose range using one of several mathematical models. The model that is routinely used by U.S. EPA is the linear multistage procedure. When compared to the other models, which are currently available for use, the linear multistage procedure consistently yields conservative predictions (Hanes and Wedel, 1985). Other areas where U.S. EPA's procedures are based on conservative assumptions include the use of surface area as opposed to body weight as a scaling factor for extrapolation from animals to humans, routinely using the most sensitive species/strain of animal showing a positive response in animal studies and not evaluating negative evidence, and the inclusion of both benign and malignant tumors in the calculation of tumor response (Park, 1989). Many scientists believe that because the assumptions used are independent, the impact of the series of choices is cumulative resulting in upper bound assessments that tend to be extreme (Moolenaar, 1989).

When the conservativeness of these procedures are considered in conjunction with the practical consideration that selecting a risk level of 10^{-5} or 10^{-6} for routine use results in a requirement for analytical detection levels which are currently not possible for some chemicals, a risk level of 10^{-4} appears warranted. Other supporting evidence for the use of 10^{-4} as an appropriate risk level for the basis of fish consumption advisories exists. U.S. EPA established a risk level of 10^{-4} as the level of concern resulting from 2,3,7,8-TCDD and 2,3,7,8-TCDF contaminated receiving waters from chlorine-bleaching pulp and paper mills (U.S. EPA, 1990a). As a result of this policy decision, U.S. EPA subsequently urged all states with sites where risk exceeded 10^{-4} , as indicated by analysis of data from 1986-1988 as part of the National Bioaccumulation Study, to issue fish consumption advisories (U.S. EPA, 1990b).

By convention, 70 years (or lifetime) has been utilized most frequently as an exposure duration. However, 30 years is the national upper-bound time (90th percentile) at one residence and 9 years is the national median time (50th percentile) at one residence (U.S. EPA, 1989c). FTAC recommends using 30 years as the exposure duration in the model to calculate fish intake. For noncarcinogenic calculations, this would result in a 30 year averaging time, but for carcinogenic effects excess risk from 30 years exposure would still be calculated on a 70 year or lifetime basis. A 30 year exposure duration is justifiable for two reasons. With the mobility of today's society, it is unlikely that many people will consume a constant diet of fish from the same waterbody for 70 years. However, it is possible that subsistence fishermen in certain areas may present an exception to this general trend. Another important consideration is how well measurements collected now

relate to fish tissue contamination 10, 20, or 30, years ago. Georgia does not have extensive historical data on toxic contaminations of fish tissue for any of its waterways sufficient to support a thorough analysis of this relationship. However, results from the National Biomonitoring Program indicate that the concentrations of both heavy metals and organochlorine chemicals in U.S. freshwater fish were lower in 1984 than any previously reported time (Schmitt and Brumbaugh, 1990; Schmitt *et al.*, 1990). The authors stated that these results support the conclusion that regulatory measures have resulted in a lower influx of these chemicals into the aquatic environment. It is likely that fish tissue contained significantly higher concentrations of some of the organic pesticides in the 1960's and 70's than are being reported from today's monitoring efforts. When one considers the fact that the toxics which have been found most consistently in Georgia's waterways (chlordane, PCB's, DDT) have all been removed from the market, an exposure period of significantly less than 70 years appears warranted.

FTAC recommends that 70 kg be utilized in calculations as the standard body weight for an adult (U.S. EPA, 1989c). Standardized recommended body weights are available for many different age groups of children and could be utilized to refine recommendations in areas where large numbers of children consume high quantities of fish. However, in the interest of keeping fish consumption advisory information simple and understandable, FTAC recommends that for all areas where contamination results in a restriction advisory of less than one meal per week, a general statement that "fish consumption by small children and nursing women (or women of child bearing age) should be severely restricted" should be added to the advisory.

When all of the scientific arguments concerning choice of models and input parameters, assumptions, and uncertainty, are put aside, the practical test of an advisory is how well it provides information to protect public health. In an effort to better judge how the proposed model would work on a real data set, the model was evaluated using the data collected by DNR on the Chattahoochee River in the fall of 1990. An advisory was issued with that data for parts of the Chattahoochee River and West Point Lake in the spring of 1991. A comparison of the original data analysis used as the basis for the advisory, and an analysis using the Dourson model are shown in Appendix C. Pages C-2 through C-7 show the text and table that were generated for the original advisory. Page C-8 shows the site abbreviations used in the following tables. The fish contaminant data for five chemicals that were used in the analyses is shown on page C-9. It should be noted that the values shown are arithmetic means from analyses of fillets from three individuals per site, not composites. Also, because the fish collected were generally of a similar size, the recommendations could not be broken out for specific size classes as is currently being recommended by FTAC. RfDs and cancer potency factors used in the analyses are shown on page C-10.

Some discrepancies are evident in the mean contaminant values on the data sheet (C-9) and the summary from the advisory (C-7). In the original analysis, all non-detect samples were treated as if the sample contained the contaminant at one-half of the analytical detection limit. In the present analysis, all non-detect samples were treated as zero. There is no general consensus as to how values below analytical detection limits should be treated. In the past, recommendations for evaluation of non-detects have

included calculating means using the detection limit for non-detects, using one-half the detection limit, using zero, or calculating means twice: once using detection limits and once using zero for nondetects to quantify the range of the estimated values (U.S. EPA, 1989a). Routinely using the detection limit for non-detect samples will result in a bias towards a higher mean value, while using zero may result in a bias towards a lower value. Because of the uncertainty involved in extrapolating estimates of contaminant concentrations below analytical detection limits, FTAC recommends that all non-detect samples be treated as zero for development of fish consumption advisories.

Pages C-11 and C-12 show the result of the carcinogen analysis utilizing the Dourson model with a 70 and 30 year exposure duration, respectively. For comparative purposes, a column is included which depicts estimated excess lifetime risk calculated using U.S. EPA's standard national input of 6.5 g/day consumption and verified potency factors (U.S. EPA, 1992) for the chemicals. The results for a toxicity analysis of the chemicals using U.S. EPA's RfDs are shown on page C-13.

A comparison of the carcinogen assessment utilizing a 70 year exposure period with the toxic assessment indicates that the carcinogen assessment resulted in much more restrictive advisory recommendations. This is not surprising, as it is generally agreed that protection against lifetime cancer risk will more than adequately protect against *most* chemicals' chronic toxic endpoints for the general population. For the carcinogen assessment, decreasing the exposure period from 70 to 30 years resulted in an approximately two fold increase in the allowable fish intake and decreased the estimated excess lifetime cancer risk by one-half. Even with these changes, the carcinogen

assessment yielded advisory recommendations that were more restrictive than those from the toxic assessment. Page C-14 and C-15 shows a comparison of the actual recommendations issued for the Chattahoochee, with those which would result from use of the Dourson model with either a 70 or 30 year exposure period. It should be noted that this is only an example of how the Dourson and Clark (1990) model may be used and does not include a breakdown of recommendations based on size class. With fish collected in the future grouped in size classes, more specific recommendations of meal limits based on size of fish should enable the State to provide better advice to anglers to ensure the best utilization of fishery resources.

5.4 Implementation

As discussed previously, FTAC's recommendations for a systematic monitoring program are that sampling be conducted on a yearly basis in the late summer to early fall, laboratory and data analysis completed over the winter, and information released to the public in early spring. The overall goal of this program, as envisioned by FTAC, would be to provide information from primary studies on Georgia's major lakes and river reaches in a five year span. In addition to primary studies, a portion of the resources and effort devoted to fish tissue monitoring should be allocated for the conduct of secondary studies on important fisheries where a significant contaminant problem has been identified from the results of the primary study. As information is generated for fish consumption advisories each year, new advisories should be issued and existing advisories reissued or updated in a systematic and consistent manner. This program would ultimately result

in the release of advisory recommendations based on fish tissue consumption for all important fresh water lakes and rivers in Georgia.

Release of advisory information in early spring is recommended because information on fish consumption and advisories should be most useful to the public if released when interest in sport fishing is highest. By keeping to this time-table, information could be released in the form of a pamphlet in conjunction with the sale of fishing licenses. This method has been used successfully in other states such as Tennessee. Releasing information in this manner should be considered in addition to the routine procedure used by DNR of issuing press releases for specific affected areas. Other methods of disseminating information to the public which might be considered by DNR include a yearly placement of new, updated, and reissued advisory summaries in major newspapers or sports/fishing related popular publications, and/or placement of short advertisements on local radio stations.

Because the method recommended by FTAC for developing and issuing fish consumption advisories is radically different from that which has been used by DNR in the past, advance planning and education will be critical for successful implementation. Methods which should be considered to ensure that the public understands and is able to interpret the type of information being presented include: developing training seminars for the field specialists in both GFD and EPD to ensure that they are able to adequately respond to public inquiries; presenting informational seminars on the method and its interpretation to appropriate fishing organizations, guides, etc., near major lakes; and preparing an article describing DNR's fish monitoring plan and consumption advisory

methodology for publication (either by in-house DNR writers, or in conjunction with a journalist) in one of the popular fishing magazines.

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TABLE 1
PARAMETERS AND DETECTION LIMITS FOR FISH SAMPLES

| <u>Parameter</u> | <u>Detection Limit</u> |
|------------------------------|------------------------|
| <u>METALS</u> | |
| Antimony | 1 |
| Arsenic | 0.02 |
| Beryllium | 1 |
| Cadmium | 1 |
| Chromium, Total | 1 |
| Copper | 1 |
| Lead | 1 |
| Mercury | 0.01 |
| Nickel | 1 |
| Selenium | 0.02 |
| Silver | 1 |
| Thalium | 1 |
| Zinc | 1 |
| <u>PESTICIDES/PCB</u> | |
| Aldrin | 0.01 |
| a-BHC | 0.01 |
| b-BHC | 0.01 |
| d-BHC | 0.01 |
| g-BHC (Lindane) | 0.01 |
| Chlordane | 0.03 |
| 4,4-DDD | 0.01 |
| 4,4-DDE | 0.01 |
| 4,4-DDT | 0.01 |
| Dieldrin | 0.01 |
| Endosulfan I | 0.02 |
| Endosulfan II | 0.03 |
| Endosulfan Sulfate | 0.05 |
| Endrin | 0.01 |
| Endrin Aldehyde | 0.05 |
| Heptachlor | 0.01 |
| Heptachlor Epoxide | 0.01 |
| Toxaphene | 0.1 |
| PCB-1016 | 0.03 |
| PCB-1221 | 0.03 |
| PCB-1232 | 0.03 |
| PCB-1242 | 0.03 |
| PCB-1248 | 0.03 |
| PCB-1254 | 0.03 |
| PCB-1260 | 0.03 |
| Methoxychlor | 0.05 |
| HCB | 0.01 |
| Mirex | 0.10 |
| Pentachloranisole | 0.01 |
| Chlorpyrifos | 0.01 |
| Total Lipid | 0.10% |

TABLE 2

| <u>CHEMICAL</u> | <u>FDA Action Level (edible tissue, ppm)</u> |
|------------------------|---|
| Aldrin | 0.3 |
| Chlordane | 0.3 |
| DDT | 5.0 |
| DDE | 5.0 |
| DDD | 5.0 |
| Dieldrin | 0.3 |
| Endrin | 0.3 |
| Heptachlor | 0.3 |
| Heptachlor Eposide | 0.3 |
| Mirex | 0.1 |
| Toxaphene | 5.0 |
| Mercury | 1.0 |
| PCBs | 2.0 ^a |
| Dioxin | 25.0 ^b |

^aThe value for PCBs is a Tolerance Level, no an Action Level.

^bThe value for dioxin is reported in ppt and is a “Level of Concern”, not an Action Level.

TABLE 3
RELATIONSHIP OF THE PROPOSED FISH CONSUMPTION ADVISORY TO THE
CALCULATED FISH INTAKE

| Fish consumption advisory (fish meal of ¼ to ½ lb assumed) | Calculated fish intake (g of fish per day) |
|---|---|
| Do not eat | nil to 3 |
| Once a month | >3 to 10 |
| Once a week | >10 to 30 |
| Three meals a week | >30 to 100 |
| One meal a day | >100 to 300 |
| Unlimited consumption | >300 |

Appendix A

United States Department of the Interior
FISH AND WILDLIFE SERVICE
NATIONAL FISHERIES CONTAMINANT RESEARCH CENTER
ROUTE 2
COLUMBIA, MISSOURI 65201
June 7, 1991

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Dear Randy:

At our last meeting you requested that I provide a brief rationale for using composite fish samples vs individual filets. In addition to addressing this issue, I am also including some information on the influence of size on contaminant residue concentrations, and also the relationship of size (age) with lipid content.

A critical concern for any study is the objective. The objective pretty well dictates the types of methods that can be employed to be successful in the study. Collecting contaminant residue data in fish is commonly used to determine if a body of water has a contaminant problem and whether the levels are sufficiently high to pose a health risk. However, there is some debate and controversy on the proper way to do this.

One area of controversy is whether to use individual filets or composites of filets from several fish. Statistically, individual filet values are, of course, the preferred way to go. Unfortunately, this is generally not possible for economic reasons, and, occasionally, analytical backlogs (laboratory workloads) may preclude analyses of the large numbers of filets required to be of any significance. If monies and lab time are not constraints, then I would recommend individual filets for assessing contaminant problems in water bodies. on the other hand, if monies are of concern, then a viable option is to use composite fish samples. Again, the objective(s) of the study should

be clearly delineated and if composite data will provide the information needed, then proceed. In other words, if it is not necessary to have residue values on individual fish (and the variability among individual fish) then composites are the way to go.

To illustrate the information provided by composite samples, the following examples are-used:

Residue concentrations of contaminant x

| | Sample 1 | Sample 2 | Sample 3 |
|------|----------|----------|----------|
| | 2.6 | 3.6 | 6.4 |
| | 25.2 | 30.2 | 32.4 |
| | 5.4 | 4.4 | 8.1 |
| | 8.2 | 1.8 | 2.2 |
| | 3.2 | 2.2 | 1.2 |
| mean | 8.92 | 8.44 | 10.06 |
| S.D. | 8.37 | 10.92 | 11.46 |
| Var. | 70.12 | 119.25 | 131.32 |
| SEM | 3.74 | 4.88 | 5.12 |
| C.V. | 93.83 | 129.38 | 113.92 |

These data show the mean, standard error of the mean, and coefficient deviation, variance, standard of variation for each set of samples.

For the composite values, we will use the mean from each of the 3 samples above (it would be better to have filets from individual fish and also have a composite from these same fish for comparison, but I do not have these data). Actual composite values would probably be pretty close to that obtained by averaging individual samples, with the differences due mainly to different size fish filets. If fish were all the same size, the composite value would be very close to the mean of the individual filets. The same would be even more true if the same size aliquot from each filet was combined to form the composite (as suggested in our last meeting).

| mean of composites | | mean of all individuals | |
|--------------------|--------------|-------------------------|--------|
| | 8.92 | | |
| | 8.44 | | |
| | <u>10.06</u> | | |
| mean | 9.14 | mean | 9.14 |
| S.D. | 0.68 | S.D. | 10.36 |
| Var. | 0.46 | Var. | 107.35 |
| SEM | 0.39 | SEM | 2.67 |
| C.V. | 7.43 | C.V. | 113.68 |

As you can see from this example, when using composite samples, the variability shown among individual fish is lost. Variability among individuals can not be determined using composite samples. The variability among individual fish is large, but variability (S.D., Var., SEM, C.V.) among composite samples is substantially smaller (note differences of means and variabilities from the individual samples, composites, and averaging of all individuals together). The variability shown among composite samples, to me, represents the 'environmental' variability -- a variability that normalizes the extremes (highs and lows), but still provides information on sampling variability.

Composites are a practical means of providing a lot of information for a minimum amount of money. Most management people (as well as biologist and other scientists) would be very skeptical about making a decision based on one value (the risks in doing so are enormous, statistically speaking) . If decisions are to be based on 1 value, then all you need is one fish. However, I think nearly everyone would have a problem accepting a plan of action based on 1 single value. For example, I would not be comfortable with the following scenario: if 5 fish were individually analyzed and only 1 of these fish had a residue concentration that exceeded some arbitrary effect level, but the fishery is closed based on that 1 value. To make a management decision with any level of confidence regarding a contaminant problem with fish, a mean calculated from a certain number of values should be required. The problem is, how many values are enough.

It is generally agreed, that at a minimum, 3 values (which provide at least 1 degree of freedom) are needed to do any comparisons or statistical manipulations. So, assuming that 3 is the magic number we need to work with, what 3 values are we going to use? If we select the 1st value from each of the 3 samples above (2.6, 3.6, and 6.4), to illustrate a point, the mean is 4.2 (S.D. = 1.61). This mean value is substantially lower than what we know the residue concentration to be from the population (mean for composites or mean of all individuals = 9.14). In this case, (where the mean is substantially lower than the actual population mean) we would under estimate the contaminant problem. For another scenario, select the 2nd fish down from each sample above (25.2, 30.2, and 32.4). The mean for this set of samples is 29.26 (S.D. = 3.01). In this case, there is a gross over estimation of the contaminant problem. Of course, it is possible, with a little luck, to pick 3 fish at random from the 15 individual values above to give a mean pretty close to the

actual population mean. Nevertheless, you can see how shaky residue data can be with using only three individual values from a particular population.

It is possible to calculate the number of samples (values) needed to be within a certain percentage of the actual population mean. Using the information from sample 1 above, the number of samples needed to be within 20% of the actual population mean is 22 (variance [70.12]/precision (0.04)*mean 18.92]²). The number of samples needed, based on all 15 values from the samples above turns out to be 32 (variance (107.35)/precision(0.04)*mean(9.14)²). However, if composites are used, the number of composites needed to provide a mean within 20% of the actual population mean is only 1 (variance CO. 46)/precision [0.04]*mean(9.14)². The individual variability is normalized within the composite, which reduces the sample variability and allows fewer samples to be taken to assess the population (contaminant levels). In other words, the individual variability inherent in the population is compensated for within the 'super' samples (composites) used to assess the population.

What this boils down to is this. Composite samples provide a lot of information for the money. Most decisions are made on 'means' not on individual values. To obtain meaningful information (some level of confidence about the data) using individual values, a large number of samples would have to be analyzed and this would be cost prohibitive. Since 'means' are the pertinent end points and composite samples can provide these means economically, then composite samples are the best route to go. The mean from 3 composite (5 fish/composite) samples provides a lot of information for a fraction of the cost needed for individual filets (assuming that the required number of fish are included in the analyses -values from each of 3 individual fish could be very unrepresentative of actual contaminant problems). I believe that composite samples of fish provide a reasonable approach to assessing contaminant problems in aquatic habitats.

In general, there is an increase in lipid content with age (size) in fish, and there is an increase in contaminant residues with an increase in age. But these are only generalities and are not clear cut. These relationships vary with species of fish, season, and with the contaminant. To illustrate these points, I have pulled some information on DDT residues in fish from Huntsville Spring Branch, AL, where Olin Chemical Company discharged high levels of DDT in the past. These data were from one reach of stream (least contaminated) and are from fish collected during one sampling interval.

| Channel catfish | | ppm | |
|--|--------------|--------------------|-------------------|
| length (cm) | lipid (%) | DDT (wet wt) | DDT (lipid wt) |
| 27 | 10.0 | 7.6 | 67 |
| 31 | 1.2 | 2.7 | 216 |
| 32 | 1.4 | 8.6 | 614 |
| 32 | 2.2 | 28.0 | 1271 |
| 32 | 2.3 | 9.3 | 404 |
| 33 | 0.8 | 16.0 | 200 |
| 33 | 2.7 | 100.0 | 3703 |
| 35 | 0.5 | 11.0 | 2200 |
| 36 | 0.9 | 17.0 | 1888 |
| x= | 32.3 | 2.44 | 22.13 |
| S.D.= | 2.54 | 2.93 | 30.11 |
| Significant Pearson Correlation Coefficients | | | |
| Lipid vs length | | -0.8351 (P=0.0051) | |
| 44 | 4.6 | 93.0 | 2022 |
| 44 | 6.0 | 8.6 | 143 |
| 45 | 19.0 | 150.0 | 789 |
| 45 | 3.2 | 46.0 | 1437 |
| 47 | 1.5 | 45.0 | 3000 |
| 47 | 2.2 | 2.0 | -90 |
| x= | 45.3 | 6.08 | 57.43 |
| S.D.= | 1.36 | 6.55 | 55.81 |
| Significant Pearson Correlation Coefficients | | | |
| DDT vs lipid | | 0.79642 (P=0.0579) | |
| 50 | 1.9 | 18.0 | 947 |
| 51 | 13.0 | 3.5 | 26 |
| 51 | 2.2 | 160.0 | 7272 |
| 52 | 0.6 | 68.0 | 11333 |
| 52 | 5.9 | 120.0 | 2033 |
| 53 | 5.5 | 8.2 | 149 |
| x= | 51.5 | 4.85 | 62.95 |
| S.D.= | 1.04 | 4.51 | 65.19 |
| Significant Pearson Correlation Coefficients | | | |
| None | | | |

All age classes combined

| | | | | |
|--|-------|------|-------|------|
| x= | 41.52 | 4.17 | 43.88 | 1895 |
| S.D.= | 8.69 | 4.66 | 50.80 | 2682 |
| Significant Pearson Correlation Coefficients | | | | |
| None | | | | |

Largemouth bass

| | length (cm) | lipid (%) | DDT (wet wt) | DDT (lipid wt) |
|-------|----------------|--------------|-----------------|-------------------|
| | 26 | 0.2 | 9.5 | 4750 |
| | 27 | 0.5 | 20.0 | 4000 |
| | 31 | 0.2 | 4.7 | 2350 |
| | 32 | 0.9 | 10.0 | 1111 |
| | 33 | 0.8 | 9.8 | 1225 |
| | 33 | 1.2 | 3.2 | 266 |
| | 33 | 0.3 | 8.0 | 2666 |
| | 35 | 1.8 | 14.0 | 777 |
| | 35 | 0.3 | 1.6 | 533 |
| | 38 | 3.0 | 7.7 | 256 |
| x= | 32.2 | 0.92 | 8.85 | 1793 |
| S.D.= | 3.62 | 0.89 | 5.34 | 1509 |

Significant Pearson Correlation Coefficients
Length vs lipid 0.68495 (P=0.0288)

These data indicate that the relationships between age vs lipid, age vs DDT concentrations, and lipid vs DDT concentrations are not clear cut. Only the significant correlations are shown below each data set in the above examples. In aquatic systems that we have assessed using individual animals, there has always been a lot of variation within and among size classes for these variables, and it is not uncommon to have the highest concentrations in the smallest (youngest) individuals.

Another point is the use of lipid weight values (convert residues from wet weight to lipid weight). From the above data, you can see that this solves nothing. There is just as much variation in lipid weight values as the wet weight and all it does is confuse the issue. The data above also indicates that even within a year class there is considerable variation in the lipid content.

Although I did not include these data, whole body residues of DDT in fish from Huntsville Spring Branch averaged between 150 and 200 ppm compared to the 20 to 60 ppm for the filets. This broaches another controversy in contaminant evaluations - whole body vs filets. I recognize that from a 'human food source' perspective that residues in filets may be required, but I am not comfortable in assessing aquatic contaminant problems using only the filets. I think that we are

being pretty narrow in our scope when we restrict our evaluation to filets. The objective should be to determine if there is a contaminant problem in a particular body of water. The best way to do that is to measure whole body residues, and if levels exceed those known to cause environmental degradation, then advisories should be issued for that body of water. In my way of thinking, if contamination exists, it is not just a 'one species' problem, but a contaminant problem of the whole system. I think we owe it to the public to alert them to these contaminant problem areas (public awareness and public reactions are the best ways to solve the problem) . To issue an advisory for only one species from a contaminated system may actually be doing a disservice to the public. Since 'residue effect levels' of most contaminants for humans are not generally known, providing the opportunity (option) to avoid as much as possible may be a prudent (and conservative) approach and should be our objective. Given the amount of harmful materials that people are exposed to every day and the potential cumulative impact of these exposures, avoiding, where possible, any additional exposure is wise. Risk assessment and other advisory information do not include cumulative impacts from multiple contaminants. Economics (reduction in fishing license sales) and politics should not be the driving force of management decisions when human health and well being are concerned.

I hope that this information is helpful to you. If I can be of further assistance, please let me know.

Sincerely,

Parley V. Winger

Appendix B

RfD = reference dose
RSD = risk specific dose
SF = cancer slope or potency factor

RfD_m = RfD for mixtures
RSD_m = risk specific dose for mixtures

E = fish contaminant concentration

Equations 1 through 3 are for calculation of fish intake for non-cancer toxicity.

Eqn 1:

$$\text{Fish Intake (kg/day)} = \frac{\text{RfD (mg/kg-day)} \times \text{bw (70kg)}}{\text{E (mg/kg)}}$$

Eqn 2:

$$\frac{E_1}{\text{RfD}_1} + \frac{E_2}{\text{RfD}_2} + \dots + \frac{E_i}{\text{RfD}_i} = \frac{\text{Total Contaminants (TC)}}{\text{RfD}_m}$$

Eqn 3:

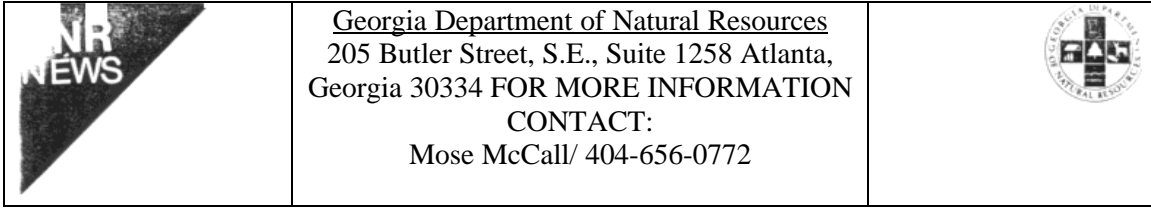
$$\therefore \text{RfD}_m = \frac{\text{TC}}{\sum \frac{E_i}{\text{RfD}_i}}$$

Eqn 4:

$$\text{RSD (mg/kg-day)} = \frac{\text{Risk (unit less)}}{\text{SF (mg/kg-day)}^{-1}}$$

For calculation of fish intake for carcinogenic effects, substitute RSD for RfD in equations 1 through 3.

Appendix C



Georgia Department of Natural Resources today released the results of a 1990 study of toxics in the Chattahoochee River south of Atlanta and West Point Lake.

Commissioner Joe D. Tanner said several species of fish were found to have concentrations of toxic chemicals exceeding the U. S. Food and Drug Administration standards

"Based on our analysis of fish tissue, we recommend that people not eat certain species of fish from the Chattahoochee River south of Atlanta," Tanner said. "Those species are largemouth bass caught in the vicinity of Georgia Highway 92 and catfish, carp and hybrid bass -1'rom the vicinity of Highway 92 through West Point Lake to the dam

These fish exceeded the Food and Drug Administration standards for chlordane. The fish were also tested for DDE, polychlorinated biphenyls (PCBs) and dieldrin, but no other FDA standards were exceeded

Tanner emphasized that the existence of these toxics in fish has no bearing on water quality in the Chattahoochee River nor in West Point Lake. They are found only in the bottom sediments of the river and lake and were not detected in any water samples taken from the river or from West Point Lake

"The cities and counties which take their drinking water from the river or the lake, from metro Atlanta to LaGrange to Columbus, all meet the state and federal safe drinking water standards," Tanner said. "Water samples were collected 16 sites on the Chattahoochee River and in West Point lake during the same period as the fish samples. No chlordane, DDE or PCBs were detected in any of the water samples."

DNR used FDA standards as the basis for evaluating levels of chlordane, PCB and DDT found in fish. Further, the Department used US EPA risk analysis techniques to calculate human lifetime cancer risks associated with the consumption of these fish. The risk analysis techniques are designed very conservatively to assure maximum protection of human health. The calculation methods are based on the consumption of these fish at one meal per month for 70 years.

In addition to the toxins discussed, the pesticide dieldrin was detectable in some fish but in levels below the FDA standard. The fish which contained dieldrin are among those DNR recommends not eating. Dieldrin, once used extensively for termite control, has been banned for a number of years.

The manufacture of PCBs and pesticides containing chlordane has been banned for several years. While the use of PCBs, chlordane and DDT have dramatically declined, they are stable, remaining for years in the environment.

The residuals of these chemicals now in the environment probably resulted from spills or legitimate uses that occurred years ago. DNR has sampled all industrial and municipal dischargers to the Chattahoochee River and found no evidence of these chemicals in wastewater discharges

In conducting the study, DNR analyzed tissue from fish taken at 10 locations between the Gwinnett County water intake on the Chattahoochee River and the West Point Lake dam pool and at one location in Lake Harding. This study follows work by DNR in 1989 which documented the presence of PCBs and chlordane in fish in the Chattahoochee River.

Samples were collected in March and in October. Laboratory analyses were completed in January 1991. Samples of edible flesh (fillets) were taken from each fish collected. Species sampled were trout, largemouth bass, hybrid bass, yellow perch, redear sunfish, catfish, carp, and spotted sucker. Samples of edible flesh from 116 fish were analyzed for 22 organic chemicals. Only the chlordane, PCBs, and DDE were found consistently in fish.

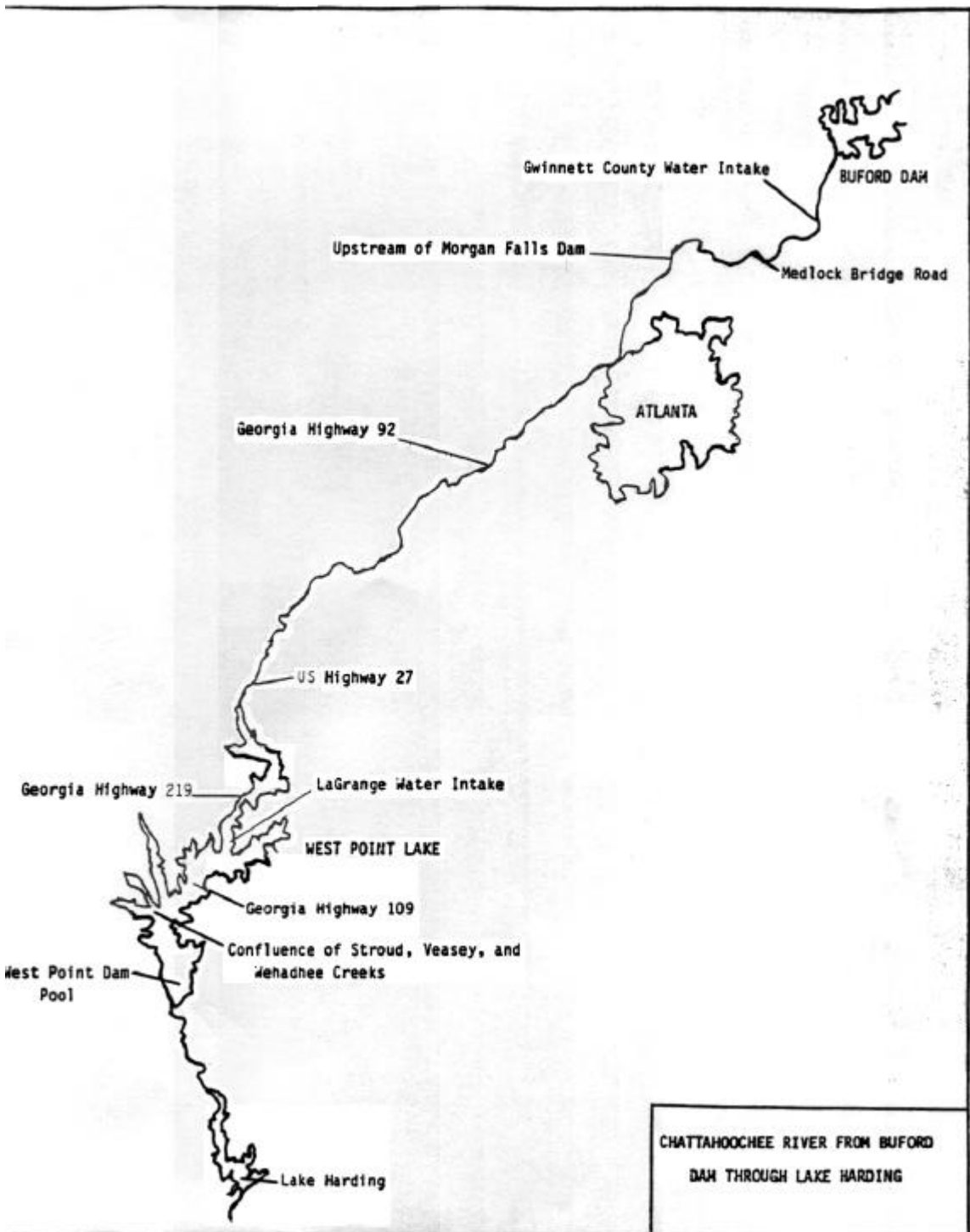
The U. S. Food and Drug Administration has established "action levels" for these chemicals in fish tissue. These are levels at which the FDA recommends steps be taken to protect human health. The action levels are 0.3 parts per million for chlordane and dieldrin, 2.0 parts per million for PCBs and 5.0 ppm for DDT (no level has been set for DDE).

Findings of low but detectable concentrations of these chemicals in fish from the entire study area support the conclusion that chlordane, DDT and PCBs are widespread pollutants as a result of previous extensive agricultural, industrial and residential use

The estimated lifetime cancer risks range from a low of 4 chances in 10,000,000 to a high of 7 chances in 10,000 for the various chemicals, types of fish and locations comparison, a 1987 EPA estimate of lifetime cancer risk from eating fish with PCB, DDE, dieldrin and chlordane found in a nationwide monitoring survey yielded a value of 3 chances in 10,000.

As another comparison, the lifetime cancer risk from smoking is about 1 chance in 10. The estimated lifetime risk of death to an individual from some other activities is as follows: automobile accident -- 1 in 4,000; drowning -- 1 in 30,000; air travel -- 1 in 100,000; lightning -- 1 in 2,000,000

DNR will continue the study of toxics in fish tissue in other sections of the Chattahoochee river and other rivers and lakes of the state.



**CONCENTRATION OF TOXICS IN FISH
AND ESTIMATED LIFETIME CANCER RISKS FOR FISH CONSUMPTION**

| SITE | SPECIES | CHLORDANE FDA Std. = 0.3 ppm | | DDE FDA Std. - 5.0 ppm | | PCB 1260 FDA Std. = 2.0 ppm | | DIELDRIN FDA Std. = 0.3 ppm | |
|--|-----------------|---|-------------------|---------------------------|-------------------|--------------------------------|-------------------|--------------------------------|-------------------|
| | | ppm ¹ | risk ² | ppm ¹ | risk ² | ppm ¹ | risk ² | ppm ¹ | risk ² |
| | | Chattahoochee River, Gwinnett Water Intake | Trout | 0.02 | 2/1,000,000 | 0.02 | 6/10,000,000 | 0.04 | 3/100,000 |
| | Carp & Sucker | 0.08 | 1/100,000 | 0.03 | 9/10,000,000 | 0.37 | 3/10,000 | 0.005 | 7/1,000,000 |
| Chattahoochee River, Medlock Bridge Road | Trout | 0.02 | 2/1,000,000 | 10.02 | 6/10,000,000 | 0.04 | 3/100,000 | 0.005 | 7/1,000,000 |
| | Largemouth Bass | 0.04 | 5/1,000,000 | 0.01 | 4/10,000,000 | 0.05 | 4/100,000 | 0.005 | 7/1,000,000 |
| | Carp & Sucker | 0.14 | 2/100,000 | 0.07 | 2/1,000,000 | 0.25 | 2/10,000 | 0.012 | 2/100,000 |
| Chattahoochee River, Upstream of Morgan Falls Dam | Largemouth Bass | 0.06 | 7/1,000,000 | 0.01 | 4/10,000,000 | 0.06 | 4/100,000 | 0.005 | 7/1,000,000 |
| | Yellow Parch | 0.10 | 8/1,000,000 | 0.02 | 6/10,000,000 | 0.07 | 4/100,000 | 0.005 | 7/1,000,000 |
| | Redear Sunfish | 0.03 | 7/1,000,000 | 0.01 | 4/10,000,000 | 0.02 | 1/100,000 | 0.005 | 7/1,000,000 |
| | Carp | 0.25 | 3/100,000 | 0.04 | 1/1,000,000 | 0.22 | 2/10,000 | 0.005 | 7/1,000,000 |
| Chattahoochee River, GA Hwy 92 | Largemouth Bass | 0.46* | 6/100,000 | 0.08 | 3/1,000,000 | 0.48 | 3/10,000 | 0.020 | 3/100,000 |
| | Carp | 0.28 | 3/100,000 | 0.36 | 1/100,000 | 0.35 | 3/10,000 | 0.007 | 1/100,000 |
| | Catfish | 0.10 | 1/100,000 | 0.01 | 4/10,000,000 | 0.14 | 1/10,000 | 0.007 | 1/100,000 |
| Chattahoochee River, US Hwy 27 | Largemouth Bass | 0.06 | 7/1,000,000 | 0.01 | 3/10,000,000 | 0.03 | 2/100,000 | 0.005 | 7/1,000,000 |
| | Carp | 0.21 | 3/100,000 | 0.09 | 3/1,000,000 | 0.67 | 5/10,000 | 0.005 | 7/1,000,000 |
| | Catfish | 0.40* | 5/100,000 | 0.06 | 2/1,000,000 | 0.36 | 3/10,000 | 0.010 | 1/100,000 |
| West Point Lake GA Hwy 219 | Largemouth Bass | 0.08 | 1/100,000 | 0.02 | 6/10,000,000 | 0.10 | 7/100,000 10 | .005 | 7/1,000,000 |
| | Hybrid Bass | 0.40* | 5/100,000 | 0.06 | 2/1,000,000 | 0.03 | 2/100,000 | 0.005 | 7/1,000,000 |
| | Carp | 0.15 | 2/100,000 | 0.04 | 1/1,000,000 | 0.31 | 2/10,000 | 0.005 | 7/1,000,000 |
| | Catfish | 0.39* | 5/100,000 | 0.07 | 2/1,000,000 | 0.29 | 2/10,000 | 0.012 | 2/100,000 |
| West Point Lake LaGrange Water Intake | Largemouth Bass | 0.14 | 2/100,000 | 0.02 | 6/10,000,000 | 0.12 | 8/100,000 | 0.005 | 7/1,000,000 |
| | Carp | 0.06 | 7/1,000,000 | 0.07 | 2/1,000,000 | 0.13 | 9/100,000 | 0.005 | 7/1,000,000 |
| | Catfish | 0.51* | 6/100,000 | 0.07 | 2/1,000,000 | 0.44 | 3/10,000 | 0.005 | 7/1,000,000 |
| West Point Lake GA Hwy 109 | Largemouth Bass | 0.06 | 7/1,000,000 | 0.02 | 6/10,000,00 | 0.08 | 6/100,000 | 0.005 | 7/1,000,000 |
| | Carp | 0.11 | 1/100,000 | 0.30 | 9/1,000,000 | 0.32 | 2/10,000 | 0.005 | 7/1,000,000 |
| | Catfish | 0.30* | 4/100,000 | 0.06 | 2/1,000,000 | 0.24 | 2/10,000 | 0.005 | 7/1,000,000 |
| West Point Lake Wehadkee Creek | Largemouth Bass | 0.04 | 5/1,000,000 | 0.02 | 6/10,000,000 | 0.05 | 4/100,000 | 0.005 | 7/1,000,000 |
| | Carp | 0.31* | 4/100,000 | 0.18 | 6/1,000,000 | 0.46 | 3/10,000 | 0.009 | 1/100,000 |
| | Catfish | 0.07 | 8/1,000,000 | 0.02 | 6/10,000,000 | 0.04 | 3/100,000 | 0.005 | 17/1,000,000 |
| West Point Lake near the Dam | Largemouth Bass | 0.02 | 2/1,000,000 | 0.01 | 3/10,000,000 | 0.02 | 1/100,000 | 0.005 | 7/1,000,000 |
| | Hybrid Bass | 0.07 | 8/1,000,000 | 0.04 | 1/1,000,000 | 0.05 | 4/100,000 | 0.005 | 7/1,000,000 |
| | Carp | 0.09 | 1/100,000 | 0.03 | 9/10,000,000 | 0.08 | 6/100,000 | 0.005 | 7/1,000,000 |
| | Catfish | 0.32* | 4/100,000 | 0.09 | 2/1,000,000 | 0.34 | 2/10,000 | 0.012 | 2/100,000 |
| Lake Harding | Largemouth Bass | 0.05 | 6/1,000,000 | 0.02 | 6/10,000,000 | 0.14 | 1/10,000 | 0.005 | 7/1,000,000 |
| | Catfish | 0.26 | 3/100,000 | 0.12 | 4/1,000,000 | 1.00 | 7/10,000 | 0.005 | 7/1,000,000 |

¹Average values. For samples below the detection limit a value of one-half the detection limit was used.

²An estimated risk of 2/1,000,000 means that if a person consumes one meal of fish per month for 70 years, that person will have 2 chances in 1,000,000 of getting cancer in their lifetime.

*Indicates value exceeds the FDA standard.

U.S. EPA's goal for acceptable lifetime cancer risk is 1 chance in 1,000,000.

A 1987 study by U.S. EPA of more than 1,000 fish samples nationwide showed estimated lifetime cancer risks of 3 chances in 10,000 from the combined effects of Chlordane, DDE, PCB 1260, and Dieldrin.

SITE ABBREVIATIONS

| | |
|--------------|--|
| GWI | Chattahoochee River at Gwinnett Water Intake |
| MBR | Chattahoochee River at Medford Bridge Road |
| MFD | Chattahoochee River upstream of Morgan Falls Dam |
| Hwy 92 | Chattahoochee River at GA Highway 92 |
| Hwy 27 | Chattahoochee River at U.S. Highway 27 |
| WPL Hwy 219 | Chattahoochee River at GA Highway 219, upper portion of West Point Lake |
| WPL LWI | Chattahoochee River at the LaGrange Water Intake in West Point Lake |
| WPL Hwy 109 | Chattahoochee River at GA Highway 109, West Point Lake |
| WPL Weh.Ck | Chattahoochee River at the confluence of Wehadkee Creek in West Point Lake |
| WPL Dam | Chattahoochee River at the West Point Lake Dam Pool |
| Lake Harding | Chattahoochee River at Lake Harding |

CHATTAHOOCHEE RIVER DATA, 1990

| Site | Species | CHLORINE Conc. mg/kg | DDD Conc. mg/kg | DDE Conc. mg/kg | DIELDRIN Conc. mg/kg | tPCB Conc. mg/kg |
|-----------------|------------------|-------------------------|-----------------------|-----------------------|----------------------------|------------------------|
| GWI | Trout | 0.000 | 0 * 000 | 0.017 | 0.000 | 0.056 |
| | Carp | 0.000 | 0.000 | 0.336 | 0.000 | 0.560 |
| | Sucker | 0.088 | 0.000 | 0.023 | 0.000 | 0.180 |
| MBR | Br-Trout | 0.011 | 0.005 | 0.018 | 0.000 | 0.054 |
| | RB-Trout | 0.015 | 0.000 | 0.014 | 0.000 | 0.106 |
| | LMB | 0.023 | 0.000 | 0.010 | 0.000 | 0.047 |
| | Carp & sucker | 0.135 | 0.000 | 0.087 | 0.058 | 0.459 |
| MFD | LMB | 0.056 | 0.000 | 0.007 | 0.000 | 0.063 |
| | YP | 0.089 | 0.000 | 0.013 | 0.000 | 0.062 |
| | RS | 0.017 | 0.000 | 0.000 | 0.000 | 0.010 |
| | Carp | 0.251 | 0.000 | 0.037 | 0.000 | 0.221 |
| HWY 92 | LMB | 0.460 | 0.000 | 0.080 | 0.020 | 0.477 |
| | Carp | 0.281 | 0.077 | 0.358 | 0.007 | 0.349 |
| | Catfish | 0.098 | 0.000 | 0.007 | 0.003 | 0.136 |
| HWY 27 | LMB | 0.044 | 0.000 | 0.007 | 0.000 | 0.017 |
| | Carp | 0.213 | 0.000 | 0.090 | 0.000 | 0.667 |
| | Catfish | 0.402 | 0.000 | 0.058 | 0.008 | 0.363 |
| WPL Hwy 219 | LMB | 0.078 | 0.000 | 0.014 | 0.000 | 0.094 |
| | HB | 0.400 | 0.000 | 0.060 | 0.000 | 0.293 |
| | Carp | 0.153 | 0.000 | 0.043 | 0.000 | 0.305 |
| | Catfish | 0.391 | 0.000 | 0.066 | 0.010 | 0.326 |
| WPL LWI | LMB | 0.133 | 0.000 | 0.019 | 0.000 | 0.117 |
| | Carp | 0.047 | 0.000 | 0.068 | 0.000 | 0.129 |
| | Catfish | 0.507 | 0.000 | 0.007 | 0.007 | 0.426 |
| WPL Hwy 109 | LMB | 0.057 | 0.000 | 0.019 | 0.000 | 0.078 |
| | Carp | 0.109 | 0.000 | 0.296 | 0.000 | 0.321 |
| | Catfish | 0.298 | 0.000 | 0.061 | 0.000 | 0.242 |
| WPL Weh. Ck | LMB | 0.043 | 0.000 | 0.019 | 0.000 | 0.047 |
| | Carp | 0.304 | 0.000 | 0.179 | 0.005 | 0.463 |
| | Catfish | 0.061 | 0.000 | 0.013 | 0.000 | 0.053 |
| WPL Dam | LMB | 0.000 | 0.000 | 0.007 | 0.000 | 0.013 |
| | HB | 0.071 | 0.000 | 0.010 | 0.003 | 0.048 |
| | Carp | 0.091 | 0.000 | 0.026 | 0.000 | 0.101 |
| Lake Harding | Catfish | 0.317 | 0.000 | 0.010 | 0.010 | 0.339 |
| | LMB | 0.040 | 0.000 | 0.020 | 0.000 | 0.140 |
| | Catfish | 0.247 | 0.000 | 0.117 | 0.000 | 1.000 |

CANCER POTENCY FACTORS and NONCANCER TOXICITY FACTORS from IRIS2

| Chemical | Potency Factor¹ (mg/kg-day)⁻¹ | Oral Reference Dose² (mg/kg-day) |
|-----------------|--|--|
| Chlordane | 1.3 | 6.0 x 10 ⁻⁵ |
| DDD | 0.24 | 5.0 x 10 ^{-4*} |
| DDE | 0.34 | 5.0 x 10 ^{-4*} |
| DDT | 0.34 | 5.0 x 10 ⁻⁴ |
| Dieldrin | 16.0 | 5.0 x 10 ⁻⁵ |
| PCBs (total) | 7.7 | 1.0 x 10 ^{-4*} |

¹Target organ for carcinogenicity of these chemicals is the liver.

²Critical effect for all of these chemicals is either liver toxicity or necrosis.

*Values are not online in IRIS2, but were estimated in existing EPA documents.

CARCINOGEN ASSESSMENT, 70 YEARS EXPOSURE

| SITE | Species | Intake g/day | Est. Excess Risk | Advisory Info meals | fish intake g/day | advisory info. 1/4-1/2 lb. meals |
|-------------------|----------------|-------------------------|-----------------------------|--------------------------------|------------------------------|---|
| GWI | Trout | 16.03183 | 4E-05 | LC,1/wk | 0-3 | DE |
| | Carp | 1.582437 | 4E-04 | DE | > 3-10 | LC,1/mo |
| | Sucker | 4.640876 | 1E-04 | LC,1/mo | > 10-30 > 30-100 | LC,1/wk LC,3/wk |
| MBR | Br-Trout | 16.00894 | 4E-05 | LC,1/wk | > 100 | UL |
| | RB-Trout | 8.333838 | 8E-05 | LC,1/mo | | |
| | LMB | 17.71031 | 4E-05 | LC,1/wk | | |
| | Carp & sucker | 1.502456 | 4E-04 | DE | DE= LC= | Don't Eat Limit Consumption |
| MFD | LMB | 12.48409 | 5E-05 | LC,1/wk | UL= | Unlimited Consumption |
| | YP | 11.69568 | 6E-05 | LC,1/wk | | |
| | RS | 70.49949 | 9E-06 | LC,3/wk | | |
| | Carp | 3.426297 | 2E-04 | LC,1/mo | | |
| HWY 92 | LMB | 1.515302 | 4E-04 | DE | | |
| | Carp | 2.116565 | 3E-04 | DE | | |
| | Catfish | 5.713660 | 1E-04 | LC,1/mo | | |
| HWY 27 | LMB | 36.63429 | 2E-05 | LC,3/wk | | |
| | Carp | 1.286275 | 5E-04 | DE | | |
| | Catfish | 2.018315 | 3E-04 | DE | | |
| WPL Hwy 219 | LMB | 8.428291 | 8E-05 | LC,1/mo | | |
| | HB | 2.499239 | 3E-04 | DE | | |
| | Carp | 2.731923 | 2E-04 | DE | | |
| | Catfish | 2.185004 | 3E-04 | DE | | |
| WPL LWI | LMB | 6.472182 | 1E-04 | LC,1/mo | | |
| | Carp | 6.495928 | 1E-04 | LC,1/mo | | |
| | Catfish | 1.725177 | 4E-04 | DE | | |
| WPL Hwy 109 | LMB | 10.27068 | 6E-05 | LC,1/wk | | |
| | Carp | 2.578534 | 3E-04 | DE | | |
| | Catfish | 3.077358 | 2E-04 | LC,1/mo | | |
| WPL Weh. Ck | LMB | 16.48342 | 4E-05 | LC,1/wk | | |
| | Carp | 1.706223 | 4E-04 | DE | | |
| | Catfish | 14.21498 | 5E-05 | LC,1/wk | | |
| WPL Dam | LMB | 68.35016 | 1E-05 | LC,3/wk | | |
| | HB | 13.62612 | 5E-05 | LC,1/wk | | |
| | Carp | 7.729464 | 8E-05 | LC,1/mo | | |
| | Catfish | 2.196439 | 3E-04 | DE | | |
| Lake Harding | LMB | 6.159525 | 1E-04 | LC,1/mo | | |
| | Catfish | 0.868739 | 7E-04 | DE | | |

CARCINOGEN ASSESSMENT, 30 YEARS EXPOSURE

| SITE | Species | Intake g/day | Est. Excess Risk | Advisory Info meals | fish intake g/day | advisory info. 1/4-1/2 lb. meals |
|-------------------|----------------|-------------------------|-----------------------------|--------------------------------|------------------------------|---|
| GWI | Trout | 37.00440 | 2E-05 | LC,3/wk | 0-3 | DE |
| | Carp | 3.653295 | 2E-04 | LC,1/mo | > 3-10 | LC,1/mo |
| | Sucker | 10.73173 | 6E-05 | LC,1/wk | > 10-30 > 30-100 | LC,1/wk LC,3/wk |
| MBR | Br-Trout | 36.98452 | 2E-05 | LC,1/wk | > 100 | UL |
| | RB-Trout | 19.24528 | 3E-05 | LC,./wk | | |
| | LMB | 40.95602 | 2E-05 | LC,1/wk | | |
| | Carp & sucker | 3.492211 | 2E-04 | LC,./mo | DE= LC= | Don't Eat Limit Consumption |
| MFD | LMB | 28.90883 | 2E-05 | LC,1/wk | UL= | Unlimited Consumption |
| | YP | 27.12937 | 2E-05 | LC,1/wk | | |
| | RS | 163.6363 | 4E-06 | UL | | |
| | Carp | 7.940538 | 8E-05 | LC,1/mo | | |
| HWY 92 | LMB | 3.516433 | 2E-04 | LC,1/mo | | |
| | Carp | 4.906718 | 1E-04 | LC,1/mo | | |
| | Catfish | 13.23733 | 5E-05 | LC,1/wk | | |
| HWY 27 | LMB | 85.21981 | 8E-06 | LC,3/wk | | |
| | Carp | 2.972522 | 2E-04 | DE | | |
| | Catfish | 4.681660 | 1E-04 | LC,1/mo | | |
| WPL Hwy 219 | LMB | 19.51352 | 3E-05 | LC,1/wk | | |
| | HB | 5.796081 | 1E-04 | LC,1/mo | | |
| | Carp | 6.317745 | 1E-04 | LC,1/mo | | |
| | Catfish | 5.071502 | 1E-04 | LC,1/mo | | |
| WPL LWI | LMB | 14.99947 | 4E-05 | LC,1/wk | | |
| | Carp | 15.01787 | 4E-05 | LC,1/wk | | |
| | Catfish | 4.001457 | 2E-04 | LC,1/mo | | |
| WPL Hwy 109 | LMB | 23.77226 | 3E-05 | LC,1/wk | | |
| | Carp | 5.962089 | 1E-04 | LC,1/mo | | |
| | Catfish | 7.134173 | 9E-05 | LC,1/mo | | |
| WPL Weh. Ck | LMB | 38.17841 | 2E-05 | LC,3/wk | | |
| | Carp | 3.950608 | 2E-04 | LC,1/mo | | |
| | Catfish | 32.94624 | 2E-05 | LC,3/wk | | |
| WPL Dam | LMB | 157.7900 | 4E-06 | UL | | |
| | HB | 31.68639 | 2E-05 | LC,3/wk | | |
| | Carp | 17.90071 | 4E-05 | LC,1/wk | | |
| | Catfish | 5.093693 | 1E-04 | LC,1/mo, | | |
| Lake Harding | LMB | 14.23255 | 5E-05 | LC,1/wk | | |
| | Catfish | 2.007018 | DE | | | |

TOXIC ASSESSMENT

| SITE | Species | Intake g/day | Advisory Info meals | fish intake g/day | advisory info. 1/4-1/2 lb. meals |
|-------------------|----------------|-------------------------|--------------------------------|------------------------------|---|
| GWI | Trout | 117.8451 | UL | 0-3 | DE |
| | Carp | 11.16071 | LC,1/wk | > 3-10 | LC,1/mo |
| | Sucker | 21.13101 | LC,1/wk | > 10-30 | LC,1/wk |
| MBR | Br-Trout | 90.98786 | LC,3/wk | > 30-100 | LC,3/wk |
| | RB-Trout | 52-31689 | LC,3/wk | > 100 | UL |
| | LMB | 80.15267 | LC,3/wk | | |
| | Carp & sucker | 8.563738 | LC,1/mo | DE= LC= | Don't Eat Limit Consumption |
| MFD | LMB | 44.37869 | LC,3/wk | UL= | Unlimited Consumption |
| | YP | 32.87413 | LC,3/wk | | |
| | RS | 182.6086 | UL | | |
| | Carp | 10.82362 | LC,1/wk | | |
| HWY 92 | LMB | 5.385996 | LC,1/mo, | | |
| | Carp | 7.622504 | LC,1/mo | | |
| | Catfish | 22.82112 | LC,1/wk | | |
| HWY 27 | LMB | 76.30813 | LC,3/wk | | |
| | Carp | 6.730769 | LC,1/mo | | |
| | Catfish | 6.600037 | LC,1/mo | | |
| WPL Hwy 219 | LMB | 30.86419 | LC,3/wk | | |
| | HB | 7.204116 | LC,1/mo | | |
| | Carp | 12.31093 | LC,1/wk | | |
| | Catfish | 6.924751 | LC,1/mo | | |
| WPL LWI | LMB | 20.43994 | LC,1/wk | | |
| | Carp | 31.68376 | LC,3/wk | | |
| | Catfish | 5.441542 | LC,1/mo | | |
| WPL Hwy 109 | LMB | 39.59276 | LC,3/wk | | |
| | Carp | 12.45847 | LC,1/wk | | |
| | Catfish | 9.322560 | LC,1/mo | | |
| WPL Weh. Ck | LMB | 57.15841 | LC,3/wk | | |
| | Carp | 6.893382 | LC,1/mo | | |
| | Catfish | 44.51038 | LC,3/wk | | |
| WPL Dam | LMB | 486.1111 | UL | | |
| | HB | 40.15296 | LC,3/wk | | |
| | Carp | 27.14581 | LC,1/wk | | |
| | Catfish | 7.871064 | LC,1/mo | | |
| Lake Harding | LMB | 33.22784 | LC,3/wk | | |
| | Catfish | 4.877822 | LC,1/mo | | |

Current Advisory (based on FDA action levels)

| | | |
|---|-------------|------------|
| Gwinnett Water Intake to Morgan Falls Dam | None | |
| Georgia Highway 92 to U.S. Highway 27 | LMB | do not eat |
| | Catfish | do not eat |
| | Carp | do not eat |
| | Hybrid Bass | do not eat |
| West Point Lake | Catfish | do not eat |
| | Carp | do not eat |
| | Hybrid Bass | do not eat |
| Lake Harding | None | |

Proposed Advisory (70 year exposure period)

| | | |
|---|---------------|----------------------------------|
| Gwinnett Water Intake to Morgan Falls Dam | Brook Trout | limit consumption - 1 meal/week |
| | Rainbow Trout | limit consumption 1 meal/month |
| | LM13 | limit consumption - 1 meal/week |
| | Carp & Sucker | do not eat |
| Georgia Highway 92 to U.S. Highway 27 | LMB | do not eat |
| | Catfish | do not eat |
| | Carp | do not eat |
| West Point Lake | Catfish | do not eat |
| | Carp | do not eat |
| | Hybrid Bass | do not eat |
| | LMB | limit consumption - 1 meal/month |
| Lake Harding | Catfish | do not eat |
| | LMB | limit consumption – 1 meal/month |

Proposed Advisory (30 year exposure period)

| | | |
|---|---------------|----------------------------------|
| Gwinnett Water Intake to Morgan Falls Dam | Brook Trout | limit consumption - 3 meals/week |
| | Rainbow Trout | limit consumption - 1 meal/week |
| | LM13 | limit consumption - 1 meal/week |
| | Carp & Sucker | limit consumption - 1 meal/month |
| Georgia Highway 92 to U.S. Highway 27 | LMB | limit consumption - 1 meal/month |
| | Catfish | limit consumption - 1 meal/month |
| | Carp | do not eat |
| West Point Lake | Catfish | limit consumption - 1 meal/month |
| | Carp | limit consumption - 1 meal/month |
| | Hybrid Bass | limit consumption - 1 meal/month |
| | LMB | limit consumption - 1 meal/week |
| Lake Harding | Catfish | do not eat |
| | LMB | limit consumption - I meal/week |