Characterization of Potential Health Effects Associated with Consumption of Fish from

Ellison Creek Reservoir

Morris County, TX

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INTRODUCTION

Ellison Creek (also known as Bruton's Creek) Reservoir is a 1,516-acre impoundment of Ellison Creek also known as Lone Star Lake. The reservoir is located west of the town of Lone Star in southern Morris County, one of the smallest counties in Texas [1]. The Ellison Creek watershed spans thirty-seven square miles. Ellison Creek Reservoir (ECR) has a maximum depth of 40 feet with moderate water clarity. Water levels fluctuate 2-3 feet annually. Aquatic vegetation is sparse, with less than 3% of the total surface area covered by aquatic macrophytes [1]. Predominant fish species include largemouth bass, hybrid striped bass, spotted bass, channel catfish, white bass, crappie, redbreast sunfish, and bluegill and readear sunfish. Texas Parks and Wildlife Department (TPWD) statewide harvest regulations govern management of fish species taken from Ellison Creek Reservoir. The reservoir has two public boat ramps and one privately operated ramp.

One small city near Ellison Creek Reservoir is Mount Pleasant, TX, a town with a population of about 14,000 according to U.S. Census data [2]. The median annual household income of Mount Pleasant is approximately $29,000, significantly below that of the median household income of Texas as a whole ($39,927 in 1999 dollars) [3]. The nearest town to Ellison Creek Reservoir is Lone Star, Texas, which actually sits on the shore of ECR. In 2000, the population of Lone Star was 1,631 [4]. Lone Star, Texas is 69.1% white, 24.9% black or African-American, and 5.6% Hispanic or Latino of any race. The median household income of Lone Star in 2000 was $23,922 (in 1999 dollars) while that for the U.S. was $41,994 [4]. Twenty-one percent of families in Lone Star, Texas, lived in poverty in 2000, in contrast to 9.2% of all U.S. families. The unemployment rate of Lone Star, at 9%, is significantly higher than that of the state of Texas (5%). In Morris County, where Ellison Creek Reservoir is situated, 24% of children under 18 years of age live in poverty, a rate almost twice that of the general population of the United States (13%). The median income for Morris County is around $30,000 per year. In contrast, the 2002 median income for Travis County – where approximately14% of children under age 18 live in poverty – was $48,506 [5]. In further support of DSHS' information that many people live within driving distance of ECR, one might also look at Longview, Gregg County, TX, a small city less than 35 miles distant and within easy commuting distance of Ellison Creek Reservoir. The 2000 population of Longview, TX was 73,344 [6]. By 2005, Longview's population had risen to 76,897, an increase of almost 5%. Gregg County had a 2000 population of 111,379; by 2005, the population of Gregg County was 112,357 [7]. Longview is much larger than Lone Star, TX or Mount Pleasant, TX. Despite this fact, the median household income of Longview residents, at $33,858, is also lower than that of the state of Texas and of the United States as a whole. In the year 2000, the percentage of children under the age of 18 years living below the poverty level in Longview, TX was 23.2% [8], similar to that of Lone Star, TX and, again, almost twice that of the U.S. as a whole. Consequently, it is not unreasonable to conclude that many people living in Longview and Gregg County, along with those from other nearby towns, cities, and counties, have relatively easy access to ECR and that these people may belong to groups at greater risk of health effects because, for instance, they may eat more locally-caught fish due to lower incomes. Although an area's poverty rate may not be directly associated with subsistence fishing, the EPA assumes that 10% of licensed fishers in any area are subsistence fishers [9], not respective of the water body or income. Thus, subsistence fishing is likely to occur in Ellison Creek Reservoir. Subsistence fishers may come from anywhere in the county or from nearby counties. To facilitate access to the reservoir, Ellison

Creek Reservoir has three boat ramps, the approach to one public ramp being through the city park of Lone Star. Homes exist near the reservoir and overnight camping facilities exist. Recreational fishing is encouraged and subsistence fishing, while not documented, probably occurs at a rate similar to that estimated by the USEPA [9].

In 1943, during the early years of World War II, the United States Defense Plant Corporation (USDC) constructed a blast furnace in Morris County. Around the same time, the USDC also built the dam that formed Ellison Creek Reservoir. In 1947, Lone Star Steel (LSS) leased the plant from the federal government, buying it outright in July 1948 [10]. In the early 1950's, Lone Star Steel completed construction of a steel mill that, for over 45 years, has manufactured steel or steel products, including oil-field casings and customized precision tubing [11], providing employment for many who make their homes in the area [11]. Lone Star Steel occupies over 600 acres in and around Lone Star, Texas. The plant abuts Hwy 259 and lies between U.S. Interstate 20 and Interstate 30 [12]. In the past, the plant was said to have utilized water from ECR to wash iron-containing ore and for other production-related tasks [1]. However, company representatives recently indicated to DSHS that the mill has not "washed ore" since 1986 [13] The American Electric Power Company (AEP) operates a power plant on Ellison Creek Reservoir [1].

Polychlorinated biphenyls (PCBs), observed in fish from Ellison Creek Reservoir on this and other occasions, are mixtures of up to 209 individual chlorinated compounds (congeners). Although a few PCB congeners are vapors at room temperatures, most are colorless to light yellow oily, liquids or waxy solids with no odor or taste. Produced commercially in the United States between 1929 and 1977 – almost exclusively by Monsanto [14] under the trade name "Aroclor"® (worldwide, German, Japanese, and other international companies also produced PCBs) – PCBs do not easily burn and can withstand high-pressures. Thus, PCBs are good insulators and flame retardants that were commonly used in tar paper, adhesives, asphalt roofing materials, carbonless copy paper, in compressor oils, as dielectric fluids, lubricants, heat transfer fluids, in fluorescent light ballasts, paints, and pesticides. Space heaters, transformers, capacitors, submersible well pumps, welding equipment, X-ray machines, household appliances (refrigerators, microwave ovens), and other electrical and electro-mechanical equipment contained PCBs [15]. A little-known direct source of environmental contamination was the extensive use of waste (used) PCB oils to control dust on roadways [16,17]. The U.S. government prohibited production of PCBs in the U.S. in 1977 because the compounds accumulate in the environment and may be harmful to the health of humans and other animals. However, at the time the USEPA banned use of PCBs, the agency allowed "totally enclosed" uses (contained, and therefore unlikely to expose the environment) to continue for the life of the equipment [17]. The EPA allowed continued use and servicing of most existing large electrical equipment containing PCBs (representing nearly 578 million pounds of the 750 million pounds of PCBs now in use) under controlled conditions because immediate replacement of all such equipment allegedly would have been prohibitively expensive [17]. Thus, it is clear that long-lasting products manufactured before 1977 may still be in use, may be currently stored away, or could have been disposed of in standard or hazardous waste facilities. Products no longer manufactured but stored or disposed of include ballasts for fluorescent lighting, microscope oils, "carbonless" carbon paper, and used hydraulic oils (hydraulic oils are used in compressors, brake fluids, elevators, and many other machines). PCB-containing oils removed from compressors require proper disposal [18]. The Toxic Substances Control Act (TSCA) provides a tight regulatory structure for storage and disposal of PCBs. Strict regulations apply to continued use of PCBs in equipment that is not isolated. The regulations apply to compressors containing PCBs, machines that require annual testing and, eventually, replacement of PCB-containing fluids with non-PCB fluids [18]. Change-out of PCB compressor oils could lead to improper storage or disposal methods and practices, especially before the advent of TSCA. Inappropriate storage or disposal of PCBs may contaminate soils, surface and ground waters, sediments, aquatic biota and, ultimately, humans.

Moreover, used PCB mixtures may well contain polychlorinated dibenzofurans (furans or PCDFs) and, perhaps, dibenzo-*p*-dioxins (dioxins or PCDDs), by-products of combustion or impurities produced during manufacture of other products. PCDD/PCDFs enter the environment during waste incineration, chemical manufacturing, petroleum refining, wood burning, metallurgical processing, fuel combustion, and electric power generation. Forest fires and volcanic activity produce small quantities of dioxins and furans [19]. Disposal of dioxins and furans in waste PCBs from industrial products would then contribute to the environmental burden of PCDFs and PCDDs.

Even in the absence of detectable PCBs in water or sediment, fish can contain measurable PCBs because many aquatic organisms take up PCBs (and other organic molecules) from sediments and/or water that contain substances at undetectable levels (due primarily to method or instrument limitations), a process known as bioconcentration. Those PCBs with higher chlorine content are more easily bioconcentrated than PCBs containing fewer chlorine atoms, which congeners undergo environmental degradation or rapid biotic metabolism and excretion [20]. Researchers studying bioconcentration potentials of various PCB congeners by fish found the log bioconcentration factor (BCF) to range from 4.4 for 2-chlorobiphenyl (2 chlorine atoms) to 6.2 for 2,2',4,4',5,5'-hexachlorobiphenyl (six chlorine atoms) [21]. If metabolism or excretion of the PCBs occurs more slowly than bioconcentration from water or sediment, PCBs build up in the organism –a process known by the term “bioaccumulation.” When high trophic-level fish eat PCB-contaminated fish from lower trophic levels, the PCBs undergo biomagnification, a process that results in even higher concentrations of PCBs in fish at the top of the food chain than concentrations in fish occupying lower trophic levels [21]. Scientists have found that PCBs containing commercial mixtures of PCBs undergo significant changes in constituent PCB congeners during their residence in the environment. Environmental persistence is correlated to the degree of chlorination. The more highly chlorinated congeners are more persistent than are less chlorinated compounds. Biodegradation is more frequent for the less substituted PCBs because these congeners are more susceptible to reductive dechlorination and metabolism, particularly by anaerobic bacteria in aquatic sediments. Ground and surface waters may be contaminated by direct release, atmospheric fall out, or leaching from land-based sources. PCBs in water may adsorb to sediment with more highly chlorinated forms preferentially adsorbing because these congeners are less water soluble than are less chlorinated PCBs. Congeners with more chlorines and fewer “ortho” substituents are more readily bioaccumulated than are other PCB congeners. These characteristic patterns of elimination result in retention of more toxic congeners of PCBs in the environment and in animal tissues, including those of humans.

PCBs are toxic chemicals that accumulate in the liver and fatty tissues of the body. The most toxic congeners are highly chlorinated – having four or more substitutions – but are not substituted in the ‘ortho’ positions (the 2, 2’, 6, or 6’ positions). These congeners have dioxin-like properties, but are less prominent constituents of the Aroclors than are other congeners.

Exposure to high levels of PCBs can cause human health effects. Most information on the human health effects of PCBs comes from studies of people exposed through accidental releases of large quantities of PCBs or from occupational exposure. The adverse human health effects of exposure to high concentrations of PCBs include a severe form of acne (chloracne), swelling of the upper eyelids, subcutaneous edema, keratin cysts in hair follicles, hyperplasia of hair follicle epithelium, hepatic hypertrophy, decreased red blood cell numbers, decreased hemoglobin, leucocytosis, and serum hyperlipidemia, skin and nail discoloration, weakness, muscle spasms, nervous system dysfunction, and chronic bronchitis [22,23]. PCB toxicity in humans was first documented in a 1968 Japanese poisoning incident in which those who consumed rice oil contaminated with an industrial oil, Kanechlor-400, that contained a mixture of PCBs, PCDFs, and polychlorinated quinones (PCQs). Those exposed consumed an average of 2 grams. The most notable signs/symptoms of the disease that came to be known as Yusho (rice oil) disease included skin and nail pigmentation, follicular accentuation, acne (chloracne), eye discharges, increased sweating of palms and reported weakness. Skin eruptions, numbness of the extremities, and liver and immune system dysfunction also occurred. The more oil the person consumed, the more severe the health effects (a dose-effect relationship) [24]. People exposed accidentally or in their workplace usually get higher doses than typical environmental exposures. Some studies of long-term, low-level exposures to PCBs in the ambient environment have suggested subtle reproductive (male infertility) [25] and developmental effects such as learning deficits and changes in activity levels [26] and visual recognition memory in offspring of women exposed to PCBs in contaminated fish) [27]. These issues are complex because the chemical make-up of PCB mixtures varies from one exposure scenario to the next; doses vary, and people exposed to PCBs are likely concurrently exposed to other contaminants.

The International Agency for Research on Cancer (IARC) concludes that some evidence links long-term, *high-level* PCB exposure in occupational settings to an increased incidence of cancers of the liver and kidney, classifying PCBs as “probably carcinogenic to humans” (Group 2A) [28]. The USEPA classifies PCBs as Group B2 carcinogens (probable human carcinogens) based on sufficient evidence in animals of carcinogenicity and insufficient evidence in humans of carcinogenicity [29] For the most part, however, scientists’ current understanding of PCB toxicity suggests that low-level exposures to PCBs are unlikely to cause adverse health effects. However, people who eat large quantities of certain fish, wild game, and marine mammals are at increased risk of higher exposures and the resultant possibility of toxic effects. People at greater risk of higher-level exposure to PCBs and associated adverse health outcomes include certain native and immigrant populations, anglers, and hunters and their families [30].

The Texas Commission on Environmental Quality (TCEQ) surveyed water and sediments from Ellison Creek Reservoir for chemical contaminants between March 1, 1998 and February 28, 2003. The TCEQ utilized these data to list segments of Ellison Creek in the draft 2004 Texas Water Quality Inventory and 303(d) list. In listing Ellison Creek Reservoir segments, the TCEQ expressed “concern for toxicity in sediment to aquatic organisms in the southeast part of the reservoir near the Lone Star facility due to … elevated levels of metal contaminants in sediment” [31].

In December 2003, the DSHS examined analytical data on nine fish fillets and five whole fish samples collected between June 2002 and July 2003 by TCEQ regional personnel. Laboratory analysis of these samples revealed several to contain lead and/or PCBs. Four of nine *fillets* contained PCBs at concentrations ranging from 0.15 to 0.32 mg/kg (mean concentration across all nine samples: 0.09 mg/kg; practical quantitation limit - PQL- 0.005 mg/kg). Three *whole fish* samples contained PCBs. The average concentration of PCBs in whole fish was 0.12 mg/kg (n=5; min-max: nd-0.21 mg/kg). The average concentration of PCBs in combined fish tissues collected from Ellison Creek Reservoir in 2002 and 2003 were approximately twice the SALG guideline for assessing systemic human health effects of regular or prolonged oral exposure to PCBs (0.047mg/kg).

In the 2002-2003 data set, two fillets contained lead at levels below the laboratory's PQL for lead (4 mg/kg). Whole fish samples did not contain demonstrable lead. SALG risk assessors were unable to assess the significance of lead in 2002-2003 fish collected from Ellison Creek Reservoir because they could not determine whether lead concentrations were listed as dry- weight or wet-weight concentrations, because lead concentrations were below the PQL, and because only two fish fillets contained lead, while no whole fish were contaminated with measurable lead.

From the TCEQ 2002-2003 data on Ellison Creek Reservoir, risk assessment staff from the SALG suggested further investigation of fish from the reservoir to adequately characterize human health risks associated with consuming contaminants in fish from Ellison Creek Reservoir [32]. Subsequent to that review, the Texas Commission on Environmental Quality (TCEQ) and the SALG determined that Ellison Creek Reservoir was a candidate for examination under the Statewide Fish Tissue Monitoring Program. In 2005, SALG staff undertook this examination [33], collecting fish from Ellison Creek Reservoir with funding provided by the TCEQ through the statewide monitoring program.

The resultant report outlines contaminants found in fish collected in 2005 from Ellison Creek Reservoir, addresses public health implications of consuming contaminated fish from the reservoir, and suggests potential actions to protect humans from possible adverse health effects of consuming contaminated fish from this water body.

METHODS

Fish Tissue Collection and Analysis

The DSHS Seafood and Aquatic Life Group (SALG) collects and analyzes edible fish from the state's public waters to evaluate potential risks to the health of people consuming contaminated fish or shellfish. Fish tissue sampling follows standard operating procedures from the DSHS *Seafood and Aquatic Life Group Survey Branch Standard Operating Procedures and Quality Control/Assurance Manual* [34]. The SALG bases its sampling and analysis protocols, in part, on procedures recommended by the United States Environmental Protection Agency (EPA) in that agency's *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories, Volume 1* [35]. Advice and direction are also received from the legislatively mandated *State of Texas Toxic Substances Coordinating Committee (TSCC) Fish Sampling Advisory Subcommittee (FSAS)* [36]. Samples usually represent species, trophic levels, and legal-sized specimens available for consumption from a water body. When practical, the DSHS collects samples from two or more sites within a water body to characterize the geographical distribution of contaminants. The Texas A&M University Geochemical and Environmental Research Group laboratory (GERG laboratory), using established EPA methodology, analyzes fillets (skin off) of fish and edible meats of shellfish (crab and oyster) for common contaminants. Seven metals – arsenic, cadmium, copper, lead, total mercury, selenium, and zinc – are typically analyzed, as are panels of volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), pesticides, dioxins, and polychlorinated biphenyls (PCBs). In the past, the DSHS laboratory analyzed PCBs as Aroclors (Aroclor® 1016, 1221, 1224, 1232, 1248, 1254, and 1260). In the present study, the GERG laboratory, analyzed fish tissues for all 209 individual PCB congeners, as suggested by the USEPA [35]. The laboratory also analyzed fish collected in 2005 from Ellison Creek Reservoir for metals and pesticides.

Although the GERG laboratory reports the presence and concentrations of 209 congeners of PCBs using extremely low detection limits (typically around 1 µg/kg), the toxicity literature does not reflect the state-of-the-art laboratory science. Therefore, DSHS uses recommendations of the National Oceanic and Atmospheric Administration (NOAA) [37] and of McFarland and Clarke [38], along with the EPA's guidance documents for assessing contaminants in fish tissues [35, 70] to assess the probable toxicity of PCB congeners in fish tissues, summing a total for 43 of a possible 209 PCB congeners as the "total" PCB concentration. The DSHS uses the summed PCB information to assess possible risk from consuming PCBs in fish from a given water body.

The above-cited authorities chose certain congeners for their occurrence in fish, for the likelihood of significant toxicity – based on structure-activity relationships – and for their relative abundance in the environment [35, 37, 38]. While using only a few of the possible PCB congeners could underestimate concentrations of PCBs in fish tissue, the method complies with expert recommendations for evaluating systemic toxicity of PCBs by comparing the derived PCB totals with information found in the USEPA's IRIS database [47], a source currently encompassing data on several Aroclors, including 1016, 1242, 1248, 1254, and 1260. Systemic toxicity estimates in this document reflect comparisons with the RfD for Aroclor 1254.

The potency of PCB mixtures to cause cancer in exposed individuals is determined using a tiered approach that depends on the information available [39]. Three tiers of human slope factors for environmental PCBs exist: Tier 1 is for "high risk and persistence," the upper bound slope factor for which is 2.0, the central tendency slope factor for which is 1.0. Criteria for use of this most restrictive slope factor include food chain exposure, sediment or soil ingestion, dust or aerosol inhalation, dermal exposure, if an absorption factor has been applied, the presence of dioxin-like, tumor-promoting, or persistent congeners, and early-life exposure. Because of the potential magnitude of early-life exposures, the possibility of greater perinatal sensitivity, and the likelihood of interactions between thyroid hormone levels and development, it is reasonable to conclude that early-life exposures may be associated with increased risks. Due to this potential for higher sensitivity early in life, the DSHS, in agreement with the USEPA, utilizes the "high risk" tier for all early-life exposures [39].

The GERG laboratory reported total arsenic for each tested sample. However, the major portion of arsenic in fish is reportedly organic arsenic, an arsenic form that is virtually non-toxic [40]. Although inorganic arsenic concentrations may differ among species, under different water conditions, and, perhaps, other variables, the predominant literature suggests that well over 90% of arsenic in fish or shellfish is likely organic arsenic [40]. DSHS, taking a conservative approach, estimated that 10% of the total arsenic in the Ellison Creek Reservoir samples to be inorganic arsenic and derived the estimates of inorganic arsenic concentrations by multiplying total arsenic by a factor of 0.1.

Nearly all mercury in upper trophic-level fish over three years of age is methylmercury [41]. Thus, in Texas, total mercury concentration in most fish of legal size for possession serves as a surrogate for methylmercury in fish and shellfish. Because methylmercury analyses cost much more than total mercury analyses, the USEPA recommends that states determine total mercury concentrations in fish and that – to protect human health – states assume that all mercury in fish or shellfish is methylmercury. DSHS analyzes fish and shellfish tissues for total mercury. In its risk characterizations, DSHS compares total mercury concentrations in tissues to a comparison value derived from the ATSDR's minimal risk level for methylmercury [42]. DSHS may utilize the terms "mercury," "methylmercury," and "organic mercury" interchangeably to refer to mercury in fish.

Description of the Ellison Creek Reservoir 2005 Sample Set

In May 2005, SALG staff collected 30 fish samples from four sites around Ellison Creek Reservoir. Risk assessors used data from fish to examine the potential for human health risks from consuming environmentally contaminated fish taken from Ellison Creek Reservoir in 2005, emphasizing analysis and interpretation of PCBs in fish.

The SALG selected four sites to provide spatial coverage of the study area (see Appendix 1 for approximate locations). Site 1 was located near Ellison Creek Reservoir dam, Site 2 near the AEP power plant intake, Site 3 in Barnes Creek Arm, and Site 4 in the upper end of the reservoir.

The SALG targeted species for collection from Ellison Creek Reservoir through use of fish-tissue sampling protocols developed by that group. Collected species represent distinct ecological groups (i.e. predators and bottom-dwellers) that have the potential to bio-accumulate chemical contaminants, have a wide geographic distribution, are of local recreational fishing value, and/or are commonly consumed throughout the study area. The SALG staff collected 30 total samples with all targeted species represented in the catch. Fish samples submitted to the GERG laboratory for analyses were individual left-side fillets. Target species selected are listed in descending order by the number of samples collected: channel catfish (8), largemouth bass (8), hybrid striped bass (6), common carp (5), white crappie (2), and flathead catfish (1).

During each day of sampling, the staff set gill nets at each of the sampling sites in the late afternoon and fished them overnight. Gill nets were set in locations to maximize available cover and habitat at each sample site in the reservoir. To keep specimens from different sample sites separated, staff placed captured fish retrieved from the nets in the early morning hours in an individual, labeled mesh bag, keeping all samples on wet ice until processed. SALG staff returned to the reservoir any remaining live fish culled from the catch. Dead fish were disposed of in an appropriate manner.

In addition to gill nets, staff utilized a boat-mounted electrofisher at each site to collect fish. Staff conducted all electrofishing activities during daylight hours. Staff utilized pulsed, direct current (8-10 amps, 60 pulses per second [pps], high range) to stun fish that crossed the electric field in front of the boat. Staff retrieved stunned fish from the water body using dip nets over the bow of the boat, netting only fish selected as samples. Staff immediately stored samples on wet ice in coolers to ensure preservation. Following completion of electrofishing at a selected sampling site, staff members placed the fish in individual, labeled mesh bags to keep fish collected from different sites separate.

SALG staff processed all fish at the Lone Star American Electric Plant (AEP) power plant. Staff weighed each fish sample to the nearest gram and measured total length (tip of nose to tip of tail fin) to the nearest millimeter. After weighing and measuring a sample, staff filleted skin-off samples on a cutting board covered with aluminum foil. Staff then wrapped the left and the right fillets separately in double layers of aluminum foil and placed each wrapped fillet in pre-labeled plastic freezer bags that were then stored on wet ice in ice chests. The SALG staff retained the left-side fillet, giving the right-side fillet to AEP staff. The SALG staff transported tissue samples on wet ice to headquarters in Austin, TX, temporarily storing the samples in a locked freezer. The week following sample collection, the SALG shipped frozen tissue samples on wet ice by common carrier to the GERG Laboratory for analysis.

Data Analyses

SALG risk assessors employed SPSS® statistical software, version 13.0 [43] installed on IBM-compatible microcomputers to generate descriptive statistics (mean, standard deviation, median, range, and minimum and maximum concentrations) on all measured compounds in each species of fish from each site along Ellison Creek Reservoir from which samples were collected. The SALG utilized SPSS® software to examine the data for significant differences in contaminants among species or at different sites. DSHS compared the effects of species and collection site on dependent variables, examined interactions between species and collection sites, and generated graphs with SPSS®. The SALG also employed Microsoft Excel® [44] spreadsheets to compute health-based assessment comparison values (HAC_{nonca}) for contaminants of interest and to calculate hazard quotients (HQ), hazard indices (HI), cancer risk probabilities, and meal consumption limits for fish collected in 2005 from Ellison Creek Reservoir. Statistical analyses and comparison matrices included all samples. SALG risk assessors utilized the USEPA Integrated Environmental Uptake and Biokinetic (IEUBK) model [45] to determine whether consumption of lead in fish collected in 2005 from Ellison Creek Reservoir would cause children's blood lead (PbB) to rise above a cutoff point of 10 µg lead per deciliter of blood.

Derivation and Application of Health-Based Assessment Comparison Values (HACs)

People who regularly consume contaminated fish or shellfish probably suffer repeated exposures to low concentrations of contaminants over an extended time. Such exposures seldom result in acute toxicity but may increase risk of subtle, chronic, and/or delayed adverse health effects that may include cancer, benign tumors, birth defects, infertility, blood disorders, brain damage, peripheral nerve damage, lung disease, and kidney disease, to name but a few [46]. Presuming people to eat a variety of fish and/or shellfish, the DSHS routinely collapses data across species and sampling sites to evaluate mean contaminant concentrations in all samples from a specific water body because such an approach likely reflects consumers' exposure to contaminants in fish or shellfish over time. However, when relevant, the agency also examines risks associated with ingestion of individual species of fish or shellfish from separate collection sites or at higher concentrations (e.g., the upper 95th percentile on the mean concentrations).

The DSHS evaluates contaminants in fish by comparing the mean concentration of a contaminant to its health-based assessment comparison (HAC) value (measured in milligrams of contaminant per kilogram of edible tissue or mg/kg) derived for non-cancer and cancer endpoints. To derive HAC values for systemic (HAC_{nonca}) effects, the department assumes a standard adult weighs 70 kilograms and that adults consume 30 grams of edible tissue per day (about one 8-ounce meal per week). The DSHS uses EPA's oral reference doses (RfDs) [47] or the Agency for Toxic Substances and Disease Registry's (ATSDR) chronic oral minimal risk levels (MRLs) [48] to generate HAC values used in evaluating systemic (noncancerous) adverse health effects. EPA defines an RfD as *"An estimate of a daily oral exposure for a given duration to the human population (including susceptible subgroups) that is likely to be without an appreciable risk of adverse health effects over a lifetime* [49]." The EPA also states, *"It is derived from a BMDL* (benchmark dose lower confidence limit)*, a NOAEL* (no observed adverse effect level)*, a LOAEL* (lowest observed adverse effect level)*, or another suitable point of departure, with uncertainty/variability factors applied to reflect limitations of the data used. [Durations include acute, short-term, subchronic, and chronic and are defined individually in this glossary]"* and "*RfDs are generally reserved for health effects thought to have a threshold or a low dose limit for producing effects* [49]." ATSDR derives minimal risk levels (MRLs) similarly [48]. The DSHS compares the estimated daily dose (mg/kg/day) – derived from the average measured concentration of a contaminant – to the contaminant's RfD or MRL by using a hazard quotient (HQ). The HQ *is "the ratio of the estimated exposure dose of a contaminant (in mg/kg/day) to the contaminant's RfD or MRL"* [50]. Increases in hazard quotients do not represent linear increases in the likelihood of systemic adverse effects (i.e., a HQ of 2 is not twice as much toxicity as an HQ of 1.0 and an HQ of 4 does not imply a likelihood of adverse events that is four times greater than for those samples having a HQ of 1.0). Thus, risk managers at the DSHS assume a threshold HQ of 1.0 as a "jumping-off point" for assessment of the likelihood of adverse systemic events. Consuming fish having a toxicant-to-RfD ratio (the HQ) that is less than 1.0 is unlikely to result in adverse health effects and – similarly – that consuming fish for which the HQ exceeds 1.0 represents an unacceptable increase in the likelihood of systemic adverse health outcomes.

The constants (RfDs, MRLs) the DSHS employs to calculate HAC_{nonca} values incorporate built-in margins of safety called "uncertainty factors," as mentioned in EPA reference materials [49]. In developing RfDs and MRLs, scientists utilize uncertainty factors to minimize potential systemic adverse health effects in people who are exposed through consumption of contaminated foodstuffs. Vulnerable groups such as women who are pregnant or lactating, women who may become pregnant, the elderly, infants, children, people with chronic illnesses, or those who consume exceptionally large servings, called "sensitivities" by the EPA, receive special consideration in the calculations [49].

The DSHS calculates cancer-risk comparison values (HAC_{ca}) from the EPA's chemical-specific cancer potency factors (CPFs) - also known as slope factors (SFs) – derived through mathematical modeling [51]. For carcinogenic outcomes, the DSHS calculates a theoretical lifetime excess risk of cancer for specific exposures to carcinogens using a standard 70-kg body weight and assuming an adult consumes 30 grams of edible tissue per day. Two additional factors are incorporated into determinations of theoretical lifetime excess cancer risk: (1) an acceptable lifetime risk level (ARL [49]) of one excess cancer case in 10,000 persons whose average daily exposure is equal and (2) an exposure period of 30 years. Comparison values used to assess the probability of cancer, thus, do not contain "uncertainty" factors as such. However, conclusions drawn from those probability determinations infer substantial safety margins for all people by virtue of the models utilized to derive the slope factors (cancer potency factors).

Because the calculated comparison values (HAC_{nonca} and HAC_{ca}) are conservative, adverse systemic or carcinogenic health effects are unlikely, even if exposures are consistently higher than comparison values. Moreover, comparison values for adverse health effects (systemic or carcinogenic) do not represent sharp dividing lines between safe and unsafe exposures. The perceived strict demarcation between acceptable and unacceptable exposures or risks is primarily a tool to assist risk managers to make decisions that ensure protection of public health. For instance, the DSHS deems it unacceptable when consumption of four or fewer meals per month of contaminated fish or shellfish would result in *exposure* to contaminant(s) in excess of a HAC value or other measure of risk *even* though most such exposures are unlikely to result in adverse health effects. The department further advises people who wish to minimize exposure to contaminants in fish or shellfish to eat a variety of fish and/or shellfish and to limit consumption of those species most likely to contain toxic contaminants. DSHS aims to protect vulnerable subpopulations with its consumption advice. The DSHS assumes that advice protective of vulnerable subgroups will also minimize the impact on the general population of consuming contaminated fish or shellfish.

Children's Health Considerations

The DSHS recognizes that fetuses, infants, and children may be uniquely susceptible to the effects of toxic chemicals and suggests that exceptional susceptibilities demand special attention [52,53]. Windows of vulnerability, known as "critical periods," exist during development. Critical periods occur particularly during early gestation, but can occur at any time during pregnancy, infancy, childhood, or adolescence – indeed, at any time during development – times when toxicants can impair or alter the structure or function of vulnerable systems [54]. Unique early vulnerabilities may occur because organs and body systems are structurally or functionally immature – even at birth – continuing to develop throughout infancy, childhood, and adolescence. Developmental variables may influence the mechanisms or rates of absorption, metabolism, storage, and excretion of toxicants, any of which factors could alter concentration of biologically effective toxicant at the target organ(s) or modulate target response to the toxicant. Children's exposures to toxicants may be more extensive than adults' exposures because, in proportion to their body weights, children consume more food and liquids than do adults, another factor that might alter the concentration of toxicant at the target. Infants can ingest toxicants through breast milk – an exposure pathway that could go unrecognized [55] (nonetheless, the advantages of breastfeeding outweigh the probability of significant exposure to infants through breast milk and women are encouraged to continue breastfeeding and to limit exposure of their infants by limiting intake of contaminated food [55]). It is also possible that children could experience effects at a lower exposure dose than adults because children's organs may be more sensitive to the effects of toxicants. Stated differently, children's systems could respond more extensively or with greater severity to a given dose than would an adult organ exposed to an equivalent dose of a toxicant. Children could be more prone to developing certain cancers from chemical exposures than are adults [56]. In any case, if a chemical – or a class of chemicals –is observed to be – or is thought to be – more toxic to the fetus, infants, or children than to adults, the constants (e.g., RfD, MRL, or CPF) are usually reduced to assure protection of the immature system's potentially greater susceptibility [47]. Additionally, in accordance with the ATSDR's *Child Health Initiative* [57] and the EPA's *National Agenda to Protect Children's Health from Environmental Threats* [58], the DSHS further seeks to protect children from the possible negative effects of toxicants in fish by suggesting that this potentially sensitive subgroup consume smaller quantities of contaminated fish or shellfish than adults consume. Thus, DSHS recommends that children weighing 35 kg or less and/or who are 11 years of age or younger limit exposure to contaminated fish or shellfish by eating smaller meals (no more than four ounces of fish or shellfish per meal). The DSHS also recommends that consumers spread out these meals out over time. For instance, if consumption advice recommends eating no more than two meals per month, children consuming affected fish or shellfish should consume no more than 24 meals per year and, ideally, should not eat such fish or shellfish more than twice per month.

RESULTS

Chemical Analyses

The GERG laboratory electronically transmitted the results of chemical analyses of the Ellison Creek Reservoir samples between August and November 2005. The laboratory reported the analytical results for metals, pesticides, and PCBs for thirty samples, also analyzing five of the same samples for semivolatile and volatile organic compounds. After receiving all data from the laboratory, SALG staff checked the quality control data submitted with the analytical results, entered field and laboratory information into the spreadsheet, reorganized the spreadsheets for analysis, checked the data for transcription accuracy, and examined other quality control measures. SALG risk assessors used the data files in SPSS to generate mean concentrations, standard deviations, median concentrations, and minimum and maximum concentrations of each analyte, using the results of descriptive statistical analyses and other statistical analyses to produce the present report.

Summary results of inorganic or "metallic" contaminants (arsenic, cadmium, copper, lead, mercury, selenium, and zinc in fish collected in May 2005 from Ellison Creek Reservoir are presented in Tables 1a-1c. Table 2 presents summary statistics for p,p'-DDE and chlordane, the two most commonly observed pesticides in tissues of fish collected in 2005 from Ellison Creek Reservoir. Table 3 presents PCB concentrations in the fish species collected from each site around the reservoir. The summaries below utilize concentration ± 1 standard deviation unless stated otherwise.

Inorganic Contaminants

Arsenic

Fifty percent of fish sampled from Ellison Creek Reservoir contained arsenic (Table 1a). Neither channel catfish (n=8) nor flathead catfish (n=1) contained detectable levels of arsenic. In fish containing arsenic, the highest mean concentration (0.058 mg/kg) occurred in hybrid striped bass. Common carp, largemouth bass, and white crappie also contained arsenic. Although the laboratory reported total arsenic concentration, arsenic in fish occurs predominantly as organic arsenic, often called "fish arsenic." The kidneys rapidly excrete organic arsenic ingested when people consume fish. Primarily due to rapid excretion of unchanged organic arsenic, this form of arsenic is essentially nontoxic to humans [59]. Additionally, in fish, inorganic arsenic – the form that can be toxic to humans – makes up less than 10% of total arsenic. Therefore, SALG risk assessors estimated average inorganic arsenic levels at 10% of mean total arsenic concentration in fish from Ellison Creek Reservoir. This algorithm predicts a mean inorganic arsenic concentration of 0.0058 mg/kg in hybrid striped bass, while the mean concentration of inorganic arsenic in all species combined would be 0.0033 mg/kg, a level calculated from all results, which include channel catfish and flathead catfish, neither species of which contained detectable arsenic (Table 1a).

Cadmium

No fish samples from Ellison Creek Reservoir contained cadmium (Table 1b). Because the reporting limit for cadmium is less than 0.10 mg/kg (ranging in the present study from 0.016 to 0.025 mg/kg). Thus, if cadmium were present in at levels below the laboratory's reporting limit, it would be present only at very low concentrations.

Copper

The laboratory reported that slightly over 50% of fish from Ellison Creek Reservoir contained copper (Table 1b). Neither of two white crappie samples contained copper. The mean concentration of copper in all fish from Ellison Creek Reservoir was, thus, 0.209 ± 0.256 mg/kg edible fish tissue.

Lead

No sample from Ellison Creek Reservoir contained lead at levels above the reporting limit for this contaminant (Table 1b). In the present analyses, the GERG laboratory's reporting limit for lead in fish tissues ranged from 0.066 to 0.101 mg/kg (not recorded in this document; however, the required reporting limit for certified laboratories is 0.40 mg/kg). Thus, lead, if present in fish from Ellison Creek Reservoir, likely occurs only at very low concentrations.

Mercury

According to the GERG analytical report, 21 of 30 fish collected from Ellison Creek Reservoir in 2005 contained mercury (Table 1c). The mean concentration of mercury in fish combined across species and sites was 0.172±0.379 mg/kg. Common carp contained the highest mean concentration

(0.443±0.911 mg/kg) of mercury but only three of five carp contained measurable mercury. Channel catfish (5 of 8 samples) contained the lowest mean concentration of mercury (0.101±0.168 mg/kg). All largemouth bass contained mercury (0.159 mg/kg ± 0.114 mg/kg). The laboratory did not report mercury in either of two white crappie samples.

Selenium

Selenium was present in 26 of 30 samples from Ellison Creek Reservoir (Table 1c). The highest concentration of selenium appeared in hybrid striped bass (0.504 ± 0.184 mg/kg tissue), the lowest in channel catfish (0.073±0.061 mg/kg). Predator fish (hybrid striped bass, largemouth bass, flathead catfish, white crappie) contained higher levels of selenium than did bottom feeders (channel catfish, common carp).

Zinc

As is common, all fish sampled in 2005 from Ellison Creek Reservoir contained zinc (Table 1c). The highest mean concentration of zinc occurred in common carp (13.484 ± 6.393 mg/kg); other species contained lower concentrations of zinc. Analysis by trophic level showed that bottom feeders contained significantly higher concentrations of zinc than did predators (Mann-Whitney U test; statistics shown).

Organic Contaminants

The laboratory analyzed all samples from Ellison Creek Reservoir for common pesticides and for all 209 PCB congeners. The laboratory also analyzed five of 30 fish tissue samples for VOCs and SVOCs.

VOCs and SVOCs

The laboratory analyzed five fish tissue samples from Ellison Creek Reservoir for a suite of volatile organic compounds (data not shown). Trace quantities of methylene chloride (dichloromethane) were present in all five samples (mean concentration = 0.069 mg/kg). The laboratory reported carbon disulfide, acetone, methyl-tert-butyl ether (MTBE), tetrahydrofuran, benzene, toluene, styrene, n-propylbenzene, 4-isopropyltoluene, and naphthalene in 1 or more samples at concentrations near or below the lowest calibration level (LCL).

The laboratory analyzed the five fish samples for many semivolatile organic compounds (data not shown), reporting several phthalate esters (including bis-2-ethylhexyl phthalate; DEHP), in one or more of the five tissue samples. However, levels were lower than the lowest calibration level (LCL). The laboratory did not identify other semivolatile compounds in this analysis except pesticides, which were quantified in a separate analysis.

Pesticides

Trace amounts of several commonly observed pesticides occurred sporadically in fish collected in 2005 from Ellison Creek Reservoir. Table 2 contains means, standard deviations, and minimum and maximum concentrations of the two most frequently occurring pesticides reported present in fish from the reservoir: p,p'-DDE and chlordane. p,p'-DDE occurred in 12 of 30 fish (0.0073±0.0096 mg/kg); chlordane was present in seven fish at a mean concentration of 0.0098±0.0112 mg/kg.

Polychlorinated biphenyls (PCBs)

Table 3 contains summary statistics for polychlorinated biphenyls measured in samples collected in 2005 from Ellison Creek Reservoir. The laboratory analyzed all samples for each of 209 PCB congeners. All fish from Ellison Creek Reservoir contained one or more of a possible 209 PCB congeners. No samples contained all 209 congeners. Hybrid striped bass contained the highest mean concentration of PCBs (0.8890 ± 0.4747 mg/kg) followed by common carp, which contained a mean concentration of 0.2615 ± 0.1479 mg PCBs per kg edible tissue. Mean PCB concentration in white crappies – the species containing the lowest levels of PCBs – was 0.0445 ± 0.0169 mg/kg.

Dioxins

Although a distinct possibility exists that dioxins are present in fish from Ellison Creek Reservoir given the discovery of PCBs in the fish and the probable history of industrial use of PCBs on land near the reservoir, the DSHS did not analyze samples for dioxins because funds were unavailable for these tests.

DISCUSSION

Possible Systemic (Noncancerous) Health Effects from Consumption of Contaminated Fish from Ellison Creek Reservoir

One must weigh conclusions about the actual risk of adverse health outcomes from exposure to toxicants that are based on experimental or epidemiological data with the known variability of individual and population responses, which may differ by orders of magnitude above or below mathematically estimated risks of systemic or local effects of toxicants in various systems under different conditions [47]. Nevertheless, this paper identifies potentially significant exposures from consumption of fish from Ellison Creek Reservoir, the most serious threat of which is from PCBs in the fish (Tables 4, 5, 6). Conclusions and recommendations predicated upon the stated goals of the DSHS to protect human health follow this discussion of findings.

Inorganic Constituents

Arsenic

Most samples from Ellison Creek Reservoir contained measurable arsenic (Table 1a). Nonetheless, risk assessors at the DSHS judged arsenic in fish from Ellison Creek Reservoir of no consequence to human health because most was assumed to be organic, a form of the toxicant found in fish that is essentially nontoxic to humans, in all likelihood by virtue of its ease of elimination from the body [59]. Estimating that 10% of the arsenic in fish from Ellison Creek Reservoir was inorganic arsenic, DSHS toxicologists determined that concentrations were far lower than the HAC_{nonca} for inorganic arsenic in fish. In fact, even if DSHS had assumed that all arsenic in fish from the reservoir was inorganic arsenic, no arsenic concentration reported in fish from Ellison Creek Reservoir would have exceeded the HAC_{nonca} for inorganic arsenic (Table 1a).

Lead

Fish from Ellison Creek Reservoir did not contain measurable (reportable) lead. Although SALG risk assessors traditionally utilize the EPA's Integrated Exposure Uptake Biokinetic model (IEUBK) to assess potential alterations in children's blood lead with varying lead consumption [60], the absence of measurable concentrations of lead in samples from Ellison Creek Reservoir precluded use of the IEUBK. Nonetheless, the finding of undetectable lead levels in fish from this reservoir is a tacit argument against a significant effect on blood lead levels in children who consume fish from Ellison Creek Reservoir.

Cadmium, copper, mercury, selenium, zinc

Fish from Ellison Creek Reservoir did not contain detectable cadmium. It is thus unlikely that cadmium is occurring in fish from this lake at concentrations toxic to humans, suggesting that systemic adverse health outcomes associated with cadmium ingestion are also improbable. Furthermore, research on potential interactions between cadmium and zinc (zinc was present in all samples taken in 2005 from Ellison Creek Reservoir) in both *in vitro and in vivo* systems indicate that zinc antagonizes the toxic effects of cadmium [46].

Most fish from Ellison Creek Reservoir contained copper, mercury, and selenium. All fish contained zinc. Copper, selenium, and zinc are essential nutrients in humans [61] and, although all may be toxic at concentrations above certain thresholds or under extraordinary conditions, none occurred in fish from Ellison Creek Reservoir at concentrations likely to prove toxic to humans. Nevertheless, SALG risk assessors formally compared the mean concentration of each contaminant in each species to its respective HAC_{nonca} (Tables 1b, 1c). Copper, mercury, selenium, and zinc concentrations were well below their respective HAC_{nonca} values in all species. No individual component exceeded a HQ of 1.0, calculated as a ratio of the mean concentration to the HAC concentration. In fact, although zinc was present in all fish collected from Ellison Creek Reservoir (Table 1c), concentrations were miniscule when compared with the HAC_{nonca} for this element of 700 mg/kg (Table 1c).

From the data on metals in fish collected in 2005 from Ellison Creek Reservoir, SALG risk assessors concluded that consumption of fish from this lake containing any one of the detected metallic components is unlikely to adversely affect human health. Furthermore, copper, selenium, and zinc are essential trace elements present at some level in most vertebrates and are necessary for optimum health in humans and many other animals [61].

Pesticides

Fish from Ellison Creek Reservoir contained trace quantities of various pesticides; combinations and concentrations of p,p'-DDD, p,p'-DDE, alpha-hexachlorohexane, chlordane, dacthal, diazinon, heptachlor, and hexachlorobenzene varied among specimens. In no instance did the concentration of any pesticide approach a level of concern for human health. In fact, only two pesticides - p,p'-DDE and chlordane - occurred with any consistency in fish from Ellison Creek Reservoir (Table 2); these two pesticides occurred only at levels far below the HAC_{nonca} for each pesticide. The DSHS concluded from the data that consuming fish from Ellison Creek Reservoir that contain trace quantities of one or more of the above-mentioned pesticides poses no apparent risk of systemic adverse health effects in humans.

Volatile and Semi-volatile Organic Compounds (VOCs and SVOCs)

Several volatile organic compounds were detected in one or more of five fish tissue samples taken from Ellison Creek Reservoir in 2005. None of these compounds was found at levels that exceeded its respective HAC_{nonca} values. Consumption of fish containing these compounds at levels similar to those identified in the present samples is not likely to result in adverse systemic health effects. Nonetheless, small sample size limits conclusions from these analyses; further examination of fish from this water body for volatile organic compounds may be warranted because industries commonly utilizing volatile organic compounds are present near the reservoir.

The laboratory detected various phthalate esters – ubiquitous compounds commonly utilized to make plastics soft and pliable – in samples from Ellison Creek Reservoir. Concentrations were not definitively quantified. Phthalate ester concentrations in those fish did not exceed the compounds' respective HAC_{nonca} values. Therefore, consumption of fish from Ellison Creek containing phthalates at levels near those detected in the present sample is unlikely to cause systemic adverse health effects.

Polychlorinated Biphenyls (PCBs)

The GERG laboratory reported polychlorinated biphenyls (PCBs) in all samples of all species from all sample sites within the confines of Ellison Creek Reservoir. Many samples contained PCBs at concentrations well in excess of the HAC_{nonca} for PCBs derived from the RfD for Aroclor 1254, but applied to all PCBs listed by McFarland and Clarke in an analysis of persistency and potential toxicity of PCBs in fish and shellfish [38]. All channel catfish (n=8), common carp (n=5), flathead catfish (n=1), and hybrid striped bass (n=6) contained PCBs at mean concentrations that exceeded DSHS guidelines for protection of human health (0.047 mg/kg) from systemic PCB effects. Eighty-five percent of largemouth bass (n=8) contained PCBs at levels in excess of 0.047 mg/kg, while 50% of white crappie samples (n=2) contained PCBs in excess of 0.047 mg/kg. Hybrid striped bass contained the highest mean concentration of PCBs (0.889 mg/kg), a concentration more than 20 times the HAC_{nonca} (Figure 1). HQ's for fish from Ellison Creek Reservoir containing PCBs ranged from a low of 1.0 (white crappie) to a high of 19 (hybrid striped bass). However, hazard quotients are measures of a consumed dose relative to a threshold dose such as the RfD or MRL. Thus, HQs are not linear representations of the probability of adverse health outcomes. The USEPA recommends that, at HQ's above 1.0, agencies managing potential risk from consumption of chemical contaminants issue consumption advice for affected species or water bodies [62].

Possibility for Excess Cancer Risk from Consumption of Contaminants in Ellison Creek Reservoir Fish

Cancer risk is complex and is seldom a straightforward subject. Conclusions from calculations of theoretical lifetime excess cancer risks must be tempered by the known variability of risk calculations. Actual risk may be much lower or much higher than calculated, varying by orders of magnitude from the calculated risk [47]. In the United States, the overall lifetime risk of cancer is approximately 40% – two of five people develop cancer during their life [63]. In addition to environmental exposures, other variables affect cancer risk. For example, genetics affect cancer risk (women who have the BrCa1 or BrCa2 gene have an increased risk of breast cancer); a woman's risk of breast cancer is also modified by whether she has children, her age at the time of her first child's birth, and whether she breast-feeds. Women infected with certain human papilloma virus strains have a greater risk of cervical cancer than do women who do not have this infection [64]. People with xeroderma pigmentosum (XP) – a genetic disorder – are at greater risk of skin cancer. Retinoblastoma, a cancer of the retina, occurs only in people who have the gene for the disorder – to name a few instances). Controllable lifestyle choices also affect the lifetime risk of cancer (tobacco and alcohol use; tanning-bed use and sunburns; food choices; obesity; sexual behaviors). A recent study suggested that people in the United States could avoid 10% of all cancers (more than 100,000 cases per year) if they maintained a normal body weight [65]. Organ recipients who take immunosuppressant drugs have increased lifetime risk of many cancers, as do those who survive cancer through treatment with chemotherapeutic agents. Certain chronic infections, namely HIV and AIDS, increase the risk of cancer, probably because the immune system is instrumental in controlling the progression of cancers and HIV/AIDS patients have depressed immune systems. Genetic and environmental factors can interact to modify cancer risk. For instance, people with XP must avoid sunlight to increase the time to occurrence of skin cancer. Environmental exposures and lifestyle choices can interact to increase risk of cancer: people who are exposed to asbestos and who also smoke have a higher risk for developing mesothelioma, a fatal lung cancer, than do those who do not smoke. In all, risk of cancer from involuntary exposure to environmental contaminants likely contributes only modestly to lifetime risk of cancer [64]. Nevertheless, that risk is real. People may reduce their risk of cancer from certain exposures by modifying behaviors. In the instance of cancer causing contaminants in fish, reducing consumption of contaminated fish may decrease the lifetime theoretical risk of cancers. To assist with informed decisions about the risk of exposure to carcinogens in fish or shellfish, the SALG analyzes these foods for cancer-causing chemicals, evaluates theoretical risk from exposure to contaminants in fish or shellfish, and communicates those risks to people. Those people can then control exposure by reducing or eliminating consumption of contaminated fish or shellfish. When calculated risks are large, DSHS risk managers may suggest that people not consume fish or shellfish from an affected water body or may act to make possession of contaminated species illegal.

Inorganic contaminants: arsenic, cadmium, copper, lead, mercury, selenium, zinc

Inorganic arsenic levels in fish from Ellison Creek Reservoir did not exceed the arsenic HAC_{ca} value (Table 1a). Inorganic arsenic (calculated as about 1/10 of total arsenic) in the fish from Ellison Creek Reservoir did not exceed DSHS cancer risk guidelines for protection of public health from theoretical increases in cancer risk (1 excess cancer in 10,000 equally exposed individuals; Table 6).

Cancer potency factors (slope factors) are not available for cadmium (EPA Cancer Group B), copper (Group D), lead (Group B), mercury (Group C), selenium (Group D), or zinc (Group D) [47]. For this reason, DSHS was unable to determine the probability of excess cancers from consuming fish or shellfish from Ellison Creek Reservoir that contain cadmium, copper, lead, mercury, selenium, or zinc. It is important to note, however, that copper, selenium, and zinc – at appropriate intake levels – are essential trace elements, necessary for health [61]. Selenium, in particular, has been the subject of much current research on protection of humans from certain cancers, including prostate and colon cancers [66].

Organic Contaminants

The USEPA classifies polychlorinated biphenyls (PCBs) as probable human carcinogens (Group B2), setting the carcinogen potency factor (slope factor) to 2.0 to account for exposure in foods, environmental persistence, and early life exposures. DSHS risk assessors calculated theoretical lifetime excess cancer risk for consumption of fish from Ellison Creek Reservoir that contain PCBs, the only organic compounds to exceed the HAC_{ca} used to assess the potential for increased cancer risk from consumption of contaminated fish (Table 6). The theoretical increase in lifetime excess risk of cancer from consuming PCB-contaminated hybrid striped bass from Ellison Creek Reservoir exceeds DSHS cancer risk guidelines for protection of public health (1 excess cancer in 10,000 equally exposed individuals). The calculated theoretical excess lifetime risk from consuming one 8-ounce meal per week of hybrid striped bass from Ellison Creek Reservoir is one excess cancer in approximately 3,000 exposed individuals (Table 6), a risk about three times that allowed by DSHS risk managers for protection of humans from excess risk of cancer after 30 years of exposure to a carcinogen. Consuming a diet of fish from Ellison Creek Reservoir consisting of equal parts of each tested species increases the risk of cancer to a level greater than that recommended by DSHS to protect from excess associated with consuming carcinogen-contaminated fish. On the other hand, consuming a diet of fish from Ellison Creek Reservoir that excludes hybrid striped bass would lower the calculated theoretical excess lifetime cancer risk to an acceptable level (Table 6). These findings (Table 6) suggest that consumption of hybrid striped bass from this reservoir poses the greatest risk to health. Nonetheless, not everyone who eats fish from Ellison Creek Reservoir will get cancer from that exposure and not all cancers arising in people who eat fish from this reservoir are attributable to consumption of those fish.

The USEPA also classifies chlordane and p,p'-DDE as Group B2 carcinogens, albeit with much lower carcinogenic potency than PCBs. However, the extremely low concentrations of chlordane and p,p'-DDE in fish from Ellison Creek Reservoir, and the variable occurrence of these contaminants led the SALG to conclude that neither chlordane nor DDE increased the theoretical lifetime excess risk of cancer for those eating fish from the reservoir containing either of these contaminants.

Cumulative Systemic Adverse Health Effects and Cumulative Cancer Risk from Consumption of Fish from Ellison Creek Reservoir

Risk assessment guidelines from the USEPA [67] suggest that estimates of adverse systemic health effects of toxicants with similar modes or mechanisms of action or those that attack the same target organ (e.g., the liver) be summed to obtain an estimate of overall risk to those who are simultaneously exposed to one or more of those contaminants. Similarly, summation of calculated theoretical excess risks of cancer is appropriate if the agent causes cancer by the same mode or mechanism of action (e.g., tumor initiator, tumor promoter, enzyme inducer). The DSHS uses these general guidelines for assessing the likelihood of cumulative systemic effects or cancer in people exposed to multiple contaminants in the same fish.

Inorganic or Metallic Contaminants

Fish from Ellison Creek Reservoir did not contain metallic contaminants with similar modes of action or any such contaminants that attack the same target organ. Thus, consumption of fish from Ellison Creek Reservoir that contain metallic contaminants should not result in cumulative systemic adverse effects. The theoretical cumulative increase in risk of cancer from consuming fish containing carcinogenic metallic contaminants did not exceed DSHS guidelines for protection of public health (1 excess cancer in 10,000 equally exposed individuals). Consumption of fish from Ellison Creek Reservoir that contain multiple metallic contaminants at concentrations similar to those measured should not cause an increase in the theoretical lifetime cancer risk.

Organic Contaminants

In addition to PCBs, the laboratory reported trace quantities of several VOCs, phthalate esters (SVOCs), and organic pesticides in fish from Ellison Creek Reservoir (Table 2). Trace quantities of individual chlorinated pesticides, SVOCs, or VOCs in samples from Ellison Creek Reservoir had no discernable effects on the hazard index (HI; The HI is the sum of all significant hazard quotients or HQs) or on cancer risk predictions in any fish species from any sampling site. Risk of adverse systemic health effects resulted overwhelmingly from the presence of PCBs in fish from the reservoir (Tables 4 and 5). Therefore, risk assessors concluded that consumption of fish from Ellison Creek Reservoir containing trace quantities of VOCs, other SVOCs, and pesticides should not cause additive or synergistic systemic adverse effects. Neither did trace concentrations of the named pesticides, SVOCs, or VOCs materially influence cancer risk from consumption of fish from Ellison Creek Reservoir.

Because the modes of action by which PCBs and inorganic arsenic cause cancer are likely different, SALG risk assessors considered it inappropriate to consider cumulative risks from these two contaminants. Arsenic may work by activating a transcription factor that controls cellular proliferation [68], while PCBs may be tumor promoters [69]. Nevertheless, as a conservative measure, the SALG risk assessors DID add the calculated risk of cancer from inorganic arsenic to that from PCBs because researchers have not strictly defined the modes or mechanisms of carcinogenicity of these toxicants. Addition of potential cancer risk from inorganic arsenic (Table 1a) to that of PCBs (Table 3) did not contribute materially to the effect of PCBs on the theoretical excess cancer risk from consuming Ellison Creek Reservoir fish (Table 6).

Conclusions

SALG risk assessors prepare risk characterizations to determine public health hazards from consumption of fish and shellfish harvested from Texas water bodies by recreational or subsistence fishers, and, if indicated, may suggest strategies for reducing risk from consuming contaminated fish to risk managers at DSHS who include the Texas Commissioner of State Health Services.

This study addressed the public health implications of consuming Ellison Creek Reservoir fish that contain PCBs and other contaminants and assessed the impact on public health of consuming contaminated fish. Risk assessors from the SALG and the EIETB conclude from the present characterization of the potential risks of adverse health effects from consuming contaminated fish from the Ellison Creek Reservoir

1. That channel catfish, common carp, flathead catfish, hybrid striped bass, and largemouth bass collected from Ellison Creek Reservoir in 2005 contained PCBs at levels exceeding DSHS guidelines for protecting humans from possible systemic effects of contaminants in fish or shellfish (Tables 4 and 5). Regular or long-term consumption of fish from Ellison Creek Reservoir could therefore result in systemic adverse health effects, including immunologic, neurologic, reproductive, or developmental abnormalities. Therefore, consumption of any species of fish from Ellison Creek Reservoir constitutes a **public health hazard.**

2. That long-term consumption of PCB-contaminated hybrid striped bass from Ellison Creek Reservoir could increase the risk of cancer in susceptible individuals (Table 6). Therefore, consumption of hybrid striped bass from this reservoir poses a **public health hazard.**

3. That consumption of white crappie collected from Ellison Creek Reservoir constitutes an **indeterminate public health hazard** because sampling size (2 fish from one site) was not large enough to definitively project hazards to human health.

4. That fish collected from Ellison Creek Reservoir do not contain pesticides, SVOCs, or VOCs at concentrations of significance to human health, either singly or in combination with other such compounds. Therefore, were people able to confine consumption of fish from Ellison Creek Reservoir to those containing only these compounds, such consumption would pose **no apparent public health hazard**.

5. That fish from Ellison Creek Reservoir do not contain inorganic contaminants in excess of DSHS guidelines for protection of human health. Were people able to confine consumption of fish from Ellison Creek Reservoir to those containing only inorganic components – some of which are essential nutrients – consumption would pose **no apparent public health hazard**.

Recommendations

Risk managers at the DSHS have established criteria for issuing fish consumption advisories based on approaches suggested by the EPA [70]. Confirmation through risk characterization that consumption of four or fewer meals per month (adults: eight ounces per meal; children: four ounces per meal) would result in exposures to toxicants in excess of DSHS health-based guidelines, risk managers may wish to recommend consumption advice for fish or shellfish from the water body in question. Fish or shellfish possession bans are enforceable under subchapter D of the Texas Health and Safety Code, part 436.061(a) [71]. Declaration of prohibited harvesting areas and classification of oyster growing areas are enforceable under subchapter D of the Texas Health and Safety Code, part 436.091and 436.101 [71]. Consumption advisories are not enforceable by law and carry no penalties for noncompliance. Nonetheless, DSHS consumption advisories inform the public of health hazards from consuming contaminated fish or shellfish from Texas waters so that members of that public can make informed decisions about eating contaminated fish or shellfish. As an alternative, the department may ban possession of fish from the affected water body. The SALG and the Environmental and Injury Epidemiology and Toxicology Branch (EIETB) of DSHS conclude from the data in this risk characterization that consuming fish from Ellison Creek Reservoir would pose a threat to public health. Therefore, the SALG and the EIETB recommend

1. That DSHS publicly advises that regular, sustained, or large-volume consumption of hybrid striped bass, channel catfish, common carp, flathead catfish, or largemouth bass from Ellison Creek Reservoir could result in systemic adverse health effects from PCB exposures –especially, perhaps, to members of vulnerable groups – such as women of childbearing age, pregnant women, young children, the elderly, and the infirm.

2. That DSHS advises that regular or sustained consumption of hybrid striped bass over a long time could contribute to an increase in the theoretical excess lifetime risk of cancer because PCB concentrations in this fish species exceed the reference concentration used by DSHS to protect human health from increased risk of cancer from PCB exposure in fish.

3. That the DSHS collects additional samples of white crappie from the Ellison Creek Reservoir to better characterize PCB contamination of this species of fish from this water body.

4. That, as resources become available, the DSHS collects more samples of fish from Ellison Creek Reservoir to better characterize potential adverse human health effects from the presence of several volatile organic compounds (VOCs) in such fish.

5. That, as resources become available, the DSHS continues to monitor fish from the Ellison Creek Reservoir for metals, pesticides, PCBs, and other contaminants.

6. That the DSHS informs relevant agencies of the need for further investigation of sources of PCBS in fish collected from Ellison Creek Reservoir.

7. That, as resources become available, DSHS continues to monitor fish from Ellison Creek Reservoir for PCBs.

8. That, as resources become available, DSHS test fish from Ellison Creek Reservoir for dioxins because, although dioxins can co-exist in fish exposed to PCBs from industrial sources, DSHS have not yet tested fish from this reservoir for dioxins.

PUBLIC HEALTH ACTION PLAN

The Texas Department of State Health Services (DSHS) publishes a booklet containing a listing of fish consumption advisories and bans available to the public from the Seafood and Aquatic Life Group: (512-834-6757) [72]. The Seafood and Aquatic Life Group (SALG) also posts this information on the Internet at URL: http://www.tdh.state.tx.us/bfds/ssd. The SALG regularly updates its web site. Some risk characterizations for water bodies surveyed by the Texas Department of State Health Services may also be available from the Agency for Toxic Substances and Disease Registry (http://www.atsdr.cdc.gov/HAC/PHA/region6.html). The Texas Department of State Health Services provides the U.S. Environmental Protection Agency (http://fish.rti.org), the Texas Commission on Environmental Quality (TCEQ; http://www.tceq.state.tx.us), and the Texas Parks and Wildlife Department (TPWD; http://www.tpwd.state.tx.us) with information on all consumption advisories and bans on possession. Each year, the TPWD informs the fishing and hunting public of fishing bans in an official hunting and fishing regulations booklet [73], available at some state parks and at establishments that sell fishing licenses.

Readers may direct questions about the scientific information or recommendations in this risk characterization to the Seafood and Aquatic Life Group (512-834-6757; http://www.tdh.state.tx.us/bfds/ssd) or to the Environmental and Injury Epidemiology Branch (512-458-7269) at the Texas Department of State Health Services (DSHS). Toxicological information on many environmental contaminants found in seafood and other environmental media may also be obtained from the EPA's IRIS website (http://www.epa.gov/iris/) or from the Agency for Toxic Substances and Disease Registry (ATSDR), Division of Toxicology (800-447-1544) or from the ATSDR website (URL: http://www.atsdr.cdc.gov).

TABLES and FIGURE

Table 1a. Arsenic (mg/kg) in Fish from Ellison Creek Reservoir, 2005					
Species	**# Detected/ # Sampled**	**Total Arsenic Mean Concentration ± S.D. (Min-Max)**	**Inorganic Arsenic Mean Concentration[1]**	**Health Assessment Comparison Value[b] (mg/kg)**	**Basis for Comparison Value**
Channel catfish	0/8	ND	**ND**	0.7 0.362	EPA chronic oral RfD for Inorganic arsenic: 0.0003 mg/kg–day EPA oral slope factor for Inorganic arsenic: 1.5 per mg/kg–day
Common carp	3/5	0.029 ± 0.016 (ND-0.049)	**0.0029**		
Flathead catfish	0/1	ND	**ND**		
Hybrid striped bass	4/6	0.058 ± 0.039 (ND-0.114)	**0.0057**		
Largemouth bass	6/8	0.037 ± 0.025 (ND-0.080)	**0.0037**		
White crappie	2/2	0.055 ± 0.006 (0.051-0.059)	**0.0055**		
All Fish Combined	15/30	0.033 ± 0.028 (ND-0.114)	**0.0033**		

[1] *Most arsenic in fish and shellfish occurs as organic arsenic, considered virtually nontoxic. For risk assessment calculations, DSHS assumes that total arsenic is composed of 10% inorganic arsenic in fish and shellfish tissues [40].*

Table 1b. Inorganic Contaminants (mg/kg) in Fish from Ellison Creek Reservoir, 2005				
Contaminant	**# Detected/ # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value[b] (mg/kg)**	**Basis for Comparison Value**
Cadmium				
Channel catfish	0/8	ND	2.3	EPA chronic oral RfD: 0.001 mg/kg–day
Common carp	0/5	ND		
Flathead catfish	0/1	ND		
Hybrid striped bass	0/6	ND		
Largemouth bass	0/8	ND		
White crappie	0/2	ND		
All Fish Combined	0/30	ND		
Copper				
Channel catfish	3/8	0.078 ± 0.062 (ND-0.208)	333	National Academy of Science Upper Limit: 0.143 mg/kg–day
Common carp	5/5	0.709 ± 0.222 (0.556-1.087)		
Flathead catfish	1/1	0.097		
Hybrid striped bass	6/6	0.226 ± 0.066 (0.149-0.305)		
Largemouth bass	2/8	0.073 ± 0.077 (ND-0.257)		
White crappie	0/2	ND		
All Fish Combined	17/30	0.209 ± 0.256 (ND-1.087)		
Lead				
Channel catfish	0/8	ND	0.6	EPA IEUBKwin[c]
Common carp	0/5	ND		
Flathead catfish	0/1	ND		
Hybrid striped bass	0/6	ND		
Largemouth bass	0/8	ND		
White crappie	0/2	ND		
All Fish Combined	0/30	ND		

[*]Basis for comparison values are as follows: EPA chronic oral RfD: 0.001 mg/kg-day for cadmium and 0.300 mg/kg- day for Zinc.

Table 1c. Inorganic Contaminants (mg/kg) in Fish from Ellison Creek Reservoir, 2005

Contaminant	# Detected / # Sampled	Mean Concentration ± S.D. (Min-Max)	Health Assessment Comparison Value (mg/kg)	Basis for Comparison Value
Mercury				
Channel catfish	5/8	0.101 ± 0.168 (ND-0.513)	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg–day
Common carp	3/5	0.443 ± 0.911 (ND-2.073)		
Flathead catfish	1/1	0.148		
Hybrid striped bass	4/6	0.114 ± 0.125 (ND-0.350)		
Largemouth bass	8/8	0.159 ± 0.114 (0.057-0.329)		
White crappie	0/2	ND		
All Fish Combined	21/30	0.172 ± 0.379 (ND-2.073)		
Selenium				
Channel catfish	5/8	0.073 ± 0.061 (ND-0.183)	6	EPA chronic oral RfD: 0 .005 mg/kg–day ATSDR chronic oral MRL: 0.005 mg/kg–day NAS UL: 0.400 mg/day (0.005 mg/kg–day) RfD or MRL/2: (0.005 mg/kg –day/2= 0.0025 mg/kg–day) to account for other sources of selenium in the diet
Common carp	4/5	0.422 ± 0.288 (ND-0.734)		
Flathead catfish	1/1	0.181		
Hybrid striped bass	6/6	0.504 ± 0.184 (0.272-0.713)		
Largemouth bass	8/8	0.268 ± 0.110 (0.045-0.393)		
White crappie	2/2	0.422 ± 0.006 (0.418-0.426)		
All Fish Combined	26/30	0.296 ± 0.220 (ND-0.734)		
Zinc				
Channel catfish	8/8	5.437 ± 1.656 (3.611-8.777)	700	EPA chronic oral RfD: 0.3 mg/kg–day
Common carp	5/5	13.484 ± 6.393 (7.158-22.199)		
Flathead catfish	1/1	5.050		
Hybrid striped bass	6/6	4.934 ±1.620 (3.789-8.131)		
Largemouth bass	8/8	3.781 ± 0.641 (2.765-4.808)		
White crappie	2/2	4.057 ± 0.107 (3.981-4.132)		
All Fish Combined	30/30	6.131 ± 4.297 (2.765-22.199)		

[b] *Derived from the MRL or RfD for noncarcinogens or the USEPA slope factor for carcinogens; assumes a body weight of 70 kg, and a consumption rate of 30 grams per day, and assumes a 30-year exposure period for carcinogens and an excess lifetime cancer risk of 1x10*^{4}.

Table 2. Pesticide Contaminants (mg/kg) in Fish from Ellison Creek Reservoir, 2005

Contaminant	# Detected/ # Sampled	Mean Concentration ± S.D. (Min-Max)	Health Assessment Comparison Value (mg/kg)[1]	Basis for Comparison Value
p,p'-DDE				
Channel catfish	3/8	0.0054 ±0.0047 (ND-0.0152)		
Common carp	3/5	0.0050 ± 0.0025 (ND-0.0082)		
Flathead catfish	0/1	ND	1.167	EPA chronic oral RfD: 0.5 µg/kg–day
Hybrid striped bass	6/6	0.0021±0.0149 (0.0075-0.0429)		
Largemouth bass	0/8	ND	1.578	EPA slope factor 0.34 per mg/kg–day
White crappie	0/2	ND		
All Fish Combined	12/30	0.0073 ± 0.0096 (ND-0.0429)		
Chlordane				
Channel catfish	1/8	0.0061 ± 0.0030 (ND-0.0134)		
Common carp	0/5	ND		
Flathead catfish	0/1	ND	1.167	EPA chronic oral RfD: 0.5 µg/kg–day
Hybrid striped bass	6/6	0.0278 ± 0.0149 (0.0127-0.0549)	1.553	EPA slope factor 0.35 per mg/kg–day
Largemouth bass	0/8	ND		
White crappie	0/2	ND		
All Fish Combined	7/30	0.0098 ± 0.0112 (ND-0.0549)		

[1]Derived from the MRL or RfD for noncarcinogens or the USEPA slope factor for carcinogens; assumes a body weight of 70 kg, and a consumption rate of 30 grams per day, and assumes a 30-year exposure period for carcinogens and an excess lifetime cancer risk of 1x10^{4}.

Table 3. Polychlorinated Biphenyls (PCBs) (mg/kg) in Fish by Species and Site from Ellison Creek Reservoir, 2005

Contaminant	# Detected / # Sampled	Mean Concentration ± S.D. (Min-Max)	Health Assessment Comparison Value (mg/kg)	Basis for Comparison Value
Site 1 (Dam)				
Common carp	1/1	**0.2006**	0.047 0.272	EPA chronic oral RfD: 0.00002 mg/kg–day EPA slope factor: 2.0 per mg/kg–day
Flathead catfish	1/1	**0.0891**		
Hybrid striped bass	5/5	**0.9818** ± 0.4659 (0.5348-1.5465)		
Largemouth bass	3/3	**0.0958** ± 0.0593 (0.0336-0.1516)		
All Sampled Fish, Site 1	10/10	**0.5486** ± 0.5539 (0.0336-1.5465)		
Site 2 (AEP Power Plant Intake)				
Channel catfish	5/5	**0.2025** ± 0.1461 (0.0838-0.4077)	0.047 0.272	EPA chronic oral RfD: 0.00002 mg/kg–day EPA slope factor: 2.0 per mg/kg–day
Common carp	1/1	**0.1951**		
Hybrid striped bass	1/1	**0.4252**		
Largemouth bass	2/2	**0.1120** ± 0.0559 (0.0725-0.1516)		
All Sampled Fish, Site 2	9/9	**0.2063** ± 0.1389 (0.0725-0.4252)		
Site 3 (Barnes Creek Arm)				
Channel catfish	3/3	**0.1540** ± 0.0270 (0.1307-0.1836)	0.047 0.272	EPA chronic oral RfD: 0.00002 mg/kg–day EPA slope factor: 2.0 per mg/kg–day
Common carp	1/1	**0.1855**		
Largemouth bass	3/3	**0.1297** ± 0.0676 (0.0633-0.1984)		
All Sampled Fish, Site 3	7/7	**0.1481**±0.0467 (0.0633-0.1984)		
Site 4 (Upper Reservoir)				
Common carp	2/2	**0.3632** ±0.2299 (0.2006-0.5258)	0.047 0.272	EPA chronic oral RfD: 0.00002 mg/kg–day EPA slope factor: 2.0 per mg/kg–day
White crappie	2/2	0.0445 ±0.0169 (0.0326-0.0565)		
All Sampled Fish, Site 4	4/4	**0.2039** ± 0.2271 (0.0326-0.5258)		
All Sites (Sites Combined)				
Channel catfish	8/8	**0.1844** ±0.1141 0.0838-0.4077)	0.047 0.272	EPA chronic oral RfD: 0.00002 mg/kg–day EPA slope factor: 2.0 per mg/kg–day
Common carp	5/5	**0.2615** ±0.1479 (0.1855-0.5258)		
Flathead catfish	1/1	**0.0891**		
Hybrid striped bass	6/6	**0.8890** ±0.4747 (0.4252-1.5465)		
Largemouth bass	8/8	**0.1126** ± 0.0548 (0.0336-0.1984)		
White crappie	2/2	0.0445±0.0169 (0.0326-0.0565)		
All Sampled Fish, All Sites	30/30	**0.3065** ±0.3703 (0.0326-1.5465)		

Table 4. Systemic effects possible from consuming PCB-contaminated fish collected from Ellison Creek Reservoir in 2005. The table lists hazard quotients (HQ) for consumption of PCBs in fish and suggests appropriate consumption in meals/week for Adults weighing 70 kg by fish species. Recommendations for children's consumption are commensurately lower than those recommended for adults.

Species/Contaminant	Hazard Quotient	Meals per Week
Channel Catfish	**4**	**0.2**
Common Carp	**6**	**0.2**
Flathead catfish	**2**	**0.5**
Hybrid striped bass	**19**	**0.0**
Largemouth bass	**2**	**0.4**
White crappie	1	1.0
All species, combined	**7**	**0.1**

Table 5. Systemic effects are possible from consuming PCB-contaminated fish from Ellison Creek Reservoir (samples collected March, 2005). The table lists hazard quotients (HQs) for each species at each sampling site and suggests appropriate consumption in eight-ounce meals per week for adults weighing 70 kg. Recommended children's consumption is commensurately lower than that recommended for adults (children should eat no more than the suggested number of 4-ounce meals each week).

	Hazard Quotient (Meals per Week)			
Species/Contaminant	**Dam (Site 1) (N=10)**	**AEP Intake (Site 2) (N=9)**	**Barnes Creek Arm (Site 3) (N=7)**	**Upper Reservoir (Site 4) (N=4)**
Total PCBs				
Channel catfish	Not collected	**4 (0.2)**[1]	**3 (0.3)**	Not collected
Common carp	**4 (0.2)**	**4 (0.2)**	**4 (0.2)**	**8 (0.1)**
Flathead catfish	**2 (0.5)**	Not collected	Not collected	Not collected
Hybrid striped bass	**21 (0.0)**	**9 (0.1)**	Not collected	Not collected
Largemouth bass	**2 (0.5)**	**2 (0.4)**	**3 (0.3)**	Not collected
White crappie	Not collected	Not collected	Not collected	0.95 (1.0)
All Fish &Sites Combined, (N=30)	**7 (0.1)**			

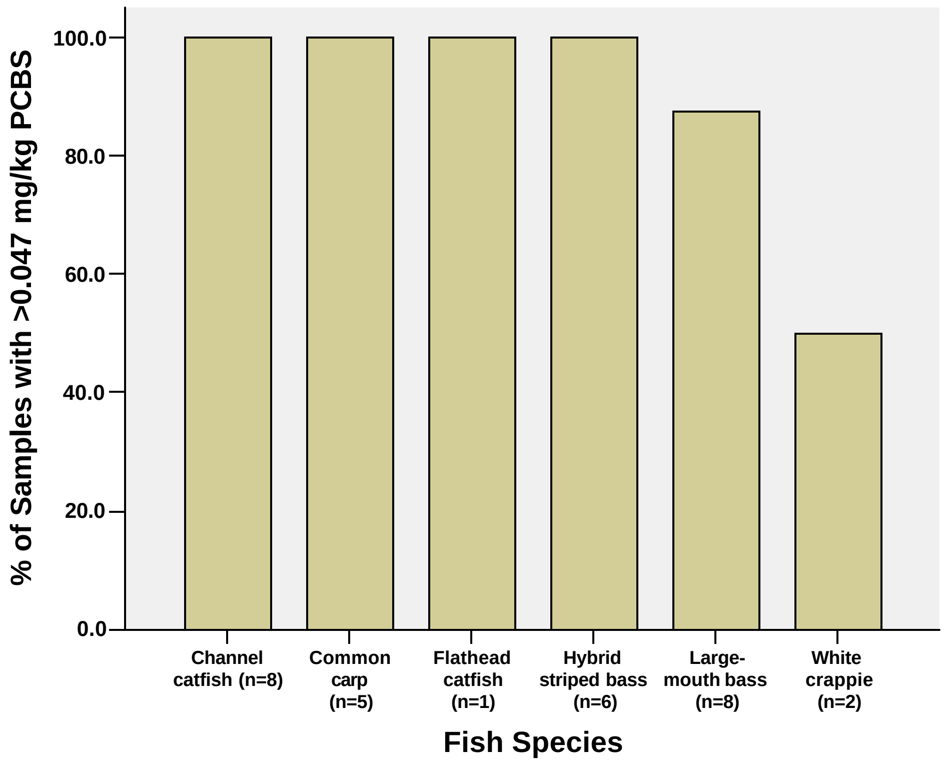
[1] *Cells in bold-face type show species and/or sites in which PCB average concentration exceeds DSHS reference concentration for PCBs used to ensure that human health is protected from systemic effects that could be associated with consuming polychlorinated biphenyls in fish collected from Ellison Creek Reservoir.*

Table 6. Theoretical lifetime excess cancer risk calculated from 2005 data for consumption of PCB-contaminated fish from Ellison Creek Reservoir. This table shows calculated theoretical excess lifetime cancer risk for each species collected and suggests weekly eight-ounce meal consumption rates for each species of fish.[1]

Species/Contaminant	Theoretical Lifetime Excess Cancer Risk		Meals per Week
	Risk	1 excess cancer per number exposed	
Channel catfish	6.8×10^{-5}	14,767	1.4
Common carp	9.6×10^{-5}	10,410	1
Flathead catfish	3.3×10^{-5}	30,539	3
Hybrid striped bass	**3.3×10^{-4}**	**3,062**	**0.3**
Largemouth bass	4.1×10^{-5}	24,185	2
White crappie	1.6×10^{-5}	61,132	6
All Fish Combined	**1.1×10^{-4}**	**8,882**	**0.8**

[1] DSHS calculated theoretical excess lifetime cancer risks and suggested consumption rates (meals/week) using a 70-kg adult who consumes 30 grams/day (approximately one 8-oz meal per week) of fish containing average concentrations of PCBs every day for 30 years.
[2] Numbers in boldface type exceed DSHS guidelines for protection of human health (1 excess cancer in 10,000 equally-exposed individuals).

Figure 1. Percentage of each species collected in 2005 from Ellison Creek Reservoir that contained PCBs in excess of DSHS guidelines for protection of human health.



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Appendix 1. Ellison Creek Reservoir Sampling Site Map