Characterization of Potential Adverse Health Effects from Consuming Fish from

CANYON RESERVOIR

Comal County, Texas

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Policy, Standards, and Quality Assurance Unit
Seafood and Aquatic Life Group
and
Division for Regulatory Services
and
Environmental and Injury Epidemiology and Toxicology Branch

INTRODUCTION

History of Canyon Reservoir

Canyon Reservoir, a 1964 impoundment of the Guadalupe River, is one of the deepest and most scenic of central Texas's "highland lakes". Nestled among the steep and wooded hills of Comal County, 44 miles north of San Antonio and 18 miles northwest of New Braunfels, Texas, Canyon Reservoir was impounded primarily for flood control and water conservation.[1] For decades, however, releases of waters from Canyon Reservoir have powered a series of small hydroelectric dams on the Guadalupe River downstream of the reservoir. Today, waters from Canyon Reservoir and the Guadalupe River have become an important component of regional plans to ensure an adequate supply of water for the 21st century along with being named the *"Water Recreation Capital of Texas"*.[2,3] The 8,308-acre reservoir, with an average depth of 43 feet, has areas as deep as 125 feet.[4,5] With approximately 90 miles of shoreline; Canyon Reservoir has normally clear, but sometimes slightly stained waters. Aquatic vegetation is sparse in Canyon Reservoir. Water-level fluctuates moderately. Over the years, Canyon Reservoir has become a popular recreational area, featuring public parks that offer excellent opportunities for outdoor recreation, especially well-utilized for boating and fishing. Several marinas, yacht clubs, and a ski club are located on the lake. Eight public parks – managed by the Fort Worth branch of the U.S. Army Corps of Engineers – are scattered along the shores of Canyon Reservoir: Canyon Park and Canyon Beach Swim Area; Comal Park; Crane's Mill Park; Guadalupe Park; Jacob's Creek Park; North Park; Overlook Park; and Potter's Creek Park.[4,5] Many of the parks near Canyon Reservoir offer well-developed campsites for tents and trailers, as well as boat ramps, restrooms, and picnic tables.

Predominant fish species in Canyon Reservoir include largemouth bass, smallmouth bass, Guadalupe bass, white and striped bass; and various species of catfish (blue, channel, and flathead).[6] Other species in Canyon Reservoir include crappie (black and white); shad (gizzard and threadfin), and sunfishes. The Texas Parks and Wildlife Department (TPWD) manages fishing activities in Canyon Reservoir under that agency's current statewide fishing regulations.[7] For the 2006-2007 fishing season, anglers may retain a total of 5 per day of largemouth bass, smallmouth bass, and Guadalupe bass, in any combination. Largemouth bass and smallmouth bass must be no less than 14 inches in length. No minimum length limit exists for Guadalupe bass. Striped bass must be at least 18 inches in length and anglers may harvest 5 per day. Fishers may keep up to 25 white bass per day. For legal possession white bass must be at least 10 inches long. Twenty-five channel catfish, blue catfish, their hybrids or subspecies may be caught each day. Catfish must be a minimum of 12 inches in length. The bag limit for flathead catfish is five per day. To be eligible for possession, flathead catfish must be at least 18 inches in length. Anglers may catch and keep 25 crappies per day. Crappies (white or black) must be 10 or more inches in length to be kept. No minimum length limit or bag limit exists for sunfish of any species.

The Texas Parks and Wildlife Department conducts creel surveys to provide estimates of fishing effort, catch and harvest rates, species size-distributions, angler valuations of fisheries and fisheries management, and angler preferences.[8] A Canyon Reservoir creel survey conducted by TPWD in 1999 revealed that the largemouth bass was the most sought after sportfish, with 46% of the total fishing effort directed toward this species.[9] White bass were the second most sought after species comprising 24.8 % of the total directed fishing effort. Directed fishing effort for striped bass during the 1990's ranged from 8-16%. Channel catfish directed fishing effort averaged less than 10% during the 1990's. Canyon Reservoir species directed fishing effort is similar to statewide angler preferences: 1) largemouth bass, 2) catfish species, 3) crappie, 4) striped bass, 5) white bass.[10]

At Canyon Reservoir, angling for largemouth bass and sunfish is rated "good." Fishing for smallmouth bass and crappie is rated as "poor," while catfish and striped/white bass fishing is "excellent." Striped bass do not reproduce in Canyon Reservoir, so this reservoir is regularly stocked by TPWD with this species.[6]

Canyon Reservoir Demographics Nearby Towns and Cities

Canyon Lake is an unincorporated area comprising the communities of Sattler, Startzville, Cranes Mill, and Hancock in Comal County, TX.[3] The 2000 estimated population of the area was 29,000 people. The lake is 18 miles West of New Braunfels, Texas (2000 population 36,494) – the Comal County seat – 23 miles west-southwest of San Marcos, TX (2000 population 34,733), 44 miles north of San Antonio (2000 population 1,144,646), and 54 miles south of Austin, TX (2000 population 656,562).[1,11]

History of the Statewide Fish Tissue Monitoring Program, State of Texas

Three Texas agencies, the Department of State Health Services (DSHS), the Texas Commission on Environmental Quality (TCEQ), and the Texas Parks and Wildlife Department (TPWD), have critical interests in – and responsibilities for –contaminants in the waters of Texas, their sediments, and the fish and shellfish that inhabit those waters. The Seafood and Aquatic Life Group (SALG) at DSHS determines whether chemical contaminants in fish or shellfish pose a health risk to those who would consume those fish or shellfish and – if so – is responsible for issuing health advisories or prohibiting possession of contaminated fish or shellfish from public water bodies in Texas.[12]

Among its other duties, the TCEQ establishes and manages state water quality standards and addresses pollution of Texas' public waters. The TPWD manages state fish and wildlife resources, addresses pollution that may adversely impact these resources, and enforces closures or bans issued by DSHS. These, and several other state and federal agencies have, for many years, coordinated efforts to oversee contaminant monitoring of fish from Texas waters – and their flora and fauna – through the Toxic Substances Coordinating Committee (TSCC), a legislatively mandated interagency committee.[13] For example, with United States Environmental Protection Agency (USEPA) funding, the DSHS, TCEQ, and the TPWD recently implemented a three-year effort to share resources, effectively establishing a pilot statewide fish tissue-monitoring project designed to assess water quality, ecological risks, and ramifications to human health of contaminants in fish or shellfish from selected water bodies. The results of the pilot study may later be used to seek state and/or federal funding for a permanent statewide fish tissue-monitoring program.

The Statewide Fish Tissue Monitoring Project (SFTMP) is a two-stage initiative (known as Tier 1 and Tier 2) that accesses the expertise and resources of the TCEQ, the TPWD, and the

DSHS.[14,15] The USEPA financed the SFTMP effort through fiscal year 2007 (ending August 31, 2007) with funds administered by the TCEQ. Most of the USEPA grant funds for this project are allocated to laboratory analysis of fish tissue for chemical contaminants that, upon regular consumption, could adversely impact the health of an individual or a population. The TPWD collects Tier 1 samples during routine fisheries management activities on major reservoirs, while the TCEQ collects Tier 1 samples from river segments. The primary goal of Tier 1 measurements is to identify frequently fished water bodies in Texas in which commonly consumed fish are contaminated with pollutants that might pose a risk to human health if eaten. Should a Tier 1 study show fish or shellfish from a water body to be contaminated, the DSHS conducts an intensive Tier 2 study, utilizing the data from the Tier 2 study to characterize potential risk to human health from consumption of such fish. In 2003, the three agencies selected for Tier 1 study 66 previously un-surveyed Texas reservoirs and 15 river segments.[14]

In October 2003, the TPWD sampled fish from Canyon Reservoir as a part of its routine fisheries management program. From this survey, TPWD collected one composite largemouth bass (predator species) sample composed of three largemouth bass ranging in length from 14.0 to 17.0 inches. The agency also prepared one composite channel catfish sample (bottom feeding fish species) from three individual channel catfish – ranging in length from 17.0 to 19.0 inches – collected during the initial survey. Samples were submitted for analysis to the TPWD laboratory in San Marcos, TX. The DSHS and TCEQ compared Tier 1 Canyon Reservoir laboratory results for target analytes to DSHS-established human health screening values (SVs) to identify contaminants that exceeded SVs and to determine whether Canyon Reservoir should be more intensively examined in a Tier 2 study.[14, 15] That comparison revealed that the concentration of mercury (0.7 mg/kg) in a composite largemouth bass sample exceeded the human health screening value for mercury (0.525 mg/kg). The mercury concentration in the composite largemouth bass sample equaled the DSHS guideline for assessing systemic human health effects of regular or prolonged oral exposure to mercury (0.7 mg/kg).

The current report (Tier 2 assessment) presents an overview of contaminants identified in fish collected from Canyon Reservoir in 2005 in response to the Tier 1 findings. The report addresses the implications to public health of consuming fish from this reservoir.

Mercury in the Environment

Mercury, an element, is present in the earth's crust, in air, water, soil, aquatic sediments, and in plants and animals, particularly in upper trophic level fish. Because mercury is an element, in nature, it is neither created nor destroyed. Thus, mercury cycles through various environmental media naturally and by human activities. Anthropogenic production of mercury is about equal to that of natural sources. Combustion of fossil fuels, especially coal, contributes significantly to environmental mercury loads, emitting elemental mercury or inorganic salts of mercury into the environment. Although mercury can exist as an element in the environment, it is a relatively reactive element, forming salts rather easily. The most important inorganic salts (those containing no carbon) include mercury monochloride (calomel-still used in topical medications), mercuric chloride (a corrosive salt that sublimates and is a violent poison), and mercuric sulfide (cinnabar ore from which mercury is mined; also known as vermilion, a red pigment used in paints). Aquatic microorganisms produce organic mercury from inorganic mercury salts or from elemental mercury; the most prominent organic mercury compound in aquatic organisms is mononmethylmercury, more commonly called "methylmercury." Certain conditions in water are conducive to the formation of methylmercury by aquatic microorganisms, including the presence of inorganic mercury in the water, a low water pH, high concentrations of organic matter in surface water or sediment, the necessary but not sufficient presence of microorganisms capable of converting inorganic mercury to organic mercury, and, because methylation of mercury is primarily an anaerobic (without oxygen) process, low dissolved oxygen concentrations.

Some aquatic organisms easily absorb methylmercury from water or from other aquatic organisms; if absorption of methylmercury is not immediately balanced by excretion, the concentration of methylmercury in the organism may exceed the concentration in the surrounding waters or foods, a process known as *bioconcentration*. Some fish have no physiological mechanisms for removing methylmercury from their bodies. Continued absorption of methylmercury without concomitant excretion results in accumulation of the substance in tissues, a process called *bioaccumulation*.[16] It follows from the process of bioaccumulation that older, larger fish may contain higher levels of methylmercury than younger, smaller fish. Predatory fish that do not excrete mercury and that eat smaller mercury-contaminated fish will accumulate higher levels of methylmercury because the source substances have higher levels of methylmercury. Thus, predators occupying niches near the top of the food chain attain even higher levels of methylmercury through the process of *biomagnification*. Humans are then often exposed to the toxicant through consumption of contaminated fish. Although humans can excrete methylmercury, the process is relatively slow. People who eat older, larger fish, those who eat predator fish, or those who eat more fish from higher on the food chain may be exposed to higher levels of methylmercury than those who eat fish dwelling near the bottom of the food chain (e.g. sunfish, channel catfish, blue catfish, common carp, etc). Those who eat fewer fish meals, or who eat smaller fish, or fish from lower on the food chain, thus, are often exposed to lower levels of methylmercury than are those who do not follow these recommendations. Certain vulnerable people who eat methylmercury-contaminated fish or shellfish – women who are pregnant or who may become pregnant, for instance – may store methylmercury in their bodies, releasing the mercury into their bloodstreams over time. These women may consume or store enough methylmercury to damage the fetal brain, thought to be the organ primarily damaged by methylmercury.[17] Although it is impossible to completely eliminate human exposure to mercury, people are primarily exposed to mono-methylmercury principally through consumption of contaminated fish. People who do not eat fish thus avoid most exposure to methylmercury. Consequently, methylmercury exposure is controllable. Knowledge of the whereabouts of methylmercury-contaminated fish or shellfish and of probable concentrations in those aquatic organisms gives people the option of limiting their exposure to this toxicant.

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*.[18] 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*.[19] Advice and direction are also received from the legislatively mandated *State of Texas Toxic Substances Coordinating Committee (TSCC) Fish Sampling Advisory Subcommittee (FSAS)*.[20] 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 better characterize geographical distributions of contaminants.

Description of the Canyon Reservoir 2005 Sample Set

In November 2005, SALG staff collected 30 fish samples from three sites around Canyon Reservoir. Risk assessors used data from these fish to examine potential human health risks from consuming fish from Canyon Reservoir.

The SALG selected three sites to provide spatial coverage of the study area (Figure 1). Site 1 was located near the Canyon Reservoir dam, Site 2 near the mid- reservoir area, and Site 3 near upper end of the reservoir. The SALG targeted species for collection from Canyon Reservoir through use of fish-tissue sampling protocols developed over many years by the SALG and it's legacy group, the Division of Seafood Safety at the Texas Department Health (now the Department of State Health Services). Collected species represent distinct ecological groups (i.e. predators and bottom-dwellers) that have some potential to bio-accumulate chemical contaminants, have a wide geographic distribution, are of local recreational fishing value, and/or are commonly consumed by anglers. The 30 fish collected from Canyon Reservoir in November 2005 represented all targeted species (Table 1). Targeted species and numbers collected are listed in descending order: largemouth bass (16), striped bass (4) blue catfish (4), flathead catfish (3), longnose gar (2), and white bass (1).

During each day of sampling, staff set gill nets at each of the sampling sites in the late afternoon and fished those overnight, collecting samples from the nets early the following morning. Gill nets were set to maximize available cover and habitat at each of the three sample sites in the reservoir. To keep specimens from different sample sites separated, staff placed captured fish retrieved from the nets in individual, labeled mesh bags, keeping all samples on wet ice until processed. SALG staff returned to the reservoir any remaining live fish culled from the catch. Staff also properly disposed of fish found dead in the gill nets.

At each site, in addition to the gill nets, staff utilized a boat-mounted electrofisher to collect fish. SALG staff conducted electrofishing activities during daylight and nighttime hours, using pulsed direct current (Smith Root 7.5 GPP electrofishing system settings: 4-6 amps, 60 pulses per second [pps], low range, 80% duty cycle) to stun fish that crossed the electric field in the water in front of the boat. Staff used dip nets over the bow of the boat to retrieve stunned fish, netting only fish pre-selected as target samples. Staff immediately stored retrieved samples on wet ice in large coolers to ensure interim preservation. Following completion of electrofishing at a selected sampling site, SALG staff placed the fish in individual, labeled mesh bags to keep separate the samples collected from different sites.

SALG staff processed fish at the TPWD Inland Fisheries District 2C office in San Marcos, TX. Each sample was weighed to the nearest gram using an electronic scale; total length (tip of nose to tip of tail fin) was measured to the nearest millimeter. After weighing and measuring a sample, staff prepared filleted skin-off fillets from the sample on a cutting board covered with aluminum foil, changing the foil between each sample. Prior to preparing each sample, distilled water was used to clean the fillet knife. Staff then double-wrapped the fillet or fillets in fresh aluminum foil, placing each wrapped fillet(s) in a clean pre-labeled plastic freezer bag. The specimens were stored on wet ice in insulated chests until further processing. At the end of the week's sampling, The SALG staff transported tissue samples on wet ice to headquarters in Austin, TX, where the samples were temporarily stored at -5° Fahrenheit (-20° Celsius) in a locked freezer, the key to which is accessible only to approved SALG staff members.

Analytical Laboratory Information

The week following the sample collection trip, the SALG shipped thirty samples frozen (skin-off fillets) on ice (wet) overnight to the Geochemical and Environmental Research (GERG) Laboratory, Texas A and M University, College Station, TX, by common carrier for contaminant analysis. The (GERG) laboratory, using established EPA methodology, analyzed fillets (skin off) of fish from Canyon Reservoir for some of the more common inorganic and organic contaminants. Seven metals – arsenic, cadmium, copper, lead, total mercury, selenium, and zinc – were analyzed, as were panels of volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), 34 pesticides representing the common pesticide classes: organophosphates, organochlorines, and carbamates, and 209 possible polychlorinated biphenyl congeners (PCBs). All thirty fish were analyzed for metals. Five of the submitted samples were also analyzed for SVOCs, VOCs, and 209 PCB congeners.[21]

The GERG laboratory notified the SALG upon receipt of the samples from Canyon Reservoir, recording the DSHS sample number and the condition of each tissue sample upon receipt of the samples. The laboratory has the capability of measuring polychlorinated dibenzo-para-dioxins and dibenzofurans; however, in the present case, these contaminants were not requested.

The GERG laboratory analyzed each of thirty fish for total (inorganic arsenic + organic arsenic = total arsenic) arsenic. Although the proportions of each form of arsenic may differ among species, under different water conditions, and, perhaps, with other variables, the literature suggests that well over 90% of arsenic in fish is likely organic arsenic – a form of arsenic that is virtually non-toxic to humans.[22] DSHS, taking a conservative approach, estimates 10% of the total arsenic in any fish is inorganic arsenic, deriving estimates of inorganic arsenic concentrations by multiplying reported total arsenic concentration/fish by a factor of 0.1.[22]

Nearly all mercury in upper trophic level fish three years of age or older is methylmercury.[23] Thus, the total mercury concentration in a fish of legal size for possession in Texas serves well as a surrogate for methylmercury concentration. Because methylmercury analyses are difficult to accurately perform and are more expensive than total mercury analyses, the USEPA recommends that states determine total mercury concentration in a fish and that – to protect human health – states conservatively assume that all reported mercury in fish or shellfish is methylmercury. The GERG laboratory thus analyzed fish tissues for total mercury. In its risk characterizations, DSHS compares mercury concentrations in tissues to a comparison value derived from the ATSDR's minimal risk level for methylmercury.[24] (In these risk characterizations, the DSHS may interchangeably utilize the terms "mercury," "methylmercury," or "organic mercury" to refer to methylmercury in fish.)

Statistical Analysis

SALG risk assessors employed SPSS® statistical software, version 13.0 installed on IBM-compatible microcomputers (Dell, Inc) 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 sample site.[25] SALG risk assessors utilized ½ the detection limit for all analytes not detected (ND) and estimated (J)[a] concentrations in computing descriptive statistics. SALG risk assessors imported previously edited Excel data files into SPSS® to generate means, standard deviations, median concentrations, and minimum and maximum concentrations of each measured analyte. SALG used the descriptive statistical results to generate the present report. SALG protocols do not require hypothesis testing. Nevertheless, when data are of sufficient quantity and quality, and, should the need arise, the SALG utilizes SPSS® software to determine significant differences in contaminant concentrations among species and/or collection sites. Hypothesis testing was not conducted on samples from Canyon Reservoir because sample size was small, samples of different species were limited, and only five fish were analyzed for PCBs, SVOCs and VOCs. The SALG employed Microsoft Excel® spreadsheets to generate figures, to compute health-based assessment comparison values (HAC_{nonca}) for contaminants, and to calculate hazard quotients (HQ), hazard indices (HI), cancer risk probabilities, and meal consumption limits for fish from Canyon Reservoir.[26] For lead, when data are of sufficient interest and quality, the SALG utilizes the USEPA's Interactive Environmental Uptake Bio-Kinetic (IEUBK) model to determine whether consumption of lead in fish could cause children's blood lead (PbB) level to exceed 10 micrograms/deciliter, a concentration designated by the Centers for Disease Control and Prevention as of concern to the health of children exposed to environmental lead.[27]

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

People who regularly consume contaminated fish or shellfish conceivably suffer repeated exposures to relatively low concentrations of contaminants over extended time periods. Such exposures are unlikely to result in acute toxicity but may increase risk of subtle, chronic, and/or delayed adverse health effects that include cancer, benign tumors, birth defects, infertility, blood disorders, brain damage, peripheral nerve damage, lung disease, and kidney disease, to name but a few.[28] Presuming people to eat a variety of fish and/or shellfish from a specific water body if species variety is available, the DSHS routinely collapses data across species and sampling sites to evaluate mean contaminant concentrations in all samples from a specific water body because this approach intuitively reflects consumers' exposure over time to contaminants in fish or shellfish from a water body – unless specific data contradict this assumption. In such cases, the agency might examine risks associated with ingestion of individual species of fish or shellfish from separate collection sites or at higher concentrations (e.g., the upper 95 percent confidence

[a] "J-value" is standard laboratory nomenclature for analyte concentrations that are detectable in a sample, but quantitation of which may be suspect because those concentrations lie on a part of the standard curve that is not linear.

limit on the mean concentration; confidence intervals are derived from Monte Carlo simulation techniques with software developed by Dr. Richard Beauchamp, of the DSHS).[29]
The DSHS evaluates contaminants in fish by comparing the mean, and – when appropriate – compares the 95% upper confidence limit on the mean concentration of a contaminant to its health-based assessment comparison (HAC) value (measured in milligrams of contaminant per kilogram of edible tissue – mg/kg) derived for non-cancer or 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)[30] or the Agency for Toxic Substances and Disease Registry's (ATSDR) chronic oral minimal risk levels (MRLs)[31] to generate HAC values used in evaluating systemic (noncancerous) adverse health effects. The USEPA 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.*[32]

EPA also states that the RfD

> … *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.*[32]

The ATSDR uses a similar technique to derive *minimal risk levels* (MRLs).[31] The DSHS compares the estimated daily dose (mg/kg/day) – derived from the mean of the measured concentrations of a contaminant – to the contaminant's RfD or MRL, using hazard quotient (HQ) methodology as suggested by the USEPA.

A HQ, defined by the EPA, *is*

> *…the ratio of the estimated exposure dose of a contaminant (mg/kg/day) to the contaminant's RfD or MRL (mg/kg/day).*[33]

Note that a linear increase in the hazard quotients for a site or species does *not* represent a linear increase in the likelihood or severity of systemic adverse effects (i.e., a substance having an HQ of 2 is not twice as toxic as if the substance had an HQ of 1.0. Similarly, a substance with a HQ of 4 does not imply that adverse events will be four times more likely than a HQ of 1.0). As stated by the EPA, a HQ (or an HI) of less than 1.0 "is no cause for concern, whereas an HQ (or HI) greater than 1.0 should indicate some cause for concern." Thus, risk managers at the DSHS utilize a HQ of 1.0 as a "jumping-off point" not for decisions concerning likelihood of occurrence of adverse systemic events, but as a point of departure for management decisions that assume, in a manner similar to EPA decisions, that fish or shellfish having a hazard quotient of less than 1.0 are unlikely to be cause for concern. Since the chronic oral RfD derived by the

USEPA represents chronic consumption, eating fish with a toxicant-to-RfD ratio (the HQ) of less than 1.0 is not likely to result in adverse health effects, whereas routine consumption of fish where the HQ for a specific chemical exceeds 1.0 represents a qualitatively unacceptable increase in the likelihood of systemic adverse health outcomes.

Although DSHS preferentially utilizes a reference dose (RfD) derived by federal scientists for each contaminant, should no RfD be available for a specific contaminant, the USEPA advises risk assessors to consider using a reference dose determined for a contaminant of similar molecular structure, or mode or mechanism of action. For instance, DSHS – as specifically directed by the USEPA – uses the published reference dose for Aroclor 1254 to assess noncarcinogenic effects of Aroclor 1260, for which no reference dose is available – the USEPA has derived one other reference dose for Aroclors – that of Aroclor 1016. However, Aroclor 1016 is not as clearly like Aroclor 1260 as is Aroclor 1254. In the past, when DSHS had access only to the relatively crude measurement of Aroclors, the agency did not attempt to determine the dioxin equivalent toxicity of coplanar PCBs found in fish. Within the past year, however, DSHS has adopted analysis of PCB congeners, as suggested by the USEPA, allowing the agency to identify the presence of coplanar or dioxin-like PCBs and to apply toxicity equivalency factors (TEFs) to those PCBs in fish should SALG staff consider this a priority.

The constants (RfDs, MRLs) the DSHS employs to calculate HAC_{nonca} values are derived by federal agencies from the peer-reviewed literature (which the federal agencies routinely re-examine). These values incorporate built-in margins of safety called "uncertainty factors" or "safety factors" as mentioned in EPA reference materials.[32] In developing oral RfDs and MRLs, federal scientists review the extant literature to determine experimentally-derived NOAELs, LOAELs, or BMDs, then utilize uncertainty factors to minimize potential systemic adverse health effects in people who are exposed through consumption of contaminated materials by accounting for certain conditions that may be undetermined by the experimental data: extrapolation from animals to humans (interspecies variability), intra-human variability, use of a subchronic study rather than a chronic study to determine the NOAEL, LOAEL, or BMD, and database insufficiencies.[30] Vulnerable groups – women who are pregnant or lactating, women who may become pregnant, the elderly, infants, children, people with chronic illnesses, those with compromised immune systems, or those who consume exceptionally large servings, called "sensitivities" by the EPA, also receive special consideration in calculations of the RfD.[32, 34]

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 of carcinogenicity studies. For carcinogenic outcomes, the DSHS calculates a theoretical lifetime excess risk of cancer for specific exposure scenarios for 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)[32] of one excess cancer case in 10,000 persons whose average daily exposure is equal and (2) daily exposure for 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 quite conservative, adverse systemic or carcinogenic health effects are unlikely to occur, even if exposures are consistently greater or for longer times than those used for comparison values. Moreover, comparison values for adverse health effects (systemic or carcinogenic) do not represent sharp dividing lines (bright-line divisions) 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 the public's health. For instance, the DSHS considers 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 to 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.[35, 36] Windows of special vulnerability; known as "critical developmental periods," exist during development. Critical periods occur particularly during early gestation (weeks 0 through 8), 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 susceptible systems.[37] Unique early sensitivities may exist 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, or excretion of toxicants, any of which factors could alter the concentration of biologically effective toxicant at the target organ(s) or which could modulate target organ 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 often goes unrecognized (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 the contaminated foodstuff). Children may experience effects at a lower exposure dose than might 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.[38] 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 further modified to assure protection of the immature system's potentially greater susceptibility.[30] Additionally, in accordance with the ATSDR's *Child Health Initiative*[39] and the EPA's *National Agenda to Protect Children's Health from Environmental Threats,*[40] 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 contaminants in fish or shellfish by eating no more than four ounces per meal of the contaminated species. The DSHS also recommends that consumers spread these meals over time. For instance, if the DSHS issues consumption advice recommending consumption of no more than two meals per month of a contaminated species, those children should eat no more than 24 meals of the contaminated fish or shellfish per year and, ideally, should not eat such fish or shellfish more than twice per month.

RESULTS

Laboratory Analysis Results

The GERG laboratory submitted electronic copies of the results of laboratory analyses of chemicals in the Canyon Reservoir samples to the DSHS in August 2006. The laboratory analyzed thirty fish for metals and five of those same samples for pesticides, PCBs, semivolatile organic compounds (SVOCs) and volatile organic compounds (VOCs).

Summary results of inorganic or “metallic” contaminants (arsenic, cadmium, copper, lead, mercury, selenium, and zinc in fish collected in November 2005 from Canyon Reservoir are presented in Tables 2a-2c, and 3. Raw data are available from the SALG upon request.

Inorganic or Metallic Contaminants

Arsenic, Cadmium, Copper, Lead, Selenium, and Zinc

Inorganic contaminants/constituents such as arsenic, cadmium, copper, selenium, and zinc were reported present in many fish at concentrations of no importance to human health. Lead in fish was reported below the laboratory’s detection limit as estimated “J” concentrations in four of thirty fish samples (Table 2b). Therefore, the present report addresses only summarily the results of analyses for these contaminants, some of which are essential nutrients.

Laboratory analysis revealed arsenic, cadmium, copper, selenium, and zinc in fish samples collected from Canyon Reservoir (Tables 2a, 2b, 2c). Twenty five of thirty samples contained arsenic, with largemouth bass containing the highest average concentration (Table 2a). One (striped bass) of thirty samples contained cadmium (Table 2b). In fish, copper averaged 0.147±0.073 mg/kg (Table 2b). Copper was present in twenty eight of thirty samples. All samples collected from Canyon Reservoir in 2005 contained selenium (Table 2c). A white bass contained the highest concentration of selenium (1.588 mg/kg) while blue catfish contained the lowest levels (0.243±0.034 mg/kg; Table 2c). Other species contained selenium at levels intermediate between these two species. Zinc was present in all samples assayed (Table 2c) Average concentrations ranged from 2.650 mg/kg in to 5.139 mg/kg. Largemouth bass tissues contained the highest mean concentration of zinc, followed by flathead catfish, blue catfish, white bass, longnose gar, and striped bass.

Mercury

Mercury, while present in all samples (Tables 2c, 3), varied in concentration among species examined; Striped bass tissues contained the highest mean mercury concentration, followed by longnose gar, largemouth bass, flathead catfish, white bass, and blue catfish. The average concentration of mercury in striped bass from Canyon Reservoir was 1.149±0.195 mg/kg (Tables 2c, 3). The median concentration of mercury in striped bass was 1.111 mg/kg. Longnose gar tissues contained a mean mercury concentration of 0.772±0.033 mg/kg (Tables 2c, 3), while the mercury concentration in largemouth bass averaged 0.417±0.172 mg/kg edible tissue (Tables 2c, 3). The maximum mercury concentration (0.844 mg/kg) in largemouth bass was observed in a nine year old largemouth bass that measured 25.71 inches and weighed 10.58 lb. The mean mercury concentration in all fish combined was 0.498±0.326 (Tables 2c, 3).

Organic Contaminants

The GERG laboratory analyzed five of thirty fish tissue samples from Canyon Reservoir for commonplace and/or legacy pesticides, the presence of a possible 209 PCB congeners, and a suite of SVOCs and VOCs.

Pesticides

Five of thirty fish from Canyon Reservoir were analyzed for thirty four (34) pesticides representative of legacy and/or major pesticide groups such as organochlorines, organophosphates, and carbamates (data not presented). Trace[b] quantities of 2,4' DDE, 4,4' DDE, and 4,4' DDD, metabolites and/or degradation products of DDT, an insecticide, were present in fish samples. All five fish contained reportable concentrations of 4,4'DDE. Diazinon was reported below the laboratory's detection limit as estimated "J" concentrations in four of five fish samples. No other pesticides were reported present in fish from Canyon Reservoir.

PCBs

Trace quantities of PCBs – representing one or more of the congeners between PCB #43 and PCB #194 (International Union of Pure and Applied Chemists [IUPAC] assigned numbers) – were reported at detectable low concentrations or estimated concentrations (J-values) (data not presented).

SVOCs

Five of thirty fish collected from Canyon Reservoir were analyzed for the standard suite of SVOCs. Trace quantities of phenol, benzo(g,h,i)perylene, dibenz(a,j)acridine, dibenz(a,h)anthracene, diethyl phthalate, di-n-butyl phthalate, and bis (2-ethylhexyl) phthalate

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[b] Trace: an extremely small amount of a chemical compound, one present in a sample at a concentration below a standard limit. Trace quantities may be designated in the data with the "less than" (<) sign or may also be represented by the alpha character "J" – called a "J-value" defining the concentration of a substance as near zero or one that is detected at a low level but that is not guaranteed quantitatively replicable.

were reported below the laboratory's method detection limit as estimated "J" concentrations (data not presented).

VOCs

Acetone, carbon disulfide, and methylene chloride were observed in most of the five samples analyzed for VOCs (data not presented). However, concentrations of these contaminants were also identified in the procedural blanks indicating the possibility of laboratory or sample handling contamination. The concentrations reported in the fish tissue samples were higher than those reported in the procedural blanks. The laboratory reported 1, 2-dichloroethane, toluene, and naphthalene in two or more samples at concentrations near or below the method detection limit (data not presented).

DISSCUSSION

Characterization of Possible Systemic (Noncancerous) Health Effects Related to Consumption of Fish from Canyon Reservoir

The actual risk of adverse health outcomes from exposure to toxicants based on experimental or epidemiological data must be weighed against the known variability of individual and population responses, which may show toxicities orders of magnitude above or below mathematically estimated risks of systemic or local effects of toxicants on various organ systems in different species under different conditions.[30] Nevertheless, the DSHS calculated risk parameters for potential toxicity to humans who consume contaminated fish from Canyon Reservoir. Conclusions and recommendations predicated upon the stated goal of the DSHS to protect human health follow this discussion of findings.

Mercury was the only contaminant in fish from Canyon Reservoir that exceeded DSHS guidelines for protection of human health. No other toxicologically significant inorganic or organic contaminant concentrations were reported. Therefore, it was not necessary to evaluate these constituents for systemic health effects related to consumption of fish from Canyon Reservoir.

Mercury

All fish collected from Canyon Reservoir in 2005 contained mercury (Tables 2c, 3). Mean mercury concentrations in blue catfish (0.199 mg/kg), flathead catfish (0.337 mg/kg), largemouth bass (0.417 mg/kg), and white bass (0.316 mg/kg) did not exceed the HAC_{nonca} for methylmercury or a HQ of 1.0 (Tables 2c, 3, 4). HQ's for these species ranged from 0.28 to 0.60 (Table 4). Therefore, consumption of blue catfish, flathead catfish, largemouth bass, and white bass from Canyon Reservoir is not expected to result in adverse health effects from mercury even if these fish are consumed for a lifetime. Mean mercury concentrations in longnose gar and striped bass exceeded the HAC_{nonca} for methylmercury and exceeded a HQ of 1.0 (Tables 2c, 3, 4). DSHS examined two longnose gar and four legal-size striped bass (21.3-24.1 inches). Based on TPWD mean length at age data for Canyon Reservoir, striped bass samples collected in this study were between four and five years old. The mean mercury concentrations in longnose gar and striped bass were 0.772 mg/kg and 1.149 mg/kg, respectively (Tables 2c, 3). SALG risk assessors calculated that adults consuming more than two eight-ounce meals per month of striped bass or three eight ounce meals of longnose gar from Canyon Reservoir could exceed the ATSDR's chronic oral minimal risk level (MRL) [31] of 0.0003 mg methylmercury/kg-day, as could a 35 kg child consuming more than two four ounce meals per month of striped bass or three four ounce meals per month of longnose gar.

Characterization of the Possibility of Excess Lifetime Cancer Risk from Consumption of Fish from Canyon Reservoir

Few published reports exist of cancer in humans after exposure to methylmercury.[17] Although, methylmercury has been associated with neoplastic changes in the kidneys of experimental animals, those changes generally occurred only at doses that caused significant systemic toxicity and were associated with alterations in structure or function classified as threshold effects.[17] Therefore, although the USEPA has determined that methylmercury is a possible human carcinogen (Group C),[17] it is likely that systemic (noncancer) effects would occur at methylmercury exposures much lower than those required for tumor formation. Long-term administration of methylmercury to experimental animals produces overt symptoms of neurotoxicity at daily doses an order of magnitude lower than those required to induce tumors in mice. Thus, the USEPA has deemed it inappropriate to derive a cancer slope factor for methylmercury. Consequently, it was unnecessary to assess carcinogenic risk from consuming mercury-contaminated fish from Canyon Reservoir.

No other toxicologically significant inorganic or organic contaminant concentrations were reported. Therefore, it was not necessary to evaluate cancer risk related to consumption of fish from Canyon Reservoir.

Characterization of Cumulative Systemic Health Effects and Cumulative Excess Lifetime Cancer Risk from Consumption of Fish from Canyon Reservoir

Risk assessment guidelines from the USEPA 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) may be additive and that risk from individual chemicals can be summed to obtain an estimate of overall risk to those who are simultaneously exposed to more than one of those contaminants.[41, 42] 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.

Mercury was the only contaminant in fish from Canyon Reservoir that exceeded DSHS guidelines for protection of human health. No other toxicologically significant inorganic or organic contaminants were reported. Therefore, it was not necessary to evaluate samples from this reservoir for cumulative toxic effects

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 to the health of those who eat contaminated fish or seafood to risk managers at DSHS, including the Texas Commissioner of State Health Services.

This study addressed the public health implications of consuming fish from Canyon Reservoir. Risk assessors from the SALG and the Environmental and Injury Epidemiology and Toxicology Branch (EIETB) conclude from the present characterization of potential adverse health effects from consuming contaminated fish from Canyon Reservoir

1. That striped bass and longnose gar collected from Canyon Reservoir in 2005 contained mercury at levels exceeding DSHS guidelines for protection of human health. Regular or long-term consumption of striped bass and/or longnose gar could result in systemic adverse health effects. Therefore consumption of striped bass and longnose gar from Canyon Reservoir constitutes a **public health hazard.**

2. That based on observed mercury concentrations in blue catfish, flathead catfish, largemouth bass, and white bass from Canyon Reservoir, people may continue to eat these species from Canyon Reservoir without restriction (DSHS defines unrestricted consumption as four or more meals per month).

3. That fish collected from Canyon Reservoir do not contain arsenic, cadmium, copper, lead, selenium, or zinc at concentrations of significance to human health. Therefore, were people able to confine consumption of fish from Canyon Reservoir to those containing only these inorganic components – some of which are essential nutrients – consumption would pose **no apparent public health hazard.**

4. That fish collected from Canyon Reservoir do not contain organic contaminants, including PCBs, pesticides, SVOCs, and 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 Canyon Reservoir to those containing only these organic contaminants 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 USEPA.[21] Confirmation through risk characterization that consumption of four or fewer meals per month (adults: eight ounces per meal; children: four ounces per meal) of fish or shellfish from a specific water body would result in exposures to toxicants in excess of DSHS health-based guidelines might lead managers to recommend consumption advice for fish or shellfish from the water body. As an alternative, the department may ban possession of fish from the affected water body. Fish or shellfish possession bans are enforceable under subchapter D of the Texas Health and Safety Code, part 436.061(a).[12] Declarations of prohibited harvesting areas are enforceable under subchapter D of the Texas Health and Safety Code, part 436.091 and 436.101.[12] Consumption advisories are informative, carrying no penalties for noncompliance. DSHS consumption advisories inform the public of health hazards from consuming contaminated fish or shellfish from Texas waters so that members of the public can make informed decisions about eating contaminated fish or shellfish. The SALG and the EIETB of DSHS conclude from this risk characterization that consuming striped bass and/or longnose gar from Canyon Reservoir poses a hazard to public health. Therefore, the SALG and the EIETB recommend

1. That the DSHS advises adults to consume no more than two (2) eight ounce (8 oz) meals per month of striped bass or longnose gar from Canyon Reservoir. Women who are of childbearing age, who are or who might become pregnant, or who are nursing, should not consume striped bass or longnose gar from Canyon Reservoir.

2. That the DSHS advises children under twelve (12) years old to consume no more than two (2) four ounce (4 oz) meals per month of striped bass or longnose gar from Canyon Reservoir.

3. That the DSHS advises people that fish species other than striped bass and longnose gar pose no risk to human health and may continue to be eaten without restriction.

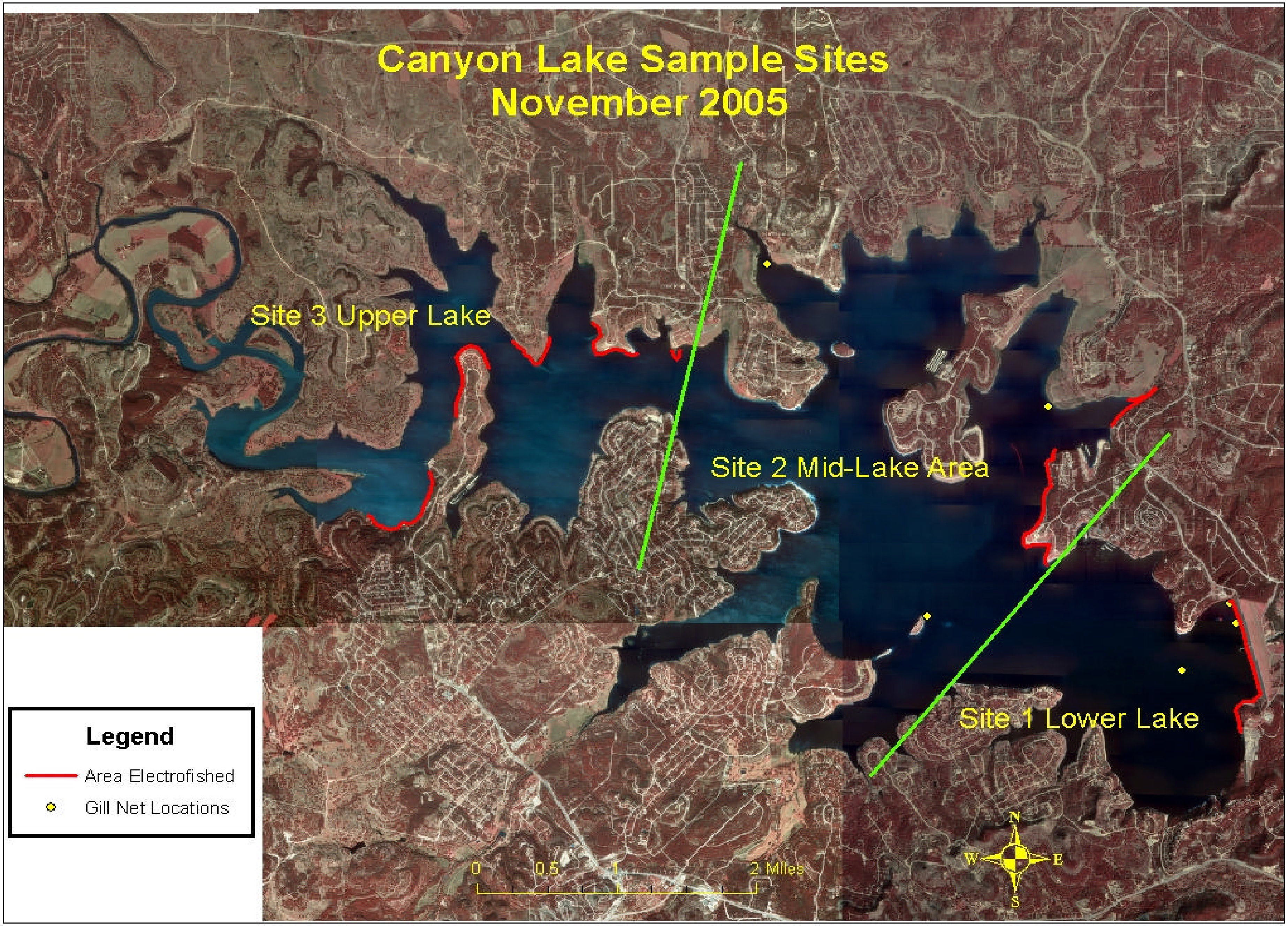
4. That as resources become available, the DSHS continues to monitor Canyon Reservoir for mercury and other contaminants that could pose a threat to human health.

PUBLIC HEALTH ACTION PLAN

The Texas Department of State Health Services (DSHS) publishes fish consumption advisories and bans in a booklet available to the public through the Seafood and Aquatic Life Group (SALG). To receive the booklet and/or the data, please contact the SALG at 1-512-834-6757.[43] The SALG also posts information on advisories and bans on the Internet at URL: http://www.dshs.state.tx.us/seafood. The SALG regularly updates this web site. The Texas Department of State Health Services provides the U.S. Environmental Protection Agency (http://epa.gov/waterscience/fish/advisories/), 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 possession bans. Each year, the TPWD informs the fishing and hunting public of consumption advisories and fishing bans in an official hunting and fishing regulations booklet available at many state parks and at all establishments selling Texas fishing licenses.[44] Readers may direct questions about the scientific information or recommendations in this risk characterization to risk managers at the Seafood and Aquatic Life Group (SALG) at 1-512-834-6757 or may find the information at the SALG's website (http://www.dshs.state.tx.us/seafood). Secondarily, one may address queries to the Environmental and Injury Epidemiology Branch at of the Department of State Health Services (1-512-458-7269. Toxicological information on these and many other 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 (1-888-42-ATSDR or 1-888-422-8737) or from the ATSDR website (URL: http://www.atsdr.cdc.gov) where brief information is available in that agency's ToxFACs.® ToxFACs is available on the ATSDR website in either English (http://www.atsdr.cdc.gov/toxfaq.html) or in Spanish (http://www.atsdr.cdc.gov/es/toxfaqs/es_toxfaqs.html). More in-depth reviews of many toxic substances are published by the ATSDR in its Toxicological Profiles. To request a copy of available Toxicological Profiles, readers may call the ATSDR at 1-404-498-0261 or email their requests to atsdric@cdc.gov. Many Toxicological Profiles are available for downloading at ATSDR's website.

FIGURE 1. Canyon Reservoir Sample Site Map November, 2005.



TABLES

Table 1. Fish Samples Collected from Canyon Reservoir. Sample Number, Species, Length, and Weight were Recorded for Each Sample Collected from Each of Three Sites within the Reservoir between November 7 and November 10, 2005.

Date	Sample Number	Species	Length (mm)	Weight (g)
Site 1 Canyon Lake Dam				
11/7-10/05	CAN14	Blue Catfish	685	3573
	CAN12	Blue Catfish	655	3058
	CAN13	Blue Catfish	647	3138
	CAN28	Largemouth Bass	653	4801
	CAN10	Largemouth Bass	421	1109
	CAN17	Largemouth Bass	400	987
	CAN18	Largemouth Bass	383	708
	CAN16	Largemouth Bass	379	628
	CAN8	Striped Bass	614	2729
	CAN6	Striped Bass	585	1898
	CAN7	Striped Bass	555	1381
	CAN9	White Bass	346	529
Site 2 Mid-Reservoir Area				
11/7-10/05	CAN29	Blue Catfish	665	2987
	CAN19	Flathead Catfish	701	3468
	CAN2	Flathead Catfish	660	3278
	CAN3	Flathead Catfish	575	2045
	CAN27	Largemouth Bass	582	3514
	CAN22	Largemouth Bass	428	1104
	CAN20	Largemouth Bass	418	885
	CAN23	Largemouth Bass	413	978
	CAN24	Largemouth Bass	397	806
	CAN21	Largemouth Bass	390	731
	CAN4	Longnose Gar	1200	5630
	CAN5	Longnose Gar	1020	3096
	CAN1	Striped Bass	541	1487
Site 3 Upper Reservoir				
11/7-10/05	CAN33	Largemouth Bass	446	1225
	CAN32	Largemouth Bass	415	912
	CAN30	Largemouth Bass	410	780
	CAN34	Largemouth Bass	395	755
	CAN31	Largemouth Bass	362	623

Table 2a. Arsenic (mg/kg) in Fish from Canyon Reservoir, 2005.

Species	# Detected/ # Sampled	Total Arsenic Mean Concentration ± S.D. (Min-Max)	Inorganic Arsenic Mean Concentration[c]	Health Assessment Comparison Value (mg/kg)[e]	Basis for Comparison Value
Blue catfish	2/4	0.038 ± 0.040 (ND-0.098)	**0.004**	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
Flathead catfish	0/3	ND[d]	**ND[d]**		
Largemouth bass	16/16	0.086 ± 0.049 (0.032-0.196)	**0.009**		
Longnose gar	2/2	0.039 ± 0.013 (0.030-0.048)	**0.004**		
Striped bass	4/4	0.062 ± 0.032 (0.031-0.101)	**0.006**		
White bass	1/1	0.184	**0.018**		
All Fish Combined	25/30	0.068 ± 0.052 (ND-0.196)	**0.007**		

[c] 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.
[d] ND: "Not Detected" was used to indicate that a compound was not present in a sample at a level greater than the MDL.

Table 2b. Inorganic Contaminants (mg/kg) in Fish from Canyon Reservoir, 2005.

Contaminant	# Detected/ # Sampled	Mean Concentration ± S.D. (Min-Max)	Health Assessment Comparison Value (mg/kg)[e]	Basis for Comparison Value
Cadmium				
Blue catfish	0/4	ND[d]	0.47	ATSDR chronic oral MRL: 0.0002 mg/kg–day
Flathead catfish	0/3	ND		
Largemouth bass	0/16	ND		
Longnose gar	0/2	ND		
Striped bass	1/4	ND-0.017		
White bass	0/1	ND		
All Fish Combined	1/30	ND		
Copper				
Blue catfish	4/4	0.119 ± 0.018 (0.107-0.145)	333	National Academy of Science Upper Limit: 0.143 mg/kg–day
Flathead catfish	3/3	0.092 ± 0.011 (0.080-0.100)		
Largemouth bass	14/16	0.092 ± 0.011 (0.038-0.266)		
Longnose gar	2/2	0.107 ± 0.011 (0.099-0.115)		
Striped bass	4/4	0.219 ± 0.069 (0.116-0.267)		
White bass	1/1	0.316		
All Fish Combined	28/30	0.147 ± 0.073 (0.038-0.316)		
Lead				
Blue catfish	0/4	ND	0.6	EPA IEUBKwin[c]
Flathead catfish	0/3	BDL[f]		
Largemouth bass	0/16	BDL		
Longnose gar	0/2	ND		
Striped bass	0/4	ND		
White bass	0/1	ND		
All Fish Combined	0/30	ND		

[e] *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}.*

[f] BDL: "Below Detection Limit" – Concentrations were reported as less than the laboratory's method detection limit ("J" values). In some instances, a "J" value was used to denote the discernable presence in a sample of a contaminant at concentrations estimated as different from the sample blank, while at other times, a "<" followed by the laboratory's MDL was utilized to note that a contaminant was detected below the detection limit, but was not quantified.

Table 2c. Inorganic Contaminants (mg/kg) in Fish from Canyon Reservoir, 2005.				
Contaminant	**# Detected / # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)[e]**	**Basis for Comparison Value**
Mercury				
Blue catfish	4/4	0.199 ± 0.086 (0.119-0.321)	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg–day
Flathead catfish	3/3	0.337 ± 0.205 (0.167-0.564)		
Largemouth bass	16/16	0.417 ± 0.172 (0.188-0.844)		
Longnose gar	2/2	**0.772** ± 0.033 (0.749-0.795)		
Striped bass	4/4	**1.149** ± 0.195 (0.955-1.418)		
White bass	1/1	0.316		
All Fish Combined	30/30	0.498 ± 0.326 (0.119-1.418)		
Selenium				
Blue catfish	4/4	0.243 ± 0.034 (0.203-0.282)	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
Flathead catfish	3/3	0.282 ± 0.105 (0.218-0.403)		
Largemouth bass	16/16	0.693 ± 0.192 (0.378-1.015)		
Longnose gar	2/2	0.593 ± 0.105 (0.518-0.667)		
Striped bass	4/4	0.978 ± 0.243 (0.731-1.211)		
White bass	1/1	1.588		
All Fish Combined	30/30	0.653 ± 0.331 (0.203-1.588)		
Zinc				
Blue catfish	4/4	3.699 ± 0.755 (2.893-4.657)	700	EPA chronic oral RfD: 0.3 mg/kg–day
Flathead catfish	3/3	3.731 ± 0.356 (3.465-4.135)		
Largemouth bass	16/16	5.139 ± 1.033 (3.331-7.214)		
Longnose gar	2/2	2.749± 0.464 (2..421-3.077)		
Striped bass	4/4	2.650 ± 0.394 (2.154-3.112)		
White bass	1/1	3.695		
All Fish Combined	30/30	4.267 ± 1.291 (2.154-7.214)		

Table 3. Mercury (mg/kg) in Fish by Species and Site collected from Canyon Reservoir in 2005.				
Contaminant	**# Detected / # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)[e]**	**Basis for Comparison Value**
Site 1 (Dam)				
Blue catfish	3/3	0.206 ± 0.104 (0.119-0.321)		
Largemouth bass	5/5	0.502 ± 0.194 (0.383-0.844)		
Striped bass	3/3	**1.059** ± 0.092 (0.955-1.132)	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg–day
White bass	1/1	0.316		
All Sampled Fish, Site 1	12/12	0.552 ± 0.0.355 (0.119-1.132)		
Site 2 (Mid-Reservoir)				
Blue catfish	1/1	0.180		
Flathead catfish	3/3	0.337 ± 0.205 (0.167-0.564)		
Largemouth bass	6/6	0.320 ± 0.129 (0.188-0.460)		
Longnose gar	2/2	**0.772** ± 0.033 (0.749-0.795)	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg–day
Striped bass	1/1	**1.418**		
All Sampled Fish, Site 2	13/13	0.467 ± 0.356 (0.167-1.418)		
Site 3 (Upper Reservoir)				
Largemouth bass	5/5	0.449 ± 0.169 (0.220-0.642)	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg–day
Combined Sites				
Blue catfish	4/4	0.199 ± 0.086 (0.119-0.321)		
Flathead catfish	3/3	0.337 ± 0.205 (0.167-0.564)		
Largemouth bass	16/16	0.417 ± 0..172 (0.188-0.844)		
Longnose gar	2/2	**0.772** ± 0.033 (0.749-0.795)	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg–day
Striped bass	4/4	**1.149** ± 0.195 (0.955-1.418)		
White bass	1/1	0.316		
All Sampled Fish, All Sites	30/30	0.498 ± 0.326 (0.119-1.418)		

Table 4. Regular or long-term consumption of some species of fish from Canyon Reservoir that contain mercury could result in systemic adverse health effects in some individuals or groups. Table 4 lists hazard quotients (HQ) for Mercury in fish based on mercury concentrations in fish collected from Canyon Reservoir in 2005 and suggests appropriate consumption rates. Adults (70 kg) should consume a total of the recommended number of meals/week consisting of any combination of fish making an 8 ounce meal, while children weighing less than 35 kg or who are younger than 12 years of age should consume no more than 4 ounces per meal for the recommended number of meals.

Species/Contaminant	Hazard Quotient	Meals per Week
Blue catfish	0.28	3.3
Flathead catfish	0.48	1.9
Largemouth bass	0.60	1.6
Longnose gar	**1.10**[g]	**0.8**
Striped bass	**1.60**	**0.6**
White bass	0.45	2.0
All species, combined	0.71	1.3

[g] ***Emboldened** type indicates that a fish species contains more mercury per kg edible tissue than is recommended by DSHS for unlimited consumption. Fish species that do not contain mercury at levels exceeding the* HAC_{nonca} *for mercury (0.7 mg/kg) may be consumed without limitation.*

Table 4. Systemic effects are possible from consuming mercury-contaminated fish collected in November 2005 from Canyon Reservoir. 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. Canyon Reservoir is a relatively small system. Therefore, DSHS suggests that site within the reservoir from which the fish were collected not be utilized to determine the number of meals per week that are appropriate for any species in which mercury concentrations exceed the HAC_{nonca} for methylmercury in fish.

Species	Dam (Site 1) (N=10)	Mid Lake (Site 2) (N=9)	Upper Lake (Site 3) (N=7)
Blue catfish	0.29 (3.1)	0.26 (3.6)[1]	Not collected
Flathead catfish	Not collected	0.48 (1.9)	Not collected
Largemouth bass	0.71 (1.3)	0.46 (2.0)	0.64 (1.4)
Longnose gar	Not collected	**1.10 (0.8)**	Not collected
Striped bass	**1.51 (0.6)**[h]	**2.03 (0.5)**	Not collected
White bass	0.45 (2.0)	Not collected	Not collected
All species, combined	0.79 (1.2)	0.67 (1.4)	0.64 (1.4)

[h] *Cells in* ***bold-face type*** *show species at each site in which mercury average concentration exceeds DSHS reference concentration (HAC_{nonca}) for methylmercury used to ensure that sensitive human groups are protected from the systemic effects that could be associated with consuming methylmercury in fish collected from Canyon Reservoir.*

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