Characterization of Potential Adverse Health Effects Associated with Consuming Fish from

Alan Henry Reservoir

Garza and Kent Counties, Texas

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INTRODUCTION

Description of Alan Henry Reservoir

Alan Henry Reservoir, constructed in 1993 six miles east of Justiceburg in Garza County, Texas, is a 2,884-acre impoundment of the Double Mountain Fork of the Brazos River.[1] Owned by the City of Lubbock and operated by the Brazos River Authority, Alan Henry Reservoir provides a water source for the City of Lubbock and recreation opportunities for area residents.[2] The maximum depth of Alan Henry Reservoir is 100 feet at its conservation pool, 2,220 feet above mean sea level.[1] The reservoir's water level fluctuates moderately throughout a typical year (2-4 feet/year). Littoral habitat characteristics of Alan Henry Reservoir include rock, boulder, standing timber, and a small amount of native aquatic vegetation.[1] Public access to the reservoir is limited to the Samuel W. Wahl Recreational Area–a 580-acre tract also owned by the City of Lubbock.[2] The Samuel W. Wahl Recreational Area provides a public boat ramp, a floating fishing dock, primitive camping, a 2.5-mile recreational trail, and hunting.

Demographics of Garza, Kent, and Lubbock Counties near Alan Henry Reservoir

Alan Henry Reservoir is located in Garza and Kent Counties. In 2007, the United States Census Bureau (USCB) reported the estimated population of Garza and Kent counties to be 4,700 and 735 people, respectively.[3] The city of Lubbock, Texas, which – with a 2007 USCB-estimated population of 217,326 persons – is the largest metropolitan statistical area near Alan Henry Reservoir, is located in Lubbock County approximately 65 miles northwest of the reservoir.[2,3] In contrast to Garza and Kent Counties, the USCB reported the 2007 estimated population of Lubbock County to be 260,901 people, showing that only 17% of Lubbock County residents reside outside the city limits of Lubbock, Texas.

Subsistence Fishing at Alan Henry Reservoir

The United States Environmental Protection Agency (USEPA) suggests that, along with ethnic characteristics and cultural practices, poverty could contribute to the rate of subsistence fishing in any area.[4] The EPA and the Texas Department of State Health Services (DSHS) consider it important to take into account subsistence fishing at any water body because subsistence fishers – along with recreational anglers and certain tribal and ethnic groups – are thought to consume more locally-caught fish than does the general population. To supplement caloric and protein intake, subsistence fishers and other high-fish-consumption groups sometimes harvest fish or shellfish from the same water body over many years. If fish from a water body in which subsistence fishing occurs contain low levels of environmentally persistent toxic chemicals, people who eat those fish over a long period, who consume large quantities at a sitting, or who belong to sensitive groups could potentially increase their risk of adverse health effects. The EPA suggests that states assume that at least 10% of licensed fishers in any area are subsistence fishers. It is possible that percentage would be larger if unlicensed fishers were counted; those who do not buy licenses may be economically disadvantaged, a factor that increases the likelihood of subsistence fishing. While the DSHS has not specifically documented the practice, subsistence fishing likely does occur at Alan Henry Reservoir. The DSHS assumes the rate of subsistence fishing along this river is similar to that estimated by the USEPA.[4]

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

Three Texas agencies, the 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.[5] Among its other duties, the TCEQ establishes and manages water quality standards for the state and addresses pollution of Texas' public waters. The TPWD manages state fish and wildlife resources, addresses pollution that may adversely affect these resources, and enforces closures or bans issued by DSHS. These, and several other state and federal agencies, coordinate to oversee contaminant monitoring of Texas waters – and their flora and fauna – through regular meetings of the Toxic Substances Coordinating Committee (TSCC), a legislatively mandated interagency committee.[6]

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.[7,8] The DSHS conducts Tier 2 studies to characterize the potential human health risks associated with consumption of fish found during Tier 1 studies to contain chemical contaminants in excess of project specific screening values. Although the DSHS may initiate Tier 1 studies, the TCEQ and/or the TWPD more likely launch the initial studies (Tier 1 studies) on a water body. The EPA financed the SFTMP project through fiscal year 2009 (ending December 31, 2008). The EPA funds were administered by the TCEQ. Most of the EPA grant funds for this project paid for laboratory analysis of fish tissue for chemical contaminants. Regular consumption of doses of chemical contaminants exceeding those unlikely to affect human health (doses represented by reference doses (RfDs) or minimal risk levels (MRLs), could adversely influence health.

In 2003, the three agencies selected for Tier 1 study 66 previously un-surveyed Texas reservoirs and 15 river segments[7], and in 2006 the Tier 1 portion of the SFTMP was extended an additional year – adding 20 previously un-surveyed reservoirs. Tier 1 studies were conducted by the TPWD Inland Fisheries Division (TPWDIF) during routine fisheries management activities on major reservoirs and TCEQ conducted Tier 1 studies on selected river segments. The DSHS, TPWD, and/or TCEQ selected for inclusion in the Tier 2 study those water bodies that yielded fish tissue sampling results that exceeded one or more SFTMP screening criteria.

In 2005, the TPWDIF sampled fish from Alan Henry Reservoir as a part of the above-outlined study. TPWD collected one composite largemouth bass (predator species) sample composed of three individual largemouth bass ranging in length from 11.6 to 17.1 inches. The TPWDIF also prepared one composite common carp (bottom feeding species) sample from three individual smallmouth buffalo ranging in length from 15.3 to 19.7 inches. The TPWD laboratory in San Marcos, Texas analyzed those samples for a suite of inorganic and organic contaminants listed in the project quality assurance project plan (QAPP). The DSHS and TCEQ compared the Tier 1 Alan Henry Reservoir target analyte concentrations to the DSHS-established human health screening values (SVs) to identify contaminants that exceeded SVs and to determine whether Alan Henry Reservoir would be intensively examined in a Tier 2 study.[7,8] That comparison revealed that the composite largemouth bass sample from the Alan Henry Reservoir contained an average mercury concentration (0.770 mg/kg) that exceeded the DSHS human health screening value (0.525 mg mercury/kg fish tissue). Based on these results, the DSHS and the TCEQ decided to include Alan Henry Reservoir in a Tier 2 study to examine fish from the reservoir comprehensively for chemical contaminants – in addition to mercury – that can result in adverse health effects.

The present report summarizes the results of the 2008 DSHS SALG Tier 2 evaluation of fish tissue from Alan Henry Reservoir. This document addresses public health implications, if any, of consuming fish from the reservoir and suggests potential actions to protect humans from possible adverse health effects of consuming chemically contaminated fish from this reservoir.

METHODS

Fish Sampling, Preparation, and Analysis

The DSHS 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 Team Standard Operating Procedures and Quality Control/Assurance Manual.*[9] The SALG bases its sampling and analysis protocols, in part, on procedures recommended by the EPA in that agency's *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories, Volume 1.*[10] Advice and direction are also received from the legislatively mandated *State of Texas Toxic Substances Coordinating Committee Fish Sampling Advisory Subcommittee (FSAS).*[11] 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.

Fish Sampling Methods and Description of the Alan Henry Reservoir 2008 Sample Set

In April 2008, SALG staff collected 100 fish samples from Alan Henry Reservoir. Risk assessors used data from these fish to assess the potential for adverse human health outcomes from consuming fish from this reservoir.

The SALG selected seven sites to provide spatial coverage of the study area (Figure 1). Site 1 was located at Grape Creek, Site 2 Dam, Site 3 Little Grape Creek, Site 4 Ince Cove, Site 5 Gobbler Creek, Site 6 Rocky Creek, and Site 7 Double Mountain Fork of the Brazos River. Species collected represent distinct ecological groups (i.e. predators and bottom-dwellers) that have some potential to bioaccumulate mercury and other chemical contaminants; have a wide geographic distribution; are of local recreational fishing value and/or local anglers and their families commonly consume the species.

The SALG 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 electro-fishing system settings: 6.0-8.0 amps, 60 pulses per second [pps], low range, 500 volts, 50% 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 enhance tissue preservation.

The SALG set gill nets at each of the sample sites in the late afternoon and fish the nets overnight. The gill nets were set in locations to maximize available cover and habitat. Staff retrieved captured fishes from the gill nets in the early morning only keeping fish pre-selected as target samples. Staff immediately stored retrieved samples on wet ice in large coolers to ensure interim preservation, while any remaining live fish culled from the catch were returned to the reservoir.

SALG staff processed fish onsite at Alan Henry Reservoir**.** The SALG team weighed each sample to the nearest gram (g) on an electronic scale and measured total length (tip of nose to tip of tail fin) to the nearest millimeter (mm). After weighing and measuring a fish, the team used a cutting board covered with aluminum foil and a fillet knife to prepare two skin-off fillets from each fish. The foil was changed and the fillet knife cleaned with distilled water after each sample was processed. The fillet(s) were wrapped in two layers of fresh aluminum foil, placed in a clean, previously unused, pre-labeled plastic freezer bag, and stored on wet ice in an insulated chest until final processing. The SALG staff transported tissue samples on wet ice to their Austin, Texas, headquarters, where the samples were stored temporarily at -5° Fahrenheit (-20° Celsius) in a locked freezer. The freezer key is accessible only to authorized SALG staff members to ensure the chain of custody remains intact while samples are in the possession of agency staff. The week following each collection trip, the SALG shipped frozen fish tissue samples by commercial carrier for contaminant analysis by the Geochemical and Environmental Research Group (GERG) Laboratory at Texas A&M University, College Station, Texas.

Analytical Laboratory Information

Upon the samples' arrival at the laboratory, GERG personnel notified the SALG of receipt of the 100 Alan Henry Reservoir samples, also recording the condition of each sample and its DSHS identification number.

Using established EPA methods, the GERG laboratory analyzed fish fillets from Alan Henry Reservoir for many inorganic and organic contaminants commonly identified in polluted environmental media. Analyses included seven metals (arsenic, cadmium, copper, lead, total mercury, selenium, and zinc), 123 semivolatile organic compounds (SVOCs), 70 volatile organic compounds (VOCs), 34 pesticides, 209 polychlorinated biphenyls (PCB) congeners, and 17 polychlorinated dibenzofurans and/or dibenzo-*p*- dioxins (PCDFs/PCDDs) congeners. The laboratory analyzed all 100 samples for mercury. The laboratory also analyzed 30 of the 100 samples for metals and six of the 100 samples for pesticides, PCBs, SVOCs, VOCs, and PCDFs/PCDDs.[12]

Specific Analyses with Explanatory Notes

Arsenic

The GERG laboratory analyzed each of 30 fish for total (including inorganic arsenic and organic) arsenic. Although the proportions of each form of arsenic may differ among fish species, under different environmental and 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.[13] 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 in each fish by a factor of 0.1.[13]

Mercury

Nearly all mercury in upper trophic level fish three years of age or older is methylmercury.[14] Thus, total mercury concentrations in upper trophic level fish of legal size for possession in Texas should serve well as surrogates for methylmercury concentration. Because methylmercury analyses are difficult to perform accurately and are more expensive than total mercury analyses, the EPA recommends that states determine total mercury concentration in a fish and that states conservatively assume that 100% of reported mercury in fish or shellfish is methylmercury. The GERG laboratory analyzed fish tissues for total mercury. In its risk characterizations, DSHS compares mercury in tissues to a comparison value derived from the Agency for Toxic Substances and Disease Registry's (ATSDR) MRL for methylmercury.[15] In its risk characterizations, the DSHS may interchangeably utilize the terms "mercury," "methylmercury," or "organic mercury" to refer to methylmercury in fish.

Polychlorinated Biphenyls (PCBs)

The EPA suggests that each state measure congeners of PCBs in fish and shellfish rather than homologs or Aroclors® because the federal agency considers congener analysis the most sensitive technique for detecting PCBs in environmental media.[12] Although only about 130 PCB congeners were routinely present in PCB mixtures manufactured and commonly used in the U.S., the GERG laboratory analyzes and reports the presence and concentrations of all 209 possible PCB congeners. From the congener analyses, the laboratory also computes and reports concentrations of PCB homologs and of Aroclor® mixtures. Despite EPA's suggestion that the states utilize PCB congeners for toxicity estimates, the toxicity literature does not reflect this state-of-the-art laboratory science. To accommodate the inconsistency, the DSHS utilizes recommendations from the National Oceanic and Atmospheric Administration (NOAA),[16] from McFarland and Clarke,[17] and from the EPA's guidance documents for assessing chemical contaminants in fish and shellfish[10, 12] to address PCB congeners in fish and shellfish samples. In accordance with available literature, 43 congeners are selected for evaluation based on the likelihood of their occurrence in fish, the likelihood of toxic effects, and relative abundance in the environment.[16, 17] SALG risk assessors sum the 43 reference congeners to derive a "total" PCB concentration in each sample. Assessors then average the summed congeners within each group (e.g., fish species, sample site, or combination of species and sample site) to derive a mean

PCB concentration for the groups. Using only a few PCB congeners to determine “total PCB concentrations” could conceivably underestimate PCB tissue levels. Nonetheless, the method complies with expert recommendations on evaluation of PCBs in fish or shellfish. Therefore, SALG risk assessors compare average concentrations of the 43 congeners with health assessment comparison (HAC) values derived from information from the EPA’s Integrated Risk Information System (IRIS) database on PCB mixtures.[18] Currently, IRIS does not contain information on the systemic toxicity of individual PCB congeners. Instead, the database contains systemic toxicity information for five Aroclor® mixtures: Aroclors® 1016, 1242, 1248, 1254, and 1260. Not all information is available for all named mixtures; for instance, IRIS contains RfDs for only two Aroclor mixtures, Aroclor 1016, a commercial mixture devoid of dibenzofurans, and Aroclor 1254. Systemic toxicity estimates in the present document reflect comparisons derived from the RfD for Aroclor 1254 because Aroclor 1254 was used more commonly than was Aroclor 1016.

For assessment of cancer risk from exposure to PCBs, the SALG uses the EPA's highest slope factor of 2.0 per (mg/kg/day) to calculate the probability lifetime excess cancer risk from PCB ingestion. The SALG based its decision to use the most restrictive slope factor available for PCBs on factors such as food chain exposure, the presence of dioxin-like, tumor-promoting, or persistent congeners, and the likelihood of early-life exposure.[18]

Calculation of Toxicity Equivalence Quotients (TEQs) for Dioxins

PCDFs/PCDDs are families of aromatic chemicals containing one to eight chlorine atoms. The molecular structures of the PCDFs/PCDDs molecules – called congeners – differ not only with respect to the number of chlorines on a molecule, but also with the placement and positions of those chlorines on the carbon atoms of that molecule. The number of chlorines on the dibenzofuran or dibenzo-*p*-dioxin nucleus and their placement on those molecules directly affect the toxicity of the congeners. Toxicity increases as the number of chlorines increases to four, then decreases with continuing increases in the number of chlorines – up to a maximum of eight. With respect to the placement of chlorines on the dibenzofuran/dibenzo-*p*-dioxin nucleus, those congeners with chlorine substitutions in the 2, 3, 7, and 8 positions appear more toxic than congeners with chlorine substitutions in other positions. To illustrate, the most toxic of polychlorinated dibenzo-p-dioxins (PCDDs) is 2,3,7,8–tetrachlorodibenzo-*p*-dioxin (2,3,7,8–TCDD), a 4-chlorine molecule having one chlorine substituted for hydrogen at each of the 2, 3, 7, and 8 – numbered carbons on the dibenzo-*p*-dioxin nucleus. Further, 2,3,7,8-TCDF is the most toxic dibenzofuran. To gain some measure of toxic equivalence, 2,3,7,8–TCDD and 2,3,7,8-TCDF – the most potent of the dioxins/furans are assigned toxicity equivalence factors (TEF) of 1.0. These, then, are the standards against which the toxicity of all other PCDF/PCDD congeners are compared. Congeners are assigned toxicity equivalence factors (weighting factors or TEFs) of 1.0 or less based on the experimentally-determined comparative toxicity (potency) of the congener to that of 2,3,7,8-TCDD or, in the case of dibenzofurans, to 2,3,7,8-TCDF.[19, 20] To arrive at a TEQ (toxicity equivalence quotient), multiply the congener’s concentration by its TEF. This mathematical manipulation yields a concentration of the congener roughly equivalent to a 1 pg/kg concentration of 2,3,7,8-TCDF or 2,3,7,8-TCDD. After converting the measured concentration of each congener in each fish tissue sample from the Alan Henry Reservoir to its TEQ, risk assessors determined the total TEQs for a sample – defined as the sum of the TEQs for each of the congeners in the sample – according to the following formula.[21]

$$\text{Total TEQs} = \sum_{i=1}^{n}(\text{CI} \times \text{TEF})$$

CI = concentration of a given congener
TEF = toxicity equivalence factor for the given congener
n = # of congeners
i = initial congener
∑ = sum

Derivation and Application of Health-Based Assessment Comparison Values (HACnonca) for Systemic (noncarcinogenic) Effects of Consumed Chemical Contaminants

The effects of exposure to any hazardous substance depend, among other factors, on the dose, the route of exposure, the duration of exposure, the manner in which the exposure occurs, the genetic makeup, personal traits, habits of the exposed, and the presence of other chemicals.[22] People who regularly consume contaminated fish or shellfish conceivably suffer repeated low-dose exposures to contaminants in fish or shellfish over extended periods (episodic exposures to low doses). Such exposures are unlikely to 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.[22] If diverse species of fish or shellfish are available, the SALG presumes that people eat a variety of species from a water body. Further, SALG risk assessors at DSHS assume that most fish species are mobile. SALG risk assessors may combine data from different fish species, blue crab, and/or sampling sites within a water body to evaluate mean contaminant concentrations of toxicants in all samples as a whole. This approach intuitively reflects consumers' likely exposure over time to contaminants in fish or shellfish from any water body but may not reflect the reality of exposure at a specific water body or a single point in time. The DSHS reserves the right to project risks associated with ingestion of individual species of fish or shellfish from separate collection sites within a water body or at higher than average concentrations (e.g. the upper 95 percent confidence limit on the mean). The SALG derives confidence intervals from Monte Carlo simulations using software developed by Richard Beauchamp, MD, a DSHS medical epidemiologist.[23] The group evaluates contaminants in fish or shellfish by comparing the mean or the 95% upper confidence limit on the average concentration of a contaminant to its HAC value (in mg/kg) for non-cancer or cancer endpoints.

In deriving HAC_{nonca} values for systemic effects, the SALG assumes a standard adult weighs 70 kilograms and consumes 30 grams of fish or shellfish per day (about one 8-ounce meal per week) and uses the EPA's oral RfD[24] or ATSDR's MRLs.[25] The 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.*[26]

The 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.*[26]

The ATSDR uses a similar technique to derive its MRLs.[25] The DSHS divides the estimated daily dose derived from the measured concentration in fish tissue by the contaminant's RfD or MRL to derive a hazard quotient (HQ). The EPA defines an HQ as

> *…the ratio of the estimated exposure dose of a contaminant (mg/kg/day) to the contaminant's RfD or MRL (mg/kg/day).*[27]

Note that, according to the EPA, a linear increase in the HQ for a toxicant does not imply a linear increase in the likelihood or severity of systemic adverse effects. Thus, a HQ of 4.0 does not mean the concentration in the dose will be four times as toxic as that same substance would be if the HQ were equal to 1.0. An HQ of 4.0 also does not imply that adverse events will occur four times as often as if the HQ for the substance in question were 1.0. Rather, the EPA suggests that risk assessors interpret an HQ or a hazard index (HI) – defined as the sum of HQs for contaminants to which an individual is exposed simultaneously – that computes to less than 1.0 as "no cause for concern" whereas an HQ or HI greater than 1.0 "should indicate some cause for concern."

The SALG does not utilize HQs to determine the likelihood of occurrence of adverse systemic health effects. Instead, in a manner similar to the EPA's decision process, the SALG may utilize computed HQs as a qualitative measurement. Qualitatively, HQs less than 1.0 are unlikely to be an issue while HQs greater than 1.0 might suggest a regulatory action to ensure protection of public health. Similarly, risk assessors at the DSHS may utilize an HQ to determine the need for further study of a water body's fauna. Notwithstanding the above discussion, the oral RfD derived by the EPA represents chronic consumption. Thus, regularly eating fish containing a toxic chemical, the HQ of which is less than 1.0 is unlikely to cause adverse systemic health effects, whereas routine consumption of fish or shellfish in which the HQ exceeds 1.0 represents a qualitatively unacceptable increase in the likelihood of systemic adverse health outcomes.

Although, as advised by the EPA, the DSHS preferentially utilizes the RfD calculated by federal scientists for a specifically named contaminant. If an RfD is not available for a contaminant, the EPA advises risk assessors to consider using the RfD (or an MRL) for a contaminant of similar molecular structure, or one of similar mode or mechanism of action. For instance, no published RfD is available for Aroclor® 1260, so the DSHS uses the RfD for Aroclor 1254 to assess the likelihood of systemic or noncarcinogenic effects of Aroclor 1260.[25]

In developing oral RfDs and MRLs, federal scientists review the extant literature to devise NOAELs, LOAELs, or benchmark doses (BMDs) from experimental studies. Uncertainty factors are then utilized 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. These include 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.[24.,26] Vulnerable groups such as women who are pregnant or lactating, women who may become pregnant, infants, children, people with chronic illnesses, those with compromised immune systems, the elderly, or those who consume exceptionally large servings are considered sensitive populations by risk assessors and the EPA and receive special consideration in calculation of an RfD. [26, 28]

The primary method for assessing the toxicity of component-based mixtures of chemicals in environmental media is the HI. The EPA recommends HI methodology for groups of toxicologically similar chemicals or chemicals that affect the same target organ. The default procedure for calculating the HI for the exposure mixture chemicals is to add the HQs (the ratio of the external exposure dose to the RfD) for all component chemicals affecting the same target organ or organ system.

The HI simulates an “HQ” for a mixture of contaminants if all chemicals in the mixture were tested simultaneously (as if a single chemical). For example, the HI for liver toxicity should approximate the degree of liver toxicity that would have been present if effects of the whole mixture were due to a single chemical. Target organs addressed by the HI's are decided for each particular mixture assessment and a separate HI calculated for each toxic effect of concern. The mixture components to be included in the HI calculation are any chemical components showing the effect described by the HI, regardless of the critical effect upon which the RfD comes.

Because the RfD is derived for the critical effect, which is the "toxic effect occurring at the lowest dose of a chemical," an HI computed from HQs based on the chemicals’ RfDs may be overly conservative. That is, using RfDs to calculate HIs may exaggerate health risks from consumption of specific mixtures for which no experimentally derived information is available.

The EPA states that

> *the HI is a quantitative decision aid that requires toxicity values as well as exposure estimates. When each organ-specific HI for a mixture is less than 1 and all relevant effects have been considered in the assessment, the exposure being assessed for potential systemic toxicity should be interpreted as unlikely to result in significant toxicity.*

And

> *When any effect-specific HI exceeds 1, concern exists over potential toxicity. As more HI’s for different effects exceed 1, the potential for human toxicity also increases.*

Thus,

> *Concern should increase as the number of effect-specific HI's exceeding 1 increases. As a larger number of effect-specific HI's exceed 1, concern over potential toxicity should also increase. As with HQs, this potential for risk is not the same as probabilistic risk; a doubling of the HI does not necessarily indicate a doubling of toxic risk.*

Derivation and Application of Health-Based Assessment Comparison Values for Application to the Carcinogenic Effects of Consumed Chemical Contaminants

The DSHS calculates HAC_{ca} values from the EPA's chemical-specific cancer potency factors (CPFs), also known as slope factors (SFs), derived through mathematical modeling from carcinogenicity studies. For carcinogenic outcomes, the DSHS calculates a theoretical lifetime excess risk of cancer from exposure to specific carcinogens, using the standard 70-kg body weight and the assumption that an adult consumes 30 grams of edible tissue per day. To these assumptions, SALG risk assessors utilize two additional factors to determine theoretical lifetime excess cancer risk: (1) an acceptable lifetime risk level (ARL) [26] of one excess cancer case in 10,000 persons whose average daily exposure is equivalent and (2) daily exposure for 30 years. Comparison values used to assess the probability of increases in background cancer rate do not contain "uncertainty" factors. However, conclusions drawn from comparisons of toxicant concentrations in fish tissue with HAC_{ca} values derived from probability determinations infer substantial safety margins for all people by virtue of the models utilized to derive the slope factors (cancer potency factors) used to calculate the HAC_{ca}.

Because comparison values are conservative, exceeding a HAC value does not necessarily mean adverse health effects will occur. The perceived strict demarcation between acceptable and unacceptable exposures or risks is primarily a tool used, along with other information, by risk managers to make decisions about the degree of risk incurred by those who consume contaminated fish or shellfish. Moreover, comparison values for adverse health effects do not represent sharp dividing lines (obvious demarcations) between safe and unsafe exposures. For example, 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, but does not necessarily expect such exposures to produce negative health effects. The DSHS also uses other measures to help people minimize their exposures. For instance, the DSHS advises people who wish to minimize exposure to contaminants in fish or shellfish to eat a variety of fish and/or shellfish, to eat smaller and younger fish, and to limit consumption of those species most likely to contain toxic contaminants. The DSHS aims to protect vulnerable subpopulations with its consumption advice, assuming that advice protective of vulnerable subgroups will also protect the general population from potential adverse health effects associated with consumption of 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.[29, 30] 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 at times when toxicants can impair or alter the structure or function of susceptible systems.[31] Unique early sensitivities may exist because organs and body systems are structurally or functionally immature 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 these factors could alter the concentration of biologically active toxicant at the target organ(s) or that could modulate target organ response to the toxicant. Children's exposures to toxicants may be more extensive than adults' exposures because children consume more food and liquids than adults do in proportion to their body weights. 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.[32] In any case, if a chemical or a class of chemicals is observed to be or 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.[24] Additionally, in accordance with the ATSDR's *Child Health Initiative*[33] and the EPA's *National Agenda to Protect Children's Health from Environmental Threats,*[34] 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 that suggests 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.

Data Analysis and Statistical Methods

The SALG risk assessors imported Excel© files into SPSS® statistical software, version 13.0 installed on IBM-compatible microcomputers (Dell, Inc), using SPSS® to generate descriptive statistics (mean, standard deviation, median, minimum and maximum concentrations, and range) on measured compounds.[35] In computing descriptive statistics, SALG risk assessors utilized ½ the reporting limit (RL) for analytes designated as not detected (ND) or estimated (J-values)[a]. PCDFs/PCDDs descriptive statistics are calculated using estimated concentrations (J-values) and assuming zero for PCDFs/PCDDs designated as ND.[b] The change in methodology for computing PCDFs/PCDDS descriptive statistics is due to the proximity of the reporting limits to the HAC value. Assuming ½ the RL for PCDFs/PCDDs designated as ND or J-values would unnecessarily overestimate the concentration of PCDFs/PCDDs in each fish tissue sample. The SALG used the descriptive statistics from the above calculations to generate the present report. The SALG employed Microsoft Excel® spreadsheets to generate figures, to compute HAC_{nonca} and HAC_{ca} values for contaminants, and to calculate HQs, HIs, cancer risk probabilities, and meal consumption limits for fish from Alan Henry Reservoir.[36] When lead concentrations in fish or shellfish are high, SALG risk assessors may use the EPA's Interactive Environmental Uptake Bio-Kinetic (IEUBK) model to determine whether consumption of lead-contaminated fish could cause a child's blood lead (PbB) level to exceed the Centers for Disease Control and Prevention's (CDC) lead concentration of concern in children's blood (10 mcg/dL).[37,38]

RESULTS

Description of Fish Collected from Alan Henry Reservoir

The 100 fish collected from Alan Henry Reservoir in the April 2008 study represented all targeted species. Table 1 lists target species harvested from each sampling site. The species sampled, in descending order of number of samples, are largemouth bass (42), channel catfish (15), white crappie (9), black crappie (8), freshwater drum (8), blue catfish (7), common carp (4), spotted bass (4), and flathead catfish (3).

The GERG laboratory completed analyses and electronically transmitted the results of the Alan Henry Reservoir fish samples collected in April 2008 to the SALG in February 2009. The laboratory reported the analytical results for mercury for all 100 fish samples along with the results of analysis of 30 of the 100 fish (LAH1, LAH2, LAH4, LAH5, LAH7, LAH8, LAH9, LAH12, LAH13, LAH15, LAH16, LAH21, LAH29, LAH30, LAH31, LAH32, LAH46, LAH50, LAH52, LAH55, LAH67, LAH68, LAH75, LAH83, LAH85,LAH95, LAH96, LAH98, LAH101, and LAH102) for metals and six of the 100 fish (LAH1, LAH12, LAH13, LAH67, LAH68, and LAH85) for pesticides, PCBs, SVOCs, VOCs, and PCDDs/PCDFs.

For reference, Table 1 contains the total number of samples collected from Alan Henry Reservoir in April 2008. Tables 2a through 2c contain summary results of metals in fish from Alan Henry Reservoir. Table 3 contains summary statistics for 4,4'-DDE and PCBs in fish from Alan Henry Reservoir. The paper does not display other pesticides, SVOC, VOC, and PCDF/PCDD data

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[a] *"J-value" is standard laboratory nomenclature for analyte concentrations that are detected and reported below the reporting limit (<RL). The reported concentration is considered an estimate, quantitation of which may be suspect and may not be reproducible. The DSHS treats J-Values as "not detected" in its statistical analyses of a sample set.*

[b] *The SALG risk assessors' rationale for computing PCDFs/PCDDs descriptive statistics using the aforementioned method is based on the proximity of the laboratory reporting limits and the health assessment comparison value for PCDFs/PCDDs. Thus, applying the standard SALG method using ½ the reporting limit for analytes designated as not detected (ND) or estimated (J) will likely overestimate the PCDFs/PCDDs fish tissue concentration.*

because these contaminants either were not detected or were reported as estimated concentrations, or as low but measurable concentrations that did not reach a level of significance to human health. Unless otherwise stated, table summaries present the number of samples containing a specific toxicant/number tested, the mean concentration ± 1 standard deviation (68% of samples should fall within ± 1 standard deviation of the arithmetic mean in a sample from a normally-distributed population; 95% should fall within ± 2 SD's of the mean concentration of a normally distributed population). The minimum and the maximum detected concentrations are shown in parentheses beneath the mean and the SD. The statistical range may be derived by subtracting the minimum concentration of a given toxicant from its maximum concentration. In the tables, results may be reported as ND, below detection limit (BDL), or as measured concentrations. According to the GERG laboratory's quality control/quality assurance materials, results reported as BDL rely upon the laboratory's method detection limit (MDL), defined as the minimum concentration of an analyte of interest that can be measured and reported with 99% confidence that the analyte concentration is greater than zero, and the RL, which is defined as the concentration that can be reliably achieved within specified limits of precision and accuracy during routine sample analyses. Contaminant concentrations reported below the RL are qualified as "J" concentrations in the GERG data report and qualified as BDL in the data tables in this report.[39]

Inorganic Contaminants

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

A subset of 30 of 100 Alan Henry Reservoir fish samples were examined for arsenic, cadmium, copper, lead, mercury, selenium, and zinc. Most samples contained some combination of two or more metalloids (Tables 2a-2c).

All 30 fish tissue samples assayed contained selenium and zinc (Table 2b) and 29 of 30 samples contained copper. The mean selenium concentration in fish from Alan Henry Reservoir was 0.367±0.155 mg/kg (Table 2b); selenium in fish ranged from 0.131 to 0.624 mg/kg. The mean zinc concentration in fish from Alan Henry Reservoir was 2.983±1.025 mg/kg (Table 2b). The mean copper concentration in fish sampled from Alan Henry Reservoir was 0.180±0.082 mg/kg. Blue catfish had the highest average concentration of copper (0.293±0.080 mg/kg).

The SALG also evaluated arsenic, cadmium, lead, and mercury in the samples from Alan Henry Reservoir. Twenty-eight of 30 fish tissue samples examined contained measured concentrations of arsenic, the mean concentration of which in combined species was 0.208 mg/kg ± 0.113 mg/kg (Table 2a). Ten of 30 tissue samples assayed contained cadmium at concentrations between 0.020 and 0.025 mg/kg (Table 2b). None of the fish from Alan Henry Reservoir contained lead at a concentration exceeding the laboratory's RL (Table 2b).

All 100 fish tissue samples from Alan Henry Reservoir contained mercury (Table 2c). Across all sites and fish species, mercury concentrations ranged from 0.084 mg/kg (channel catfish) to 3.435 mg/kg (blue catfish).

Of the nine species analyzed channel catfish, common carp, and freshwater drum had the lowest mercury concentrations (Table 2c). The mean concentration of mercury in flathead catfish (N=3) from Alan Henry Reservoir was 0.688±0.393 mg/kg (Table 2c). The black crappie and white crappie mean mercury concentrations were 1.013 mg/kg and 1.008 mg/kg, respectively (Table 2c). TPWD harvest regulations combine crappie species, in part due to difficulty in distinguishing a black from a white crappie. A t-test revealed that mercury concentrations in black crappie (N=8) and white crappie (N=9) were not significantly different (p>0.05), The two species were therefore combined for data analysis. The mean mercury concentration for the combined crappie species was 1.010±0.311 mg/kg. The mean concentration of mercury in blue catfish (N=7) from Alan Henry Reservoir was 1.100±1.108 mg/kg (Table 2c). Mercury concentrations in largemouth bass (N=42) samples ranged from 0.143 mg/kg to 1.789 mg/kg (Table 2c). The median mercury concentration in largemouth bass was 1.111 mg/kg. The mean mercury concentration for largemouth bass was 1.136±0.378 mg/kg (Table 2c), suggesting the sample represents a relatively normally distributed population. The lower and upper 95% confidence limits on the largemouth bass mean mercury concentration were 1.018 mg/kg and 1.254 mg/kg, respectively. Spotted bass (N=4) mercury concentrations ranged from 0.331 mg/kg to 2.321 mg/kg (Table 2c). The mean mercury concentration for spotted bass was 1.367±0.870 mg/kg.

The DSHS SALG examined the mercury data from Alan Henry Reservoir fish by species for relationships between total length (TL) and mercury concentration. Fish considered for linear regression analysis had a minimum sample size of seven. Blue catfish linear regression analysis revealed a significant, positive slope indicating that mercury concentration increases with increasing length (R^2= 0.817, n=7, p=0.005). TL and mercury concentration were unrelated in other species from Alan Henry Reservoir.

Organic Contaminants

<u>Pesticides</u>

The GERG laboratory analyzed a subsample of six of 100 fish samples from Alan Henry Reservoir for 34 pesticides. Low but quantifiable concentrations of 4,4'-DDE, 4,4'-DDD, 2,4'-DDT, chlordane, mirex, hexachlorobenzene, pentachloroanisole, alachlor, and dacthal were reported in one or more samples (data not presented). All fish tissue samples assayed contained 4,4'-DDE, a metabolite and/or degradation product of the insecticide 4,4'-DDT (Table 3). Trace[c] quantities of pentachlorobenzene, heptachlor epoxide, endosulfan I, malathion, and methoxychlor were present in the samples analyzed (data not presented). No other pesticides were reported in fish samples collected in 2008 from Alan Henry Reservoir.

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[c] *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.*

PCBs

The GERG laboratory analyzed the same sub sample of six fish for 209 PCB congeners as were examined for pesticides from Alan Henry Reservoir. Table 3 contains summary statistics for PCBs measured in fish samples. The laboratory detected measurable quantities of PCBs representing one or more of the congeners between PCB 15 and PCB 209 (International Union of Pure and Applied Chemists [IUPAC] assigned numbers) in the six fish samples analyzed. No sample contained all PCB congeners (data not shown). Assessing summary statistics for PCBs in each species and all fish combined without regard to collection site, blue catfish contained the highest PCB concentration (0.032±0.016 mg/kg), followed by common carp (0.011±0.001 mg/kg) and largemouth bass (0.010±0.001 mg/kg). The mean PCB concentration for all fish combined was 0.018±0.013 mg/kg (Table 3).

SVOCs

The GERG laboratory analyzed a subsample of six fish of 100 fish samples for SVOCs from Alan Henry Reservoir. The laboratory detected traces of BEHP in five of six samples assayed; in each case, the laboratory reported BEHP as an estimated concentration (J-value) (data not presented). The laboratory detected no other SVOCs in fish from Alan Henry Reservoir.

VOCs

The GERG laboratory analyzed the same six fish tissue samples for VOCs as were examined for metals, pesticides, PCBs, and SVOCs from Alan Henry Reservoir. Low but quantifiable concentrations of carbon disulfide, methylene chloride, 2-butanone, trichloroflurомethane, toluene, ethylbenzene, m+p-xylene, o-xylene, 1,2,4-trimethylbenzene, 1,3-dichlorobenzene, and 1,4-dichlorobenzene were present in some of the fish tissue samples analyzed (data not presented). Trace quantities of chloromethane, vinyl chloride, bromomethane, chloromethane, 1,1-dichloroethene, acetone, iodomethane, trans-1,2-dichloroethene, 1,1-dichloroethane, cis-1,2-dichloroethene, 2,2-dichloropropane, bromochloromethane, 1,2-dichloroethane, 1,1,1-trichloroethane, 1,1-dichloropropene, benzene, trichloroethene, methyl methacrylate, cis,-1,3-dichloropropene, trans-1,3-dichloropropene, bromodichloromethane, 1,2-dibromomethane, bromoform, tetrachloroethene, 1,3-dichloropropene, 2-hexanone, chlorobenzene, 1,1,1,2-tetrachloroethane, styrene, isopropylbenzene, bromobenzene, 1,1,2,2-tetrachloroethane, 2-chlorotoluene, 4-chlorotoluene, 1,3,5-trimethylbenzene, 1,3-dichlorobenzene, 1,2-dichlorobenzene, n-propylbenzene, 4-isopropyl toluene, tert-butylbenzene, sec-butylbenzene, n-butylbenzene, 1,2,3-trichlorbenzene, 1,2,4-trichlorobenzene, hexachlorobutadiene, and naphthalene were also present in one or more fish tissue samples assayed from Alan Henry Reservoir (data not present). Concentrations of methylene chloride, trichloroethene, bromoform, toluene, tetrachloroethene, chlorobenzene, ethylbenzene, m+p-xylene, o-xylene, styrene, isopropylbenzene, bromobenzene, 2-chlorotoluene, 4-chlorotoluene, 1,3,5-trimethylbenzene, 1,2,4 trimethylbenzene, 1,3-dichlorobenzene, 1,4-dichlorobenzene, 1,2-dichlorobenzene, n-propylbenzene, 4-isopropyl toluene, sec-butylbenzene, n-butylbenzene, and naphthalene were also identified in the procedural blanks, indicating the possibility that these compounds were introduced during sample preparation. The presence of many VOCs at concentrations <RL may be the result of incomplete removal of the calibration standard from the adsorbent trap, so they

are observed in the blank (VOC analytical methodology requires that VOCs are thermally released from the adsorbent trap, transferred to the gas chromatograph (GC), and into the GC/mass spectrometer (MS) for quantification). No other VOCs were reported present in fish collected from Alan Henry Reservoir.

PCDFs/PCDDs

The GERG laboratory analyzed the same six fish tissue samples for PCDFs/PCDDs as were examined for metals, pesticides, PCBs, SVOCs, and VOCs from Alan Henry Reservoir. The laboratory analyzed six fish samples for 17 of the 210 possible PCDF/PCDD (135 PCDFs + 75 PCDDs) congeners. The congeners examined consist of 10 PCDFs and 7 PCDDs that contain chlorine substitutions in, at a minimum, the 2, 3, 7, and 8 positions on the dibenzofuran or dibenzo-*p*-dioxin nucleus and are the only congeners reported to pose dioxin-like adverse human health effects.[40] Although 12 of the 209 PCB congeners – those often referred to as "coplanar PCBs," meaning the molecule can assume a flat configuration with both phenyl rings in the same plane – may also have dioxin-like toxicity, the SALG does not assess PCBs for dioxin-like qualities because the dioxin-like behavior has been less extensively evaluated. One of six fish, a largemouth bass, contained 15.7 pg/g of octochlorodibenzo-*p*-dioxin (OCDD). No other PCDFs/PCDDs were reported present in fish collected from Alan Henry Reservoir.

DISCUSSION

Risk Characterization

Variability and uncertainty are inherent to quantitative assessment of risk. Thus, calculations that model risks of adverse health outcomes from exposure to toxicants can be orders of magnitude above or below “actual” risks. Variability between calculated and actual risk may depend upon factors such as the use of animals rather than humans, use of subchronic rather than chronic studies, interspecies variability, intra-species variability, and database insufficiency. Many factors used to calculate comparison values come from experiments conducted in the laboratory on nonhuman subjects. Variability and uncertainty in the estimates of toxicity might therefore arise from judgment calls by investigators or reviewers, e.g., the study chosen as the "critical" investigation, the species/strain of animal used in the critical study, the target organ determined the "critical organ," exposure periods, exposure route, or exposure doses. Uncontrolled (confounding) variables or variations in other conditions could occur. Some contaminants are overtly toxic, while others have only subtle effects. Finally, available information varies by contaminant. The literature is replete with information on some toxicants while others have hardly any toxicity data.[24] Risk assessors often must calculate parameters to represent potential toxicity to humans who consume contaminants in fish and other environmental media despite these limitations. For those contaminants appearing in Alan Henry Reservoir fish for which enough information is given, the DSHS calculated risk parameters for systemic toxicity and for carcinogenicity in those who would consume fish from the reservoir. The SALG uses risk parameters in meal consumption calculations – integral to the SALG's risk characterizations as consumption limits are among the variables DSHS risk managers use to determine departmental actions to protect human health from adverse effects of consuming toxicants in fish from Texas waters. Conclusions and recommendations predicated upon the stated goal of the DSHS to protect human health follow the discussion of the relevance of the Alan Henry Reservoir results to risk of human health effects.

Characterization of Systemic (Noncancerous) Health Effects from Consumption of Fish from Alan Henry Reservoir

Inorganic Contaminants

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

Thirty of the original 100 fish samples collected from Alan Henry Reservoir were examined for arsenic, cadmium, copper, lead, mercury, selenium, and zinc. Most samples contained some combination of two or more metalloids (Tables 2a-2c).

Copper, selenium, and zinc are essential to human health and to the health of other animals. All can be toxic . Toxicity occurs most often with ingestion of high doses but also can occasionally occur with long-term, low level consumption.[41]

Twenty-nine of 30 fish samples contained copper, while all 30 contained selenium and zinc (Table 2b). Blue catfish had the highest average concentration of copper (0.293±0.080 mg/kg) of any species from Alan Henry Reservoir – a concentration less than 1/1000 that of the HAC_{nonca} for copper (333 mg/kg). The average copper concentration of the 30 fish from Alan Henry Reservoir was approximately 0.1% of the HAC_{nonca} for copper. The mean copper concentration thus did not exceed the HAC_{nonca} for this element nor did the HQ for copper in the 30 fish or in any species of fish exceed 1.0 (data not shown). Therefore, SALG risk assessors concluded that consumption of copper in fish from Alan Henry Reservoir should cause no concern for human health.

All samples analyzed contained selenium (Table 2b), the highest concentration of which was present in freshwater drum (9% of the $HAC_{nonca)}$ followed closely by the mean concentration in spotted bass (Table 2b). The lowest concentration of selenium occurred in the blue catfish (3% of the selenium HAC_{nonca}). The average concentration of selenium in combined species was just under 6% of the HAC_{nonca} for this metalloid. HQs for selenium did not approach 1.0 in any species of fish (data not shown). Consumption of fish from Alan Henry Reservoir containing selenium should not cause concern for public health.

As with selenium, zinc was present in the 30 fish from Alan Henry Reservoir analyzed. Zinc concentrations in different species ranged from an average of 2.178 mg/kg in largemouth bass (0.3% of the zinc HAC_{nonca}) to an average of 4.873 mg/kg (0.7% of the HAC_{nonca}) in blue catfish. Zinc concentrations in fish from Alan Henry Reservoir did not exceed the HAC_{nonca} for this element (Table 2b). HQs for zinc did not approach 1.0 in any species of fish (data not shown). SALG risk assessors conclude that eating zinc in fish from Alan Henry Reservoir at concentrations similar to those observed in samples from this water body should not result in deleterious effects on individuals' health nor should eating any combination of these essential nutrients affect public health negatively.

In contrast to copper, selenium, and zinc, arsenic, cadmium, lead, and mercury have no known human physiological function. The GERG analyzed arsenic (Table 2a), cadmium, lead (Table 2b), and mercury (Table 2c) in the samples from Alan Henry Reservoir. The laboratory reported measurable concentrations of arsenic in 28 of 30 fish samples. Total arsenic occurred at an average of 0.208 mg/kg in all fish combined (Table 2a) with white crappie containing the highest mean concentration (0.338 mg/kg). The SALG used a ratio of 1 mg/kg inorganic arsenic to 10 mg/kg of total arsenic to calculate inorganic arsenic from total arsenic (see methods section for explanation). The mean concentration of inorganic arsenic calculated was 0.021 mg/kg. The highest (0.034 mg/kg) occurred in white crappie and the lowest in flathead catfish (0.009 mg/kg). The mean calculated inorganic arsenic concentration if fish from Alan Henry Reservoir did not exceed the arsenic HAC_{nonca} nor did the highest calculated mean concentration exceed the arsenic HAC_{nonca}. HQs for arsenic in any form did not exceed 1.0. Consequently, the SALG concluded that consumption of arsenic in fish from Alan Henry Reservoir, if similar to those concentrations observed in samples from 2008, would be unlikely to affect systemic human health outcomes adversely. Ten of 30 samples from Alan Henry contained cadmium at concentrations from a low of 0.012 to highs of 0.025 mg/kg (2.5% to 5.3% of the HAC_{nonca} for cadmium (Table 2b). HQs for cadmium did not exceed 1.0 in fish from Alan Henry Reservoir. No fish from Alan Henry Reservoir contained lead at a concentration exceeding the laboratory's RL (Table 2b). Thus, lead, if present in fish from Alan Henry Reservoir, occurred at levels much lower than levels necessary to increase children's blood lead levels by a significant quantity. Consumption of fish from Alan Henry Reservoir that contain lead at levels below the laboratory's RL pose no hazard to the developing nervous system or to adults who might consume fish from this reservoir.

All fish tissue samples (100 fish) from Alan Henry Reservoir contained mercury (Table 2c). Five of nine species (black crappie, blue catfish, largemouth bass, spotted bass, and white crappie) contained mercury at concentrations in excess of the methylmercury HAC_{nonca} (0.7 mg/kg; Table 2c; Figure 2). Ninety three percent of largemouth bass samples contained mercury at levels exceeding the HAC_{nonca} (Figure 3). The mean mercury concentration in flathead catfish, at 0.688 mg/kg effectively matched the HAC_{nonca} for methylmercury. HQs for mercury in these fish species equaled or exceeded 1.0. Mercury concentrations in channel catfish, common carp, and freshwater drum did not exceed the methylmercury HAC_{nonca} (Table 2c) nor did the HQs for these species exceed 1.0 (Table 4). These results suggest that consumption of mercury in black crappie, blue catfish, flathead catfish, largemouth bass, spotted bass, and white crappie could have a detrimental effect upon the developing CNS. SALG risk assessors suggest that consuming these species from Alan Henry Reservoir may pose a mercury related hazard to certain vulnerable people or groups, including pregnant women. Channel catfish, common carp, and freshwater drum are unlikely to pose such a risk to human health.

Organic Contaminants

Pesticides

Table 3 lists summary statistics for 4,4′-DDE in six fish (two blue catfish, two common carp, and two largemouth bass) collected from Alan Henry Reservoir and analyzed for 34 common pesticides. 4,4′-DDE is a metabolite or breakdown product of the legacy pesticide 4,4'-DDT. As such, its presence in the absence of DDT suggests that levels of the legacy pesticide have declined in recent years, leaving behind only substances such as DDE that have a longer environmental half life than does DDT. Concentrations of 4,4′-DDE were well below the HAC_{nonca} for 4,4′-DDE (1.167 mg/kg) in all fish and in combined fish. HQs were far below the 1.0 level that is protective of risk from this toxicant. Other pesticides such as 4,4′-DDD, 2,4′-DDT, chlordane, mirex, hexachlorobenzene, and pentachloroanisole were noted sporadically in one or more fish at estimated (J-value) to low concentrations in one or more samples. These pesticides did not reach concentrations in excess of their respective HAC_{nonca} values. No pesticide, including 4,4′-DDE generated a HQ greater than 1.0. SALG risk assessors concluded that consumption of fish from Alan Henry Reservoir containing any one pesticide at concentrations similar to observed concentrations in samples from the 2008 survey is unlikely to constitute a hazard to human health.

SVOCs

Five of the six fish from Alan Henry Reservoir tested for SVOCs contained traces of bis (ethylhexyl) phthalate (BEHP). BEHP, a compound used to make plastic more pliable, is a ubiquitous environmental pollutant. Consumption of trace quantities of BEHP in fish from this reservoir is unlikely to affect human health adversely.

VOCs

The same six fish discussed under pesticides, PCBs, and SVOCs, also contained VOCs. The GERG laboratory reported 11 VOCs at measurable but low concentrations, including carbon disulfide and methylene chloride, both used as solvents in many laboratory procedures, xylenes, toluene, and others. The laboratory reported traces of over 40 VOCs in one or more of the samples from Alan Henry Reservoir (data not shown). Fish may have VOCs contaminating a water body present in their bodies. In these instances, fish tissue concentrations will have reached equilibrium with VOCs in the water. In some instances, VOCs in fish could be considered a harbinger of contaminants in the ambient waters. In fish tissues collected from Alan Henry Reservoir, however, 24 VOCs were present in the procedural blanks, including 21 also identified in fish tissue samples. Since procedural blanks do not ordinarily contain tissue, the presence of VOCs in both blanks and samples makes it difficult to confirm the VOCs to be contaminants present at the time of collection. On the other hand, the data met quality control criteria. Although VOCs not reported present in the procedural blanks could have come from the reservoir water, normal cellular activities also produce trace quantities of many VOCs; some VOCs may even be products of tissue necrosis or decomposition. Most important to this project, all reported VOCs in the Alan Henry Reservoir samples occurred at concentrations below their respective HAC_{nonca} concentrations (data not presented). No one VOC reported in the 2008 Alan Henry Reservoir samples generated a HQ greater than 1.0 The SALG therefore concludes that consuming fish from Alan Henry Reservoir that contain a trace to a low concentration of a reported VOC is unlikely to cause adverse systemic effects on human health.

PCBs

Table 3 also presents the results of PCB analyses in fish collected from Alan Henry Reservoir during the present survey. The six fish contained PCBs at mean concentrations from 0.010 ±

0.001 mg/kg in largemouth bass to 0.032 ± 0.016 mg/kg in blue catfish. PCBs in fish from Alan Henry Reservoir did not exceed the HAC_{nonca} for Aroclor 1254, upon which the RfD is based (0.047 mg/kg) nor did HQs exceed 1.0. These data suggest that consumption of PCBs in fish from Alan Henry Reservoir containing PCBs at levels at or below those reported in this survey should not affect human health adversely.

PCDFs/PCDDs

The laboratory also analyzed these six fish for PCDFs/PCDDs. One of six fish tissue samples contained OCDD at a concentration of 15.7 pg/g. OCDD did not exceed the HAC_{nonca} for PCDFs/PCDDs. The HQ did not approach 1.0/ The average concentration of OCDD was much lower than was that in the single largemouth bass. Consumption of fish from Alan Henry Reservoir is unlikely to result in adverse systemic health outcomes in those who eat fish from this reservoir.

Characterization of Theoretical of Lifetime Excess Cancer Risk from Consumption of Fish from Alan Henry Reservoir

Inorganic Contaminants

Inorganic arsenic is a known human carcinogen. In fish from Alan Henry Reservoir, calculated concentrations of inorganic arsenic did not exceed the HAC_{ca} for inorganic arsenic. No fish sample or fish species contained inorganic arsenic at concentrations that would likely increase excess lifetime risk of cancer from daily exposure for 30 years to inorganic arsenic. Thus, exposure to inorganic arsenic in fish from Alan Henry Reservoir is unlikely to pose a significant risk for cancer in those who eat those fish.

CPFs (CSFs) are not available for cadmium, copper, lead, mercury, selenium, or zinc. The SALG was, consequently, unable to determine the probability of excess cancers from consuming fish from the 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.[41] For instance, one observational study reported selenium to protect humans from prostate and colon cancers.[42] A more recent evaluation – a randomized double-blind investigation – reported that selenium supplementation did not protect men from prostate cancer.[43]

Organic Contaminants

Pesticides

The GERG laboratory reported fish from Alan Henry Reservoir to contain pesticides, the list of which included pentachlorobenzene, hexachlorobenzene, heptachlor epoxide, chlordane, methoxychlor, and others, most at trace levels (data not shown). Table 3 shows summary statistics for 4,4’-DDE, a metabolite or degradation product of 4,4’-DDT. 4,4’-DDE was the only pesticide identified at measurable concentrations in six of six fish for Alan Henry Reservoir. The lifetime cancer estimate calculated for 4,4’-DDE was far lower than concentrations needed to increase cancer risk in those who consume fish from the reservoir. No other observed pesticide exceeded its respective HAC_{ca} value. The SALG concludes that, accepting the limitation of small sample numbers analyzed for pesticides, consumption of fish from Alan Henry Reservoir containing traces of one or more pesticides would be unlikely to increase the risk of excess cancers substantially in those who eat these fish.

VOCs

The reported VOCs in fish tissue samples from Alan Henry Reservoir were reported at concentrations well below their respective HAC_{ca} concentrations (data not presented). Predicted excess cancer incidences calculated from mean concentrations of measured VOCs were each less than 1 excess cancer per 10,000 equivalently exposed individuals. This finding suggests that consumption of fish from Alan Henry Reservoir that contain one or more VOCs at levels similar to those in the 2008 samples is unlikely to increase or to contribute to an increase in the calculated theoretical excess lifetime risk of cancer in people who eat fish from this reservoir.

SVOCs

Five of six fish collected in 2008 from Alan Henry Reservoir contained traces of BEHP, a probable human carcinogen.[44]. However, trace concentrations of BEHP in fish from the reservoir did not exceed the HAC_{ca} for this compound (data not shown). Consuming BEHP in fish from Alan Henry Reservoir is unlikely to increase the likelihood of excess cancers to a level greater than 1 excess cancer in 10,000 equivalently exposed people, the cutoff point above which the DSHS may wish to issue consumption advice for people eating fish containing a carcinogen.

PCBs

The six fish collected in 2008 from Alan Henry Reservoir all contained PCB. Concentrations ranged from 0.010 to 0.043 mg/kg (Table 3). No species of fish or all fish combined, contained PCBs at a concentration that would raise the calculated theoretical excess cancer risk to a calculated risk greater than 1 in 10,000 equivalently exposed persons (data not presented). Consumption of fish from Alan Henry Reservoir is not expected to increase excess cancer risk in those who eat fish from this reservoir.

PCDFs/PCDDs

One of six samples, a largemouth bass, contained 15.7 pg/g of octochlorodibenzo-p-dioxin (OCDD). OCDD did not exceed the HACca for PCDFs/PCDDs. The average concentration of OCDD was much lower than was that in the single largemouth bass. Consumption of fish from Alan Henry Reservoir is unlikely to increase the theoretical excess cancer risk in those who eat fish from this reservoir.

Characterization of Calculated Cumulative Systemic Health Effects and of Cumulative Excess Lifetime Cancer Risk from Consumption of Fish from Alan Henry Reservoir

Cumulative Systemic Effects

Cumulative systemic effects of toxicants may occur if more than one contaminant acts upon the same target organ or acts by the same mode or mechanism of action. For instance, chlorinated pesticides, PCBs, some VOCs and some SVOCs affect the liver at concentrations that are often higher than concentrations needed to exert an effect on the critical organ. The SALG calculated cumulative effects for systemic toxicity by adding the hazard quotient for 4,4'-DDE (0.04) to that for PCBs (0.38) to yield an HI of 0.4 for combined pesticides and PCBs. The HI of 0.4 for pesticides and PCBs in fish from Alan Henry Reservoir did not reach 1.0, suggesting that these contaminants combined did not increase the likelihood of systemic adverse health outcomes from consuming fish from Alan Henry Reservoir containing both contaminants.

Cumulative Cancer Risks

The SALG risk assessors also calculated the probability of increasing the lifetime excess cancer risk from consuming fish containing PCBs and pesticides by adding the risk of excess cancers from PCBs to that of 4,4'-DDE. The result, 1 excess cancer in 348,102 equivalently exposed persons, did not increase the calculated lifetime excess cancer risk to a risk greater than 1 excess cancer in 10,000 equivalently exposed persons. VOCs and SVOCs were not included in this calculation because only traces to low concentrations were found sporadically among the six fish examined for these contaminants. Consumption of fish from Alan Henry Reservoir is, thus, unlikely to result in discernable excess numbers of cancers in people who eat fish from this reservoir. OCDD in a single largemouth buffalo did not contribute to the cumulative excess cancer risk.

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. If necessary, the SALG may suggest strategies for reducing risk to the health of those who may eat contaminated fish or seafood to risk managers at DSHS, including the Texas Commissioner of Health.

This study addressed the public health implications of consuming fish from Alan Henry Reservoir. Risk assessors from the SALG conclude from the present characterization of potential adverse health effects from consuming fish from Alan Henry Reservoir:

1. That Black crappie, blue catfish, flathead catfish, largemouth bass, spotted bass, and white crappie collected in 2008 from Alan Henry Reservoir contain mercury at concentrations exceeding DSHS guidelines for protection of human health. Regular or long-term consumption of fish from Alan Henry Reservoir may result in adverse health

effects. Therefore, consumption of blue catfish, crappie, flathead catfish, largemouth bass, and spotted bass from Alan Henry Reservoir **poses an apparent risk to human health.**

2. Mercury in channel catfish, common carp, and freshwater drum collected in 2008 from Alan Henry Reservoir is not at concentrations that exceed the methylmercury HAC_{nonca}. Thus, consuming channel catfish, common carp, or freshwater drum from Alan Henry Reservoir **poses no apparent hazard to human health.**

3. Fish from Alan Henry Reservoir contain no other contaminants at concentrations that, if consumed individually or in large quantities, would pose a hazard to human health.

RECOMMENDATIONS

Risk managers at the DSHS have established criteria for issuing fish consumption advisories based on approaches suggested by the EPA.[10, 12, 45] Risk managers at the DSHS may decide to take some action to protect public health if a risk characterization confirms that people can eat four, or fewer meals per month (adults: eight ounces per meal; children: four ounces per meal) of fish or shellfish from a water body under investigation. Risk management recommendations may be in the form of consumption advice or a ban on 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).[46] Declarations of prohibited harvesting areas are enforceable under the Texas Health and Safety Code, Subchapter D, parts 436.091 and 436.101.[46] DSHS consumption advice carries no penalty for noncompliance. Consumption advisories, instead, inform the public of potential health hazards associated with consuming contaminated fish or shellfish from Texas waters. With this information, members of the public can make informed decisions about whether and/or how much contaminated fish or shellfish they wish to consume. The SALG risk assessors conclude from this risk characterization that mercury in most species of fish from Alan Henry Reservoir poses **an apparent hazard to public health**, and, especially to the health of sensitive groups that include those who have a rapidly developing CNS**.** Therefore, SALG risk assessors recommend

1. That pregnant women, women who may become pregnant, women who are nursing an infant, and small children (those ≤12 years of age or who weigh less than 75 pounds) should eat no black crappie, blue catfish, flathead catfish, largemouth bass, spotted bass, or white crappie from Alan Henry Reservoir.

2. That adult men and women past childbearing may consume up to two eight-ounce meals per month (preferably no more than one 8-ounce meal every two weeks) of black crappie, blue catfish, largemouth bass, spotted bass or white crappie from Alan Henry Reservoir or of any combination of black crappie, blue catfish, flathead catfish, largemouth bass, spotted bass or white crappie from Alan Henry Reservoir.

3. That sensitive groups such as pregnant women, women who may become pregnant, women who are nursing an infant, and small children (those less than or equal to 12 years

of age or who weigh less than 75 pounds) should limit consumption of channel catfish, common carp, and freshwater drum to one meal per week.

4. That adult men and women past childbearing need not restrict their consumption of people need not restrict consumption of channel catfish, common carp, or freshwater drum from Alan Henry Reservoir.

PUBLIC HEALTH ACTION PLAN

Communication to the public of new and continuing possession bans or consumption advisories, or the removal of either, is essential to effective management of risk from consuming contaminated fish. In fulfillment of the responsibility for communication, the DSHS takes several steps. The agency publishes fish consumption advisories and bans in a booklet available to the public through the SALG. To receive the booklet and/or the data, please contact the SALG at 1-512-834-6757.[47] The SALG also posts the most current information about advisories, bans, and the removal of either on the internet at http://www.dshs.state.tx.us/seafood. The SALG regularly updates this Web site. The DSHS also provides the EPA http://epa.gov/waterscience/fish/advisories/), the TCEQ (http://www.tceq.state.tx.us), and the 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 on it's Web site and in an official hunting and fishing regulations booklet available at many state parks and at all establishments selling Texas fishing licenses.[48] Readers may direct questions about the scientific information or recommendations in this risk characterization to the SALG at 512-834-6757 or may find the information at the SALG's Web site. Secondarily, one may address inquiries to the Environmental and Injury Epidemiology and Toxicology Branch (EIETB) of the DSHS (512-458-7269). The EPA's IRIS Web site (http://www.epa.gov/iris/) contains information on environmental contaminants found in food and environmental media. The Agency for Toxic Substances and Disease Registry (ATSDR), Division of Toxicology (888-42-ATSDR or 888-422-8737 or the ATSDR's Web site (http://www.atsdr.cde.gov) supplies brief information via *ToxFAQs*.™ *ToxFAQs*™ are available on the ATSDR Web site in either English http://www.atsdr.cdc.gov/toxfaq.html) or Spanish (http://www.atsdr.cdc.gov/es/toxfaqs/es _toxfaqs.html). The ATSDR also publishes more in-depth reviews of many toxic substances in its *Toxicological Profiles*™. To request a copy of the *ToxProfiles*™ CD-ROM, PHS, or *ToxFAQs*™ call 1-800-CDC-INFO (800-232-4636) or email a request to cdcinfo@cdc.gov.

Figure 1. Alan Henry Reservoir Sample Sites

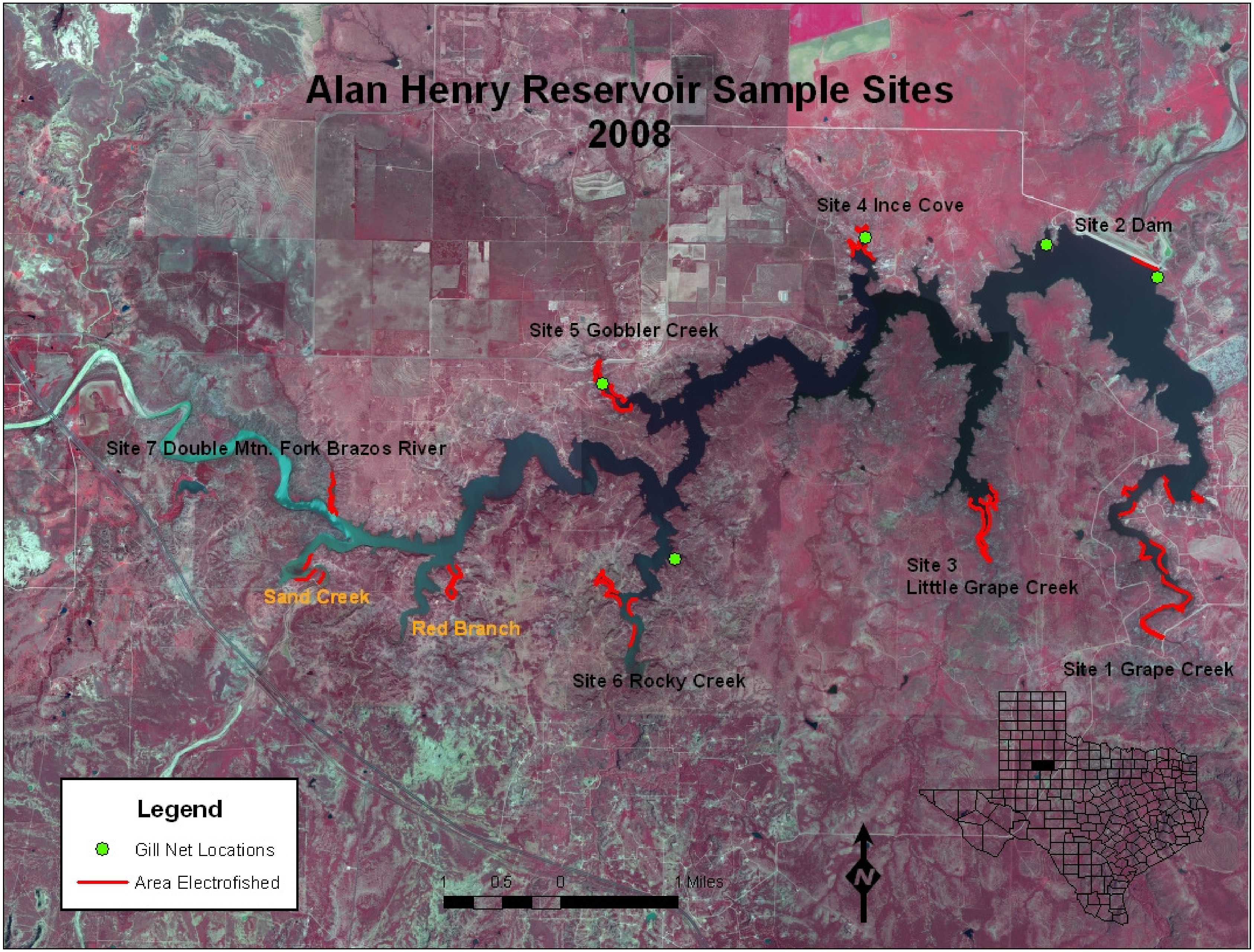


Figure 2. Mean Mercury Concentrations by Species Collected from Alan Henry Reservoir, April 2008.

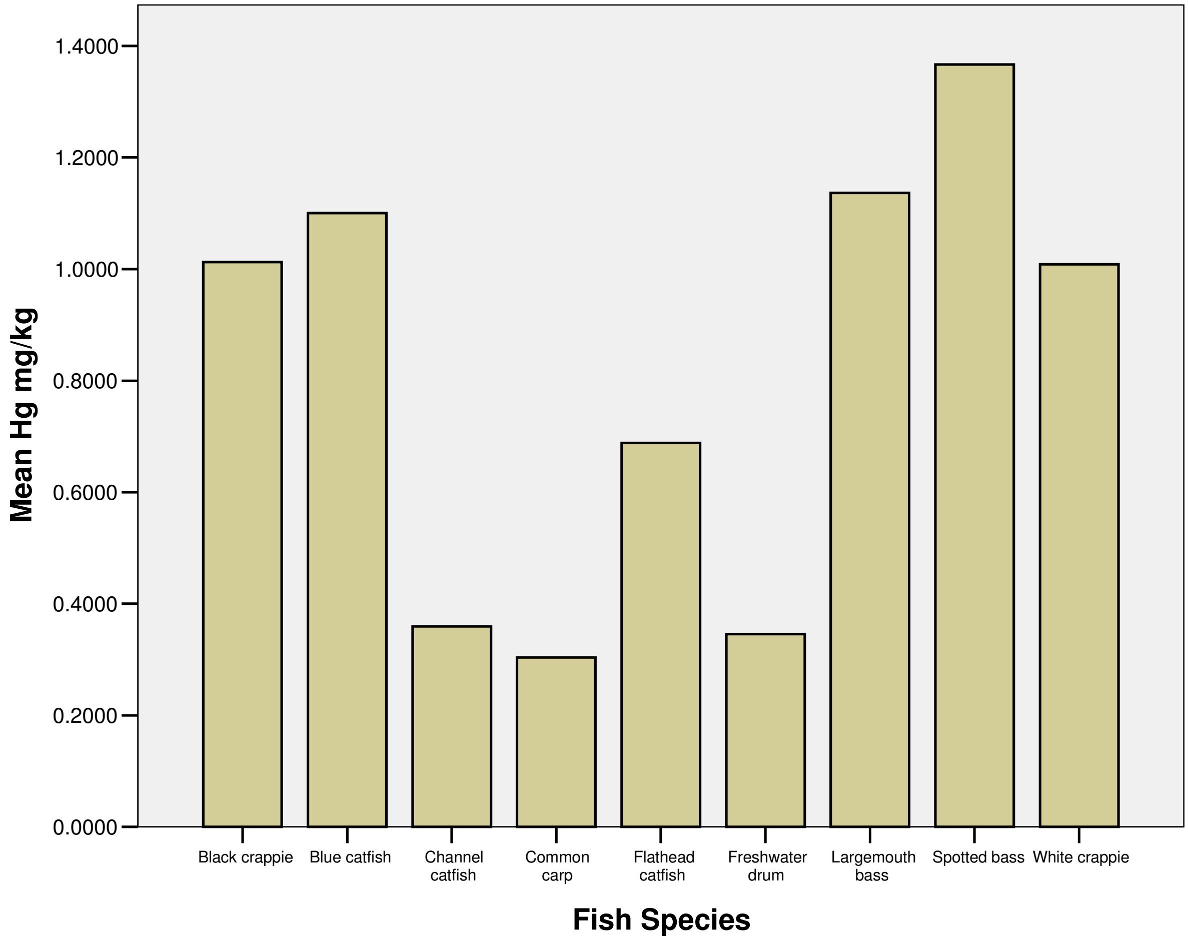
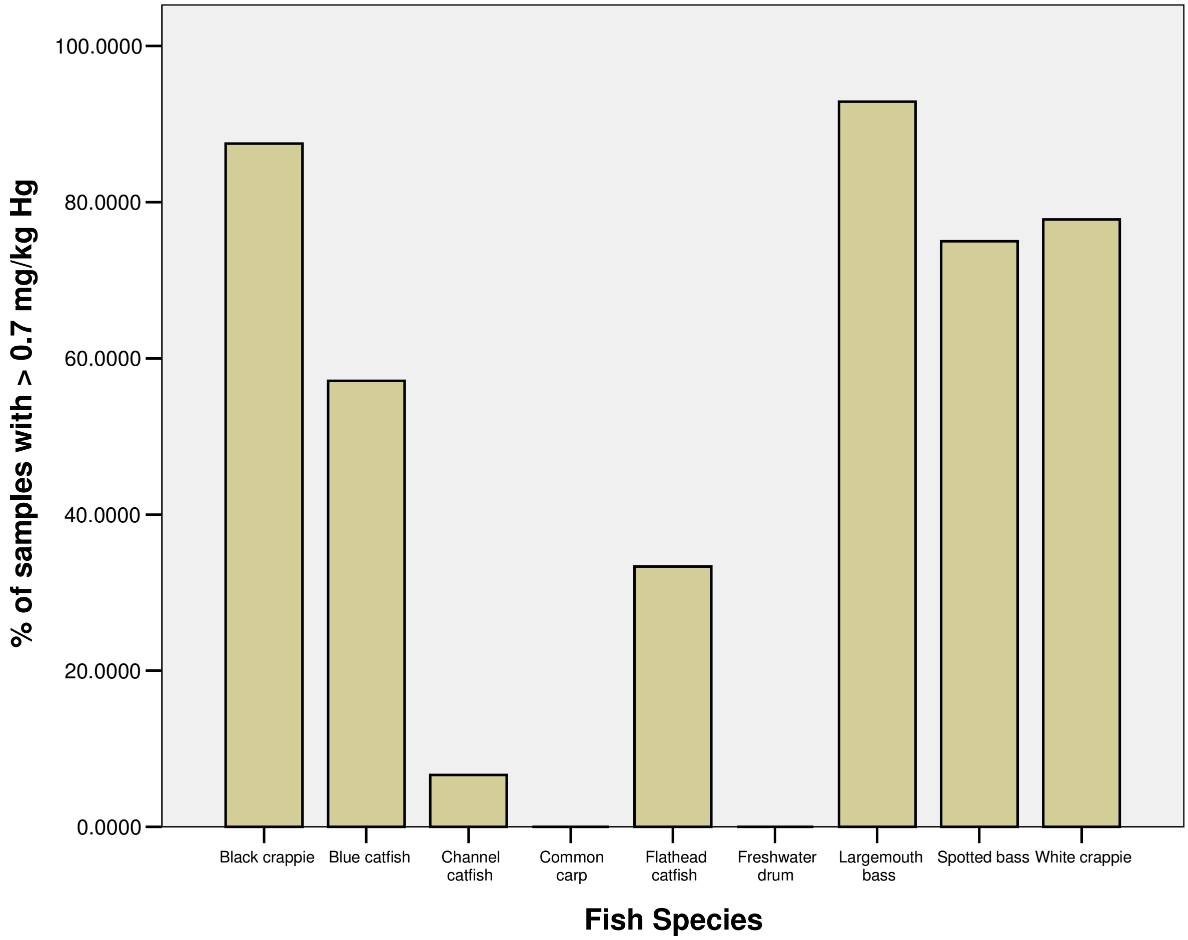


Figure 3. Percent of Fish Samples Examined by Species Exceeding the DSHS Mercury HAC value (0.7 mg/kg). Fish Collected from Alan Henry Reservoir, April 2008.



TABLES

Table 1. Fish samples collected from Alan Henry Reservoir, April 2008. Sample ID, species, length, and weight were recorded for each sample.

Sample Number	Species	Length (mm)	Weight (g)
Site 1 Alan Henry Reservoir @ Grape Creek			
LAH55	Largemouth bass	485	1677
LAH56	Largemouth bass	467	1293
LAH57	Largemouth bass	434	1206
LAH58	Largemouth bass	379	781
LAH59	Largemouth bass	400	709
LAH60	Largemouth bass	351	576
LAH61	Spotted bass	369	518
LAH62	Black crappie	318	477
LAH63	Black crappie	299	429
LAH64	White crappie	260	184
LAH65	Freshwater drum	332	446
LAH66	Freshwater drum	334	388
LAH67	Common carp	640	4291
Site 2 Alan Henry Reservoir @ Dam			
LAH4	Spotted bass	499	1252
LAH5	Spotted bass	447	1037
LAH6	Largemouth bass	380	735
LAH7	Blue catfish	592	2490
LAH8	Blue catfish	660	3230
LAH9	Blue catfish	705	3671
LAH10	Blue catfish	567	2022
LAH11	Blue catfish	525	1510
LAH12	Blue catfish	905	9299
LAH13	Blue catfish	804	7129
LAH14	Channel catfish	536	1270
LAH15	Channel catfish	638	3030
LAH16	Channel catfish	650	3012
LAH17	Channel catfish	540	1421
LAH18	Channel catfish	600	2074
LAH20	Common carp	615	3436
Site 3 Alan Henry Reservoir @ Little Grape Creek			
LAH68	Largemouth bass	510	2259
LAH69	Largemouth bass	400	993
LAH70	Largemouth bass	387	794
LAH71	Largemouth bass	372	726
LAH72	Largemouth bass	377	671

Table 1. Fish samples collected from Alan Henry Reservoir, April 2008. Sample ID, species, length, and weight were recorded for each sample.

Sample Number	Species	Length (mm)	Weight (g)
Site 3 Alan Henry Reservoir @ Little Grape Creek Continued			
LAH73	Largemouth bass	362	659
LAH74	Largemouth bass	361	625
LAH75	Spotted bass	412	800
LAH76	Black crappie	318	573
LAH77	Black crappie	305	487
LAH78	Black crappie	292	369
LAH79	Black crappie	284	337
LAH80	White crappie	263	161
LAH81	Channel catfish	640	2701
LAH82	Channel catfish	520	1227
LAH83	Channel catfish	575	1780
Site 4 Alan Henry Reservoir @ Ince Cove			
LAH21	Largemouth bass	483	1659
LAH22	Largemouth bass	379	633
LAH23	Largemouth bass	380	779
LAH24	Largemouth bass	402	1088
LAH25	Largemouth bass	366	717
LAH26	Largemouth bass	365	721
LAH27	Black crappie	298	361
LAH28	Black crappie	316	537
LAH29	Freshwater drum	350	461
LAH30	Freshwater drum	376	700
LAH31	Flathead catfish	520	1449
LAH32	Channel catfish	649	3458
LAH33	Channel catfish	602	2192
LAH34	Channel catfish	550	1924
LAH36	Common carp	545	2528
Site 5 Alan Henry Reservoir @ Gobbler Creek			
LAH37	Largemouth bass	395	893
LAH38	Largemouth bass	400	983
LAH39	Largemouth bass	452	1380
LAH40	Largemouth bass	395	903
LAH41	Largemouth bass	400	944
LAH42	Largemouth bass	376	764
LAH43	Largemouth bass	390	788
LAH44	Largemouth bass	372	755
LAH45	Largemouth bass	383	736
LAH46	White crappie	375	706
LAH47	White crappie	373	661
LAH48	Freshwater drum	320	408

Table 1. Fish samples collected from Alan Henry Reservoir, April 2008. Sample ID, species, length, and weight were recorded for each sample.

Sample Number	Species	Length (mm)	Weight (g)
Site 5 Alan Henry Reservoir @ Gobbler Creek Continued			
LAH49	Freshwater drum	321	437
LAH50	Flathead catfish	589	2110
LAH51	Channel catfish	528	1259
LAH52	Channel catfish	644	3170
LAH53	Channel catfish	587	1701
LAH54	Channel catfish	555	1849
LAH84	Largemouth bass	545	2588
LAH85	Largemouth bass	591	3603
LAH86	Largemouth bass	510	2015
LAH87	Largemouth bass	351	524
LAH88	Largemouth bass	424	1105
LAH89	Largemouth bass	509	2254
LAH90	Largemouth bass	439	1226
LAH91	Largemouth bass	468	1416
LAH92	Largemouth bass	463	1422
LAH93	Largemouth bass	421	1141
LAH94	Largemouth bass	423	1014
LAH95	Freshwater drum	367	604
LAH96	Freshwater drum	362	514
Site 6 Alan Henry Reservoir @ Rocky Creek			
LAH1	Common carp	660	3970
LAH2	Flathead catfish	842	8028
LAH3	White crappie	307	369
LAH97	Largemouth bass	428	1206
LAH98	White crappie	400	921
LAH99	White crappie	349	527
LAH100	White crappie	290	340
Site 7 Alan Henry Reservoir @ Double Mountain Fork of Brazos River			
LAH101	Largemouth bass	466	1569
LAH102	White Crappie	342	554

Table 2a. Arsenic (mg/kg) in fish collected from Alan Henry Reservoir, 2008.

Species	#Detected/ # Sampled	Total Arsenic Mean Concentration ± S.D. (Min-Max)	Inorganic Arsenic Mean Concentration[d]	Health Assessment Comparison Value (mg/kg)[e]	Basis for Comparison Value

[d] *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.*

Blue catfish	4/5	0.105±0.086 (ND-0.233)	0.011	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
Channel catfish	4/5	0.148±0.123 (ND-0.307)	0.015		
Common carp	2/2	0.147±0.057 (0.107, 0.187)	0.015		
Flathead catfish	3/3	0.091±0.053 (0.044-0.148)	0.009		
Freshwater drum	4/4	0.296±0.067 (0.236-0.383)	0.030		
Largemouth bass	5/5	0.297±0.049 (0.237-0.366)	0.030		
Spotted bass	3/3	0.238±0.046 (0.187-0.275)	0.024		
White crappie	3/3	0.338±0.014 (0.325-0.352)	0.034		
All Species	28/30	0.208±0.113 (ND-0.383)	0.021		

[e] *Derived from the MRL or RfD for noncarcinogens or the EPA 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 2b. Inorganic contaminants (mg/kg) in fish collected from Alan Henry Reservoir, 2008.

Species	# Detected/ # Sampled	Mean Concentration ± S.D. (Min-Max)	Health Assessment Comparison Value (mg/kg)	Basis for Comparison Value
Cadmium				
Blue catfish	0/5	ND	0.47	ATSDR chronic oral MRL: 0.0002 mg/kg–day
Channel catfish	1/5	0.012±0.004 (ND-0.020)		
Common carp	1/2	0.017±0.011 (ND, 0.025)		
Flathead catfish	0/3	ND		
Freshwater drum	2/4	0.013±0.004 (ND-0.020)		
Largemouth bass	3/5	0.016±0.007 (ND-0.025)		
Spotted bass	1/3	BDL		
White crappie	2/3	0.017±0.008 (ND-0.024)		
All Species	10/30	0.013±0.005 (ND-0.025)		
Copper				
Blue catfish	5/5	0.293±0.080 (0.210-0.405)	333	National Academy of Science Upper Limit: 0.143 mg/kg–day
Channel catfish	5/5	0.192±0.027 (0.157-0.232)		
Common carp	2/2	0.267±0.079 (0.211, 0.323)		
Flathead catfish	3/3	0.106±0.009 (0.096-0.113)		
Freshwater drum	4/4	0.170±0.028 (0.148-0.210)		
Largemouth bass	5/5	0.123±0.013 (0.113-0.146)		
Spotted bass	3/3	0.205±0.054 (0.143-0.240)		
White crappie	2/3	0.076±0.039 (BDL-0.109)		
All Species	29/30	0.180±0.082 (BDL-0.405)		

Table 2b Continued. Inorganic contaminants (mg/kg) in fish collected from the Alan Henry Reservoir, 2008.

Species	# Detected/ # Sampled	Mean Concentration ± S.D. (Min-Max)	Health Assessment Comparison Value (mg/kg)	Basis for Comparison Value
Lead				
Blue catfish	1/5	BDL	0.6	EPA IEUBKwin
Channel catfish	4/5	BDL		
Common carp	1/2	BDL		
Flathead catfish	1/3	BDL		
Freshwater drum	2/4	BDL		
Largemouth bass	4/5	BDL		
Spotted bass	0/3	ND		
White crappie	2/3	BDL		
All Species	15/30	ND-BDL		
Selenium				
Blue catfish	5/5	0.186±0.027 (0.157-0.219)	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
Channel catfish	5/5	0.264±0.171 (0.131-0.545)		
Common carp	2/2	0.312±0.11 (0.304, 0.319)		
Flathead catfish	3/3	0.252±0.0.37 (0.212-0.286)		
Freshwater drum	4/4	0.522±0.086 (0.428-0.615)		
Largemouth bass	5/5	0.491±0.094 (0.382-0.624)		
Spotted bass	3/3	0.506±0.053 (0.446, 0.548)		
White crappie	3/3	0.441±0.036 (0.411, 0.480)		
All Species	30/30	0.367±0.155 (0.131-0.624)		

Table 2b Continued. Inorganic contaminants (mg/kg) in fish collected from the Alan Henry Reservoir, 2008.

Species	# Detected/ # Sampled	Mean Concentration ± S.D. (Min-Max)	Health Assessment Comparison Value (mg/kg)	Basis for Comparison Value
Zinc				
Blue catfish	5/5	4.873±0.728 (4.015-5.596)	700	EPA chronic oral RfD: 0.3 mg/kg–day
Channel catfish	5/5	3.250±0.439 (2.601-3.685)		
Common carp	2/2	2.340±0.351 (2.092, 2.588)		
Flathead catfish	3/3	2.346±0.349 (2.005-2.703)		
Freshwater drum	4/4	2.883±0.632 (2.218-3.731)		
Largemouth bass	5/5	2.178±0.239 (1.857-2.486)		
Spotted bass	3/3	2.489±0.133 (2.344-2.605)		
White crappie	3/3	2.424±0.521 (1.868, 2.900)		
All Species	30/30	2.983±1.025 (1.857-5.596)		

Table 2c. Mercury (mg/kg) in fish collected from Alan Henry Reservoir, 2008.

Species	# Detected/ # Sampled	Mean Concentration ± S.D. (Min-Max)	Health Assessment Comparison Value (mg/kg)	Basis for Comparison Value
Site 1 Grape Creek				
Black crappie	2/2	**1.337**[f]±0.366 (**1.078, 1.596**)	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg–day
Common carp	1/1	0.300		
Freshwater drum	2/2	0.299±0.116 (0.217, 0.382)		
Largemouth bass	6/6	**1.093**±0.338 (**0.730-1.692**)		
Spotted bass	1/1	0.331		
White crappie	1/1	0.697		
All Species	13/13	**0.858**±0.478 (0.217-**1.692**)		
Site 2 Dam				
Blue catfish	7/7	**1.105**±1.108 (0.270-**3.434**)	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg–day
Channel catfish	5/5	0.276±0.169 (0.096-0.557)		
Common carp	1/1	0.373		
Largemouth bass	1/1	**1.184**		
Spotted bass	2/2	**1.676**±0.911 (**1.032-2.321**)		
All Species	16/16	**0.875**±0.888 (0.096-**3.434**)		
Site 3 Little Grape Creek				
Black crappie	4/4	**0.875**±0.154 (**0.719, 1.042**)	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg–day
Channel catfish	3/3	0.347±0.121 (0.212-0.445)		
Largemouth bass	7/7	**1.339**±0.246 (**0.838-1.537**)		
Spotted bass	1/1	**1.784**		
White crappie	1/1	**1.084**		
All Species	16/16	**1.071**±0.476 (0.212-**1.784**)		

[f] **Emboldened numbers** indicate the concentration of a contaminant exceeded a DSHS HAC Value

Table 2c Continued. Mercury (mg/kg) in fish collected from the Alan Henry Reservoir, 2008.				
Species	**# Detected/ # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
Site 4 Ince Cove				
Black crappie	2/2	**0.964**±0.465 (**0.635, 1.293**)	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg–day
Channel catfish	3/3	0.172±0.081 (0.084, 0.244)		
Common carp	1/1	0.248		
Flathead catfish	1/1	0.487		
Freshwater drum	2/2	0.296±0.192 (0.160, 0.432)		
Largemouth bass	6/6	**1.007**±0.452 (0.417-**1.776**)		
All Species	10/10	0.654±0.491 (0.084, **1.776**)		
Site 5 Gobbler Creek				
Channel catfish	4/4	0.613±0.738 (0.150-**1.714**)	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg–day
Flathead catfish	1/1	0.436		
Freshwater drum	4/4	0.394±0.219 (0.225-0.699)		
Largemouth bass	20/20	**1.087**±0.414 (0.143-**1.789**)		
White crappie	2/2	**1.104**±0.269 (**0.914, 1.294**)		
All Species	31/31	**0.917**±0.498 (0.142-**1.789**)		
Site 6 Rocky Creek				
Common carp	1/1	0.294	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg–day
Flathead catfish	1/1	**1.141**		
Largemouth bass	1/1	**1.122**		
White crappie	4/4	**1.043**±0.459 (0.586-**1.479**)		
All Species	7/7	**0.961**±0.440 (0.294-**1.479**)		

Table 2c Continued. Mercury (mg/kg) in fish collected from the Alan Henry Reservoir, 2008.

Species	# Detected/ # Sampled	Mean Concentration ± S.D. (Min-Max)	Health Assessment Comparison Value (mg/kg)	Basis for Comparison Value
Site 7 Double Mountain Fork Brazos River				
Largemouth bass	1/1	**1.347**	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg–day
White crappie	1/1	**0.917**		
All Species	2/2	**1.132**±0.304 (**0.917, 1.347**)		
Alan Henry Reservoir-All Sites				
Black crappie	8/8	**1.013**±0.319 (0.635-**1.596**)	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg–day
Blue catfish	7/7	**1.100**±1.108 (0.270-**3.435**)		
Channel catfish	15/15	0.359±0.396 (0.084-**1.714**)		
Common carp	4/4	0.304±0.052 (0.248-0.373)		
Flathead catfish	3/3	0.688±0.393 (0.436-**1.141**)		
Freshwater drum	8/8	0.346±0.175 (0.160-0.699)		
Largemouth bass	42/42	**1.136**±0.378 (0.143-**1.789**)		
Spotted bass	4/4	**1.367**±0.870 (0.331-**2.321**)		
White crappie	9/9	**1.008**±0.324 (0.586-**1.479**)		
All Species	100/100	**0.895**±0.567 (0.084-**3.435**)		

Table 3. Pesticides and PCBs (mg/kg) in fish collected from the Alan Henry Reservoir, 2008

Species	# Detected / # Sampled	Mean Concentration ± S.D. (Min-Max)	Health Assessment Comparison Value (mg/kg)	Basis for Comparison Value
4,4'-DDE				
Blue catfish	2/2	0.122±0.073 (0.070, 0.174)	1.167 1.599	EPA chronic oral RfD: 0.0005 mg//kg–day EPA slope factor 0.34 per mg/kg - day
Common carp	2/2	0.011±0.007 (0.006, 0.017)		
Largemouth bass	2/2	0.005±0.002 (0.004, 0.006)		
All Species	6/6	0.046±0.067 (0.004-0.174)		
PCBs				
Blue catfish	2/2	0.032±0.016 (0.021, 0.043)	0.047 0.272	EPA chronic oral RfD: 0.00002 mg/kg–day EPA slope factor: 2.0 per mg/kg–day
Common carp	2/2	0.011±0.001 (0.010, 0.012)		
Largemouth bass	2/2	0.010±0.001 (0.010, 0.011)		
All Species	6/6	0.018±0.013 (0.010-0.043)		

Table 4. Hazard quotients for mercury in fish collected from Alan Henry Reservoir in 2008. Table 3 also provides suggested weekly eight-ounce meal consumption rates for 70-kg adults.[g]

Species	Hazard Quotient	Meals per Week
Black crappie	**1.4**[h]	**0.6**
Blue catfish	**1.6**	**0.6**
Channel catfish	0.5	1.8
Common carp	0.4	2.1
Flathead catfish	**1.0**	**0.9**
Freshwater drum	0.5	1.9
Largemouth bass	**1.6**	**0.6**
Spotted bass	**2.0**	**0.5**
White crappie	**1.4**	**0.6**
All Species	**1.3**	**0.7**

[g] *DSHS assumes that children under the age of 12 years and/or those who weigh less than 35 kg eat 4-ounce meals.*
[h] ***Emboldened numerals** denote a HQ or HI or Cancer Risk that exceeds the HAC for that chemical and the suggested meal consumption limit for an adult is less than 1 per week.*

Table 5. Hazard quotients by site for mercury in fish collected from Alan Henry Reservoir in 2008. Table 4 also provides suggested weekly eight-ounce meal consumption rates for 70-kg adults.[i]

Site	Hazard Quotient	Meals per Week
Site 1 Alan Henry Reservoir @ Grape Creek	**1.2**	**0.8**
Site 2 Alan Henry Reservoir @ Dam	**1.3**	**0.7**
Site 3 Alan Henry Reservoir @ Little Grape Creek	**1.5**	**0.6**
Site 4 Alan Henry Reservoir @ Ince Cove	0.9	1.0
Site 5 Alan Henry Reservoir @ Gobbler Creek	**1.3**	**0.7**
Site 6 Alan Henry Reservoir @ Rocky Creek	**1.4**	**0.7**
Site 7 Alan Henry Reservoir @ Double Mtn. Fork Brazos River	**1.6**	**0.6**
Alan Henry Reservoir-All Sites	**1.3**	**0.7**

[i] *DSHS assumes that children under the age of 12 years and/or those who weigh less than 35 kg eat 4-ounce meals.*

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