Characterization of Potential Adverse Health Effects from Consuming Fish from

CLEAR LAKE

Panola County, Texas

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

INTRODUCTION

History of Clear Lake

Clear Lake is a 15-acre oxbow lake located within the Sabine River watershed in Panola County, Texas. The Sabine River is relatively long and narrow, with a length of 300 miles.[1] From the headwaters in Hunt County, the river extends in a southeasterly direction for approximately 165 miles flowing through Lake Tawakoni to the Texas-Louisiana border near Logansport, Louisiana, then in a southerly direction as the Texas-Louisiana state line through Toledo Bend Reservoir to Sabine Lake and the Gulf of Mexico. The Sabine River watershed contains approximately 15 major reservoirs of which Lake Fork, Lake Tawakoni, and Toledo Bend Reservoir are the largest. The Sabine River basin lies within three major land resource areas: Blackland Prairie, East Texas Timberlands, and Coastal Prairie. The East Texas Timberlands comprise about 88 percent of the basin.

Clear Lake Demographics Nearby Towns and Cities

The 2000 Panola County population was 22,756 people.[2] The lake is 12 miles Northwest of Logansport, LA (2000 population 1,630) 22 miles southeast of Carthage, TX (2000 population 6,664) – the Panola County seat –, 50 miles southeast of Marshall (2000 population 23,965), and 50 miles east of Henderson, TX (2000 population 11,273).[3, 4]

Mercury in the Environment

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

Some aquatic organisms easily absorb methylmercury from water or from other aquatic organisms; if absorption of methylmercury is not immediately balanced by excretion, the concentration of methylmercury in the organism may exceed the concentration in the surrounding waters or foods, a process known as *bioconcentration*. Some fish have no physiological mechanisms for removing methylmercury from their bodies. Continued absorption of methylmercury without concomitant excretion results in accumulation of the substance in tissues, a process called *bioaccumulation*.[5] It follows from the process of bioaccumulation that older, larger fish may contain higher levels of methylmercury than younger, smaller fish. Predatory fish that do not excrete mercury and that eat smaller mercury-contaminated fish will accumulate higher levels of methylmercury because the source substances have higher levels of methylmercury. Thus, predators occupying niches near the top of the food chain attain even higher levels of methylmercury through the process of *biomagnification*. Humans are then often exposed to the toxicant through consumption of contaminated fish. Although humans can excrete methylmercury, the process is relatively slow. People who eat older, larger fish, those who eat predator fish, or those who eat more fish from higher on the food chain may be exposed to higher levels of methylmercury than those who eat fish dwelling near the bottom of the food chain (e.g. sunfish, channel catfish, blue catfish, common carp, etc). Those who eat fewer fish meals, or who eat smaller fish, or fish from lower on the food chain, thus, are often exposed to lower levels of methylmercury than are those who do not follow these recommendations. Certain vulnerable people who eat methylmercury-contaminated fish or shellfish – women who are pregnant or who may become pregnant, for instance – may store methylmercury in their bodies, releasing the mercury into their bloodstreams over time. These women may consume or store enough methylmercury to damage the fetal brain, thought to be the organ primarily damaged by methylmercury.[6] Although it is impossible to completely eliminate human exposure to mercury, people are primarily exposed to mono-methylmercury principally through consumption of contaminated fish. People who do not eat fish thus avoid most exposure to methylmercury. Consequently, methylmercury exposure is controllable. Knowledge of the whereabouts of methylmercury-contaminated fish or shellfish and of probable concentrations in those aquatic organisms gives people the option of limiting their exposure to this toxicant.

History of the Tier 2 Mercury in East Texas Water Bodies Project

Three Texas agencies, the Department of State Health Services (DSHS), the Texas Commission on Environmental Quality (TCEQ), and the Texas Parks and Wildlife Department (TPWD), have critical interests in – and responsibilities for – contaminants in the waters of Texas, their sediments, and the fish and shellfish that inhabit those waters. The Seafood and Aquatic Life Group (SALG) at DSHS determines whether chemical contaminants in fish or shellfish pose a health risk to those who would consume those fish or shellfish and – if so – is responsible for issuing health advisories or prohibiting possession of contaminated fish or shellfish from public water bodies in Texas.[7]

Among its other duties, the TCEQ establishes and manages state water quality standards and addresses pollution of Texas' public waters. The TPWD manages state fish and wildlife resources, addresses pollution that may adversely impact these resources, and enforces closures or bans issued by DSHS. These, and several other state and federal agencies have, for many years, coordinated efforts to oversee contaminant monitoring of fish from Texas waters – and their flora and fauna – through the Toxic Substances Coordinating Committee (TSCC), a legislatively mandated interagency committee.[8]

The Tier 2 Mercury in East Texas Water Bodies Project is a two-stage project that accesses the expertise and resources of the TCEQ, the TPWD, and the DSHS.[9,10] The United States Environmental Protection Agency (USEPA) financed the effort through fiscal year 2007 (ending October 31, 2007) with funds administered by the TCEQ. Most of the USEPA grant funds for this project are allocated to laboratory analysis of fish tissue for chemical contaminants that, upon regular consumption, could adversely impact the health of an individual or a population. Tier 1 studies were conducted by the TPWD Resource Protection Division Contaminants Assessment Team as part of a three-year special study and by TCEQ during field operations. Water bodies surveyed by TPWD and TCEQ exceeding fish tissue mercury screening criteria (0.525 mg/kg) were selected for intensive Tier 2 study. DSHS conducts the Tier 2 studies to characterize the potential human health risks associated with consumption of such fish.

In 1999, the TPWD Resource Protection Division Contaminants Assessment Team began a three-year study of sixty (60) reservoirs in fifty-seven (57) East Texas counties to delineate the geographical extent of mercury bioaccumulation and to study the interactions between the biotic and abiotic factors resulting in mercury bioaccumulation.[11] In addition to these objectives, the study identified water bodies where fish tissue mercury concentrations exceeded human health risk screening criteria. East Texas was selected as the study area because the Piney Woods and Oak Woodlands ecoregions have water, soil, and terrestrial plant communities that may be correlated with an increased risk of bioaccumulation of mercury in fish tissue.

In 2001, the TPWD sampled fish from Clear Lake as a part of its special study. From this sample collection effort, TPWD collected four largemouth bass samples ranging in length from 15.6 to 19.2 inches. The agency also collected three channel catfish (19.8-21.2 inches) and three freshwater drum (20.8-24.3 inches) samples. Samples were submitted for analysis to the TPWD laboratory in San Marcos, TX. The DSHS and TCEQ compared Tier 1 Clear Lake laboratory results for mercury to the DSHS-established human health mercury screening value (SV) to determine whether Clear Lake should be more intensively examined in a Tier 2 study. That comparison revealed that the mean concentration of mercury (1.071 mg/kg) in largemouth bass exceeded the human health screening value for mercury (0.525 mg/kg). The mean mercury concentration for the largemouth bass samples also exceeded the DSHS guideline for assessing systemic human health effects of regular or prolonged oral exposure to mercury (0.7 mg/kg). Mean mercury concentrations reported for channel catfish and freshwater drum were 0.559 mg/kg and 0.708 mg/kg, respectively. These mean mercury concentrations reported in channel catfish and freshwater drum also exceeded the human health screening value for mercury (0.525 mg/kg).

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

METHODS

Fish Tissue Collection and Analysis

The DSHS Seafood and Aquatic Life Group (SALG) collects and analyzes edible fish from the state's public waters to evaluate potential risks to the health of people consuming contaminated fish or shellfish. Fish tissue sampling follows standard operating procedures from the DSHS *Seafood and Aquatic Life Group Survey Branch Standard Operating Procedures and Quality Control/Assurance Manual.*[12] The SALG bases its sampling and analysis protocols, in part, on procedures recommended by the United States Environmental Protection Agency (EPA) in that agency's *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories, Volume 1.*[13] Advice and direction are also received from the legislatively mandated *State of Texas Toxic Substances Coordinating Committee (TSCC) Fish Sampling Advisory Subcommittee (FSAS).*[14] Samples usually represent species, trophic levels, and legal-sized specimens available for consumption from a water body. When practical, the DSHS collects samples from two or more sites within a water body to better characterize geographical distributions of contaminants.

Description of the Clear Lake 2005 Sample Set

In October 2005, SALG staff collected 15 fish samples from Clear Lake. Risk assessors used data from these fish to examine potential human health risks from consuming fish from Clear Lake.

Because of the small size of Clear Lake (15 acres), the SALG did not select samples sites in order to provide spatial coverage of the study area; rather the entire lake was assessed (Figure 1). The SALG targeted species for collection from Clear Lake through use of fish-tissue sampling protocols developed over many years by the SALG and it's legacy group, the Division of Seafood Safety at the Texas Department Health (now the Department of State Health Services). Collected species represent distinct ecological groups (i.e. predators and bottom-dwellers) that have some potential to bio-accumulate chemical contaminants, have a wide geographic distribution, are of local recreational fishing value, and/or are commonly consumed by anglers. The 15 fish collected from Clear Lake in October 2005 represented all targeted species (Table 1). Targeted species and numbers collected are listed in descending order: largemouth bass (10), freshwater drum (3), bowfin (1), and smallmouth buffalo (1).

The SALG staff utilized a boat-mounted electrofisher to collect fish. SALG staff conducted electrofishing activities during daylight hours, using pulsed direct current (Smith Root 7.5 GPP electrofishing system settings: 4.5-5 amps, 60 pulses per second [pps], high range, 80% duty cycle) to stun fish that crossed the electric field in the water in front of the boat. Staff used dip nets over the bow of the boat to retrieve stunned fish, netting only fish pre-selected as target samples. Staff immediately stored retrieved samples on wet ice in large coolers to ensure interim preservation.

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

Analytical Laboratory Information

The week following the sample collection trip, the SALG shipped fifteen samples frozen (skin-off fillets) on ice (wet) overnight to the Geochemical and Environmental Research (GERG) Laboratory, Texas A and M University, College Station, TX, by common carrier for contaminant analysis. The GERG laboratory, using established EPA methodology, analyzed fillets (skin off) of fish from Clear Lake for some of the more common inorganic and organic contaminants. Seven metals – arsenic, cadmium, copper, lead, total mercury, selenium, and zinc – were analyzed, as were panels of volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), 34 pesticides representing the common pesticide classes: organophosphates, organochlorines, and carbamates, and 209 possible polychlorinated biphenyl congeners (PCBs). All fifteen fish were analyzed for mercury. Three of the submitted samples were also analyzed for metals, SVOCs, VOCs, and 209 PCB congeners.[15]

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

The GERG laboratory analyzed each of three fish for total (inorganic arsenic + organic arsenic = total arsenic) arsenic. Although the proportions of each form of arsenic may differ among species, under different water conditions, and, perhaps, with other variables, the literature suggests that well over 90% of arsenic in fish is likely organic arsenic – a form of arsenic that is virtually non-toxic to humans.[16] DSHS, taking a conservative approach, estimates 10% of the total arsenic in any fish is inorganic arsenic, deriving estimates of inorganic arsenic concentrations by multiplying reported total arsenic concentration/fish by a factor of 0.1.[16]

Nearly all mercury in upper trophic level fish three years of age or older is methylmercury.[17] Thus, the total mercury concentration in a fish of legal size for possession in Texas serves well as a surrogate for methylmercury concentration. Because methylmercury analyses are difficult to accurately perform and are more expensive than total mercury analyses, the USEPA recommends that states determine total mercury concentration in a fish and that – to protect human health – states conservatively assume that all reported mercury in fish or shellfish is methylmercury. The GERG laboratory thus analyzed fish tissues for total mercury. In its risk characterizations, DSHS compares mercury concentrations in tissues to a comparison value derived from the ATSDR's minimal risk level for methylmercury.[18] (In these risk characterizations, the DSHS may interchangeably utilize the terms "mercury," "methylmercury," or "organic mercury" to refer to methylmercury in fish.)

Statistical Analysis

SALG risk assessors employed SPSS® statistical software, version 13.0 installed on IBM-compatible microcomputers (Dell, Inc) to generate descriptive statistics (mean, standard deviation, median, range, and minimum and maximum concentrations) on all measured compounds in each species of fish from each sample site.[19] SALG risk assessors utilized ½ the detection limit for all analytes not detected (ND) and estimated (J)[a] concentrations in computing descriptive statistics. SALG risk assessors imported previously edited Excel data files into SPSS® to generate means, standard deviations, median concentrations, and minimum and maximum concentrations of each measured analyte. SALG used the descriptive statistical results to generate the present report. SALG protocols do not require hypothesis testing. Nevertheless, when data are of sufficient quantity and quality, and, should the need arise, the SALG utilizes SPSS® software to determine significant differences in contaminant concentrations among species and/or collection sites. Hypothesis testing was not conducted on samples from Clear Lake because sample size was small, samples of different species were limited, and only three fish were analyzed for PCBs, SVOCs and VOCs. The SALG employed Microsoft Excel® spreadsheets to generate figures, to compute health-based assessment comparison values (HAC_{nonca}) for contaminants, and to calculate hazard quotients (HQ), hazard indices (HI), cancer risk probabilities, and meal consumption limits for fish from Clear Lake.[20] For lead, when data are of sufficient interest and quality, the SALG utilizes the USEPA's Interactive Environmental Uptake Bio-Kinetic (IEUBK) model to determine whether consumption of lead in fish could cause children's blood lead (PbB) level to exceed 10 micrograms/deciliter, a concentration designated by the Centers for Disease Control and Prevention as of concern to the health of children exposed to environmental lead.[21]

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

People who regularly consume contaminated fish or shellfish conceivably suffer repeated exposures to relatively low concentrations of contaminants over extended time periods. Such exposures are unlikely to result in acute toxicity but may increase risk of subtle, chronic, and/or delayed adverse health effects that include cancer, benign tumors, birth defects, infertility, blood disorders, brain damage, peripheral nerve damage, lung disease, and kidney disease, to name but a few.[22] Presuming people to eat a variety of fish and/or shellfish from a specific water body if species variety is available, the DSHS routinely collapses data across species and sampling sites to evaluate mean contaminant concentrations in all samples from a specific water body because this approach intuitively reflects consumers' exposure over time to contaminants in fish or shellfish from a water body – unless specific data contradict this assumption. In such cases, the agency might examine risks associated with ingestion of individual species of fish or shellfish from separate collection sites or at higher concentrations (e.g., the upper 95 percent confidence limit on the mean concentration; confidence intervals are derived from Monte Carlo simulation techniques with software developed by Dr. Richard Beauchamp, of the DSHS).[23]
The DSHS evaluates contaminants in fish by comparing the mean, and – when appropriate – compares the 95% upper confidence limit on the mean concentration of a contaminant to its

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

health-based assessment comparison (HAC) value (measured in milligrams of contaminant per kilogram of edible tissue – mg/kg) derived for non-cancer or cancer endpoints. To derive HAC values for systemic (HAC_{nonca}) effects, the department assumes a standard adult weighs 70 kilograms and that adults consume 30 grams of edible tissue per day (about one 8-ounce meal per week). The DSHS uses EPA's oral reference doses (RfDs)[24] or the Agency for Toxic Substances and Disease Registry's (ATSDR) chronic oral minimal risk levels (MRLs)[25] to generate HAC values used in evaluating systemic (noncancerous) adverse health effects. The USEPA defines an RfD as

> *An estimate of a daily oral exposure for a given duration to the human population (including susceptible subgroups) that is likely to be without an appreciable risk of adverse health effects over a lifetime.*[26]

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 *minimal risk levels* (MRLs).[25] The DSHS compares the estimated daily dose (mg/kg/day) – derived from the mean of the measured concentrations of a contaminant – to the contaminant's RfD or MRL, using hazard quotient (HQ) methodology as suggested by the USEPA.

A HQ, defined by the EPA, *is*

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

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

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

The constants (RfDs, MRLs) the DSHS employs to calculate HAC_{nonca} values are derived by federal agencies from the peer-reviewed literature (which the federal agencies routinely re-examine). These values incorporate built-in margins of safety called "uncertainty factors" or "safety factors" as mentioned in EPA reference materials.[26] In developing oral RfDs and MRLs, federal scientists review the extant literature to determine experimentally-derived NOAELs, LOAELs, or BMDs, then utilize uncertainty factors to minimize potential systemic adverse health effects in people who are exposed through consumption of contaminated materials by accounting for certain conditions that may be undetermined by the experimental data: extrapolation from animals to humans (interspecies variability), intra-human variability, use of a subchronic study rather than a chronic study to determine the NOAEL, LOAEL, or BMD, and database insufficiencies.[24] Vulnerable groups – women who are pregnant or lactating, women who may become pregnant, the elderly, infants, children, people with chronic illnesses, those with compromised immune systems, or those who consume exceptionally large servings, called "sensitivities" by the EPA, also receive special consideration in calculations of the RfD.[26, 28]

The DSHS calculates cancer-risk comparison values (HAC_{ca}) from the EPA's chemical-specific cancer potency factors (CPFs) – also known as slope factors (SFs) – derived through mathematical modeling of carcinogenicity studies. For carcinogenic outcomes, the DSHS calculates a theoretical lifetime excess risk of cancer for specific exposure scenarios for carcinogens, using a standard 70-kg body weight and assuming an adult consumes 30 grams of edible tissue per day. Two additional factors are incorporated into determinations of theoretical lifetime excess cancer risk: (1) an acceptable lifetime risk level (ARL)[26] of one excess cancer case in 10,000 persons whose average daily exposure is equal and (2) daily exposure for 30 years. Comparison values used to assess the probability of cancer, thus, do not contain "uncertainty" factors as such. However, conclusions drawn from those probability determinations infer substantial safety margins for all people by virtue of the models utilized to derive the slope factors (cancer potency factors).

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

Children's Health Considerations

The DSHS recognizes that fetuses, infants, and children may be uniquely susceptible to the effects of toxic chemicals and suggests that exceptional susceptibilities demand special attention.[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 – indeed, at any time during development – 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 – even at birth – continuing to develop throughout infancy, childhood, and adolescence. Developmental variables may influence the mechanisms or rates of absorption, metabolism, storage, or excretion of toxicants, any of which factors could alter the concentration of biologically effective toxicant at the target organ(s) or which could modulate target organ response to the toxicant. Children's exposures to toxicants may be more extensive than adults' exposures because, in proportion to their body weights, children consume more food and liquids than do adults, another factor that might alter the concentration of toxicant at the target. Infants can ingest toxicants through breast milk – an exposure pathway that often goes unrecognized (nonetheless, the advantages of breastfeeding outweigh the probability of significant exposure to infants through breast milk and women are encouraged to continue breastfeeding and to limit exposure of their infants by limiting intake of the contaminated foodstuff). Children may experience effects at a lower exposure dose than might adults because children's organs may be more sensitive to the effects of toxicants. Stated differently, children's systems could respond more extensively or with greater severity to a given dose than would an adult organ exposed to an equivalent dose of a toxicant. Children could be more prone to developing certain cancers from chemical exposures than are adults.[32] In any case, if a chemical – or a class of chemicals –is observed to be – or is thought to be – more toxic to the fetus, infants, or children than to adults, the constants (e.g., RfD, MRL, or CPF) are usually further modified to assure protection of the immature system's potentially greater susceptibility.[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 recommending consumption of no more than two meals per month of a contaminated species, those children should eat no more than 24 meals of the contaminated fish or shellfish per year and, ideally, should not eat such fish or shellfish more than twice per month.

RESULTS

Laboratory Analysis Results

The GERG laboratory submitted electronic copies of the results of laboratory analyses of chemicals in the Clear Lake samples to the DSHS in July 2006. The laboratory analyzed fifteen fish for mercury and three of those same samples for metals, pesticides, PCBs, semivolatile organic compounds (SVOCs) and volatile organic compounds (VOCs).

Summary results of inorganic or "metallic" contaminants (arsenic, cadmium, copper, lead, mercury, selenium, and zinc in fish collected in October 2005 from Clear Lake are presented in Tables 2a- 2c. Raw data are available from the SALG upon request.

Inorganic or Metallic Contaminants

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

Inorganic contaminants/constituents such as arsenic, cadmium, copper, selenium, and zinc were reported present in many fish at concentrations of no importance to human health. Cadmium in fish was reported below the laboratory's detection limit as estimated "J" concentrations in the three fish samples examined (Table 2b). Lead was not detected in any of the three fish samples analyzed. Therefore, the present report addresses only summarily the results of analyses for these contaminants, some of which are essential nutrients.

Laboratory analysis revealed arsenic, copper, selenium, and zinc in fish samples collected from Clear Lake (Tables 2a- 2c). Three of three samples contained arsenic, with freshwater drum containing the highest concentration (Table 2a). In the three fish analyzed, copper averaged 0.227±0.092 mg/kg (Table 2b). Copper was present in all samples examined. The three samples analyzed from Clear Lake in 2005 contained selenium (Table 2c). The mean selenium concentration for all fish examined was 0.387±0.028 mg/kg (Table 2c). Zinc was present in all samples assayed (Table 2c). The average zinc concentration in fish from Clear Lake was 5.208±0.579.

Mercury

Mercury, was present in all samples examined (Table 2b); largemouth bass tissues contained the highest mean mercury concentration, followed by freshwater drum. One bowfin sample analyzed contained 1.564 mg/kg mercury (Table 2b). One smallmouth buffalo sample analyzed contained 0.563 mg/kg mercury (Table 2b). The average concentration of mercury in largemouth bass from Clear Lake was 1.233±0.287 mg/kg (Table 2b). The median concentration of mercury in largemouth bass was 1.200 mg/kg. Freshwater drum tissues contained a mean mercury concentration of 0.912±0.251 mg/kg (Table 2b). The maximum mercury concentration (1.728 mg/kg) was observed in a largemouth bass that measured 18.86 inches and weighed 3.74 lb. The mean mercury concentration in all fish combined was 1.146±0.340 (Table 2b). The lower and upper 95% confidence limit for the mean mercury concentration for all fish combined was 0.958 mg/kg and 1.335 mg/kg, respectively.

Organic Contaminants

The GERG laboratory analyzed three of fifteen fish tissue samples from Clear Lake for commonplace and/or legacy pesticides, the presence of a possible 209 PCB congeners, and a suite of SVOCs and VOCs.

Pesticides

Three of fifteen fish from Clear Lake were analyzed for thirty four (34) pesticides representative of legacy and/or major pesticide groups such as organochlorines, organophosphates, and carbamates (data not presented). Trace quantities of 4,4'-DDE, and 4,4'-DDD, metabolites and/or degradation products of DDT, an insecticide, were present in fish samples. Trace[b] quantities of chlordane and mirex were also present in fish samples. No other pesticides were reported present in fish from Clear Lake.

PCBs

Trace quantities of PCBs – representing one or more of the congeners between PCB #43 and PCB #196 (International Union of Pure and Applied Chemists [IUPAC] assigned numbers) – were reported as estimated concentrations (J-values) (data not presented).

SVOCs

Three of fifteen fish collected from Clear Lake were analyzed for the standard suite of SVOCs. Trace quantities of bis (2-ethylhexyl) phthalate were reported below the laboratory's method detection limit as estimated "J" concentrations (data not presented).

VOCs

Acetone, carbon disulfide, and methylene chloride, 1, 2-dichloroethane, toluene, and naphthalene were observed as estimated "J" concentrations in most of the three samples analyzed (data not presented). However, concentrations of these contaminants were also identified in the procedural blanks indicating the possibility of laboratory or sample handling contamination or sample necrosis. The concentrations reported in the fish tissue samples were generally higher than those reported in the procedural blanks. Trace quantities of chloromethane, acrolein

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

(propenal), benzene, and n-butylbenzene were reported in the three fish samples analyzed (data not presented).

DISSCUSSION

Characterization of Possible Systemic (Noncancerous) Health Effects Related to Consumption of Fish from Clear Lake

The actual risk of adverse health outcomes from exposure to toxicants based on experimental or epidemiological data must be weighed against the known variability of individual and population responses, which may show toxicities orders of magnitude above or below mathematically estimated risks of systemic or local effects of toxicants on various organ systems in different species under different conditions.[24] Nevertheless, the DSHS calculated risk parameters for potential toxicity to humans who consume contaminated fish from Clear Lake. Conclusions and recommendations predicated upon the stated goal of the DSHS to protect human health follow this discussion of findings.

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

Mercury

All fish collected from Clear Lake in 2005 contained mercury (Table 2b). Mean mercury concentrations in freshwater drum and largemouth bass exceeded the HAC_{nonca} for methylmercury and exceeded a HQ of 1.0 (Tables 2b, 3). The mercury concentration reported in one bowfin sample also exceeded the HAC_{nonca} for methylmercury and exceeded a HQ of 1.0 (Tables 2b, 3). The mercury concentration (0.563 mg/kg) reported in one smallmouth buffalo sample did not exceed the HAC_{nonca} for methylmercury or a HQ of 1.0 (Tables 2b, 3). Consumption of smallmouth buffalo from Clear Lake constitutes an indeterminate health risk due to collecting one smallmouth buffalo sample. DSHS examined one bowfin (26.1 inches). The mercury concentration for one bowfin was 1.564 mg/kg (Table 2b). DSHS also examined four freshwater drum (14.1-19.69 inches) and ten legal-size largemouth bass (14.5-20.9 inches). The mean mercury concentrations in freshwater drum and largemouth bass were 0.912 mg/kg and 1.233 mg/kg, respectively (Table 2b). SALG risk assessors calculated that adults consuming more than two eight-ounce meals per month of bowfin, freshwater drum, or largemouth bass from Clear Lake could exceed the ATSDR's chronic oral minimal risk level (MRL) [25] of 0.0003 mg methylmercury/kg-day, as could a 35 kg child consuming more than two four ounce meals per month of freshwater drum or largemouth bass.

Characterization of the Possibility of Excess Lifetime Cancer Risk from Consumption of Fish from Clear Lake

Few published reports exist of cancer in humans after exposure to methylmercury.[6] Although, methylmercury has been associated with neoplastic changes in the kidneys of experimental animals, those changes generally occurred only at doses that caused significant systemic toxicity and were associated with alterations in structure or function classified as threshold effects.[6] Therefore, although the USEPA has determined that methylmercury is a possible human carcinogen (Group C),[6] it is likely that systemic (noncancer) effects would occur at methylmercury exposures much lower than those required for tumor formation. Long-term administration of methylmercury to experimental animals produces overt symptoms of neurotoxicity at daily doses an order of magnitude lower than those required to induce tumors in mice. Thus, the USEPA has deemed it inappropriate to derive a cancer slope factor for methylmercury. Consequently, it was unnecessary to assess carcinogenic risk from consuming mercury-contaminated fish from Clear Lake.

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

Characterization of Cumulative Systemic Health Effects and Cumulative Excess Lifetime Cancer Risk from Consumption of Fish from Clear Lake

Risk assessment guidelines from the USEPA suggest that estimates of adverse systemic health effects of toxicants with similar modes or mechanisms of action or those that attack the same target organ (e.g., the liver) may be additive and that risk from individual chemicals can be summed to obtain an estimate of overall risk to those who are simultaneously exposed to more than one of those contaminants.[35, 36] Similarly, summation of calculated theoretical excess risks of cancer is appropriate if the agent causes cancer by the same mode or mechanism of action (e.g., tumor initiator, tumor promoter, enzyme inducer). The DSHS uses these general guidelines for assessing the likelihood of cumulative systemic effects or cancer in people exposed to multiple contaminants in the same fish.

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

CONCLUSIONS

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

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

1. That bowfin, freshwater drum, and largemouth bass collected from Clear Lake in 2005 contained mercury at levels exceeding DSHS guidelines for protection of human health. Regular or long-term consumption of bowfin, freshwater drum, or largemouth bass could result in systemic adverse health effects. Therefore, consumption of bowfin, freshwater drum, or largemouth bass from Clear Lake constitutes a **public health hazard.**

2. That consumption of smallmouth buffalo from Clear Lake constitutes an **indeterminate public health hazard** because the mercury concentration reported in one smallmouth buffalo sample did not exceed DSHS guidelines for protection of human health and the sampling size was not large enough to definitively project hazards to human health.

3. That fish collected from Clear Lake do not contain arsenic, cadmium, copper, lead, selenium, or zinc at concentrations of significance to human health. Therefore, were people able to confine consumption of fish from Clear Lake to those containing only these inorganic components – some of which are essential nutrients – consumption would pose **no apparent public health hazard.** The adequacy of this conclusion may be limited due to the sample size evaluated.

4. That fish collected from Clear Lake do not contain organic contaminants, including PCBs, pesticides, SVOCs, and VOCs at concentrations of significance to human health, either singly or in combination with other such compounds. Therefore, were people able to confine consumption of fish from Clear Lake to those containing only these organic contaminants consumption would pose **no apparent public health hazard.** The adequacy of this conclusion may be limited due to the sample size evaluated.

RECOMMENDATIONS

Risk managers at the DSHS have established criteria for issuing fish consumption advisories based on approaches suggested by the USEPA.[15] Confirmation through risk characterization that consumption of four or fewer meals per month (adults: eight ounces per meal; children: four ounces per meal) of fish or shellfish from a specific water body would result in exposures to toxicants in excess of DSHS health-based guidelines might lead managers to recommend consumption advice for fish or shellfish from the water body. As an alternative, the department may ban possession of fish from the affected water body. Fish or shellfish possession bans are enforceable under subchapter D of the Texas Health and Safety Code, part 436.061(a).[7] Declarations of prohibited harvesting areas are enforceable under subchapter D of the Texas Health and Safety Code, part 436.091 and 436.101.[7] Consumption advisories are informative, carrying no penalties for noncompliance. DSHS consumption advisories inform the public of health hazards from consuming contaminated fish or shellfish from Texas waters so that members of the public can make informed decisions about eating contaminated fish or shellfish. The SALG and the EIETB of DSHS conclude from this risk characterization that consuming freshwater drum, largemouth bass and/or bowfin from Clear Lake poses a hazard to public health. Therefore, the SALG and the EIETB recommend

1. That the DSHS advises adults to consume no more than two (2) eight ounce (8 oz) meals per month of bowfin, freshwater drum, or largemouth bass from Clear Lake. Women who are of childbearing age, who are or who might become pregnant, or who are nursing, should not consume bowfin, freshwater drum, or largemouth bass from Clear Lake.

2. That the DSHS advises children under twelve (12) years old to consume no more than two (2) four ounce (4 oz) meals per month of bowfin, freshwater drum, or largemouth bass from Clear Lake.

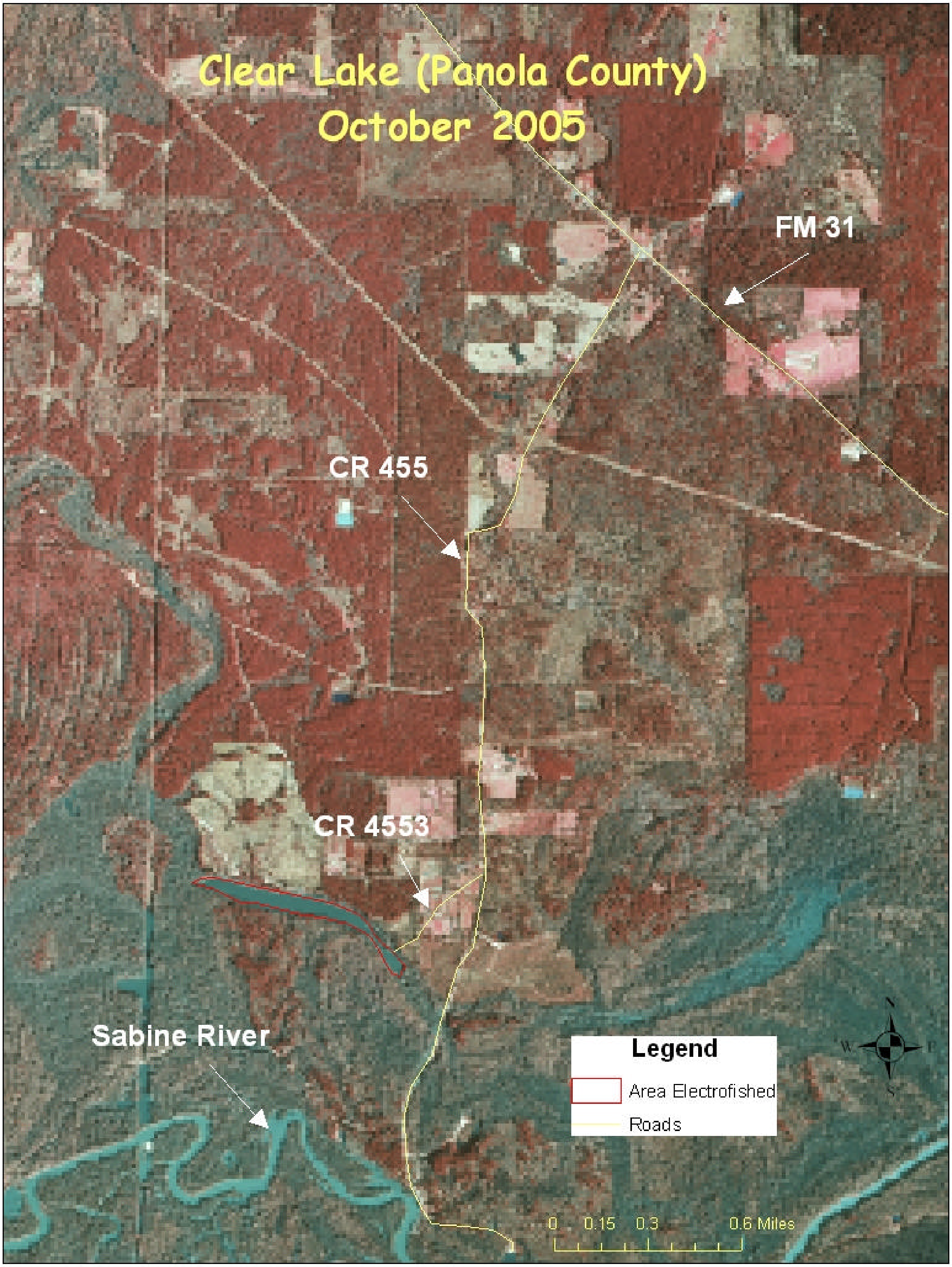
3. That the DSHS collects additional samples of smallmouth buffalo, bowfin, and other predominant species to better characterize mercury contamination in fish from Clear Lake.

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

PUBLIC HEALTH ACTION PLAN

The Texas Department of State Health Services (DSHS) publishes fish consumption advisories and bans in a booklet available to the public through the Seafood and Aquatic Life Group (SALG). To receive the booklet and/or the data, please contact the SALG at 1-512-834-6757.[37] The SALG also posts information on advisories and bans on the Internet at URL: http://www.dshs.state.tx.us/seafood). The SALG regularly updates this web site. The Texas Department of State Health Services provides the U.S. Environmental Protection Agency (http://epa.gov/waterscience/fish/advisories/), the Texas Commission on Environmental Quality (TCEQ; http://www.tceq.state.tx.us), and the Texas Parks and Wildlife Department (TPWD; http://www.tpwd.state.tx.us) with information on all consumption advisories and possession bans. Each year, the TPWD informs the fishing and hunting public of consumption advisories and fishing bans in an official hunting and fishing regulations booklet available at many state parks and at all establishments selling Texas fishing licenses.[38] Readers may direct questions about the scientific information or recommendations in this risk characterization to risk managers at the Seafood and Aquatic Life Group (SALG) at 1-512-834-6757 or may find the information at the SALG's website (http://www.dshs.state.tx.us/seafood). Secondarily, one may address queries to the Environmental and Injury Epidemiology and Toxicology Branch at the Texas Department of State Health Services (1-512-458-7269). Toxicological information on these and many other environmental contaminants found in seafood and other environmental media may also be obtained from the EPA's IRIS website (http://www.epa.gov/iris/) or from the Agency for Toxic Substances and Disease Registry (ATSDR), Division of Toxicology (1-888-42-ATSDR or 1-888-422-8737) or from the ATSDR website (URL: http://www.atsdr.cdc.gov) where brief information is available in that agency's ToxFACs.® ToxFACs is available on the ATSDR website in either English (http://www.atsdr.cdc.gov/toxfaq.html) or in Spanish (http://www.atsdr.cdc.gov/es/toxfaqs/es_toxfaqs.html). More in-depth reviews of many toxic substances are published by the ATSDR in its Toxicological Profiles. To request a copy of available Toxicological Profiles, readers may call the ATSDR at 1-404-498-0261 or email their requests to atsdric@cdc.gov. Many Toxicological Profiles are available for downloading at ATSDR's website.

FIGURE 1. Clear Lake Map October, 2005.



TABLES

Table 1. Fish Samples Collected from Clear Lake. Sample Number, Species, Length, and Weight were Recorded for Each Sample Collected from Clear Lake on October 18, 2005.

Date	Sample Number	Species	Length (mm)	Weight (g)
10/18/05	CLR1	Largemouth Bass	470	1472
	CLR2	Largemouth Bass	469	1503
	CLR3	Largemouth Bass	479	1696
	CLR4	Largemouth Bass	400	1017
	CLR5	Largemouth Bass	432	1006
	CLR6	Largemouth Bass	410	920
	CLR7	Largemouth Bass	375	812
	CLR8	Largemouth Bass	402	790
	CLR9	Largemouth Bass	370	714
	CLR10	Largemouth Bass	531	2519
	CLR11	Freshwater Drum	500	1618
	CLR12	Freshwater Drum	437	994
	CLR13	Freshwater Drum	359	465
	CLR14	Bowfin	664	2902
	CLR15	Smallmouth buffalo	810	10124

Table 2a. Arsenic (mg/kg) in Fish from Clear Lake, 2005.

Species	# Detected/ # Sampled	Total Arsenic Mean Concentration ± S.D. (Min-Max)	Inorganic Arsenic Mean Concentration[c]	Health Assessment Comparison Value (mg/kg)[d]	Basis for Comparison Value
Freshwater drum	1/1	0.068	**0.007**	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
Largemouth bass	1/1	0.061	**0.006**		
Smallmouth buffalo	1/1	0.025	**0.003**		
All Fish Combined	3/3	0.051 ± 0.023 (0.025-0.068)	**0.005**		

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

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

Contaminant	# Detected/ # Sampled	Mean Concentration ± S.D. (Min-Max)	Health Assessment Comparison Value (mg/kg)[d]	Basis for Comparison Value
Cadmium				
Freshwater drum	1/1	BDL[e]	0.47	ATSDR chronic oral MRL: 0.0002 mg/kg–day
Largemouth bass	1/1	BDL		
Smallmouth buffalo	1/1	BDL		
All Fish Combined	3/3	BDL		
Copper				
Freshwater drum	1/1	0.168	333	National Academy of Science Upper Limit: 0.143 mg/kg–day
Largemouth bass	1/1	0.333		
Smallmouth buffalo	1/1	0.179		
All Fish Combined	3/3	0.227 ± 0.092 (0.168-0.333)		
Lead				
Freshwater drum	0/1	ND[f]	0.6	EPA IEUBKwin[c]
Largemouth bass	0/1	ND		
Smallmouth buffalo	0/1	ND		
All Fish Combined	0/3	ND		
Mercury				
Bowfin	1/1	1.564	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg–day
Freshwater drum	3/3	0.912 ± 0.251 (0.710-1.193)		
Largemouth bass	10/10	1.233 ± 0.287 (0.855-1.728)		
Smallmouth buffalo	1/1	0.563		
All Fish Combined	15/15	1.146 ± 0.340 (0.563-1.728)		

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

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

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

Table 2c. Inorganic Contaminants (mg/kg) in Fish from Clear Lake, 2005.				
Contaminant	**# Detected/ # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)[d]**	**Basis for Comparison Value**
Selenium				
Freshwater drum	1/1	0.355	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
Largemouth bass	1/1	0.403		
Smallmouth buffalo	1/1	0.403		
All Fish Combined	3/3	0.387 ± 0.028 (0.355-0.403)		
Zinc				
Freshwater drum	1/1	5.125	700	EPA chronic oral RfD: 0.3 mg/kg–day
Largemouth bass	1/1	4.676		
Smallmouth buffalo	1/1	5.825		
All Fish Combined	3/3	5.208 ± 0.579 (4.676-5.825)		

Table 3. Regular or long-term consumption of some species of fish from Hills Lake that contain mercury could result in systemic adverse health effects in some individuals or groups. Table 3 lists hazard quotients (HQ) for Mercury in fish based on mercury concentrations in fish collected from Clear Lake in 2005 and suggests appropriate consumption rates. Adults (70 kg) should consume a total of the recommended number of meals/week consisting of any combination of fish making an 8 ounce meal, while children weighing less than 35 kg or who are younger than 12 years of age should consume no more than 4 ounces per meal for the recommended number of meals.		
Species/Contaminant	**Hazard Quotient**	**Meals per Week**
Bowfin	**2.23**[g]	**0.4**
Freshwater drum	**1.30**	**0.7**
Largemouth bass	**1.76**	**0.5**
Smallmouth buffalo	0.80	1.2
All Fish Combined	**1.64**	**0.7**

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

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