Characterization of Potential Adverse Health Effects Associated with Consuming Fish from

Sabine Lake

Jefferson and Orange Counties, Texas

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INTRODUCTION

On September 13, 2008, Hurricane Ike made landfall on the north end of Galveston Island, Texas as a strong Category 2 hurricane.[1] The expansive storm surge associated with Hurricane Ike caused significant flooding spanning over 200 miles of coastline from Galveston Island into Louisiana.[2] Catastrophic flooding occurred along the Texas coastline from Galveston Island to the Texas-Louisiana border. The Galveston Bay system and Sabine Lake system received floodwaters from some of the most populated and industrialized coastal areas in the country. Run-off during the flood and receding storm surge waters contained industrial pollutants, household chemicals and waste, and sediment from inland areas. Since Hurricane Ike, the Department of State Health Services (DSHS) Seafood and Aquatic Life Group (SALG) and the Texas Parks and Wildlife Department (TPWD) Coastal Fisheries Division (CFD) have received many inquires from the public regarding the safety of consuming fish from Galveston Bay and Sabine Lake. To this point, the DSHS have not been able to assure the public that fish are safe to eat following Hurricane Ike. The DSHS issued a fish consumption advisory in July 2008 for Galveston Bay due to polychlorinated biphenyl (PCB) and dioxin contamination. The advisory recommended limited consumption of spotted seatrout and catfish. In January 2010, the DSHS SALG was awarded project funding through the Social Services Block Grant to assess the potential health risks associated with consuming contaminated fish from Galveston Bay and Sabine Lake post Hurricane Ike.

Description of Sabine Lake

The Sabine Lake estuary is located on the Texas-Louisiana border in Jefferson and Orange Counties, Texas and Cameron Parish, Louisiana.[3] The estuary is composed of Sabine Lake, a 68.7 square mile brackish water lake, formed by the confluence of the Neches and Sabine Rivers, the Sabine-Neches Canal, and the Port Arthur Canal.[4] The Sabine Lake estuary drains 50,000 square miles of Texas and Louisiana into the Gulf of Mexico through Sabine Pass. The Sabine Lake estuary is adjacent to the large petrochemical producing complex of Beaumont, Orange, and Port Arthur, Texas.

Demographics of Hardin, Jefferson, and Orange Counties Surrounding the Area of Sabine Lake

Sabine Lake is adjacent to the Beaumont-Port Arthur metropolitan statistical area (MSA).[5] The Beaumont-Port Arthur MSA is a three-county region composed of Hardin, Jefferson, and Orange Counties in southeast Texas known as the *Golden Triangle*[6]. The *golden* refers to the wealth produced from the Spindletop oil strike near Beaumont, Texas in 1901, and the *triangle* refers to the area between the cities of Beaumont, Port Arthur, and Orange, Texas. In 2009, the United States Census Bureau (USCB) reported the Beaumont-Port Arthur MSA to have an estimated population of 378,477 people.[7]

Subsistence Fishing in Sabine Lake

The United States Environmental Protection Agency (USEPA or EPA) suggests that, along with ethnic characteristics and cultural practices of an area's population, the poverty rate could contribute to any determination of the rate of subsistence fishing in an area.[8] The USEPA and the Department of State Health Services (DSHS) find, in concert with the USEPA, it is important to consider subsistence fishing to occur at any water body because subsistence fishers (as well as recreational anglers and certain tribal and ethnic groups) usually consume more locally caught fish than the general population. These groups sometimes harvest fish or shellfish from the same water body over many years to supplement caloric and protein intake. Should local water bodies contain chemically contaminated fish or shellfish, people who routinely eat fish from the water body or those who eat large quantities of fish from the same waters, could increase their risk of adverse health effects. The USEPA suggests that states assume that at least 10% of licensed fishers in any area are subsistence fishers. Subsistence fishing, while not explicitly documented by the DSHS, likely occurs. The DSHS assumes the rate of subsistence fishing to be similar to that estimated by the USEPA.

METHODS

Fish Sampling, Preparation, 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 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 USEPA 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 (TSCC) 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 Sabine Lake 2010 Sample Set

In March and May 2010, the SALG staff collected 75 fish samples from Sabine Lake. Risk assessors used data from these fish to assess the potential for adverse human health outcomes from consuming fish from this estuary.

The SALG selected four sample sites to provide spatial coverage of the study area (Figure 1). Site 1 was located at Sabine Pass, Site 2 at Sabine Lake north of Mesquite Point, Site 3 at Keith Lake, and Site 4 Sabine Lake at Pleasure Island. Species collected 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 that anglers and their families commonly consume. The 75 fish collected from Sabine Lake in March and May 2010 represented all species targeted for collection from this water body (Table 1). Targeted species and number collected are listed in descending order: spotted seatrout (32), black drum (10), gafftopsail catfish (10), red drum (10), southern flounder (7), sand trout (2), striped bass (2), and alligator gar (2).

The survey team set gill nets at sampling sites 1 through 4 in late afternoon (Figure 1); fished the sites overnight, and collected samples from the nets early the following morning. The gill nets were set at locations to maximize available cover and habitat in the bay. During collection, to keep specimens from different sample sites separated, the team placed samples from each site into mesh bags labeled with the site number. The survey team immediately stored retrieved samples on wet ice in large coolers to ensure interim preservation. Survey team members returned to the bay any live fish culled from the catch and properly disposed of samples found dead in the gill nets.

SALG staff processed fish onsite at Sabine Lake**.** Staff 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, staff 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 knife cleaned with distilled water after each sample was processed. The team wrapped fillet(s) in two layers of fresh aluminum foil, placed in an unused, clean, pre-labeled plastic freezer bag, and stored on wet ice in an insulated chest until further 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 the collection trip, the SALG delivered the frozen fish tissue samples to the Geochemical and Environmental Research Group (GERG) Laboratory, Texas A&M University, College Station, Texas, for contaminant analysis.

Fish Age Estimation

The DSHS SALG staff removed sagittal otoliths from 32 spotted seatrout samples for age estimation and identified the sex of each fish sample (Figure 2). The DSHS SALG staff followed otolith extraction procedures recommended by the Gulf States Marine Fisheries Commission (GSMFC) for spotted seatrout.[12] Staff performed all otolith extractions on each fish sample after the preparation of the two skin-off fillets for chemical contaminant analysis. Following extraction, staff placed otoliths in an individually labeled vial and then stored the vials in a plastic freezer bag to transport to their Austin, Texas headquarters. Staff processed otoliths and estimated ages according to procedures recommended by the TPWD and GSMFC.[12, 13]

Analytical Laboratory Information

Upon arrival of the samples at the laboratory, GERG personnel notified the SALG of receipt of the 75 Sabine Lake samples and recorded the condition of each sample along with its DSHS identification number.

Using established USEPA methods, the GERG laboratory analyzed fish fillets from Sabine Lake for 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 PCB congeners, and 17 polychlorinated dibenzofurans and/or dibenzo-*p*-dioxins (PCDFs/PCDDs) congeners. The laboratory analyzed all 75 samples for metals, PCBs, and PCDFs/PCDDs and a subset of 20 (SAB05, SAB06, SAB07, SAB10, SAB13, SAB17, SAB18, SAB22, SAB33, SAB38, SAB44, SAB48, SAB50, SAB57, SAB62, SAB67, SAB71, SAB78, SAB86, and SAB92) of the original 75 samples for pesticides, SVOCs, and VOCs.[14]

Details of Some Analyses with Explanatory Notes

Arsenic

The GERG laboratory analyzed all 75 fish for total (inorganic arsenic + organic arsenic = total arsenic) arsenic. Although the proportions of each form of arsenic may differ among fish 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.[15] The DSHS, taking a conservative approach, estimates 10% of the total arsenic in any fish is inorganic arsenic, deriving estimates of inorganic arsenic concentration in each fish by multiplying reported total arsenic concentration in the sample by a factor of 0.1.

Mercury

Nearly all mercury in upper trophic level fish three years of age or older is methylmercury.[16] 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 perform accurately 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, The DSHS compares mercury concentrations in tissues to a comparison value derived from the Agency for Toxic Substances and Disease Registry's (ATSDR) minimal risk level (MRL) for methylmercury.[17] (In these risk characterizations, the DSHS may interchangeably utilize the terms "mercury," "methylmercury," or "organic mercury" to refer to methylmercury in fish).

Polychlorinated Biphenyls (PCBs)

For PCBs, the USEPA suggests that each state measures congeners of PCBs in fish and shellfish rather than homologs or Aroclors® because the USEPA considers congener analysis the most sensitive technique for detecting PCBs in environmental media.[14] 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 the USEPA's suggestion that the states utilize PCB congeners rather than Aroclors® or homologs for toxicity estimates, the toxicity literature does not reflect state-of-the-art laboratory science. To accommodate this inconsistency, the DSHS utilizes recommendations from the National Oceanic and Atmospheric Administration (NOAA),[18] from McFarland and Clarke,[19] and from the USEPA's guidance documents for assessing contaminants in fish and shellfish[10, 14] to address PCB congeners in fish and shellfish samples, selecting the 43 congeners encompassed by the McFarland and Clark and the NOAA articles. The referenced authors chose to use congeners that were relatively abundant in the environment, were likely to occur in aquatic life, and likely to show toxic effects. SALG risk assessors summed the 43 congeners to derive "total" PCB concentration in each sample. SALG risk assessors then averaged the summed congeners within each group (e.g., fish species, sample site, or combination of species and site) to derive a mean PCB concentration for each group.

Using only a few PCB congeners to determine total PCB concentrations could underestimate PCB levels in fish tissue. Nonetheless, the method complies with expert recommendations on evaluation of PCBs in fish or shellfish. Therefore, SALG risk assessors compare average PCB concentrations of the 43 congeners with health assessment comparison (HAC) values derived from information on PCB mixtures held in the USEPA's Integrated Risk Information System (IRIS) database.[20] IRIS currently contains systemic toxicity information for five Aroclor® mixtures: Aroclors® 1016, 1242, 1248, 1254, and 1260. IRIS does not contain all information for all mixtures. For instance, only one other reference dose (RfD) occurs in IRIS – the one derived for Aroclor 1016, a commercial mixture produced in the latter years of commercial production of PCBs in the United States. Aroclor 1016 was a fraction of Aroclor 1254 that was supposedly devoid of dibenzofurans, in contrast to Aroclor 1254.[21] Systemic toxicity estimates in the present document reflect comparisons derived from the USEPA's RfD for Aroclor 1254 because Aroclor 1254 contains many of the 43 congeners selected by McFarland and Clark and NOAA. As of yet, IRIS does not contain information on the systemic toxicity of individual PCB congeners.

For assessment of cancer risk from exposure to PCBs, the SALG uses the USEPA's highest slope factor of 2.0 milligram per kilogram per day (mg/kg/day) to calculate the probability of 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.[20]

Calculation of Toxicity Equivalent Quotients (TEQs) for Dioxins

PCDDs/PCDFs are families of aromatic chemicals containing one to eight chlorine atoms. The molecular structures differ not only with respect to the number of chlorines on the molecule, but also with the positions of those chlorines on the carbon atoms of the molecule. The number and positions of the chlorines on the dibenzofuran or dibenzo-*p*-dioxin nucleus directly affects the toxicity of the various congeners. Toxicity increases as the number of chlorines increases to four chlorines, then decreases with increasing numbers of chlorine atoms - up to a maximum of eight. With respect to the position of chlorines on the dibenzo-*p*-dioxin/dibenzofuran nucleus, it appears that those congeners with chlorine substitutions in the 2, 3, 7, and 8 positions are more toxic than congeners with chlorine substitutions in other positions. To illustrate, the most toxic of 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 carbon positions on the dibenzo-*p*-dioxin. To gain some measure of toxic equivalence, 2,3,7,8–TCDD – assigned a toxicity equivalency factor (TEF) of 1.0 – is the standard against which other congeners are measured. Other congeners are given weighting factors or TEFs of 1.0 or less based on experiments comparing the toxicity of the congener relative to that of 2,3,7,8-TCDD.[22, 23] Using this technique, risk assessors from the DSHS converted PCDF or PCDD congeners in each tissue sample from the present survey to TEQs by multiplying each congener's concentration by its TEF, producing a dose roughly equivalent in toxicity to that of the same dose of 2,3,7,8-TCDD. The total TEQ for any sample is the sum of the TEQs for each of the congeners in the sample, calculated according to the following formula.[24]

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

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 for Systemic Effects (HAC_{nonca}) 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, or the presence of other chemicals.[25] 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.[25]

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 assume that most fish species are mobile. SALG risk assessors may combine data from different fish species 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 a DSHS medical epidemiologist.[26] The SALG evaluates contaminants in fish or shellfish by comparing the mean or the 95% upper confidence limit on the mean concentration of a contaminant to its HAC value (in mg/kg) for non-cancer or cancer endpoints.

In deriving HAC values for systemic (HAC_{nonca}) effects, the SALG assumes a standard adult weighs 70 kilograms (kg) and consumes 30 g of fish or shellfish per day (about one 8-ounce meal per week) and uses the USEPA's RfD[27] or the ATSDR's chronic oral MRLs.[28] 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.*[29]

The USEPA 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.*[29]

The ATSDR uses a similar technique to derive its MRLs.[28] 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 USEPA defines a 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).*[30]

Note that, according to the USEPA, 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. A 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 USEPA suggests that a 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 should be interpreted as "no cause for concern" whereas, a 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 USEPA'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 a HQ to determine the need for further study of a water body's fauna. Notwithstanding the above discussion, the oral RfD derived by the USEPA 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 the DSHS utilizes chemical specific RfDs when possible, if an RfD is not available for a contaminant, the USEPA advises risk assessors to consider evaluating the contaminant by comparing it to the published RfD (or the MRL) of a contaminant of similar molecular structure or one with a similar mode or mechanism of action. For instance, Aroclor® 1260 has no RfD, so the DSHS uses the reference dose for Aroclor 1254 to assess the likelihood of systemic (noncarcinogenic) effects of Aroclor 1260.[28]

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, and use of a subchronic study rather than a chronic study to determine the NOAEL, LOAEL, or BMD, and database insufficiencies.[27,29] 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 USEPA and also receive special consideration in calculation of a RfD.[29]

The primary method for assessing the toxicity of component-based mixtures of chemicals in environmental media is the HI. The USEPA recommends HI methodology for groups of toxicologically similar chemicals or chemicals that affect the same target organ. The HI for the toxic effects of a chemical mixture on a single target organ is actually a simulated HQ calculated as if the mixture were a single chemical. The default procedure for calculating the HI for the exposure mixture is to add the hazard quotients (the ratio of the external exposure dose to the RfD) for all the mixture’s component chemicals that affect the same target organ (e.g., the liver). The toxicity of a particular mixture on the liver represented by the HI should approximate the toxicity that would have occurred were the observed effects caused by a higher dose of a single toxicant (additive effects). The components to be included in the HI calculation are any chemical components of the mixture that show the effect described by the HI, regardless of the critical effect from which the RfD came. Assessors should calculate a separate HI for each toxic effect.

Because the RfD is derived for the critical effect (the "toxic effect occurring at the lowest dose of a chemical"), a HI computed from HQs based on the RfDs for the separate chemicals 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 USEPA 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 one 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 one, concern exists over potential toxicity. As more HIs for different effects exceed one, the potential for human toxicity also increases.

Thus,

Concern should increase as the number of effect-specific HI's exceeding one increases. As a larger number of effect-specific HIs exceed one, 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 (HAC_{ca}) of Consumed Chemical Contaminants

The DSHS calculates cancer-risk comparison values (HAC_{ca}) from the USEPA's chemical-specific cancer potency factors (CPFs), also known as cancer slope factors (CSFs), derived through mathematical modeling from 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. The SALG risk assessors incorporate two additional factors into determinations of theoretical lifetime excess cancer risk: (1) an acceptable lifetime risk level (ARL)[29] of one excess cancer case in 10,000 persons whose average daily exposure is equivalent and (2) daily exposure for 30 years, a modification of the 70-year lifetime exposure assumed by the USEPA. Comparison values used to assess the probability of cancer do not contain "uncertainty" factors. However, conclusions drawn 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 in calculating the HAC_{ca}.

Because the calculated comparison values (HAC 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 by risk managers along with other information 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. The DSHS also 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. 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.[31, 32] 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 development (pregnancy, infancy, childhood, or adolescence) at times when toxicants can impair or alter the structure or function of susceptible systems.[33] Unique early sensitivities may exist after birth 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 effective toxicant at the target organ(s) or 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 in proportion to their body weights than adults consume. 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.[34] In any case, if a chemical or a class of chemicals is observed to be, or is thought to be, more toxic to fetuses, infants, or children, the constants (e.g., RfD, MRL, or CPF) are usually modified further to assure the immature systems' potentially greater susceptibilities are not perturbed.[27] Additionally, in accordance with the ATSDR's *Child Health Initiative*[35] and the USEPA's *National Agenda to Protect Children's Health from Environmental Threats,*[36] 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, the 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 recommends 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 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.[37] In computing descriptive statistics, SALG risk assessors utilized ½ the reporting limit (RL) for analytes designated as not detected (ND) or estimated (J-values)[*]. PCDFs/PCDDs descriptive statistics are calculated using estimated concentrations (J-values) and assuming zero for PCDFs/PCDDs designated as ND.[†] 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 Sabine Lake.[38] When lead concentrations in fish or shellfish are high, SALG risk assessors may utilize 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).[39,40]

RESULTS

The GERG laboratory completed analyses and electronically transmitted the results of the Sabine Lake samples collected in March and May 2010 to the SALG in August 2010. The laboratory reported the analytical results for metals, pesticides, PCBs, PCDFs/PCDDs, SVOCs, and VOCs.

For reference, Table 1 contains the total number of samples collected. Tables 2a through 2d present the results of metals analyses. Table 3a and 3b contain summary results of 4,4-DDE, chlordane, and alpha-HCH. Tables 4a and 4b summarize the PCB analyses, and table 5a and 5b summarize PCDFs/PCDDs analyses. This paper does not display SVOC and VOC data because these contaminants were not present at concentrations of interest in fish collected from Sabine Lake during the described survey. Unless otherwise stated, table summaries present the number of samples containing a specific contaminant/number tested, the mean concentration ± 1 standard deviation (68% of samples should fall within one standard deviation of the arithmetic mean in a sample from a normally-distributed population), and, in parentheses under the mean and standard deviation, the minimum and the maximum detected concentrations. Those who prefer to use the range may derive this statistic by subtracting the minimum concentration of a given contaminant from its maximum concentration. In the tables, results may be reported as ND, BDL for estimated concentrations, or as measured concentrations. According to the laboratory's quality control/quality assurance materials, estimated concentrations reported as BDL rely upon the laboratory's method detection limit (MDL) or its reporting limit (RL). The MDL is the minimum concentration of an analyte that be reported with 99% confidence that the analyte concentration

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[*] *"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.*

[†] *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 utilizing ½ the reporting limit for analytes designated as not detected (ND) or estimated (J) will likely overestimate the PCDFs/PCDDs fish tissue concentration.*

is greater than zero, while the RL is the concentration of an analyte reliably achieved within specified limits of precision and accuracy during routine analyses. Contaminant concentrations reported below the RL are qualified as “J-values” in the laboratory data report.[41]

Inorganic Contaminants

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

All 75 fish tissue samples from Sabine Lake contained some level of copper, mercury, selenium, and zinc (Tables 2b-2d).

Three of the metalloids analyzed are essential trace elements: copper, selenium, and zinc. All 75 fish tissue samples contained copper (Table 2b). The mean copper concentration in fish sampled from Sabine Lake was 0.213±0.087 mg/kg. Gafftopsail catfish had the highest average concentration of copper (0.338±0.044 mg/kg). All fish tissue samples contained selenium. The average selenium concentration in fish from Sabine Lake was 0.576 mg/kg with a standard deviation of ±0.212 mg/kg (Table 2d). Selenium in fish from Sabine Lake ranged from 0.099 to 1.112 mg/kg. All samples also contained zinc (Table 2d). The mean zinc concentration in fish tissue samples from Sabine Lake was 2.714±0.830 mg/kg.

The SALG evaluated four toxic metalloids having no known human physiological function (arsenic, cadmium, lead, and mercury) in the samples collected from Sabine Lake. Fifty-nine of seventy-five fish assayed contained arsenic ranging from ND-5.299 mg/kg (Table 2a). No fish from Sabine Lake contained cadmium at a concentration exceeding the laboratory's RL (Table 2b). All species of fish assayed had at least one sample that contained lead at concentrations greater than the RL (Table 2c). The average lead concentration in all fish combined was 0.042±0.037 mg/kg (Table 2c).

All species of fish collected in 2010 from Sabine Lake contained mercury (Table 2c). A black drum contained the lowest concentration of mercury (0.051 mg/kg), while the highest concentration occurred in a red drum (0.456 mg/kg). The mean mercury concentration in fish (collapsed across species and sites) was 0.211±0.109 mg/kg (Table 2c).

Organic Contaminants

Pesticides

The GERG laboratory analyzed 20 fish for 34 pesticides. All 20 samples examined contained concentrations of 4,4′-DDE (Table 3a). Gafftopsail catfish contained the highest concentration of 4,4′-DDE (0.031 mg/kg). The mean 4,4′-DDE concentration in fish (*n*=20) was 0.006±0.009 mg/kg. Chlordane concentrations ranged from ND-0.008 mg/kg in fish (Table 3a; *n*=20). Ten of twenty samples contained low concentrations of alpha-HCH (ND-0.0118 mg/kg).

Nine of twenty samples contained trace* to low concentrations of 4,4′-DDD, while five of 20 samples contained low concentrations (> RL) of 4,4′-DDD (data not presented). Trace quantities of pentachlorobenzene, hexachlorobenzene, dieldrin, pentachloroanisole, mirex, 4,4′-DDT, alachlor, dacthal, endosulfan sulfate, malathion, and methoxychlor were present in some fish samples (data not presented).

PCBs

All fish tissue samples contained concentrations of one or more PCB congeners (Table 4a and 4b). No fish tissue sample contained all PCB congeners (data not shown). Across all sites and species, PCB concentrations ranged from BDL to 0.0.648 mg/kg (Table 4b). One of twelve fish species evaluated had mean PCB congener concentrations that exceeded the DSHS HAC_{nonca} value for PCBs (0.047 mg/kg; Table 4b). Gafftopsail catfish contained the highest mean concentration of PCBs (0.056±0.027 mg/kg). Red drum and southern flounder contained the lowest mean concentration of PCBs (Tables 4b). The mean PCB concentration in all 75 fish tissue samples assayed was 0.021±0.021 mg/kg (Table 4b).

PCDFs/PCDDs

The GERG laboratory analyzed all fish tissue samples for 17 of the 210 possible PCDF/PCDD (135 PCDFs + 75 PCDDs) congeners from Sabine Lake. 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.[42] 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. Table 5a and 5b contains site and species-specific summary statistics for PCDFs/PCDDs in fish collected from Sabine Lake. Before generating summary statistics for PCDFs/PCDDs, the SALG risk assessors converted the reported concentration of each PCDF or PCDD congener reported present in a tissue sample to a concentration equivalent in toxicity to that of 2,3,7,8-TCDD (a TEQ concentration - expressed as picogram per gram [pg/g]or nanogram per kilogram [ng/kg]). Thirty-three of seventy-five fish tissue samples contained at least one of the 17 congeners assayed (minimum – to – maximum concentration after conversion: ND-2.622 pg/g; Table 5b). No samples contained all 17 congeners (data not shown). Alligator gar contained the highest mean TEQ concentration (0.751±1.061 pg/g), followed by gafftopsail catfish (0.401±0.874 pg/g –or ng/kg).

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* *Trace: in analytical chemistry, a trace is 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 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.*

SVOCs

The GERG laboratory analyzed a subset of 20 Sabine Lake fish tissue samples for SVOCs. The laboratory reported quantifiable concentrations (≥RL) of the following SVOCs in one or more fish samples: benzoic acid, diethyl phthalate, benzyl alcohol, and benzidine. These concentrations did not pose a threat to human health. Trace concentrations of benzo(b)fluoranthene and benzo(k)fluoranthene were present in some fish samples assayed (data not presented). The laboratory detected no other SVOCs in fish from Sabine Lake.

VOCs

The GERG laboratory reported the 20 fish tissue samples selected for analysis from Sabine Lake to contain quantifiable concentrations >RL of one or more VOCs: acetone, methylene chloride, 2-butanone (MEK), trichlorofluoromethane, toluene, 2-hexanone, and 1,2,3-trichlorobenzene (data not presented). Trace quantities of most VOCs were also present in one or more fish tissue samples assayed from Sabine Lake (data not presented). The Seafood and Aquatic Life Group Survey Team Standard Operating Procedures and Quality Control/Assurance Manual contain a complete list of the 70 VOCs selected for analysis. Numerous VOCs were also identified in one or more of the procedural blanks, indicating the possibility that these compounds were introduced during sample preparation. VOC concentrations <RL are difficult to interpret due to their uncertainty and may represent a false positive. 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 the VOCs be thermally released from the adsorbent trap, transferred to the gas chromatograph (GC), and into the GC/mass spectrometer (MS) for quantification.

DISCUSSION

Risk Characterization

Because variability and uncertainty are inherent to quantitative assessment of risk, the calculated risks of adverse health outcomes from exposure to toxicants can be orders of magnitude above or below actual risks. Variability in calculated and in actual risk may depend upon factors such as the use of animal instead of human studies, use of subchronic rather than chronic studies, interspecies variability, intra-species variability, and database insufficiency. Since most factors used to calculate comparison values result from experimental studies conducted in the laboratory on nonhuman subjects, variability and uncertainty might arise from the study chosen as the "critical" one, the species/strain of animal used in the critical study, the target organ selected as the "critical organ," exposure periods, exposure route, doses, or uncontrolled variations in other conditions.[27] Despite such limitations, risk assessors must calculate parameters to represent potential toxicity to humans who consume contaminants in fish and other environmental media. The DSHS calculated risk parameters for systemic and carcinogenic endpoints in those who would consume fish from Sabine Lake. Conclusions and recommendations predicated upon the stated goal of the DSHS to protect human health follow the discussion of the relevance of findings to risk.

Characterization of Systemic (Noncancerous) Health Effects from Consumption of Fish from Sabine Lake

PCBs were observed in fish from Sabine Lake that equaled or exceeded its HAC_{nonca} (0.047 mg/kg). One (gafftopsail catfish) of 75 fish samples assayed contained PCDFs/PCDDs exceeding the HAC_{nonca} for PCDFs/PCDDs (2.33 pg/g; Tables 5a and 5b). Mean PCDFs/PCDDs concentrations of the eight fish species evaluated and the all fish combined mean concentration did not exceed the PCDFs/PCDDs HAC_{nonca} value nor did the HQs exceed 1.0. No species of fish collected contained any other inorganic or organic contaminants at concentrations that equaled or exceeded the DSHS guidelines for protection of human health or would likely cause systemic risk to human health from consumption of fish from Sabine Lake. Potential systemic health risks related to the consumption of fish from Sabine Lake containing inorganic and organic contaminants (other than PCBs) are not of public health concern. Consequently, this risk characterization concentrates on assessing the likelihood of adverse health outcomes that could occur from consumption of Sabine Lake PCB-contaminated fish. Table 6 provides HQs for PCBs in each species of fish from Sabine Lake and the recommended weekly consumption rate for each species.

PCBs

Seventy-four of seventy-five fish collected from Sabine Lake in 2010 contained PCBs (Tables 4a and 4b). Eight percent of all samples (N = 75; five gafftopsail catfish and one spotted seatrout) analyzed contained PCB concentrations that equaled or exceeded the HAC_{nonca} for PCBs (0.047 mg/kg). The gafftopsail catfish was the only species of fish examined from Sabine Lake that had a mean PCB concentration exceed the HAC_{nonca} for PCBs or a HQ of 1.0 (Tables 4b and 6). The consumption of gafftopsail catfish from Sabine Lake may pose potential systemic health risks. Meal consumption calculations may be useful for decisions about consumption advice or regulatory actions. The SALG risk assessors calculated the number of 8-ounce meals of fish from Sabine Lake that healthy adults could consume without significant risk of adverse systemic effects (Table 6). The SALG estimated this group could consume 0.8 (8-ounce) meals per week of gafftopsail catfish containing PCBs (Table 6), suggesting that gafftopsail catfish from Sabine Lake contain PCBs at concentrations that could result in adverse effects on human health and that people should limit their consumption of gafftopsail catfish from Sabine Lake. The developing nervous system of the human fetus may be especially susceptible to these effects.

Characterization of Theoretical Lifetime Excess Cancer Risk from Consumption of Fish from Sabine Lake

The USEPA classifies arsenic, most chlorinated pesticides, PCBs, and PCDFs/PCDDs as carcinogens. Although arsenic, chlorinated pesticides, PCBs, and PCDFs/PCDDs were present in fish samples from Sabine Lake, none of these contaminants evaluated singly by species or all fish combined had mean contaminant concentrations that would be likely to increase the risk of cancer to exceed the DSHS guideline for protection of human health of one excess cancer in 10,000 equally exposed individuals (Tables 2a through 5a and 7a through 8b). The arsenic concentration observed in one of two alligator gar samples assayed would increase the risk of cancer to exceed the DSHS's guideline for protection of human health of one excess cancer in 10,000 equally exposed individuals (data not presented).

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

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. PCBs and PCDFs/PCDDs in Sabine Lake fish could have these properties, especially with respect to effects on the immune system. Multiple inorganic or organic contaminants in the Sabine Lake samples did not increase the likelihood of systemic adverse health outcomes from consuming any species of fish from Sabine Lake.

The SALG also queried the probability of increasing lifetime excess cancer risk from consuming fish containing multiple inorganic and organic contaminants. Consumption of multiple contaminants (arsenic, chlorinated pesticides, PCBs, and PCDF/PCDDs) in fish evaluated by species and all fish combined from Sabine Lake did not increase the calculated lifetime excess cancer risk to a risk that exceeds the DSHS guideline for protection of human health of one excess cancer in 10,000 equally exposed individuals (all data not presented; Table 8a-8b).

CONCLUSIONS

The 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 the DSHS, including the Texas Commissioner of Health.

This study addressed the public health implications of consuming fish from Sabine Lake, located in Jefferson and Orange Counties, Texas. Risk assessors from the SALG conclude from the present characterization of potential adverse health effects from consuming fish from Sabine Lake that:

1. Black drum, red drum, sand trout, southern flounder, spotted seatrout, and striped bass do not contain any inorganic or organic contaminant concentrations, either singly or in combination, that exceed the DSHS guidelines for protection of human health. Therefore, consumption of these fish species **poses no apparent risk to human health**.

2. Gafftopsail catfish contain PCBs at concentrations exceeding DSHS's guidelines for protection of human health. Regular or long-term consumption of gafftopsail catfish may result in adverse systemic health effects. Therefore, consumption of gafftopsail catfish from Sabine Lake **poses an apparent risk to human health**.

3. One of two alligator gar samples assayed contains arsenic at a concentration exceeding the DSHS guidelines for protection of human health of one excess cancer in 10,000 equally exposed individuals. Due to the small sample size and the variability of the arsenic concentrations reported in the two alligator gar samples, the SALG risk assessors are unable to characterize adequately health risks associated with consuming alligator gar

from Sabine Lake. Therefore, the SALG characterizes the likelihood of adverse health effects from regular consumption of alligator gar from Sabine Lake as of **unknown significance to human health.**

4. Consumption of multiple inorganic or organic contaminants in fish does not significantly increase the likelihood of systemic or carcinogenic health risks observed in fish from Sabine Lake. Therefore, SALG risk assessors conclude that consuming fish containing multiple contaminants at concentrations near those observed in fish from Sabine Lake does not significantly increase the risk of adverse health effects.

RECOMMENDATIONS

Risk managers at the DSHS have established criteria for issuing fish consumption advisories based on approaches suggested by the EPA.[10, 14, 43] 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).[44]. Declarations of prohibited harvesting areas are enforceable under the Texas Health and Safety Code, Subchapter D, parts 436.091 and 436.101.[44] The 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 concludes from this risk characterization that consuming gafftopsail catfish from Sabine Lake **poses an apparent hazard to public health.** Therefore, SALG risk assessors recommend that:

1. Pregnant women, women who may become pregnant, women who are nursing infants, and children less than 12 years of age or who weigh less than 75 pounds may consume up to one 4-ounce meal per month of gafftopsail catfish from Sabine Lake.

2. Women past childbearing age and adult men may consume up to three 8-ounce meals per month of gafftopsail catfish from Sabine Lake.

3. As resources become available, the DSHS should continue to monitor fish from Sabine Lake for changes or trends in contaminants or contaminant concentrations that would necessitate a change in consumption advice.

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 512-834-6757.[45] 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.[46] The SALG regularly updates this Web site. The DSHS also provides 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 its Web site and in an official downloadable PDF file containing general hunting and fishing regulations booklet available at http://www.tpwd.state.tx.us/publications/nonpwdpubs/media/regulations_summary_2009_2010.pdf. [47] A booklet containing this information is available 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 (http://www.dshs.state.tx.us/seafood). Secondarily, one may address inquiries to the Environmental and Injury Epidemiology and Toxicology Branch of 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 ATSDR, Division of Toxicology (888-42-ATSDR or 888-422-8737 or the ATSDR's Web site (http://www.atsdr.cdc.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* (ToxProfiles™). 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. Sabine Lake Sample Sites

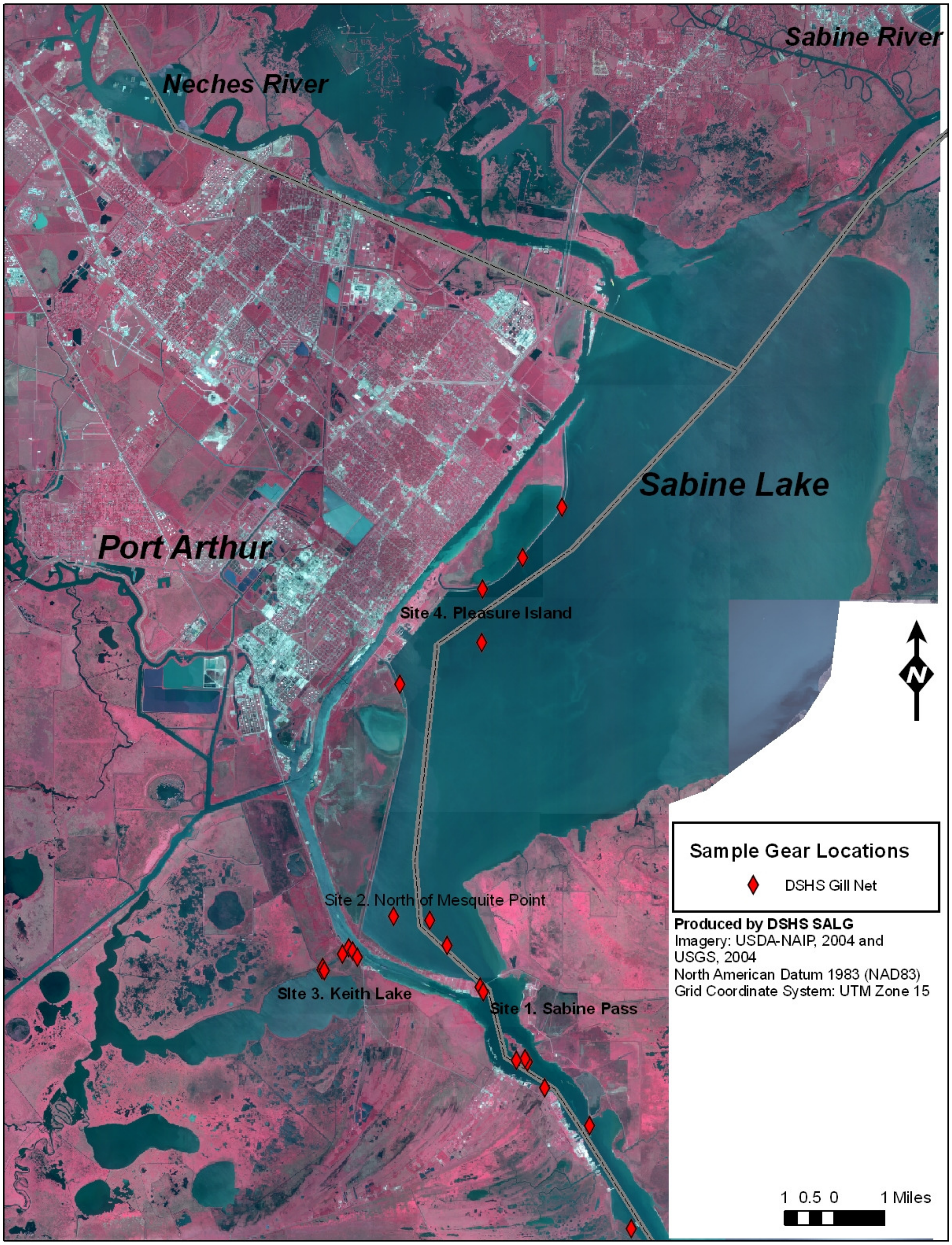
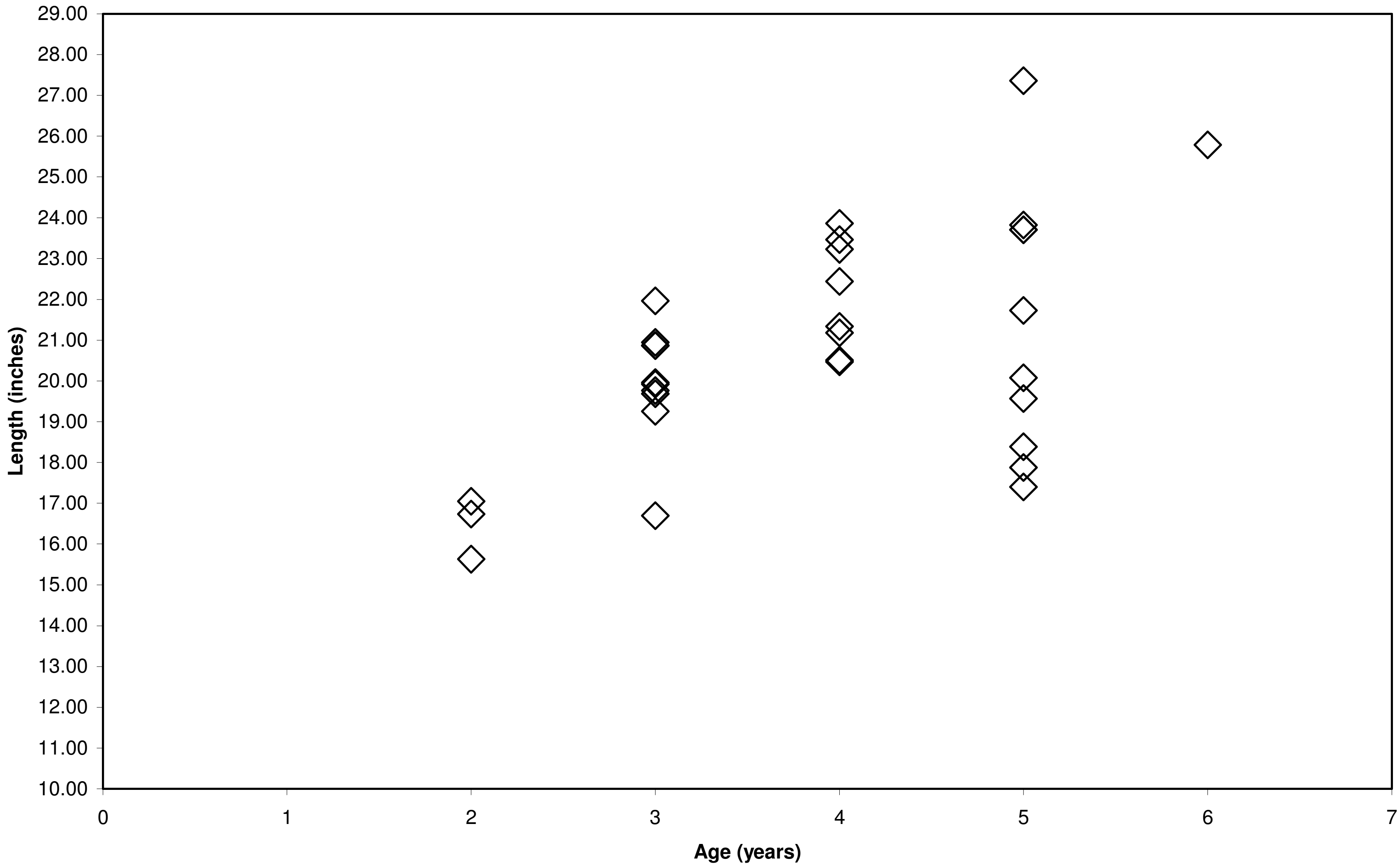


Figure 2. Length at age for spotted seatrout collected from Sabine Lake, Texas, 2010



TABLES

Table 1. Fish samples collected from Sabine Lake on March 22, 2010 through March 23, 2010 and May 3, 2010. Sample number, species, length, and weight are recorded for each sample.

Sample Number	Species	Length (mm)	Weight (g)
Site 1 Sabine Lake at Sabine Pass			
SAB1	Black drum	568	2535
SAB3	Black drum	552	2507
SAB5	Black drum	831	10092
SAB6	Gafftopsail catfish	513	1532
SAB7	Gafftopsail catfish	545	1395
SAB8	Southern flounder	401	788
SAB9	Southern flounder	405	791
SAB10	Red drum	675	3177
SAB11	Red drum	540	1612
SAB12	Striped bass	573	2441
SAB76	Spotted seatrout	542	1630
SAB77	Spotted seatrout	530	1505
SAB78	Gafftopsail catfish	590	2105
SAB79	Gafftopsail catfish	555	1582
SAB81	Gafftopsail catfish	524	1231
SAB82	Gafftopsail catfish	560	1701
SAB85	Spotted seatrout	507	1335
SAB86	Southern flounder	562	2403
SAB87	Sand trout	339	341
Site 2 Sabine Lake north of Mesquite Point/Sabine Causeway			
SAB13	Red drum	646	2893
SAB14	Red drum	565	1811
SAB15	Red drum	564	1719
SAB17	Black drum	421	909
SAB18	Spotted seatrout	442	833
SAB88	Spotted seatrout	521	1541
SAB89	Spotted seatrout	454	871
SAB90	Spotted seatrout	520	1529
SAB91	Gafftopsail catfish	580	1886
SAB92	Gafftopsail catfish	624	2027
SAB93	Gafftopsail catfish	575	1748
SAB95	Gafftopsail catfish	566	1737
Site 3 Sabine Lake at Keith Lake			
SAB32	Spotted seatrout	510	1381
SAB33	Spotted seatrout	552	1693
SAB34	Spotted seatrout	506	1196

Table 1. Fish samples collected from Sabine Lake March 22, 2010 through March 23, 2010 and May 3, 2010. Sample number, species, length, and weight are recorded for each sample.			
Sample Number	**Species**	**Length (mm)**	**Weight (g)**
Site 3 at Keith Lake (continued)			
SAB35	Spotted seatrout	433	780
SAB36	Spotted seatrout	425	731
SAB37	Southern flounder	363	616
SAB38	Red drum	665	3069
SAB41	Red drum	615	2263
SAB43	Black drum	517	2030
SAB44	Black drum	550	2302
SAB46	Black drum	500	1723
SAB48	Striped bass	650	4819
SAB49	Alligator gar	702	1604
Site 4 at Pleasure Island			
SAB20	Red drum	602	2158
SAB21	Red drum	633	2535
SAB22	Red drum	677	3202
SAB24	Southern flounder	387	622
SAB25	Southern flounder	380	617
SAB28	Spotted seatrout	655	2410
SAB29	Spotted seatrout	538	1629
SAB30	Spotted seatrout	500	1169
SAB31	Spotted seatrout	489	1189
SAB50	Alligator gar	1918	45216
SAB55	Spotted seatrout	467	919
SAB56	Spotted seatrout	532	1382
SAB57	Spotted seatrout	695	2949
SAB58	Spotted seatrout	397	608
SAB59	Spotted seatrout	596	2135
SAB60	Spotted seatrout	502	1243
SAB61	Spotted seatrout	530	1444
SAB62	Spotted seatrout	605	2181
SAB63	Spotted seatrout	606	1889
SAB64	Spotted seatrout	558	1778
SAB65	Spotted seatrout	424	769
SAB66	Spotted seatrout	497	1243
SAB67	Spotted seatrout	602	2120
SAB68	Spotted seatrout	570	1747
SAB69	Sand trout	298	279
SAB71	Black drum	625	4032

Table 1. Fish samples collected from Sabine Lake March 22, 2010 through March 23, 2010 and May 3, 2010. Sample number, species, length, and weight are recorded for each sample.

Sample Number	Species	Length (mm)	Weight (g)
Site 4 at Pleasure Island (continued)			
SAB72	Black drum	518	1916
SAB75	Black drum	461	1470
SAB51	Spotted seatrout	602	2313
SAB52	Spotted seatrout	590	1890
SAB53	Southern flounder	400	698

Table 2a. Arsenic (mg/kg) in fish collected from Sabine Lake, 2010.					
Species	**# Detected/ # Sampled**	**Total Arsenic Mean Concentration ± S.D. (Min-Max)**	**Inorganic Arsenic Mean Concentration***	**Health Assessment Comparison Value (mg/kg)†**	**Basis for Comparison Value**
Alligator gar	1/2	2.660±3.733 (ND‡-5.299)	0.266	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
Black drum	10/10	1.163±1.213 (0.145-4.296)	0.116		
Gafftopsail catfish	10/10	1.312±0.518 (0.636-2.038)	0.131		
Red drum	10/10	0.460±0.224 (0.059-0.781)	0.046		
Sand trout	2/2	0.280±0.163 (0.164-0.395)	0.028		
Southern flounder	6/7	0.565±0.618 (ND-1.843)	0.057		
Spotted seatrout	18/32	0.154±0.203 (ND-0.824)	0.015		
Striped bass	1/2	0.098±0.104 (ND-0.171)	0.010		
All fish combined	58/75	0.591±0.882 (ND-5.299)	0.059		

* *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.*

† *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* $1x10^{-4}$.

‡ *ND:* "Not Detected" was used to indicate that a compound was not present in a sample at a level greater than the RL.

Table 2b. Inorganic contaminants (mg/kg) in fish collected from Sabine Lake, 2010.				
Species	**# Detected/ # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
Cadmium				
Alligator gar	1/2	BDL*	0.47	ATSDR chronic oral MRL: 0.0002 mg/kg–day
Black drum	6/10	BDL		
Gafftopsail catfish	7/10	BDL		
Red drum	6/10	BDL		
Sand trout	1/2	BDL		
Southern flounder	4/7	BDL		
Spotted seatrout	15/32	BDL		
Striped bass	1/2	BDL		
All fish combined	42/75	BDL		
Copper				
Alligator gar	2/2	0.133±0.011 (0.125-0.141)	333	National Academy of Science Upper Limit: 0.143 mg/kg–day
Black drum	10/10	0.211±0.080 (0.150-0.421)		
Gafftopsail catfish	10/10	0.338±0.044 (0.273-0.400)		
Red drum	10/10	0.267±0.094 (0.171-0.476)		
Sand trout	2/2	0.220±0.026 (0.201-0.238)		
Southern flounder	7/7	0.144±0.041 (0.079-0.188)		
Spotted seatrout	32/32	0.171±0.051 (0.066-0.272)		
Striped bass	2/2	0.337±0.051 (0.301-0.373)		
All fish combined	75/75	0.213±0.087 (0.066-0.476)		

* *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.*

Table 2c. Inorganic contaminants (mg/kg) in fish collected from Sabine Lake, 2010.				
Species	**# Detected/ # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
Lead				
Alligator gar	2/2	0.036±0.022 (BDL-0.051)	NA	EPA IEUBKwin32 Version 1.1 Build 9
Black drum	6/10	0.034±0.028 (ND-0.092)		
Gafftopsail catfish	8/10	0.024±0.009 (ND-0.050)		
Red drum	5/10	0.028±0.017 (ND-0.070)		
Sand trout	2/2	0.032±0.017 (BDL-0.044)		
Southern flounder	5/7	0.041±0.028 (ND-0.084)		
Spotted seatrout	31/32	0.057±0.048 (ND-0.205)		
Striped bass	1/2	0.023±0.001 (ND-BDL)		
All fish combined	60/75	0.042±0.037 (ND-0.205)		
Mercury				
Alligator gar	2/2	0.235±0.168 (0.116-0.354)	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg–day
Black drum	10/10	0.105±0.072 (0.051-0.265)		
Gafftopsail catfish	10/10	0.288±0.074 (0.199-0.428)		
Red drum	10/10	0.255±0.103 (0.129-0.456)		
Sand trout	2/2	0.084±0.030 (0.062-0.105)		
Southern flounder	7/7	0.088±0.039 (0.058-0.171)		
Spotted seatrout	32/32	0.232±0.094 (0.094-0.445)		
Striped bass	2/2	0.346±0.030 (0.324-0.367)		
All fish combined	75/75	0.211±0.109 (0.051-0.456)		

Table 2d. Inorganic contaminants (mg/kg) in fish collected from Sabine Lake, 2010.				
Species	**# Detected/ # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
Selenium				
Alligator gar	2/2	0.248±0.210 (0.099-0.396)	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
Black drum	10/10	0.775±0.198 (0.435-1.112)		
Gafftopsail catfish	10/10	0.195±0.023 (0.167-0.230)		
Red drum	10/10	0.665±0.149 (0.320-0.834)		
Sand trout	2/2	0.593±0.010 (0.586-0.600)		
Southern flounder	7/7	0.600±0.166 (0.284-0.774)		
Spotted seatrout	32/32	0.621±0.105 (0.441-0.856)		
Striped bass	2/2	0.563±0.066 (0.516-0.610)		
All fish combined	75/75	0.576±0.212 (0.099-1.112)		
Zinc				
Alligator gar	2/2	2.056±0.023 (2.040-2.072)	700	EPA chronic oral RfD: 0.3 mg/kg–day
Black drum	10/10	2.671±0.721 (2.026-4.451)		
Gafftopsail catfish	10/10	4.333±0.676 (3.421-5.509)		
Red drum	10/10	2.880±0.373 (2.260-3.462)		
Sand trout	2/2	2.123±0.237 (1.955-2.290)		
Southern flounder	7/7	2.423±0.600 (1.778-3.178)		
Spotted seatrout	32/32	2.323±0.407 (1.717-3.367)		
Striped bass	2/2	2.512±0.069 (2.463-2.560)		
All fish combined	75/75	2.714±0.830 (1.717-5.509)		

Table 3a. Pesticides (mg/kg) in fish collected from Sabine Lake, 2010				
Species	**# Detected / # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
4,4' DDE				
Alligator gar	1/1	0.008	1.167 1.599	EPA chronic oral RfD: 0.0005 mg//kg–day EPA oral slope factor 0.34 per mg/kg -day
Black drum	4/4	0.0006±0.0003 (BDL-0.001)		
Gafftopsail catfish	4/4	0.014±0.011 (0.007-0.031)		
Red drum	4/4	BDL		
Southern flounder	1/1	BDL		
Spotted seatrout	5/5	0.002±0.001 (BDL-0.004)		
Striped bass	1/1	0.031		
All fish combined	20/20	0.006±0.009 (BDL-0.031)		
Chlordane				
Alligator gar	1/1	0.004	1.167 1.553	EPA chronic oral RfD: 0.0005 mg//kg–day EPA oral slope factor 0.35 per mg/kg–day
Black drum	3/4	0.002±0.003 (ND-0.007)		
Gafftopsail catfish	4/4	0.004±0.003 (0.002-0.008)		
Red drum	2/4	0.0005±0.000005 (ND-BDL)		
Southern flounder	0/1	ND		
Spotted seatrout	5/5	0.001±0.001 (BDL-0.003)		
Striped bass	1/1	0.005		
All fish combined	16/20	0.002±0.002 (ND-0.008)		

Table 3b. Pesticides (mg/kg) in fish collected from Sabine Lake, 2010				
Species	**# Detected / # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
Alpha-HCH				
Alligator gar	1/1	BDL	0.086	EPA oral slope factor 6.3 mg/kg–day
Black drum	2/4	0.0008±0.0004 (ND-0.0012)		
Gafftopsail catfish	3/4	0.0051±0.0052 (ND-0.0118)		
Red drum	2/4	0.0009±0.0005 (ND-0.0014)		
Southern flounder	1/1	BDL		
Spotted seatrout	1/5	0.0011±0.0013 (ND-0.0034)		
Striped bass	0/1	ND		
All fish combined	10/20	0.0017±0.0028 (ND-0.0118)		

Table 4a. PCBs (mg/kg) in fish collected from Sabine Lake, 2010.				
Species	**# Detected / # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
Site 1 Sabine Lake at Sabine Pass				
Black drum	2/3	0.017±0.012 (ND- 0.031)	0.047 0.272	EPA chronic oral RfD: 0.00002 mg/kg–day EPA oral slope factor: 2.0 per mg/kg–day
Gafftopsail catfish	6/6	0.038±0.014 (0.028-**0.066***)		
Red drum	2/2	0.0103±0.0006 (BDL- 0.0107)		
Sand trout	1/1	0.011		
Southern flounder	3/3	0.0106±0.0007 (BDL-0.0114)		
Spotted seatrout	3/3	0.014±0.002 (0.012-0.017)		
Striped bass	1/1	0.013		
All fish combined	18/19	0.021±0.015 (ND-**0.066**)		
Site 2 Sabine Lake north of Mesquite Point/Sabine Causeway				
Black drum	1/1	0.011	0.047 0.272	EPA chronic oral RfD: 0.00002 mg/kg-day EPA oral slope factor: 2.0 per mg/kg-day
Gafftopsail catfish	4/4	**0.083**±0.014 (**0.071-0.100**)		
Red drum	3/3	0.012±0.001 (0.011-0.013)		
Spotted seatrout	4/4	0.016±0.002 (0.015-0.019)		
All fish combined	12/12	0.037±0.035 (0.011-**0.100**)		
Site 3 Sabine Lake at Keith Lake				
Alligator gar	1/1	BDL	0.047 0.272	EPA chronic oral RfD: 0.00002 mg/kg–day EPA slope factor: 2.0 per mg/kg–day
Black drum	3/3	BDL		
Red drum	2/2	0.011±0.002 (BDL-0.012)		
Southern flounder	1/1	BDL		
Spotted seatrout	5/5	0.016±0.006 (0.011-0.024)		
Striped bass	1/1	0.018		
All fish combined	13/13	0.013±0.005 (BDL-0.024)		

* Emboldened numbers denote concentrations of PCBs that exceed the HAC_{nonca} for Aroclor 1254

Table 4b. PCBs (mg/kg) in fish collected from Sabine Lake, 2010.				
Species	**# Detected / # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
Site 4 Sabine Lake at Pleasure Island				
Alligator gar	1/1	0.040	0.047 0.272	EPA chronic oral RfD: 0.00002 mg/kg–day EPA slope factor: 2.0 per mg/kg–day
Black drum	3/3	0.0107±0.0007 (BDL-0.0115)		
Red drum	3/3	0.0107±0.0003 (0.0103-0.0109)		
Sand trout	1/1	0.013		
Southern flounder	3/3	0.0108±0.0010 (BDL-0.0120)		
Spotted seatrout	20/20	0.020±0.022 (BDL-**0.110**)		
All fish combined	31/31	0.018±0.018 (BDL-**0.110**)		
Sabine Lake All Sites				
Alligator gar	2/2	0.025±0.021 (BDL-0.040)	0.047 0.272	EPA chronic oral RfD: 0.00002 mg/kg–day EPA slope factor: 2.0 per mg/kg–day
Black drum	9/10	0.012±0.006 (ND-0.031)		
Gafftopsail catfish	10/10	**0.056**±0.027 (0.028-**0.100**)		
Red drum	10/10	0.011±0.001 (BDL-0.031		
Sand trout	2/2	0.012±0.001 (0.011-0.013)		
Southern flounder	7/7	0.011±0.0008 (BDL-0.012)		
Spotted seatrout	32/32	0.018±0.017 (BDL-**0.110**)		
Striped bass	2/2	0.016±0.003 (0.013-0.018)		
All fish combined	74/75	0.021±0.021 (ND-0.110)		

Table 5a. PCDFs/PCDDs toxicity equivalent (TEQ) concentrations (pg/g) in fish collected from Sabine Lake, 2010.

Species	# Detected / # Sampled	Mean Concentration ± S.D. (Min-Max)	Health Assessment Comparison Value (pg/g)	Basis for Comparison Value
Site 1 Sabine Lake at Sabine Pass				
Black drum	3/3	0.0005±0.0003 (0.0002-0.0009)	2.33 3.49	ATSDR chronic oral MRL: 1.0×10^{-9} mg/kg/day EPA slope factor: 1.56×10^{5} per mg/kg/day
Gafftopsail catfish	3/6	0.0007±0.0008 (ND-0.0015)		
Red drum	0/2	ND		
Sand trout	0/1	ND		
Southern flounder	2/3	0.0006±0.0009 (ND-0.0016)		
Spotted seatrout	2/3	0.0005±0.0005 (ND-0.0011)		
Striped bass	1/1	0.00009		
All fish combined	11/19	0.0005±0.0006 (ND-0.0016)		
Site 2 Sabine Lake north of Mesquite Point/Sabine Causeway				
Black drum	0/1	ND	2.33 3.49	ATSDR chronic oral MRL: 1.0×10^{-9} mg/kg/day EPA slope factor: 1.56×10^{5} per mg/kg/day
Gafftopsail catfish	4/4	1.001±1.220 (0.001-**2.622**)		
Red drum	0/3	ND		
Spotted seatrout	2/4	0.0004±0.0005 (ND-0.0010)		
All fish combined	6/12	0.334±0.806 (ND-**2.622**)		
Site 3 Sabine Lake at Keith Lake				
Alligator gar	1/1	0.0003	2.33 3.49	ATSDR chronic oral MRL: 1.0×10^{-9} mg/kg/day EPA slope factor: 1.56×10^{5} per mg/kg/day
Black drum	0/3	ND		
Red drum	0/2	ND		
Southern flounder	1/1	0.0002		
Spotted seatrout	3/5	0.0005±0.0005 (ND-0.0013)		
Striped bass	0/1	ND		
All fish combined	5/13	0.0002±0.0004 (ND-0.0013)		

Table 5b. PCDFs/PCDDs toxicity equivalent (TEQ) concentrations (pg/g) in fish collected from Sabine Lake, 2010.				
Species	**# Detected / # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (pg/g)**	**Basis for Comparison Value**
Site 4 Sabine Lake at Pleasure Island				
Alligator gar	1/1	1.501	2.33 3.49	ATSDR chronic oral MRL: 1.0 x 10^{-9} mg/kg/day EPA slope factor: 1.56 x 10^{5} per mg/kg/day
Black drum	0/3	ND		
Red drum	1/3	0.00001±0.00002 (ND-0.00003)		
Sand trout	1/1	0.0002		
Southern flounder	1/3	0.0001±0.0002 (ND-0.0004)		
Spotted seatrout	7/20	0.018±0.080 (ND-0.360)		
All fish combined	11/31	0.060±0.275 (ND-1.501)		
Sabine Lake All Sites				
Alligator gar	2/2	0.751±1.061 (0.0003-1.501)	2.33 3.49	ATSDR chronic oral MRL: 1.0 x 10^{-9} mg/kg/day EPA slope factor: 1.56 x 10^{5} per mg/kg/day
Black drum	3/10	0.0002±0.0003 (ND-0.0009)		
Gafftopsail catfish	7/10	0.401±0.874 (ND-**2.622**)		
Red drum	1/10	0.000003±0.000009 (ND-0.00003)		
Sand trout	1/2	0.0001±0.0001 (ND-0.0002)		
Southern flounder	4/7	0.0003±0.0006 (ND-0.0016)		
Spotted seatrout	14/32	0.012±0.0.064 (ND-0.360)		
Striped bass	1/2	0.00005±0.00006 (ND-0.00009)		
All fish combined	33/75	0.079±0.375 (ND-**2.622**)		

Table 6. Hazard quotients (HQs) for PCBs in fish collected from Sabine Lake in 2010. Table 6 also provides suggested weekly eight-ounce meal consumption rates 70-kg adults.			
Species	**Number (N)**	**Hazard Quotient**	**Meals per Week**
Sabine Lake All Sites			
Alligator gar	2	0.5	1.7
Black drum	10	0.3	3.6
Gafftopsail catfish	10	**1.2**[*]	**0.8**[†]
Red drum	10	0.2	3.8
Sand trout	2	0.3	3.7
Southern flounder	7	0.2	4.1
Spotted seatrout	32	0.4	2.4
Striped bass	2	0.3	2.8
All fish combined	75	0.5	2.1

[*] Emboldened numbers denote the HQ for PCBs exceeds 1.0

[†] Emboldened numbers denote the calculated allowable meal consumption rate for an adult is less than one/week.

Table 7a. Calculated theoretical lifetime excess cancer risk from consuming fish containing Arsenic collected in 2010 from Sabine Lake and suggested consumption (8-ounce meals/week) for 70 kg adults who regularly eat fish from Sabine Lake over a 30-year period.

Species	Number (N)	Theoretical Lifetime Excess Cancer Risk		Meals per Week
		Risk	1 excess cancer per number of people exposed	
Sabine Lake All Sites				
Alligator gar	2	7.3E-05	13,645	1.3
Black drum	10	3.2E-05	31,290	2.9
Gafftopsail catfish	10	3.6E-05	27,707	2.6
Red drum	10	1.3E-05	78,905	7.3
Sand trout	2	7.7E-06	129,630	12.0
Southern flounder	7	1.6E-05	63,678	5.9
Spotted seatrout	32	4.1E-06	241,975	22.4
Striped bass	2	2.8E-06	362,963	33.5
All fish combined	75	1.6E-05	61,519	5.7

Table 7b. Calculated theoretical lifetime excess cancer risk from consuming fish containing PCBs collected in 2010 from Sabine Lake and suggested consumption (8-ounce meals/week) for 70 kg adults who regularly eat fish from Sabine Lake over a 30-year period.

Species	Number (N)	Theoretical Lifetime Excess Cancer Risk		Meals per Week
		Risk	1 excess cancer per number of people exposed	
Sabine Lake All Sites				
Alligator gar	2	9.3E-06	108,025	10.0
Black drum	10	4.4E-06	226,852	21.0
Gafftopsail catfish	10	2.1E-05	48,352	4.5
Red drum	10	4.2E-06	240,905	22.3
Sand trout	2	4.3E-06	232,669	21.5
Southern flounder	7	3.9E-06	256,813	23.7
Spotted seatrout	32	6.6E-06	151,235	14.0
Striped bass	2	5.7E-06	174,501	16.1
All fish combined	75	7.7E-06	129,630	12.0

Table 8a. Calculated theoretical lifetime excess cumulative cancer risk from consuming fish containing arsenic and PCBs collected in 2010 from Sabine Lake and suggested consumption (8-ounce meals/week) for 70 kg adults who regularly eat fish from Sabine Lake over a 30-year period.				
Species/Contaminant	**Number (N)**	**Theoretical Lifetime Excess Cancer Risk**		**Meals per Week**
		Risk	**1 excess cancer per number of people exposed**	
Alligator gar				
Arsenic	2	7.3E-05	13,645	1.3
PCBs	2	9.3E-06	108,025	10.0
Cumulative Cancer Risk		8.3E-05	12,115	1.1
Black drum				
Arsenic	10	3.2E-05	31,290	2.9
PCBs	10	4.4E-06	226,852	21.0
Cumulative Cancer Risk		3.6E-05	27,497	2.5
Gafftopsail catfish				
Arsenic	10	3.6E-05	27,707	2.6
PCBs	10	2.1E-05	48,352	4.5
Cumulative Cancer Risk		5.7E-05	17,614	1.6
Red drum				
Arsenic	10	1.3E-05	78,905	7.3
PCBs	10	4.2E-06	240,905	22.3
Cumulative Cancer Risk		1.7E-05	59,437	5.5
Sand trout				
Arsenic	2	7.7E-06	129,630	12.0
PCBs	2	4.3E-06	232,669	21.5
Cumulative Cancer Risk		1.2E-05	83,248	7.7

Table 8b. Calculated theoretical lifetime excess cumulative cancer risk from consuming fish containing arsenic and PCBs collected in 2010 from Sabine Lake and suggested consumption (8-ounce meals/week) for 70 kg adults who regularly eat fish from Sabine Lake over a 30-year period.				
Species/Contaminant	**Number (N)**	**Theoretical Lifetime Excess Cancer Risk**		**Meals per Week**
		Risk	**1 excess cancer per number of people exposed**	
Southern flounder				
Arsenic	7	1.6E-05	63,678	5.9
PCBs	7	3.9E-06	256,813	23.7
Cumulative Cancer Risk		2.0E-05	51,026	4.7
Spotted seatrout				
Arsenic	32	4.1E-06	241,975	22.4
PCBs	32	6.6E-06	151,235	14.0
Cumulative Cancer Risk		1.1E-05	93,067	8.6
Striped bass				
Arsenic	2	2.8E-06	362,963	33.5
PCBs	2	5.7E-06	174,501	16.1
Cumulative Cancer Risk		8.5E-06	117,845	10.9
All fish combined				
Arsenic	75	1.6E-05	61,519	5.7
PCBs	75	7.7E-06	129,630	12.0
Cumulative Cancer Risk		2.4E-05	41,720	3.9

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