Characterization of Potential Adverse Health Effects Associated with Consuming Fish from the

Neches River

Angelina, Hardin, Houston, Jasper, Jefferson, Orange, Trinity, and Tyler Counties, Texas

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INTRODUCTION

This document summarizes the results of a survey of the Neches River conducted in 2007 by the Texas Department of State Health Services (DSHS) Seafood and Aquatic Life Group (SALG). The SALG did this study to characterize potential human health risks associated with consumption of fish found to contain chemical contaminants in excess of project specific screening values established under the aegis of the Statewide Fish Tissue Monitoring Project. The present study, ensuing from surveys by the Texas Parks and Wildlife Department (TPWD) and the Texas Commission on Environmental Quality (TCEQ), examined fish from the Neches River for the presence and concentrations of environmental toxicants that, if eaten, potentially could affect human health negatively. The report addresses the public health implications of consuming fish from segments of the Neches River and suggests actions to reduce potential adverse health outcomes

Description of the Neches River

Originating in Van Zandt County near Colfax, Texas, the Neches River courses 416 miles east southeast through Smith, Henderson, Cherokee, Anderson, Houston, Angelina, Jasper, Tyler, Hardin, and Orange Counties on its journey to Sabine Lake at Port Neches and then into the Gulf of Mexico. The Neches River serves as the county line between Van Zandt and Smith counties, Smith and Henderson counties, Henderson and Cherokee counties, Cherokee and Anderson counties, and between Cherokee and Houston counties. Other counties separated by the Neches River include Houston and Angelina counties, Angelina and Trinity counties, and Angelina and Polk counties. Continuing, the Neches River makes up the county line between Angelina and Tyler counties, Tyler and Jasper counties, Jasper and Hardin counties, Hardin and Orange counties, and Orange and Jefferson counties.[1,2] The Neches River drains approximately 10,000 square miles of the Piney Woods ecoregion that subsumes the Angelina National Forest,[3] Davy Crockett National Forest,[4] and the Big Thicket National Preserve.[5] Abundant rainfall over the river basin produces a river flow of some 6,000,000 acre-feet per year. Major tributaries of the Neches River include the Angelina River, which drains one-third of the basin area, Bayou La Nana, Ayish Bayou, Pine Island Bayou, Village Creek, Kickapoo Creek, and Flat Creek. Two major reservoirs are located on the Neches River: Lake Palestine, 15 miles southwest of Tyler in Smith County, Texas, and B.A. Steinhagen Reservoir.[1 2] Rhine Lake, another small reservoir lies just above Lake Palestine. The scenic and remote settings along the river's course endow the Neches with quality recreational areas. The Angelina National Forest, Davy Crockett National Forest, and the Big Thicket National Preserve provide river access, camping, canoeing, fishing (largemouth bass and catfish are abundant; other species are also found), and other public recreation activities.[3,4,5] People gain access to the river using Texas Parks and Wildlife Department (TPWD) boat ramps at State Highway (SH) 7, United States Highway (US Hwy) 59, and US Hwy 96; the Lower Neches Valley Authority (LNVA) boat ramp at the salt-water barrier, or .[2,6] additional public access available at other major highway crossing rights-of-way.

Demographics of the Neches River Basin

In 2007, the census bureau estimated the population of the 14 Neches River Basin counties at 1,031,864 people.[7] The Neches River flows through a predominantly rural landscape. Approximately 56% of the population living within the Neches River Basin resides in two major metropolitan areas of Texas: the Beaumont-Port Arthur (381,452) and the Tyler (197,415) metropolitan statistical areas (MSA).[8] In 2007, the Neches River Basin contained seven cities with estimated populations of at least 15,000 people: Beaumont (109,579), Tyler (96,451), Port Arthur (55,313), Lufkin (34,070), Palestine (18,130), Orange (17,425), and Nederland (16,178).[9]

Subsistence Fishing at the Neches River

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

History of the Texas Statewide Fish Tissue Monitoring Project (SFTMP)

Three Texas agencies, DSHS, TCEQ, and 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 SALG at DSHS determines whether chemical contaminants in fish or shellfish pose a potential health risk to those who would consume such 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.[11] Among its other duties, the TCEQ establishes and manages water quality standards for the state and addresses pollution of Texas' public waters. The TPWD manages state fish and wildlife resources, addresses pollution that may adversely affect these resources, and enforces closures or bans issued by DSHS. These, and several other state and federal agencies, coordinate to oversee contaminant monitoring of Texas waters – and their flora and fauna – through regular meetings of the legislatively mandated interagency Toxic Substances Coordinating Committee (TSCC).[12]

The *Statewide Fish Tissue Monitoring Project* (SFTMP) is a two-stage initiative (Tiers 1 and 2) that uses the experience and resources of the TCEQ, the TPWD, and the DSHS.[13,14] to conduct cross-state studies of fish tissue contamination. The DSHS conducts Tier 2 studies to characterize potential human health risks associated with consuming fish found during Tier 1 studies to contain chemical contaminants in excess of project specific screening values. Although the DSHS may initiate Tier 1 studies, the TCEQ and/or the TWPD more likely launch the initial studies of a water body. The USEPA financed the SFTMP project through fiscal year 2009 (ending December 31, 2008). The TCEQ administered the USEPA funds. Most grant funds paid for laboratory analysis of contaminants in fish tissue to determine whether those contaminants existed in fish at concentrations consumption of which would exceed a daily dose unlikely to affect human health (doses derived from USEPA reference doses (RfDs) or Agency for Toxic Substances and Disease Registry (ATSDR) minimal risk levels (MRLs)). Consuming high levels of such contaminants, some found only in fish, could – over time – influence human health negatively.

In 2003, the three agencies selected for Tier 1 studies 66 previously un-surveyed Texas reservoirs and 15 river segments.[13] In 2006, the Tier 1 portion of the SFTMP was extended for one year, adding 20 more un-surveyed reservoirs. The TPWD Inland Fisheries Division (TPWDIF) conducted Tier 1 studies during routine fisheries management activities on major reservoirs; TCEQ conducted Tier 1 studies on selected river segments. The DSHS, TPWD, and/or TCEQ selected for Tier 2 examination those water bodies yielding fish samples containing contaminants that exceeded SFTMP Tier 1 screening criteria.

In 2004, the TCEQ conducted Tier 1 tests on fish the agency sampled from the Neches River at U.S. 59 as a part of the above-outlined project. TCEQ collected three freshwater drum (predator species) samples ranging in length from 14.8 to 16.7 inches, preparing from these three samples one composite freshwater drum sample. The TCEQ also collected three bottom-feeding smallmouth buffalo samples ranging in length from 19.5 to 21.1 inches. From the three smallmouth buffalo samples, the TCEQ prepared one composite smallmouth buffalo sample. The TPWD laboratory in San Marcos, Texas analyzed the two composite samples (1 freshwater drum; 1 smallmouth buffalo) for suites of inorganic and organic contaminants listed in the SFTMP quality assurance project plan (QAPP). The DSHS and TCEQ compared target analyte concentrations in the two Tier 1 tissue samples from the Neches River to the DSHS-established human health screening values (SVs) to identify contaminants that exceeded SVs and to determine whether the DSHS should examine fish from the Neches River more intensively in a Tier 2 study.[13,14] That comparison revealed that both the composite freshwater drum sample and the composite smallmouth buffalo sample from the Neches River contained mercury at concentrations (0.550 mg/kg and 0.540 mg/kg, respectively) in excess of the DSHS human health screening value (0.525 mg mercury/kg edible tissue). Based on these results, the DSHS and the TCEQ scheduled the Neches River for a Tier 2 study to examine Neches River fish more intensively for mercury and other chemical contaminants, regular or long-term consumption of which could potentially result in adverse health effects.

Following upon the results of the 2004 TCEQ Tier 1 study of fish from the Neches River, the TPWD Inland Fisheries Contaminant Assessment Team (TPWDIFCAT) sampled the river in August 2005 to assess the distribution of mercury in fish throughout the Neches River Basin.

During the 2005 survey, the TPWDIFCAT collected 38 samples consisting of six flathead catfish, 13 freshwater drum, one largemouth bass, four longnose gar, four spotted bass, and 10 spotted gar[15] from a total of six Neches River sites: the Lower Neches Valley Authority (LNVA) saltwater barrier, FM 1013, R-255, U.S. 59, S.H. 21, and U.S. 79. The data from the TPWDIFCAT study revealed that mercury in four of the six sampled species (flathead catfish, freshwater drum, largemouth bass, and spotted bass) exceeded the DSHS human health screening value (0.525 mg mercury/kg fish tissue), further suggesting the need for more intensive evaluation of fish from the Neches River for mercury and other contaminants.

METHODS

Fish Sampling, Preparation, and Analysis

The DSHS SALG collects and analyzes edible fish from the state's public waters to evaluate potential risks to the health of people consuming contaminated fish or shellfish. Fish tissue sampling follows standard operating procedures from the DSHS *Seafood and Aquatic Life Group Survey Team Standard Operating Procedures and Quality Control/Assurance Manual.*[16] 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.*[17] Advice and direction are also received from the legislatively mandated *State of Texas Toxic Substances Coordinating Committee Fish Sampling Advisory Subcommittee (FSAS).*[18] 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 2007 Neches River Sample Set

In June 2007 and September 2007, SALG staff collected 60 fish samples from the Neches River. Risk assessors used contaminant data from these fish to assess the potential for adverse human health outcomes from consuming fish from the Neches River.

The SALG selected six sites to provide spatial coverage of the study area (Figure 1). Site 1 was located near the LNVA saltwater barrier, Site 2 at U.S. 96, Site 3 at FM 1013, Site 4 at R-255, Site 5 at U.S. 59 and Site 6 at S.H. 7. Four of the sites mirrored sites sampled by TPWD in 2005. Species collected represent a distinct ecological group (predators) that have the potential to bio-accumulate mercury and, perhaps, other chemical contaminants; have a wide geographic distribution; are of local recreational fishing value; or are species that anglers and their families commonly consume. The 60 fish collected from the Neches River in the June and September 2007 sampling trips represented all targeted species. Table 1 lists species collected at each site, individual body weight, and length. Species collected are listed in descending order by number sampled: freshwater drum (18), longnose gar (10), blue catfish (9), Smallmouth buffalo (8), flathead catfish (3), largemouth bass (3), spotted gar (2), white bass (2), white crappie (2), black crappie (1), channel catfish (1), and spotted bass (1).

The SALG utilized a boat-mounted electrofisher to collect fish. SALG staff conducted electrofishing activities during daylight hours. They used pulsed direct current (Smith Root 5.0

GPP electrofishing system settings: 4.0-6.0 amps, 60 pulses per second [pps], low range, 50-500 volts, 60% duty cycle- and 1.0-2.0 amps, 15 pps, low range, 50-500 volts, 100% duty cycle (catfish species)) to stun fish that crossed the electric field in the water in front of the boat. Staff used dip nets over the bow of the boat to retrieve stunned fish, netting only fish pre-selected as target samples. Staff immediately stored retrieved samples on wet ice in large coolers to enhance tissue preservation.

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

Analytical Laboratory Information

Upon arrival of the 60 Neches River samples at the GERG laboratory, personnel notified the SALG of receipt of the samples, logged the samples into the GERG system, and recorded the condition of each sample along with its DSHS identification number.

Using established USEPA methods, the GERG laboratory analyzed fish fillets from the Neches River for seven metals (total arsenic, cadmium, copper, lead, total mercury, selenium, and zinc), 123 semivolatile organic compounds (SVOCs), 70 volatile organic compounds (VOCs), 34 pesticides, 209 polychlorinated biphenyl (PCB) congeners, and 17 congeners of polychlorinated dibenzofurans and/or polychlorinated dibenzo-*p*-dioxins (PCDFs/PCDDs). Many such contaminants occur commonly in polluted environmental media. The laboratory analyzed all 60 samples for mercury and analyzed 12 of the 60 for metals, pesticides, PCBs, SVOCs, VOCs, and PCDFs/PCDDs.[19]

Specific Details and Explanatory Notes for Specific Laboratory Analyses

Arsenic

The GERG laboratory analyzed 12 of 60 fish for total arsenic, which consists of both inorganic and organic arsenic. Although the proportion of inorganic to organic arsenic may differ among species, under different environmental and water conditions, and, perhaps, with other variables, the literature suggests that well over 90% of arsenic in fish occurs as organic arsenic – a form that is virtually non-toxic to humans.[20] DSHS, taking a conservative approach, estimates that 10% of the arsenic reported in any fish is inorganic arsenic. The agency derives its estimates of

inorganic arsenic concentration in a fish tissue sample by multiplying reported total arsenic concentration in the sample by a factor of 0.10.[20]

Mercury

Nearly all mercury in upper trophic level fish three years of age or older is methylmercury.[21] Thus, total mercury concentrations in upper trophic level fish of legal size for possession in Texas should serve well as surrogates for methylmercury concentrations. Because methylmercury analyses are difficult to perform accurately and are more expensive than analyses of total mercury, the USEPA recommends that states determine total mercury concentration in a fish and that – to protect human health – the state assumes that 100% of mercury reported in a sample is methylmercury. The GERG laboratory thus analyzed fish tissues for total mercury. In its characterization of risk from consuming mercury in fish, the SALG compares mercury in tissues to a comparison value derived from the ATSDR's minimal risk level (MRL) for methylmercury.[22] In risk characterization reports, the DSHS may interchangeably utilize the terms "mercury," "methylmercury," or "organic mercury" in reference to methylmercury in fish.

Polychlorinated Biphenyls (PCBs)

The USEPA suggests that states measure PCB congeners in fish and shellfish rather than homologs or Aroclors® because that agency considers congener analysis the most sensitive technique for detecting PCBs in environmental media (Aroclor analysis, for instance, can underestimate PCB concentrations by up to 35%).[19] Although only about 130 PCB congeners were routinely present in PCB mixtures manufactured and commonly used in the United States, the GERG laboratory analysis can detect all 209 PCB congeners. The laboratory reports the presence and concentration of each detected congener. 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 for toxicity estimates, the toxicity literature does not reflect state-of-the-art laboratory science. To accommodate the incomplete database, the DSHS utilizes recommendations from the National Oceanic and Atmospheric Administration (NOAA),[23] from McFarland and Clarke,[24] and from the USEPA's guidance documents for assessing chemical contaminants in fish and shellfish[17, 19] to address PCB congeners in fish and shellfish samples. The NOAA and McFarland and Clark papers each utilized some 18 congeners, each chosen for its likelihood of occurring in fish, the likelihood of significant toxicity of the congener based on structure-activity relationships, and for the relative environmental abundance of the named congeners.[23, 24] The USEPA recommends concatenating the NOAA and McFarland and the Clark lists to yield a composite list of 43 specific congeners for risk characterization.[17, 19] SALG risk assessors, following USEPA guidance, sums concentrations of any of the 43 congeners reported present in a sample to derive a "total" concentration of PCBs in each sample. Assessors then average the summed congeners within each species, site, or combined species and site to derive a mean PCB concentration for each group of interest.

Using only a few PCB congeners to determine "total" PCB concentrations could conceivably underestimate tissue levels of PCBs. Nonetheless, this mathematical method complies with expert recommendations on evaluation of PCBs in fish or shellfish. Therefore, SALG risk

assessors compare average concentrations of the 43 congeners with health-based assessment comparison (HAC) values derived from information on PCB mixtures archived in the USEPA's Integrated Risk Information System (IRIS) database.[25] As of yet, IRIS does not contain information on the systemic toxicity of individual PCB congeners. Instead, the database contains systemic toxicity information for five Aroclor® mixtures: Aroclors® 1016, 1242, 1248, 1254, and 1260. Not all information is available for all named mixtures; for instance, IRIS contains reference doses (RfDs) for only two Aroclor mixtures – Aroclor 1016, a late-arriving commercial mixture reportedly devoid of dibenzofurans, and Aroclor 1254. Systemic toxicity estimates in the present document reflect comparisons derived from the RfD for Aroclor 1254 because Aroclor 1254 was more commonly used than was Aroclor® 1016 and because dioxin-like compounds present in Aroclor 1254 may contribute to the reported toxicity. This mixture of PCBs, which, along with Aroclor 1260, was heavily used in the U.S.

For assessment of cancer risk from exposure to PCBs, the SALG uses the USEPA's most conservative slope factor or unit risk factor – 2.0 per (mg/kg/day) to calculate theoretical lifetime excess cancer risk from ingestion of PCBs. The SALG based the decision to use the most restrictive unit risk factor available in the IRIS database on characteristics of PCBs in fish that include food chain exposure, the presence of dioxin-like, tumor-promoting, or persistent congeners, and the likelihood of early-life exposure.[25]

Data Analysis and Statistical Methods

The SALG risk assessors imported Excel© data 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) for compounds measured by the GERG laboratory.[26] In computing descriptive statistics, SALG risk assessors used ½ the reporting limit (RL) for analytes designated as not detected (ND) or estimated (J)[a]. The SALG computed descriptive statistics for PCDFs/PCDDs from estimated (J) concentrations but assumed zero for concentrations of PCDFs/PCDDs designated as ND.[b] The change in methodology for computing PCDFs/PCDDS descriptive statistics was necessary because the reporting limits for PCDFs/PCDDs lie proximate to the HAC value such that assuming ½ the RL for PCDFs/PCDDs designated as "ND" or "J" concentrations would have inappropriately overestimated concentrations of PCDFs/PCDDs in each fish tissue sample. The SALG compares means, medians, and/or ranges with HAC values to estimate a degree of risk for its risk characterizations. Although SALG protocols do not require hypothesis testing, if data are of sufficient quantity and quality, and, should the SALG assessors deem it necessary, risk assessors may determine whether differences among contaminant concentrations in different species and/or at various collection sites are significantly different; such differences may be used in risk management strategies. The SALG employs Microsoft Excel® spreadsheets to generate figures, to compute noncarcinogenic health-based assessment comparison (HAC_{nonca}) and

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

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

carcinogenic health-based assessment comparison (HAC_{ca}) values for contaminants, and to calculate hazard quotients (HQs), hazard indexes (HIs), cancer risk probabilities, and meal consumption limits for fish from a water body under investigation.[27] SALG risk assessors may also utilize the USEPA'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).[28,29]

Calculation of Toxicity Equivalence Quotients (TEQs) for Dioxins

PCDFs/PCDDs are families of aromatic chemicals containing one to eight chlorine atoms. The molecular structures of the PCDFs/PCDDs molecules – called congeners – differ not only with respect to the number of chlorines on a molecule, but also with the placement and positions of those chlorines on the carbon atoms of that molecule. The number of chlorines on the dibenzofuran or dibenzo-*p*-dioxin nucleus and their placement on those molecules directly affect the toxicity of the congeners. Toxicity increases as the number of chlorines increases to four, then decreases with continuing increases in the number of chlorines – up to a maximum of eight. With respect to the placement of chlorines on the dibenzofuran/dibenzo-*p*-dioxin nucleus, those congeners with chlorine substitutions in the 2, 3, 7, and 8 positions appear more toxic than congeners with chlorine substitutions in other positions. To illustrate, the most toxic of polychlorinated dibenzo-p-dioxins (PCDDs) is 2,3,7,8–tetrachlorodibenzo-*p*-dioxin (2,3,7,8–TCDD), a 4-chlorine molecule having one chlorine substituted for hydrogen at each of the 2, 3, 7, and 8 – numbered carbons on the dibenzo-*p*-dioxin nucleus. Further, 2,3,7,8-TCDF is the most toxic dibenzofuran. To gain some measure of toxic equivalence, 2,3,7,8–TCDD and 2,3,7,8-TCDF – the most potent of the dioxins/furans are assigned toxicity equivalence factors (TEF) of 1.0. These, then, are the standards against which the toxicity of all other PCDF/PCDD congeners are compared. Congeners are assigned toxicity equivalence factors (weighting factors or TEFs) of 1.0 or less based on the experimentally-determined comparative toxicity (potency) of the congener to that of 2,3,7,8-TCDD or, in the case of dibenzofurans, to 2,3,7,8-TCDF.[30, 31] To arrive at a TEQ (toxicity equivalence quotient), multiply the congener's concentration by its TEF. This mathematical manipulation yields a concentration of the congener roughly equivalent to a 1 pg/kg concentration of 2,3,7,8-TCDF or 2,3,7,8-TCDD. After converting the measured concentration of each congener in each fish tissue sample from the Neches River to its TEQ, risk assessors determined the total TEQs for a sample – defined as the sum of the TEQs for each of the congeners in the sample – according to the following formula.[32]

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

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

Derivation and Application of Health-Based Assessment Comparison Values (HAC_{nonca}) for Systemic (noncarcinogenic) Effects of Consumed Chemical Contaminants

The effects of exposure to any hazardous substance depend, among other factors, on the dose, the route of exposure, the duration of exposure, the manner in which the exposure occurs, the genetic makeup, personal traits, and habits of the exposed, and the presence of other chemicals.[33] 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 include cancer, benign tumors, birth defects, infertility, blood disorders, brain damage, peripheral nerve damage, lung and kidney disease, to name but a few.[33] If diverse species of fish or shellfish is available, the SALG presumes that people eat a variety of species from a water body. Further, SALG risk assessors at DSHS assume that most fish species are mobile. SALG risk assessors may combine data from different fish species, blue crab, and/or sampling sites within a water body to evaluate mean contaminant concentrations of toxicants in all samples as a whole. This approach intuitively reflects consumers' likely exposure over time to contaminants in fish or shellfish from any water body, but may not reflect the reality of exposure at a specific water body or a single point in time. The DSHS reserves the right to project risks associated with ingestion of individual species of fish or shellfish from separate collection sites within a water body or at higher than average concentrations (e.g. the upper 95 percent confidence limit on the mean). The SALG derives confidence intervals from Monte Carlo simulations using software developed by Richard Beauchamp, MD, a DSHS medical epidemiologist (personal communication, 1999). The group evaluates contaminants in fish or shellfish by comparing the mean or the 95% upper confidence limit on the average concentration of a contaminant to its HAC value (in mg/kg) for non-cancer or cancer endpoints.

In deriving HAC_{nonca} values for systemic effects, the SALG assumes a standard adult weighs 70 kilograms and consumes 30 grams of fish or shellfish per day (about one 8-ounce meal per week) and uses the USEPA's oral RfD[34] or the ATSDR chronic oral MRLs.[35] 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.*[36]

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.*[36]

The ATSDR uses a similar technique to derive its MRLs.[35] The DSHS compares the estimated daily dose (calculated in mg/kg/day as: Dose (mg/kg/day) = concentration of toxicant in sample

(mg/kg) *daily consumption (kg/day)/body weight (kg) – 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 USEPA, is

> *…the ratio of the estimated exposure dose of a contaminant (mg/kg/day) to the contaminant's RfD or MRL (mg/kg/day).*[37]

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. An HQ of 4.0 also does not imply that adverse events will occur four times as often as if the HQ for the substance in question were 1.0. Rather, the USEPA suggests that risk assessors interpret an HQ or a HI that computes to less than 1.0 as "no cause for concern" whereas an HQ or HI greater than 1.0 "should indicate some cause for concern." Therefore, 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 point of departure for management decisions – assuming, for instance, that HQs less than 1.0 are unlikely to be an issue while HQs greater than 1.0 might suggest that risk managers could take a regulatory action to ensure protection of public health. Similarly, risk assessors at the DSHS may utilize an HQ to determine the need for further study of a water body's fauna. Notwithstanding the above discussion, the oral RfD derived by the USEPA represents chronic consumption. Thus, regularly eating fish containing a toxic chemical with an HQ of less than 1.0 is unlikely to be associated with adverse systemic health effects. On the other hand, 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 based on comparison of a consumption dose with the HAC_{nonca} derived from the RfD.

Although, as advised by the USEPA, the DSHS preferentially utilizes the RfD calculated by federal scientists for a specifically named contaminant, should an RfD not be available for a contaminant, the USEPA advises risk assessors to consider using the RfD (or an MRL) for a contaminant of similar molecular structure, or one of similar mode or mechanism of action. For instance, an RfD is not available for Aroclor® 1260, so the DSHS uses the RfD for Aroclor 1254 to assess the likelihood of systemic or noncarcinogenic effects of Aroclor 1260, which contains congeners overlapping those of Aroclor 1254.[35]

In developing oral RfDs and MRLs, federal risk assessors review the extant literature to devise NOAELs, LOAELs, or BMDs from experimental studies. To minimize potential systemic adverse health effects in people exposed through consumption of contaminated materials, scientists who derive RfDs, etc. utilize uncertainty factors to account for certain conditions that may not be determined by the experimental data. The classic factors used to mitigate uncertainty are interspecies variability (extrapolation from animal studies to predict effects in humans), intra-human variability (differences among human subjects in the effects of a toxicant), using a subchronic rather than a chronic study to determine the NOAEL, LOAEL, or BMD, and database insufficiencies.[34,36] When deriving an RfD or an MRL, exceptionally vulnerable groups also receive special consideration. Such groups may include women who are pregnant or lactating, women who may become pregnant (in both of which groups, the fetus is the vulnerable

organism), infants, children, people with chronic illnesses or compromised immune systems, the elderly – who may have a senescent immune system – or people who consume exceptionally large servings – all groups that risk assessors and the USEPA consider sensitive populations.[36, 38]

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. Although knowing the mode or mechanism of action of chemicals of interest, this information is often missing. The lack of such information often forces risk assessors to use as their definition of “toxicological similarity” the "similarity of target organs." The default procedure for calculating the HI for the exposure mixture chemicals is to add together the HQs (HQ = the ratio of the external exposure dose to the RfD) for all component chemicals affecting the same target organ.

Summing HQs to arrive at a HI approximates the value the mixture’s “hazard quotient” likely would have taken if all chemicals in the mixture could have been simultaneously tested (as if the mixture was a single chemical). For example, the HI for liver toxicity should approximate the degree of liver toxicity likely to have been present if effects of the whole mixture were due to a single chemical at a higher concentration. Typically, all target organs for which an HI can be calculated should be decided for each particular mixture assessment and a separate HI calculated for each toxic effect of concern. The mixture components to be included in the HI calculation are any chemical components showing the effect described by the HI, regardless of the critical effect from which the RfD is derived. A note of caution: because the RfD is derived for the critical effect – the "toxic effect occurring at the lowest dose of a chemical" – an HI computed from HQs derived from RfDs may be overly conservative, resulting in an exaggeration of health risk from consumption of the chemical mixture.

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 1 and all relevant effects have been considered in the assessment, the exposure being assessed for potential systemic toxicity should be interpreted as unlikely to result in significant toxicity.*

And

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

Thus,

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

Derivation and Application of Health-Based Assessment Comparison Values (HAC_{ca}) for Application to the Carcinogenic Effects of Consumed Chemical Contaminants

The DSHS calculates HAC_{ca} values from the USEPA's chemical-specific cancer potency factors (CPFs) – also known as slope factors (SFs) – derived through mathematical modeling from carcinogenicity studies. For carcinogenic outcomes, the DSHS calculates a theoretical lifetime excess risk of cancer from exposure to specific carcinogens, using the standard 70-kg body weight and the assumption that an adult consumes 30 grams of edible tissue per day. To these assumptions, SALG risk assessors utilize two additional factors to determine theoretical lifetime excess cancer risk: (1) an acceptable lifetime risk level (ARL) [36] of one excess cancer case in 10,000 persons whose average daily exposure is equivalent and (2) daily exposure for 30 years. Comparison values used to assess the probability of increases in background cancer rate do not contain "uncertainty" factors as such. However, conclusions drawn from comparing toxicant concentrations in fish tissues with HAC_{ca} values derived from probability determinations infer substantial safety margins for all people by virtue of the models utilized to derive the slope factors (cancer potency factors) used to calculate the HAC_{ca}.

Because comparison values are conservative, exceeding a HAC value does not necessarily mean adverse health effects will occur. The perceived strict demarcation between acceptable and unacceptable exposures or risks is primarily a tool used, 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 ("bright-line" divisions) between safe and unsafe exposures. For example, the DSHS considers it unacceptable when consumption of four or fewer meals per month of contaminated fish or shellfish would result in exposure to contaminant(s) in excess of a HAC value or other measure of risk, but does not necessarily expect such exposures to produce negative health effects. The DSHS also uses other measures to help people minimize their exposures. For instance, the DSHS advises that people who wish to minimize exposure to contaminants in fish or shellfish eat a variety of fish and/or shellfish, to eat smaller and younger fish, and to limit consumption of those species most likely to contain toxic contaminants. The DSHS aims to protect vulnerable subpopulations with its consumption advice, assuming that advice protective of vulnerable subgroups will also protect the general population from potential adverse health effects associated with consumption of contaminated fish or shellfish.

Children's Health Considerations

The DSHS recognizes that fetuses, infants, and children may be uniquely susceptible to the effects of toxic chemicals and suggests that exceptional susceptibilities demand special attention. [39, 40] Windows of special vulnerability; known as "critical developmental periods," exist during gestation of the organism. 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.[41] 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 active toxicant at the target organ(s) or that could modulate target organ response to the toxicant. Children's exposures to toxicants may be

more extensive than adults' exposures because, in proportion to their body weights, children consume more food and liquids than adults do, 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.[42] 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.[34] Additionally, in accordance with the ATSDR's *Child Health Initiative*[43] and the USEPA's *National Agenda to Protect Children's Health from Environmental Threats,*[44] the DSHS further seeks to protect children from the possible negative effects of toxicants in fish by suggesting that this potentially sensitive subgroup consume smaller quantities of contaminated fish or shellfish than adults consume. Thus, DSHS recommends that children weighing 35 kg or less and/or who are 11 years of age or younger limit exposure to contaminants in fish or shellfish by eating no more than four ounces per meal of the contaminated species. The DSHS also recommends that consumers spread these meals over time. For instance, if the DSHS issues consumption advice that suggests consumption of no more than two meals per month of a contaminated species, those children should eat no more than 24 meals of the contaminated fish or shellfish per year and, ideally, should not eat such fish or shellfish more than twice per month.

RESULTS

The GERG laboratory electronically sent completed analytical results to the SALG at the DSHS in 2008. The laboratory reported mercury concentrations in all 60 fish tissue samples along with the results of analysis of 12 of the 60 fish (NEC2, NEC9, NEC37, NEC44, NEC49, NEC52, NEC34, NEC36, NEC13, NEC62, NEC19, and NEC63) for metals, pesticides, PCBs, SVOCs, VOCs, and PCDFs/PCDDs.

For reference, Table 1 contains the total number of samples collected from the Neches River in June and September of 2007. Tables 2a through 2c contain summary results of metals in fish from the Neches River. Table 3 contains summary results for selected pesticides. Tables 4a and 4b contain summary results for PCBs while Tables 5a and 5b show the summary statistics for PCDFs/PCDDs. The paper does not display SVOC and VOC data because these contaminants either were not detected, were reported as estimated concentrations, or were observed only at low, although measurable, concentrations. Unless otherwise stated, table summaries present the number of samples containing a specific toxicant over the number of samples tested; the mean concentration ± 1 standard deviation (68% of samples should fall within one standard deviation (SD) of a sample's arithmetic mean if the population is normally distributed; 95% should fall between ± 2 SD units). Finally, in parentheses under the mean and standard deviation, the tables indicate the minimum and the maximum detected concentrations (this is not the statistical range). In the tables, results may be given as "ND" (not detected), BDL (below detection limit), or as

measured concentrations. Samples with results given as BDL rely upon the laboratory's method detection limit (MDL) and the reporting limit (RL). Laboratory scientists define an MDL as the minimum concentration of an analyte of interest that it can measure and report with 99% confidence that the analyte concentration is greater than zero. The RL is the concentration that the laboratory can reliably achieve during routine sample analyses. The RL depends upon specified limits of precision and accuracy designated by those who order the tests. Contaminant concentrations reported below the RL are qualified as "J" concentrations in the laboratory's data report.[45]

Inorganic Contaminants

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

Three of the 12 samples from the Neches River contained arsenic (Table 2a). The laboratory reported cadmium as an estimated concentration in one blue catfish (Table 2b). Trace[c] quantities of lead were present in eight of 12 samples assayed (Table 2b). The laboratory reported all 12 samples to contain copper, selenium, and zinc (Table 2b). The mean copper, selenium, and zinc concentrations were 0.172 mg/kg, 0.493 mg/kg, and 3.729 mg/kg, respectively (Table 2b).

All 60 samples from the Neches River contained mercury (Table 2c). Table 2c shows mercury in each species at each site sampled. Across all sites and species, mercury concentrations in fish ranged from 0.114 mg/kg (channel catfish) to 2.522 mg/kg (longnose gar) (Table 2c). The lower and upper 95% confidence limits (n=60) on the *All Species* mean mercury concentration were 0.472 mg/kg and 0.684 mg/kg, respectively.

The single black crappie sampled contained 0.628 mg/kg; the channel catfish contained 0.114 mg/kg, while the only spotted bass examined contained 1.019 mg/kg mercury (Table 2c). The mean concentration of mercury in flathead catfish (N=3) and longnose gar (N=10) were 1.185±1.058 mg/kg and 0.709±0.657 mg/kg, respectively (Table 2c). The mean concentration of mercury in freshwater drum (N=18) from the Neches River was 0.536±0.218 mg/kg (Table 2c). The lower and upper 95% confidence limits on the freshwater drum mean mercury concentration were 0.523 mg/kg and 0.725 mg/kg, respectively. The median mercury concentration in freshwater drum was 0.503 mg/kg. The mean mercury concentration for freshwater drum ≥18 inches (n=6) was 0.713±0.207 mg/kg). Smallmouth buffalo (N=8) mercury concentrations ranged from 0.399 mg/kg to 0.711 mg/kg. Table 7 shows that mercury from the Neches River in combined species was highest at sites 4 and 5 (R-255 and U.S. 59, respectively).

The SALG risk assessors visually examined the mercury summary data noting that mercury appeared to break naturally between down-stream and up-stream sections of the surveyed length of the Neches River. The SALG risk assessors condensed the six original collection sites into two composite sites based on the apparent natural break in the results (Figure 2): Composite Site 1 (Neches River-Lower) consists of original collection sites 1 and 2 and Composite Site 2 (Neches River-Upper) consists of the remaining four of six original collection sites (3, 4, 5, and 6). Univariate analysis of variance showed that the mean fish tissue mercury concentration in fish from Composite Site 2 (Neches River-Upper) was significantly higher than the mean concentration in fish collected from the Composite Site 1 (Neches River-Lower; $F = 2.406$; df = 58; $P = 0.016$). The mean mercury concentration for combined species at the Composite Site 1 (Neches River-Lower) was 0.401±0.167 mg/kg while, at Composite Site 2 (Neches River-

Upper), the mean mercury concentration was 0.667±0.0.465 mg/kg. The minimum and maximum concentrations at Composite Site 2 (Neches River-Upper) were 0.157-2.522 mg/kg, respectively (Table 2d).

Although discussed in different ways from summary data tables showing the data in various cuts, the SALG used the data sets from the two composite sites to recommend advisory or regulatory action to protect public health along the Neches River survey as described in the current risk characterization.

Organic Contaminants

Pesticides

The GERG laboratory analyzed a subsample of 12 of 60 fish samples from the Neches River for 34 pesticides. Low but quantifiable concentrations of 4,4'-DDD, Mirex, hexachlorobenzene, heptachlor epoxide, pentachloroanisole, 2,4'-DDD, 2,4'-DDT, and methoxychlor were reported in at least one sample (data not presented). All samples assayed contained 4,4'-DDE – a metabolite and/or degradation product of the insecticide 4,4'-DDT – and chlordane (Table 3). These samples analyzed for pesticides contained trace[c] quantities of pentachlorobenzene, endosulfan I, endosulfan II, malathion, ethyl parathion, and methyl parathion (data not presented). The 12 samples contained no other detectible pesticides.

SVOCs

The GERG laboratory analyzed the same 12 samples from the Neches River for SVOCs as were examined for pesticides. Low but quantifiable concentrations of phenol were present in one freshwater drum (NEC37) sample (data not presented). One smallmouth buffalo (NEC44) and one flathead catfish (NEC63) contained measurable 4-methylphenol. One freshwater drum (NEC37) contained an estimated concentration (J-value) of 4-methylphenol (data not presented). The laboratory detected traces of bis (ethylhexyl) phthalate (BEHP) and fluorene in a few samples (data not presented). The laboratory detected no other SVOCs in fish collected in 2007 from the Neches River.

VOCs

The GERG laboratory analyzed the same 12 samples for VOCs as were examined for pesticides, and SVOCs from the Neches River. Low but measurable concentrations of carbon disulfide, methylene chloride, trichlorofluoromethane, toluene, m+p-xylene, and 1,2,4-trimethylbenzene occurred in some samples (data not presented). Trace[c] quantities of acetone, 2-butanone, chloroform, 1,2-dichloroethane, dibromomethane, benzene, trichloroethene, bromodichloromethane, dichlorodifluoromethane, dibromochloromethane, 1,2-dibromomethane, bromoform, tetrachloroethene, 1,3-dichloropropane, 2-hexanone, chlorobenzene, ethylbenzene, o-xylene, styrene, isopropylbenzene, bromobenzene, 1,1,2,2-tetrachloroethane, 2-chlorotoluene,

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

4-chlorotoluene, 1,3,5-trimethylbenzene, 1,3-dichlorobenzene, 1,4-dichlorobenzene, 1,2-dichlorobenzene, n-propylbenzene, 4-isopropyl toluene, tert-butylbenzene, sec-butylbenzene, n-butylbenzene, 1,2,3-trichlorobenzene, 1,2,4-trichlorobenzene, hexachlorobutadiene, and naphthalene were also present in one or more samples from the Neches River (data not presented). Carbon disulfide, methylene chloride, toluene, 1,2,4-trimethylbenzene, benzene, trichloroethene, bromoform, chlorobenzene, ethylbenzene, m+p-xylene, o-xylene, styrene, isopropylbenzene, 1,1,2,2-tetrachloroethane, 2-chlorotoluene, 1,2-dichlorobenzene, n-propylbenzene, 4-chlorotoluene, 1,3,5-trimethylbenzene, 1,3-dichlorobenzene,1,4-dichlorobenzene, 4-isopropyl toluene, tert-butylbenzene, sec-butylbenzene, n-butylbenzene, 1,2,4-trichlorobenzene, hexachlorobutadiene, and naphthalene were also reported present in the procedural blanks.

PCBs

The GERG laboratory analyzed the same 12 samples from the 2007 Neches River survey for 209 PCB congeners as were examined for pesticides, SVOCs, and VOCs. Table 4a contains summary statistics for PCBs in fish samples. The laboratory detected measurable quantities of PCBs representing one or more of the congeners between PCB 8 and PCB 209 (International Union of Pure and Applied Chemists [IUPAC] assigned numbers) in the 12 samples. No sample contained all PCB congeners (data not shown). Assessing summary statistics for PCBs in each species and in all species combined – without regard to collection site – smallmouth buffalo contained the highest PCB concentration (0.067 mg/kg), followed by flathead catfish (0.038 mg/kg) and longnose gar (0.036 mg/kg). The single largemouth bass sample contained the lowest PCB concentration, reported as an estimated concentration (Table 4a). The mean concentration of PCBs in all fish combined was 0.027±0.020 mg/kg (Table 4a). The mean PCB concentration in fish from Composite Site 1 (Neches-Lower) was 0.017±0.012 mg/kg (Table 4b). At 0.032 ± 0.022 mg/kg, the mean concentration of PCBs in fish from Composite Site 2 (Neches-Upper) was approximately double the mean concentration in samples from Composite Site 1 (Table 4b). The higher mean PCB concentration in samples from Composite Site 2 was likely due to the presence of one smallmouth buffalo that contained 0.067 mg/kg of PCBs, the highest PCB concentration observed in the current study (Table 4b).

PCDFs/PCDDs

Table 5a contains summary statistics for PCDFs/PCDDs in fish collected in 2007 from the Neches River. The laboratory analyzed 12 fish samples for 17 of the 210 possible PCDF/PCDD (135 PCDFs + 75 PCDDs) congeners. The analysis consisted of 10 PCDFs and 7 PCDDs that contain chlorine substitutions in, at a minimum, the 2, 3, 7, and 8 carbon positions on the dibenzofuran or dibenzo-*p*-dioxin nucleus and are the only congeners reported to pose dioxin-like adverse human health effects.[46] Although 12 of the 209 PCB congeners – those often referred to as "coplanar PCBs," meaning the molecule can assume a flat configuration with both benzene rings in the same plane – may also have dioxin-like toxicity. The SALG, however, does not specifically assess co-planar PCBs for dioxin-like qualities. Ten of 12 fish samples contained one or more of the 17 PCDF/PCDD congeners (ranging from a minimum TEQ concentration of ND to a maximum 5.253 pg/g (Table 5a). No samples contained all 17 congeners. Longnose gar contained the highest TEQ concentration (5.253 pg/g; Table 5a). The mean PCDF/PCDD TEQ in smallmouth buffalo was 0.808±0.970 pg/g (Table 5a). Table 5b shows the average concentrations of PCDFs/PCDDs at each of the two composite sites. The mean concentration of

PCDFs/PCDDs in fish from Composite Site 1 (Neches River-Lower) was 0.607±1.164 pg/g while that of fish from Composite Site 2 (Neches River-Upper) was 1.140±1.759 pg/g.

DISCUSSION

Risk Characterization

Variability and uncertainty are inherent to quantitative assessment of risk. Thus, calculations that model risks of adverse health outcomes from exposure to toxicants can be orders of magnitude above or below "actual" risks. Variability between calculated and actual risk may depend upon factors such as the use of animals rather than humans, use of subchronic rather than chronic studies, interspecies variability, intra-species variability, and database insufficiency. Many factors used to calculate comparison values come from experiments conducted in the laboratory on nonhuman subjects. Variability and uncertainty in the estimates of toxicity might therefore arise from judgment calls by investigators or reviewers, e.g., the study chosen as the "critical" investigation, the species/strain of animal used in the critical study, the target organ determined the "critical organ," exposure periods, exposure route, or exposure doses. Uncontrolled (confounding) variables or variations in other conditions could occur. Some contaminants are overtly toxic, while others have only subtle effects. Finally, available information varies by contaminant. The literature is replete with information on some toxicants while others have hardly any toxicity data.[34] Risk assessors often must calculate parameters to represent potential toxicity to humans who consume contaminants in fish and other environmental media despite these limitations. For those contaminants appearing in Neches River fish for which enough information is given, the DSHS calculated risk parameters for systemic toxicity and for carcinogenicity in those who would consume fish from the lake. The SALG utilizes risk parameters in meal consumption calculations – integral to the SALG's risk characterizations as consumption limits are among the variables DSHS risk managers utilize to determine departmental actions to protect human health from adverse effects of consuming toxicants in fish from Texas waters. Conclusions and recommendations predicated upon the stated goal of the DSHS to protect human health follow the discussion of the relevance of the Neches River results to risk of human health effects.

Characterization of Systemic (Noncancerous) Health Effects from Consumption of Fish from the Neches River

Inorganic Contaminants

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

A subset of 12 of the original 60 fish sampled in 2007 from the Neches River survey– one blue catfish, two flathead catfish, one freshwater drum, one largemouth bass, one longnose gar, and six smallmouth buffalo – were analyzed for copper, selenium, zinc, arsenic, cadmium, lead, and mercury.

Copper, selenium, and zinc (Table 2b) are essential to human health and to the health of other animals but may be toxic at high concentrations. Toxicity occurs most often with acute ingestion of high doses but also can occasionally occur with long-term, low level consumption.[47] Of twelve fish analyzed, all except the freshwater drum contained copper, selenium, and zinc.

Copper concentrations in the twelve samples averaged 0.172 mg/kg or about 0.05% of the HAC_{nonca} for copper. Copper concentrations in fish from the Neches River did not exceed the HAC_{nonca} for this element nor did the HQ exceed 1.0 (data not shown). Thus, consumption of copper in fish from the Neches River should cause no concern for human health. All samples analyzed contained selenium (Table 2b), the highest concentration of which was in the largemouth bass (14% of the HAC_{nonca} for selenium) and the lowest concentration of which occurred in the flathead catfish (2.1% of the HAC_{nonca}). The average concentration of selenium was approximately 8% of the HAC_{nonca} for this metalloid. HQs for selenium did not approach 1.0 in any species or at any collection site. Selenium concentrations in fish from this section of the Neches River did not exceed the HAC_{nonca} for selenium (data not shown). Consumption of fish from these sites containing selenium should cause no concern for human health. Zinc in fish from the Neches River did not exceed the HAC_{nonca} for this element (Table 2b). HQs for zinc in each species at any collection site were well below 1.0. SALG risk assessors conclude, therefore, that eating copper, selenium, and zinc in fish from the Neches River at concentrations similar to those observed in samples from this water body should not result in deleterious effects on individuals' health.

In contrast to copper, selenium, and zinc, neither arsenic (Table 2a) nor cadmium nor lead (Table 2b) nor mercury (Table 2c) has a known physiological function in mammals – and all four of the latter are toxic to terrestrial mammals. Arsenic was present at measurable concentrations in the freshwater drum and the largemouth bass, while the smallmouth buffalo contained only an estimated arsenic concentration (J-value) reported as BDL (Table 2a). Most of the arsenic in fish, including arsenobetaine, also called "fish arsenic," is a form of organic arsenic that is virtually nontoxic to humans, in part because the human kidney easily eliminates “fish arsenic” from the body.[48] Inorganic arsenic, on the other hand, may be toxic to humans. To assess the likelihood of toxicity from consuming inorganic arsenic in fish from the Neches River, SALG risk assessors first calculated an estimate of the inorganic portion of total arsenic in the fish (using a factor of 0.1 as outlined in the methods section). SALG risk assessors then compared the inorganic fraction of arsenic in each species to the HAC_{nonca} for inorganic arsenic. Inorganic arsenic in the freshwater drum was 4% of the HAC_{nonca} for consumption of inorganic arsenic in fish (Table 2a). In the largemouth bass, the inorganic arsenic concentration was 0.6% of the HAC_{nonca} (Table 2a). In smallmouth buffalo, the laboratory reported arsenic at levels below the detection limit (Table 2a). The HQ for inorganic arsenic did not approach 1.0 in any of these species. Although calculated concentrations of inorganic arsenic were present in some fish from the Neches River (Table 2a), this toxicant was of no significance to human health. Based on these observations, the DSHS concludes that consuming fish from the Neches River that contain small amounts of inorganic arsenic would be unlikely to affect human health adversely.

Cadmium, found in one sample, a blue catfish was reported at a concentration below the laboratory’s detection limit for this metalloid (Table 2b). Cadmium is unlikely to present an issue for human health if consumed in the minute quantities suggested by those observed in the single blue catfish from the Neches River.

Lead was present at concentrations below the detection limit in a blue catfish, two flathead catfish, a freshwater drum, a longnose gar, and in a smallmouth buffalo (Table 2b). The toxic effects of lead are primarily those of abnormal nervous system development and/or function,

with fetuses and children the sensitive population.[33] Lead reportedly does not penetrate the mucus barrier ("slime layer") or the scales of fish and apparently does not bioconcentrate in fish tissue, factors that lessen the likelihood of toxicity from consuming lead in fish.[49] Researchers, however, have not found a threshold for the neurotoxic effects and trends suggest no such threshold exists.[50] Thus, any lead ingested in fish could potentially have adverse effects in sensitive individuals. When appropriate, the SALG subjects the results of lead analyses in fish tissue to USEPA's IEUBK model to determine whether concentrations are high enough to elevate children's blood lead if consumed. However, lead in the fish from the Neches River occurred only at trace concentrations (Table 2b), Therefore, the data from this survey were not subjected to IEUBK analysis because children's blood lead levels would likely be unaffected by consumption of lead in fish from the Neches River as observed only at levels below the laboratory's detection limit.

All sixty fish collected in 2007 from the Neches River contained mercury (Table 2c). The mean concentration of mercury in flathead catfish (N=3; 1.185±1.058 mg/kg) and longnose gar (N=10; 0.709±0.657 mg/kg) exceeded the 0.7 mg/kg mercury HAC value (Table 2c). Flathead catfish contained the highest mean mercury concentration. The HQ for mercury in flathead catfish (n=3) was 1.7 (Table 6). Black crappie, white bass, and white crappie contained average mercury concentrations in excess of 0.6 mg/kg (Table 2c). The HQs for these species approached 1.0 (Table 6). At average concentrations of approximately 0.540 mg/kg, mercury in freshwater drum (n=18), largemouth bass (n=3), and spotted gar (n=2) were lower than the HAC_{nonca} for methylmercury. Consequently, the HQs for mercury in these species were below 1.0 (Table 6). The single channel catfish collected during this survey contained the lowest mercury concentration (0.114 mg/kg), followed by mercury in the blue catfish (0.347 mg/kg; Table 2c). The mean concentration of mercury in all samples (0.578 mg/kg ± 0.410 mg/kg; n=60; Table 2c) did not exceed the methylmercury HAC_{nonca} nor did the composite HQ of combined species exceed 1.0 (Table 6). The DSHS concludes from these data that mercury in flathead catfish, longnose gar, and spotted bass pose a risk to the health of sensitive groups that consume these species from the Neches River. The SALG also notes that, although mercury in black crappie, white bass, white crappie, freshwater drum, largemouth bass, and spotted gar did not exceed the HAC_{nonca} for methylmercury, concentrations of mercury in these species ranged from a low of 0.535 mg/kg to a high of 0.648 mg/kg (Table 2c), perilously close to the HAC_{nonca} for methylmercury (0.7 mg/kg).

Figure 2 and Table 2d showed that mercury in combined fish species from Composite Site 2 (Neches River-Upper consisting of Collection Sites 3-6; n = 40) contained higher concentrations of mercury than did fish from Composite Site 1 (Neches River-Lower consisting of Collection Sites 1 and 2; n=20). The average concentration of mercury in all fish species combined from Composite Site 1 was 0.401±0.167 (Table 2d) while that in combined species from Composite Site 2 was 0.667 mg/kg with a standard deviation of ±0.465 (Table 2d). Fish collected at Composite Site 2 (Neches River-Upper) contained mercury at a concentration virtually the same as the HAC_{nonca} for this toxicant, resulting in an HQ of 1.0 (Table 8). In keeping with the observation that the average mercury concentration was higher in fish from Composite Site 2, the mean mercury concentration of species collected at Site 4 Neches River at R-255 and Site 5 Neches River at U.S. 59 – both sites within Composite Site 2 (Neches River-Upper) – exceeded the mercury HAC_{nonca} value (0.7 mg/kg; Tables 7 and 8). No species from Composite Site 1

contained an average mercury concentration in excess of the HAC_{nonca} for methylmercury (Table 8). These results suggest that while fish containing mercury collected from Composite Site 1 pose no particular hazard to human health, those found along Composite Site 2 are likely to pose a mercury-related hazard to human health. Sensitive groups such as pregnant women should not consume fish from the stretch of the Neches River comprising Composite Site 2.

Organic Contaminants

Pesticides

Of the 34 pesticides analyzed in the 12-sample subset of fish collected in 2007 from the Neches River, at least one sample contained trace to low concentrations of one or more of the following: 4,4'-DDD, mirex, hexachlorobenzene, heptachlor epoxide, pentachloroanisole, 2,4'-DDD, 2,4'-DDT, or methoxychlor (data not presented). All twelve samples contained 4,4'-DDE and chlordane at concentrations of no significance to human health (Table 3). The 12 samples also contained traces of pentachlorobenzene, endosulfan I, endosulfan II, malathion, ethyl-, and methyl-parathion, again at concentrations of no significance to human health (data not presented). Combined species at different collections sites also did not exceed the HAC_{nonca} for any pesticide nor were HQs or HIs greater than 1.0. Thus, pesticides in fish from the Neches River are unlikely to be associated with systemic adverse human health outcomes.

SVOCs

Of the SVOCs examined in the subsample of 12 fish from the Neches River, one freshwater drum contained low-level phenol; one smallmouth buffalo and one flathead catfish contained small quantities of 4-methylphenol; a freshwater drum contained an estimated concentration of 4-methylphenol. The laboratory detected traces of BEHP and fluorene (reported as estimated concentrations or J-values) in one or more samples (data not presented). The laboratory reported no other SVOCs in fish collected in 2007 from the Neches River. No sample contained any SVOC at a concentration in excess of the respective contaminant's HAC_{nonca} and no HQ for any SVOC exceeded 1.0. Combined species at different collections sites also did not exceed the HAC_{nonca} for any SVOC nor were HQs or HIs greater than 1.0. Thus, SVOCs in fish from the Neches River are unlikely to be associated with systemic adverse human health outcomes.

VOCs

Low but measurable concentrations of carbon disulfide, methylene chloride, trichlorofluoromethane, toluene, m+p-xylene, and 1,2,4-trimethylbenzene were present in a few of the 12 samples examined for VOCs. Traces of many VOCs were also present in the 12 samples, including acetone, dibromochloromethane, 1,2-dibromomethane, tetrachloroethene, chlorobenzene, ethylbenzene, styrene, isopropylbenzene, bromobenzene, 1,1,2,2-tetrachloroethane, 2- and 4-chlorotoluene, 1,3,5-trimethylbenzene, 1,2-,1,3-and 1,4-dichlorobenzene, n-propylbenzene, n-butyl- and sec-butyl-benzene, hexachlorobutadiene, and naphthalene.

The procedural blanks contained several VOCs not present in the samples; these consisted of 1,2,4-trimethylbenzene, carbon disulfide, m+p-xylene, methylene chloride, n-propylbenzene,

styrene, and toluene. Many VOCs observed in samples were also present in procedural blanks. In fact, of 43 reported VOCs, 20 were in both samples and blanks. Examples include benzene, ethylbenzene, 1,4-dichlorobenzene, 1,1,2,2-tetrachloroethane, and others. The significance of this observation is unknown, but suggests significant post harvest contamination.

For those compounds occurring in the samples, only, and for which HAC values exist – the only contaminants that can be evaluated – concentrations were low with respect to the HAC values; additionally, the HQ for each compound came nowhere close to 1.0. Thus, it is unlikely that even regular consumption of fish from any site along the Neches River that contain only VOCs for which health hazards are estimable would be associated with adverse systemic health outcomes in humans.

PCBs

Table 4a contains summary statistics for PCBs measured in 12 fish collected in 2007 from the Neches River. Assessing summary statistics for PCBs in each sample of each species, within each species, and among all species combined – without regard to collection site –a smallmouth buffalo sample contained the highest PCB concentration (0.067 mg/kg), followed by a flathead catfish (0.038 mg/kg) and a longnose gar (0.036 mg/kg). The average concentration of PCBs in smallmouth buffalo did not exceed the HAC_{nonca} for Aroclor 1254 nor did PCBs in any other fish sample or species exceed the systemic HAC_{nonca} value for PCBs (Table 4a). The overall average concentration in combined species (0.027 mg/kg) did not exceed the HAC_{nonca} for PCBs derived from Aroclor 1254 (Table 4a). In no instance did the HQ for PCBs exceed 1.0 nor were suggested meals of any species containing PCBs less than one per week (Table 9). These data suggest that regular or long-term consumption of low levels of PCBs in fish from the Neches River is unlikely to result in adverse systemic health effects.

PCBs were also evaluated at two composite sample sites: Composite Sample Site 1 (Neches River-Lower) and Composite Sample Site 2 (Neches River-Upper). The mean concentration of PCBs in combined species at Composite Site 1 was 0.017±0.012 mg/kg while at Composite Site 2 PCBs, at 0.032±0.022 mg/kg, were nearly double the concentration at Composite Site 1 (Table 4b). Nonetheless, PCB average concentrations in combined species at each composite site did not exceed the HAC_{nonca} for Aroclor 1254, the standard against which all PCBs are compared for systemic adverse human health effects (Table 10). Thus, eating a diet of mixed fish from either of these sites that contain *only* PCBs would be unlikely to be associated with adverse systemic human health outcomes.

PCDFs/PCDDs

Table 5a contains summary statistics for PCDFs/PCDDs in a 12-fish subsample of all fish collected in 2007 from the Neches River. The laboratory analyzed the 12 samples for 17 PCDFs/PCDDS (10 PCDFs and 7 PCDDs) that have chlorine substitutions in, at a minimum, the 2, 3, 7, and 8 carbon positions on the dibenzofuran or dibenzo-*p*-dioxin nucleus – the seventeen congeners reported as associated with adverse human health effects.[51]. Eleven of 12 fish samples contained one or more of the 17 PCDF/PCDD congeners (Table 5a). Toxicity equivalents in fish from the Neches River ranged from non-detectable to a high of 5.253 pg/g (Table 5a). The single

longnose gar from the Neches River contained the highest TEQ concentration – 5.253 pg/g (Table 5a). Table 9 shows a concentration that exceeded the HAC_{nonca} by a factor of 2.3. That concentration resulted in an HQ for longnose gar substantially greater than 1.0 and a suggested meal consumption rate of only 0.4 eight-ounce meals per week (2 meals/month) for a 70-kg adult (Table 9). Smallmouth buffalo contained the second highest average concentration of PCDFs/PCDDs (Table 5a). The six smallmouth buffalo samples contained an average TEQ concentration of 0.808±0.970 pg/g. One smallmouth buffalo sample contained 2.353 pg/g. The average concentration of PCDFs/PCDDs in smallmouth buffalo did not exceed the HAC_{nonca} for these contaminants nor did the HQ exceed 1.0 (Tables 5a and 9). The average concentration of PCDFs/PCDDS in combined species did not exceed the HAC_{nonca} for PCDFs/PCDDs (Table 5a). The HQ for all species combined across collection sites did not exceed 1.0 (Table 9). These findings indicate that although regularly consuming longnose gar from the Neches River could be associated with adverse systemic health outcomes, routine consumption of other fish species containing PCDFs/PCDDs would not likely result in adverse systemic health effects. PCDFs/PCDDs were also compared in combined species from Composite Sites 1 and 2 to the PCDF/PCDD HAC_{nonca}. The mean concentration of PCDFs/PCDDs in fish from Composite Site 1 was 0.607±1.164 pg/g while that in fish from Composite Site 2 was 1.140±1.759 pg/g. Although the average concentration of PCDFs/PCDDs in fish from Composite Site 2 was approximately twice that of the PCDF/PCDD concentration in fish from Composite Site 1, neither the mean concentration at Composite Site 1 or Composite Site 2 exceeded the HAC_{nonca} for PCDFs/PCDDs (Table 5b). The HQs for PCDFs/PCDDs in fish from neither site exceeded 1.0 (Table 10). Thus, consumption of a mixed diet of fish from either the Composite Site 1 (Neches River-Lower) or Composite Site 2 (Neches River-Upper) from the present survey that contain *only* PCDFs/PCDDs would be unlikely to affect human systemic health adversely.

Characterization of Theoretical Lifetime Excess Cancer Risk from Consumption of Fish from the Neches River

Inorganic Contaminants

Cancer potency factors (slope factors; SFs) are not available for cadmium (EPA 2005 classification:[52] LI – likely human carcinogen – cancer potential established but limited human data; 1986 classification: Group B [53]). Neither are SFs available for copper (IN – inadequate; data inadequate to assess; 1985 classification, Group D); lead (LI; Group B), mercury (SU – suggestive evidence – human or animal data suggestive; Group C), selenium (IN; Group D), or zinc (IN; Group D). Because of database inadequacies, the SALG was unable to determine the probability of excess cancers from consuming fish from any section of the Neches River that contain mercury, copper, selenium, or zinc (neither cadmium nor lead were observed at levels above their respective detection limits). It is also important to note in this context that copper, selenium, and zinc – at appropriate daily intake levels – are essential trace elements, necessary for the health of many organisms, including that of humans.[47]

Organic Contaminants

Pesticides

Of the 34 pesticides analyzed in the 12-sample subset of fish collected in 2007 from the Neches River, the laboratory reported that some fish contained trace to low concentrations of 4,4'-DDD, mirex, hexachlorobenzene, heptachlor epoxide, pentachloroanisole, 2,4'-DDD, 2,4'-DDT, or methoxychlor (data not presented); all twelve samples contained 4,4'-DDE and chlordane (Table 3). All 12 samples also contained traces of pentachlorobenzene, endosulfan I, endosulfan II, malathion, ethyl-, and methyl-parathion (data not presented). The low concentrations of each pesticide, alone, did not increase the calculated lifetime excess cancer risk. These data suggest that consuming fish from the Neches River that contain pesticides at concentrations similar to those in the 2007 samples would not likely increase the likelihood of cancer in people who eat those fish. This conclusion is applicable to each species of fish, all species combined, species by collection site, and combined fish by composite collection site.

SVOCs

Of the 12 fish from the Neches River examined for SVOCs, one freshwater drum contained low-level phenol; one smallmouth buffalo and one flathead catfish contained small quantities of 4-methylphenol; a freshwater drum contained an estimated concentration of 4-methylphenol. The laboratory detected traces of BEHP and fluorene in one or more samples (data not presented). No SVOC in samples collected in fish from the Neches River increased the calculated theoretical lifetime excess cancer risk for people who eat fish containing any one SVOC. The laboratory reported no SVOCs in fish collected in 2007 from the Neches River at a concentration higher than that calculated to increase the theoretical excess cancer risk to 1 excess cancer in less than 10,000 people. Therefore, consumption of fish from the Neches River containing any one SVOC at concentrations near those sampled in 2007 from the Neches River should not result in a measurable increase in the maximum likelihood of cancer even if regularly consumed over 30 years. No evidence existed to suggest that SVOCs were different at Composite Site 2 than at Composite Site 1 or that consumption of fish from either site would increase the calculated theoretical excess risk of cancer.

VOCs

Traces of many VOCs, (see “RESULTS”) were present in the subsample of 12 fish collected in 2007 from the Neches River. Of those VOCs identified in samples, many were also present in the procedural blanks and could not be evaluated easily for potential increases in carcinogenic effects. Nevertheless, no VOC exceeded its respective HAC_{ca}. In fact, all concentrations were quite low with respect to the respective HAC values. Thus, it is unlikely that even regular consumption of VOCs in fish from the Neches River would result in an increase in the theoretical lifetime excess cancer risk. This statement held true for VOCs from Composite Sites 1 and 2.

PCBs

Table 4a shows concentrations of PCBs in the 12 fish collected in 2007 from the Neches River that were assayed for PCBs. Assessing summary statistics for PCBs in each species and in all species combined – without regard to collection site –a smallmouth buffalo contained the highest PCB concentration (0.067 mg/kg) followed by a flathead catfish (0.038 mg/kg) and a longnose gar (0.036 mg/kg). Despite the slightly elevated PCB concentration in a single smallmouth buffalo, the average concentration of PCBs in smallmouth buffalo did not exceed the HAC_{ca} for PCBs nor did PCBs in any other fish sample or any species of fish exceed the HAC_{ca} value used to assess the potential carcinogenicity of PCBs in fish tissue (Table 4a). The overall average concentration in combined species (0.027 mg/kg) did not exceed the $HAC_{ca.}$ These data indicate that long-term consumption of fish from the Neches River that contain only PCBs – at concentrations near those in the samples collected in 2007 is unlikely to increase a person's theoretical excess risk of contracting cancer (Table 11).

The mean concentrations of PCBs in fish from Composite Site 1 and from Composite Site 2 (Table 4b) were compared to the HAC_{ca} for PCBs. Average concentrations of PCBs in fish from the two sites did not exceed the HAC_{ca} for PCBs (Table 12). Thus, the calculated theoretical excess risk of cancer did not exceed 1 in 10,000 equivalently exposed persons at either site (Table 12).

PCDFs/PCDDs

Table 5a shows summary statistics for PCDFs/PCDDs in fish collected from all six sites along the Neches River collected in 2007. Eleven of 12 fish contained one or more of the 17 PCDF/PCDD congeners for which the GERG laboratory analyzed the samples with all species containing these contaminants, albeit at different concentrations. Toxicity equivalents in fish from the Neches River ranged from not detected to 5.253 pg/g (ng/kg) with a single longnose gar containing the highest concentration (5.253 pg/g) followed by a mean concentration in six smallmouth buffalo of 0.808± 0.970 pg/g. Table 11 lists the calculated theoretical lifetime excess cancer risk for PCDFs/PCDDs in each species from the Neches River. Table 11 shows the single longnose gar, with a concentration of 5.253 pg/g PCDFs/PCDDs, has a calculated theoretical lifetime excess cancer risk of 1.5E-4 or 1 excess cancer in 6,644 equivalently exposed persons and a calculated consumption rate of 0.6 meals/week or 2.4 meals per month. The calculated theoretical lifetime excess cancer risk thus exceeds the 1 in 10,000 rate judged as significantly increased by risk assessors at the DSHS. Thus, people regularly consuming longnose gar from the Neches River over approximately 30 years could potentially increase their risk of cancer to a level above background cancer rates. People likely should not consume longnose gar from the Neches River because of the increase in the risk of cancer. PCDF/PCDD average concentrations in fish from Composite Site 1 and Composite Site 2 were also compared to the HAC_{ca} for PCDFs/PCDDs. In neither instance did the mean concentration of PCDFs/PCDDs exceed the HAC_{ca} for these contaminants (Table 5a). The calculated theoretical risk of cancer did not exceed 1 in 10,000 equivalently exposed individuals at either site (Table 12). Thus, consuming a diet of mixed fish species from either the Composite Site 1 (Neches River-Lower) or Composite Site 2 (Neches River-Upper) should not increase an individual's theoretical excess risk of cancer (Table 12). Nonetheless, the longnose gar containing the very high concentration of PCDFs/PCDDs

was collected from one of the sites comprising Composite Site 2 (Neches River-Upper) again suggesting that one should not eat longnose gar from Composite Site 2 (Neches River-Upper), rather than from Composite Site 1 (Neches River-Lower; Tables 5a, 5b, and 12).

Characterization of Calculated Cumulative Systemic Health Effects and of Cumulative Excess Lifetime Cancer Risk from Consumption of Fish from the Neches River

Cumulative adverse health effects may be of concern if people are exposed simultaneously to more than one contaminant in one environmental medium (e.g., fish) or in multiple media (multiple media are not discussed in this report because the SALG has no way of knowing the toxicants to which people may be exposed through other media).

In the present risk characterization, risk assessors observed various combinations of metals, pesticides, VOCs, SVOCs, PCBs, and PCDFs/PCDDs in samples collected from the Neches River. Although it is possible that exposure to combinations of observed contaminants could potentially increase damage to one or more organ systems the individual metalloids did not affect the same target organ, had different mode/mechanism of action or the constant SALG utilizes to quantify toxic effects (RfDs, MRLs, or CPFs) was not available.[54] Therefore, SALG risk assessors did not calculate cumulative effects for metals.

HIs for combined pesticides, VOCs and/or SVOCs– many of which do affect the same target organ (for instance, the liver) or do act by the same mode or mechanism – were generally far lower than 1.0 indicating that consuming fish from the Neches River containing various combinations of pesticides, VOCs, and/or SVOCs is unlikely to result in cumulative systemic toxicity.[55]

On the other hand, consuming longnose gar or smallmouth buffalo that contain both PCDFs/PCDDs and PCBs (Tables 4a and 5a) may additively increase toxicity. Table 9 clearly indicates that the greater portion of potential systemic toxicity from consuming longnose gar from the Neches River would come from eating PCDFs/PCDDs in that species. Table 9 also shows that although neither PCBs nor PCDFs/PCDDs in smallmouth buffalo exceeded a hazard quotient of 1.0, the additive effects of the two toxicants did cause the HI to exceed 1.0 in this species. Thus, consumption of longnose gar or smallmouth buffalo from the length of the Neches River surveyed for the present study – which could contain both contaminants – could increase the likelihood of systemic adverse health effects.

As it also turns out, collection site also affects the presence and concentrations of these contaminants in fish from the Neches River. Table 10 shows Composite Site 1 (Neches River-Lower) to have a HI of 0.6 and that the suggested meal consumption rate is greater than one (8-ounce) meal per week for a 70-lb adult, indicating that the additive systemic effects of PCBs and PCDFs/PCDDs at Composite Site 1 (Neches River-Lower) are of minor concern to human health. Conversely, although neither PCBs nor PCDFs/PCDDs in combined fish species from either site exceed a HI of 1.0, the additive effects of these toxicants in fish from Composite Site 2 (Neches River-Upper) have an HI of 1.2 and a recommended consumption rate of 0.8 meals per week. Thus, some fish, including smallmouth buffalo, contain excess combined concentrations of PCBs and PCDFs/PCDDs. Consuming fish from Composite Site 2 (Neches River-Upper),

likely to contain excess quantities of both PCBs and PCDFs/PCDDs could affect the likelihood of adverse systemic health outcomes.

Although using hazard index methodology to determine cumulative effects of toxicants is common, risk assessors advise caution if the toxic endpoint is not the same and/or does not utilize the critical effect of each toxicant because assessing cumulative noncarcinogenic effects estimated by hazard quotient/hazard index methodology may overestimate the cumulative toxicity of the combined toxicants.[55] The critical organs or critical effects of PCBs and of PCDFs/PCDDs used to derive an RfD or an MRL for these contaminants are different. Research suggests, however, that both are developmental toxicants, affecting function of the reproductive organs as well as in utero development.[56] Thus, if one knew the RfDs for developmental effects, the RfDs for those effects could be used to calculate cumulative risk more accurately. This information is unavailable for PCDFs/PCDDs, so the SALG utilized the HQs from the RfD for critical effects for each toxicant to estimate the cumulative toxicity of consuming low-level concentrations of PCBs and PCDFs/PCDDs in fish from the Neches River. Cumulative effects derived from adding HQs for the two toxicants (Tables 9 and 10) may therefore over or underestimate effect size to an unknown extent.

Cumulative Carcinogenicity

In most assessments of cancer risk from environmental exposures to mixtures of contaminants, researchers consider any increase in neoplastic activity, whether cancerous or benign or in one or more organs to be cumulative, no matter the mode or mechanism of action of the contaminant. The single longnose gar collected in 2007 from the Neches River contained a high concentration (in pg/g TEQs) of PCDFs/PCDDs; consuming longnose gar from the Neches River would increase the calculated theoretical lifetime excess cancer risk (Table 11). In this assessment, risk assessors added the calculated carcinogenic risks of consuming PCDFs/PCDDs in each species to that of the corresponding risk of excess cancers from eating PCBs in each species (Table 11). In all instances, when the effects of PCDFs/PCDDs are added to those of PCBs, theoretical excess cancer risk is slightly increased but this increase does not increase the theoretical excess cancer risk to a level greater than 1 excess cancer in 10,000 equivalently-exposed people. Even in the case of longnose gar, in which cancer risk from consuming PCDFs/PCDDs is calculated to be approximately 1 excess cancer in 6000 equivalently exposed persons, adding the risk from eating PCBs in this species in addition to eating PCDFs/PCDDs did not result in a further significant increase in excess cancer risk over that produced by consuming PCDFs/PCDDs alone in this species (Table 11).

As it turns out, the calculated excess risk of cancer from consuming a diet of mixed fish species from Composite Site 1 (Neches River-Lower) or Composite Site 2 (Neches River-Upper) did not increase the calculated excess cancer risk to a level greater than 1 in 10,000 equivalently exposed persons (Table 12). Thus, when all species are combined at either site, the excess risk of cancer is not affected by the composite collection site (Table 12).

CONCLUSIONS

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

This study addressed the public health implications of consuming fish from the Neches River. Risk assessors from the SALG conclude from the present characterization of potential adverse health effects from consuming fish from the Neches River

1. That fish species, collection site, and in some instances, size of fish affect the likelihood of systemic adverse health outcomes from mercury in fish from the Neches River. Black bass species, flathead catfish, freshwater drum over 18 inches in length, longnose gar, and white bass sampled in 2007 from Composite Site 2 (Neches River-Upper) contained mercury at concentrations exceeding the HAC_{nonca} for methylmercury. Regular consumption by sensitive groups – breast-fed infants, small children, pregnant or lactating women, or women who may become pregnant – of fish from Composite Site 2 (Neches River-Upper) that contain mercury at levels closely approximating those observed in the 2007 survey **poses an apparent hazard to public health**.

2. That one longnose gar sampled in 2007 from Composite Site 2 (Neches River-Upper) contained PCDFs/PCDDs at concentrations that, if eaten regularly over time, could cause adverse systemic or carcinogenic health effects. Based on sampling results for that longnose gar, SALG risk assessors concluded that consuming longnose gar from Composite Site 2 (Neches River-Upper) **poses an apparent hazard to public health**.

3. That one smallmouth buffalo collected from Composite Site 2 (Neches River-Upper) contained PCBs and PCDFs/PCDDs at concentrations that when combined increase the HI to a number greater than 1.0, suggesting that when both PCBs and PCDFs/PCDDs are present in this species at levels similar to those in the sampled fish, these toxicants additively increase the likelihood of systemic adverse health outcomes in people who regularly eat smallmouth buffalo from the Neches River. This effect is likely due to a smallmouth buffalo collected from Composite Site 2 in this survey. Therefore, consuming smallmouth buffalo from Composite Site 2 (Neches River-Upper) **poses an apparent hazard to public health.**

4. That the above-noted fish species from the Neches River contain no other inorganic or organic contaminants at concentrations of concern for systemic health or carcinogenic effects either when consumed alone or in combination with other such contaminants.

5. That blue catfish, channel catfish, and white crappie contain neither PCBs nor PCDFs/PCDDs nor any other single contaminant or combination of contaminants at levels that, upon consumption, should cause concern for human health. Consuming blue catfish, channel catfish, and white crappie thus **pose no apparent hazard to public**

health.

6. That, although the number of samples tested for mercury assured that conclusions about the likelihood of toxicity from eating fish from the Neches River that contained mercury were likely accurate, the small number of samples tested for organic contaminants could affect the reliability of conclusions about risk from consuming fish containing organic contaminants.

RECOMMENDATIONS

Risk managers at the DSHS have established criteria for issuing fish consumption advisories based on approaches suggested by the USEPA.[17, 19, 57] If a risk characterization confirms that people can eat four or fewer fish or shellfish meals per month (adults: eight ounces per meal; children: four ounces per meal) from the water body under investigation, risk managers at DSHS might recommend consumption advice for that water body. Alternatively, 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).[58] Declarations of prohibited harvesting areas are enforceable under the Texas Health and Safety Code, Subchapter D, parts 436.091 and 436.101.[58] 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 how much – contaminated fish or shellfish they wish to consume. SALG risk assessors conclude from the data evaluated in this survey and risk characterization that consuming black bass species, flathead catfish, freshwater drum, longnose gar, smallmouth buffalo, or white bass from the Composite Site 2 (Neches River-Upper) poses **an apparent hazard to public health** because samples of these species contained mercury and/or PCDFs/PCDDs or combinations of PCBs and PCDFs/PCDDs at concentrations that exceeded the HAC_{nonca} for these contaminants, and, in the case of longnose gar and smallmouth buffalo, increased the calculated theoretical lifetime excess cancer risk to a number greater than 1 excess cancer in 10,000 equivalently exposed people. Thus, consumption of longnose gar or smallmouth buffalo is not acceptable because concentrations of PCDFs/PCDDs (longnose gar) combined with PCBs (smallmouth buffalo) increased the HI or the theoretical excess cancer risk to levels that increased the theoretical risk of cancer to levels greater than the background rate of cancer.. Therefore, the SALG recommends

1. That pregnant women, women who may become pregnant, women who are nursing, and infants should eat no black bass species, flathead catfish, freshwater drum, longnose gar, or white bass from Composite Site 2 (Neches River-Upper) because these species from Composite Site 2 contain mercury at levels that could adversely affect the developing nervous system of the fetus, infant, or very small child.

2. That adult men and women past childbearing may consume up to two eight-ounce meals per month (preferably no more than one 8-ounce meal every two weeks) of black bass species, flathead catfish, freshwater drum, longnose gar, or white bass or 2 meals per month of any combination of these species from Composite Site 2 (Neches River-

Upper).

3. That the parents or caregivers of children less than 12 years of age or who weigh less than 75 pounds should limit their children's consumption of black bass species, flathead catfish, freshwater drum, longnose gar, or white bass from Composite Site 2 (Neches River-Upper) to two (4-ounce) meals per month (preferably no more than one 4 ounce meal every two weeks) because black bass species, flathead catfish, freshwater drum, longnose gar, or white bass from Composite Site 2 (Neches River-Upper) contain mercury at concentrations greater than the neurodevelopmentally-based HAC_{nonca} effects of mercury.

4. That people should not consume longnose gar from Composite Site 2 of the Neches River because the single sampled longnose gar contained PCDFs/PCDDs at concentrations that, if eaten regularly over a 30-year period can increase the calculated theoretical lifetime excess cancer risk to a level 50% (with an error of ±1 magnitude) above background cancer rates. This recommendation assumes that the single longnose gar is representative of all longnose gar from Composite Site 2 (Neches River-Upper).

5. That people should not consume smallmouth buffalo from Composite Site 2 of the Neches River because this species contained PCDFs/PCDDs and PCBs at concentrations that may additively increase the likelihood of systemic adverse health outcomes in both adults and children.

6. That people need not restrict their consumption of blue catfish or white crappie from Composite Site 2 (Neches River-Upper).

7. That fish from the lower section of the Neches River appeared to contain no contaminants at levels that exceeded the systemic or the carcinogenic HAC for any contaminant. Therefore, consumption of fish from Composite Site 1 (Neches River-Lower) may be consumed without undue restrictions.

PUBLIC HEALTH ACTION PLAN

Communication to the public of new and continuing possession bans or consumption advisories, or the removal of either, is essential to effective management of risk from consuming contaminated fish. In fulfillment of the responsibility for communication, the DSHS takes several steps. The agency publishes fish consumption advisories and bans in a booklet available to the public through the SALG. To receive the booklet and/or the data, please contact the SALG at 1-512-834-6757.[59] The SALG also posts the most current information about advisories, bans, and the removal of either on the internet at http://www.dshs.state.tx.us/seafood. The SALG regularly updates this Web site. The DSHS also provides the USEPA http://epa.gov/waterscience/fish/advisories/), the TCEQ (http://www.tceq.state.tx.us), and the TPWD (http://www.tpwd.state.tx.us) with information on all consumption advisories and possession bans. Each year, the TPWD informs the fishing and hunting public of consumption advisories and fishing bans on it's Web site and in an official hunting and fishing regulations booklet available at many state parks and at all establishments selling Texas fishing licenses.[60]

Readers may direct questions about the scientific information or recommendations in this risk characterization to the SALG at 512-834-6757 or may find the information at the SALG's Web site. Secondarily, one may address inquiries to the Environmental and Injury Epidemiology and Toxicology Branch (EIETB) of the DSHS (512-458-7269). The USEPA's IRIS Web site (http://www.epa.gov/iris/) contains information on environmental contaminants found in food and environmental media. The Agency for Toxic Substances and Disease Registry (ATSDR), Division of Toxicology (888-42-ATSDR or 888-422-8737 or the ATSDR's Web site (http://www.atsdr.cde.gov) supplies brief information via *ToxFAQs*.™ *ToxFAQs*™ are available on the ATSDR Web site in English http://www.atsdr.cdc.gov/toxfaq.html) and in Spanish-language translations (http://www.atsdr.cdc.gov/es/toxfaqs/es_toxfaqs.html). The ATSDR also publishes more in-depth reviews of many toxic substances in its *Toxicological Profiles*™. To request *ToxProfiles*™ CD-ROM, Public Health Statements (PHS), or *ToxFAQs*™ on any contaminant for which these documents are available, call 1-800-CDC-INFO (800-232-4636) or email a request to cdcinfo@cdc.gov.

Figure 1. Neches River Sample Sites, 2007.

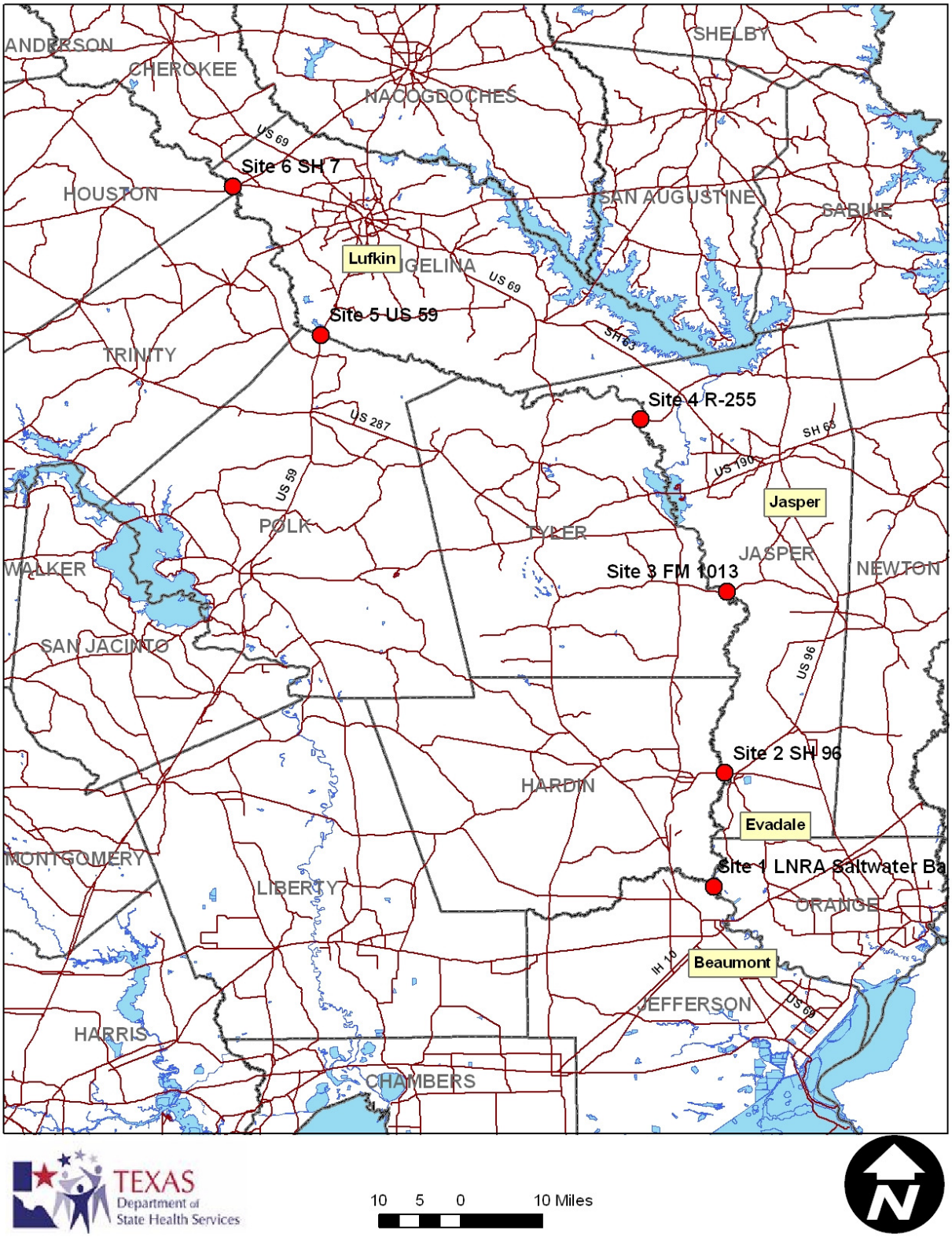
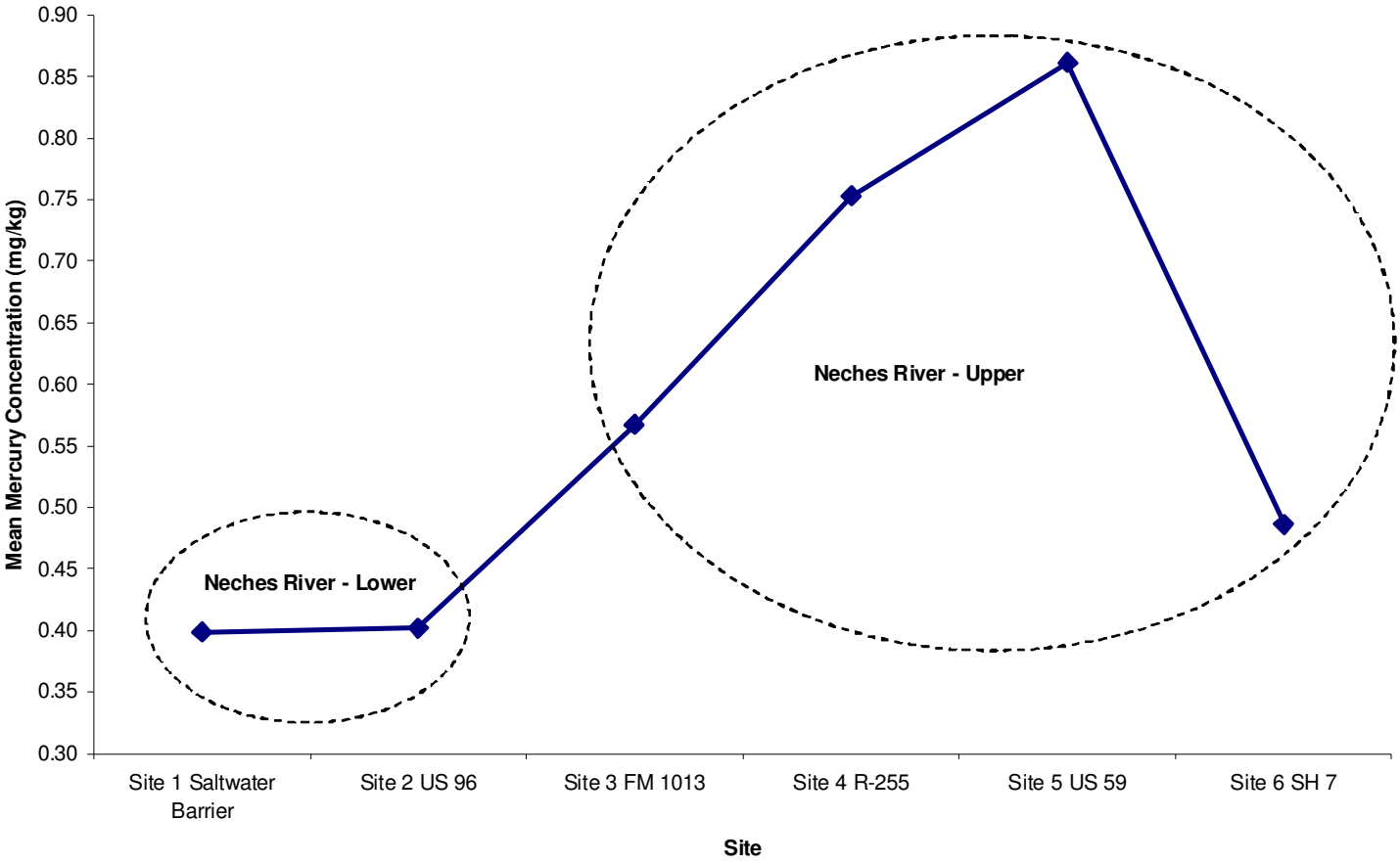


Figure 2. Means plot of mercury (mg/kg wet weight) in fish tissue collected from six Neches River sample sites in June and September 2007.



TABLES

Table 1. Fish samples collected from the Neches River June 2007 and September 2007. Sample number, species, length, and weight were recorded for each sample collected.

Sample Number	Species	Length (mm)	Weight (g)
Site 1 Neches River at LNVA Saltwater Barrier			
NEC1	Channel catfish	403	632
NEC5	Freshwater drum	320	454
NEC4	Freshwater drum	454	1674
NEC3	Largemouth bass	387	881
NEC2	Largemouth bass	424	992
NEC10	Longnose gar	810	1416
NEC8	Smallmouth buffalo	590	5008
NEC9	Smallmouth buffalo	701	7258
NEC11	Spotted gar	537	730
NEC7	White bass	271	228
Site 2 Neches River at U.S. 96			
NEC43	Blue catfish	370	416
NEC42	Blue catfish	380	479
NEC41	Freshwater drum	335	510
NEC39	Freshwater drum	432	1196
NEC40	Freshwater drum	444	1217
NEC38	Freshwater drum	451	1292
NEC37	Freshwater drum	465	1896
NEC45	Longnose gar	788	1204
NEC46	Longnose gar	1260	5808
NEC44	Smallmouth buffalo	670	4810
Site 3 Neches River at FM 1013			
NEC53	Blue catfish	480	1177
NEC50	Blue catfish	575	2156
NEC48	Blue catfish	640	2589
NEC49	Blue catfish	700	3740
NEC47	Freshwater drum	475	1129
NEC55	Longnose gar	745	1024
NEC54	Longnose gar	782	1085
NEC52	Smallmouth buffalo	677	5664
NEC56	Spotted gar	640	1079
NEC51	White bass	395	622
Site 4 Neches River at R-255			
NEC27	Black crappie	274	328
NEC30	Blue catfish	541	1327

Table 1. Fish samples collected from the Neches River June 2007 and September 2007. Sample number, species, length, and weight were recorded for each sample collected.

Sample Number	Species	Length (mm)	Weight (g)
Site 4 Neches River at R-255 Continued			
NEC33	Freshwater drum	419	1097
NEC22	Freshwater drum	430	1196
NEC23	Freshwater drum	435	1244
NEC24	Largemouth bass	389	934
NEC35	Longnose gar	870	1737
NEC36	Longnose gar	1463	11350
NEC34	Smallmouth buffalo	597	3771
NEC26	White crappie	324	492
Site 5 Neches River at U.S. 59			
NEC61	Flathead catfish	580	2442
NEC62	Flathead catfish	1060	19278
NEC12	Freshwater drum	345	579
NEC59	Freshwater drum	473	1628
NEC58	Freshwater drum	532	2214
NEC57	Freshwater drum	539	2863
NEC15	Longnose gar	701	837
NEC14	Longnose gar	805	1518
NEC13	Smallmouth buffalo	562	3843
NEC60	Spotted bass	371	769
Site 6 Neches River at S.H. 7			
NEC64	Blue catfish	400	545
NEC17	Blue catfish	510	1191
NEC63	Flathead catfish	484	1203
NEC21	Freshwater drum	325	420
NEC16	Freshwater drum	384	762
NEC65	Freshwater drum	469	1571
NEC20	Longnose gar	741	956
NEC18	Smallmouth buffalo	490	2180
NEC19	Smallmouth buffalo	569	3123
NEC66	White crappie	341	668

Table 2a. Arsenic (mg/kg) in fish from the Neches River, 2007.

Species	# Detected/ # Sampled	Total Arsenic Mean Concentration ± S.D. (Min-Max)	Inorganic Arsenic Mean Concentration[d]	Health Assessment Comparison Value (mg/kg)[e]	Basis for Comparison Value
Blue catfish	0/1	ND[f]	ND	0.7 0.362	EPA chronic oral RfD for Inorganic arsenic: 0.0003 mg/kg–day EPA oral slope factor for inorganic arsenic: 1.5 per mg/kg–day
Flathead catfish	0/2	ND	ND		
Freshwater drum	1/1	0.294	0.029		
Largemouth bass	1/1	0.038	0.004		
Longnose gar	0/1	ND	ND		
Smallmouth buffalo	1/6	BDL[g]	BDL		
All species	3/12	0.039±0.080 (ND-0.294)	0.004		

[d] *Most arsenic in fish and shellfish occurs as organic arsenic, considered virtually nontoxic. For risk assessment calculations, DSHS assumes that total arsenic is composed of 10% inorganic arsenic in fish and shellfish tissues.*
[e] *Derived from the MRL or RfD for noncarcinogens or the USEPA slope factor for carcinogens; assumes a body weight of 70 kg, and a consumption rate of 30 grams per day, and assumes a 30-year exposure period for carcinogens and an excess lifetime cancer risk of* $1x10^{-4}$.
[f] ND: not detected
[g] BDL: Below the laboratory's detection limit

Table 2b. Inorganic contaminants (mg/kg) in fish from the Neches River, 2007.

Species	# Detected/ # Sampled	Mean Concentration ± S.D. (Min-Max)	Health Assessment Comparison Value (mg/kg)	Basis for Comparison Value
Cadmium				
Blue catfish	1/1	BDL[g]	0.47	ATSDR chronic oral MRL: 0.0002 mg/kg–day
Flathead catfish	0/2	ND[f]		
Freshwater drum	0/1	ND		
Largemouth bass	0/1	ND		
Longnose gar	0/1	ND		
Smallmouth buffalo	0/6	ND		
All species	1/12	BDL		
Copper				
Blue catfish	1/1	0.267	333	National Academy of Science Upper Limit: 0.143 mg/kg–day
Flathead catfish	2/2	0.152±0.006 (0.148-0.156)		
Freshwater drum	1/1	BDL		
Largemouth bass	1/1	0.157		
Longnose gar	1/1	0.165		
Smallmouth buffalo	6/6	0.185±0.087 (BDL-0.270)		
All species	12/12	0.172±0.074 (BDL-0.270)		
Lead				
Blue catfish	1/1	BDL	- -	EPA IEUBKwin
Flathead catfish	2/2	BDL		
Freshwater drum	1/1	BDL		
Largemouth bass	0/1	ND		
Longnose gar	1/1	BDL		
Smallmouth buffalo	3/6	BDL		
All species	8/12	BDL		

Table 2b Continued. Inorganic contaminants (mg/kg) in fish from the Neches River, 2007.

Species	# Detected/ # Sampled	Mean Concentration ± S.D. (Min-Max)	Health Assessment Comparison Value (mg/kg)	Basis for Comparison Value
Selenium				
Blue catfish	1/1	0.752	6	EPA chronic oral RfD: 0 .005 mg/kg–day ATSDR chronic oral MRL: 0.005 mg/kg–day NAS UL: 0.400 mg/day (0.005 mg/kg–day) RfD or MRL/2: (0.005 mg/kg –day/2= 0.0025 mg/kg–day) to account for other sources of selenium in the diet
Flathead catfish	2/2	0.126±0.027 (0.107-0.145)		
Freshwater drum	1/1	0.603		
Largemouth bass	1/1	0.865		
Longnose gar	1/1	0.651		
Smallmouth buffalo	6/6	0.466±0.527 (0.089-1.505)		
All species	12/12	0.493±0.417 (0.089-1.505)		
Zinc				
Blue catfish	1/1	5.766	700	EPA chronic oral RfD: 0.3 mg/kg–day
Flathead catfish	2/2	4.378±0.872 (3.761-4.994)		
Freshwater drum	1/1	3.452		
Largemouth bass	1/1	4.344		
Longnose gar	1/1	3.055		
Smallmouth buffalo	6/6	3.230±1.255 (1.593-5.294)		
All species	12/12	3.729±1.207 (1.593-5.766)		

Table 2c. Mercury (mg/kg) in fish from the Neches River, 2007.

Species	# Detected/ # Sampled	Mean Concentration ± S.D. (Min-Max)	Health Assessment Comparison Value (mg/kg)	Basis for Comparison Value
Site 1 Neches River at LNVA Saltwater Barrier				
Channel catfish	1/1	0.114	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg–day
Freshwater drum	2/2	0.293±0.122 (0.206, 0.380)		
Largemouth bass	2/2	0.446±0.035 (0.421, 0.471)		
Longnose gar	1/1	0.503		
Smallmouth buffalo	2/2	0.541±0.201 (0.399, 0.683)		
Spotted gar	1/1	0.468		
White bass	1/1	0.349		
All species	10/10	0.399±0.157 (0.114-0.683)		
Site 2 Neches River at U.S. 96				
Blue catfish	2/2	0.138±0.020 (0.124, 0.153)	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg–day
Freshwater drum	5/5	0.410±0.121 (0.219-0.550)		
Longnose gar	2/2	0.630±0.067 (0.583, 0.678)		
Smallmouth buffalo	1/1	0.428		
All species	10/10	0.402±0.185 (0.124-0.678)		
Site 3 Neches River at FM 1013				
Blue catfish	4/4	0.471±0.260 (0.157- **0.767**)	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg–day
Freshwater drum	1/1	0.587		
Longnose gar	2/2	0.469±0.328 (0.237, **0.701**)		
Smallmouth buffalo	1/1	**0.710**[h]		
Spotted gar	1/1	0.600		
White bass	1/1	**0.946**		
All species	10/10	0.567±0.243 (0.157-**0.946**)		

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

Table 2c Continued. Mercury (mg/kg) in fish from the Neches River, 2007.

Species	# Detected/ # Sampled	Mean Concentration ± S.D. (Min-Max)	Health Assessment Comparison Value (mg/kg)	Basis for Comparison Value
Site 4 Neches River at RR-255				
Black crappie	1/1	0.628	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg–day
Blue catfish	1/1	0.230		
Freshwater drum	3/3	0.664±0.078 (0.584-**0.740**)		
Largemouth bass	1/1	**0.714**		
Longnose gar	2/2	**1.475**±1.480 (0.429, **2.522**)		
Smallmouth buffalo	1/1	0.513		
White crappie	1/1	0.504		
All species	10/10	**0.753**±0.640 (0.230-**2.522**)		
Site 5 Neches River at U.S. 59				
Flathead catfish	2/2	**1.475**±1.317 (0.544, **2.406**)	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg–day
Freshwater drum	4/4	**0.732**±0.234 (0.457-**0.928**)		
Longnose gar	2/2	0.581±0.096 (0.514, 0.649)		
Smallmouth buffalo	1/1	0.555		
Spotted bass	1/1	**1.019**		
All species	10/10	**0.861**±0.578 (0.457-**2.406**)		
Site 6 Neches River at S.H. 7				
Blue catfish	2/2	0.365±0.097 (0.296, 0.434)	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg–day
Flathead catfish	1/1	0.604		
Freshwater drum	3/3	0.497±0.273 (0.278-**0.803**)		
Longnose gar	1/1	0.268		
Smallmouth buffalo	2/2	0.525±0.130 (0.433-0.617)		
White crappie	1/1	**0.720**		
All species	10/10	0.486±0.190 (0.268-**0.803**)		

Table 2c, continued. Mercury (mg/kg) in fish collected in 2007 from the Neches River. Summary statistics represent individual species collapsed across sites.

Species	# Detected/ # Sampled	Mean Concentration ± S.D. (Min-Max)	Health Assessment Comparison Value (mg/kg)	Basis for Comparison Value
Neches River-All Sites				
Black crappie	1/1	0.628	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg–day
Blue catfish	9/9	0.347±0.217 (0.124-**0.767**)		
Channel catfish	1/1	0.114		
Flathead catfish	3/3	**1.185**±1.058 (0.544-**2.406**)		
Freshwater drum	18/18	0.536±0.218 (0.206-**0.928**)		
Largemouth bass	3/3	0.535±0.156 (0.421-**0.714**)		
Longnose gar	10/10	**0.709**±0.657 (0.237-**2.522**)		
Smallmouth buffalo	8/8	0.542±0.120 (0.399-**0.711**)		
Spotted bass	1/1	**1.019**		
Spotted gar	2/2	0.534±0.093 (0.468, 0.600)		
White bass	2/2	0.648±0.422 (0.349, **0.946**)		
White crappie	2/2	0.612±0.152 (0.504, **0.720**)		
All species	60/60	0.578±0.410 (0.114-**2.522**)		

Table 2d. Mercury (mg/kg) in fish collected in 2007 from Composite Site 1 (Neches River-Lower) and Composite Site 2 (Neches River-Upper).

Species	# Detected/ # Sampled	Mean Concentration ± S.D. (Min-Max)	Health Assessment Comparison Value (mg/kg)	Basis for Comparison Value
Composite Site 1 (Neches River-Lower consisting of sites 1 and 2)				
Blue catfish	2/2	0.138±0.020 (0.124, 0.153)	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg–day
Channel catfish	1/1	0.114		
Freshwater drum	7/7	0.377±0.125 (0.206-0.550)		
Largemouth bass	2/2	0.446±0.035 (0.421, 0.471)		
Longnose gar	3/3	0.588±0.088 (0.503-0.678)		
Smallmouth buffalo	1/1	0.503±0.156 (0.399-0.683)		
Spotted gar	1/1	0.468		
White bass	10/10	0.349		
All species	20/20	0.401±0.167 (0.114-0.683)		
Composite Site 2 (Neches River-Upper consisting of sites 3, 4, 5, and 6)				
Black crappie	1/1	0.628	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg–day
Blue catfish	7/7	0.406±0.209 (0.157-0.767)		
Flathead catfish	3/3	**1.185**±1.058 (0.544-**2.406**)		
Freshwater drum	11/11	0.636±0.206 (0.278-**0.928**)		
Largemouth bass	1/1	**0.714**		
Longnose gar	7/7	**0.760**±0.797 (0.237-**2.522**)		
Smallmouth buffalo	5/5	0.566±0.105 (0.433-**0.711**)		
Spotted bass	1/1	**1.019**		
Spotted gar	1/1	0.600		
White bass	1/1	**0.946**		
White crappie	2/2	0.612±0.152 (0.504, **0.720**)		
All species	10/10	0.667±0.465 (0.157-**2.522**)		

Table 3. Pesticides (mg/kg) in fish collected from the Neches River, 2007.

Species	# Detected / # Sampled	Mean Concentration ± S.D. (Min-Max)	Health Assessment Comparison Value (mg/kg)	Basis for Comparison Value
4,4' DDE				
Blue catfish	1/1	0.004	1.167 1.599	EPA chronic oral RfD: 0.0005 mg//kg–day EPA slope factor 0.34 per mg/kg - day
Flathead catfish	2/2	0.005±0.005 (0.001, 0.009)		
Freshwater drum	1/1	0.002		
Largemouth bass	1/1	BDL		
Longnose gar	1/1	0.020		
Smallmouth buffalo	6/6	0.007±0.005 (BDL-0.014)		
All species	12/12	0.006±0.006 (BDL-0.020)		
Chlordane				
Blue catfish	1/1	BDL	1.167 1.553	EPA chronic oral RfD: 0.0005 mg//kg–day EPA slope factor 0.35 per mg/kg–day
Flathead catfish	2/2	0.004±0.003 (BDL, 0.007)		
Freshwater drum	1/1	BDL		
Largemouth bass	1/1	BDL		
Longnose gar	1/1	0.007		
Smallmouth buffalo	6/6	0.006±0.004 (BDL-0.013)		
All species	12/12	0.005±0.003 (BDL-0.013)		

Table 4a. PCBs (mg/kg) in fish collected from the Neches River, 2007.

Species	# Detected / # Sampled	Mean Concentration ± S.D. (Min-Max)	Health Assessment Comparison Value (mg/kg)	Basis for Comparison Value
PCBs				
Blue catfish	1/1	0.020	0.047 0.272	EPA chronic oral RfD: 0.00002 mg/kg–day EPA slope factor: 2.0 per mg/kg–day
Flathead catfish	2/2	0.024±0.019 (0.011, 0.038)		
Freshwater drum	1/1	0.011		
Largemouth bass	1/1	BDL		
Longnose gar	1/1	0.036		
Smallmouth buffalo	6/6	0.033±0.025 (BDL-**0.067**)		
All species	12/12	0.027±0.020 (BDL-**0.067**)		

Table 4b. PCBs (mg/kg) in fish collected in 2007 from Composite Site 1 (Neches River-Lower) and Composite Site 2 (Neches River-Upper).

# Detected / # Sampled	Mean Concentration ± S.D. (Min-Max)	Health Assessment Comparison Value (mg/kg)	Basis for Comparison Value
Composite Site 1 (Neches River-Lower consisting of sites 1 and 2)			
4/4	0.017±0.012 (BDL-0.035)	0.047 0.272	EPA chronic oral RfD: 0.00002 mg/kg–day EPA slope factor: 2.0 per mg/kg–day
Composite Site 2 (Neches River-Upper consisting of sites 3, 4, 5, and 6)			
8/8	0.032±0.022 (BDL-**0.067**)	0.047 0.272	EPA chronic oral RfD: 0.00002 mg/kg–day EPA slope factor: 2.0 per mg/kg–day

Table 5a. PCDFs/PCDDs toxicity equivalent concentrations (TEQ; pg/g) in fish collected from the Neches River, 2007.

Species	# Detected / # Sampled	Mean Concentration ± S.D. (Min-Max)	Health Assessment Comparison Value (pg/g)	Basis for Comparison Value
PCDFs/PCDDs				
Blue catfish	1/1	0.262	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
Flathead catfish	1/2	0.569±0.804 (ND, 1.138)		
Freshwater drum	1/1	0.045		
Largemouth bass	1/1	0.001		
Longnose gar	1/1	**5.253**		
Smallmouth buffalo	6/6	0.808±0.970 (0.003-**2.353**)		
All species	11/12	0.962±1.551 (ND-5.253)		

Table 5b. PCDFs/PCDDs toxicity equivalent concentrations (TEQ; pg/g) in fish collected in 2007 from Composite Site 1 (Neches River-Lower) and Composite Site 2 (Neches River-Upper).

# Detected / # Sampled	Mean Concentration ± S.D. (Min-Max)	Health Assessment Comparison Value (mg/kg)	Basis for Comparison Value
Composite Site 1 (Neches River-Lower consisting of sites 1 and 2)			
4/4	0.607±1.164 (0.001-**2.353**)	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
Composite Site 2 (Neches River-Upper consisting of sites 3, 4, 5, and 6)			
7/8	1.140±1.759 (ND-**5.253**)	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

Table 6. Hazard quotients for mercury in fish collected from the Neches River in 2007. Table 6 also provides suggested weekly eight-ounce meal consumption rates for 70-kg adults.[i]

Species	Hazard Quotient	Meals per Week
Black crappie	0.9	1.0
Blue catfish	0.5	1.9
Channel catfish	0.2	5.7
Flathead catfish	**1.7**[j]	**0.5**[j]
Freshwater drum	0.8	1.2
Freshwater drum (≥18")	**1.0**	**0.9**
Largemouth bass	0.8	1.2
Longnose gar	**1.0**	**0.9**
Smallmouth buffalo	0.8	1.2
Spotted bass	**1.5**	**0.6**
Spotted gar	0.8	1.2
White bass	0.9	1.0
White crappie	0.9	1.1
All species	0.8	1.1

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

Table 7. Hazard quotients by site for mercury in fish collected from the Neches River in 2007. Table 7 also provides suggested weekly eight-ounce meal consumption rates for 70-kg adults.[i]

Site	Hazard Quotient	Meals per Week
Site 1 Neches River at LNVA Saltwater Barrier	0.6	1.6
Site 2 Neches River at U.S. 96	0.6	1.6
Site 3 Neches River at FM 1013	0.8	1.1
Site 4 Neches River at R-255	**1.1**[j]	**0.9**[j]
Site 5 Neches River at U.S. 59	**1.2**	**0.8**
Site 6 Neches River at S.H. 7	0.7	1.3
Neches River-All Sites	0.8	1.1

Table 8. Hazard quotients for mercury in fish collected from the Neches River in 2007 categorized as Composite Site 1 (Neches River-Lower) and Composite Site 2 (Neches River-Upper). Table 8 also provides suggested weekly eight-ounce meal consumption rates for 70-kg adults.[i]

Species	Hazard Quotient	Meals per Week
Composite Site 1 (Neches River-Lower consisting of sites 1 and 2)		
Blue catfish	0.2	4.7
Channel catfish	0.2	5.7
Freshwater drum	0.5	1.7
Largemouth bass	0.6	1.5
Longnose gar	0.8	1.1
Smallmouth buffalo	0.7	1.3
Spotted gar	0.7	1.4
White bass	0.5	1.9
All Species	0.6	1.6
Composite Site 2 (Neches River-Upper consisting of sites 3, 4, 5, and 6)		
Black crappie	0.9	1.0
Blue catfish	0.6	1.6
Flathead catfish	**1.7**[j]	**0.5**[j]
Freshwater drum	0.9	1.0
Largemouth bass	**1.0**	**0.9**
Longnose gar	**1.1**	**0.9**
Smallmouth buffalo	0.8	1.1
Spotted bass	**1.5**	**0.6**
Spotted gar	0.9	1.1
White bass	**1.4**	**0.7**
White crappie	0.9	1.1
All Species	**1.0**	**1.0**

Table 9. Hazard quotients (HQ's) for PCBs or PCDFs/PCDDs and hazard indices (HI's) defining the additive effects of PCBs and PCDFs/PCDDs by species in fish collected from the Neches River in 2007. This table also provides suggested weekly eight-ounce meal consumption rates (in 70-kg adults) for each species.[i]

Species/Contaminant	Hazard Quotient	Meals per Week
Blue catfish		
PCBs	0.4	2.2
PCDDs/PCDFs	0.1	8.2
Hazard Index (meals per week)	0.5 (1.7)	
Flathead catfish		
PCBs	0.5	1.8
PCDDs/PCDFs	0.2	3.8
Hazard Index (meals per week)	0.8 (1.2)	
Freshwater drum		
PCBs	0.2	3.9
PCDDs/PCDFs	0.02	48.0
Hazard Index (meals per week)	0.3 (3.6)	
Largemouth bass		
PCBs	BDL	BDL
PCDDs/PCDFs	0.0004	2158.7
Longnose gar		
PCBs	0.8	1.2
PCDDs/PCDFs	**2.3**[j]	**0.4**[j]
Hazard Index (meals per week)	**3.0 (0.3)**	
Smallmouth buffalo		
PCBs	0.7	1.3
PCDDs/PCDFs	0.3	2.7
Hazard Index (meals per week)	**1.1 (0.9)**	
All species		
PCBs	0.6	1.6
PCDDs/PCDFs	0.4	2.2
Hazard Index (meals per week)	**1.0 (0.9)**	

Table 10. Hazard quotients (HQ's) for PCBs or PCDFs/PCDDs and hazard indices (HI's) defining the additive effects of PCBs and PCDFs/PCDDs in fish collected from the Neches River in 2007 categorized by Composite Site 1 (Neches River-Lower) and Composite Site 2 (Neches River-Upper). This table also provides suggested weekly eight-ounce meal consumption rates (in 70-kg adults) for each species.[i]

Contaminant/Area	Hazard Quotient	Meals per Week
Composite Site 1 (Neches River-Lower consisting of sites 1 and 2)		
PCBs	0.4	2.6
PCDDs/PCDFs	0.3	3.6
Hazard Index (meals per week)	0.6 (1.5)	
Composite Site 2 (Neches River-Upper consisting of sites 3, 4, 5, and 6)		
PCBs	0.7	1.3
PCDDs/PCDFs	0.5	1.9
Hazard Index (meals per week)	**1.2 (0.8)[j]**	

Table 11. Theoretical lifetime excess cancer risk from consuming PCDFs/PCDDs, and/or PCBs in fish collected in 2007 from the Neches River (presented by species and contaminant). Table 10 also provides suggested weekly eight-ounce meal consumption rates for 70-kg adults.[i]

Species/Contaminant	Theoretical Lifetime Excess Cancer Risk		Meals per Week
	Risk	1 excess cancer per number exposed	
Blue catfish			
PCBs	7.3E-06	136,111	12.6
PCDDs/PCDFs	7.5E-06	133,207	12.3
Cumulative Theoretical Lifetime Excess Cancer Risk	1.5E-05	67,322	6.2
Flathead catfish			
PCBs	8.8E-06	113,426	10.5
PCDDs/PCDFs	1.6E-05	61,336	5.7
Cumulative Theoretical Lifetime Excess Cancer Risk	2.5E-05	39,809	3.7
Freshwater drum			
PCBs	4.0E-06	247,475	22.9
PCDDs/PCDFs	1.3E-06	775,562	71.7
Cumulative Theoretical Lifetime Excess Cancer Risk	5.3E-06	187,610	17.3
Largemouth bass			
PCBs	BDL	BDL	BDL
PCDDs/PCDFs	2.9E-08	34,900,285	3224.3
Longnose gar			
PCBs	1.3E-05	75,617	7.0
PCDDs/PCDFs	**1.5E-04**[j]	**6,644**[j]	**0.6**[j]
Cumulative Theoretical Lifetime Excess Cancer Risk	**1.6E-04**	**6,107**	**0.6**
Smallmouth buffalo			
PCBs	1.2E-05	82,492	7.6
PCDDs/PCDFs	2.3E-05	43,193	4.0
Cumulative Theoretical Lifetime Excess Cancer Risk	3.5E-05	28,349	2.6
All species			
PCBs	9.9E-06	100,823	9.3
PCDDs/PCDFs	2.8E-05	36,279	3.4
Cumulative Theoretical Lifetime Excess Cancer Risk	3.7E-05	26,679	2.5

Table 12. Theoretical lifetime excess cancer risk from consuming PCDFs/PCDDs, and/or PCBs in fish collected in 2007 from the Neches River categorized by Composite Site 1 (Neches River-Lower) and Composite Site 2 (Neches River-Upper). Table 10 also provides suggested weekly eight-ounce meal consumption rates for 70-kg adults.[i]

Contaminant/Area	Theoretical Lifetime Excess Cancer Risk		Meals per Week
	Risk	1 excess cancer per number exposed	
Composite Site 1 (Neches River-Lower consisting of sites 1 and 2)			
PCBs	6.2E-06	161,078	14.9
PCDDs/PCDFs	1.7E-05	57,496	5.3
Cumulative Theoretical Lifetime Excess Cancer Risk	2.4E-05	42,372	3.9
Composite Site 2 (Neches River-Upper consisting of sites 3, 4, 5, and 6)			
PCBs	1.2E-05	84,804	7.8
PCDDs/PCDFs	3.3E-05	30,614	2.8
Cumulative Theoretical Lifetime Excess Cancer Risk	4.4E-05	22,494	2.1

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