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

San Jacinto River–Houston Ship Channel

Harris County, Texas

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Department of State Health Services
Division for Regulatory Services
Policy, Standards, and Quality Assurance Unit
Seafood and Aquatic Life Group
Austin, Texas

INTRODUCTION

This document summarizes the results of a survey of the San Jacinto River–Houston Ship Channel conducted in 2010–2011 by the Texas Department of State Health Services (DSHS) Seafood and Aquatic Life Group (SALG). The SALG did this study to investigate any potential change in blue crab and fish tissue contaminant concentrations in the San Jacinto River–Houston Ship Channel following the discovery of three former disposal pits located along the San Jacinto River north of Interstate Highway 10 (IH 10).[1] In 2008, the United States Environmental Protection Agency (USEPA or EPA) placed the former disposal pit site, referred to as the San Jacinto River Waste Pits Superfund Site, on the National Priorities List. The former disposal pits property covers approximately 20 acres and historically received wastes from paper mill activities containing polychlorinated dibenzo-*p*-dioxins and/or dibenzofurans (PCDDs/PCDFs).[2] The property is currently inactive and portions of the original waste pits have subsided into the San Jacinto River. The present study examined blue crab and fish from the San Jacinto River–Houston Ship Channel 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 San Jacinto River–Houston Ship Channel and suggests actions to reduce potential adverse health outcomes.

History of DSHS Monitoring of Chemical Contaminants in Fish and Shellfish from the Galveston Bay Estuary including the San Jacinto River–Houston Ship Channel

The USEPA's *National Dioxin Study* [3] was a nationwide investigation of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD) contamination of soil, water, sediment, air, and fish. In 1986, as a part of the National Study of Chemical Residues in Fish (NSCRF - formerly the *National Bioaccumulation Study*) [4] that grew out of the USEPA's *National Dioxin Study,*[3] the EPA conducted a one-time nationwide survey of contaminant residues in fish. In the report of that evaluation of fish-borne contaminants, the EPA described the presence of dioxin congeners in samples of fish and some shellfish (e.g., blue crab) from 11 sites within its Region 6. These sites were almost invariably located downstream of "bleach kraft" pulp and paper mill discharges.[4]

In 1990, the Texas Department of Health (TDH)[a] – in its first detailed evaluation of the Texas sites reported in the *National Dioxin Study* [3] to harbor dioxin-contaminated fish or shellfish – collected 12 fish and composite blue crab samples from the Houston Ship Channel and from Upper Galveston Bay. The 1990 TDH study confirmed polychlorinated dibenzofurans (PCDFs) and polychlorinated dibenzo-*p*-dioxins (PCDDs) in catfish species and blue crab at concentrations that could pose a risk to human health. As a result, the TDH issued Fish and Shellfish Consumption Advisory 3 (ADV-3), a consumption advisory for Upper Galveston Bay. The advisory covered Upper Galveston Bay to the north of a line connecting Red Bluff Point to Houston Point (by way of the Five Mile Cut marker) along with the Houston Ship Channel and its contiguous waters. ADV-3 recommended that adult recreational and/or subsistence fishers limit consumption of [any species of] catfish and/or blue crab to no more than one eight-ounce

[a] Now the Department of State Health Services (DSHS)

meal per month. In addition, the TDH advised that children whose age is less than 12 years and women of childbearing age not consume catfish or blue crab from these waters.[5]

Furthermore, fish and blue crab samples collected in 1993 from Clear Creek contained several volatile organic compounds – including dichloroethane and trichloroethane at concentrations that, if consumed, constituted an apparent risk to public health. To address the public health hazard introduced by consumption of fish and blue crab from Clear Creek – which empties into Upper Galveston Bay – the TDH issued Fish and Shellfish Consumption Advisory 7 (ADV-7) on November 18, 1993. ADV-7 recommended that persons should not consume any fish or blue crab from Clear Creek upstream and West of Texas Highway 3.[5]

In 1994, through its *Near Coastal Water Grant* (NCWG), the USEPA funded the TDH to investigate chemical contaminants in fish and shellfish from four locations along the Texas coast. As part of the NCWG study, the DSHS collected and analyzed five samples from the Houston Ship Channel and Upper Galveston Bay for PCDDs/PCDFs. Results from the NCWG study showed what could have been a slight decrease in average PCDF/PCDD concentrations in catfish, blue crab, and oysters when compared to the 1990 data. However, the small number of samples limited conclusions, and made it impossible for the TDH to reassess the health risks from consumption of fish, blue crab, or oysters from the Houston Ship Channel and Upper Galveston Bay or to revise risk management decisions for the area. Consequently, the TDH continued unchanged ADV-3, the consumption advisory issued in 1990 for these areas.

In 1996, the TDH collected 10 fish, four composite oyster samples, and 10 composite blue crab samples from the Houston Ship Channel and Upper Galveston Bay to re-evaluate ADV-3, the aforementioned 1990 consumption advisory. The results of the 1996 study also suggested that the 1990 advisory limiting consumption of catfish species and blue crab should continue unchanged. Again, the TDH continued ADV-3 in its original form.

Between 1997 and 2000, the USEPA funded three grants to the TDH for study of the Galveston Bay system. (1) *The USEPA Children's Uses of Galveston Bay* grant; (2) a Texas Commission on Environmental Quality (TCEQ)[b] Total Maximum Daily Load (TMDL) program grant and (3) a grant from the Galveston Bay Estuary Program (GBEP)[6] The three studies allowed the TDH to more comprehensively evaluate chemical contaminants in fish and shellfish from the Galveston Bay estuary. During these studies, the TDH collected more than 400 fish and blue crab samples from East and West Galveston Bay, Lower Galveston Bay, Trinity Bay, Upper Galveston Bay, and the Houston Ship Channel (including the Lower San Jacinto River and Tabbs Bay). In addition to these major bay areas, the TDH surveyed the Christmas Bay system (Bastrop, Christmas, and Drum Bays), Clear Creek (for which ADV-7 was issued in 1993), and Clear Lake.

The Galveston Bay studies conducted from 1997 to 2000 revealed that – with few exceptions – fish and blue crab from the Christmas Bay system, East Bay, West Bay, Lower Galveston Bay, Trinity Bay, Clear Creek, and Clear Lake showed little evidence of contamination with pollutants capable of causing adverse human health effects. None of these contaminants exceeded the health-based assessment comparison values (HAC values) TDH used at the time to

[b] *Formerly the Texas Natural Resource Conservation Commission (TNRCC)*

evaluate the likelihood of adverse human health effects from consumption of chemically contaminated fish and shellfish. The TDH concluded from these investigations that eating fish and blue crab from the named portions of the Galveston Bay estuary posed no apparent public health hazard. Furthermore, on October 9, 2001, as a direct result of these studies – which showed that fish and shellfish from Clear Creek no longer contained chemical contaminants at levels likely to pose an apparent human health hazard, the TDH rescinded the 1993 advisory (ADV-7) that had suggested no consumption of any fish or blue crab taken from Clear Creek.

On the other hand, the same studies (1997-2000) yielded other data that prompted the DSHS to modify ADV-3. That modification, embodied in Fish and Shellfish Consumption Advisory 20 (ADV-20), extended ADV-3 to the upper Houston Ship Channel (including the Lower San Jacinto River). ADV-20 recommended that adults eat no more than one eight-ounce meal per month of blue crab or any fish species from the Houston Ship Channel upstream of the Lynchburg Ferry crossing and from the San Jacinto River downstream of the bridge at U.S. Highway 90. ADV-20 further stressed that children and women who were nursing an infant, who were pregnant, or who might become pregnant should eat no fish or blue crab from the above-described areas.[7]

In 1987, the U.S. Congress had established the National Estuary Program (NEP) to promote long-term planning and management of nationally significant estuaries.[8] Early on, the NEP identified 28 nationally significant estuaries, of which Galveston Bay was one (the other Texas estuary identified by the NEP was the Coastal Bend Bays and Estuaries system). The Galveston Bay Estuary Program (GBEP), formed as a state-supported program from the NEP in 1989, is one of two such programs in Texas.[9] The GBEP is a non-regulatory program administered by the TCEQ. Working with local governments, businesses, ports, commercial fisheries, recreational anglers, environmental organizations, and state and federal natural resource agencies, the GBEP implements the *Galveston Bay Plan (GBP*), a comprehensive conservation management plan for Galveston Bay.[6] The GBEP provides ecosystem management through collaborative partnerships and ensures preservation of Galveston Bay's multiple uses. The GBEP has enhanced water quality through promotion of reduction of pollutants in bayous, creeks, and Galveston Bay, and has established a seafood-safety monitoring program to assist the state to protect the health of those who consume fish and shellfish from the Galveston Bay Estuary.

In 2003-2004, the GBEP received a grant from the USEPA under Section 104(b)(3) of the Clean Water Act. That grant provided funds to demonstrate implementation of Action PH-1: Develop a Seafood Consumption Safety Program for the *Galveston Bay Plan*. This project constituted the first phase of the Seafood Consumption Safety Monitoring Program for Galveston Bay, a project that evaluated the following areas of the Galveston Bay estuary: Upper Galveston Bay near LaPorte, Texas, the Houston Ship Channel, and the Lower San Jacinto River. The objectives of the Seafood Consumption Safety Monitoring Program, as set forth in the *Galveston Bay Plan,* are to regularly characterize and monitor potential health risks associated with consumption of seafood from the Galveston Bay estuary and to inform the public of seafood consumption risks identified by the monitoring program.

The results of the 2004 characterization of health risks of consuming fish and blue crab tissue from the study area showed unequivocally that ADV-3, issued in 1990 and modified with ADV-

20 in 2001 should continue. Those results also revealed that spotted seatrout contained polychlorinated biphenyls (PCBs) at levels exceeding the DSHS' HAC values for PCBs in fish. The presence of PCBs in spotted seatrout at the observed levels caused concern among public health officials. The DSHS thus issued Fish and Shellfish Consumption Advisory 28 (ADV-28) on January 25, 2005 for the Houston Ship Channel and Upper Galveston Bay. ADV-28 recommended that adults limit consumption of spotted seatrout from the Houston Ship Channel – including the tidal portion of the San Jacinto River below the U.S. Highway 90 bridge, Tabbs Bay and its contiguous waters, and Upper Galveston Bay north of a line drawn from Red Bluff Point to Five Mile Cut Marker to Houston Point – to no more than one eight-ounce meal per month. Children and women who were nursing, pregnant, or who may have become pregnant were advised not to consume spotted seatrout from these waters.[10]

The 2004 risk characterization also recommended additional fish tissue monitoring to determine if spotted seatrout collected from the Galveston Bay system contain PCBs at concentrations of concern to public health. Tagging data from the TPWD indicate that spotted seatrout tend to move around the entire Galveston Bay estuary. Spotted seatrout are a top predator fish found throughout Gulf coast waters. The species is one of the most sought after sport fishes along the Texas coast. Because spotted seatrout are a primary target for recreational anglers, determining the extent of PCB contamination has public health, regulatory, and economic implications for the Galveston Bay system.

The DSHS acquired two grants in 2005 and 2006 to evaluate the extent of spotted seatrout PCB contamination and continue seafood contaminant monitoring in the Galveston Bay estuary. These two grants provided funding to collect 204 fish and blue crab samples from the Galveston Bay estuary in 2006 and 2007.

The results of the 2006 and 2007 study revealed that gafftopsail catfish and spotted seatrout collected from the Galveston Bay estuary contain dioxins and PCBs at concentrations that exceed DSHS guidelines for protection of human health. Based on these results, the DSHS issued Fish and Shellfish Consumption Advisory 35 (ADV-35) on July 8, 2008 that extended the extant Houston Ship Channel and Upper Galveston Bay fish consumption advisory to the remainder of the Galveston Bay estuary. ADV-35 advised that persons should limit consumption of catfish and spotted seatrout from this area to no more than one eight-ounce meal per month. Women who are nursing, pregnant, or who may become pregnant and children were advised not consume catfish or spotted seatrout from these waters.

Description of the San Jacinto River, Buffalo Bayou, and Houston Ship Channel

The San Jacinto River Basin is composed of two main forks encompassing a drainage area of 4,000 square miles: the West Fork of the San Jacinto River and the East Fork of the San Jacinto River.[11] The West Fork of the San Jacinto River originates west of Huntsville, Texas in Walker County and flows southeast to Montgomery County where the river is dammed to form Lake Conroe. Downstream of Lake Conroe, the West Fork of the San Jacinto River continues to flow southeast to its confluence with the East Fork of the San Jacinto River forming the main stream. The East Fork of the San Jacinto River begins in eastern Walker County near Dodge, Texas and flows southeast to its confluence with the West Fork of the San Jacinto River. The main stream is dammed below the confluence of the two main forks to form Lake Houston. The main stem of the San Jacinto River below Lake Houston continues to flow southward to its confluence with the Houston Ship Channel near the Lynchburg Ferry Crossing. The Buffalo Bayou watershed originates in north central Fort Bend County and covers approximately 103 square miles; it flows southeast into Harris County through the City of Houston to form part of the Houston Ship Channel. The Houston Ship Channel, formed by dredging and widening of Buffalo Bayou and the San Jacinto River is highly industrialized. .

Demographics of Harris County Surrounding the San Jacinto River–Houston Ship Channel

The estimated population in 2010 of Harris County was 4,092,459 people.[12] The San Jacinto River within Harris County is adjacent to one of the most urbanized and industrialized areas in Texas and in the United States. The City of Houston, Texas (2010 estimated population 2,099,451)[12] is the fourth largest city in the United States and the Harris County seat. According to the United States Census Bureau, Harris County is the most populous county in Texas.

Subsistence Fishing in the San Jacinto River–Houston Ship Channel

The USEPA suggests that, along with ethnic characteristics and cultural practices of an area's population, the poverty rate could contribute to any determination of the rate of subsistence fishing in an area.[13] The USEPA and the Texas Department of State Health Services (DSHS) find it important to consider subsistence fishing occurs at any water body because subsistence fishers (as well as recreational anglers and certain tribal and ethnic groups) usually consume more locally caught fish than the general population. These groups sometimes harvest fish or shellfish from the same water body over many years to supplement caloric and protein intake. Should local water bodies contain chemically contaminated fish or shellfish, people who routinely eat fish from the water body or those who eat large quantities of fish from the same waters, could increase their risk of adverse health effects. The USEPA suggests that states assume that at least 10% of licensed fishers in any area are subsistence fishers. Subsistence fishing, while not explicitly documented by the DSHS, likely occurs. The DSHS assumes the rate of subsistence fishing to be similar to that estimated by the USEPA.

METHODS

Fish Sampling, Preparation, and Analysis

The DSHS Seafood and Aquatic Life Group (SALG) collects and analyzes edible fish from the state's public waters to evaluate potential risks to the health of people consuming contaminated fish or shellfish. Fish tissue sampling follows standard operating procedures from the DSHS *Seafood and Aquatic Life Group Survey Team Standard Operating Procedures and Quality Control/Assurance Manual.*[14] 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.*[15] Advice and direction are also received from the legislatively mandated *State of Texas Toxic Substances Coordinating Committee (TSCC) Fish Sampling Advisory Subcommittee (FSAS).*[16] 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 San Jacinto River–Houston Ship Channel 2010–2011 Sample Set

In November 2010 and January 2011, the SALG collected 45 fish samples from the San Jacinto River (Table 1). The DSHS risk assessors used data from these fish to assess the potential for adverse human health outcomes from consuming fish from this estuary.

The SALG collected fish samples from three sites to provide spatial coverage of the study area (Figure 1). Species collected represent distinct ecological groups (i.e. predators and bottom-dwellers) that have some potential to bio-accumulate chemical contaminants, have a wide geographic distribution, are of local recreational fishing value, and/or that anglers and their families commonly consume. Target species and number collected are listed in descending order: red drum (8), black drum (6), spotted seatrout (6), blue catfish (5), sheepshead (5), blue crab (4), hardhead catfish (3), southern flounder (3), flathead catfish (2), sand trout (2), and striped bass (1).

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

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

Analytical Laboratory Information

Upon arrival of the fish samples at the laboratory, GERG personnel documented receipt of the 45 San Jacinto River fish samples by recording the condition of each sample along with its DSHS identification number.

Using established USEPA methods, the GERG laboratory analyzed fish fillets from the San Jacinto River for inorganic and organic contaminants commonly identified in polluted environmental media. Analyses included seven metals (arsenic, cadmium, copper, lead, total mercury, selenium, and zinc), 123 semivolatile organic compounds (SVOCs), 70 volatile organic compounds (VOCs), 34 pesticides, 209 polychlorinated biphenyl (PCBs) congeners, and 17 polychlorinated dibenzofurans and/or dibenzo-*p*-dioxins (PCDDs/PCDFs) congeners. The laboratory analyzed all 45 samples for mercury, PCBs and PCDDs/PCDFs and a subset of 15 (SJR2, SJR3, SJR12, SJR13, SJR21, SJR22, SJR23, SJR24, SJR34, SJR37, SJR38, SJR40, SJR43, SJR45, and SJR50) of the original 45 samples for trace metals, pesticides, SVOCs, and VOCs.[17]

Details of Some Analyses with Explanatory Notes

Arsenic

The GERG laboratory analyzed a subset of 15 of the original 45 samples for total (inorganic arsenic + organic arsenic = total arsenic) arsenic. Although the proportions of each form of arsenic may differ among fish species, under different water conditions, and, perhaps, with other variables, the literature suggests that well over 90% of arsenic in fish is likely organic arsenic – a form of arsenic that is virtually non-toxic to humans.[18] DSHS, taking a conservative approach, estimates 10% of the total arsenic in any fish is inorganic arsenic, deriving estimates of inorganic arsenic concentration in each fish by multiplying reported total arsenic concentration in the sample by a factor of 0.1.

Mercury

Nearly all mercury in upper trophic level fish three years of age or older is methylmercury.[19] Thus, the total mercury concentration in a fish of legal size for possession in Texas serves well as a surrogate for methylmercury concentration. Because methylmercury analyses are difficult to perform accurately and are more expensive than total mercury analyses, the USEPA recommends that states determine total mercury concentration in a fish and that – to protect human health – states conservatively assume that all reported mercury in fish or shellfish is methylmercury. The GERG laboratory thus analyzed fish tissues for total mercury. In its risk characterizations, The DSHS compares mercury concentrations in tissues to a comparison value derived from the Agency for Toxic Substances and Disease Registry’s (ATSDR) minimal risk level (MRL) for methylmercury.[20] (In these risk characterizations, the DSHS may interchangeably utilize the terms “mercury,” “methylmercury,” or “organic mercury” to refer to methylmercury in fish).

Polychlorinated Biphenyls (PCBs)

For PCBs, the USEPA suggests that each state measure congeners of PCBs in fish and shellfish rather than homologs or Aroclors® because the USEPA considers congener analysis the most sensitive technique for detecting PCBs in environmental media.[17] Although only about 130 PCB congeners were routinely present in PCB mixtures manufactured and commonly used in the United States (US), the GERG laboratory analyzes and reports the presence and concentrations of all 209 possible PCB congeners. From the congener analyses, the laboratory also computes and reports concentrations of PCB homologs and of Aroclor® mixtures. Despite the USEPA's suggestion that the states utilize PCB congeners rather than Aroclors® or homologs for toxicity estimates, the toxicity literature does not reflect state-of-the-art laboratory science. To accommodate this inconsistency, the DSHS utilizes recommendations from the National Oceanic and Atmospheric Administration (NOAA),[21] from McFarland and Clarke,[22] and from the USEPA's guidance documents for assessing contaminants in fish and shellfish[15, 17] to address PCB congeners in fish and shellfish samples, selecting the 43 congeners encompassed by the McFarland and Clark and the NOAA articles. The referenced authors chose to use congeners that were relatively abundant in the environment, were likely to occur in aquatic life, and likely to show toxic effects. SALG risk assessors summed the 43 congeners to derive "total" PCB concentration in each sample. SALG risk assessors then averaged the summed congeners within each group (e.g., fish species, sample site, or combination of species and site) to derive a mean PCB concentration for each group.

Using only a few PCB congeners to determine total PCB concentrations could underestimate PCB levels in fish tissue. Nonetheless, the method complies with expert recommendations on evaluation of PCBs in fish or shellfish. Therefore, SALG risk assessors compare average PCB concentrations of the 43 congeners with health assessment comparison (HAC) values derived from information on PCB mixtures held in the USEPA's Integrated Risk Information System (IRIS) database.[23] IRIS currently contains systemic toxicity information for five Aroclor® mixtures: Aroclors® 1016, 1242, 1248, 1254, and 1260. IRIS does not contain all information for all mixtures. For instance, only one other reference dose (RfD) occurs in IRIS – the one derived for Aroclor 1016, a commercial mixture produced in the latter years of commercial production of PCBs in the United States. Aroclor 1016 was a fraction of Aroclor 1254 that was supposedly devoid of dibenzofurans, in contrast to Aroclor 1254.[24] Systemic toxicity estimates in the present document reflect comparisons derived from the USEPA's RfD for Aroclor 1254 because Aroclor 1254 contains many of the 43 congeners selected by McFarland and Clark and NOAA. As of yet, IRIS does not contain information on the systemic toxicity of individual PCB congeners.

For assessment of cancer risk from exposure to PCBs, the SALG uses the USEPA's highest slope factor of 2.0 milligrams per kilogram per day (mg/kg/day) to calculate the probability of lifetime excess cancer risk from PCB ingestion. The SALG based its decision to use the most restrictive slope factor available for PCBs on factors such as food chain exposure; the presence of dioxin-like, tumor-promoting, or persistent congeners; and the likelihood of early-life exposure.[23]

Calculation of Toxicity Equivalent Quotients (TEQs) for Dioxins

PCDDs/PCDFs are families of aromatic chemicals containing one to eight chlorine atoms. The molecular structures differ not only with respect to the number of chlorines on the molecule, but also with the positions of those chlorines on the carbon atoms of the molecule. The number and positions of the chlorines on the dibenzofuran or dibenzo-*p*-dioxin nucleus directly affects the toxicity of the various congeners. Toxicity increases as the number of chlorines increases to four chlorines, then decreases with increasing numbers of chlorine atoms - up to a maximum of eight. With respect to the position of chlorines on the dibenzo-*p*-dioxin/dibenzofuran nucleus, it appears that those congeners with chlorine substitutions in the 2, 3, 7, and 8 positions are more toxic than congeners with chlorine substitutions in other positions. To illustrate, the most toxic of PCDDs is 2,3,7,8–tetrachlorodibenzo-*p*-dioxin (2,3,7,8–TCDD), a 4-chlorine molecule having one chlorine substituted for hydrogen at each of the 2, 3, 7, and 8 carbon positions on the dibenzo-*p*-dioxin. To gain some measure of toxic equivalence, 2,3,7,8–TCDD – assigned a toxicity equivalency factor (TEF) of 1.0 – is the standard against which other congeners are measured. Other congeners are given weighting factors or TEFs of 1.0 or less based on experiments comparing the toxicity of the congener relative to that of 2,3,7,8-TCDD.[25, 26] Using this technique, risk assessors from the DSHS converted PCDF or PCDD congeners in each tissue sample from the present survey to TEQs by multiplying each congener's concentration by its TEF, producing a dose roughly equivalent in toxicity to that of the same dose of 2,3,7,8-TCDD. The total TEQ for any sample is the sum of the TEQs for each of the congeners in the sample, calculated according to the following formula.[27]

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

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

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

The effects of exposure to any hazardous substance depend, among other factors, on the dose, the route of exposure, the duration of exposure, the manner in which the exposure occurs, the genetic makeup, personal traits, habits of the exposed, or the presence of other chemicals.[28] People who regularly consume contaminated fish or shellfish conceivably suffer repeated low-dose exposures to contaminants in fish or shellfish over extended periods (episodic exposures to low doses). Such exposures are unlikely to result in acute toxicity but may increase risk of subtle, chronic, and/or delayed adverse health effects that may include cancer, benign tumors, birth defects, infertility, blood disorders, brain damage, peripheral nerve damage, lung disease, and kidney disease.[28]

If diverse species of fish or shellfish are available, the SALG presumes that people eat a variety of species from a water body. Further, SALG risk assessors assume that most fish species are mobile. SALG risk assessors may combine data from different fish species and/or sampling sites within a water body to evaluate mean contaminant concentrations of toxicants in all samples as a whole. This approach intuitively reflects consumers' likely exposure over time to contaminants in fish or shellfish from any water body but may not reflect the reality of exposure at a specific water body or a single point in time. The DSHS reserves the right to project risks associated with ingestion of individual species of fish or shellfish from separate collection sites within a water body or at higher than average concentrations (e.g. the upper 95 percent confidence limit on the mean). The SALG derives confidence intervals from Monte Carlo simulations using software developed by a DSHS medical epidemiologist.[29] The SALG evaluates contaminants in fish or shellfish by comparing the mean or the 95% upper confidence limit on the mean concentration of a contaminant to its HAC value (in mg/kg) for non-cancer or cancer endpoints.

In deriving HAC values for systemic (HAC_{nonca}) effects, the SALG assumes a standard adult weighs 70 kilograms (kg) and consumes 30 grams (g) of fish or shellfish per day (about one 8-ounce meal per week) and uses the USEPA's RfD[30] or the ATSDR's chronic oral MRLs.[31] The USEPA defines an RfD as

> *An estimate of a daily oral exposure for a given duration to the human population (including susceptible subgroups) that is likely to be without an appreciable risk of adverse health effects over a lifetime.*[32]

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.*[32]

The ATSDR uses a similar technique to derive its MRLs.[31] The DSHS divides the estimated daily dose derived from the measured concentration in fish tissue by the contaminant's RfD or MRL to derive a hazard quotient (HQ). The USEPA defines a HQ as

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

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

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

Although the DSHS utilizes chemical specific RfDs when possible, if an RfD is not available for a contaminant, the USEPA advises risk assessors to consider evaluating the contaminant by comparing it to the published RfD (or the MRL) of a contaminant of similar molecular structure or one with a similar mode or mechanism of action. For instance, Aroclor® 1260 has no RfD, so the DSHS uses the reference dose for Aroclor 1254 to assess the likelihood of systemic (noncarcinogenic) effects of Aroclor 1260.[31]

In developing oral RfDs and MRLs, federal scientists review the extant literature to devise NOAELs, LOAELs, or benchmark doses (BMDs) from experimental studies. Uncertainty factors are then utilized to minimize potential systemic adverse health effects in people who are exposed through consumption of contaminated materials by accounting for certain conditions that may be undetermined by the experimental data. These include extrapolation from animals to humans (interspecies variability), intra-human variability, and use of a subchronic study rather than a chronic study to determine the NOAEL, LOAEL, or BMD, and database insufficiencies.[30,32] Vulnerable groups such as women who are pregnant or lactating, women who may become pregnant, infants, children, people with chronic illnesses, those with compromised immune systems, the elderly, or those who consume exceptionally large servings are considered sensitive populations by risk assessors and USEPA and also receive special consideration in calculation of a RfD.[32]

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

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

The USEPA states that

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

And

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

Thus,

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

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

The DSHS calculates cancer-risk comparison values (HAC_{ca}) from the USEPA's chemical-specific cancer potency factors (CPFs), also known as cancer slope factors (CSFs), derived through mathematical modeling from carcinogenicity studies. For carcinogenic outcomes, the DSHS calculates a theoretical lifetime excess risk of cancer for specific exposure scenarios for carcinogens, using a standard 70-kg body weight and assuming an adult consumes 30 grams of edible tissue per day. The SALG risk assessors incorporate two additional factors into determinations of theoretical lifetime excess cancer risk: (1) an acceptable lifetime risk level (ARL)[32] of one excess cancer case in 10,000 persons whose average daily exposure is equivalent and (2) daily exposure for 30 years, a modification of the 70-year lifetime exposure assumed by the USEPA. Comparison values used to assess the probability of cancer do not contain "uncertainty" factors. However, conclusions drawn from probability determinations infer substantial safety margins for all people by virtue of the models utilized to derive the slope factors (cancer potency factors) used in calculating the HAC_{ca}. Because the calculated comparison values (HAC values) are conservative, exceeding a HAC value does not necessarily mean adverse health effects will occur. The perceived strict demarcation between acceptable and unacceptable exposures or risks is primarily a tool used by risk managers along with other information to make decisions about the degree of risk incurred by those who consume contaminated fish or shellfish. Moreover, comparison values for adverse health effects do not represent sharp dividing lines (obvious demarcations) between safe and unsafe exposures. For example, the DSHS considers it unacceptable when consumption of four or fewer meals per month of contaminated fish or shellfish would result in exposure to contaminant(s) in excess of a HAC value or other measure of risk. The DSHS also advises people who wish to minimize exposure to contaminants in fish or shellfish to eat a variety of fish and/or shellfish and to limit consumption of those species most likely to contain toxic contaminants. The DSHS aims to protect vulnerable subpopulations with its consumption advice, assuming that advice protective of vulnerable subgroups will also protect the general population from potential adverse health effects associated with consumption of contaminated fish or shellfish.

Children's Health Considerations

The DSHS recognizes that fetuses, infants, and children may be uniquely susceptible to the effects of toxic chemicals and suggests that exceptional susceptibilities demand special attention.[34, 35] Windows of special vulnerability (known as "critical developmental periods") exist during development. Critical periods occur particularly during early gestation (weeks 0 through 8) but can occur at any time during development (pregnancy, infancy, childhood, or adolescence) at times when toxicants can impair or alter the structure or function of susceptible systems.[36] Unique early sensitivities may exist after birth because organs and body systems are structurally or functionally immature at birth, continuing to develop throughout infancy, childhood, and adolescence. Developmental variables may influence the mechanisms or rates of absorption, metabolism, storage, or excretion of toxicants. Any of these factors could alter the concentration of biologically effective toxicant at the target organ(s) or could modulate target organ response to the toxicant. Children's exposures to toxicants may be more extensive than adults' exposures because children consume more food and liquids in proportion to their body weights than adults consume. Infants can ingest toxicants through breast milk, an exposure pathway that often goes unrecognized. Nonetheless, the advantages of breastfeeding outweigh the probability of significant exposure to infants through breast milk and women are encouraged to continue breastfeeding and to limit exposure of their infants by limiting intake of the contaminated foodstuff. Children may experience effects at a lower exposure dose than might adults because children's organs may be more sensitive to the effects of toxicants. Stated differently, children's systems could respond more extensively or with greater severity to a given dose than would an adult organ exposed to an equivalent dose of a toxicant. Children could be more prone to developing certain cancers from chemical exposures than are adults.[37] In any case, if a chemical or a class of chemicals is observed to be, or is thought to be, more toxic to fetuses, infants, or children, the constants (e.g., RfD, MRL, or CPF) are usually modified further to assure the immature systems' potentially greater susceptibilities are not perturbed.[30] Additionally, in accordance with the ATSDR's *Child Health Initiative*[38] and the USEPA's *National Agenda to Protect Children's Health from Environmental Threats,*[39] the DSHS further seeks to protect children from the possible negative effects of toxicants in fish by suggesting that this potentially sensitive subgroup consume smaller quantities of contaminated fish or shellfish than adults consume. Thus, the DSHS recommends that children weighing 35 kg or less and/or who are 11 years of age or younger limit exposure to contaminants in fish or shellfish by eating no more than four ounces per meal of the contaminated species. The DSHS also recommends that consumers spread these meals over time. For instance, if the DSHS issues consumption advice that recommends consumption of no more than two meals per month of a contaminated species, those children should eat no more than 24 meals of the contaminated fish or shellfish per year and should not eat such fish or shellfish more than twice per month.

Data Analysis and Statistical Methods

The SALG risk assessors imported Excel© files into SPSS® statistical software, version 13.0 installed on IBM-compatible microcomputers (Dell, Inc), using SPSS® to generate descriptive statistics (mean, standard deviation, median, minimum and maximum concentrations, and range) on measured compounds.[40] In computing descriptive statistics, SALG risk assessors utilized ½ the reporting limit (RL) for analytes designated as not detected (ND) or estimated (J-values)[c]. PCDDs/PCDFs descriptive statistics are calculated using estimated concentrations (J-values) and assuming zero for PCDDs/PCDFs designated as ND.[d] The change in methodology for computing PCDDs/PCDFs descriptive statistics is due to the proximity of the reporting limits to the HAC value. Assuming ½ the RL for PCDDs/PCDFs designated as ND or J-values would unnecessarily overestimate the concentration of PCDDs/PCDFs in each fish tissue sample. The SALG used the descriptive statistics from the above calculations to generate the present report. The SALG employed Microsoft Excel® spreadsheets to generate figures, to compute HAC_{nonca} and HAC_{ca} values for contaminants, and to calculate HQs, HIs, cancer risk probabilities, and meal consumption limits for fish from the San Jacinto River.[41] When lead concentrations in fish or shellfish are high, the SALG risk assessors may utilize the EPA's Interactive Environmental Uptake Bio-Kinetic (IEUBK) model to determine whether consumption of lead-contaminated fish could cause a child's blood lead (PbB) level to exceed the Centers for Disease Control and Prevention's (CDC) reference value in children's blood (5 mcg/dL).[42, 43, 44, 45, 46]

RESULTS

The GERG laboratory completed the contaminant analyses and electronically transmitted the results of the San Jacinto River samples collected in November 2010 and January 2011 to the SALG in October 2011. The laboratory reported the analytical results for metals, pesticides, PCBs, PCDDs/PCDFs, SVOCs, and VOCs.

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[c] *"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.*

[d] *The SALG risk assessors' rationale for computing PCDDs/PCDFs descriptive statistics using the aforementioned method is based on the proximity of the laboratory reporting limits and the health assessment comparison value for PCDDs/PCDFs. 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 PCDDs/PCDFs fish tissue concentration.*

For reference, Table 1 contains the total number of samples collected. Tables 2a through 2c present the results of metals analyses. Tables 3a and 3b contain summary results for selected pesticide analyses. Tables 4a and 4b summarize the PCB analyses. Tables 5a and 5b summarize PCDDs/PCDFs analyses. Table 6 contains summary results for selected VOC analyses. This paper does not display SVOC data because these contaminants were not present at concentrations of interest in fish collected from the San Jacinto River during the described survey. Unless otherwise stated, table summaries present the number of samples containing a specific contaminant/number tested, the mean concentration ± 1 standard deviation (68% of samples should fall within one standard deviation of the arithmetic mean in a sample from a normally-distributed population), and, in parentheses under the mean and standard deviation, the minimum and the maximum detected concentrations. Those who prefer to use the range may derive this statistic by subtracting the minimum concentration of a given contaminant from its maximum concentration. In the tables, results may be reported as ND, below detection limit (BDL) for estimated concentrations, or as reported concentrations. According to the laboratory's quality control/quality assurance materials, estimated concentrations reported as BDL rely upon the laboratory's method detection limit (MDL) or its reporting limit (RL). The MDL is the minimum concentration of an analyte that is reported with 99% confidence that the analyte concentration is greater than zero, while the RL is the concentration of an analyte reliably achieved within specified limits of precision and accuracy during routine analyses. Contaminant concentrations reported below the RL are qualified as "J-values" in the laboratory data report.[47]

Inorganic Contaminants

<u>Arsenic, Cadmium, Copper, Lead, Mercury, Selenium, and Zinc</u>

All fish tissue samples assayed from the San Jacinto River contained concentrations of arsenic, copper, lead, mercury, selenium, and zinc (Tables 2a-2c). Three of the metalloids analyzed are essential trace elements: copper, selenium, and zinc. All fish tissue samples contained copper (Table 2b). The mean copper concentration in fish sampled from the San Jacinto River was 0.259±0.119 mg/kg. All fish tissue samples contained selenium. The average selenium concentration in fish from the San Jacinto River was 0.791 mg/kg with a standard deviation of ±0.482 mg/kg (Table 2c). Selenium in fish from the San Jacinto River ranged from 0.080 to 1.368 mg/kg. All samples also contained zinc. The mean zinc concentration in fish tissue samples from the San Jacinto River was 5.373±3.512 mg/kg (Table 2c).

The SALG evaluated four toxic metalloids having no known human physiological function (arsenic, cadmium, lead, and mercury) in the samples collected from the San Jacinto River. Fifteen of 15 samples assayed contained arsenic ranging from BDL-1.858 mg/kg (Table 2a). Nine of 15 samples analyzed contain estimated concentrations of cadmium (Table 2b). All species of fish assayed contained lead at concentrations greater than the RL (Table 2c). The average lead concentration in all fish combined was 0.142±0.058 mg/kg (Table 2c). All species of fish collected from the San Jacinto River contained mercury (Table 2c). A sand trout contained the lowest concentration of mercury (0.040 mg/kg), while the highest concentration occurred in a sheepshead (0.405 mg/kg). The mean mercury concentration in fish (all species and all sites) was 0.125±0.092 mg/kg (Table 2c).

Organic Contaminants

Pesticides

The GERG laboratory analyzed 15 fish for 34 pesticides. All 15 samples examined contained concentrations of 4,4′-DDD and 4,4′-DDE (Table 3a). 4,4′-DDD concentrations ranged from BDL–0.012 mg/kg in fish (Table 3a). The mean concentration of 4,4′-DDE in fish (n = 15) was 0.009±0.007 mg/kg. Thirteen of 15 samples assayed contained chlordane. Chlordane concentrations in fish ranged from ND–0.048 mg/kg. Dieldrin and hexachlorobenzene concentrations were reported in 13 of 15 and 11 of 15 samples, respectively (Table 3b). The mean concentration of dieldrin in fish was 0.002±0.002 mg/kg. Hexachlorobenzene concentrations in fish ranged from ND–0.012 mg/kg). Several fish samples contained trace[e] to low concentrations of pentachlorobenzene, alpha HCH, mirex, 2,4′-DDD, 2,4′-DDE, 2,4′-DDT, and alachlor (data not presented).

PCBs

All fish tissue samples contained concentrations of one or more PCB congeners (Tables 4a and 4b). No fish tissue sample contained all PCB congeners (data not shown). Across all sample sites and species, PCB concentrations ranged from 0.006 to 0.237 mg/kg (Table 4b). Flathead catfish contained the highest mean concentration of PCBs (0.181±0.012 mg/kg). Seven (blue catfish, flathead catfish, hardhead catfish, sand trout, sheepshead, spotted seatrout, and striped bass) of ten fish species evaluated had mean PCB congener concentrations across all sample sites that exceeded the DSHS HAC_{nonca} value for PCBs (0.047 mg/kg; Table 4b). Southern flounder contained the lowest mean concentration of PCBs (0.013±0.002) for the fish species assayed (Tables 4b). PCB congener concentrations in blue crab ranged from 0.006 to 0.013 mg/kg. The mean PCB concentration in the 45 fish and blue crab tissue samples assayed was 0.069±0.062 mg/kg (Table 4b).

For the 2010–2011 sampling event, the SALG risk assessors were unable to perform reliable statistical sample site comparisons of PCB concentrations in fish and blue crab due to species composition variability at each sample site. The SALG risk assessors were also unable to compare statistically PCB concentrations in fish by sampling event due to PCB analytical methodology differences. For the 2004 sampling event, PCB concentrations were derived using PCB Aroclor® analytical methodology and for the 2010–2011 sampling event, PCB concentrations were derived using PCB congener analytical methodology.

PCDDs/PCDFs

The GERG laboratory analyzed all fish tissue samples for 17 of the 210 possible PCDD/PCDF (75 PCDDs + 135 PCDFs) congeners from the San Jacinto River and the Houston Ship Channel.

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

The congeners examined consist of 7 PCDDs and 10 PCDFs that contain chlorine substitutions in, at a minimum, the 2, 3, 7, and 8 positions on the dibenzo-*p*-dioxin or dibenzofuran nucleus and are the only congeners reported to pose dioxin-like adverse human health effects.[48] Although 12 of the 209 PCB congeners – those often referred to as "coplanar PCBs," meaning the molecule can assume a flat configuration with both phenyl rings in the same plane – may also have dioxin-like toxicity, the SALG does not assess PCBs for dioxin-like qualities because the dioxin-like behavior has been less extensively evaluated. Tables 5a and 5b contain site and species-specific summary statistics for PCDDs/PCDFs in fish collected from the San Jacinto River. Before generating summary statistics for PCDDs/PCDFs, the SALG risk assessors converted the concentration of each PCDD or PCDF congener reported present in a tissue sample to a concentration equivalent in toxicity to that of 2,3,7,8-TCDD (a TEQ concentration - expressed as picogram per gram [pg/g]or nanogram per kilogram [ng/kg]). Twenty-nine of 45 fish tissue samples contained at least one of the 17 congeners assayed (minimum – to – maximum concentration after conversion: ND–76.383 pg/g–or ng/kg; Table 5b). No samples contained all 17 congeners (data not shown). Sheepshead contained the highest mean PCDD/PCDF TEQ concentration (18.512±36.603 pg/g).

For the 2010–2011 sampling event, the SALG risk assessors were unable to perform reliable statistical sample site comparisons of PCDD/PCDF TEQ concentrations in fish and blue crab due to species composition variability at each sample site. The assessment of PCDD/PCDF TEQ concentrations in fish and blue crab by sampling event indicate that the 2004 and 2010–2011 data do not statistically differ by sampling event (2004, $n = 18$ and 2010–2011, $n = 45$; $t\,[61] = -0.437$, $p = 0.664$).

<u>SVOCs</u>

The GERG laboratory analyzed a subset of 15 San Jacinto River fish tissue samples for SVOCs. The laboratory reported quantifiable concentrations (≥ RL) and/or trace concentrations of the following SVOCs in one or more fish samples: benzoic acid and bis (2-ethylhexyl) phthalate. The laboratory detected no other SVOCs in fish from the San Jacinto River.

<u>VOCs</u>

The GERG laboratory analyzed a subset of 15 San Jacinto River fish tissue samples for VOCs. All 15 samples examined contained concentrations of 1,4-dichlorobenzene and methylene chloride. 1,4-dichlorobenzene concentrations ranged from BDL–0.028 mg/kg in fish (Table 6). The mean concentration of methylene chloride in fish was 0.047±0.0042 mg/kg (Table 6). The GERG laboratory reported the 15 fish tissue samples selected for analysis from the San Jacinto River to contain one or more quantifiable concentrations >RL of the following VOCs: carbon disulfide, 2-butanone (MEK), benzene, trichlorofluoromethane, methyl methacrylate, toluene, 2-hexanone, ethylbenzene, m+p-xylene, o-xylene, 1,3,5-trimethylbenzene, and 1,2,4-trimethylbenzene (data not presented). Trace quantities of many VOCs were also present in one or more fish tissue samples assayed from the San Jacinto River (data not presented). The *Seafood and Aquatic Life Group Survey Team Standard Operating Procedures and Quality Control/Assurance Manual* contains a complete list of the 70 VOCs selected for analysis. Numerous VOCs were also identified in one or more of the procedural blanks, indicating the possibility that these compounds were introduced during sample preparation. VOC concentrations < RL are difficult to interpret due to their uncertainty and may represent a false positive. The presence of many VOCs at concentrations < RL may be the result of incomplete removal of the calibration standard from the adsorbent trap, so they are observed in the blank. VOC analytical methodology requires that the VOCs be thermally released from the adsorbent trap, transferred to the gas chromatograph (GC), and into the GC/mass spectrometer (MS) for quantification.

DISCUSSION

Risk Characterization

Because variability and uncertainty are inherent to quantitative assessment of risk, the calculated risks of adverse health outcomes from exposure to toxicants can be orders of magnitude above or below actual risks. Variability in calculated and in actual risk may depend upon factors such as the use of animal instead of human studies, use of subchronic rather than chronic studies, interspecies variability, intra-species variability, and database insufficiency. Since most factors used to calculate comparison values result from experimental studies conducted in the laboratory on nonhuman subjects, variability and uncertainty might arise from the study chosen as the "critical" one, the species/strain of animal used in the critical study, the target organ selected as the "critical organ," exposure periods, exposure route, doses, or uncontrolled variations in other conditions.[30] Despite such limitations, risk assessors must calculate parameters to represent potential toxicity to humans who consume contaminants in fish and other environmental media. The DSHS calculated risk parameters for systemic and carcinogenic endpoints in those who would consume fish from the San Jacinto River–Houston Ship Channel. Conclusions and recommendations predicated upon the stated goal of the DSHS to protect human health follow the discussion of the relevance of findings to risk.

Characterization of Systemic (Noncancerous) Health Effects from Consumption of Fish from the San Jacinto River–Houston Ship Channel

Tables 7a–8c provide HQs for arsenic, mercury, PCBs, and PCDDs/PCDFs in blue crab and each species of fish from the San Jacinto River and the recommended weekly consumption rate. Table 8d provides HQs for PCBs and PCDDs/PCDFs by sample site. PCBs were observed in fish from the San Jacinto River that equaled or exceeded its HAC_{nonca} (0.047 mg/kg; Tables 4a–4b and 8a–8c). Blue crab and fish samples assayed contained PCDDs/PCDFs exceeding the HAC_{nonca} for PCDDs/PCDFs (2.330 pg/g; Tables 5a–5b and Tables 8a–8c). No blue crab or fish collected contained any other inorganic or organic contaminants at concentrations that equaled or exceeded the DSHS guidelines for protection of human health or would likely cause systemic risk to human health from consumption of blue crab or fish from the San Jacinto River–Houston Ship Channel. Potential systemic health risks related to the consumption of blue crab or fish from the San Jacinto River–Houston Ship Channel containing inorganic and organic contaminants (other than PCBs and PCDDs/PCDFs) are not of public health concern. Consequently, this risk characterization concentrates on assessing the likelihood of adverse health outcomes that could occur from consumption of the San Jacinto River PCB and PCDD/PCDF-contaminated seafood.

PCBs

Forty-five of 45 blue crab and fish collected from the San Jacinto River–Houston Ship Channel contained PCBs (Tables 4a–4b). Forty-nine percent of all samples (N = 45) analyzed contained PCB concentrations that equaled or exceeded the HAC_{nonca} for PCBs (0.047 mg/kg). PCB concentrations that equaled or exceeded the HAC_{nonca} for PCBs (0.047 mg/kg) were observed in one or more samples of the following species: blue catfish, flathead catfish, hardhead catfish, red drum, sand trout, sheepshead, spotted seatrout, and striped bass. Seven (blue catfish, flathead catfish, hardhead catfish, sand trout, sheepshead, spotted seatrout, and striped bass) of ten fish species evaluated had mean PCB concentrations exceeding the HAC_{nonca} for PCBs or an HQ of 1.0 (Tables 4b and 8a–8c). The overall mean PCB concentration for all species combined exceeded the HAC_{nonca} for PCBs or an HQ of 1.0 (Tables 4b and 8c). The consumption of seafood from the San Jacinto River–Houston Ship Channel may pose potential systemic health risks.

Meal consumption calculations may be useful for decisions about consumption advice or regulatory actions. The SALG risk assessors calculated the number of 8-ounce meals from the San Jacinto River that healthy adults could consume without significant risk of adverse systemic effects (Tables 8a–8c). The SALG estimated this group could consume 0.6 (8-ounce) meals per week of fish containing PCBs. Therefore, SALG risk assessors suggest that people should limit their consumption of fish from the San Jacinto River–Houston Ship Channel. Because the developing nervous system of the human fetus and children may be especially susceptible to these effects, the SALG risk assessors recommend more conservative consumption guidance for this sensitive subpopulation.

PCDDs/PCDFs

Twenty-nine of 45 blue crab and fish collected from the San Jacinto River–Houston Ship Channel contained PCDDs/PCDFs (Tables 5a–5b). Thirteen percent of all samples (N = 45) analyzed contained PCDD/PCDF concentrations that equaled or exceeded the HAC_{nonca} for PCDDs/PCDFs (2.330 ng/kg). PCDD/PCDF concentrations that equaled or exceeded the HAC_{nonca} for PCDDs/PCDFs (2.330 ng/kg) were observed in one or more samples of the following species: blue catfish, blue crab, red drum, and sheepshead. Three (blue catfish, blue crab, and sheepshead) of 11 species evaluated had mean PCDD/PCDF concentrations exceeding the HAC_{nonca} for PCDDs/PCDFs or an HQ of 1.0 (Tables 5b and 8a–8c). The overall mean PCDD/PCDF concentration for all species combined exceeded the HAC_{nonca} for PCDDs/PCDFs or an HQ of 1.0 (Tables 5b and 8c). The consumption of seafood from the San Jacinto River-Houston Ship Channel may pose potential systemic health risks.

Meal consumption calculations may be useful for decisions about consumption advice or regulatory actions. The SALG risk assessors calculated the number of 8-ounce meals from the San Jacinto River–Houston Ship Channel that healthy adults could consume without significant risk of adverse systemic effects (Tables 8a–8c). The SALG estimated this group could consume 0.7 (8-ounce) meals per week of blue crab and/or fish containing PCDDs/PCDFs. Therefore, SALG risk assessors suggest that people should limit their consumption of blue crab and/or fish from the San Jacinto River–Houston Ship Channel. Because the developing nervous system of the human fetus may be especially susceptible to these effects, the SALG risk assessors recommend more conservative consumption guidance for this sensitive subpopulation.

Characterization of Theoretical Lifetime Excess Cancer Risk from Consumption of Fish from the San Jacinto River–Houston Ship Channel

The USEPA classifies arsenic, most chlorinated pesticides, PCBs, and PCDDs/PCDFs as carcinogens. The mean PCDD/PCDF concentration observed in blue catfish, blue crab, and sheepshead samples assayed exceeds the DSHS guideline for protection of human health of one excess cancer in 10,000 equally exposed individuals (Tables 5b and 9a-9e). Arsenic, chlorinated pesticides, PCBs, and PCDDs/PCDFs were present in most other samples assayed from the San Jacinto River–Houston Ship Channel, but none of these contaminants evaluated singly by species or all species combined had mean contaminant concentrations that would be likely to increase the risk of cancer to exceed the DSHS guideline for protection of human health of one excess cancer in 10,000 equally exposed individuals (Tables 2a–9e).

Meal consumption calculations may be useful for decisions about consumption advice or regulatory actions. The SALG risk assessors calculated the number of 8-ounce meals from the San Jacinto River–Houston Ship Channel that healthy adults could consume without significant risk of cancer (Tables 9a–9e). The SALG estimated this group could consume 1.0 (8-ounce) meal per week of blue crab and/or fish containing PCDDs/PCDFs. Therefore, SALG risk assessors suggest that people should limit their consumption of blue crab and/or fish from the San Jacinto River–Houston Ship Channel. Because human fetus and children may be especially susceptible to these risks, the SALG risk assessors recommend more conservative consumption guidance for this sensitive subpopulation.

Characterization of Calculated Cumulative Systemic Health Effects and of Cumulative Excess Lifetime Cancer Risk from Consumption of Fish from San Jacinto River–Houston Ship Channel

Cumulative systemic effects of toxicants may occur if more than one contaminant acts upon the same target organ or acts by the same mode or mechanism of action.[49, 47] PCBs and PCDDs/PCDFs in blue crab and fish from the San Jacinto River–Houston Ship Channel could have these properties, especially with respect to effects on the immune system. Multiple inorganic or organic contaminants (other than PCBs and PCDDs/PCDFs) in the San Jacinto River–Houston Ship Channel samples did not significantly increase the likelihood of systemic adverse health outcomes from consuming blue crab or any species of fish from the San Jacinto River–Houston Ship Channel. The combination of PCB and PCDD/PCDF concentrations in seafood from the San Jacinto River exceeded an HI of 1.0 and significantly increased the likelihood of systemic adverse health outcomes (Tables 8a–8d). The SALG risk assessors calculated the number of 8-ounce meals from the San Jacinto River–Houston Ship Channel that healthy adults could consume without significant risk of adverse systemic effects from the cumulative effects of PCBs and PCDDs/PCDFs (Tables 8a–8d). The SALG estimated this group could consume 0.3 (8-ounce) meals per week of blue crab and/or fish containing PCBs and/or PCDDs/PCDFs. Therefore, SALG risk assessors suggest that people should limit their consumption of seafood from the San Jacinto River–Houston Ship Channel. Because the developing nervous system of the human fetus may be especially susceptible to these effects, the SALG risk assessors recommend more conservative consumption guidance for this sensitive subpopulation.

The SALG also queried the probability of increasing lifetime excess cancer risk from consuming blue crab and/or fish containing multiple inorganic and organic contaminants. In most assessments of cancer risk from environmental exposures to chemical mixtures, researchers have considered any increase in cancerous or benign growths in one or more organs as cumulative, no matter the mode or mechanism of action of the contaminant.[46, 50] In this assessment, risk assessors added the calculated carcinogenic effect of arsenic, chlorinated pesticides, PCBs, and PCDDs/PCDFs (Tables 9a–9e). In each instance, addition of the cancer risk numbers for these chemicals increased the theoretical lifetime excess cancer risk; albeit, a majority of the increased cancer risk was due to the addition of PCB and PCDD/PCDF cancer risks. The combination of PCBs and PCDDs/PCDFs increased the lifetime excess cancer risk to a level greater than the DSHS guideline for protection of human health of one excess cancer in 10,000 persons equivalently exposed. The SALG risk assessors calculated the number of 8-ounce meals from the San Jacinto River–Houston Ship Channel that healthy adults could consume without significant risk of cancer (Tables 9a–9e). The SALG estimated this group could consume 0.7 (8-ounce) meals per week of seafood containing PCDDs/PCDFs. Therefore, SALG risk assessors suggest that people should limit their consumption of seafood from the San Jacinto River–Houston Ship Channel. Because human fetus and children may be especially susceptible to these risks, the SALG risk assessors recommend more conservative consumption guidance for this sensitive subpopulation.

San Jacinto River–Houston Ship Channel Consumption Advisory

Currently, ADV-3, ADV-20, and ADV-35 recommend consumption advice for the San Jacinto River–Houston Ship Channel. ADV-20 specifically lists organochlorine pesticides and PCBs as contaminants of concern for fish from the Houston Ship Channel upstream of the Lynchburg Ferry crossing and all contiguous waters, including the San Jacinto River below the U.S. Highway 90 Bridge. Based on the evaluation of data from this study, organochlorine pesticides, singly, or in combination with other contaminants no longer contribute significantly to systemic and/or carcinogenic health risks. The SALG risk assessors are of the opinion that they lack sufficient data from the Houston Ship Channel upstream of the Lynchburg Ferry crossing to characterize adequately the health risks associated with organochlorine pesticides and do not recommend the delisting of organochlorine pesticides as a contaminant of concern. The SALG risk assessors suggest collection of additional fish samples from an area of the Houston Ship Channel upstream of the Lynchburg Ferry Crossing to provide a satisfactory dataset to characterize these health risks.

CONCLUSIONS

The SALG risk assessors prepare risk characterizations to determine public health hazards from consumption of fish and shellfish harvested from Texas water bodies by recreational or subsistence fishers. If necessary, the SALG risk assessors may suggest strategies for reducing risks to public health.

This study addressed the public health implications of consuming fish from the San Jacinto River–Houston Ship Channel, located in Harris County, Texas. The risk assessors from the SALG conclude from the present characterization of potential adverse health effects from consuming blue crab and/or fish from the San Jacinto River–Houston Ship Channel that:

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

2. Nine (blue catfish, blue crab, flathead catfish, hardhead catfish, red drum, sand trout, sheepshead, spotted seatrout, and striped bass) of 11 species assayed contain mean PCB and/or PCDD/PCDF, either singly or in combination that exceed the DSHS guidelines for protection of human health. Regular or long-term consumption of blue crab and/or fish from the San Jacinto River–Houston Ship Channel may increase the likelihood of systemic or carcinogenic health risks. Therefore, consumption of blue crab and/or fish **poses an apparent risk to human health**.

3. Consumption of multiple organic contaminants (i.e. PCBs and PCDDs/PCDFs) in fish from the San Jacinto River–Houston Ship Channel does significantly increase the likelihood of systemic or carcinogenic health risks. Therefore, SALG risk assessors conclude that consuming fish containing multiple contaminants at concentrations near those observed in fish from the San Jacinto River–Houston Ship Channel does significantly increase the risk of adverse health effects.

It is important to note that this study represents a "snapshot" of risk throughout the San Jacinto River–Houston Ship Channel on the day(s) of sampling. This study does not account for potential PCB and PCDD/PCDF concentration variation in blue crab and fish tissue due to environmental variables (i.e. seasonal fish movement, freshwater inflow, salinity, etc.).

RECOMMENDATIONS

Risk managers at the DSHS have established criteria for issuing fish consumption advisories based on approaches suggested by the EPA.[15, 17, 51] Risk managers at the DSHS may decide to take some action to protect public health if a risk characterization confirms that people can eat four or fewer meals per month (adults: eight ounces per meal; children: four ounces per meal) of fish or shellfish from a water body under investigation. Risk management recommendations may be in the form of consumption advice or a ban on possession of fish from the affected water body. Fish or shellfish possession bans are enforceable under Subchapter D of the Texas Health and Safety Code, part 436.061(a).[52] Declarations of prohibited harvesting areas are enforceable under the Texas Health and Safety Code, Subchapter G, part 436.091 and Subchapter H, part 436.101.[52] The DSHS consumption advice carries no penalty for noncompliance. Consumption advisories, instead, inform the public of potential health hazards associated with consuming contaminated fish or shellfish from Texas waters. With this information, members of the public can make informed decisions about whether and/or how much – contaminated fish or shellfish they wish to consume. The SALG concludes from this risk characterization that consuming blue crab and/or fish from the San Jacinto River–Houston Ship Channel **poses an apparent hazard to public health.** Therefore, SALG risk assessors recommend that:

1. The DSHS modify the extant consumption guidance for the San Jacinto River–Houston Ship Channel and Upper Galveston Bay to advise persons to limit consumption of blue crab and all species of fish to no more than one eight-ounce meal per month and women who are nursing, pregnant, or who may become pregnant and children less than 12 years of age or who weigh less than 75 pounds should not consume blue crab and/or all species of fish. The DSHS modify the advisory area to include the Houston Ship Channel north of the Fred Hartman Bridge, State Highway 146 and San Jacinto River below the Lake Houston Dam.

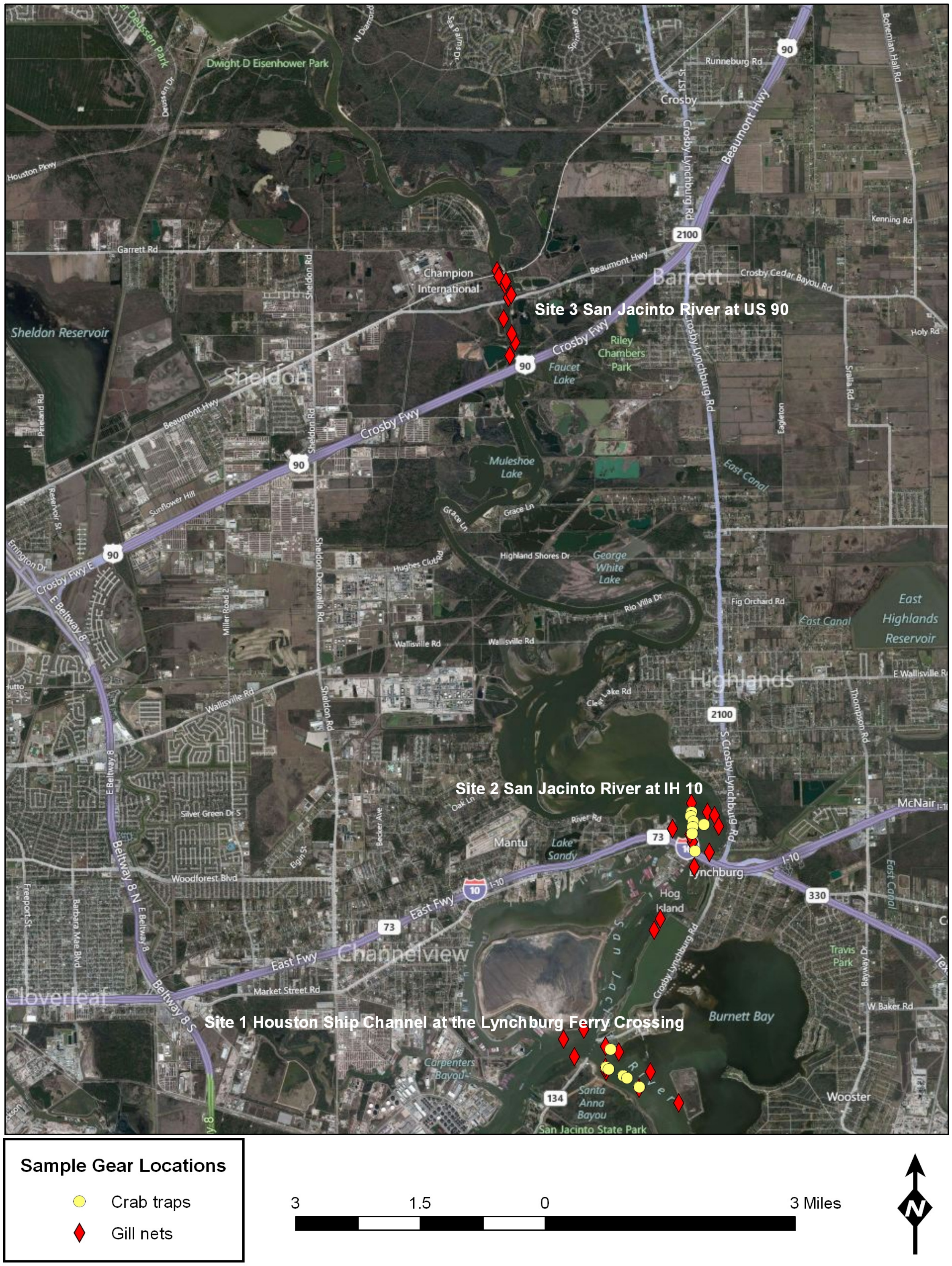
2. The DSHS continue listing organochlorine pesticides as contaminants of concern for the San Jacinto River–Houston Ship Channel consumption advisory until sufficient data are evaluated to characterize adequately the health risks associated with organochlorine pesticides.

3. As resources become available, the DSHS should continue to monitor fish from the San Jacinto River–Houston Ship Channel for changes or trends in contaminants or contaminant concentrations that would necessitate a change in consumption advice.

PUBLIC HEALTH ACTION PLAN

Communication to the public of new and continuing possession bans or consumption advisories, or the removal of either, is essential to effective management of risk from consuming contaminated fish. In fulfillment of the responsibility for communication, the DSHS takes several steps. The agency publishes fish consumption advisories and bans in a booklet available to the public through the SALG. To receive the booklet and/or the data, please contact the SALG at 512-834-6757.[53] 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.[54] The SALG regularly updates this Web site. The DSHS also provides EPA (http://epa.gov/waterscience/fish/advisories/), the TCEQ (http://www.tceq.state.tx.us), and the TPWD (http://www.tpwd.state.tx.us) with information on all consumption advisories and possession bans. Each year, the TPWD informs the fishing and hunting public of consumption advisories and fishing bans on its Web site and in an official downloadable PDF file containing general hunting and fishing regulations booklet available at http://www.tpwd.state.tx.us/publications/nonpwdpubs/media/regulations_summary_2009_2010.pdf.[55] A booklet containing this information is available at all establishments selling Texas fishing licenses.[56] Readers may direct questions about the scientific information or recommendations in this risk characterization to the SALG at 512-834-6757 or may find the information at the SALG's Web site (http://www.dshs.state.tx.us/seafood). Secondarily, one may address inquiries to the Environmental and Injury Epidemiology and Toxicology Unit of DSHS (512-458-7269). The EPA's IRIS Web site (http://www.epa.gov/iris/) contains information on environmental contaminants found in food and environmental media. The ATSDR, Division of Toxicology (888-42-ATSDR or 888-422-8737 or the ATSDR's Web site (http://www.atsdr.cdc.gov) supplies brief information via ToxFAQs.™ ToxFAQs™ are available on the ATSDR Web site in either English (http://www.atsdr.cdc.gov/toxfaq.html) or Spanish (http://www.atsdr.cdc.gov/es/toxfaqs/es _toxfaqs.html). The ATSDR also publishes more in-depth reviews of many toxic substances in its *Toxicological Profiles* (ToxProfiles™). To request a copy of the ToxProfiles™ CD-ROM, PHS, or ToxFAQs™ call 1-800-CDC-INFO (800-232-4636) or email a request to cdcinfo@cdc.gov.

Figure 1. San Jacinto River–Houston Ship Channel Sample Sites



TABLES

Table 1. Fish samples collected from the San Jacinto River–Houston Ship Channel November 2010 and January 2011. Sample number, species, length, and weight are recorded for each sample.

Sample Number	Species	Length (mm)	Weight (g)
Site 1 Houston Ship Channel at the Lynchburg Ferry Crossing			
SJR43	Spotted seatrout	617	2400
SJR45	Spotted seatrout	549	1559
SJR47	Red drum	534	1639
SJR48	Red drum	569	1771
SJR49	Black drum	615	3717
SJR50	Black drum	776	7023
SJR51	Sheepshead	537	3298
SJR52	Sheepshead	484	2400
SJR53	Sand trout	309	298
SJR54	Sand trout	304	318
Site 2 San Jacinto River at IH 10			
SJR2	Black drum	838	9750
SJR3	Black drum	640	3748
SJR5	Sheepshead	547	3076
SJR6	Sheepshead	536	3070
SJR9	Southern flounder	512	1523
SJR10	Southern flounder	470	1388
SJR11	Southern flounder	480	1319
SJR12	Black drum	537	2232
SJR13	Black drum	524	1933
SJR14	Sheepshead	531	2906
SJR15	Spotted seatrout	500	1301
SJR16	Spotted seatrout	410	706
SJR17	Red drum	630	2372
SJR18	Red drum	660	2607
SJR19	Red drum	555	1704
SJR20	Red drum	653	3023
SJR21	Blue catfish	525	1300
SJR22	Blue catfish	505	1080
SJR23	Hardhead catfish	400	789
SJR24	Hardhead catfish	425	696

Table 1 cont. Fish samples collected from the San Jacinto River–Houston Ship Channel November 2010 and January 2011. Sample number, species, length, and weight are recorded for each sample.			
Sample Number	**Species**	**Length (mm)**	**Weight (g)**
Site 2 San Jacinto River at IH 10 cont.			
SJR25	Hardhead catfish	396	645
SJR27	Blue crab	192[f]	N/A
SJR28	Blue crab	159	N/A
SJR29	Blue crab	179	N/A
SJR30	Blue crab	184	N/A
Site 3 San Jacinto River at US 90			
SJR31	Spotted seatrout	387	660
SJR32	Red drum	554	1676
SJR33	Red drum	535	1560
SJR34	Spotted seatrout	451	1060
SJR36	Blue catfish	770	5187
SJR37	Blue catfish	853	8552
SJR38	Blue catfish	835	7615
SJR39	Flathead catfish	817	6658
SJR40	Flathead catfish	829	8367
SJR42	Striped bass	541	2083

[f] The length denoted for each blue crab composite sample is the mean length of the combined blue crab samples used to make the composite sample.

Table 2a. Arsenic (mg/kg) in fish collected from the San Jacinto River–Houston Ship Channel, 2010–2011.					
Species	**# Detected/ # Sampled**	**Total Arsenic Mean Concentration ± S.D. (Min-Max)**	**Inorganic Arsenic Mean Concentration[g]**	**Health Assessment Comparison Value (mg/kg)[h]**	**Basis for Comparison Value**
Black drum	5/5	0.403±0.245 (BDL[i]-0.675)	0.040	0.7 0.363	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
Blue catfish	4/4	0.160±0.166 (0.044-0.402)	0.016		
Flathead catfish	1/1	0.554	0.055		
Hardhead catfish	2/2	0.420±0.246 (0.246-0.594)	0.042		
Spotted seatrout	3/3	0.783±0.957 (BDL-1.858)	0.078		
All fish combined	15/15	0.426±0.455 (BDL-1.858)	0.043		

[g] *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.*

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

[i] B*DL: "Below Detection Limit" – Concentrations were reported as less than the laboratory's reporting limit ("J" values). In some instances, a "J" value was used to denote the discernable presence in a sample of a contaminant at concentrations estimated as different from the sample blank.*

Table 2b. Inorganic contaminants (mg/kg) in fish collected from the San Jacinto River–Houston Ship Channel, 2010–2011.				
Species	**# Detected/ # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
Cadmium				
Black drum	4/5	BDL	0.467	ATSDR chronic oral MRL: 0.0002 mg/kg–day
Blue catfish	2/4	BDL		
Flathead catfish	0/1	ND		
Hardhead catfish	1/2	BDL		
Spotted seatrout	2/3	BDL		
All fish combined	9/15	BDL		
Copper				
Black drum	5/5	0.180±0.022 (0.155-0.205)	334	National Academy of Science Upper Limit: 0.143 mg/kg–day
Blue catfish	4/4	0.204±0.045 (0.146-0.254)		
Flathead catfish	1/1	0.533		
Hardhead catfish	2/2	0.420±0.117 (0.337-0.502)		
Spotted seatrout	3/3	0.265±0.057 (0.228-0.330)		
All fish combined	15/15	0.259±0.119 (0.146-0.533)		
Lead				
Black drum	5/5	0.123±0.042 (0.059-0.170)	NA	EPA IEUBKwin32 Version 1.1 Build 9
Blue catfish	4/4	0.127±0.031 (0.093-0.158)		
Flathead catfish	1/1	0.159		
Hardhead catfish	2/2	0.250±0.011 (0.242-0.257)		
Spotted seatrout	3/3	0.117±0.069 (0.046-0.183)		
All fish combined	15/15	0.142±0.058 (0.046-0.257)		

Table 2c. Inorganic contaminants (mg/kg) in fish and blue crab collected from the San Jacinto River–Houston Ship Channel, 2010–2011.				
Species	**# Detected/ # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
Mercury				
Black drum	6/6	0.104±0.075 (0.060-0.256)	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg–day
Blue catfish	5/5	0.205±0.125 (0.052-0.322)		
Blue crab	4/4	0.044±0.003 (0.041-0.048)		
Flathead catfish	2/2	0.257±0.099 (0.187-0.327)		
Hardhead catfish	3/3	0.174±0.055 (0.121-0.230)		
Red drum	8/8	0.088±0.029 (0.051-0.141)		
Sand trout	2/2	0.079±0.055 (0.040-0.118)		
Sheepshead	5/5	0.178±0.129 (0.099-0.405)		
Southern flounder	3/3	0.054±0.010 (0.045-0.065)		
Spotted seatrout	6/6	0.125±0.086 (0.060-0.282)		
Striped bass	1/1	0.085		
All fish combined	45/45	0.125±0.092 (0.040-0.405)		
Selenium				
Black drum	5/5	1.012±0.550 (0.080-1.368)	6.0	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
Blue catfish	4/4	0.496±0.368 (0.129-1.007)		
Flathead catfish	1/1	1.283		
Hardhead catfish	2/2	0.759±0.528 (0.386-1.132)		
Spotted seatrout	3/3	0.671±0.490 (0.151-1.124)		
All fish combined	15/15	0.791±0.482 (0.080-1.368)		
Zinc				
Black drum	5/5	3.698±0.507 (3.290-4.486)	700	EPA chronic oral RfD: 0.3 mg/kg–day
Blue catfish	4/4	4.332±0.876 (3.327-5.188)		
Flathead catfish	1/1	4.891		
Hardhead catfish	2/2	13.049±5.397 (9.232-16.865)		
Spotted seatrout	3/3	4.599±0.994 (3.686-5.657)		
All fish combined	15/15	5.373±3.512 (3.290-16.865)		

Table 3a. Pesticides (mg/kg) in fish collected from the San Jacinto River–Houston Ship Channel, 2010–2011				
Species	# Detected / # Sampled	Mean Concentration ± S.D. (Min-Max)	Health Assessment Comparison Value (mg/kg)	Basis for Comparison Value
Chlordane				
Black drum	3/5	0.0008±0.0004 (ND-0.001)	1.167 1.556	EPA chronic oral RfD: 0.0005 mg/kg–day EPA slope factor 0.35 per mg/kg –day
Blue catfish	4/4	0.024±0.019 (0.007-0.048)		
Flathead catfish	1/1	0.042		
Hardhead catfish	2/2	0.011±0.002 (0.010-0.012)		
Spotted seatrout	3/3	0.018±0.011 (0.009-0.031)		
All fish combined	13/15	0.015±0.016 (ND-0.048)		
4,4′-DDD				
Black drum	5/5	0.0006±0.0002 (BDL-0.0009)	1.167 2.269	EPA chronic oral RfD: 0.0005 mg/kg–day EPA slope factor 0.24 per mg/kg–day
Blue catfish	4/4	0.008±0.002 (0.006-0.012)		
Flathead catfish	1/1	0.005		
Hardhead catfish	2/2	0.006±0.003 (0.004-0.008)		
Spotted seatrout	3/3	0.005±0.005 (0.002-0.011)		
All fish combined	15/15	0.005±0.004 (BDL-0.012)		
4,4′-DDE				
Black drum	5/5	0.001±0.0005 (0.0008-0.002)	1.167 1.601	EPA chronic oral RfD: 0.0005 mg/kg–day EPA slope factor 0.34 per mg/kg–day
Blue catfish	4/4	0.012±0.006 (0.008-0.021)		
Flathead catfish	1/1	0.014		
Hardhead catfish	2/2	0.012±0.001 (0.011-0.012)		
Spotted seatrout	3/3	0.015±0.008 (0.007-0.023)		
All fish combined	15/15	0.009±0.007 (0.0008-0.023)		

Table 3b. Pesticides (mg/kg) in fish collected from the San Jacinto River–Houston Ship Channel, 2010–2011				
Species	**# Detected / # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
Dieldrin				
Black drum	4/5	0.001±0.001 (ND-0.004)	0.117 0.034	EPA chronic oral RfD: 0.00005 mg/kg–day EPA slope factor 16 per mg/kg–day
Blue catfish	3/4	0.002±0.002 (ND-0.004)		
Flathead catfish	1/1	0.004		
Hardhead catfish	2/2	0.002±0.00007 (0.002-0.003)		
Spotted seatrout	3/3	0.004±0.003 (0.002-0.008)		
All fish combined	13/15	0.002±0.002 (ND-0.008)		
Hexachlorobenzene				
Black drum	1/5	0.0003±0.00009 (ND-0.0005)	1.867 0.340	EPA chronic oral RfD: 0.0008 mg/kg–day EPA slope factor 1.6 per mg/kg–day
Blue catfish	4/4	0.002±0.0007 (0.002-0.003)		
Flathead catfish	1/1	0.002		
Hardhead catfish	2/2	0.002±0.0008 (0.002-0.003)		
Spotted seatrout	3/3	0.005±0.006 (0.0006-0.012)		
All fish combined	11/15	0.002±0.003 (ND-0.012)		

Table 4a. PCBs (mg/kg) in fish and blue crab collected from the San Jacinto River–Houston Ship Channel, 2010–2011.

Species	# Detected / # Sampled	Mean Concentration ± S.D. (Min-Max)	Health Assessment Comparison Value (mg/kg)	Basis for Comparison Value
Site 1 Houston Ship Channel at the Lynchburg Ferry Crossing				
Black drum	2/2	0.016±0.007 (0.011-0.021)	0.047 0.272	EPA chronic oral RfD: 0.00002 mg/kg–day EPA slope factor: 2.0 per mg/kg–day
Red drum	2/2	0.042±0.025 (0.024-**0.060***)		
Sand trout	2/2	**0.088**±0.009 (**0.082-0.095**)		
Sheepshead	2/2	**0.075**±0.044 (0.043-**0.106**)		
Spotted seatrout	2/2	**0.186**±0.072 (**0.135-0.237**)		
All fish combined	10/10	**0.081**±0.068 (0.011-**0.237**)		
Site 2 San Jacinto River at IH 10				
Black drum	4/4	0.019±0.006 (0.013-0.027)	0.047 0.272	EPA chronic oral RfD: 0.00002 mg/kg–day EPA slope factor: 2.0 per mg/kg–day
Blue catfish	2/2	**0.113**±0.051 (**0.077-0.150**)		
Blue crab	4/4	0.009±0.003 (0.006-0.013)		
Hardhead catfish	3/3	**0.116**±0.043 (**0.087-0.166**)		
Red drum	4/4	0.035±0.007 (0.029-0.045)		
Sheepshead	3/3	**0.069**±0.047 (0.033-**0.121**)		
Southern flounder	3/3	0.013±0.002 (0.011-0.014)		
Spotted seatrout	2/2	0.033±0.020 (0.019-**0.048**)		
All fish combined	25/25	0.046±0.045 (0.006-**0.166**)		
Site 3 San Jacinto River at US Highway 90				
Blue catfish	3/3	**0.141**±0.058 (**0.082-0.198**)	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	**0.181**±0.012 (**0.172-0.190**)		
Red drum	2/2	0.025±0.009 (0.019-0.031)		
Spotted seatrout	2/2	**0.124**±0.056 (**0.084-0.164**)		
Striped bass	1/1	**0.050**		
All fish combined	10/10	**0.113**±0.068 (0.019-**0.198**)		

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

Table 4b. PCBs (mg/kg) in fish and blue crab collected from the San Jacinto River–Houston Ship Channel, 2010–2011.				
Species	**# Detected / # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
All Sample Sites				
Black drum	6/6	0.018±0.006 (0.011-0.027)	0.047 0.272	EPA chronic oral RfD: 0.00002 mg/kg–day EPA slope factor: 2.0 per mg/kg–day
Blue catfish	5/5	**0.130**±0.050 (**0.077-0.198**)		
Blue crab	4/4	0.009±0.003 (0.006-0.013)		
Flathead catfish	2/2	**0.181**±0.012 (**0.172-0.190**)		
Hardhead catfish	3/3	**0.116**±0.043 (**0.087-0.166**)		
Red drum	8/8	0.034±0.013 (0.019-**0.060**)		
Sand trout	2/2	**0.088**±0.009 (**0.082-0.095**)		
Sheepshead	5/5	**0.071**±0.040 (0.033-**0.121**)		
Southern flounder	3/3	0.013±0.002 (0.011-0.014)		
Spotted seatrout	6/6	**0.114**±0.081 (0.019-**0.237**)		
Striped bass	1/1	**0.050**		
All fish combined	45/45	**0.069**±0.062 (0.006-**0.237**)		

Table 5a. PCDDs/PCDFs toxicity equivalent (TEQ) concentrations (pg/g) in fish and blue crab collected from the San Jacinto River–Houston Ship Channel, 2010–2011.

Species	# Detected / # Sampled	Mean Concentration ± S.D. (Min-Max)	Health Assessment Comparison Value (mg/kg)	Basis for Comparison Value
Site 1 Houston Ship Channel at the Lynchburg Ferry Crossing				
Black drum	0/2	ND	2.330 3.490	ATSDR chronic oral MRL: 1.0 x 10^{-9} mg/kg–day EPA slope factor: 1.56 x 10^{5} per mg/kg–day
Red drum	0/2	ND		
Sand trout	0/2	ND		
Sheepshead	2/2	**7.416***±4.440 (**4.277-10.556**)		
Spotted seatrout	1/2	0.015±0.021 (ND-0.030)		
All fish combined	3/10	1.486±3.458 (ND-**10.556**)		
Site 2 San Jacinto River at IH 10				
Black drum	2/4	0.052±0.104 (ND-0.208)	2.330 3.490	ATSDR chronic oral MRL: 1.0 x 10^{-9} mg/kg–day EPA slope factor: 1.56 x 10^{5} per mg/kg–day
Blue catfish	2/2	**11.223**±13.706 (1.531-**20.914**)		
Blue crab	1/4	**4.579**±9.159 (ND-**18.316**)		
Hardhead catfish	2/3	0.870±0.766 (ND-1.444)		
Red drum	3/4	0.371±0.286 (ND-0.696)		
Sheepshead	3/3	**25.909**±43.713 (0.364-**76.383**)		
Southern flounder	3/3	0.037±0.052 (0.001-0.096)		
Spotted seatrout	2/2	0.512±0.219 (0.357-0.668)		
All fish combined	18/25	**4.957**±15.813 (ND-**76.383**)		
Site 3 San Jacinto River at US Highway 90				
Blue catfish	2/3	0.0004±0.0007 (ND-0.001)	2.330 3.490	ATSDR chronic oral MRL: 1.0 x 10^{-9} mg/kg–day EPA slope factor: 1.56 x 10^{5} per mg/kg–day
Flathead catfish	1/2	0.003±0.004 (ND-0.005)		
Red drum	2/2	**2.405**±3.401 (0.0002-**4.811**)		
Spotted seatrout	2/2	0.001±0.002 (0.0001-0.003)		
Striped bass	1/1	0.0001		
All fish combined	8/10	0.482±1.521 (ND-**4.811**)		

*Emboldened numbers indicate the concentration of a contaminant exceeded a DSHS HAC Value.

Table 5b. PCDDs/PCDFs toxicity equivalent (TEQ) concentrations (pg/g) in fish and blue crab collected from the San Jacinto River–Houston Ship Channel, 2010–2011.				
Species	**# Detected / # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
All Sample Sites				
Black drum	2/6	0.035±0.085 (ND-0.208)		
Blue catfish	4/5	**4.489**±9.206 (ND-**20.914**)		
Blue crab	1/4	**4.579**±9.159 (ND-**18.318**)		
Flathead catfish	1/2	0.003±0.004 (ND-0.005)		
Hardhead catfish	2/3	0.870±0.766 (ND-1.444)		
Red drum	5/8	0.787±1.647 (ND-**4.811**)	2.330	ATSDR chronic oral MRL: 1.0 x 10^{-9} mg/kg–day
Sand trout	0/2	ND	3.490	EPA slope factor: 1.56 x 10^{5} per mg/kg–day
Sheepshead	5/5	**18.512**±36.603 (0.364-**76.383**)		
Southern flounder	3/3	0.037±0.052 (0.001-0.096)		
Spotted seatrout	5/6	0.176±0.278 (ND-0.668)		
Striped bass	1/1	0.0001		
All fish combined	29/45	**3.191**±11.976 (ND-**76.383**)		

Table 6. VOCs (mg/kg) in fish collected from the San Jacinto River–Houston Ship Channel, 2010–2011.

Species	# Detected / # Sampled	Mean Concentration ± S.D. (Min-Max)	Health Assessment Comparison Value (mg/kg)	Basis for Comparison Value
1,4-Dichlorobenzene				
Black drum	5/5	0.015±0.009 (BDL-0.028)	163.000	ATSDR Chronic Oral MRL: 7.0E-2 mg/kg–day
Blue catfish	4/4	0.008±0.003 (BDL-0.012)		
Flathead catfish	1/1	0.017		
Hardhead catfish	2/2	BDL		
Spotted seatrout	3/3	0.006±0.006 (BDL-0.013)		
All fish combined	15/15	0.010±0.007 (BDL-0.028)		
Methylene Chloride				
Black drum	5/5	0.038±0.018 (BDL-0.051)	72.593 140.000	EPA Oral Slope Factor — 7.5E-3 per mg/kg–day EPA Chronic Oral RfD — 6.0E-2 mg/kg–day
Blue catfish	4/4	0.052±0.022 (0.025-0.076)		
Flathead catfish	1/1	0.180		
Hardhead catfish	2/2	0.027±0.022 (BDL-0.043)		
Spotted seatrout	3/3	0.027±0.018 (0.015-0.048)		
All fish combined	15/15	0.047±0.042 (BDL-0.180)		

Table 7a. Hazard quotients (HQs) for arsenic in fish collected from the San Jacinto River–Houston Ship Channel, 2010–2011. Table 7a also provides suggested weekly eight-ounce meal consumption rates for 70-kg adults.

Species	Number (N)	Hazard Quotient	Meals per Week
All Sample Sites			
Black drum	5	0.06	16.2
Blue catfish	4	0.02	unrestricted‡
Flathead catfish	1	0.08	11.8
Hardhead catfish	2	0.06	15.4
Spotted seatrout	3	0.11	8.3
All fish combined	15	0.06	15.1

‡ Denotes the allowable 8-ounce meals per week are greater than 21.0.

Table 7b. Hazard quotients (HQs) for mercury in fish collected from the San Jacinto River–Houston Ship Channel, 2010–2011. Table 7b also provides suggested weekly eight-ounce meal consumption rates for 70-kg adults.			
Species	**Number (N)**	**Hazard Quotient**	**Meals per Week**
All Sample Sites			
Black drum	6	0.15	6.2
Blue catfish	5	0.29	3.2
Blue crab	4	0.06	14.7
Flathead catfish	2	0.37	2.5
Hardhead catfish	3	0.25	3.7
Red drum	3	0.13	7.4
Sand trout	2	0.11	8.2
Sheepshead	5	0.25	3.6
Southern flounder	3	0.08	12.0
Spotted seatrout	6	0.18	5.2
Striped bass	1	0.12	7.6
All fish combined	45	0.18	5.2

Table 8a. Hazard quotients (HQs) and hazard indices (HIs) for PCBs and/or PCDDs/PCDFs in fish and blue crab collected from the San Jacinto River–Houston Ship Channel in 2010–2011. Table 8a also provides suggested weekly eight-ounce meal consumption rates for 70-kg adults.[j]

Species/Contaminant	Number (N)	Hazard Quotient	Meals per Week
Black drum			
PCBs	6	0.39	2.4
PCDDs/PCDFs	6	0.01	unrestricted[‡]
Hazard Index (meals per week)		0.40 (2.3)	
Blue catfish			
PCBs	5	**2.79***	**0.3**[†]
PCDDs/PCDFs	5	**1.92**	**0.5**
Hazard Index (meals per week)		**4.71 (0.2)**	
Blue crab			
PCBs	4	0.19	4.8
PCDDs/PCDFs	4	**1.96**	**0.5**
Hazard Index (meals per week)		**2.16 (0.4)**	
Flathead catfish			
PCBs	2	**3.88**	**0.2**
PCDDs/PCDFs	2	0.001	unrestricted
Hazard Index (meals per week)		**3.88 (0.2)**	
Hardhead catfish			
PCBs	3	**2.49**	**0.4**
PCDDs/PCDFs	3	0.37	2.5
Hazard Index (meals per week)		**2.86 (0.3)**	

[*] Emboldened numbers denote the HQ exceeds 1.0.
[†] Emboldened numbers denote the calculated allowable meal consumption rate for an adult is less than one per week.
[‡] Denotes the allowable 8-ounce meals per week are greater than 21.0.

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

Table 8b. Hazard quotients (HQs) and hazard indices (HIs) for PCBs and/or PCDDs/PCDFs in fish and blue crab collected from the San Jacinto River–Houston Ship Channel in 2010–2011. Table 8b also provides suggested weekly eight-ounce meal consumption rates for 70-kg adults.[k]

Species/Contaminant	Number (N)	Hazard Quotient	Meals per Week
Red drum			
PCBs	8	0.73	1.3
PCDDs/PCDFs	8	0.34	2.7
Hazard Index (meals per week)		**1.07**[*] **(0.9)** [†]	
Sand trout			
PCBs	2	**1.89**	**0.5**
PCDDs/PCDFs	2	0.0	unrestricted[‡]
Hazard Index (meals per week)		**1.89 (0.5)**	
Sheepshead			
PCBs	5	**1.52**	**0.61**
PCDDs/PCDFs	5	**7.93**	**0.12**
Hazard Index (meals per week)		**9.46 (0.1)**	
Southern flounder			
PCBs	3	0.28	3.3
PCDDs/PCDFs	3	0.02	unrestricted
Hazard Index (meals per week)		0.29 (3.1)	
Spotted seatrout			
PCBs	6	**2.44**	**0.4**
PCDDs/PCDFs	6	0.08	12.3
Hazard Index (meals per week)		**2.52 (0.4)**	
Striped bass			
PCBs	1	**1.07**	**0.9**
PCDDs/PCDFs	1	0.00003	unrestricted
Hazard Index (meals per week)		**1.07 (0.9)**	

[*] Emboldened numbers denote the HQ exceeds 1.0.
[†] Emboldened numbers denote the calculated allowable meal consumption rate for an adult is less than one per week.
[‡] Denotes the allowable 8-ounce meals per week are greater than 21.0.

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

Table 8c. Hazard quotients (HQs) and hazard indices (HIs) for PCBs and/or PCDDs/PCDFs in fish and blue crab collected from the San Jacinto River–Houston Ship Channel in 2010–2011. Table 8c also provides suggested weekly eight-ounce meal consumption rates for 70-kg adults.[1]			
Species/Contaminant	**Number (N)**	**Hazard Quotient**	**Meals per Week**
All Species Combined			
PCBs	45	**1.48***	**0.6†**
PCDDs/PCDFs	45	**1.37**	**0.7**
Hazard Index (meals per week)		**2.85 (0.3)**	

* Emboldened numbers denote the HQ exceeds 1.0.
† Emboldened numbers denote the calculated allowable meal consumption rate for an adult is less than one per week.

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

Table 8d. Hazard quotients (HQs) and hazard indices (HIs) by sample site for PCBs and/or PCDDs/PCDFs in fish and blue crab collected from the San Jacinto River–Houston Ship Channel. Table 8d also provides suggested weekly eight-ounce meal consumption rates for 70-kg adults.[m]			
Contaminant	**Number (N)**	**Hazard Quotient**	**Meals per Week**
Site 1 Houston Ship Channel at the Lynchburg Ferry Crossing			
PCBs	10	**1.74**[*]	**0.5**[†]
PCDDs/PCDFs	10	0.64	1.5
Hazard Index (meals per week)		**2.37 (0.4)**	
Site 2 San Jacinto River at IH 10			
PCBs	25	**0.99**	**0.9**
PCDDs/PCDFs	25	**2.12**	**0.4**
Hazard Index (meals per week)		**3.11 (0.3)**	
Site 3 San Jacinto River at US Highway 90			
PCBs	10	**2.42**	**0.4**
PCDDs/PCDFs	10	0.21	4.5
Hazard Index (meals per week)		**2.63 (0.4)**	
All Sample Sites			
PCBs	45	**1.48**	**0.6**
PCDDs/PCDFs	45	**1.37**	**0.7**
Hazard Index (meals per week)		**2.85 (0.3)**	

[*] Emboldened numbers denote the HQ exceeds 1.0.
[†] Emboldened numbers denote the calculated allowable meal consumption rate for an adult is less than one per week.

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

Table 9a. Calculated theoretical lifetime excess cumulative cancer risk from consuming fish and blue crab containing arsenic, organochlorine (OC) pesticides, PCBs, and PCDDs/PCDFs collected in 2010–2011 from the San Jacinto River–Houston Ship Channel and suggested consumption (8-ounce meals/week) for 70 kg adults who regularly eat fish from the San Jacinto River over a 30-year period.[n]

Species/Contaminant	Number (N)	Theoretical Lifetime Excess Cancer Risk		Meals per Week
		Risk	1 excess cancer per number of people exposed	
Black drum				
Arsenic	5	1.1E-05	90,741	8.4
OC Pesticides	5	3.2E-06	315,730	unrestricted‡
PCBs	6	6.6E-06	151,235	14.0
PCDDs/PCDFs	6	1.0E-06	1,003,747	unrestricted
Cumulative Cancer Risk PCBs and PCDDs/PCDFs		7.6E-06	131,432	12.1
Cumulative Cancer Risk		2.2E-05	45,880	4.2
Blue catfish				
Arsenic	4	4.4E-06	226,852	unrestricted
OC Pesticides	4	9.2E-06	109,238	10.1
PCBs	5	4.8E-05	20,940	1.9
PCDDs/PCDFs	5	**1.3E-04***	**7,775**	**0.7†**
Cumulative Cancer Risk PCBs and PCDDs/PCDFs		**1.8E-04**	**5,670**	**0.5**
Cumulative Cancer Risk		**1.9E-04**	**5,265**	**0.5**
Blue crab				
PCBs	4	3.3E-06	302,469	unrestricted
PCDDs/PCDFs	4	**1.3E-04**	**7,621**	**0.7**
Cumulative Cancer Risk		**1.3E-04**	**7,434**	**0.7**

* Emboldened numbers denote calculated excess lifetime cancer risk after 30 years exposure is greater than 1 X 10^{-4}

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

‡ Denotes the allowable 8-ounce meals per week are greater than 21.0.

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

Table 9b. Calculated theoretical lifetime excess cumulative cancer risk from consuming fish and blue crab containing arsenic, organochlorine (OC) pesticides, PCBs, and PCDDs/PCDFs collected in 2010–2011 from the San Jacinto River–Houston Ship Channel and suggested consumption (8-ounce meals/week) for 70 kg adults who regularly eat fish from the San Jacinto River over a 30-year period.[o]

Species/Contaminant	Number (N)	Theoretical Lifetime Excess Cancer Risk		Meals per Week
		Risk	1 excess cancer per number of people exposed	
Flathead catfish				
Arsenic	1	1.5E-05	65,993	6.1
OC Pesticides	1	1.6E-05	61,967	5.7
PCBs	2	6.6E-05	15,040	1.4
PCDDs/PCDFs	2	7.8E-08	12,854,617	unrestricted[‡]
Cumulative Cancer Risk PCBs and PCDDs/PCDFs		6.7E-05	15,022	1.4
Cumulative Cancer Risk		9.8E-05	10,219	**0.9**[†]
Hardhead catfish				
Arsenic	2	1.2E-05	86,420	8.0
OC Pesticides	2	8.2E-06	122,155	11.3
PCBs	3	4.3E-05	23,467	2.2
PCDDs/PCDFs	3	2.5E-05	40,102	3.7
Cumulative Cancer Risk PCBs and PCDDs/PCDFs		6.8E-05	14,804	1.4
Cumulative Cancer Risk		8.7E-05	11,454	1.1
Red drum				
PCBs	8	1.2E-05	80,065	7.4
PCDDs/PCDFs	8	2.3E-05	44,365	4.1
Cumulative Cancer Risk		3.5E-05	28,547	2.6
Sand trout				
PCBs	2	3.2E-05	30,934	2.9
PCDDs/PCDFs	2	-----	-----	unrestricted
Cumulative Cancer Risk		3.2E-05	30,934	2.9

[†] Emboldened numbers denote the calculated allowable meal consumption rate for an adult is less than one per week.
[‡] Denotes the allowable 8-ounce meals per week are greater than 21.0.

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

Table 9c. Calculated theoretical lifetime excess cumulative cancer risk from consuming fish and blue crab containing arsenic, organochlorine (OC) pesticides, PCBs, and PCDDs/PCDFs collected in 2010–2011 from the San Jacinto River–Houston Ship Channel and suggested consumption (8-ounce meals/week) for 70 kg adults who regularly eat fish from the San Jacinto River over a 30-year period.[p]

Species/Contaminant	Number (N)	Theoretical Lifetime Excess Cancer Risk		Meals per Week
		Risk	1 excess cancer per number of people exposed	
Sheepshead				
PCBs	5	2.6E-05	38,341	3.5
PCDDs/PCDFs	5	**5.3E-04**[*]	**1,885**	**0.2**[†]
Cumulative Cancer Risk		**5.6E-04**	**1,797**	**0.2**
Southern flounder				
PCBs	3	4.8E-06	209,402	19.4
PCDDs/PCDFs	3	1.1E-06	942,403	unrestricted[‡]
Cumulative Cancer Risk		5.8E-06	171,332	15.8
Spotted seatrout				
Arsenic	3	2.1E-05	46,534	4.3
OC Pesticides	3	1.6E-05	64,355	6.0
PCBs	6	4.2E-05	23,879	2.2
PCDDs/PCDFs	6	5.1E-06	198,005	18.3
Cumulative Cancer Risk PCBs and PCDDs/PCDFs		4.7E-05	21,309	2.0
Cumulative Cancer Risk		8.4E-05	11,911	1.1
Striped bass				
PCBs	1	1.8E-05	54,444	5.0
PCDDs/PCDFs	1	2.3E-09	436,253,561	unrestricted
Cumulative Cancer Risk		1.8E-05	54,438	5.0

[*] Emboldened numbers denote calculated excess lifetime cancer risk after 30 years exposure is greater than 1 X 10^{-4}

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

[‡] Denotes the allowable 8-ounce meals per week are greater than 21.0.

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

Table 9d. Calculated theoretical lifetime excess cumulative cancer risk from consuming fish and blue crab containing arsenic, organochlorine (OC) pesticides, PCBs, and PCDDs/PCDFs collected in 2010–2011 from the San Jacinto River–Houston Ship Channel and suggested consumption (8-ounce meals/week) for 70 kg adults who regularly eat fish from the San Jacinto River over a 30-year period.[q]

Species/Contaminant	Number (N)	Theoretical Lifetime Excess Cancer Risk		Meals per Week
		Risk	1 excess cancer per number of people exposed	
All species combined				
Arsenic	15	1.2E-05	84,410	7.8
OC Pesticides	15	8.2E-06	121,772	11.3
PCBs	45	2.5E-05	39,452	3.6
PCDDs/PCDFs	45	9.1E-05	10,937	1.0
Cumulative Cancer Risk PCBs and PCDDs/PCDFs		**1.2E-04**[*]	**8,563**	**0.8**[†]
Cumulative Cancer Risk		**1.4E-04**	**7,308**	**0.7**

[*] Emboldened numbers denote calculated excess lifetime cancer risk after 30 years exposure is greater than 1 X 10^{-4}
[†] Emboldened numbers denote the calculated allowable meal consumption rate for an adult is less than one per week.

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

Table 9e. Calculated theoretical lifetime excess cumulative cancer risk by sample site for fish and blue crab containing arsenic, organochlorine (OC) pesticides, PCBs, and PCDDs/PCDFs collected in 2010–2011 from the San Jacinto River–Houston Ship Channel and suggested consumption (8-ounce meals/week) for 70 kg adults who regularly eat fish from the San Jacinto River over a 30-year period.[r]

Site/Contaminant	Number (N)	Theoretical Lifetime Excess Cancer Risk		Meals per Week
		Risk	1 excess cancer per number of people exposed	
Site 1 Houston Ship Channel at the Lynchburg Ferry Crossing				
Arsenic	3	1.7E-05	57,613	5.3
OC Pesticides	3	1.5E-05	67,455	6.2
PCBs	10	3.0E-05	33,608	3.1
PCDDs/PCDFs	10	4.3E-05	23,486	2.2
Cumulative Cancer Risk PCBs and PCDDs/PCDFs		7.2E-05	13,825	1.3
Cumulative Cancer Risk		**1.0E-04***	**9,568**	**0.9**†
Site 2 San Jacinto River at IH 10				
Arsenic	8	1.0E-05	95,517	8.8
OC Pesticides	8	6.3E-06	158,529	14.7
PCBs	25	1.7E-05	59,179	5.5
PCDDs/PCDFs	25	**1.4E-04**	**7,041**	**0.7**
Cumulative Cancer Risk PCBs and PCDDs/PCDFs		**1.6E-04**	**6,292**	**0.6**
Cumulative Cancer Risk		**1.8E-04**	**5,691**	**0.5**
Site 3 San Jacinto River at US Highway 90				
Arsenic	4	1.0E-05	98,098	9.1
OC Pesticides	4	1.1E-05	87,365	8.1
PCBs	10	4.2E-05	24,090	2.2
PCDDs/PCDFs	10	1.4E-05	72,407	6.7
Cumulative Cancer Risk PCBs and PCDDs/PCDFs		5.5E-05	18,076	1.7
Cumulative Cancer Risk		7.7E-05	12,994	1.2

* Emboldened numbers denote calculated excess lifetime cancer risk after 30 years exposure is greater than 1 X 10^{-4}
† Emboldened numbers denote the calculated allowable meal consumption rate for an adult is less than one per week.

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

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