CHARACTERIZATION of POTENTIAL HEALTH RISKS associated with CONSUMPTION of FISH or BLUE CRABS

from the

Houston Ship Channel, the San Jacinto River (Tidal Portions), Tabbs Bay, and Upper Galveston Bay

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Texas Department of State Health Services
Seafood and Aquatic Life Group
Policy, Standards, and Quality Assurance Unit
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INTRODUCTION

Background and Statement of the Issues

The Texas Department of Health (TDH; now the Texas Department of State Health Services or DSHS) first issued consumption advice (ADV-3) for the Houston Ship Channel in 1990. The extant ADV-3 covered portions of the Houston Ship Channel and all contiguous waters downstream of the Lynchburg Ferry crossing – including tidal portions of the San Jacinto River and Tabbs Bay – where catfish and blue crab samples were found contaminated with dioxin[1] [1]. TDH reevaluated the 1990 consumption advisory in 1997, extending ADV-3 because catfish and blue crabs continued to show evidence of dioxin contamination. In 1999, TDH collaborated with the Texas Commission on Environmental Quality (TCEQ – formerly the Texas Natural Resource Conservation Commission – TNRCC) to reexamine fish and crabs from the Houston Ship Channel (HSC), tidal portions of the San Jacinto River (SJR), and Tabbs Bay (TB). In the 1999 survey, the agency analyzed samples for pesticides, volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), polychlorinated biphenyls (PCBs), and several metallic or semi-metallic elements. Financial constraints prevented the TDH from including chlorinated dioxins or furans in the 1999 parametric coverage. On October 9, 2001, TDH augmented ADV-3 with ADV-20. ADV-20 expanded ADV-3 to cover all species of fish and blue crabs taken from the Houston Ship Channel from the turning basin to the Lynchburg Ferry crossing and contiguous waters, including tidal portions of the San Jacinto River downstream of the bridge at U.S. Hwy 90. Both advisories recommend that adults eat no more than one eight-ounce meal each month from the advisory area and suggest that women of childbearing age and children not consume catfish or blue crabs from the advisory areas. In 2004, the DSHS, in collaboration with the TCEQ, once again sampled fish and blue crabs from Upper Galveston Bay, Tabbs Bay, the tidal portion of the San Jacinto River and the Houston Ship Channel (at the Lynchburg Ferry crossing and in the turning basin) for metals, VOCs, SVOCs, PCBs, pesticides, and dioxin. Consumption of fish or blue crabs containing contaminants, including those previously reported in seafood from the HSC and Upper Galveston Bay, (UGB) could pose a risk of adverse health effects.

Along its length, the HSC receives permitted discharges from many industrial sites and municipal sources as well as non-point source runoff from parts of metropolitan Houston. Approximately fifteen miles downstream of the turning basin, the HSC traverses the San Jacinto State Park, where the San Jacinto River joins it on the north side near the San Jacinto State Monument. Channel waters then course east-southeast through the park, emptying into the Upper Galveston Bay. Upper Galveston Bay, the San Jacinto River, Tabbs Bay and the San Jacinto State Park have many points of public access and support both recreational and subsistence fishing activities.

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[1] In this document, "dioxins" or "dioxin" refers to polychlorinated dibenzo-p-dioxins (PCDDs) and/or polychlorinated dibenzofurans (PCDFs).

METHODS

Fish Tissue Collection and Analysis

The DSHS collects and analyzes edible fish and shellfish tissues from the state's public waters to evaluate potential health risks to recreational and subsistence fishers and others who consume chemically-contaminated fish or shellfish. In sampling fish and shellfish for tissue analysis, samplers follow standard operating procedures from the DSHS *Seafood and Aquatic Life Group Standard Operating Procedures and Quality Control/Assurance Manual* [1]. The Seafood and Aquatic Life Group (SALG) bases its sampling and analysis protocols in part on procedures established by the United States Environmental Protection Agency (EPA) in *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories, Volume 1* [2] and on guidance from the State of Texas' Toxic Substances Coordinating Committee (TSCC) Fish Sampling Advisory Subcommittee (FSAS) [3]. Samples usually represent species, trophic levels, and legal-sized specimens available for consumption from a water body. When practical, DSHS collects samples from two or more sites within a water body to characterize the geographical distribution of contaminants. Using established EPA methodology, the DSHS laboratory analyzes fillets (skin off) of fish and edible meats of shellfish (crab and oyster) for common contaminants. DSHS typically analyzes tissues for seven metals – arsenic, cadmium, copper, lead, total mercury[2], selenium, and zinc – and for volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), pesticides, and polychlorinated biphenyls (PCBs, analyzed as Aroclors 1016, 1221, 1224, 1232, 1248, 1254, and 1260). Wright State University (WSU), which analyzes dioxin for DSHS, utilizes established EPA methodology to assess edible fillets (skin off) of fish and edible meats of shellfish (crab and oyster) for polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs).

Description of the Houston Ship Channel and Upper Galveston Bay 2004 Sample Set

With input from the Galveston Bay Estuary Program (GBEP) Seafood Safety Task Force, a team from the DSHS SAL group selected five previously sampled sites to provide coverage of the study area. These included a site near the Houston Yacht Club in UGB (Site 1); one near Morgan's Point in Tabbs Bay (Site 2); a site within the HSC near the Lynchburg Ferry crossing (Site 3); the tidal portion of the San Jacinto River immediately upstream of IH-10 (Site 4); and the HSC turning basin (Site 5). A map in Appendix 1 shows the chosen sites. The SALG field team made four sampling trips in early 2004 (February and March-April) to collect fish and blue crab tissue samples from the previously designated sites. The field team set five to seven gill nets (125 to 300 feet in length) and seven to eight baited crab traps (bait for crab traps was obtained from non-game fish caught in gill nets) at each site. The SALG group set nets and traps in the afternoon and fished overnight. The gill nets were set parallel to the current and direction of the tides in deep and shallow areas of each site to maximize available cover and habitat. The crab traps were set at a variety of depths at each site near available cover and structure. Surveyors

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[2] Nearly all mercury in upper trophic-level fish over three years of age is methylmercury [25]. Total mercury is a surrogate for methylmercury concentration in fish and shellfish. Because of the cost of methylmercury analyses, USEPA recommends that states determine total mercury concentrations in fish and that – to protect human health – states assume that all mercury in fish or shellfish is methylmercury. TDH analyzes fish and shellfish tissues for total mercury. In its risk characterizations, TDH compares total mercury concentrations in tissues to a comparison value derived from the ATSDR's minimal risk level for methylmercury [26]. TDH may utilize the terms "mercury" and "methylmercury" interchangeably to refer to methylmercury in fish.

reset gill nets and crab traps each day at the same or different sites depending upon the previous day's catch. During its four trips, the SALG team collected thirty-five fish tissue samples – seven per sample site – and ten composite blue crab tissue samples – two per sample site. From each of the referenced sites, surveyors produced composite crab samples by combining nine to sixteen individual crabs per sample. Fish species consisted of five black drum; ten blue catfish; one channel catfish; two common carp; two hybrid striped bass; four red drum; one southern flounder; six spotted seatrout; and one white bass. DSHS was unable to collect samples of all species at all sites. All fish collected for this study conformed to Texas Parks and Wildlife (TPWD) guidelines for legal possession [4].

The fish tissue samples were prepared by removing the skin from each fish. SALG staff took fillets both the left and the right sides of each sample, packaging, labeling, and freezing the right fillet for hand delivery to the DSHS laboratory for analysis. The left fillet from each fish was packaged, labeled, frozen, and shipped by overnight freight to Wright State University for analysis of dioxins. Blue crab samples were delivered concurrently with fish tissue samples. In preparation of crab samples, surveyors removed the top shell and apron of each crab by hand, and then removed the gills and all loose viscera and eggs from the body cavity. Surveyors then split each crab in half along the ventral mid-line, combining nine to sixteen crab halves from each site to form a composite sample. Half of each composite crab sample was then packaged, labeled, and delivered to the DSHS laboratory. The other half of the sample was shipped frozen to the WSU laboratory. The DSHS laboratory analyzed 35 edible fish fillets (skin off) and 10 composite blue crab tissue samples for metals, PCBs, and selected pesticides. The DSHS laboratory analyzed twenty-six edible fish fillets and five composite blue crab tissue samples for SVOCs and VOCs. The WSU laboratory analyzed all 35 edible fish fillets and all 10 composite blue crab tissue samples for dioxin.

Data Analysis

DSHS used SPSS® statistical software [5] on IBM-compatible microcomputers to generate descriptive statistics (mean, standard deviation, median, range, and minimum and maximum concentrations) for each reported contaminant in each species at each sampling site or for combinations of species and/or sampling site. DSHS utilized SPSS® software for hypothesis testing when appropriate [5]. DSHS employed Microsoft Excel® [6] spreadsheets to generate health-based assessment comparison values (HAC values) and calculate hazard quotients, hazard indices, cancer risk values, and meal consumption rates for fish and blue crab samples collected in 2004 from the HSC and UGB. Statistical analyses and comparison matrices included all data from all samples.

Calculation of toxicity equivalent concentrations (TEQs) for dioxins

Polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans (dioxins/furans; PCDD/PCDFs; dioxin) 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 parent molecule. Toxicity varies with the number of chlorine atoms, increasing with chlorine numbers up to four atoms, decreasing thereafter with increasing chlorine number up to a maximum of eight chlorines.

Those congeners of PCDD/PCDFs having chlorine atoms in the 2, 3, 7, and 8 positions appear more toxic than other PCDD/PCDF congeners. The most toxic of all PCDDs/PCDFs is 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD). To gain some measure of toxicity equivalency, 2,3,7,8-TCDD has been designated the standard against which the toxicity of other congeners is measured. Scientists have developed toxicity equivalency factors (TEFs) to compare the relative toxicity of other dioxins or dioxin-like compounds to that of 2,3,7,8-TCDD, assigned a toxicity equivalence factor (TEF) of 1.0. Researchers gave other PCDF/PCDD congeners weighting factors based on their toxicity relative to that of 2,3,7,8-TCDD [7]. DSHS risk assessors converted dioxin congeners in fish from the present survey to toxicity equivalents by multiplying a congener's concentration by its TEF to produce a concentration roughly equivalent in toxicity to that of a given concentration of 2,3,7,8-TCDD (concentration x TEF). The total TEQ for any given sample is defined as the sum of the TEQs for each of the congeners in the sample, calculated according to the following formula:

$$\text{Total TEQs} = \operatorname*{Sum}_{i=1}^{n} (CI \times TEF)$$

where

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

[8].

Derivation of Health-Based Assessment Comparison Values (HACs)

People who regularly consume contaminated fish or shellfish generally are repeatedly exposed to low concentrations of contaminants over an extended time. Such a pattern of exposure seldom results 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, to name but a few [9]. Presuming people to eat a variety of fish or shellfish, DSHS routinely evaluates average contaminant concentrations across species living in and locations around a specific water body because such an approach likely reflects consumers' exposure to contaminants in seafood over time. However, the agency also may examine the risks associated with ingestion of individual species of fish or shellfish from individual collection sites at higher concentrations (e.g., the upper 95th percentile of average concentrations), should the need arise.

DSHS evaluates chemical contaminants in fish by comparing contaminant concentrations to health-based assessment comparison (HAC) values (in mg contaminant per kg edible tissue or mg/kg) for non-cancer and cancer endpoints. To calculate HAC values for either carcinogenic (HAC_{ca}) or systemic (HAC_{nonca}) effects, DSHS assumes that a standard adult weighs 70 kilograms and that adults consume 30 grams of fish per day (about one eight-ounce meal per week). DSHS uses EPA's oral reference doses (RfDs) [10] or the Agency for Toxic Substances and Disease Registry's (ATSDR) chronic oral minimal risk levels (MRLs) to derive HAC values for evaluating systemic (noncancerous) adverse health effects [11]. The EPA defines the RfD for a toxic chemical substance as *"An estimate (with uncertainty spanning perhaps an order of magnitude) of a daily oral exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime*." RfDs may be derived from a NOAEL, a LOAEL, or a benchmark dose, with uncertainty factors generally applied to reflect limitations of the data used. RfDs are generally used for health effects that are thought to have a threshold or low dose limit for producing effects [12]." DSHS compares the measured average concentration of a contaminant to its RfD or MRL, producing a hazard quotient (HQ) for the average concentration of the contaminant in the samples from a site. A hazard quotient is the ratio of the estimated exposure dose of a contaminant (in mg/kg/day) to the contaminant's RfD or MRL [13]. DSHS assumes for risk management that consumption of fish for which the toxicant – to –RfD ratio (the HQ) is less than 1.0 is unlikely to result in adverse health effects. The cancer risk comparison values (HAC_{ca}) DSHS uses to assess risk of cancer incurred from consumption of fish or shellfish containing carcinogenic chemicals are calculated from EPA's chemical-specific cancer slope factors (SFs) [10]. In calculating excess cancer risk, DSHS uses standard weights and consumption rates, an acceptable lifetime risk level (ARL) of one excess cancer in 10,000 persons equally exposed to the toxicant over a period of 30 years to calculate cancer risk.

Most constants that DSHS employs to calculate HAC_{nonca} values contain built-in margins of safety (uncertainty factors). Uncertainty factors are chosen by those who develop RfDs to minimize the potential for systemic adverse health effects in those people – such as women of childbearing age, pregnant or lactating women, infants, children, the elderly, people who have chronic illnesses, those who consume exceptionally large quantities of fish or shellfish – who eat chemically-contaminated fish and shellfish [10]. Although comparison values used for assessing the probability of cancer do not contain uncertainty factors as such, conclusions drawn from those probability determinations do represent substantial safety margins by virtue of the models used to derive the factors. Therefore, adverse health effects, either systemic or carcinogenic, are very unlikely to occur at concentrations that approach or are even greater than calculated comparison values. Moreover, HACs for systemic or carcinogenic effects do not represent a sharp dividing line between safe and unsafe exposures. The strict demarcation between acceptable and unacceptable exposures or risks is primarily a tool used to make risk management decisions that assure protection of public health. For instance, DSHS finds it unacceptable when consumption of four or fewer meals per month would result in exposures to a contaminant or contaminants that exceed a HAC value or other measure of risk. DSHS further advises that those who wish to minimize exposure to chemical contaminants in fish or shellfish eat a variety of fish and/or shellfish and that they limit consumption of those species that are most likely to contain toxic contaminants.

Cumulative Effects

When multiple chemicals that affect the same organ or that have the same mechanism of action (systemic or carcinogenic) exist together in one or more samples from a water body, a standard assumption is that potential adverse health effects are cumulative [14, 15]. Therefore, DSHS conservatively assumes that each time people eat fish or shellfish from an affected water body, exposure occurs to all of the chemicals present in any of the samples. DSHS assumes that potential cumulative adverse systemic or carcinogenic effects will be additive rather than multiplicative (synergistic) or antagonistic [9, 14].

Cumulative Systemic (Noncancerous) Effects

To evaluate the importance of possible cumulative systemic (noncancerous) health effects from consumption of contaminants with similar toxicity profiles, DSHS calculates a hazard index (HI) by summing hazard quotients (HQ) initially calculated for each contaminant. A HI of less than 1.0 may suggest that no significant hazard is present for the observed combination of contaminants at the observed concentrations. While a HI that exceeds 1.0 may indicate some level of hazard, it does not imply that exposure to the contaminants at observed concentrations will result in adverse health effects. Nonetheless, finding an HI that exceeds 1.0 may prompt the agency to consider public health action.

Cumulative Carcinogenic Effects

To estimate the potential additive effects of multiple carcinogens on excess lifetime cancer risk, DSHS sums the risks calculated for each carcinogenic contaminant observed in a sample set. DSHS recommends limiting consumption of fish or shellfish containing multiple carcinogenic chemicals to quantities that would result in an estimated combined theoretical excess lifetime cancer risk of not more than one extra cancer in 10,000 persons so exposed.

Children's Health Considerations

DSHS recognizes that fetuses, infants, and children may be uniquely susceptible to the effects of toxic chemicals and that any such vulnerabilities demand special attention [16, 17]. Windows of vulnerability (i.e., critical periods) exist during development. These critical periods are particularly evident during early gestation, but may appear during pregnancy, infancy, childhood, and adolescence – indeed, at any time during development, when toxicants can permanently impair or alter the structure or function of vulnerable systems [16]. Unique childhood vulnerabilities may result from the fact that, at birth, most organs and body systems have not achieved structural or functional maturity; rather, these organs continue to develop throughout childhood and adolescence. Because of these structural and functional differences, children may differ from adults in absorption, metabolism, storage, and excretion of toxicants, any one of which factors could alter the concentration of biologically effective toxicant at the target organ(s). Children's exposures to toxicants may be more extensive than adult's exposures because children consume more food and liquids in proportion to their body weight than do adults [17], a factor that also may increase the concentration of toxicant at the target. Infants can ingest toxicants through breast milk – often unrecognized as an exposure pathway [17]. Children may also experience toxic effects at a lower exposure dose than adults because of differences in target organ sensitivity. Stated differently, children could respond more severely than would adults to an equivalent exposure dose [16]. Children may also be more prone to developing certain cancers from chemical exposures than are adults, although this assumption may not always be appropriate [18]. If a chemical – or a class of chemicals – is more toxic to children than to adults, the RfD, MRL, or carcinogen potency factor will be commensurately lower to reflect a child's potentially greater susceptibility to a toxicant. Additionally, in accordance with

ATSDR's *Child Health Initiative* [19] and EPA's *National Agenda to Protect Children's Health from Environmental Threats* [16], DSHS seeks to further protect children from the potential effects of toxicants in fish and shellfish by suggesting that this sensitive group consume smaller quantities of contaminated fish or shellfish than adults do. Therefore, DSHS routinely recommends that children weighing 35 kg or less and/or who are eleven years of age or younger limit exposure to fish or shellfish assumed to contain chemical contaminants to no more than four ounces of fish or shellfish per meal. DSHS also recommends that consumers spread these meals out over time. For instance, if the consumption advice recommends eating no more than two meals per month, children consuming fish or shellfish from the affected water body should consume no more than twenty-four meals per year. Ideally, children should not eat such fish or shellfish more than twice per month.

RESULTS

Analytical and Statistical Results

Table 1a through 4c summarize the laboratory analytical results from the samples. The following paragraphs contain written summaries of those data arranged by contaminant.

Inorganic Contaminants

Inorganic contaminants/constituents such as arsenic, cadmium, lead, and mercury were reported present in many fish (Tables 1a, 1b) and blue crabs (Tables 1c, 1d) at concentrations of no importance to human health, as were selenium and zinc. Therefore, the present report addresses only summarily results of analyses for these contaminants, some of which are essential nutrients [20].

Organic Contaminants

SVOCs

Analysis of samples for semivolatile organic compounds (data not shown) revealed that a smallmouth buffalo (ID = #HSC8) from the turning basin (Site 5) weighing 3859 grams and measuring 620 mm contained several SVOCs at estimated concentrations at or below the practical quantitation limit (PQL) for the constituent; these contaminants included phenanthrene and acenaphthylene. A single blue crab from the Lynchburg Ferry crossing site (Site 3) contained 1.3 mg of pyridine. Pyridine, a naturally occurring compound in blue crabs, is of no toxicological significance [21].

VOCs

The smallmouth buffalo (HSC8) from the turning basin contained 1,2,4-trimethylbenzene, 1,2,5-trimethylbenzene, 4-isopropyl toluene, naphthalene, and toluene (data not shown) at concentrations estimated to be at or below the laboratory's PQL. Sample HSC8 also contained 4-isopropyl toluene, as did HSC11, a common carp from the turning basin. The smallmouth buffalo, sample HSC8, contained 26 ug/kg naphthalene; this sample also contained toluene at a concentration reported as “below the PQL” for toluene. Five fish also contained acetone, which can be a field or laboratory contaminant, a natural metabolic compound, or can result from necrosis. Because occurrences of volatile organic compounds were infrequent, excursions from reporting limits were small or were estimated concentrations near the PQL, and because most observations of VOCs were confined to the smallmouth buffalo sample (HSC8) from the turning basin, VOCs are discussed only briefly in the remainder of this paper. Raw data are available upon request.

Pesticides

Twenty-seven organophosphate or organ chlorine pesticides were analyzed in fish and blue crabs for this study. Tables 2a-2c contain summary data for those compounds observed in fish and blue crab samples taken in 2004 from the HSC or UGB. The raw data, available upon request, contains a full listing of the twenty-seven analyzed pesticides.

Organophosphate pesticides

Laboratory analysis of fish and blue crabs from the HSC and UGB did not detect organophosphate pesticides. Thus, risk assessors did not further address these contaminants in this risk characterization.

Organochlorine Pesticides

Fish from each of the HSC and UGB sites surveyed in 2004 contained a few organochlorine pesticides; these contaminants consisted of chlordane, DDD, DDE, DDT, dieldrin, heptachlor epoxide, and hexachlorobenzene, observed in many fish at levels near the reporting limits for these compounds (Tables 2a, 2b). Typically, the DSHS laboratory reported from four to seven organochlorine pesticides in fish collected from the Houston Yacht Club marina up into the HSC turning basin. Fish from the HSC turning basin contained up to seven organochlorine pesticides. Not all fish contained all organochlorine pesticides and concentrations of these contaminants varied considerably from site to site and from species to species. Fish from the HSC turning basin generally contained the largest number of organochlorine pesticides at the highest concentrations. Greater numbers of fish from the turning basin contained organochlorine pesticides than from any other sampling site (Tables 2a, 2b). Eight of the ten blue crab composites – those from sample sites 2-5 – contained chlordane in concentrations ranging from undetectable levels to 0.050 mg/kg; crabs from the HSC turning basin contained the most chlordane (0.032 ±0.025 mg/kg) while blue crabs from Site 1, near the Houston Yacht Club marina, did not contain quantifiable chlordane. Blue crabs contained no other organochlorine pesticides in measurable quantities (Table 2c).

Polychlorinated Biphenyls (Aroclor 1248, Aroclor 1260)

Eleven fish contained PCBs identified as Aroclor 1260; three of those fish – two spotted seatrout from the Houston Yacht Club Marina and one blue catfish from the HSC turning basin (Site 5) – contained Aroclor 1248 (Tables 3a-3c). One or more fish from each of the five sites surveyed in 2004 contained PCBs. The highest concentration of PCBs (1.17 mg/kg) occurred in a blue catfish

(HSC9) from the HSC turning basin. However, only three of ten blue catfish contained PCBs. On the other hand, PCBs were measurable in five of six spotted seatrout. The highest concentrations of PCBs in spotted seatrout were observed in the two spotted seatrout samples collected from Site 1 near the Houston Yacht Club marina. Including samples from 2004, the DSHS database contains some 60 spotted seatrout collected between 1982 and 2004 from the Galveston Bay complex (including the tidal portion of the San Jacinto River and the Houston Ship Channel), only 16 (27%) of which contained PCBs.

Blue crab samples did not contain quantifiable concentrations of PCBs (data not shown).

Dioxin (PCDFs/PCDDs)

Polychlorinated dibenzo-p-dioxins and/or polychlorinated dibenzofurans (PCDDs/PCDFs – dioxin) were detected in 28 of 35 fish at concentrations ranging from 0.092 pg/g to 8.895 pg/g (Tables 5a, 5b) and in all 10 blue crab samples. The single southern flounder collected (Site 1) in 2004 did not contain detectable levels of dioxin, nor did the one channel catfish (Site 3) collected during the present survey contain dioxin. Not all congeners of PCDDs/PCDFs were contained in all samples. Before generating summary statistics, dioxin and furan congeners were converted to concentrations equivalent in toxicity (TEQs) to that of 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD; see method section for details). Risk assessors generated summary statistics on TEQ concentrations in each species collected at each sampling site (Tables 5a, 5b). All blue catfish (10/10) contained PCDD/PCDF congeners, as did hybrid striped bass (2/2), common carp (2/2), smallmouth buffalo (3/3), and the single white bass collected. Four of six spotted seatrout, four of five black drum, and two of four red drum contained measurable dioxin equivalents. Blue catfish had the highest average concentration of dioxin equivalents (3.7±3.1 pg/g), followed by smallmouth buffalo (2.27±1.2 pg/g).

Blue crabs contained an average of 2.03 pg/g dioxin equivalents. At 0.11 (±0.03) pg/g, red drum contained the lowest concentrations of dioxin equivalents. Dioxin equivalent concentrations increased from Site 1, with an average concentration of 0.56±0.7 pg/g to Site 5 (HSC turning basin) where the average concentration was the highest (2.89±2.3 pg/g).

DISCUSSION

Risk Characterization

Systemic (Noncancerous) Health Effects from Consumption of Contaminants in Houston Ship Channel/Upper Galveston Bay Fish and Shellfish

Inorganic or Metallic Contaminants

Fish and blue crabs from the HSC and those from the UGB contained some concentration of five metallic or semi-metallic elements – copper, cadmium, mercury, selenium, and zinc. DSHS compared the average concentration of each contaminant to its respective HAC_{nonca} for each contaminant (Tables 1a through 1d). No metallic contaminant exceeded its respective HAC_{nonca} value and none exceeded a hazard quotient of 1.0. Thus, consumption of fish containing any one of these metalloid components is unlikely to have any effect on human health, obviating further discussion of such toxic effects. Furthermore, copper, selenium, and zinc are essential trace elements present in all vertebrates that are necessary for optimum health in humans and other animals [20].

Organic Contaminants

VOCs and SVOCs:

Volatile and semivolatile organic compounds were observed sporadically in fish or blue crabs from the HSC or UGB. No VOCs or SVOCs occurred at concentrations in excess of the respective contaminant's HAC value. Individual VOCs or SVOCs or similar contaminants identified in samples collected from the HSC-UGB complex did not exceed their respective HQs in any species of fish at any site surveyed. Thus, the DSHS concludes that consumption of fish or blue crabs from the survey area containing any one common SVOC or VOC at concentrations similar to those observed in samples from the HSC or UGB should pose no exceptional risk to human health.

Organochlorine Pesticide Contaminants

The laboratory reported various combinations of seven organochlorine pesticides (Tables 2a, 2b), ranging from chlordane to hexachlorobenzene in fish from the five sites surveyed in 2004. In many instances, concentrations of these pesticides were near the reporting limits for the contaminants. No pesticide exceeded its respective HAC_{nonca} in any species of fish. Thus, consumption of fish containing one of the listed pesticides at concentrations near those observed in the samples from the HSC or UGB pose no risk to human health.

Blue crabs from sites 2 through 5 contained trace amounts of chlordane, but no other organochlorine pesticides (Table 2c). In no instance did the concentration of chlordane in a blue crab sample exceed that of the HAC_{nonca} for chlordane. Thus, DSHS does not expect that consumption of blue crabs containing chlordane at concentrations similar to those observed in the 2004 samples will negatively impact human health.

Polychlorinated Biphenyls (PCBs; Aroclors 1248, 1260)

The laboratory quantified Aroclors for this survey. These analyses showed that Aroclor 1248 and/or Aroclor 1260 could have originally contributed to observed PCBs in 11 fish from the 2004 samples. However, the compositions of Aroclor 1248 and Aroclor 1260 overlap. Compositions of both mixtures overlap other mixtures of Aroclors. Moreover, it may be unreliable to conclude that the PCBs in a "weathered" sample originated with a specific Aroclor mixture. Additionally, the DSHS calculates a HAC_{nonca} for all PCBs from the RfD for Aroclor 1254, as suggested by the EPA [10]. For these reasons, DSHS did not differentiate among Aroclor mixtures. In this paper, PCBs or total PCBs are the sum of the concentration of each detected Aroclor mixtures in each sample. In the remaining paragraphs of this report, DSHS refers to these additive results as "PCBs."

Blue Crabs

PCBs were not observed in blue crabs – this despite the fact that this species contained small quantities of chlordane and dioxins. Thus, DSHS does not expect that consumption of blue crabs would result in adverse health effects from PCBs. The remainder of this section is therefore devoted to potential risks of systemic adverse health effects from consumption of fish from the HSC-UGB complex that contain PCBs.

Spotted Seatrout and Other Fish

The laboratory at DSHS detected PCBs in fish at all 2004 sampling sites (Table 3a). PCB levels at several sites exceeded the HAC_{nonca} for these compounds (0.047 mg/kg). The HAC_{nonca} was calculated from the RfD for Aroclor 1254 – a mixture of PCB congeners that are structurally similar to those of Aroclor 1248 and Aroclor 1260 – because no reference dose has been developed for Aroclor 1248 or Aroclor 1260. The EPA based the RfD for Aroclor 1254 on immune system dysfunctions in rhesus monkeys dosed for many months with that mixture of PCBs [10]. To derive the RfD for Aroclor 1254, the EPA divided the lowest observed adverse effects level (LOAEL) from the definitive study by a composite uncertainty factor of 300 – 10 for use of a LOAEL, 10 for human variability, and 3 for extrapolation from animals to humans.

PCBs in spotted seatrout collected from Site 1near the Houston Yacht Club marina yielded a hazard quotient (HQ) of 5.5. The highest-ranked HQ for PCBs in fish other than spotted seatrout occurred at the turning basin (mean concentration = 0.254 mg/kg; range nd-1.190), where the HQ was 5.4 (Table 5). The lowest HQ for fish containing PCBs was reported at Site 4 (tidal portion of the San Jacinto River), with an HQ of 0.65, followed closely by the HQ at Site 2 (HQ =0.7) and Site 3(1.0). The HQ for PCBs in all fish species from the Houston Yacht Club marina, which included spotted seatrout, was 2.2. Thus, consumption of fish from the HSC and UGB could pose a risk to human health from the presence of PCBs.

PCB concentrations and resultant hazards varied in fish from species to species at different sites as well. Black drum, red drum, channel catfish, southern flounder, and white bass did not contain measurable levels of PCBs (Tables 3b, 3c). Blue catfish from the turning basin averaged 0.513 mg/kg (HQ = 11.1); blue catfish from Site 4, with a mean concentration of 0.046 mg/kg, had a HQ of 1.2. The HQ for common carp from the turning basin was 2.4. A hybrid striped bass from Morgan's point contained PCBs at quantities sufficient to yield a HQ of 1.7, while a hybrid striped bass from Site 4 contained no measurable quantities of PCBs. The average HQ for hybrid striped bass was, therefore, 1.3 (DSHS used ½ the laboratory's PCB detection limit for the single sample of spotted seatrout that did not contain detectable levels of PCBs). The HQ for a smallmouth buffalo from Site 3 (near the Lynchburg Ferry crossing) was 4.4, while the smallmouth buffalo from the HSC turning basin contained no measurable PCBs, a finding that resulted in a composite HQ of 2.0 for smallmouth buffalo (data not shown). Spotted seatrout were collected from Sites 1, 2, and 4 (n=2 per site). Five of the six (6) spotted seatrout collected during the 2004 survey contained PCBs. The highest concentration of PCBs in spotted seatrout was observed in the two samples collected from Site 1 (mean concentration = 0.256 mg/kg ± 0.175). The hazard quotient for spotted seatrout from Site 1 resulting from the average concentration of PCBs in these samples was 5.0. The lowest concentration of PCBs in spotted seatrout was 0.065 mg/kg, found at Site 2, a concentration that yielded a hazard quotient of 1.6 in spotted seatrout from this site.

Spotted seatrout from Site 4 had a HQ of 1.87 (Table 6). In all, five of six seatrout sampled contained PCBs (Tables 3a, 3b, 3c). Three fish – two spotted seatrout from the Houston Yacht Club marina and one smallmouth buffalo from Site 3 near the Lynchburg Ferry crossing – reportedly contained both Aroclor 1248 and Aroclor 1260 (Tables 3a, 3b).

PCBs in blue catfish, spotted seatrout, common carp, smallmouth buffalo, and hybrid striped bass exceeded the HAC_{nonca} for PCBs (0.047 mg/kg), the comparison value by which risk assessors at DSHS assess PCBs for potential noncarcinogenic (systemic) effects. The average concentration of PCBs in combined fish species (0.095 ±0.21 mg/kg) was approximately twice the HAC_{nonca} for PCBs. At an average concentration of 0.513 mg/kg, the margin of exposure for PCBs in blue catfish from the HSC turning basin was greater than 10.

At 0.257 mg/kg, the average concentration of PCBs in spotted seatrout at the Houston Yacht Club marina site (HQ = 5.5) was three times the PCB level in spotted seatrout from Tabbs Bay-Morgan's Point (HQ = 1.6). The hazard quotient for PCBs in spotted seatrout from the San Jacinto River site was 1.89.

These data indicate that consumption of fish containing PCBs poses a risk to human health.

PCDFs and PCDDs (dioxin)

Twenty-eight of 35 fish and all blue crabs collected from the HSC-UGB system in 2004 contained polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans. Dioxins were highest in blue catfish, followed by smallmouth buffalo, blue crabs, hybrid striped bass, and common carp. All other species contained lower levels of dioxin. Dioxin exceeded the HAC_{nonca} in fish other than spotted seatrout collected at the San Jacinto River site and at the HSC turning basin. Dioxin concentration in spotted seatrout, while present, did not exceed the HAC_{nonca} for dioxin. Dioxin in blue crabs collected at Morgan's Point in Tabbs Bay slightly exceeded the HAC_{nonca} for dioxin, as indicated by the hazard quotient of 1.04, and in the two blue crab samples from the tidal portion of the San Jacinto River near I-19 (HQ=1.33). Although dioxin concentrations in blue crabs from the HSC and UGB may have decreased since the last time DSHS surveyed these contaminants in 1996, conclusions to this effect are premature – primarily because fluctuations in estuary environmental conditions could influence concentrations of dioxin in samples from this complex system due to the mobility of fish and shellfish in estuary systems. Dioxin in blue crabs from Site 2 (Morgan's Point in Tabbs Bay) and Site 4 (tidal portion of the San Jacinto River near I-10) exceeded the HAC_{nonca} value for this contaminant. These findings contribute to an overall hazard index for blue crabs that approaches 1.0. Thus, the DSHS concludes that consumption of blue crabs from waters covered by the present (2004) survey continues to pose a hazard to human health.

Cancer Risk from Consumption of Individual Contaminants in Fish and Blue Crabs from the Houston Ship Channel-Upper Galveston Bay Complex

Inorganic or Metallic Contaminants

Arsenic, cadmium, and lead in fish and blue crabs from the HSC or UGB did not exceed their respective HAC_{ca} values. Consumption of fish or blue crabs containing concentrations of these metalloid contaminants at concentrations near those observed in the samples from this estuary system would not be expected to result an in crease in the lifetime excess risk of cancer. Cancer potency factors (slope factors) are not available for copper (EPA Cancer Group D), mercury (Group C), selenium (Group D), or zinc (Group D) [10]. Thus, DSHS was unable to determine the probability of excess cancers from consuming fish from the HSC and UGB that contain copper, mercury, selenium, or zinc. It is also important to note that copper, selenium, and zinc are essential trace elements, necessary for health [20].

Organic Contaminants

DSHS toxicologists calculated theoretical lifetime excess cancer risks from spotted seatrout, other fish, or blue crabs from the HSC, tidal portions of the San Jacinto River and UGB. Table 6 contains those risks calculated by DSHS. Table 6 also shows estimated consumption rates (in meals per week) for an average adult. The theoretical increase in risk of cancer from consuming spotted seatrout from any one of the sampled sites does not exceed 1 in 10,000 persons equally exposed to the toxicants but excess lifetime risk of cancer from exposure to toxicants may vary by one or more orders of magnitude in either direction. Thus, excess risk from consumption of spotted seatrout, for instance, could be as high as one in 2000 or as low as 1 in 117,000 equally exposed persons. Excess cancer risk from consuming other fish or blue crab from any sampled site within the HSC or the UGB that contain chlorinated pesticides, PCBs, or dioxin does not exceed 1 in 10,000 equally exposed persons. Again, however, one must temper conclusions from such calculations by the variability of cancer risk calculations, which may differ by orders of magnitude above or below any calculation of theoretical excess risk of cancer [10].

Cumulative Systemic Adverse Health Effects and Cumulative Cancer Risk from Consumption of Fish or Blue Crabs from the Houston Ship Channel or Upper Galveston Bay

Inorganic or Metallic Contaminants

Fish and blue crabs from the Houston Ship Channel and Upper Galveston Bay contained no metallic contaminants with the same mechanism of action or that attack the same target organ. Thus, consumption of fish from this estuary that contain metallic contaminants should not result in cumulative systemic adverse effects. The cumulative risk of cancer from consuming fish containing carcinogenic metallic contaminants did not exceed DSHS guidelines for protection of public health (1 excess cancer in 10,000 equally exposed individuals). Consumption of fish or blue crabs from the HSC or UGB that contain multiple metallic contaminants at concentrations similar to those measured thus would pose no significant increase in the lifetime risk of cancer.

Organic Contaminants

A hazard index (HI) exceeding 1.0 may signify a hazard from consumption of contaminated fish or shellfish. The DSHS generated hazard indices (HI's) for combinations of organochlorine pesticides, dioxin, and PCBs in spotted seatrout, other fish, and blue crabs (Table 6) from sites along the HSC and within UGB. HI's for spotted seatrout collected from Sites 1, 2, and 4 exceeded 1.0, due, primarily, to the presence of PCBs. The contribution of chlorinated pesticides and dioxin to the HI's for spotted seatrout at each site was modest, with most of the hazard attributed to PCB contamination. DSHS therefore concludes that consumption of spotted seatrout from any site sampled in this survey poses a hazard to human health. Similarly, hazard indices for other fish exceeded 1.0 at four of five sites and were below 1.0 only at Site 1, near the Houston Yacht Club marina. The highest HI for fish other than spotted seatrout was 7.9 at the HSC turning basin. Thus, consumption of fish other than spotted seatrout also poses a hazard to human health (Table 6).

Hazard indices for blue crab samples varied with the sampling site. The HI for blue crabs from Sites 2 and 4 was greater than 1.0 (2 composite samples per site). The HI for blue crabs (n=10) from all sites (n=10) was 0.9, an index perilously close to 1.0. DSHS concludes that consumption of blue crabs from the HSC could pose a hazard to human health.

The cumulative theoretical lifetime risk of cancer is greater than 1 in 10,000 at the HSC Yacht Club marina (Site 1) and at the HSC turning basin (Site 5). Most of the calculated increase in cancer risk is attributable to the presence of PCBs in multiple fish species. Table 6 shows an increase in the overall risk of cancer throughout the survey area from consumption of species other than spotted seatrout (Table 6, "Other Fish"). Thus, consumption of fish from the survey area could increase the relative risk of cancer.

Consumption of blue crabs, alone, from these water bodies does not increase the theoretical lifetime risk of cancer (Table 6).

Conclusions

DSHS toxicologists prepare quantitative risk characterizations to determine public health hazards from consumption of fish and shellfish harvested from Texas water bodies by recreational or subsistence fishers, and, if indicated, may suggest risk management strategies to DSHS risk managers who include the Texas Commissioner of State Health Services and others.

This study is limited by small sample sizes for different species of fish and blue crabs from each sampling site and by the dynamic nature of the estuary. Past samples of spotted seatrout, for instance, have not shown a preponderance of PCBs in this species, yet PCBs dominate the present sample (DSHS historical data). In the past, dioxins have been prevalent contaminants of catfish and blue crabs, yet in the present data set dioxin contributes only modestly to the toxicity associated with consumption of blue crabs and catfish from the HSC or UGB. Environmental conditions and hydrology vary considerably in this estuary, limiting species and sizes of samples available for collection at different times of the year. Sampling limitations consequently may limit conclusions about present samples from this water body as well as any prognostic value of historical trends – or the lack thereof – in data from this complex system. These limitations not withstanding, the DSHS concludes from the results of the present quantitative risk characterization

1. That, based on samples collected in 2004 from the Houston Ship Channel and Upper Galveston Bay, consumption of spotted seatrout and other species of fish from the HSC or UGB continues to present health hazards to those who consume seafood from this estuary regularly or over a long period. These hazards primarily result from polychlorinated biphenyls observed in the fish. Dioxins and chlorinated pesticides contribute modestly to the health hazards from consumption of fish from the HSC or UGB from as far south as the Houston Yacht Club marina.

2. That consumption of blue crabs from the HSC continues to pose a hazard to human health from dioxins.

3. That polychlorinated biphenyls in spotted seatrout from as far south as the Houston Yacht Club marina in UGB is disturbing because spotted seatrout are one of the most sought-after sport fishes along the Texas Coast, contributing significantly to recreational fishing in the Galveston Bay complex.

Public Health Implications

Consumption of fish and blue crab from the Houston Ship Channel - including tidal portions of the San Jacinto River - and from areas of Upper Galveston Bay **poses a hazard to human health** due to the presence of polychlorinated biphenyls, dioxins, and other chlorinated organic contaminants in the fish and blue crabs.

Recommendations

Risk managers at the Texas Department of State Health Services (DSHS) have established criteria for issuing fish consumption advisories based on approaches suggested by the EPA [22]. Confirmation through risk characterization that consumption of four or fewer meals per month (adults: eight ounces per meal; children: four ounces per meal) would result in exposures to toxicants in excess of DSHS health-based guidelines, risk managers may wish to recommend consumption advice for fish from the water body in question. Possession bans are enforceable under subchapter D of the Texas Health and Safety Code, part 436.061(a) [23]. Consumption advisories are not enforceable by law and carry no penalties for noncompliance. Nonetheless, DSHS consumption advisories inform the public of health hazards from consuming contaminated fish or shellfish so that members of the public can make informed decisions about eating environmentally contaminated fish or shellfish. As an alternative, however, the department may ban possession of fish from the affected water body. The SALG and the Environmental and Injury Epidemiology and Toxicology Branch (EIETB) of DSHS conclude from the data in this risk characterization that consuming fish from the HSC (including the tidal portion of the San Jacinto River and Tabbs Bay) or UGB that contain PCBs and other toxicants would pose a threat to public health. Therefore, DSHS recommends

1. That DSHS continues the existing advisory on consumption of blue crabs and catfish from the HSC and contiguous waters, including UGB and Tabbs Bay.

2. That DSHS continues the advisory for the HSC and the San Jacinto River that includes all species of fish due to the presence of pesticides and PCBs in concentrations exceeding health-based assessment comparison values (HAC values) and exhibiting hazard quotients or hazard indices in excess of 1.0.

3. That DSHS modifies consumption advice for the HSC – including the tidal portion of the San Jacinto River, Tabbs Bay, and all contiguous waters – and UGB to inform people that health risks may be associated with consumption of spotted seatrout containing polychlorinated biphenyls (PCBs), chlorinated pesticides, or dioxin. Adverse health effects associated with long-term or regular ingestion of PCBs, chlorinated pesticides, or dioxins may include liver dysfunction, chloracne (dioxin), immunological effects, reproductive or developmental effects, and cancer.

4. That the DSHS rapidly conduct additional fish tissue monitoring to determine the extent of PCB contamination in spotted seatrout throughout the Galveston Bay complex. Because spotted seatrout is a primary target of recreational anglers, determining the extent of PCB contamination also has economic implications in addition to public health and regulatory implications.

5. That, as resources become available, DSHS continues to monitor fish and blue crabs from the Galveston Bay complex for PCBs, dioxin, and other contaminants.

Communication of the Possibility of Health Risks from Consumption of Contaminated Fish or Shellfish

The DSHS publishes fish consumption advisories and bans in a booklet available to the public through the SALG: (512-719-0215) [24]. The SALG also posts this information on the Internet at URL: http://www.DSHS.state.tx.us/bfds/ssd. SALG regularly updates its web site. Some risk characterizations for water bodies surveyed by the DSHS may also be available from the ATSDR (http://www.atsdr.cdc.gov/HAC/PHA/region6.html). The DSHS provides the EPA (URL: http://fish.rti.org), the TCEQ (URL: http://www.tceq.state.tx.us), and the TPWD (URL: 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 fish consumption advisories and bans in an official hunting and fishing regulations booklet [4], available at some state parks and at establishments that sell fishing licenses.

Readers may direct questions about the scientific information or recommendations in this risk characterization to the SALG (512-719-0215) or the EIETB (512-458-7269) at the DSHS. Toxicological information on a variety of contaminants in seafood and other environmental media may also be obtained from the ATSDR Division of Toxicology by telephoning ATSDR at the toll free number (800-447-1544) or from the ATSDR website (URL: http://www.atsdr.cdc.gov).

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TABLES

Table 1a. Inorganic Contaminants (mg/kg) in Fish from the Houston Ship Channel (HSC) and Upper Galveston Bay, 2004.

Contaminant	# Detected/ # Sampled	Mean Concentration ± S.D. (Min-Max)[1]	Health Assessment Comparison Value[2]	Basis for Comparison Value
Upper Galveston Bay – Yacht Club Marina (Site 1)				
Copper	6/7	0.209±0.050 (nd-0.270)	333	NAS UL: 0.143 mg/kg-day
Lead	1/7	0.039±0.019 (nd-0.067)	--------	None Available
Mercury	4/7	0.053±0.024 (nd –0.083)	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg-day
Selenium	7/7	1.13 ±0.543 (0.618-2.02)	6	EPA chronic oral RfD: 0.005mg/kg-day
Zinc	7/7	1.76±0.225 (1.57-2.18)	700	EPA chronic oral RFD: 0.3 mg/kg-day
Upper Galveston Bay- Tabbs Bay / Morgan's Point (Site 2)				
Copper	4/7	0.159±0.096 (nd-0.334)	333	NAS UL: 0.143 mg/kg-day
Mercury	7/7	0.163±0.085 (0.067-0.287)	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg-day
Selenium	7/7	0.937±0.777 (0.124-2.28)	6	EPA chronic oral RfD: 0.005 mg/kg-day
Zinc	7/7	1.85±0.277 (1.61-2.24)	700	EPA chronic oral RFD: 0.3 mg/kg-day
HSC-Lynchburg ferry (Site 3)				
Copper	6/7	0.203±0.073 (nd-0.294)	333	NAS UL: 0.143 mg/kg-day
Lead	2/7	0.034±0.018 (nd-0.063)	--------	None Available
Mercury	3/7	0.188±0.300 (nd-0.853)	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg-day
Selenium	7/7	0.401±0.338 (0.199-1.14)	6	EPA chronic oral RfD: 0.005mg/kg-day
Zinc	7/7	2.14±0.49 (1.57-2.95)	700	EPA chronic oral RFD: 0.3 mg/kg-day

Table 1b. Inorganic Contaminants (mg/kg) in Fish from the Houston Ship Channel (HSC) and Upper Galveston Bay (UGB), 2004.

Contaminant	# Detected/ # Sampled	Mean Concentration ± S.D. (Min-Max) [1]	Health Assessment Comparison Value[2]	Basis for Comparison Value
Tidal Portions, San Jacinto River near I-10 (Site 4)				
Copper	6/7	0.141±0.060 (nd-0.214)	333	NAS UL: 0.143 mg/kg-day
Lead	1/7	0.049±0.044 (nd-0.130)	--------	None Available
Mercury	7/7	0.192±0.117 (nd-0.426)	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg/day
Selenium	7/7	0.794±0.499 (0.234-1.44)	6	EPA chronic oral RfD: 0.005mg/kg-day
Zinc	7/7	2.86±0.83 (2.13-4.21)	700	EPA chronic oral RFD: 0.3 mg/kg-day
HSC- Turning Basin (Site 5)				
Arsenic	1/7	0.022± 0.010 (nd-0.037)	0.7	EPA chronic oral RfD: 0.0003 mg/kg-day
			0.36	EPA Oral Slope Factor: 1.5 per mg/kg-day
Copper	6/7	0.307±0.114 (nd-0.502)	333	NAS UL: 0.143 mg/kg-day
Lead	2/7	0.056±0.057 (nd-0.145)	--------	None Available
Mercury	4/7	0.107±0.082 (nd-0.260)	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg-day
Selenium	7/7	0.465±0.248 (0.22-0.917)	6	EPA chronic oral RfD: 0.005mg/kg-day
Zinc	7/7	3.99±2.60 (1.67-9.05)	700	EPA chronic oral RFD :0.3 mg/kg-day

Table 1c. Inorganic Contaminants (mg/kg) in Blue Crabs from the Houston Ship Channel (HSC) and Upper Galveston Bay, 2004.

Contaminant	# Detected/ # Sampled	Mean Concentration ± S.D. (Min-Max) [1]	Health Assessment Comparison Value[2]	Basis for Comparison Value
Upper Galveston Bay – Yacht Club Marina (Site 1)				
Arsenic	1/2	0.034± 0.006 (nd, 0.038)	0.7	EPA chronic oral RfD: 0.0003 mg/kg-day
			0.36	EPA Oral Slope Factor: 1.5 per mg/kg-day
Cadmium	1/2	0.053± 0.063 (nd, 0.097)	0.47	ATSDR oral chronic MRL: 0.0002 mg/kg-day
Copper	2/2	6.87± 3.10 (4.67, 9.06)	333	NAS UL: 0.143 mg/kg-day
Mercury	1/2	0.057± 0.048 (nd, 0.092)	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg-day
Selenium	2/2	1.32± 0.141 (1.22, 1.42)	6	EPA chronic oral RfD: 0.005mg/kg-day
Zinc	2/2	39.6±1.20 (38.7, 40.4)	700	EPA chronic oral RFD: 0.3 mg/kg-day
Upper Galveston Bay- Tabbs Bay / Morgan's Point (Site 2)				
Arsenic	2/2	0.055± 0.005 (nd, 0.06)	0.7	EPA chronic oral RfD: 0.0003 mg/kg-day
			0.36	EPA Oral Slope Factor: 1.5 per mg/kg-day
Cadmium	1/2	0.014± 0.003 (nd, 0.016)	0.47	ATSDR oral chronic MRL: 0.0002 mg/kg-day
Copper	2/2	8.17± 0.255 (7.99, 8.35)	333	NAS UL: 0.143 mg/kg-day
Mercury	2/2	0.058± 0.008 (0.052, 0.064)	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg-day
Selenium	2/2	1.55± 0.283 (1.35, 1.75)	6	EPA chronic oral RfD: 0.005mg/kg-day
Zinc	2/2	42.5± 0.424 (42.2, 42.8)	700	EPA chronic oral RFD: 0.3 mg/kg-day
HSC-Lynchburg Ferry (Site 3)				
Arsenic	1/2	0.043±0.019 (nd, 0.056)	0.7	EPA chronic oral RfD: 0.0003 mg/kg-day
			0.36	EPA Oral Slope Factor: 1.5 per mg/kg-day
Cadmium	1/2	0.023± 0.012 (nd, 0.032)	0.47	ATSDR oral chronic MRL: 0.0002 mg/kg-day
Copper	2/2	11.95± 0.495 (11.6, 12.3)	333	NAS UL: 0.143 mg/kg-day
Lead	1/2	0.023± 0.008 (nd, 0.129)	-------	None Available
Mercury	2/2	0.058± 0.010 (0.051, 0.065)	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg-day
Selenium	2/2	1.13± 0.250 (0.956, 1.31)	6	EPA chronic oral RfD: 0.005mg/kg-day
Zinc	2/2	36.8± 1.98 (35.4, 38.2)	700	EPA chronic oral RFD: 0.3 mg/kg-day

Table 1d. Inorganic Contaminants (mg/kg) in Blue Crabs from the Houston Ship Channel (HSC) and Upper Galveston Bay, 2004.				
Contaminant	**# Detected/ # Sampled**	**Mean Concentration ± S.D. (Min-Max)** [1]	**Health Assessment Comparison Value**[2]	**Basis for Comparison Value**
Tidal Portions, San Jacinto River near I-10 (Site 4)				
Cadmium	1/2	0.019± 0.009 (nd, 0.025)	0.47	ATSDR oral chronic MRL: 0.0002 mg/kg-day
Copper	2/2	8.16± 0.460 (7.83, 8.48)	333	NAS UL: 0.143 mg/kg-day
Mercury	2/2	0.077± 0.001 (0.076, 0.078)	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg-day
Selenium	2/2	0.929± 0.037 (0.903, 0.955)	6	EPA chronic oral RfD: 0.005mg/kg-day
Zinc	2/2	30.0±0.884 (29.4, 30.6)	700	EPA chronic oral RFD: 0.3 mg/kg-day
HSC- Turning Basin (Site 5)				
Cadmium	2/2	0.043± 0.011 (0.035, 0.051)	0.47	ATSDR oral chronic MRL: 0.0002 mg/kg-day
Copper	2/2	7.38± 1.21 (6.52, 8.23)	333	NAS UL: 0.143 mg/kg-day
Lead	1/2	0.095± 0.116 (nd, 0.177)	--------	None Available
Mercury	2/2	0.091±0.019 (0.078, 0.105)	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg-day
Selenium	2/2	0.942±0.02 (0.928, 0.956)	6	EPA chronic oral RfD: 0.005mg/kg-day
Zinc	2/2	29.7±3.11 (27.5, 31.9)	700	EPA chronic oral RFD: 0.3 mg/kg-day

Table 2a. Pesticide Contaminants (mg/kg) Detected in Fish from the Houston Ship Channel (HSC) and Upper Galveston Bay, 2004.

Contaminant	# Detected/ # Sampled	Mean Concentration ± S.D. (Min-Max)[1]	Health Assessment Comparison Value[2]	Basis for Comparison Value
Upper Galveston Bay – Yacht Club Marina (Site 1)				
Chlordane	5/7	0.042±0.053 (nd-0.140)	1.6	EPA slope factor: 0.35 per mg/kg-day
			1.17	EPA chronic oral RfD: 0.0005 mg/kg-day
p,p'-DDE	2/7	0.004±0.003 (nd-0.009)	1.6	EPA slope factor: 0.34 per mg/kg-day
p,p'-DDD	2/7	0.008±0.004 (nd-0.015)	2.3	EPA slope factor: 0.24 per mg/kg-day
Heptachlor epoxide	1/7	0.003 ±0.002 (nd-0.006)	0.06	EPA Slope Factor: 9.1 per mg/kg-day
			0.03	EPA chronic oral RfD: 0.000013 mg/kg-day
Hexachlorobenzene	2/7	0.002±0.002 (nd-0.006)	0.34	EPA Slope Factor: 1.6 per mg/kg-day
			1.87	EPA chronic oral RfD: 0.0008 mg/kg-day
Upper Galveston Bay- Tabbs Bay / Morgan's Point (Site 2)				
Chlordane	5/7	0.022±0.019 (nd-0.051)	1.6	EPA slope factor: 0.35 per mg/kg-day
			1.17	EPA chronic oral RfD: 0.0005 mg/kg-day
p,p'-DDE	1/7	0.003±0.002 (nd-0.009)	1.6	EPA slope factor: 0.34 per mg/kg-day
p,p'-DDD	1/7	0.006±0.002 (nd-0.011)	2.3	EPA slope factor: 0.24 per mg/kg-day
Hexachlorobenzene	1/7	0.001±0.0004 (nd-0.002)	0.34	EPA Slope Factor: 1.6 per mg/kg-day
			1.87	EPA chronic oral RfD: 0.0008 mg/kg-day
HSC-Lynchburg ferry (Site 3)				
Chlordane	4/7	0.045±0.048 (nd-0.120)	1.6	EPA slope factor: 0.35 per mg/kg-day
			1.17	EPA chronic oral RfD: 0.0005 mg/kg-day
p,p'-DDE	1/7	0.004±0.005 (nd-0.015)	1.6	EPA slope factor: 0.34 per mg/kg-day
p,p'-DDD	1/7	0.008±0.008 (nd-0.027)	2.3	EPA slope factor: 0.24 per mg/kg-day
Heptachlor epoxide	2/7	0.003±0.002 (nd-0.008)	0.06	EPA Slope Factor: 9.1 per mg/kg-day
			0.03	EPA chronic oral RfD: 0.000013 mg/kg-day
Hexachlorobenzene	1/7	0.001±0.0005 (nd-0.002)	0.34	EPA Slope Factor: 1.6 per mg/kg-day
			1.87	EPA chronic oral RfD: 0.0008 mg/kg-day

[1] *Minimum concentration to Maximum concentration (to calculate the range, subtract the minimum concentration from the maximum concentration)*

[2] *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* $1x10^{-4}$

[3] *nd-not detected at concentrations above the laboratory's reporting limit*

Table 2b. Pesticide Contaminants (mg/kg) Detected in Fish from the Houston Ship Channel (HSC) and Upper Galveston Bay (UGB), 2004.

Contaminant	# Detected/ # Sampled	Mean Concentration ± S.D. (Min-Max)[1]	Health Assessment Comparison Value[2]	Basis for Comparison Value
Tidal Portions, San Jacinto River near I-10 (Site 4)				
Chlordane	5/7	0.036±0.025 (nd-0.076)	1.6	EPA slope factor: 0.35 per mg/kg-day
			1.17	EPA chronic oral RfD: 0.0005 mg/kg-day
p,p'-DDE	3/7	0.004±0.002 (nd-0.006)	1.6	EPA slope factor: 0.34 per mg/kg-day
p,p'-DDD	1/7	0.006±0.003 (nd-0.012)	2.3	EPA slope factor: 0.24 per mg/kg-day
Heptachlor epoxide	2/7	0.003±0.001 (nd-0.005)	0.06	EPA Slope Factor: 9.1 per mg/kg-day
			0.03	EPA chronic oral RfD: 0.000013 mg/kg-day
Hexachlorobenzene	2/7	0.001±0.0009 (nd-0.003)	0.34	EPA Slope Factor: 1.6 per mg/kg-day
			1.87	EPA chronic oral RfD: 0.0008 mg/kg-day
HSC- Turning Basin (Site 5)				
Chlordane	7/7	0.439±0.351 (0.072-0.980)	1.6	EPA slope factor: 0.35 per mg/kg-day
			1.17	EPA chronic oral RfD: 0.0005 mg/kg-day
p,p'-DDE	6/7	0.017±0.018 (nd-0.054)	1.6	EPA slope factor: 0.34 per mg/kg-day
p,p'-DDD	6/7	0.041±0.032 (nd-0.095)	2.3	EPA slope factor: 0.24 per mg/kg-day
p,p'-DDT	1/7	0.006±0.003 (nd-0.013)	1.6	EPA slope factor: 0.34 per mg/kg-day
Dieldrin	5/7	0.012±0.007 (nd-0.020)	0.034	EPA slope factor: 16 per mg/kg-day
			0.117	EPA chronic oral RfD: 0.00005 mg/kg-day
Heptachlor epoxide	6/7	0.010±0.009 (nd-0.027)	0.06	EPA Slope Factor: 9.1 per mg/kg-day
			0.03	EPA chronic oral RfD: 0.000013 mg/kg-day
Hexachlorobenzene	4/7	0.003±0.002 (nd-0.007)	0.34	EPA Slope Factor: 1.6 per mg/kg-day
			1.87	EPA chronic oral RfD: 0.0008 mg/kg-day

Table 2c. Pesticide Contaminants (mg/kg) Detected in Blue Crabs from the Houston Ship Channel (HSC) and Upper Galveston Bay, 2004.

Contaminant	# Detected/ # Sampled	Mean Concentration ± S.D. (Min-Max)[1]	Health Assessment Comparison Value[2]	Basis for Comparison Value
Upper Galveston Bay – Yacht Club Marina (Site 1)				
Chlordane	0/2	nd	1.6	EPA slope factor: 0.35 per mg/kg-day
			1.17	EPA chronic oral RfD: 0.0005 mg/kg-day
Upper Galveston Bay- Tabbs Bay / Morgan's Point (Site 2)				
Chlordane	2/2	0.011±0.0007 (0.010, 0.011)	1.6	EPA slope factor: 0.35 per mg/kg-day
			1.17	EPA chronic oral RfD: 0.0005 mg/kg-day
HSC-Lynchburg ferry (Site 3)				
Chlordane	2/2	0.019±0.006 (0.014, 0.023)	1.6	EPA slope factor: 0.35 per mg/kg-day
			1.17	EPA chronic oral RfD: 0.0005 mg/kg-day
Tidal Portions, San Jacinto River near I-10 (Site 4)				
Chlordane	2/2	0.017±0.006 (0.013, 0.021)	1.6	EPA slope factor: 0.35 per mg/kg-day
			1.17	EPA chronic oral RfD: 0.0005 mg/kg-day
HSC- Turning Basin (Site 5)				
Chlordane	2/2	0.032±0.025 (0.014, 0.050)	1.6	EPA slope factor: 0.35 per mg/kg-day
			1.17	EPA chronic oral RfD: 0.0005 mg/kg-day

Table 3a. Polychlorinated Biphenyls (PCBs) (mg/kg) Detected in Fish from the Houston Ship Channel (HSC) and Upper Galveston Bay, 2004.

Contaminant	# Detected/ # Sampled	Mean Concentration ± S.D. (Min-Max)[1]	Health Assessment Comparison Value[2]	Basis for Comparison Value
Upper Galveston Bay – Yacht Club Marina (Site 1)				
Aroclor 1248	2/7	0.042±0.093 (nd-0.250)	0.047	EPA chronic oral RfD: 0.00002 mg/kg-day
Aroclor 1260	2/7	0.031±0.05 (nd-0.130)		
Total PCBs	2/7	0.088±0.136 (nd-0.380)	0.27	EPA slope factor: 2.0 per mg/kg-day
Upper Galveston Bay- Tabbs Bay / Morgan's Point (Site 2)				
Aroclor 1260	2/7	0.024±0.036 (nd-0.090)	0.047	EPA chronic oral RfD: 0.00002 mg/kg-day
Total PCBs	2/7	0.044±0.036 (nd-0.110)	0.27	EPA slope factor: 2.0 per mg/kg-day
HSC-Lynchburg ferry (Site 3)				
Aroclor 1248	1/7	0.008±0.02 (nd-0.055)	0.047	EPA chronic oral RfD: 0.00002 mg/kg-day
Aroclor 1260	1/7	0.021±0.057 (nd-0.150)	0.047	
Total PCBs	1/7	0.046±0.070 (nd-0.205)	0.27	EPA slope factor: 2.0 per mg/kg-day
Tidal Portions, San Jacinto River near I-10 (Site 4)				
Aroclor 1260	3/7	0.027±0.034 (nd-0.072)	0.047	EPA chronic oral RfD: 0.00002 mg/kg-day
Total PCBs	3/7	0.047±0.033 (nd-0.092)	0.27	EPA slope factor: 2.0 per mg/kg-day
HSC- Turning Basin (Site 5)				
Aroclor 1260	3/7	0.234±0.429 (nd-1.170)	0.047	EPA chronic oral RfD: 0.00002 mg/kg-day
Total PCBs	3/7	0.254±0.429 (nd-1.190)	0.27	EPA slope factor: 2.0 per mg/kg-day

[1] *Minimum concentration to maximum concentration; (range = maximum conc - minimum conc)*

[2] *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* $1x10^{-4}$

[3] *nd-not detected at concentrations above the laboratory's reporting limit*

Table 3b. Polychlorinated Biphenyls (PCBs) (Aroclor 1248, Aroclor 1260, and Total PCBs, mg/kg) Detected in Fish from the Houston Ship Channel (HSC) and Upper Galveston Bay, 2004.

Species*	# Detected/ # Sampled	Mean Concentration ± S.D. (Min-Max)[1]	Health Assessment Comparison Value[2]	Basis for Comparison Value
Aroclor 1248				
Spotted seatrout	2/6	0.062±0.092 (nd-0.250)	0.047 0.27	EPA chronic oral RfD: 0.00002 mg/kg-day EPA slope factor: 2.0 per mg/kg-day
Smallmouth buffalo	1/3	0.018±0.032 (nd-0.055)		
All fish species	3/35	0.015±0.043 (nd-0.250)		
Aroclor 1260				
Blue Catfish	3/10	0.153±0.370 (nd-1.170)	0.047 0.27	EPA chronic oral RfD: 0.00002 mg/kg-day EPA slope factor: 2.0 per mg/kg-day
Common carp	1/2	0.080±0.113 (nd-0.160)		
Spotted seatrout	5/6	0.078±0.036 (nd-0.130)		
Smallmouth buffalo	1/3	0.050±0.087 (nd-0.150)		
Hybrid striped bass	1/2	0.030±0.042 (nd-0.060)		
All fish species	11/35	0.068±0.203 (nd-1.170)		
Total PCBs				
Blue catfish	3/10	0.173±0.370 (nd-1.190)	0.047 0.27	EPA chronic oral RfD: 0.00002 mg/kg-day EPA slope factor: 2.0 per mg/kg-day
Spotted seatrout	5/6	0.140±0.122 (nd-0.380)		
Common carp	1/2	0.100±0.113 (nd-0.180)		
Smallmouth buffalo	1/3	0.082±0.107 (nd-0.205)		
Hybrid striped bass	1/2	0.050±0.042 (nd-0.080)		
All fish species	11/35	0.096±0.209 (nd-1.190)		

* Sampled fish species not listed in the table did not contain detectable levels of PCBs.

Table 3c. Polychlorinated Biphenyls (Total PCBs; mg/kg) Detected in Fish (shown by species and site) from the Houston Ship Channel (HSC) and Upper Galveston Bay (UGB), 2004.

Species*	# Detected/ # Sampled	Mean Concentration ± S.D. (Min-Max)[1]	Health Assessment Comparison Value[2]	Basis for Comparison Value
Upper Galveston Bay – Yacht Club Marina (Site 1)				
Spotted seatrout	2/2	0.257±0.175 (0.133, 0.380)	0.047 0.27	EPA chronic oral RfD: 0.00002 mg/kg-day EPA slope factor: 2.0 per mg/kg-day
Upper Galveston Bay- Tabbs Bay / Morgan's Point (Site 2)				
Hybrid striped bass	1/1	0.080	0.047 0.27	EPA chronic oral RfD: 0.00002 mg/kg-day EPA slope factor: 2.0 per mg/kg-day
Spotted seatrout	1/2	0.075±0.05 (nd-0.110)		
HSC-Lynchburg ferry (Site 3)				
Smallmouth buffalo	1/1	0.205	0.047 0.27	EPA chronic oral RfD: 0.00002 mg/kg-day EPA slope factor: 2.0 per mg/kg-day
Tidal Portions, San Jacinto River near I-10 (Site 4)				
Blue catfish	1/2	0.046±0.037 (nd, 0.072)	0.047 0.27	EPA chronic oral RfD: 0.00002 mg/kg-day EPA slope factor: 2.0 per mg/kg-day
Spotted seatrout	2/2	0.088±0.006 (0.083, 0.092)		
HSC- Turning Basin (Site 5)				
Blue catfish	2/3	0.513±0.61 (nd-1.190)	0.047 0.27	EPA chronic oral RfD: 0.00002 mg/kg-day EPA slope factor: 2.0 per mg/kg-day[1]
Common carp	1/2	0.100±0.13 (nd, 0.180)		

* Sampled fish species not listed in the table did not contain detectable levels of PCBs.

Table 4a. Dioxin/Furan Toxic Equivalent Concentration (TEC) (pg/g) Detected in Fish and Blue Crabs from the Houston Ship Channel (HSC) and Upper Galveston Bay, 2004.

Species	# Detected/ # Sampled	Mean TEC ± S.D. (Min-Max)[1]	Health Assessment Comparison Value[2] (pg/g)	Basis for Comparison Value
Upper Galveston Bay – Yacht Club Marina (Site 1)				
Blue crab	2/2	1.165± 0.837 (0.574, 1.757)	2.33 3.49	ATSDR chronic oral MRL: 1.0 pg/kg –day EPA slope factor: 1.56 X 10^{-4} per pg/kg –day
Spotted seatrout	1/2	0.958± 1.098 (nd, 1.734)		
Black drum	2/2	0.168± 0.093 (0.102, 0.234)		
Red drum	1/2	0.123± 0.036 (nd, 0.148)		
Southern flounder	0/1	nd		
All fish species	4/7	0.384± 0.597 (0.098-1.734)		
All species	6/9	0.558± 0.698 (0.098-1.757)		
Upper Galveston Bay- Tabbs Bay / Morgan's Point (Site 2)				
Blue crab	2/2	2.419± 0.245 (2.245, 2.592)	2.33 3.49	ATSDR chronic oral MRL: 1.0 pg/kg –day EPA slope factor: 1.56 X 10^{-4} per pg/kg –day
Blue catfish	2/2	0.229± 0.028 (0.209, 0.248)		
Spotted seatrout	2/2	0.201± 0.001 (0.200, 0.201)		
Hybrid striped bass	1/1	1.525		
Black drum	1/2	0.184± 0.131 (nd, 0.277)		
All fish species	6/7	0.393± 0.502 (0.092-1.525)		
All species	8/9	0.843± 0.997 (0.092-2.592)		
HSC-Lynchburg ferry (Site 3)				
Blue crab	2/2	2.247± 0.232 (2.083, 2.411)	2.33 3.49	ATSDR chronic oral MRL: 1.0 pg/kg –day EPA slope factor: 1.56 X 10^{-4} per pg/kg –day
Blue catfish	3/3	2.764± 2.673 (0.967-5.837)		
Smallmouth buffalo	1/1	3.474		
White bass	1/1	1.254		
Black drum	1/1	0.132		
Channel catfish	0/1	nd		
All fish species	6/7	1.916± 2.051 (0.132-5.837)		
All species	8/9	1.990± 1.784 (0.132-5.837)		

[1] *Minimum concentration to maximum concentration; (range = maximum conc - minimum conc)*

[2] *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 $1x10^{-4}$*

[3] *nd-not detected at concentrations above the laboratory's reporting limit*

Table 4b. Dioxin/Furan Toxic Equivalent Concentration (TEC) (pg/g) Detected in Fish and Blue Crabs from the Houston Ship Channel (HSC) and Upper Galveston Bay, 2004.

Species	# Detected/ # Sampled	Mean TEC ± S.D. (Min-Max)[1]	Health Assessment Comparison Value[2]	Basis for Comparison Value
Tidal Portions, San Jacinto River near I-10 (Site 4)				
Blue crab	2/2	3.107± 0.013 (3.098, 3.116)	2.33 3.49	ATSDR chronic oral MRL: 1.0 pg/kg-day EPA slope factor: 1.56 X 10^{-4} per pg/kg-day
Blue catfish	2/2	6.040± 4.164 (3.096, 8.985)		
Spotted seatrout	1/2	0.233± 0.161 (nd, 347)		
Hybrid striped bass	1/1	1.541		
Red drum	1/2	0.097± 0.006 (nd, 0.102)		
All fish species	5/7	2.040± 3.258 (0.093-8.985)		
All species	7/9	2.277± 2.860 (0.093-8.985)		
HSC- Turning Basin (Site 5)				
Blue crab	2/2	1.216± 0.209 (1.068, 1.363)	2.33 3.49	ATSDR chronic oral MRL: 1.0 pg/kg-day EPA slope factor: 1.56 X 10^{-4} per pg/kg-day
Blue catfish	3/3	5.491± 2.113 (3.370- 7.596)		
Common Carp	2/2	1.461± 0.574 (1.056, 1.867)		
Smallmouth buffalo	2/2	1.673± 0.840 (1.079, 2.267)		
All fish species	7/7	3.249± 2.464 (1.056-7.596)		
All species	9/9	2.797± 2.315 (1.056-7.596)		
All Sites Combined				
Blue crab	10/10	2.031± 0.843 (0.574- 3.116)	2.33 3.49	ATSDR chronic oral MRL: 1.0 pg/kg-day EPA slope factor: 1.56 X 10^{-4} per pg/kg-day
Blue catfish	10/10	3.730± 3.125 (0.209- 8.985)		
Common carp	2/2	1.461± 0.574 (1.056, 1.867)		
Hybrid striped bass	2/2	1.532± 0.011 (1.525, 1.541)		
Smallmouth buffalo	3/3	2.273± 1.198 (1.079- 3.474)		
White bass	1/1	1.254		
Spotted seatrout	4/6	0.464± 0.627 (nd - 1.734)		
Black drum	4/5	0.167± 0.083 (nd - 0.277)		
Red drum	2/4	0.110±0.026 (nd - 0.148)		
All fish species	28/35	1.597± 2.240 (nd - 8.985)		
All species	38/45	1.693± 2.014 (nd - 8.985)		

[1] *Minimum concentration to maximum concentration; (range = maximum conc - minimum conc)*

[2] *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* $1x10^{-4}$

[3] *nd-not detected at concentrations above the laboratory's reporting limit*

Table 5. Systemic effects possible from consuming fish or blue crabs collected from the Houston Ship Channel, tidal portions of the San Jacinto River, or Upper Galveston Bay in 2004. The table lists hazard quotients (HQ), hazard indices (HI), and suggested consumption rate (meals/week) for Adults weighing 70 kg. Recommendations for children's consumption would be commensurately lower than those recommended for adults.

Species/Contaminant	**Hazard Ratio (Meals per Week)**				
	HSC Yacht Club Marina	**Tabbs Bay-Morgan's Point**	**Lynchburg Ferry Crossing**	**San Jacinto River near I-10**	**HSC-Turning Basin**
Spotted Seatrout					
Chlorinated pesticides	0.3 (3)	0.13 (7)	Spotted Seatrout Not Collected	0.23 (4)	Spotted Seatrout Not Collected
Polychlorinated biphenyls (PCBs)	**5.5 (0.2)**[1]	**1.6 (0.6)**		**1.9** (0.5)	
PCDFs/PCDDs	0.4 (2.3)	0.09 (11)		0.1 (9)	
HAZARD INDEX	6.2 (0.2)	1.8 (0.5)		2.2 (0.4)	
HAZARD INDEX, Combined Sites, All Contaminants	**3.4(0.3)**				
Other Fish					
Chlorinated pesticides	0.1 (8)	0.12 (8)	0.2 (5)	0.13 (7)	0.85 (1.1)
Polychlorinated Biphenyls (PCBs)	Not Detected	**0.7(1)**	**1.0 (0.9)**	0.65 (1.4)	**5.4 (0.2)**
PCDFs/PCDDs	0.07 (14)	0.2 (5)	0.82 (1.1)	**1.2 (0.8)**	**1.4 (0.7)**
HAZARD INDEX, Other Fish	0.6 (1.5)	**1.0 (0.9)**	**2.0 (0.5)**	**2.0 (0.5)**	**7.7 (0.1)**
HAZARD INDEX, Combined Sites, Fish other than Spotted Seatrout	**3.0 (0.3)**				
Blue Crab					
Chlorinated pesticides	Not Detected	0.009 (103)	0.02 (58)	0.01 (64)	0.03 (34)
Polychlorinated Biphenyls (PCBs)	Not Detected	Not Detected	Not Detected	Not Detected	Not Detected
PCDFs/PCDDs	0.5 (2)	**1.04 (0.9)**	0.96 (1.0)	**1.33 (0.7)**	0.52 (1.8)
HAZARD INDEX, Blue Crabs, Each Site	0.5 (2)	**1.05 (0.9)**	0.98 (1.0)	**1.34 (0.7)**	0.55 (1.7)
HAZARD INDEX Blue Crab, Combined Sites	0.9 (1)				

[1] Hazard quotients or hazard indices that exceed 1.0 are given in bold face type in this table

Table 6. Theoretical lifetime excess cancer risk from consumption of fish or blue crabs from the Houston Ship Channel, the San Jacinto River near I-10, or Upper Galveston Bay in which environmental contaminants were measured in 2004. The table lists excess risk and suggested weekly consumption rates for 70-kg adults exposed for up to 30 years.

Species/Contaminant	**Theoretical Lifetime Excess Cancer Risk (Recommended Consumption Rate)**				
	HSC Yacht Club Marina	**Tabbs Bay-Morgan's Point**	**Lynchburg Ferry Crossing**	**San Jacinto River near I-10**	**HSC-Turning Basin**
Spotted Seatrout					
Chlorinated Pesticides	2.6 x 10^{-5} (3.6)	1.6 x 10^{-5} (6)	Spotted Seatrout Not Collected	2.1 x 10^{-5} (4)	Spotted Seatrout Not Collected
Polychlorinated biphenyls (PCBs)	9.4 x 10^{-5} (1)	2.8 x 10^{-5} (3)		3.2 x 10^{-5} (3)	
PCDFs/PCDDs	2.7 x 10^{-5} (3)	5.9 x 10^{-6} (16)		6.7 x 10^{-6} (14)	
Cumulative Excess Cancer Risk, Spotted Seatrout	**1.5 x 10^{-4} (0.6)**	5.0 x 10^{-5} (2)		6.0 x 10^{-5} (1.5)	
Cumulative Excess Cancer Risk, Spotted Seatrout, Combined Sites	**8.5 x 10^{-5} (1)**				
Other Fish					
Chlorinated pesticides	1.4 x 10^{-5} (7)	1.4 x 10^{-5} (7)	1.8 x 10^{-5} (5)	1.5 x 10^{-5} (6)	8.4 x 10^{-5} (1)
Polychlorinated Biphenyls (PCBs)	Not Detected	1.2 x 10^{-5} (8)	1.7 x 10^{-5} (5)	1.12 x 10^{-5} (8)	9.3 x 10^{-5} (1)
PCDFs/PCDDs	4.4 x 10^{-6} (21)	1.4 x 10^{-5} (7)	5.5 10^{-5} (1.7)	8.0 x 10^{-5} (1)	9.3 x 10^{-5} (1)
Cumulative Excess Cancer Risk, Other Fish	2.6 x 10^{-5} (4)	4.0 x 10^{-5} (3.6)	9.0 x 10^{-5} (1)	1.1 x 10^{-4} (0.9)	**2.7 x 10^{-4} (0.3)**
Cumulative Excess Cancer Risk, Other Fish, Combined Sites	**1.2 x 10^{-4} (0.8)**[4]				
Blue Crab					
Chlordane [1]	3.2 x 10^{-7} (287)[2]	6.8 x 10^{-7} (136)	1.2 x 10^{-6} (78)	1.1 x 10^{-6} (85)	2.1 x 10^{-6} (45)
Polychlorinated biphenyls (PCBs) [3]	Not Detected	Not Detected	Not Detected	Not Detected	Not Detected
PCDFs/PCDDs	3.3 x 10^{-5} (3)	6.9 x 10^{-5} (1)	6.4 x 10^{-5} (1)	9.0 x 10^{-5} (1)	3.5 x 10^{-5} (3)
Cumulative Excess Cancer Risk, blue crabs	3.3 x 10^{-5} (3)	7.0 x 10^{-5} (1)	6.6 x 10^{-5} (1)	9 x 10^{-5} (1)	3.7 x 10^{-5} (2.5)
Cumulative Excess Cancer Risk, Blue Crab, Sites Combined	5.9 x 10^{-5} (1.6)				

[1] *Of organochlorine pesticides analyzed, only chlordane was present in blue crab samples.*

[2] *Chlordane was not detected in blue crab samples from Site 1 (HSC Yacht Club marina); this risk value was calculated from the reporting limit for chlordane (RL=0.010 mg/kg; used ½ the RL - .005 mg/kg in calculation)*

[3] *Because the laboratory did not report PCBs in any blue crab samples from this survey, DSHS considered this toxicant "not present" in this species; thus, no risk values were calculated for PCBs in this species.*

[4] *Calculated excess risks that are greater than 1x10^{-4} are printed in bold-faced type in this table.*

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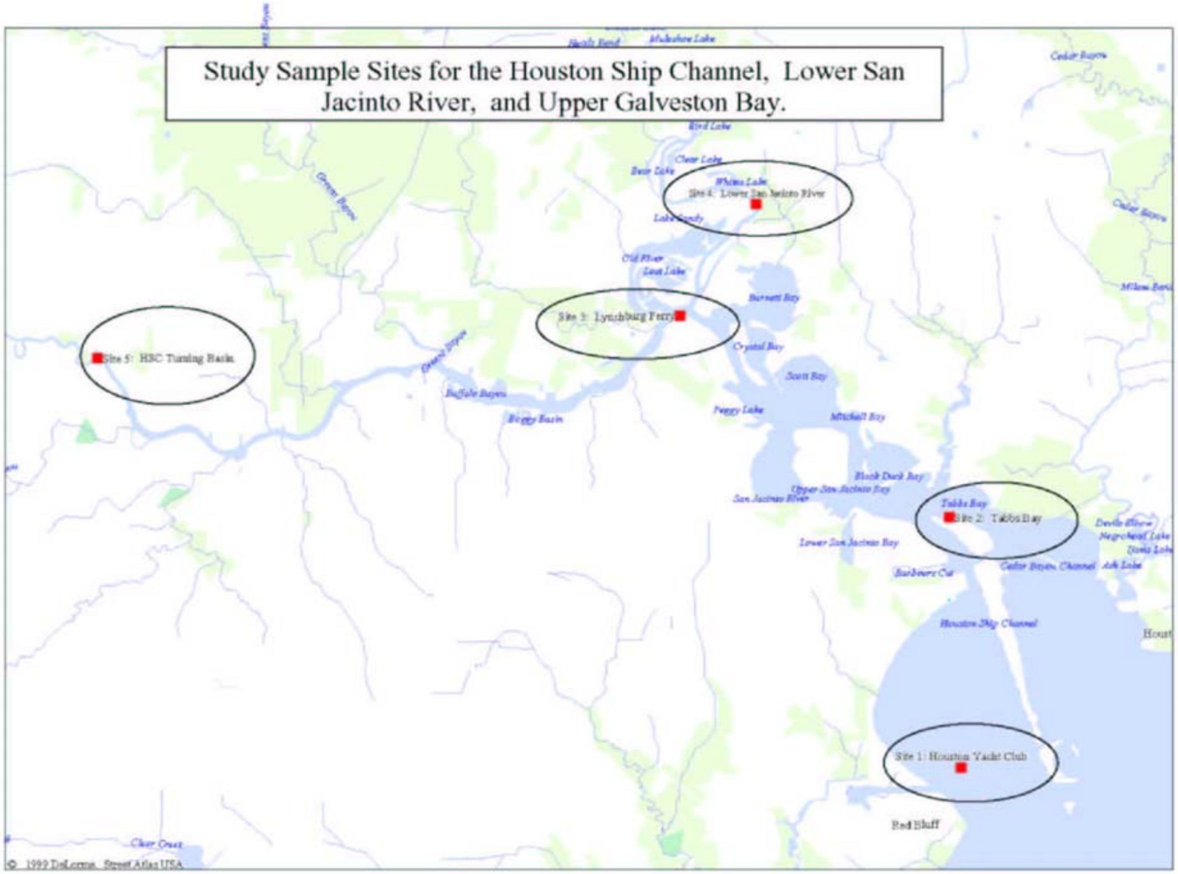
APPENDIX



Study Sample Sites for the Houston Ship Channel, Lower San Jacinto River, and Upper Galveston Bay.

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