Characterization of Potential Adverse Health Effects Associated with Consuming Fish from

Houston Ship Channel

Harris County, Texas

2015

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INTRODUCTION

This document summarizes the results of a survey of the Houston Ship Channel (HSC) conducted in 2012 by the Texas Department of State Health Services (DSHS) Seafood and Aquatic Life Group (SALG).[a] The SALG did this study to investigate any potential change in blue crab- and fish-tissue contaminant concentrations in the HSC. The present study examined blue crab and fish from the HSC 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 blue crab and fish from the HSC 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* [1] 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*) [2] that grew out of the USEPA's *National Dioxin Study,*[1] the EPA conducted a one-time nationwide survey of contaminant residues in fish. In this report, 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.[2]

In 1990, the Texas Department of Health (TDH)[b] – in its first detailed evaluation of the Texas sites reported in the *National Dioxin Study* [1] to harbor dioxin-contaminated fish or shellfish – collected 12 fish and composite blue crab samples from the HSC and from Upper Galveston Bay. The 1990 TDH study confirmed polychlorinated dibenzo-*p*-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) 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 HSC 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 meal per month. In addition, the TDH advised that children less than 12 years of age and women of childbearing age not consume catfish or blue crab from these waters.[3]

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

[a] The terms DSHS and SALG are used interchangeably throughout this document and refer to the same agency.
[b] Now the Department of State Health Services (DSHS)

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.[4]

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 HSC and Upper Galveston Bay for PCDDs/PCDFs. Results from the NCWG study showed an apparent decrease in average PCDD/PCDF concentrations in catfish, blue crab, and oysters when compared to the 1990 data. However, the small number of samples evaluated made it impossible for the TDH to reassess adequately the health risks from consumption of fish, blue crab, or oysters from the HSC and Upper Galveston Bay or to revise risk management decisions for the area. Consequently, the TDH continued to implement ADV-3 without modifications, 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 HSC and Upper Galveston Bay to re-evaluate ADV-3. 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 provided the TDH with funding to study the Galveston Bay system. The grant projects included: (1) *The USEPA Children's Uses of Galveston Bay* grant; (2) a Texas Commission on Environmental Quality (TCEQ)[c] Total Maximum Daily Load (TMDL) program grant, and (3) the Galveston Bay Estuary Program (GBEP)[5]. 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 HSC (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 the contaminants identified in fish and blue crab collected from these water systems exceeded existing health-based assessment comparison values (HAC values) used to 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,

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

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 HSC (including the Lower San Jacinto River) and included organochlorine pesticides as contaminants of concern. ADV-20 recommended that adults eat no more than one eight-ounce meal per month of blue crab or any fish species from the HSC 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 pregnant women, those who may become pregnant, breastfeeding mothers, and young children should not eat fish or blue crab from the above-described areas.[6]

In 1987, the U.S. Congress established the National Estuary Program (NEP) to promote long-term planning and management of nationally significant estuaries.[7] 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 and is one of two such programs in Texas.[8] 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.[5] 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 ways to reduce 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 HSC, 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 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 HSC and Upper Galveston Bay. ADV-28 recommended that adults limit consumption of spotted seatrout from the HSC – 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. Pregnant women, those who may become pregnant, breastfeeding mothers, and young children were advised not to consume spotted seatrout from these waters.[9]

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 Texas Parks and Wildlife Department (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. This 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 a grant in 2005 and another in 2006 to evaluate the extent of spotted seatrout-PCB contamination and to 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 HSC 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. Pregnant women, those who may become pregnant, breastfeeding mothers, and young children were advised not consume catfish or spotted seatrout from these waters.[10]

On September 13, 2008, Hurricane Ike made landfall on the north end of Galveston Island, Texas as a strong Category 2 hurricane.[11] The expansive storm surge associated with Hurricane Ike caused significant flooding spanning over 200 miles of coastline from Galveston Island into Louisiana.[12] Catastrophic flooding occurred along the Texas coastline from Galveston Island to the Texas-Louisiana border. The Galveston Bay and Sabine Lake estuaries received floodwaters from some of the most populated and industrialized coastal areas in the U.S. Run-off during the flood and receding storm surge waters contained industrial pollutants, household chemicals and waste, and sediment from inland areas. Since Hurricane Ike, the DSHS SALG and the TPWD

Coastal Fisheries Division (CFD) received many inquiries from the public regarding the safety of consuming fish from Galveston Bay and the Sabine Lake estuaries. The DSHS SALG and TPWD CFD were unable to assure the public that fish were safe to eat following Hurricane Ike because data were unavailable to assess. In January 2010, the DSHS SALG acquired project funding through the Social Services Block Grant to assess the potential health risks associated with consuming fish from Galveston Bay and the Sabine Lake estuaries post Hurricane Ike.

In 2010–2011, prompted by the discovery of three former disposal pits located along the San Jacinto River north of Interstate Highway 10 (IH 10), the DSHS assessed any potential change in blue crab and fish tissue contaminant concentrations in the San Jacinto River below the Lake Houston Dam to the HSC.[13] 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 PCDDs/PCDFs.[14] The property is currently inactive and portions of the original waste pits have subsided into the San Jacinto River.

The results of the 2010–2011 studies showed that blue crab and fish collected from the Galveston Bay Estuary continue to contain PCBs and PCDDs/PCDFs at concentrations that exceed DSHS guidelines for protection of human health. Based on these results, the DSHS issued Fish and Shellfish Consumption Advisories 49 and 50 (ADV-49 and ADV-50) on June 26, 2013 that rescinded and modified extant Galveston Bay Estuary consumption advisories. ADV-49 recommended that people limit consumption of blue crab and fish from the HSC and all contiguous waters north of the Fred Hartman Bridge, State Highway 146, including the San Jacinto River below the Lake Houston Dam, to no more than one eight-ounce meal per month. Pregnant women, those who may become pregnant, breastfeeding mothers, and children less than 12 years of age were advised not to consume blue crab and fish from these waters.[15]

Consumption advice issued in July 2008 (ADV-35) for spotted seatrout was predicated on multiple contaminant exposure (i.e., PCBs and PCDDs/PCDFs) and movement of the species throughout the Galveston Bay Estuary (unpublished TPWD spotted seatrout tagging data). Evaluation of 2010-2011 spotted seatrout data indicate that PCDD/PCDF concentrations had decreased to an acceptable level of risk and that PCB concentrations varied by Galveston Bay Estuary section or bay. Because of these findings, ADV-50 advised that women past childbearing age and adult men should limit consumption of blue crab, all species of catfish, and spotted seatrout from Upper Galveston Bay and all contiguous waters north of a line from Red Bluff Point to Five-Mile Cut Marker to Houston Point to no more than one eight-ounce meal per month. Pregnant women, those who may become pregnant, breastfeeding mothers, and children less than 12 years of age were advised not to consume blue crab, all species of catfish, and spotted seatrout from these waters. ADV-50 also advised that women past childbearing age and adult men should limit consumption of all species of catfish from Galveston Bay and all contiguous waters including Chocolate Bay, East Bay, Trinity Bay, and West Bay to no more than one eight-ounce meal per month. Pregnant women, those who may become pregnant, breastfeeding mothers, and children less than 12 years of age were advised not to consume all species of catfish from these waters.[16]

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.[17] 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 HSC 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 HSC. The HSC, formed by dredging and widening of Buffalo Bayou and the San Jacinto River is highly industrialized.

Demographics of Harris County Surrounding the Houston Ship Channel

The estimated population in 2013 of Harris County was 4,336,853 people.[18] The HSC within Harris County is adjacent to one of the most urbanized and industrialized areas in Texas and in the U.S. The City of Houston, Texas (2013 estimated population 2,195,914) is the fourth largest city in the United States and the Harris County seat. According to the U.S. Census Bureau, Harris County is the most populous county in Texas.

Subsistence Fishing at the 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.[19] The USEPA and the DSHS find it is important to consider subsistence fishing to occur at any water body because subsistence fishers (as well as recreational anglers and certain tribal and ethnic groups) usually consume more locally caught fish than the general population. These groups sometimes harvest fish or shellfish from the same water body over many years to supplement caloric and protein intake. People, who routinely eat fish from chemically contaminated water bodies 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 in Texas. 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 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.*[20] The SALG bases its sampling and analysis protocols, in part, on procedures recommended by the USEPA's *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories, Volume 1.*[21] Advice and direction are also received from the *Fish Sampling Advisory Subcommittee* of the legislatively mandated *State of Texas Toxic Substances Coordinating Committee.*[22] 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 Houston Ship Channel 2013 Sample Set

In September 2012, the SALG staff collected 48 blue crab and fish samples from the HSC. Risk assessors used data from these samples to assess the potential for adverse human health outcomes from consuming blue crab and fish from this body of water.

The SALG selected four sample sites to provide spatial coverage of the study area (Figure 1): Site 1 HSC at Turning Basin; Site 2 HSC at Greens Bayou; and Site 3 HSC at Patrick Bayou; and Site 4 HSC at Lynchburg Ferry Crossing. Species collected represent distinct ecological groups (i.e., predators and bottom-feeders) that have some potential to bio-accumulate chemical contaminants, have a wide geographic distribution, are of local recreational fishing value, and/or commonly consumed by anglers and their families. The 48 blue crab and fish collected from the HSC represent all species targeted for collection from this water body (Table 1). The list below contains the number of each target species, listed in descending order collected for this study: blue crab (composite samples; 8); black drum (6); sheepshead (6); smallmouth buffalo (4); southern flounder (4); blue catfish (3); hardhead catfish (3); spotted seatrout (3); alligator gar (2); channel catfish (2); common carp (2); gafftopsail catfish (2); red drum (2); and white bass (1).

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

The SALG staff processed blue crab and fish samples at the SALG Field Office in Bacliff, Texas. Staff weighed each fish sample to the nearest gram (g) on an electronic scale and measured total length (TL; tip of nose to tip of tail fin) to the nearest millimeter (mm; Table 1). All TL measurements were converted to inches for use in this report. 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. Blue crab carapace width was also measured to the nearest millimeter (individual blue crab samples were not weighed). The SALG staff worked from an aluminum foil-wrapped cutting board, removing the carapace from each blue crab specimen to expose the body cavity and eviscerate the specimen by removing the feathery gills just proximal to the legs, along with all loose viscera, mouthparts, and eggs. After thoroughly rinsing the body cavity with distilled water, survey staff combined four eviscerated whole blue crab samples to produce each composite blue crab sample.

To ensure that cross-sample contamination did not occur, the SALG staff changed the foil and cleaned the knife with distilled water after each sample was processed. The team wrapped the fillet(s) and eviscerated whole blue crab bodies 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 chain of custody while samples are in the possession of agency staff. 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

The GERG personnel documented receipt of the 48 HSC fish samples and recorded the condition of each sample along with its DSHS identification number. Using established USEPA methods, the GERG laboratory analyzed fish fillets from the HSC for inorganic and organic contaminants commonly identified in polluted environmental media. Analyses included seven metals (arsenic, cadmium, copper, lead, total mercury, selenium, and zinc), 123 semivolatile organic compounds (SVOCs), 70 volatile organic compounds (VOCs), 34 pesticides, 209 PCB congeners,[d, 23] and 17 polychlorinated dibenzofurans and/or dibenzo-*p*-dioxins (PCDDs/PCDFs) congeners. The laboratory analyzed all 48 samples for metals, pesticides, PCBs, and PCDDs/PCDFs. A subset of 12 of the original 48 samples was analyzed for SVOCs, and VOCs.[24] The SALG risk assessors selected the subset of samples based on target species and size class selection procedures outlined in SALG standard operating procedures (SOPs). In addition to

[d] A PCB congener is any single, unique well-defined chemical compound in the PCB category. The name of a congener specifies the total number of chlorine substituents and the position of each chlorine (e.g., 4,4' Dichlorobiphenyl is a congener comprising the biphenyl structure with two chlorine substituents, one on each of the number 4 carbons of the two rings). In 1980, a numbering system was developed, which assigned a sequential number to each of the 209 PCB congeners.

SALG SOPs, if available, the SALG risk assessors use TPWD creel surveys to determine the species of fish most frequently harvested from the body of water being evaluated and choose large specimens of the selected species of fish. The SALG risk assessors choose large fish to assess conservatively contaminant exposure when evaluating small sample sizes.

Details of Some Analyses with Explanatory Notes

Arsenic

The GERG laboratory analyzed four fish 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.[25] The DSHS, taking a conservative approach, estimates 10% of the total arsenic in any fish is inorganic arsenic, and derives estimates of inorganic arsenic concentration in each fish by multiplying the 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.[26] 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 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.[27] (In these risk characterizations, the DSHS interchangeably utilizes the terms "mercury," "methylmercury," or "organic mercury" to refer to methylmercury in fish).

Percent Lipids

The percent lipids content (wet weight basis) of a tissue sample is defined as the percent of material extracted from biological tissue with methylene chloride.[28] Tissue samples were extracted with methylene chloride in the presence of sodium sulfate and an aliquot of the extract was removed for lipid determination, filtered and concentrated to a known volume. A subsample is removed, the solvent is evaporated, the lipid residue weighed, and the percent lipid content is determined. The percent lipids were determine following the method described by GERG.

Polychlorinated Biphenyls (PCBs)

For PCBs, the USEPA suggests that each state measures congeners of PCBs in fish and shellfish rather than homologs[e] or Aroclors®[f] because the USEPA considers congener analysis the most sensitive technique for detecting PCBs in environmental media.[24, 29] Although only about 130 PCB congeners were routinely present in PCB mixtures manufactured and commonly used in the U.S., the GERG laboratory analyzes and reports the presence and concentrations of all 209 possible PCB congeners. From the congener analyses, the laboratory also computes and reports concentrations of PCB homologs and of Aroclor® mixtures. Despite the USEPA's suggestion that the states utilize PCB congeners rather than Aroclors® or homologs for toxicity estimates, the toxicity literature does not reflect state-of-the-art laboratory science. To accommodate this inconsistency, the DSHS utilizes recommendations from the National Oceanic and Atmospheric Administration (NOAA),[30] from McFarland and Clarke,[31] and from the USEPA's guidance documents for assessing contaminants in fish and shellfish.[24] Based on evaluation of these recommendations, the DSHS selected 43 of 209 congeners to characterize "total" PCBs. 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 HAC values derived from information on PCB mixtures held in the USEPA's Integrated Risk Information System (IRIS) database.[32] IRIS currently contains noncarcinogenicc toxicity information for five Aroclor® mixtures: Aroclors® 1016, 1242, 1248, 1254, and 1260. IRIS does not contain complete information for all mixtures. For instance, IRIS has derived, reference doses (RfDs) for Aroclors 1016 and 1254. Aroclor 1016 was 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.[33] 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.

[e] PCB homologs are subcategories of PCB congeners having equal numbers of chlorine substituents (e.g., the tetrachlorobiphenyls are all PCB congeners with exactly four chlorine substituents that may be in any arrangement).

[f] Aroclor is a PCB mixture produced from 1930 to 1979. It is one of the most commonly known trade names for PCB mixtures. There are many types of Aroclors and each has a distinguishing suffix number that indicates the degree of chlorination. The numbering standard is as follows: The first two digits refer to the number of carbon atoms in the phenyl rings and the third and fourth digits indicate the percentage of chlorine by mass in the mixture (e.g., Aroclor 1254 means that the mixture has 12 carbon atoms and contains 54% chlorine by weight.).

For assessment of cancer risk from exposure to PCBs, the SALG uses the USEPA's highest slope factor of 2.0 milligram per kilogram per day (mg/kg/day) to calculate the probability of lifetime excess cancer risk from PCB ingestion. The SALG based its decision to use the most conservative 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.[32]

Calculation of Dioxin Toxicity Equivalence (TEQ)

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.[34, 35] Using this technique, risk assessors from the DSHS converted PCDD or PCDF congeners in each tissue sample from the present survey to toxic equivalent concentrations (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.[36]

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

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 (Noncarcinogenic) 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, and habits of the exposed, or the presence of other chemicals.[37] 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.[37]

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 sample 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 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 (e.g., in mg/kg) for non-cancer or cancer endpoints. The mean is the preferred comparison statistic. However, the 95% upper confidence limit may be used when evaluating small sample sizes.

In deriving HAC values for systemic (noncarcinogenic; HAC_{nonca}) effects, the SALG assumes a standard adult weighs 70 kilograms (kg) and consumes 30 g of fish or shellfish per day (about one eight-ounce meal per week) and uses the USEPA's RfD[38] or the ATSDR's chronic oral MRLs.[39] When RfDs or MRLs are not available the SALG may use a Food and Nutrition Board, Institute of Medicine, National Academies tolerable upper intake level (UL) for nutrients.[g] 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.*[40]

[g] A tolerable upper intake level (UL) is the highest average daily nutrient intake level that is likely to pose no risk of adverse health effects to almost all individuals in the general population. As intake increases above the UL, the potential risk of adverse effects may increase. The UL represents total intake from food, water, and supplements.

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.*[40]

The ATSDR uses a similar technique to derive its MRLs.[39] 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 an 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).*[41]

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, an HQ of 4.0 does not mean the concentration in the dose will be four times as toxic as that same substance would be if the HQ were equal to 1.0. An HQ of 4.0 also does not imply that adverse events will occur four times as often as if the HQ for the substance in question were 1.0. Rather, the USEPA suggests that an 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, an HQ or HI greater than or equal to 1.0 "should indicate some cause for concern."

The SALG does not utilize HQs to determine the likelihood of occurrence of adverse systemic (noncarcinogenic) 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 cause for concern while HQs greater than or equal to 1.0 might suggest the recommendation of a regulatory action to ensure protection of public health. Similarly, risk assessors at the DSHS may utilize an HQ to determine the need for further study of a water body's fauna. Notwithstanding the above discussion, the oral RfD derived by the USEPA represents chronic consumption. Thus, regularly eating fish containing a toxic chemical, 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 equals or 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.[39]

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.[38,40] 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. These sensitive groups also receive special consideration in calculation of an RfD.[40]

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"), an 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)[40] 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. [42, 43] 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.[44] 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 (a) biologically effective toxicant(s) 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.[45]

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.[38] Additionally, in accordance with the ATSDR's *Child Health Initiative*[46] and the USEPA's *National Agenda to Protect Children's Health from Environmental Threats,*[47] 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 Systat® statistical software, version 13.1 installed on IBM-compatible microcomputers (Dell, Inc), to generate descriptive statistics (mean, 95% confidence limits of the arithmetic mean, standard deviation, median, minimum, and maximum concentrations) for reported chemical contaminants.[48] In computing descriptive statistics, SALG risk assessors utilized ½ the reporting limit (RL) for analytes designated as not detected (ND) or estimated (J-values).[h] The SALG risk assessors calculated PCDDs/PCDFs descriptive statistics using estimated concentrations (J-values) and assuming zero for PCDDs/PCDFs designated as ND.[i] 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 HSC.[49] When lead concentrations in fish or shellfish are high, SALG risk assessors may utilize the USEPA's Interactive Environmental Uptake Bio-Kinetic (IEUBK) model to determine whether consumption of lead-contaminated fish could cause a child's blood lead (PbB) level to exceed the Centers for Disease Control and Prevention's (CDC) lead concentration of concern in children's blood (5 mcg/dL).[50,51]

The SALG risk assessors also performed other types of statistical analyses to evaluate the data. Statistical significance was determined at $p \le 0.05$ for all statistical analyses. When appropriate and as needed to meet assumptions of the statistical tests, the SALG risk assessors $\log_e$-transformed the data to improve normality and best fit. PCDD/PCDF data were excluded from these analyses because the data did meet assumptions of the statistical tests and the data could not be appropriately $\log_e$-transformed because of the 16 non-detects or zero concentrations. The SALG risk assessors performed linear correlation (r) to describe associations between contaminant concentrations and total length (TL), and percent lipid composition. For those associations that were positive and significant, the SALG risk assessors performed linear regression analyses (r^2) to measure the strength and further describe the relationships. The SALG risk assessors performed analysis of variance (ANOVA) and used Tukey's honestly significant difference (HSD) or Games-Howell post-hoc comparisons to compare sample site contaminant concentrations for all fish combined and to compare

[h] *"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.*

[i] *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.*

contaminant concentrations between sampling events. The SALG risk assessors used Tukey's HSD for data that meet the assumption of homogeneity of variances and used the Games-Howell test for data that did not meet the homogeneity of variances assumption.

RESULTS

The GERG laboratory completed analyses and electronically transmitted the results of the HSC samples collected in September 2012 to the SALG in December 2013. The laboratory reported the analytical results for metals, pesticides, PCBs, PCDDs/PCDFs, SVOCs, and VOCs.

For reference, Table 1 contains a list of fish samples collected by sample site. Tables 2.1–2.9 present the results of metals analyses. Tables 3.1–3.7 and 4.1–4.3 contain summary results for pesticides and PCBs, respectively. Tables 5.1–5.3 summarizes the PCDD/PCDF analyses and Table 6 depicts the trichlorofluoromethane results. This report does not display SVOC and most VOC data because these contaminants were not present at concentrations of concern in blue crab and fish collected from the HSC during the described survey. Unless otherwise stated, table summaries present the number of samples with detected concentrations of contaminants, the number of samples tested, the mean concentration and standard deviation, and the minimum and the maximum concentrations. In the tables, results may be reported as ND, below detection limit (BDL) for estimated concentrations or "J-values", or as concentrations at or above the reporting limit (RL).

Inorganic Contaminants

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

The GERG laboratory analyzed 48 blue crab and fish tissue samples for six inorganic contaminants and mercury. All fish tissue samples from the HSC contained concentrations of arsenic, copper, mercury, selenium, and zinc (Tables 2.1–2.9).

The SALG evaluated three toxic metalloids having no known human physiological function (arsenic, cadmium, and lead) in the samples collected from the HSC. All samples analyzed contained arsenic ranging from 0.033–1.370 mg/kg (Table 2.1). Thirty-nine of 48 samples contained cadmium 0.014±0.009 mg/kg (Table 2.2). Lead concentrations ranged from ND to 0.167 mg/kg with a mean of 0.037±0.036 mg/kg (Table 2.4).

Three of the metalloids analyzed are essential trace elements: copper, selenium, and zinc. All 48 fish tissue samples contained copper, selenium, and zinc (Tables 2.3–2.6). The mean copper concentration in blue crab and fish sampled from the HSC was 0.1.856±4.009 mg/kg (Table 2.3). Selenium concentrations ranged from 0.283 to 1.908 mg/kg with a mean of 0.977±0.436 mg/kg and a median of 1.027 mg/kg (Table 2.5). The mean zinc concentration in blue crab and fish tissue samples from the HSC was 8.598±9.842 mg/kg (Table 2.6).

Mercury

All blue crab and fish tissue samples evaluated from the HSC contained mercury (Tables 2.7–2.9). Across all sample sites and species, mercury concentrations ranged from 0.051 mg/kg (common carp) to 0.446 mg/kg (sheepshead). The mean mercury concentration for the 48 blue crab and fish tissue samples analyzed was 0.149±0.086 mg/kg (Table 2.9).

Organic Contaminants

Pesticides

All samples examined contained concentrations of chlordane, 4,4′-DDE, 4,4′-DDD, and hexachlorobenzene. Chlordane (total) concentrations ranged from 0.0006 to 0.153 mg/kg with a mean of 0.018±0.030 mg/kg (Table 3.1). DDT (total) [2,4′-DDE+4,4′-DDE + 2,4′-DDD +4,4′-DDD+2,4′-DDT+4,4′-DDT] ranged from 0.0004 to 0.826 mg/kg with a mean 0.030±0.120 mg/kg and a median of 0.005 mg/kg (Table 3.2). Hexachlorobenzene concentrations ranged from ND to 0.242 mg/kg with a mean of 0.018±0.044 mg/kg (Table 3.6). The SALG risk assessors computed Pearson product-moment correlation coefficients to assess the relationships between organochlorine pesticides (chlordane [total], DDT [total], and hexachlorobenzene) concentrations and TL. There was no apparent correlation between organochlorine pesticide concentrations in fish from the HSC and TL ([chlordane] r = -0.109, n = 40, p = 0.503; [DDT] r = -0.061, n = 40, p = 0.707; [hexachlorobenzene] r = 0.108, n = 40, p = 0.506). Chlordane (total) and DDT (total) concentrations in fish were positively related to percent lipids, respectively (r^2 = 0.591, n = 40, p < 0.0005; r^2 = 0.608, n = 40, p < 0.0005; Figures 2–3).

The SALG risk assessors visually examined the fish chlordane (total) concentrations noting that chlordane (total) concentrations decreased from upstream to downstream sample sites (Figure 4). Fish chlordane (total) concentrations differed significantly across the four samples sites (F [3, 36] = 6.069, p = 0.002; Figure 4). Tukey's HSD post-hoc comparisons of fish chlordane (total) concentrations indicate that fish from the HSC Turning Basin (sample site 1) had significantly higher chlordane (total) concentrations than fish from Patrick Bayou and the Lynchburg Ferry Crossing (sample sites 3 and 4; Table 11.1).

The SALG risk assessors visually examined the fish DDT (total) concentrations noting that DDT (total) concentrations appeared higher at Greens Bayou (sample site 2; Figure 5). Fish DDT (total) concentrations differed significantly across the four samples sites (F [3, 36] = 5.678, p = 0.003; Figure 5). Tukey's HSD post-hoc comparisons of fish DDT (total) concentrations indicate that fish from Greens Bayou (sample site 2) had significantly higher DDT (total) concentrations than fish from Patrick Bayou (sample site 3) and the Lynchburg Ferry Crossing (sample site 4; Table 11.2).

The SALG risk assessors visually examined the fish hexachlorobenzene concentrations noting that hexachlorobenzene concentrations appeared higher at Patrick Bayou (sample site 3; Figure 6). Fish hexachlorobenzene concentrations differed significantly across the four samples sites (F

[3, 36] = 37.6314, p < 0.0005; Figure 6). Tukey's HSD post-hoc comparisons of fish hexachlorobenzene concentrations indicate that fish from Patrick Bayou (sample site 3) had significantly higher hexachlorobenzene concentrations than fish from the HSC Turning Basin, Greens Bayou, and the Lynchburg Ferry Crossing (sample sites 1, 2, and 4; Table 11.3).

Low concentrations of dieldrin, endrin, heptachlor epoxide, and pentachlorobenzene greater than the reporting limit were reported in at least 36 samples assayed (Tables 3.3–3.7). Trace to low concentrations of alachlor, aldrin, alpha HCH, beta HCH, chlorpyrifos, delta HCH, dacthal, endosulfan II, endosulfan sulfate, gamma HCH, heptachlor, methoxychlor, mirex, parathion ethyl, pentachloroanisole, and tetrachlorobenzene, were present in one or more fish samples (data not presented).

PCBs

All blue crab and fish tissue samples evaluated from the HSC contained PCBs (Tables 4.1–4.3). Across all sample sites and species, PCB concentrations ranged from 0.009 (black drum) to 2.333 mg/kg (alligator gar). The mean PCB concentration for the 48 blue crab and fish tissue samples assayed was 0.183±0.370 mg/kg (Table 4.3). There appeared to be no correlation between PCB concentrations in fish and TL ($r = 0.193$, $n = 40$, $p = 0.233$). PCB concentrations in fish were positively related to percent lipids ($r^2 = 0.451$, $n = 40$, $p < 0.0005$; Figure 7).

The SALG risk assessors visually examined the fish PCB concentrations noting that PCB concentrations appeared lower in the HSC at the Lynchburg Ferry Crossing (sample site 4) than at the three upstream sites (sample sites 2–4; Figure 8). Fish PCB concentrations differed significantly across the four samples sites (F [3, 36] = 7.850, p = 0.005; Figure 8). Tukey's HSD post-hoc comparisons of PCB concentrations indicate that fish from Patrick Bayou (sample site 3) had significantly higher PCB concentrations than fish from the Lynchburg Ferry Crossing (sample site 4; Table 11.4).

PCDDs/PCDFs

Thirty-two of 48 blue crab and fish tissue samples contained at least one of the 17 PCDD/PCDF congeners ranging from ND–13.309 TEQ pg/g with a mean of 0.945±2.423 pg/g and a median of 0.222 TEQ pg/g (Tables 5.1–5.3). No samples contained all 17 congeners (data not shown). Alligator gar contained the highest mean PCDD/PCDF TEQ concentration (7.289±8.514 pg/g; Table 5.3). The SALG risk assessors plotted mean PCDD/PCDF TEQ concentrations for all fish to show how concentrations vary between sample sites (Figure 9).

SVOCs

A subset of 12 HSC fish tissue samples was analyzed for SVOCs. Quantifiable concentrations greater than the reporting limit were reported for phenol in one of 12 fish samples evaluated (data not presented in tables). Estimated concentrations of benzyl alcohol, disulfoton, isodrin, and 4-methylphenol were present in one or more fish samples analyzed (data not presented in tables). The laboratory detected no other SVOCs in fish from the HSC.

VOCs

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.
A subset of 12 HSC fish tissue samples was analyzed for VOCs. Eleven of 12 fish tissue samples contained trichlorofluoromethane ranging from ND–0.020 mg/kg (Table 6). Quantifiable concentrations greater than the reporting limit were reported for acetone, 1,1-dichloroethene, and methylene chloride in one or more fish samples (data not presented in tables). Estimated quantities of many VOCs were also present in one or more fish tissue samples assayed from the HSC (data not presented).

Numerous VOCs were also identified in one or more of the procedural blanks, suggesting that these compounds were introduced during sample preparation. VOC concentrations less than the reporting limit are difficult to interpret due to their uncertainty and may represent a false positive. The presence of many VOCs at concentrations less than the reporting limit 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 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. Because 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.[38] 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 noncarcinogenic and carcinogenic endpoints in those who would consume fish from the HSC. 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 (Noncarcinogenic) Health Effects from Consumption of Fish from the Houston Ship Channel

Inorganic Contaminants

No species of fish evaluated contained arsenic, cadmium, copper, lead, mercury, selenium, or zinc at concentrations that equaled or exceeded 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 HSC.

Organic Contaminants

PCBs and PCDDs/PCDFs were observed in fish from the HSC at concentrations at or above their respective HAC_{nonca} (0.047 mg/kg [PCBs]; 2.330 pg/g [PCDDs/PCDFs]; Tables 4.1–5.3 and 9.1–9.3). No species of fish evaluated contained any other organic contaminants at concentrations assessed singly that equaled or exceeded 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 HSC.

PCBs

All blue crab and fish tissue samples (n = 48) assayed contained PCBs. Fifty-six percent of all samples analyzed contained PCB concentrations exceeding the HAC_{nonca} for PCBs (0.047 mg/kg; Tables 4.1–4.3 and 9.1–9.3). Nine of 14 species evaluated had mean PCB concentrations exceeding the HAC_{nonca} for PCBs or an HQ of 1.0 or more (Tables 4.1–4.3 and 9.1–9.3). The all species combined mean PCB concentration (0.183 mg/kg) exceeded the HAC_{nonca} for PCBs or an HQ of 1.0. PCB concentrations were positively related to percent lipids indicating that PCB concentrations increase as their body fat increases (Figure 7). People should consider this relationship when choosing the species of fish they consume. The consumption of fish from the HSC may pose potential systemic (noncarcinogenic) health risks.

The SALG risk assessors were unable to perform comparisons of PCB concentrations in blue crab and fish between historic sampling events due the differences in analytical methodology used to determine PCB concentrations. Prior to 2005, all tissue sample PCB concentrations were quantified using a PCB Aroclor analytical methodology. Since 2005, all PCB concentrations have been quantified by PCB congener analytical methodology (see METHODS, *Analytical Laboratory Information*).

Comparisons of PCB concentrations in blue crab and fish from the 2011 and 2012 sampling events indicate that blue crab and fish from the HSC continue to exceed DSHS guidelines for protection of human health (Figure 10). An independent samples t-test confirmed that PCB concentrations in blue crab and fish from the HSC are not significantly different between sampling events (2011, n = 45; 2012, n = 48; $t[86.6] = -1.596$, p = 0.114). The SALG risk assessors visually examined fish PCB concentrations at the Lynchburg Ferry Crossing noting that PCB concentrations appeared higher in 2011 than 2012 (Figure 11). Independent samples *t*-test analysis also confirmed that PCB concentrations in fish from the Lynchburg Ferry Crossing are significantly different between sampling events (2011, $n = 10$; 2012, $n = 12$; $t[20] = 2.101$, $p = 0.05$; Figure 11). It is important to consider when evaluating the results of these statistical tests that the 2011 and 2012 studies represent a "snapshot" of risk throughout the HSC on the days of sampling. Both of these studies do not account for potential PCB concentration variation due to seasonal differences and other environmental variables (i.e., natural fish movement, fish movement due to salinity changes, freshwater inflow, etc.).

Meal consumption calculations are useful for risk managers to make fish consumption recommendations and/or take regulatory action. The SALG risk assessors calculated the number of eight-ounce meals of fish from the HSC that healthy adults could consume without significant risk of PCB-related adverse systemic effects (Tables 9.1–9.3). Meal consumption rates were based on the overall mean PCB concentration by species. The SALG risk assessors estimated that healthy adults could consume less than one eight-ounce meal per week of blue crab and fish (0.2 meals per week). The SALG risk assessors suggest that blue crab and fish from the HSC contain PCBs at concentrations that may pose potential systemic (noncarcinogenic) health risks and that people should limit their consumption of blue crab and fish from the HSC. Because the developing nervous system of the human fetus and young children may be especially susceptible to adverse systemic (noncarcinogenic) health effects associated with consuming PCB-contaminated fish, the SALG risk assessors recommend more conservative consumption guidance for this sensitive subpopulation.

PCDDs/PCDFs

Thirty-two of 48 blue crab and fish tissue samples assayed contained PCDDs/PCDFs. Eight percent of all samples analyzed contained PCDD/PCDF concentrations exceeding the HAC_{nonca} for PCBs (2.330 pg/g; Tables 5.1–5.3 and 9.1–9.3). Two of 14 species evaluated had mean PCDD/PCDF concentrations exceeding the HAC_{nonca} for PCDDs/PCDFs or an HQ of 1.0 or more (Tables 5.1–5.3 and 9.1–9.3). The all species combined mean PCDD/PCDF concentration (0.945 pg/g) did not exceed the HAC_{nonca} for PCDDs/PCDFs or an HQ of 1.0. The consumption of alligator gar and blue catfish from the HSC may pose potential systemic noncarcinogenic health risks.

The SALG risk assessors plotted mean PCDD/PCDF TEQ concentrations from the 1990–2012 sampling events to show how concentrations have changed over time in the HSC (Figure 12).

Meal consumption calculations are useful for risk managers to make fish consumption recommendations and/or take regulatory action. The SALG risk assessors calculated the number of eight-ounce meals of fish from the HSC that healthy adults could consume without significant risk of PCDD/PCDF-related adverse systemic effects (Tables 9.1–9.3). Meal consumption rates were based on the overall mean PCDD/PCDF concentration by species. The SALG risk assessors estimated that healthy adults could consume less than one eight-ounce meal per week of alligator gar (0.3 meals per week) and blue catfish (0.9 meals per week). The

SALG risk assessors suggest that alligator gar and blue catfish from the HSC contain PCDDs/PCDFs at concentrations that may pose potential systemic health risks and that people should limit their consumption of alligator gar and blue catfish from the HSC. Because the developing nervous system of the human fetus and young children may be especially susceptible to adverse systemic health effects associated with consuming PCDD/PCDF-contaminated fish, 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 Houston Ship Channel

The USEPA classifies arsenic, most chlorinated pesticides, PCBs, and PCDDs/PCDFs as carcinogens. Arsenic, chlorinated pesticides, and PCDDs/PCDFs were present in fish samples analyzed from the HSC, 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.

PCBs

The mean PCB concentrations observed in alligator gar, hardhead catfish, and smallmouth buffalo exceed the DSHS guideline for protection of human health of one excess cancer in 10,000 equally exposed individuals and the HAC_{ca} for PCBs (0.272 mg/kg; Tables 4.1–4.3 and 10.1–10.8). PCB concentrations that equaled or exceeded the HAC_{ca} for PCBs were observed in one or more samples of the following species: alligator gar; black drum; blue catfish; hardhead catfish; sheepshead; and, smallmouth buffalo. The all blue crab and fish combined mean PCB concentration did not exceed the HAC_{ca} for PCBs.

The SALG risk assessors calculated the number of eight-ounce meals of blue crab and fish from the HSC that healthy adults could consume without significantly increasing their lifetime excess cancer risk (Tables 10.1–10.8). The SALG risk assessors estimated that healthy adults could consume less than one eight-ounce meal per week of alligator gar (0.2 meals per week), hardhead catfish (0.6 meals per week), and smallmouth buffalo (0.6 meals per week). Because children may experience effects at a lower exposure dose than adults, the SALG risk assessors recommend more conservative consumption guidance for this sensitive subpopulation. The SALG risk assessors suggest that consumption of alligator gar, hardhead catfish, and smallmouth buffalo from the HSC would be likely to increase the risk of cancer to exceed the DSHS guideline for protection of human health from PCB exposure.

PCDDs/PCDFs

The mean PCDD/PCDF concentrations observed in alligator gar exceed the DSHS guideline for protection of human health of one excess cancer in 10,000 equally exposed individuals or the HAC_{ca} for PCDDs/PCDFs (3.490 pg/g; Tables 5.1–5.3 and 10.1–10.8). The all blue crab and fish combined mean PCDD/PCDF concentration did not exceed the HAC_{ca} for PCDDs/PCDFs. The consumption of alligator gar from the HSC would be likely to increase the risk of cancer to exceed the DSHS guideline for protection of human health.

The SALG risk assessors calculated the number of eight-ounce meals of alligator gar from the HSC that healthy adults could consume without significantly increasing their lifetime excess cancer risk (Tables 10.1–10.8). The SALG risk assessors estimated that healthy adults could consume less than one eight-ounce meal per week of alligator gar (0.4 meals per week). Because children may experience effects at a lower exposure dose than adults, the SALG risk assessors recommend more conservative consumption guidance for this sensitive subpopulation. The SALG risk assessors suggest that consumption of alligator gar from the HSC would be likely to increase the risk of cancer to exceed the DSHS guideline for protection of human health from PCDD/PCDF exposure.

Characterization of Calculated Cumulative Systemic (Noncarcinogenic) Health Effects and of Cumulative Excess Lifetime Cancer Risk from Consumption of Fish from the Houston Ship Channel

Cumulative Systemic Health Effects

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. The SALG risk assessors utilize HI methodology to assess the likelihood of cumulative systemic adverse effects. This methodology requires that the contaminants of concern have a common target organ or a similar mode of action. In the case of mercury, chlorinated pesticides, PCBs, and PCDD/PCDFs in blue crab and fish from the HSC, neither assumption is true. The target organ for mercury is the central nervous system. The target organ for chlordane (total) is the liver, while the target organ identified for PCBs and PCDDs/PCDFs is the immune system. Thus, cumulative systemic effects from consumption of fish from the HSC for a contaminant mixture of two dissimilar contaminants and two similar contaminants are not likely to occur. PCBs and PCDDs/PCDFs, the two similar contaminants, increased the likelihood of systemic adverse health outcomes for several species of fish assayed (Tables 9.1–9.3). The combined toxicity of PCBs and PCDDs/PCDFs in alligator gar, black drum, blue catfish, blue crab, channel catfish, common carp, gafftopsail catfish, hardhead catfish, sheepshead, smallmouth buffalo, and white bass exceeded an HI of 1.0.

Meal consumption calculations are useful for risk managers to make fish consumption recommendations and/or take regulatory action. The SALG risk assessors calculated the number of eight-ounce meals of blue crab and fish from the HSC that healthy adults could consume without significant risk of PCB and/or PCDD/PCDF -related adverse systemic effects (Tables 9.1–9.3). Meal consumption rates were based on cumulative toxicity from exposure to PCBs, and PCDDs/PCDFs by species. The SALG risk assessors estimated that healthy adults could consume less than one eight-ounce meal per week of alligator gar, black drum, blue catfish, blue crab, channel catfish, common carp, gafftopsail catfish, hardhead catfish, sheepshead, smallmouth buffalo, and white bass (Tables 9.1–9.3). The SALG risk assessors suggest that blue crab and fish from the HSC contain PCBs and PCDDs/PCDFs at concentrations that may pose potential systemic (noncarcinogenic) health risks and that people should limit their consumption of blue crab and fish from the HSC. Because the developing nervous system of the human fetus and young children may be especially susceptible to adverse systemic health effects may be especially susceptible, the SALG risk assessors recommend more conservative consumption guidance for this sensitive subpopulation.

Cumulative Carcinogenic Health Effects

The SALG also queried the probability of increasing lifetime excess cancer risk from consuming 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. In this assessment, risk assessors added the calculated carcinogenic effect of arsenic, chlorinated pesticides, PCBs, and PCDDs/PCDFs (all data not presented; Tables 10.1–10.8). In each instance, addition of the cancer risk for these chemicals increased the theoretical lifetime excess cancer risk. However, PCBs and PCDDs/PCDFs are culpable for most of the increased theoretical lifetime excess cancer risk. The SALG risk assessors suggest that consumption of alligator gar, blue catfish, gafftopsail catfish, hardhead catfish, sheepshead, and smallmouth buffalo from the HSC likely increases the risk of cancer to exceed the DSHS guideline for protection of human health of one excess cancer in 10,000 persons equivalently exposed from multiple contaminant exposures. The SALG risk assessors estimated that healthy adults could consume less than one eight-ounce meal per week of fish (0.7 meals per week) from the HSC (Tables 10.1–10.8). Because children may experience effects at a lower exposure dose than adults, the SALG risk assessors recommend more conservative consumption guidance for this sensitive subpopulation. The SALG risk assessors suggest that consumption of alligator gar, blue catfish, gafftopsail catfish, hardhead catfish, sheepshead, and smallmouth buffalo from the HSC would be likely to increase the risk of cancer to exceed the DSHS guideline for protection of human health from multiple contaminant exposures.

<u>Organochlorine Pesticides</u>

Reevaluation of the HSC fish consumption advisory in 2004 revealed that chlordane (total), dieldrin, and heptachlor epoxide concentrations in blue crab and fish continued to contribute significantly to cumulative carcinogenic health risks. These findings prompted the DSHS to continue listing organochlorine pesticides as contaminants of concern in the HSC consumption advisory. Reassessment of the HSC consumption advisory in 2011–2012 suggested a decreasing trend for organochlorine pesticide concentrations in blue crab and fish. Comparisons of organochlorine pesticide concentrations in blue crab and fish from the 1999–2012 sampling events indicate that organochlorine pesticides no longer significantly contribute to cumulative carcinogenic health risks.

The SALG risk assessors performed ANOVA to test for differences in blue crab and fish organochlorine pesticide concentrations between the 1999–2012 HSC sampling events. Blue crab and fish chlordane (total) concentrations differed significantly across the four sampling events ($F [3, 136] = 15.735$, $p < 0.0005$; Figure 13). Tukey's HSD post-hoc comparisons of blue crab and fish chlordane (total) concentrations indicate that blue crab and fish had significantly higher chlordane (total) concentrations in 1999 and 2004 than 2011–2012 suggesting a decreasing trend (Table 11.5). Blue crab and fish dieldrin concentrations differed significantly across the four sampling events ($F [3, 136] = 19.956$, $p < 0.0005$; Figure 14). Games-Howell post-hoc comparisons of blue crab and fish dieldrin concentrations indicate that blue crab and fish had significantly higher dieldrin concentrations in 1999 and 2004 than 2011–2012 suggesting a decreasing trend (Table 11.6). Blue crab and fish heptachlor epoxide concentrations differed significantly across the four sampling events ($F [3, 136] = 24.628$, $p < 0.0005$; Figure 15). Games-Howell post-hoc comparisons of blue crab and fish heptachlor epoxide concentrations indicate that blue crab and fish had significantly higher heptachlor epoxide concentrations in 1999 and 2004 than 2011–2012 suggesting a decreasing trend (Table 11.7). In 2012, there was a significant increase in heptachlor epoxide concentrations from the 2011 sampling event, albeit, concentrations were significantly lower than 1999 and 2004 sampling events. Most tissue samples in the 2011 sampling event were collected from the San Jacinto River not the HSC. The Lynchburg Ferry Crossing was the only sample site in common between the 2011 and 2012 sampling events.

Characterization of Potential Exposure to Contaminants from Consumption of Fish from the Houston Ship Channel

The SALG risk assessors are also of the opinion that it is important to consider potential exposure when developing fish consumption advisories. Studies have shown that recoveries and yields from whole fish to skin-off fillets range from 17–58%.[52] The SALG risk assessors used an average of 38% recovery and yield from whole fish to skin-off fillets to estimate the number of eight-ounce meals for an average weight fish of each species from the HSC in 2012 (Table 12). The recoveries and yields for an average fish from the HSC in 2012 ranged from 0.5–23.5 eight-ounce meals. Based on recoveries and yields ($\overline{X}$ – 38%) from whole fish to skin-off fillets for this project, the average HSC fish yields 2.3 pounds of skin-off fillets or approximately 5 eight-ounce meals (Table 12). Due to the potential exposure from large-sized fish (i.e., catfish, drum, or gar), it is important for high volume fish consumers (persons who eat more than 2 eight-ounce meals per week) to understand that they could consume high doses of contaminants over multiple meals if they do not strictly adhere to DSHS consumption recommendations. For the reasons stated in the above discussion, the SALG risk assessors considered both standard meal consumption calculations and potential exposure scenarios to develop fish consumption advice for fish from the HSC.

CONCLUSIONS

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

This study addressed the public health implications of consuming fish from the Houston Ship Channel, located in Harris County, Texas. Risk assessors from the SALG conclude from the present characterization of potential adverse health effects from consuming blue crab and fish from the Houston Ship Channel that:

1. Southern flounder do not contain mean inorganic or organic contaminant concentrations, either singly or in combination, that exceeds the DSHS guidelines for protection of human health. Therefore, consumption of southern flounder **poses no apparent risk to human health.**

2. Red drum and spotted seatrout do not contain mean inorganic or organic contaminant concentrations, either singly or in combination, that exceeds the DSHS guidelines for protection of human health. However, due to the small sample size of red drum and spotted seatrout in this study and the variability of PCB and PCDD/PCDF concentrations observed between the 2011 and 2012 sampling events, the SALG risk assessors are of the opinion that potential health risks continue to be associated with consumption of red drum and spotted seatrout from the HSC.

3. Eleven (alligator gar, black drum, blue catfish, blue crab, channel catfish, common carp, gafftopsail catfish, hardhead catfish, sheepshead, smallmouth buffalo, and white bass) of 14 species evaluated contain mean PCB and/or PCDD/PCDF, either singly or in combination, that exceeds the DSHS guidelines for protection of human health. Regular or long-term consumption of blue crab and/or fish from the HSC – San Jacinto River may increase the likelihood of systemic (noncarcinogenic) or carcinogenic health risks. Therefore, consumption of blue crab and/or fish **poses an apparent risk to human health**.

4. Comparisons of organochlorine pesticide concentrations in blue crab and fish from the 1999–2012 HSC– San Jacinto River sampling events indicate that organochlorine pesticides no longer significantly contribute to cumulative carcinogenic health risks.

5. Consumption of multiple organic contaminants (i.e., PCBs and PCDDs/PCDFs) in blue crab and /or fish from the HSC– San Jacinto River increases the likelihood of systemic (noncarcinogenic) or carcinogenic health risks. Therefore, SALG risk assessors conclude that consuming fish containing multiple contaminants at concentrations near those

observed in fish from the HSC– San Jacinto River does significantly increase the risk of adverse health effects.

RECOMMENDATIONS

Risk managers at the DSHS have established criteria for issuing fish consumption advisories based on approaches suggested by the USEPA.[21, 24, 53] Risk managers at the DSHS may decide to take 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).[54] Declarations of prohibited harvesting areas are enforceable under the Texas Health and Safety Code, Subchapter D, parts 436.091 and 436.101.[54] 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, people 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 fish from HSC and the San Jacinto River below the Lake Houston Dam **poses an apparent hazard to public health.** Therefore, SALG risk assessors recommend that:

1. The DSHS continue consumption advice recommended by Fish and Shellfish Consumption Advisories 49 and 50 issued on June 26, 2013 for the Galveston Bay Estuary, including the HSC and all contiguous waters north of the Fred Hartman Bridge, State Highway 146 and the San Jacinto River below the Lake Houston Dam (Table 13).[15, 16]

2. The DSHS remove organochlorine pesticides from the contaminants of concern included in Advisories 49 and 50.

3. As resources become available, the DSHS should continue to monitor fish from the HSC for changes and establish trends in contaminant concentrations that would require 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.[55]
- 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.[56] The SALG regularly updates this Web site.
- The DSHS also provides the USEPA (http://epa.gov/waterscience/fish/advisories/), the TCEQ (http://www.tceq.state.tx.us), and the TPWD (http://www.tpwd.state.tx.us) with information on all consumption advisories and possession bans. Each year, the TPWD informs the fishing and hunting public of consumption advisories and fishing bans on its Web site and in an official downloadable PDF file containing general hunting and fishing regulations available at http://www.tpwd.state.tx.us/publications/pwdpubs/media/outdoorannual_2014_15.pdf. A booklet containing this information is available at all establishments selling Texas fishing licenses.[57]

Communication to the public of scientific information related to this risk characterization and information for environmental contaminants found in seafood is essential to effective risk management. To achieve this responsibility for communication, the DSHS provides contact information to ask specific questions and/or resources to obtain more information about environmental contaminants in seafood.

- 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 (800-588-1248).
- The USEPA'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™) http://www.atsdr.cdc.gov/toxprofiles/index.asp. 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. 2012 Houston Channel Sample Sites

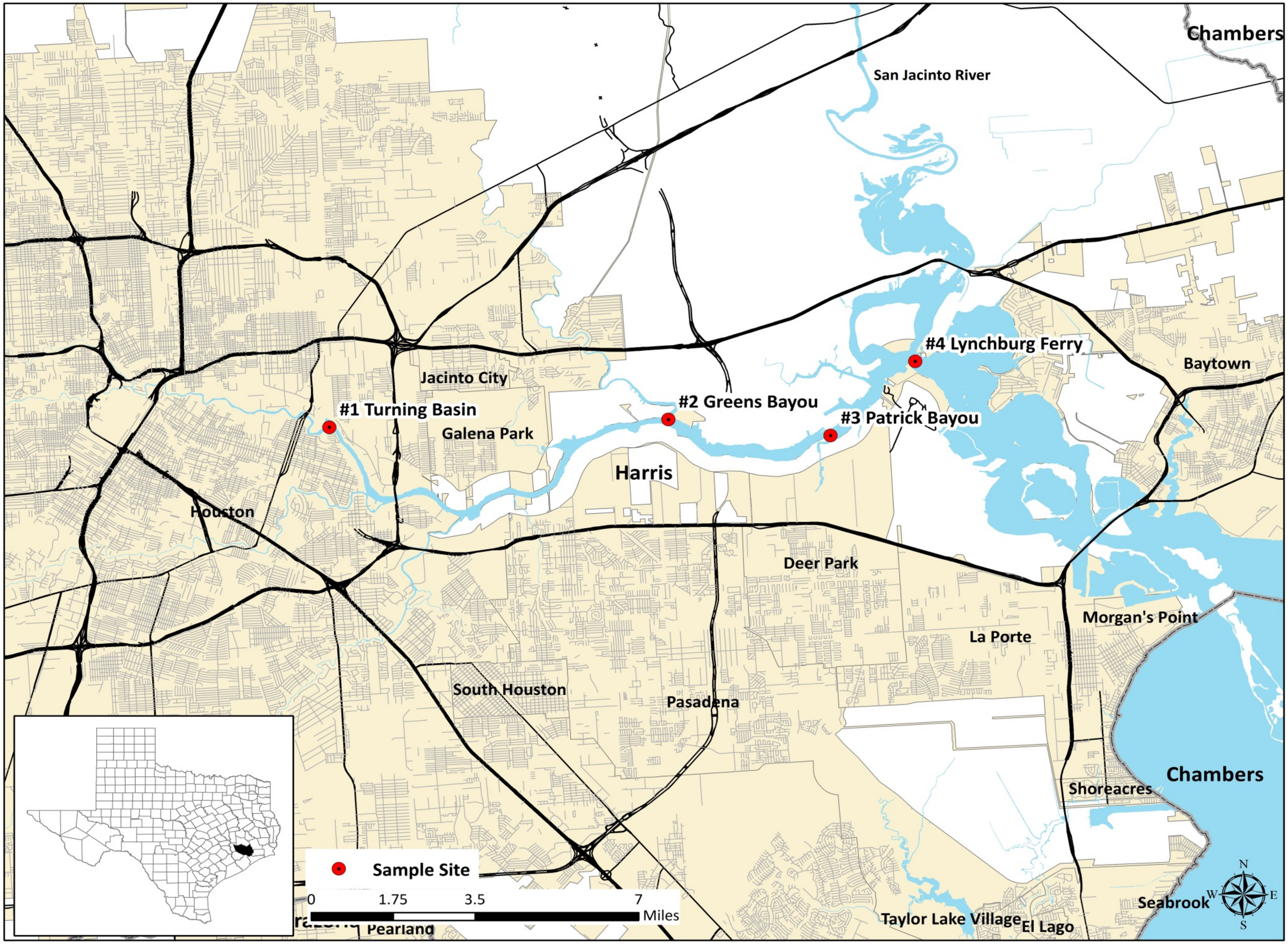


Figure 2. The relationship between chlordane (total) concentration and percent lipids for fish collected from the Houston Ship Channel, Texas, 2012.

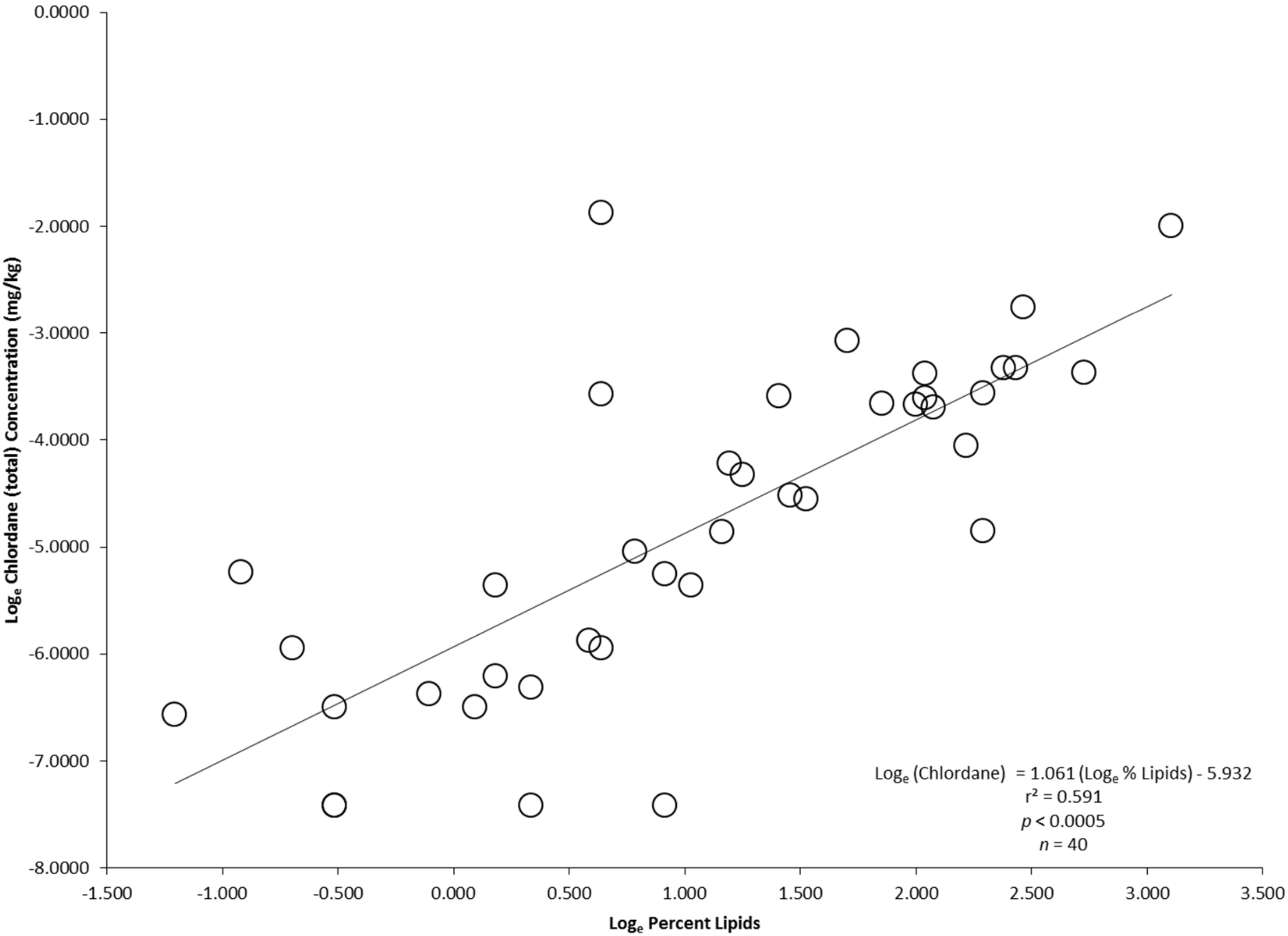


Figure 3. The relationship between DDT (total) concentration and percent lipids for fish collected from the Houston Ship Channel, Texas, 2012.

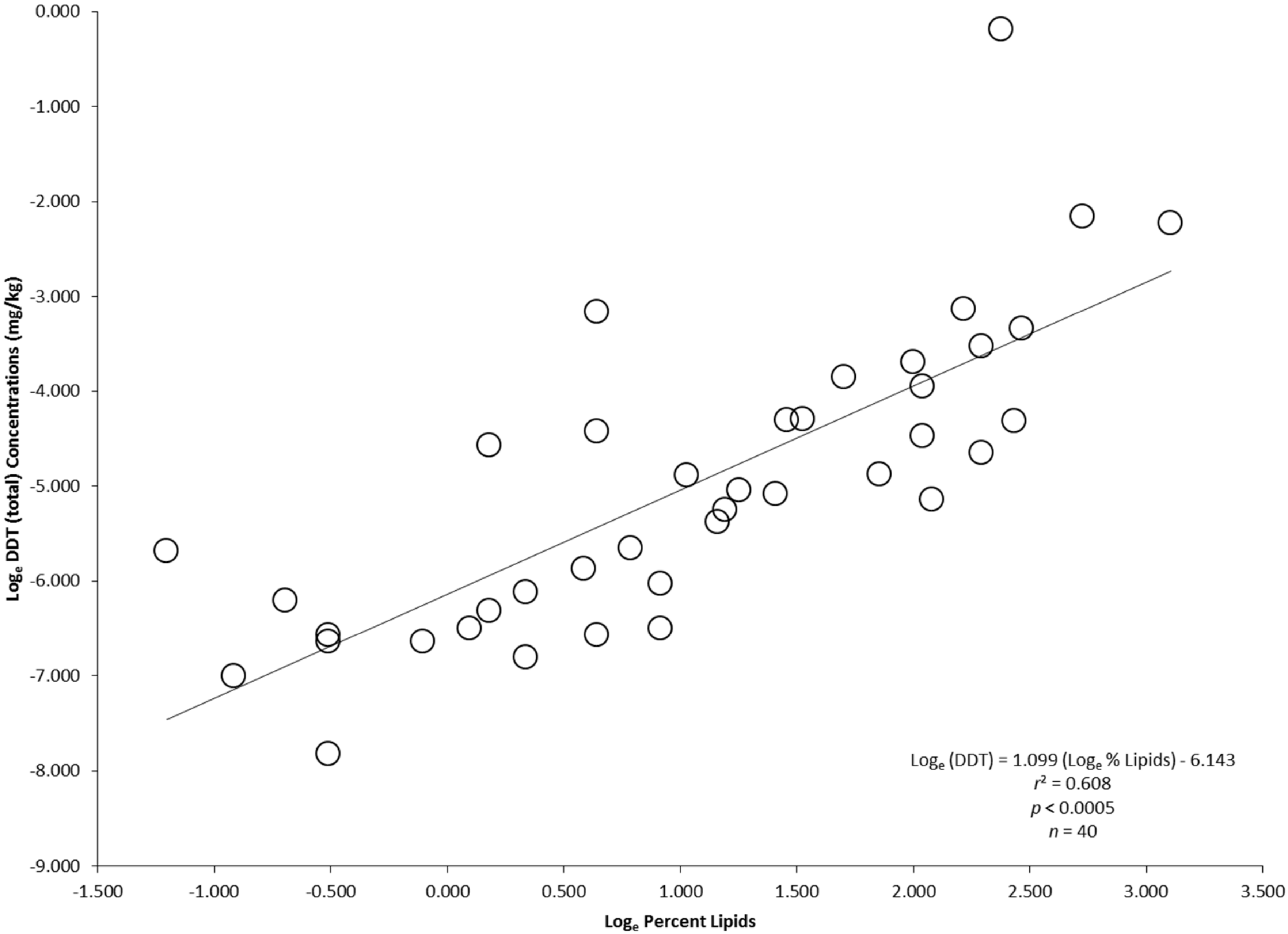


Figure 4. Mean Log_e chlordane (total; mg/kg, wet wt.) in fish by sample site collected from the Houston Ship Channel, Texas 2012. The error bars denote the standard error of the mean.

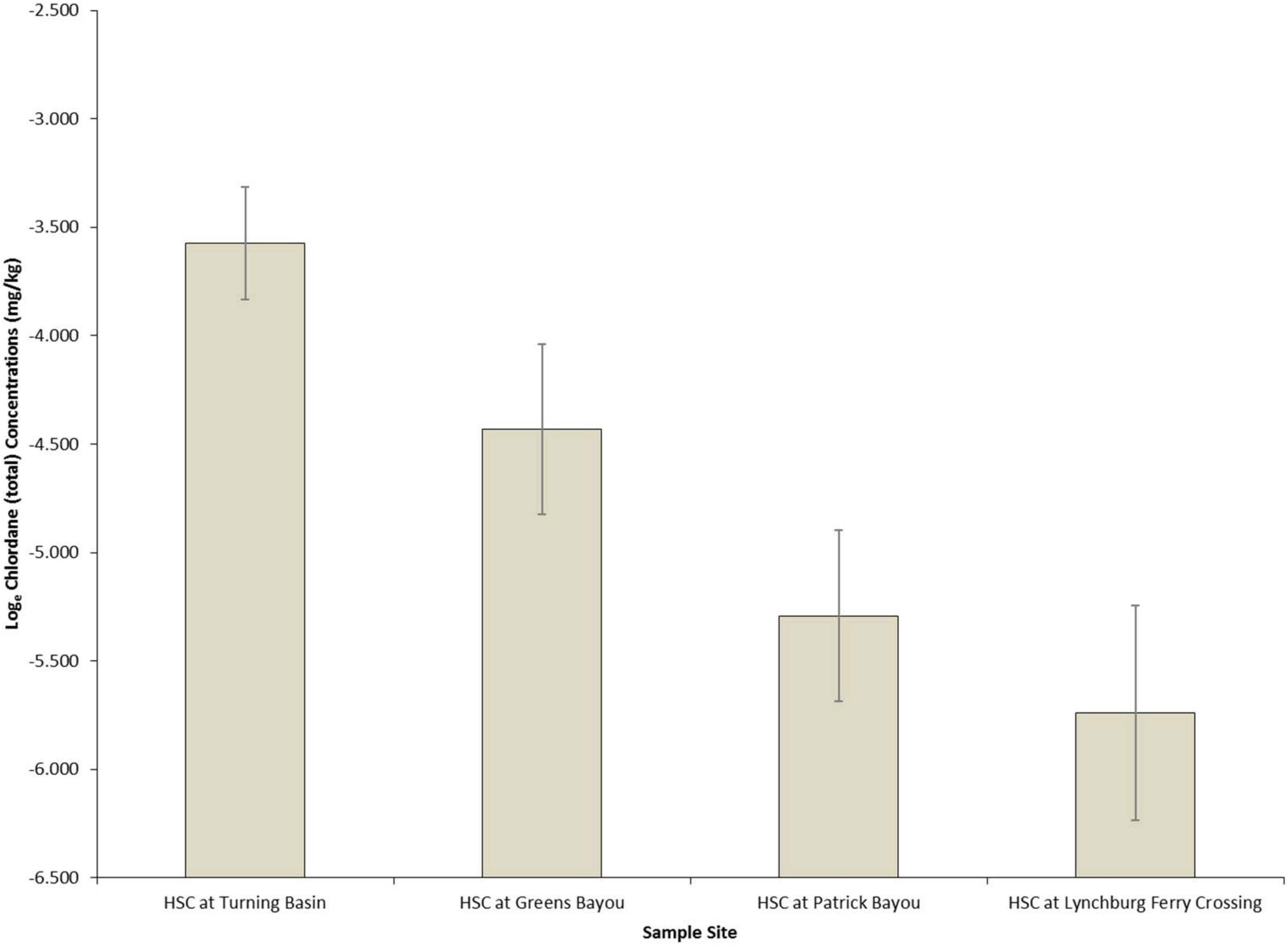


Figure 5. Mean Log_e DDT (total; mg/kg, wet wt.) in fish by sample site collected from the Houston Ship Channel, Texas 2012. The error bars denote the standard error of the mean.

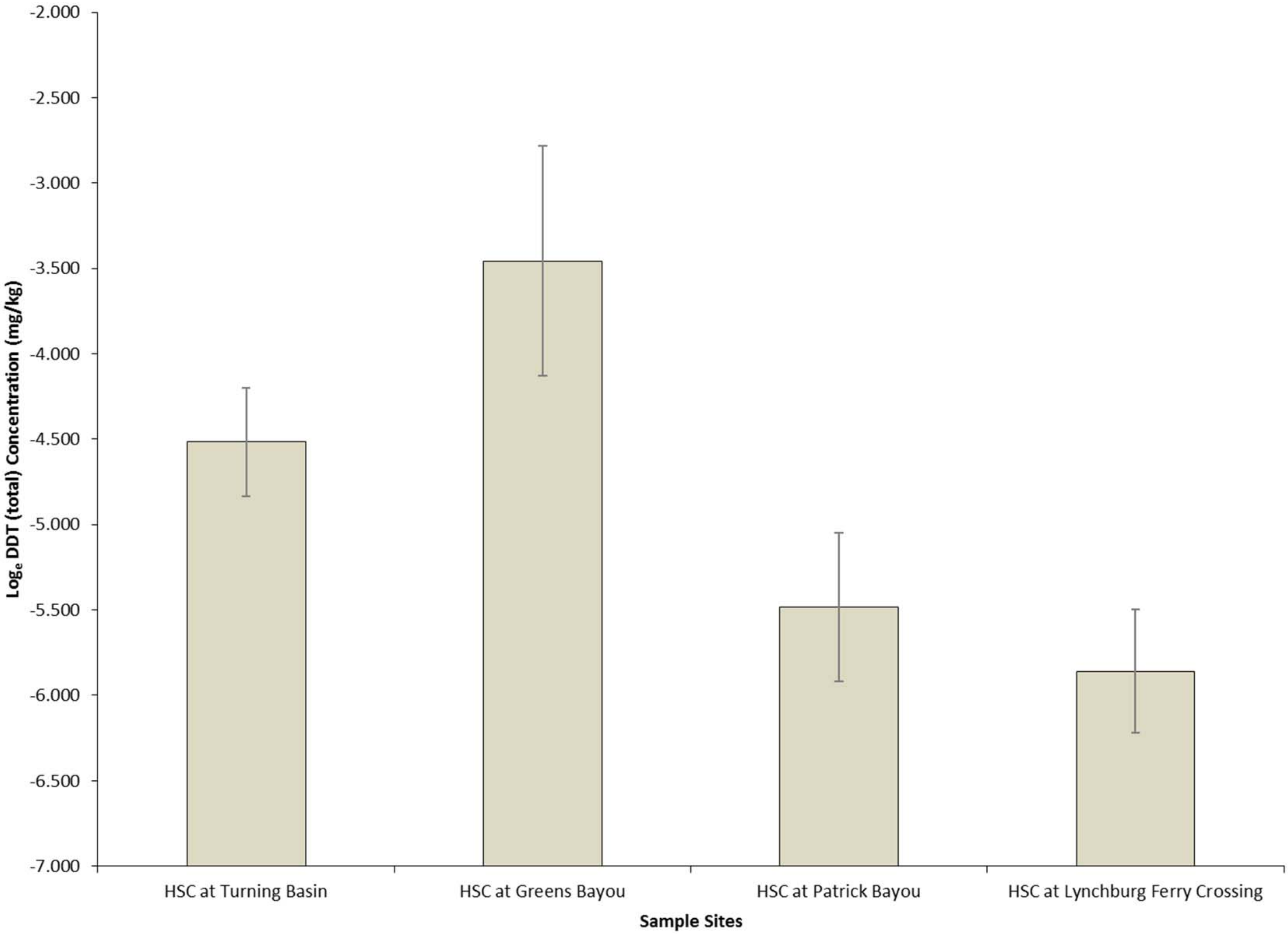


Figure 6. Mean Log_e hexachlorobenzene (mg/kg, wet wt.) in fish by sample site collected from the Houston Ship Channel, Texas 2012. The error bars denote the standard error of the mean.

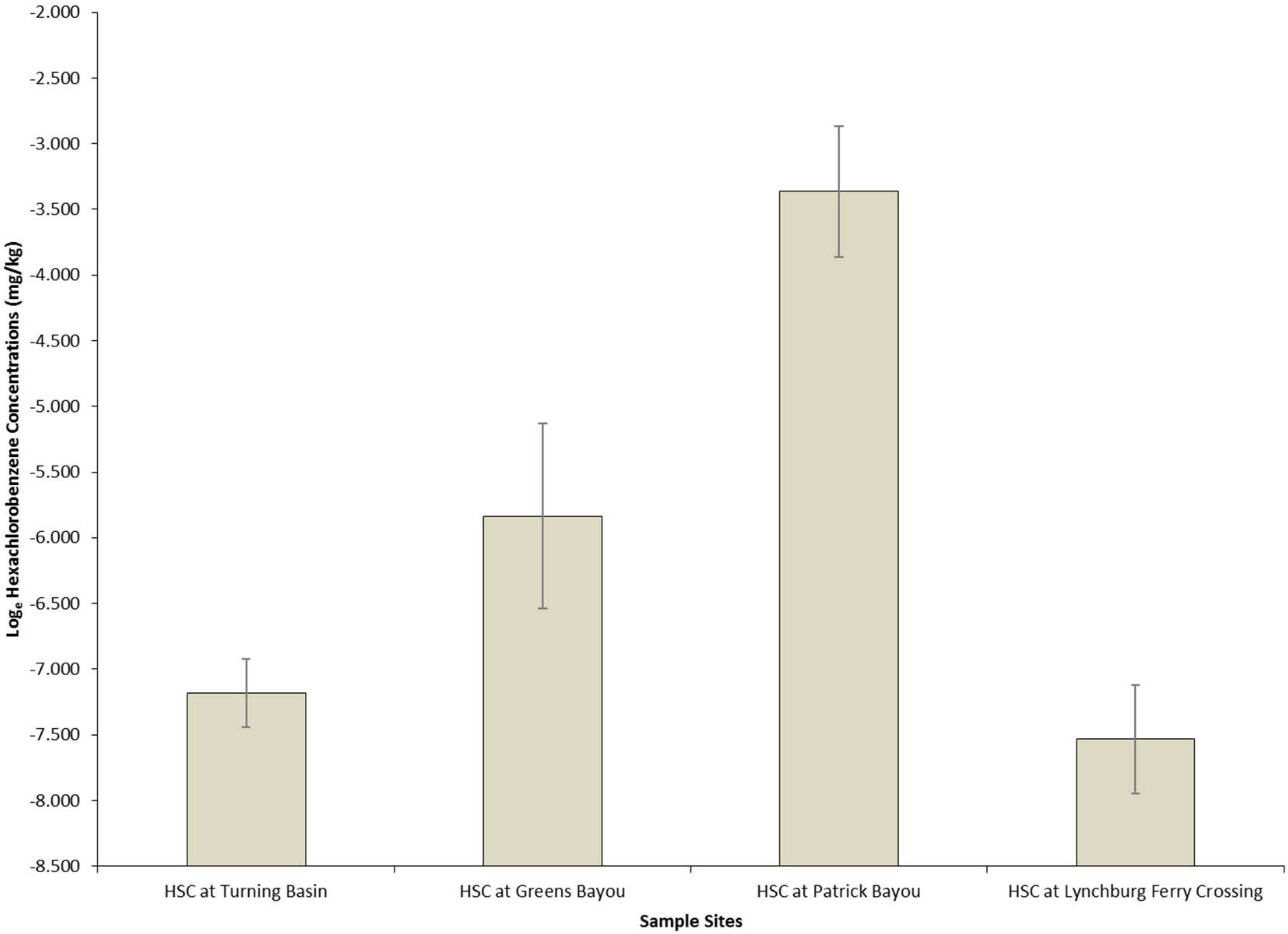


Figure 7. The relationship between PCB concentration and percent lipids for fish collected from the Houston Ship Channel, Texas, 2012.

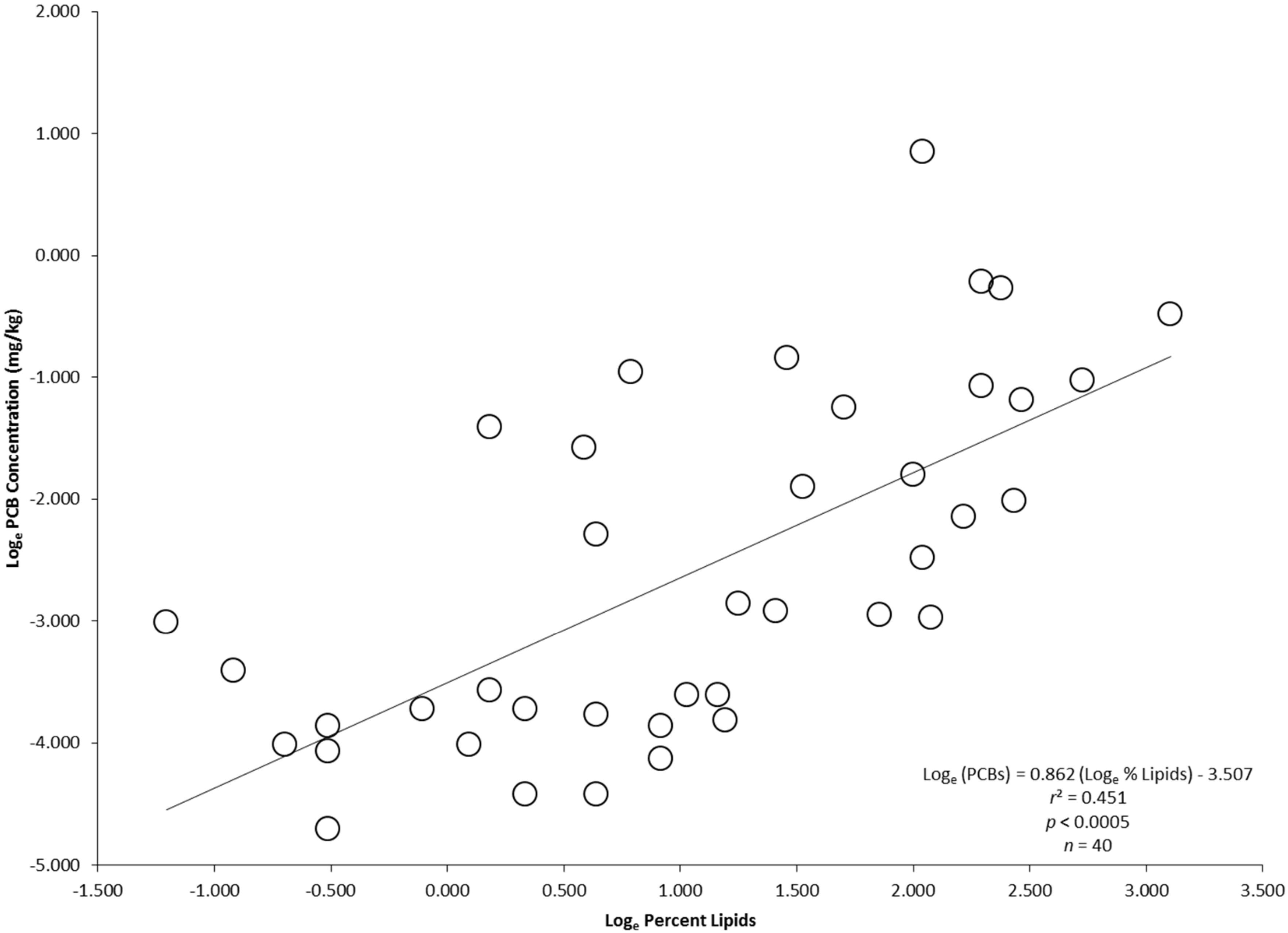


Figure 8. Mean Log_e PCBs (mg/kg, wet wt.) in fish by sample site collected from the Houston Ship Channel, Texas 2012. The error bars denote the standard error of the mean.

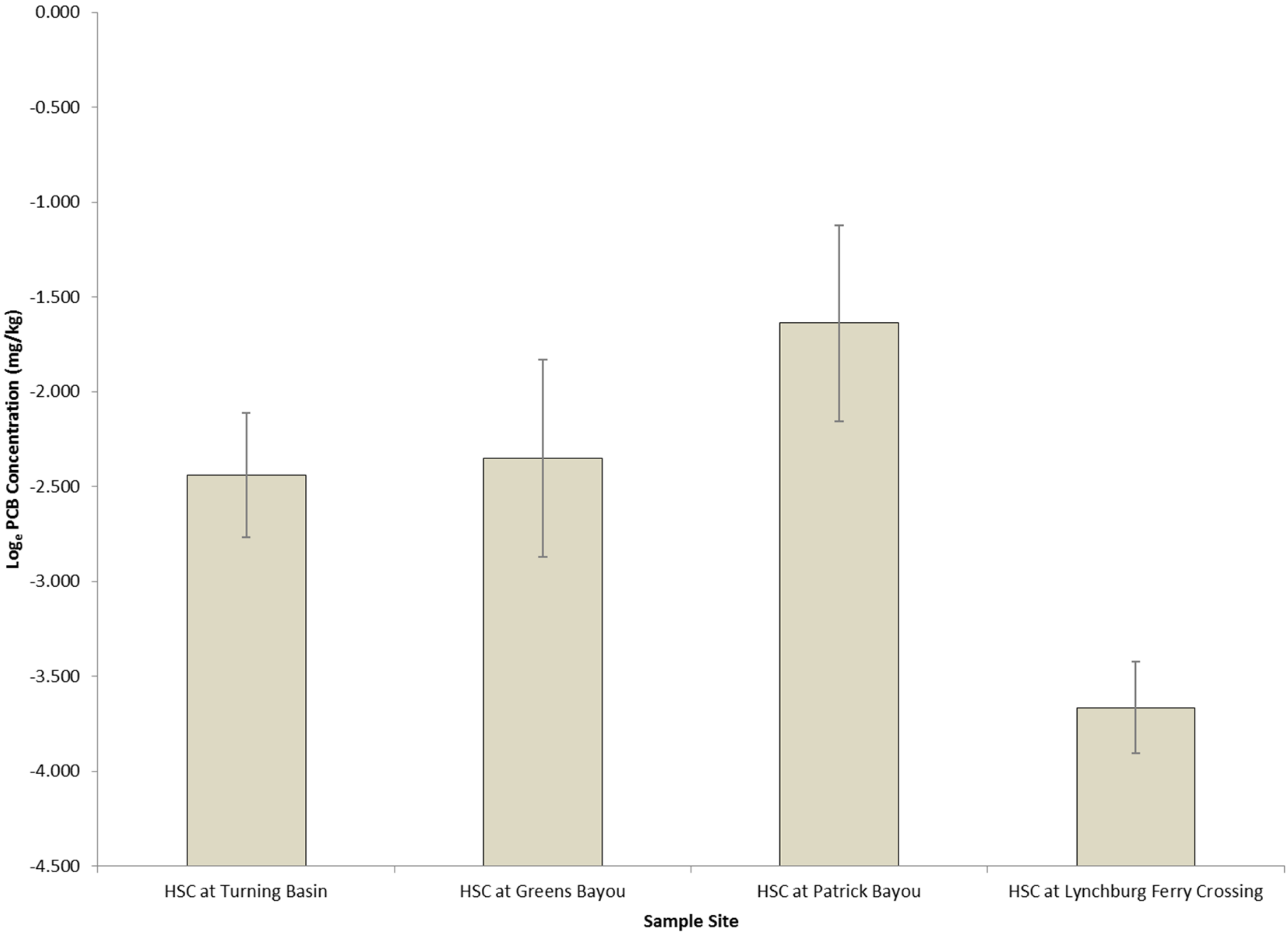


Figure 9. Mean PCDD/PCDF TEQ (pg/g, wet wt.) in fish by sample site collected from the Houston Ship Channel, Texas 2012. The error bars denote the standard error of the mean.

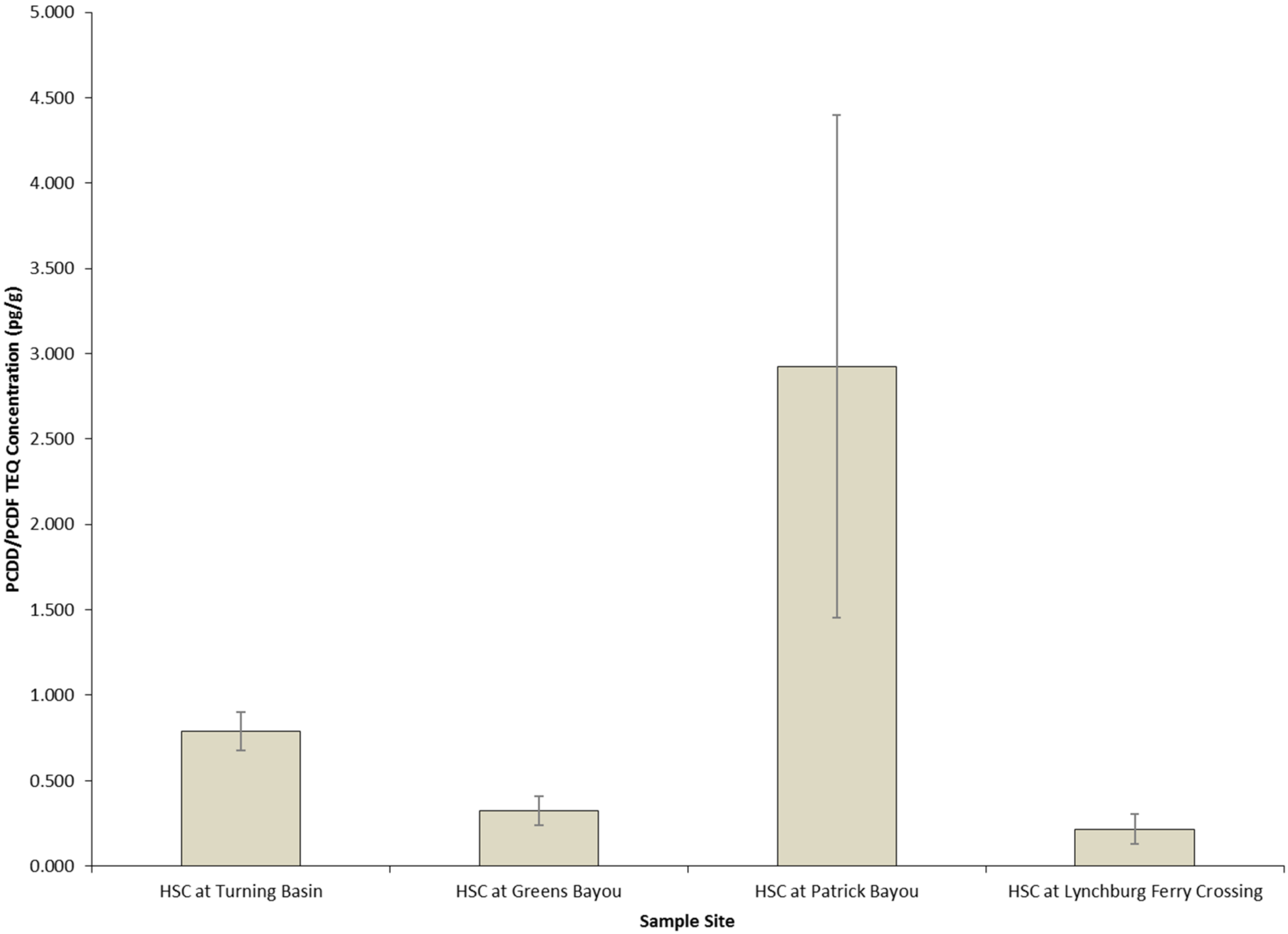


Figure 10. Box-and-whisker plot of PCBs (mg/kg, wet wt.) in blue crab and fish from the Houston Ship Channel, Texas for the 2011 and 2012 sampling events.

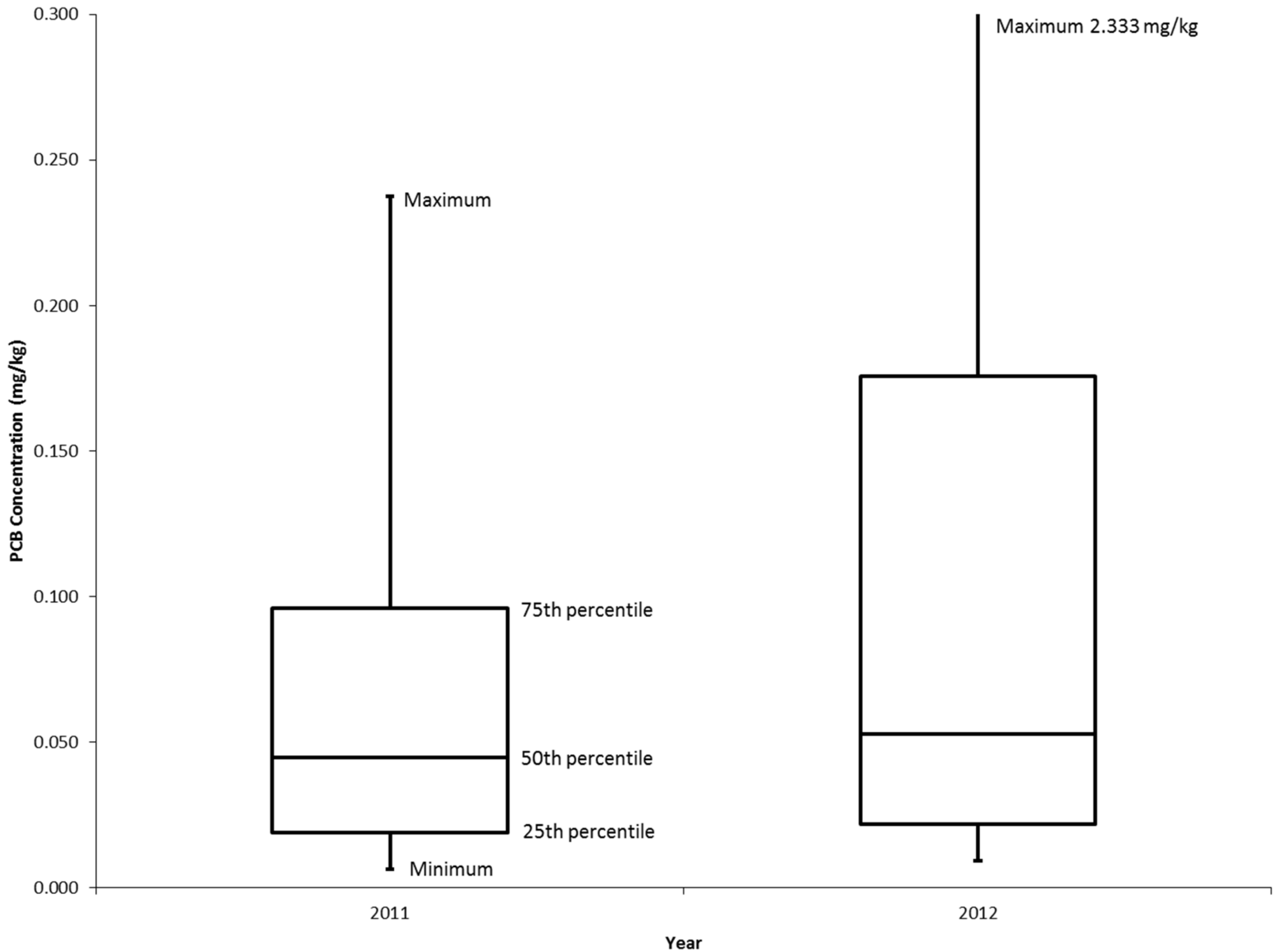


Figure 11. Box-and-whisker plot of PCBs (mg/kg, wet wt.) in fish from the Lynchburg Ferry Crossing of the Houston Ship Channel, Texas for the 2011 and 2012 sampling events.

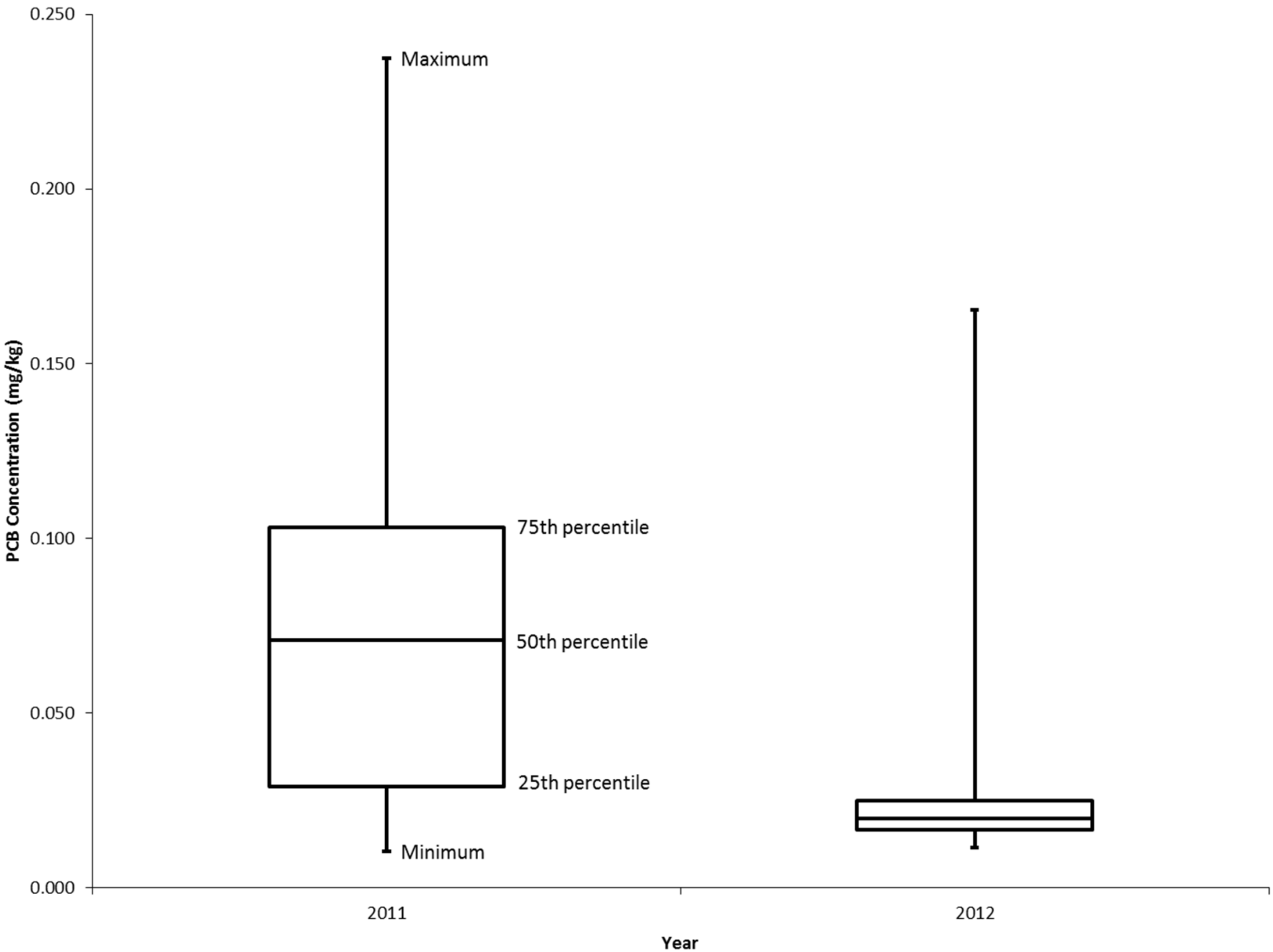


Figure 12. Mean PCDD/PCDF TEQ (pg/g, wet wt.) in blue crab and fish by sample event collected from the Houston Ship Channel, Texas 1990–2012. The error bars denote the standard error of the mean.

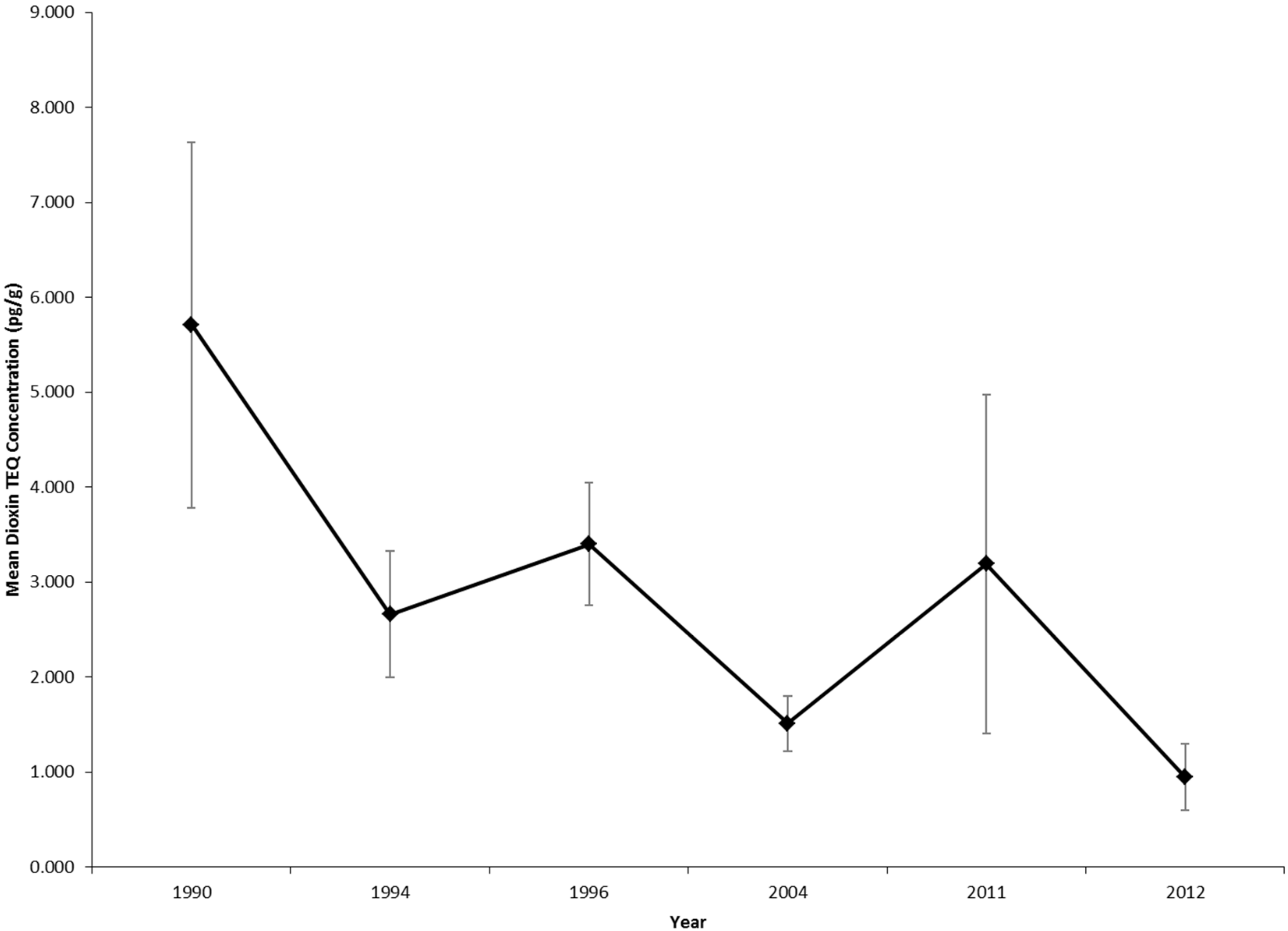


Figure 13. Mean Log$_e$ chlordane (total; mg/kg, wet wt.) in blue crab and fish by sample event collected from the Houston Ship Channel, Texas 1999–2012. The error bars denote the standard error of the mean.

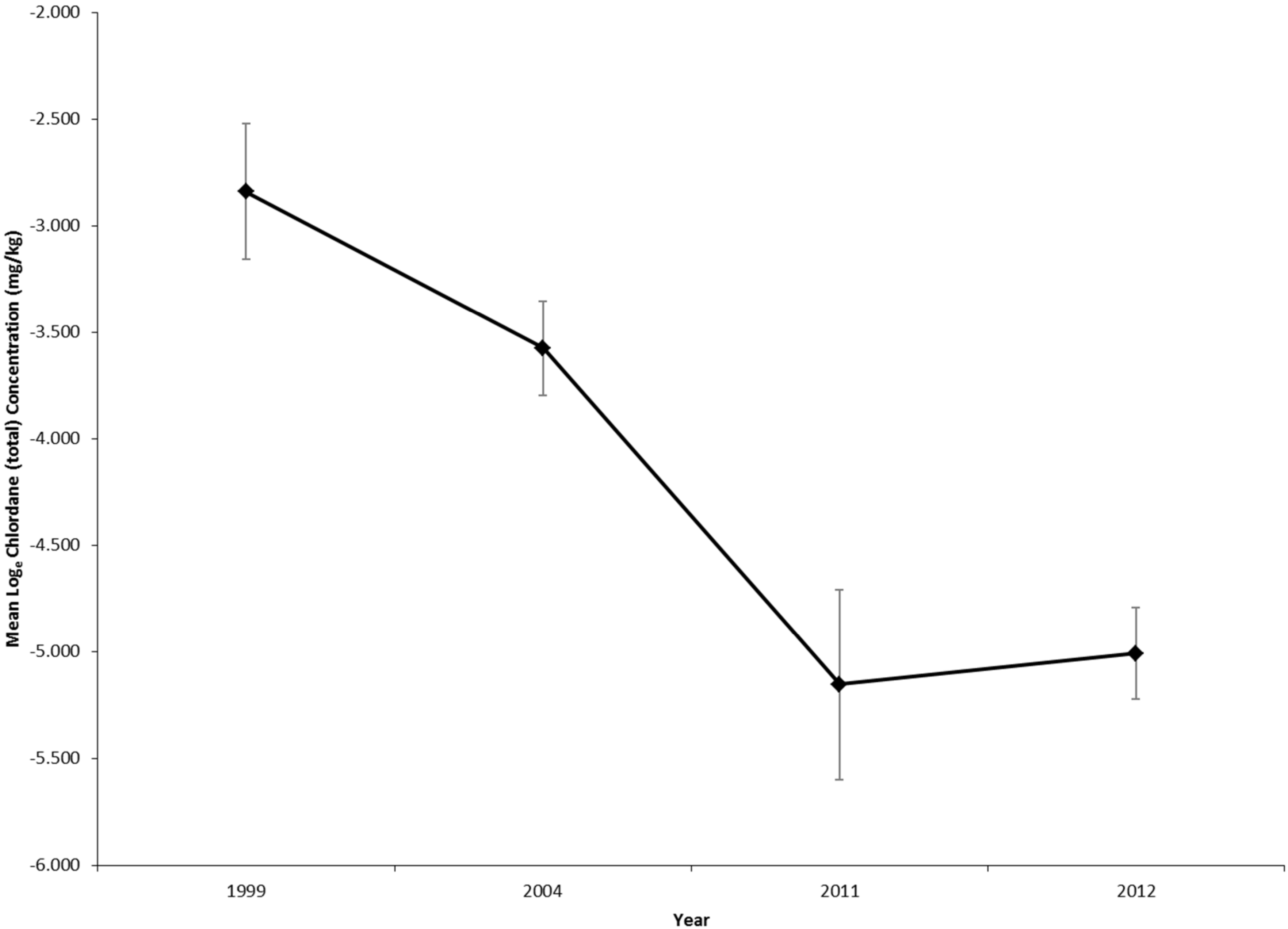


Figure 14. Mean Log_e dieldrin (mg/kg, wet wt.) in blue crab and fish by sample event collected from the Houston Ship Channel, Texas 1999–2012. The error bars denote the standard error of the mean.

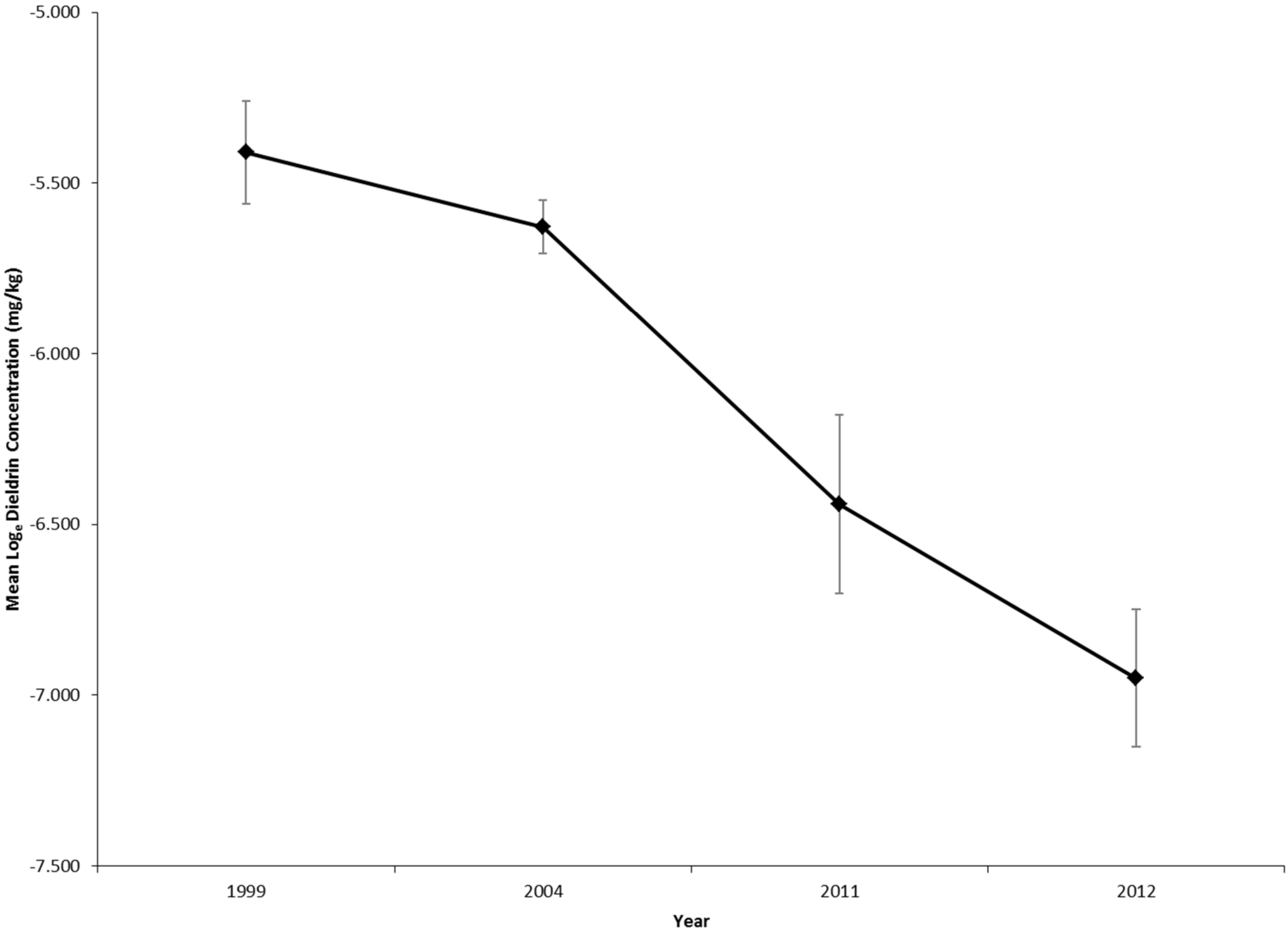
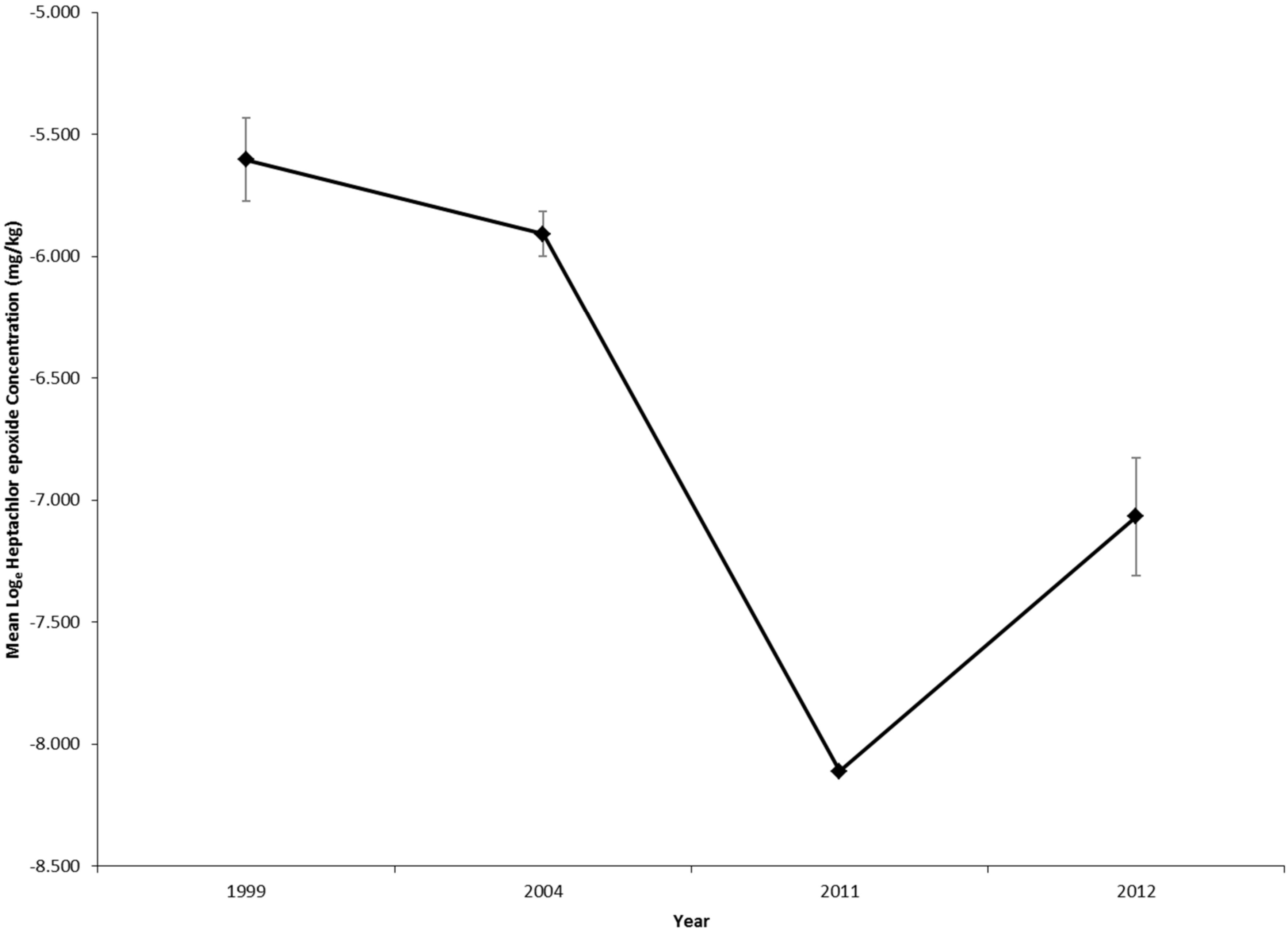


Figure 15. Mean Log_e Heptachlor epoxide (mg/kg, wet wt.) in blue crab and fish by sample event collected from the Houston Ship Channel, Texas 1999–2012. The error bars denote the standard error of the mean.



TABLES

Table 1. Fish samples collected from the Houston Ship Channel 2012. Sample number, species, length, and weight recorded for each sample.			
Sample Number	**Species**	**Length (mm)**	**Weight (g)**
Site 1 Houston Ship Channel at Turning Basin			
HSC49	Smallmouth buffalo	681	6150
HSC50	Smallmouth buffalo	624	4856
HSC52	Common carp	614	2802
HSC53	Channel catfish	527	1342
HSC54	Channel catfish	536	1590
HSC55	White bass	390	839
HSC56	Blue catfish	549	1565
HSC57	Common carp	556	2725
HSC58	Smallmouth buffalo	622	4927
HSC59	Blue catfish	642	2791
HSC60	Black drum	547	2274
Site 2 Houston Ship Channel at Greens Bayou			
HSC40	Smallmouth buffalo	611	4342
HSC41	Hardhead catfish	356	443
HSC42	Hardhead catfish	321	274
HSC43	Blue catfish	547	1487
HSC44	Sheepshead	447	1478
HSC45	Sheepshead	516	2546
HSC46	Red drum	638	2712
HSC47	Blue crab composite	165[j]	N/A
HSC48	Blue crab composite	143	N/A
Site 3 Houston Ship Channel at Patrick Bayou			
HSC1	Black drum	718	5280
HSC3	Black drum	916	13500
HSC5	Black drum	708	5402
HSC6	Hardhead catfish	350	395
HSC7	Southern flounder	479	1023
HSC8	Sheepshead	532	3223
HSC9	Sheepshead	339	708
HSC11	Southern flounder	412	780
HSC12	Alligator gar	1128	10250
HSC13	Alligator gar	1018	7500
HSC14	Blue crab composite	168	N/A
HSC15	Blue crab composite	167	N/A
HSC16	Blue crab composite	166	N/A
HSC17	Blue crab composite	181	N/A

[j] Each blue crab composite sample is composed of four individual blue crab samples. Carapace length for blue crab composite samples is the mean carapace length of the four individuals for each sample.

Table 1 cont. Fish samples collected from HSC 2012. Sample number, species, length, and weight recorded for each sample.			
Sample Number	**Species**	**Length (mm)**	**Weight (g)**
Site 4 Houston Ship Channel at Lynchburg Ferry Crossing			
HSC18	Spotted seatrout	453	965
HSC20	Spotted seatrout	485	1052
HSC22	Spotted seatrout	459	773
HSC23	Southern flounder	470	1086
HSC24	Southern flounder	441	1024
HSC27	Red drum	550	1607
HSC29	Black drum	925	14000
HSC30	Black drum	609	3030
HSC32	Sheepshead	500	2021
HSC33	Sheepshead	527	2463
HSC35	Gafftopsail catfish	550	1463
HSC37	Gafftopsail catfish	544	1691
HSC38	Blue crab composite	172	N/A
HSC39	Blue crab composite	184	N/A

Table 2.1. Arsenic (mg/kg) in blue crab and fish collected from the Houston Ship Channel, 2012.					
Species	**Number Detected/ Number Tested**	**Total Arsenic Mean ± S.D. (Min-Max)**	**Inorganic Arsenic Mean [k]**	**HAC Value (nonca) and HAC Value (ca; mg/kg)[l]**	**Basis for Comparison Value**
Alligator gar	2/2	0.862±0.100 (0.791-0.933)	0.086	0.700 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
Black drum	6/6	0.841±0.376 (0.429-1.370)	0.084		
Blue catfish	3/3	0.222±0.261 (0.057-0.523)	0.022		
Blue crab composite	8/8	0.700±0.324 (0.051-1.159)	0.070		
Channel catfish	2/2	0.079±0.065 (0.033-0.125)	0.008		
Common carp	2/2	0.134±0.035 (0.109-0.159)	0.013		
Gafftopsail catfish	2/2	0.657±0.143 (0.556-0.758)	0.066		
Hardhead catfish	3/3	0.467±0.301 (0.138-0.727)	0.047		
Red drum	2/2	0.308±0.013 (0.299-0.317)	0.031		
Sheepshead	6/6	0.439±0.114 (0.292-0.574)	0.044		
Smallmouth buffalo	4/4	0.195±0.048 (0.130-0.244)	0.020		
Southern flounder	4/4	0.302±0.043 (0.261-0.363)	0.030		
Spotted seatrout	3/3	0.144±0.031 (0.109-0.167)	0.014		
White bass	1/1	0.178	0.018		
All fish	40/40	0.411±0.312 (0.033-1.370)	0.041		
All blue crab and fish	48/48	0.459±0.329 (0.033-1.370)	0.046		

[k] *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.*
[l] *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 $1x10^{-4}$.*

Table 2.2. Cadmium (mg/kg) in blue crab and fish collected from the Houston Ship Channel, 2012.				
Species	**Number Detected/ Number Tested**	**Mean ± S.D. (Min-Max)**	**HAC Value (nonca; mg/kg)**	**Basis for Comparison Value**
Alligator gar	2/2	BDL	0.233	ATSDR Chronic Oral MRL—0.0001 mg/kg–day
Black drum	4/6	ND-BDL		
Blue catfish	3/3	0.021±0.021 (BDL-0.046)		
Blue crab composite	7/8	0.026±0.014 (ND-0.047)		
Channel catfish	2/2	BDL		
Common carp	1/2	ND-BDL		
Gafftopsail catfish	2/2	BDL		
Hardhead catfish	3/3	BDL		
Red drum	2/2	BDL		
Sheepshead	5/6	ND-BDL		
Smallmouth buffalo	4/4	BDL		
Southern flounder	3/4	ND-BDL		
Spotted seatrout	0/3	ND		
White bass	1/1	BDL		
All fish	31/40	0.012±0.006 (ND-0.046)		
All blue crab and fish	39/48	0.014±0.009 (ND-0.047)		

Table 2.3. Copper (mg/kg) in blue crab and fish collected from the Houston Ship Channel, 2012.				
Species	**Number Detected/ Number Tested**	**Mean ± S.D. (Min-Max)**	**HAC Value (nonca; mg/kg)**	**Basis for Comparison Value**
Alligator gar	2/2	0.254±0.271 (0.062-0.445)	334	Based on the Tolerable Upper Intake Level (UL) — 0.143 mg/kg–day[m]
Black drum	6/6	0.162±0.057 (0.100-0.253)		
Blue catfish	3/3	2.283±3.645 (0.167-6.492)		
Blue crab composite	8/8	9.419±4.891 (0.222-16.694)		
Channel catfish	2/2	0.217±0.084 (0.157-0.276)		
Common carp	2/2	0.228±0.018 (0.216-0.241)		
Gafftopsail catfish	2/2	0.301±0.004 (0.299-0.304)		
Hardhead catfish	3/3	0.243±0.037 (0.215-0.285)		
Red drum	2/2	0.207±0.057 (0.166-0.247)		
Sheepshead	6/6	0.174±0.047 (0.107-0.237)		
Smallmouth buffalo	4/4	0.163±0.031 (0.136-0.205)		
Southern flounder	4/4	0.125±0.058 (0.070-0.200)		
Spotted seatrout	3/3	0.114±0.004 (0.110-0.118)		
White bass	1/1	0.225		
All fish	40/40	0.343±1.000 (0.062-6.492)		
All blue crab and fish	48/48	1.856±4.009 (0.062-16.694)		

[m] The Food and Nutrition Board, Institute of Medicine, National Academies Upper Limit for copper is 10 mg/day.

Table 2.4. Lead (mg/kg) in blue crab and fish collected from the Houston Ship Channel, 2012.				
Species	**Number Detected/ Number Tested**	**Mean ± S.D. (Min-Max)**	**HAC Value (nonca; mg/kg)**	**Basis for Comparison Value**
Alligator gar	0/2	ND	N/A	N/A
Black drum	4/6	0.020±0.008 (ND-0.028)		
Blue catfish	3/3	0.027±0.031 (BDL-0.063)		
Blue crab composite	7/8	0.084±0.038 (ND-0.136)		
Channel catfish	2/2	0.017±0.008 (BDL-0.023)		
Common carp	2/2	BDL		
Gafftopsail catfish	2/2	0.049±0.013 (0.039-0.058)		
Hardhead catfish	2/3	0.032±0.021 (BDL-0.052)		
Red drum	2/2	0.096±0.100 (0.025-0.167)		
Sheepshead	4/6	0.024±0.010 (ND-0.032)		
Smallmouth buffalo	4/4	0.042±0.009 (0.034-0.051)		
Southern flounder	3/4	0.019±0.011 (ND-0.033)		
Spotted seatrout	1/3	ND-BDL		
White bass	1/1	BDL		
All fish	30/40	0.027±0.027 (ND-0.167)		
All blue crab and fish	37/48	0.037±0.036 (ND-0.167)		

Table 2.5. Selenium (mg/kg) in blue crab and fish collected from the Houston Ship Channel, 2012.				
Species	**Number Detected/ Number Tested**	**Mean ± S.D. (Min-Max)**	**HAC Value (nonca; mg/kg)**	**Basis for Comparison Value**
Alligator gar	2/2	0.695±0.118 (0.611-0.778)	6	EPA Chronic Oral RfD — 0.005 mg/kg–day ATSDR Chronic Oral MRL — 0.005 mg/kg–day 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)[n, 58]
Black drum	6/6	1.258±0.176 (1.013-1.504)		
Blue catfish	3/3	0.610±0.495 (0.309-1.181)		
Blue crab composite	8/8	1.367±0.463 (0.485-1.908)		
Channel catfish	2/2	0.379±0.134 (0.284-0.474)		
Common carp	2/2	0.545±0.041 (0.516-0.574)		
Gafftopsail catfish	2/2	0.308±0.035 (0.283-0.332)		
Hardhead catfish	3/3	0.524±0.158 (0.375-0.689)		
Red drum	2/2	1.121±0.111 (1.042-1.199)		
Sheepshead	6/6	1.153±0.253 (0.841-1.429)		
Smallmouth buffalo	4/4	0.707±0.084 (0.603-0.809)		
Southern flounder	4/4	1.209±0.280 (0.970-1.601)		
Spotted seatrout	3/3	1.201±0.386 (0.807-1.578)		
White bass	1/1	0.739		
All fish	40/40	0.899±0.391 (0.283-1.601)		
All blue crab and fish	48 /48	0.977±0.436 (0.283-1.908)		

[n] The DSHS applied relative source contribution methodology (RSC) developed by EPA to derive a HAC value for selenium. DSHS risk assessor's assumed that 50% of the daily selenium intake is from other foods or supplements (≈ 200 µg/day for a 70 kg adult or one-half the RfD) and subtracted an amount equal to 50% of the RfD from the RfD to account for other sources of exposure to selenium. The remainder of the RfD, 0.0025 mg/kg/day, was utilized to calculate the HAC value for selenium.

Table 2.6. Zinc (mg/kg) in blue crab and fish collected from the Houston Ship Channel, 2012.				
Species	**Number Detected/ Number Tested**	**Mean ± S.D. (Min-Max)**	**HAC Value (nonca; mg/kg)**	**Basis for Comparison Value**
Alligator gar	2/2	2.783±0.023 (2.767-2.799)	700	EPA Chronic Oral RfD — 0.3 mg/kg–day
Black drum	6/6	5.690±3.000 (4.017-11.702)		
Blue catfish	3/3	9.815±8.330 (4.554-19.419)		
Blue crab composite	8/8	27.698±9.512 (5.200-34.968)		
Channel catfish	2/2	4.469±0.243 (4.297-4.641)		
Common carp	2/2	4.654±1.435 (3.639-5.668)		
Gafftopsail catfish	2/2	6.989±0.592 (6.570-7.407)		
Hardhead catfish	3/3	9.190±2.012 (7.393-11.364)		
Red drum	2/2	3.702±1.580 (2.584-4.819)		
Sheepshead	6/6	3.264±0.691 (2.594-4.558)		
Smallmouth buffalo	4/4	3.351±0.744 (2.731-4.425)		
Southern flounder	4/4	2.670±0.247 (2.324-2.857)		
Spotted seatrout	3/3	2.541±0.224 (2.339-2.782)		
White bass	1/1	3.469		
All fish	40/40	4.778±3.271 (2.324-19.419)		
All blue crab and fish	48 /48	8.598±9.842 (2.324-34.968)		

Table 2.7. Mercury (mg/kg) in blue crab and fish collected from the Houston Ship Channel, 2012.				
Species	**Number Detected/ Number Tested**	**Mean ± S.D. (Min-Max)**	**HAC Value (nonca; mg/kg)**	**Basis for Comparison Value**
Site 1 Houston Ship Channel at Turning Basin				
Black drum	1/1	0.055	0.7	ATSDR Chronic Oral MRL for Methylmercury — 0.0003 mg/kg–day
Blue catfish	2/2	0.177±0.064 (0.132-0.223)		
Channel catfish	2/2	0.102±0.009 (0.095-0.108)		
Common carp	2/2	0.059±0.012 (0.051-0.068)		
Smallmouth buffalo	3/3	0.131±0.024 (0.115-0.159)		
White bass	1/1	0.208		
All fish	11/11	0.121±0.057 (0.051-0.223)		
Site 2 Houston Ship Channel at Greens Bayou				
Blue catfish	1/1	0.090	0.7	ATSDR Chronic Oral MRL for Methylmercury — 0.0003 mg/kg–day
Blue crab Composite	2/2	0.109±0.047 (0.076-0.143)		
Hardhead catfish	2/2	0.159±0.042 (0.129-0.188)		
Red drum	1/1	0.160		
Sheepshead	2/2	0.130±0.006 (0.126-0.134)		
Smallmouth buffalo	1/1	0.161		
All fish	7/7	0.141±0.032 (0.090-0.188)		
All blue crab and fish	9/9	0.134±0.035 (0.076-0.188)		

Table 2.8. Mercury (mg/kg) in blue crab and fish collected from the Houston Ship Channel, 2012.				
Species	**Number Detected/ Number Tested**	**Mean ± S.D. (Min-Max)**	**HAC Value (nonca; mg/kg)**	**Basis for Comparison Value**
Site 3 Houston Ship Channel at Patrick Bayou				
Alligator gar	2/2	0.086±0.022 (0.070-0.101)	0.7	ATSDR Chronic Oral MRL for Methylmercury — 0.0003 mg/kg–day
Black drum	3/3	0.303±0.122 (0.194-0.435)		
Blue crab Composite	4/4	0.161±0.021 (0.140-0.185)		
Hardhead catfish	1/1	0.133		
Sheepshead	2/2	0.318±0.181 (0.190-0.446)		
Southern flounder	2/2	0.087±0.012 (0.079-0.096)		
All fish	10/10	0.202±0.141 (0.070-0.446)		
All blue crab and fish	14/14	0.191±0.119 (0.070-0.446)		
Site 4 Houston Ship Channel Lynchburg Ferry Crossing				
Black drum	2/2	0.215±0.180 (0.087-0.342)	0.7	ATSDR Chronic Oral MRL for Methylmercury — 0.0003 mg/kg–day
Blue crab Composite	2/2	0.092±0.008 (0.086-0.098)		
Gafftopsail catfish	2/2	0.236±0.042 (0.206-0.266)		
Red drum	1/1	0.152		
Sheepshead	2/2	0.129±0.031 (0.107-0.151)		
Southern flounder	2/2	0.072±0.008 (0.066-0.078)		
Spotted seatrout	3/3	0.101±0.017 (0.083-0.117)		
All fish	12/12	0.146±0.085 (0.066-0.342)		
All blue crab and fish	14/14	0.139±0.081 (0.066-0.342)		

Table 2.9. Mercury (mg/kg) in blue crab and fish collected from the Houston Ship Channel, 2012.

Species	Number Detected/ Number Tested	Mean ± S.D. (Min-Max)	HAC Value (nonca; mg/kg)	Basis for Comparison Value
Alligator gar	2/2	0.086 ±0.022 (0.070-0.101)	0.7	ATSDR Chronic Oral MRL for Methylmercury — 0.0003 mg/kg–day
Black drum	6/6	0.232±0.148 (0.055-0.435)		
Blue catfish	3/3	0.148±0.068 (0.090-0.223)		
Blue crab composite	8/8	0.131±0.040 (0.076-0.185)		
Channel catfish	2/2	0.102±0.009 (0.095-0.108)		
Common carp	2/2	0.059±0.012 (0.051-0.068)		
Gafftopsail catfish	2/2	0.236±0.042 (0.206-0.266)		
Hardhead catfish	3/3	0.150±0.033 (0.129-0.188)		
Red drum	2/2	0.156±0.006 (0.152-0.160)		
Sheepshead	6/6	0.192±0.127 (0.107-0.446)		
Smallmouth buffalo	4/4	0.139±0.744 (0.115-0.161)		
Southern flounder	4/4	0.080±0.012 (0.066-0.096)		
Spotted seatrout	3/3	0.101±0.017 (0.083-0.117)		
White bass	1/1	0.208		
All fish	40/40	0.153±0.092 (0.051-0.446)		
All blue crab and fish	48/48	0.149±0.086 (0.051-0.446)		

Table 3.1. Chlordane (total; mg/kg) in blue crab and fish collected from the Houston Ship Channel, 2012.

Species	Number Detected/ Number Tested	Mean ± S.D. (Min-Max)	HAC Value (nonca) and HAC Value (ca; mg/kg)	Basis for Comparison Value
Alligator gar	2/2	0.0145±0.0177 (0.0020-0.0270)		
Black drum	6/6	0.0031±0.0029 (0.0006-0.0078)		
Blue catfish	3/3	0.0290±0.0164 (0.0132-0.0459)		
Blue crab composite	8/8	0.0031±0.0025 (0.0011-0.0071)		
Channel catfish	2/2	0.0297±0.0057 (0.0257-0.0338)		
Common carp	2/2	0.0197±0.0071 (0.0146-0.0247)		
Gafftopsail catfish	2/2	0.0213±0.0057 (0.0173-0.0253)		
Hardhead catfish	3/3	0.0243±0.0123 (0.0105-0.0342)	1.167	EPA Chronic Oral RfD — 0.0005 mg/kg–day
Red drum	2/2	0.0031±0.0023 (0.0015-0.0047)	1.556	EPA Oral Slope Factor — 0.35 per mg/kg–day
Sheepshead	6/6	0.0056±0.0035 (0.0015-0.0109)		
Smallmouth buffalo	4/4	0.0676±0.0473 (0.0356-0.1359)		
Southern flounder	4/4	0.0025±0.0021 (0.0006-0.0053)		
Spotted seatrout	3/3	0.0516±0.0874 (0.0006-0.1526)		
White bass	1/1	0.0276		
All fish	40/40	0.0213±0.0323 (0.0006-0.1526)		
All blue crab and fish	48/48	0.0183±0.0303 (0.0006-0.1526)		

Table 3.2. DDT (total; mg/kg) in blue crab and fish collected from the Houston Ship Channel, 2012.				
Species	**Number Detected/ Number Tested**	**Mean ± S.D. (Min-Max)**	**HAC Value (nonca) and HAC Value (ca; mg/kg)**	**Basis for Comparison Value**
Alligator gar	2/2	0.0104±0.0122 (0.0018-0.0191)		
Black drum	6/6	0.0031±0.0033 (0.0004-0.0095)		
Blue catfish	3/3	0.0232±0.0179 (0.0064-0.0421)		
Blue crab composite	8/8	0.0024±0.0009 (0.0015-0.0045)		
Channel catfish	2/2	0.0095±0.0027 (0.0076-0.0114)		
Common carp	2/2	0.0055±0.0004 (0.0052-0.0058)		
Gafftopsail catfish	2/2	0.0341±0.0132 (0.0248-0.0434)		
Hardhead catfish	3/3	0.0528±0.0549 (0.0136-0.1156)	1.167	EPA Chronic Oral RfD for DDT — 5.0E-4 mg/kg–day
Red drum	2/2	0.0058±0.0064 (0.0013-0.0103)	1.601	EPA Oral Slope Factor for DDT — 3.4E-1 per mg/kg–day
Sheepshead	6/6	0.0071±0.0048 (0.0015-0.0134)		
Smallmouth buffalo	4/4	0.2455±0.3892 (0.0133-0.8262)		
Southern flounder	4/4	0.0019±0.0011 (0.0009-0.0034)		
Spotted seatrout	3/3	0.0014±0.0001 (0.0013-0.0015)		
White bass	1/1	0.0062		
All fish	40/40	0.0355±0.1306 (0.0004-0.8262)		
All blue crab and fish	48/48	0.0300±0.1197 (0.0004-0.8262)		

Table 3.3. Dieldrin (mg/kg) in blue crab and fish collected from the Houston Ship Channel, 2012.				
Species	**Number Detected/ Number Tested**	**Mean ± S.D. (Min-Max)**	**HAC Value (nonca) and HAC Value (ca; mg/kg)**	**Basis for Comparison Value**
Alligator gar	2/2	0.0024±0.0025 (0.0006-0.0041)		
Black drum	6/6	0.0010±0.0008 (0.0004-0.0022)		
Blue catfish	3/3	0.0020±0.0016 (0.0007-0.0038)		
Blue crab composite	5/8	0.0003±0.0003 (ND-0.0008)		
Channel catfish	2/2	0.0051±0.0024 (0.0034-0.0068)		
Common carp	2/2	0.0032±0.0007 (0.0027-0.0037)		
Gafftopsail catfish	2/2	0.0036±0.0007 (0.0031-0.0041)		
Hardhead catfish	3/3	0.0040±0.0021 (0.0016-0.0052)	0.117	EPA Chronic Oral RfD — 0.00005 mg/kg–day
Red drum	2/2	0.0005±0.0003 (0.0003-0.0007)	0.034	EPA Oral Slope Factor — 16 per mg/kg–day
Sheepshead	6/6	0.0014±0.0008 (0.0004-0.0024)		
Smallmouth buffalo	4/4	0.0077±0.0032 (0.0037-0.0113)		
Southern flounder	4/4	0.0002±0.0002 (BDL-0.0005)		
Spotted seatrout	3/3	0.0002±0.0002 (BDL-0.0003)		
White bass	1/1	0.0033		
All fish	40/40	0.0024±0.0026 (0.0001-0.0113)		
All blue crab and fish	45/48	0.0021±0.0025 (ND-0.0113)		

Table 3.4. Endrin (mg/kg) in blue crab and fish collected from the Houston Ship Channel, 2012.

Species	Number Detected/ Number Tested	Mean ± S.D. (Min-Max)	Health Assessment Comparison Value (mg/kg)	Basis for Comparison Value
Alligator gar	2/2	0.0019±0.0025 (BDL-0.0037)	0.700	EPA Chronic Oral RfD — 3.0E-4 mg/kg–day
Black drum	6/6	0.0012±0.0006 (0.0006-0.0021)		
Blue catfish	3/3	0.0032±0.0015 (0.0021-0.0049)		
Blue crab composite	3/8	0.0004±0.0005 (ND-0.0012)		
Channel catfish	2/2	0.0071±0.0020 (0.0057-0.0085)		
Common carp	2/2	0.0112±0.0107 (0.0036-0.0188)		
Gafftopsail catfish	2/2	0.0046±0.0011 (0.0039-0.0054)		
Hardhead catfish	2/3	0.0052±0.0044 (ND-0.0078)		
Red drum	2/2	0.0004±0.0001 (0.0004-0.0005)		
Sheepshead	6/6	0.0017±0.0006 (0.0009-0.0023)		
Smallmouth buffalo	4/4	0.0092±0.0040 (0.0048-0.0141)		
Southern flounder	4/4	0.0005±0.0003 (BDL-0.0008)		
Spotted seatrout	3/3	0.0008±0.0006 (0.0003-0.0014)		
White bass	1/1	0.0058		
All fish	39/40	0.0035±0.0041 (0.0001-0.0188)		
All blue crab and fish	42/48	0.0030±0.0039 (ND-0.0188)		

Table 3.5. Heptachlor epoxide (mg/kg) in blue crab and fish collected from the Houston Ship Channel, 2012.

Species	Number Detected/ Number Tested	Mean ± S.D. (Min-Max)	HAC Value (nonca) and HAC Value (ca; mg/kg)	Basis for Comparison Value
Alligator gar	1/2	0.0017±0.0023 (ND-0.0034)	0.030 0.060	EPA Chronic Oral RfD — 1.3E-5 mg/kg–day EPA Oral Slope Factor — 9.1E+0 per mg/kg–day
Black drum	3/6	0.0006±0.0007 (ND-0.0020)		
Blue catfish	2/3	0.0020±0.0019 (ND-0.0038)		
Blue crab composite	5/8	0.0006±0.0006 (ND-0.0017)		
Channel catfish	1/2	0.0010±0.0013 (ND-0.0019)		
Common carp	2/2	0.0046±0.0052 (0.0009-0.0083)		
Gafftopsail catfish	2/2	0.0036±0.0017 (0.0024-0.0048)		
Hardhead catfish	3/3	0.0035±0.0026 (0.0011-0.0063)		
Red drum	2/2	0.0005±0.0001 (0.0005-0.0006)		
Sheepshead	6/6	0.0011±0.0008 (0.0003-0.0024)		
Smallmouth buffalo	4/4	0.0070±0.0063 (0.0035-0.0165)		
Southern flounder	2/4	0.0013±0.0022 (ND-0.0045)		
Spotted seatrout	2/3	0.0505±0.0874 (ND-0.1514)		
White bass	1/1	0.0027		
All fish	31/40	0.0059±0.0238 (ND-0.1514)		
All blue crab and fish	36/48	0.0051±0.0218 (ND-0.1514)		

Table 3.6. Hexachlorobenzene (mg/kg) in blue crab and fish collected from the Houston Ship Channel, 2012.				
Species	**Number Detected/ Number Tested**	**Mean ± S.D. (Min-Max)**	**HAC Value (nonca) and HAC Value (ca; mg/kg)**	**Basis for Comparison Value**
Alligator gar	2/2	0.1678±0.1048 (0.0937-0.2419)	1.867 0.340	EPA Chronic Oral RfD — 8.0E-4 mg/kg–day EPA Oral Slope Factor — 1.6E+0 per mg/kg–day
Black drum	6/6	0.0084±0.0161 (BDL-0.0405)		
Blue catfish	3/3	0.0022±0.0029 (0.0005-0.0055)		
Blue crab composite	8/8	0.0084±0.0099 (0.0003-0.0254)		
Channel catfish	2/2	0.0008±0.0002 (0.0006-0.0009)		
Common carp	2/2	0.0011±0.0001 (0.0010-0.0011)		
Gafftopsail catfish	2/2	0.0046±0.0023 (0.0030-0.0062)		
Hardhead catfish	3/3	0.0255±0.0246 (0.0016-0.0508)		
Red drum	2/2	BDL		
Sheepshead	6/6	0.0413±0.0684 (0.0011-0.1688)		
Smallmouth buffalo	4/4	0.0066±0.0095 (0.0013-0.0208)		
Southern flounder	4/4	0.0113±0.0125 (0.0006-0.0245)		
Spotted seatrout	3/3	0.0004±0.0003 (BDL-0.0006)		
White bass	1/1	0.0006		
All fish	40/40	0.0201±0.0484 (BDL-0.2419)		
All blue crab and fish	48/48	0.0181±0.0444 (ND-0.2419)		

Table 3.7. Pentachlorobenzene (mg/kg) in blue crab and fish collected from the Houston Ship Channel, 2012.				
Species	**Number Detected/ Number Tested**	**Mean ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
Alligator gar	2/2	0.0086±0.0060 (0.0043-0.0128)	1.867	EPA Chronic Oral RfD — 8.0E-4 mg/kg–day
Black drum	6/6	0.0019±0.0032 (BDL-0.0082)		
Blue catfish	2/3	0.0003±0.0002 (ND-0.0004)		
Blue crab composite	8/8	0.0011±0.0011 (BDL-0.0028)		
Channel catfish	2/2	0.0005±0.0001 (0.0004-0.0006)		
Common carp	1/2	ND-BDL		
Gafftopsail catfish	2/2	0.0006±0.0002 (0.0004-0.0007)		
Hardhead catfish	3/3	0.0015±0.0014 (BDL-0.0029)		
Red drum	2/2	BDL		
Sheepshead	6/6	0.0016±0.0024 (BDL-0.0057)		
Smallmouth buffalo	4/4	0.0008±0.0003 (0.0004-0.0011)		
Southern flounder	4/4	0.0007±0.0006 (BDL-0.0014)		
Spotted seatrout	3/3	BDL		
White bass	0/1	ND		
All fish	37/40	0.0013±0.0025 (ND-0.0128)		
All blue crab and fish	45/48	0.0013±0.0023 (ND-0.0128)		

Table 4.1. PCBs (mg/kg) in blue crab and fish collected from the Houston Ship Channel, 2012.				
Species	**Number Detected/ Number Tested**	**Mean ± S.D. (Min-Max)**	**HAC Value (nonca) and HAC Value (ca; mg/kg)**	**Basis for Comparison Value**
Site 1 Houston Ship Channel at Turning Basin				
Black drum	1/1	0.021	0.047 0.272	EPA Chronic Oral RfD for Aroclor 1254 — 0.00002 mg/kg–day EPA Slope Factor — 2.0 per mg/kg–day
Blue catfish	2/2	**0.171**[o]±0.162 (**0.057**-**0.286**)		
Channel catfish	2/2	**0.067**±0.022 (**0.052**-**0.083**)		
Common carp	2/2	0.036±0.021 (0.022-**0.051**)		
Smallmouth buffalo	3/3	**0.351**±0.244 (**0.133**-**0.615**)		
White bass	1/1	**0.054**		
All fish	11/11	**0.153**±0.183 (0.021-**0.615**)		
Site 2 Houston Ship Channel at Greens Bayou				
Blue catfish	1/1	0.101	0.047 0.272	EPA Chronic Oral RfD for Aroclor 1254 — 0.00002 mg/kg–day EPA Slope Factor — 2.0 per mg/kg–day
Blue crab composite	2/2	0.022±0.010 (0.015-0.029)		
Hardhead catfish	2/2	**0.252**±0.146 (**0.149**-**0.356**)		
Red drum	1/1	0.028		
Sheepshead	2/2	0.025±0.003 (0.023-0.027)		
Smallmouth buffalo	1/1	**0.763**		
All fish	7/7	**0.207**±0.272 (0.023-**0.763**)		
All blue crab and fish	9/9	**0.165**±0.249 (0.015-**0.763**)		

[o] *Emboldened numbers denote that PCB concentrations equal and/or exceed the DSHS HAC value for PCBs.*

Table 4.2. PCBs (mg/kg) in blue crab and fish collected from the Houston Ship Channel, 2012.				
Species	**Number Detected/ Number Tested**	**Mean ± S.D. (Min-Max)**	**HAC Value (nonca) and HAC Value (ca; mg/kg)**	**Basis for Comparison Value**
Site 3 Houston Ship Channel at Patrick Bayou				
Alligator gar	2/2	**1.288**[p]±1.478 (**0.243**-**2.333**)		
Black drum	3/3	**0.185**±0.166 (0.009-**0.340**)		
Blue crab composite	4/4	**0.070**±0.015 (**0.056**-**0.084**)		
Hardhead catfish	1/1	**0.807**	0.047	EPA Chronic Oral RfD for Aroclor 1254 — 0.00002 mg/kg–day
Sheepshead	2/2	**0.405**±0.032 (**0.383**-**0.428**)	0.272	EPA Slope Factor — 2.0 per mg/kg–day
Southern flounder	2/2	0.041±0.011 (0.033-**0.049**)		
All fish	10/10	**0.483**±0.692 (0.009-**2.333**)		
All blue crab and fish	14/14	**0.365**±0.608 (0.009-**2.333**)		
Site 4 Houston Ship Channel at Lynchburg Ferry Crossing				
Black drum	2/2	0.018±0.009 (0.012-0.024)		
Blue crab composite	2/2	0.011±0.001 (0.011-0.012)		
Gafftopsail catfish	2/2	**0.141**±0.034 (**0.117**-**0.165**)		
Red drum	1/1	0.017		
Sheepshead	2/2	0.023±0.007 (0.018-0.027)	0.047 0.272	EPA Chronic Oral RfD for Aroclor 1254 — 0.00002 mg/kg–day EPA Slope Factor — 2.0 per mg/kg–day
Southern flounder	2/2	0.020±0.002 (0.018-0.021)		
Spotted seatrout	3/3	0.017±0.006 (0.012-0.024)		
All fish	12/12	0.039±0.049 (0.012-**0.165**)		
All blue crab and fish	14/14	0.035±0.046 (0.011-**0.165**)		

[p] *Emboldened numbers denote that PCB concentrations equal and/or exceed the DSHS HAC value for PCBs.*

Table 4.3. PCBs (mg/kg) in blue crab and fish collected from the Houston Ship Channel by species, 2012.

Species	Number Detected/ Number Tested	Mean ± S.D. (Min-Max)	HAC Value (nonca) and HAC Value (ca; mg/kg)	Basis for Comparison Value
Alligator gar	2/2	**1.288**[q]±1.478 (**0.243**-**2.333**)	0.047 0.272	EPA Chronic Oral RfD for Aroclor 1254 — 0.00002 mg/kg–day EPA Slope Factor — 2.0 per mg/kg–day
Black drum	6/6	**0.102**±0.139 (0.009-**0.340**)		
Blue catfish	3/3	**0.148**±0.122 (**0.057**-**0.286**)		
Blue crab composite	8/8	0.043±0.031 (0.011-**0.084**)		
Channel catfish	2/2	**0.067**±0.022 (**0.052**-**0.083**)		
Common carp	2/2	0.036±0.021 (0.022-**0.051**)		
Gafftopsail catfish	2/2	**0.141**±0.034 (**0.117**-**0.165**)		
Hardhead catfish	3/3	**0.437**±0.337 (**0.149**-**0.807**)		
Red drum	2/2	0.022±0.008 (0.017-0.028)		
Sheepshead	6/6	**0.151**±0.198 (0.018-**0.428**)		
Smallmouth buffalo	4/4	**0.454**±0.287 (**0.133**-**0.763**)		
Southern flounder	4/4	0.030±0.014 (0.018-**0.049**)		
Spotted seatrout	3/3	0.017±0.006 (0.012-0.024)		
White bass	1/1	**0.054**		
All fish	40/40	**0.211**±0.400 (0.009-**2.333**)		
All blue crab and fish	48/48	**0.183**±0.370 (0.009-**2.333**)		

[q] *Emboldened numbers denote that PCB concentrations equal and/or exceed the DSHS HAC value for PCBs.*

Table 5.1. PCDDs/PCDFs toxicity equivalent (TEQ) concentrations (pg/g) in blue crab and fish collected from Houston Ship Channel by sample site, 2012.

Species	Number Detected/ Number Tested	Mean ± S.D. (Min-Max)	HAC Value (nonca) and HAC Value (ca; pg/g)	Basis for Comparison Value
Site 1 Houston Ship Channel at Turning Basin				
Black drum	0/1	ND	2.33 3.49	ATSDR Chronic Oral MRL for 2,3,7,8 – TCDD —1.0 x 10^{-9} mg/kg–day EPA Slope Factor — 1.56 x 10^{5} per mg/kg–day
Blue catfish	2/2	**3.075**[r]±3.479 (0.615-**5.535**)		
Channel catfish	0/2	ND		
Common carp	1/2	0.210±0.297 (ND-0.420)		
Smallmouth buffalo	1/3	0.363±0.629 (ND-1.090)		
White bass	1/1	1.035		
All fish	5/11	0.790±1.630 (ND-**5.535**)		
Site 2 Houston Ship Channel at Greens Bayou				
Blue catfish	1/1	1.001	2.33 3.49	ATSDR Chronic Oral MRL for 2,3,7,8 – TCDD —1.0 x 10^{-9} mg/kg–day EPA Slope Factor — 1.56 x 10^{5} per mg/kg–day
Blue crab Composite	1/2	0.205±0.290 (ND-0.410)		
Hardhead catfish	1/2	0.121±0.171 (ND-0.242)		
Red drum	1/1	0.300		
Sheepshead	2/2	0.197±0.009 (0.190-0.203)		
Smallmouth buffalo	1/1	0.330		
All fish	7/7	0.324±0.317 (ND-1.001)		
All blue crab and fish	7/8	0.297±0.298 (ND-1.001)		

[r] *Emboldened numbers denote that PCDD/PCDF TEQ concentrations equal and/or exceed the DSHS HAC value for PCDDs/PCDFs.*

Table 5.2. PCDDs/PCDFs toxicity equivalent (TEQ) concentrations (pg/g) in blue crab and fish collected from Houston Ship Channel by sample site, 2012.				
Species	**Number Detected/ Number Tested**	**Mean ± S.D. (Min-Max)**	**HAC Value (nonca) and HAC Value (ca; pg/g)**	**Basis for Comparison Value**
Site 3 Houston Ship Channel at Patrick Bayou				
Alligator gar	2/2	**7.289**[s]±8.514 (1.268-**13.309**)	2.33 3.49	ATSDR Chronic Oral MRL for 2,3,7,8 – TCDD —1.0 x 10^{-9} mg/kg–day EPA Slope Factor — 1.56 x 10^{5} per mg/kg–day
Black drum	2/3	0.327±0.415 (ND-0.793)		
Blue crab Composite	3/4	0.366±0.482 (ND-1.076)		
Hardhead catfish	1/1	**2.892**		
Sheepshead	2/2	**5.407**±5.892 (1.240-**9.573**)		
Southern flounder	0/2	ND		
All fish	7/10	**2.926**±4.659 (ND-**13.309**)		
All blue crab and fish	10/14	2.195±4.064 (ND-**13.309**)		
Site 4 Houston Ship Channel at Lynchburg Ferry Crossing				
Black drum	0/2	ND	2.33 3.49	ATSDR Chronic Oral MRL for 2,3,7,8 – TCDD —1.0 x 10^{-9} mg/kg–day EPA Slope Factor — 1.56 x 10^{5} per mg/kg–day
Blue crab Composite	2/2	0.345± 0.021 (0.330-0.360)		
Gafftopsail catfish	2/2	0.727±0.116 (0.645-0.809)		
Red drum	1/1	0.140		
Sheepshead	2/2	0.023±0.007 (0.018-0.027)		
Southern flounder	2/2	0.087±0.033 (0.064-0.110)		
Spotted seatrout	1/3	0.119±0.206 (ND-0.357)		
All fish	8/12	0.215±0.267 (ND-0.809)		
All blue crab and fish	10/14	0.234±0.250 (ND-0.809)		

[s] *Emboldened numbers denote that PCDD/PCDF TEQ concentrations equal and/or exceed the DSHS HAC value for PCDDs/PCDFs.*

Table 5.3. PCDDs/PCDFs toxicity equivalent (TEQ) concentrations (pg/g) in blue crab and fish collected from Houston Ship Channel by species, 2012.				
Species	**Number Detected/ Number Tested**	**Mean ± S.D. (Min-Max)**	**HAC Value (nonca) and HAC Value (ca; pg/g)**	**Basis for Comparison Value**
Alligator gar	2/2	**7.289**[t]±8.514 (1.268-**13.309**)		
Black drum	2/6	0.163±0.317 (ND-0.793)		
Blue catfish	3/3	**2.384**±2.736 (0.615-**5.535**)		
Blue crab Composite	6/8	0.320±0.342 (ND-1.076)		
Channel catfish	0/2	ND		
Common carp	1/2	0.210±0.297 (ND-0.420)		
Gafftopsail catfish	2/2	0.727±0.116 (0.645-0.809)		
Hardhead catfish	2/3	1.045±1.604 (ND-**2.892**)	2.33	ATSDR Chronic Oral MRL for 2,3,7,8 – TCDD —1.0 x 10^{-9} mg/kg–day
Red drum	2/2	0.220±0.113 (0.140-0.300)	3.49	EPA Slope Factor — 1.56 x 10^{5} per mg/kg–day
Sheepshead	6/6	1.944±3.760 (0.190-**9.573**)		
Smallmouth buffalo	2/4	0.355±0.514 (ND-1.090)		
Southern flounder	2/4	0.043±0.054 (ND-0.110)		
Spotted seatrout	1/3	0.119±0.206 (ND-0.357)		
White bass	1/1	1.035		
All fish	26/40	1.070±2.637 (ND-**13.309**)		
All blue crab and fish	32/48	0.945±2.423 (ND-**13.309**)		

[t] *Emboldened numbers denote that PCDD/PCDF TEQ concentrations equal and/or exceed the DSHS HAC value for PCDDs/PCDFs.*

Table 6. Trichlorfluoromethane (mg/kg) in blue crab and fish collected from the Houston Ship Channel by species, 2012.

Species	Number Detected/ Number Tested	Mean ± S.D. (Min-Max)	HAC Value (nonca; mg/kg)	Basis for Comparison Value
Alligator gar	0/1	ND	700	EPA Chronic Oral RfD — 3.0E-1 mg/kg–day
Black drum	3/3	0.012±0.008 (BDL-0.020)		
Blue catfish	1/1	BDL		
Gafftopsail catfish	1/1	0.011		
Red drum	1/1	0.008		
Sheepshead	3/3	0.013±0.004 (0.009-0.016)		
Smallmouth buffalo	2/2	0.012±0.003 (0.010-0.014)		
All fish	11/12	0.010±0.005 (ND-0.020)		

Table 7. Hazard quotients (HQs) for mercury in fish collected from the Houston Ship Channel in 2012. Table 7. also provides suggested weekly eight-ounce meal consumption rates for 70-kg adults.[u]			
Species	**Number of Samples**	**Hazard Quotient**	**Meals per Week**
Houston Ship Channel All Sites			
Alligator gar	2	0.12	7.5
Black drum	6	0.33	2.8
Blue catfish	3	0.21	4.4
Blue crab	8	0.19	4.9
Channel catfish	2	0.15	6.3
Common carp	2	0.08	11.0
Gafftopsail catfish	2	0.34	2.7
Hardhead catfish	3	0.21	4.3
Red drum	2	0.22	4.2
Sheepshead	6	0.27	3.4
Smallmouth buffalo	4	0.20	4.7
Southern flounder	4	0.11	8.1
Spotted seatrout	3	0.14	6.4
White bass	1	0.30	3.1
All fish	40	0.22	4.2
All blue crab and fish	48	0.21	4.3

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

Table 8.1. Hazard quotients (HQs) and hazard indices (HIs) for organochlorine pestidcides in blue crab and fish collected from the Houston Ship Channel in 2012. Table 8.1. also provides suggested weekly eight-ounce meal consumption rates for 70-kg adults.[v]			
Contaminant/Species	**Number of Samples**	**Hazard Quotient**	**Meals per Week**
Alligator gar			
Chlordane	2	0.01	unrestricted[w]
Dieldrin		0.02	unrestricted
Endrin		0.003	unrestricted
Hepatchlor epoxide		0.001	unrestricted
Hexachlorobenzene		0.09	10.3
Pentachlorobenzene		0.005	unrestricted
DDT (total)		0.01	unrestricted
Hazard Index (meals per week)		0.14	6.6
Black drum			
Chlordane	6	0.003	unrestricted
Dieldrin		0.01	unrestricted
Endrin		0.002	unrestricted
Hepatchlor epoxide		0.001	unrestricted
Hexachlorobenzene		0.005	unrestricted
Pentachlorobenzene		0.001	unrestricted
DDT (total)		0.003	unrestricted
Hazard Index (meals per week)		0.02	unrestricted

[v] *DSHS assumes that children under 12 years of age and/or those that weigh less than 35 kg eat four-ounce meals.*
[w] *Denotes that the allowable eight-ounce meals per week are > 16.0.*

Table 8.2. Hazard quotients (HQs) and hazard indices (HIs) for organochlorine pestidcides in blue crab and fish collected from the Houston Ship Channel in 2012. Table 8.2. also provides suggested weekly eight-ounce meal consumption rates for 70-kg adults.[x]

Contaminant/Species	Number of Samples	Hazard Quotient	Meals per Week
Blue catfish			
Chlordane	3	0.02	unrestricted[y]
Dieldrin		0.02	unrestricted
Endrin		0.005	unrestricted
Hepatchlor epoxide		0.002	unrestricted
Hexachlorobenzene		0.001	unrestricted
Pentachlorobenzene		0.0002	unrestricted
DDT (total)		0.02	unrestricted
Hazard Index (meals per week)		0.07	13.3
Blue crab			
Chlordane	8	0.003	unrestricted
Dieldrin		0.003	unrestricted
Endrin		0.001	unrestricted
Hepatchlor epoxide		0.001	unrestricted
Hexachlorobenzene		0.005	unrestricted
Pentachlorobenzene		0.001	unrestricted
DDT (total)		0.003	unrestricted
Hazard Index (meals per week)		0.01	unrestricted

[x] *DSHS assumes that children under 12 years of age and/or those that weigh less than 35 kg eat four-ounce meals.*
[y] *Denotes that the allowable eight-ounce meals per week are > 16.0.*

Table 8.3. Hazard quotients (HQs) and hazard indices (HIs) for organochlorine pestidcides in blue crab and fish collected from the Houston Ship Channel in 2012. Table 8.3. also provides suggested weekly eight-ounce meal consumption rates for 70-kg adults.[z]			
Contaminant/Species	**Number of Samples**	**Hazard Quotient**	**Meals per Week**
Channel catfish			
Chlordane	2	0.03	unrestricted[aa]
Dieldrin		0.04	unrestricted
Endrin		0.01	unrestricted
Hepatchlor epoxide		0.001	unrestricted
Hexachlorobenzene		0.0004	unrestricted
Pentachlorobenzene		0.0003	unrestricted
DDT (total)		0.01	unrestricted
Hazard Index (meals per week)		0.09	10.4
Common carp			
Chlordane	2	0.02	unrestricted
Dieldrin		0.03	unrestricted
Endrin		0.02	unrestricted
Hepatchlor epoxide		0.004	unrestricted
Hexachlorobenzene		0.001	unrestricted
Pentachlorobenzene		0.0001	unrestricted
DDT (total)		0.005	unrestricted
Hazard Index (meals per week)		0.07	13.3

[z] *DSHS assumes that children under 12 years of age and/or those that weigh less than 35 kg eat four-ounce meals.*
[aa] *Denotes that the allowable eight-ounce meals per week are > 16.0.*

Table 8.4. Hazard quotients (HQs) and hazard indices (HIs) for organochlorine pestidcides in blue crab and fish collected from the Houston Ship Channel in 2012. Table 8.4. also provides suggested weekly eight-ounce meal consumption rates for 70-kg adults.[bb]			
Contaminant/Species	**Number of Samples**	**Hazard Quotient**	**Meals per Week**
Gafftopsail catfish			
Chlordane	2	0.02	unrestricted[cc]
Dieldrin		0.03	unrestricted
Endrin		0.01	unrestricted
Hepatchlor epoxide		0.003	unrestricted
Hexachlorobenzene		0.002	unrestricted
Pentachlorobenzene		0.0003	unrestricted
DDT (total)		0.03	unrestricted
Hazard Index (meals per week)		0.09	10.2
Hardhead catfish			
Chlordane	3	0.02	unrestricted
Dieldrin		0.03	unrestricted
Endrin		0.01	unrestricted
Hepatchlor epoxide		0.003	unrestricted
Hexachlorobenzene		0.01	unrestricted
Pentachlorobenzene		0.001	unrestricted
DDT (total)		0.05	unrestricted
Hazard Index (meals per week)		0.13	7.4

[bb] *DSHS assumes that children under 12 years of age and/or those that weigh less than 35 kg eat four-ounce meals.*
[cc] *Denotes that the allowable eight-ounce meals per week are > 16.0.*

Table 8.5. Hazard quotients (HQs) and hazard indices (HIs) for organochlorine pestidcides in blue crab and fish collected from the Houston Ship Channel in 2012. Table 8.5. also provides suggested weekly eight-ounce meal consumption rates for 70-kg adults.[dd]			
Contaminant/Species	**Number of Samples**	**Hazard Quotient**	**Meals per Week**
Red drum			
Chlordane	2	0.003	unrestricted[ee]
Dieldrin		0.004	unrestricted
Endrin		0.001	unrestricted
Hepatchlor epoxide		0.0004	unrestricted
Hexachlorobenzene		0.0001	unrestricted
Pentachlorobenzene		0.0001	unrestricted
DDT (total)		0.005	unrestricted
Hazard Index (meals per week)		0.01	unrestricted
Sheepshead			
Chlordane	6	0.005	unrestricted
Dieldrin		0.01	unrestricted
Endrin		0.002	unrestricted
Hepatchlor epoxide		0.001	unrestricted
Hexachlorobenzene		0.02	unrestricted
Pentachlorobenzene		0.001	unrestricted
DDT (total)		0.01	unrestricted
Hazard Index (meals per week)		0.05	unrestricted

[dd] *DSHS assumes that children under 12 years of age and/or those that weigh less than 35 kg eat four-ounce meals.*
[ee] *Denotes that the allowable eight-ounce meals per week are > 16.0.*

Table 8.6. Hazard quotients (HQs) and hazard indices (HIs) for organochlorine pestidcides in blue crab and fish collected from the Houston Ship Channel in 2012. Table 8.6. also provides suggested weekly eight-ounce meal consumption rates for 70-kg adults.[ff]			
Contaminant/Species	**Number of Samples**	**Hazard Quotient**	**Meals per Week**
Smallmouth buffalo			
Chlordane	4	0.06	16.0
Dieldrin		0.07	14.0
Endrin		0.01	unrestricted[gg]
Hepatchlor epoxide		0.01	unrestricted
Hexachlorobenzene		0.004	unrestricted
Pentachlorobenzene		0.0004	unrestricted
DDT (total)		0.21	4.4
Hazard Index (meals per week)		0.36	2.6
Southern flounder			
Chlordane	4	0.002	unrestricted
Dieldrin		0.003	unrestricted
Endrin		0.001	unrestricted
Hepatchlor epoxide		0.001	unrestricted
Hexachlorobenzene		0.01	unrestricted
Pentachlorobenzene		0.0004	unrestricted
DDT (total)		0.002	unrestricted
Hazard Index (meals per week)		0.01	unrestricted

[ff] *DSHS assumes that children under 12 years of age and/or those that weigh less than 35 kg eat four-ounce meals.*
[gg] *Denotes that the allowable eight-ounce meals per week are > 16.0.*

Table 8.7. Hazard quotients (HQs) and hazard indices (HIs) for organochlorine pestidcides in blue crab and fish collected from the Houston Ship Channel in 2012. Table 8.7. also provides suggested weekly eight-ounce meal consumption rates for 70-kg adults.[hh]

Contaminant/Species	Number of Samples	Hazard Quotient	Meals per Week
Spotted seatrout			
Chlordane	3	0.04	unrestricted[ii]
Dieldrin		0.002	unrestricted
Endrin		0.001	unrestricted
Hepatchlor epoxide		0.04	unrestricted
Hexachlorobenzene		0.0002	unrestricted
Pentachlorobenzene		0.0001	unrestricted
DDT (total)		0.001	unrestricted
Hazard Index (meals per week)		0.09	10.1
White bass			
Chlordane	1	0.02	unrestricted
Dieldrin		0.03	unrestricted
Endrin		0.01	unrestricted
Hepatchlor epoxide		0.002	unrestricted
Hexachlorobenzene		0.0003	unrestricted
Pentachlorobenzene		0.0001	unrestricted
DDT (total)		0.01	unrestricted
Hazard Index (meals per week)		0.07	13.5

[hh] *DSHS assumes that children under 12 years of age and/or those that weigh less than 35 kg eat four-ounce meals.*
[ii] *Denotes that the allowable eight-ounce meals per week are > 16.0.*

Table 8.8. Hazard quotients (HQs) and hazard indices (HIs) for organochlorine pestidcides in blue crab and fish collected from the Houston Ship Channel in 2012. Table 8.8. also provides suggested weekly eight-ounce meal consumption rates for 70-kg adults.[jj]			
Contaminant/Species	**Number of Samples**	**Hazard Quotient**	**Meals per Week**
All fish			
Chlordane	40	0.02	unrestricted[kk]
Dieldrin		0.02	unrestricted
Endrin		0.01	unrestricted
Hepatchlor epoxide		0.01	unrestricted
Hexachlorobenzene		0.01	unrestricted
Pentachlorobenzene		0.001	unrestricted
DDT (total)		0.03	unrestricted
Hazard Index (meals per week)		0.09	10.2
All blue crab and fish			
Chlordane	48	0.02	unrestricted
Dieldrin		0.02	unrestricted
Endrin		0.004	unrestricted
Hepatchlor epoxide		0.004	unrestricted
Hexachlorobenzene		0.01	unrestricted
Pentachlorobenzene		0.001	unrestricted
DDT (total)		0.03	unrestricted
Hazard Index (meals per week)		0.08	11.8

[jj] *DSHS assumes that children under 12 years of age and/or those that weigh less than 35 kg eat four-ounce meals.*
[kk] *Denotes that the allowable eight-ounce meals per week are > 16.0.*

Table 9.1. Hazard quotients (HQs) and hazard indices (HIs) for PCBs and/or PCDDs/PCDFs in fish collected from the Houston Ship Channel in 2012. Table 9.1 also provides suggested weekly eight-ounce meal consumption rates for 70-kg adults.[ll]			
Contaminant/Species	**Number of Samples**	**Hazard Quotient**	**Meals per Week**
Alligator gar			
PCBs	2	**27.60**[mm]	**0.0**[nn]
PCDDs/PCDFs		**3.12**	**0.3**
Hazard Index (meals per week)		**30.72**	**0.0**
Black drum			
PCBs	6	**2.19**	**0.4**
PCDDs/PCDFs		0.07	13.2
Hazard Index (meals per week)		**2.26**	**0.4**
Blue catfish			
PCBs	3	**3.17**	**0.3**
PCDDs/PCDFs		**1.02**	**0.9**
Hazard Index (meals per week)		**4.19**	**0.2**
Blue crab			
PCBs	8	0.92	1.0
PCDDs/PCDFs		0.14	6.7
Hazard Index (meals per week)		**1.06**	**0.9**
Channel catfish			
PCBs	2	**1.44**	**0.6**
PCDDs/PCDFs		0.00	unrestricted[oo]
Hazard Index (meals per week)		**1.44**	**0.6**
Common carp			
PCBs	2	0.77	1.2
PCDDs/PCDFs		0.09	10.3
Hazard Index (meals per week)		0.86	**1.1**

[ll] *DSHS assumes that children under 12 years of age and/or those that weigh less than 35 kg eat four-ounce meals.*
[mm] *Emboldened numbers denote that the HQ or HI is ≥ 1.0.*
[nn] *Emboldened numbers denote that the calculated allowable meals for an adult are ≤ one meal per week.*
[oo] *Denotes that the allowable eight-ounce meals per week are > 16.0.*

Table 9.2. Hazard quotients (HQs) and hazard indices (HIs) for PCBs and/or PCDDs/PCDFs in fish collected from the Houston Ship Channel in 2012. Table 9.2 also provides suggested weekly eight-ounce meal consumption rates for 70-kg adults.[pp]			
Contaminant/Species	**Number of Samples**	**Hazard Quotient**	**Meals per Week**
Gafftopsail catfish			
PCBs	2	**3.02**[qq]	**0.3**[rr]
PCDDs/PCDFs		0.31	3.0
Hazard Index (meals per week)		**3.33**	**0.3**
Hardhead catfish			
PCBs	3	**9.36**	**0.1**
PCDDs/PCDFs		0.45	2.1
Hazard Index (meals per week)		**9.81**	**0.1**
Red drum			
PCBs	2	0.47	2.0
PCDDs/PCDFs		0.09	9.8
Hazard Index (meals per week)		0.57	1.6
Sheepshead			
PCBs	6	**3.24**	**0.3**
PCDDs/PCDFs		0.83	1.1
Hazard Index (meals per week)		**4.07**	**0.2**
Smallmouth buffalo			
PCBs	4	**9.73**	**0.1**
PCDDs/PCDFs		0.15	6.1
Hazard Index (meals per week)		**9.88**	**0.1**
Southern flounder			
PCBs	4	0.64	1.4
PCDDs/PCDFs		0.02	unrestricted[ss]
Hazard Index (meals per week)		0.66	1.4

[pp] *DSHS assumes that children under 12 years of age and/or those that weigh less than 35 kg eat four-ounce meals.*
[qq] *Emboldened numbers denote that the HQ or HI is ≥ 1.0.*
[rr] *Emboldened numbers denote that the calculated allowable meals for an adult are ≤ one meal per week.*
[ss] *Denotes that the allowable eight-ounce meals per week are > 16.0.*

Table 9.3. Hazard quotients (HQs) and hazard indices (HIs) for PCBs and/or PCDDs/PCDFs in fish collected from the Houston Ship Channel in 2012. Table 9.3 also provides suggested weekly eight-ounce meal consumption rates for 70-kg adults.[tt]			
Contaminant/Species	**Number of Samples**	**Hazard Quotient**	**Meals per Week**
Spotted seatrout			
PCBs	3	0.36	2.5
PCDDs/PCDFs		0.05	18.1
Hazard Index (meals per week)		0.42	2.2
White bass			
PCBs	1	**1.16**[uu]	**0.8**[vv]
PCDDs/PCDFs		0.44	2.1
Hazard Index (meals per week)		**1.60**	**0.6**
All fish			
PCBs	40	**4.52**	**0.2**
PCDDs/PCDFs		0.41	2.3
Hazard Index (meals per week)		**4.93**	**0.2**
All blue crab and fish			
PCBs	48	**3.92**	**0.2**
PCDDs/PCDFs		0.41	2.3
Hazard Index (meals per week)		**4.33**	**0.2**

[tt] *DSHS assumes that children under 12 years of age and/or those that weigh less than 35 kg eat four-ounce meals.*
[uu] *Emboldened numbers denote that the HQ or HI is ≥ 1.0.*
[vv] *Emboldened numbers denote that the calculated allowable meals for an adult are ≤ one meal per week.*

Table 10.1. Calculated theoretical lifetime excess cumulative cancer risk from consuming fish collected in 2012 from the Houston Ship Channel containing contaminants and suggested consumption rate (eight-ounce meals/week) for 70 kg adults who regularly eat fish the Houston Ship Channel over a 30-year period.[ww]				
Species/Contaminant	**Number of Samples**	**Theoretical Lifetime Excess Cancer Risk**		**Meals per Week**
		Risk	**Population Size that Would Result in One Excess Cancer**	
Alligator gar				
Arsenic	2	2.4E-05	42,205	3.9
Chlordane		9.3E-07	1,072,797	unrestricted[xx]
DDT (total)		6.5E-07	1,539,718	unrestricted
Dieldrin		7.1E-06	141,782	13.1
Heptachlor epoxide		1.1E-07	9,150,327	unrestricted
Hexachlorobenzene		4.9E-05	20,279	1.9
PCBs		**4.7E-04**	**2,114**	**0.2**
PCDDs/PCDFs		**2.1E-04**	**4,788**	**0.4**
Cumulative Cancer Risk		**7.6E-04**	**1,309**	**0.1**
Black drum				
Arsenic	6	2.3E-05	43,210	4.0
Chlordane		2.0E-07	5,017,921	unrestricted
DDT (total)		1.9E-07	5,165,507	unrestricted
Dieldrin		2.9E-06	340,278	unrestricted
Heptachlor epoxide		3.9E-08	25,925,926	unrestricted
Hexachlorobenzene		2.5E-06	405,093	unrestricted
PCBs		3.7E-05	26,688	2.5
PCDDs/PCDFs		4.7E-06	214,112	unrestricted
Cumulative Cancer Risk		7.1E-05	14,060	1.3

[ww] *DSHS assumes that children under 12 years of age and/or those who weigh less than 35 kg eat 4-ounce meals.*
[xx] *Denotes that the allowable eight-ounce meals per week are > 16.0.*

Table 10.2. Calculated theoretical lifetime excess cumulative cancer risk from consuming blue crab and fish collected in 2012 from the Houston Ship Channel containing carcinogens and suggested consumption rate (eight-ounce meals/week) for 70 kg adults who regularly eat fish the Houston Ship Channel over a 30-year period.[yy]

Species/Contaminant	Number of Samples	Theoretical Lifetime Excess Cancer Risk		Meals per Week
		Risk	Population Size that Would Result in One Excess Cancer	
Blue catfish				
Arsenic	3	6.1E-06	164,983	15.2
Chlordane		1.9E-06	536,398	unrestricted[zz]
DDT (total)		1.4E-06	690,219	unrestricted
Dieldrin		5.9E-06	170,139	15.7
Heptachlor epoxide		1.3E-07	7,777,778	unrestricted
Hexachlorobenzene		6.5E-07	1,546,717	unrestricted
PCBs		5.4E-05	18,393	1.7
PCDDs/PCDFs		6.8E-05	14,639	1.4
Cumulative Cancer Risk		**1.4E-04**[aaa]	**7,210**	**0.7**[bbb]
Blue crab				
Arsenic	8	1.9E-05	51,852	4.8
Chlordane		2.0E-07	5,017,921	unrestricted
DDT (total)		1.5E-07	6,672,113	unrestricted
Dieldrin		8.8E-07	1,134,259	unrestricted
Heptachlor epoxide		3.9E-08	25,925,926	unrestricted
Hexachlorobenzene		3.2E-07	3,093,434	unrestricted
PCBs		1.6E-05	63,307	5.8
PCDDs/PCDFs		9.2E-06	109,063	10.1
Cumulative Cancer Risk		4.6E-05	21,813	2.0

[yy] *DSHS assumes that children under 12 years of age and/or those who weigh less than 35 kg eat 4-ounce meals.*
[zz] *Denotes that the allowable eight-ounce meals per week are > 16.0.*
[aaa] *Emboldened numbers denote calculated excess lifetime cancer risk after 30 years exposure is greater than 1.0E-04.*
[bbb] *Emboldened numbers denote that the calculated allowable meals for an adult are ≤ one meal per week.*

Table 10.3. Calculated theoretical lifetime excess cumulative cancer risk from consuming fish collected in 2012 from the Houston Ship Channel containing carcinogens and suggested consumption rate (eight-ounce meals/week) for 70 kg adults who regularly eat fish the Houston Ship Channel over a 30-year period.[ccc]				
Species/Contaminant	**Number of Samples**	**Theoretical Lifetime Excess Cancer Risk**		**Meals per Week**
		Risk	**Population Size that Would Result in One Excess Cancer**	
Channel catfish				
Arsenic	2	2.2E-06	453,704	unrestricted[ddd]
Chlordane		1.9E-06	523,756	unrestricted
DDT (total)		5.9E-07	1,685,587	unrestricted
Dieldrin		1.5E-05	66,721	6.2
Heptachlor epoxide		6.4E-08	15,555,556	unrestricted
Hexachlorobenzene		2.4E-07	4,253,472	unrestricted
PCBs		2.5E-05	40,630	3.8
PCDDs/PCDFs		0.0E+0	N/A	unrestricted
Cumulative Cancer Risk		4.5E-05	22,418	2.1
Common carp				
Arsenic	2	3.6E-06	279,202	unrestricted
Chlordane		1.3E-06	789,622	unrestricted
DDT (total)		3.4E-07	2,911,468	unrestricted
Dieldrin		9.4E-06	106,337	15.4
Heptachlor epoxide		3.0E-07	3,381,643	unrestricted
Hexachlorobenzene		3.2E-07	3,093,434	unrestricted
PCBs		1.3E-05	75,617	7.0
PCDDs/PCDFs		6.0E-06	166,192	15.4
Cumulative Cancer Risk		3.4E-05	29,022	2.7

[ccc] *DSHS assumes that children under 12 years of age and/or those who weigh less than 35 kg eat 4-ounce meals.*
[ddd] *Denotes that the allowable eight-ounce meals per week are > 16.0.*

Table 10.4. Calculated theoretical lifetime excess cumulative cancer risk from consuming fish collected in 2012 from the Houston Ship Channel containing carcinogens and suggested consumption rate (eight-ounce meals/week) for 70 kg adults who regularly eat fish the Houston Ship Channel over a 30-year period.[eee]

Species/Contaminant	Number of Samples	Theoretical Lifetime Excess Cancer Risk		Meals per Week
		Risk	Population Size that Would Result in One Excess Cancer	
Gafftopsail catfish				
Arsenic	2	1.8E-05	54,994	5.1
Chlordane		1.4E-06	730,308	unrestricted[fff]
DDT (total)		2.1E-06	469,592	unrestricted
Dieldrin		1.1E-05	94,522	8.7
Heptachlor epoxide		2.3E-07	4,320,988	unrestricted
Hexachlorobenzene		1.4E-06	739,734	unrestricted
PCBs		5.2E-05	19,307	1.8
PCDDs/PCDFs		2.1E-05	48,006	4.4
Cumulative Cancer Risk		**1.1E-04**[ggg]	**9,392**	**0.9**[hhh]
Hardhead catfish				
Arsenic	3	1.3E-05	77,226	7.1
Chlordane		1.6E-06	640,146	unrestricted
DDT (total)		3.3E-06	303,278	unrestricted
Dieldrin		1.2E-05	85,069	7.9
Heptachlor epoxide		2.3E-07	4,444,444	unrestricted
Hexachlorobenzene		7.5E-06	133,442	12.3
PCBs		**1.6E-04**	**6,229**	**0.6**
PCDDs/PCDFs		3.0E-05	33,397	3.1
Cumulative Cancer Risk		**2.3E-04**	**4,391**	**0.4**

[eee] *DSHS assumes that children under 12 years of age and/or those who weigh less than 35 kg eat 4-ounce meals.*
[fff] *Denotes that the allowable eight-ounce meals per week are > 16.0.*
[ggg] *Emboldened numbers denote calculated excess lifetime cancer risk after 30 years exposure is greater than 1.0E-04.*
[hhh] *Emboldened numbers denote that the calculated allowable meals for an adult are ≤ one meal per week.*

Table 10.5. Calculated theoretical lifetime excess cumulative cancer risk from consuming fish collected in 2012 from the Houston Ship Channel containing carcinogens and suggested consumption rate (eight-ounce meals/week) for 70 kg adults who regularly eat fish the Houston Ship Channel over a 30-year period.[iii]				
Species/Contaminant	Number of Samples	Theoretical Lifetime Excess Cancer Risk		Meals per Week
		Risk	Population Size that Would Result in One Excess Cancer	
Red drum				
Arsenic	2	8.5E-06	117,085	10.8
Chlordane		2.0E-07	5,017,921	unrestricted[jjj]
DDT (total)		3.6E-07	2,760,874	unrestricted
Dieldrin		1.5E-06	680,556	unrestricted
Heptachlor epoxide		3.2E-08	31,111,111	unrestricted
Hexachlorobenzene		2.9E-08	34,027,778	unrestricted
PCBs		8.1E-06	123,737	11.4
PCDDs/PCDFs		6.3E-06	158,638	14.7
Cumulative Cancer Risk		2.5E-05	39,970	3.7
Sheepshead				
Arsenic	6	1.2E-05	82,492	7.6
Chlordane		3.6E-07	2,777,778	unrestricted
DDT (total)		4.4E-07	2,255,362	unrestricted
Dieldrin		4.1E-06	243,056	unrestricted
Heptachlor epoxide		7.1E-08	14,141,414	unrestricted
Hexachlorobenzene		1.2E-05	82,392	7.6
PCBs		5.5E-05	18,028	1.7
PCDDs/PCDFs		5.6E-05	17,953	1.7
Cumulative Cancer Risk		**1.4E-04**[kkk]	**7,122**	**0.7**[lll]

[iii] *DSHS assumes that children under 12 years of age and/or those who weigh less than 35 kg eat 4-ounce meals.*
[jjj] *Denotes that the allowable eight-ounce meals per week are > 16.0.*
[kkk] *Emboldened numbers denote calculated excess lifetime cancer risk after 30 years exposure is greater than 1.0E-04.*
[lll] *Emboldened numbers denote that the calculated allowable meals for an adult are ≤ one meal per week.*

Table 10.6. Calculated theoretical lifetime excess cumulative cancer risk from consuming fish collected in 2012 from the Houston Ship Channel containing carcinogens and suggested consumption rate (eight-ounce meals/week) for 70 kg adults who regularly eat fish the Houston Ship Channel over a 30-year period.[mmm]				
Species/Contaminant	**Number of Samples**	**Theoretical Lifetime Excess Cancer Risk**		**Meals per Week**
		Risk	**Population Size that Would Result in One Excess Cancer**	
Smallmouth buffalo				
Arsenic	4	5.5E-06	181,481	unrestricted[nnn]
Chlordane		4.3E-06	230,112	unrestricted
DDT (total)		1.5E-05	65,226	6.0
Dieldrin		2.3E-05	44,192	4.1
Heptachlor epoxide		4.5E-07	2,222,222	unrestricted
Hexachlorobenzene		1.9E-06	515,572	unrestricted
PCBs		**1.7E-04**[ooo]	**5,996**	**0.6**[ppp]
PCDDs/PCDFs		1.0E-05	98,311	9.1
Cumulative Cancer Risk		**2.3E-04**	**4,402**	**0.4**
Southern flounder				
Arsenic	4	8.3E-06	120,988	11.2
Chlordane		1.6E-07	6,222,222	unrestricted
DDT (total)		1.2E-07	8,427,933	unrestricted
Dieldrin		8.8E-07	1,134,259	unrestricted
Heptachlor epoxide		8.4E-08	11,965,812	unrestricted
Hexachlorobenzene		3.3E-06	301,131	unrestricted
PCBs		1.1E-05	90,741	unrestricted
PCDDs/PCDFs		1.2E-06	811,635	unrestricted
Cumulative Cancer Risk		2.5E-05	39,867	3.7

[mmm] *DSHS assumes that children under 12 years of age and/or those who weigh less than 35 kg eat 4-ounce meals.*
[nnn] *Denotes that the allowable eight-ounce meals per week are > 16.0.*
[ooo] *Emboldened numbers denote calculated excess lifetime cancer risk after 30 years exposure is greater than 1.0E-04.*
[ppp] *Emboldened numbers denote that the calculated allowable meals for an adult are ≤ one meal per week.*

Table 10.7. Calculated theoretical lifetime excess cumulative cancer risk from consuming fish collected in 2012 from the Houston Ship Channel containing carcinogens and suggested consumption rate (eight-ounce meals/week) for 70 kg adults who regularly eat fish the Houston Ship Channel over a 30-year period.[qqq]				
Species/Contaminant	**Number of Samples**	**Theoretical Lifetime Excess Cancer Risk**		**Meals per Week**
		Risk	**Population Size that Would Result in One Excess Cancer**	
Spotted seatrout				
Arsenic	3	3.9E-06	259,259	unrestricted[rrr]
Chlordane		3.3E-06	301,464	unrestricted
DDT (total)		8.7E-08	11,437,908	unrestricted
Dieldrin		5.9E-07	1,701,389	unrestricted
Heptachlor epoxide		3.2E-06	308,031	unrestricted
Hexachlorobenzene		1.2E-07	8,506,944	unrestricted
PCBs		6.2E-06	160,131	14.8
PCDDs/PCDFs		3.4E-06	293,280	unrestricted
Cumulative Cancer Risk		2.1E-05	47,920	4.4
White bass				
Arsenic	1	5.0E-06	201,646	unrestricted
Chlordane		1.8E-06	563,607	unrestricted
DDT (total)		3.9E-07	2,582,754	unrestricted
Dieldrin		9.7E-06	103,114	9.5
Heptachlor epoxide		1.7E-07	5,761,317	unrestricted
Hexachlorobenzene		1.8E-07	5,671,296	unrestricted
PCBs		2.0E-05	50,412	4.7
PCDDs/PCDFs		3.0E-05	33,720	3.1
Cumulative Cancer Risk		6.7E-05	15,001	1.4

[qqq] *DSHS assumes that children under 12 years of age and/or those who weigh less than 35 kg eat 4-ounce meals.*
[rrr] *Denotes that the allowable eight-ounce meals per week are > 16.0.*

Table 10.8. Calculated theoretical lifetime excess cumulative cancer risk from consuming fish collected in 2012 from the Houston Ship Channel containing carcinogens and suggested consumption rate (eight-ounce meals/week) for 70 kg adults who regularly eat fish the Houston Ship Channel over a 30-year period.[sss]

Species/Contaminant	Number of Samples	Theoretical Lifetime Excess Cancer Risk		Meals per Week
		Risk	Population Size that Would Result in One Excess Cancer	
All fish				
Arsenic	40	1.1E-05	88,528	8.2
Chlordane		1.4E-06	730,308	unrestricted[ttt]
DDT (total)		2.2E-06	451,072	unrestricted
Dieldrin		7.1E-06	141,782	13.1
Heptachlor epoxide		3.8E-07	2,636,535	unrestricted
Hexachlorobenzene		5.9E-06	169,292	unrestricted
PCBs		7.8E-05	12,902	1.2
PCDDs/PCDFs		2.7E-05	36,932	3.4
Cumulative Cancer Risk		**1.3E-04**[uuu]	**7,530**	**0.7**[vvv]
All blue crab and fish				
Arsenic	48	1.3E-05	78,905	7.3
Chlordane		1.2E-06	850,030	unrestricted
DDT (total)		1.9E-06	533,769	unrestricted
Dieldrin		6.2E-06	162,037	15.0
Heptachlor epoxide		3.3E-07	3,050,109	unrestricted
Hexachlorobenzene		5.3E-06	187,999	unrestricted
PCBs		6.7E-05	14,876	1.4
PCDDs/PCDFs		2.7E-05	36,932	3.4
Cumulative Cancer Risk		**1.2E-04**	**8,207**	**0.8**

[sss] *DSHS assumes that children under 12 years of age and/or those who weigh less than 35 kg eat 4-ounce meals.*
[ttt] *Denotes that the allowable eight-ounce meals per week are > 16.0.*
[uuu] *Emboldened numbers denote calculated excess lifetime cancer risk after 30 years exposure is greater than 1.0E-04.*
[vvv] *Emboldened numbers denote that the calculated allowable meals for an adult are ≤ one meal per week.*

Table 11.1. Tukey HSD post hoc comparisons of all fish combined chlordane (total) concentrations between samples sites from the Houston Ship Channel, 2012.					
Site	Site	Difference	p-Value	95% Confidence Interval	
				Lower	Upper
1	2	0.8574	0.5257	-0.8279	2.5428
1	3	1.7179	**0.0219**	0.1949	3.2410
1	4	2.1656	**0.0016**	0.7105	3.6206
2	3	0.8605	0.5386	-0.8573	2.5783
2	4	1.3081	0.1645	-0.3497	2.9659
3	4	0.4476	0.8504	-1.0449	1.9401

Table 11.2. Tukey HSD post hoc comparisons of all fish combined DDT (total) concentrations between samples sites from the Houston Ship Channel, 2012.					
Site	Site	Difference	p-Value	95% Confidence Interval	
				Lower	Upper
1	2	-1.0588	0.3702	-2.7985	0.6808
1	3	0.9668	0.3611	-0.6053	2.5389
1	4	1.3430	0.0936	-0.1590	2.8449
2	3	2.0256	**0.0199**	0.2525	3.7988
2	4	2.4018	**0.0031**	0.6906	4.1130
3	4	0.3761	0.9122	-1.1645	1.9167

Table 11.3. Tukey HSD post hoc comparisons of all fish combined hexachlorobenzene concentrations between samples sites from the Houston Ship Channel, 2012.					
Site	Site	Difference	p-Value	95% Confidence Interval	
				Lower	Upper
1	2	-1.3441	0.2264	-3.2017	0.5135
1	3	-3.8162	**0.0000**	-5.4949	-2.1375
1	4	0.3549	0.9326	-1.2488	1.9587
2	3	-2.4721	**0.0063**	-4.3655	-0.5787
2	4	1.6991	0.0762	-0.1282	3.5263
3	4	4.1711	**0.0000**	2.5260	5.8162

Table 11.4. Tukey HSD post hoc comparisons of all fish combined PCB concentrations between samples sites from the Houston Ship Channel, 2012.					
Site	**Site**	**Difference**	**p-Value**	**95% Confidence Interval**	
				Lower	**Upper**
1	2	-0.0881	0.9988	-1.6973	1.5211
1	3	-0.8008	0.4579	-2.2550	0.6534
1	4	1.2249	0.1004	-0.1644	2.6142
2	3	-0.7127	0.6491	-2.3529	0.9275
2	4	1.3130	0.1334	-0.2699	2.8959
3	4	2.0257	**0.0027**	0.6006	3.4508

Table 11.5. Tukey HSD post hoc comparisons of blue crab and fish chlordane (total) concentrations between samples sampling events from the Houston Ship Channel, 1999–2012.					
Site	**Site**	**Difference**	**p-Value**	**95% Confidence Interval**	
				Lower	**Upper**
1999	2004	0.7360	0.1875	-0.2089	1.6809
1999	2011	2.3135	**0.0000**	1.0348	3.5921
1999	2012	2.1701	**0.0000**	1.2376	3.1027
2004	2011	1.5775	**0.0049**	0.3592	2.7957
2004	2012	1.4341	**0.0001**	0.5862	2.2820
2011	2012	-0.1434	0.9902	-1.3521	1.0653

Table 11.6. Games-Howell post hoc comparisons of blue crab and fish dieldrin concentrations between samples sampling events from the Houston Ship Channel, 1999–2012.					
Site	**Site**	**Difference**	**p-Value**	**95% Confidence Interval**	
				Lower	**Upper**
1999	2004	0.2191	0.5757	-0.2342	0.6725
1999	2011	1.0311	**0.0116**	0.1964	1.8658
1999	2012	1.5409	**0.0000**	0.8812	2.2007
2004	2011	0.8120	**0.0394**	0.0333	1.5908
2004	2012	1.3218	**0.0000**	0.7528	1.8909
2011	2012	0.5098	0.4232	-0.3839	1.4035

Table 11.7. Games-Howell post hoc comparisons of blue crab and fish heptachlor epoxide concentrations between samples sampling events from the Houston Ship Channel, 1999–2012.					
Site	**Site**	**Difference**	**p-Value**	**95% Confidence Interval**	
				Lower	**Upper**
1999	2004	0.3044	0.3994	-0.2082	0.8170
1999	2011	2.5078	**0.0000**	2.0468	2.9687
1999	2012	1.4645	**0.0000**	0.6895	2.2394
2004	2011	2.2034	**0.0000**	1.9604	2.4464
2004	2012	1.1600	**0.0002**	0.4786	1.8415
2011	2012	-1.0433	**0.0005**	-1.6860	-0.4006

Table 12. The number of eight-ounce meals assuming 38% yield from whole fish to skin-off fillets for an average, minimum, and maximum weight fish of each species collected from the Houston Ship Channel in 2012.

Species	Average	Minimum	Maximum
	Number of Eight-Ounce Meals		
Alligator gar	14.9	12.6	17.2
Black drum	12.1	3.8	23.5
Blue catfish	3.3	2.5	4.7
Channel catfish	2.5	2.2	2.7
Common carp	4.6	4.6	4.7
Gafftopsail catfish	2.6	2.5	2.8
Hardhead catfish	0.6	0.5	0.7
Red drum	3.6	2.7	4.5
Sheepshead	3.5	1.2	5.4
Smallmouth buffalo	8.5	7.3	10.3
Southern flounder	1.6	1.3	1.8
Spotted seatrout	1.6	1.3	1.8
White bass	1.4	1.4	1.4
All fish	4.7	0.5	23.5

Table 13. SALG recommended consumption advice for the Houston Ship Channel, 2012.			
Contaminants of Concern	**Species**	**Women of childbearing age and children < 12**	**Women past childbearing age and adult men**
Dioxins and PCBs	All species of fish and blue crab	**DO NOT EAT**	1 meal/month

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