Characterization of Potential Adverse Health Effects Associated with Consuming Fish from

Galveston Bay

Brazoria, Chambers, Galveston, and Harris Counties, Texas

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INTRODUCTION

On September 13, 2008, Hurricane Ike made landfall on the north end of Galveston Island, Texas as a strong Category 2 hurricane.[1] The expansive storm surge associated with Hurricane Ike caused significant flooding spanning over 200 miles of coastline from Galveston Island into Louisiana.[2] Catastrophic flooding occurred along the Texas coastline from Galveston Island to the Texas-Louisiana border. The Galveston Bay and Sabine Lake estuaries received floodwaters from some of the most populated and industrialized coastal areas in the United States. Run-off during the flood and receding storm surge waters contained industrial pollutants, household chemicals and waste, and sediment from inland areas. Since Hurricane Ike, the Department of State Health Services (DSHS) Seafood and Aquatic Life Group (SALG) and the Texas Parks and Wildlife Department (TPWD) Coastal Fisheries Division (CFD) have received many inquiries from the public regarding the safety of consuming fish from Galveston Bay and the Sabine Lake estuaries. To this end, the DSHS has not been able to assure the public that fish are safe to eat following Hurricane Ike. 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.

Description of the Galveston Bay Estuary

Galveston Bay, the largest estuary on the Texas coast (600 square miles or 384,000 acres; 232 miles of shoreline) and the seventh largest in the United States, is a shallow bar-built estuary in a drowned river delta.[3] The average depth of the bay is 7 feet, the maximum non-dredged depth approximately 10 feet.[4] Galveston Bay is composed of four major sub-bays: Galveston Bay, Trinity Bay, East Bay, and West Bay.[5] The Galveston Bay watershed encompasses approximately 33,000 square miles comprised of three main drainages: the Trinity River watershed, the San Jacinto River watershed, and the coastal bayou watershed. The Trinity River basin provides about 51% of the freshwater inflow into Galveston Bay.[5]

The Galveston Bay watershed includes all or portions of 44 Texas counties; five counties surround the estuary: Brazoria, Chambers, Galveston, Harris, and Liberty. The watershed also includes the two largest metropolitan areas in Texas: Houston and Dallas–Fort Worth.[4] To lend perspective to the size of this watershed, note that the city of Houston lies approximately 250 miles south-southeast of Dallas-Fort Worth.

Galveston Bay, Texas' largest fishery resource, contributes approximately one third of the state's commercial fishing income.[6] Commercial and recreational fishing on Galveston Bay generates over one billion dollars per year; over one-half of the state's expenditures for recreational fishing go directly or indirectly to Galveston Bay.[6] The areas around the Galveston Bay system are also home to one of the nation's largest petrochemical and industrial complexes[7]. Nearly half of all U.S. petrochemical production occurs in the greater Houston area. The Port of Houston is the second largest port (by tonnage shipment) in the United States, and is the eighth largest in the world.[8] As a result, industrial and municipal point source discharges contribute to the bay's major pollution. Non-point source pollution remains the bay's top water quality problem, with much originating from storm water runoff generated by agricultural, urban, suburban, and rural land users near the bay. Some 90% of the oil and grease loading, for instance, originate in subwatersheds with high-density urban land use. Much of the oil and grease flows from the surfaces of roadways.[5]

History of DSHS Monitoring of Chemical Contaminants in Fish and Shellfish from the Galveston Bay Estuary

The United States Environmental Protection Agency's (USEPA or EPA) *National Dioxin Study* [9] 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*) [10] that grew out of the USEPA's *National Dioxin Study,*[9] the EPA conducted a one-time nationwide survey of contaminant residues in fish. In the report of that evaluation of fish-borne contaminants, the EPA described the presence of dioxin congeners in samples of fish and some shellfish (e.g., blue crab) from 11 sites within its Region 6. These sites were almost invariably located downstream of "bleach Kraft" pulp and paper mill discharges.[10]

In 1990, the Texas Department of Health (TDH)[a] – in its first detailed evaluation of the Texas sites reported in the *National Dioxin Study* [9] to harbor dioxin-contaminated fish or shellfish – collected 12 fish and composite blue crab samples from the Houston Ship Channel and from Upper Galveston Bay. The 1990 DSHS study confirmed polychlorinated dibenzofurans (PCDFs) and polychlorinated dibenzo-*p*-dioxins (PCDDs) in catfish species and blue crab at concentrations that could pose a risk to human health. As a result, the TDH issued Fish and Shellfish Consumption Advisory 3 (ADV-3), a consumption advisory for Upper Galveston Bay. The advisory covered Upper Galveston Bay to the north of a line connecting Red Bluff Point to Houston Point (by way of the Five Mile Cut marker) along with the Houston Ship Channel and its contiguous waters. ADV-3 recommended that adult recreational and/or subsistence fishers limit consumption of [any species of] catfish and/or blue crab to no more than one eight-ounce meal per month. In addition, the TDH advised that children whose age is less than 12 years and women of childbearing age not consume catfish or blue crab from these waters.[11]

Furthermore, fish and blue crab samples collected in 1993 from Clear Creek contained several volatile organic compounds – including dichloroethane and trichloroethane at concentrations that, if consumed, constituted an apparent risk to public health. To address the public health hazard introduced by consumption of fish and blue crab from Clear Creek – which empties into Upper Galveston Bay – the TDH issued Fish and Shellfish Consumption Advisory 7 (ADV-7) on November 18, 1993. ADV-7 recommended that persons should not consume any fish or blue crab from Clear Creek upstream and West of Texas Highway 3.[11]

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

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

from consumption of fish, blue crab, or oysters from the Houston Ship Channel and Upper Galveston Bay or to revise risk management decisions for the area. Consequently, the TDH continued unchanged ADV-3, the consumption advisory issued in 1990 for these areas.

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

Between 1997 and 2000, the USEPA funded three grants to the TDH for study of the Galveston Bay system. (1) *The USEPA Children's Uses of Galveston Bay* grant; (2) a Texas Commission on Environmental Quality (TCEQ)[b] Total Maximum Daily Load (TMDL) program grant and (3) a grant from the Galveston Bay Estuary Program (GBEP)[12] The three studies allowed the TDH to more comprehensively evaluate chemical contaminants in fish and shellfish from the Galveston Bay Estuary. During these studies, the TDH collected more than 400 fish and blue crab samples from East and West Galveston Bay, Lower Galveston Bay, Trinity Bay, Upper Galveston Bay, and the Houston Ship Channel (including the Lower San Jacinto River and Tabbs Bay). In addition to these major bay areas, the TDH surveyed the Christmas Bay system (Bastrop, Christmas, and Drum Bays), Clear Creek (for which ADV-7 was issued in 1993), and Clear Lake.

The Galveston Bay studies conducted from 1997 to 2000 revealed that – with few exceptions – fish and blue crab from the Christmas Bay system, East Bay, West Bay, Lower Galveston Bay, Trinity Bay, Clear Creek, and Clear Lake showed little evidence of contamination with pollutants capable of causing adverse human health effects. None of these contaminants exceeded the health-based assessment comparison values (HAC values) TDH used at the time to evaluate the likelihood of adverse human health effects from consumption of chemically contaminated fish and shellfish. The TDH concluded from these investigations that eating fish and blue crab from the named portions of the Galveston Bay Estuary posed no apparent public health hazard. Furthermore, on October 9, 2001, as a direct result of these studies – which showed that fish and shellfish from Clear Creek no longer contained chemical contaminants at levels likely to pose an apparent human health hazard, the TDH rescinded the 1993 advisory (ADV-7) that had suggested no consumption of any fish or blue crab taken from Clear Creek.

On the other hand, the same studies (1997-2000) yielded other data that prompted the DSHS to modify ADV-3. That modification, embodied in Fish and Shellfish Consumption Advisory 20 (ADV-20), extended ADV-3 to the upper Houston Ship Channel (including the Lower San Jacinto River). ADV-20 recommended that adults eat no more than one eight-ounce meal per month of blue crab or any fish species from the Houston Ship Channel upstream of the Lynchburg Ferry crossing and from the San Jacinto River downstream of the bridge at U.S. Highway 90. ADV-20 further stressed that children and women who were nursing an infant, who were pregnant, or who might become pregnant should eat no fish or blue crab from the above-described areas.[13]

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

In 1987, the U.S. Congress had established the National Estuary Program (NEP) to promote long-term planning and management of nationally significant estuaries.[14] Early on, the NEP identified 28 nationally significant estuaries, of which Galveston Bay was one (the other Texas estuary identified by the NEP was the Coastal Bend Bays and Estuaries system). The Galveston Bay Estuary Program (GBEP), formed as a state-supported program from the NEP in 1989, is one of two such programs in Texas.[15] 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.[12] The GBEP provides ecosystem management through collaborative partnerships and ensures preservation of Galveston Bay's multiple uses. The GBEP has enhanced water quality through promotion of reduction of pollutants in bayous, creeks, and Galveston Bay, and has established a seafood-safety monitoring program to assist the state to protect the health of those who consume fish and shellfish from the Galveston Bay Estuary.

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

The results of the 2004 characterization of the health risks of consuming fish and blue crab tissue from the study area showed unequivocally that ADV-3, issued in 1990 and modified with ADV-20 in 2001 should continue. Those results also revealed that spotted seatrout contained polychlorinated biphenyls (PCBs) at levels exceeding the DSHS' HAC values for PCBs in fish. The presence of PCBs in spotted seatrout at the observed levels caused concern among public health officials. The DSHS thus issued Fish and Shellfish Consumption Advisory 28 (ADV-28) on January 25, 2005 for the Houston Ship Channel and Upper Galveston Bay. ADV-28 recommended that adults limit consumption of spotted seatrout from the Houston Ship Channel – including the tidal portion of the San Jacinto River below the U.S. Highway 90 bridge, Tabbs Bay and its contiguous waters, and Upper Galveston Bay north of a line drawn from Red Bluff Point to Five Mile Cut Marker to Houston Point – to no more than one eight-ounce meal per month. Children and women who were nursing, pregnant, or who may have become pregnant were advised not to consume spotted seatrout from these waters.[16]

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

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

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

Demographics of the Five Texas Counties (Brazoria, Chambers, Galveston, Harris, and Liberty) Surrounding the Galveston Bay Estuary

The estimated population in 2010 of the five counties bordering the Galveston Bay Estuary – Brazoria (313,166), Chambers (35,096), Galveston (291,309), Harris (4,092,459), and Liberty (75,643) – was 4,807,673 people.[17] The Galveston Bay Estuary is adjacent to one of the most urbanized and industrialized areas in Texas and in the United States. In comparison to suburban communities in the five-county area, the larger central cities, such as Houston, TX (2010 estimated population 2,099,451)[17] – the fourth largest city in the United States and the Harris County seat – and Galveston (2010 estimated population 47,743)[17] experienced little or no population growth during the recent past. The City of Galveston experienced a slight population decline following Hurricane Ike in September 2008. According to the United States Census Bureau, Harris County is the most populous county in Texas. The Houston-Galveston Area Council calculated that 70% of the Galveston County population and almost 45% of the Chambers County population (or approximately 20 % of the 4.5 million people in the five counties bordering Galveston Bay) reside within a two-mile buffer zone around Galveston Bay and its tidally influenced tributaries.[5]

Subsistence Fishing in the Galveston Bay Estuary

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

METHODS

Fish Sampling, Preparation, and Analysis

The DSHS Seafood and Aquatic Life Group (SALG) collects and analyzes edible fish from the state's public waters to evaluate potential risks to the health of people consuming contaminated fish or shellfish. Fish tissue sampling follows standard operating procedures from the DSHS *Seafood and Aquatic Life Group Survey Team Standard Operating Procedures and Quality Control/Assurance Manual.*[19] The SALG bases its sampling and analysis protocols, in part, on procedures recommended by the USEPA in that agency's *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories, Volume 1.*[20] Advice and direction are also received from the legislatively mandated *State of Texas Toxic Substances Coordinating Committee (TSCC) Fish Sampling Advisory Subcommittee (FSAS).*[21] 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 Galveston Bay 2010 Sample Set

In February through April 2010, the SALG and TPWD CFD collected 133 fish samples from the Galveston Bay Estuary (Table 1). The SALG requested fish collection assistance from the CFD for spotted seatrout and gafftopsail catfish because of the short sample collection opportunity due to the grant contract timeline associated with this project. The SALG staff collected 108 fish samples and the TPWD CFD staff collected 18 spotted seatrout and seven gafftopsail catfish samples. The DSHS risk assessors used data from these fish to assess the potential for adverse human health outcomes from consuming fish from this estuary.

The SALG and CFD collected fish samples from 19 general sample areas or sites to provide spatial coverage of the study area (Figures 1a–1b). Species collected represent distinct ecological groups (i.e. predators and bottom-dwellers) that have some potential to bio-accumulate chemical contaminants, have a wide geographic distribution, are of local recreational fishing value, and/or that anglers and their families commonly consume. Spotted seatrout comprised 50% of the fish tissue samples collected for this study. Target species and number collected are listed in descending order: spotted seatrout (66), gafftopsail catfish (18), sand trout (17), red drum (10), black drum (9), southern flounder (9), striped bass (2), and alligator gar (2).

The SALG survey team set gill nets at 11 of 19 sample sites (Figure 1a and 1b). All gill nets were set in late afternoon, fished overnight, and retrieved early the following morning. The SALG gill nets were set at locations to maximize available cover and habitat within the general sample areas. During gill net retrieval and sample collection, to keep specimens from different sample sites separated, the survey team placed samples from each site into mesh bags labeled with the site number. The survey team immediately stored fish samples on wet ice in large coolers to ensure interim preservation. Survey team members returned to the bay any live fish culled from the catch and properly disposed of samples found dead in the gill nets.

Due to the low gill net catch rate for spotted seatrout, the survey team also utilized hook and line techniques to increase spotted seatrout catch. The survey team targeted habitats (e.g., oyster reefs, oil and gas rigs, bayou cuts, piers, pilings, channel breaks, and schooling fish under feeding birds) likely to harbor spotted seatrout, with live shrimp and artificial baits. The survey team fished these habitats with the boat anchored near the above-itemized structures or drifting with the wind or tide.

The CFD provided SALG with spotted seatrout and gafftopsail catfish samples from gill net sets at four of 19 samples sites (Figures 1a–1b). Standardized gill net sampling is part of the CFD's resource monitoring program. Each spring and fall over a 10-week period, the CFD perform 45-gill net sets at randomly selected locations in every major bay system. The CFD stored fish samples on wet ice in a cooler to ensure interim preservation. The SALG coordinated with the CFD to pick-up fish samples either on the bay or at the TPWD CFD office in Dickinson, Texas.

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

Additional Fish Tissue Samples

In November 2010 and January 2011, the SALG collected 45 fish and blue crab samples from the San Jacinto River and Houston Ship Channel (part of the Galveston Bay Estuary, Figure 1c) following collection and processing procedures described above. Because of the extant Galveston Bay Estuary spotted seatrout fish consumption advisory, SALG risk assessors recommended inclusion of the six-spotted seatrout collected from this sampling event to increase sample size and confidence in the spotted seatrout data set for this risk assessment.

Fish Age Estimation

The DSHS SALG staff removed sagittal otoliths from 60 spotted seatrout samples for age estimation and identified the sex of each fish sample (Figure 2). The DSHS SALG staff followed otolith extraction procedures recommended by the Gulf States Marine Fisheries Commission (GSMFC) for spotted seatrout.[22] Staff performed all otolith extractions on each fish sample after the preparation of the two skin-off fillets for chemical contaminant analyses. Following extraction, staff placed otoliths in an individually labeled vial and then stored the vials in a plastic freezer bag to transport to their Austin, Texas headquarters. Staff processed otoliths and estimated ages according to procedures recommended by the TPWD and GSMFC.[22, 23]

Analytical Laboratory Information

Upon arrival of the fish samples at the laboratory, GERG personnel documented receipt of the 133 Galveston Bay fish samples plus six additional spotted seatrout samples collected from the San Jacinto River / Houston Ship Channel and recorded the condition of each sample along with its DSHS identification number.

Using established USEPA methods, the GERG laboratory analyzed fish fillets from Galveston Bay for inorganic and organic contaminants commonly identified in polluted environmental media. Analyses included seven metals (arsenic, cadmium, copper, lead, total mercury, selenium, and zinc), 123 semivolatile organic compounds (SVOCs), 70 volatile organic compounds (VOCs), 34 pesticides, 209 polychlorinated biphenyls (PCBs) congeners, and 17 polychlorinated dibenzofurans and/or dibenzo-*p*-dioxins (PCDDs/PCDFs) congeners. The laboratory analyzed all 133 samples for metals, PCBs, and PCDDs/PCDFs and a subset of 20 (GAL01, GAL02, GAL04, GAL14, GAL15, GAL32, GAL50, GAL54, GAL55, GAL61, GAL65, GAL74, GAL79, GAL80, GAL85, GAL87, GAL107, GAL130, GAL139, and GAL218) of the original 133 samples for pesticides, SVOCs, and VOCs.[24] The laboratory analyzed all six spotted seatrout samples collected from the San Jacinto / Houston Ship Channel for mercury, 209 PCB congeners, and PCDDs/PCDFs and a subset of three (SJR34, SJR43, and SJR45) of the original six samples for metals, pesticides, SVOCs, and VOCs.

Details of Some Analyses with Explanatory Notes

Arsenic

The GERG laboratory analyzed all fish for total (inorganic arsenic + organic arsenic = total arsenic) arsenic. Although the proportions of each form of arsenic may differ among fish species, under different water conditions, and, perhaps, with other variables, the literature suggests that well over 90% of arsenic in fish is likely organic arsenic – a form of arsenic that is virtually non-toxic to humans.[25] DSHS, taking a conservative approach, estimates 10% of the total arsenic in any fish is inorganic arsenic, deriving estimates of inorganic arsenic concentration in each fish by multiplying reported total arsenic concentration in the sample by a factor of 0.1.

Mercury

Nearly all mercury in upper trophic level fish three years of age or older is methylmercury.[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 that all reported mercury in fish or shellfish is methylmercury. The GERG laboratory thus analyzed fish tissues for total mercury. In its risk characterizations, the DSHS compares mercury concentrations in tissues to a comparison value derived from the Agency for Toxic Substances and Disease Registry's (ATSDR) minimal risk level (MRL) for methylmercury.[27] (In these risk characterizations, the DSHS may interchangeably utilize the terms "mercury," "methylmercury," or "organic mercury" to refer to methylmercury in fish).

Polychlorinated Biphenyls (PCBs)

For PCBs, the USEPA suggests that each state measures congeners of PCBs in fish and shellfish rather than homologs or Aroclors® because the USEPA considers congener analysis the most sensitive technique for detecting PCBs in environmental media.[24] Although only about 130 PCB congeners were routinely present in PCB mixtures manufactured and commonly used in the United States (US), the GERG laboratory analyzes and reports the presence and concentrations of all 209 possible PCB congeners. From the congener analyses, the laboratory also computes and reports concentrations of PCB homologs and of Aroclor® mixtures. Despite the USEPA's suggestion that the states utilize PCB congeners rather than Aroclors® or homologs for toxicity estimates, the toxicity literature does not reflect state-of-the-art laboratory science. To accommodate this inconsistency, the DSHS utilizes recommendations from the National Oceanic and Atmospheric Administration (NOAA),[28] from McFarland and Clarke,[29] and from the USEPA's guidance documents for assessing contaminants in fish and shellfish[20, 24] to address PCB congeners in fish and shellfish samples, selecting the 43 congeners encompassed by the McFarland and Clark and the NOAA articles. The referenced authors chose to use congeners that were relatively abundant in the environment, were likely to occur in aquatic life, and likely to show toxic effects. SALG risk assessors summed the 43 congeners to derive "total" PCB concentration in each sample. SALG risk assessors then averaged the summed congeners within each group (e.g., fish species, sample site, or combination of species and site) to derive a mean PCB concentration for each group.

Using only a few PCB congeners to determine total PCB concentrations could underestimate PCB levels in fish tissue. Nonetheless, the method complies with expert recommendations on evaluation of PCBs in fish or shellfish. Therefore, SALG risk assessors compare average PCB concentrations of the 43 congeners with health assessment comparison (HAC) values derived from information on PCB mixtures held in the USEPA's Integrated Risk Information System (IRIS) database.[30] IRIS currently contains systemic toxicity information for five Aroclor® mixtures: Aroclors® 1016, 1242, 1248, 1254, and 1260. IRIS does not contain all information for all mixtures. For instance, only one other reference dose (RfD) occurs in IRIS – the one derived for Aroclor 1016, a commercial mixture produced in the latter years of commercial production of

PCBs in the United States. Aroclor 1016 was a fraction of Aroclor 1254 that was supposedly devoid of dibenzofurans, in contrast to Aroclor 1254.[31] Systemic toxicity estimates in the present document reflect comparisons derived from the USEPA's RfD for Aroclor 1254 because Aroclor 1254 contains many of the 43 congeners selected by McFarland and Clark and NOAA. As of yet, IRIS does not contain information on the systemic toxicity of individual PCB congeners.

For assessment of cancer risk from exposure to PCBs, the SALG uses the USEPA's highest slope factor of 2.0 milligram per kilogram per day (mg/kg/day) to calculate the probability of lifetime excess cancer risk from PCB ingestion. The SALG based its decision to use the most restrictive slope factor available for PCBs on factors such as food chain exposure; the presence of dioxin-like, tumor-promoting, or persistent congeners; and the likelihood of early-life exposure.[30]

Calculation of Toxicity Equivalent Quotients (TEQs) for Dioxins

PCDDs/PCDFs are families of aromatic chemicals containing one to eight chlorine atoms. The molecular structures differ not only with respect to the number of chlorines on the molecule, but also with the positions of those chlorines on the carbon atoms of the molecule. The number and positions of the chlorines on the dibenzofuran or dibenzo-*p*-dioxin nucleus directly affects the toxicity of the various congeners. Toxicity increases as the number of chlorines increases to four chlorines, then decreases with increasing numbers of chlorine atoms - up to a maximum of eight. With respect to the position of chlorines on the dibenzo-*p*-dioxin/dibenzofuran nucleus, it appears that those congeners with chlorine substitutions in the 2, 3, 7, and 8 positions are more toxic than congeners with chlorine substitutions in other positions. To illustrate, the most toxic of PCDDs is 2,3,7,8–tetrachlorodibenzo-*p*-dioxin (2,3,7,8–TCDD), a 4-chlorine molecule having one chlorine substituted for hydrogen at each of the 2, 3, 7, and 8 carbon positions on the dibenzo-*p*-dioxin. To gain some measure of toxic equivalence, 2,3,7,8–TCDD – assigned a toxicity equivalency factor (TEF) of 1.0 – is the standard against which other congeners are measured. Other congeners are given weighting factors or TEFs of 1.0 or less based on experiments comparing the toxicity of the congener relative to that of 2,3,7,8-TCDD.[32, 33] Using this technique, risk assessors from the DSHS converted PCDF or PCDD congeners in each tissue sample from the present survey to TEQs by multiplying each congener's concentration by its TEF, producing a dose roughly equivalent in toxicity to that of the same dose of 2,3,7,8-TCDD. The total TEQ for any sample is the sum of the TEQs for each of the congeners in the sample, calculated according to the following formula.[34]

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

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

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

The effects of exposure to any hazardous substance depend, among other factors, on the dose, the route of exposure, the duration of exposure, the manner in which the exposure occurs, the genetic makeup, personal traits, habits of the exposed, or the presence of other chemicals.[35] 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.[35]

If diverse species of fish or shellfish are available, the SALG presumes that people eat a variety of species from a water body. Further, SALG risk assessors assume that most fish species are mobile. SALG risk assessors may combine data from different fish species and/or sampling sites within a water body to evaluate mean contaminant concentrations of toxicants in all samples as a whole. This approach intuitively reflects consumers' likely exposure over time to contaminants in fish or shellfish from any water body but may not reflect the reality of exposure at a specific water body or a single point in time. The DSHS reserves the right to project risks associated with ingestion of individual species of fish or shellfish from separate collection sites within a water body or at higher than average concentrations (e.g. the upper 95 percent confidence limit on the mean). The SALG derives confidence intervals from Monte Carlo simulations using software developed by a DSHS medical epidemiologist.[36] The SALG evaluates contaminants in fish or shellfish by comparing the mean or the 95% upper confidence limit on the mean concentration of a contaminant to its HAC value (in mg/kg) for non-cancer or cancer endpoints.

In deriving HAC values for systemic (HAC_{nonca}) effects, the SALG assumes a standard adult weighs 70 kilograms (kg) and consumes 30 g of fish or shellfish per day (about one 8-ounce meal per week) and uses the USEPA's RfD[37] or the ATSDR's chronic oral MRLs.[38] 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.*[39]

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.*[39]

The ATSDR uses a similar technique to derive its MRLs.[38] The DSHS divides the estimated daily dose derived from the measured concentration in fish tissue by the contaminant's RfD or MRL to derive a hazard quotient (HQ). The USEPA defines a HQ as

> *…the ratio of the estimated exposure dose of a contaminant (mg/kg/day) to the contaminant's RfD or MRL (mg/kg/day).*[40]

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

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

Although the DSHS utilizes chemical specific RfDs when possible, if an RfD is not available for a contaminant, the USEPA advises risk assessors to consider evaluating the contaminant by comparing it to the published RfD (or the MRL) of a contaminant of similar molecular structure or one with a similar mode or mechanism of action. For instance, Aroclor® 1260 has no RfD, so the DSHS uses the reference dose for Aroclor 1254 to assess the likelihood of systemic (noncarcinogenic) effects of Aroclor 1260.[38]

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.[37,39] Vulnerable groups such as women who are pregnant or lactating, women who may become pregnant, infants, children, people with chronic illnesses, those with compromised immune systems, the elderly, or those who consume exceptionally large servings are considered sensitive populations by risk assessors and USEPA and also receive special consideration in calculation of a RfD.[39]

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

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

The USEPA states that

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

And

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

Thus,

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

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

The DSHS calculates cancer-risk comparison values (HAC_{ca}) from the USEPA's chemical-specific cancer potency factors (CPFs), also known as cancer slope factors (CSFs), derived through mathematical modeling from carcinogenicity studies. For carcinogenic outcomes, the DSHS calculates a theoretical lifetime excess risk of cancer for specific exposure scenarios for carcinogens, using a standard 70-kg body weight and assuming an adult consumes 30 grams of edible tissue per day. The SALG risk assessors incorporate two additional factors into determinations of theoretical lifetime excess cancer risk: (1) an acceptable lifetime risk level (ARL)[39] 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.[41, 42] 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.[43] Unique early sensitivities may exist after birth because organs and body systems are structurally or functionally immature at birth, continuing to develop throughout infancy, childhood, and adolescence. Developmental variables may influence the mechanisms or rates of absorption, metabolism, storage, or excretion of toxicants. Any of these factors could alter the concentration of biologically effective toxicant at the target organ(s) or could modulate target organ response to the toxicant. Children's exposures to toxicants may be more extensive than adults' exposures because children consume more food and liquids in proportion to their body weights than adults consume. Infants can ingest toxicants through breast milk, an exposure pathway that often goes unrecognized. Nonetheless, the advantages of breastfeeding outweigh the probability of significant exposure to infants through breast milk and women are encouraged to continue breastfeeding and to limit exposure of their infants by limiting intake of the contaminated foodstuff. Children may experience effects at a lower exposure dose than might adults because children's organs may be more sensitive to the effects of toxicants. Stated differently, children's systems could respond more extensively or with greater severity to a given dose than would an adult organ exposed to an equivalent dose of a toxicant. Children could be more prone to developing certain cancers from chemical exposures than are adults.[44] 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.[37] Additionally, in accordance with the ATSDR's *Child Health Initiative*[45] and the USEPA's *National Agenda to Protect Children's Health from Environmental Threats,*[46] the DSHS further seeks to protect children from the possible negative effects of toxicants in fish by suggesting that this potentially sensitive subgroup consume smaller quantities of contaminated fish or shellfish than adults consume. Thus, the DSHS recommends that children weighing 35 kg or less and/or who are 11 years of age or younger limit exposure to contaminants in fish or shellfish by eating no more than four ounces per meal of the contaminated species. The DSHS also recommends that consumers spread these meals over time. For instance, if the DSHS issues consumption advice that recommends consumption of no more than two meals per month of a contaminated species, those children should eat no more than 24 meals of the contaminated fish or shellfish per year and should not eat such fish or shellfish more than twice per month.

Data Analysis and Statistical Methods

The SALG risk assessors imported Excel© files into SPSS® statistical software, version 13.0 installed on IBM-compatible microcomputers (Dell, Inc), using SPSS® to generate descriptive statistics (mean, standard deviation, median, minimum and maximum concentrations, and range) on measured compounds.[47] In computing descriptive statistics, SALG risk assessors utilized ½ the reporting limit (RL) for analytes designated as not detected (ND) or estimated (J-values)[c]. PCDDs/PCDFs descriptive statistics are calculated using estimated concentrations (J-values) and assuming zero for PCDDs/PCDFs designated as ND.[d] The change in methodology for computing PCDDs/PCDFs descriptive statistics is due to the proximity of the reporting limits to the HAC value. Assuming ½ the RL for PCDDs/PCDFs designated as ND or J-values would unnecessarily overestimate the concentration of PCDDs/PCDFs in each fish tissue sample. The SALG used the descriptive statistics from the above calculations to generate the present report. The SALG

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

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

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 Galveston Bay Estuary.[48] When lead concentrations in fish or shellfish are high, SALG risk assessors may utilize the EPA's Interactive Environmental Uptake Bio-Kinetic (IEUBK) model to determine whether consumption of lead-contaminated fish could cause a child's blood lead (PbB) level to exceed the Centers for Disease Control and Prevention's (CDC) lead concentration of concern in children's blood (10 mcg/dL).[49,50]

RESULTS

The GERG laboratory completed the contaminant analyses and electronically transmitted the results of the Galveston Bay samples collected in February through April 2010 to the SALG in September 2010. The laboratory reported the analytical results for metals, pesticides, PCBs, PCDDs/PCDFs, SVOCs, and VOCs. The GERG laboratory reported metals, pesticides, PCBs, PCDDs/PCDFs, SVOCs, and VOCs results for six additional spotted seatrout samples collected from the San Jacinto River / Houston Ship Channel in November 2010 and January 2011 to the SALG in October 2011.

For reference, Tables 1a and 1b contain the total number of samples collected. Tables 2a through 2d present the results of metals analyses. Table 3 contains summary results for selected pesticide analyses. Tables 4a through 4f summarize the PCB analyses. Tables 5a through 5f summarize PCDDs/PCDFs analyses. Table 6 contains summary results for selected VOC analyses. This paper does not display SVOC data because these contaminants were not present at concentrations of interest in fish collected from Galveston Bay during the described survey. Unless otherwise stated, table summaries present the number of samples containing a specific contaminant/number tested, the mean concentration ± 1 standard deviation (68% of samples should fall within one standard deviation of the arithmetic mean in a sample from a normally-distributed population), and, in parentheses under the mean and standard deviation, the minimum and the maximum detected concentrations. Those who prefer to use the range may derive this statistic by subtracting the minimum concentration of a given contaminant from its maximum concentration. In the tables, results may be reported as ND, below detection limit (BDL) for estimated concentrations, or as reported concentrations. According to the laboratory's quality control/quality assurance materials, estimated concentrations reported as BDL rely upon the laboratory's method detection limit (MDL) or its reporting limit (RL). The MDL is the minimum concentration of an analyte that is reported with 99% confidence that the analyte concentration is greater than zero, while the RL is the concentration of an analyte reliably achieved within specified limits of precision and accuracy during routine analyses. Contaminant concentrations reported below the RL are qualified as "J-values" in the laboratory data report.[51]

Inorganic Contaminants

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

All 136 fish tissue samples from the Galveston Bay Estuary contained concentrations of copper, selenium, and zinc (Tables 2b-2d). All 139 fish tissue samples from Galveston Bay and the San Jacinto River / Houston Ship Channel contained concentrations of mercury (Table 2c).

Three of the metalloids analyzed are essential trace elements: copper, selenium, and zinc. All 136 fish tissue samples contained copper (Table 2b). The mean copper concentration in fish sampled from the Galveston Bay Estuary was 0.233±0.215 mg/kg. Gafftopsail catfish had the highest average concentration of copper (0.346±0.104 mg/kg). All fish tissue samples contained selenium. The average selenium concentration in fish from the Galveston Bay Estuary was 0.607 mg/kg with a standard deviation of ±0.244 mg/kg (Table 2d). Selenium in fish from Galveston Bay Estuary ranged from 0.124 to 1.263 mg/kg. All samples also contained zinc (Table 2d). The mean zinc concentration in fish tissue samples from Galveston Bay Estuary was 3.134±1.148 mg/kg (Table 2d).

The SALG evaluated four toxic metalloids having no known human physiological function (arsenic, cadmium, lead, and mercury) in the samples collected from the Galveston Bay Estuary. One hundred thirty-five of 136 samples assayed contained arsenic ranging from ND-7.951 mg/kg (Table 2a). Seventy-nine of 136 samples analyzed contain cadmium (Table 2b). All species of fish assayed had at least one sample that contained lead at concentrations greater than the RL except striped bass (Table 2c). The average lead concentration in all fish combined was 0.048±0.055 mg/kg (Table 2c).

All species of fish collected in 2010–2011 from the Galveston Bay Estuary contained mercury (Table 2c). A black drum contained the lowest concentration of mercury (0.043 mg/kg), while the highest concentration occurred in a spotted seatrout (0.825 mg/kg). The mean mercury concentration in fish (all species and all sites) was 0.155±0.128 mg/kg (Table 2c).

Organic Contaminants

Pesticides

The GERG laboratory analyzed 23 fish for 34 pesticides. All 23 samples examined contained concentrations of chlordane and 4,4′-DDE (Table 3a). Chlordane concentrations ranged from BDL-0.059 mg/kg in fish (Table 3; *n*=23). A striped bass contained the highest concentration of 4,4′-DDE (0.116 mg/kg). The mean 4,4′-DDE concentration in fish (*n*=23) was 0.013±0.026 mg/kg. Several fish samples contained trace[e] to low concentrations of 1,2,3,4 tetrachlorobenzene, 1,2,4,5 tetrachlorobenzene, pentachlorobenzene, hexachlorobenzene, alpha HCH, delta HCH, gamma HCH, heptachlor, heptachlor epoxide, dieldrin, pentachloroanisole, mirex, endosulfan II, 2,4′-DDD, 2,4′-DDE, 2,4′-DDT , 4,4′-DDT, alachlor, endosulfan sulfate, ethyl parathion, malathion, and methoxychlor (data not presented).

PCBs

All fish tissue samples contained concentrations of one or more PCB congeners (Table 4a–4f). No fish tissue sample contained all PCB congeners (data not shown). Across all sample sites and

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

species, PCB concentrations ranged from BDL to 0.255 mg/kg (Table 4e). Gafftopsail catfish contained the highest mean concentration of PCBs (0.073±0.060 mg/kg). One (gafftopsail catfish) of eight fish species evaluated had mean PCB congener concentrations across all sample sites that exceeded the DSHS HAC_{nonca} value for PCBs (0.047 mg/kg; Table 4e). Southern flounder contained the lowest mean concentration of PCBs (Tables 4e). The mean PCB concentration in the 139 fish tissue samples assayed was 0.036±0.039 mg/kg (Table 4e).

Assessment of PCB concentrations in gafftopsail catfish by sampling event indicate that the 2005–2006 and 2010–2011 data do not statistically differ by sampling event (2005–2006, n = 24 and 2010, n = 18; t [40] = 1.414, p = 0.165). Further comparison of PCB concentrations in gafftopsail catfish from the 2005–2006 and 2010–2011 assessments by subdivided Galveston Bay Estuary section or bay could not be performed because of insufficient sample size.

The SALG risk assessors evaluated the 2010–2011 spotted seatrout PCB data by subdividing the Galveston Bay Estuary into five sections: Section 1 delineates an area of the estuary north of a line from Red Bluff Point to Five-Mile Cut Marker to Houston Point (Sample sites 1, 2, and additional spotted seatrout samples from the San Jacinto River / Houston Ship Channel; n = 16); Section 2 delineates an area south of a line from Red Bluff Point to Five-Mile Cut Marker to Houston Point and north of a line from Eagle Point to Smith Point including Trinity Bay (Sample sites 3, 5, and 16; n = 21); Section 3 delineates an area south of a line from Eagle Point to Smith Point excluding East Bay and West Bay (Sample sites 6, 12, 14, and 15; n = 8); Section 4 delineates East Bay east of a line from Smith Point to Bolivar Peninsula (Sample sites 8, 17, and 18; N = 19); and Section 5 delineates Christmas Bay, Cold Pass, and San Luis Pass (Sample Sites 10 and 19; n = 8). The SALG risk assessors visually examined the spotted seatrout PCB summary data subdivided into five sections noting that PCBs appeared to break naturally between Section 1 and Sections 2, 3, 4, and 5 (Figure 3). Univariate analysis of variance showed that the mean PCB concentrations in spotted seatrout differed significantly across the five Galveston Bay Estuary sections (F [4, 67] = 11.698, p <0.0005). The SALG risk assessors condensed the five sections into two composite sites based on the results of the univariate analysis of variance and apparent natural break in the data: Composite Area 1 delineates an area north of a line from Red Bluff Point to Five-Mile Cut Marker to Houston Point (spotted seatrout samples from sample sites 1 and 2 including the additional spotted seatrout samples from the San Jacinto River / Houston Ship Channel; n = 16) and Composite Area 2 delineates an area south of a line from Red Bluff Point to Five-Mile Cut Marker to Houston Point (spotted seatrout samples from sample sites 3, 5, 6, 8, 10, 12, 14, 15, 16, 17, 18, and 19; n = 56). The mean PCB concentration for spotted seatrout at Composite Area 1 was 0.081±0.060 mg/kg while, at Composite Area 2, the mean PCB concentration was 0.026±0.015 mg/kg (Table 4f). The minimum and maximum concentrations for spotted seatrout at Composite Area 1 and Composite Area 2 were 0.019-0.237 mg/kg and BDL- 0.064 mg/kg, respectively (Table 4f).

The SALG risk assessors performed statistical analyses to assess the relationship between spotted seatrout age and PCB concentration and to determine if there were differences in PCB concentration by sex. The data were not subdivided into Galveston Bay Estuary sections for these analyses. A Pearson product-moment correlation coefficient was computed to assess the relationship between the age of spotted seatrout and their PCB concentration within the Galveston Bay Estuary (Figure 2). There was no correlation between the two variables (r =

0.086, n = 60, p = 0.512). The mean PCB concentration (mg/kg) for female spotted seatrout was 0.034±0.026, whereas the mean PCB concentration for males was 0.030±0.015. There was not a significant difference between female and male spotted seatrout PCB concentrations (female, n = 39; male, n = 20; t [57] = -0.648, p = 0.520).

Evaluation of PCB concentrations in spotted seatrout by sampling event indicate that the 2005–2006 and 2010–2011 data do not statistically differ by sampling event (2005–2006; n = 118; 2010-2011, n = 72; t [188] = 1.550, p = 0.123). Comparison of PCB concentrations in spotted seatrout from the 2005–2006 and 2010–2011 assessments by subdivided Galveston Bay Estuary section, as discussed above, are difficult to perform because the samples sizes are remarkably unequal by section and no spotted seatrout were collected in 2005–2006 from Sections 4 and 5.

Although discussed in different ways from summary data tables showing the spotted seatrout data in various cuts, the SALG used the data sets from the two composite areas to recommend advisory or regulatory action to protect public health.

PCDDs/PCDFs

The GERG laboratory analyzed all fish tissue samples for 17 of the 210 possible PCDD/PCDF (75 PCDDs + 135 PCDFs) congeners from the Galveston Bay Estuary. The congeners examined consist of 7 PCDDs and 10 PCDFs that contain chlorine substitutions in, at a minimum, the 2, 3, 7, and 8 positions on the dibenzo-*p*-dioxin or dibenzofuran nucleus and are the only congeners reported to pose dioxin-like adverse human health effects.[52] Although 12 of the 209 PCB congeners – those often referred to as "coplanar PCBs," meaning the molecule can assume a flat configuration with both phenyl rings in the same plane – may also have dioxin-like toxicity, the SALG does not assess PCBs for dioxin-like qualities because the dioxin-like behavior has been less extensively evaluated. Tables 5a through 5f contain site and species-specific summary statistics for PCDDs/PCDFs in fish collected from Galveston Bay Estuary. Before generating summary statistics for PCDDs/PCDFs, the SALG risk assessors converted the reported concentration of each PCDD or PCDF congener reported present in a tissue sample to a concentration equivalent in toxicity to that of 2,3,7,8-TCDD (a TEQ concentration - expressed as picogram per gram [pg/g]or nanogram per kilogram [ng/kg]). Sixty-eight of 139 fish tissue samples contained at least one of the 17 congeners assayed (minimum – to – maximum concentration after conversion: ND-6.487 pg/g–or ng/kg; Table 5e). No samples contained all 17 congeners (data not shown). Gafftopsail catfish contained the highest mean PCDD/PCDF TEQ concentration (0.695±1.776 pg/g).

Assessment of PCDD/PCDF TEQ concentrations in gafftopsail catfish by sampling event indicate that the 2005–2006 and 2010–2011 data do not statistically differ by sampling event (2005–2006, n = 24; 2010, n = 18; t [34] = 1.710, p = 0.096). Further comparison of PCDD/PCDF TEQ concentrations in gafftopsail catfish from the 2005–2006 and 2010–2011 assessments by subdivided Galveston Bay Estuary section or bay could not be performed because of insufficient sample size.

The SALG risk assessors evaluated the spotted seatrout PCDD/PCDF data by subdivided section as described in the PCBs results above. Visual examination of the PCDD/PCDF data revealed that the data did not break naturally or statistically as the PCB data did (Figure 4). Univariate analysis of variance showed that the PCDD/PCDF TEQ concentration in spotted seatrout differed significantly across the five Galveston Bay Estuary sections (F [4, 67] = 4.236, p = 0.004). Although, the PCDD/PCDF data did not break similar to the PCB data, SALG risk assessors condensed the data into the two composite areas discussed in the PCB results to facilitate consistency for spotted seatrout samples assessed, concerning single and multiple contaminant exposures. The mean PCDD/PCDF TEQ concentration for spotted seatrout at Composite Area 1 was 0.066±0.183 pg/g while, at Composite Area 2, the mean PCDD/PCDF TEQ concentration was 0.154±0.314 (Table 5f). The minimum and maximum concentrations for spotted seatrout at Composite Area 1 and Composite Area 2 were ND–0.668 and ND–1.407 pg/g, respectively (Table 5f).

The SALG risk assessors performed statistical analyses to determine if a relationship existed between spotted seatrout age and PCDD/PCDF TEQ concentration and to determine if there were differences in PCDD/PCDF TEQ concentration by sex. The data were not subdivided into Galveston Bay Estuary sections for these analyses. A Pearson product-moment correlation coefficient was computed to assess the relationship between the age of spotted seatrout and their PCDD/PCDF TEQ concentration within the Galveston Bay Estuary. There was no significant correlation between the two variables (r = 0.234, n = 60, p = 0.072). The mean PCDD/PCDF TEQ concentration (pg/g) for female spotted seatrout was 0.151±0.282, whereas the mean PCDD/PCDF TEQ concentration for males was 0.136±0.360. There was not a significant difference between female and male spotted seatrout PCDD/PCDF TEQ concentrations. (female, n = 39; male, n = 20; t [57] = -0.177, p = 0.860).

Evaluation of PCDD/PCDF TEQ concentrations in spotted seatrout by sampling event indicate that the 2005–2006 mean PCDD/PCDF TEQ concentration was significantly higher than the 2010–2011 mean PCDD/PCDF TEQ concentration (2005–2006, n = 17; 2010, n = 72); t [87] = 6.256, p <0.0005). Comparison of PCB concentrations in spotted seatrout from the 2005–2006 and 2010–2011 assessments by subdivided Galveston Bay Estuary section, as discussed above, could not be performed because of insufficient sample size.

Although discussed in different ways from summary data tables showing the spotted seatrout data in various cuts, the SALG used the data sets from the two composite areas to recommend advisory or regulatory action to protect public health.

SVOCs

The GERG laboratory analyzed a subset of 23 Galveston Bay Estuary fish tissue samples for SVOCs. The laboratory reported quantifiable concentrations (≥RL) and/or trace concentrations of the following SVOCs in one or more fish samples: benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, benzyl alcohol, dibenz(a,j)acridine, bis (2-ethylhexyl) phthalate, diethyl phthalate, and phenol. These concentrations did not pose a threat to human health (data not presented). The laboratory detected no other SVOCs in fish from the Galveston Bay Estuary.

VOCs

The GERG laboratory reported the 23 fish tissue samples selected for analysis from the Galveston Bay Estuary to contain quantifiable concentrations >RL of one or more VOCs: acetone, carbon disulfide, methylene chloride, 2-butanone (MEK), methyl methacrylate, and 1,4-dichlorobenzene (data not presented). Trace quantities of many VOCs were also present in one or more fish tissue samples assayed from the Galveston Bay Estuary (data not presented). The Seafood and Aquatic Life Group Survey Team Standard Operating Procedures and Quality Control/Assurance Manual contain a complete list of the 70 VOCs selected for analysis. Numerous VOCs were also identified in one or more of the procedural blanks, indicating the possibility that these compounds were introduced during sample preparation. VOC concentrations <RL are difficult to interpret due to their uncertainty and may represent a false positive. The presence of many VOCs at concentrations <RL may be the result of incomplete removal of the calibration standard from the adsorbent trap, so they are observed in the blank. VOC analytical methodology requires that the VOCs be thermally released from the adsorbent trap, transferred to the gas chromatograph (GC), and into the GC/mass spectrometer (MS) for quantification.

DISCUSSION

Risk Characterization

Because variability and uncertainty are inherent to quantitative assessment of risk, the calculated risks of adverse health outcomes from exposure to toxicants can be orders of magnitude above or below actual risks. Variability in calculated and in actual risk may depend upon factors such as the use of animal instead of human studies, use of subchronic rather than chronic studies, interspecies variability, intra-species variability, and database insufficiency. Since most factors used to calculate comparison values result from experimental studies conducted in the laboratory on nonhuman subjects, variability and uncertainty might arise from the study chosen as the "critical" one, the species/strain of animal used in the critical study, the target organ selected as the "critical organ," exposure periods, exposure route, doses, or uncontrolled variations in other conditions.[37] Despite such limitations, risk assessors must calculate parameters to represent potential toxicity to humans who consume contaminants in fish and other environmental media. The DSHS calculated risk parameters for systemic and carcinogenic endpoints in those who would consume fish from the Galveston Bay Estuary. Conclusions and recommendations predicated upon the stated goal of the DSHS to protect human health follow the discussion of the relevance of findings to risk.

Characterization of Systemic (Noncancerous) Health Effects from Consumption of Fish from the Galveston Bay Estuary

One (alligator gar) of 136 fish samples evaluated contained arsenic exceeding the HAC_{nonca} for arsenic (0.700 mg/kg; Tables 2a and 7a). The mean arsenic concentrations of the eight fish species evaluated and the all fish combined mean concentration did not exceed the arsenic HAC_{nonca} value nor did the HQs exceed 1.0. PCBs were observed in fish from the Galveston Bay Estuary that equaled or exceeded its HAC_{nonca} (0.047 mg/kg; Tables 4a–4f and 8a–8c). Two (gafftopsail catfish) of 139 fish samples assayed contained PCDDs/PCDFs exceeding the HAC_{nonca} for PCDDs/PCDFs (2.330 pg/g; Tables 5a–5f and Tables 8a–8c). The mean PCDD/PCDF concentrations of the eight fish species evaluated and the all fish combined mean concentration did not exceed the PCDDs/PCDFs HAC_{nonca} value nor did the HQs exceed 1.0. No species of fish collected contained any other inorganic or organic contaminants at concentrations that equaled or exceeded the DSHS guidelines for protection of human health or would likely cause systemic risk to human health from consumption of fish from the Galveston Bay Estuary. Potential systemic health risks related to the consumption of fish from the Galveston Bay Estuary containing inorganic and organic contaminants (other than PCBs) are not of public health concern. Consequently, this risk characterization concentrates on assessing the likelihood of adverse health outcomes that could occur from consumption of the Galveston Bay Estuary PCB-contaminated fish. Tables 8a through 8c provide HQs for PCBs in each species of fish from the Galveston Bay Estuary and the recommended weekly consumption rate for each species.

PCBs

One hundred thirty nine of 139 fish collected from the Galveston Bay Estuary contained PCBs (Tables 4a–4e). Twenty four percent of all samples (n = 139) analyzed contained PCB concentrations that equaled or exceeded the HAC_{nonca} for PCBs (0.047 mg/kg). PCB concentrations that equaled or exceeded the HAC_{nonca} for PCBs (0.047 mg/kg) were observed in one or more samples of the following species: gafftopsail catfish, sand trout, spotted seatrout, and striped bass. The gafftopsail catfish was the only species of fish examined from the Galveston Bay Estuary that had an overall mean PCB concentration exceed the HAC_{nonca} for PCBs or a HQ of 1.0 (Tables 4e and 8a). The consumption of gafftopsail catfish from the Galveston Bay Estuary may pose potential systemic health risks.

Figure 3 and Table 4f show that PCBs in spotted seatrout from Composite Area 1 contain higher concentrations of PCBs than spotted seatrout from Composite Area 2. The mean PCB concentration for spotted seatrout at Composite Area 1 exceeded the HAC_{nonca} for PCBs or a HQ of 1.0 (Table 4f and 8c) suggesting that consumption of spotted seatrout from Composite Area 1 may pose potential systemic health risks. The mean PCB concentration for spotted seatrout at Composite Area 2 does not exceed the HAC_{nonca} for PCBs or a HQ of 1.0.

Meal consumption calculations may be useful for decisions about consumption advice or regulatory actions. The SALG risk assessors calculated the number of 8-ounce meals from the Galveston Bay Estuary that healthy adults could consume without significant risk of adverse systemic effects (Table 8a-8c). The SALG estimated this group could consume 0.6 (8-ounce) meals per week of gafftopsail catfish containing PCBs (Table 8a) or 0.5 (8-ounce) meals per week of spotted seatrout from Composite Area 1 (Table 8c). Therefore, SALG risk assessors suggest that people should limit their consumption of gafftopsail catfish from the Galveston Bay Estuary and that people should limit their consumption of spotted seatrout from the area delineated as Composite Area 1 of the Galveston Bay Estuary. Because the developing nervous system of the human fetus may be especially susceptible to these effects, the SALG risk assessors recommend more conservative consumption guidance for this sensitive subpopulation.

Characterization of Theoretical Lifetime Excess Cancer Risk from Consumption of Fish from Galveston Bay Estuary

The USEPA classifies arsenic, most chlorinated pesticides, PCBs, and PCDDs/PCDFs as carcinogens. The mean arsenic concentration observed in alligator gar samples assayed exceeds the DSHS guideline for protection of human health of one excess cancer in 10,000 equally exposed individuals (Tables 2a and 9a); albeit, the arsenic concentration observed in one of two alligator gar samples assayed exceeded the DSHS ARL. Arsenic, chlorinated pesticides, PCBs, and PCDDs/PCDFs were present in most other fish samples from the Galveston Bay Estuary, but none of these contaminants evaluated singly by species or all fish combined had mean contaminant concentrations that would be likely to increase the risk of cancer to exceed the DSHS guideline for protection of human health of one excess cancer in 10,000 equally exposed individuals (Tables 2a–9d).

Characterization of Calculated Cumulative Systemic Health Effects and of Cumulative Excess Lifetime Cancer Risk from Consumption of Fish from Galveston Bay Estuary

Cumulative systemic effects of toxicants may occur if more than one contaminant acts upon the same target organ or acts by the same mode or mechanism of action. PCBs and PCDDs/PCDFs in the Galveston Bay Estuary fish could have these properties, especially with respect to effects on the immune system. Multiple inorganic or organic contaminants in the Galveston Bay Estuary samples did not significantly increase the likelihood of systemic adverse health outcomes from consuming any species of fish from the Galveston Bay Estuary.

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 PCDFs/PCDDs (all data not presented; Tables 9a–9d). In each instance, addition of the cancer risk numbers for these chemicals increased the theoretical lifetime excess cancer risk, albeit the cancer risk increase did not elevate lifetime excess cancer risk to a level greater than the DSHS guideline for protection of human health of one excess cancer in 10,000 persons equivalently exposed.

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 Galveston Bay Estuary, located in Chambers, Galveston, and Harris Counties, Texas. Risk assessors from the

SALG conclude from the present characterization of potential adverse health effects from consuming fish from the Galveston Bay Estuary that:

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

2. One of two alligator gar samples assayed contains arsenic at a concentration exceeding the DSHS guidelines for protection of human health of one excess cancer in 10,000 equally exposed individuals. Due to the small sample size and the variability of the arsenic concentrations reported in the two alligator gar samples, the SALG risk assessors are unable to characterize adequately health risks associated with consuming alligator gar from the Galveston Bay Estuary. Therefore, the SALG characterizes the likelihood of adverse health effects from regular consumption of alligator gar from the Galveston Bay Estuary as of **unknown significance to human health.**

3. Spotted seatrout collected from the portion of the Galveston Bay Estuary delineated as Composite Area 1 contain PCBs at concentrations exceeding the DSHS guidelines for protection of human health. Regular or long-term consumption of spotted seatrout may result in adverse systemic health effects. Therefore, consumption of spotted seatrout from the portion of the Galveston Bay Estuary delineated as Composite Area 1 **poses an apparent risk to human health**. Consumption advice issued in July 2008 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 TEQ concentrations have decreased to an acceptable level of risk and that there are differences in PCB concentrations by Galveston Bay Estuary section or bay.

4. Gafftopsail catfish contain PCBs at concentrations exceeding the DSHS guidelines for protection of human health. Regular or long-term consumption of gafftopsail catfish may result in adverse systemic health effects. Therefore, consumption of gafftopsail catfish from the Galveston Bay Estuary **poses an apparent risk to human health**.

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

It is important to note that this study and the 2005–2006 study represent a “snapshot” of risk throughout the Galveston Bay Estuary on the day(s) of sampling. Both of these studies do not account for potential PCB and PCDD/PCDF concentration variation in fish tissue due to environmental variables (i.e. seasonal fish movement, freshwater inflow, salinity, etc.). For this assessment, SALG risk assessors based its conclusions and recommendations solely on the evaluation of the 2010–2011 data.

RECOMMENDATIONS

Risk managers at the DSHS have established criteria for issuing fish consumption advisories based on approaches suggested by the EPA.[20, 24, 53] Risk managers at the DSHS may decide to take some action to protect public health if a risk characterization confirms that people can eat only 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 G, part 436.091 and Subchapter H, part 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, members of the public can make informed decisions about whether and/or how much – contaminated fish or shellfish they wish to consume. The SALG concludes from this risk characterization that consuming gafftopsail catfish and spotted seatrout from the Galveston Bay Estuary **poses an apparent hazard to public health.** Therefore, SALG risk assessors recommend that:

1. The DSHS continue the extant consumption guidance for gafftopsail catfish as recommended by Fish Consumption Advisory 35 (ADV-35). ADV-35 advised persons to limit consumption of all catfish species from Galveston Bay to no more than one eight-ounce meal per month and women who are nursing, pregnant, or who may become pregnant and children less than 12 years of age or who weigh less than 75 pounds should not consume catfish from Galveston Bay.

2. The DSHS continue the extant meal consumption guidance for spotted seatrout as recommended by Fish Consumption Advisory 35 (ADV-35). ADV-35 advised persons to limit consumption of spotted seatrout to no more than one eight-ounce meal per month and women who are nursing, pregnant, or who may become pregnant and children less than 12 years of age or who weigh less than 75 pounds should not consume spotted seatrout. The DSHS modify the spotted seatrout advisory area to include the portion of the Galveston Bay Estuary north of a line from Red Bluff Point to Five-Mile Cut Marker to Houston Point.

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

PUBLIC HEALTH ACTION PLAN

Communication to the public of new and continuing possession bans or consumption advisories, or the removal of either, is essential to effective management of risk from consuming contaminated fish. In fulfillment of the responsibility for communication, the DSHS takes several steps. The agency publishes fish consumption advisories and bans in a booklet available to the public through the SALG. To receive the booklet and/or the data, please contact the SALG at 512-834-6757.[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 EPA (http://epa.gov/waterscience/fish/advisories/), the TCEQ (http://www.tceq.state.tx.us), and the TPWD (http://www.tpwd.state.tx.us) with information on all consumption advisories and possession bans. Each year, the TPWD informs the fishing and hunting public of consumption advisories and fishing bans on its Web site and in an official downloadable PDF file containing general hunting and fishing regulations booklet available at http://www.tpwd.state.tx.us/publications/nonpwdpubs/media/regulations_summary_2009_2010.pdf.[57] A booklet containing this information is available at all establishments selling Texas fishing licenses.[58] Readers may direct questions about the scientific information or recommendations in this risk characterization to the SALG at 512-834-6757 or may find the information at the SALG's Web site (http://www.dshs.state.tx.us/seafood). Secondarily, one may address inquiries to the Environmental and Injury Epidemiology and Toxicology Branch of DSHS (512-458-7269). The EPA's IRIS Web site (http://www.epa.gov/iris/) contains information on environmental contaminants found in food and environmental media. The ATSDR, Division of Toxicology (888-42-ATSDR or 888-422-8737 or the ATSDR's Web site (http://www.atsdr.cdc.gov) supplies brief information via ToxFAQs.™ ToxFAQs™ are available on the ATSDR Web site in either English (http://www.atsdr.cdc.gov/toxfaq.html) or Spanish (http://www.atsdr.cdc.gov/es/toxfaqs/es _toxfaqs.html). The ATSDR also publishes more in-depth reviews of many toxic substances in its *Toxicological Profiles* (ToxProfiles™). To request a copy of the ToxProfiles™ CD-ROM, PHS, or ToxFAQs™ call 1-800-CDC-INFO (800-232-4636) or email a request to cdcinfo@cdc.gov.

Figure 1a. Galveston Bay Estuary Sample Sites

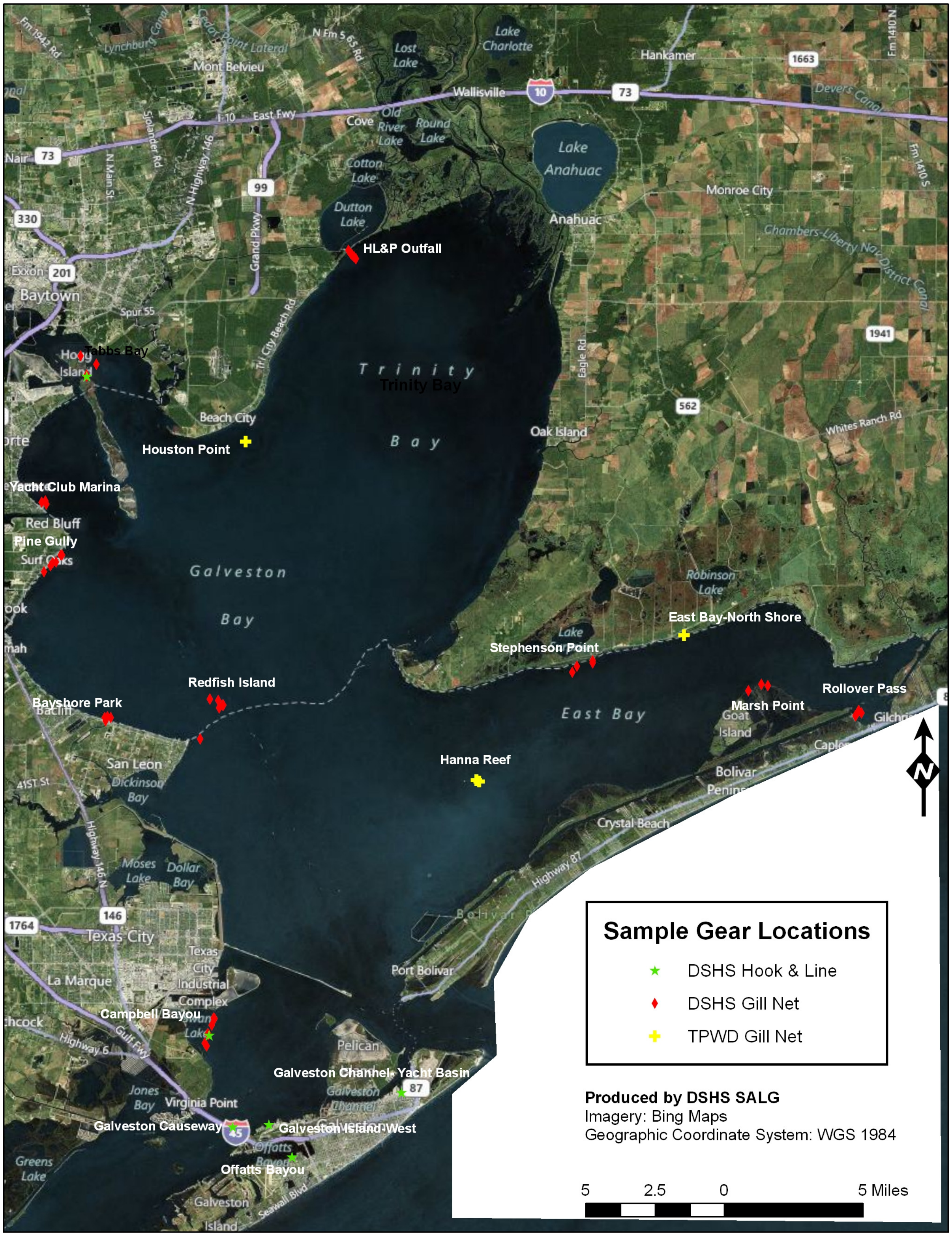


Figure 1b. Galveston Bay Estuary Sample Sites

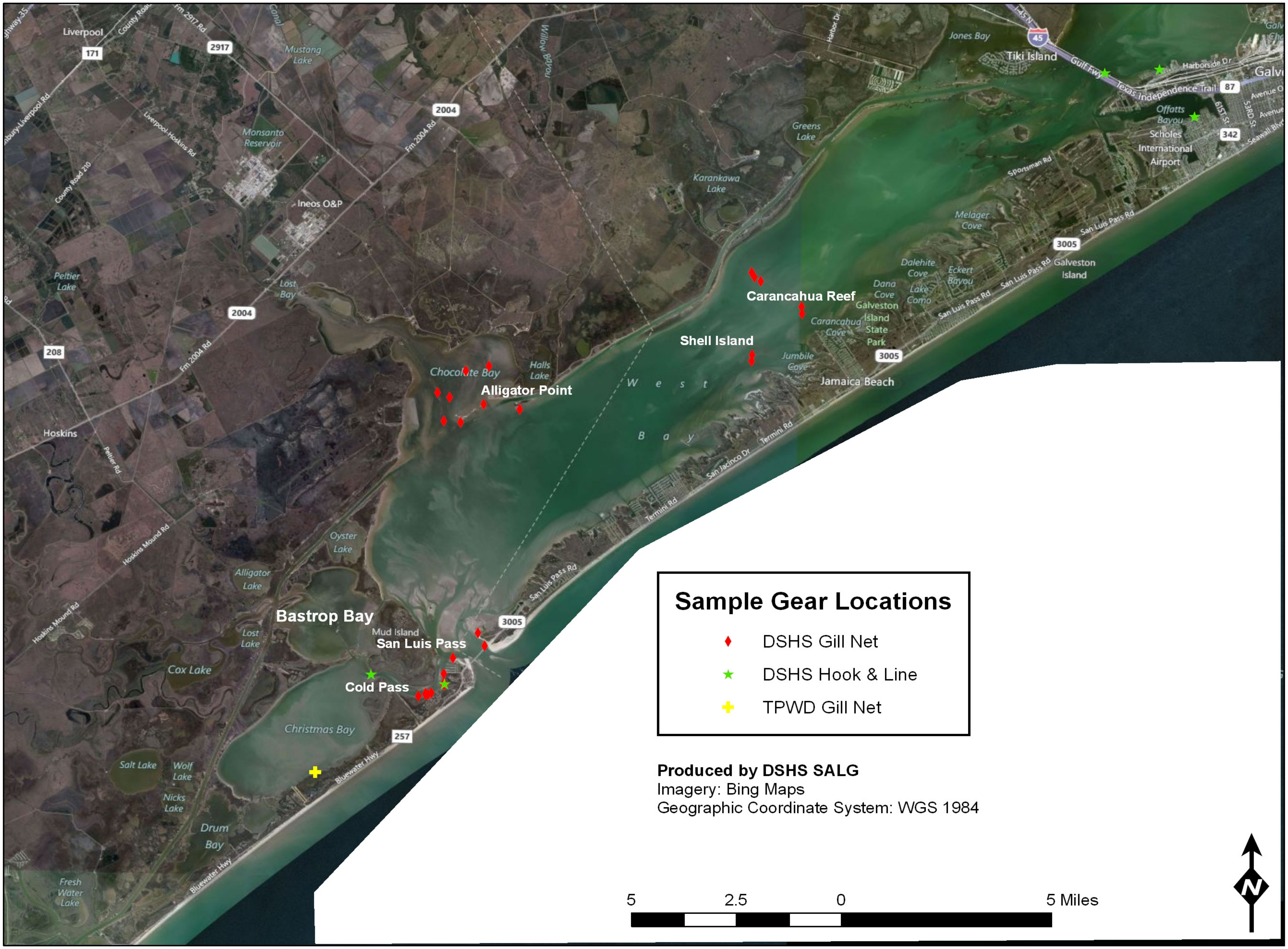


Figure 1c. San Jacinto River / Houston Ship Channel Sample Sites

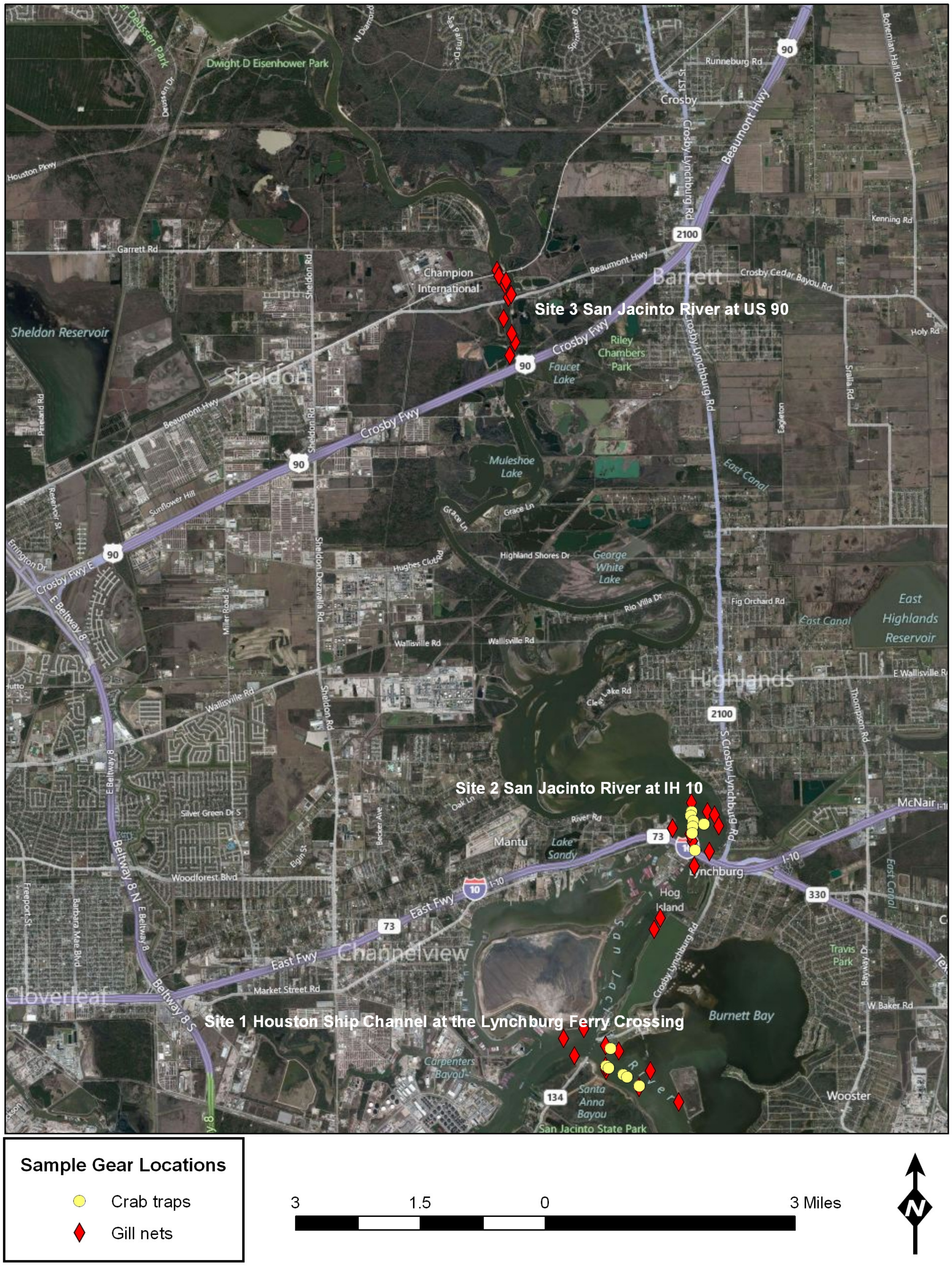


Figure 2. Length at age for spotted seatrout collected from the Galveston Bay Estuary, Texas, 2010.

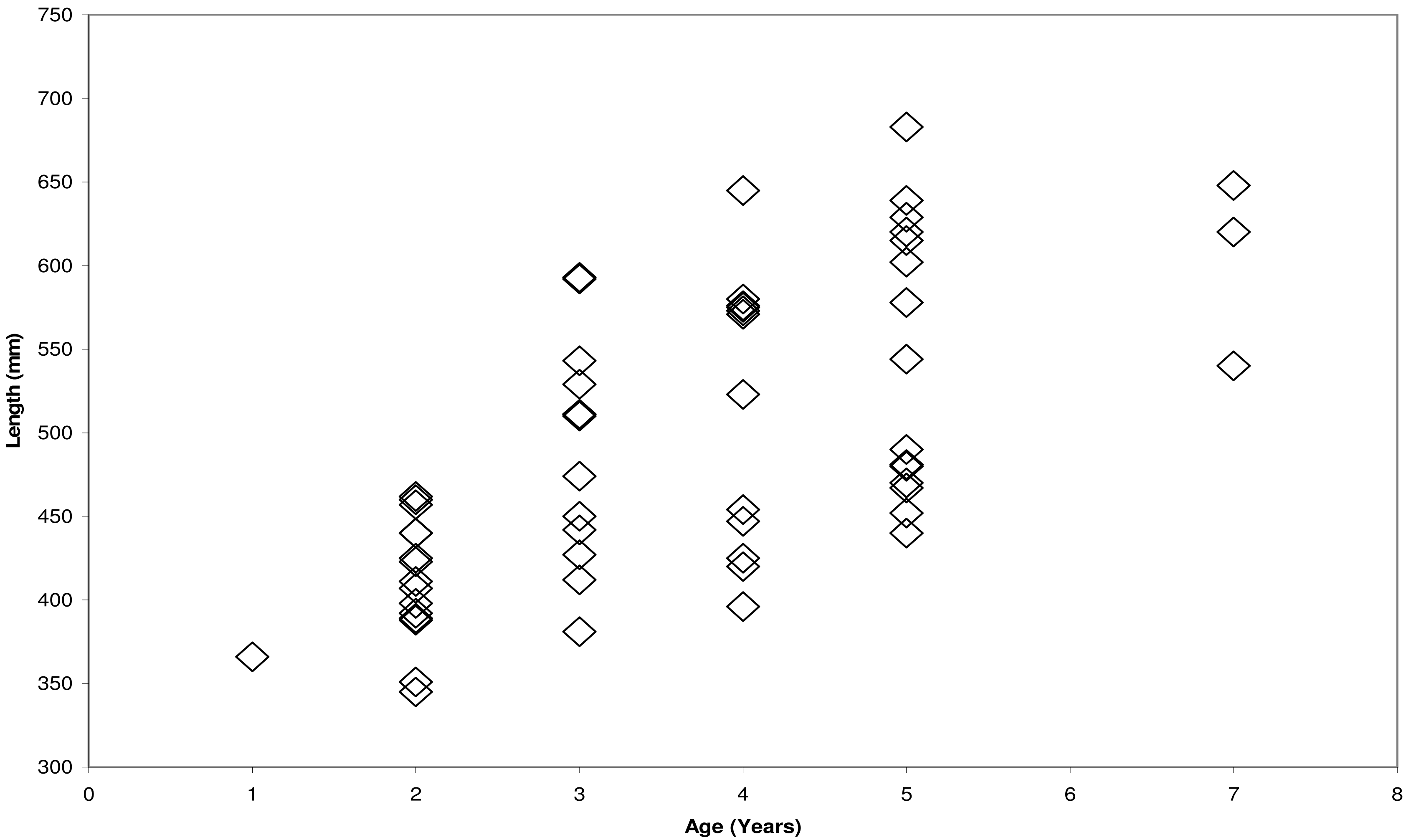
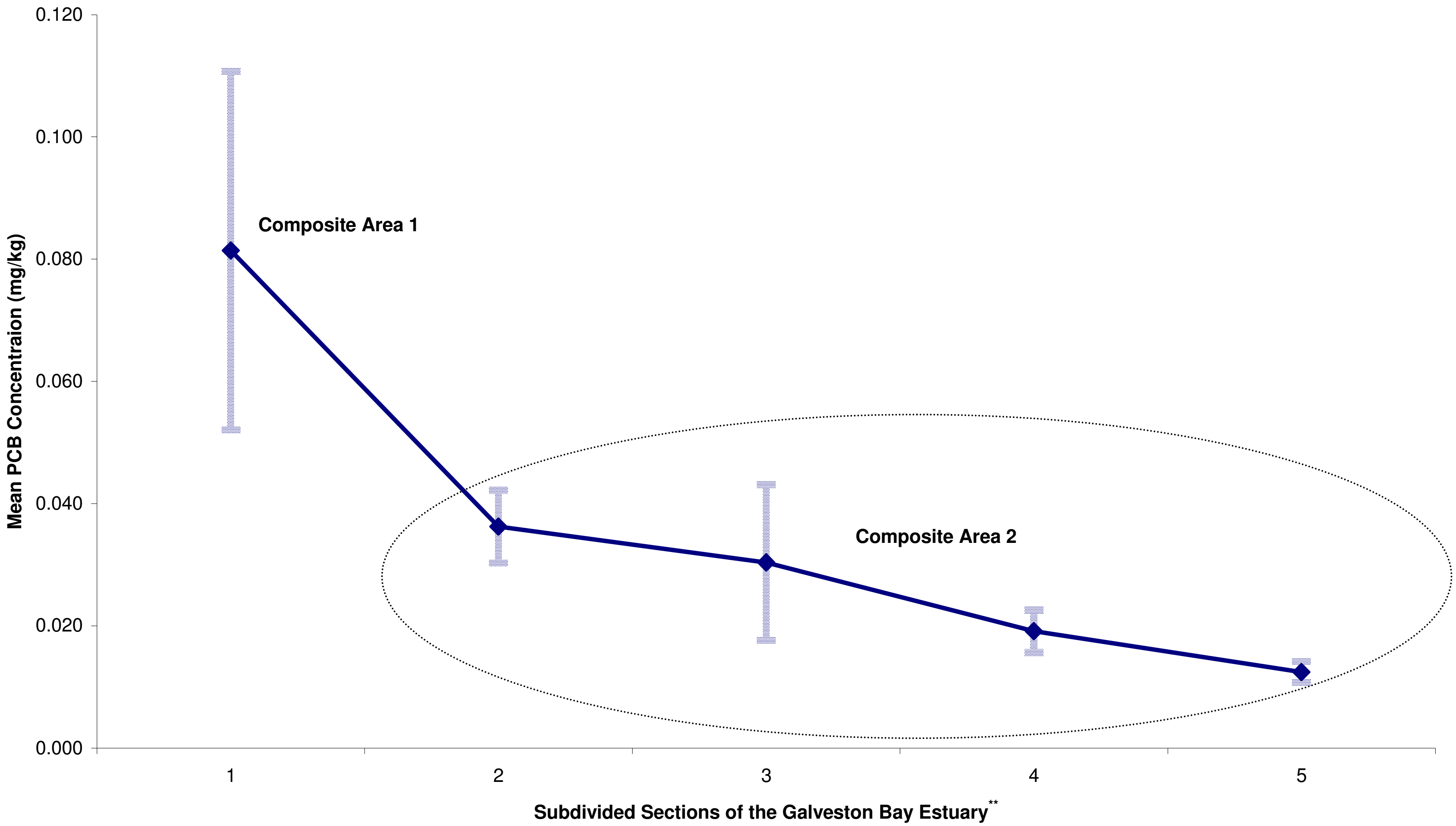
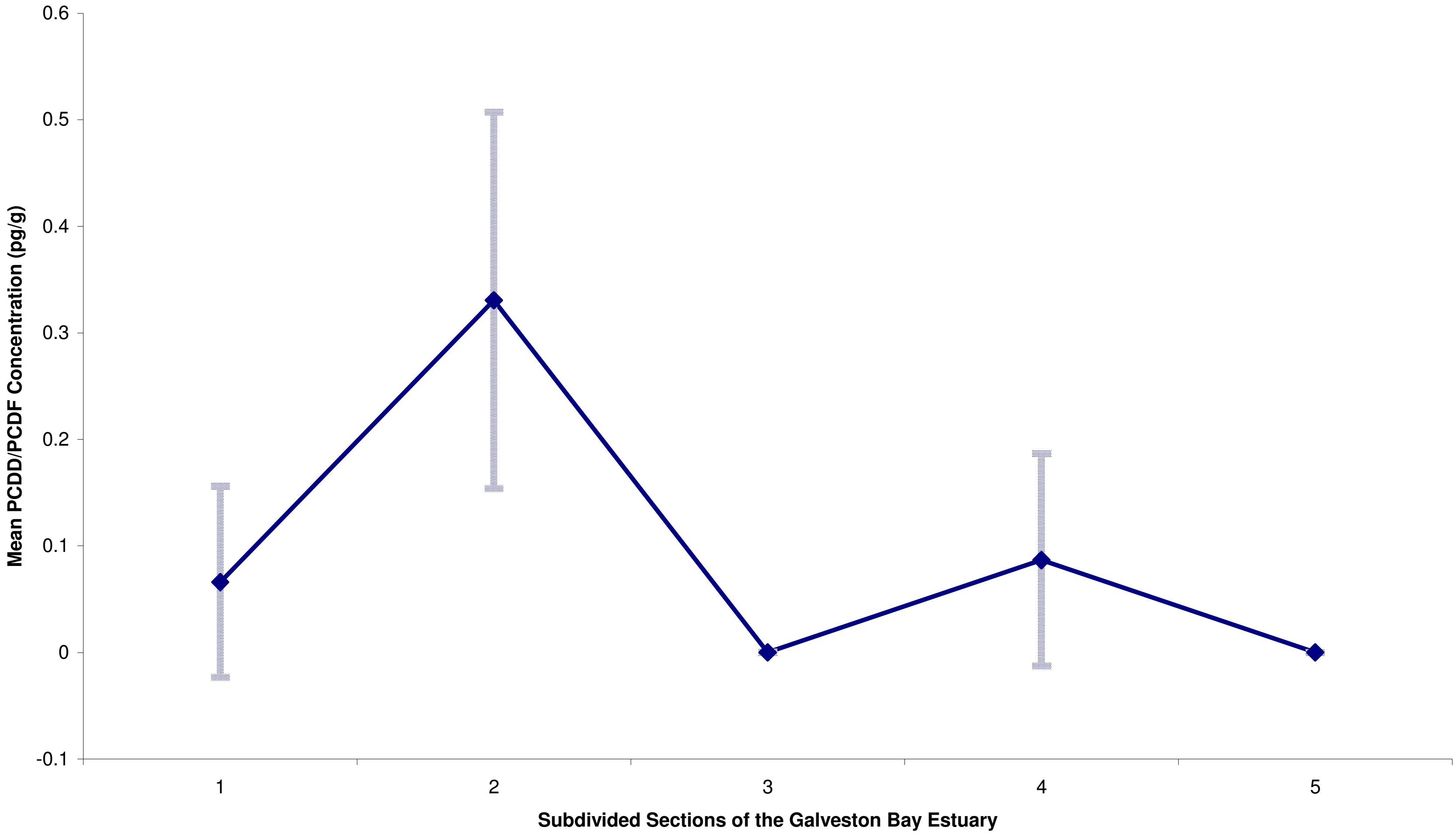


Figure 3. Means plot of PCBs (mg/kg wet weight) in spotted seatrout tissue collected from the Galveston Bay Estuary in 2010–2011. The error bars denote the 95% confidence interval of the mean.



******Section 1*** *delineates an area of Galveston Bay north of a line from Red Bluff Point to Five-mile Cut Marker to Houston Point (Sample sites 1 and 2 and additional spotted seatrout samples from the San Jacinto River / Houston Ship Channel; N = 16).* ***Section 2*** *delineates an area south of a line from Red Bluff Point to Five-mile Cut Marker to Houston Point and north of a line from Eagle Point to Smith Point including Trinity Bay (Sample sites 3, 5, and 16; N = 21).* ***Section 3*** *delineates an area south of a line from Eagle Point to Smith Point excluding East Bay and West Bay (Sample sites 6, 12, 14, and 15; N = 8).* ***Section 4*** *delineates East Bay east of a line from Smith Point to Bolivar Peninsula (Sample sites 8, 17, and 18; N = 19).* ***Section 5*** *delineates Christmas Bay, Cold Pass, and San Luis Pass (Sample Sites 10 and 19; N = 8).*

Figure 4. Means plot of PCDDs/PCDFs (pg/g wet weight) in spotted seatrout tissue collected from the Galveston Bay Estuary in 2010–2011. The error bars denote the 95% confidence interval of the mean.



*****Section 1** delineates an area of Galveston Bay north of a line from Red Bluff Point to Five-mile Cut Marker to Houston Point (Sample sites 1 and 2 and additional spotted seatrout samples from the San Jacinto River / Houston Ship Channel; N = 16). **Section 2** delineates an area south of a line from Red Bluff Point to Five-mile Cut Marker to Houston Point and north of a line from Eagle Point to Smith Point including Trinity Bay (Sample sites 3, 5, and 16; N = 21). **Section 3** delineates an area south of a line from Eagle Point to Smith Point excluding East Bay and West Bay (Sample sites 6, 12, 14, and 15; N = 8). **Section 4** delineates East Bay east of a line from Smith Point to Bolivar Peninsula (Sample sites 8, 17, and 18; N = 19). **Section 5** delineates Christmas Bay, Cold Pass, and San Luis Pass (Sample Sites 10 and 19; N = 8).*

TABLES

Table 1a. Fish samples collected from the Galveston Bay Estuary from February 9, 2010 through April 27, 2010. Sample number, species, length, and weight are recorded for each sample.			
Sample Number	**Species**	**Length (mm)**	**Weight (g)**
Site 1 Galveston Bay at Tabbs Bay			
GAL103	Spotted seatrout	593	2403
GAL104	Spotted seatrout	592	2374
GAL105	Spotted seatrout	411	840
GAL107	Gafftopsail catfish	601	1942
GAL109	Gafftopsail catfish	587	1751
GAL111	Gafftopsail catfish	606	1931
GAL116	Black drum	598	3217
Site 2 Galveston Bay at Yacht Club Marina			
GAL117	Spotted seatrout	629	3056
GAL118	Spotted seatrout	470	1081
GAL119	Spotted seatrout	511	1394
GAL120	Spotted seatrout	440	1006
GAL121	Spotted seatrout	467	1022
GAL122	Spotted seatrout	412	779
GAL124	Spotted seatrout	392	675
GAL128	Sand trout	306	265
GAL130	Gafftopsail catfish	610	1854
GAL131	Gafftopsail catfish	490	1050
GAL132	Gafftopsail catfish	495	1053
Site 3 Galveston Bay at Houston Light and Power			
GAL133	Spotted seatrout	460	1001
GAL134	Spotted seatrout	540	1836
GAL136	Spotted seatrout	398	739
GAL137	Spotted seatrout	490	1223
GAL138	Southern flounder	471	1273
GAL139	Gafftopsail catfish	630	2567
GAL142	Gafftopsail catfish	586	2012
GAL144	Gafftopsail catfish	578	1921
GAL145	Gafftopsail catfish	602	2008

Table 1a cont. Fish samples collected from the Galveston Bay Estuary from February 9, 2010 through April 27, 2010. Sample number, species, length, and weight are recorded for each sample.			
Sample Number	**Species**	**Length (mm)**	**Weight (g)**
Site 4 Galveston Bay at Pine Gulley			
GAL1	Striped bass	594	3118
GAL2	Striped bass	672	4608
GAL3	Red drum	660	2748
GAL4	Red drum	635	2466
GAL5	Sand trout	370	534
GAL6	Sand trout	383	624
GAL7	Black drum	610	3197
Site 5 at Redfish Island/Bayshore Park			
GAL12	Spotted seatrout	442	880
GAL13	Spotted seatrout	481	1090
GAL14	Spotted seatrout	620	2858
GAL15	Spotted seatrout	645	3031
GAL16	Spotted seatrout	580	2249
GAL17	Spotted seatrout	575	2218
GAL18	Spotted seatrout	544	1798
GAL19	Spotted seatrout	573	2009
GAL20	Spotted seatrout	511	1511
GAL21	Spotted seatrout	462	909
GAL22	Spotted seatrout	571	2159
GAL23	Spotted seatrout	481	1085
GAL26	Red drum	676	2897
GAL28	Black drum	799	8978
GAL39	Spotted seatrout	620	2209
GAL40	Spotted seatrout	639	2118
GAL41	Spotted seatrout	457	912
GAL42	Spotted seatrout	440	805
Site 6 Galveston Bay at Campbell Bayou			
GAL29	Red drum	680	3261
GAL30	Red drum	700	3518
GAL31	Sand trout	360	534
GAL32	Black drum	801	12825
GAL34	Southern flounder	450	928
GAL36	Southern flounder	429	861
GAL37	Southern flounder	410	735
GAL77	Spotted seatrout	388	532
GAL78	Spotted seatrout	351	385
GAL79	Spotted seatrout	407	713

Table 1a cont. Fish samples collected from the Galveston Bay Estuary from February 9, 2010 through April 27, 2010. Sample number, species, length, and weight are recorded for each sample.			
Sample Number	**Species**	**Length (mm)**	**Weight (g)**
Site 7 Galveston Bay at Stephenson Point			
GAL55	Red drum	680	3270
GAL58	Black drum	587	2840
GAL59	Southern flounder	383	613
GAL61	Alligator gar	1244	12144
Site 8 Galveston Bay at Marsh Point/Rollover Pass			
GAL62	Black drum	622	3731
GAL65	Red drum	645	2727
GAL67	Southern flounder	416	952
GAL68	Southern flounder	402	785
GAL69	Spotted seatrout	366	423
GAL70	Spotted seatrout	389	577
GAL71	Spotted seatrout	543	1601
GAL72	Spotted seatrout	425	726
GAL73	Spotted seatrout	523	1352
GAL74	Spotted seatrout	648	2701
GAL75	Spotted seatrout	529	1369
GAL76	Spotted seatrout	510	1261
Site 9 Galveston Bay at Alligator Point			
GAL50	Black drum	738	6599
GAL52	Red drum	710	3843
GAL53	Southern flounder	435	920
GAL54	Alligator gar	1397	20203
Site 10 Galveston Bay at Cold Pass/San Luis Pass			
GAL8	Southern flounder	412	770
GAL10	Red drum	890	6749
GAL11	Black drum	480	1779
GAL84	Sand trout	298	226
GAL92	Spotted seatrout	345	398
GAL93	Spotted seatrout	425	733
Site 11 Galveston Bay at Carancahua Reef/Shell Island			
GAL45	Red drum	725	3886
GAL48	Black drum	632	3578
Site 12 Galveston Bay at the Galveston Causeway			
GAL80	Spotted seatrout	480	1149
GAL81	Spotted seatrout	474	1058
GAL82	Spotted seatrout	381	527
GAL83	Sand trout	329	321

Table 1a cont. Fish samples collected from the Galveston Bay Estuary from February 9, 2010 through April 27, 2010. Sample number, species, length, and weight are recorded for each sample.			
Sample Number	**Species**	**Length (mm)**	**Weight (g)**
Site 13 Galveston Bay at Offatts Bayou			
GAL147	Gafftopsail catfish	557	1802
Site 14 Galveston Bay at Galveston Island West			
GAL146	Spotted seatrout	450	925
Site 15 Galveston Bay at Galveston Ship Channel/Yacht Basin			
GAL94	Spotted seatrout	427	710
GAL95	Sand trout	292	222
GAL96	Sand trout	311	315
GAL97	Sand trout	294	195
GAL98	Sand trout	297	224
GAL99	Sand trout	282	217
GAL100	Sand trout	275	194
GAL101	Sand trout	277	230
GAL102	Sand trout	282	195
GAL148	Sand trout	288	236
GAL149	Sand trout	269	211
GAL150	Sand trout	294	244
Site 16 Galveston Bay at Houston Point			
GAL200	Spotted seatrout	423	907
GAL201	Gafftopsail catfish	582	2106
GAL202	Gafftopsail catfish	410	619
GAL203	Gafftopsail catfish	389	488
Site 17 Galveston Bay at Hanna Reef			
GAL211	Spotted seatrout	420	NA
GAL212	Spotted seatrout	452	NA
GAL213	Spotted seatrout	396	NA
GAL215	Spotted seatrout	440	NA
GAL217	Spotted seatrout	447	NA
Site 18 Galveston Bay at East Bay/North Shore			
GAL218	Spotted seatrout	683	3753
GAL220	Spotted seatrout	578	2076
GAL224	Spotted seatrout	615	2359
GAL225	Spotted seatrout	576	2029
GAL226	Spotted seatrout	602	2170
GAL227	Spotted seatrout	454	901
Site 19 Galveston Bay at Christmas Bay			
GAL85	Gafftopsail catfish	580	NA
GAL86	Spotted seatrout	389	NA

Table 1a cont. Fish samples collected from the Galveston Bay Estuary from February 9, 2010 through April 27, 2010. Sample number, species, length, and weight are recorded for each sample.			
Sample Number	**Species**	**Length (mm)**	**Weight (g)**
Site 19 Galveston Bay at Christmas Bay (cont.)			
GAL87	Spotted seatrout	593	NA
GAL88	Spotted seatrout	560	NA
GAL89	Spotted seatrout	508	NA
GAL90	Spotted seatrout	312	NA
GAL91	Spotted seatrout	550	NA
GAL204	Gafftopsail catfish	526	1393
GAL205	Gafftopsail catfish	511	1329
GAL206	Gafftopsail catfish	420	589

Table 1b. Spotted seatrout samples collected from the San Jacinto River and Houston Ship Channel in January 2011. Sample number, species, length, and weight are recorded for each sample.			
Sample Number	**Species**	**Length (mm)**	**Weight (g)**
San Jacinto River / Houston Ship Channel			
SJR15	Spotted seatrout	500	1301
SJR16	Spotted seatrout	410	706
SJR31	Spotted seatrout	387	660
SJR34	Spotted seatrout	451	1060
SJR43	Spotted seatrout	617	2400
SJR45	Spotted seatrout	549	1559

Table 2a. Arsenic (mg/kg) in fish collected from the Galveston Bay Estuary, 2010–2011.					
Species	**# Detected/ # Sampled**	**Total Arsenic Mean Concentration ± S.D. (Min-Max)**	**Inorganic Arsenic Mean Concentration***	**Health Assessment Comparison Value (mg/kg)†**	**Basis for Comparison Value**
Alligator gar	2/2	5.350±3.679 (2.748-7.951)	**0.535**‡*	0.7 0.363	EPA chronic oral RfD for Inorganic arsenic: 0.0003 mg/kg–day EPA oral slope factor for inorganic arsenic: 1.5 per mg/kg–day
Black drum	9/9	2.137±1.119 (0.377-4.077)	0.214		
Gafftopsail catfish	18/18	1.581±0.701 (0.326-2.622)	0.158		
Red drum	10/10	1.075±0.932 (0.334-2.909)	0.108		
Sand trout	16/17	0.393±0.576 (ND-2.303)	0.040		
Southern flounder	9/9	0.966±0.529 (0.261-1.834)	0.097		
Spotted seatrout	69/69	0.680±0.978 (BDL-4.117)	0.068		
Striped bass	2/2	0.146±0.032 (0.123-0.168)	0.015		
All fish combined	135/136	0.969±1.163 (ND-7.951)	0.097		

* *Most arsenic in fish and shellfish occurs as organic arsenic, considered virtually nontoxic. For risk assessment calculations, DSHS assumes that total arsenic is composed of 10% inorganic arsenic in fish and shellfish tissues.*

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

‡ *Emboldened numbers denote that arsenic concentrations equaled or exceeded the DSHS HAC value for arsenic.*

Table 2b. Inorganic contaminants (mg/kg) in fish collected from the Galveston Bay Estuary, 2010–2011.				
Species	**# Detected/ # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
Cadmium				
Alligator gar	2/2	BDL[*]	0.47	ATSDR chronic oral MRL: 0.0002 mg/kg–day
Black drum	6/9	BDL		
Gafftopsail catfish	7/18	BDL		
Red drum	6/10	0.023±0.013 (ND-0.060)		
Sand trout	7/17	BDL		
Southern flounder	6/9	BDL		
Spotted seatrout	44/69	0.031±0.036 (ND-0.262)		
Striped bass	1/2	BDL		
All fish combined	79/136	0.027±0.031 (ND[†]-0.262)		
Copper				
Alligator gar	2/2	0.076±0.001 (0.075-0.077)	334	National Academy of Science Upper Limit: 0.143 mg/kg–day
Black drum	9/9	0.244±0.083 (0.171-0.413)		
Gafftopsail catfish	18/18	0.346±0.104 (0.175-0.600)		
Red drum	10/10	0.218±0.058 (0.145-0.319)		
Sand trout	17/17	0.173±0.041 (0.078-0.239)		
Southern flounder	9/9	0.119±0.010 (0.104-0.134)		
Spotted seatrout	69/69	0.238±0.283 (0.087-2.043)		
Striped bass	2/2	0.274±0.072 (0.223-0.325)		
All fish combined	136/136	0.233±0.215 (0.075-2.043)		

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

[†] *ND: "Not Detected" was used to indicate that a compound was not present in a sample at a level greater than the reporting limit.*

Table 2c. Inorganic contaminants (mg/kg) in fish collected from the Galveston Bay Estuary, 2010–2011.				
Species	**# Detected/ # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
Lead				
Alligator gar	2/2	0.038±0.023 (BDL-0.054)	NA	EPA IEUBKwin32 Version 1.1 Build 9
Black drum	7/9	0.070±0.057 (ND-0.190)		
Gafftopsail catfish	17/18	0.027±0.012 (ND-0.054)		
Red drum	5/10	0.060-0.063 (ND-0.223)		
Sand trout	14/17	0.025±0.019 (ND-0.095)		
Southern flounder	8/9	0.074±0.080 (ND-0.253)		
Spotted seatrout	60/69	0.052±0.061 (ND-0.423)		
Striped bass	2/2	BDL		
All fish combined	115/136	0.048±0.055 (ND-0.423)		
Mercury				
Alligator gar	2/2	0.197±0.061 (0.154-0.240)	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg–day
Black drum	9/9	0.228±0.201 (0.043-0.607)		
Gafftopsail catfish	18/18	0.292±0.135 (0.127-0.626)		
Red drum	10/10	0.161±0.121 (0.074-0.485)		
Sand trout	17/17	0.074±0.023 (0.046-0.121)		
Southern flounder	9/9	0.064±0.013 (0.049-0.090)		
Spotted seatrout	72/72	0.134±0.104 (0.048-**0.825**[*])		
Striped bass	2/2	0.346±0.151 (0.239-0.453)		
All fish combined	139/139	0.155±0.128 (0.043-**0.825**)		

[*] *Emboldened numbers denote that mercury concentrations equaled or exceeded a DSHS HAC value for mercury.*

Table 2d. Inorganic contaminants (mg/kg) in fish collected from the Galveston Bay Estuary, 2010–2011.				
Species	**# Detected/ # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
Selenium				
Alligator gar	2/2	0.349±0.167 (0.231-0.467)	6	EPA chronic oral RfD: 0 .005 mg/kg–day ATSDR chronic oral MRL: 0.005 mg/kg–day NAS UL: 0.400 mg/day (0.005 mg/kg–day) RfD or MRL/2: (0.005 mg/kg –day/2= 0.0025 mg/kg–day) to account for other sources of selenium in the diet
Black drum	9/9	0.846±0.137 (0.628-1.041)		
Gafftopsail catfish	18/18	0.202±0.058 (0.124-0.323)		
Red drum	10/10	0.587±0.148 (0.366-0.807)		
Sand trout	17/17	0.605±0.163 (0.470-1.107)		
Southern flounder	9/9	0.597±0.067 (0.490-0.720)		
Spotted seatrout	69/69	0.696±0.208 (0.151-1.263)		
Striped bass	2/2	0.525±0.218 (0.371-0.679)		
All fish combined	136/136	0.607±0.244 (0.124-1.263)		
Zinc				
Alligator gar	2/2	2.629±0.049 (2.594-2.663)	700	EPA chronic oral RfD: 0.3 mg/kg–day
Black drum	9/9	3.392±0.660 (2.579-4.440)		
Gafftopsail catfish	18/18	5.059±1.260 (3.112-7.691)		
Red drum	10/10	2.701±0.283 (2.179-3.055)		
Sand trout	17/17	2.825±0.810 (2.018-5.420)		
Southern flounder	9/9	2.658±0.824 (1.982-4.787)		
Spotted seatrout	69/69	2.820±0.862 (1.220-6.843)		
Striped bass	2/2	2.933±0.428 (2.630-3.235)		
All fish combined	136/136	3.134±1.148 (1.220-7.691)		

Table 3. Pesticides (mg/kg) in fish collected from the Galveston Bay Estuary, 2010–2011.				
Species	**# Detected / # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
Chlordane				
Alligator gar	2/2	0.002±0.0003 (0.001-0.002)	1.167 1.556	EPA chronic oral RfD: 0.0005 mg/kg–day EPA slope factor 0.35 per mg/kg - day
Black drum	2/2	0.002±0.002 (BDL-0.028)		
Gafftopsail catfish	4/4	0.017±0.028 (0.001-0.059)		
Red drum	3/3	0.006±0.006 (BDL-0.012)		
Spotted seatrout	10/10	0.013±0.008 (BDL-0.031)		
Striped bass	2/2	0.010±0.008 (0.005-0.016)		
All fish combined	23/23	0.011±0.013 (BDL-0.059)		
4,4′-DDE				
Alligator gar	2/2	0.004±0.004 (0.001-0.007)	1.167 1.601	EPA chronic oral RfD: 0.0005 mg//kg–day EPA slope factor 0.34 per mg/kg–day
Black drum	2/2	BDL		
Gafftopsail catfish	4/4	0.021±0.028 (0.005-0.063)		
Red drum	3/3	0.0007±0.0004 (BDL-0.001)		
Spotted seatrout	10/10	0.009±0.007 (BDL-0.023)		
Striped bass	2/2	0.062±0.075 (0.009-0.116)		
All fish combined	23/23	0.013±0.026 (BDL-0.116)		
4,4′-DDD				
Alligator gar	2/2	BDL	1.167 2.269	EPA chronic oral RfD: 0.0005 mg//kg–day EPA slope factor 0.24 per mg/kg–day
Black drum	1/2	BDL		
Gafftopsail catfish	4/4	0.006±0.010 (BDL-0.020)		
Red drum	2/3	BDL		
Spotted seatrout	9/10	0.003±0.003 (ND-0.011)		
Striped bass	2/2	0.002±0.002 (BDL-0.003)		
All fish combined	20/23	0.002±0.004 (ND-0.020)		

Table 4a. PCBs (mg/kg) in fish collected from the Galveston Bay Estuary, 2010–2011.				
Species	**# Detected / # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
Site 1 Galveston Bay at Tabbs Bay				
Black drum	1/1	0.010	0.047 0.272	EPA chronic oral RfD: 0.00002 mg/kg–day EPA slope factor: 2.0 per mg/kg–day
Gafftopsail catfish	3/3	**0.166**[*]±0.083 (**0.092**-**0.255**)		
Spotted seatrout	3/3	**0.103**±0.035 (**0.081**-**0.143**)		
All fish combined	7/7	**0.117**±0.077 (0.010-**0.255**)		
Site 2 Galveston Bay at Yacht Club Marina				
Gafftopsail catfish	3/3	**0.075**±0.029 (**0.047**-**0.104**)	0.047 0.272	EPA chronic oral RfD: 0.00002 mg/kg–day EPA slope factor: 2.0 per mg/kg–day
Sand trout	1/1	0.015		
Spotted seatrout	7/7	0.044±0.011 (0.023-**0.056**)		
All fish combined	11/11	**0.050**±0.024 (0.015-**0.104**)		
Site 3 Galveston Bay at Houston Light and Power				
Gafftopsail catfish	4/4	**0.074**±0.043 (0.037-**0.137**)	0.047 0.272	EPA chronic oral RfD: 0.00002 mg/kg–day EPA slope factor: 2.0 per mg/kg–day
Southern flounder	1/1	0.010		
Spotted seatrout	4/4	0.028±0.013 (0.013-0.041)		
All fish combined	9/9	**0.047**±0.039 (0.010-**0.137**)		
Site 4 Galveston Bay at Pine Gulley				
Black drum	1/1	0.013	0.047 0.272	EPA chronic oral RfD: 0.00002 mg/kg–day EPA slope factor: 2.0 per mg/kg–day
Red drum	2/2	0.021±0.011 (0.013-0.028)		
Sand trout	2/2	**0.065**±0.005 (**0.061**-**0.068**)		
Striped bass	2/2	0.033±0.019 (0.019-**0.047**)		
All fish combined	7/7	0.036±0.023 (0.013-**0.068**)		

[*] *Emboldened numbers denote that PCB concentrations equaled or exceeded the DSHS HAC value for PCBs.*

Table 4b. PCBs (mg/kg) in fish collected from the Galveston Bay Estuary, 2010–2011.				
Species	**# Detected / # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
Site 5 Galveston Bay at Redfish Island/Bayshore Park				
Black drum	1/1	0.037	0.047 0.272	EPA chronic oral RfD: 0.00002 mg/kg–day EPA slope factor: 2.0 per mg/kg–day
Red drum	1/1	0.034		
Spotted seatrout	16/16	0.039±0.014 (0.019-**0.064***)		
All fish combined	18/18	0.039±0.013 (0.019-**0.064**)		
Site 6 Galveston Bay at Campbell Bayou				
Black drum	1/1	0.022	0.047 0.272	EPA chronic oral RfD: 0.00002 mg/kg–day EPA slope factor: 2.0 per mg/kg–day
Red drum	2/2	0.020±0.002 (0.019-0.022)		
Sand trout	1/1	**0.083**		
Southern flounder	3/3	0.013±0.003 (0.010-0.016)		
Spotted seatrout	3/3	0.042±0.019 (0.028-**0.064**)		
All fish combined	10/10	0.031±0.024 (0.010-**0.083**)		
Site 7 Galveston Bay at Stephenson Point				
Alligator gar	1/1	0.020	0.047 0.272	EPA chronic oral RfD: 0.00002 mg/kg–day EPA slope factor: 2.0 per mg/kg–day
Black drum	1/1	0.009		
Red drum	1/1	BDL		
Southern flounder	1/1	0.020		
All fish combined	4/4	0.015±0.006 (BDL-0.020)		
Site 8 Galveston Bay at Marsh Point/Rollover Pass				
Black drum	1/1	BDL	0.047 0.272	EPA chronic oral RfD: 0.00002 mg/kg–day EPA slope factor: 2.0 per mg/kg–day
Red drum	1/1	BDL		
Southern flounder	2/2	BDL		
Spotted seatrout	8/8	0.014±0.005 (BDL-0.023)		
All fish combined	12/12	0.013±0.005 (BDL-0.023)		

[*] *Emboldened numbers denote that PCB concentrations equaled or exceeded the DSHS HAC value for PCBs.*

Table 4c. PCBs (mg/kg) in fish collected from the Galveston Bay Estuary, 2010–2011.				
Species	**# Detected / # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
Site 9 Galveston Bay at Alligator Point				
Alligator gar	1/1	0.019	0.047 0.272	EPA chronic oral RfD: 0.00002 mg/kg–day EPA slope factor: 2.0 per mg/kg–day
Black drum	1/1	0.010		
Red drum	1/1	0.011		
Southern flounder	1/1	BDL		
All fish combined	4/4	0.012±0.005 (BDL-0.019)		
Site 10 Galveston Bay at Cold Pass/San Luis Pass				
Black drum	1/1	BDL	0.047 0.272	EPA chronic oral RfD: 0.00002 mg/kg–day EPA slope factor: 2.0 per mg/kg–day
Red drum	1/1	0.015		
Sand trout	1/1	0.013		
Southern flounder	1/1	0.010		
Spotted seatrout	2/2	0.013±0.001 (0.012-0.014)		
All fish combined	6/6	0.012±0.002 (BDL-0.015)		
Site 11 Galveston Bay at Carancahua Reef/Shell Island				
Black drum	1/1	BDL	0.047 0.272	EPA chronic oral RfD: 0.00002 mg/kg–day EPA slope factor: 2.0 per mg/kg–day
Red drum	1/1	BDL		
All fish combined	2/2	BDL		
Site 12 Galveston Bay at Galveston Causeway				
Sand trout	1/1	0.012	0.047 0.272	EPA chronic oral RfD: 0.00002 mg/kg–day EPA slope factor: 2.0 per mg/kg–day
Spotted seatrout	3/3	0.027±0.021 (0.013-**0.050**[*])		
All fish combined	4/4	0.023±0.018 (0.012-**0.050**)		
Site 13 Galveston Bay at Offatts Bayou				
Gafftopsail catfish	1/1	**0.083**	0.047 0.272	EPA chronic oral RfD: 0.00002 mg/kg–day EPA slope factor: 2.0 per mg/kg–day
All fish combined	1/1	**0.083**		

[*] *Emboldened numbers denote that PCB concentrations equaled or exceeded the DSHS HAC value for PCBs.*

Table 4d. PCBs (mg/kg) in fish collected from the Galveston Bay Estuary, 2010–2011.

Species	# Detected / # Sampled	Mean Concentration ± S.D. (Min-Max)	Health Assessment Comparison Value (mg/kg)	Basis for Comparison Value
Site 14 Galveston Bay at Galveston Island West				
Spotted seatrout	1/1	0.024	0.047	EPA chronic oral RfD: 0.00002 mg/kg–day
All fish combined	1/1	0.024	0.272	EPA slope factor: 2.0 per mg/kg–day
Site 15 Galveston Bay at Galveston Ship Channel/Yacht Basin				
Sand trout	11/11	0.019±0.011 (BDL-0.043)	0.047	EPA chronic oral RfD: 0.00002 mg/kg–day
Spotted seatrout	1/1	0.013	0.272	EPA slope factor: 2.0 per mg/kg–day
All fish combined	12/12	0.018±0.010 (BDL-0.043)		
Site 16 Galveston Bay at Houston Point				
Gafftopsail catfish	3/3	0.036±0.011 (0.028-**0.048**[*])	0.047	EPA chronic oral RfD: 0.00002 mg/kg–day
Spotted seatrout	1/1	0.025	0.272	EPA slope factor: 2.0 per mg/kg–day
All fish combined	4/4	0.033±0.010 (0.025-**0.048**)		
Site 17 Galveston Bay at Hanna Reef				
Spotted seatrout	5/5	0.022±0.005 (0.016-0.029)	0.047	EPA chronic oral RfD: 0.00002 mg/kg–day
All fish combined	5/5	0.022±0.005 (0.016-0.029)	0.272	EPA slope factor: 2.0 per mg/kg–day
Site 18 Galveston Bay at East Bay/North Shore				
Spotted seatrout	6/6	0.023±0.010 (0.014-0.039)	0.047	EPA chronic oral RfD: 0.00002 mg/kg–day
All fish combined	6/6	0.023±0.010 (0.014-0.039)	0.272	EPA slope factor: 2.0 per mg/kg–day
Site 19 Galveston Bay at Christmas Bay				
Gafftopsail catfish	4/4	0.028±0.020 (0.011-**0.056**)	0.047	EPA chronic oral RfD: 0.00002 mg/kg–day
Spotted seatrout	6/6	0.012±0.003 (BDL-0.016)	0.272	EPA slope factor: 2.0 per mg/kg–day
All fish combined	10/10	0.018±0.014 (BDL-**0.056**)		

[*] *Emboldened numbers denote that PCB concentrations equaled or exceeded the DSHS HAC value for PCBs.*

Table 4e. PCBs (mg/kg) in fish collected from the Galveston Bay Estuary, 2010–2011.				
Species	**# Detected / # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
San Jacinto River / Houston Ship Channel				
Spotted seatrout	6/6	**0.114**[*]±0.081 (0.019-**0.237**)	0.047 0.272	EPA chronic oral RfD: 0.00002 mg/kg–day EPA slope factor: 2.0 per mg/kg–day
All fish combined	6/6	**0.114**±0.081 (0.019-**0.237**)		
All Sample Sites				
Alligator gar	2/2	0.020±0.0007 (0.019-0.020)	0.047 0.272	EPA chronic oral RfD: 0.00002 mg/kg–day EPA slope factor: 2.0 per mg/kg–day
Black drum	9/9	0.015±0.009 (BDL-0.037)		
Gafftopsail catfish	18/18	**0.073**±0.060 (0.011-**0.255**)		
Red drum	10/10	0.017±0.009 (BDL-0.034)		
Sand trout	17/17	0.027±0.023 (BDL-**0.083**)		
Southern flounder	9/9	0.012±0.004 (BDL-0.020)		
Spotted seatrout	72/72	0.038±0.038 (BDL-**0.237**)		
Striped bass	2/2	0.033±0.019 (0.019-**0.047**)		
All fish combined	139/139	0.036±0.039 (BDL-**0.255**)		

[*] *Emboldened numbers denote that PCB concentrations equaled or exceeded the DSHS HAC value for PCBs.*

Table 4f. PCBs (mg/kg) in spotted seatrout collected from the Galveston Bay Estuary, 2010–2011.			
# Detected / # Sampled	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
Composite Area 1 Galveston Bay System (North of line from Red Bluff Point to Five-Mile Cut Marker to Houston Point)			
16/16	**0.081**±0.060 (0.019-**0.237**)	0.047 0.272	EPA chronic oral RfD: 0.00002 mg/kg–day EPA slope factor: 2.0 per mg/kg–day
Composite Area 2 Galveston Bay System (South of line from Red Bluff Point to Five-Mile Cut Marker to Houston Point)			
56/56	0.026±0.015 (BDL-**0.064**)	0.047 0.272	EPA chronic oral RfD: 0.00002 mg/kg–day EPA slope factor: 2.0 per mg/kg–day
All Sample Sites			
72/72	0.038±0.038 (BDL-**0.237**)	0.047 0.272	EPA chronic oral RfD: 0.00002 mg/kg–day EPA slope factor: 2.0 per mg/kg–day

Table 5a. PCDDs/PCDFs toxicity equivalent (TEQ) concentrations (pg/g) in fish collected from the Galveston Bay Estuary, 2010–2011.

Species	# Detected / # Sampled	Mean Concentration ± S.D. (Min-Max)	Health Assessment Comparison Value (pg/kg)	Basis for Comparison Value
Site 1 Galveston Bay at Tabbs Bay				
Black Drum	0/1	ND		
Gafftopsail catfish	1/3	1.352±2.342 (ND-**4.056**[*])	2.33	ATSDR chronic oral MRL: 1.0×10^{-9} mg/kg/day
Spotted seatrout	1/3	0.00006±0.0001 (ND-0.0002	3.49	EPA slope factor: 1.56×10^{5} per mg/kg/day
All fish combined	2/7	0.579±1.533 (ND-**4.056**)		
Site 2 Galveston Bay at Yacht Club Marina				
Gafftopsail catfish	3/3	2.163±3.745 (0.0003-**6.487**)		
Sand trout	0/1	ND	2.33	ATSDR chronic oral MRL: 1.0×10^{-9} mg/kg/day
Spotted seatrout	3/7	0.0002±0.0004 (ND-0.001)	3.49	EPA slope factor: 1.56×10^{5} per mg/kg/day
All fish combined	6/11	0.590±1.956 (ND-**6.487**)		
Site 3 Galveston Bay at Houston Light and Power				
Gafftopsail catfish	1/4	0.0003±0.0006 (ND-0.001)		
Southern flounder	0/1	ND	2.33	ATSDR chronic oral MRL: 1.0×10^{-9} mg/kg/day
Spotted seatrout	1/4	0.0001±0.0002 (ND-0.0005)	3.49	EPA slope factor: 1.56×10^{5} per mg/kg/day
All fish combined	2/9	0.0002±0.0004 (ND-0.001)		
Site 4 Galveston Bay at Pine Gulley				
Black drum	1/1	0.297		
Red drum	1/2	0.625±0.884 (ND-1.251)	2.33	ATSDR chronic oral MRL: 1.0×10^{-9} mg/kg/day
Sand trout	2/2	1.711±0.198 (1.571-1.851)	3.49	EPA slope factor: 1.56×10^{5} per mg/kg/day
Striped bass	2/2	0.002±0.001 (BDL-0.003)		
All fish combined	6/7	0.711±0.818 (ND-1.851)		

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[*] *Emboldened numbers denote that PCDD/PCDF concentrations equaled or exceeded the DSHS HAC value for PCDDs/PCDFs.*

Table 5b. PCDDs/PCDFs toxicity equivalent (TEQ) concentrations (pg/g) in fish collected from the Galveston Bay Estuary, 2010–2011.				
Species	**# Detected / # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (pg/kg)**	**Basis for Comparison Value**
Site 5 Galveston Bay at Redfish Island/Bayshore Park				
Black drum	1/1	0.0005	2.33 3.49	ATSDR chronic oral MRL: 1.0×10^{-9} mg/kg/day EPA slope factor: 1.56×10^{5} per mg/kg/day
Red drum	1/1	1.678		
Spotted seatrout	11/16	0.434±0.424 (ND-1.407)		
All fish combined	13/18	0.479±0.509 (ND-1.678)		
Site 6 Galveston Bay at Campbell Bayou				
Black drum	0/1	ND	2.33 3.49	ATSDR chronic oral MRL: 1.0×10^{-9} mg/kg/day EPA slope factor: 1.56×10^{5} per mg/kg/day
Red drum	0/2	ND		
Sand Trout	1/1	0.0003		
Southern flounder	1/3	0.00004±0.00006 (ND-0.00001)		
Spotted seatrout	0/3	ND		
All fish combined	2/10	0.00004±0.00009 (ND-0.0003)		
Site 7 Galveston Bay at Stephenson Point				
Alligator gar	0/1	ND	2.33 3.49	ATSDR chronic oral MRL: 1.0×10^{-9} mg/kg/day EPA slope factor: 1.56×10^{5} per mg/kg/day
Black drum	0/1	ND		
Red drum	1/1	0.00007		
Southern flounder	0/1	ND		
All fish combined	1/4	0.00002±0.00004 (ND-0.00007)		

Table 5c. PCDDs/PCDFs toxicity equivalent (TEQ) concentrations (pg/g) in fish collected from the Galveston Bay Estuary, 2010–2011.				
Species	**# Detected / # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (pg/kg)**	**Basis for Comparison Value**
Site 8 Galveston Bay at Marsh Point/Rollover Pass				
Black drum	0/1	ND	2.33 3.49	ATSDR chronic oral MRL: 1.0 x 10^{-9} mg/kg/day EPA slope factor: 1.56 x 10^{5} per mg/kg/day
Red drum	0/1	ND		
Southern flounder	1/2	0.033±0.046 (ND-0.066)		
Spotted seatrout	4/8	0.033±0.092 (ND-0.260)		
All fish combined	5/12	0.028±0.076 (ND-0.260)		
Site 9 Galveston Bay at Alligator Point				
Alligator gar	0/1	ND	2.33 3.49	ATSDR chronic oral MRL: 1.0 x 10^{-9} mg/kg/day EPA slope factor: 1.56 x 10^{5} per mg/kg/day
Black Drum	0/1	ND		
Red drum	0/1	ND		
Southern flounder	0/1	ND		
All fish combined	0/4	ND		
Site 10 Galveston Bay at Cold Pass/San Luis Pass				
Black drum	1/1	0.020	2.33 3.49	ATSDR chronic oral MRL: 1.0 x 10^{-9} mg/kg/day EPA slope factor: 1.56 x 10^{5} per mg/kg/day
Red drum	1/1	0.451		
Sand trout	0/1	ND		
Southern flounder	1/1	0.377		
Spotted seatrout	1/2	0.00008±0.0001 (ND-0.0002)		
All fish combined	4/6	0.141±0.212 (ND-0.451)		
Site 11 Galveston Bay at Carancahua Reef/Shell Island				
Black drum	1/1	0.003	2.33 3.49	ATSDR chronic oral MRL: 1.0 x 10^{-9} mg/kg/day EPA slope factor: 1.56 x 10^{5} per mg/kg/day
Red drum	1/1	0.040		
All fish combined	2/2	0.022±0.026 (0.003-0.040)		

Table 5d. PCDDs/PCDFs toxicity equivalent (TEQ) concentrations (pg/g) in fish collected from the Galveston Bay Estuary, 2010–2011.

Species	# Detected / # Sampled	Mean Concentration ± S.D. (Min-Max)	Health Assessment Comparison Value (pg/kg)	Basis for Comparison Value
Site 12 Galveston Bay at Galveston Causeway				
Sand trout	0/1	ND	2.33	ATSDR chronic oral MRL: 1.0×10^{-9} mg/kg/day
Spotted seatrout	3/3	0.0004±0.0003 (0.00005-0.0006)	3.49	EPA slope factor: 1.56×10^{5} per mg/kg/day
All fish combined	3/4	0.0003±0.0003 (ND-0.0006)		
Site 13 Galveston Bay at Offatts Bayou				
Gafftopsail catfish	1/1	1.943	2.33	ATSDR chronic oral MRL: 1.0×10^{-9} mg/kg/day
All fish combined	1/1	1.943	3.49	EPA slope factor: 1.56×10^{5} per mg/kg/day
Site 14 Galveston Bay at Galveston Island West				
Spotted seatrout	0/1	ND	2.33	ATSDR chronic oral MRL: 1.0×10^{-9} mg/kg/day
All fish combined	0/1	ND	3.49	EPA slope factor: 1.56×10^{5} per mg/kg/day
Site 15 Galveston Bay at Galveston Ship Channel/Yacht Basin				
Sand trout	3/11	0.0002±0.0004 (ND-0.001)	2.33	ATSDR chronic oral MRL: 1.0×10^{-9} mg/kg/day
Spotted seatrout	0/1	ND	3.49	EPA slope factor: 1.56×10^{5} per mg/kg/day
All fish combined	3/12	0.0001±0.0004 (ND-0.001)		
Site 16 Galveston Bay at Houston Point				
Gafftopsail catfish	2/3	0.007±0.011 (ND-0.020)	2.33	ATSDR chronic oral MRL: 1.0×10^{-9} mg/kg/day
Spotted seatrout	0/1	ND	3.49	EPA slope factor: 1.56×10^{5} per mg/kg/day
All fish combined	2/4	0.006±0.010 (ND-0.020)		
Site 17 Galveston Bay at Hanna Reef				
Spotted seatrout	1/5	0.00004±0.00009 (ND-0.0002)	2.33	ATSDR chronic oral MRL: 1.0×10^{-9} mg/kg/day
All fish combined	1/5	0.00004±0.00009 (ND-0.0002)	3.49	EPA slope factor: 1.56×10^{5} per mg/kg/day

Table 5e. PCDDs/PCDFs toxicity equivalent (TEQ) concentrations (pg/g) in fish collected from the Galveston Bay Estuary, 2010–2011.

Species	# Detected / # Sampled	Mean Concentration ± S.D. (Min-Max)	Health Assessment Comparison Value (pg/kg)	Basis for Comparison Value
Site 18 Galveston Bay at East Bay/North Shore				
Spotted seatrout	5/6	0.231±0.357 (ND-0.707)	2.33	ATSDR chronic oral MRL: 1.0 x 10^{-9} mg/kg/day
All fish combined	5/6	0.231±0.357 (ND-0.707)	3.49	EPA slope factor: 1.56 x 10^{5} per mg/kg/day
Site 19 Galveston Bay at Christmas Bay				
Gafftopsail catfish	1/4	0.0005±0.001 (ND-0.002)	2.33	ATSDR chronic oral MRL: 1.0 x 10^{-9} mg/kg/day
Spotted seatrout	4/6	0.0002±0.0002 (ND-0.0004)		
All fish combined	5/10	0.0004±0.0007 (ND-0.002)	3.49	EPA slope factor: 1.56 x 10^{5} per mg/kg/day
San Jacinto River / Houston Ship Channel				
Spotted seatrout	5/6	0.176±0.278 (ND-0.667)	2.33	ATSDR chronic oral MRL: 1.0 x 10^{-9} mg/kg/day
All fish combined	5/6	0.176±0.278 (ND-0.667)	3.49	EPA slope factor: 1.56 x 10^{5} per mg/kg/day
All Sample Sites				
Alligator gar	0/2	ND		
Black drum	4/9	0.036±0.098 (ND-0.297)		
Gafftopsail catfish	9/18	0.695±1.776 (ND-**6.487***)		
Red drum	5/10	0.342±0.616 (ND-1.678)	2.33	ATSDR chronic oral MRL: 1.0 x 10^{-9} mg/kg/day
Sand trout	6/17	0.201±0.570 (ND-1.851)		
Southern flounder	3/9	0.049±0.125 (ND-0.377)	3.49	EPA slope factor: 1.56 x 10^{5} per mg/kg/day
Spotted seatrout	39/72	0.134±0.291 (ND-1.407)		
Striped bass	2/2	0.002±0.001 (0.001-0.003)		
All fish combined	68/139	0.214±0.732 (ND-**6.487**)		

[*] Emboldened numbers denote that PCDD/PCDF concentrations equaled or exceeded the DSHS HAC value for PCDDs/PCDFs

Table 5f. PCDDs/PCDFs toxicity equivalent (TEQ) concentrations (pg/g) in spotted seatrout collected from the Galveston Bay Estuary, 2010–2011.

# Detected / # Sampled	Mean Concentration ± S.D. (Min-Max)	Health Assessment Comparison Value (mg/kg)	Basis for Comparison Value
Composite Area 1 Galveston Bay System (North of line from Red Bluff Point to Five-Mile Cut Marker to Houston Point)			
9/16	0.066±0.183 (ND-0.667)	2.33 3.49	ATSDR chronic oral MRL: 1.0×10^{-9} mg/kg/day EPA slope factor: 1.56×10^{5} per mg/kg/day
Composite Area 2 Galveston Bay System (South of line from Red Bluff Point to Five-Mile Cut Marker to Houston Point)			
30/56	0.154±0.314 (ND-1.407)	2.33 3.49	ATSDR chronic oral MRL: 1.0×10^{-9} mg/kg/day EPA slope factor: 1.56×10^{5} per mg/kg/day
All Sampling Sites			
39/72	0.134±0.291 (ND-1.407)	2.33 3.49	ATSDR chronic oral MRL: 1.0×10^{-9} mg/kg/day EPA slope factor: 1.56×10^{5} per mg/kg/day

Table 6. VOCs (mg/kg) in fish collected from the Galveston Bay Estuary, 2010–2011.				
Species	**# Detected / # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
Trichlorofluoromethane				
Alligator gar	2/2	0.015±0.010 (BDL-0.022)	700	EPA chronic oral RfD: 0.3 mg/kg–day
Black drum	2/2	0.017±0.002 (BDL-0.018)		
Gafftopsail catfish	4/4	BDL		
Red drum	3/3	BDL		
Spotted seatrout	10/10	0.020±0.011 (BDL-0.039)		
Striped bass	2/2	0.013±0.006 (BDL-0.017)		
All fish combined	23/23	0.015±0.009 (BDL-0.039)		

Table 7a. Hazard quotients (HQs) for arsenic in fish collected from the Galveston Bay Estuary, 2010–2011. Table 7a also provides suggested weekly eight-ounce meal consumption rates for 70-kg adults.			
Species	**Number (N)**	**Hazard Quotient**	**Meals per Week**
All Sample Sites			
Alligator gar	2	0.76	1.2
Black drum	9	0.31	3.0
Gafftopsail catfish	18	0.23	4.1
Red drum	10	0.15	6.0
Sand trout	17	0.06	16.2
Southern flounder	9	0.14	6.7
Spotted seatrout	69	0.10	9.5
Striped bass	2	0.02	unrestricted[‡*]
All fish combined	136	0.14	6.7

Table 7b. Hazard quotients (HQs) for mercury in fish collected from Galveston Bay Estuary, 2010–2011. Table 7b also provides suggested weekly eight-ounce meal consumption rates for 70-kg adults.			
Species	**Number (N)**	**Hazard Quotient**	**Meals per Week**
All Sample Sites			
Alligator gar	2	0.28	3.3
Black drum	9	0.33	2.8
Gafftopsail catfish	18	0.42	2.2
Red drum	10	0.23	4.0
Sand trout	17	0.11	8.8
Southern flounder	9	0.09	10.1
Spotted seatrout	72	0.19	4.8
Striped bass	2	0.49	1.9
All fish combined	139	0.22	4.2

[*] *The term, unrestricted, denotes that the allowable 8-ounce meals per week are > 21.0.*

Table 8a. Hazard quotients (HQs) and hazard indices (HIs) for PCBs and/or PCDDs/PCDFs in fish species collected from the Galveston Bay Estuary in 2010–2011. Table 8a also provides suggested weekly eight-ounce meal consumption rates for 70-kg adults.*			
Species/Contaminant	**Number (N)**	**Hazard Quotient**	**Meals per Week**
Alligator gar			
PCBs	2	0.4	2.2
PCDDs/PCDFs	2	0.0	unrestricted†
Hazard Index (meals per week)		0.4 (2.2)	
Black drum			
PCBs	9	0.3	3.0
PCDDs/PCDFs	9	0.0	unrestricted
Hazard Index (meals per week)		0.3 (3.0)	
Gafftopsail catfish			
PCBs	18	**1.6**‡	**0.6**§
PCDDs/PCDFs	18	0.3	3.1
Hazard Index (meals per week)		**1.9 (0.5)**	
Red drum			
PCBs	10	0.4	2.5
PCDDs/PCDFs	10	0.1	6.3
Hazard Index (meals per week)		0.5 (1.8)	
Sand trout			
PCBs	17	0.6	1.6
PCDDs/PCDFs	17	0.1	10.7
Hazard Index (meals per week)		0.7 (1.4)	

* *DSHS assumes that children under 12 years of age and/or those who weigh less than 35 kg eat 4-ounce meals.*
† *The term, unrestricted, denotes that the allowable 8-ounce meals per week are >21.0.*
‡ *Emboldened numbers denote that the HQ or HI is ≥ 1.0.*
§ *Emboldened numbers denote that the calculated allowable meal consumption rate for an adult is < 1.0 meal per week.*

Table 8b. Hazard quotients (HQs) and hazard indices (HIs) for PCDDs/PCDFs and/or PCBs in fish species collected from the Galveston Bay Estuary in 2010–2011. Table 8b also provides suggested weekly eight-ounce meal consumption rates for 70-kg adults.*			
Species/Contaminant	**Number (N)**	**Hazard Quotient**	**Meals per Week**
Southern flounder			
PCBs	9	0.3	3.6
PCDDs/PCDFs	9	0.0	unrestricted†
Hazard Index (meals per week)		0.3 (3.3)	
Spotted seatrout			
PCBs	72	0.8	1.1
PCDDs/PCDFs	72	0.1	16.1
Hazard Index (meals per week)		0.9 (1.1)	
Striped bass			
PCBs	2	0.7	1.3
PCDDs/PCDFs	2	0.0	unrestricted
Hazard Index (meals per week)		0.7 (1.3)	
All fish combined			
PCBs	139	0.8	1.2
PCDDs/PCDFs	139	0.1	10.1
Hazard Index (meals per week)		0.9 (1.1)	

* *DSHS assumes that children under 12 years of age and/or those who weigh less than 35 kg eat 4-ounce meals.*
† *The term, unrestricted, denotes that the allowable 8-ounce meals per week are >21.0.*

Table 8c. Hazard quotients (HQs) and hazard indices (HIs) for PCDDs/PCDFs and/or PCBs in spotted seatrout collected from the Galveston Bay Estuary in 2010–2011. Table 8c also provides suggested weekly eight-ounce meal consumption rates for 70-kg adults.*

Species/Contaminant	Number (N)	Hazard Quotient	Meals per Week
Composite Area 1 Galveston Bay System (North of line from Red Bluff Point to Five-Mile Cut Marker to Houston Point)			
PCBs	16	**1.7**†	**0.5**‡
PCDDs/PCDFs	16	0.0	unrestricted‡
Hazard Index (meals per week)		1.7 (0.5)	
Composite Area 2 Galveston Bay System (South of line from Red Bluff Point to Five-Mile Cut Marker to Houston Point)Spotted seatrout			
PCBs	55	0.6	1.7
PCDDs/PCDFs	55	0.1	14.0
Hazard Index (meals per week)		0.6 (1.5)	
All Sample Sites			
PCBs	72	0.8	1.1
PCDDs/PCDFs	72	0.1	16.1
Hazard Index (meals per week)		0.9 (1.1)	

* *DSHS assumes that children under 12 years of age and/or those who weigh less than 35 kg eat 4-ounce meals.*
† *Emboldened numbers denote that the HQ or HI is ≥ 1.0.*
‡ *Emboldened numbers denote that the calculated allowable meal consumption rate for an adult is < 1.0 meal per week.*

Table 9a. Calculated theoretical lifetime excess cumulative cancer risk from consuming fish containing Arsenic, PCBs, and PCDDs/PCDFs collected in 2010–2011 from the Galveston Bay Estuary and suggested consumption (8-ounce meals/week) for 70 kg adults who regularly eat fish from Galveston Bay over a 30-year period.[*]

Species/Contaminant	Number (N)	Theoretical Lifetime Excess Cancer Risk		Meals per Week
		Risk	1 excess cancer per number of people exposed	
Alligator gar				
Arsenic	2	**1.5E-04**[†]	**6,784**	**0.6**[‡]
PCBs	2	7.3E-06	136,111	12.6
PCDDs/PCDFs	2	----	----	unrestricted[‡]
Cumulative Cancer Risk		**1.5E-04**	**6,462**	**0.6**
Black drum				
Arsenic	9	5.9E-05	16,985	1.6
PCBs	9	5.5E-06	181,481	16.8
PCDDs/PCDFs	9	1.0E-06	977,599	unrestricted[§]
Cumulative Cancer Risk		6.5E-05	15,288	1.4
Gafftopsail catfish				
Arsenic	18	4.4E-05	22,958	2.1
PCBs	18	2.7E-05	37,291	3.4
PCDDs/PCDFs	18	2.0E-05	50,199	4.6
Cumulative Cancer Risk		9.0E-05	11,075	1.0
Red drum				
Arsenic	10	3.0E-05	33,764	3.1
PCBs	10	6.2E-06	160,131	14.8
PCDDs/PCDFs	10	9.8E-06	102,063	9.4
Cumulative Cancer Risk		4.6E-05	21,901	2.0

[*] *DSHS assumes that children under 12 years of age and/or those who weigh less than 35 kg eat 4-ounce meals.*
[†] *Emboldened numbers denote that the calculated excess lifetime cancer risk after 30 years exposure is greater than 1×10^{-4}.*
[‡] *Emboldened numbers denote that the calculated allowable meal consumption rate for an adult < 1.0 meal per week.*
[§] *The term, unrestricted, denotes that the allowable 8-ounce meals per week are 21.0.*

Table 9b. Calculated theoretical lifetime excess cumulative cancer risk from consuming fish containing Arsenic, PCBs, and PCDDs/PCDFs collected in 2010–2011 from the Galveston Bay Estuary and suggested consumption (8-ounce meals/week) for 70 kg adults who regularly eat fish from Galveston Bay over a 30-year period.[*]

Species/Contaminant	Number (N)	Theoretical Lifetime Excess Cancer Risk		Meals per Week
		Risk	1 excess cancer per number of people exposed	
Sand trout				
Arsenic	17	1.1E-05	92,357	8.5
PCBs	17	9.9E-06	100,823	9.3
PCDDs/PCDFs	17	5.8E-06	173,202	16.0
Cumulative Cancer Risk		2.7E-05	37,708	3.5
Southern flounder				
Arsenic	9	2.7E-05	37,574	3.5
PCBs	9	4.4E-06	226,852	21.0
PCDDs/PCDFs	9	1.4E-06	709,355	unrestricted[‡]
Cumulative Cancer Risk		3.2E-05	30,834	2.8
Spotted seatrout				
Arsenic	69	1.9E-05	53,693	5.0
PCBs	72	1.4E-05	71,637	6.6
PCDDs/PCDFs	72	3.8E-06	260,450	unrestricted[†]
Cumulative Cancer Risk		3.6E-05	27,455	2.5
Striped bass				
Arsenic	2	4.0E-06	248,605	unrestricted
PCBs	2	1.2E-05	82,931	7.7
PCDDs/PCDFs	2	5.9E-08	16,941,886	unrestricted
Cumulative Cancer Risk		1.6E-05	61,959	5.7

[*] *DSHS assumes that children under 12 years of age and/or those who weigh less than 35 kg eat 4-ounce meals.*
[†] *The term, unrestricted, denotes that the allowable 8-ounce meals per week are 21.0.*

Table 9c. Calculated theoretical lifetime excess cumulative cancer risk from consuming fish containing Arsenic, PCBs, and PCDDs/PCDFs collected in 2010–2011 from Galveston Bay Estuary and suggested consumption (8-ounce meals/week) for 70 kg adults who regularly eat fish from Galveston Bay over a 30-year period.*

Species/Contaminant	Number (N)	Theoretical Lifetime Excess Cancer Risk		Meals per Week
		Risk	1 excess cancer per number of people exposed	
All fish combined				
Arsenic	136	2.7E-05	37,303	3.4
PCBs	139	1.3E-05	75,617	7.0
PCDDs/PCDFs	139	6.1E-06	163,085	15.1
Cumulative Cancer Risk		4.6E-05	21,662	2.0

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

Table 9d. Calculated theoretical lifetime excess cumulative cancer risk from consuming spotted seatrout containing Arsenic, PCBs, and PCDDs/PCDFs collected in 2010–2011 from the Galveston Bay Estuary and suggested consumption (8-ounce meals/week) for 70 kg adults who regularly eat spotted seatrout from the Galveston Bay System over a 30-year period.*

Site/Contaminant	Number (N)	Theoretical Lifetime Excess Cancer Risk		Meals per Week
		Risk	1 excess cancer per number of people exposed	
Composite Area 1 Galveston Bay System (North of line from Red Bluff Point to Five-Mile Cut Marker to Houston Point)				
Arsenic	13	8.5E-06	117,085	10.8
PCBs	16	3.0E-05	33,447	3.1
PCDDs/PCDFs	16	1.9E-06	527,195	unrestricted†
Cumulative Cancer Risk		4.0E-05	24,792	2.3
Composite Area 2 Galveston Bay System (South of line from Red Bluff Point to Five-Mile Cut Marker to Houston Point)				
Arsenic	56	2.1E-05	47,322	4.4
PCBs	56	9.6E-06	104,701	9.7
PCDDs/PCDFs	56	4.4E-06	226,225	20.9
Cumulative Cancer Risk		3.5E-05	28,494	2.6
All Sample Sites				
Arsenic	69	1.9E-05	53,377	4.9
PCBs	72	1.4E-05	71,637	6.6
PCDDs/PCDFs	72	3.8E-06	260,256	unrestricted
Cumulative Cancer Risk		3.7E-05	27,370	2.5

* *DSHS assumes that children under the age of 12 years and/or those who weigh less than 35 kg eat 4-ounce meals.*
† *The term, unrestricted, denotes that the allowable 8-ounce meals per week are 21.0.*

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