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

Arroyo Colorado

Cameron and Hidalgo Counties, Texas

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INTRODUCTION

This document summarizes the results of a survey of the Arroyo Colorado conducted in 2013 by the Texas Department of State Health Service (DSHS) Seafood and Aquatic Life Group (SALG).[a] The SALG did this study to investigate any potential change in fish tissue contamination in the Arroyo Colorado. The present study examined fish from the Arroyo Colorado for the presence and concentrations of environmental toxicants that, if eaten, potentially could affect human health negatively. The report addresses the public health implications of consuming fish from the Arroyo Colorado and suggests actions to reduce potential adverse health outcomes.

History of the Arroyo Colorado Fish Consumption Advisory

The United States Fish and Wildlife Service (USFWS) requested in 1980 that the United States Environmental Protection Agency (USEPA) investigate contamination of the Arroyo Colorado, reporting that fish collected from the Arroyo Colorado as far back as the 1960s consistently contained dichlorodiphenyltrichloroethane (DDT), dichlorodiphenyldichloroethylene (DDE), and toxaphene.[1] The USEPA referred that request to the Texas Department of Health (TDH) – now known as the Department of State Health Services (DSHS) region office in Harlingen, Texas. Oral history has it that, in September 1980, region staff issued a press release recommending that – based on the USFWS data – people not consume fish from the Arroyo Colorado upstream of the Port of Harlingen, presumably, because fish from this stretch of the Arroyo Colorado likely contained DDT and "other organic substances" that could be harmful to human health.[2] Between the 1980 statement and the TDH's first trip to sample fish from the Arroyo Colorado, the press release served as a reference for continuing the advice that people not eat fish from this stretch of the Arroyo Colorado. In 1984, the TDH reiterated the advice. Sampling between 1980 and later years repeatedly revealed that fish from the Arroyo Colorado still contained DDE, chlordane, toxaphene, and/or other pesticides that made those fish unfit for consumption.

On June 24, 1993, the TDH issued Fish and Shellfish Consumption Advisory 5 (ADV-5), its first numbered consumption advisory for the Arroyo Colorado. ADV-5 covered the Donna Reservoir, the North Floodway, and all irrigation canals in Hidalgo County. The advisory suggested that people not eat any species of fish from these waters because fish contained polychlorinated biphenyls (PCBs).[3] The TDH issued ADV-6, a modification of ADV-5, on November 17, 1993, after additional sampling of area waters confirmed the presence of PCBs and several types of organic contaminants, including DDE in fish.[4] ADV-6 included all species of fish in the Donna Reservoir, its interconnecting canal system, and the Arroyo Colorado upstream of the Port of Harlingen in Cameron, Hidalgo, and Willacy Counties. The un-numbered advisory issued in September 1980 for the Arroyo Colorado upstream of the Port of Harlingen remained intact.

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[a] The terms DSHS and SALG may be used interchangeably throughout this document and mean the same agency.

In 2001, the TDH issued ADV-19, which modified ADV-6 and the un-numbered advisory dated September 1980.[5] ADV-19 indicated that PCBs have decreased to acceptable levels in all species of fish tested and that concentrations of pesticides have decreased to acceptable levels in all species tested except smallmouth buffalo. Smallmouth buffalo continue to contain elevated levels of chlorinated pesticides. Consumption of smallmouth buffalo continues to pose a risk to human health. ADV-19 included all waters of the Arroyo Colorado, the Llano Grande Lake, and the main floodway upstream of the Port of Harlingen in Cameron and Hidalgo Counties. ADV-19 suggested that adults eat no more than two eight-ounce meals per month of smallmouth buffalo from the Arroyo Colorado. Children were recommended to eat no more than two four-ounce meals per month of smallmouth buffalo.

In 2006, in the Texas Commission on Environmental Quality (TCEQ) requested a survey of the Arroyo Colorado as a five-year follow-up study under the Total Maximum Daily Load (TMDL) Program for previously adopted TMDLs. The 2006 survey revealed the presence of DDE, mercury, and PCBs at concentrations exceeding health-based guidelines in longnose gar and smallmouth buffalo. The DSHS issued ADV-34 on January 31, 2008 to rescind ADV-19 and to advise people not to consume longnose gar and smallmouth buffalo from the Arroyo Colorado, Llano Grande Lake, and the Main Floodway upstream of the Port of Harlingen.[6]

Description of the Arroyo Colorado

The Arroyo Colorado, a stream running through the Lower Rio Grande Valley of South Texas, originates near the Mission, Texas. It flows approximately 90 miles through Hidalgo, Cameron and southeastern Willacy Counties into the Laguna Madre.[7] The Arroyo is navigable to barges through parts of the channel dredged from the Gulf Intracoastal Waterway to the Port of Harlingen.[8] From the Port of Harlingen to a point near the headwaters of the Arroyo Colorado, the water body is navigable only by small boats. The Arroyo Colorado was likely an early channel of the Rio Grande. As a former outlet of the Rio Grande, the Arroyo Colorado still carries excess water from the Rio Grande to the Laguna Madre. The upper drainage area of the Arroyo Colorado includes rich land used for farming and for growing citrus trees. The Arroyo Colorado also includes the cities of Harlingen and Rio Hondo. The lower arroyo courses through an area of farms, ranches, and coastal playas. Typical bank-side vegetation includes reeds overhung by such trees as the huisache, mesquite, and Texas ebony. The final reaches of the Arroyo Colorado pass through Laguna Atascosa National Wildlife Refuge. In the refuge, the Arroyo Colorado’s banks and adjoining thorn forests and marshes shelter various endangered and rare species such as ocelots, jaguarundis, and indigo snakes. The estuary protects roseate spoonbills, brown pelicans, and many other bird species.

Population of Cameron and Hidalgo Counties Surrounding the Arroyo Colorado

The Arroyo Colorado flows through the Brownsville-Harlingen metropolitan statistical area (MSA) or Cameron County and the McAllen-Edinburg-Mission MSA or Hidalgo County in the Rio Grande Valley region of South Texas. According to the United States Census Bureau’s (USCB), the estimated 2013 population of the Brownsville-Harlingen MSA was 417,276.[9] The USCB also reported that the McAllen-Edinburg-Mission MSA at 815,996 people. The McAllen-Edinburg-Mission MSA and Brownsville-Harlingen MSA were the sixth and ninth largest metropolitan areas in Texas, respectively.[9]

Subsistence Fishing within the Arroyo Colorado Watershed

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.[10] The USEPA and the DSHS find it is important to consider subsistence fishing to occur at any water body because subsistence fishers (as well as recreational anglers and certain tribal and ethnic groups) usually consume more locally caught fish than the general population. These groups sometimes harvest fish or shellfish from the same water body over many years to supplement caloric and protein intake. 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 in Texas. The DSHS assumes the rate of subsistence fishing to be similar to that estimated by the USEPA.

METHODS

Fish Sampling, Preparation, and Analysis

The DSHS SALG collects and analyzes edible fish from the state's public waters to evaluate potential risks to the health of people consuming contaminated fish or shellfish. Fish tissue sampling follows standard operating procedures from the DSHS *Seafood and Aquatic Life Group Survey Team Standard Operating Procedures and Quality Control/Assurance Manual.*[11] The SALG bases its sampling and analysis protocols, in part, on procedures recommended by the USEPA's *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories, Volume 1.*[12] Advice and direction are also received from the legislatively mandated *State of Texas Toxic Substances Coordinating Committee Fish Sampling Advisory Subcommittee.*[13] 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 Arroyo Colorado 2013 Sample Set

In January–February 2013, the SALG staff collected 40 fish samples from the Arroyo Colorado. Risk assessors used data from these fish to assess the potential for adverse human health outcomes from consuming fish from this body of water.

The SALG selected five sample sites to provide spatial coverage of the study area (Figure 1): Site 1 Arroyo Colorado at Port of Harlingen; Site 2 Arroyo Colorado at Harlingen Wastewater Treatment Plant (WWTP) outfall; Site 3 Arroyo Colorado at Farm-to-Market (FM) 506; Site 4 Arroyo Colorado at FM 1015; and, Site 5 Arroyo Colorado at FM 493. 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. The 40 fish collected from the Arroyo Colorado represent all species targeted for collection from this water body (Table 1). The list below contains the number of each target species, listed in descending order collected for this study: smallmouth buffalo (11); blue catfish (9); spotted searout (5); common carp (4); red drum (3); black drum (2); hardhead catfish (2); sheepshead (2); flathead catfish (1); and, longnose gar (1).

The survey team set gill nets at sample sites 1–5 in late afternoon (Figure 1); fished the sites overnight, and collected samples from the nets early the following morning. The gill nets were set at locations to maximize available cover and habitat at each sample site. During collection, to keep specimens from different sample sites separated, the team placed samples from each site into mesh bags labeled with the site number. The survey team immediately stored retrieved samples on wet ice in large coolers to ensure interim preservation. Survey team members returned to the water any live fish culled from the catch and properly disposed of samples found dead in the gill nets.

The SALG staff processed fish onsite at the Arroyo Colorado. Staff weighed each sample to the nearest gram (g) on an electronic scale and measured total length (TL; tip of nose to tip of tail fin) to the nearest millimeter (mm; Table 1). All TL measurements were converted to inches for use in this report. After weighing and measuring a fish, staff used a cutting board covered with aluminum foil and a fillet knife to prepare two skin-off fillets from each fish. The SALG staff used game shears and a fillet knife to prepare fillets from the longnose gar sample. The foil was changed and the game shears and knife cleaned with distilled water after each sample was processed. The SALG staff 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 chain of custody while samples are in the possession of agency staff. The SALG delivered the frozen fish tissue samples to the Geochemical and Environmental Research Group (GERG) Laboratory, Texas A&M University, College Station, Texas, for contaminant analysis.

Analytical Laboratory Information

The GERG personnel documented receipt of the 40 Arroyo Colorado fish samples and recorded the condition of each sample along with its DSHS identification number. Using established USEPA methods, the GERG laboratory analyzed fish fillets from the Arroyo Colorado for inorganic and organic contaminants commonly identified in polluted environmental media.

Analyses included seven metals (arsenic, cadmium, copper, lead, total mercury, selenium, and zinc), 123 semivolatile organic compounds (SVOCs), 70 volatile organic compounds (VOCs), 34 pesticides, 209 PCB congeners,[b, 14] and 17 polychlorinated dibenzofurans and/or dibenzo-*p*-dioxins (PCDDs/PCDFs) congeners. The laboratory analyzed all 40 samples for mercury, pesticides, and PCBs. Of the original 40 samples, a subset of 10 were analyzed for PCDDs/PCDFs and a subset of four was analyzed for metals, SVOCs, and VOCs.[15] The SALG risk assessors selected the subset of samples based on target species and size class selection procedures outlined in SALG standard operating procedures (SOPs). In addition to SALG SOPs, if available, the SALG risk assessors use TPWD creel surveys to determine the species of fish most frequently harvested from the body of water being evaluated and choose large specimens of the selected species of fish. The SALG risk assessors choose large fish to assess conservatively contaminant exposure when evaluating small sample sizes.

Details of Some Analyses with Explanatory Notes

Arsenic

The GERG laboratory analyzed four fish samples for total (inorganic arsenic + organic arsenic = total arsenic) arsenic. Although the proportions of each form of arsenic may differ among fish species, under different water conditions, and, perhaps, with other variables, the literature suggests that well over 90% of arsenic in fish is likely organic arsenic – a form of arsenic that is virtually non-toxic to humans.[16] The 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 the reported total arsenic concentration in the sample by a factor of 0.1.

Mercury

Nearly all mercury in upper trophic level fish three years of age or older is methylmercury.[17] 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.[18] (In these risk characterizations, the DSHS may interchangeably

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

utilize the terms "mercury," "methylmercury," or "organic mercury" to refer to methylmercury in fish).

Percent Lipids

The percent lipids content (wet weight basis) of a tissue sample is defined as the percent of material extracted from biological tissue with methylene chloride.[19] A tissue sample is extracted with methylene chloride in the presence of sodium sulfate. An aliquot of the extract is removed for lipid determination, filtered and concentrated to a known volume. A subsample is removed, the solvent is evaporated, the lipid residue weighed, and the percent lipid content is determined.

Polychlorinated Biphenyls (PCBs)

For PCBs, the USEPA suggests that each state measures congeners of PCBs in fish and shellfish rather than homologs[c] or Aroclors®[d] because the USEPA considers congener analysis the most sensitive technique for detecting PCBs in environmental media.[18, 20] Although only about 130 PCB congeners were routinely present in PCB mixtures manufactured and commonly used in the United States (US), the GERG laboratory analyzes and reports the presence and concentrations of all 209 possible PCB congeners. From the congener analyses, the laboratory also computes and reports concentrations of PCB homologs and of Aroclor® mixtures. Despite the USEPA's suggestion that the states utilize PCB congeners rather than Aroclors® or homologs for toxicity estimates, the toxicity literature does not reflect state-of-the-art laboratory science. To accommodate this inconsistency, the DSHS utilizes recommendations from the National Oceanic and Atmospheric Administration (NOAA),[21] from McFarland and Clarke,[22] and from the USEPA's guidance documents for assessing contaminants in fish and shellfish.[12, **Error! Bookmark not defined.**] Based on evaluation of these recommendations, the DSHS selected 43 of 209 congeners to characterize "total" PCBs. The referenced authors chose to use congeners that were relatively abundant in the environment, were likely to occur in aquatic life, and likely to show toxic effects. SALG risk assessors summed the 43 congeners to derive "total" PCB concentration in each sample. SALG risk assessors then averaged the summed congeners within each group (e.g., fish species, sample site, or combination of species and site) to derive a mean PCB concentration for each group.

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

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

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

For assessment of cancer risk from exposure to PCBs, the SALG uses the USEPA's highest slope factor of 2.0 milligram per kilogram per day (mg/kg/day) to calculate the probability of lifetime excess cancer risk from PCB ingestion. The SALG based its decision to use the most conservative slope factor available for PCBs on factors, such as food chain exposure; the presence of dioxin-like, tumor-promoting, or persistent congeners; and, the likelihood of early-life exposure.[234]

Calculation of Dioxin Toxicity Equivalence (TEQ)

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

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

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 (Noncarcinogenic) Effects (HAC_{nonca}) of Consumed Chemical Contaminants

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

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

In deriving HAC values for systemic (noncarcinogenic; HAC_{nonca}) effects, the SALG assumes a standard adult weighs 70 kilograms (kg) and consumes 30 g of fish or shellfish per day (about one eight-ounce meal per week) and uses the USEPA's RfD[29] or the ATSDR's chronic oral MRLs.[30] When RfDs or MRLs are not available the SALG may use a Food and Nutrition Board, Institute of Medicine, National Academies tolerable upper intake level (UL) for nutrients.[e] 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.*[31]

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.*[31]

The ATSDR uses a similar technique to derive its MRLs.[30] The DSHS divides the estimated daily dose derived from the measured concentration in fish tissue by the contaminant's RfD or MRL to derive a hazard quotient (HQ). The USEPA defines an HQ as

> *…the ratio of the estimated exposure dose of a contaminant (mg/kg/day) to the contaminant's RfD or MRL (mg/kg/day).*[32]

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

The SALG does not utilize HQs to determine the likelihood of occurrence of adverse systemic health effects. Instead, in a manner similar to the USEPA's decision process, the SALG may utilize computed HQs as a qualitative measurement. Qualitatively, HQs less than 1.0 are unlikely to be cause for concern while HQs greater than or equal to 1.0 might suggest the recommendation of a regulatory action to ensure protection of public health. Similarly, risk

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

assessors at the DSHS may utilize an HQ to determine the need for further study of a water body's fauna. Notwithstanding the above discussion, the oral RfD derived by the USEPA represents chronic consumption. Thus, regularly eating fish containing a toxic chemical, the HQ of which is less than 1.0 is unlikely to cause adverse systemic (noncarcinogenic) health effects, whereas routine consumption of fish or shellfish in which the HQ equals or exceeds 1.0 represents a qualitatively unacceptable increase in the likelihood of systemic adverse health outcomes.

Although the DSHS utilizes chemical specific RfDs when possible, if an RfD is not available for a contaminant, the USEPA advises risk assessors to consider evaluating the contaminant by comparing it to the published RfD (or the MRL) of a contaminant of similar molecular structure or one with a similar mode or mechanism of action. For instance, Aroclor® 1260 has no RfD, so the DSHS uses the reference dose for Aroclor 1254 to assess the likelihood of systemic (noncarcinogenic) effects of Aroclor 1260.[30]

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.[29,31] Vulnerable groups such as women who are pregnant or lactating, women who may become pregnant, infants, children, people with chronic illnesses, those with compromised immune systems, the elderly, or those who consume exceptionally large servings are considered sensitive populations by risk assessors and USEPA. These sensitive groups also receive special consideration in calculation of an RfD.[31]

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

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

The USEPA states that

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

And

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

Thus,

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

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

The DSHS calculates cancer-risk comparison values (HAC_{ca}) from the USEPA's chemical-specific cancer potency factors (CPFs), also known as cancer slope factors (CSFs), derived through mathematical modeling from carcinogenicity studies. For carcinogenic outcomes, the DSHS calculates a theoretical lifetime excess risk of cancer for specific exposure scenarios for carcinogens, using a standard 70-kg body weight and assuming an adult consumes 30 grams of edible tissue per day. The SALG risk assessors incorporate two additional factors into determinations of theoretical lifetime excess cancer risk: (1) an acceptable lifetime risk level (ARL)[31] 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. [33, 34] 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.[35] 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.[36] 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.[29] Additionally, in accordance with the ATSDR's *Child Health Initiative*[37] and the USEPA's *National Agenda to Protect Children's Health from Environmental Threats,*[38] 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 two four ounce meals of the contaminated fish or shellfish per year and should not eat such fish or shellfish more than twice per month.

Data Analysis and Statistical Methods

The SALG risk assessors imported Excel© files into Systat® statistical software, version 13.1 installed on IBM-compatible microcomputers (Dell, Inc), using Systat® to generate descriptive statistics (mean, 95% confidence limits of the arithmetic mean, standard deviation, median, minimum, and maximum concentrations) for reported chemical contaminants.[39] In computing descriptive statistics, SALG risk assessors utilized ½ the reporting limit (RL) for analytes designated as not detected (ND) or estimated (J-values).[f] The SALG risk assessors calculated PCDDs/PCDFs descriptive statistics using estimated concentrations (J-values) and assuming zero for PCDDs/PCDFs designated as ND.[g] 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 produce the present report. The SALG employed Microsoft Excel® spreadsheets to create figures, to compute HAC_{nonca} and HAC_{ca} values for contaminants, and to calculate HQs, HIs, cancer risk probabilities, and meal consumption limits for fish from the Arroyo Colorado.[40] When lead concentrations in fish or shellfish are high, SALG risk assessors may utilize the USEPA's Interactive Environmental Uptake Bio-Kinetic (IEUBK) model to determine whether consumption of lead-contaminated fish could cause a child's blood lead (PbB) level to exceed the Centers for Disease Control and Prevention's (CDC) lead concentration of concern in children's blood (5 mcg/dL).[41,42]

The SALG risk assessors also performed other types of statistical analyses to evaluate the data. Statistical significance was determined at $p \leq 0.05$ for all statistical analyses. When appropriate and as needed to meet assumptions of the statistical tests, the SALG risk assessors $\log_e$-

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[f] *"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.*

[g] *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.*

transformed the data to improve normality and best fit. The SALG risk assessors performed linear correlation (r) to describe associations between contaminant concentrations and total length (TL) and percent lipid composition. For those associations that were positive and significant, the SALG risk assessors performed linear regression analyses (r^2) to measure the strength and further describe the relationships. The SALG risk assessors performed analysis of variance (ANOVA) and used Tukey's honestly significant difference (HSD) post-hoc comparisons to compare sample site contaminant concentrations for all fish combined. Individual species of fish were not collected at all sample sites, so SALG risk assessors were unable to compare sample site contaminant concentrations. The SALG performed t-tests to determine differences between contaminant concentrations in fish collected in 2006 and 2013. Box and whisker plots were used to display patterns of contaminant concentrations for all fish combined and smallmouth buffalo between the 2006 and 2013 sampling events.

RESULTS

The GERG laboratory completed analyses and electronically transmitted the results of the Arroyo Colorado samples collected January–February 2013 to the SALG in February 2014. The laboratory reported the analytical results for metals, pesticides, PCBs, PCDDs/PCDFs, SVOCs, and VOCs.

For reference, Table 1 contains a list of fish samples collected by sample site. Tables 2.1–2.5 present the results of metals analyses. Tables 3.1–3.5 and 4.1–4.2 contain summary results for pesticides and PCBs, respectively. Table 5 summarizes the PCDD/PCDF analyses and Table 6 the trichlorofluoromethane results. This report does not display SVOC and most VOC data because these contaminants were not present at concentrations of concern in fish collected from the Arroyo Colorado during the described survey. Unless otherwise stated, table summaries present the number of samples with detected concentrations of contaminants, the number of samples tested, the mean concentration and standard deviation, and the minimum and the maximum concentrations. In the tables, results may be reported as ND, below detection limit (BDL) for estimated concentrations or "J-values", or as concentrations at or above the reporting limit (RL).

Inorganic Contaminants

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

The GERG laboratory analyzed a subset of four fish tissue samples for six inorganic contaminants and 40 samples for mercury. All fish tissue samples from the Arroyo Colorado contained some concentration of arsenic, copper, mercury, selenium, and zinc (Tables 2.1–2.5).

The SALG evaluated three toxic metalloids having no known human physiological function (arsenic, cadmium, and lead) in the samples collected from the Arroyo Colorado. All fish analyzed contained arsenic ranging from 0.123–0.468 mg/kg (Table 2.1). Trace concentrations of cadmium were reported in fish sampled from the Arroyo Colorado (Table 2.2). Lead was not detected in any of the four samples analyzed.

Three of the metalloids analyzed are essential trace elements: copper, selenium, and zinc. All four fish tissue samples contained copper (Table 2.2). The mean copper concentration in fish sampled from the Arroyo Colorado was 0.151±0.063 mg/kg. All fish tissue samples analyzed contained selenium. Selenium concentrations ranged from 0.327 to 0.703 mg/kg with a mean of 0.502±0.157 mg/kg (Table 2.2). All samples also contained zinc. The mean zinc concentration in fish tissue samples from the Arroyo Colorado was 4.259±2.171 mg/kg (Table 2.3).

Mercury

All fish tissue samples evaluated from the Arroyo Colorado contained mercury (Tables 2.4–2.5). Across all sample sites and species, mercury concentrations ranged from 0.105 (common carp) to 0.767 mg/kg (longnose gar). The mean mercury concentration for the 40 fish tissue samples assayed was 0.291±0.155 mg/kg (Table 2.5). Mercury concentrations in fish were positively related to total length (TL; $r^2 = 0.172$, $n = 40$, $p = 0.008$; Figure 2).

Organic Contaminants

Pesticides

All samples examined contained concentrations of chlordane, dieldrin, 4,4'-DDE, 2,4'-dichlorodiphenyldichlorethane (DDD), and 4,4'-DDD. Chlordane (total) concentrations ranged from 0.0006 to 0.052 mg/kg with a mean of 0.011±0.012 mg/kg (Table 3.1). The mean dieldrin concentration in fish tissues samples from the Arroyo Colorado was 0.004±0.004 mg/kg (Table 3.2). DDT (total) [2,4'-DDE+4,4'-DDE + 2,4'-DDD +4,4'-DDD+2,4'-DDT+4,4'-DDT] ranged from 0.0008 to 1.056 mg/kg with a mean 0.276±0.282 mg/kg and a median of 0.163 mg/kg (Tables 3.4–3.5). DDT (total) concentrations in fish were positively related to TL and percent lipids ($r^2 = 0.139$, $n = 40$, $p = 0.018$; $r^2 = 0.612$, $n = 40$, $p < 0.0005$; Figures 3–5).

The SALG risk assessors visually examined the fish DDT (total) concentrations noting that DDT (total) concentrations appeared higher in the Arroyo Colorado above the Port of Harlingen (sample sites 2–5) than at the Port of Harlingen (sample site 1; Figure 6). The SALG risk assessors determined that fish DDT (total) concentrations differed significantly across the five samples sites ($F [4, 35] = 9.663$, $p < 0.0005$; Figure 6) and that sample sites above the Port of Harlingen had significantly higher DDT (total) concentrations than fish from the Port of Harlingen (sample site one; Table 11.1).

Concentrations of chlorpyrifos, dacthal, endrin, and endosulfan II > RL were reported in at least 20 samples analyzed (Tables 3.1–3.3). Trace to low concentrations of aldrin, alpha-hexachlorocyclohexane (HCH), beta-HCH, delta-HCH, diazinon, endosulfan sulfate, heptachlor, heptachlor epoxide, hexachlorobenzene, malathion, ethoxychlor, mirex, parathion ethyl and methyl, pentachloroanisole, pentachlorobenzene, tetrachlorobenzene, and toxaphene were present in one or more fish samples (data not presented).

PCBs

All fish tissue samples evaluated from the Arroyo Colorado contained PCBs (Tables 4.1–4.2). Across all sample sites and species, PCB concentrations ranged from 0.006 (red drum) to 0.153 mg/kg (smallmouth buffalo). The mean PCB concentration for the 40 fish tissue samples analyzed was 0.029±0.032 mg/kg (Table 4.2). PCB concentrations in fish were positively related to TL and percent lipids ($r^2 = 0.159$, $n = 40$, $p = 0.011$; $r^2 = 0.722$, $n = 40$, $p < 0.0005$; Figures 7–9).

The SALG risk assessors visually examined the fish PCB concentrations noting that PCB concentrations appeared higher in the Arroyo Colorado above the Port of Harlingen (sample sites 2–5) than at the Port of Harlingen (sample site 1; Figure 10). The SALG risk assessors determined that fish PCB concentrations differed significantly across the five samples sites ($F [4, 35] = 8.358$, $p = 0.0001$; Figure 10) and that fish PCB concentrations from sample sites two, three, and five upstream of the Port of Harlingen had significantly higher PCB concentrations than fish from the Port of Harlingen (sample site one; Table 11.2).

PCDDs/PCDFs

A subset of 10 Arroyo Colorado fish tissue samples were assayed for PCDDs/PCDFs. Seven of 10 fish tissue samples contained at least one of the 17 PCDD/PCDF congeners ranging from ND–1.434 TEQ pg/g with a mean of 0.296±0.425 and a median of 0.187 TEQ pg/g (Table 5). No samples contained all 17 congeners (data not shown).

SVOCs

A subset of four Arroyo Colorado fish tissue samples was analyzed for SVOCs. Quantifiable concentrations > RL were reported for phenol in one or more fish samples (data not presented). Estimated concentrations of 2–4 dimethylphenol, nitrobenzene, and n nitrosodi-n-propylamine were present in one or more fish samples analyzed (data not presented). The laboratory detected no other SVOCs in fish from the Arroyo Colorado.

VOCs

A subset of four Arroyo Colorado fish tissue samples was analyzed for VOCs. Four of four fish tissue samples contained trichlorofluoromethane ranging from 0.014–0.091 mg/kg with a mean of 0.041±0.036 mg/kg and a median of 0.029 mg/kg (Table 6). Quantifiable concentrations > RL were reported for acetone, carbon disulfide, methylene chloride, and 2-butanone (MEK; data not presented). Estimated quantities of many VOCs were also present in one or more fish tissue samples assayed from the Arroyo Colorado (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 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.[29] 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 Arroyo Colorado. 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 Arroyo Colorado

Inorganic Contaminants

No species of fish evaluated contained arsenic, cadmium, copper, lead, selenium, or zinc at concentrations that equaled or exceeded DSHS guidelines for protection of human health or would likely cause systemic (noncarcinogenic) risk to human health from consumption of fish from the Arroyo Colorado.

Mercury was observed in two of 40 fish from the Arroyo Colorado that equaled or exceeded its HAC_{nonca} (0.700 mg/kg; Tables 2.4–2.5 and 7). The SALG risk assessors are unable to characterize adequately health risks associated with consuming mercury-contaminated black drum and longnose gar from the Arroyo Colorado because of the small sample sizes evaluated. The mean mercury concentrations of the 10 species evaluated and the all fish combined mean concentration did not exceed the mercury HAC_{nonca} nor did the HQs exceed 1.0. Even though mercury concentrations in most species of fish did not exceed DSHS guidelines for protection of human health, it is important to understand that mercury concentrations in fish from the Arroyo Colorado were positively related to TL indicating that mercury concentrations increase over time as fish grow (Figure 2). This relationship may also be affected by the slow rate at which fish eliminate mercury compared to the rate at which it is accumulated. People should consider this relationship when choosing the size and species of fish they consume.

Organic Contaminants

PCBs were observed in fish from the Arroyo Colorado that equaled or exceeded its HAC_{nonca} (0.047 mg/kg; Tables 4.1–4.2, 8, and 9.1–9.2). No species of fish evaluated contained any other organic contaminants at concentrations assessed singly that equaled or exceeded DSHS guidelines for protection of human health or would likely cause systemic (noncarcinogenic) risk to human health from consumption of fish from the Arroyo Colorado.

DDT (total)

Reevaluation of the Arroyo Colorado fish consumption advisory in 2006 revealed that DDT (total) concentrations in fish continued to exceed DSHS guidelines for protection of human health. This finding prompted the DSHS to continue listing DDE, a breakdown product of, DDT (total) as a contaminant of concern in the Arroyo Colorado fish consumption advisory. Reassessment of the Arroyo Colorado fish consumption advisory in 2013 suggested a decreasing trend for DDT (total) concentrations in fish. Comparisons of DDT (total) concentrations in fish from the 2006 and 2013 sampling events indicate that fish from the Arroyo Colorado no longer exceed DSHS guidelines for protection of human health. An independent samples *t*-test confirmed that DDT (total) concentrations in fish from the Arroyo Colorado have significantly decreased from 2006 to 2013 (2006, n = 30; 2013, n = 40; $t[68]$ = 4.044, p = 0.0001; Figure 11). Independent samples *t*-test analysis also confirmed that DDT (total) concentrations in smallmouth buffalo from the Arroyo Colorado have significantly decreased from 2006 to 2013 (2006, n = 8; 2013, n = 11; $t[17]$ = 4.756, p = 0.0002; Figure 12).

PCBs

All fish tissue samples (n = 40) assayed contained PCBs. Twenty percent of all samples analyzed contained PCB concentrations exceeding the HAC_{nonca} for PCBs (0.047 mg/kg; Tables 4.1–4.2 and 9.1–9.2). One (smallmouth buffalo) of 10 species evaluated had mean PCB concentrations exceeding the HAC_{nonca} for PCBs or an HQ of 1.0 (Tables 4.1–4.2 and 9.1–9.2). The all fish combined mean PCB concentration (0.029 mg/kg) did not exceed the HAC_{nonca} for PCBs or an HQ of 1.0. PCB concentrations were positively related to TL and percent lipids indicating that PCB concentrations increase as fish grow and as fish, percent body fat increases (Figures 8–9). People should consider these relationships when choosing the size and species of fish they consume. The consumption of smallmouth buffalo from the Arroyo Colorado may pose potential systemic (noncarcinogenic) health risks.

Reassessment of the Arroyo Colorado fish consumption advisory in 2013 suggested a decreasing trend for PCB concentrations in fish. Comparisons of PCB concentrations in fish from the 2006 and 2013 sampling events indicate that fish from the Arroyo Colorado continue exceed DSHS guidelines for protection of human health. An independent samples *t*-test confirmed that PCB concentrations in fish collected in 2013 from the Arroyo Colorado are significantly lower than in fish collected in 2006 (2006, $n = 30$; 2013, $n = 40$; $t[68] = 2.807$, $p = 0.007$; Figure 13). Independent samples *t*-test analysis also confirmed that PCB concentrations in smallmouth buffalo from the Arroyo Colorado have significantly decreased from 2006 to 2013 (2006, $n = 8$; 2013, $n = 11$; $t[17] = 2.074$, $p = 0.05$; Figure 14).

Meal consumption calculations are useful for risk managers to make fish consumption recommendations and/or take regulatory action. The SALG risk assessors calculated the number of eight-ounce meals of fish from the Arroyo Colorado that healthy adults could consume without significant risk of PCB-related adverse systemic effects (Tables 9.1–9.2). Meal consumption rates were based on the overall mean PCB concentration by species. The SALG risk assessors estimated that healthy adults could consume less than one eight-ounce meal per week of smallmouth buffalo (0.7 meals per week). The SALG risk assessors suggest that smallmouth buffalo from the Arroyo Colorado contain PCBs at concentrations that may pose potential systemic (noncancerous) health risks and that people should limit their consumption of smallmouth buffalo from the Arroyo Colorado. Because the developing nervous system of the human fetus and young children may be especially susceptible to adverse systemic (noncarcinogenic) health effects associated with consuming PCB-contaminated fish, the SALG risk assessors recommend more conservative consumption guidance for this sensitive subpopulation.

Characterization of Theoretical Lifetime Excess Cancer Risk from Consumption of Fish from the Arroyo Colorado

The USEPA classifies arsenic, most chlorinated pesticides, PCBs, and PCDDs/PCDFs as carcinogens. Arsenic, chlorinated pesticides, PCBs, and PCDDs/PCDFs were present in fish samples analyzed from the Arroyo Colorado, but none of these contaminants evaluated singly by species or all species combined had mean contaminant concentrations that would be likely to exceed the DSHS guideline for protection of human health of one excess cancer in 10,000 equally exposed individuals.

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

Cumulative Systemic Health Effects

Cumulative systemic effects of toxicants may occur if more than one contaminant acts upon the same target organ or acts by the same mode or mechanism of action. The SALG risk assessors utilize HI methodology to assess the likelihood of cumulative systemic adverse effects. This methodology requires that the contaminants of concern have a common target organ or a similar mode of action. In the case of mercury, DDT (total), PCBs, and PCDD/PCDFs in fish from the Arroyo Colorado, neither assumption is true. The target organ for mercury is the central nervous system. The target organ for DDT (total) is the liver, while the target organ identified for PCBs and PCDDs/PCDFs is the immune system. Thus, cumulative systemic effects from consumption of fish from the Arroyo Colorado for a contaminant mixture of two dissimilar contaminants and two similar contaminants are not likely to occur. PCBs and PCDDs/PCDFs, the two similar contaminants, increased the likelihood of systemic adverse health outcomes for several species of fish assayed (Tables 9.1–9.2). The combined toxicity of PCBs and PCDDs/PCDFs in smallmouth buffalo exceeded an HI of 1.0.

Meal consumption calculations are useful for risk managers to make fish consumption recommendations and/or take regulatory action. The SALG risk assessors calculated the number of eight-ounce meals of fish from the Arroyo Colorado that healthy adults could consume without significant risk of PCB and/or PCDD/PCDF -related adverse systemic effects (Tables 9.1–9.2). Meal consumption rates were based on cumulative toxicity from exposure to PCBs, and PCDDs/PCDFs by species. The SALG risk assessors estimated that healthy adults could consume less than one eight-ounce meal per week of smallmouth buffalo (Tables 9.1–9.2). The SALG risk assessors suggest that smallmouth buffalo from the Arroyo Colorado contain PCBs, and PCDDs/PCDFs at concentrations that may pose potential systemic health risks and that people should limit their consumption of smallmouth buffalo from the Arroyo Colorado. Because the developing nervous system of the human fetus and young children may be especially susceptible to adverse systemic health effects may be especially susceptible to these effects, the SALG risk assessors recommend more conservative consumption guidance for this sensitive subpopulation.

Cumulative Carcinogenic Health Effects

The SALG also queried the probability of increasing lifetime excess cancer risk from consuming fish containing multiple inorganic and organic contaminants. In most assessments of cancer risk from environmental exposures to chemical mixtures, researchers have considered any increase in cancerous or benign growths in one or more organs as cumulative, no matter the mode or mechanism of action of the contaminant. In this assessment, risk assessors added the calculated carcinogenic effect of arsenic, chlorinated pesticides, PCBs, and PCDFs/PCDDs (all data not presented; Tables 10.1–10.5). In each instance, addition of the cancer risk for these chemicals increased the theoretical lifetime excess cancer risk. However, 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.

Characterization of Potential Exposure to Contaminants from Consumption of Fish from the Arroyo Colorado

The SALG risk assessors are also of the opinion that it is important to consider potential exposure when developing fish consumption advisories. Studies have shown that recoveries and yields from whole fish to skin-off fillets range from 17–58%.[43] The SALG risk assessors used an average of 38% recovery and yield from whole fish to skin-off fillets to estimate the number of eight-ounce meals for an average weight fish of each species from the Arroyo Colorado in 2013 (Table 11). The recoveries and yields for an average fish of each species from the Arroyo Colorado in 2013 ranged from 0.8–17.1 eight-ounce meals. Based on recoveries and yields ($\overline{X}$ – 38%) from whole fish to skin-off fillets for this project, the average Arroyo Colorado fish yields two pounds of skin-off fillets or approximately 4 eight-ounce meals (Table 11). To illustrate the importance of potential exposure from large catfish, buffalo, or gar DSHS considered the blue catfish mean PCB concentration (0.027 mg/kg) for this project. Based on a mean PCB concentration of 0.027 mg/kg, a person consuming seven eight-ounce meals per month or 1.6 eight-ounce meals per week would consume equivalent to the RfD. The maximum size blue catfish (22.5 pounds) for this project yields 8.5 pounds of skin-off fillets, approximately 17 eight-ounce meals. Due to the potential exposure from large-sized fish, it is important for high volume fish consumers (persons who eat more than 2 eight-ounce meals per week) to understand that even though an average fish PCB concentration does not exceed the HAC_{nonca} for PCBs a person may easily consume enough fish meals to exceed the MRL. For the reasons stated in the above discussion, the SALG risk assessors considered both standard meal consumption calculations and potential exposure scenarios to develop fish consumption advice for fish from the Arroyo Colorado.

CONCLUSIONS

The SALG risk assessors prepare risk characterizations to determine public health hazards from consumption of fish and shellfish harvested from Texas water bodies by recreational or subsistence fishers. If necessary, the SALG risk assessors may suggest strategies for reducing 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 Arroyo Colorado, located in Cameron and Hidalgo Counties, Texas. Risk assessors from the SALG conclude from the present characterization of potential adverse health effects from consuming fish from the Arroyo Colorado that:

1. Many of the conclusions for individual species of fish in this risk assessment may be suspect due to the small sample size evaluated.

2. Fish tissue concentrations of arsenic, cadmium, copper, lead, selenium, zinc, pesticides, PCDDs/PCDFs, SVOCs, or VOCs, evaluated singly or in combination, do not exceed the

DSHS guidelines for protection of human health. Therefore, consumption of fish containing the above-listed contaminants **poses no apparent risk to human health**.

3. Blue catfish, common carp, flathead catfish, hardhead catfish, red drum, sheepshead, smallmouth buffalo, and spotted seatrout mercury concentrations do not exceed DSHS guidelines for protection of human health. Therefore, consumption of these species containing only mercury **poses no apparent risk to human health**.

4. One of two black drum samples contained mercury exceeding the DSHS guidelines for protection of human health. Due to the small sample size, the SALG risk assessors are unable to characterize adequately health risks associated with consuming black drum from the Arroyo Colorado. Therefore, the SALG risk assessors characterize the likelihood of adverse health effects from regular consumption of black drum from the Arroyo Colorado as of **unknown significance to human health.**

5. One longnose gar sample contained mercury exceeding the DSHS guidelines for protection of human health. Regular or long-term consumption of longnose gar may result in adverse systemic health effects. Based on this result and review of the 2006 mercury concentrations, consumption of longnose gar containing mercury **poses an apparent risk to human health.**

6. Black drum, blue catfish, common carp, flathead catfish, hardhead catfish, longnose gar, red drum, sheepshead, and spotted seatrout PCB concentrations do not exceed the DSHS guidelines for protection of human health. Therefore, consumption of these species of fish **poses no apparent risk to human health**.

7. Smallmouth buffalo mean PCB concentrations exceed the DSHS guidelines for protection of human health upstream of the Port of Harlingen. Regular or long-term consumption of smallmouth buffalo may result in adverse systemic health effects. Therefore, consumption of smallmouth buffalo **poses apparent risk to human health**.

8. Consumption of multiple inorganic and/or organic contaminants (i.e., PCDDs/PCDFs and PCBs) observed in smallmouth buffalo does increase the likelihood of systemic health risks. Regular or long-term consumption of smallmouth buffalo may result in adverse systemic health effects. Therefore, consumption smallmouth buffalo from the Arroyo Colorado **poses an apparent risk to human health**.

9. Consumption of multiple inorganic and/or organic contaminants observed in fish does increase the likelihood of carcinogenic health risks. However, these risks do not exceed the DSHS guidelines for protection of human health. The SALG risk assessors conclude that consuming fish containing multiple contaminants at concentrations near those observed in fish from the Arroyo Colorado does not significantly increase the risk of cancer.

RECOMMENDATIONS

Risk managers at the DSHS have established criteria for issuing fish consumption advisories based on approaches suggested by the USEPA.[12, 15, 44] Risk managers at the DSHS may decide to take action to protect public health if a risk characterization confirms that people can eat four or fewer meals per month (adults: eight-ounces per meal; children: four-ounces per meal) of fish or shellfish from a water body under investigation. Risk management recommendations may be in the form of consumption advice or a ban on possession of fish from the affected water body. Fish or shellfish possession bans are enforceable under subchapter D of the Texas Health and Safety Code, part 436.061(a).[45] Declarations of prohibited harvesting areas are enforceable under the Texas Health and Safety Code, Subchapter D, parts 436.091 and 436.101.[45] The DSHS consumption advice carries no penalty for noncompliance. Consumption advisories, instead, inform the public of potential health hazards associated with consuming contaminated fish or shellfish from Texas waters. With this information, people can make informed decisions about whether and/or how much, contaminated fish or shellfish, they wish to consume. The SALG concludes from this risk characterization that consuming longnose gar and smallmouth buffalo from the Arroyo Colorado **poses an apparent hazard to public health.** Therefore, SALG risk assessors recommend that:

1. People should not consume longnose gar from the Arroyo Colorado upstream of the Port of Harlingen (Table 13). The SALG risk assessors recommend continuation of existing consumption advice for longnose gar due to the variability of mercury, DDT (total), and PCB concentrations and the small sample size assessed.

2. Pregnant women, women who may become pregnant, women who are nursing infants, and children less than 12 years of age or who weigh less than 75 pounds should not consume smallmouth buffalo from the Arroyo Colorado upstream of the Port of Harlingen.

3. Women past childbearing age and adult men may consume up to two eight-ounce meals per month of smallmouth buffalo from the Arroyo Colorado upstream of the Port of Harlingen.

4. As resources become available, the DSHS should continue to monitor fish from the Arroyo Colorado for changes or trends in contaminants of concern or contaminant concentrations that would require a change in consumption advice.

PUBLIC HEALTH ACTION PLAN

Communication to the public of new and continuing possession bans or consumption advisories, or the removal of either, is essential to effective management of risk from consuming contaminated fish. In fulfillment of the responsibility for communication, the DSHS takes several steps.

- The agency publishes fish consumption advisories and bans in a booklet available to the public through the SALG. To receive the booklet and/or the data, please contact the SALG at 512-834-6757.[46]
- 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.[47] The SALG regularly updates this Web site.
- The DSHS also provides the USEPA (http://epa.gov/waterscience/fish/advisories/), the TCEQ (http://www.tceq.state.tx.us), and the TPWD (http://www.tpwd.state.tx.us) with information on all consumption advisories and possession bans. Each year, the TPWD informs the public of consumption advisories and fishing bans on its Web site and in an official downloadable PDF file containing general hunting and fishing regulations available at http://www.tpwd.state.tx.us/publications/pwdpubs/media/outdoorannual_2014_15.pdf. A booklet containing this information is available at all establishments selling Texas fishing licenses.[48]

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

- Readers may direct questions about the scientific information or recommendations in this risk characterization to the SALG at 512-834-6757 or may find the information at the SALG's Web site (http://www.dshs.state.tx.us/seafood). Secondarily, one may address inquiries to the Environmental and Injury Epidemiology and Toxicology Unit of DSHS (800-588-1248).
- The USEPA's IRIS Web site (http://www.epa.gov/iris/) contains information on environmental contaminants found in food and environmental media.
- The ATSDR, Division of Toxicology (888-42-ATSDR or 888-422-8737 or the ATSDR's Web site (http://www.atsdr.cdc.gov) supplies brief information via ToxFAQs.™ ToxFAQs™ are available on the ATSDR Web site in either English or Spanish (http://www.atsdr.cdc.gov/toxfaqs/index.asp). The ATSDR also publishes more in-depth reviews of many toxic substances in its *Toxicological Profiles* (ToxProfiles™) http://www.atsdr.cdc.gov/toxprofiles/index.asp. To request a copy of the ToxProfiles™ CD-ROM, PHS, or ToxFAQs™ call 1-800-CDC-INFO (800-232-4636) or email a request to cdcinfo@cdc.gov.

Figure 1. 2013 Arroyo Colorado Sample Sites

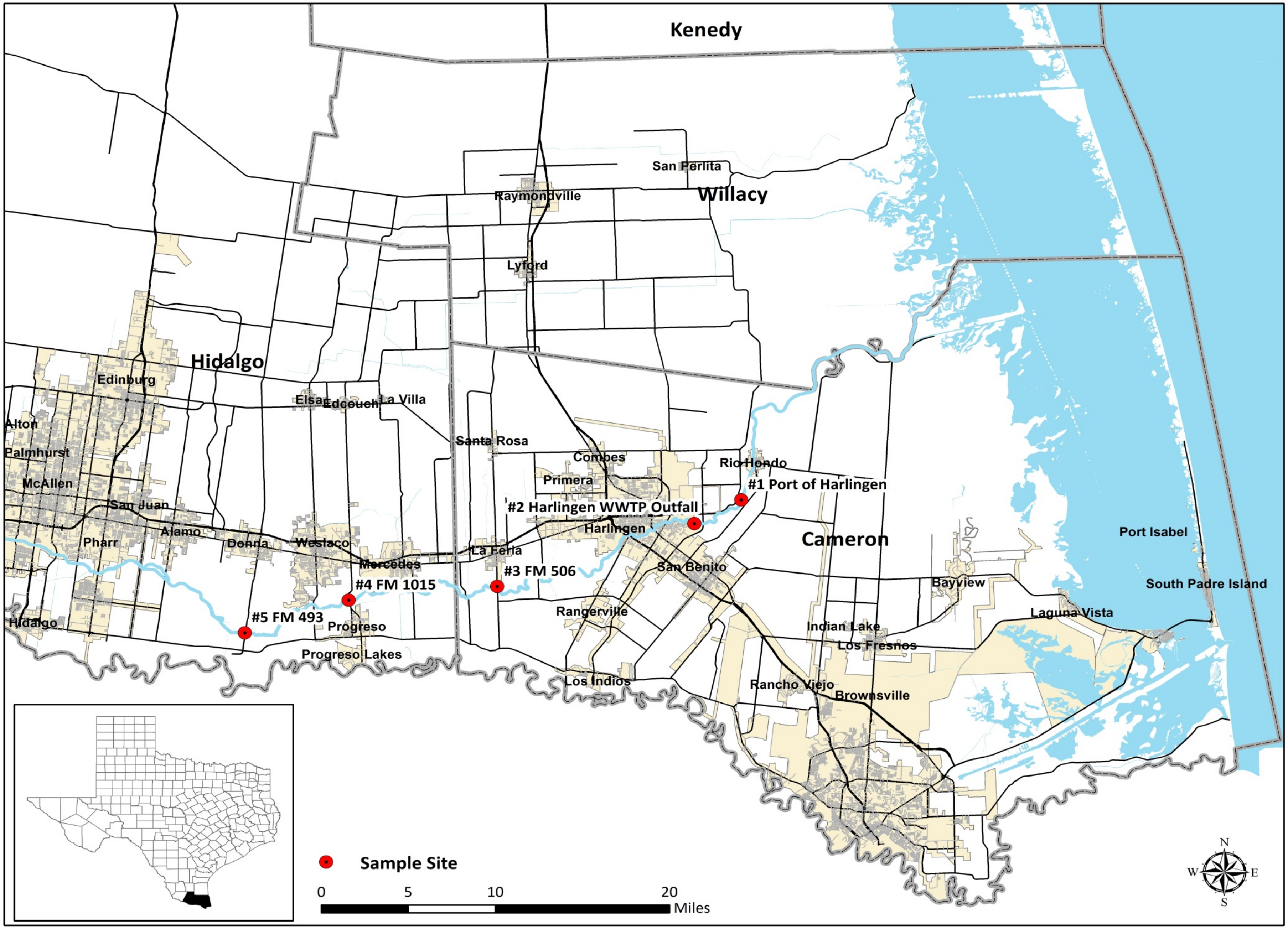


Figure 2. The relationship between mercury concentration and total length for fish collected from the Arroyo Colorado, Texas, 2013.

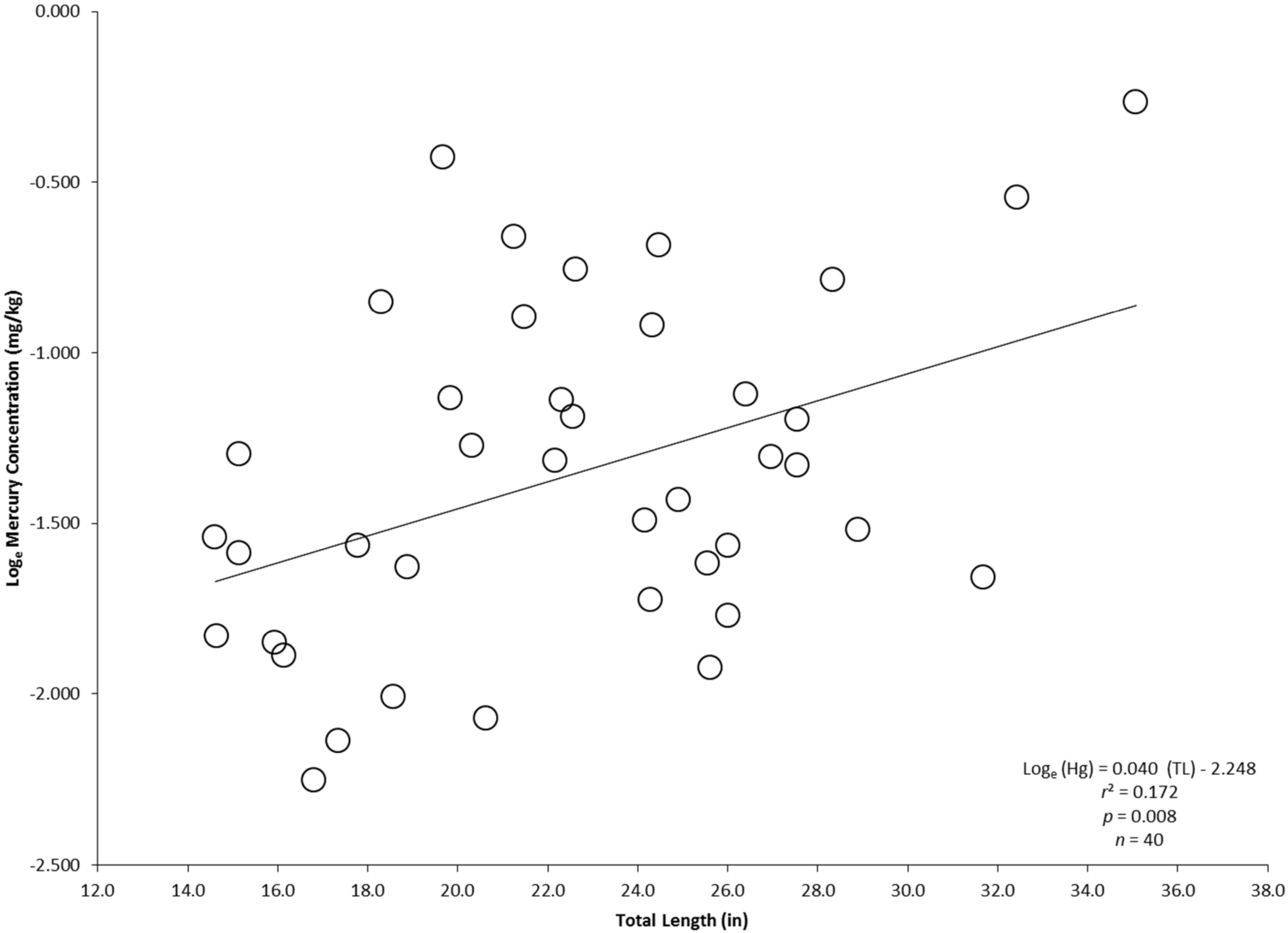


Figure 3. The relationship between DDT (total) concentration and total length for fish collected from the Arroyo Colorado, Texas, 2013.

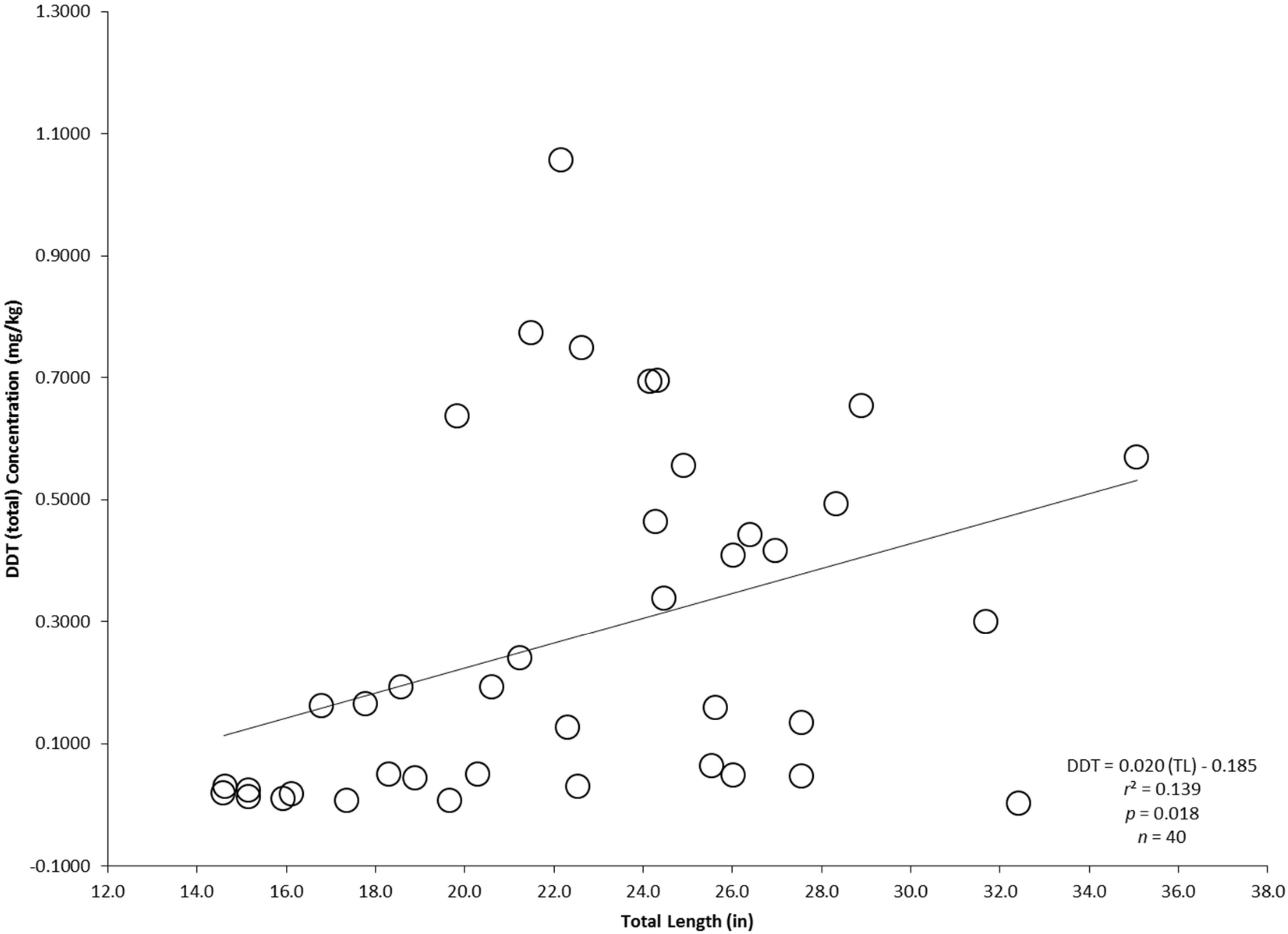


Figure 4. The relationship between DDT (total) concentration and percent lipids for fish collected from the Arroyo Colorado, Texas, 2013.

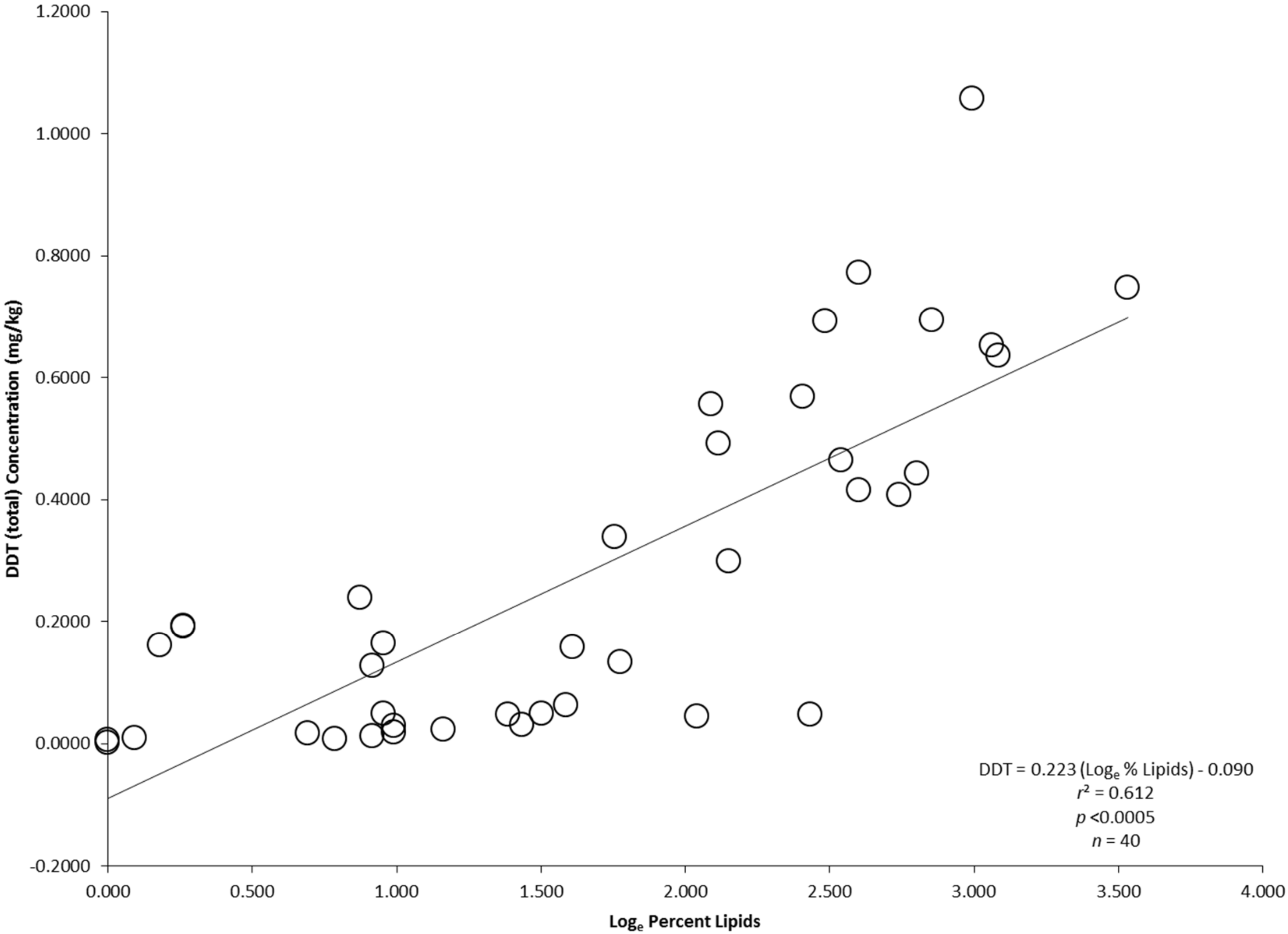


Figure 5. Mean Percent lipids and DDT (total) concentration by species Arroyo Colorado, Texas, 2013.

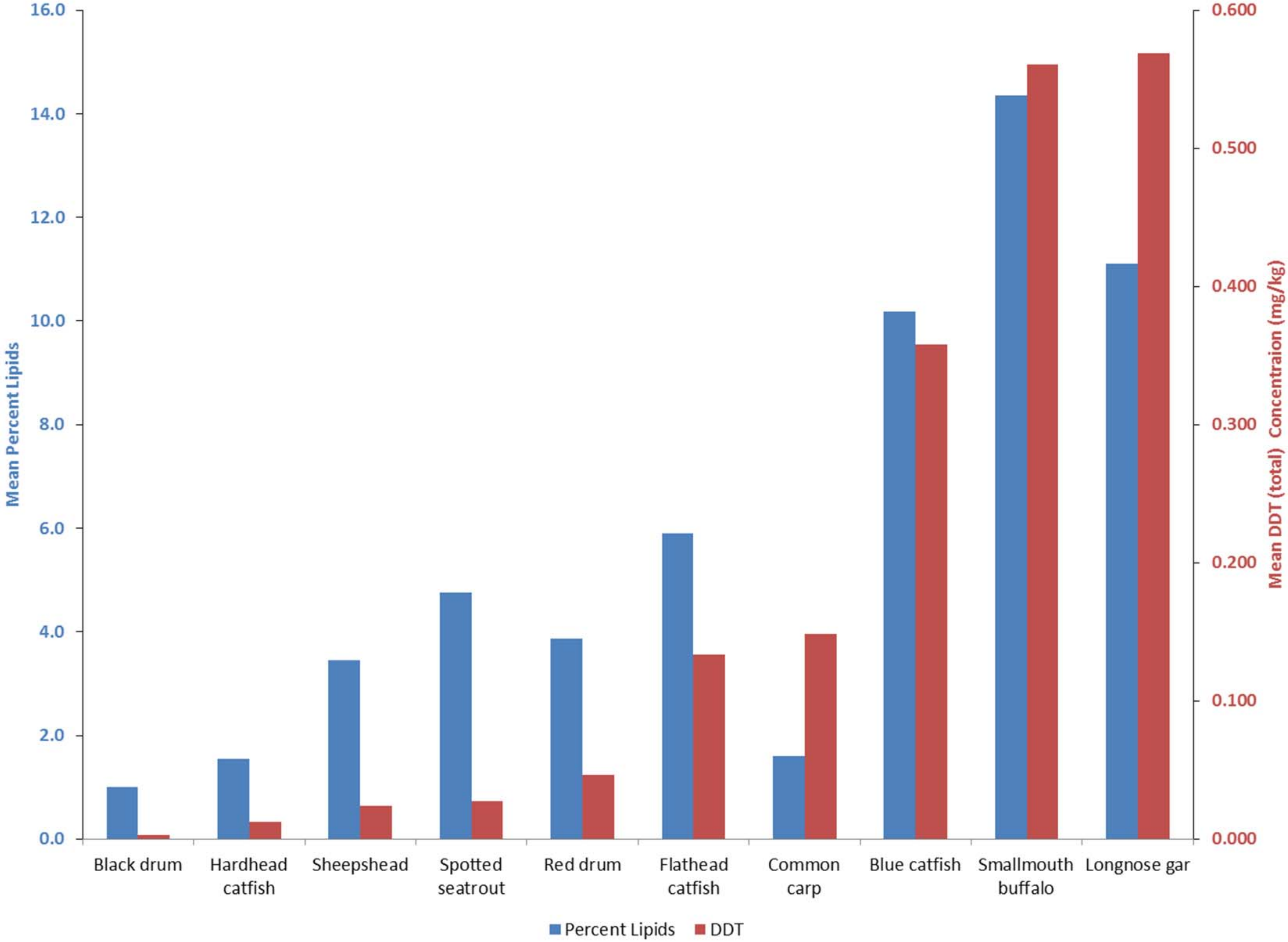


Figure 6. Means plot of DDT (total; mg/kg, wet wt.) in fish by sample site collected from the Arroyo Colorado, Texas 2013. The error bars denote the standard error of the mean.

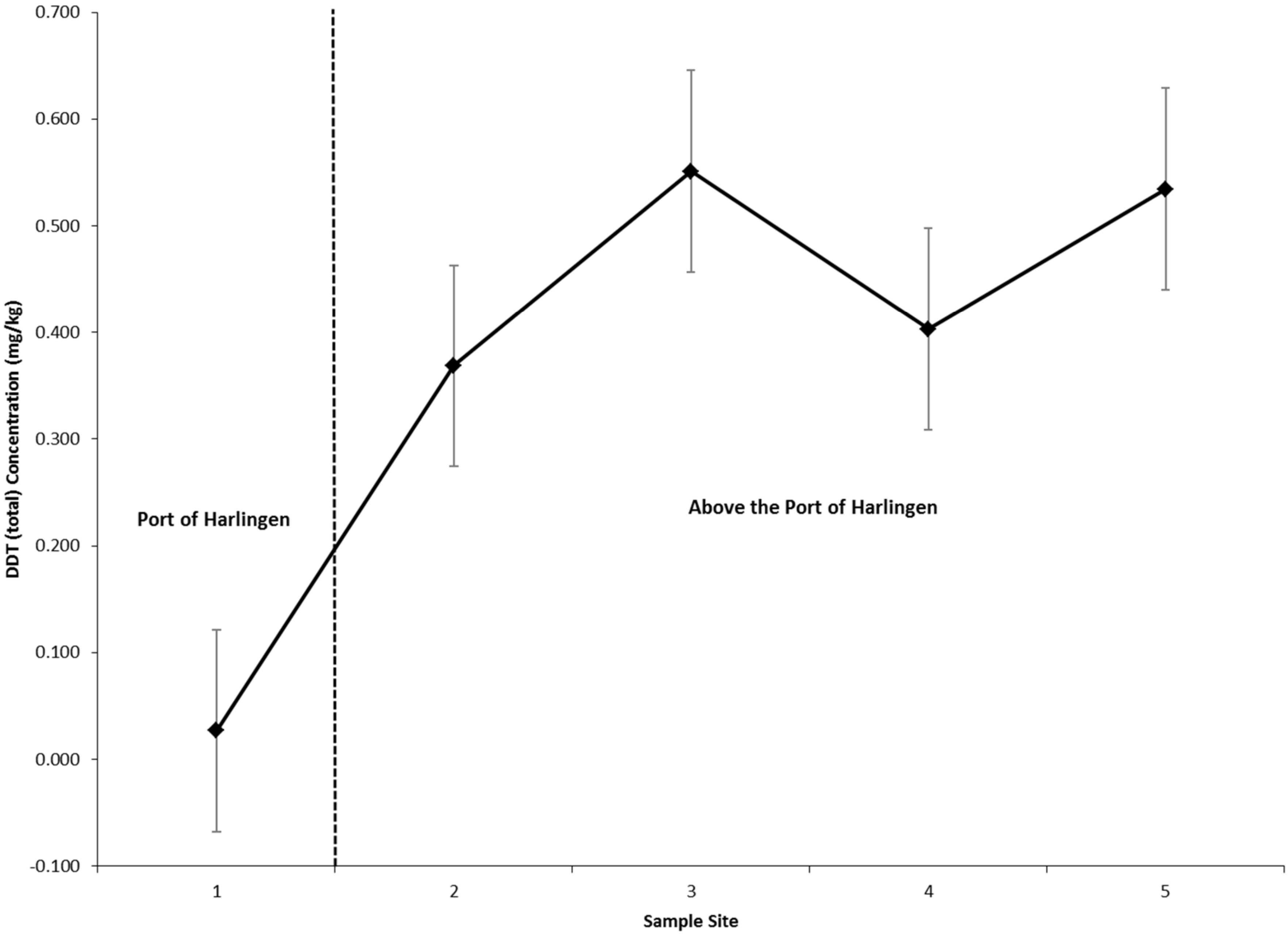


Figure 7. The relationship between PCB concentration and total length for fish collected from the Arroyo Colorado, Texas, 2013.

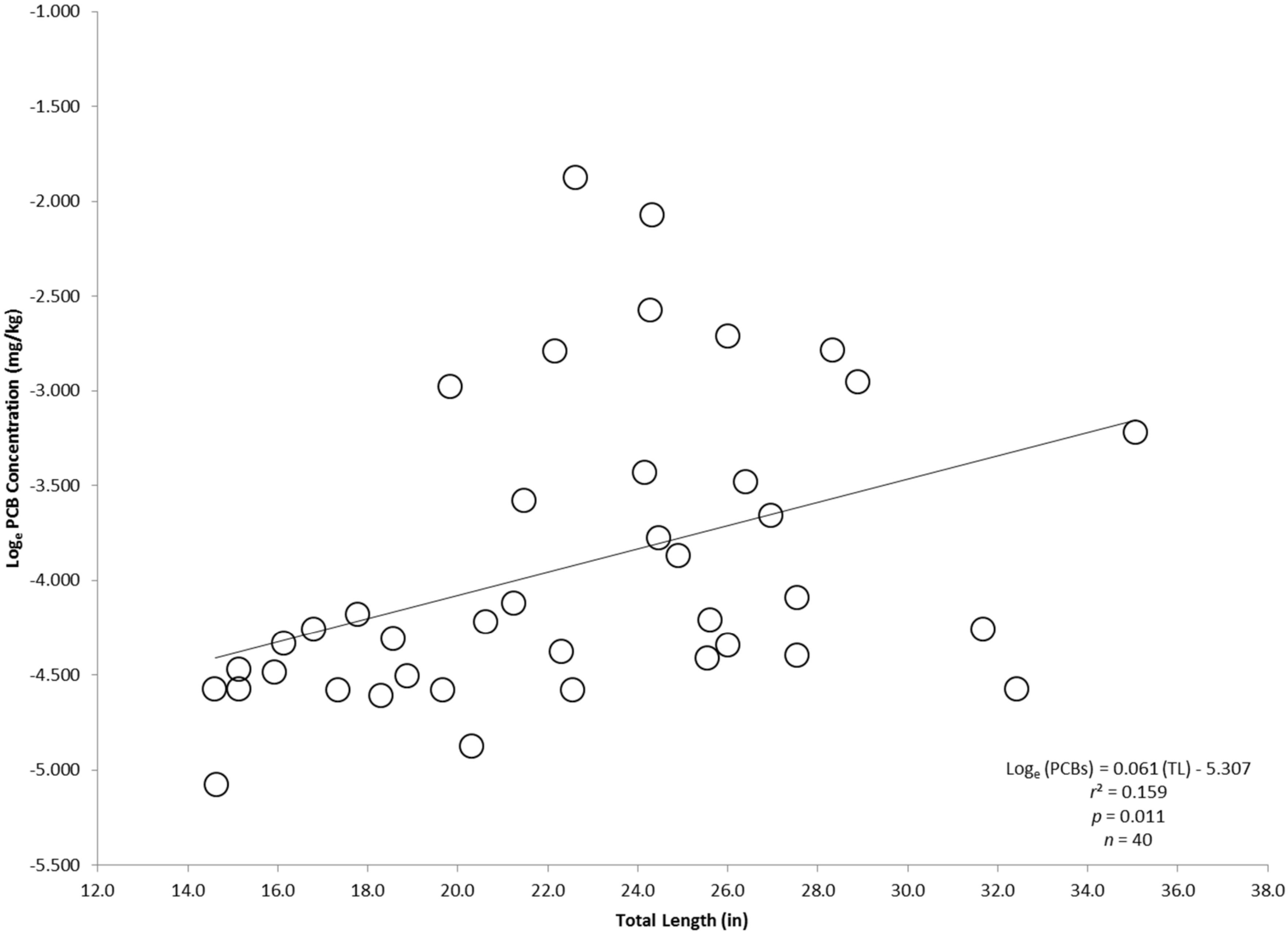


Figure 8. The relationship between PCB concentration and percent lipids for fish collected from the Arroyo Colorado, Texas, 2013.

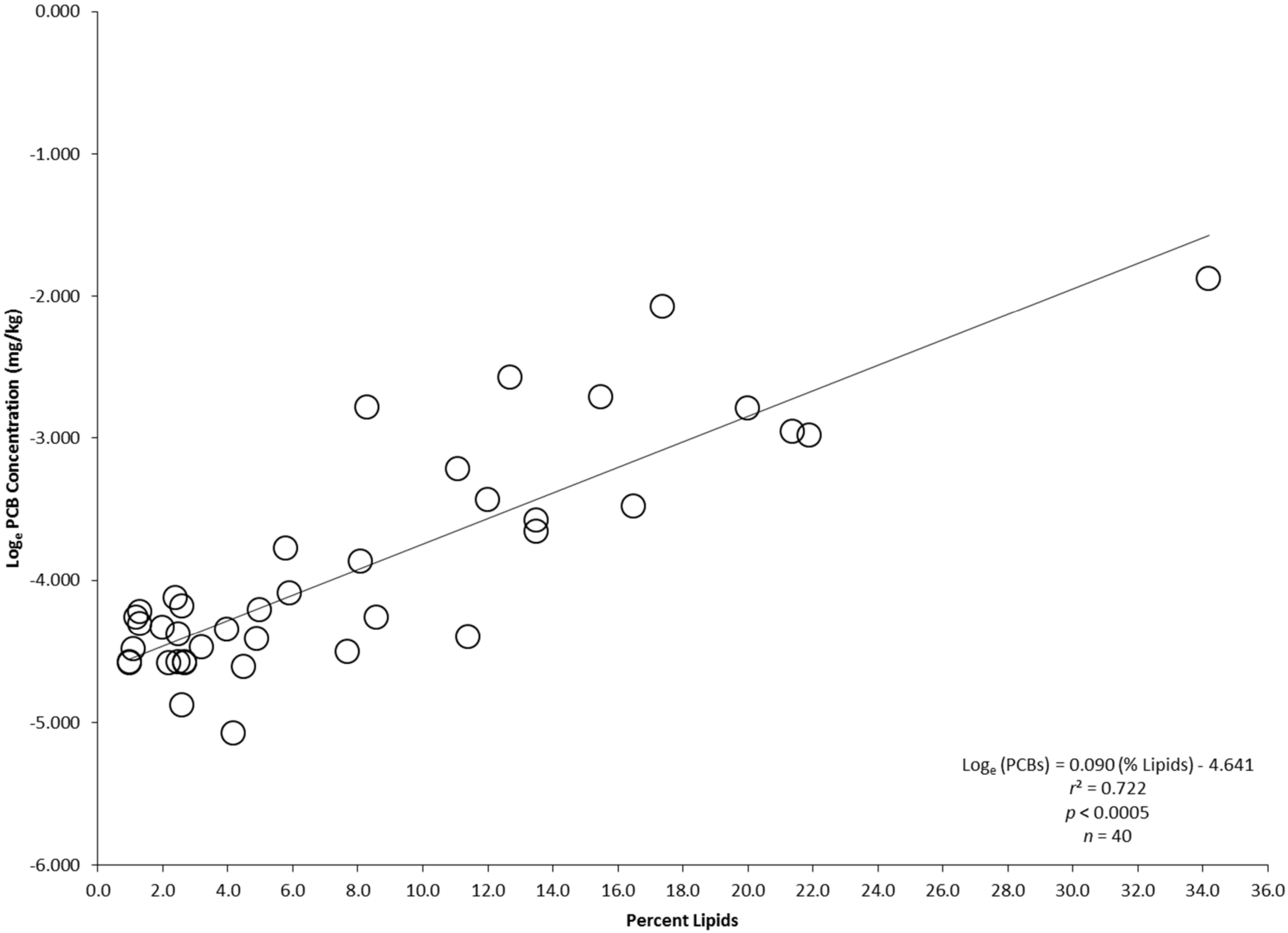


Figure 9. Mean Percent lipids and PCB concentration by species Arroyo Colorado, Texas, 2013.

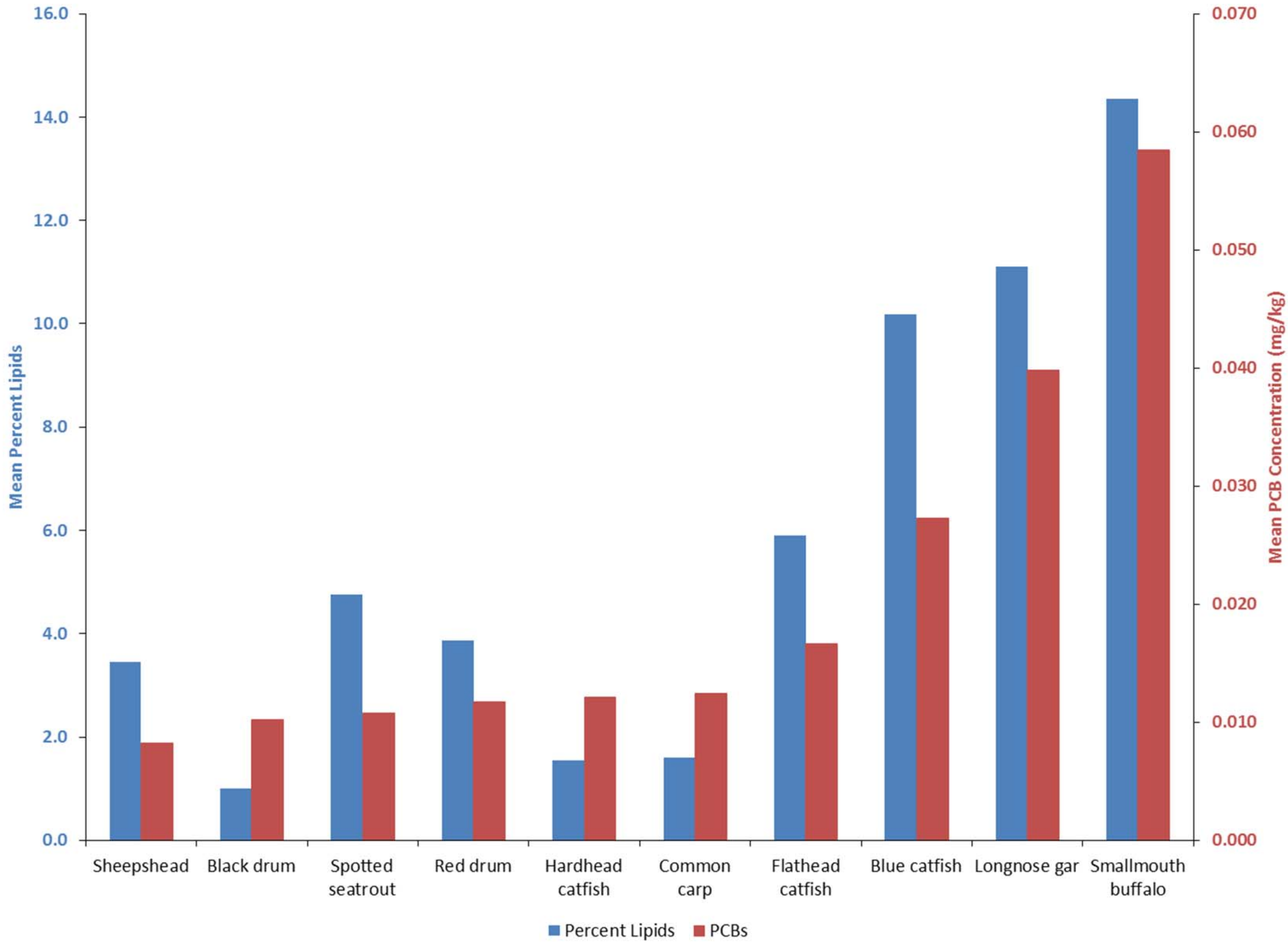


Figure 10. Means plot of PCBs (mg/kg, wet wt.) in fish by sample site collected from the Arroyo Colorado, Texas 2013. The error bars denote the standard error of the mean.

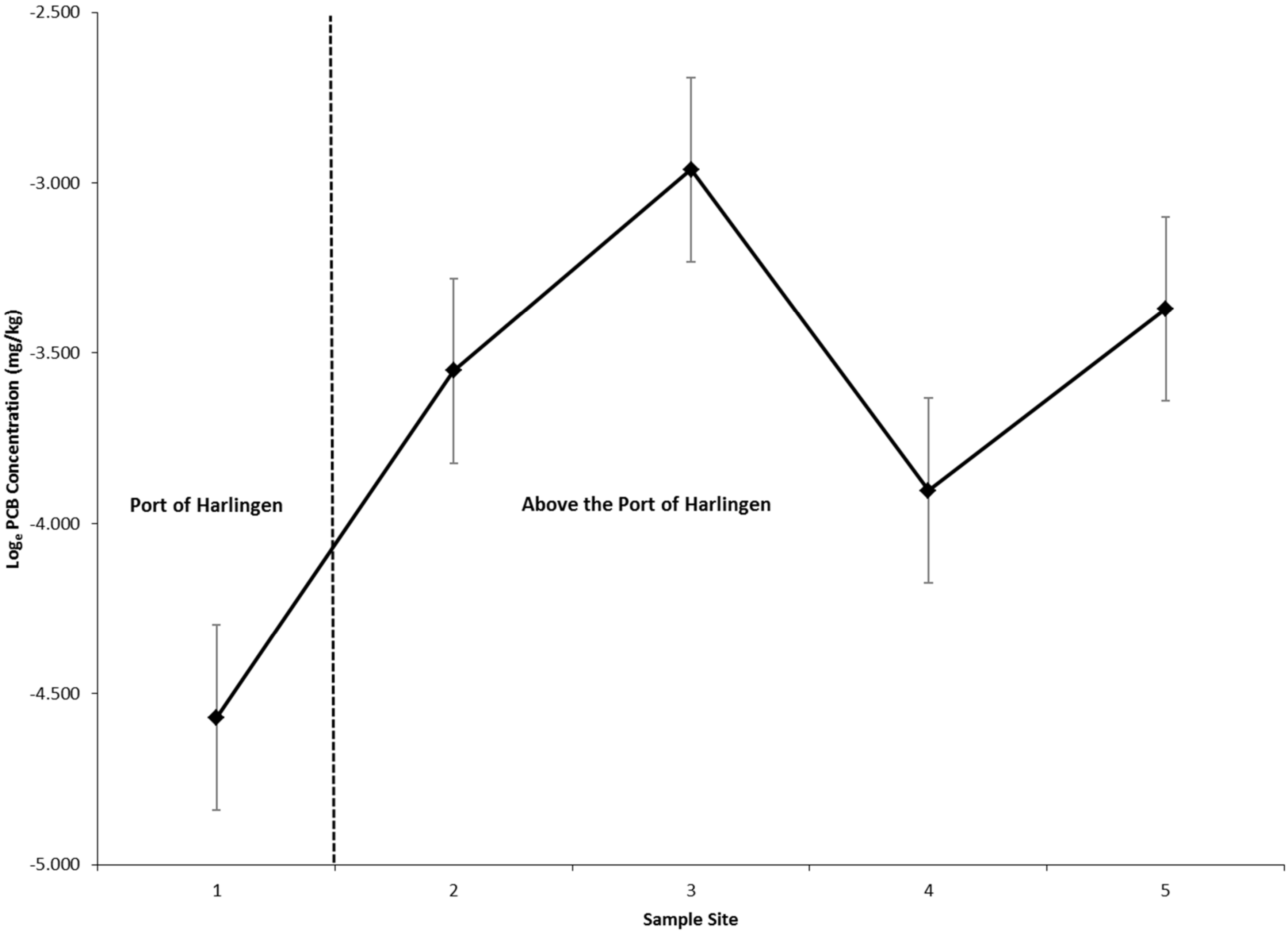


Figure 11. Box-and-whisker plot of DDT (total; mg/kg, wet wt.) in fish from the Arroyo Colorado, Texas for the 2006 and 2013 sampling events.

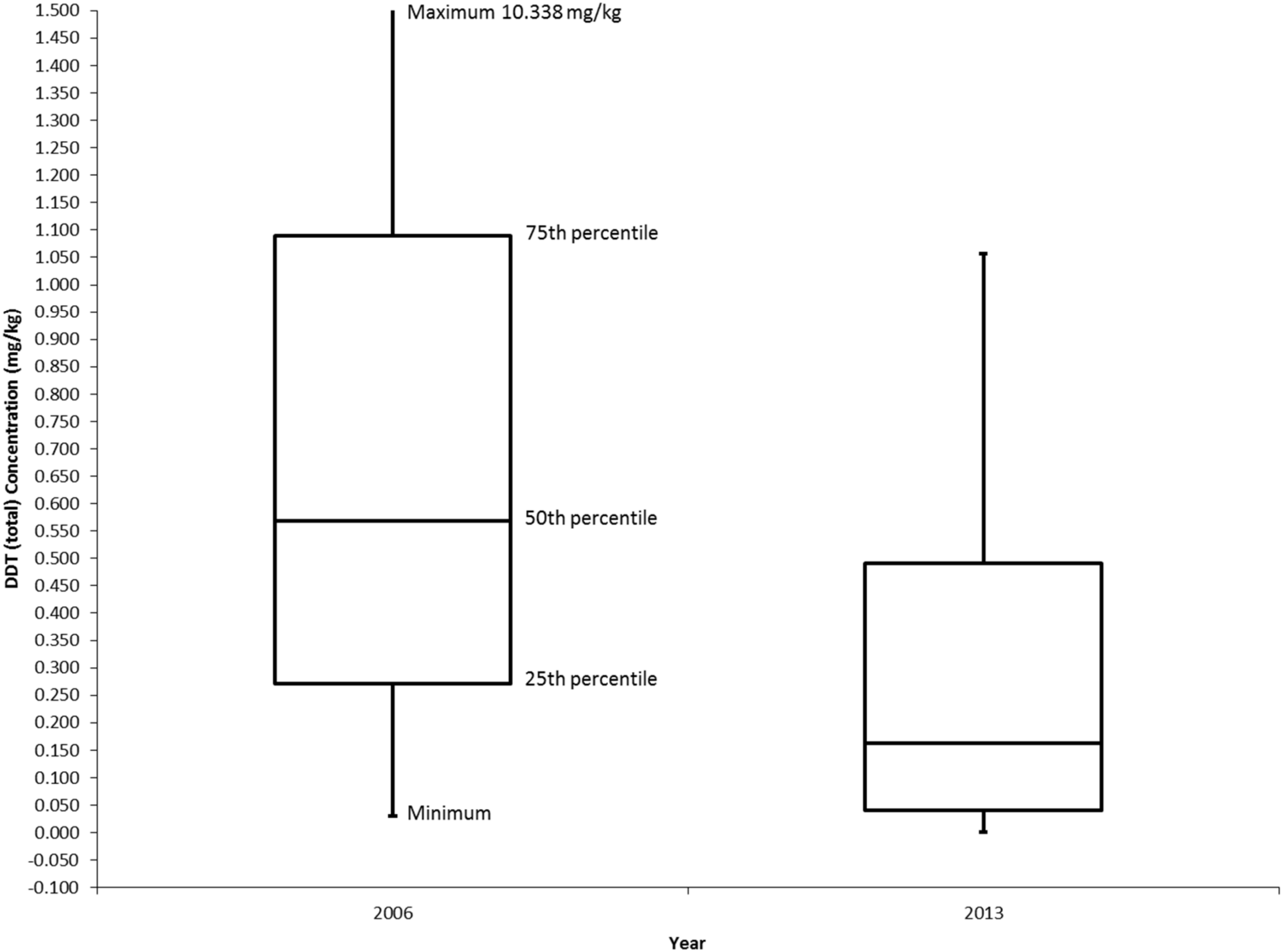


Figure 12. Box-and-whisker plot of DDT (total; mg/kg, wet wt.) in smallmouth buffalo from the Arroyo Colorado, Texas for the 2006 and 2013 sampling events.

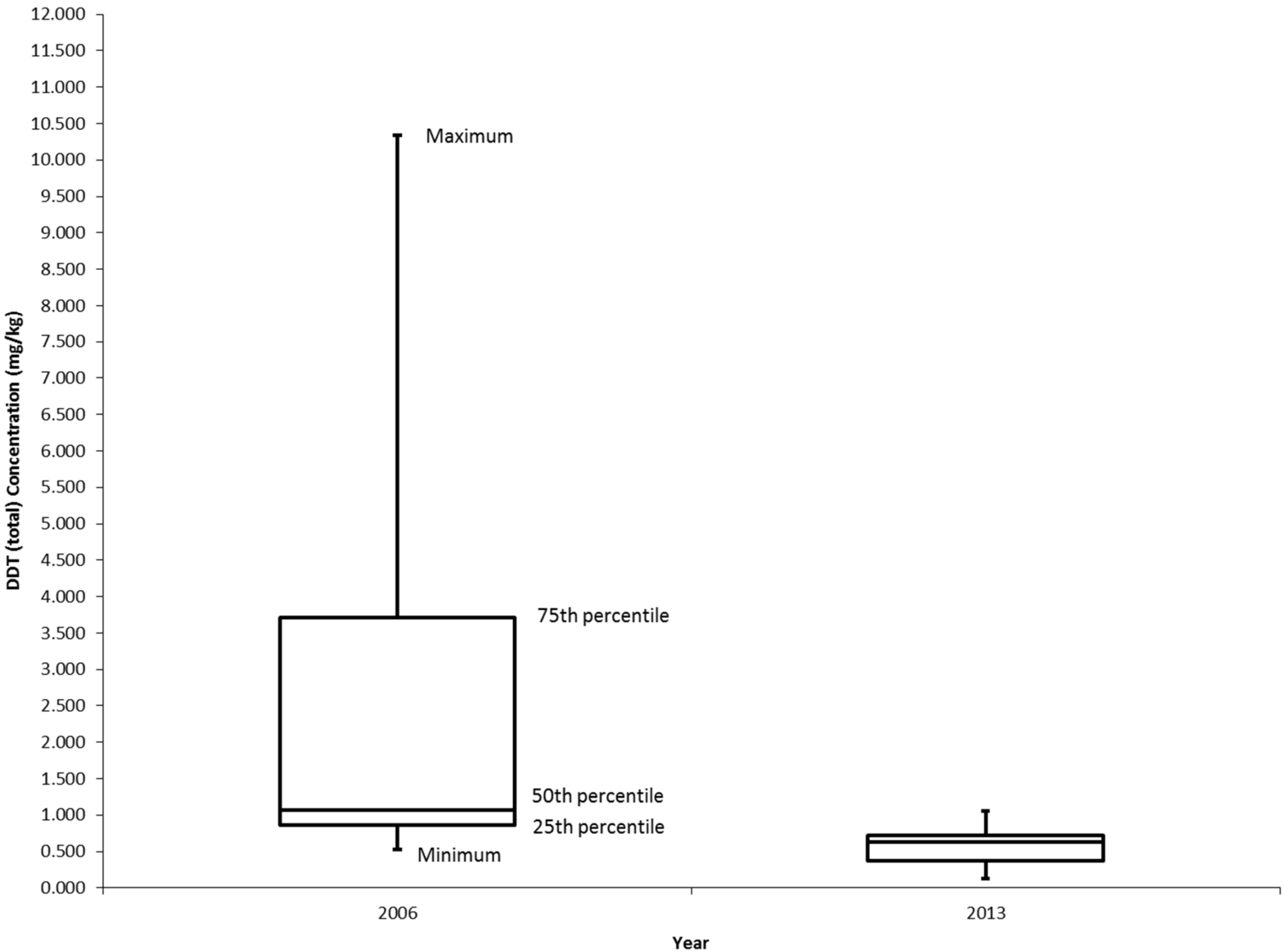


Figure 13. Box-and-whisker plot of PCBs (mg/kg, wet wt.) in fish from the Arroyo Colorado, Texas for the 2006 and 2013 sampling events.

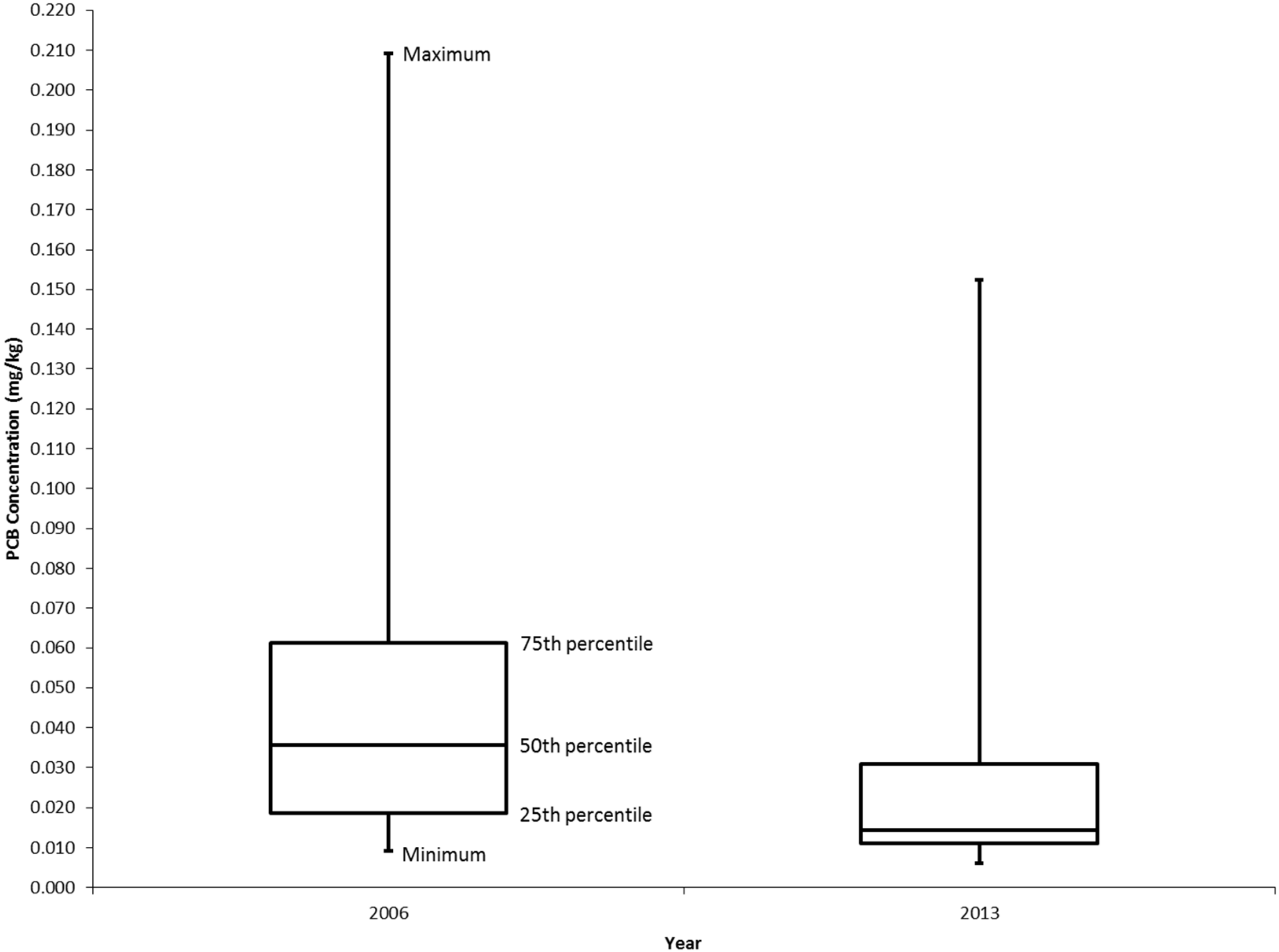
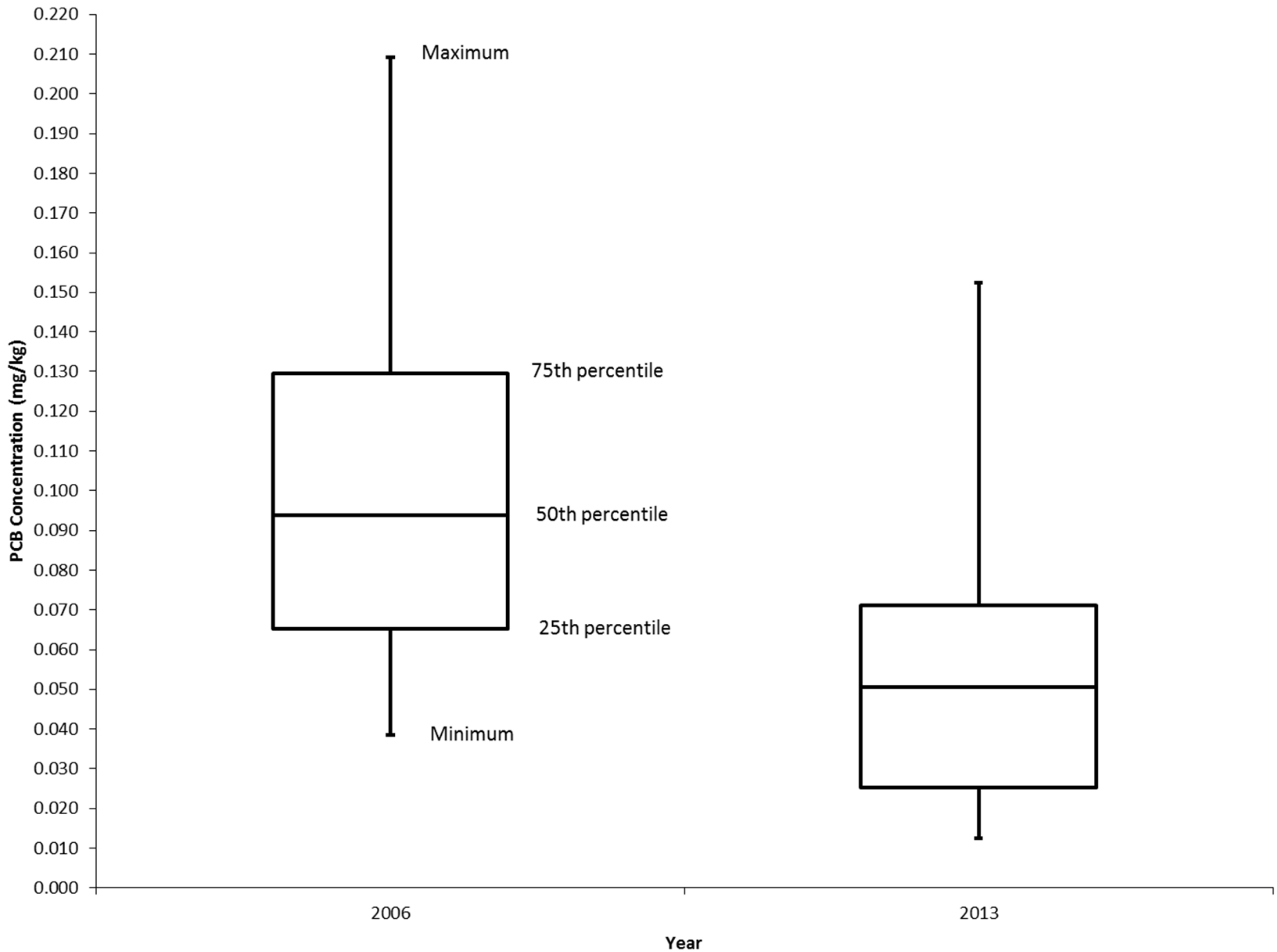


Figure 14. Box-and-whisker plot of PCBs (mg/kg, wet wt.) in smallmouth buffalo from the Arroyo Colorado, Texas for the 2006 and 2013 sampling events.



TABLES

Table 1. Fish samples collected from the Arroyo Colorado 2013. Sample number, species, length, and weight recorded for each sample.

Sample Number	Species	Length (mm)	Weight (g)
Site 1 Arroyo Colorado at Port of Harlingen			
ARC1	Black drum	824	10200
ARC2	Black drum	500	1545
ARC3	Sheepshead	372	1127
ARC4	Common carp	516	1957
ARC5	Red drum	661	3509
ARC6	Spotted seatrout	700	3834
ARC7	Hardhead catfish	405	767
ARC8	Spotted seatrout	465	976
ARC9	Red drum	649	3363
ARC10	Sheepshead	371	892
ARC11	Hardhead catfish	410	566
ARC12	Spotted seatrout	441	863
ARC13	Spotted seatrout	385	494
ARC14	Spotted seatrout	385	538
ARC15	Red drum	573	2115
Site 2 Arroyo Colorado near Harlingen WWTP Outfall			
ARC41	Blue catfish	734	5246
ARC42	Blue catfish	805	6798
ARC43	Blue catfish	671	3297
ARC44	Blue catfish	685	3740
ARC45	Blue catfish	633	2527
ARC46	Blue catfish	480	1079
ARC47	Blue catfish	452	772
ARC48	Blue catfish	651	4004
ARC49	Flathead catfish	700	5305
ARC50	Smallmouth buffalo	661	4600
ARC51	Smallmouth buffalo	617	3648
ARC52	Smallmouth buffalo	618	4206
Site 3 Arroyo Colorado at FM 506			
ARC16	Longnose gar	891	2367
ARC17	Smallmouth buffalo	575	3790
ARC18	Smallmouth buffalo	622	3727

Table 1. cont. Fish samples collected from the Arroyo Colorado 2013. Sample number, species, length, and weight recorded for each sample.			
Sample Number	**Species**	**Length (mm)**	**Weight (g)**
Site 4 Arroyo Colorado at FM 1015			
ARC26	Smallmouth buffalo	563	3576
ARC33	Smallmouth buffalo	614	3935
ARC34	Smallmouth buffalo	567	3301
ARC37	Common carp	472	1287
ARC38	Common carp	427	1043
ARC39	Common carp	524	1891
Site 5 Arroyo Colorado FM 493			
ARC19	Blue catfish	720	NA
ARC21	Smallmouth buffalo	504	2053
ARC22	Smallmouth buffalo	540	2195
ARC23	Smallmouth buffalo	546	2732

Table 2.1. Arsenic (mg/kg) in fish collected from the Arroyo Colorado 2013.					
Species	**Number Detected/ Number Tested**	**Total Arsenic Mean ± S.D. (Min-Max)**	**Inorganic Arsenic Mean[h]**	**HAC Value (nonca) and HAC Value (ca; mg/kg)[i]**	**Basis for Comparison Value**
Blue catfish	1/1	0.123	0.012	0.700 0.363	EPA Chronic Oral RfD for Inorganic Arsenic — 0.0003 mg/kg–day EPA Oral Slope Factor for Inorganic Arsenic — 1.5 per mg/kg–day
Longnose gar	1/1	0.347	0.035		
Smallmouth buffalo	1/1	0.184	0.018		
Spotted seatrout	1/1	0.468	0.047		
All fish combined	4/4	0.281±0.157 (0.123-0.468)	0.028		

[h] *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.*

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

Table 2.2. Inorganic contaminants (mg/kg) in fish collected from the Arroyo Colorado 2013.				
Species	**Number Detected/ Number Tested**	**Mean ± S.D. (Min-Max)**	**HAC Value (nonca; mg/kg)**	**Basis for Comparison Value**
Cadmium				
Blue catfish	1/1	BDL	0.233	ATSDR Chronic Oral MRL— 0.0001 mg/kg–day
Longnose gar	1/1	BDL		
Smallmouth buffalo	0/1	ND		
Spotted seatrout	1/1	BDL		
All fish combined	4/4	0.012±0.001 (ND-BDL)		
Copper				
Blue catfish	1/1	0.169	334	Based on the Tolerable Upper Intake Level (UL) — 0.143 mg/kg–day[j]
Longnose gar	1/1	0.077		
Smallmouth buffalo	1/1	0.227		
Spotted seatrout	1/1	0.129		
All fish combined	4/4	0.151±0.063 (0.077-0.227)		
Lead				
Blue catfish	0/1	ND	N/A	N/A
Longnose gar	0/1	ND		
Smallmouth buffalo	0/1	ND		
Spotted seatrout	0/1	ND		
All fish combined	0/4	ND		
Selenium				
Blue catfish	1/1	0.327	6	EPA Chronic Oral RfD — 0.005 mg/kg–day ATSDR Chronic Oral MRL — 0.005 mg/kg–day UL: 0.400 mg/day (0.005 mg/kg–day) RfD or MRL/2 — (0.005 mg/kg –day/2= 0.0025 mg/kg–day)[k, 49]
Longnose gar	1/1	0.456		
Smallmouth buffalo	1/1	0.703		
Spotted seatrout	1/1	0.523		
All fish combined	4/4	0.502±0.157 (0.327-0.703)		

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

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

Table 2.3. Zinc (mg/kg) in fish collected from the Arroyo Colorado 2013.				
Species	**Number Detected/ Number Tested**	**Mean ± S.D. (Min-Max)**	**HAC Value (nonca; mg/kg)**	**Basis for Comparison Value**
Zinc				
Blue catfish	1/1	4.348	700	EPA Chronic Oral RfD — 0.3 mg/kg–day
Longnose gar	1/1	2.322		
Smallmouth buffalo	1/1	3.100		
Spotted seatrout	1/1	7.266		
All fish combined	4/4	4.259±2.171 (2.322-7.266)		

Table 2.4. Mercury (mg/kg) in fish collected from the Arroyo Colorado by sample site, 2013.				
Species	**Number Detected/ Number Tested**	**Mean ± S.D. (Min-Max)**	**HAC Value (nonca; mg/kg)**	**Basis for Comparison Value**
Site 1 Arroyo Colorado at Port of Harlingen				
Black drum	2/2	0.616± 0.051 (0.580-**0.652**[1])	0.7	ATSDR Chronic Oral MRL for Methylmercury — 0.0003 mg/kg–day
Common carp	1/1	0.280		
Hardhead catfish	2/2	0.154±0.004 (0.151-0.157)		
Red drum	3/3	0.224±0.071 (0.170-0.305)		
Sheepshead	2/2	0.187± 0.038 (0.160-0.214)		
Spotted seatrout	5/5	0.257± 0.113 (0.118-0.427)		
All fish combined	15/15	0.277±0.159 (0.118-**0.652**)		
Site 2 Arroyo Colorado near Harlingen WWTP Outfall				
Blue catfish	8/8	0.224±0.055 (0.146-0.325)	0.7	ATSDR Chronic Oral MRL for Methylmercury — 0.0003 mg/kg–day
Flathead catfish	1/1	0.302		
Smallmouth buffalo	3/3	0.262±0.119 (0.178-0.398)		
All fish combined	12/12	0.240±0.072 (0.146-0.398)		
Site 3 Arroyo Colorado at FM 506				
Longnose gar	1/1	**0.767**	0.7	ATSDR Chronic Oral MRL for Methylmercury — 0.0003 mg/kg–day
Smallmouth buffalo	2/2	0.487±0.025 (0.469-0.504)		
All fish combined	3/3	0.580±0.163 (0.469-**0.767**)		
Site 4 Arroyo Colorado at FM 1015				
Common carp	3/3	0.122±0.015 (0.105-0.134)	0.7	ATSDR Chronic Oral MRL for Methylmercury — 0.0003 mg/kg–day
Smallmouth buffalo	3/3	0.271±0.048 (0.225-0.320)		
All fish combined	6/6	0.196±0.088 (0.105-0.320)		
Site 5 Arroyo Colorado at FM 493				
Blue catfish	1/1	0.456	0.7	ATSDR Chronic Oral MRL for Methylmercury — 0.0003 mg/kg–day
Smallmouth buffalo	3/3	0.416±0.098 (0.322-0.517)		
All fish combined	4/4	0.426±0.082 (0.322-0.517)		

[1] *Emboldened numbers denote that mercury concentrations equal and/or exceed the DSHS HAC value for mercury.*

Table 2.5. Mercury (mg/kg) in fish collected from the Arrroyo Colorado by species, 2013.				
Species	**Number Detected/ Number Tested**	**Mean ± S.D. (Min-Max)**	**HAC Value (nonca; mg/kg)**	**Basis for Comparison Value**
Black drum	2/2	0.616± 0.051 (0.580-**0.652**[m])	0.7	ATSDR Chronic Oral MRL for Methylmercury — 0.0003 mg/kg–day
Blue catfish	9/9	0.250±0.093 (0.146-0.456)		
Common carp	4/4	0.161±0.080 (0.105-0.280)		
Flathead catfish	1/1	0.302		
Hardhead catfish	2/2	0.154±0.004 (0.151-0.157)		
Longnose gar	1/1	**0.767**		
Red drum	3/3	0.224±0.071 (0.170-0.305)		
Sheepshead	2/2	0.187± 0.038 (0.160-0.214)		
Smallmouth buffalo	11/11	0.347±0.120 (0.178-0.517)		
Spotted seatrout	5/5	0.257± 0.113 (0.118-0.427)		
All fish combined	40/40	0.291±0.155 (0.105-**0.767**)		
All fish combined (upstream of POH)	25/25	0.300±0.155 (0.105-**0.767**)		

[m] *Emboldened numbers denote that mercury concentrations equal and/or exceed the DSHS HAC value for mercury.*

Table 3.1. Pesticides (mg/kg) in fish collected from the Arroyo Colorado by species, 2013.				
Species	**Number Detected/ Number Tested**	**Mean ± S.D. (Min-Max)**	**HAC Value (nonca) and HAC Value (ca; mg/kg)**	**Basis for Comparison Value**
Chlordane (Total)				
Black drum	2/2	BDL	1.167 1.556	EPA Chronic Oral RfD — 0.0005 mg/kg–day EPA Oral Slope Factor — 0.35 per mg/kg–day
Blue catfish	9/9	0.015±0.008 (0.004-0.031)		
Common carp	4/4	0.003±0.001 (0.002-0.004)		
Flathead catfish	1/1	0.011		
Hardhead catfish	2/2	BDL		
Longnose gar	1/1	0.015		
Red drum	3/3	0.003±0.0008 (0.002-0.004)		
Sheepshead	2/2	0.002±0.0009 (0.001-0.003)		
Smallmouth buffalo	11/11	0.022±0.014 (0.004-0.052)		
Spotted seatrout	5/5	0.002±0.002 (0.0006-0.004)		
All fish combined	40/40	0.011±0.012 (0.0006-0.052)		
All fish combined (upstream of POH)	25/25	0.016±0.012 (0.002-0.052)		
Chlorpyrifos				
Black drum	1/2	ND-BDL	2.333	EPA Chronic Oral RfD — 1.0E-3 mg/kg–day
Blue catfish	7/9	0.002±0.002 (ND-0.007)		
Common carp	3/4	0.0002±0.0001 (ND-0.0003)		
Flathead catfish	1/1	0.0005		
Hardhead catfish	0/2	ND		
Longnose gar	1/1	0.004		
Red drum	3/3	BDL		
Sheepshead	1/2	ND-BDL		
Smallmouth buffalo	10/11	0.001±0.001 (ND-0.005)		
Spotted seatrout	4/5	0.0001±0.00004 (ND-0.0002)		
All fish combined	31/40	0.0009±0.002 (ND-0.007)		
All fish combined (upstream of POH)	21/25	0.002±0.002 (ND-0.007)		

Table 3.2. Pesticides (mg/kg) in fish collected from Arroyo Colorado by sample site, 2013.				
Species	**Number Detected/ Number Tested**	**Mean ± S.D. (Min-Max)**	**HAC Value (nonca) and HAC Value (ca; mg/kg)**	**Basis for Comparison Value**
Dacthal				
Black drum	2/2	0.003±0.0013 (0.002-0.004)	23.333	EPA Chronic Oral RfD — 1.0E-2 mg/kg–day
Blue catfish	9/9	0.101±0.093 (0.015-0.290)		
Common carp	4/4	0.015±0.007 (0.009-0.025)		
Flathead catfish	1/1	0.045		
Hardhead catfish	2/2	0.004±0.0008 (0.003-0.004)		
Longnose gar	0/1	ND		
Red drum	3/3	0.009±0.002 (0.008-0.011)		
Sheepshead	2/2	0.012±0.004 (0.009-0.015)		
Smallmouth buffalo	10/11	0.200±0.168 (ND-0.520)		
Spotted seatrout	5/5	0.015±0.012 (0.007-0.036)		
All fish combined	38/40	0.084±0.125 (ND-0.520)		
All fish combined (upstream of POH)	23/25	0.128±0.140 (ND-0.520)		
Dieldrin				
Black drum	2/2	0.0002±0.0001 (BDL-0.0003)	0.117 0.034	EPA Chronic Oral RfD — 0.00005 mg/kg–day EPA Oral Slope Factor — 16 per mg/kg–day
Blue catfish	9/9	0.005±0.004 (0.001-0.014)		
Common carp	3/4	0.0008±0.0007 (ND-0.002)		
Flathead catfish	1/1	0.001		
Hardhead catfish	2/2	0.0004±0.00007 (0.0003-0.0004)		
Longnose gar	1/1	0.006		
Red drum	3/3	0.001±0.004 (0.0007-0.001)		
Sheepshead	2/2	0.001±0.0003 (0.0008-0.001)		
Smallmouth buffalo	11/11	0.007±0.005 (0.0009-0.018)		
Spotted seatrout	5/5	0.0009±0.0007 (0.0003-0.002)		
All fish combined	39/40	0.004±0.004 (ND-0.018)		
All fish combined (upstream of POH)	24/25	0.005±0.005 (ND-0.018)		

Table 3.3. Pesticides (mg/kg) in fish collected from Arroyo Colorado by sample site, 2013.				
Species	**Number Detected/ Number Tested**	**Mean ± S.D. (Min-Max)**	**HAC Value (nonca) and HAC Value (ca; mg/kg)**	**Basis for Comparison Value**
Endrin				
Black drum	1/2	0.0002±0.0001 (ND-0.0003)	0.7	EPA Chronic Oral RfD — 3.0E-4 mg/kg–day
Blue catfish	8/9	0.006±0.006 (ND-0.020)		
Common carp	3/4	0.002±0.002 (ND-0.004)		
Flathead catfish	1/1	0.003		
Hardhead catfish	2/2	0.0005±0.00007 (0.0004-0.0005)		
Longnose gar	1/1	0.006		
Red drum	3/3	0.001±0.0004 (0.0008-0.002)		
Sheepshead	2/2	0.001±0.0004 (0.0008-0.001)		
Smallmouth buffalo	11/11	0.010±0.007 (0.0007-0.021)		
Spotted seatrout	5/5	0.0009±0.0008 (0.0003-0.002)		
All fish combined	36/40	0.005±0.006 (ND-0.021)		
All fish combined (upstream of POH)	23/25	0.007±0.006 (ND-0.021)		
Endosulfan II				
Black drum	1/2	ND-BDL	4.667	EPA Chronic Oral RfD — 2.0E-3 mg/kg–day
Blue catfish	8/9	0.014±0.011 (ND-0.034)		
Common carp	1/4	0.0002±0.0002 (ND-0.0004)		
Flathead catfish	1/1	0.004		
Hardhead catfish	0/2	ND		
Longnose gar	1/1	0.011		
Red drum	1/3	0.0002±0.0002 (ND-0.0004)		
Sheepshead	0/2	ND		
Smallmouth buffalo	11/11	0.020±0.014 (0.0009-0.049)		
Spotted seatrout	0/5	ND		
All fish combined	24/40	0.009±0.012 (ND-0.049)		
All fish combined (upstream of POH)	21/25	0.014±0.013 (ND-0.049)		

Table 3.4. DDT (total; mg/kg) in fish collected from the Arroyo Colorado by sample site, 2013.				
Species	**Number Detected/ Number Tested**	**Mean ± S.D. (Min-Max)**	**HAC Value (nonca) and HAC Value (ca; mg/kg)**	**Basis for Comparison Value**
Site 1 Arroyo Colorado at Port of Harlingen				
Black drum	2/2	0.003±0.003 (0.0008-0.005)	1.167 1.601	EPA Chronic Oral RfD for DDT — 5.0E-4 mg/kg–day EPA Oral Slope Factor for DDT— 3.4E-1 per mg/kg–day
Common carp	1/1	0.049		
Hardhead catfish	2/2	0.013±0.005 (0.009-0.016)		
Red drum	3/3	0.046±0.017 (0.029-0.063)		
Sheepshead	2/2	0.024± 0.008 (0.019-0.030)		
Spotted seatrout	5/5	0.027± 0.020 (0.007-0.049)		
All fish combined	15/15	0.027±0.020 (0.0008-0.063)		
Site 2 Arroyo Colorado near Harlingen WWTP Outfall				
Blue catfish	8/8	0.341±0.212 (0.043-0.652)	1.167 1.601	EPA Chronic Oral RfD for DDT — 5.0E-4 mg/kg–day EPA Oral Slope Factor for DDT— 3.4E-1 per mg/kg–day
Flathead catfish	1/1	0.134		
Smallmouth buffalo	3/3	0.521±0.152 (0.407-0.694)		
All fish combined	12/12	0.369±0.211 (0.043-0.694)		
Site 3 Arroyo Colorado at FM 506				
Longnose gar	1/1	0.569	1.167 1.601	EPA Chronic Oral RfD for DDT — 5.0E-4 mg/kg–day EPA Oral Slope Factor for DDT— 3.4E-1 per mg/kg–day
Smallmouth buffalo	2/2	0.543±0.290 (0.338-0.747)		
All fish combined	3/3	0.551±0.205 (0.337-0.747)		
Site 4 Arroyo Colorado at FM 1015				
Common carp	3/3	0.181±0.018 (0.161-0.192)	1.167 1.601	EPA Chronic Oral RfD for DDT — 5.0E-4 mg/kg–day EPA Oral Slope Factor for DDT— 3.4E-1 per mg/kg–day
Smallmouth buffalo	3/3	0.625±0.469 (0.126-1.056)		
All fish combined	6/6	0.403±0.383 (0.126-1.056)		
Site 5 Arroyo Colorado at FM 493				
Blue catfish	1/1	0.492	1.167 1.601	EPA Chronic Oral RfD for DDT — 5.0E-4 mg/kg–day EPA Oral Slope Factor for DDT— 3.4E-1 per mg/kg–day
Smallmouth buffalo	3/3	0.549±0.277 (0.239-0.772)		
All fish combined	4/4	0.534±0.228 (0.239-0.772)		

Table 3.5. DDT (total; mg/kg) in fish collected from the Arrroyo Colorado by species, 2013.				
Species	**Number Detected/ Number Tested**	**Mean ± S.D. (Min-Max)**	**HAC Value (nonca) and HAC Value (ca; mg/kg)**	**Basis for Comparison Value**
Black drum	2/2	0.003± 0.003 (0.0008-0.005)	1.167 1.601	EPA Chronic Oral RfD for DDT — 5.0E-4 mg/kg–day EPA Oral Slope Factor for DDT— 3.4E-1 per mg/kg–day
Blue catfish	9/9	0.358±0.204 (0.043-0.652)		
Common carp	4/4	0.148±0.068 (0.049-0.192)		
Flathead catfish	1/1	0.134		
Hardhead catfish	2/2	0.013±0.005 (0.009-0.016)		
Longnose gar	1/1	0.569		
Red drum	3/3	0.046±0.017 (0.029-0.063)		
Sheepshead	2/2	0.024± 0.008 (0.019-0.030)		
Smallmouth buffalo	11/11	0.561±0.272 (0.126-1.056)		
Spotted seatrout	5/5	0.027± 0.020 (0.007-0.049)		
All fish combined	40/40	0.276±0.282 (0.0008-1.056)		
All fish combined (upstream of POH)	25/25	0.425±0.258 (0.043-1.056)		

Table 4.1. PCBs (mg/kg) in fish collected from the Arroyo Colorado by sample site, 2013.

Species	Number Detected/ Number Tested	Mean ± S.D. (Min-Max)	HAC Value (nonca) and HAC Value (ca; mg/kg)	Basis for Comparison Value
Site 1 Arroyo Colorado at Port of Harlingen				
Black drum	2/2	0.010± 0.00004 (0.010-0.010)	0.047 0.272	EPA Chronic Oral RfD for Aroclor 1254 — 0.00002 mg/kg–day EPA Slope Factor — 2.0 per mg/kg–day
Common carp	1/1	0.008		
Hardhead catfish	2/2	0.012±0.001 (0.011-0.013)		
Red drum	3/3	0.012±0.001 (0.010-0.013)		
Sheepshead	2/2	0.008±0.003 (0.006-0.010)		
Spotted seatrout	5/5	0.011± 0.010 (0.010-0.012)		
All fish combined	15/15	0.011±0.002 (0.006-0.013)		
Site 2 Arroyo Colorado near Harlingen WWTP Outfall				
Blue catfish	8/8	0.023 ±0.013 (0.011-**0.052**[n])	0.047 0.272	EPA Chronic Oral RfD for Aroclor 1254 — 0.00002 mg/kg–day EPA Slope Factor — 2.0 per mg/kg–day
Flathead catfish	1/1	0.017		
Smallmouth buffalo	3/3	**0.089**±0.032 (**0.066-0.126**)		
All fish combined	12/12	0.039±0.035 (0.011-**0.126**)		
Site 3 Arroyo Colorado at FM 506				
Longnose gar	1/1	0.040	0.047 0.272	EPA Chronic Oral RfD for Aroclor 1254 — 0.00002 mg/kg–day EPA Slope Factor — 2.0 per mg/kg–day
Smallmouth buffalo	2/2	**0.088**±0.092 (0.023-**0.153**)		
All fish combined	3/3	**0.072**±0.070 (0.023-**0.153**)		
Site 4 Arroyo Colorado at FM 1015				
Common carp	3/3	0.014±0.0006 (0.013-0.015)	0.047 0.272	EPA Chronic Oral RfD for Aroclor 1254 — 0.00002 mg/kg–day EPA Slope Factor — 2.0 per mg/kg–day
Smallmouth buffalo	3/3	0.035±0.024 (0.012-**0.061**)		
All fish combined	6/6	0.025±0.019 (0.012-**0.061**)		
Site 5 Arroyo Colorado at FM 493				
Blue catfish	1/1	**0.062**	0.047 0.272	EPA Chronic Oral RfD for Aroclor 1254 — 0.00002 mg/kg–day EPA Slope Factor — 2.0 per mg/kg–day
Smallmouth buffalo	3/3	0.032±0.018 (0.016-**0.051**)		
All fish combined	4/4	0.039±0.021 (0.016-**0.062**)		

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

Table 4.2. PCBs (mg/kg) in fish collected from the Arrroyo Colorado by species, 2013.				
Species	**Number Detected/ Number Tested**	**Mean ± S.D. (Min-Max)**	**HAC Value (nonca) and HAC Value (ca; mg/kg)**	**Basis for Comparison Value**
Black drum	2/2	0.010± 0.00004 (0.010-0.010)		
Blue catfish	9/9	0.027±0.018 (0.011-**0.062**[o])		
Common carp	4/4	0.012±0.003 (0.008-0.015)		
Flathead catfish	1/1	0.017		
Hardhead catfish	2/2	0.012±0.001 (0.011-0.013)		
Longnose gar	1/1	0.040	0.047	EPA Chronic Oral RfD for Aroclor 1254 — 0.00002 mg/kg–day
Red drum	3/3	0.012±0.001 (0.010-0.013)	0.272	EPA Slope Factor — 2.0 per mg/kg–day
Sheepshead	2/2	0.008±0.003 (0.006-0.010)		
Smallmouth buffalo	11/11	**0.058**±0.045 (0.012-**0.153**)		
Spotted seatrout	5/5	0.011± 0.010 (0.010-0.012)		
All fish combined	40/40	0.029±0.032 (0.006-**0.153**)		
All fish combined (upstream of POH)	25/25	0.039±0.036 (0.011-**0.153**)		

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

Table 5. PCDDs/PCDFs toxicity equivalent (TEQ) concentrations (pg/g) in fish collected from the Arroyo Colorado by species, 2013.				
Species	**Number Detected/ Number Tested**	**Mean ± S.D. (Min-Max)**	**HAC Value (nonca) and HAC Value (ca; mg/kg)**	**Basis for Comparison Value**
Blue catfish	2/2	0.846±0.832 (0.258-1.434)	2.33 3.49	ATSDR Chronic Oral MRL for 2,3,7,8 – TCDD — 1.0 x 10^{-9} mg/kg–day EPA Slope Factor — 1.56 x 10^{5} per mg/kg–day
Common carp	1/1	0.144		
Flathead catfish	1/1	0.326		
Longnose gar	0/1	ND		
Sheepshead	0/1	ND		
Smallmouth buffalo	2/2	0.301±0.170 (0.180-0.421)		
Spotted seatrout	1/2	0.097±0.137 (ND-0.193)		
All fish combined	7/10	0.296±0.425 (ND-1.434)		
All fish combined (upstream of POH)	5/6	0.437±0.509 (ND-1.434)		

Table 6. Trichlorofluoromethane (mg/kg) in fish collected from the Arroyo Colorado by species, 2013.				
Species	**Number Detected/ Number Tested**	**Mean ± S.D. (Min-Max)**	**HAC Value (nonca; mg/kg)**	**Basis for Comparison Value**
Blue catfish	1/1	0.014	700	EPA Chronic Oral RfD — 3.0E-01 mg/kg–day
Longnose gar	1/1	0.040		
Smallmouth buffalo	1/1	0.091		
Spotted seatrout	1/1	0.018		
All fish combined	4/4	0.041±0.036 (0.014-0.091)		

Table 7. Hazard quotients (HQs) for mercury in fish collected from the Arroyo Colorado in 2013. Table 7. also provides suggested weekly eight-ounce meal consumption rates for 70-kg adults.[p]

Species	Number of Samples	Hazard Quotient	Meals per Week
Arroyo Colorado All Sites			
Black drum	2	0.88	1.1
Blue catfish	9	0.36	2.6
Common carp	4	0.23	4.0
Flathead catfish	1	0.51	1.8
Hardhead catfish	2	0.22	4.2
Longnose gar	1	**1.10**[q]	**0.8**[r]
Red drum	3	0.32	2.9
Sheepshead	2	0.27	3.5
Smallmouth buffalo	11	0.50	1.9
Spotted seatrout	5	0.37	2.5
All fish combined	40	0.42	2.2
All fish combined (POH)	15	0.40	2.3
All fish combined (upstream of POH)	25	0.43	2.2

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

Table 8. Hazard quotients (HQs) for DDT (total) in fish collected from the Arroyo Colorado in 2013. Table 8. also provides suggested weekly eight-ounce meal consumption rates for 70-kg adults.[s]			
Species	**Number of Samples**	**Hazard Quotient**	**Meals per Week**
Arroyo Colorado All Sites			
Black drum	2	0.00	unrestricted[t]
Blue catfish	9	0.31	3.0
Common carp	4	0.13	7.3
Flathead catfish	1	0.11	8.1
Hardhead catfish	2	0.01	unrestricted
Longnose gar	1	0.49	1.9
Red drum	3	0.04	unrestricted
Sheepshead	2	0.02	unrestricted
Smallmouth buffalo	11	0.48	1.9
Spotted seatrout	5	0.02	unrestricted
All fish combined	40	0.24	3.9
All fish combined (POH)	15	0.02	unrestricted
All fish combined (upstream of POH)	25	0.36	2.5

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

Table 9.1. Hazard quotients (HQs) and hazard indices (HIs) for PCBs and/or PCDDs/PCDFs in fish collected from the Arroyo Colorado in 2013. Table 9.1 also provides suggested weekly eight-ounce meal consumption rates for 70-kg adults.[u]			
Contaminant/Species	**Number of Samples**	**Hazard Quotient**	**Meals per Week**
Black drum			
PCBs	2	0.21	4.3
Blue catfish			
PCBs	9	0.58	1.6
PCDDs/PCDFs	2	0.36	2.6
Hazard Index (meals per week)		0.94	1.0
Common carp			
PCBs	4	0.26	3.6
PCDDs/PCDFs	1	0.06	15.0
Hazard Index (meals per week)		0.32	2.9
Flathead catfish			
PCBs	1	0.36	2.5
PCDDs/PCDFs		0.14	6.6
Hazard Index (meals per week)		0.50	1.8
Hardhead catfish			
PCBs	2	0.26	3.6
Longnose gar			
PCBs	1	0.86	1.1
PCDDs/PCDFs		0.00	unrestricted[v]
Hazard Index (meals per week)		0.86	1.1
Red drum			
PCBs	3	0.17	5.4

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

Table 9.2. Hazard quotients (HQs) and hazard indices (HIs) for PCBs and/or PCDDs/PCDFs in fish collected from the Arroyo Colorado in 2013. Table 9.2 also provides suggested weekly eight-ounce meal consumption rates for 70-kg adults.[w]			
Contaminant/Species	**Number of Samples**	**Hazard Quotient**	**Meals per Week**
Sheepshead			
PCBs	2	0.26	3.6
PCDDs/PCDFs	1	0.00	unrestricted[x]
Hazard Index (meals per week)		0.26	3.6
Smallmouth buffalo			
PCBs	11	**1.24**[y]	**0.7**[z]
PCDDs/PCDFs	2	0.13	7.2
Hazard Index (meals per week)		**1.37**	**0.7**
Spotted seatrout			
PCBs	5	0.24	3.9
PCDDs/PCDFs	2	0.04	unrestricted
Hazard Index (meals per week)		0.28	3.3
All fish combined			
PCBs	40	0.62	1.5
PCDDs/PCDFs	10	0.13	7.3
Hazard Index (meals per week)		0.75	1.2
All fish combined (Port of Harlingen)			
PCBs	15	0.24	3.9
PCDDs/PCDFs	4	0.04	unrestricted
Hazard Index (meals per week)		0.27	3.4
All fish combined (upstream of Port of Harlingen)			
PCBs	25	0.84	1.1
PCDDs/PCDFs	6	0.19	4.9
Hazard Index (meals per week)		**1.02**	**0.9**

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

Table 10.1. Calculated theoretical lifetime excess cumulative cancer risk from consuming fish collected in 2013 from the Arroyo Colorado containing carcinogens and suggested consumption rate (eight-ounce meals/week) for 70 kg adults who regularly eat fish the Arroyo Colorado over a 30-year period.[aa]				
Species/Contaminant	**Number of Samples**	**Theoretical Lifetime Excess Cancer Risk**		**Meals per Week**
		Risk	**Population Size that Would Result in One Excess Cancer**	
Black drum				
Chlordane	2	3.9E-08	25,925,926	unrestricted[bb]
DDT (total)		1.9E-07	5,337,691	unrestricted
Dieldrin		5.9E-07	1,701,389	unrestricted
PCBs		3.7E-06	272,222	unrestricted
Cumulative Cancer Risk		4.5E-06	222,859	unrestricted
Blue catfish				
Arsenic	1	3.3E-06	302,469	unrestricted
Chlordane	9	9.6E-07	1,037,037	unrestricted
DDT (total)		2.2E-05	44,729	4.1
Dieldrin		1.5E-05	68,056	6.3
PCBs		9.9E-06	100,823	9.3
PCDDs/PCDFs	2	2.4E-05	41,253	3.8
Cumulative Cancer Risk		7.5E-05	13,249	1.2
Common carp				
Chlordane	4	1.9E-07	5,185,185	unrestricted
DDT (total)		9.2E-06	108,196	10.0
Dieldrin		2.4E-06	425,347	unrestricted
PCBs		4.4E-06	226,852	unrestricted
PCDDs/PCDFs	1	4.1E-06	242,363	unrestricted
Cumulative Cancer Risk		2.0E-05	49,211	4.5

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

Table 10.2. Calculated theoretical lifetime excess cumulative cancer risk from consuming fish collected in 2013 from the Arroyo Colorado containing carcinogens and suggested consumption rate (eight-ounce meals/week) for 70 kg adults who regularly eat fish the Arroyo Colorado over a 30-year period.[cc]				
Species/Contaminant	**Number of Samples**	**Theoretical Lifetime Excess Cancer Risk**		**Meals per Week**
		Risk	**Population Size that Would Result in One Excess Cancer**	
Flathead catfish				
Chlordane	1	7.1E-07	1,414,141	unrestricted[dd]
DDT (total)		8.4E-06	119,501	11.0
Dieldrin		2.9E-06	340,278	unrestricted
PCBs		6.2E-06	160,131	14.8
PCDDs/PCDFs		9.3E-06	107,056	9.9
Cumulative Cancer Risk		2.8E-05	36,232	3.3
Hardhead catfish				
Chlordane	2	3.9E-08	25,925,926	unrestricted
DDT (total)		8.1E-07	1,231,775	unrestricted
Dieldrin		1.2E-06	850,694	unrestricted
PCBs		4.4E-06	226,852	unrestricted
Cumulative Cancer Risk		6.4E-06	155,422	14.4
Longnose gar				
Arsenic	1	9.6E-06	103,704	9.6
Chlordane		9.6E-07	1,037,037	unrestricted
DDT (total)		3.6E-05	28,142	2.6
Dieldrin		1.8E-05	56,713	5.2
PCBs		1.5E-05	68,056	6.3
PCDDs/PCDFs		0.0E+00	N/A	unrestricted
Cumulative Cancer Risk		7.8E-05	12,744	1.2

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

Table 10.3. Calculated theoretical lifetime excess cumulative cancer risk from consuming fish collected in 2013 from the Arroyo Colorado containing carcinogens and suggested consumption rate (eight-ounce meals/week) for 70 kg adults who regularly eat fish the Arroyo Colorado over a 30-year period.[ee]				
Species/Contaminant	**Number of Samples**	**Theoretical Lifetime Excess Cancer Risk**		**Meals per Week**
		Risk	**Population Size that Would Result in One Excess Cancer**	
Red drum				
Chlordane	3	1.9E-07	5,185,185	unrestricted[ff]
DDT (total)		2.9E-06	348,110	unrestricted
Dieldrin		2.9E-06	340,278	unrestricted
PCBs		2.9E-06	340,278	unrestricted
Cumulative Cancer Risk		8.9E-06	111,819	10.3
Sheepshead				
Chlordane	2	1.3E-07	7,777,778	unrestricted
DDT (total)		1.5E-06	667,211	unrestricted
Dieldrin		2.9E-06	340,278	unrestricted
PCBs		4.4E-06	226,852	unrestricted
PCDDs/PCDFs	1	0.0E+00	N/A	unrestricted
Cumulative Cancer Risk		9.0E-06	111,429	unrestricted
Smallmouth buffalo				
Arsenic	1	5.0E-06	201,646	unrestricted
Chlordane	11	1.4E-06	707,071	unrestricted
DDT (total)		3.5E-05	28,544	2.6
Dieldrin		2.1E-05	48,611	4.5
PCBs		2.1E-05	46,935	4.3
PCDDs/PCDFs	2	8.6E-06	115,948	10.7
Cumulative Cancer Risk		9.2E-05	10,880	1.0

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

Table 10.4. Calculated theoretical lifetime excess cumulative cancer risk from consuming fish collected in 2013 from the Arroyo Colorado containing carcinogens and suggested consumption rate (eight-ounce meals/week) for 70 kg adults who regularly eat fish the Arroyo Colorado over a 30-year period.[gg]

Species/Contaminant	Number of Samples	Theoretical Lifetime Excess Cancer Risk		Meals per Week
		Risk	Population Size that Would Result in One Excess Cancer	
Spotted seatrout				
Arsenic	1	1.3E-05	77,226	7.1
Chlordane	5	1.3E-07	7,777,778	unrestricted[hh]
DDT (total)		1.7E-06	593,077	unrestricted
Dieldrin		2.6E-06	378,086	unrestricted
PCBs		4.0E-06	247,475	unrestricted
PCDDs/PCDFs	2	2.8E-06	359,797	unrestricted
Cumulative Cancer Risk		2.4E-05	41,273	3.8
All fish combined				
Arsenic	4	7.7E-06	129,630	12.0
Chlordane	40	7.1E-07	1,414,141	unrestricted
DDT (total)		1.7E-05	58,018	5.4
Dieldrin		1.2E-05	85,069	7.9
PCBs		1.1E-05	93,870	8.7
PCDDs/PCDFs	10	8.5E-06	117,906	10.9
Cumulative Cancer Risk		5.7E-05	17,684	1.6

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

Table 10.5. Calculated theoretical lifetime excess cumulative cancer risk from consuming fish collected in 2013 from the Arroyo Colorado containing carcinogens and suggested consumption rate (eight-ounce meals/week) for 70 kg adults who regularly eat fish the Arroyo Colorado over a 30-year period.[ii]				
Species/Contaminant	**Number of Samples**	**Theoretical Lifetime Excess Cancer Risk**		**Meals per Week**
		Risk	**Population Size that Would Result in One Excess Cancer**	
All fish combined (Port of Harlingen)				
Arsenic	1	1.3-05	77,226	7.1
Chlordane	15	1.2E-07	8,641,975	unrestricted[jj]
DDT (total)		1.7E-06	593,077	unrestricted
Dieldrin		2.1E-06	486,111	unrestricted
PCBs		4.0E-06	247,475	unrestricted
PCDDs/PCDFs	4	2.4E-06	414,001	unrestricted
Cumulative Cancer Risk		2.3E-05	42,984	4.0
All fish combined (upstream of Port of Harlingen)				
Arsenic	3	6.1E-06	164,983	15.2
Chlordane	25	1.0E-06	972,222	unrestricted
DDT (total)		2.7E-05	37,678	3.5
Dieldrin		1.5E-05	68,056	6.3
PCBs		1.4E-05	69,801	6.4
PCDDs/PCDFs	6	1.3E-05	79,863	7.4
Cumulative Cancer Risk		7.5E-05	13,303	1.2

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

Table 11.1. Tukey HSD post hoc comparisons of all fish combined DDT (total) concentrations between samples sites from the Arroyo Colorado 2013.					
Site	Site	Difference	p-Value	95% Confidence Interval	
				Lower	Upper
1	2	-0.3419	**0.0011**[kk]	-0.5702	-0.1135
1	3	-0.5243	**0.0024**	-0.8972	-0.1514
1	4	-0.3763	**0.0047**	-0.6611	-0.0915
1	5	-0.5075	**0.0009**	-0.8392	-0.1757
2	3	-0.1824	0.6453	-0.5630	0.1982
2	4	-0.0344	0.9971	-0.3292	0.2604
2	5	-0.1656	0.6326	-0.5060	0.1748
3	4	0.1480	0.8442	-0.2689	0.5649
3	5	0.0168	1.0000	-0.4335	0.4671
4	5	-0.1312	0.8576	-0.5117	0.2494

Table 11.2. Tukey HSD post hoc comparisons of all fish combined PCB concentrations between samples sites from the Arroyo Colorado 2013.					
Site	Site	Difference	p-Value	95% Confidence Interval	
				Lower	Upper
1	2	-1.0178	**0.0009**	-1.6828	-0.3528
1	3	-1.6080	**0.0013**	-2.6940	-0.5221
1	4	-0.6663	0.1659	-1.4957	0.1631
1	5	-1.1995	**0.0088**	-2.1657	-0.2333
2	3	-0.5903	0.5499	-1.6986	0.5181
2	4	0.3515	0.7641	-0.5070	1.2100
2	5	-0.1817	0.9840	-1.1730	0.8096
3	4	0.9417	0.1926	-0.2724	2.1558
3	5	0.4085	0.8966	-0.9029	1.7199
4	5	-0.5332	0.6421	-1.6415	0.5751

[kk] *Emboldened numbers denote that the p-Value is < 0.05.*

Table 12. The number of eight-ounce meals assuming 38% yield from whole fish to skin-off fillets for an average, minimum, and maximum weight fish of each species collected from the Arroyo Colorado in 2013.

Species	Average	Minimum	Maximum
	Number of Eight-Ounce Meals		
Black drum	9.8	2.6	17.1
Blue catfish	5.8	1.3	11.4
Common carp	2.6	1.7	3.3
Flathead catfish	8.9	8.9	8.9
Hardhead catfish	1.1	0.9	1.3
Longnose gar	4.0	4.0	4.0
Red drum	5.0	3.5	5.9
Sheepshead	1.7	1.5	1.9
Smallmouth buffalo	5.8	3.4	7.7
Spotted seatrout	2.2	0.8	6.4
All fish combined	4.7	0.4	34.3

Table 13. Recommended fish consumption advice by species for the Arroyo Colorado upstream of the Port of Harlingen, 2013.

Contaminants of Concern	Species	Women of childbearing age and children < 12	Women past childbearing age and adult men
Mercury and PCBs	Longnose gar	**DO NOT EAT**	**DO NOT EAT**
	Smallmouth buffalo	**DO NOT EAT**	2 meals/month

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