Characterization of Potential Adverse Health Effects Associated with Consuming Fish from

Lake Livingston

Polk, San Jacinto, Trinity, and Walker Counties, Texas

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INTRODUCTION

This document summarizes the results of a survey of Lake Livingston conducted in 2012-2013 by the Texas Department of State Health Service (DSHS) Seafood and Aquatic Life Group (SALG).[a] The SALG did this study to investigate potential polychlorinated biphenyls (PCBs) and polychlorinated dibenzo-*p*-dioxins and/or dibenzofurans (PCDDs/PCDFs) fish tissue contamination in the Lower Trinity River Basin and Lake Livingston. Previous studies of the Upper Trinity River Basin within the Dallas Fort Worth metropolitan area indicated the need to complete a comprehensive survey of the entire Trinity River Basin. The present study, ensuing from surveys of the Upper Trinity River Basin examined fish from Lake Livingston 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 Lake Livingston and suggests actions to reduce potential adverse health outcomes.

History of the Upper Trinity River Basin Fish Consumption Advisory

From 1990–2010, portions of the Clear Fork Trinity River, West Fork Trinity River, and the Upper Trinity River in the Dallas-Fort Worth metropolitan area (from the Seventh Street Bridge in Fort Worth downstream to the Interstate Highway (IH) 20 Bridge southeast of Dallas have been closed to the harvesting of fish. The Texas Department of Health (TDH)[b] issued Aquatic Life Order Number 2 (AL-2) on January 4, 1990, prohibiting possession of fish from this stretch of the river because fish samples contained chlordane, an organochlorine insecticide that posed a significant public health issue.[1] In 1996, the Texas Natural Resource Conservation Commission (TNRCC)[c] listed these segments of the Trinity River on the State of Texas Clean Water Act Section 303(d) List of impaired waters for not supporting the designated fish consumption use due to chlordane contamination.[2]

In 1998, the TNRCC requested that the TDH reassess the possession ban issued in 1990. This survey examined fish samples from several sites along the Trinity River between Fort Worth and Dallas; an assessment that supported the continuation of AL-2 due to the presence of PCBs at concentrations exceeding TDH health-based guidelines. The results of this survey also showed that chlordane concentrations in fish from this portion of the Trinity River were of less concern, in part due to decreases in concentration and to changes in the knowledge of the toxicity of chlordane.

In 2000 and 2001, the TDH re-examined fish from stretches of the Trinity River previously investigated as well as areas up- and downstream of the area delineated by AL-2. The 2000 and 2001 surveys revealed the presence of PCBs at concentration exceeding health-based guidelines in fish further downstream from the original area closed to the harvesting of fish.

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[a] The terms DSHS and SALG may be used interchangeably throughout this document and mean the same agency.
[b] Now the Department of State Health Services (DSHS)
[c] Now the Texas Commission on Environmental Quality (TCEQ)

Because of these findings, TDH issued Fish Consumption Advisory 25 (ADV-25) on September 13, 2002 recommending no consumption of all species of gar from Texas State Highway (SH) 34 downstream to its confluence with the discharge canal of Cedar Creek Reservoir.[3] Subsequently, on September 27, 2002, TDH issued Aquatic Life Order Number 14 (AL-14), extending the Trinity River prohibited area to include waters of the Trinity River from the Seventh Street Bridge in Fort Worth downstream to SH 34.[4]

In 2008, the Texas Commission on Environmental Quality (TCEQ) requested that the DSHS perform a survey of the Trinity River as a five-year follow-up study under the Total Maximum Daily Load (TMDL) program for previously adopted TMDLs. The follow-up survey included sample sites up- and downstream of the prohibited and advisory areas. The 2008 survey revealed the presence of PCBs and PCDDs/PCDFs at concentrations exceeding health-based guidelines in fish up- and downstream of the prohibited and advisory areas. The DSHS issued AL-17 on July 7, 2010 to rescind AL-2 and AL-14.[5] Subsequently, DSHS issued ADV-43 advising people not to consume fish from the Clear Fork of the Trinity River below Benbrook Reservoir and the West Fork of the Trinity River below Lake Worth, including the main stem of the Trinity River downstream to the U.S. Highway 287 Bridge.[6]

Description of Lake Livingston

Lake Livingston is an 83,277-acre impoundment of the Trinity River in Polk, San Jacinto, Trinity, and Walker Counties.[7] The Trinity River Authority (TRA) and the City of Houston completed reservoir construction in 1971 to provide water for municipal, industrial, agricultural, and recreational uses.[8] Lake Livingston has no flood control or storage capacity. The TRA operates the spillway based on current river flow conditions and as river flow increases, reservoir discharges increase. The reservoir has a normal pool elevation of 131 feet above mean sea level and shoreline length of 350 miles. Predominant shoreline habitat types include boat docks, bulkheads, and eroded bank. The middle portion of the reservoir has approximately 5,700 acres of standing timber. Angler access and recreational opportunities are plentiful at Lake Livingston, which includes boating, fishing, swimming, and camping. Six public boat ramps and numerous privately operated marinas offer access to the reservoir. Camping is available at Wolf Creek Park operated by TRA, Lake Livingston State Park, and many private marinas and resorts.[9]

Demographics of Polk, San Jacinto, Trinity, and Walker Counties Surrounding the Area of Lake Livingston

Lake Livingston is located in rural East Texas covering portions of four counties: Polk, San Jacinto, Trinity, and Walker Counties. The United States Census Bureau estimated 2013 population of the four county area surrounding Lake Livingston at 155,856 people.[10] Huntsville, Texas positioned approximately 25 miles west of Lake Livingston is the closest metropolitan area (population ≥ 20,000 people) in East Texas.[10]

Subsistence Fishing at Lake Livingston

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.[11] The USEPA and the DSHS find it is important to consider subsistence fishing to occur at any water body because subsistence fishers (as well as recreational anglers and certain tribal and ethnic groups) usually consume more locally caught fish than the general population. These groups sometimes harvest fish or shellfish from the same water body over many years to supplement caloric and protein intake. People, who routinely eat fish from chemically contaminated bodies of water 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.*[12] 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.*[13] Advice and direction are also received from the legislatively mandated *State of Texas Toxic Substances Coordinating Committee Fish Sampling Advisory Subcommittee.*[14] 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 Lake Livingston 2012-2013 Sample Set

In July–September 2012 and March–May 2013, the SALG staff collected 122 fish samples from Lake Livingston. Risk assessors used data from these fish to assess the potential for adverse human health outcomes from consuming fish from this reservoir.

The SALG selected six sample sites to provide spatial coverage of the study area (Figure 1): Site 1 Lake Livingston at dam; Site 2 Lake Livingston at Wolf Creek; Site 3 Lake Livingston near Kickapoo Creek; Site 4 Lake Livingston at US Highway 190; Site 5 Lake Livingston near Rosewood Lane; and, Site 6 Trinity River at State Highway (SH) 19. 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 122 fish collected from Lake Livingston 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: white bass (30); blue catfish (31); crappie species (spp.) (15); largemouth bass (11); striped bass (8); channel catfish (7); flathead catfish (12); smallmouth buffalo (6); and, longnose gar (2).

The survey team set gill nets at sample sites 1–6 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 reservoir any live fish culled from the catch and properly disposed of samples found dead in the gill nets.

The SALG utilized a boat-mounted electrofisher to collect fish. The SALG staff conducted electrofishing activities during daylight and nighttime hours using pulsed direct current (Smith Root 7.5 GPP electrofishing system settings: 6.0-8.0 amps, 60 pulses per second [pps], low range, 500 volts, 40-50% duty cycle and 1.0-2.0 amps, 15 pps, low range, 500 volts, 100% duty cycle) to stun fish that crossed the electric field in the water in front of the boat. Staff used dip nets over the bow of the boat to retrieve stunned fish, netting only fish pre-selected as target samples. Staff immediately stored retrieved samples on wet ice in large coolers to enhance tissue preservation.

The survey team also utilized juglines (a fishing line with one circle hook tied to a free-floating device) baited with live sunfish to increase flathead catfish and blue catfish catch. The survey team targeted habitat within sample sites likely to hold these species.

The SALG staff processed fish onsite at Lake Livingston. 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). 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 foil was changed and the knife cleaned with distilled water after each sample was processed. The team wrapped fillet(s) in two layers of fresh aluminum foil, placed in an unused, clean, pre-labeled plastic freezer bag, and stored on wet ice in an insulated chest until further processing. The SALG staff transported tissue samples on wet ice to their Austin, Texas headquarters, where the samples were stored temporarily at -5° Fahrenheit (-20° Celsius) in a locked freezer. The freezer key is accessible only to authorized SALG staff members to ensure 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.

Fish Age Estimation

The DSHS SALG staff removed sagittal otoliths from blue catfish, channel catfish, crappie spp., flathead catfish, largemouth bass, striped bass and white bass samples for age estimation. The DSHS SALG staff followed otolith extraction procedures recommended by the Gulf States Marine Fisheries Commission (GSMFC) and unpublished procedures recommended by the Texas Parks and Wildlife Department (TPWD).[15, 16] Staff performed all otolith extractions on each fish sample after the preparation of the two skin-off fillets for chemical contaminant analysis. Following extraction, staff placed otoliths in an individually labeled envelope and then stored the envelopes in a plastic freezer bag to transport to their Austin, Texas headquarters. Staff processed otoliths and estimated ages according to procedures recommended by the GSMFC and TPWD.[15, 16]

Analytical Laboratory Information

GERG personnel documented receipt of the 122 Lake Livingston 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 Lake Livingston for inorganic and organic contaminants commonly identified in polluted environmental media. Analyses included seven metals (arsenic, cadmium, copper, lead, total mercury, selenium, and zinc), 123 semivolatile organic compounds (SVOCs), 70 volatile organic compounds (VOCs), 34 pesticides, 209 PCB congeners,[d, 17] and 17 polychlorinated dibenzofurans and/or dibenzo-*p*-dioxins (PCDDs/PCDFs) congeners. The laboratory analyzed all 122 samples for mercury, PCBs, and PCDDs/PCDFs . A subset of five of the original 122 samples was analyzed for metals, pesticides, SVOCs, and VOCs.[18] 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.

<u>Details of Some Analyses with Explanatory Notes</u>

<u>Arsenic</u>

The GERG laboratory analyzed six fish samples for total (inorganic arsenic + organic arsenic = total arsenic) arsenic. Although the proportions of each form of arsenic may differ among fish

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

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.[19] The DSHS, taking a conservative approach, estimates 10% of the total arsenic in any fish is inorganic arsenic and derives estimates of inorganic arsenic concentration in each fish by multiplying 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.[20] 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.[21] (In these risk characterizations, the DSHS may interchangeably 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.[22] 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[e] or Aroclors®[f] because the USEPA considers congener analysis the most

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

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

sensitive technique for detecting PCBs in environmental media.[18, 23] 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),[24] from McFarland and Clarke,[25] and from the USEPA's guidance documents for assessing contaminants in fish and shellfish.[13, 18] Based on evaluation of these recommendations, the DSHS selected 43 of 209 congeners to characterize "total" PCBs. The referenced authors chose to use congeners that were relatively abundant in the environment, were likely to occur in aquatic life, and likely to show toxic effects. SALG risk assessors summed the 43 congeners to derive "total" PCB concentration in each sample. SALG risk assessors then averaged the summed congeners within each group (e.g., fish species, sample site, or combination of species and site) to derive a mean PCB concentration for each group.

Using only a few PCB congeners to determine total PCB concentrations could underestimate PCB levels in fish tissue. Nonetheless, the method complies with expert recommendations on evaluation of PCBs in fish or shellfish. Therefore, SALG risk assessors compare average PCB concentrations of the 43 congeners with health assessment comparison (HAC) values derived from information on PCB mixtures held in the USEPA's Integrated Risk Information System (IRIS) database.[26] 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.[27] 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.[26]

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 form 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.[28, 29] Using this technique, 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.[30]

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

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.[31] 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.[31]

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[32] or the ATSDR's chronic oral MRLs.[33] When RfDs or MRLs are not available the SALG may use a Food and Nutrition Board, Institute of Medicine, National Academies tolerable upper intake level (UL) for nutrients.[g] The USEPA defines an RfD as

> *An estimate of a daily oral exposure for a given duration to the human population (including susceptible subgroups) that is likely to be without an appreciable risk of adverse health effects over a lifetime.*[34]

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.*[34]

The ATSDR uses a similar technique to derive its MRLs.[33] 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

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

…the ratio of the estimated exposure dose of a contaminant (mg/kg/day) to the contaminant's RfD or MRL (mg/kg/day).[35]

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

Although the DSHS utilizes chemical specific RfDs when possible, if an RfD is not available for a contaminant, the USEPA advises risk assessors to consider evaluating the contaminant by comparing it to the published RfD (or the MRL) of a contaminant of similar molecular structure or one with a similar mode or mechanism of action. For instance, Aroclor® 1260 has no RfD, so the DSHS uses the reference dose for Aroclor 1254 to assess the likelihood of systemic (noncarcinogenic) effects of Aroclor 1260.[33]

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.[32,34] 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.[34]

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 overestimate 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)[34] 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. [36, 37] 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.[38] 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.[39]

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.[32] Additionally, in accordance with the ATSDR's *Child Health Initiative*[40] and the USEPA's *National Agenda to Protect Children's Health from Environmental Threats,*[41] 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.[42] In computing descriptive statistics, SALG risk assessors utilized ½ the reporting limit (RL) for analytes designated as not detected (ND) or estimated (J-values).[h] The SALG risk assessors calculated

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

PCDDs/PCDFs descriptive statistics using estimated concentrations (J-values) and assuming zero for PCDDs/PCDFs designated as ND.[i] The change in methodology for computing PCDDs/PCDFs descriptive statistics is due to the proximity of the reporting limits to the HAC value. Assuming ½ the RL for PCDDs/PCDFs designated as ND or J-values would unnecessarily overestimate the concentration of PCDDs/PCDFs in each fish tissue sample. The SALG used the descriptive statistics from the above calculations to 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 Lake Livingston.[43] 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).[44,45]

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 $\log_e$-transformed the data to improve normality and best fit. PCDD/PCDF data were excluded from these analyses because the data were not normally distributed and the data could not be appropriately $\log_e$-transformed because of the 17 non-detects or zero concentrations. The SALG risk assessors performed linear correlation (r) to describe associations between contaminant concentrations and total length (TL), fish age, 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) to compare sample site PCB concentrations for all fish combined.

RESULTS

The GERG laboratory completed analyses and electronically transmitted the results of the Lake Livingston samples collected in July–September 2012 and March–May 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 2.1–2.6 present the results of metals analyses. Tables 3.1–3.3 and 4.1–4.3 contain summary results for pesticides and PCBs, respectively. Tables 5.1–5.3 summarize the PCDD/PCDF analyses. This report does not display SVOC and VOC data because these contaminants were not present at

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

concentrations of concern in fish collected from Lake Livingston during the described survey. Unless otherwise stated, table summaries present the number of samples with detected concentrations of contaminants, the number of samples tested, the mean concentration and standard deviation, and the minimum and the maximum concentrations. In the tables, results may be reported as ND, below detection limit (BDL) for estimated concentrations or "J-values", or as concentrations at or above the reporting limit (RL).

Inorganic Contaminants

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

The GERG laboratory analyzed a subset of six fish tissue samples (blue catfish [n = 5] and flathead catfish [n = 1]) for six inorganic contaminants and 122 samples for mercury. All fish tissue samples from Lake Livingston contained some concentration of arsenic, copper, mercury, selenium, and zinc (Tables 2.1–2.6).

The SALG evaluated three toxic metalloids having no known human physiological function (arsenic, cadmium, and lead) in the samples collected from Lake Livingston. All fish analyzed contained arsenic ranging from BDL–0.313 mg/kg (Table 2.1). The mean cadmium concentration in fish sampled from Lake Livingston was 0.035±0.058 mg/kg. Lead concentrations ranged from ND to 0.103 mg/kg with a mean of 0.026±0.038 mg/kg (Table 2.2).

Three of the metalloids analyzed are essential trace elements: copper, selenium, and zinc. All six fish tissue samples assayed contained copper (Table 2.2). The mean copper concentration in fish sampled from the Lake Livingston was 0.230±0.149 mg/kg. All fish tissue samples contained selenium. Selenium concentrations ranged from 0.268 to 1.056 mg/kg with a mean of 0.430±0.308 mg/kg (Table 2.2). All samples also contained zinc (Table 2.2). The mean zinc concentration in fish tissue samples from the Lake Livingston was 4.405±0.816 mg/kg.

<u>Mercury</u>

All fish tissue samples evaluated from Lake Livingston contained mercury (Tables 2.4–2.6). Across all sample sites and species, mercury concentrations ranged from 0.056 (white bass) to 0.691 mg/kg (blue catfish). The mean mercury concentration for the 122 fish tissue samples analyzed was 0.184±0.117 mg/kg (Table 2.6).

<u>Black crappie</u>

Nine black crappie ranging from 10.2 to 13.7 inches TL ($\overline{X}$ – 12.3 inches TL) and from three to six years of age were analyzed for mercury (Table 1; Figure 2). One-hundred percent of the black crappie samples examined were of legal size (≥ 10 inches TL).[46] Mercury concentrations ranged from 0.062 to 0.162 mg/kg with a mean of 0.101±0.033 mg/kg and a median of 0.082 mg/kg (Tables 2.3–2.6).

Blue catfish

Thirty-one blue catfish ranging from 15.6 to 39.0 inches TL ($\overline{X}$ – 27.5 inches TL) and from eight to 20 years of age were analyzed for mercury (Table 1; Figure 3). One-hundred percent of the blue catfish samples examined were of legal size (≥ 12 inches TL).[44] **Error! Bookmark not defined.** Mercury concentrations ranged from 0.080 to 0.691 mg/kg with a mean of 0.218±0.168 mg/kg and a median of 0.137 mg/kg (Tables 2.4–2.6). Mercury concentrations in blue catfish were positively related to TL and age (r^2 = 0.385, n = 31, p < 0.0005; r^2 = 0.450, n = 31, p < 0.0005; Figures 4–5).

Channel catfish

Seven channel catfish ranging from 15.7 to 17.8 inches TL ($\overline{X}$ – 16.4 inches TL) and from six to seven years of age were analyzed for mercury (Table 1; Figure 6). One-hundred percent of the channel catfish samples examined were of legal size (≥ 12 inches TL).[46] Mercury concentrations ranged from 0.077 to 0.160 mg/kg with a mean of 0.109±0.031 mg/kg and a median of 0.103 mg/kg (Tables 2.4–2.6).

Flathead catfish

Twelve flathead catfish ranging from 22.6 to 42.5 inches TL ($\overline{X}$ – 29.6 inches TL) and from five to 10 years of age were analyzed for mercury (Table 1; Figure 7). One-hundred percent of the flathead catfish samples examined were of legal size (≥ 18 inches TL).[46] Mercury concentrations ranged from 0.102 to 0.345 mg/kg with a mean of 0.160±0.070 mg/kg and a median of 0.137 mg/kg (Tables 2.4–2.6). Mercury concentrations in flathead catfish were positively related to TL and age (r^2= 0.622, n = 12, p = 0.002; r^2= 0.618, n = 12, p = 0.002; Figures 8–9).

Largemouth bass

Eleven largemouth bass ranging from 15.7 to 21.1 inches TL ($\overline{X}$ – 18.3 inches TL) and from three to seven years of age were analyzed for mercury (Table 1; Figure 10). One-hundred percent of the largemouth bass samples examined were of legal size (≥ 14 inches TL).[44] Mercury concentrations ranged from 0.119 to 0.552 mg/kg with a mean of 0.276±0.146 (Tables 2.4–2.6). The SALG risk assessors computed a Pearson product-moment correlation coefficient (r) to assess the relationship between mercury concentration and TL and age for largemouth bass. There were no correlations between the variables (r = 0.065, n = 11, p = 0.849; r = 0.291, n = 11, p = 0.386).

Longnose gar

Two longnose gar ranging from 33.6 to 35.4 inches TL ($\overline{X}$ – 34.5 inches TL) were analyzed for mercury (Table 1). Currently, there is no minimum length limit for gar in Texas waters.[44] Mercury concentrations ranged from 0.284 to 0.390 mg/kg with a mean of 0.337±0.075 mg/kg and a median of 0.337 mg/kg (Tables 2.4–2.6).

Smallmouth buffalo

Six smallmouth buffalo ranging from 20.2 to 30.4 inches TL ($\overline{X}$ – 25.3 inches TL) were analyzed for mercury (Table 1). Currently, there is no minimum length limit for smallmouth buffalo in Texas waters.[46] Mercury concentrations ranged from 0.082 to 0.235 mg/kg with a mean of 0.147±0.052 mg/kg and a median of 0.138 mg/kg (Tables 2.4–2.6).

Striped bass

Eight striped bass ranging from 21.5 to 25.4 inches TL ($\overline{X}$ – 23.1 inches TL) and from three to five years of age were analyzed for mercury (Table 1; Figure 11). One-hundred percent of the striped bass samples examined were of legal size (≥ 18 inches TL).[46] Mercury concentrations in striped bass ranged from 0.081 to 0.271 mg/kg with a mean of 0.164±0.069 mg/kg and a median of 0.139 mg/kg (Tables 2.4–2.6).

White bass

Thirty white bass ranging from 11.5 to 17.1 inches TL ($\overline{X}$ – 14.3 inches TL) and from one to five years of age were analyzed for mercury (Table 1; Figure 12). One-hundred percent of the white bass samples examined were of legal size (≥ 10 inches TL).[46] Mercury concentrations ranged from 0.056 to 0.372 mg/kg with a mean of 0.183±0.071 mg/kg and a median of 0.164 mg/kg (Tables 2.4–2.6). Mercury concentrations in white bass were positively related to TL and age (r^2= 0.533, n = 30, p < 0.0005; r^2 = 0.628, n = 30, p < 0.0005; Figures 13–14).

White crappie

Six white crappie ranging from 11.6 to 15.2 inches TL ($\overline{X}$ – 13.8 inches TL) were analyzed for mercury (Table 1). All white crappie and were three years of age. One-hundred percent of the white crappie samples examined were of legal size (≥ 10 inches TL).[46] Mercury concentrations ranged from 0.086 to 0.185 mg/kg with a mean of 0.117±0.039 mg/kg and a median of 0.101 mg/kg (Tables 2.4–2.6).

Organic Contaminants

Pesticides

The GERG laboratory analyzed six fish for 34 pesticides. All samples examined contained concentrations of chlordane, dieldrin, endrin, 4,4'- dichlorodiphenyldichloroethylene (DDE), and 4,4'- dichlorodiphenyldichloroethane (DDD) (Tables 3.1–3.3). Chlordane concentrations ranged from 0.007 to 0.021 mg/kg with a mean of 0.011±0.006 and a median of 0.009 mg/kg. Dieldrin concentrations ranged from 0.001 to 0.004 mg/kg with a mean of 0.002±0.001 and a median of 0.002 mg/kg. Endrin concentrations ranged from 0.001 to 0.005 mg/kg with a mean of 0.003±0.002 and a median of 0.003 mg/kg. Total dichlorodiphenyltrichloroethane (DDT) [2,4'-

DDE +4,4′-DDE +2,4′-DDD + 4,4′-DDD+2,4′-DDT + 4,4′-DDT] ranged from 0.023 to 0.155 mg/kg with a mean 0.069±0.050 and a median of 0.048 mg/kg. Trace to low concentrations of tetrachlorobenzene 1,2,4,5, tetrachlorobenzene 1,2,3,4, pentachlorobenzene, hexachlorobenzene, gamma-hexachlorocyclohexane (HCH), delta-HCH, heptachlor epoxide, 2,4′-DDE, 2,4′-DDD, and 4,4′-DDT were present in one or more fish samples (data not presented).

PCBs

All fish tissue samples evaluated from Lake Livingston contained PCBs (Tables 4.1–4.3). Across all sample sites and species, PCB concentrations ranged from 0.005 (black and white crappie) to 0.980 mg/kg (longnose gar). The mean PCB concentration for the 122 fish tissue samples assayed was 0.056±0.118 mg/kg (Table 4.3). PCB concentrations in fish were positively related to TL and percent lipids ($r^2 = 0.380$, $n = 122$, $p < 0.0005$; $r^2 = 0.586$, $n = 122$, $p < 0.0005$; Figures 15–17).

The SALG risk assessors visually examined the fish PCB concentrations noting that PCB concentrations appeared higher at sample site two (Lake Livingston at Wolf Creek) than the other five sample sites (Figure 18). PCB concentrations also appeared lower at sample site three (Lake Livingston at Kickapoo Creek) than the other five sample sites. Fish PCB concentrations differed significantly across the six samples sites ($F [5, 116] = 5.226$, $p < 0.0005$; Figure 18). Post-hoc comparisons of fish PCB concentrations indicate that sample sites two and six had significantly higher PCB concentrations than fish from sample site three (Table 9.).

Black crappie

PCB concentrations ranged from 0.005 to 0.009 mg/kg with a mean of 0.006±0.001 mg/kg and median 0.006 mg/kg ($n = 9$; Tables 4.1–4.3).

Blue catfish

PCB concentrations ranged from 0.009 to 0.280 mg/kg with a mean of 0.072±0.066 and a median of 0.051 mg/kg ($n = 31$; Tables 4.1–4.3). The SALG risk assessors computed a Pearson product-moment correlation coefficient to assess the relationship between PCB concentration and percent lipids. There was no apparent correlation between the two variables ($r = 0.307$, $n = 31$, $p = 0.093$). PCB concentrations in blue catfish were positively related to TL and age ($r^2 = 0.251$, $n = 31$, $p = 0.004$; $r^2 = 0.378$, $n = 31$, $p < 0.0005$; Figures 19–20).

Channel catfish

PCB concentrations ranged from 0.010 to 0.033 mg/kg with a mean of 0.018±0.008 mg/kg and a median of 0.015 mg/kg ($n = 7$; Tables 4.1–4.3).

Flathead catfish

PCB concentrations ranged from 0.012 to 0.072 mg/kg with a mean of 0.032±0.016 mg/kg and a median of 0.027 mg/kg (n = 12; Tables 4.1–4.3). The SALG risk assessors computed a Pearson product-moment correlation coefficient to assess the relationships between PCB concentration and TL and age. There were no apparent correlations between PCB concentration and TL, age, and percent lipids, respectively (r = 0.231, n = 12, p = 0.470; r = 0.355, n = 12, p = 0.258; r = 0.460, n = 12, p = 0.132).

Largemouth bass

PCB concentrations ranged from 0.006 to 0.018 mg/kg with a mean of 0.008±0.004 mg/kg and a median of 0.007 mg/kg (n = 11; Tables 4.1–4.3). The SALG risk assessors computed a Pearson product-moment correlation coefficient to assess the relationships between PCB concentration and TL and age. There were no apparent correlations between PCB concentration and TL and age, respectively (r = 0.414, n = 11, p = 0.206; r = 0.364, n = 11, p = 0.271). PCB concentrations in largemouth bass were positively related to percent lipids (r^2 = 0.560, n = 11, p = 0.008; Figure 21).

Longnose gar

PCB concentrations ranged from 0.573 to 0.980 mg/kg with a mean of 0.776±0.288 mg/kg (n = 2; Tables 4.1–4.3).

Smallmouth buffalo

PCB concentrations ranged from 0.057 to 0.597 mg/kg with a mean of 0.178±0.210 mg/kg and a median of 0.090 mg/kg (n = 6; Tables 4.1–4.3).

Striped bass

PCB concentrations in striped bass ranged from 0.024 to 0.046 mg/kg with a mean of 0.033±0.008 mg/kg and a median of 0.033 mg/kg (n = 8; Tables 4.1–4.3).

White bass

PCB concentrations ranged from 0.013 to 0.066 mg/kg with a mean of 0.032±0.012 mg/kg and a median of 0.029 mg/kg (n = 30; Tables 4.1–4.3). The SALG risk assessors computed a Pearson product-moment correlation coefficient to assess the relationships between PCB concentration and and age. There was no apparent correlation between PCB concentration and age, respectively (r = 0.299, n = 30, p = 0.108).PCB concentrations in white bass were positively related to TL and percent lipids (r^2 = 0.264, n = 30, p = 0.004; r^2 = 0.133, n = 30, p = 0.048; Figure 22; Figure for PCBs and percent lipids not shown).

White crappie

PCB concentrations ranged from 0.005 to 0.006 mg/kg with a mean of 0.006±0.001 mg/kg and median 0.005 mg/kg (*n* = 6; Tables 4.1–4.3).

PCDDs/PCDFs

One-hundred five of 122 fish tissue samples contained at least one of the 17 PCDD/PCDF congeners ranging from ND–16.909 TEQ pg/g with a mean of 1.379±2.750 TEQ pg/g and a median of 0.480 TEQ pg/g (Tables 5.1–5.3). None of the samples contained all 17 congeners (data not shown). Longnose gar contained the highest mean PCDD/PCDF TEQ concentration (10.388±2.553 pg/g; Table 5.3). The SALG risk assessors plotted mean PCDD/PCDF TEQ concentrations for all fish to show how concentrations vary between sample sites (Figure 23).

SVOCs

The GERG laboratory analyzed a subset of six Lake Livingston fish tissue samples for SVOCs. Quantifiable concentrations > RL were reported for benzoic acid, phenol, and indeno (1,2,3-cd) pyrene in one or more fish samples (data not presented). Estimated concentrations of benz(a)anthracene, benzo(k)fluoranthene, benzo(a)pyrene, dibenz(a,j)acridine, dibenz(a,h)anthracene, bis (2-ethylhexyl) phthalate, and n-nitrosodi-n-methylamine were present in one or more fish samples analyzed (data not presented). The laboratory detected no other SVOCs in fish from Lake Livingston.

VOCs

The GERG laboratory analyzed a subset of six fish tissue samples selected for analysis from Lake Livingston. Quantifiable concentrations > RL were reported for acetone, methylene chloride, methyl-tert-butyl ether, and trichlorofluoromethane in one or more fish samples (data not presented). Estimated concentrations of many VOCs were also present in one or more fish tissue samples assayed from Lake Livingston (data not presented).

The Seafood and Aquatic Life Group Survey Team Standard Operating Procedures and Quality Control/Assurance Manual contain a complete list of the 70 VOCs selected for analysis. Numerous VOCs were also identified in one or more of the procedural blanks, indicating the possibility that these compounds were introduced during sample preparation. VOC concentrations < RL are difficult to interpret due to their uncertainty and may represent a false positive. The presence of many VOCs at concentrations < RL may be the result of incomplete removal of the calibration standard from the adsorbent trap, so they are observed in the blank. VOC analytical methodology requires that the VOCs be thermally released from the adsorbent trap, transferred to the gas chromatograph (GC), and into the GC/mass spectrometer (MS) for quantification.

DISCUSSION

Risk Characterization

Because variability and uncertainty are inherent to quantitative assessment of risk, the calculated risks of adverse health outcomes from exposure to toxicants can be orders of magnitude above or below actual risks. Variability in calculated and in actual risk may depend upon factors such as the use of animal instead of human studies, use of subchronic rather than chronic studies, interspecies variability, intra-species variability, and database insufficiency. Since most factors used to calculate comparison values result from experimental studies conducted in the laboratory on nonhuman subjects, variability and uncertainty might arise from the study chosen as the "critical" one, the species/strain of animal used in the critical study, the target organ selected as the "critical organ," exposure periods, exposure route, doses, or uncontrolled variations in other conditions.[32] 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 Lake Livingston. Conclusions and recommendations predicated upon the stated goal of the DSHS to protect human health follow the discussion of the relevance of findings to risk.

Characterization of Systemic (Noncarcinogenic) Health Effects from Consumption of Fish from Lake Livingston

Inorganic Contaminants

None of the 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 Lake Livingston.

Mercury was observed in one of 122 fish from Lake Livingston that equaled or exceeded its HAC_{nonca} (0.700 mg/kg; Tables 2.4–2.6 and 6). 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 did not exceed DSHS guidelines for protection of human health, it is important to understand that mercury concentrations in most predatory species of fish from Lake Livingston were positively related to TL and age indicating that mercury concentrations increase over time as fish grow (Figures 2–13). These relationships are also affected by the slow rate at which fish eliminate mercury compared to the rate at which it is accumulated. People should consider these relationships when choosing the size and species of fish they consume. No species of fish evaluated contained any other inorganic contaminants at concentrations that equaled or exceeded DSHS guidelines for protection of human health or would likely cause systemic risk to human health from consumption of fish from Lake Livingston.

Organic Contaminants

None of the species of fish evaluated contained any pesticides, SVOCs, and/or VOCs at concentrations that equaled or exceeded DSHS guidelines for protection of human health or would likely cause systemic risk to human health from consumption of fish from Lake Livingston.

<u>PCBs</u>

All fish tissue samples (*n* = 122) analyzed contained PCBs. Twenty-five percent of all samples analyzed contained PCB concentrations exceeding the HAC_{nonca} for PCBs (0.047 mg/kg; Tables 4.1–4.3 and 7.1–7.3). Three (blue catfish, longnose gar, and smallmouth buffalo) of 10 species evaluated had mean PCB concentrations exceeding the HAC_{nonca} for PCBs or an HQ of 1.0 (Tables 4.1–4.3 and 7.1–7.3). The all fish combined mean PCB concentration (0.056 mg/kg) exceeded 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 15–22). People should consider these relationships when choosing the size and species of fish they consume. The consumption of blue catfish, longnose gar, and smallmouth buffalo from Lake Livingston may pose potential systemic health risks.

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 Lake Livingston that healthy adults could consume without significant risk of PCB-related adverse systemic effects (Tables 7.1–7.3). Meal consumption rates were based on the mean PCB concentration by species. The SALG risk assessors estimated that healthy adults could consume less than one eight-ounce meal per week for these species of fish: 0.6 meals per week of blue catfish; 0.1 meals per week of longnose gar, or 0.2 meals per week of smallmouth buffalo. The SALG risk assessors suggest that fish from Lake Livingston contain PCBs at concentrations that may pose potential systemic (noncarcinogenic) health risks and that people should limit their consumption of fish from Lake Livingston. Because the developing nervous system of the human fetus and young children may be especially susceptible to adverse systemic health effects associated with consuming PCB-contaminated fish, the SALG risk assessors recommend more conservative consumption guidance for this sensitive subpopulation.

<u>PCDDs/PCDFs</u>

One-hundred five of 122 fish tissue samples analyzed contained PCDDs/PCDFs. Thirteen percent of all samples analyzed contained PCDD/PCDF concentrations exceeding the HAC_{nonca} for PCDDs/PCDFs (2.330 pg/g; Tables 5.1–5.3 and 7.1–7.3). Two (longnose gar an smallmouth buffalo) of 10 species evaluated had mean PCDD/PCDF concentrations exceeding the HAC_{nonca} for PCDDs/PCDFs or an HQ of 1.0 (Tables 5.1–5.3 and 7.1–7.3). PCDD/PCDF concentrations that equaled or exceeded the HAC_{nonca} for PCDDs/PCDFs were observed in one or more samples of the following species: blue catfish, flathead catfish, longnose gar, smallmouth buffalo, striped bass, white bass, and white crappie. The all fish combined mean PCDD/PCDF concentration did not exceed the HAC_{nonca} for PCDDs/PCDFs or an HQ of 1.0. The consumption of longnose gar and smallmouth buffalo from Lake Livingston may pose potential systemic (noncarcinogenic) health risks.

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 Lake Livingston that healthy adults could consume without significant risk of PCDD/PCDF -related adverse systemic effects (Tables 7.1–7.3). Meal consumption rates were based on the mean PCDD/PCDF concentration by species. The SALG risk assessors estimated that healthy adults could consume less than one eight-ounce meal per week for these species of fish: 0.2 meals per week of longnose gar or 0.3 meals per week of smallmouth buffalo. The SALG risk assessors suggest that fish from Lake Livingston contain PCDDs/PCDFs at concentrations that may pose potential systemic health risks and that people should limit their consumption of fish from Lake Livingston. Because the developing nervous system of the human fetus and young children may be especially susceptible to adverse systemic health effects associated with consuming PCDD/PCDF-contaminated fish, the SALG risk assessors recommend more conservative consumption guidance for this sensitive subpopulation.

Characterization of Theoretical Lifetime Excess Cancer Risk from Consumption of Fish from Lake Livingston

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

<u>PCBs</u>

The mean PCB concentrations observed in longnose gar exceed the DSHS guideline for protection of human health of one excess cancer in 10,000 equally exposed individuals and the HAC_{ca} for PCBs (0.272 mg/kg; Tables 4.1–4.3 and 8.1–8.4). PCB concentrations that equaled or exceeded the HAC_{ca} for PCBs were observed in one or more samples of the following species: blue catfish; longnose gar; and, smallmouth buffalo. The all fish combined mean PCB concentration did not exceed the HAC_{ca} for PCBs.

The SALG risk assessors calculated the number of eight-ounce meals of longnose gar from Lake Livingston that healthy adults could consume without significantly increasing their lifetime excess cancer risk (Tables 8.1–8.4). The SALG risk assessors estimated that healthy adults could consume less than one eight-ounce meal per week of longnose gar (0.3 meals per week). Because children may experience effects at a lower exposure dose than adults, the SALG risk assessors recommend more conservative consumption guidance for this sensitive subpopulation. The SALG risk assessors suggest that consumption of longnose gar from Lake Livingston likely increases the risk of cancer to exceed the DSHS guideline for protection of human health from PCB exposure.

PCDDs/PCDFs

The mean PCDD/PCDF concentrations observed in longnose gar and smallmouth buffalo exceed the DSHS guideline for protection of human health of one excess cancer in 10,000 equally exposed individuals or the HAC_{ca} for PCDDs/PCDFs (3.490 pg/g; Tables 5.1–5.3 and 8.1–8.4). PCDD/PCDF concentrations that equaled or exceeded the HAC_{ca} for PCDDs/PCDFs were observed in one or more samples of the following species: blue catfish; longnose gar; smallmouth buffalo; striped bass; and, white bass. The all fish combined mean PCDD/PCDF concentration did not exceed the HAC_{ca} for PCDDs/PCDFs. The consumption of longnose gar and smallmouth buffalo from Lake Livingston would be likely to increase the risk of cancer to exceed the DSHS guideline for protection of human health.

The SALG risk assessors calculated the number of eight-ounce meals of longnose gar or smallmouth buffalo from Lake Livingston that healthy adults could consume without significantly increasing their lifetime excess cancer risk (Tables 8.1–8.4). The SALG risk assessors estimated that healthy adults could consume less than one eight-ounce meal per week of longnose gar (0.3 meals per week) or smallmouth buffalo (0.5 meals per week). Because children may experience effects at a lower exposure dose than adults, the SALG risk assessors recommend more conservative consumption guidance for this sensitive subpopulation. The SALG risk assessors suggest that consumption of longnose gar and smallmouth buffalo from Lake Livingston likely increases the risk of cancer to exceed the DSHS guideline for protection of human health from PCDD/PCDF exposure.

Characterization of Calculated Cumulative Systemic (Noncarcinogenic) Health Effects and of Cumulative Excess Lifetime Cancer Risk from Consumption of Fish from Lake Livingston

Cumulative Systemic (Noncarcinogenic) Health Effects

Cumulative systemic (noncarcinogenic) effects of toxicants may occur if more than one contaminant acts upon the same target organ or acts by the same mode or mechanism of action. PCBs and PCDDs/PCDFs in fish from Lake Livingston could have these properties, especially with respect to effects on the immune system. Multiple organic contaminants in Lake Livingston fish increased the likelihood of systemic adverse health outcomes for all species of fish assayed (Tables 7.1–7.3). The combined toxicity of PCBs and PCDDs/PCDFs in blue catfish, flathead catfish, longnose gar, smallmouth buffalo, striped bass and white bass exceeded an HI of 1.0.

Meal consumption calculations are useful for risk managers to make fish consumption recommendations and/or take regulatory action. The SALG risk assessors calculated the number of eight-ounce meals of fish from Lake Livingston that healthy adults could consume without significant risk of PCB and/or PCDD/PCDF -related adverse systemic effects (Tables 7.1–7.3). Meal consumption rates were based on cumulative toxicity from exposure to PCBs and PCDDs/PCDFs by species. The SALG risk assessors estimated that healthy adults could consume less than one eight-ounce meal per week for these species of fish: blue catfish; flathead catfish; longnose gar; smallmouth buffalo; striped bass; or, white bass (Tables 7.1–7.3). The SALG risk assessors suggest that fish from Lake Livingston contain PCBs and PCDDs/PCDFs at concentrations that may pose potential systemic (noncarcinogenic) health risks and that people should limit their consumption of fish from Lake Livingston. Because the developing nervous system of the human fetus and young children may be especially susceptible, the SALG risk assessors recommend more conservative consumption guidance for this sensitive subpopulation.

Cumulative Carcinogenic Health Effects

The SALG also queried the probability of increasing lifetime excess cancer risk from consuming fish containing multiple inorganic and organic contaminants. In most assessments of cancer risk from environmental exposures to chemical mixtures, researchers have considered any increase in cancerous or benign growths in one or more organs as cumulative, no matter the mode or mechanism of action of the contaminant. In this assessment, risk assessors added the calculated carcinogenic effect of arsenic, chlorinated pesticides, PCBs, and PCDFs/PCDDs (Tables 8.1–8.4). In each instance, addition of the cancer risk for these chemicals increased the theoretical lifetime excess cancer risk. The cancer risk increase did 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 for longnose gar and smallmouth buffalo.

The consumption of longnose gar or smallmouth buffalo from Lake Livingston would be likely to increase the risk of cancer to exceed the DSHS guideline for protection of human health. The SALG risk assessors estimated that healthy adults could consume less than one eight-ounce meal per week of longnose gar (0.2 meals per week) or smallmouth buffalo (0.4 meals per week; Tables 8.1–8.4). Because children may experience effects at a lower exposure dose than adults, the SALG risk assessors recommend more conservative consumption guidance for this sensitive subpopulation. The SALG risk assessors suggest that consumption of longnose gar and smallmouth buffalo from Lake Livingston likely increases the risk of cancer to exceed the DSHS guideline for protection of human health from multiple contaminant exposures.

Characterization of Potential Exposure to Contaminants from Consumption of Fish from Lake Livingston

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%.[47] 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 Lake Livingston in 2012–

2013 (Table 10). The recoveries and yields for an average fish of each species from the Lake Livingston in 2012–2012 ranged from 0.4–34.3 eight-ounce meals. Based on recoveries and yields ($\overline{X}$ – 38%) from whole fish to skin-off fillets for this project, the average Lake Livingston fish yields two pounds of skin-off fillets or approximately four eight-ounce meals (Table 10). To illustrate the importance of potential exposure from large catfish, buffalo, or gar, DSHS considered the flathead catfish mean PCB concentration (0.032 mg/kg) for this project. Based on a mean PCB concentration of 0.032 mg/kg, a person consuming five eight-ounce meals per month or slightly more than one eight-ounce meals per week would consume equivalent to the RfD. The maximum size flathead catfish (45.2 pounds) for this project yields 17.2 pounds of skin-off fillets, approximately 34 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 two 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 RfD. 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 Lake Livingston.

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 Lake Livingston, located in Polk, San Jacinto, Trinity, and Walker Counties, Texas. Risk assessors from the SALG conclude from the present characterization of potential adverse health effects from consuming fish from Lake Livingston that:

1. Blue and flathead catfish concentrations of arsenic, cadmium, copper, lead, mercury, selenium, zinc, pesticides, SVOCs, or VOCs, either singly or in combination, do not exceed the DSHS guidelines for protection of human health. Therefore, consumption of these species of fish containing the above-listed contaminants **poses no apparent risk to human health**.

2. Black and white crappie, channel catfish, flathead catfish, largemouth bass, striped bass, and white bass mean PCB concentrations do not exceed the DSHS guidelines for protection of human health. Therefore, consumption of these species containing only PCBs **poses no apparent risk to human health**.

3. Black and white crappie, blue catfish, channel catfish, flathead catfish, largemouth bass, striped bass, and white bass mean PCDD/PCDF TEQ concentrations do not exceed the

DSHS guidelines for protection of human health. Therefore, consumption of these species containing only PCDDs/PCDFs **poses no apparent risk to human health**.

4. Blue catfish, longnose gar, and smallmouth buffalo mean PCB concentrations exceed the DSHS guidelines for protection of human health. Regular or long-term consumption of these species of fish may result in adverse systemic health effects. Therefore, consumption of these species from Lake Livingston **poses an apparent risk to human health**.

5. Longnose gar and smallmouth buffalo mean PCDD/PCDF TEQ concentrations exceed the DSHS guidelines for protection of human health. Regular or long-term consumption may result in adverse systemic health effects and/or increase the likelihood of carcinogenic health risks. Therefore, consumption of these species of fish from Lake Livingston **poses an apparent risk to human health**.

6. Consumption of multiple organic contaminants (i.e., PCDDs/PCDFs and PCBs) in blue catfish, flathead catfish, longnose gar, smallmouth buffalo, striped bass, and white bass does increase the likelihood of systemic health risks. Regular or long-term consumption of these species of fish may result in adverse systemic health effects. Therefore, consumption of these species of fish from Lake Livingston **poses an apparent risk to human health**.

7. Consumption of multiple inorganic and/or organic contaminants observed in longnose gar and smallmouth buffalo does significantly increase the likelihood of carcinogenic health risks. Therefore, consumption of longnose gar and smallmouth buffalo containing multiple contaminants **poses an apparent risk to human health**.

RECOMMENDATIONS

Risk managers at the DSHS have established criteria for issuing fish consumption advisories based on approaches suggested by the USEPA.[13, 18, 48] 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).[49] Declarations of prohibited harvesting areas are enforceable under the Texas Health and Safety Code, Subchapter D, parts 436.091 and 436.101.[49] The DSHS consumption advice carries no penalty for noncompliance. Consumption advisories, instead, inform the public of potential health hazards associated with consuming contaminated fish or shellfish from Texas waters. With this information, people can make informed decisions about whether and/or how much, contaminated fish or shellfish, they wish to consume. The SALG concludes from this risk characterization that consuming blue catfish, flathead catfish, longnose gar, smallmouth buffalo, striped bass, and white bass from Lake Livingston **poses an apparent hazard to public health.** Therefore, SALG risk assessors recommend that:[j]

1. People should not consume alligator gar and longnose gar from Lake Livingston (Table 11). No alligator gar samples were evaluated from Lake Livingston. However, alligator gar samples from the Trinity River above and below Lake Livingston indicate that there is significant cause for concern. SALG risk assessors recommend including alligator gar in the Lake Livingston fish consumption advisory.

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 blue catfish, flathead catfish, freshwater drum, gar (all species), and smallmouth buffalo from Lake Livingston. No freshwater drum samples were evaluated from Lake Livingston. However, freshwater drum samples from the Trinity River Basin indicate that there is significant cause for concern. SALG risk assessors recommend including freshwater drum in the Lake Livingston fish consumption advisory.

3. 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 may consume up to one eight-ounce meal per month of striped bass or white bass from Lake Livingston.

4. Women past childbearing age and adult men may consume up to one eight-ounce meal per month of blue catfish, flathead catfish, or smallmouth buffalo from Lake Livingston.

5. Women past childbearing age and adult men may consume up to two eight-ounce meals per month of freshwater drum from Lake Livingston.

6. Women past childbearing age and adult men may consume up to three eight-ounce meals per month of striped bass or white bass from Lake Livingston.

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

[j] SALG risk assessor's consumption recommendations are based on evaluation of the Trinity River Basin data (i.e., Lake Livingston and the Trinity River).

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.[50]
- 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.[51] 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.[46]

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. Lake Livingston Sample Sites

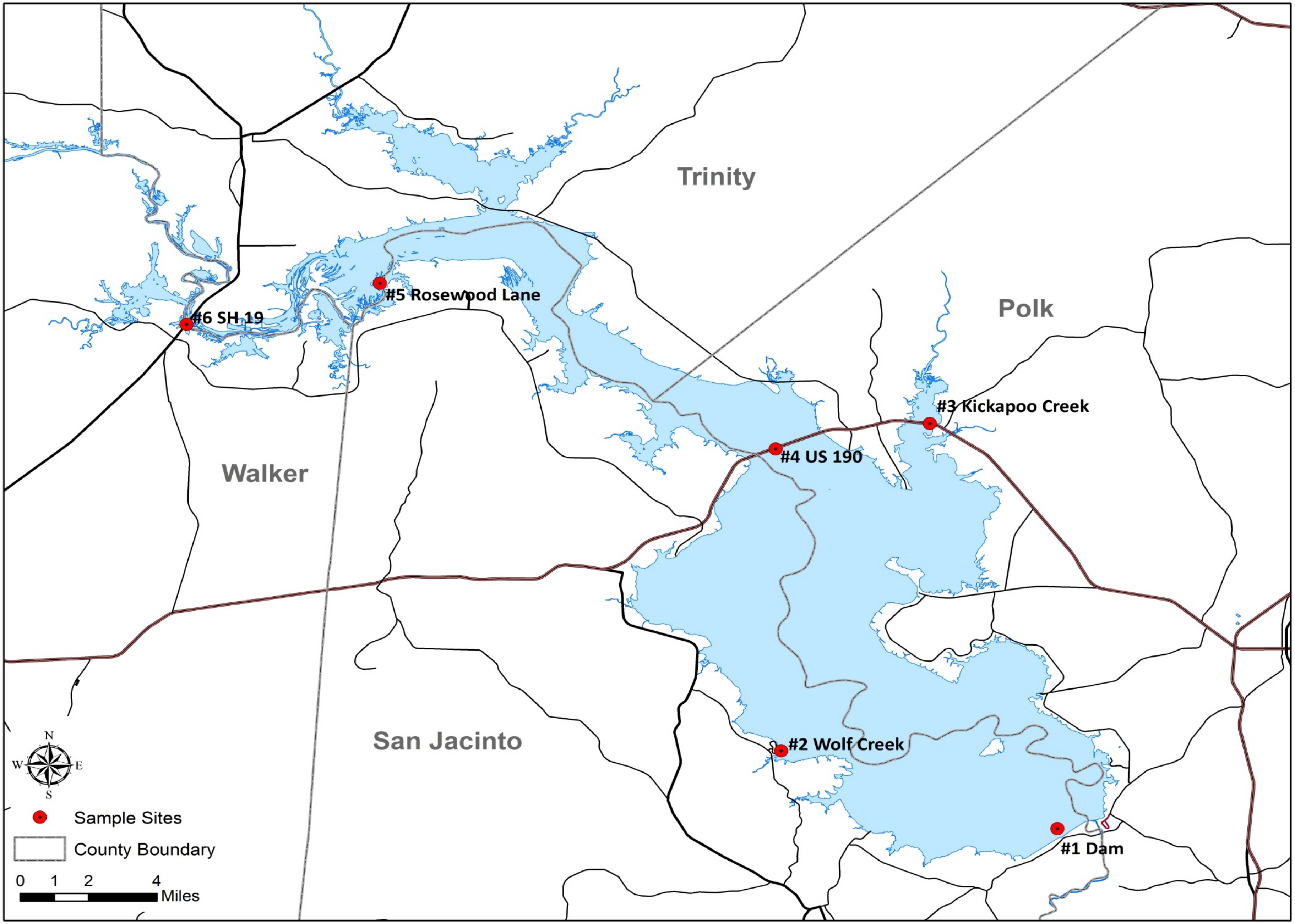


Figure 2. Length at age for black crappie collected from Lake Livingston, Texas, 2012–2013.

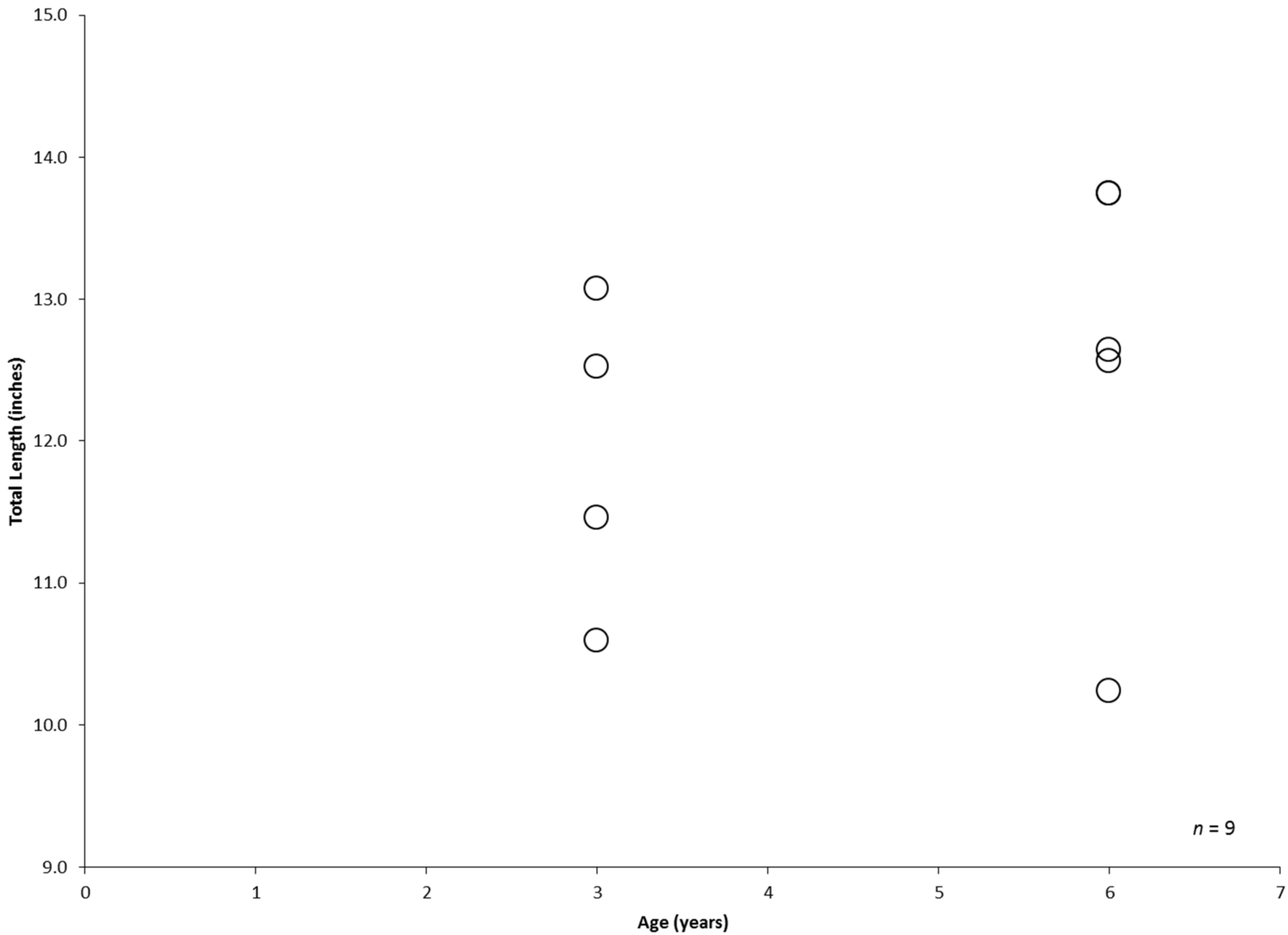


Figure 3. Length at age for blue catfish collected from Lake Livingston, Texas, 2012–2013.

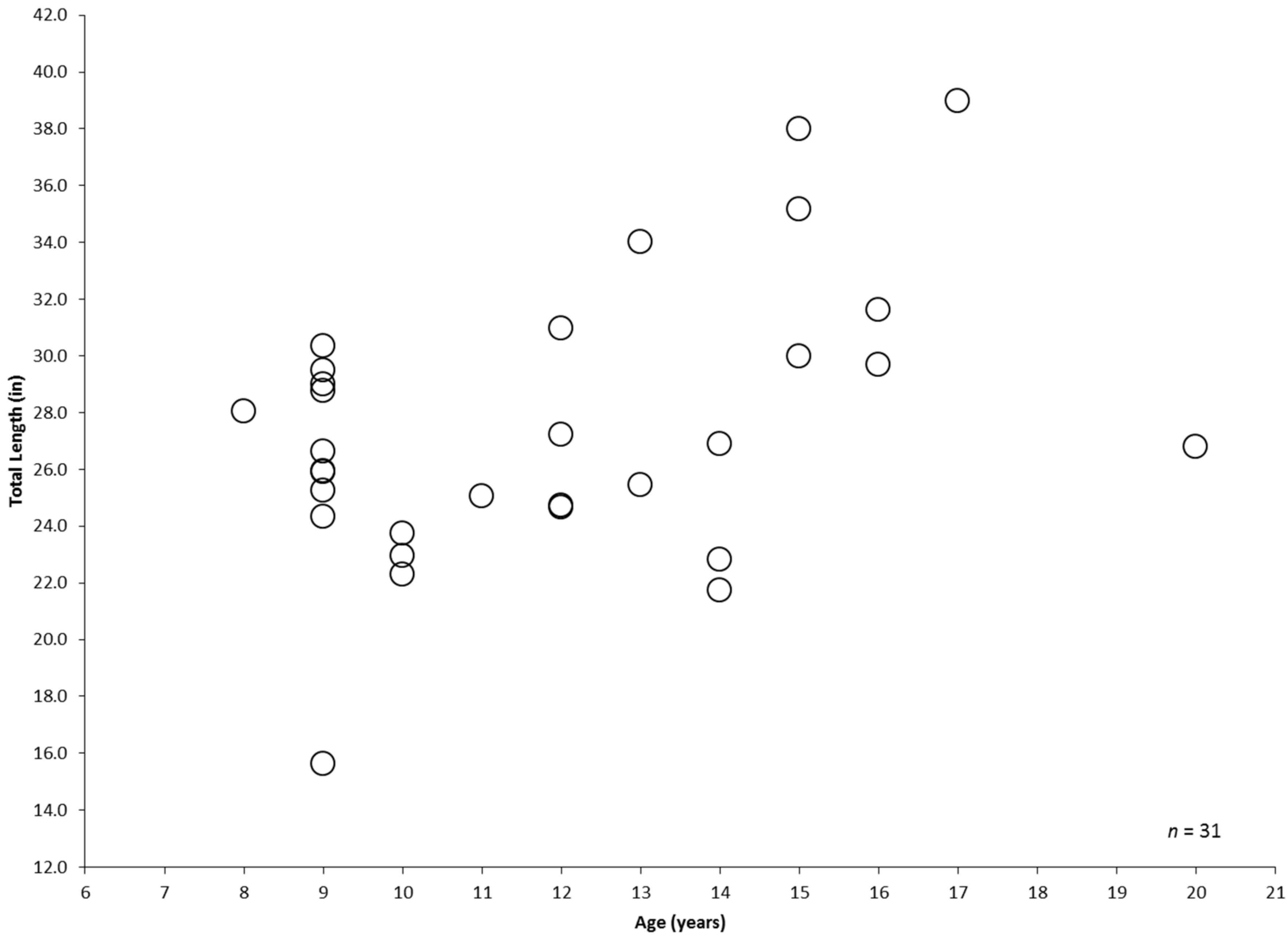


Figure 4. The relationship between mercury concentration and total length for blue catfish collected from Lake Livingston, Texas, 2012–2013.

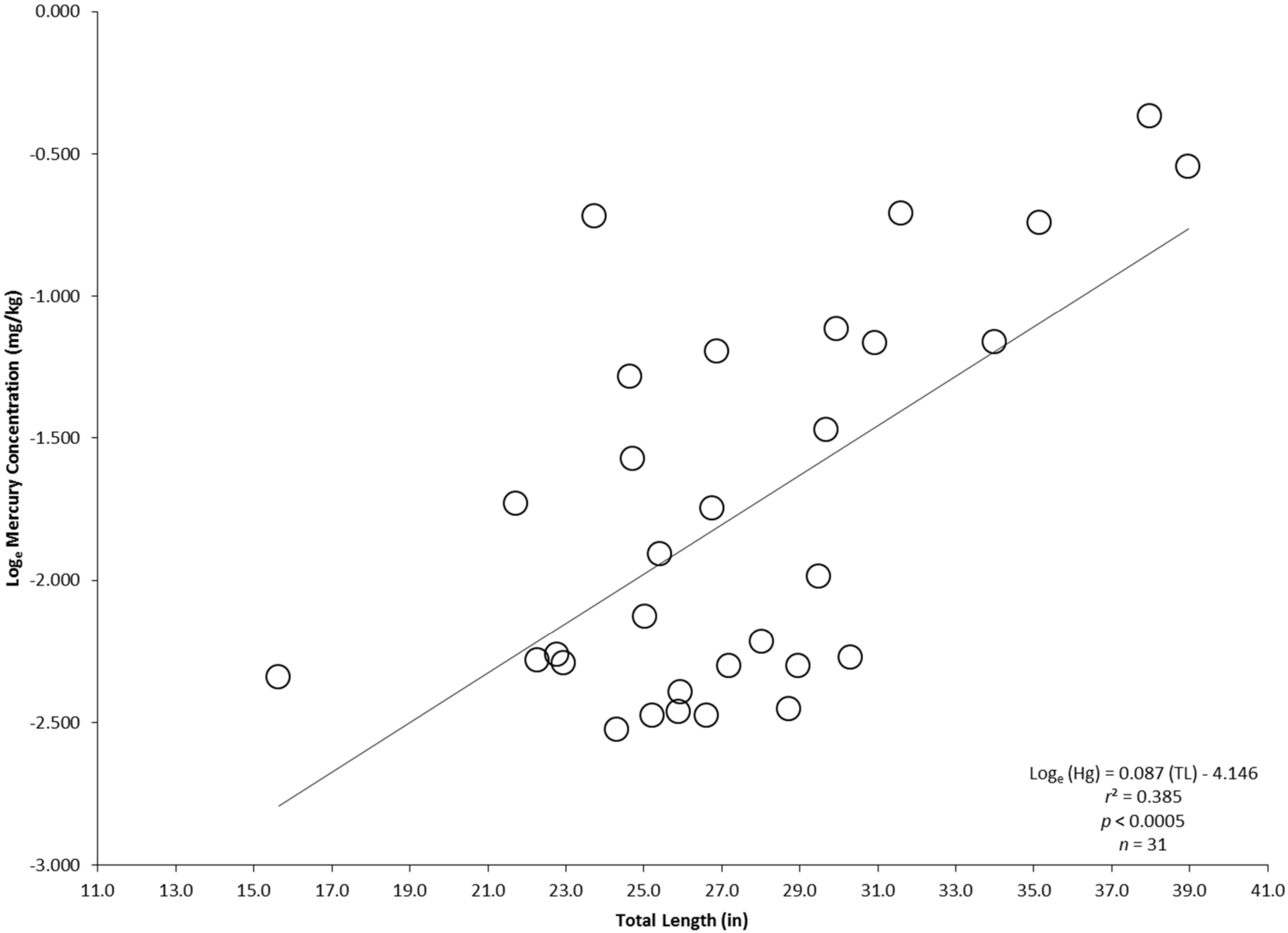


Figure 5. The relationship between mercury concentration and age for blue catfish collected from Lake Livingston, Texas, 2012–2013.

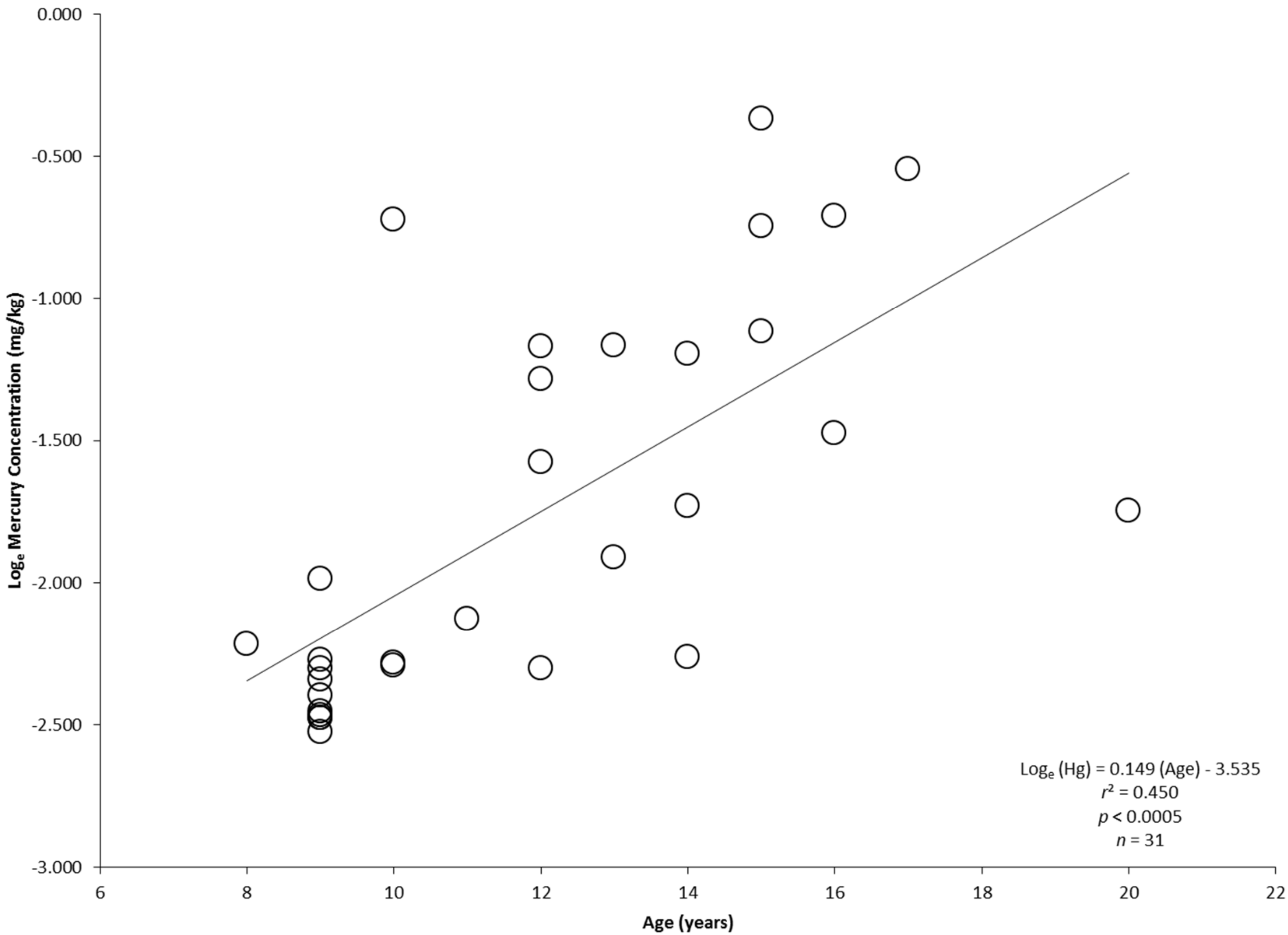


Figure 6. Length at age for channel catfish collected from Lake Livingston, Texas, 2012–2013.

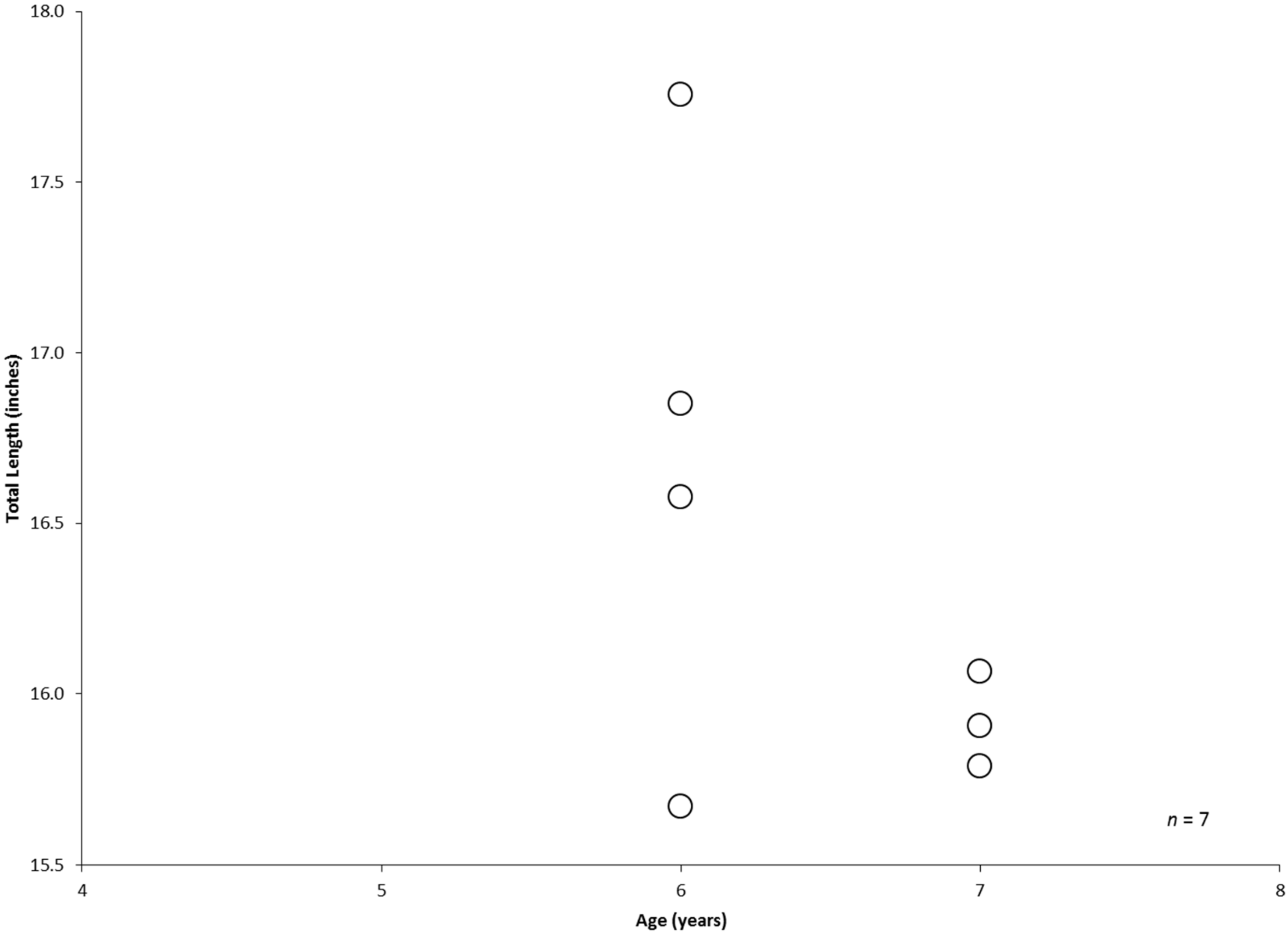


Figure 7. Length at age for flathead catfish collected from Lake Livingston, Texas, 2012–2013.

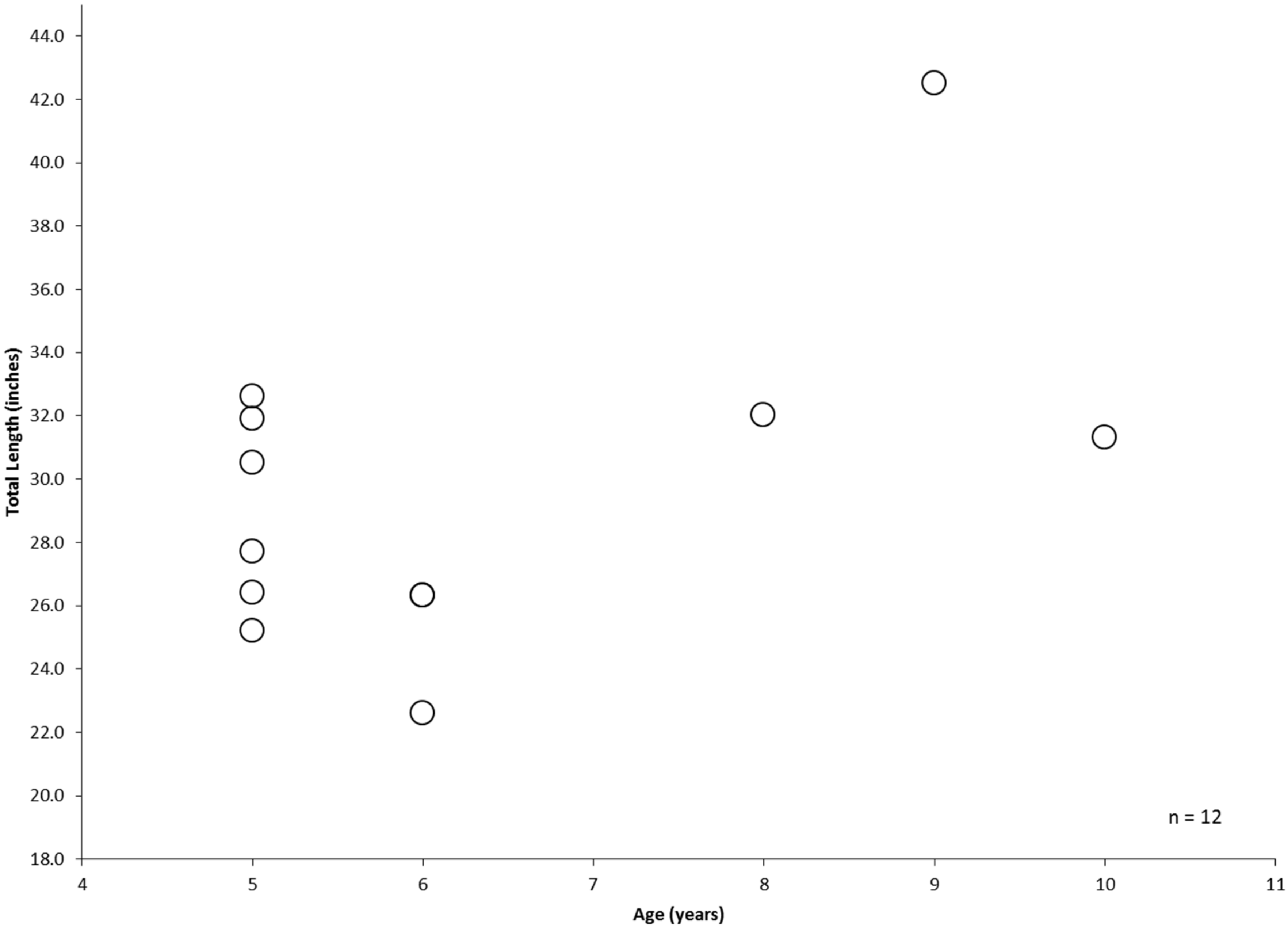


Figure 8. The relationship between mercury concentration and total length for flathead catfish collected from Lake Livingston, Texas, 2012–2013.

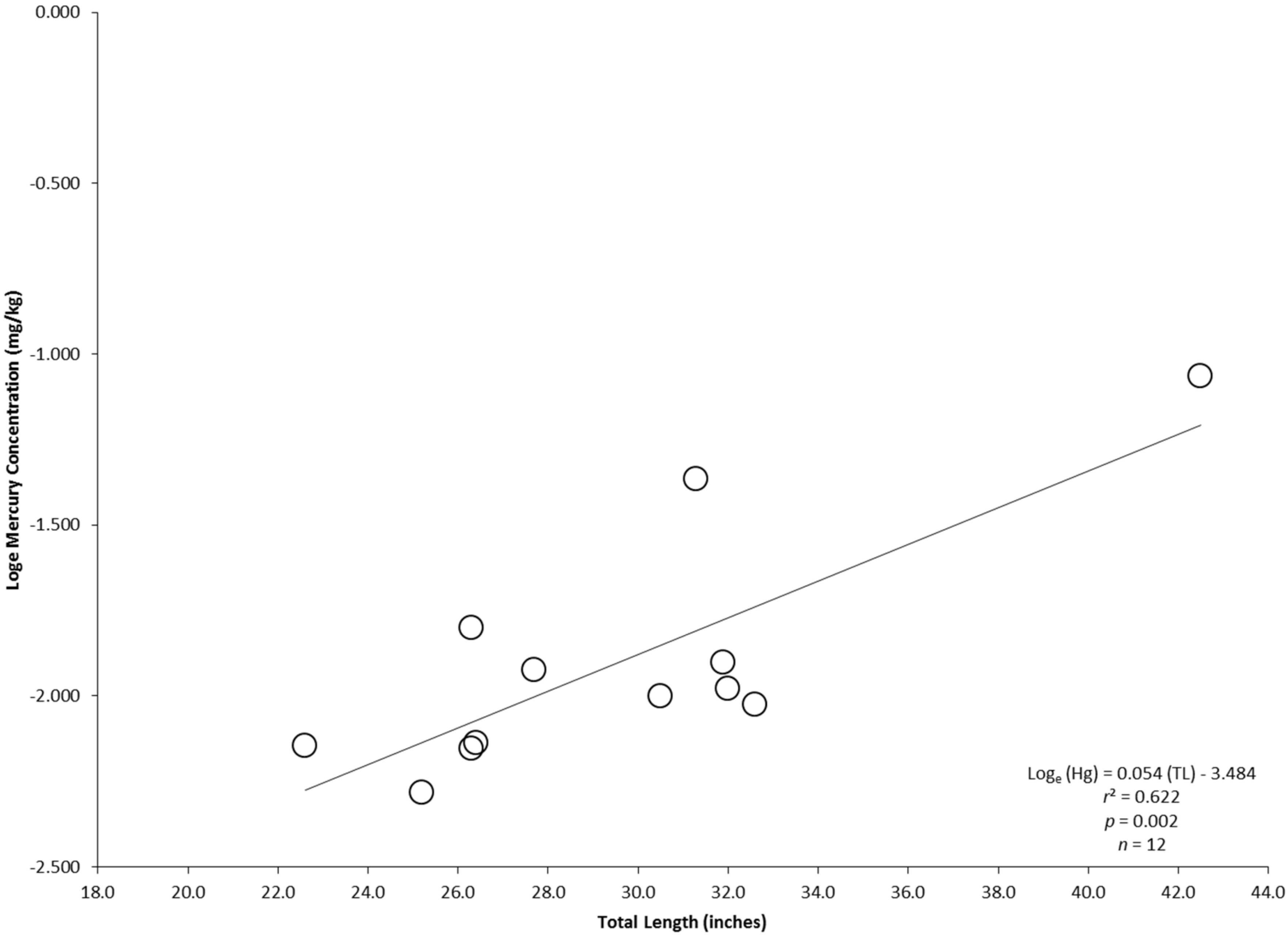


Figure 9. The relationship between mercury concentration and age for flathead catfish collected from Lake Livingston, Texas, 2012–2013.

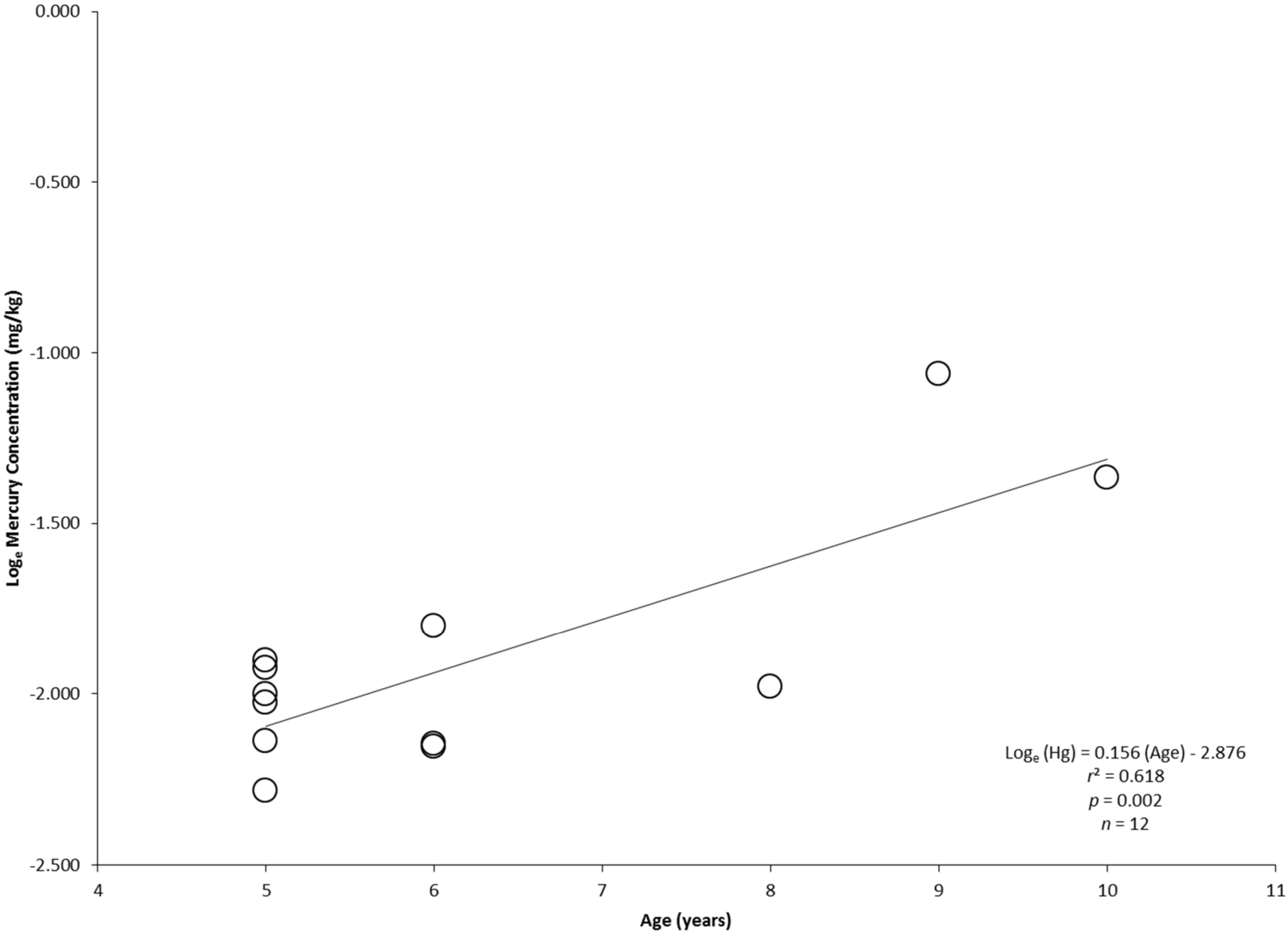


Figure 10. Length at age for largemouth bass collected from Lake Livingston, Texas, 2012-2013.

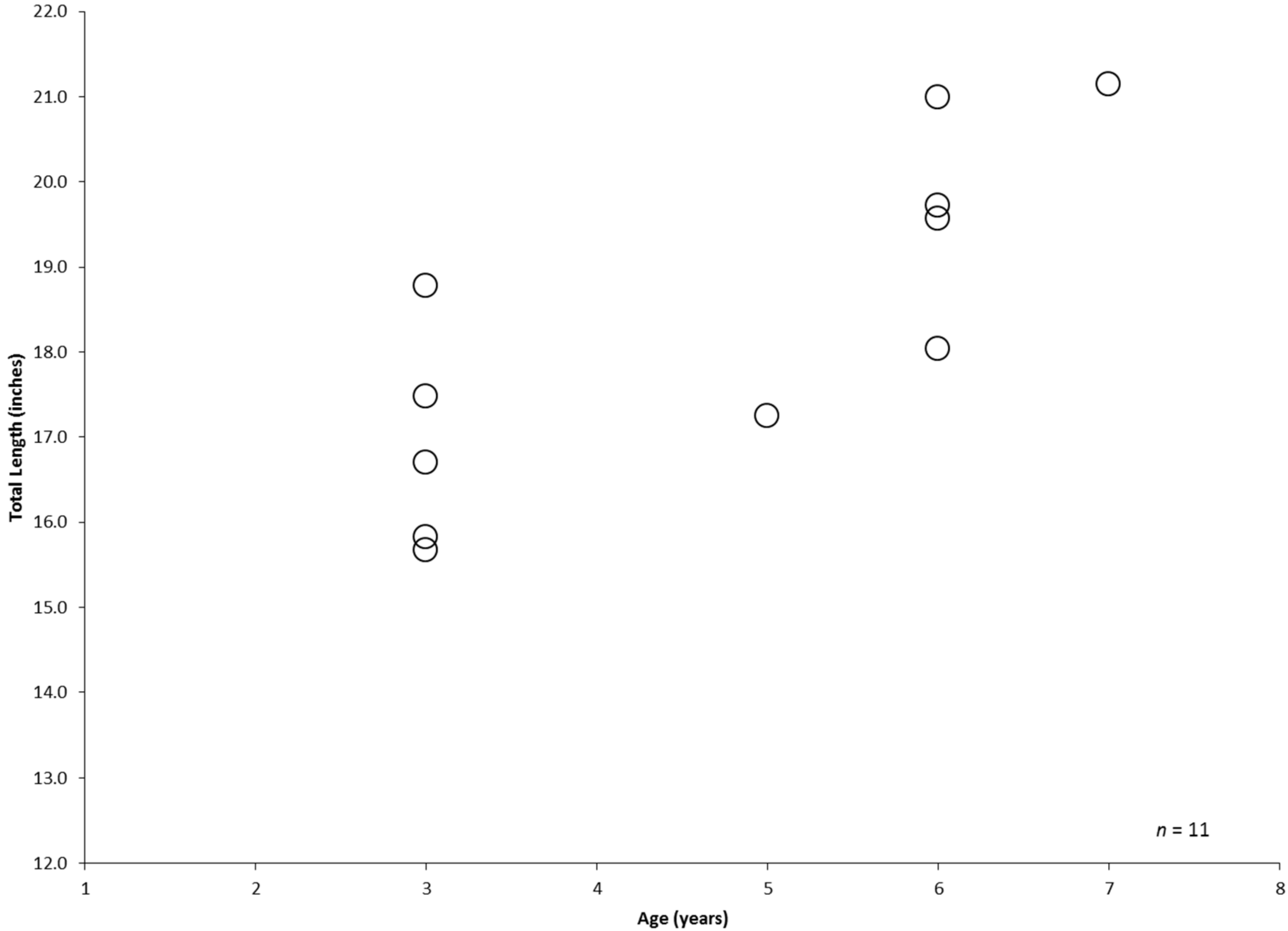


Figure 11. Length at age for striped bass collected from Lake Livingston, Texas, 2012-2013.

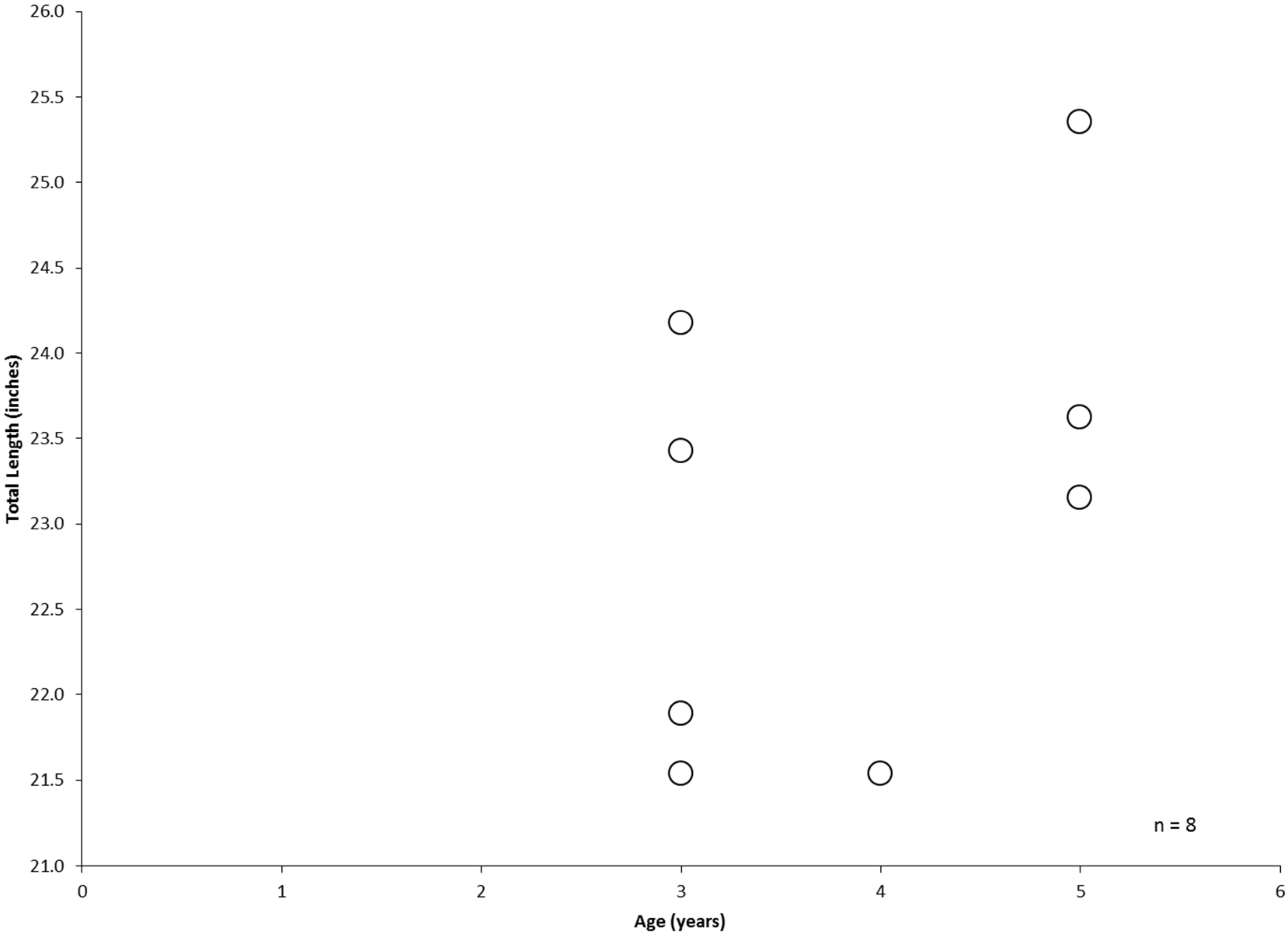


Figure 12. Length at age for white bass collected from Lake Livingston, Texas, 2012–2013.

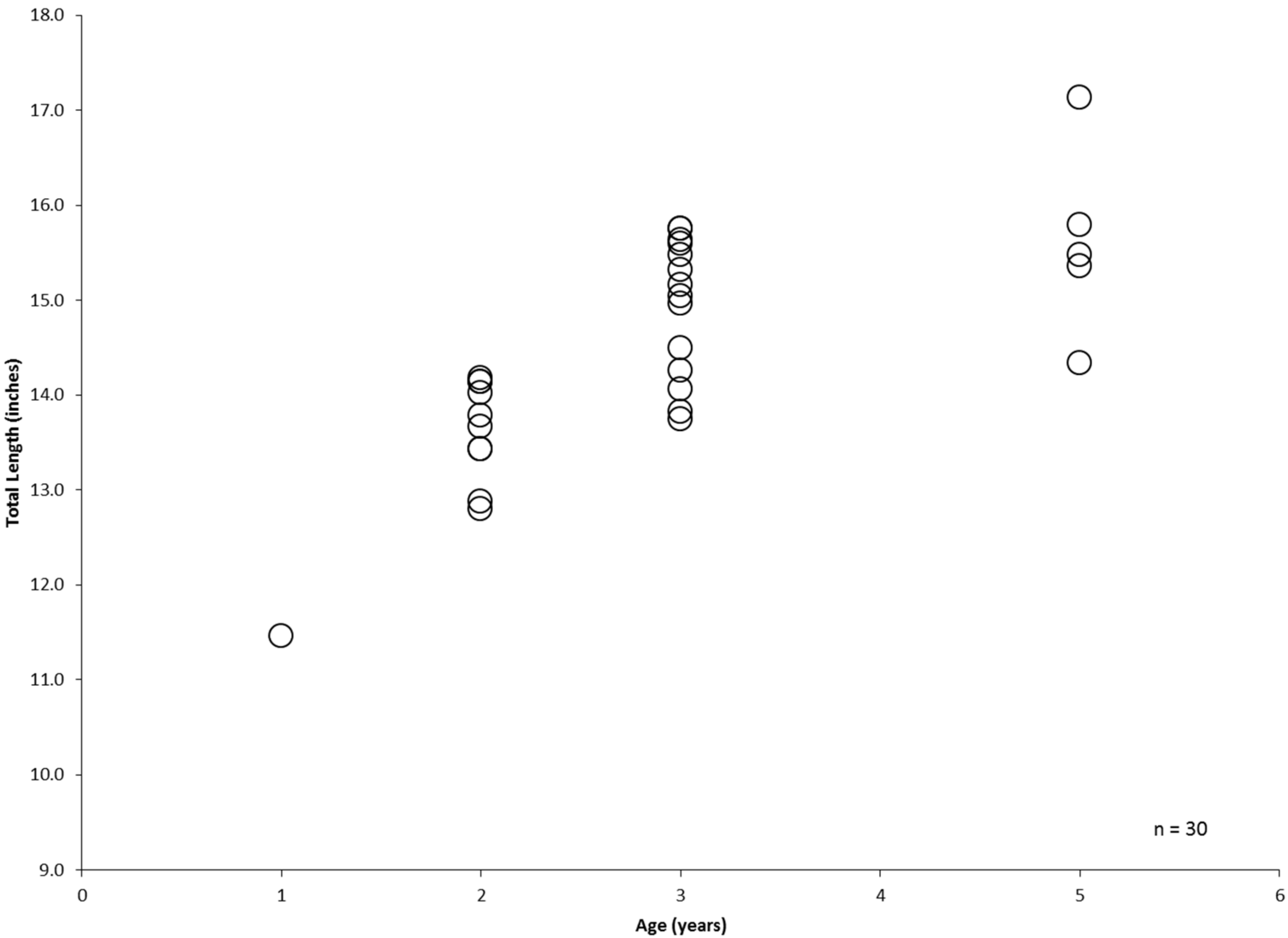


Figure 13. The relationship between mercury concentration and total length for white bass collected from Lake Livingston, Texas, 2012–2013.

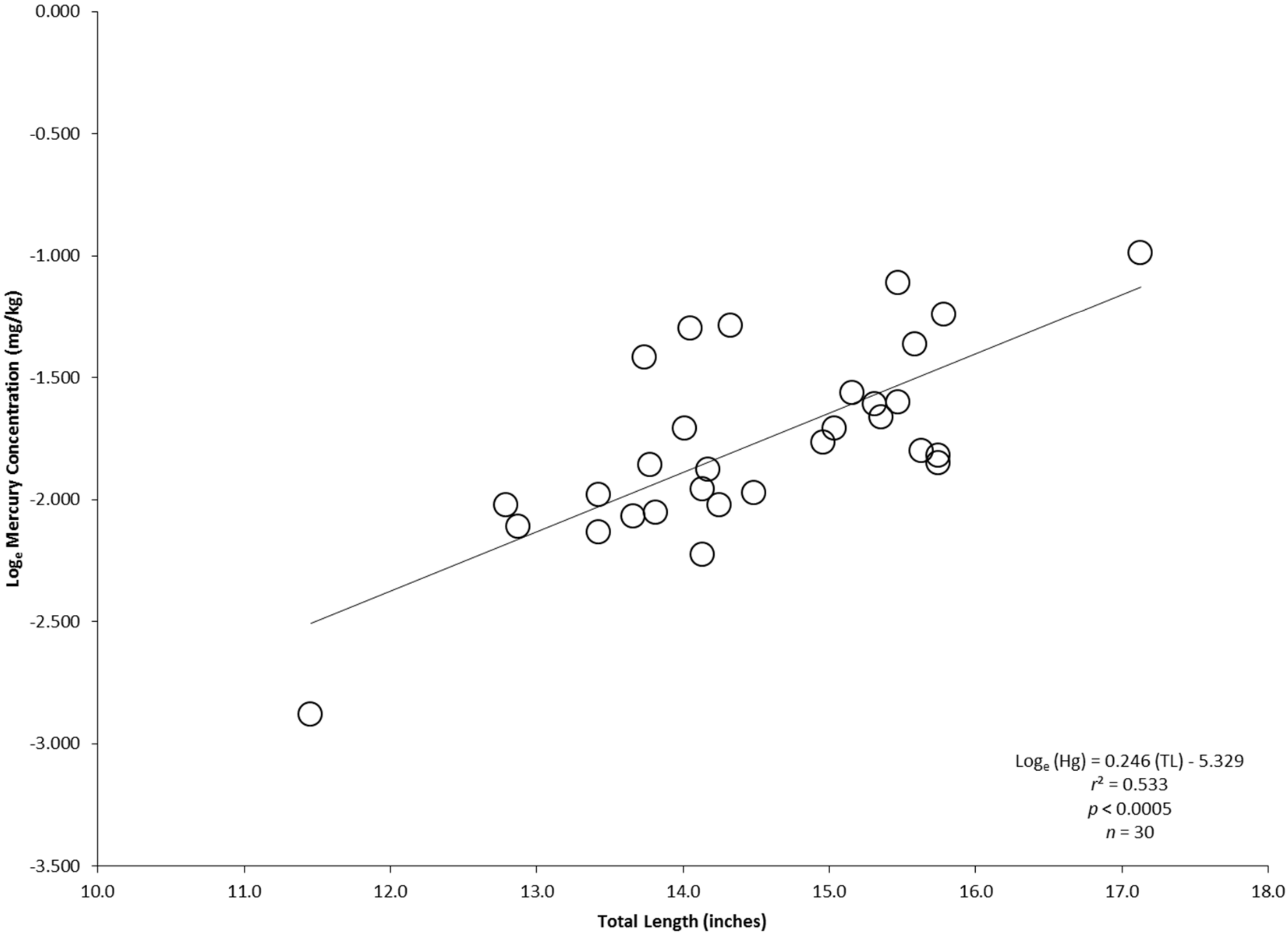


Figure 14. The relationship between mercury concentration and age for white bass collected from Lake Livingston, Texas, 2012–2013.

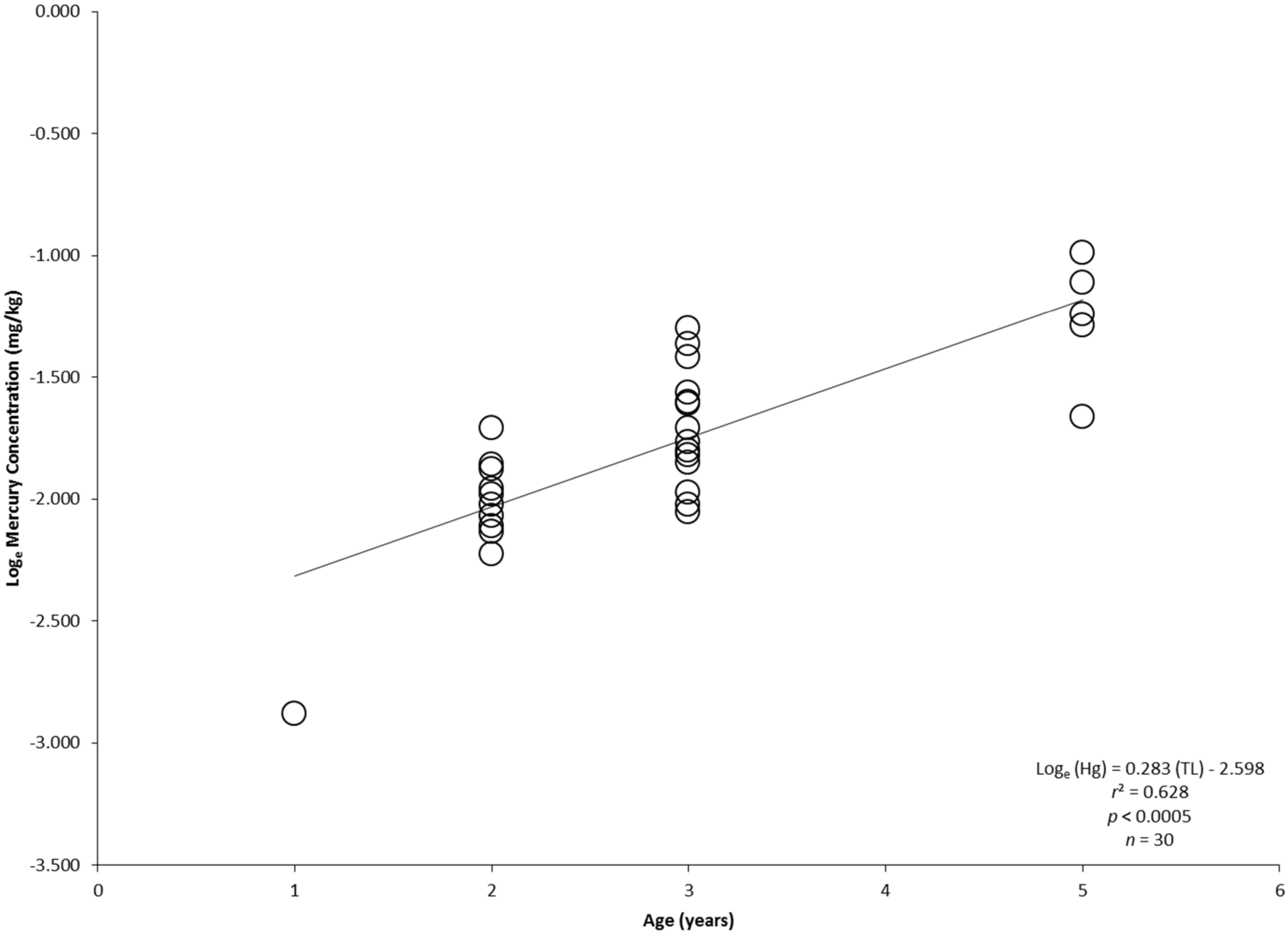


Figure 15. The relationship between PCB concentration and total length for fish collected from Lake Livingston, Texas, 2012–2013.

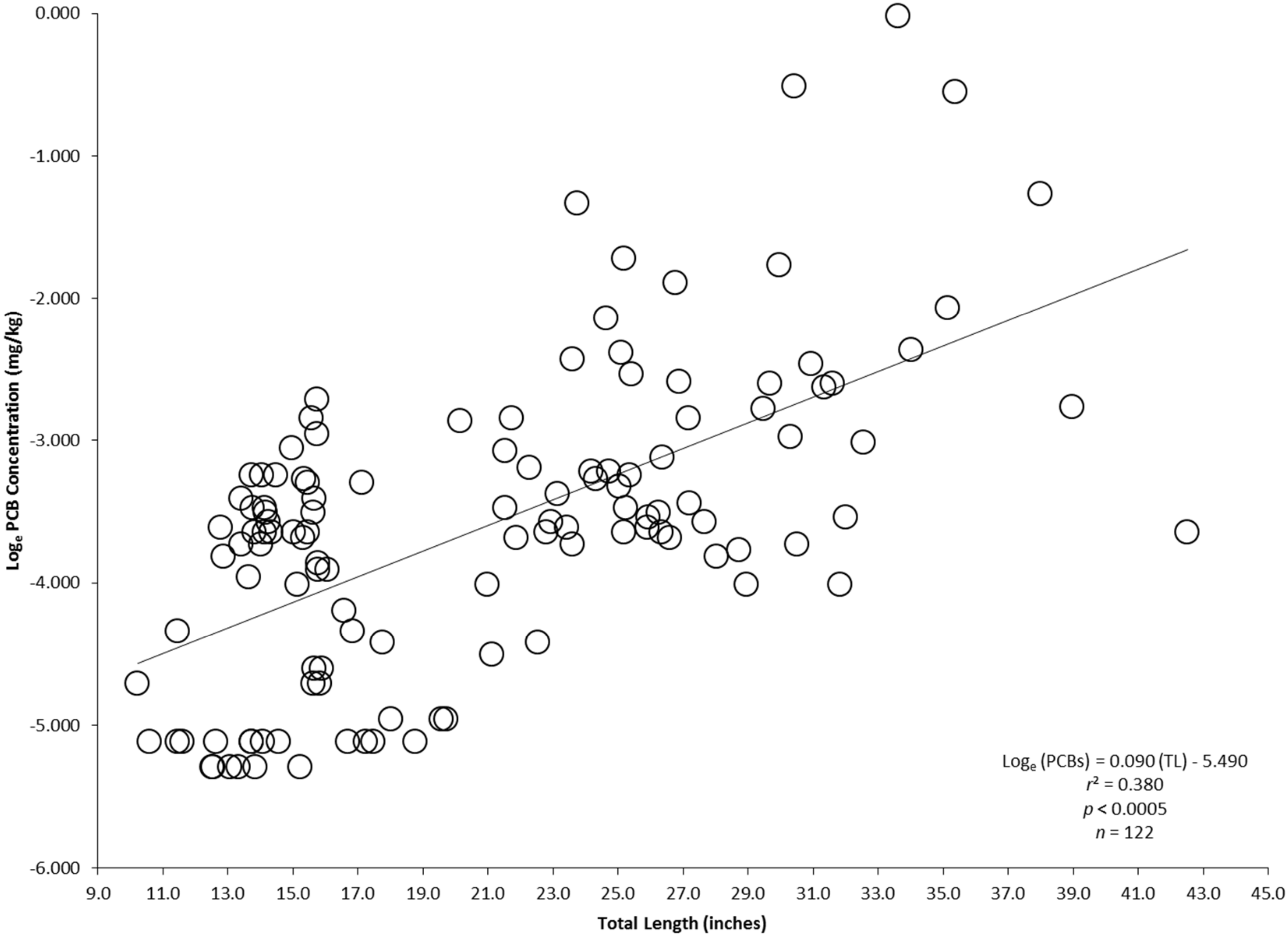


Figure 16. The relationship between PCB concentration and percent lipids for fish collected from Lake Livingston, Texas, 2012–2013.

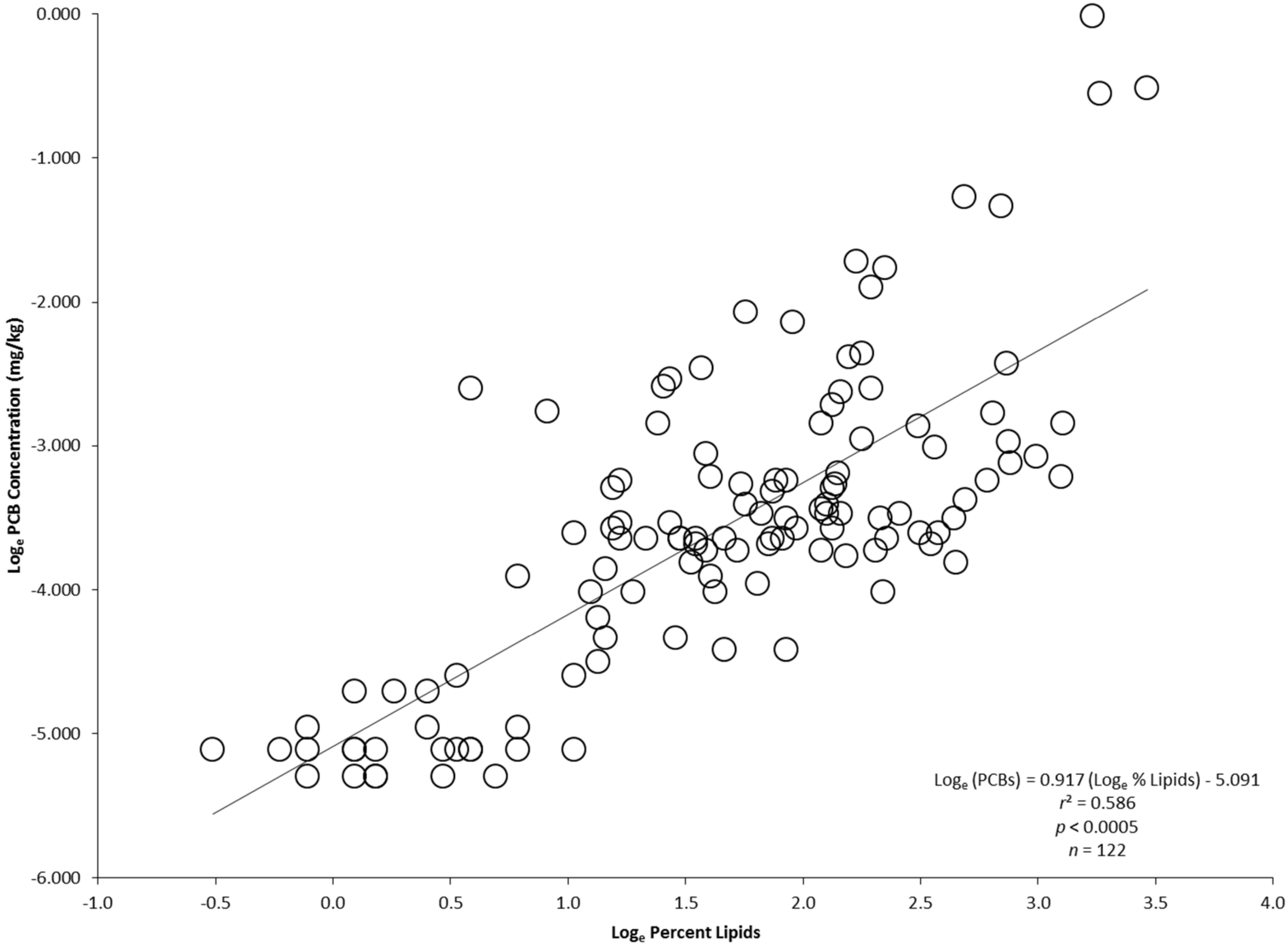


Figure 17. Mean percent lipids and PCB concentration by species Lake Livingston, Texas, 2012–2013.

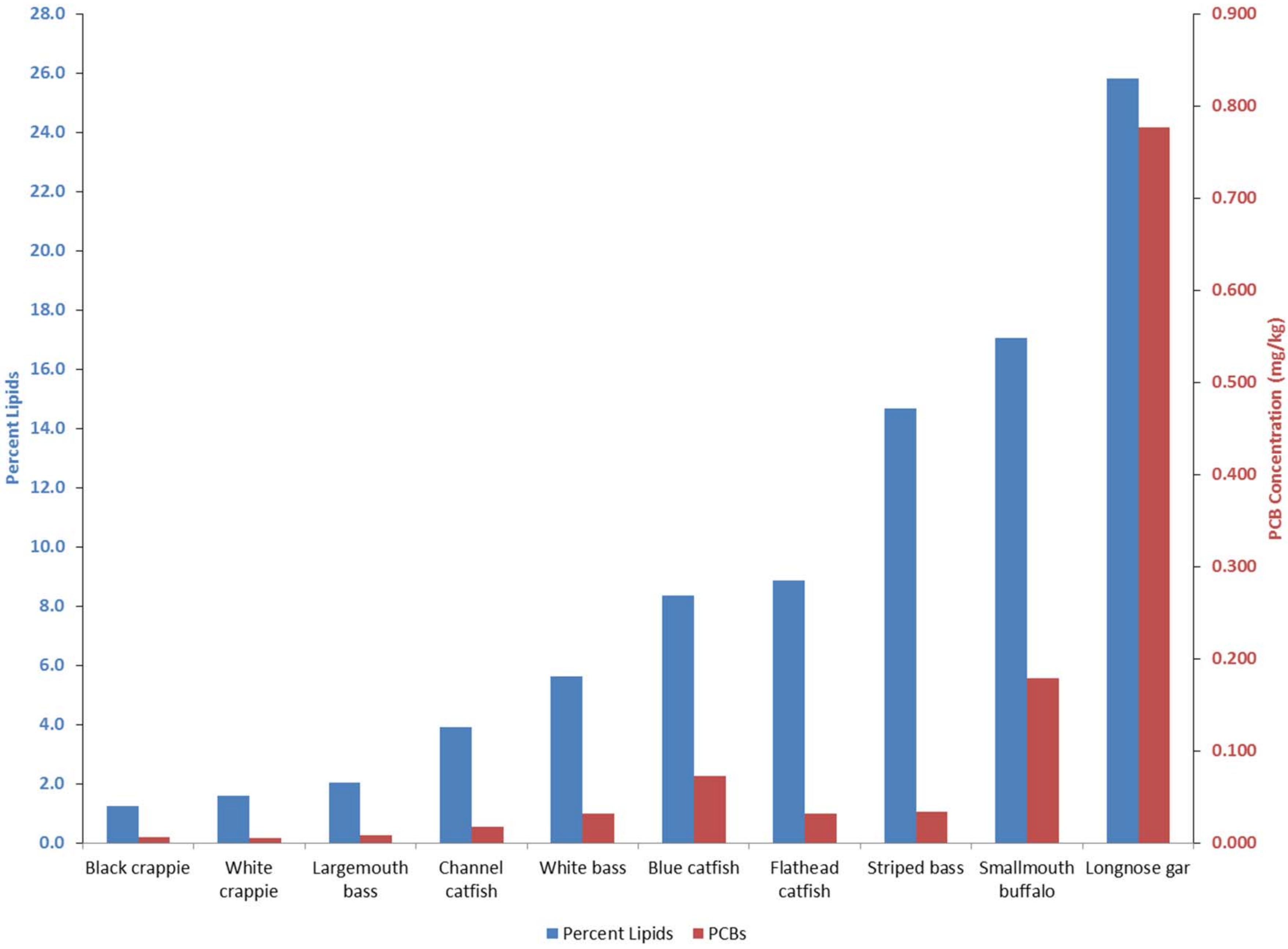


Figure 18. Mean Log_e PCBs (mg/kg, wet wt.) in fish by sample site collected from Lake Livingston, Texas 2012–2013. The error bars denote the standard error of the mean.

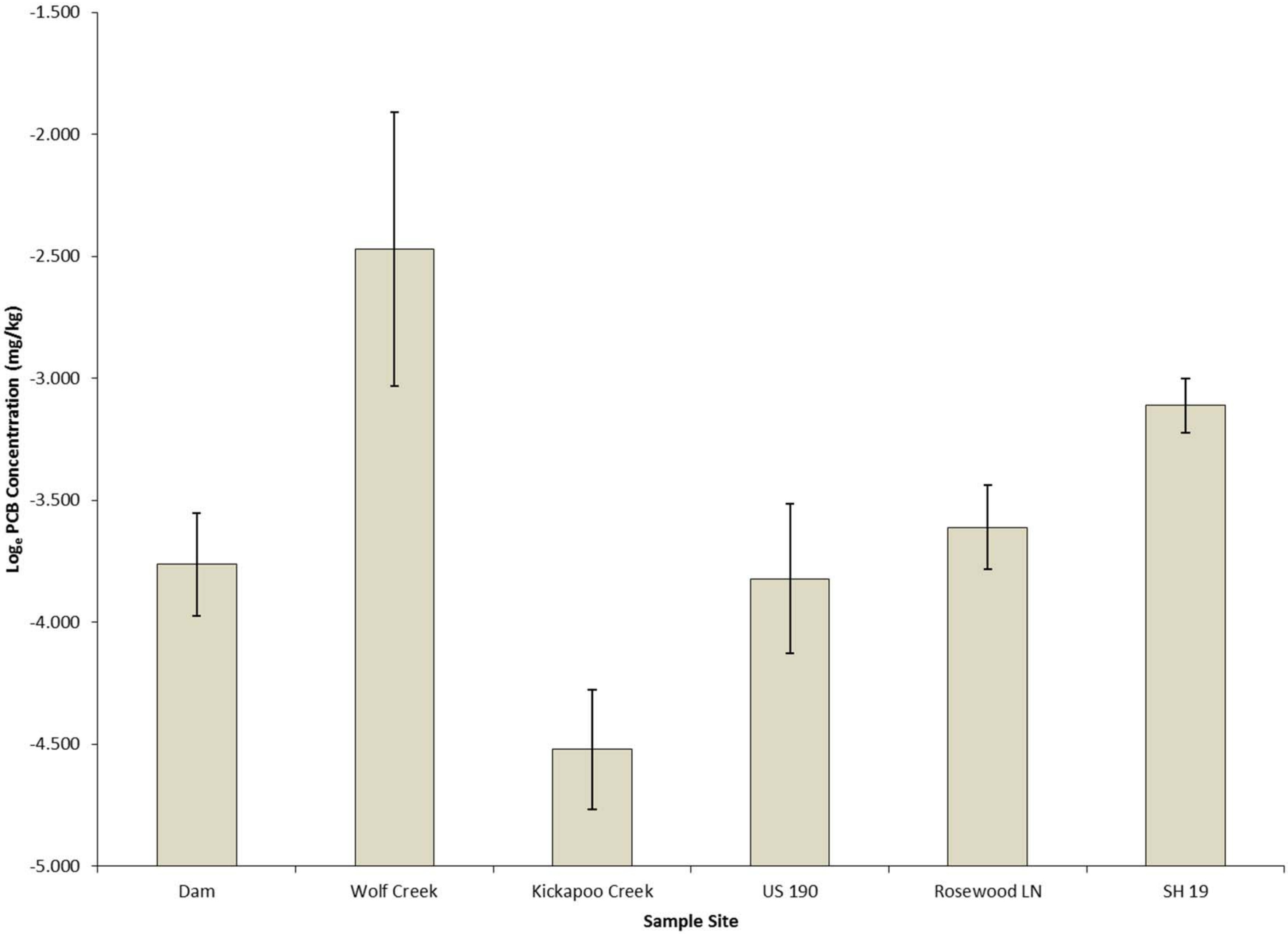


Figure 19. The relationship between PCB concentration and total length for blue catfish collected from Lake Livingston, Texas, 2012–2013.

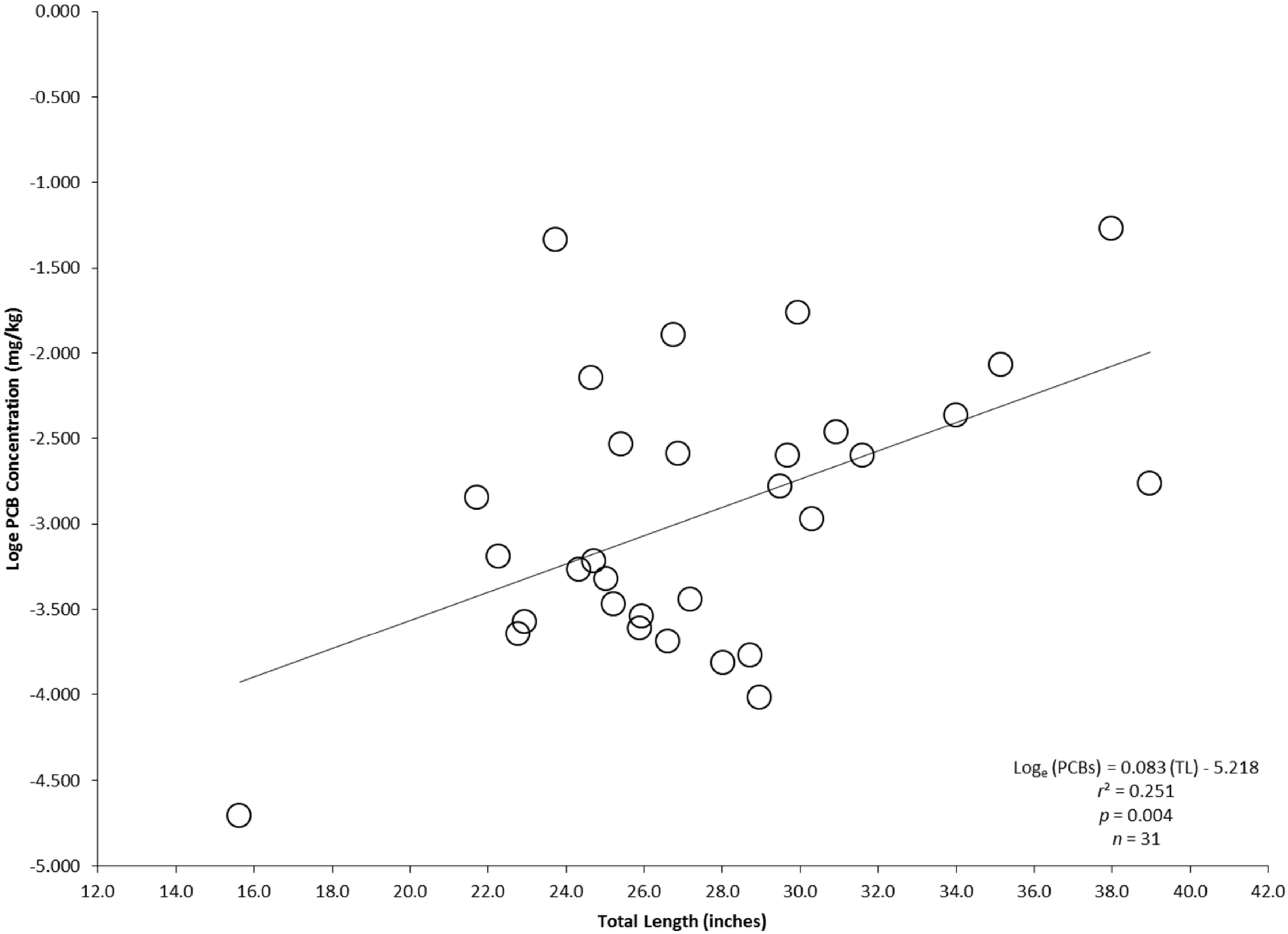


Figure 20. The relationship between PCB concentration and age for blue catfish collected from Lake Livingston, Texas, 2012–2013.

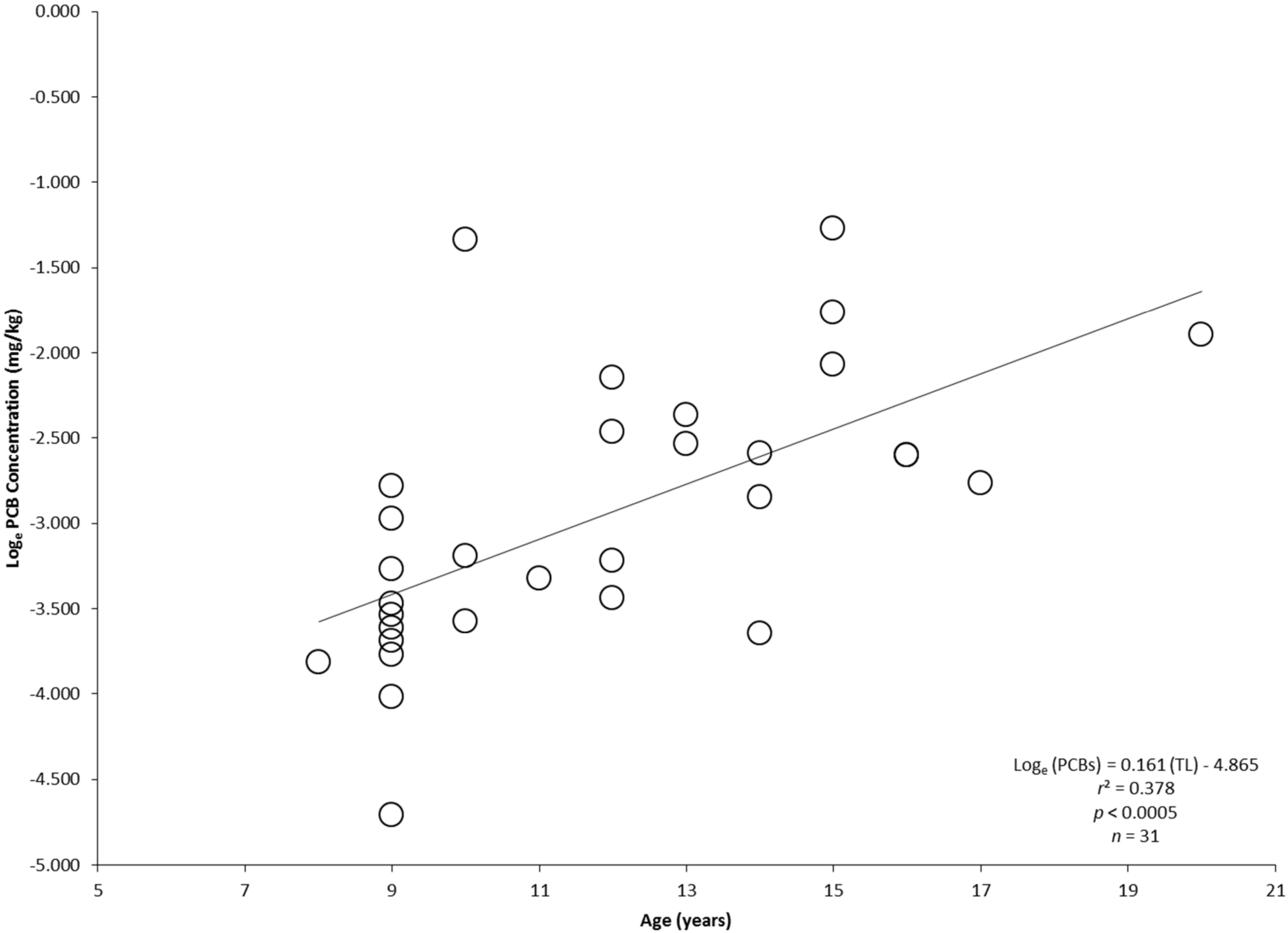


Figure 21. The relationship between PCB concentration and percent lipids for largemouth bass collected from Lake Livingston, Texas, 2012–2013.

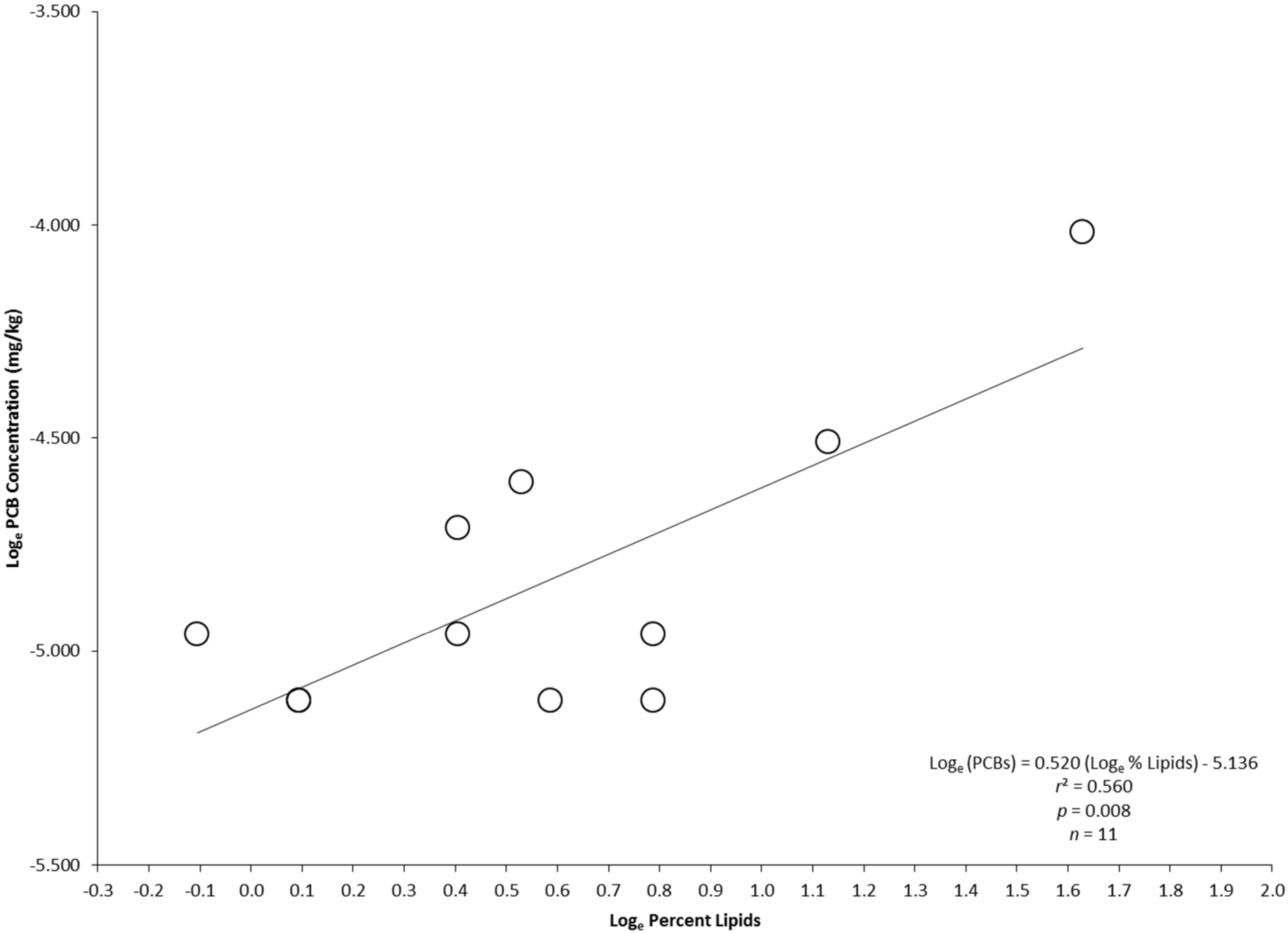


Figure 22. The relationship between PCB concentration and TL for white bass collected from Lake Livingston, Texas, 2012–2013.

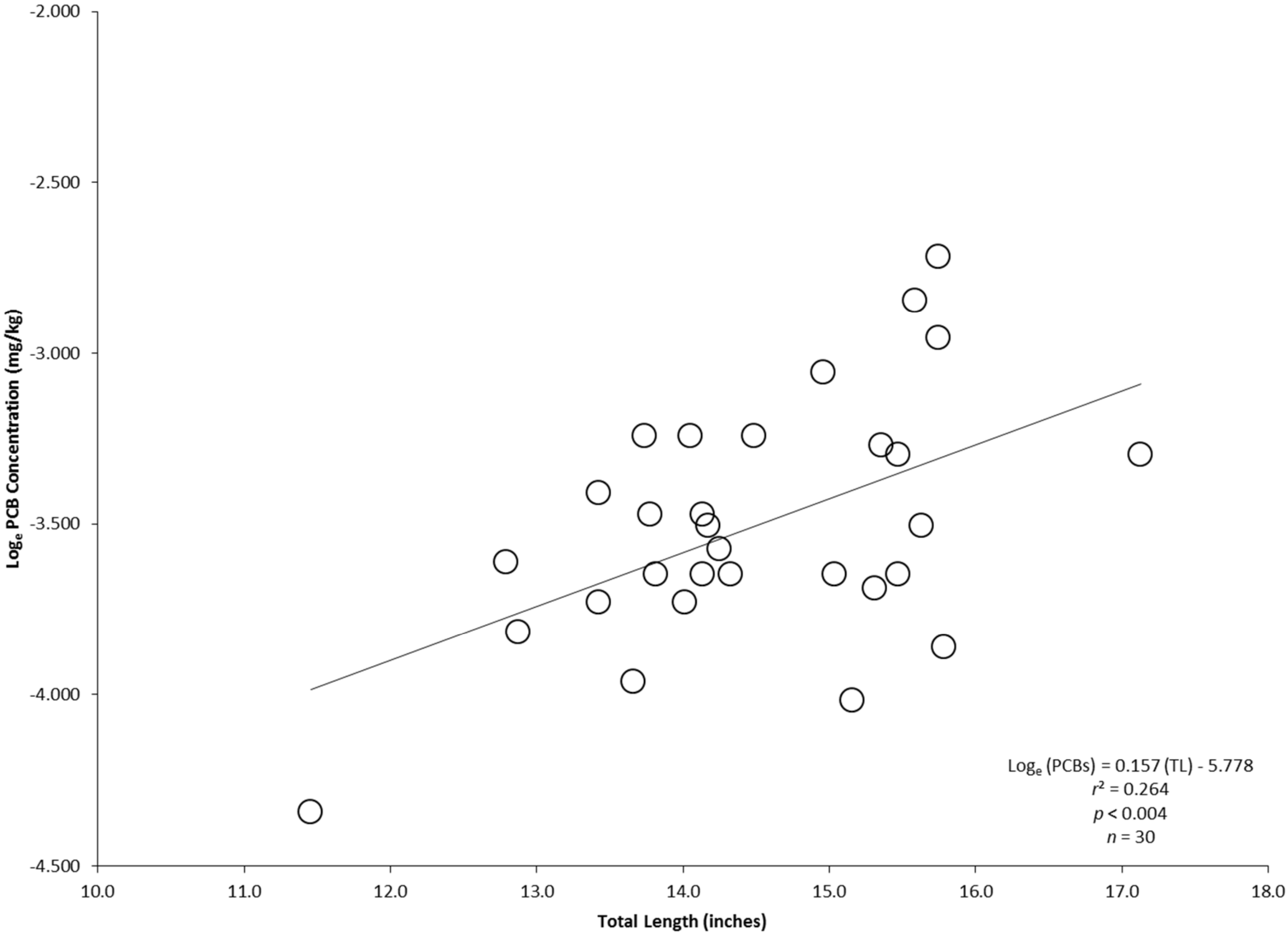
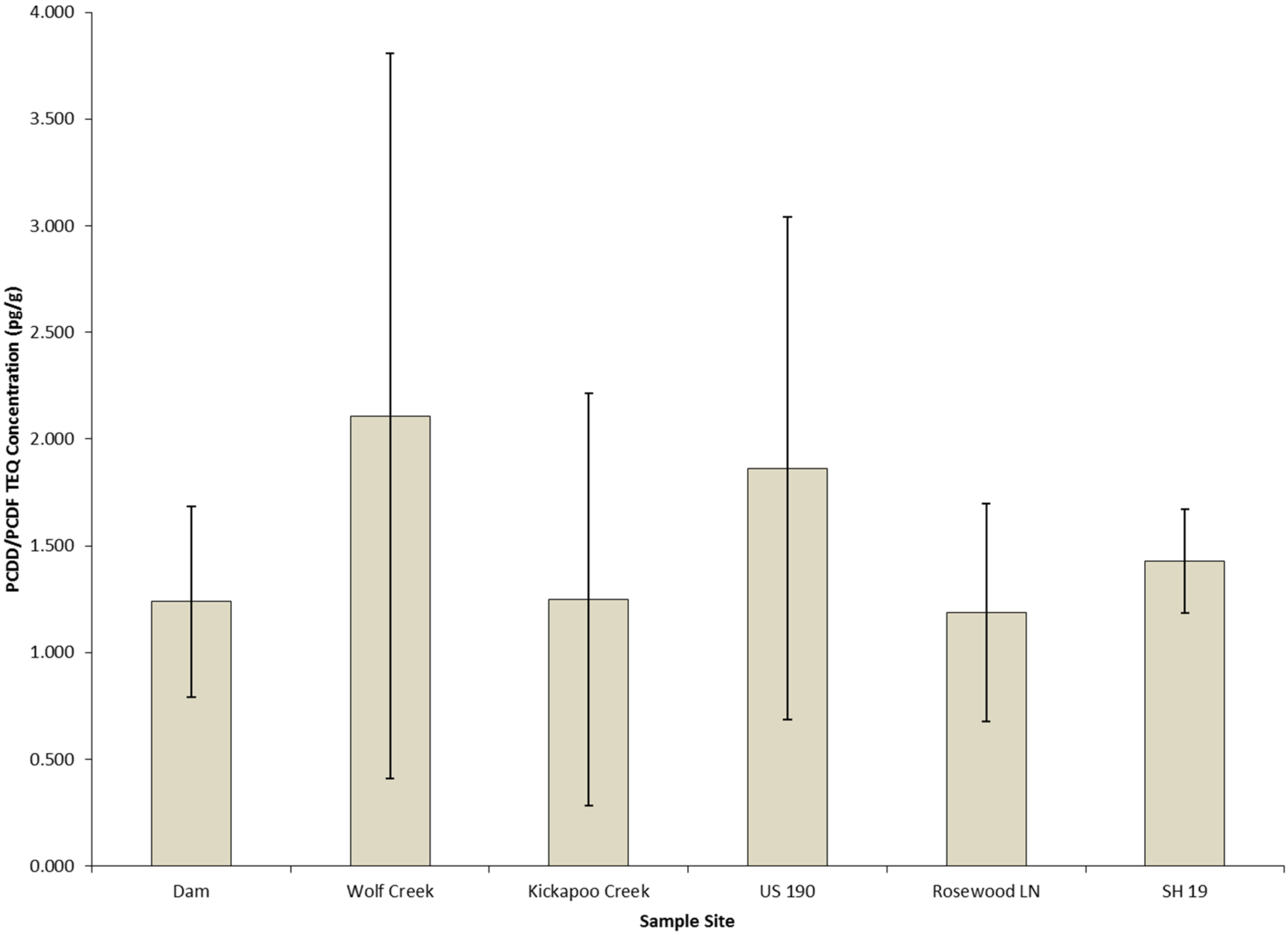


Figure 23. Mean PCDD/PCDF TEQs (pg/g, wet wt.) in fish by sample site collected from Lake Livingston, Texas 2012–2013. The error bars denote the standard error of the mean.



TABLES

Table 1. Fish samples collected from Lake Livingston 2012-2013. Sample number, species, length, and weight recorded for each sample.

Sample Number	Species	Length (mm)	Weight (g)
Site 1 Lake Livingston at Dam			
LLV86	Blue catfish	658	3117
LLV87	Blue catfish	583	2251
LLV88	Blue catfish	736	4720
LLV89	Blue catfish	770	6157
LLV90	Channel catfish	398	617
LLV91	Channel catfish	404	697
LLV92	Channel catfish	451	950
LLV93	Smallmouth buffalo	638	6049
LLV94	Channel catfish	408	565
LLV95	Channel catfish	428	714
LLV96	Channel catfish	421	750
LLV97	Channel catfish	401	590
LLV98	Largemouth bass	537	2893
LLV99	Largemouth bass	533	2852
LLV100	Largemouth bass	477	1844
LLV104	White crappie	358	772
LLV105	White crappie	352	735
LLV112	White crappie	339	627
LLV114	White crappie	387	1138
LLV115	White crappie	370	959
LLV116	Blue catfish	730	4799
LLV117	Blue catfish	749	5700
LLV118	Blue catfish	712	4622
LLV119	Blue catfish	659	3141
LLV121	Longnose gar	899	3383
LLV122	Longnose gar	854	3271
LLV152	Flathead catfish	703	5018
LLV153	Flathead catfish	670	3923
LLV154	Flathead catfish	667	4381
LLV155	Flathead catfish	775	6139
LLV158	Flathead catfish	669	4160
LLV159	Striped bass	614	3101
Site 2 Lake Livingston at Wolf Creek			
LLV123	Smallmouth buffalo	773	12250
LLV124	Blue catfish	579	2306
LLV126	Blue catfish	691	3529

Table 1 cont. Fish samples collected from Lake Livingston 2012-2013. Sample number, species, length, and weight recorded for each sample.			
Sample Number	**Species**	**Length (mm)**	**Weight (g)**
Site 2 Lake Livingston at Wolf Creek (cont.)			
LLV127	Blue catfish	626	2577
LLV128	Blue catfish	754	5495
Site 3 Lake Livingston at Kickapoo Creek			
LLV41	Smallmouth buffalo	690	5945
LLV42	Largemouth bass	501	2192
LLV43	Largemouth bass	497	2149
LLV44	Largemouth bass	458	1435
LLV46	Largemouth bass	444	1427
LLV47	Largemouth bass	424	1214
LLV52	Striped bass	556	2421
LLV53	Striped bass	595	2795
LLV54	Striped bass	547	2420
LLV56	Black crappie	349	743
LLV58	Black crappie	319	609
LLV60	Black crappie	349	760
Site 4 Lake Livingston at US Highway 190			
LLV67	Flathead catfish	640	3609
LLV68	Flathead catfish	573	2303
LLV71	White crappie	295	520
LLV72	Black crappie	332	663
LLV75	Largemouth bass	402	994
LLV76	Largemouth bass	438	1188
LLV78	Smallmouth buffalo	600	5058
LLV79	White bass	291	324
LLV80	Blue catfish	397	559
LLV81	Blue catfish	552	1761
LLV83	Blue catfish	628	2889
LLV84	Blue catfish	761	5344
LLV85	Blue catfish	683	3889
LLV151	White bass	435	917
Site 5 Lake Livingston near Rosewood Lane			
LLV1	Smallmouth buffalo	640	5900
LLV3	Black crappie	318	510
LLV5	Black crappie	260	261
LLV8	Black crappie	291	408
LLV9	Black crappie	321	642
LLV10	Black crappie	269	321

Table 1 cont. Fish samples collected from Lake Livingston 2012-2013. Sample number, species, length, and weight recorded for each sample.			
Sample Number	**Species**	**Length (mm)**	**Weight (g)**
Site 5 Lake Livingston near Rosewood Lane (cont.)			
LLV13	Largemouth bass	398	1320
LLV14	White bass	382	978
LLV15	White bass	393	1007
LLV16	White bass	362	693
LLV17	White bass	385	829
LLV18	White bass	390	851
LLV19	White bass	327	538
LLV21	White bass	389	935
LLV22	White bass	347	689
LLV23	White bass	341	637
LLV24	White bass	351	587
LLV27	Blue catfish	676	3519
LLV28	Blue catfish	646	3250
LLV29	Blue catfish	680	3880
LLV30	Blue catfish	641	2905
LLV31	Blue catfish	636	3149
LLV32	Blue catfish	618	2651
LLV33	Blue catfish	603	2069
LLV34	Blue catfish	566	2039
LLV36	White bass	397	1025
LLV37	Striped bass	547	2577
LLV38	Striped bass	588	3568
LLV39	Striped bass	644	4332
LLV40	Striped bass	600	3038

Table 1 cont. Fish samples collected from Lake Livingston 2012-2013. Sample number, species, length, and weight recorded for each sample.			
Sample Number	**Species**	**Length (mm)**	**Weight (g)**
Site 6 Lake Livingston at SH19			
LLV130	White bass	341	532
LLV131	White bass	364	570
LLV132	White bass	393	882
LLV134	White bass	357	537
LLV135	White bass	350	631
LLV136	White bass	349	501
LLV137	White bass	359	679
LLV138	White bass	401	774
LLV139	White bass	360	634
LLV140	White bass	400	847
LLV143	White bass	380	809
LLV144	White bass	400	860
LLV146	White bass	359	625
LLV147	White bass	396	885
LLV148	White bass	368	588
LLV149	White bass	356	654
LLV150	White bass	325	453
TRR117	Smallmouth buffalo	512	2367
TRR121	Blue catfish	990	12750
TRR122	Blue catfish	965	12500
TRR123	Blue catfish	893	11000
TRR124	Blue catfish	803	5749
TRR127	Flathead catfish	1080	20500
TRR128	Flathead catfish	827	7818
TRR130	Flathead catfish	809	6432
TRR131	Flathead catfish	813	7852
TRR134	Flathead catfish	796	6979
TRR135	Blue catfish	786	5477
TRR138	Blue catfish	864	9750

Table 2.1. Arsenic (mg/kg) in fish collected from Lake Livingston 2012–2013.					
Species	**Number Detected/ Number Tested**	**Total Arsenic Mean ± S.D. (Min-Max)**	**Inorganic Arsenic Mean[k]**	**HAC Value (nonca) and HAC Value (ca; mg/kg)[l]**	**Basis for Comparison Value**
Blue catfish	5/5	0.043±0.043 (BDL-0.116)	0.004	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
Flathead catfish	1/1	0.313	0.031		
All fish combined	6/6	0.088±0.117 (BDL-0.313)	0.009		

Table 2.2. Inorganic contaminants (mg/kg) in fish collected from Lake Livingston 2012–2013.				
Species	**Number Detected/ Number Tested**	**Mean ± S.D. (Min-Max)**	**HAC Value (nonca; mg/kg)**	**Basis for Comparison Value**
Cadmium				
Blue catfish	4/5	0.011±0.001 (ND-BDL)	0.233	ATSDR Chronic Oral MRL— 0.0001 mg/kg–day
Flathead catfish	1/1	0.154		
All fish combined	5/6	0.035±0.058 (ND-0.154)		
Copper				
Blue catfish	5/5	0.252±0.156 (0.142-0.521)	334	Based on the Tolerable Upper Intake Level (UL) — 0.143 mg/kg–day[m]
Flathead catfish	1/1	0.119		
All fish combined	6/6	0.230±0.149 (0.119-0.521)		

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

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

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

Table 2.3. Inorganic contaminants (mg/kg) in fish collected from Lake Livingston 2012–2013.				
Species	**Number Detected/ Number Tested**	**Mean ± S.D. (Min-Max)**	**HAC Value (nonca; mg/kg)**	**Basis for Comparison Value**
Lead				
Blue catfish	1/5	0.029±0.041 (ND-0.103)	N/A	N/A
Flathead catfish	1/1	0.011		
All fish combined	2/6	0.026±0.038 (ND-0.103)		
Selenium				
Blue catfish	5/5	0.305±0.036 (0.268-0.354)	6	EPA Chronic Oral RfD — 0.005 mg/kg–day ATSDR Chronic Oral MRL — 0.005 mg/kg–day UL: 0.400 mg/day (0.005 mg/kg–day) RfD or MRL/2 — (0.005 mg/kg –day/2= 0.0025 mg/kg–day)[n, 52]
Flathead catfish	1/1	1.056		
All fish combined	6/6	0.430±0.308 (0.268-1.056)		
Zinc				
Blue catfish	5/5	4.459±0.901 (3.804-5.832)	700	EPA Chronic Oral RfD — 0.3 mg/kg–day
Flathead catfish	1/1	4.138		
All fish combined	6/6	4.405±0.816 (3.804-5.832)		

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

Table 2.4. Mercury (mg/kg) in fish collected from Lake Livingston 2012–2013.				
Species	**Number Detected/ Number Tested**	**Mean ± S.D. (Min-Max)**	**HAC Value (nonca; mg/kg)**	**Basis for Comparison Value**
Site 1 Lake Livingston at the Dam				
Blue catfish	8/8	0.102±0.017 (0.085-0.137)	0.7	ATSDR Chronic Oral MRL for Methylmercury — 0.0003 mg/kg–day
Channel catfish	7/7	0.109±0.031 (0.077-0.160)		
Flathead catfish	5/5	0.136±0.020 (0.116-0.165)		
Largemouth bass	3/3	0.212±0.066 (0.155-0.285)		
Longnose gar	2/2	0.337±0.075 (0.284-0.390)		
Smallmouth buffalo	1/1	0.082		
Striped bass	1/1	0.126		
White crappie	5/5	0.104±0.023 (0.086-0.141)		
All fish combined	32/32	0.134±0.069 (0.077-0.390)		
Site 2 Lake Livingston at Wolf Creek				
Blue catfish	4/4	0.178±0.089 (0.100-0.277)	0.7	ATSDR Chronic Oral MRL for Methylmercury — 0.0003 mg/kg–day
Smallmouth buffalo	1/1	0.118		
All fish combined	5/5	0.166±0.082 (0.100-0.277)		
Site 3 Lake Livingston at Kickapoo Creek				
Black crappie	3/3	0.107±0.048 (0.076-0.162)	0.7	ATSDR Chronic Oral MRL for Methylmercury — 0.0003 mg/kg–day
Largemouth bass	5/5	0.312±0.177 (0.124-0.552)		
Smallmouth buffalo	1/1	0.128		
Striped bass	3/3	0.132±0.071 (0.081-0.213)		
All fish combined	12/12	0.200±0.150 (0.076-0.552)		

Table 2.5. Mercury (mg/kg) in fish collected from Lake Livingston 2012–2013.				
Species	**Number Detected/ Number Tested**	**Mean ± S.D. (Min-Max)**	**HAC Value (nonca; mg/kg)**	**Basis for Comparison Value**
Site 4 Lake Livingston at US Highway 190				
Black crappie	1/1	0.107	0.7	ATSDR Chronic Oral MRL for Methylmercury — 0.0003 mg/kg–day
Blue catfish	5/5	0.222±0.094 (0.096-0.327)		
Flathead catfish	2/2	0.110±0.011 (0.102-0.117)		
Largemouth bass	2/2	0.362±0.151 (0.256-0.469)		
Smallmouth buffalo	1/1	0.147		
White bass	2/2	0.214±0.223 (0.056-0.372)		
White crappie	1/1	0.185		
All fish combined	14/14	0.209±0.121 (0.056-0.469)		
Site 5 Lake Livingston near Rosewood Lane				
Black crappie	5/5	0.096±0.032 (0.062-0.142)	0.7	ATSDR Chronic Oral MRL for Methylmercury — 0.0003 mg/kg–day
Blue catfish	8/8	0.160±0.136 (0.080-0.486)		
Largemouth bass	1/1	0.119		
Smallmouth buffalo	1/1	0.235		
Striped bass	4/4	0.198±0.069 (0.132-0.271)		
White bass	11/11	0.161±0.036 (0.118-0.209)		
All fish combined	30/30	0.156±0.082 (0.062-0.486)		
Site 6 Trinity River at SH 19				
Blue catfish	6/6	0.477±0.149 (0.311-0.691)	0.7	ATSDR Chronic Oral MRL for Methylmercury — 0.0003 mg/kg–day
Flathead catfish	5/5	0.204±0.094 (0.132-0.345)		
Smallmouth buffalo	1/1	0.170		
White bass	17/17	0.194±0.067 (0.108-0.329)		
All fish combined	29/29	0.253±0.146 (0.108-0.691)		

Table 2.6. Mercury (mg/kg) in fish collected from Lake Livingston by species, 2012–2013.				
Species	**Number Detected/ Number Tested**	**Mean ± S.D. (Min-Max)**	**HAC Value (nonca; mg/kg)**	**Basis for Comparison Value**
Black crappie	9/9	0.101±0.033 (0.062-0.162)	0.7	ATSDR Chronic Oral MRL for Methylmercury — 0.0003 mg/kg–day
Blue catfish	31/31	0.218±0.168 (0.080-**0.691**[o])		
Channel catfish	7/7	0.109±0.031 (0.077-0.160)		
Flathead catfish	12/12	0.160±0.070 (0.102-0.345)		
Largemouth bass	11/11	0.276±0.146 (0.119-0.552)		
Longnose gar	2/2	0.337±0.075 (0.284-0.390)		
Smallmouth buffalo	6/6	0.147±0.052 (0.082-0.235)		
Striped bass	8/8	0.164±0.069 (0.081-0.271)		
White bass	30/30	0.183±0.071 (0.056-0.372)		
White crappie	6/6	0.117±0.039 (0.086-0.185)		
All fish combined	122/122	0.184±0.117 (0.056-**0.691**)		

[o] *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 Lake Livingston by species, 2012–2013.				
Species	**Number Detected/ Number Tested**	**Mean ± S.D. (Min-Max)**	**HAC Value (nonca) and HAC Value (ca; mg/kg)**	**Basis for Comparison Value**
Tetrachlorobenzene 1,2,4,5				
Blue catfish	5/5	0.0005±0.0005 (BDL-0.0013)	0.700	EPA Chronic Oral RfD — 3.0E-4 mg/kg/day
Flathead catfish	0/1	ND		
All fish combined	5/6	0.0004±0.0004 (ND-0.0013)		
Hexachlorobenzene				
Blue catfish	5/5	0.0004±0.0005 (BDL-0.0013)	1.867 0.340	EPA Chronic Oral RfD — 8.0E-4 mg/kg–day EPA Oral Slope Factor — 1.6E+0 per mg/kg/day
Flathead catfish	1/1	BDL		
All fish combined	6/6	0.0004±0.0005 (BDL-0.0013)		
Gamma HCH				
Blue catfish	5/5	0.0004±0.0003 (BDL-0.0009)	0.700	EPA Chronic Oral RfD — 3.0E-4 mg/kg–day
Flathead catfish	0/1	ND		
All fish combined	5/6	0.0004±0.0003 (ND-0.0009)		
Heptachlor Epoxide				
Blue catfish	3/5	0.0004±0.0002 (ND-0.0007)	0.030 0.060	EPA Chronic Oral RfD — 1.3E-5 mg/kg–day EPA Oral Slope Factor — 9.1E+0 per mg/kg/day
Flathead catfish	1/1	0.0009		
All fish combined	4/6	0.0005±0.0003 (ND-0.0009)		
Chlordane				
Blue catfish	5/5	0.0119±0.0062 (0.0070-0.0214)	1.167 1.556	EPA Chronic Oral RfD — 0.0005 mg/kg–day EPA Oral Slope Factor — 0.35 per (mg/kg)/day
Flathead catfish	1/1	0.0092		
All fish combined	6/6	0.0115±0.0056 (0.0070-0.0214)		

Table 3.2. Pesticides (mg/kg) in fish collected from Lake Livingston by species, 2012–2013.				
Species	**Number Detected/ Number Tested**	**Mean ± S.D. (Min-Max)**	**HAC Value (nonca) and HAC Value (ca; mg/kg)**	**Basis for Comparison Value**
Dieldrin				
Blue catfish	5/5	0.0016±0.0010 (0.0008-0.0034)	0.117 0.034	EPA Chronic Oral RfD — 0.00005 mg/kg–day EPA Oral Slope Factor — 16 per mg/kg/day
Flathead catfish	1/1	0.0039		
All fish combined	6/6	0.0020±0.0013 (0.0008-0.0039)		
Endrin				
Blue catfish	5/5	0.0027±0.0016 (0.0010-0.0052)	0.700	EPA Chronic Oral RfD — 3.0E-4 mg/kg/day
Flathead catfish	1/1	0.0048		
All fish combined	6/6	0.0030±0.0017 (0.0010-0.0052)		
Pentachloroanisole				
Blue catfish	5/5	0.0004±0.0003 (BDL-0.0009)	N/A	N/A
Flathead catfish	1/1	0.0004		
All fish combined	6/6	0.0004±0.0003 (BDL-0.0009)		
Mirex				
Blue catfish	4/5	0.0007±0.0006 (ND-0.0016)	0.467	EPA Chronic Oral RfD — 2.0E-4 mg/kg–day
Flathead catfish	1/1	BDL		
All fish combined	5/6	0.0006±0.0006 (ND-0.0016)		
4,4'-DDE				
Blue catfish	5/5	0.0703±0.0451 (0.0328-0.1391)	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	0.0206		
All fish combined	6/6	0.0620±0.0451 (0.0206-0.1391)		
4,4'-DDD				
Blue catfish	5/5	0.0049±0.0034 (0.0023-0.0106)	1.167 2.269	EPA Chronic Oral RfD for DDT — 5.0E-4 mg/kg–day EPA Oral Slope Factor for DDD — 2.4E-1 per mg/kg–day
Flathead catfish	1/1	0.0013		
All fish combined	6/6	0.0043±0.0033 (0.0013-0.0106)		

Table 3.3. Pesticides (mg/kg) in fish collected from Lake Livingston by sample site, 2012–2013.				
Species	**# Detected / # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
Total DDT				
Blue catfish	5/5	0.078±0.050 (0.037-0.155)	1.167 1.601	EPA Chronic Oral RfD for DDT — 5.0E-4 mg/kg–day EPA Oral Slope Factor for DDT — 2.4E-1 per mg/kg–day
Flathead catfish	1/1	0.023		
All fish combined	6/6	0.069±0.050 (0.023-0.155)		

Table 4.1. PCBs (mg/kg) in fish collected from Lake Livingston by sample site, 2012–2013.				
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 Lake Livingston at the Dam				
Blue catfish	8/8	0.033±0.016 (0.018-**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
Channel catfish	7/7	0.018±0.008 (0.010-0.033)		
Flathead catfish	5/5	0.030±0.008 (0.024-0.044)		
Largemouth bass	3/3	0.012±0.006 (0.006-0.018)		
Longnose gar	2/2	**0.776**[p]±0.288 (**0.573**-**0.980**)		
Smallmouth buffalo	1/1	**0.092**		
Striped bass	1/1	0.040		
White crappie	5/5	0.005±0.001 (0.005-0.006)		
All fish combined	32/32	**0.071**±0.193 (0.005-**0.980**)		
Site 2 Lake Livingston at Wolf Creek				
Blue catfish	4/4	**0.062**±0.042 (0.026-**0.117**)	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	1/1	**0.597**		
All fish combined	5/5	**0.169**±0.242 (0.026-**0.597**)		

[p] *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 Lake Livingston by sample site, 2012–2013.				
Species	**Number Detected/ Number Tested**	**Mean ± S.D. (Min-Max)**	**HAC Value (nonca) and HAC Value (ca; mg/kg)**	**Basis for Comparison Value**
Site 3 Lake Livingston at Kickapoo Creek				
Black crappie	3/3	0.006±0.001 (0.005-0.006)	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
Largemouth bass	5/5	0.007±0.001 (0.006-0.007)		
Smallmouth buffalo	1/1	**0.058**[q]		
Striped bass	3/3	0.028±0.003 (0.025-0.031)		
All fish combined	12/12	0.016±0.016 (0.005-**0.058**)		
Site 4 Lake Livingston at US Highway 190				
Black crappie	1/1	0.005	0.047 0.272	EPA Chronic Oral RfD for Aroclor 1254 — 0.00002 mg/kg–day EPA Slope Factor — 2.0 per mg/kg–day
Blue catfish	5/5	**0.071**±0.061 (0.009-**0.171**)		
Flathead catfish	2/2	0.019±0.010 (0.012-0.026)		
Largemouth bass	2/2	0.007±0.002 (0.006-0.009)		
Smallmouth buffalo	1/1	**0.088**		
White bass	2/2	0.025±0.017 (0.013-0.037)		
White crappie	1/1	0.006		
All fish combined	14/14	0.040±0.047 (0.005-**0.171**)		
Site 5 Lake Livingston near Rosewood Lane				
Black crappie	5/5	0.006±0.002 (0.005-0.009)	0.047 0.272	EPA Chronic Oral RfD for Aroclor 1254 — 0.00002 mg/kg–day EPA Slope Factor — 2.0 per mg/kg–day
Blue catfish	8/8	**0.083**±0.084 (0.025-**0.263**)		
Largemouth bass	1/1	0.010		
Smallmouth buffalo	1/1	**0.179**		
Striped bass	4/4	0.036±0.009 (0.024-0.046)		
White bass	11/11	0.026±0.005 (0.018-0.038)		
All fish combined	30/30	0.044±0.056 (0.005-**0.263**)		

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

Table 4.3. PCBs (mg/kg) in fish collected from Lake Livingston by sample site, 2012–2013.				
Species	**Number Detected/ Number Tested**	**Mean ± S.D. (Min-Max)**	**HAC Value (nonca) and HAC Value (ca; mg/kg)**	**Basis for Comparison Value**
Site 6 Trinity River at SH 19				
Blue catfish	6/6	**0.120**[r]±0.081 (**0.063**-**0.280**)	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	5/5	0.039±0.022 (0.018-**0.072**)		
Smallmouth buffalo	1/1	**0.057**		
White bass	17/17	0.037±0.013 (0.021-**0.066**)		
All fish combined	29/29	**0.055**±0.050 (0.018-**0.280**)		
All Sample Sites				
Black crappie	9/9	0.006±0.001 (0.005-0.009)	0.047 0.272	EPA Chronic Oral RfD for Aroclor 1254 — 0.00002 mg/kg–day EPA Slope Factor — 2.0 per mg/kg–day
Blue catfish	31/31	**0.072**±0.066 (0.009-**0.280**)		
Channel catfish	7/7	0.018±0.008 (0.010-0.033)		
Flathead catfish	12/12	0.032±0.016 (0.012-**0.072**)		
Largemouth bass	11/11	0.008±0.004 (0.006-0.018)		
Longnose gar	2/2	**0.776**±0.288 (**0.573**-**0.980**)		
Smallmouth buffalo	6/6	**0.178**±0.210 (**0.057**-**0.597**)		
Striped bass	8/8	0.033±0.008 (0.024-0.046)		
White bass	30/30	0.032±0.012 (0.013-**0.066**)		
White crappie	6/6	0.006±0.001 (0.005-0.009)		
All fish combined	122/122	**0.056**±0.118 (0.005-**0.980**)		

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

Table 5.1. PCDDs/PCDFs toxicity equivalent (TEQ) concentrations (pg/g) in fish collected from Lake Livingston by sample site, 2012–2013.

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 Lake Livingston at the dam				
Blue catfish	8/8	0.671±0.706 (0.099-2.300)	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
Channel catfish	6/7	0.332±0.210 (ND-0.512)		
Flathead catfish	5/5	0.882±0.695 (0.477-2.110)		
Largemouth bass	3/3	0.587±0.667 (0.089-1.345)		
Longnose gar	2/2	**10.388**[s]±2.553 (**8.583**-**12.193**)		
Smallmouth buffalo	1/1	1.488		
Striped bass	1/1	0.703		
White crappie	2/5	0.557±1.230 (ND-**2.757**)		
All fish combined	28/32	1.238±2.537 (ND-**12.193**)		
Site 2 Lake Livingston at Wolf Creek				
Blue catfish	4/4	0.414±0.354 (0.086-0.915)	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
Smallmouth buffalo	1/1	**8.889**		
All fish combined	5/5	2.109±3.803 (0.086-**8.889**)		
Site 3 Lake Livingston at Kickapoo Creek				
Black crappie	2/3	0.162±0.176 (ND-0.349)	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
Largemouth bass	5/5	0.220±0.109 (0.128-0.404)		
Smallmouth buffalo	1/1	**11.873**		
Striped bass	3/3	0.509±0.091 (0.434-0.611)		
All fish combined	11/12	1.249±3.350 (ND-**11.873**)		

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

Table 5.2. PCDDs/PCDFs toxicity equivalent (TEQ) concentrations (pg/g) in fish collected from Lake Livingston by sample site, 2012–2013.				
Species	**Number Detected/ Number Tested**	**Mean ± S.D. (Min-Max)**	**HAC Value (nonca) and HAC Value (ca; mg/kg)**	**Basis for Comparison Value**
Site 4 Lake Livingston at US Highway 190				
Black crappie	0/1	ND	2.33 3.49	ATSDR Chronic Oral MRL for 2,3,7,8 – TCDD —1.0 x 10^{-9} mg/kg–day EPA Slope Factor — 1.56 x 10^{5} per mg/kg–day
Blue catfish	5/5	0.714±0.671 (0.150-1.730)		
Flathead catfish	2/2	0.643±0.432 (0.338-0.949)		
Largemouth bass	2/2	0.218±0.100 (0.147-0.289)		
Smallmouth buffalo	1/1	**16.909**[t]		
White bass	2/2	1.906±1.388 (0.925-**2.888**)		
White crappie	1/1	0.077		
All fish combined	13/14	1.864±4.402 (ND-**16.909**)		
Site 5 Lake Livingston near Rosewood Lane				
Black crappie	0/5	ND	2.33 3.49	ATSDR Chronic Oral MRL for 2,3,7,8 – TCDD —1.0 x 10^{-9} mg/kg–day EPA Slope Factor — 1.56 x 10^{5} per mg/kg–day
Blue catfish	8/8	1.849±4.153 (0.095-**12.078**)		
Largemouth bass	0/1	ND		
Smallmouth buffalo	1/1	0.749		
Striped bass	4/4	**2.708**±4.364 (0.112-**9.225**)		
White bass	6/11	0.839±1.602 (ND-**4.243**)		
All fish combined	19/30	1.187±2.793 (ND-**12.078**)		
Site 6 Trinity River at SH 19				
Blue catfish	6/6	**3.108**±1.922 (1.033-**6.348**)	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
Flathead catfish	5/5	1.255±1.150 (0.474-**3.201**)		
Smallmouth buffalo	1/1	0.978		
White bass	17/17	0.911±0.418 (0.464-2.149)		
All fish combined	29/29	1.427±1.315 (0.464-**6.348**)		

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

Table 5.3. PCDDs/PCDFs toxicity equivalent (TEQ) concentrations (pg/g) in fish collected from Lake Livingston by species, 2012–2013.

Species	Number Detected/ Number Tested	Mean ± S.D. (Min-Max)	HAC Value (nonca) and HAC Value (ca; mg/kg)	Basis for Comparison Value
Black crappie	2/9	0.054±0.119 (ND-0.349)	2.33 3.49	ATSDR Chronic Oral MRL for 2,3,7,8 – TCDD —1.0 x 10^{-9} mg/kg–day EPA Slope Factor — 1.56 x 10^{5} per mg/kg–day
Blue catfish	31/31	1.420±2.412 (0.086-**12.078**[u])		
Channel catfish	6/7	0.332±0.210 (ND-0.512)		
Flathead catfish	12/12	0.997±0.856 (0.338-**3.201**)		
Largemouth bass	10/11	0.300±0.365 (ND-1.345)		
Longnose gar	2/2	**10.388**±2.553 (**8.583**-**12.193**)		
Smallmouth buffalo	6/6	**6.814**±6.797 (0.749-**16.909**)		
Striped bass	8/8	1.633±3.081 (0.112-**9.225**)		
White bass	25/30	0.951±1.057 (ND-**4.243**)		
White crappie	3/6	0.477±1.117 (ND-**2.757**)		
All fish combined	105/122	1.379±2.750 (ND-**16.909**)		

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

Table 6. Hazard quotients (HQs) for mercury in fish collected from Lake Livingston in 2012–2013. Table 6 also provides suggested weekly eight-ounce meal consumption rates for 70-kg adults.[v]			
Species	**Number of Samples**	**Hazard Quotient**	**Meals per Week**
Lake Livingston All Sites			
Black crappie	9	0.26	3.5
Blue catfish	31	0.31	3.0
Channel catfish	7	0.16	5.9
Flathead catfish	12	0.23	4.0
Largemouth bass	11	0.39	2.3
Longnose gar	2	0.48	1.9
Smallmouth buffalo	6	0.21	4.4
Striped bass	8	0.23	3.9
White bass	30	0.26	3.5
White crappie	6	0.17	5.5
Black and white crappie (*Pomoxis* spp.)	15	0.15	6.1
Striped and white bass (*Morone* spp.)	38	0.26	3.6
All fish combined	122	0.26	3.5

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

Table 7.1. Hazard quotients (HQs) and hazard indices (HIs) for PCBs and/or PCDDs/PCDFs in fish collected from Lake Livingston in 2012–2013. Table 7a also provides suggested weekly eight-ounce meal consumption rates for 70-kg adults.[w]			
Contaminant/Species	**Number of Samples**	**Hazard Quotient**	**Meals per Week**
Black crappie			
PCBs	9	0.13	7.2
PCDDs/PCDFs		0.02	unrestricted[x]
Hazard Index (meals per week)		0.15	6.1
Blue catfish			
PCBs	31	**1.54**[y]	**0.6**[z]
PCDDs/PCDFs		0.61	1.5
Hazard Index (meals per week)		**2.15**	**0.4**
Channel catfish			
PCBs	7	0.39	2.4
PCDDs/PCDFs		0.14	6.5
Hazard Index (meals per week)		0.53	1.8
Flathead catfish			
PCBs	12	0.69	1.3
PCDDs/PCDFs		0.43	2.2
Hazard Index (meals per week)		**1.11**	**0.8**
Largemouth bass			
PCBs	11	0.17	5.4
PCDDs/PCDFs		0.13	7.2
Hazard Index (meals per week)		0.30	3.1

[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 7.2. Hazard quotients (HQs) and hazard indices (HIs) for PCBs and/or PCDDs/PCDFs in fish collected from Lake Livingston in 2012–2013. Table 7b also provides suggested weekly eight-ounce meal consumption rates for 70-kg adults.[aa]

Contaminant/Species	Number of Samples	Hazard Quotient	Meals per Week
Longnose gar			
PCBs	2	**16.63**[bb]	**0.1**[cc]
PCDDs/PCDFs		**4.43**	**0.2**
Hazard Index (meals per week)		**21.06**	**0.0**
Smallmouth buffalo			
PCBs	6	**3.81**	**0.2**
PCDDs/PCDFs		**2.92**	**0.3**
Hazard Index (meals per week)		**6.73**	**0.1**
Striped bass			
PCBs	8	0.71	1.3
PCDDs/PCDFs		0.70	1.3
Hazard Index (meals per week)		**1.41**	**0.7**
White bass			
PCBs	30	0.69	1.3
PCDDs/PCDFs		0.41	2.3
Hazard Index (meals per week)		**1.09**	**0.8**
White crappie			
PCBs	6	0.13	7.2
PCDDs/PCDFs		0.20	4.5
Hazard Index (meals per week)		0.33	2.8

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

Table 7.3. Hazard quotients (HQs) and hazard indices (HIs) for PCBs and/or PCDDs/PCDFs in fish collected from Lake Livingston in 2012–2013. Table 7b also provides suggested weekly eight-ounce meal consumption rates for 70-kg adults.[dd]			
Contaminant/Species	**Number of Samples**	**Hazard Quotient**	**Meals per Week**
Black and white crappie (*Pomoxis* spp.)			
PCBs	15	0.13	7.2
PCDDs/PCDFs		0.10	9.7
Hazard Index (meals per week)		0.22	4.1
Striped and white bass (*Morone* spp.)			
PCBs	38	0.69	1.3
PCDDs/PCDFs		0.47	2.0
Hazard Index (meals per week)		**1.16**[ee]	**0.8**[ff]
All fish combined			
PCBs	122	**1.20**	**0.8**
PCDDs/PCDFs		0.59	1.6
Hazard Index (meals per week)		**1.79**	**0.5**

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

Table 8.1. Calculated theoretical lifetime excess cumulative cancer risk from consuming fish collected in 2012–2013 from Lake Livingston containing carcinogens and suggested consumption rate (eight-ounce meals/week) for 70 kg adults who regularly eat fish from Lake Livingston 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**	
Black crappie				
PCBs	9	2.2E-06	453,704	unrestricted[hh]
PCDDs/PCDFs		1.5E-06	646,302	unrestricted
Cumulative Cancer Risk		3.8E-06	266,571	unrestricted
Blue catfish				
Arsenic	5	1.1E-06	907,407	unrestricted
Chlordane		7.7E-07	1,307,190	unrestricted
DDT (total)		4.9E-06	205,296	unrestricted
Dieldrin		4.7E-06	212,674	unrestricted
Heptachlor epoxide		6.7E-07	1,495,726	unrestricted
Hexachlorobenzene		1.2E-07	8,506,944	unrestricted
PCBs	31	2.6E-05	37,809	3.5
PCDDs/PCDFs		4.1E-05	24,578	2.3
Cumulative Cancer Risk		7.9E-05	12,600	1.2
Channel catfish				
PCBs	7	6.6E-06	151,235	14.0
PCDDs/PCDFs		9.5E-06	105,121	9.7
Cumulative Cancer Risk		1.6E-05	62,015	5.7

[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 8.2. Calculated theoretical lifetime excess cumulative cancer risk from consuming fish collected in 2012–2013 from Lake Livingston containing carcinogens and suggested consumption rate (eight-ounce meals/week) for 70 kg adults who regularly eat fish from Lake Livingston 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	
Flathead catfish				
Arsenic	1	8.6E-06	115,963	10.7
Chlordane		7.7E-07	1,307,190	unrestricted[jj]
DDT (total)		4.9E-06	205,296	unrestricted
Dieldrin		4.7E-06	212,674	unrestricted
Heptachlor epoxide		6.7E-07	1,495,726	unrestricted
Hexachlorobenzene		1.2E-07	8,506,944	unrestricted
PCBs	12	1.2E-05	85,069	7.9
PCDDs/PCDFs		2.9E-05	35,005	3.2
Cumulative Cancer Risk		6.0E-05	16,647	1.5
Largemouth bass				
PCBs	11	2.9E-06	340,278	unrestricted
PCDDs/PCDFs		8.6E-06	116,334	10.7
Cumulative Cancer Risk		1.2E-05	86,695	8.0
Longnose gar				
PCBs	2	**2.9E-04**[kk]	**3,508**	**0.3**[ll]
PCDDs/PCDFs		**3.0E-04**	**3,376**	**0.3**
Cumulative Cancer Risk		**5.8E-04**	**1,720**	**0.2**

[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.*
[kk] *Emboldened numbers denote calculated excess lifetime cancer risk after 30 years exposure is greater than 1.0E-04.*
[ll] *Emboldened numbers denote that the calculated allowable meals for an adult are ≤ one meal per week.*

Table 8.3. Calculated theoretical lifetime excess cumulative cancer risk from consuming fish collected in 2012–2013 from Lake Livingston containing carcinogens and suggested consumption rate (eight-ounce meals/week) for 70 kg adults who regularly eat fish from Lake Livingston over a 30-year period.[mm]				
Species/Contaminant	**Number of Samples**	**Theoretical Lifetime Excess Cancer Risk**		**Meals per Week**
		Risk	**Population Size that Would Result in One Excess Cancer**	
Smallmouth buffalo				
PCBs	6	6.5E-05	15,293	1.4
PCDDs/PCDFs		**2.0E-04**[nn]	**5,122**	**0.5**[oo]
Cumulative Cancer Risk		**2.6E-04**	**3,837**	**0.4**
Striped bass				
PCBs	8	1.2E-05	82,492	7.6
PCDDs/PCDFs		4.7E-05	21,372	2.0
Cumulative Cancer Risk		5.9E-05	16,974	1.6
White bass				
PCBs	30	1.2E-05	85,069	7.9
PCDDs/PCDFs		2.7E-05	36,699	3.4
Cumulative Cancer Risk		3.9E-05	25,638	2.4
White crappie				
PCBs	6	2.2E-06	453,704	unrestricted[pp]
PCDDs/PCDFs		1.4E-05	73,166	6.8
Cumulative Cancer Risk		1.6E-05	63,006	5.8
Black and white crappie (*Pomoxis* spp.)				
PCBs	15	2.2E-06	453,704	unrestricted
PCDDs/PCDFs		6.4E-06	156,504	14.5
Cumulative Cancer Risk		8.6E-06	116,364	10.8

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

Table 8.4. Calculated theoretical lifetime excess cumulative cancer risk from consuming fish collected in 2012–2013 from Lake Livingston containing carcinogens and suggested consumption rate (eight-ounce meals/week) for 70 kg adults who regularly eat fish from Lake Livingston over a 30-year period.[qq]

Species/Contaminant	Number of Samples	Theoretical Lifetime Excess Cancer Risk		Meals per Week
		Risk	Population Size that Would Result in One Excess Cancer	
Striped and white bass (*Morone* spp.)				
PCBs	38	1.2E-05	85,069	7.9
PCDDs/PCDFs		3.1E-05	31,872	2.9
Cumulative Cancer Risk		4.3E-05	23,186	2.1
All fish combined				
PCBs	122	2.1E-05	48,611	4.5
PCDDs/PCDFs		4.0E-05	25,308	2.3
Cumulative Cancer Risk		6.0E-05	16,643	1.5

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

Table 9. Tukey HSD post hoc comparisons of all fish combined PCB concentrations between samples sites from Lake Livingston 2012–2013.					
Site	**Site**	**Difference**	**p-Value**	**95% Confidence Interval**	
				Lower	**Upper**
1	2	-1.292	0.074	-2.657	0.072
1	3	0.759	0.207	-0.202	1.719
1	4	0.059	1.000	-0.850	0.968
1	5	-0.152	0.990	-0.873	0.569
1	6	-0.652	0.106	-1.379	0.076
2	3	2.051	**0.002**[rr]	0.541	3.561
2	4	1.351	0.094	-0.127	2.830
2	5	1.141	0.161	-0.230	2.511
2	6	0.640	0.756	-0.734	2.014
3	4	-0.700	0.459	-1.816	0.416
3	5	-0.911	0.078	-1.880	0.059
3	6	-1.411	**0.001**	-2.385	-0.437
4	5	-0.211	0.985	-1.129	0.708
4	6	-0.711	0.232	-1.634	0.213
5	6	-0.500	0.371	-1.239	0.239

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

Table 10. 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 Lake Livingston in 2012–2013.

Species	Average	Minimum	Maximum
	Number of Eight-Ounce Meals		
Black crappie	0.9	0.4	1.3
Blue catfish	7.8	0.9	21.4
Channel catfish	1.2	0.9	1.6
Flathead catfish	11.0	3.9	34.3
Largemouth bass	3.0	1.7	4.8
Longnose gar	5.6	5.5	5.7
Smallmouth buffalo	10.5	4.0	20.5
Striped bass	5.1	4.1	7.3
White bass	1.2	0.5	1.7
White crappie	1.3	0.9	1.9
All fish combined	4.8	0.4	34.3

Table 11. Recommended fish consumption advice by species for Lake Livingston 2012–2013.

Contaminants of Concern	Species	Women of childbearing age and children < 12	Women past childbearing age and adult men
Dioxins and PCBs	Blue catfish	**DO NOT EAT**	1 meal/month
	Flathead catfish	**DO NOT EAT**	1 meal/month
	Freshwater drum	**DO NOT EAT**	2 meals/month
	Gar (all species)	**DO NOT EAT**	**DO NOT EAT**
	Smallmouth buffalo	**DO NOT EAT**	1 meal/month
	Striped bass	1 meal/month	3 meals/month
	White bass	1 meal/month	3 meals/month

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