Characterization of Potential Adverse Health Effects Associated with Consuming Fish from

Sam Rayburn Reservoir

Angelina, Jasper, Nacogdoches, Sabine, San Augustine, and Tyler Counties, Texas

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Department of State Health Services
Division for Regulatory Services
Policy, Standards, and Quality Assurance Unit
Seafood and Aquatic Life Group
Austin, Texas

INTRODUCTION

This document summarizes the results of a survey of Sam Rayburn Reservoir conducted in 2010–2011 by the Texas Department of State Health Service (DSHS) Seafood and Aquatic Life Group (SALG). The SALG did this study to investigate potential polychlorinated dibenzo-*p*-dioxins and/or dibenzofurans (PCDDs/PCDFs) fish tissue contamination identified through the National Study of Chemical Residues in Lake Fish Tissue[1] (or National Lake Fish Tissue Study; NLFTS), a national-level fish tissue contaminant screening survey. The study design also allowed the SALG to re-evaluate the extant 15-year-old mercury fish consumption advisory. The present study, ensuing from the NLFTS examined fish from Sam Rayburn Reservoir 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 Sam Rayburn Reservoir and suggests actions to reduce potential adverse health outcomes.

History of the Sam Rayburn Reservoir Fish Consumption Advisory

Public health issues relating to mercury in fish from East Texas reservoirs originated in 1992 when Louisiana and Arkansas responded to a discovery of mercury in largemouth bass from the Ouachita River by issuing fish advisories for several rivers and lakes in south Arkansas and north Louisiana. Researchers, unable to identify point sources for mercury, surmised that mercury in these fish arose from bioaccumulation and bio-magnification of mercury deposited from the atmosphere and that the water and sediment chemistry (i.e. low pH and high organic matter) of rivers and lakes in south Arkansas and north Louisiana encourage formation of organic (methyl) mercury from inorganic mercury.[2] Due to these findings, Texas' concern about possible mercury contamination in fish from East Texas reservoirs intensified because East Texas waters share common water and sediment characteristics with south Arkansas and north Louisiana waters. In 1994, these concerns prompted Texas to investigate reservoirs located on or near the Texas-Louisiana border to determine if mercury concentrations in fish posed any potential public health issues.

The Texas Department of Health (TDH), now the DSHS, initial East Texas mercury investigation began in the summer of 1994 at Caddo Lake. The initial study found mercury in largemouth bass and freshwater drum. Mercury concentrations in largemouth bass reportedly increased with increased body size. In January 1995, consequent to the 1994 finding of mercury in largemouth bass and freshwater drum from Caddo Lake, the DSHS issued Fish and Shellfish Consumption Advisory 11(ADV-11) for Caddo Lake.[3] ADV-11 recommended that people refrain from consuming freshwater drum and largemouth bass that were over 18 inches in length. ADV-11 also suggested that women of childbearing age and children under the age of six years limit consumption of largemouth bass less than 14 inches in length to one meal (eight-ounces-women; four-ounces-children) per month. The Texas Parks and Wildlife Department (TPWD) has an established slot length limit for largemouth bass at Caddo Lake, making it illegal to possess largemouth bass that are between 14 and 18 inches in length.[4]

The investigations of mercury in fish from East Texas reservoirs continued in April 1995 when DSHS expanded the survey of Caddo Lake including Big Cypress Creek and also surveyed B.A. Steinhagen Reservoir, Sam Rayburn Reservoir and Toledo Bend Reservoir. Results of these investigations indicated that mercury concentrations in freshwater drum, largemouth bass, and white bass (B.A. Steinhagen only) exceeded DSHS guidelines for protection of human health.[5] The DSHS prepared individual risk assessments for all reservoirs studied; however, DSHS risk assessors determined that a comprehensive risk assessment based on a reasonable maximum exposure scenario was appropriate for protection of public health.[6] The comprehensive risk assessment would provide clear, easily understandable consumption guidance and protect those that may consume fish from several reservoirs.

In November 1995, the DSHS issued Fish and Shellfish Consumption Advisory 12 (ADV-12) for mercury in freshwater drum and largemouth bass taken from several East Texas waters: B.A. Steinhagen Reservoir, Caddo Lake including Big Cypress Creek, Sam Rayburn Reservoir, and Toledo Bend Reservoir.[7] ADV-12, which superseded earlier consumption advice for Caddo Lake fish, recommended that people eat no more than two meals (meal size: adults eight-ounces per meal and children < 12 years old four-ounces per meal) per month of freshwater drum and largemouth bass combined. ADV-12 also recommended that people should not consume more than two meals per month of white bass or hybrid hybrid striped bass from B.A. Steinhagen Reservoir.

National Study of Chemical Residues in Lake Fish Tissue and Its Relationship to DSHS Fish Tissue Monitoring

In the fall of 1998, the United States Environmental Protection Agency (USEPA or EPA) began planning the NLFTS. This study is a national screening survey designed to estimate the national distribution of 268 persistent, bioaccumulative, and toxic (PBT) chemicals in fish tissue from lakes and reservoirs in the contiguous United States; estimate the percentage of lakes and reservoirs with fish tissue concentrations above specified thresholds related to human health; and define national baseline information for tracking changes in concentrations of PBT chemicals in freshwater fish because of the combined effects of pollution control activities and natural degradation.[1] The NLFTS relied on a national network of partners that included 47 states, three tribes, and two other federal agencies to collect predator and bottom-dwelling fish from 500 lakes and reservoirs selected according to a statistical random design over a period of four years (2000-2003).

From 2000 to 2003, the Texas Commission on Environmental Quality (TCEQ) collaborated with the EPA to collect fish from 41 reservoirs in Texas as part of the NLFTS. The TCEQ packaged and shipped all fish tissue samples according to EPA protocol to a single laboratory selected by EPA to prepare all fish samples in a strictly-controlled, contamination free environment. This laboratory prepared different tissue fractions for predator composites (fillets) and bottom-dweller composites (whole bodies) to obtain chemical residue data and then distributed fish tissue samples to four laboratories that specialize in analysis of metals, pesticides, semivolatile organic chemicals (SVOCs), and polychlorinated biphenyls (PCBs) and PCDDs/PCDFs. To minimize variability among sample results, EPA used the same laboratory for each type of analysis, and these laboratories applied the same analytical method for each chemical for the duration of the study.

Throughout the duration of the NLFTS, the EPA shared PBT chemical residue data with TCEQ and subsequently DSHS as the analytical laboratories completed chemical analysis of the fish tissue samples. The DSHS compared predator and bottom-dweller PBT chemical fish tissue concentrations to the DSHS-established human health screening values (SVs) to identify fish tissue contaminant concentrations that exceeded DSHS SVs.[8] The DSHS's comparison of the fish tissue PBT chemical residue data to DSHS SVs revealed that 49% of the reservoirs examined in the Texas fraction of the NLFTS had PBT chemical concentrations that exceeded DSHS SVs. Reservoirs that contained fish samples exceeding DSHS SVs were placed on the DSHS Tier 2 Fish Tissue Monitoring and Human Health Risk Assessment Priority Water Body Assessment Ranking List (hereafter Tier 2 Study Ranking List) along with water bodies identified through other screening studies.[9] The Tier 2 Study Ranking List is a means for DSHS and TCEQ to establish *Tier 2 Study* priorities cooperatively and objectively. The DSHS and TCEQ have developed these general guidelines or ranking criteria to numerical rank water bodies on the Tier 2 Study Ranking List: water body use and accessibility, human fish consumption patterns and exposure, quantity and type of chemical contamination, evaluation of potential point and non-point pollution sources, and the identification of an improvement in ambient water quality or a known reduction in pollutant loading including natural degradation.

The Sam Rayburn Reservoir bottom-dweller composite from the NLFTS contained PBT chemical concentrations in excess of DSHS SVs. The bottom dweller composite (channel catfish) contained a PCDD/PCDF concentration of 4.29 ng/kg (PCDD/PCDF SV = 1.74 ng/kg). The DSHS selected Sam Rayburn Reservoir for *Tier 2 Study* based on these results and its ranking on the Tier 2 Study Ranking List.

Description of Sam Rayburn Reservoir

Sam Rayburn Reservoir is an 111,422-acre impoundment of the Angelina River, a major tributary of the Neches River, inundating portions of Angelina, Jasper, Nacogdoches, Sabine, San Augustine, and Tyler Counties in East Texas.[10] The United States Army Corps of Engineers (USACE) oversees Sam Rayburn Reservoir daily operation including generation of hydroelectric power, flood control, and conservation of water for municipal, industrial, agricultural, and recreational uses.[11] The reservoir has a shoreline length of 750 miles and a mean depth of 20 feet. Predominant habitat types include submerged aquatic vegetation, flooded terrestrial vegetation, and standing timber. Annual and seasonal habitat conditions at Sam Rayburn Reservoir change due to water level fluctuation. Severe water level fluctuation may decrease the quantity of aquatic vegetation and high water levels flood shoreline trees and bushes increasing habitat. Angler access and recreational opportunities are plentiful at Sam Rayburn Reservoir, which includes boating, fishing, swimming, camping, trails, and hunting. Twenty-two maintained access areas composed of federal, state, and county parks and private concessions are located around the reservoir.[12]

Demographics of Angelina, Jasper, Nacogdoches, Sabine, San Augustine, and Tyler Counties Surrounding the Area of Sam Rayburn Reservoir

Sam Rayburn Reservoir is located in rural East Texas covering portions of six counties: Angelina, Jasper, Nacogdoches, Sabine, San Augustine, and Tyler Counties. The United States

Census 2010 calculated the population of the six county area surrounding Sam Rayburn Reservoir at 228,470 people.[13] Lufkin, Texas positioned approximately 25 miles northwest of Sam Rayburn Reservoir's "mid-lake area" is the closest major metropolitan area (population ≥ 20,000 people) in East Texas.[13]

Subsistence Fishing at Sam Rayburn Reservoir

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

METHODS

Fish Sampling, Preparation, and Analysis

The DSHS 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.*[15] 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.*[16] Advice and direction are also received from the legislatively mandated *State of Texas Toxic Substances Coordinating Committee (TSCC) Fish Sampling Advisory Subcommittee (FSAS).*[17] 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 Sam Rayburn Reservoir 2010–2011 Sample Set

In October–November 2010 and February–April 2011, the SALG staff collected 660 fish samples from Sam Rayburn Reservoir. 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 twelve sample sites to provide spatial coverage of the study area (Figure 1): Site 1 confluence of Papermill Creek and Angelina River, Site 2 Sam Rayburn Reservoir at

Marion Ferry Park, Site 3 Sam Rayburn Reservoir at State Highway (SH) 103 Angelina River, Site 4 Sam Rayburn Reservoir at Hanks Creek, Site 5 Sam Rayburn Reservoir at SH 103 Attoyac River, Site 6 Sam Rayburn Reservoir at SH 147, Site 7 Sam Rayburn Reservoir at Harvey Creek, Site 8 Sam Rayburn Reservoir at Caney Creek, Site 9 Sam Rayburn Reservoir at Norris Creek / Five Fingers area, Site 10 Sam Rayburn Reservoir at Dam, Site 11 Sam Rayburn Reservoir at Bear Creek, and Site 12 Sam Rayburn Reservoir at Farm-to-Market (FM) 83 Ayish Bayou. 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 660 fish collected from Sam Rayburn Reservoir 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: largemouth bass (240), white bass (72), freshwater drum (70), crappie species (spp.) (65), blue catfish (50), channel catfish (50), gar spp. (24), sunfish spp. (24), flathead catfish (23), smallmouth buffalo (21), spotted bass (15), and hybrid striped bass (6).

The survey team set gill nets at sample sites 1 through 12 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: 4.0-8.0 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.

Due to low gill net and electrofisher catch rates for flathead catfish and gar species, the survey team utilized juglines (a fishing line with one circle hook tied to a free-floating device) baited with live sunfish to increase flathead catfish and gar species catch. The survey team targeted habitat within each sample site likely to hold flathead catfish or gar species.

The SALG staff processed fish onsite at Sam Rayburn Reservoir. Staff weighed each sample to the nearest gram (g) on an electronic scale and measured total length (tip of nose to tip of tail fin) to the nearest millimeter (mm). After weighing and measuring a fish, staff used a cutting board covered with aluminum foil and a fillet knife to prepare two skin-off fillets from each fish. The foil was changed and the knife cleaned with distilled water after each sample was processed. The team wrapped fillet(s) in two layers of fresh aluminum foil, placed in an unused, clean, pre-labeled plastic freezer bag, and stored on wet ice in an insulated chest until further processing.

The SALG staff transported tissue samples on wet ice to their Austin, Texas headquarters, where the samples were stored temporarily at -5° Fahrenheit (-20° Celsius) in a locked freezer. The freezer key is accessible only to authorized SALG staff members to ensure 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, 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 TPWD.[18] 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 vial and then stored the vials in a plastic freezer bag to transport to their Austin, Texas headquarters. Staff processed otoliths and estimated ages according to procedures recommended by the GSMFC and TPWD.[18, 19]

Analytical Laboratory Information

Upon arrival of the fish samples at the laboratory, GERG personnel documented receipt of the 660 Sam Rayburn Reservoir 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 Sam Rayburn Reservoir 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, and 17 polychlorinated dibenzofurans and/or dibenzo-*p*-dioxins (PCDDs/PCDFs) congeners. The laboratory analyzed all 660 samples for mercury. A subset of the original 660 samples was assayed for the following contaminant groupings: 155 samples for PCDDs/PCDFs, 71 samples for PCBs, and 24 samples for metals, pesticides, SVOCs, and VOCs.[20]

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

<u>Arsenic</u>

The GERG laboratory analyzed 24 fish samples for total (inorganic arsenic + organic arsenic = total arsenic) arsenic. Although the proportions of each form of arsenic may differ among fish species, under different water conditions, and, perhaps, with other variables, the literature suggests that well over 90% of arsenic in fish is likely organic arsenic – a form of arsenic that is virtually non-toxic to humans.[21] The DSHS, taking a conservative approach, estimates 10% of the total arsenic in any fish is inorganic arsenic, deriving estimates of inorganic arsenic concentration in each fish by multiplying 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.[22] 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.[23] (In these risk characterizations, the DSHS may interchangeably utilize the terms "mercury," "methylmercury," or "organic mercury" to refer to methylmercury in fish).

Polychlorinated Biphenyls (PCBs)

For PCBs, the USEPA suggests that each state measures congeners of PCBs in fish and shellfish rather than homologs or Aroclors® because the USEPA considers congener analysis the most sensitive technique for detecting PCBs in environmental media.[20] Although only about 130 PCB congeners were routinely present in PCB mixtures manufactured and commonly used in the United States (US), the GERG laboratory analyzes and reports the presence and concentrations of all 209 possible PCB congeners. From the congener analyses, the laboratory also computes and reports concentrations of PCB homologs and of Aroclor® mixtures. Despite the USEPA's suggestion that the states utilize PCB congeners rather than Aroclors® or homologs for toxicity estimates, the toxicity literature does not reflect state-of-the-art laboratory science. To accommodate this inconsistency, the DSHS utilizes recommendations from the National Oceanic and Atmospheric Administration (NOAA),[24] from McFarland and Clarke,[25] and from the USEPA's guidance documents for assessing contaminants in fish and shellfish[16, 20] to address PCB congeners in fish and shellfish samples, selecting the 43 congeners encompassed by the McFarland and Clark and the NOAA articles. The referenced authors chose to use congeners that were relatively abundant in the environment, were likely to occur in aquatic life, and likely to show toxic effects. SALG risk assessors summed the 43 congeners to derive "total" PCB concentration in each sample. SALG risk assessors then averaged the summed congeners within each group (e.g., fish species, sample site, or combination of species and site) to derive a mean PCB concentration for each group.

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

mixtures: Aroclors® 1016, 1242, 1248, 1254, and 1260. IRIS does not contain all information for all mixtures. For instance, only one other reference dose (RfD) occurs in IRIS – the one derived for Aroclor 1016, a commercial mixture produced in the latter years of commercial production of PCBs in the United States. Aroclor 1016 was a fraction of Aroclor 1254 that was supposedly devoid of dibenzofurans, in contrast to Aroclor 1254.[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 restrictive slope factor available for PCBs on factors such as food chain exposure; the presence of dioxin-like, tumor-promoting, or persistent congeners; and the likelihood of early-life exposure.[26]

Calculation of Toxicity Equivalent Quotients (TEQs) for Dioxins

PCDDs/PCDFs are families of aromatic chemicals containing one to eight chlorine atoms. The molecular structures differ not only with respect to the number of chlorines on the molecule, but also with the positions of those chlorines on the carbon atoms of the molecule. The number and positions of the chlorines on the dibenzofuran or dibenzo-*p*-dioxin nucleus directly affects the toxicity of the various congeners. Toxicity increases as the number of chlorines increases to four chlorines, then decreases with increasing numbers of chlorine atoms - up to a maximum of eight. With respect to the position of chlorines on the dibenzo-*p*-dioxin/dibenzofuran nucleus, it appears that those congeners with chlorine substitutions in the 2, 3, 7, and 8 positions are more toxic than congeners with chlorine substitutions in other positions. To illustrate, the most toxic of PCDDs is 2,3,7,8–tetrachlorodibenzo-*p*-dioxin (2,3,7,8–TCDD), a 4-chlorine molecule having one chlorine substituted for hydrogen at each of the 2, 3, 7, and 8 carbon positions on the dibenzo-*p*-dioxin. To gain some measure of toxic equivalence, 2,3,7,8–TCDD – assigned a toxicity equivalency factor (TEF) of 1.0 – is the standard against which other congeners are measured. Other congeners are given weighting factors or TEFs of 1.0 or less based on experiments comparing the toxicity of the congener relative to that of 2,3,7,8-TCDD.[28, 29] Using this technique, risk assessors from the DSHS converted PCDF or PCDD congeners in each tissue sample from the present survey to TEQs by multiplying each congener's concentration by its TEF, producing a dose roughly equivalent in toxicity to that of the same dose of 2,3,7,8-TCDD. The total TEQ for any sample is the sum of the TEQs for each of the congeners in the sample, calculated according to the following formula.[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

$\sum$ = sum

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

The effects of exposure to any hazardous substance depend, among other factors, on the dose, the route of exposure, the duration of exposure, the manner in which the exposure occurs, the genetic makeup, personal traits, 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 derives confidence intervals from Monte Carlo simulations using software developed by a DSHS medical epidemiologist.[32] The SALG evaluates contaminants in fish or shellfish by comparing the mean or the 95% upper confidence limit on the mean concentration of a contaminant to its HAC value (in mg/kg) for non-cancer or cancer endpoints.

In deriving HAC values for systemic (HAC_{nonca}) effects, the SALG assumes a standard adult weighs 70 kilograms (kg) and consumes 30 g of fish or shellfish per day (about one eight-ounce meal per week) and uses the USEPA's RfD[33] or the ATSDR's chronic oral MRLs.[34] 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.*[35]

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.[35]

The ATSDR uses a similar technique to derive its MRLs.[34] The DSHS divides the estimated daily dose derived from the measured concentration in fish tissue by the contaminant's RfD or MRL to derive a hazard quotient (HQ). The USEPA defines an HQ as

…the ratio of the estimated exposure dose of a contaminant (mg/kg/day) to the contaminant's RfD or MRL (mg/kg/day).[36]

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 1.0 "should indicate some cause for concern."

The SALG does not utilize HQs to determine the likelihood of occurrence of adverse systemic health effects. Instead, in a manner similar to the USEPA's decision process, the SALG may utilize computed HQs as a qualitative measurement. Qualitatively, HQs less than 1.0 are unlikely to be an issue while HQs greater than 1.0 might suggest a regulatory action to ensure protection of public health. Similarly, risk assessors at the DSHS may utilize 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 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.[34]

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.[33,35] 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 a RfD.[35]

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

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

The USEPA states that

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

And

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

Thus,

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

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

The DSHS calculates cancer-risk comparison values (HAC_{ca}) from the USEPA's chemical-specific cancer potency factors (CPFs), also known as cancer slope factors (CSFs), derived through mathematical modeling from carcinogenicity studies. For carcinogenic outcomes, the DSHS calculates a theoretical lifetime excess risk of cancer for specific exposure scenarios for carcinogens, using a standard 70-kg body weight and assuming an adult consumes 30 grams of edible tissue per day. The SALG risk assessors incorporate two additional factors into determinations of theoretical lifetime excess cancer risk: (1) an acceptable lifetime risk level (ARL)[35] 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.[37, 38] 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.[39] 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.[40]

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.[33] Additionally, in accordance with the ATSDR's *Child Health Initiative*[41] and the USEPA's *National Agenda to Protect Children's Health from Environmental Threats,*[42] the DSHS further seeks to protect children from the possible negative effects of toxicants in fish by suggesting that this potentially sensitive subgroup consume smaller quantities of contaminated fish or shellfish than adults consume. Thus, the DSHS recommends that children weighing 35 kg or less and/or who are 11 years of age or younger limit exposure to contaminants in fish or shellfish by eating no more than four-ounces per meal of the contaminated species. The DSHS also recommends that consumers spread these meals over time. For instance, if the DSHS issues consumption advice that recommends consumption of no more than two meals per month of a contaminated species, those children should eat no more than 24 meals of the contaminated fish or shellfish per year and should not eat such fish or shellfish more than twice per month.

Data Analysis and Statistical Methods

The SALG risk assessors imported Excel© files into SPSS® statistical software, version 13.0 installed on IBM-compatible microcomputers (Dell, Inc), using SPSS® to generate descriptive statistics (mean, standard deviation, median, minimum and maximum concentrations, and range) on measured compounds.[43] In computing descriptive statistics, SALG risk assessors utilized ½ the reporting limit (RL) for analytes designated as not detected (ND) or estimated (J-values)[*]. PCDDs/PCDFs descriptive statistics are calculated using estimated concentrations (J-values) and assuming zero for PCDDs/PCDFs designated as ND.[†] The change in methodology for computing PCDDs/PCDFs descriptive statistics is due to the proximity of the reporting limits to the HAC

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[*] *"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.*

[†] *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.*

value. Assuming ½ the RL for PCDDs/PCDFs designated as ND or J-values would unnecessarily overestimate the concentration of PCDDs/PCDFs in each fish tissue sample. The SALG used the descriptive statistics from the above calculations to generate the present report. The SALG risk assessors performed correlation and regression analyses to describe relationships between mercury concentration and total length (TL) and mercury concentration and fish age. When appropriate and as needed, the SALG risk assessors $\log_e$-transformed mercury concentrations to improve normality and best fit of the data. The SALG risk assessors performed sample site mercury concentration comparisons for largemouth bass. Largemouth bass were the only species collected at all sample sites where sample size and size class distribution were adequate to perform reliable comparisons. The SALG risk assessors used an independent samples *t*-test to examine differences in mercury concentrations in largemouth bass and freshwater drum by sampling event (1995 and 2010–2011). The sample sizes were inadequate for other species to perform this test. Statistical significance was determined at $p \leq 0.05$ for all statistical analyses. The SALG employed Microsoft Excel® spreadsheets to generate figures, to compute HAC_{nonca} and HAC_{ca} values for contaminants, and to calculate HQs, HIs, cancer risk probabilities, and meal consumption limits for fish from Sam Rayburn Reservoir.[44] 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 (10 mcg/dL).[45,46]

RESULTS

The GERG laboratory completed analyses and electronically transmitted the results of the Sam Rayburn Reservoir samples collected in October–November 2010 and February–April 2011to the SALG in October 2011. 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 2a–2k present the results of metals analyses. Tables 3 and 4 contain summary results for pesticides and PCBs, respectively. Tables 5a–5g summarize the PCDD/PCDF analyses. This paper does not display SVOC and VOC data because these contaminants were not present at concentrations of interest in fish collected from Sam Rayburn Reservoir during the described survey. Unless otherwise stated, table summaries present the number of samples containing a specific contaminant/number tested, the mean concentration ± 1 standard deviation (68% of samples should fall within one standard deviation of the arithmetic mean in a sample from a normally-distributed population), and, in parentheses under the mean and standard deviation, the minimum and the maximum detected concentrations. Those who prefer to use the range may derive this statistic by subtracting the minimum concentration of a given contaminant from its maximum concentration. In the tables, results may be reported as ND, below detection limit (BDL) for estimated concentrations, or as concentrations at or above the reporting limit (RL). According to the laboratory's quality control/quality assurance materials, estimated concentrations reported as BDL rely upon the laboratory's method detection limit (MDL) or its reporting limit (RL). The MDL is the minimum concentration of an analyte that can be reported with 99% confidence that the analyte concentration is greater than zero, while the RL is the concentration of an analyte reliably achieved within specified limits of precision and accuracy during routine analyses. Contaminant concentrations reported below the RL are qualified as "J-values" in the laboratory data report.[47]

Inorganic Contaminants

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

The GERG laboratory analyzed a subset of 24 fish tissue samples for six inorganic contaminants and 660 samples for mercury. All fish tissue samples from Sam Rayburn Reservoir contained some concentration of cadmium, copper, lead, mercury, selenium, and zinc (Tables 2a–2k).

The SALG evaluated three toxic metalloids having no known human physiological function (arsenic, cadmium, and lead) in the samples collected from Sam Rayburn Reservoir. Fourteen of 24 fish assayed contained arsenic ranging from ND–0.062 mg/kg (Table 2a). All cadmium concentrations reported in fish were BDL (Table 2b). Lead concentrations ranged from 0.053 to 0.469 mg/kg with a mean of 0.203±0.112 and a median of 0.190 mg/kg (Table 2b).

Three of the metalloids analyzed are essential trace elements: copper, selenium, and zinc. All 24 fish tissue samples contained copper (Table 2b). The mean copper concentration in fish sampled from Sam Rayburn Reservoir was 0.158±0.062 mg/kg. All fish tissue samples contained selenium. Selenium concentrations ranged from 0.106 to 0.447 mg/kg with a mean of 0.278±0.081 and a median of 0.286 mg/kg (Table 2b). All samples also contained zinc (Table 2b). The mean zinc concentration in fish tissue samples from Sam Rayburn Reservoir was 4.128±1.209 mg/kg.

<u>Mercury</u>

All fish tissue samples evaluated from Sam Rayburn Reservoir contained mercury (Tables 2c–2k). Across all sample sites and species, mercury concentrations ranged from BDL (smallmouth buffalo) to 1.979 mg/kg (largemouth bass). The mean mercury concentration for the 660 fish tissue samples assayed was 0.424±0.271 mg/kg (Table 2j).

The relationships between mercury concentration and TL were positive and significant (p <0.05) for seven of 12 species (Figures 2–24). The SALG risk assessors did not include hybrid striped bass in these analyses due to insufficient sample size. TL explained from seven to 57% of the variation in mercury concentration (Figures 2–22). Correlation was strongest for blue catfish.

The relationships between mercury concentration and age were positive and significant (p <0.05) for four of seven species (Figures 2–23). Age explained from 41 to 53% of the variation in mercury concentration (Figures 2–23). Correlation was strongest for white bass.

<u>Blue catfish</u>

Fifty blue catfish ranging from 14.4 to 37.5 inches TL ($\overline{X}$ – 25.0 inches TL) and from four to 16 years of age were analyzed for mercury (Table 1; Figure 2). One-hundred percent of the blue catfish samples examined were of legal size (≥ 12 inches TL). [48] Mercury concentrations ranged from 0.031 to 1.332 mg/kg with a mean of 0.268±0.252 and a median of 0.186 mg/kg (Tables 2c–2j). Mercury concentrations in blue catfish were positively related to TL and age ($r^2 = 0.573$, $n = 50$, p <0.0005; $r^2 = 0.424$, $n = 50$, p <0.0005; Figures 3–4).

Channel catfish

Fifty channel catfish ranging from 12.2 to 21.5 inches TL ($\bar{X}$ – 17.0 inches TL) and from four to 10 years of age were analyzed for mercury (Table 1; Figure 5). One-hundred percent of the channel catfish samples examined were of legal size (≥ 12 inches TL).[48] Mercury concentrations ranged from 0.028 to 0.449 mg/kg with a mean of 0.143±0.093 and a median of 0.118 mg/kg (Tables 2c–2j). The SALG risk assessors computed Pearson product-moment correlation coefficients to assess the relationships between mercury concentration and TL and mercury concentration and age. There was no correlation between the mercury concentrations in channel catfish and TL or age ($r = 0.259$, $n = 50$, $p = 0.070$; $r = 0.178$, $n = 48$, $p = 0.225$).

Crappie

Sixty-one black crappie and four white crappie ranging from 10.39 to 15.47 inches TL ($\bar{X}$ – 12.4 inches TL) and from two to 10 years of age were analyzed for mercury (Table 1; Figure 6). One-hundred percent of the black and white crappie samples examined were of legal size (≥ 10 inches TL).[48] Mercury concentrations ranged from 0.077 to 1.118 mg/kg with a mean of 0.280±0.213 and a median of 0.224 mg/kg (Tables 2c–2j). The SALG risk assessors computed a Pearson product-moment correlation coefficient to assess the relationship between mercury concentration and TL. There was no correlation between the two variables ($r = 0.156$, $n = 65$, $p = 0.215$). Mercury concentrations in crappie were positively related to age ($r^2 = 0.440$, $n = 63$, p <0.0005; Figure 7).

Flathead catfish

Twenty-three flathead catfish ranging from 18.0 to 38.1 inches TL ($\bar{X}$ – 26.4 inches TL) and from four to 21 years of age were analyzed for mercury (Table 1; Figure 8). One-hundred percent of the flathead catfish samples examined were of legal size (≥ 18 inches TL).[48] Mercury concentrations ranged from 0.126 to 1.010 mg/kg with a mean of 0.521±0.257 and a median of 0.450 mg/kg (Tables 2c–2j). The mean mercury concentrations for flathead catfish < 27 inches and > 27 inches were 0.437±0.248 and 0.652±0.223 mg/kg, respectively (Table 2k).Mercury concentrations in flathead catfish were positively related to TL (r^2= 0.243, $n = 23$, $p = 0.017$; Figure 9). The SALG risk assessors computed a Pearson product-moment correlation coefficient to assess the relationship between mercury concentration and age. There was no correlation between the two variables ($r = 0.284$, $n = 23$, $p = 0.189$). The SALG risk assessors visually examined the flathead catfish mercury concentrations noting that mercury concentrations appeared higher in the forested–riverine sections (sample sites 1, 2, and 12) of the reservoir than the open–water sections of the reservoir (data not presented; flathead catfish were not collected from all sample sites). An independent samples t-test confirmed that mercury concentrations in flathead catfish from forested–riverine sections of the reservoir were significantly higher than open–water sections of the reservoir (forested–riverine, $n = 6$; open–water, $n = 17$; t [21] = 4.158, $p < 0.0005$).

Freshwater drum

Seventy freshwater drum ranging from 12.6 to 25.6 inches TL ($\overline{X}$ – 17.6 inches TL) were analyzed for mercury (Table 1). Currently, there is no minimum length limit for freshwater drum in Texas waters. [48] Mercury concentrations ranged from 0.085 to 0.963 mg/kg with a mean of 0.407±0.252 and a median of 0.329 mg/kg (Tables 2c–2j). Mercury concentrations in freshwater drum were positively related to TL ($r^2 = 0.195$, $n = 70$, $p < 0.0005$; Figure 10). Comparison of mercury concentrations in freshwater drum by sampling event indicate that the mercury concentrations reported in 1994–1995 were significantly higher than 2010–2011 mercury concentrations (1994–1995, $n = 15$; 2010–2011, $n = 70$; t [83] = 2.200, $p = 0.031$).

Hybrid striped bass

Six hybrid striped bass ranging from 14.4 to 24.0 inches TL ($\overline{X}$ – 21.7 inches TL) and from three to 10 years of age were analyzed for mercury (Table 1; Figure 11). Eighty-three percent of the hybrid striped bass samples examined were of legal size (≥ 18 inches TL). [48] Mercury concentrations ranged from 0.386 to 0.799 mg/kg with a mean of 0.670±0.148 and a median of 0.713 mg/kg (Tables 2c–2j).

Largemouth bass

Two-hundred forty largemouth bass ranging from 11.8 to 24.6 inches TL ($\overline{X}$ – 17.0 inches TL) and from one to 10 years of age were analyzed for mercury (Table 1; Figure 12). Ninety-four percent of the largemouth bass samples examined were of legal size (≥ 14 inches TL). [48] Mercury concentrations ranged from 0.097 to 1.979 mg/kg with a mean of 0.582±0.259 and a median of 0.549 mg/kg (Tables 2c–2k). The mean mercury concentrations for largemouth bass < 14 inches, ≥ 14 inches, ≥ 16 inches, and ≥ 18 inches were 0.447±0.204, 0.590±0.260, 0.652±0.266 and 0.697±0.245 mg/kg, respectively (Table 2k). Mercury concentrations in largemouth bass were positively related to TL and age ($r^2 = 0.178$, $n = 240$, $p < 0.0005$; $r^2 = 0.405$, $n = 238$, $p < 0.0005$; Figures 13–14). The SALG risk assessors visually examined the largemouth bass mean mercury concentrations noting that mercury concentrations appeared higher in the forested–riverine sections (sample sites 1, 2, 5, and 12) of the reservoir than the open–water sections of the reservoir (Figure 15). An independent samples t-test confirmed that mercury concentrations in largemouth bass from forested–riverine sections of the reservoir were significantly higher than open–water sections of the reservoir (forested–riverine, $n = 67$; open–water, $n = 173$; t [238] = 6.002, $p < 0.0005$). Evaluation of mercury concentrations in largemouth bass (all size classes) by sampling event indicate that the 1994–1995 and 2010–2011 data do not statistically differ by sampling event (1994–1995, $n = 53$; 2010–2011, $n = 240$; t [291] = -0.878, $p = 0.381$).

Longnose gar

Twenty-four longnose gar ranging from 25.8 to 55.0 inches TL ($\overline{X}$ – 42.9 inches TL) were analyzed for mercury (Table 1). Currently, there is no minimum length limit for gar in Texas waters. [48] Mercury concentrations ranged from 0.175 to 0.747 mg/kg with a mean of 0.470±0.153 and a median of 0.475 mg/kg (Tables 2c–2j). The SALG risk assessors computed a Pearson product-moment correlation coefficient to assess the relationship between mercury concentration and TL for longnose gar. There was no correlation between the two variables ($r = 0.285$, $n = 24$, $p = 0.178$).

Smallmouth buffalo

Twenty-one smallmouth buffalo ranging from 21.7 to 36.6 inches TL ($\overline{X}$ – 27.3 inches TL) were analyzed for mercury (Table 1). Currently, there is no minimum length limit for smallmouth buffalo in Texas waters.[48] Mercury concentrations ranged from BDL to 0.693 mg/kg with a mean of 0.207±0.187 and a median of 0.130 mg/kg (Tables 2c–2j). Mercury concentrations in smallmouth buffalo were positively related to TL ($r^2 = 0.219$, $n = 21$, $p = 0.032$; Figure 16).

Spotted bass

Fifteen spotted bass ranging from 9.4 to 14.6 inches TL ($\overline{X}$ – 12.5 inches TL) and from one to four years of age were analyzed for mercury (Table 1; Figure 17). Currently, there is no minimum length limit for spotted bass in Texas waters.[48] Mercury concentrations ranged from 0.159 to 0.414 mg/kg with a mean of 0.277±0.081 and a median of 0.264 mg/kg (Tables 2c–2j). The SALG risk assessors computed Pearson product-moment correlation coefficients to assess the relationships between mercury concentration and TL and mercury concentration and age. There was no correlation between the mercury concentrations in spotted bass and TL or age ($r = -0.074$, $n = 15$, $p = 0.793$; $r = 0.069$, $n = 15$, $p = 0.808$).

Sunfishes

Four species of sunfish or *panfish* (bluegill, longear sunfish, redear sunfish, and warmouth) ranging from 5.6 to 8.5 inches TL ($\overline{X}$ – 7.5 inches TL) were analyzed for mercury (Table 1). Mercury concentrations in all sunfish combined ranged from 0.049 to 0.739 mg/kg with a mean of 0.272±0.233 and a median of 0.138 mg/kg (Tables 2c–2j). The SALG risk assessors evaluated the relationship between mercury concentration and TL for sunfish. Mercury concentrations in sunfish were positively related to TL ($r^2 = 0.487$, $n = 24$, $p < 0.0005$; Figure 18). The SALG risk assessors also computed a Pearson product-moment correlation coefficient to assess the relationship between mercury concentration and TL for redear sunfish and warmouth. There was no correlation between the two variables for redear sunfish and warmouth, respectively ($r = 0.477$, $n = 9$, $p = 0.194$; $r = 0.200$, $n = 8$, $p = 0.635$). ANOVA showed that the mean mercury concentrations in sunfish differed significantly by species (F [3, 20] = 12.152, $p < 0.0005$). Tukey post-hoc comparisons of the four sunfish species indicate that warmouth ($\overline{X} = 0.528$, 95% CI [0.410, 0.645], $p < 0.0005$) had significantly higher mercury concentrations than bluegill, longear sunfish, and redear sunfish (Figure 19).

White bass

Seven-two white bass ranging from 13.7 to 17.5 inches TL ($\overline{X}$ – 15.6 inches TL) and from two to seven years of age were analyzed for mercury (Table 1; Figure 20). One-hundred percent of the white bass samples examined were of legal size (≥ 10 inches TL).[48] Mercury concentrations ranged from 0.186 to 1.045 mg/kg with a mean of 0.426±0.181 and a median of 0.375 mg/kg

(Tables 2c–2j). Mercury concentrations in white bass were positively related to TL and age (r^2 = 0.067, n = 72, p = 0.028; r^2 = 0.527, n = 70, p < 0.0005; Figures 21–22).

Organic Contaminants

<u>Pesticides</u>

The GERG laboratory analyzed 24 fish for 34 pesticides. Twenty-four of 24 samples examined contained concentrations of 4,4′-DDE (Table 3a). 4,4′-DDE concentrations ranged from BDL to 0.028 mg/kg with a mean of 0.004±0.006 and a median of 0.002 mg/kg (Table 3). Trace to low concentrations of 2,4′-DDE, 2,4′-DDD, 4,4′-DDD, 4,4′-DDT, chlordane, dieldrin, heptachlor, mirex, and pentachloroanisole were present in one or more fish samples (data not presented).

<u>PCBs</u>

Sixty-seven of 71 fish tissue samples contained concentrations of one or more PCB congeners (Table 4). No fish tissue sample contained all PCB congeners (data not shown). Across all sites and species, PCB concentrations ranged from ND to 0.116 mg/kg with a mean of 0.016±0.016 and a median of 0.011 mg/kg (Table 4). Longnose gar contained the highest mean concentration of PCBs (0.030±0.038 mg/kg).

<u>PCDDs/PCDFs</u>

The GERG laboratory analyzed a subset of 155 fish tissue samples for 17 of the 210 possible PCDF/PCDD (135 PCDFs + 75 PCDDs) congeners from Sam Rayburn Reservoir. The congeners examined consist of 10 PCDFs and 7 PCDDs that contain chlorine substitutions in, at a minimum, the 2, 3, 7, and 8 positions on the dibenzofuran or dibenzo-*p*-dioxin nucleus and are the only congeners reported to pose dioxin-like adverse human health effects.[49] Although 12 of the 209 PCB congeners – those often referred to as "coplanar PCBs," meaning the molecule can assume a flat configuration with both phenyl rings in the same plane, may also have dioxin-like toxicity, the SALG does not assess PCBs for dioxin-like qualities because the dioxin-like behavior has been less extensively evaluated. Tables 5a–5g contain summary statistics for PCDDs/PCDFs in fish collected from Sam Rayburn Reservoir. Before generating summary statistics for PCDDs/PCDFs, the SALG risk assessors converted the reported concentration of each PCDD or PCDF congener reported present in a tissue sample to a concentration equivalent in toxicity to that of 2,3,7,8-TCDD (a TEQ concentration - expressed as picogram per gram [pg/g]or nanogram per kilogram [ng/kg]). Ninety-four of 155 fish tissue samples contained at least one of the 17 congeners ranging from ND–21.162 pg/g with a mean of 1.173±3.359 and a median of 0.003 pg/g (Table 5g). No samples contained all 17 congeners (data not shown). Smallmouth buffalo contained the highest mean PCDD/PCDF TEQ concentration (6.112±7.898 pg/g; Table 5g). ANOVA was used to test for differences in PCDD/PCDF TEQ concentrations across sample site. PCDD/PCDF TEQ concentrations were not significantly different across sample sites (F [11, 143] = 0.851, p = 0.589).

SVOCs

The GERG laboratory analyzed a subset of 24 Sam Rayburn Reservoir fish tissue samples for SVOCs. Trace concentrations of acetophenone, bis (2-ethylhexyl) phthalate, benzyl alcohol, and diethyl phthalate were present in one or more fish samples assayed (data not presented). The laboratory detected no other SVOCs in fish from Sam Rayburn Reservoir.

VOCs

The GERG laboratory reported the 24 fish tissue samples selected for analysis from Sam Rayburn Reservoir to contain quantifiable concentrations > RL of one or more VOCs: acetone, carbon disulfide, methylene chloride, 2-butanone (MEK), trichlorofluoromethane, toluene, ethylbenzene, m+p-xylene, o-xylene, 1,3,5-trimethylbenzene, 1,2,4-trimethylbenzene, 1,3-dichlorobenzene, 1,4-dichlorobnzene, 4-isopropyltoluene, 1,2,3-trichlorobenzene, 1,2,4-trichlorobenzene, and naphthalene (data not presented). Trace quantities of many VOCs were also present in one or more fish tissue samples assayed from Sam Rayburn Reservoir (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.[33] 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 Sam Rayburn Reservoir. Conclusions and recommendations predicated upon the stated goal of the DSHS to protect human health follow the discussion of the relevance of findings to risk.

Characterization of Systemic (Noncancerous) Health Effects from Consumption of Fish from Sam Rayburn Reservoir

Mercury was observed in fish from Sam Rayburn Reservoir that equaled or exceeded its HAC_{nonca} (0.700 mg/kg; Tables 2c–2k and 6a–6b). Two (flathead catfish and longnose gar) of 71 fish tissue samples evaluated contained PCBs exceeding the HAC_{nonca} for PCBs (0.047 mg/kg; Tables 4 and 7a–7c). The mean PCB concentrations of the 11 species evaluated and the all fish combined mean concentration did not exceed the PCB HAC_{nonca} nor did the HQs exceed 1.0. PCDDs/PCDFs were observed in fish from Sam Rayburn Reservoir that equaled or exceeded its HAC_{nonca} (2.330 pg/g; Tables 5a–5g and 7a–7c). No species of fish evaluated contained any other inorganic or organic contaminants at concentrations that equaled or exceeded the DSHS guidelines for protection of human health or would likely cause systemic risk to human health from consumption of fish from Sam Rayburn Reservoir.

Mercury

Six-hundred sixty of 660 fish collected from Sam Rayburn Reservoir in 2010–2011 contained mercury (Tables 2b–2j). Twenty-two percent of all samples (n = 660) analyzed contained mercury concentrations that equaled or exceeded the HAC_{nonca} for mercury (0.700 mg/kg). Mercury concentrations that equaled or exceeded the HAC_{nonca} for mercury were observed in one or more samples of the following species: black crappie, blue catfish, flathead catfish, freshwater drum, hybrid striped bass, largemouth bass, longnose gar, smallmouth buffalo, warmouth, white bass, and white crappie.

Positive relationships between mercury concentration and TL and mercury concentration and age were observed in many fish from Sam Rayburn Reservoir, indicating that mercury concentrations increase as fish grow (Figures 2–22). The SALG risk assessors evaluated these relationships and corresponding regression models to predict the TL by species at which the mercury concentration equaled or exceeded the HAC_{nonca} for mercury. Smallmouth buffalo, sunfish, and white bass regression analyses predicted that mercury concentrations equivalent to the HAC_{nonca} for mercury occurred at larger TLs than represented by the study data. Thus, the SALG risk assessors considered the use of mercury–TL regression models for smallmouth buffalo, sunfish, and white bass inappropriate for recommending size class fish consumption advice. The mercury–TL linear regression model for blue catfish estimated that blue catfish > 35 inches TL contain mercury concentrations equivalent to the HAC_{nonca} for mercury (Figure 3). The calculation of size class mean mercury concentrations for blue catfish show that blue catfish > 30 inches TL contain mercury concentrations equivalent to the HAC_{nonca} for mercury (Table 2k). The mercury–age linear regression model for crappie predicted that crappie > 9 years of age contain mercury concentrations equivalent to the HAC_{nonca} for mercury (Figure 7). The mercury–TL linear regression model for flathead catfish estimated that flathead catfish > 33 inches TL contain mercury concentrations equivalent to the HAC_{nonca} for mercury (Figure 9). The calculation of size class mean mercury concentrations for flathead catfish show that flathead catfish ≥ 27 inches TL contain mercury concentrations equivalent to the HAC_{nonca} for mercury (Table 2k). The linear regression model for freshwater drum indicated that freshwater drum > 24 inches TL contain mercury concentrations equivalent to the HAC_{nonca} for mercury (Figure 10). The mercury–TL linear regression model for largemouth bass estimated that largemouth bass > 19 inches TL contain mercury concentrations equivalent to the HAC_{nonca} for mercury (Figure 13). The mercury–age linear regression model for largemouth bass estimated that largemouth bass > 5 years of age contain mercury concentrations equivalent to the HAC_{nonca} for mercury (Figure 14). The calculation of size class mean mercury concentrations for largemouth show that largemouth bass ≥ 16 inches TL contain mercury concentrations equivalent to the HAC_{nonca} for mercury (Table 2k). The mercury–age linear regression model for white bass predicted that white bass > 6 years of age contain mercury concentrations equivalent to the HAC_{nonca} for mercury (Figure 22).

Meal consumption calculations may be useful for decisions about consumption advice or regulatory actions. The SALG risk assessors calculated the number of eight-ounce meals of fish from Sam Rayburn Reservoir that healthy adults could consume without significant risk of adverse systemic effects (Tables 6a–6b). Meal consumption rates were based on the most conservative mercury concentration (i.e. overall mean mercury concentration, predicted mercury concentration by regression model, or size class mean mercury concentration) by species. The SALG risk assessors estimated that healthy adults could consume 0.9 (eight-ounce) meals per week of blue catfish > 30 inches TL, 0.9 meals per week of flathead catfish > 27 inches TL, 0.9 meals per week of hybrid striped bass, or 0.9 meals per week of largemouth bass ≥ 16 inches TL containing mercury. The SALG risk assessors suggest that fish from Sam Rayburn Reservoir contain mercury at concentrations that may pose potential systemic health risks and that people should limit their consumption of blue catfish > 30 inches TL, flathead catfish > 27 inches TL, hybrid striped bass, or largemouth bass ≥ 16 inches TL, from Sam Rayburn Reservoir. Because the developing nervous system of the human fetus and young children may be especially susceptible to adverse systemic health effects associated with consuming mercury-contaminated fish, the SALG risk assessors recommend more conservative consumption guidance for this sensitive subpopulation.

PCDDs/PCDFs

Twenty of 151 fish tissue samples assayed contained PCDDs/PCDFs exceeding the HAC_{nonca} for PCDDs/PCDFs (2.330 pg/g; Tables 5a–5g and 7a–7c). 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, channel catfish, flathead catfish, largemouth bass, longnose gar, smallmouth buffalo, and white bass. Two (flathead catfish and smallmouth buffalo) of 12 species evaluated had mean PCDD/PCDF concentrations exceeding the HAC_{nonca} for PCDDs/PCDFs or an HQ of 1.0 (Tables 5a–5g and 7a–7c). 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 flathead catfish and smallmouth buffalo from Sam Rayburn Reservoir may pose potential systemic health risks.

Meal consumption calculations may be useful for decisions about consumption advice or regulatory actions. The SALG risk assessors calculated the number of eight-ounce meals of fish from Sam Rayburn Reservoir that healthy adults could consume without significant risk of adverse systemic effects (Tables 7a–7c). The SALG risk assessors estimated that healthy adults could consume 0.5 (eight-ounce) meals per week of flathead catfish or 0.4 (eight-ounce) meals per week of smallmouth buffalo containing PCDDs/PCDFs. Therefore, SALG risk assessors suggest that people should limit their consumption of flathead catfish and/or smallmouth buffalo from Sam Rayburn Reservoir. Because the developing nervous system of the human fetus and young children may be especially susceptible to adverse systemic health effects associated with consuming 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 Sam Rayburn Reservoir

The USEPA classifies arsenic, most chlorinated pesticides, PCBs, and PCDDs/PCDFs as carcinogens. Arsenic, chlorinated pesticides, and PCBs were present in fish samples assayed from Sam Rayburn Reservoir, 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. The mean PCDD/PCDF concentrations observed in flathead catfish 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 5a–5g and 8a–8c). PCDDs/PCDFs were also present in other species collected from Sam Rayburn Reservoir, but none of these species had mean PCDD/PCDF 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 or the HAC_{ca} for PCDDs/PCDFs (Tables 5a–5g and 8a–8c).

Meal consumption calculations may be useful for decisions about consumption advice or regulatory actions. The SALG risk assessors calculated the number of eight-ounce meals of fish from Sam Rayburn Reservoir that healthy adults could consume without significant risk of cancer (Tables 8a–8c). The SALG risk assessors estimated that healthy adults could consume 0.7 (eight-ounce) meals per week of flathead catfish or 0.5 (eight-ounce) meals per week of smallmouth buffalo containing PCDDs/PCDFs. Therefore, SALG risk assessors suggest that people should limit their consumption of flathead catfish and/or smallmouth buffalo from Sam Rayburn Reservoir. Because the developing nervous system of the human fetus and young children may be especially susceptible to these effects, the SALG risk assessors recommend more conservative consumption guidance for this sensitive subpopulation.

Characterization of Calculated Cumulative Systemic Health Effects and of Cumulative Excess Lifetime Cancer Risk from Consumption of Fish from Sam Rayburn Reservoir

Cumulative systemic effects of toxicants may occur if more than one contaminant acts upon the same target organ or acts by the same mode or mechanism of action. PCBs and PCDDs/PCDFs in fish from Sam Rayburn Reservoir could have these properties, especially with respect to effects on the immune system. Multiple organic contaminants in the Sam Rayburn Reservoir samples did increase the likelihood of systemic adverse health outcomes from consuming flathead catfish and longnose gar from Sam Rayburn Reservoir (Tables 7a–7c). The combined toxicity of PCBs and PCDDs/PCDFs in flathead catfish and longnose gar exceeded a HI of 1.0.

Consuming other fish from Sam Rayburn Reservoir containing multiple inorganic or organic contaminants is unlikely to result in cumulative systemic toxicity.

Meal consumption calculations may be useful for decisions about consumption advice or regulatory actions. The SALG risk assessors calculated the number of eight-ounce meals of fish from Sam Rayburn Reservoir that healthy adults could consume without significant risk of adverse systemic effects (Tables 7a–7c). The SALG estimated this group could consume 0.4 (eight-ounce) meals per week of flathead catfish and 0.8 (eight-ounce) meals per week of longnose gar containing PCBs and PCDDs/PCDFs. The SALG risk assessors suggest that fish from Sam Rayburn Reservoir contain PCBs and PCDDs/PCDFs at concentrations that may pose potential systemic health risks and that people should limit their consumption of flathead catfish and longnose gar from Sam Rayburn Reservoir. Because the developing nervous system of the human fetus and young children may be especially susceptible to these effects, the SALG risk assessors recommend more conservative consumption guidance for this sensitive subpopulation.

The SALG also queried the probability of increasing lifetime excess cancer risk from consuming fish containing multiple inorganic and organic contaminants. In most assessments of cancer risk from environmental exposures to chemical mixtures, researchers have considered any increase in cancerous or benign growths in one or more organs as cumulative, no matter the mode or mechanism of action of the contaminant. In this assessment, risk assessors added the calculated carcinogenic effect of arsenic, chlorinated pesticides, PCBs, and PCDFs/PCDDs (all data not presented; Tables 8a–8c). In each instance, addition of the cancer risk for these chemicals increased the theoretical lifetime excess cancer risk; albeit, the cancer risk increase did not elevate lifetime excess cancer risk to a level greater than the DSHS guideline for protection of human health of one excess cancer in 10,000 persons equivalently exposed.

Characterization of Potential Exposure to Contaminants from Consumption of Fish from Sam Rayburn Reservoir

Notwithstanding, the 2010–2011 Sam Rayburn Reservoir characterization of risk, the DSHS SALG risk assessors will follow the paradigm established in 1995 and continue to recommend mercury consumption advice based on a reasonable maximum exposure scenario (e.g. mean mercury concentration [1.050 mg/kg] for largemouth bass and freshwater drum from Caddo Lake in 1995) for East Texas waters. This approach allows DSHS to protect people who fish Sam Rayburn Reservoir only, as well as protect those who may consume fish from other waters within the same watershed (i.e. B.A. Steinhagen Reservoir or Neches River) or other East Texas waters. The same species of fish from the Neches River, B.A. Steinhagen Reservoir, and Sam Rayburn Reservoir all within the Angelina-Neches River Basin show a consistent pattern of mercury contamination thus justifying the reasonable maximum exposure scenario as a plausible risk management approach to protect public health.

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%.[50] 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 Sam Rayburn Reservoir in

2010–2011 (Table 9). The recoveries and yields for an average fish of each species from Sam Rayburn Reservoir in 2010–2011 ranged from 0.3–15.1 eight-ounce meals. Based on recoveries and yields ($\overline{X}$ – 38%) from whole fish to skin-off fillets for this project, the average Sam Rayburn Reservoir fish yields 2.0 pounds of skin-off fillets or approximately four eight-ounce meals (Table 9). To illustrate the importance of potential exposure from large catfish, buffalo, or gar let's consider the flathead catfish mean mercury concentration (0.521 mg/kg) for this project. Based on a mean mercury concentration of 0.521 mg/kg, a person consuming five eight-ounce meals per month would exceed the MRL. The maximum size flathead catfish (33.1 pounds) for this project yields 12.6 pounds of skin-off fillets, approximately 25 eight-ounce meals. Due to the potential exposure from large-sized fish, it is important for high volume fish consumers (persons who eat more than 2 eight-ounce meals per week) to understand that even though an average fish mercury concentration does not exceed the HAC_{nonca} for mercury a person may easily consume enough fish meals to exceed the MRL. For the reasons stated in the above discussion, the SALG risk assessors considered both standard meal consumption calculations and potential exposure scenarios to develop fish consumption advice for fish from Sam Rayburn Reservoir.

CONCLUSIONS

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

This study addressed the public health implications of consuming fish from Sam Rayburn Reservoir, located in Angelina, Jasper, Nacogdoches, Sabine, San Augustine, and Tyler Counties, Texas. Risk assessors from the SALG conclude from the present characterization of potential adverse health effects from consuming fish from Sam Rayburn Reservoir that:

1. Blue catfish and largemouth bass do not contain any arsenic, cadmium, copper, lead, selenium, zinc, pesticide, SVOC, or VOC concentrations, either singly or in combination, that exceed the DSHS guidelines for protection of human health. Therefore, consumption of these fish species containing the above-listed contaminants **poses no apparent risk to human health**.

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

3. Black and white crappie, blue catfish, channel catfish, freshwater drum, hybrid striped bass, largemouth bass, longnose gar, spotted 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 PCDDs/PCDFs **poses no apparent risk to human health**.

4. Black and white crappie, bluegill, channel catfish, longear sunfish, redear sunfish, smallmouth buffalo, spotted bass, and warmouth mean mercury concentrations do not exceed the DSHS guidelines for protection of human health. Therefore, consumption of these species containing mercury **poses no apparent risk to human health.**

5. Larger size classes or older age classes of gar not represented in the samples of this assessment may contain mercury concentrations that exceed the DSHS guidelines for protection of human health. Therefore, the SALG characterizes the likelihood of adverse health effects from regular consumption of the larger size classes or older age classes of gar from Sam Rayburn Reservoir as of **unknown significance to human health.**

6. Blue catfish > 30 inches TL, flathead catfish > 27 inches TL, hybrid striped bass, and largemouth bass ≥ 16 inches TL contain mercury at concentrations exceeding the DSHS guidelines for protection of human health. Regular or long-term consumption of these fish may result in adverse systemic health effects. Therefore, consumption of these species from Sam Rayburn Reservoir **poses an apparent risk to human health**.

7. Flathead catfish and smallmouth buffalo contain PCDD/PCDF TEQ concentrations exceeding the DSHS guidelines for protection of human health. Regular or long-term consumption of flathead catfish and smallmouth buffalo may result in adverse systemic health effects and/or increase the likelihood of carcinogenic health risks. Therefore, consumption of flathead catfish and smallmouth buffalo from Sam Rayburn Reservoir **poses an apparent risk to human health**.

8. Consumption of multiple organic contaminants (PCDDs/PCDFs and PCBs) in longnose gar does increase the likelihood of systemic health risks. Regular or long-term consumption of longnose gar may result in adverse systemic health effects. Therefore, consumption of longnose gar from Sam Rayburn Reservoir **poses an apparent risk to human health**.

9. Consumption of multiple inorganic or organic contaminants observed in fish from Sam Rayburn Reservoir does not significantly increase the likelihood of systemic or carcinogenic health risks (excluding longnose gar). Therefore, SALG risk assessors conclude that consuming fish (excluding longnose gar) containing multiple contaminants at concentrations near those observed in fish from Sam Rayburn Reservoir does not significantly increase the risk of adverse health effects. Therefore, consumption of fish containing multiple contaminants **poses no 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.[16, 20, 51] Risk managers at the DSHS may decide to take some 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).[52]. Declarations of prohibited harvesting areas are enforceable under the Texas Health and Safety Code, Subchapter D, parts 436.091 and 436.101.[52] The DSHS consumption advice carries no penalty for noncompliance. Consumption advisories, instead, inform the public of potential health hazards associated with consuming contaminated fish or shellfish from Texas waters. With this information, members of the public can make informed decisions about whether and/or how much, contaminated fish or shellfish, they wish to consume. The SALG concludes from this risk characterization and the comprehensive risk assessment of the Neches River Basin that consuming blue catfish, flathead catfish, gar (all species), hybrid striped bass, largemouth bass, and smallmouth buffalo from Sam Rayburn Reservoir **poses an apparent hazard to public health.** Therefore, SALG risk assessors recommend that:

1. People should not consume smallmouth buffalo from Sam Rayburn Reservoir.

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 > 30 inches TL, flathead catfish, gar (all species), largemouth bass > 16 inches TL, and spotted bass > 16 inches TL from Sam Rayburn Reservoir (Table 10).

3. Women past childbearing age and adult men may consume up to one eight-ounce meal per month of flathead catfish or gar (all species) from Sam Rayburn Reservoir.

4. Women past childbearing age and adult men may consume up to two eight-ounce meals per month of blue catfish > 30 inches TL, largemouth bass > 16 inches TL, or spotted bass > 16 inches TL from Sam Rayburn Reservoir.

5. The issuance of consumption advice for hybrid striped bass is not necessary because TPWD has discontinued stocking of hybrid striped bass in Sam Rayburn Reservoir. The TPWD gill net surveys have documented low, decreasing catch rates (≤ 1.2/ net night) of hybrid striped bass from 2005–2009 and none collected in 2011. The hybrid striped bass samples collected in this study are presumably remnants of the last stocking by TPWD in 2000. The average lifespan of a hybrid striped bass is five to six years.

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

PUBLIC HEALTH ACTION PLAN

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

- The agency publishes fish consumption advisories and bans in a booklet available to the public through the SALG. To receive the booklet and/or the data, please contact the SALG at 512-834-6757.[53]
- 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.[54] The SALG regularly updates this Web site.
- The DSHS also provides the USEPA (http://epa.gov/waterscience/fish/advisories/), the TCEQ (http://www.tceq.state.tx.us), and the TPWD (http://www.tpwd.state.tx.us) with information on all consumption advisories and possession bans. Each year, the TPWD informs the fishing and hunting public of consumption advisories and fishing bans on its Web site and in an official downloadable PDF file containing general hunting and fishing regulations available at http://www.txoutdoorannual.com/PDFs/OutdoorAnnual_2011-12.pdf [55] A booklet containing this information is available at all establishments selling Texas fishing licenses.[56]

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

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

Figure 1. Sam Rayburn Reservoir Sample Sites

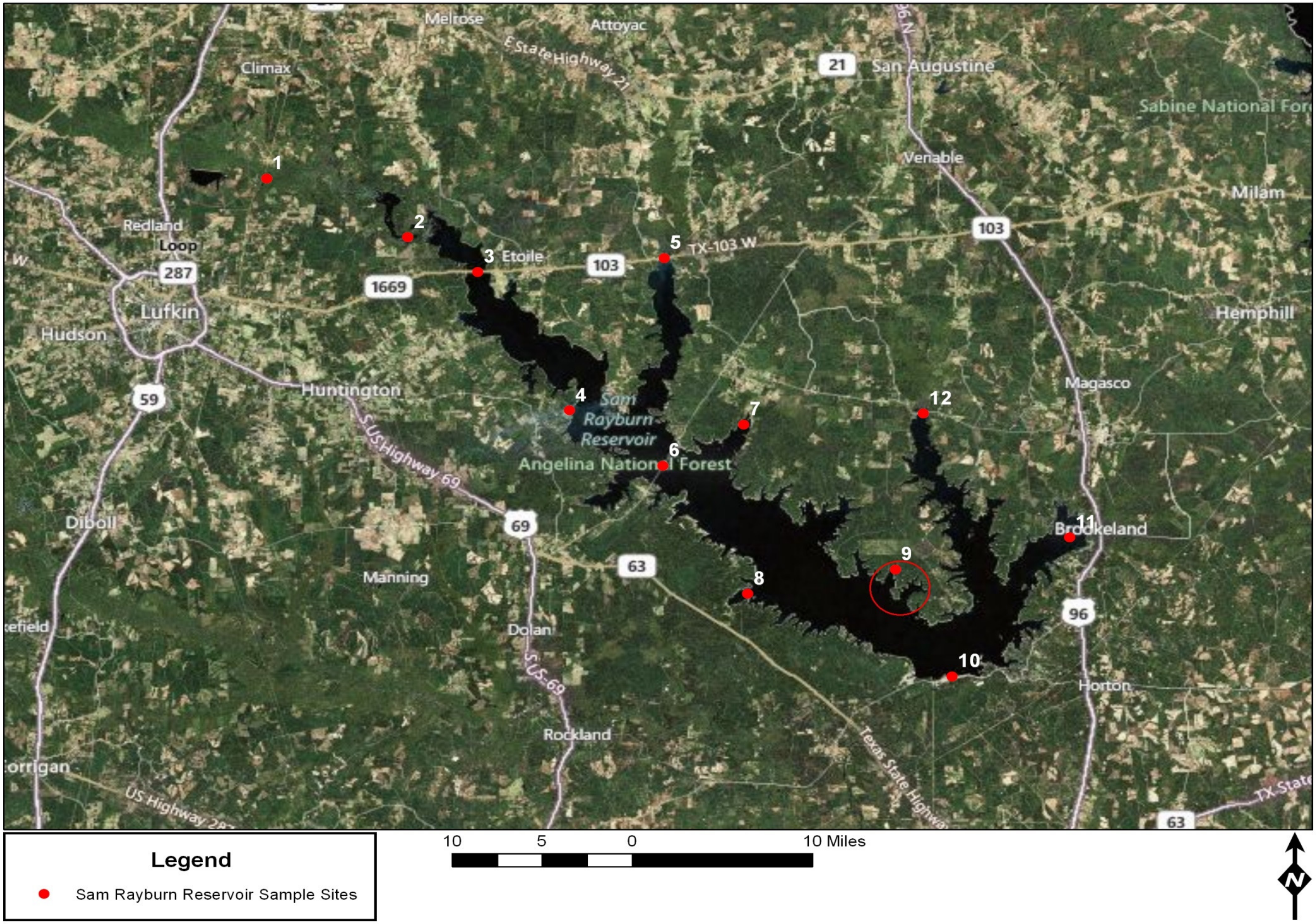


Figure 2. Length at age for blue catfish collected from Sam Rayburn Reservoir, Texas, 2010–2011.

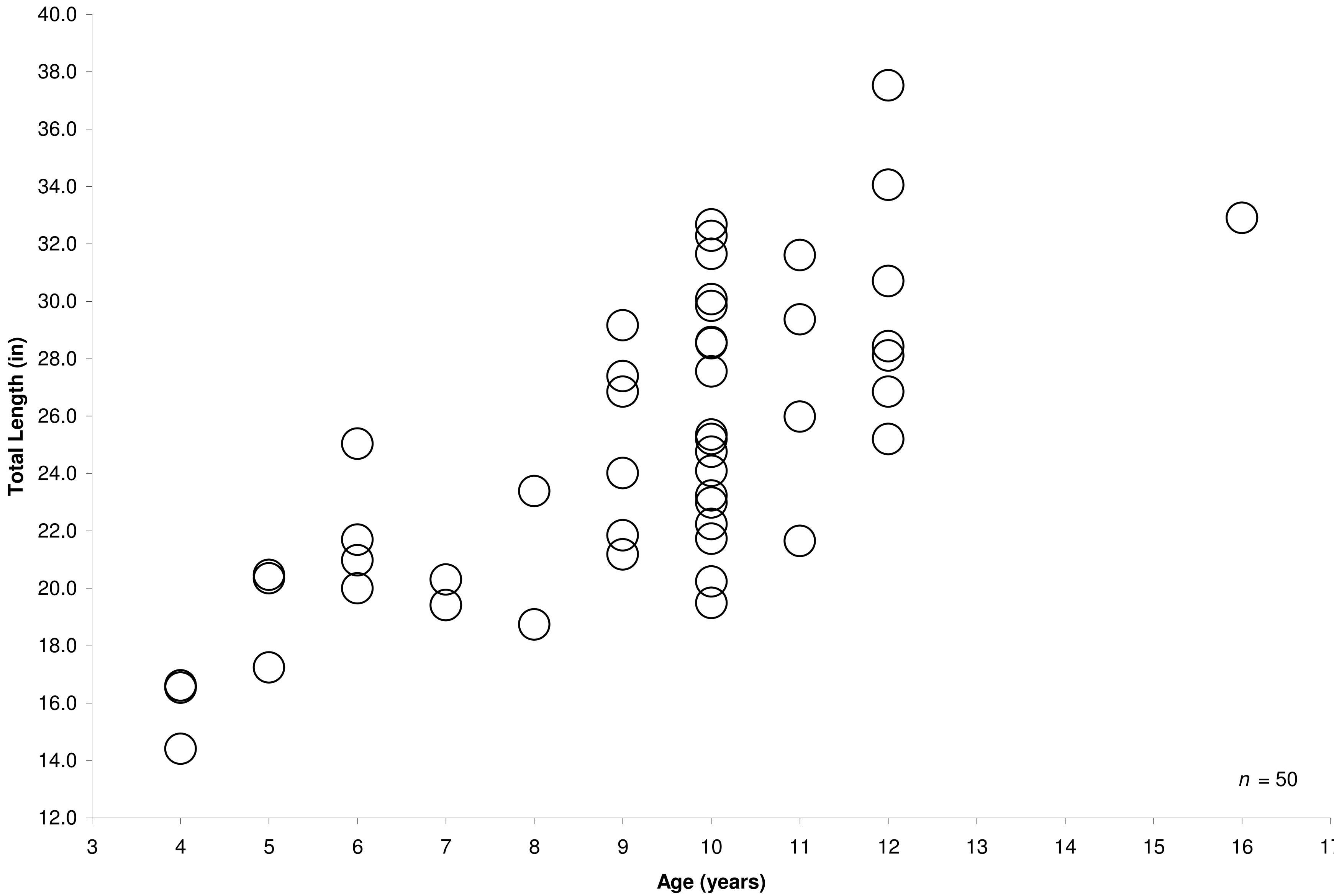


Figure 3. The relationship between mercury concentration and total length for blue catfish collected from Sam Rayburn Reservoir, Texas, 2010–2011.

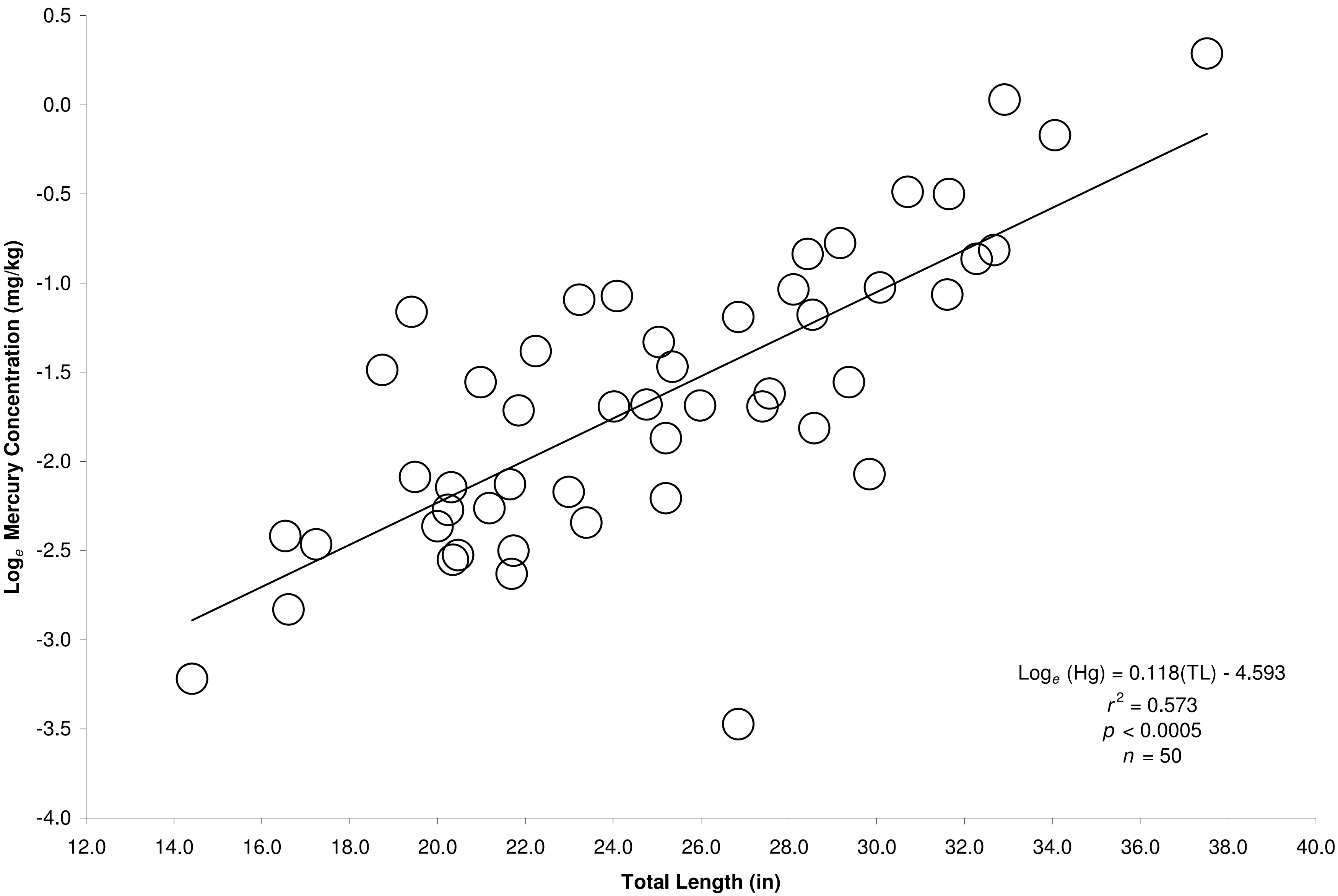


Figure 4. The relationship between mercury concentration and age for blue catfish collected from Sam Rayburn Reservoir, Texas, 2010–2011.

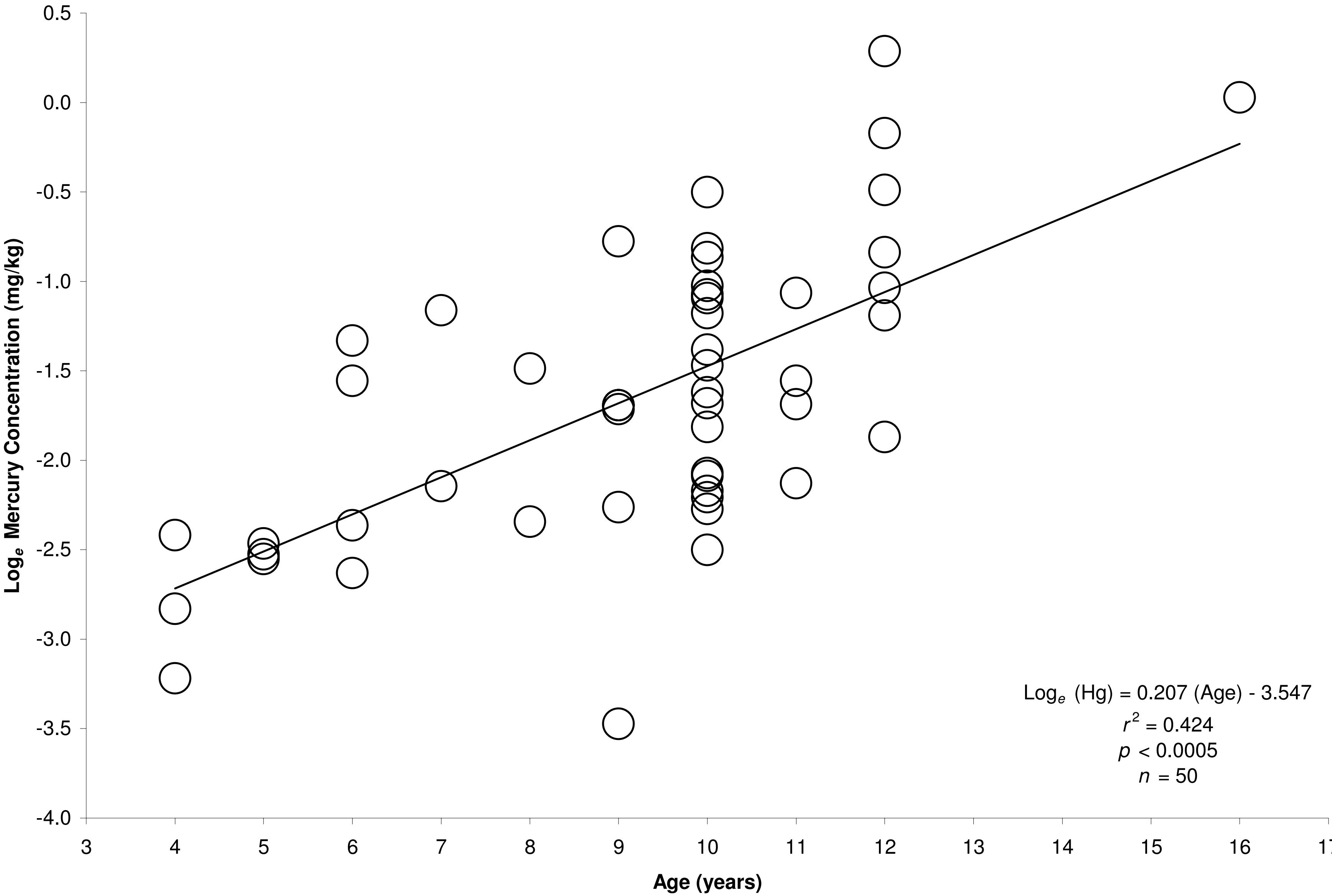


Figure 5. Length at age for channel catfish collected from Sam Rayburn Reservoir, Texas, 2010–2011.

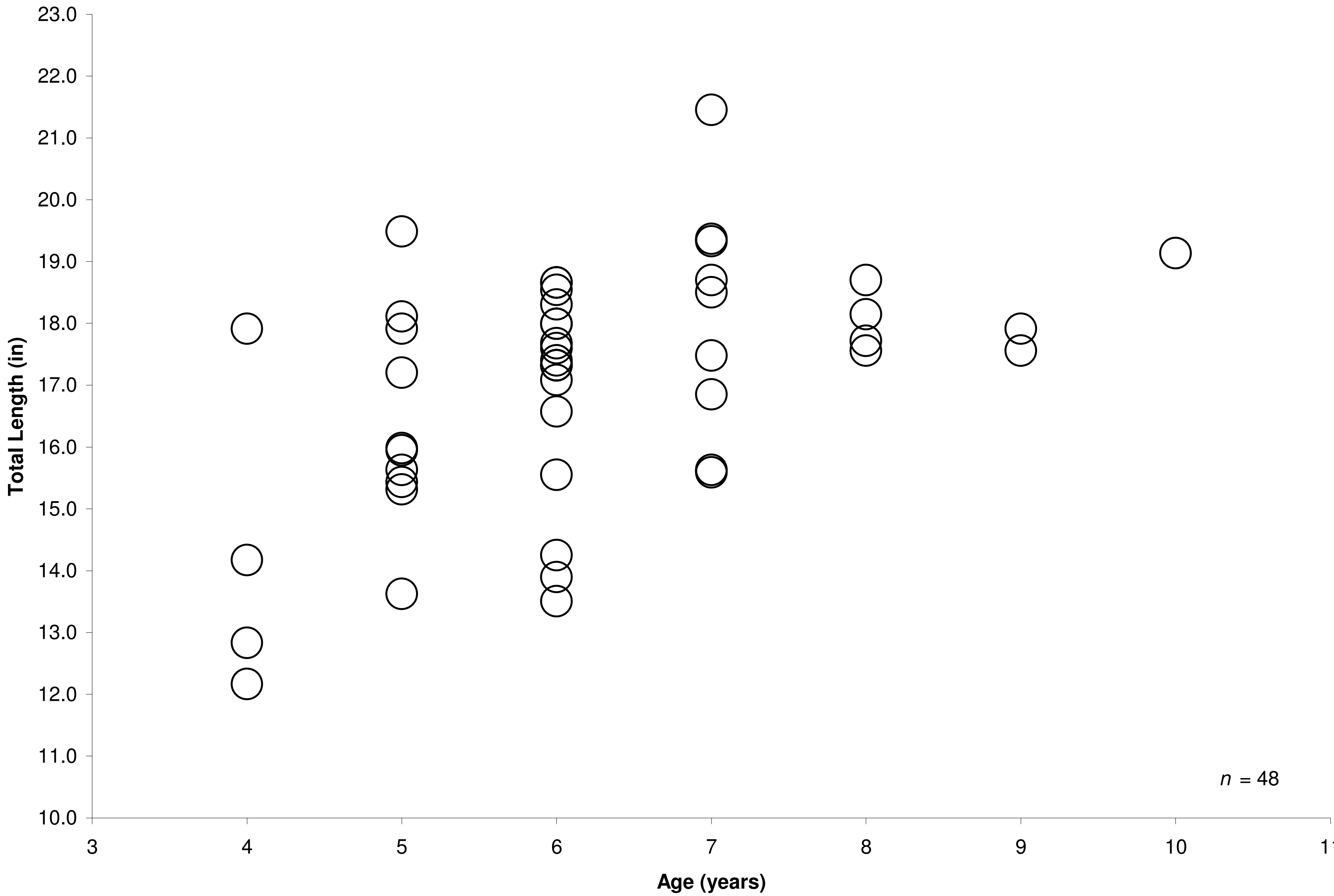


Figure 6. Length at age for black and white crappie collected from Sam Rayburn Reservoir, Texas, 2010–2011.

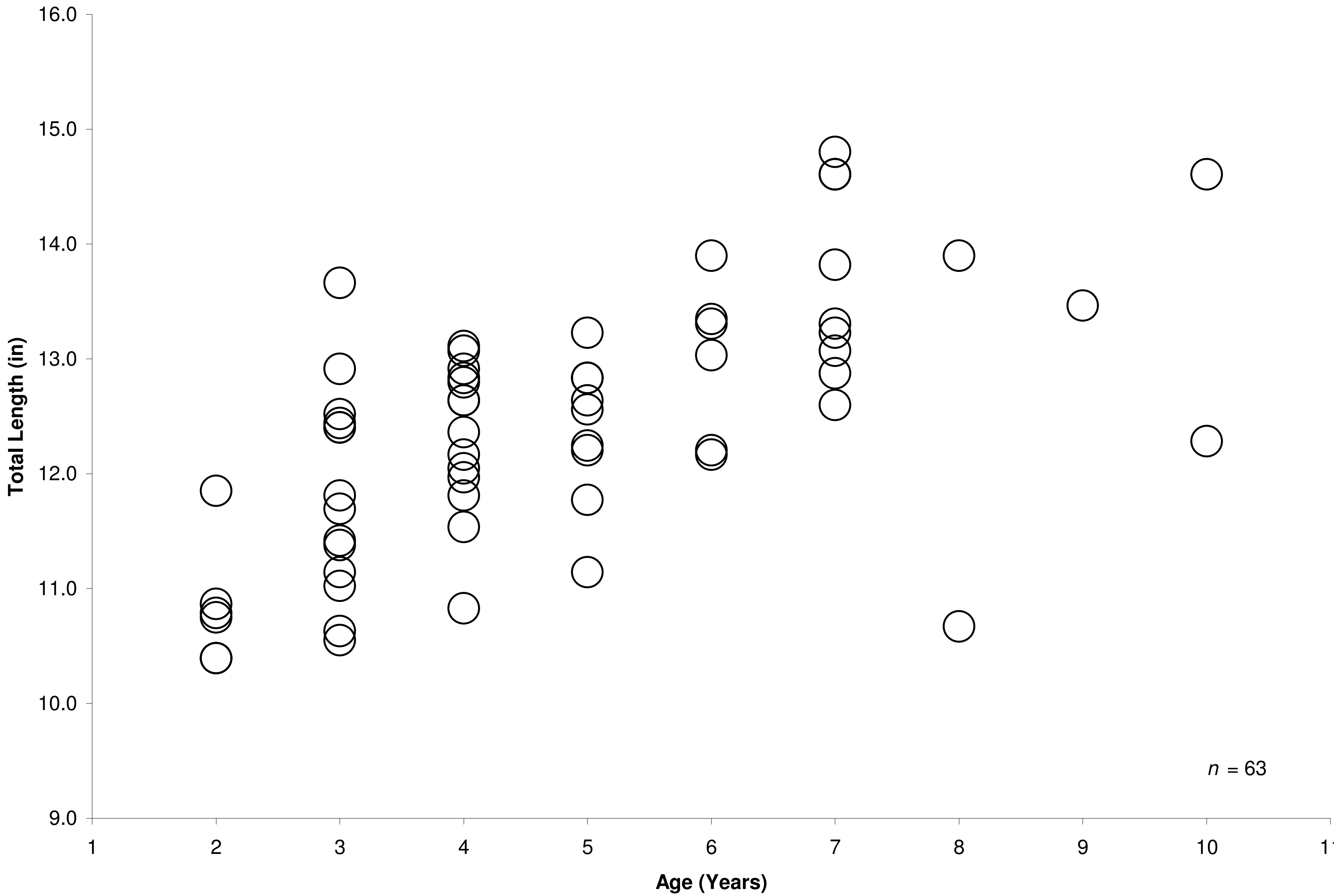


Figure 7. The relationship between mercury concentration and age for black and white crappie collected from Sam Rayburn Reservoir, Texas, 2010–2011.

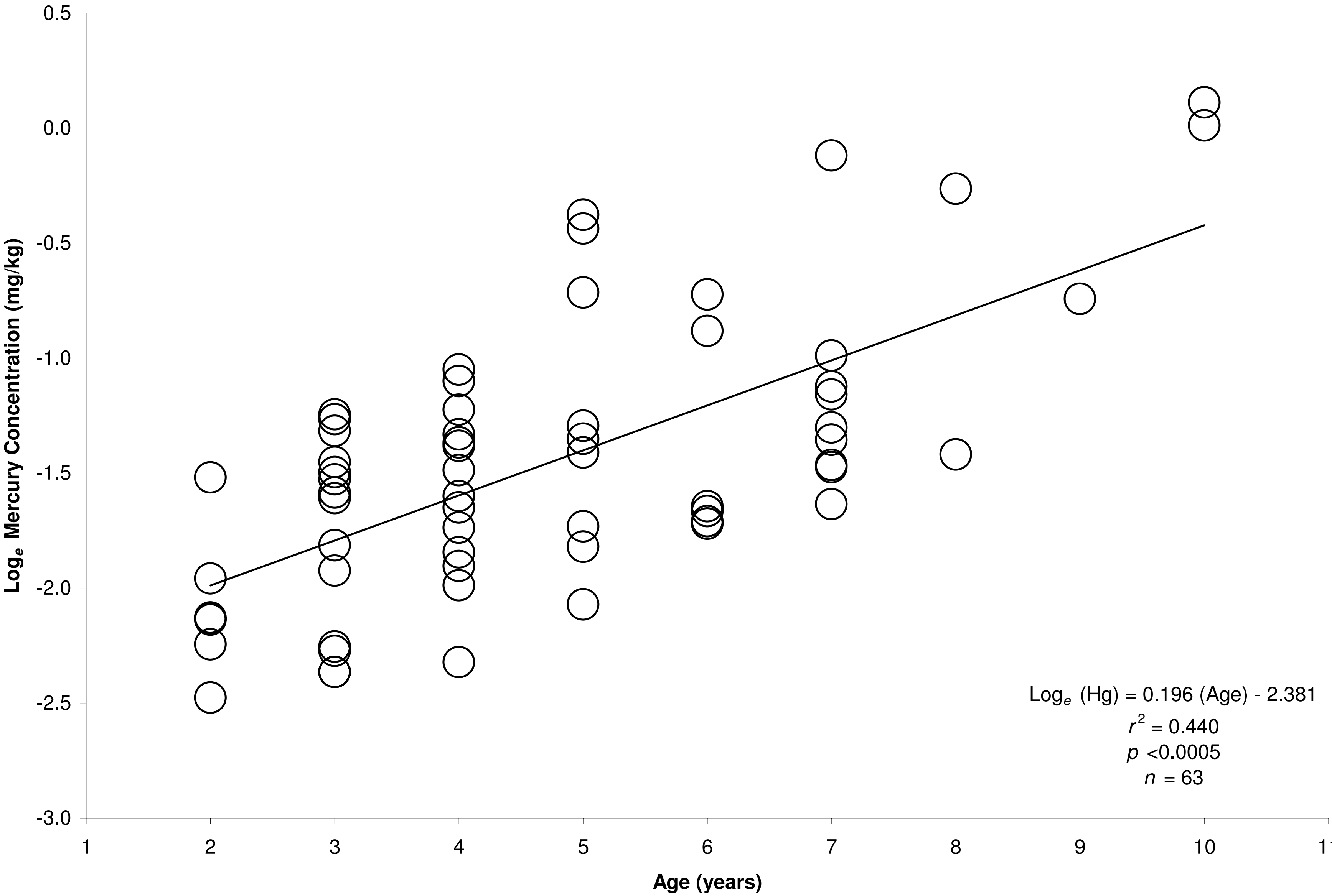


Figure 8. Length at age for flathead catfish collected from Sam Rayburn Reservoir, Texas, 2010–2011.

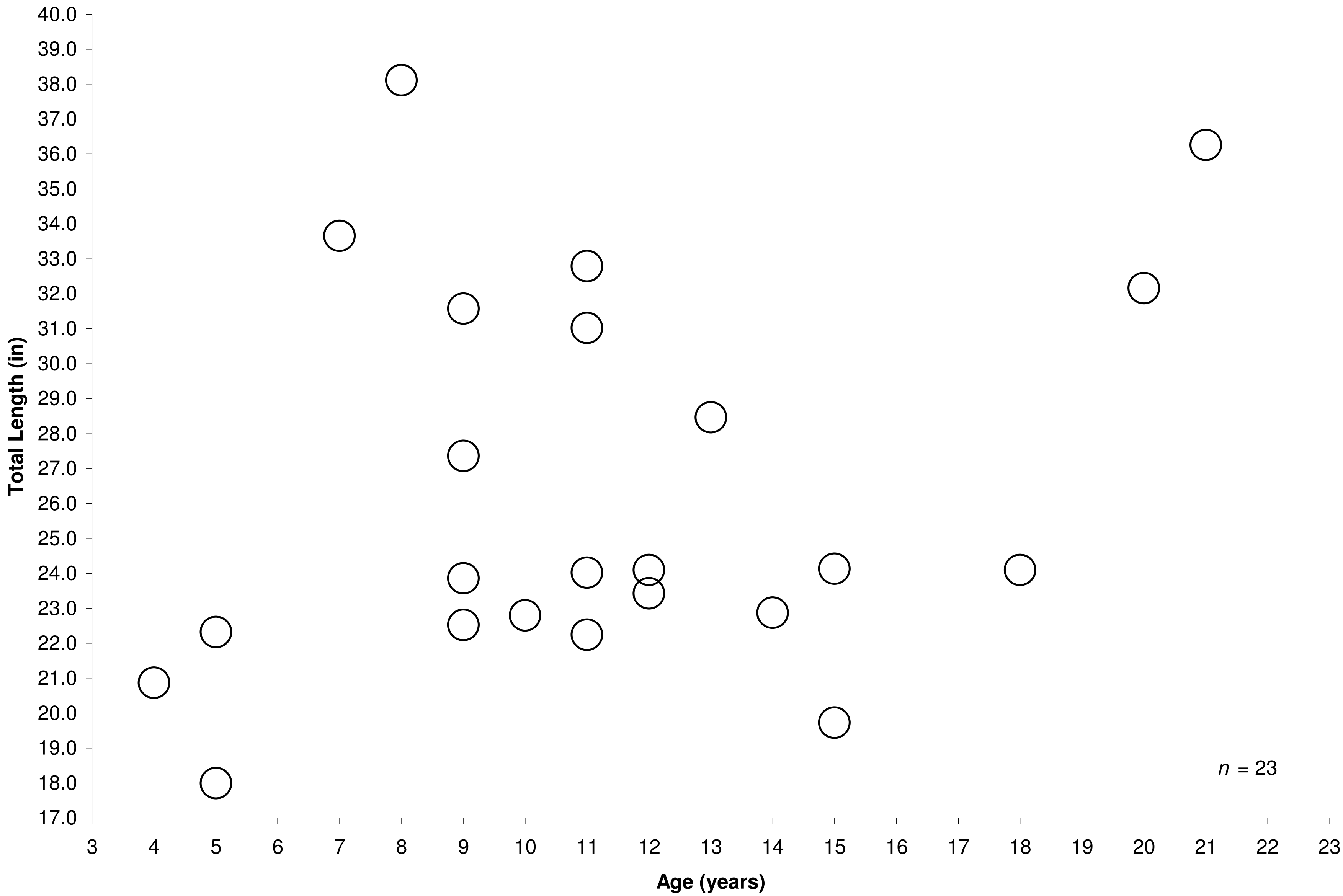


Figure 9. The relationship between mercury concentration and total length for flathead catfish collected from Sam Rayburn Reservoir, Texas, 2010–2011.

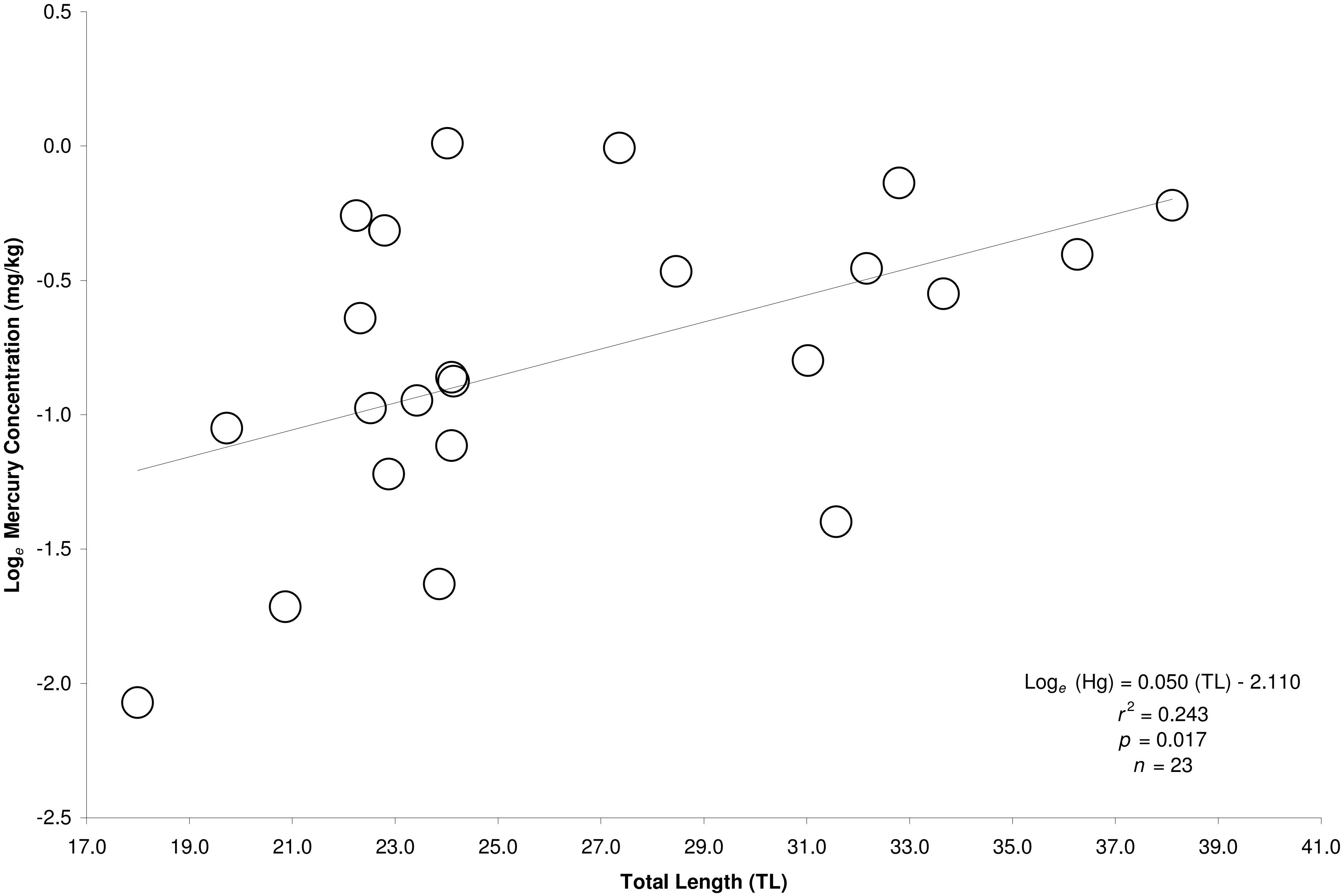


Figure 10. The relationship between mercury concentration and total length for freshwater drum collected from Sam Rayburn Reservoir, Texas, 2010–2011.

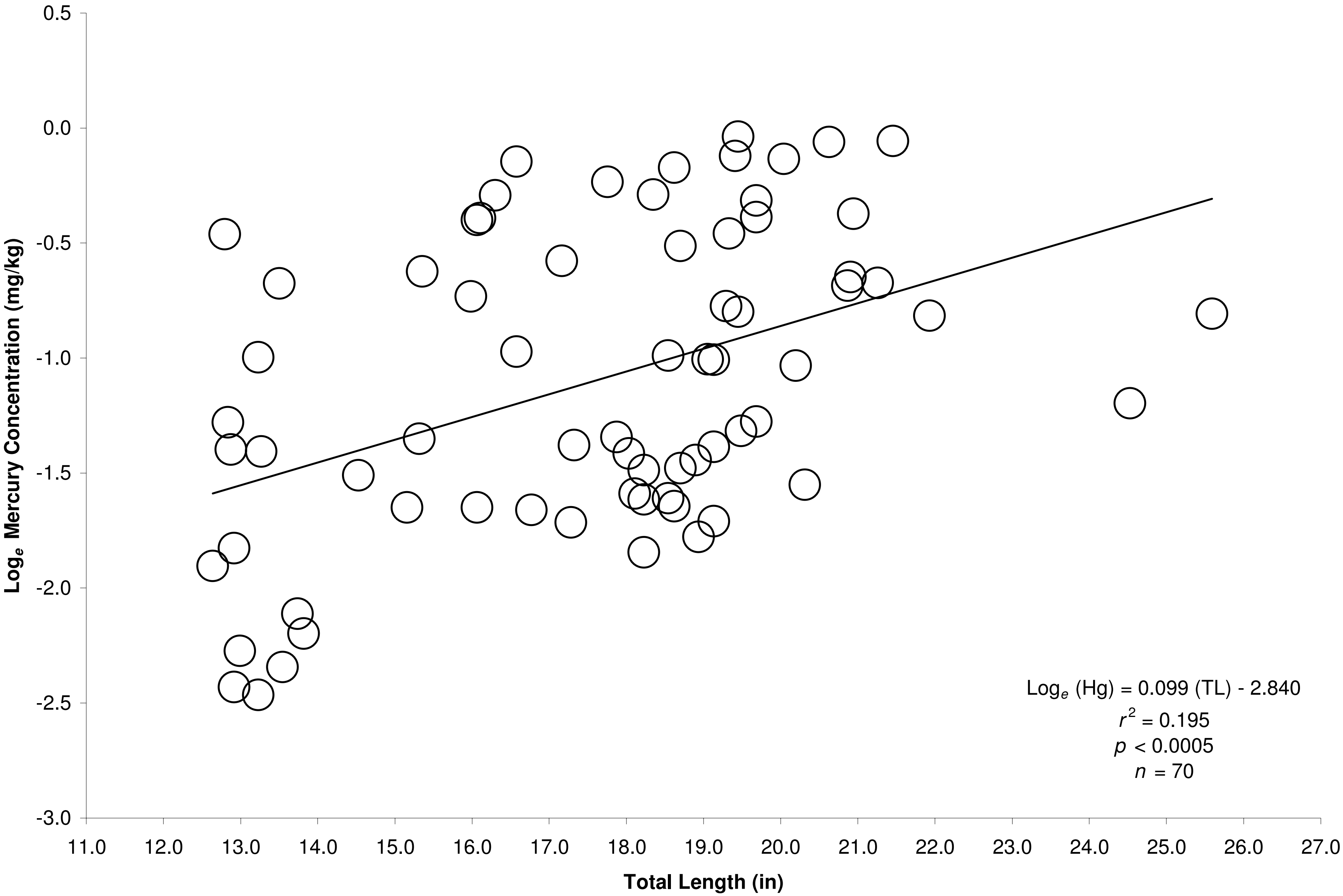


Figure 11. Length at age for hybrid striped bass collected from Sam Rayburn Reservoir, Texas, 2010–2011.

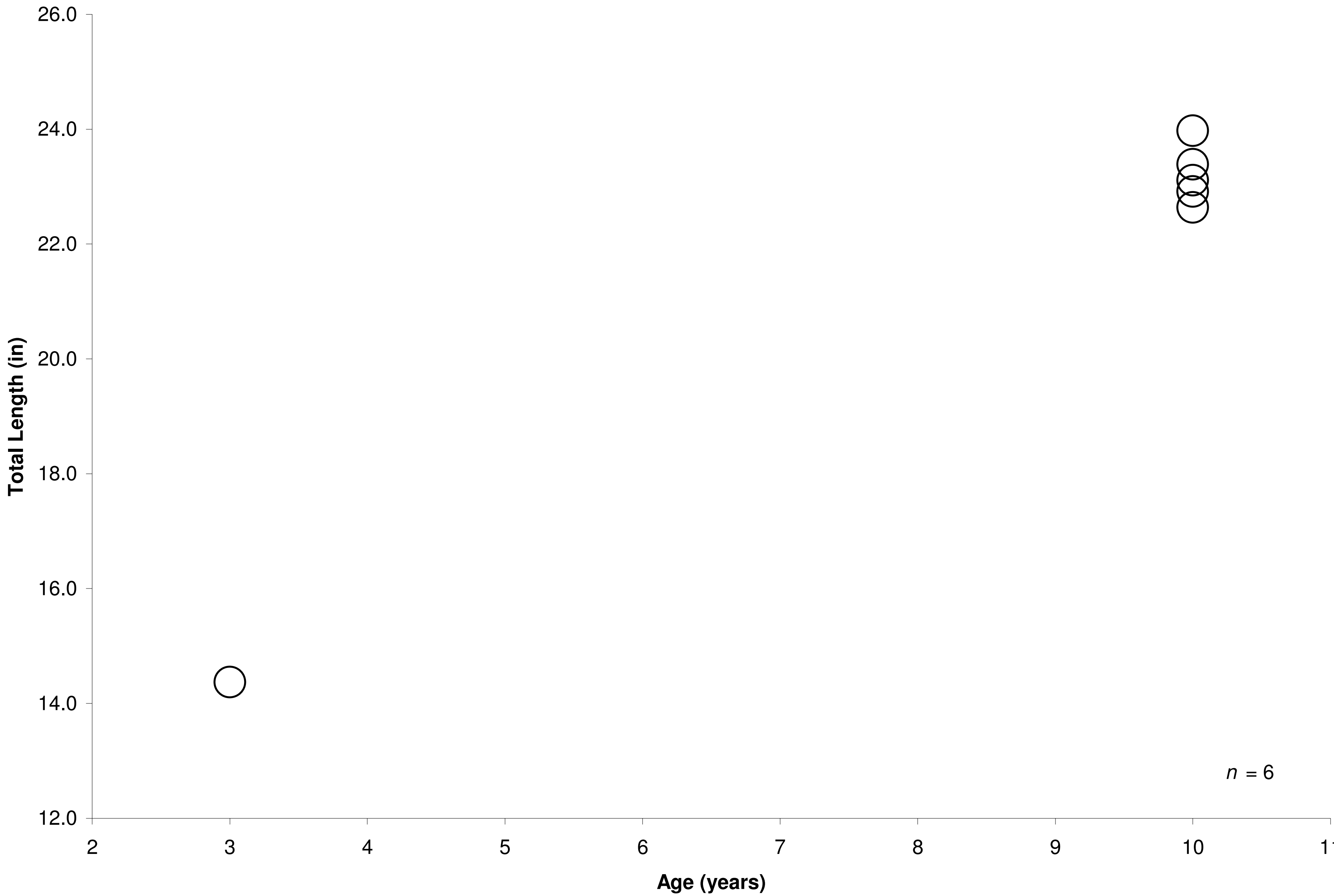


Figure 12. Length at age for largemouth bass collected from Sam Rayburn Reservoir, Texas, 2010–2011.

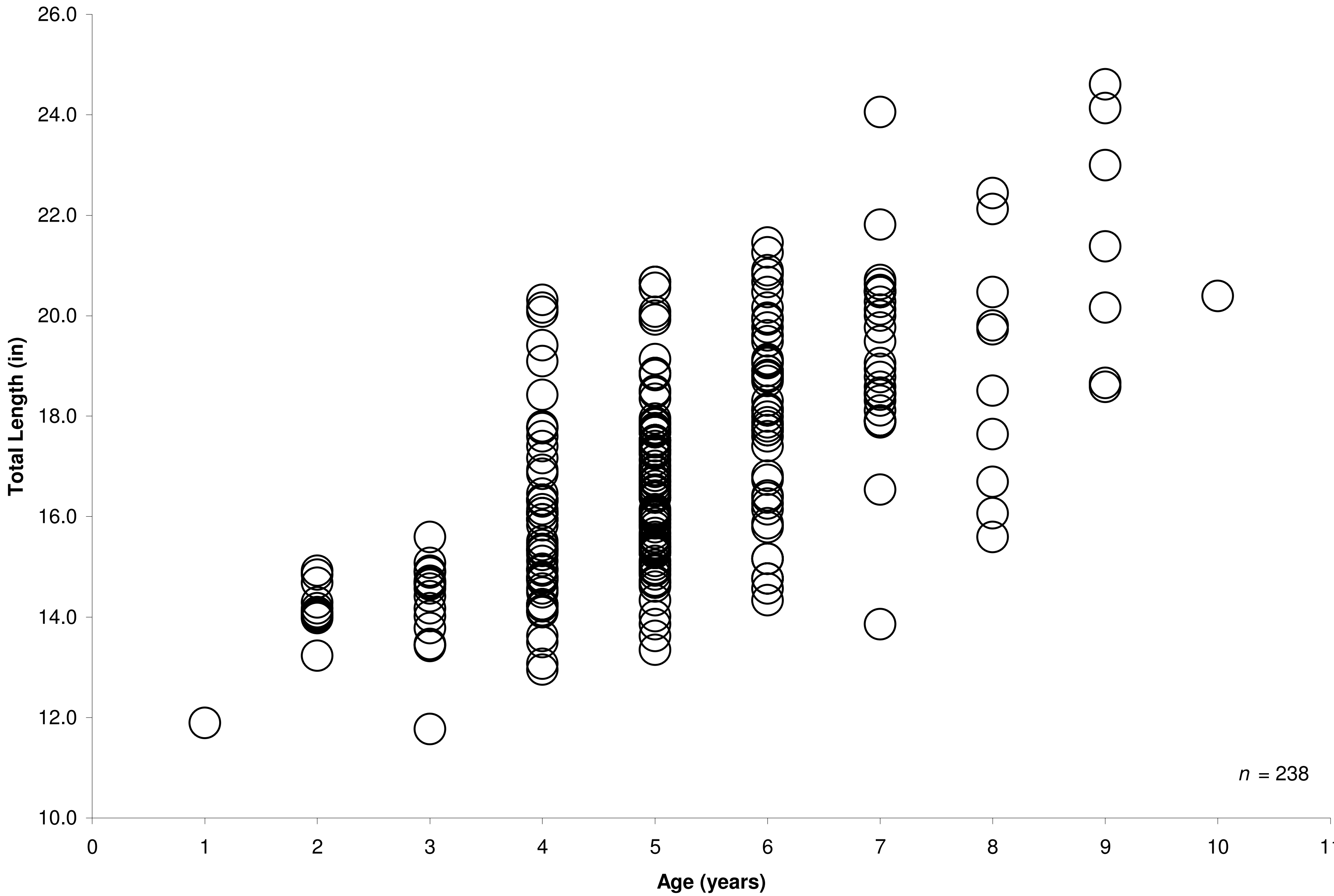


Figure 13. The relationship between mercury concentration and total length for largemouth bass collected from Sam Rayburn Reservoir, Texas, 2010–2011.

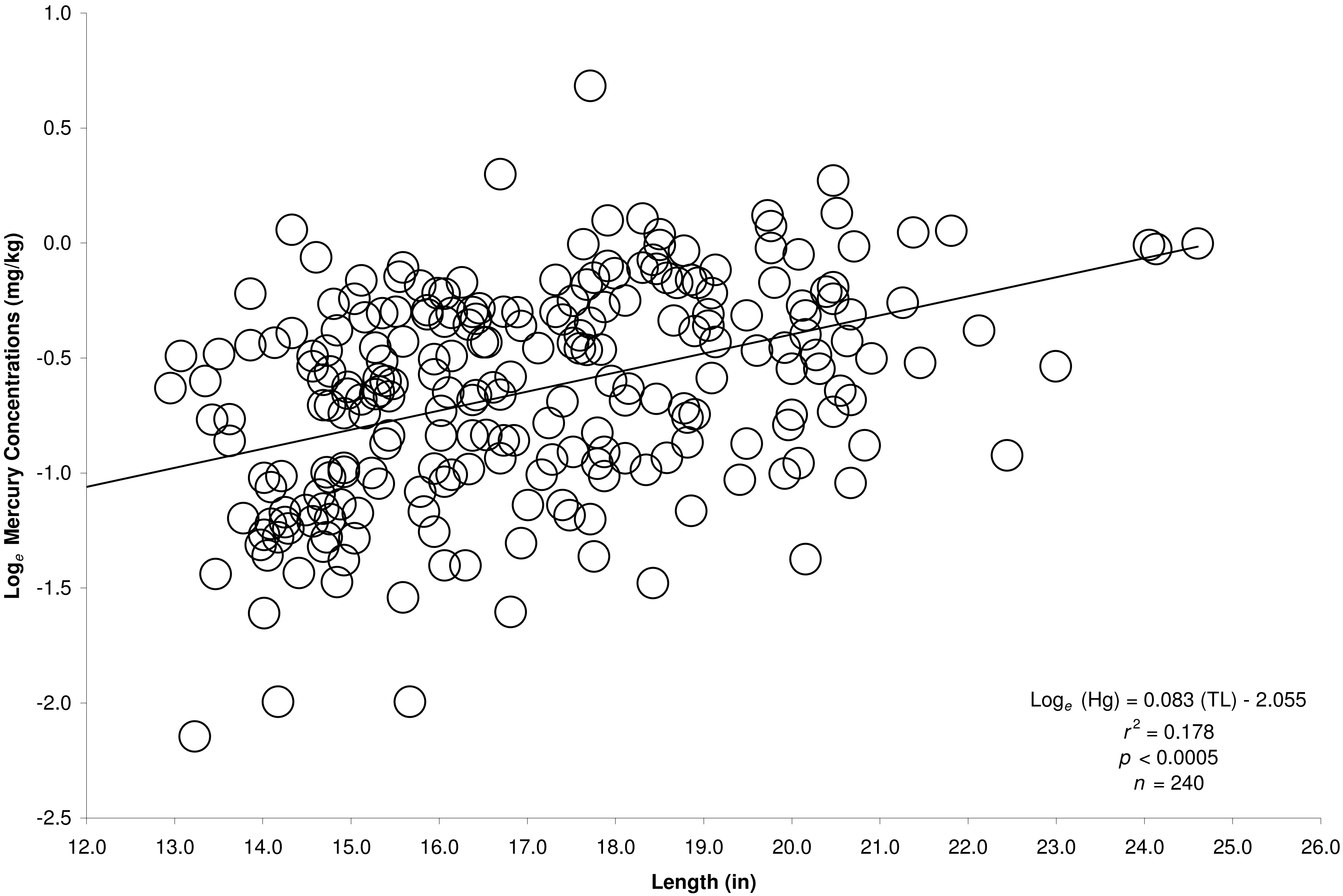


Figure 14. The relationship between mercury concentration and age for largemouth bass collected from Sam Rayburn Reservoir, Texas, 2010–2011.

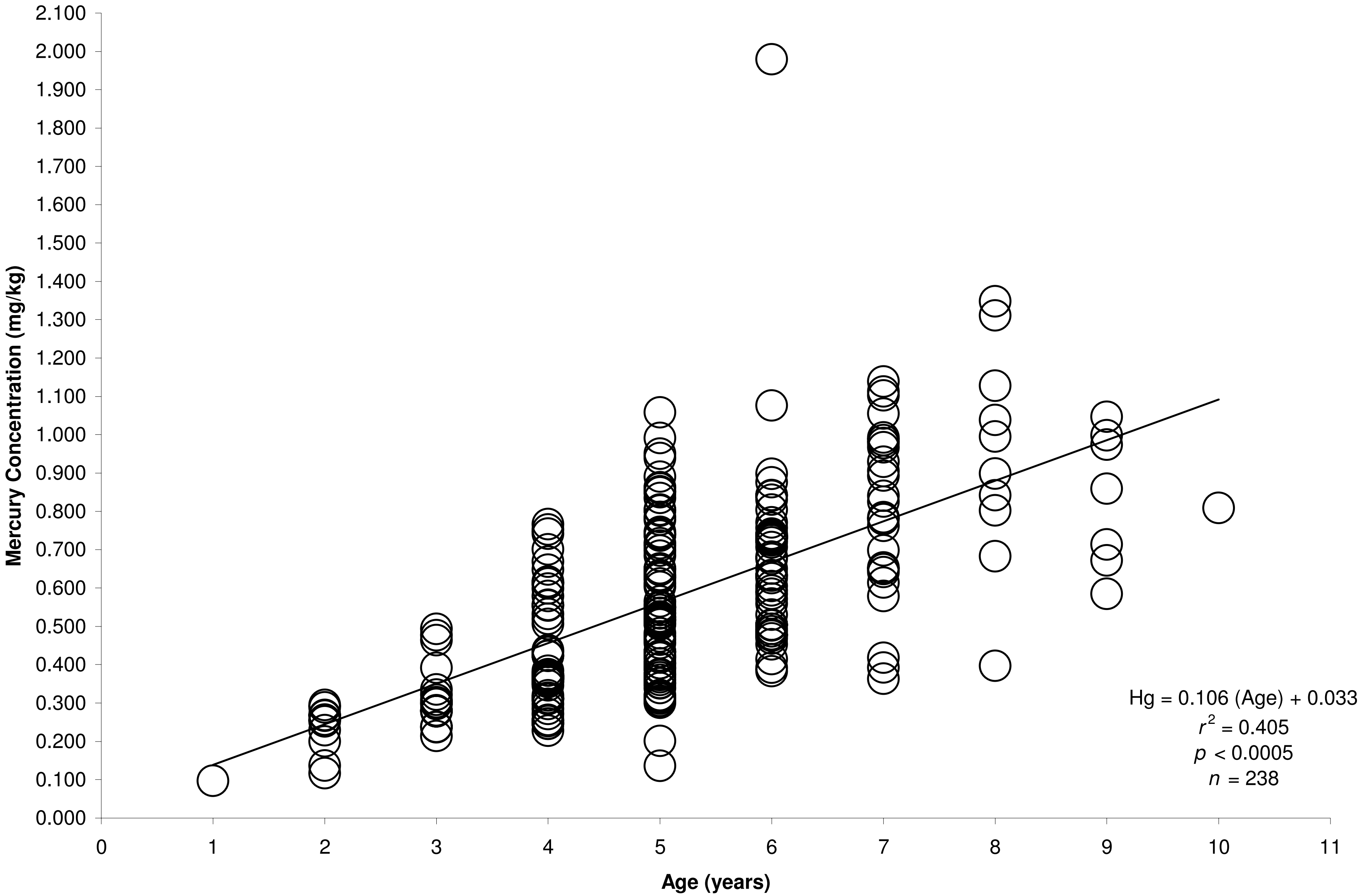


Figure 15. Means plot of mercury (mg/kg, wet wt.) in largemouth bass tissue by sample site collected from Sam Rayburn Reservoir, Texas 2010–2011. The error bars denote the 95% confidence interval of the mean.

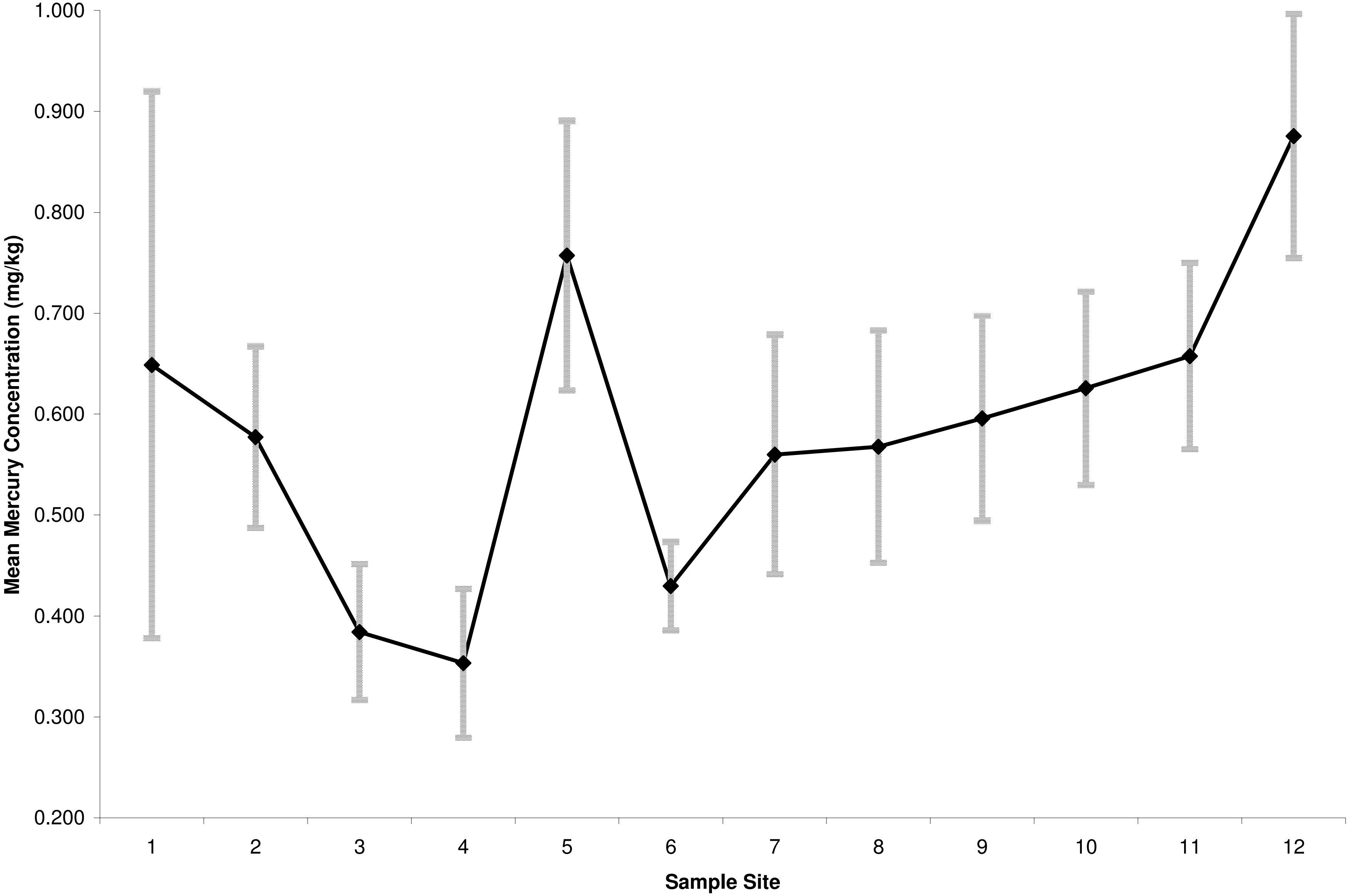


Figure 16. The relationship between mercury concentration and total length for smallmouth buffalo collected from Sam Rayburn Reservoir, Texas, 2010–2011.

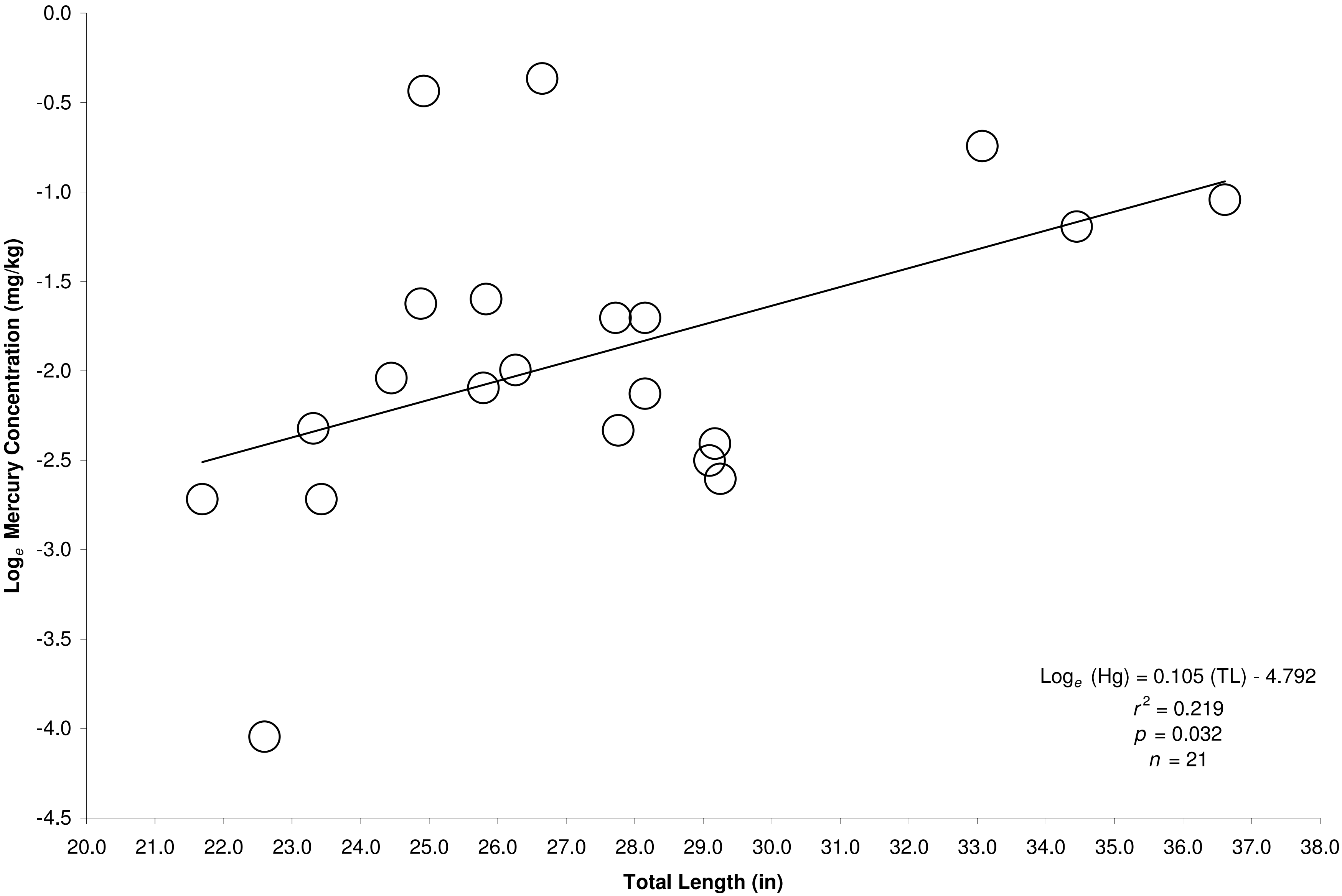


Figure 17. Length at age for spotted bass collected from Sam Rayburn Reservoir, Texas, 2010–2011.

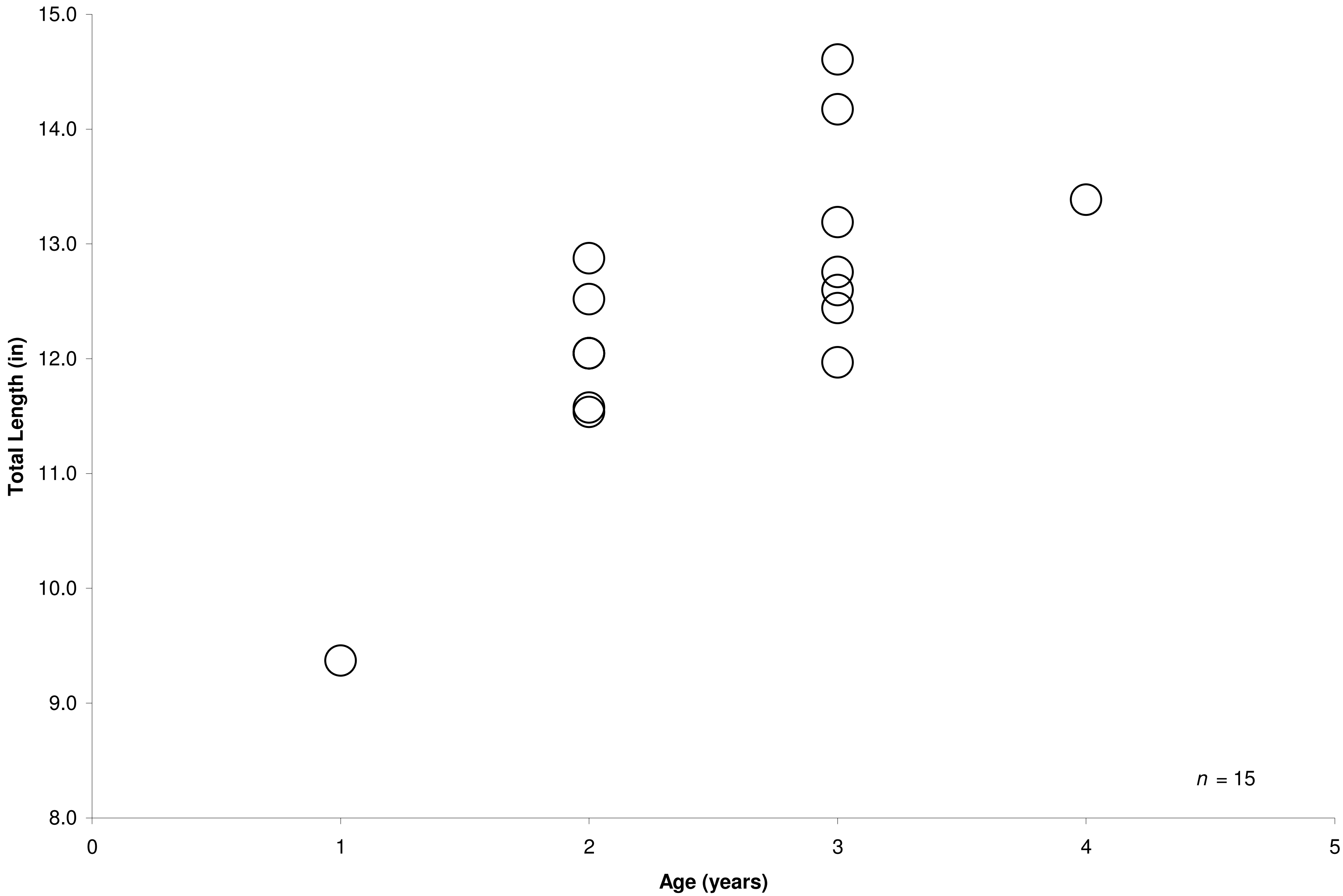


Figure 18. The relationship between mercury concentration and TL for sunfish species (bluegill, longear sunfish, redear sunfish, and warmouth) collected from Sam Rayburn Reservoir, Texas, 2010–2011.

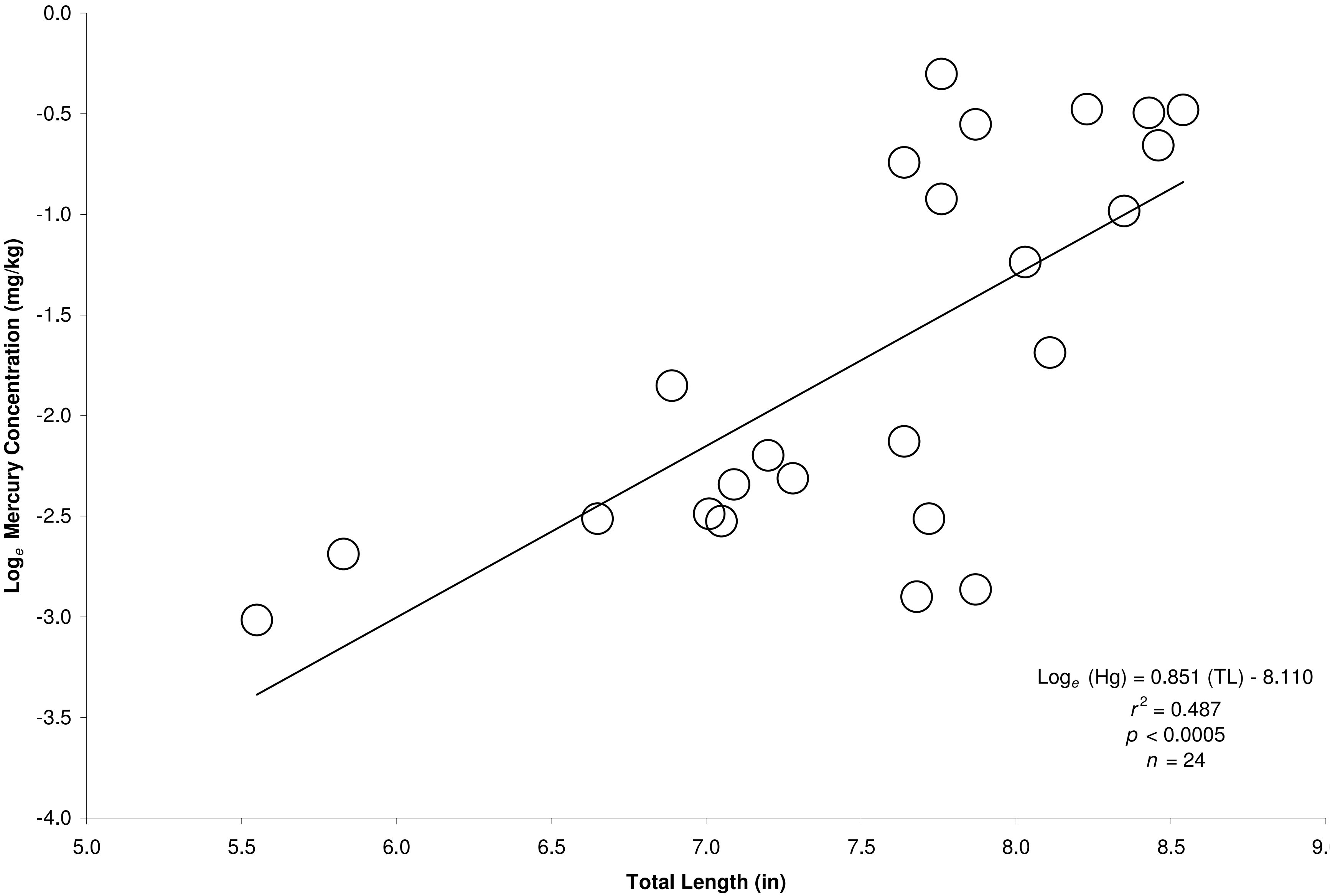


Figure 19. Means plot of mercury (mg/kg, wet wt.) in sunfish species (bluegill [BLG], longear sunfish [LES], redear sunfish [RES], warmouth [WAM]) collected from Sam Rayburn Reservoir, Texas 2010–2011. The error bars denote the 95% confidence interval of the mean.

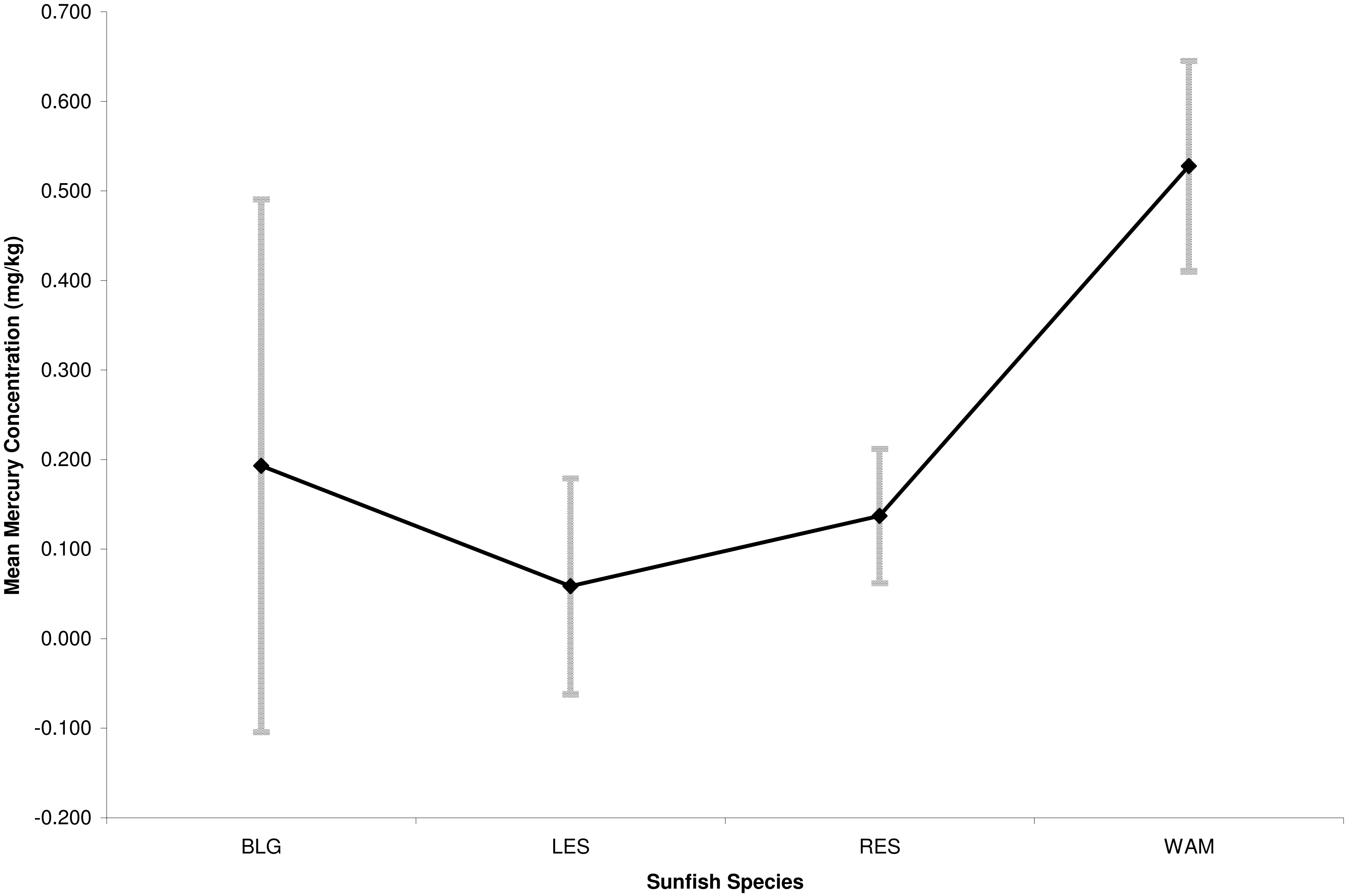


Figure 20. Length at age for white bass collected from Sam Rayburn Reservoir, Texas, 2010–2011.

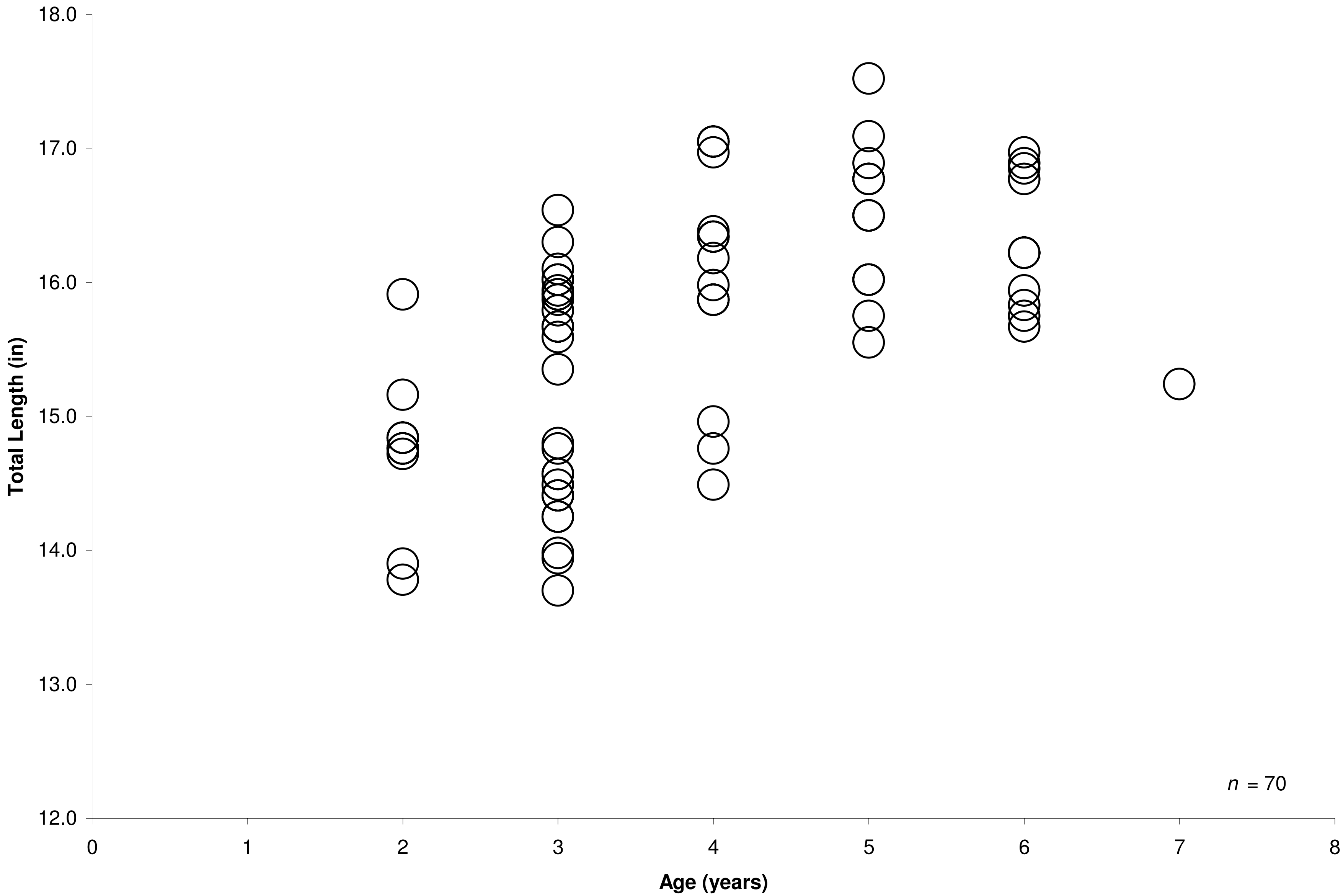


Figure 21. The relationship between mercury concentration and TL for white bass collected from Sam Rayburn Reservoir, Texas, 2010–2011.

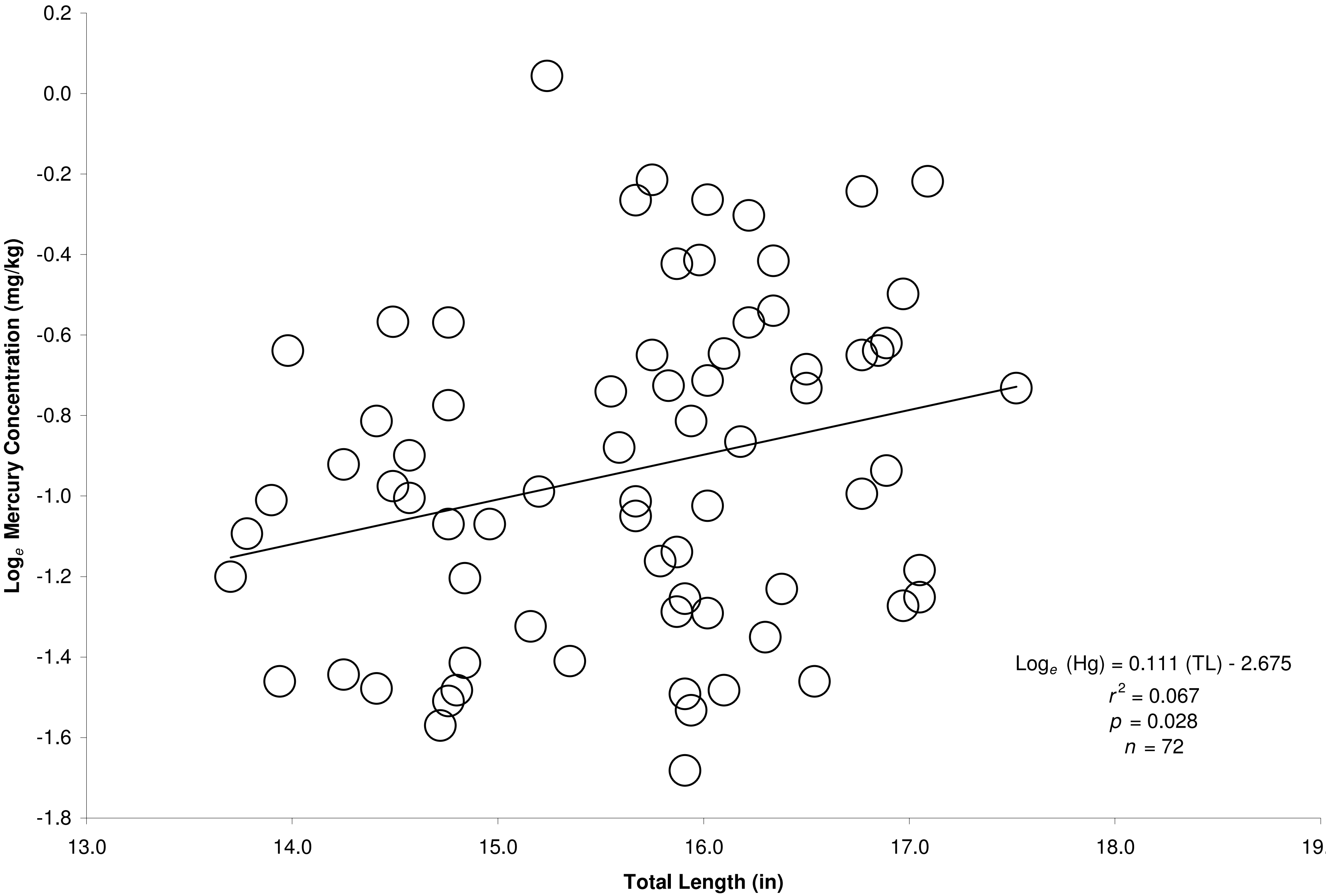
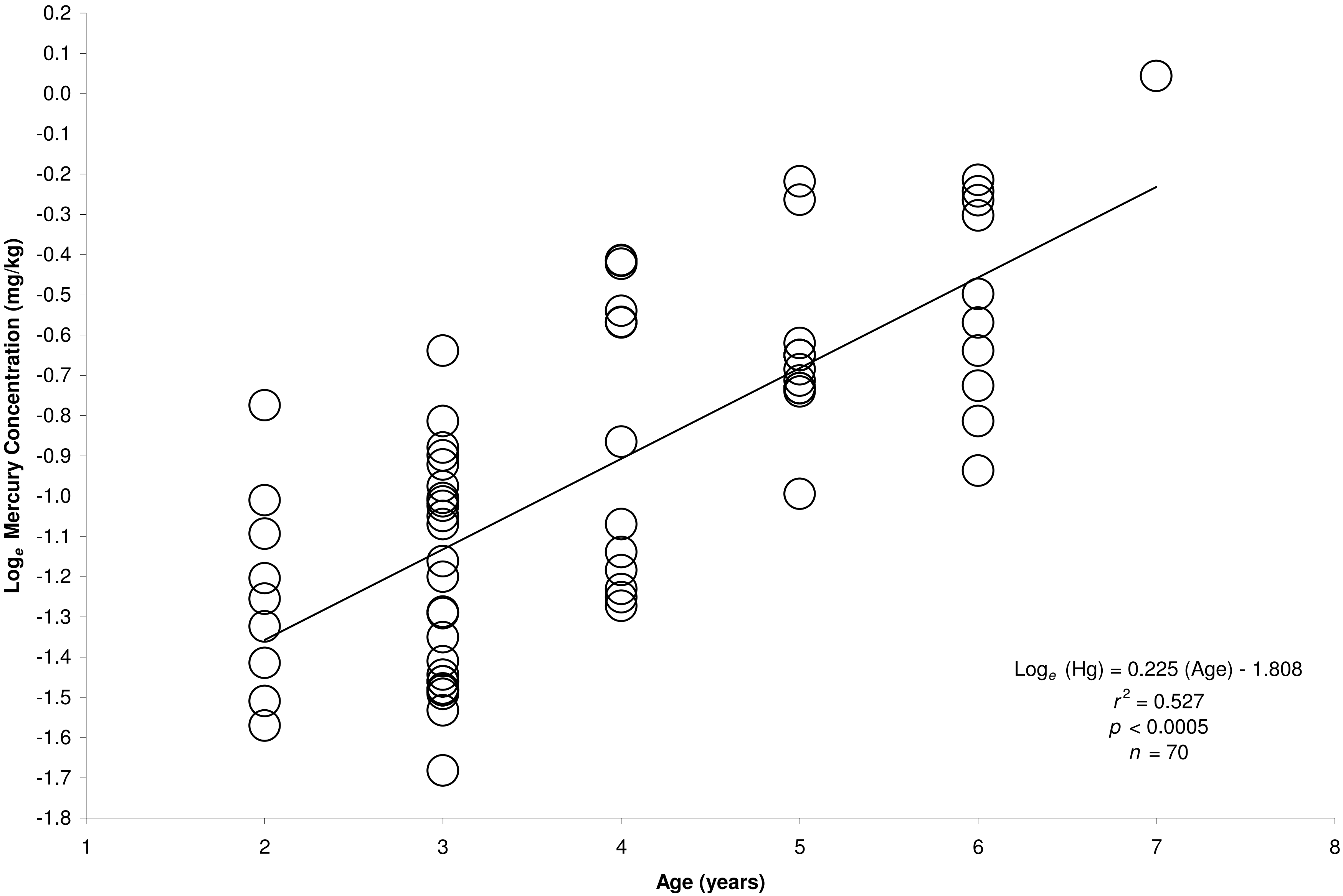


Figure 22. The relationship between mercury concentration and age for white bass collected from Sam Rayburn Reservoir, Texas, 2010–2011.



TABLES

Table 1. Fish samples collected from Sam Rayburn Reservoir 2010–2011. Sample number, species, length, and weight recorded for each sample.

Sample Number	Species	Length (mm)	Weight (g)
Site 1 Confluence of Papermill Creek and Angelina River			
SRR439	Channel catfish	437	705
SRR442	Blue catfish	590	1735
SRR443	Blue catfish	493	1147
SRR444	Flathead catfish	610	2709
SRR445	Flathead catfish	565	1969
SRR446	Flathead catfish	695	4735
SRR447	Largemouth bass	396	1034
SRR448	Largemouth bass	373	714
SRR449	Longnose gar	1288	8000
SRR450	Longnose gar	1075	4203
SRR451	Smallmouth buffalo	633	4738
SRR452	Smallmouth buffalo	677	5060
SRR453	Freshwater drum	532	2143
SRR454	Freshwater drum	491	1686
SRR455	Freshwater drum	408	1551
SRR456	Freshwater drum	500	2122
SRR457	Freshwater drum	509	2510
SRR458	Freshwater drum	369	537
SRR459	Freshwater drum	325	365
SRR460	Freshwater drum	421	1445
SRR461	Freshwater drum	390	670
SRR463	Warmouth	194	177
SRR464	Bluegill	183	134
SRR465	Blue catfish	533	1360
SRR466	Blue catfish	476	896
SRR467	Channel catfish	405	523
SRR468	Flathead catfish	579	2070
SRR469	Largemouth bass	332	599
SRR470	Largemouth bass	329	470
SRR471	White crappie	371	769
SRR472	White crappie	371	717
SRR474	White crappie	312	437
SRR475	Black crappie	293	439
SRR476	Black crappie	271	302
SRR477	Black crappie	268	307
SRR479	Black crappie	326	601

Table 1 cont. Fish samples collected from Sam Rayburn Reservoir 2010–2011. Sample number, species, length, and weight recorded for each sample.			
Sample Number	**Species**	**Length (mm)**	**Weight (g)**
Site 1 Confluence of Papermill Creek and Angelina River (cont.)			
SRR480	White bass	386	692
SRR481	White bass	376	667
SRR484	White bass	412	769
SRR485	White bass	370	648
SRR486	White bass	380	696
Site 2 Sam Rayburn Reservoir at Marion Ferry Park			
SRR359	Smallmouth buffalo	715	8802
SRR360	Blue catfish	565	1855
SRR361	Blue catfish	836	6930
SRR362	White bass	429	1036
SRR363	White bass	407	954
SRR365	White bass	348	557
SRR368	White bass	414	1240
SRR369	White bass	405	843
SRR371	White bass	366	627
SRR373	White bass	404	1026
SRR376	White bass	390	1013
SRR377	White bass	431	1288
SRR379	White bass	401	980
SRR381	White bass	403	1014
SRR382	Longnose gar	935	3466
SRR383a	Smallmouth buffalo	551	3779
SRR384a	Blue catfish	714	4237
SRR385a	Blue catfish	516	1238
SRR386a	Largemouth bass	570	4022
SRR387a	Largemouth bass	358	811
SRR388a	Largemouth bass	424	1166
SRR389a	Largemouth bass	346	601
SRR390a	Largemouth bass	409	1034
SRR391a	Largemouth bass	370	882
SRR392a	Black crappie	300	490
SRR393a	Black crappie	321	567
SRR394a	Spotted bass	316	488
SRR553	Freshwater drum	524	2002
SRR554	Freshwater drum	451	1361
SRR555	Freshwater drum	406	1202
SRR556	Freshwater drum	336	531

Table 1 cont. Fish samples collected from Sam Rayburn Reservoir 2010–2011. Sample number, species, length, and weight recorded for each sample.			
Sample Number	**Species**	**Length (mm)**	**Weight (g)**
Site 2 Sam Rayburn Reservoir at Marion Ferry Park (cont.)			
SRR557	Flathead catfish	968	15000
SRR558	Largemouth bass	518	2369
SRR559	Largemouth bass	445	1350
SRR560	Largemouth bass	375	932
SRR561	Largemouth bass	417	1366
SRR562	Largemouth bass	403	1206
SRR563	Largemouth bass	419	1262
SRR564	Largemouth bass	370	755
SRR565	Largemouth bass	405	967
SRR566	Largemouth bass	391	1031
SRR567	Largemouth bass	447	1574
SRR568	Largemouth bass	465	1503
SRR569	Largemouth bass	477	1898
SRR570	Largemouth bass	415	1194
SRR571	Largemouth bass	413	989
SRR572	Freshwater drum	473	1523
SRR573	Warmouth	204	201
SRR574	Warmouth	197	176
SRR575	Channel catfish	455	862
SRR576	Channel catfish	326	257
SRR577	Channel catfish	309	228
SRR578	Black crappie	336	667
SRR579	Black crappie	327	617
SRR580	Black crappie	326	679
Site 3 Sam Rayburn Reservoir at SH 103 Angelina River			
SRR278	Longnose gar	1003	3932
SRR279	Longnose gar	983	3560
SRR281	Longnose gar	1008	3923
SRR282	Longnose gar	993	4037
SRR284	Longnose gar	978	3593
SRR286	Longnose gar	1268	9500

Table 1 cont. Fish samples collected from Sam Rayburn Reservoir 2010–2011. Sample number, species, length, and weight recorded for each sample.			
Sample Number	**Species**	**Length (mm)**	**Weight (g)**
Site 3 Sam Rayburn Reservoir at SH 103 Angelina River (cont.)			
SRR287	Longnose gar	1378	13250
SRR288	Smallmouth buffalo	656	7850
SRR289	Smallmouth buffalo	840	13500
SRR290	Blue catfish	550	810
SRR291	Blue catfish	366	347
SRR292	White bass	407	1266
SRR293	White bass	433	1255
SRR294	White bass	431	1061
SRR296	White bass	433	1373
SRR297	White bass	428	1070
SRR298	White bass	405	1058
SRR300	White bass	426	1047
SRR305	White bass	416	1210
SRR311	White bass	354	639
SRR315	White bass	404	977
SRR318	White bass	375	937
SRR325	Largemouth bass	584	2799
SRR326	Largemouth bass	427	1349
SRR327	Largemouth bass	469	1788
SRR328	Largemouth bass	388	687
SRR329	Largemouth bass	375	802
SRR330	Freshwater drum	475	1646
SRR331	Freshwater drum	490	1790
SRR332	Freshwater drum	493	1616
SRR333	Freshwater drum	326	430
SRR334	Blue catfish	552	1716
SRR335	Blue catfish	514	1274
SRR336	Spotted bass	335	617
SRR337	Spotted bass	304	531
SRR338	Spotted bass	340	639
SRR341	Black crappie	338	715
SRR342	Black crappie	331	662
SRR343	Black crappie	319	614
SRR344	Black crappie	321	600

Table 1 cont. Fish samples collected from Sam Rayburn Reservoir 2010–2011. Sample number, species, length, and weight recorded for each sample.			
Sample Number	**Species**	**Length (mm)**	**Weight (g)**
Site 3 Sam Rayburn Reservoir at SH 103 Angelina River (cont.)			
SRR345	Black crappie	338	765
SRR348	Black crappie	309	480
SRR349	Black crappie	304	457
SRR581	Channel catfish	449	863
SRR582	Channel catfish	474	997
SRR583	Channel catfish	457	908
SRR584	Channel catfish	389	591
SRR585	Largemouth bass	436	1317
SRR586	Largemouth bass	520	2079
SRR587	Largemouth bass	442	1224
SRR588	Largemouth bass	478	1833
SRR589	Largemouth bass	392	947
SRR590	Largemouth bass	414	1233
SRR591	Largemouth bass	454	1450
SRR592	Largemouth bass	389	1069
SRR593	Largemouth bass	438	1342
SRR594	Largemouth bass	356	787
SRR595	Largemouth bass	360	648
SRR596	Largemouth bass	356	641
SRR597	Largemouth bass	342	515
SRR598	Channel catfish	343	368
SRR599	Longear sunfish	148	81
SRR601	Longear sunfish	141	66
Site 4 Sam Rayburn Reservoir at Hanks Creek			
SRR180	Blue catfish	640	2687
SRR181	Blue catfish	610	2427
SRR182	Blue catfish	612	2760
SRR183	Blue catfish	660	3038
SRR184	Blue catfish	594	1793
SRR185	Flathead catfish	802	8293
SRR186	Channel catfish	446	829
SRR187	Channel catfish	447	687
SRR188	Channel catfish	360	357
SRR189	Channel catfish	471	1010
SRR191	Freshwater drum	545	2722
SRR192	Freshwater drum	516	1967
SRR193	Freshwater drum	486	1669

Table 1 cont. Fish samples collected from Sam Rayburn Reservoir 2010–2011. Sample number, species, length, and weight recorded for each sample.			
Sample Number	**Species**	**Length (mm)**	**Weight (g)**
Site 4 Sam Rayburn Reservoir at Hanks Creek (cont.)			
SRR194	Longnose gar	1069	5044
SRR195	Longnose gar	1138	5427
SRR196	Longnose gar	1048	4132
SRR197	Longnose gar	1156	6222
SRR198	Smallmouth buffalo	705	9796
SRR199	Freshwater drum	650	4662
SRR201	White bass	374	704
SRR202	White bass	407	867
SRR203	White bass	419	768
SRR204	White bass	445	965
SRR205	White bass	426	849
SRR210	White bass	395	742
SRR211	White bass	419	956
SRR212	White bass	404	840
SRR215	Largemouth bass	451	1349
SRR216	Largemouth bass	468	1735
SRR217	Largemouth bass	430	1194
SRR218	Largemouth bass	495	2037
SRR219	Largemouth bass	512	2179
SRR220	Largemouth bass	408	1016
SRR221	Largemouth bass	390	596
SRR222	Spotted bass	371	740
SRR223	Spotted bass	327	477
SRR224	Largemouth bass	302	365
SRR225	Black crappie	376	810
SRR226	Black crappie	318	546
SRR227	Black crappie	393	419
SRR228	Black crappie	328	515
SRR233	Black crappie	333	591
SRR234	Black crappie	316	491
SRR235	Black crappie	371	900
SRR240	Hybrid striped bass	594	2086
SRR241	Hybrid striped bass	609	2402
SRR242	Smallmouth buffalo	595	4775
SRR397	Spotted bass	294	342
SRR398	Spotted bass	360	692
SRR399	Largemouth bass	508	2158

Table 1 cont. Fish samples collected from Sam Rayburn Reservoir 2010–2011. Sample number, species, length, and weight recorded for each sample.

Sample Number	Species	Length (mm)	Weight (g)
Site 4 Sam Rayburn Reservoir at Hanks Creek (cont.)			
SRR400	Largemouth bass	427	1074
SRR401	Largemouth bass	336	579
SRR402	Largemouth bass	466	1257
SRR403	Largemouth bass	384	855
SRR404	Largemouth bass	450	1509
SRR405	Largemouth bass	432	1346
SRR406	Largemouth bass	360	683
SRR407	Largemouth bass	396	1052
SRR408	Largemouth bass	484	1858
SRR409	Largemouth bass	407	1042
SRR410	Largemouth bass	356	514
SRR411	Largemouth bass	379	811
SRR412	Largemouth bass	472	1832
SRR413	Channel catfish	470	1039
SRR414	Freshwater drum	466	1309
SRR415	Redear sunfish	200	154
SRR417	Bluegill	185	136
Site 5 Sam Rayburn Reservoir at SH 103 Attoyac River			
SRR490	Smallmouth buffalo	655	8064
SRR491	Smallmouth buffalo	667	7580
SRR492	Longnose gar	1138	5562
SRR493	Longnose gar	1225	7500
SRR494	Blue catfish	640	2959
SRR495	Blue catfish	700	4406
SRR496	Blue catfish	629	2593
SRR497	Blue catfish	495	1280
SRR499	Channel catfish	428	650
SRR500	Channel catfish	434	646
SRR501	Channel catfish	362	395
SRR502	Channel catfish	353	367
SRR503	Freshwater drum	336	430
SRR504	Freshwater drum	343	471
SRR505	Freshwater drum	327	432
SRR506	Freshwater drum	321	424
SRR507	White bass	420	1220
SRR508	White bass	398	1029
SRR510	White bass	402	812

Table 1 cont. Fish samples collected from Sam Rayburn Reservoir 2010–2011. Sample number, species, length, and weight recorded for each sample.

Sample Number	Species	Length (mm)	Weight (g)
Site 5 Sam Rayburn Reservoir at SH 103 Attoyac River (cont.)			
SRR512	White bass	409	846
SRR513	White bass	409	1165
SRR514	White bass	403	1003
SRR516	White bass	398	938
SRR518	White bass	411	972
SRR522	Largemouth bass	396	904
SRR523	Largemouth bass	382	774
SRR524	Largemouth bass	448	1481
SRR525	Largemouth bass	503	2054
SRR526	Largemouth bass	405	946
SRR527	Largemouth bass	410	993
SRR528	Largemouth bass	481	1745
SRR529	Largemouth bass	390	1098
SRR530	Largemouth bass	380	750
SRR531	Largemouth bass	425	1239
SRR532	Largemouth bass	450	1259
SRR533	Largemouth bass	377	822
SRR534	Largemouth bass	339	591
SRR535	Largemouth bass	470	1650
SRR536	Largemouth bass	401	948
SRR537	Largemouth bass	395	942
SRR538	Largemouth bass	385	913
SRR539	Largemouth bass	374	818
SRR540	Largemouth bass	341	639
SRR541	Largemouth bass	364	735
SRR542	Largemouth bass	352	611
SRR543	Largemouth bass	343	547
SRR544	Largemouth bass	299	348
SRR545	Hybrid striped bass	365	967
SRR546	Black crappie	353	815
SRR547	Black crappie	353	772
SRR548	Black crappie	339	611
SRR549	Black crappie	336	642
SRR550	Black crappie	326	536
SRR551	Bluegill	209	200
SRR552	Redear sunfish	212	168

Table 1 cont. Fish samples collected from Sam Rayburn Reservoir 2010–2011. Sample number, species, length, and weight recorded for each sample.			
Sample Number	**Species**	**Length (mm)**	**Weight (g)**
Site 6 Sam Rayburn Reservoir at SH 147			
SRR55	Flathead catfish	530	1921
SRR56	Blue catfish	551	1748
SRR57	Blue catfish	682	3295
SRR58	Blue catfish	584	1798
SRR60	Blue catfish	538	1396
SRR61	Blue catfish	508	1106
SRR63	Channel catfish	446	800
SRR64	Channel catfish	406	616
SRR65	Freshwater drum	454	1502
SRR66	Freshwater drum	344	440
SRR67	Freshwater drum	531	2252
SRR68	Freshwater drum	484	1526
SRR69	Freshwater drum	351	545
SRR70	Freshwater drum	328	424
SRR71	Largemouth bass	363	669
SRR72	Spotted bass	320	402
SRR73	Longnose gar	656	487
SRR74	Smallmouth buffalo	743	9977
SRR75	Smallmouth buffalo	632	6239
SRR631	Channel catfish	486	928
SRR632	Channel catfish	395	506
SRR633	Channel catfish	346	310
SRR635	Largemouth bass	525	2651
SRR636	Largemouth bass	508	1884
SRR637	Largemouth bass	479	1949
SRR638	Largemouth bass	524	2537
SRR639	Largemouth bass	452	1500
SRR640	Largemouth bass	460	1693
SRR641	Largemouth bass	525	1910
SRR642	Largemouth bass	362	693
SRR643	Largemouth bass	480	1713
SRR644	Largemouth bass	389	868
SRR645	Largemouth bass	392	823
SRR646	Largemouth bass	389	928
SRR647	Largemouth bass	444	1342
SRR648	Largemouth bass	393	1388
SRR649	Largemouth bass	445	1224

Table 1 cont. Fish samples collected from Sam Rayburn Reservoir 2010–2011. Sample number, species, length, and weight recorded for each sample.			
Sample Number	**Species**	**Length (mm)**	**Weight (g)**
Site 6 Sam Rayburn Reservoir at SH 147 (cont.)			
SRR650	Largemouth bass	373	697
SRR651	Largemouth bass	350	565
SRR652	Largemouth bass	401	998
SRR653	Largemouth bass	425	1158
SRR654	Largemouth bass	442	1348
SRR655	Largemouth bass	416	1187
SRR656	Largemouth bass	388	877
SRR657	Largemouth bass	452	1548
SRR658	Largemouth bass	529	2151
SRR659	Redear sunfish	206	206
SRR660	Bluegill	169	110
SRR662	Black crappie	314	525
SRR663	Black crappie	297	443
SRR664	Black crappie	310	522
SRR665	Black crappie	300	400
Site 7 Sam Rayburn Reservoir at Harvey Creek			
SRR131	Blue catfish	803	6364
SRR134	Blue catfish	726	4620
SRR136	Blue catfish	517	953
SRR138	Smallmouth buffalo	574	3769
SRR139	Blue catfish	758	4507
SRR140	Blue catfish	722	5063
SRR141	Blue catfish	780	6041
SRR144	Blue catfish	725	4285
SRR151	Channel catfish	440	690
SRR152	Channel catfish	475	739
SRR153	Channel catfish	474	836
SRR157	Channel catfish	492	1066
SRR158	Black crappie	351	780
SRR159	Black crappie	274	377
SRR160	Black crappie	276	324
SRR161	Black crappie	264	287
SRR162	White bass	429	951
SRR163	White bass	407	730
SRR164	White bass	377	715

Table 1 cont. Fish samples collected from Sam Rayburn Reservoir 2010–2011 Sample number, species, length, and weight recorded for each sample.			
Sample Number	**Species**	**Length (mm)**	**Weight (g)**
Site 7 Sam Rayburn Reservoir at Harvey Creek (cont.)			
SRR165	White bass	385	914
SRR166	White bass	375	698
SRR167	White bass	377	732
SRR168	White bass	400	678
SRR169	Freshwater drum	463	1410
SRR170	Freshwater drum	328	416
SRR171	Freshwater drum	349	457
SRR172	Freshwater drum	330	390
SRR173	Largemouth bass	378	712
SRR174	Largemouth bass	366	733
SRR175	Largemouth bass	374	775
SRR176	Largemouth bass	493	1367
SRR177	Spotted bass	306	368
SRR178	Spotted bass	306	388
SRR179	Smallmouth buffalo	621	6640
SRR419	Largemouth bass	506	1994
SRR420	Largemouth bass	507	1957
SRR421	Largemouth bass	495	2163
SRR422	Largemouth bass	416	1104
SRR423	Largemouth bass	512	2136
SRR424	Largemouth bass	465	1450
SRR425	Largemouth bass	402	939
SRR426	Largemouth bass	410	1040
SRR427	Largemouth bass	385	825
SRR428	Largemouth bass	470	1790
SRR429	Largemouth bass	540	2737
SRR430	Largemouth bass	429	1117
SRR431	Largemouth bass	545	3050
SRR432	Largemouth bass	372	855
SRR433	Largemouth bass	375	852
SRR434	Largemouth bass	405	1040
SRR435	Black crappie	289	457
SRR436	Freshwater drum	500	1608
SRR437	Bluegill	195	141
SRR438	Warmouth	217	210

Table 1 cont. Fish samples collected from Sam Rayburn Reservoir 2010–2011. Sample number, species, length, and weight recorded for each sample.

Sample Number	Species	Length (mm)	Weight (g)
Site 8 Sam Rayburn Reservoir at Caney Creek			
SRR92	Freshwater drum	530	1995
SRR93	Freshwater drum	557	2265
SRR94	Smallmouth buffalo	741	13166
SRR95	Smallmouth buffalo	704	8802
SRR97	Blue catfish	741	5144
SRR98	Blue catfish	682	3437
SRR99	Blue catfish	555	1581
SRR102	Blue catfish	830	6765
SRR103	Flathead catfish	833	7333
SRR104	Longnose gar	1323	5545
SRR105	Freshwater drum	513	2037
SRR106	Freshwater drum	458	1302
SRR107	Freshwater drum	471	1193
SRR110	Black crappie	273	318
SRR111	Black crappie	264	297
SRR112	Flathead catfish	855	8350
SRR113	White bass	362	615
SRR114	White bass	375	673
SRR115	Freshwater drum	408	944
SRR116	Freshwater drum	426	1030
SRR117	White bass	387	530
SRR118	Channel catfish	442	710
SRR119	Channel catfish	461	832
SRR120	Channel catfish	444	682
SRR121	Spotted bass	318	412
SRR122	Spotted bass	238	184
SRR123	Largemouth bass	450	1407
SRR124	Largemouth bass	379	761
SRR125	Largemouth bass	410	907
SRR126	Largemouth bass	361	662
SRR127	Largemouth bass	506	1873
SRR128	Largemouth bass	485	1701
SRR129	Largemouth bass	531	2403
SRR130	Largemouth bass	368	699
SRR383	Largemouth bass	455	1436
SRR384	Largemouth bass	370	646
SRR385	Largemouth bass	374	748

Table 1 cont. Fish samples collected from Sam Rayburn Reservoir 2010–2011. Sample number, species, length, and weight recorded for each sample.			
Sample Number	**Species**	**Length (mm)**	**Weight (g)**
Site 8 Sam Rayburn Reservoir at Caney Creek (cont.)			
SRR386	Largemouth bass	469	1420
SRR387	Largemouth bass	449	1257
SRR388	Largemouth bass	478	1425
SRR389	Largemouth bass	376	787
SRR390	Largemouth bass	435	1128
SRR391	Largemouth bass	383	608
SRR392	Largemouth bass	420	1155
SRR393	Largemouth bass	364	729
SRR394	Black crappie	280	335
SRR395	Redear sunfish	179	92
SRR396	Redear sunfish	175	98
SRR418	Blue catfish	746	5104
Site 9 Sam Rayburn Reservoir at Norris Creek / Five Fingers			
SRR76	Smallmouth buffalo	739	9941
SRR77	Largemouth bass	416	1107
SRR78	Largemouth bass	355	680
SRR79	Largemouth bass	373	791
SRR80	Largemouth bass	377	771
SRR81	Freshwater drum	540	2655
SRR82	Freshwater drum	337	413
SRR83	Freshwater drum	623	3913
SRR84	Blue catfish	820	8144
SRR85	Blue catfish	644	2688
SRR86	Blue catfish	696	3248
SRR87	Blue catfish	422	595
SRR88	Channel catfish	460	765
SRR89	Channel catfish	350	305
SRR602	Longnose gar	948	2978
SRR603	Channel catfish	450	773
SRR604	Channel catfish	455	595
SRR605	Channel catfish	397	505
SRR606	Channel catfish	396	492
SRR607	Largemouth bass	520	2916
SRR608	Largemouth bass	440	1187
SRR609	Largemouth bass	543	2389
SRR610	Largemouth bass	526	2117
SRR611	Largemouth bass	449	1288

Table 1 cont. Fish samples collected from Sam Rayburn Reservoir 2010–2011. Sample number, species, length, and weight recorded for each sample.			
Sample Number	**Species**	**Length (mm)**	**Weight (g)**
Site 9 Sam Rayburn Reservoir at Norris Creek / Five Fingers (cont.)			
SRR612	Largemouth bass	525	2006
SRR613	Largemouth bass	484	1360
SRR614	Largemouth bass	387	784
SRR615	Largemouth bass	362	677
SRR616	Largemouth bass	408	820
SRR617	Largemouth bass	408	926
SRR618	Largemouth bass	460	1359
SRR619	Largemouth bass	456	1403
SRR620	Largemouth bass	422	1061
SRR621	Largemouth bass	407	918
SRR622	Largemouth bass	394	800
SRR623	Largemouth bass	375	707
SRR624	Largemouth bass	380	698
SRR625	Warmouth	215	229
SRR626	Warmouth	200	163
SRR627	Black crappie	342	671
SRR628	Black crappie	283	404
SRR629	Black crappie	309	514
SRR630	Black crappie	306	507
Site 10 Sam Rayburn Reservoir at Dam			
SRR1	Smallmouth buffalo	592	6592
SRR4	Black crappie	328	534
SRR6	Black crappie	321	534
SRR7	Black crappie	315	479
SRR11	Black crappie	332	566
SRR12	White bass	350	501
SRR13	White bass	426	710
SRR14	Largemouth bass	461	1454
SRR15	Largemouth bass	346	509
SRR16	Largemouth bass	382	737
SRR17	Largemouth bass	428	1201
SRR18	Largemouth bass	522	2286
SRR19	Largemouth bass	477	1620
SRR20	Largemouth bass	408	1114
SRR21	Largemouth bass	510	2227
SRR22	Largemouth bass	357	608
SRR23	Largemouth bass	391	931

Table 1 cont. Fish samples collected from Sam Rayburn Reservoir 2010–2011. Sample number, species, length, and weight recorded for each sample.			
Sample Number	**Species**	**Length (mm)**	**Weight (g)**
Site 10 Sam Rayburn Reservoir at Dam (cont.)			
SRR24	Hybrid striped bass	582	1931
SRR25	Freshwater drum	463	1355
SRR26	Freshwater drum	471	1407
SRR27	Freshwater drum	475	1397
SRR28	Freshwater drum	486	1614
SRR29	Freshwater drum	486	1453
SRR33	Freshwater drum	440	1099
SRR35	Freshwater drum	500	1490
SRR37	Black crappie	315	498
SRR39	Hybrid striped bass	575	2034
SRR40	Hybrid striped bass	587	1945
SRR41	White bass	353	545
SRR42	Smallmouth buffalo	715	8753
SRR43	Blue catfish	865	7950
SRR44	Blue catfish	764	5848
SRR45	Blue catfish	438	691
SRR46	Blue catfish	420	543
SRR47	Channel catfish	397	496
SRR48	Channel catfish	475	941
SRR49	Channel catfish	440	651
SRR51	Spotted bass	293	329
SRR52	Spotted bass	324	387
SRR53	Freshwater drum	463	1350
SRR54	Freshwater drum	460	1313
SRR689	Redear sunfish	196	120
SRR690	Redear sunfish	180	121
SRR691	Channel catfish	440	801
SRR692	Flathead catfish	457	1002
SRR693	Largemouth bass	625	3771
SRR694	Largemouth bass	515	1860
SRR695	Largemouth bass	451	1456
SRR696	Largemouth bass	486	1371
SRR697	Largemouth bass	417	973
SRR698	Largemouth bass	454	1443
SRR699	Largemouth bass	457	1329
SRR700	Largemouth bass	460	1438
SRR701	Largemouth bass	454	1284

Table 1 cont. Fish samples collected from Sam Rayburn Reservoir 2010–2011. Sample number, species, length, and weight recorded for each sample.			
Sample Number	**Species**	**Length (mm)**	**Weight (g)**
Site 10 Sam Rayburn Reservoir at Dam (cont.)			
SRR702	Largemouth bass	455	1221
SRR703	Largemouth bass	424	1056
SRR704	Largemouth bass	439	1076
SRR705	Longnose gar	983	3281
SRR706	Largemouth bass	501	1687
SRR707	Largemouth bass	562	2418
SRR708	Largemouth bass	512	2122
SRR709	Largemouth bass	472	1388
SRR710	Largemouth bass	474	1612
SRR711	Largemouth bass	611	3337
SRR712	Flathead catfish	788	6877
SRR713	Flathead catfish	921	10315
SRR714	Longnose gar	1108	2798
SRR715	Flathead catfish	501	2640
SRR716	Flathead catfish	612	3147
SRR717	Flathead catfish	581	2265
SRR718	Flathead catfish	572	2439
SRR719	Flathead catfish	723	4519
SRR720	Flathead catfish	612	2583
SRR721	Flathead catfish	595	2642
SRR722	Flathead catfish	613	2793
SRR723	Flathead catfish	817	5059
Site 11 Sam Rayburn Reservoir at Bear Creek			
SRR243	Freshwater drum	481	1578
SRR244	Largemouth bass	379	827
SRR245	Largemouth bass	453	1458
SRR246	Largemouth bass	373	673
SRR247	Largemouth bass	379	808
SRR248	Largemouth bass	415	1017
SRR249	Largemouth bass	516	1886
SRR250	Blue catfish	953	9040
SRR251	Channel catfish	465	858
SRR252	Longnose gar	1396	10062
SRR253	Freshwater drum	473	1337
SRR254	Freshwater drum	421	935
SRR255	Longnose gar	1048	4212
SRR256	Smallmouth buffalo	930	21000

Table 1 cont. Fish samples collected from Sam Rayburn Reservoir 2010–2011. Sample number, species, length, and weight recorded for each sample.			
Sample Number	**Species**	**Length (mm)**	**Weight (g)**
Site 11 Sam Rayburn Reservoir at Bear Creek (cont.)			
SRR257	Smallmouth buffalo	875	20071
SRR258	Flathead catfish	606	2744
SRR259	Freshwater drum	439	1233
SRR260	Blue catfish	804	6374
SRR261	Blue catfish	636	2548
SRR262	Channel catfish	421	561
SRR263	Largemouth bass	418	992
SRR264	Largemouth bass	358	630
SRR265	Largemouth bass	405	817
SRR267	Largemouth bass	447	1207
SRR268	Largemouth bass	420	1107
SRR269	Largemouth bass	371	756
SRR270	Freshwater drum	480	1477
SRR271	Freshwater drum	494	1927
SRR272	Black crappie	314	495
SRR273	Black crappie	301	435
SRR274	Black crappie	310	472
SRR275	Black crappie	290	366
SRR276	Black crappie	325	576
SRR277	White crappie	347	582
SRR667	White bass	403	1015
SRR668	White bass	406	889
SRR669	White bass	398	671
SRR670	White bass	370	821
SRR671	White bass	400	828
SRR672	White bass	415	1112
SRR673	Channel catfish	545	1532
SRR674	Channel catfish	491	1086
SRR675	Channel catfish	457	931
SRR678	Freshwater drum	495	1819
SRR679	Largemouth bass	613	4563
SRR680	Largemouth bass	511	2195
SRR681	Largemouth bass	520	2252
SRR682	Largemouth bass	480	1519
SRR683	Largemouth bass	498	1569
SRR684	Largemouth bass	475	1422
SRR685	Largemouth bass	440	1057

Table 1 cont. Fish samples collected from Sam Rayburn Reservoir 2010–2011. Sample number, species, length, and weight recorded for each sample.			
Sample Number	**Species**	**Length (mm)**	**Weight (g)**
Site 11 Sam Rayburn Reservoir at Bear Creek (cont.)			
SRR686	Redear sunfish	178	119
SRR687	Redear sunfish	194	122
Site 12 Sam Rayburn Reservoir at FM 83 Ayish Bayou			
SRR724	Freshwater drum	389	691
SRR725	Freshwater drum	436	1291
SRR726	Freshwater drum	414	886
SRR727	Freshwater drum	494	1895
SRR728	Freshwater drum	385	507
SRR729	White bass	434	912
SRR730	White bass	355	644
SRR731	White bass	366	745
SRR732	White bass	415	900
SRR733	White bass	412	992
SRR734	White bass	396	1010
SRR735	White bass	362	703
SRR736	White bass	368	663
SRR737	White bass	375	695
SRR738	Blue catfish	520	1330
SRR739	Channel catfish	460	1052
SRR740	Channel catfish	495	1164
SRR741	Channel catfish	392	505
SRR743	Flathead catfish	567	2683
SRR744	Longnose gar	1004	3859
SRR745	Largemouth bass	445	1271
SRR746	Largemouth bass	424	1054
SRR747	Largemouth bass	468	1560
SRR748	Largemouth bass	486	1793
SRR749	Largemouth bass	502	1860
SRR750	Largemouth bass	502	1953
SRR751	Largemouth bass	520	2312
SRR752	Largemouth bass	485	1688
SRR753	Largemouth bass	398	933
SRR754	Largemouth bass	479	1623
SRR755	Largemouth bass	554	3034
SRR756	Largemouth bass	442	1271
SRR757	Largemouth bass	430	1036
SRR758	Largemouth bass	384	936

Table 1 cont. Fish samples collected from Sam Rayburn Reservoir 2010–2011. Sample number, species, length, and weight recorded for each sample.			
Sample Number	**Species**	**Length (mm)**	**Weight (g)**
Site 12 Sam Rayburn Reservoir at FM 83 Ayish Bayou (cont.)			
SRR759	Largemouth bass	510	1978
SRR760	Largemouth bass	521	2081
SRR761	Largemouth bass	406	991
SRR762	Largemouth bass	403	893
SRR763	Largemouth bass	359	603
SRR764	Largemouth bass	352	646
SRR765	White bass	368	751
SRR766	Channel catfish	455	851
SRR769	Warmouth sunfish	214	234
SRR770	Warmouth sunfish	197	160
SRR771	Freshwater drum	409	833
SRR772	Black crappie	311	458
SRR773	Black crappie	332	561
SRR774	Black crappie	320	514
SRR775	Black crappie	299	381
SRR776	Black crappie	275	305
SRR777	Black crappie	270	307
SRR778	Black crappie	283	359

Table 2a. Arsenic (mg/kg) in fish collected from Sam Rayburn Reservoir, 2010–2011.					
Species	**# Detected/ # Sampled**	**Total Arsenic Mean Concentration ± S.D. (Min-Max)**	**Inorganic Arsenic Mean Concentration***	**Health Assessment Comparison Value (mg/kg)†**	**Basis for Comparison Value**
Blue catfish	5/12	BDL‡	BDL	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
Largemouth bass	9/12	0.033±0.015 (ND§-0.062)	0.003		
All fish combined	14/24	0.027±0.012 (ND-0.062)	0.003		

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

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

‡ BDL: "Below Detection Limit" is used to indicate estimated concentrations.

§ *ND: "Not Detected" is used to indicate that a compound was not present in a sample at a level greater than the RL.*

Table 2b. Inorganic contaminants (mg/kg) in fish collected from Sam Rayburn Reservoir, 2010–2011.

Species	# Detected/ # Sampled	Mean Concentration ± S.D. (Min-Max)	Health Assessment Comparison Value (mg/kg)	Basis for Comparison Value
Cadmium				
Blue catfish	12/12	BDL	0.47	ATSDR chronic oral MRL: 0.0002 mg/kg–day
Largemouth bass	12/12	BDL		
All fish combined	24/24	BDL		
Copper				
Blue catfish	12/12	0.189±0.062 (0.090-0.310)	334	National Academy of Science Upper Limit: 0.143 mg/kg–day
Largemouth bass	12/12	0.128±0.047 (0.064-0.219)		
All fish combined	24/24	0.158±0.062 (0.064-0.319)		
Lead				
Blue catfish	12/12	0.179±0.107 (0.053-0.469)	N/A	EPA IEUBKwin32 Version 1.1 Build 9
Largemouth bass	12/12	0.226±0.116 (0.065-0.414)		
All fish combined	24/24	0.203±0.112 (0.053-0.469)		
Selenium				
Blue catfish	12/12	0.217±0.055 (0.106-0.316)	6	EPA chronic oral RfD: 0 .005 mg/kg–day ATSDR chronic oral MRL: 0.005 mg/kg–day NAS UL: 0.400 mg/day (0.005 mg/kg–day) RfD or MRL/2: (0.005 mg/kg –day/2= 0.0025 mg/kg–day) to account for other sources of selenium in the diet
Largemouth bass	12/12	0.340±0.050 (0.282-0.447)		
All fish combined	24/24	0.278±0.081 (0.106-0.447)		
Zinc				
Blue catfish	12/12	4.725±1.336 (2.927-6.670)	700	EPA chronic oral RfD: 0.3 mg/kg–day
Largemouth bass	12/12	3.531±0.703 (2.713-4.568)		
All fish combined	24/24	4.128±1.209 (2.713-6.670)		

Table 2c. Mercury (mg/kg) in fish collected from Sam Rayburn Reservoir by sample site, 2010–2011.				
Species	**# Detected/ # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
Site 1 Confluence of Paper Mill Creek and Angelina River				
Black crappie	4/4	0.286±0.323 (0.098-**0.768***)	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg–day
Blue catfish	4/4	0.271±0.062 (0.211-0.335)		
Bluegill	1/1	0.111		
Channel catfish	2/2	0.169±0.013 (0.159-0.178)		
Flathead catfish	4/4	**0.876**±0.146 (**0.730-1.010**)		
Freshwater drum	9/9	**0.650**±0.194 (0.221-**0.875**)		
Largemouth bass	4/4	0.649±0.170 (0.532-**0.899**)		
Longnose gar	2/2	0.475±0.006 (0.471-0.479)		
Smallmouth buffalo	2/2	**0.670**±0.033 (0.646-**0.693**)		
Warmouth	1/1	0.476		
White bass	5/5	0.383±0.123 (0.227-0.566)		
White crappie	3/3	**1.006**±0.115 (**0.888-1.118**)		
All fish combined	41/41	0.544±0.287 (0.098-**1.118**)		
Site 2 Sam Rayburn Reservoir at Marion Ferry Park				
Black crappie	5/5	0.231±0.073 (0.146-0.314)	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg–day
Blue catfish	4/4	0.438±0.405 (0.117-**1.028**)		
Channel catfish	3/3	0.165±0.024 (0.139-0.185)		
Flathead catfish	1/1	**0.802**		
Freshwater drum	5/5	**0.685**±0.246 (0.369-**0.941**)		
Largemouth bass	20/20	0.577±0.192 (0.298-**0.967**)		
Longnose gar	1/1	0.242		
Smallmouth buffalo	2/2	0.124±0.082 (0.066-0.182)		
Spotted bass	1/1	0.348		

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

Table 2d. Mercury (mg/kg) in fish collected from Sam Rayburn Reservoir by sample site, 2010–2011.				
Species	**# Detected/ # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
Site 2 Sam Rayburn Reservoir at Marion Ferry Park (cont.)				
Warmouth	2/2	0.344±0.076 (0.290-0.397)	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg–day
White bass	11/11	0.298±0.075 (0.186-0.443)		
All fish combined	55/55	0.436±0.246 (0.066-**1.028**[*])		
Site 3 Sam Rayburn Reservoir at SH 103 Angelina River				
Black crappie	7/7	0.177±0.023 (0.137-0.202)	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg–day
Blue catfish	4/4	0.086±0.034 (0.040-0.119)		
Channel catfish	5/5	0.073±0.028 (0.028-0.097)		
Freshwater drum	4/4	0.556±0.256 (0.278-**0.886**)		
Largemouth bass	18/18	0.384±0.135 (0.200-0.634)		
Longear sunfish	2/2	0.059±0.013 (0.049-0.068)		
Longnose gar	7/7	0.499±0.113 (0.300-0.667)		
Smallmouth buffalo	2/2	0.339±0.193 (0.202-0.475)		
Spotted bass	3/3	0.230±0.032 (0.200-0.264)		
White bass	11/11	0.335±0.126 (0.216-0.608)		
All fish combined	63/63	0.313±0.186 (0.028-**0.886**)		
Site 4 Sam Rayburn Reservoir at Hanks Creek				
Black crappie	7/7	0.160±0.074 (0.077-0.272)	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg–day
Blue catfish	5/5	0.192±0.091 (0.096-0.342)		
Bluegill	1/1	0.099		
Channel catfish	5/5	0.078±0.032 (0.040-0.114)		
Flathead catfish	1/1	0.247		
Freshwater drum	5/5	0.507±0.334 (0.181-**0.945**)		
Hybrid striped bass	2/2	**0.681**±0.049 (0.646-**0.716**)		

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

Table 2e. Mercury (mg/kg) in fish collected from Sam Rayburn Reservoir by sample site, 2010–2011.				
Species	**# Detected/ # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
Site 4 Sam Rayburn Reservoir at Hanks Creek (cont.)				
Largemouth bass	22/22	0.353±0.166 (0.097-**0.734**[*])	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg–day
Longnose gar	4/4	0.501±0.071 (0.441-0.595)		
Redear sunfish	1/1	0.057		
Smallmouth buffalo	2/2	0.082±0.022 (0.066-0.097)		
Spotted bass	4/4	0.208±0.054 (0.159-0.285)		
White bass	5/5	0.431±0.117 (0.208-0.522)		
All fish combined	67/67	0.313±0.204 (0.040-**0.945**)		
Site 5 Sam Rayburn Reservoir at SH 103 Attoyac River				
Black crappie	5/5	0.195±0.046 (0.126-0.242)	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg–day
Blue catfish	4/4	0.155±0.044 (0.110-0.198)		
Bluegill	1/1	0.620		
Channel catfish	4/4	0.148±0.040 (0.108-0.203)		
Freshwater drum	4/4	0.248±0.187 (0.085-0.509)		
Hybrid striped bass	1/1	0.386		
Largemouth bass	23/23	**0.757**±0.309 (0.392-**1.979**)		
Longnose gar	2/2	0.301±0.083 (0.242-0.360)		
Redear sunfish	1/1	0.374		
Smallmouth buffalo	2/2	0.130±0.009 (0.123-0.136)		
White bass	8/8	0.365±0.108 (0.227-0.524)		
All fish combined	55/55	0.468±0.334 (0.085-**1.979**)		
Site 6 Sam Rayburn Reservoir at SH 147				
Black crappie	4/4	0.215±0.043 (0.163-0.255)	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg–day
Blue catfish	5/5	0.083±0.033 (0.031-0.114)		

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

Table 2f. Mercury (mg/kg) in fish collected from Sam Rayburn Reservoir by sample site, 2010–2011.				
Species	**# Detected/ # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
Site 6 Sam Rayburn Reservoir at SH 147 (cont.)				
Bluegill	1/1	0.081	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg–day
Channel catfish	5/5	0.093±0.035 (0.060-0.145)		
Flathead catfish	1/1	0.180		
Freshwater drum	6/6	0.253±0.167 (0.096-0.523)		
Largemouth bass	25/25	0.429±0.106 (0.289-**0.653***)		
Longnose gar	1/1	0.175		
Redear sunfish	1/1	0.185		
Smallmouth buffalo	2/2	0.136±0.087 (0.074-0.197)		
Spotted bass	1/1	0.369		
All fish combined	52/52	0.293±0.171 (0.031-**0.653**)		
Site 7 Sam Rayburn Reservoir at Harvey Creek				
Black crappie	5/5	0.160±0.066 (0.106-0.258)	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg–day
Blue catfish	7/7	0.295±0.190 (0.078-0.613)		
Bluegill	1/1	0.055		
Channel catfish	4/4	0.153±0.050 (0.103-0.209)		
Freshwater drum	5/5	0.238±0.250 (0.088-**0.679**)		
Largemouth bass	20/20	0.560±0.254 (0.238-**1.112**)		
Smallmouth buffalo	2/2	0.078±0.074 (BDL-0.130)		
Spotted bass	2/2	0.288±0.057 (0.247-0.328)		
Warmouth	1/1	0.618		
White bass	7/7	0.408±0.206 (0.221-**0.768**)		
All fish combined	54/54	0.373±0.260 (0.026-**1.112**)		

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

Table 2g. Mercury (mg/kg) in fish collected from Sam Rayburn Reservoir by sample site, 2010–2011.				
Species	**# Detected/ # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
Site 8 Sam Rayburn Reservoir at Caney Creek				
Black crappie	3/3	0.147±0.067 (0.084-0.217)		
Blue catfish	5/5	0.319±0.129 (0.180-0.460)		
Channel catfish	3/3	0.092±0.034 (0.059-0.127)		
Flathead catfish	2/2	**0.725**[*]±0.209 (0.577-**0.872**)		
Freshwater drum	7/7	0.304±0.130 (0.190-0.504)		
Largemouth bass	19/19	0.568±0.238 (0.252-**1.059**)		
Longnose gar	1/1	0.567	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg–day
Redear sunfish	2/2	0.119±0.054 (0.080-0.157)		
Smallmouth buffalo	2/2	0.136±0.065 (0.090-0.182)		
Spotted bass	2/2	0.353±0.086 (0.292-0.414)		
White bass	3/3	0.581±0.418 (0.236-**1.045**)		
All fish combined	49/49	0.412±0.264 (0.059-**1.059**)		
Site 9 Sam Rayburn Reservoir at Norris Creek / Five Fingers				
Black crappie	4/4	0.382±0.121 (0.234-0.485)		
Blue catfish	4/4	0.224±0.150 (0.059-0.421)		
Channel catfish	6/6	0.238±0.164 (0.050-0.449)		
Freshwater drum	3/3	0.352±0.139 (0.245-0.510)		
Largemouth bass	22/22	0.596±0.229 (0.229-**1.047**)	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg–day
Longnose gar	1/1	0.349		
Smallmouth buffalo	1/1	0.082		
Warmouth	2/2	0.547±0.040 (0.518-0.575)		
All fish combined	43/43	0.454±0.246 (0.050-**1.047**)		

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

Table 2h. Mercury (mg/kg) in fish collected from Sam Rayburn Reservoir by sample site, 2010–2011.				
Species	**# Detected/ # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
Site 10 Sam Rayburn Reservoir at Dam				
Black crappie	5/5	0.214±0.075 (0.094-0.294)		
Blue catfish	4/4	0.344±0.356 (0.085-**0.842**[*])		
Channel catfish	4/4	0.095±0.043 (0.052-0.152)		
Flathead catfish	12/12	0.423±0.156 (0.126-**0.668**)		
Freshwater drum	9/9	0.259±0.071 (0.158-0.372)		
Hybrid striped bass	3/3	**0.757**±0.044 (**0.711-0.799**)		
Largemouth bass	28/28	0.626±0.247 (0.257-**1.128**)	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg–day
Longnose gar	2/2	0.573±0.247 (0.398-**0.747**)		
Redear sunfish	2/2	0.089±0.011 (0.081-0.096)		
Smallmouth buffalo	2/2	0.109±0.015 (0.098-0.119)		
Spotted bass	2/2	0.317±0.129 (0.226-0.408)		
White bass	3/3	0.494±0.251 (0.335-**0.784**)		
All fish combined	76/76	0.443±0.270 (0.052-**1.128**)		
Site 11 Sam Rayburn Reservoir at Bear Creek				
Black crappie	5/5	0.278±0.079 (0.219-0.414)		
Blue catfish	3/3	**0.734**±0.545 (0.264-**1.332**)		
Channel catfish	5/5	0.179±0.116 (0.101-0.384)		
Flathead catfish	1/1	0.196		
Freshwater drum	7/7	0.268±0.108 (0.169-0.450)	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg–day
Largemouth bass	19/19	**0.657**±0.192 (0.295-**0.974**)		
Longnose gar	2/2	0.510±0.236 (0.343-**0.677**)		
Redear sunfish	2/2	0.101±0.025 (0.083-0.119)		
Smallmouth buffalo	2/2	0.328±0.035 (0.303-0.352)		

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

Table 2i. Mercury (mg/kg) in fish collected from Sam Rayburn Reservoir by sample site, 2010–2011.				
Species	**# Detected/ # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
Site 11 Sam Rayburn Reservoir at Bear Creek (cont.)				
White bass	6/6	0.640±0.157 (0.366-**0.807**[*])	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg–day
White crappie	1/1	0.288		
All fish combined	53/53	0.473±0.276 (0.083-**1.332**)		
Site 12 Sam Rayburn Reservoir at FM 83 Ayish Bayou				
Black crappie	7/7	0.450±0.161 (0.282-**0.686**)	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg–day
Blue catfish	1/1	0.080		
Channel catfish	4/4	0.235±0.089 (0.152-0.359)		
Flathead catfish	1/1	0.527		
Freshwater drum	6/6	0.566±0.295 (0.192-**0.963**)		
Largemouth bass	20/20	**0.876**±0.259 (0.136-**1.348**)		
Longnose gar	1/1	**0.729**		
Warmouth	2/2	**0.674**±0.092 (0.609-**0.739**		
White bass	10/10	0.550±0.148 (0.377-**0.804**)		
All fish combined	52/52	0.638±0.299 (0.080-**1.348**)		

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

Table 2j. Mercury (mg/kg) in fish collected from Sam Rayburn Reservoir by sample site, 2010–2011.				
Species	**# Detected/ # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
All Sites				
Black crappie	61/61	0.244±0.142 (0.077-**0.768**[*])	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg–day
Blue catfish	50/50	0.268±0.252 (0.031-**1.332**)		
Bluegill	5/5	0.193±0.240 (0.055-0.620)		
Channel catfish	50/50	0.143±0.093 (0.028-0.449)		
Flathead catfish	23/23	0.521±0.257 (0.126-**1.010**)		
Freshwater drum	70/70	0.407±0.252 (0.085-**0.963**)		
Hybrid striped bass	6/6	**0.670**±0.148 (0.386-**0.799**)		
Largemouth bass	240/240	0.582±0.259 (0.097-**1.979**)		
Longear sunfish	2/2	0.059±0.013 (0.049-0.068)		
Longnose gar	24/24	0.470±0.153 (0.175-**0.747**)		
Redear sunfish	9/9	0.137±0.098 (0.057-0.374)		
Smallmouth buffalo	21/21	0.207±0.187 (BDL-**0.693**)		
Spotted bass	15/15	0.277±0.081 (0.159-0.414)		
Warmouth	8/8	0.528±0.140 (0.290-**0.739**)		
White bass	72/72	0.426±0.181 (0.186-**1.045**)		
White crappie	4/4	**0.827**±0.371 (0.288-**1.118**)		
Crappie (black and white)	65/65	0.280±0.213 (0.077-**1.118**)		
Sunfish *spp.*	24/24	0.272±0.233 (0.049-**0.739**)		
All fish combined	660/660	0.424±0.271 (BDL-**1.979**)		

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

Table 2k. Mercury (mg/kg) in select fish by size class collected from Sam Rayburn Reservoir, 2010–2011.				
Species	**# Detected/ # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
Mercury				
Blue catfish < 30”	41/41	0.180±0.107 (0.031-0.460)	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg–day
Blue catfish > 30”	9/9	**0.665**[*]±0.339 (0.345-**1.332**)		
Flathead catfish < 27”	14/14	0.437±0.248 (0.126-**1.010**)		
Flathead catfish > 27”	9/9	**0.652**±0.223 (0.247-**0.993**)		
Largemouth bass < 14”	14/14	0.447±0.204 (0.097-**0.802**)		
Largemouth bass ≥ 14”	226/226	0.590±0.260 (0.136-**1.979**)		
Largemouth bass ≥ 16”	147/147	**0.652**±0.266 (0.201-**1.979**)		
Largemouth bass ≥ 18”	79/79	**0.697**±0.245 (0.228-**1.311**)		

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

Table 3. Pesticides (mg/kg) in fish collected from Sam Rayburn Reservoir, 2010–2011.				
Species	**# Detected / # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
4,4' DDE				
Blue catfish	12/12	0.005±0.007 (BDL-0.028)	1.167 1.601	EPA chronic oral RfD for DDT: 5.0E-4 mg/kg–day EPA oral slope factor: 3.4E-1 per mg/kg–day
Largemouth bass	12/12	0.002±0.003 (BDL-0.010)		
All fish combined	24/24	0.004±0.006 (BDL-0.028)		

Table 4. PCBs (mg/kg) in fish collected from Sam Rayburn Reservoir, 2010–2011.				
Species	**# Detected / # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
PCBs				
Black crappie	3/5	0.009±0.002 (ND-0.010)	0.047 0.272	EPA chronic oral RfD: 0.00002 mg/kg–day EPA slope factor: 2.0 per mg/kg–day
Blue catfish	11/12	0.015±0.009 (ND-0.038)		
Channel catfish	7/7	0.012±0.006 (0.007-0.026)		
Flathead catfish	7/7	0.027±0.020 (BDL-**0.064***)		
Freshwater drum	7/7	0.017±0.010 (0.005-0.028)		
Hybrid striped bass	5/5	0.018±0.011 (0.012-0.038)		
Largemouth bass	11/12	0.008±0.003 (ND-0.014)		
Longnose gar	7/7	0.030±0.038 (0.011-**0.116**)		
White bass	7/7	0.013±0.002 (0.011-0.016)		
White crappie	2/2	0.010±0.007 (BDL-0.014)		
Crappie (black and white)	5/7	0.009±0.003 (ND-0.014)		
All fish combined	67/71	0.016±0.016 (ND-**0.116**)		

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

Table 5a. PCDDs/PCDFs toxicity equivalent (TEQ) concentrations (pg/g) in fish collected from Sam Rayburn Reservoir, 2010–2011.

Species	# Detected / # Sampled	Mean Concentration ± S.D. (Min-Max)	Health Assessment Comparison Value (pg/g)	Basis for Comparison Value
Site 1 Confluence of Paper Mill Creek and Angelina River				
Blue catfish	0/2	ND	2.33 3.49	ATSDR chronic oral MRL: 1.0 x 10^{-9} mg/kg/day EPA slope factor: 1.56 x 10^{5} per mg/kg/day
Channel catfish	1/1	0.042		
Flathead catfish	2/2	1.828±2.556 (0.020-**3.635**[*])		
Freshwater drum	2/2	0.019±0.015 (0.008-0.029)		
Largemouth bass	1/2	0.0002±0.0002 (ND-0.0003)		
Longnose gar	0/1	ND		
Smallmouth buffalo	1/1	0.094		
White bass	1/3	0.003±0.005 (ND-0.008)		
White crappie	1/2	0.002±0.003 (ND-0.004)		
All fish combined	9/16	0.240±0.906 (ND-**3.635**)		
Site 2 Sam Rayburn Reservoir at Marion Ferry Park				
Black crappie	1/2	0.005±0.007 (ND-0.010)	2.33 3.49	ATSDR chronic oral MRL: 1.0 x 10^{-9} mg/kg/day EPA slope factor: 1.56 x 10^{5} per mg/kg/day
Blue catfish	1/2	0.00006±0.00008 (ND-0.0001)		
Channel catfish	1/1	0.003		
Flathead catfish	1/1	**3.079**		
Freshwater drum	0/1	ND		
Largemouth bass	0/2	ND		
Longnose gar	1/1	**3.833**		
Smallmouth buffalo	1/1	0.039		
Spotted bass	1/1	0.0003		
White bass	2/3	0.009±0.013 (ND-0.024)		
All fish combined	9/15	0.466±1.222 (ND-**3.833**)		

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

Table 5b. PCDDs/PCDFs toxicity equivalent (TEQ) concentrations (pg/g) in fish collected from Sam Rayburn Reservoir, 2010–2011.				
Species	**# Detected / # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (pg/g)**	**Basis for Comparison Value**
Site 3 Sam Rayburn Reservoir at SH 103 Angelina River				
Black crappie	0/1	ND	2.33 3.49	ATSDR chronic oral MRL: 1.0 x 10^{-9} mg/kg/day EPA slope factor: 1.56 x 10^{5} per mg/kg/day
Blue catfish	0/1	ND		
Channel catfish	1/2	0.030±0.042 (ND-0.060)		
Freshwater drum	1/2	0.016±0.023 (ND-0.033)		
Largemouth bass	1/2	0.0002±0.0003 (ND-0.0005)		
Longnose gar	2/2	**2.970**[*]±4.158 (0.030-**5.910**)		
Smallmouth buffalo	1/1	0.349		
Spotted bass	1/1	0.020		
White bass	2/2	0.431±0.605 (0.003-0.858)		
All fish combined	9/14	0.519±1.570 (ND-**5.910**)		
Site 4 Sam Rayburn Reservoir at Hanks Creek				
Black crappie	1/2	0.00003±0.00004 (ND-0.00006)	2.33 3.49	ATSDR chronic oral MRL: 1.0 x 10^{-9} mg/kg/day EPA slope factor: 1.56 x 10^{5} per mg/kg/day
Blue catfish	0/2	ND		
Channel catfish	1/2	0.020±0.028 (ND-0.040)		
Flathead catfish	1/1	**8.953**		
Freshwater drum	0/1	ND		
Hybrid striped bass	1/2	0.160±0.226 (ND-0.320)		
Largemouth bass	0/1	ND		
Longnose gar	1/2	0.050±0.071 (ND-0.100)		
Smallmouth buffalo	1/1	**3.840**		
Spotted bass	1/1	0.420		

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

Table 5c. PCDDs/PCDFs toxicity equivalent (TEQ) concentrations (pg/g) in fish collected from Sam Rayburn Reservoir, 2010–2011.				
Species	**# Detected / # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (pg/g)**	**Basis for Comparison Value**
Site 4 Sam Rayburn Reservoir at Hanks Creek (cont.)				
White bass	3/3	**2.401***±1.480 (1.190-**4.051**)	2.33	ATSDR chronic oral MRL: 1.0×10^{-9} mg/kg/day
All fish combined	10/18	1.160±2.335 (ND-**8.953**)	3.49	EPA slope factor: 1.56×10^{5} per mg/kg/day
Site 5 Sam Rayburn Reservoir at SH 103 Attoyac River				
Black crappie	0/1	ND	2.33 3.49	ATSDR chronic oral MRL: 1.0×10^{-9} mg/kg/day EPA slope factor: 1.56×10^{5} per mg/kg/day
Blue catfish	2/2	0.062±0.086 (0.001-0.123)		
Channel catfish	1/1	0.003		
Freshwater drum	1/1	0.0003		
Hybrid striped bass	1/1	0.004		
Largemouth bass	0/1	ND		
Longnose gar	1/1	0.006		
Smallmouth buffalo	1/1	**9.209**		
White bass	2/2	0.005±0.0005 (0.005-0.006)		
All fish combined	9/11	0.851±2.772 (ND-**9.209**)		
Site 6 Sam Rayburn Reservoir at SH 147				
Black crappie	0/1	ND	2.33 3.49	ATSDR chronic oral MRL: 1.0×10^{-9} mg/kg/day EPA slope factor: 1.56×10^{5} per mg/kg/day
Blue catfish	1/2	0.015±0.021 (ND-0.030)		
Channel catfish	1/1	0.0006		
Freshwater drum	1/1	0.020		
Largemouth bass	0/1	ND		
Longnose gar	1/1	0.012		
Smallmouth buffalo	1/1	**8.060**		

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

Table 5d. PCDDs/PCDFs toxicity equivalent (TEQ) concentrations (pg/g) in fish collected from Sam Rayburn Reservoir, 2010–2011.				
Species	**# Detected / # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (pg/g)**	**Basis for Comparison Value**
Site 6 Sam Rayburn Reservoir at SH 147 (cont.)				
Spotted bass	1/1	0.011	2.33	ATSDR chronic oral MRL: 1.0 x 10^{-9} mg/kg/day
All fish combined	6/9	0.904±2.683 (ND-**8.060***)	3.49	EPA slope factor: 1.56 x 10^{5} per mg/kg/day
Site 7 Sam Rayburn Reservoir at Harvey Creek				
Black crappie	0/1	ND	2.33 3.49	ATSDR chronic oral MRL: 1.0 x 10^{-9} mg/kg/day EPA slope factor: 1.56 x 10^{5} per mg/kg/day
Blue catfish	3/3	**3.339**±5.622 (0.043-**9.830**)		
Channel catfish	1/1	1.800		
Freshwater drum	1/1	0.403		
Largemouth bass	0/1	ND		
Smallmouth buffalo	1/1	1.827		
White bass	1/2	0.030±0.042 (ND-0.060)		
All fish combined	7/10	1.411±3.046 (ND-**9.830**)		
Site 8 Sam Rayburn Reservoir at Caney Creek				
Black crappie	0/1	ND	2.33 3.49	ATSDR chronic oral MRL: 1.0 x 10^{-9} mg/kg/day EPA slope factor: 1.56 x 10^{5} per mg/kg/day
Blue catfish	1/2	0.060±0.085 (ND-0.120)		
Channel catfish	1/1	0.009		
Flathead catfish	2/2	**14.758**±2.097 (**13.275**-**16.240**)		
Freshwater drum	0/1	ND		
Largemouth bass	0/1	ND		
Longnose gar	1/1	0.002		
Smallmouth buffalo	1/1	0.792		
Spotted bass	1/1	1.104		

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

Table 5e. PCDDs/PCDFs toxicity equivalent (TEQ) concentrations (pg/g) in fish collected from Sam Rayburn Reservoir, 2010–2011.				
Species	**# Detected / # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (pg/g)**	**Basis for Comparison Value**
Site 8 Sam Rayburn Reservoir at Caney Creek (cont.)				
White bass	0/1	ND	2.33	ATSDR chronic oral MRL: 1.0 x 10^{-9} mg/kg/day
All fish combined	7/12	**2.629***±5.712 (ND-**16.240**)	3.49	EPA slope factor: 1.56 x 10^{5} per mg/kg/day
Site 9 Sam Rayburn Reservoir at Norris Creek / Five Fingers				
Black crappie	0/1	ND	2.33 3.49	ATSDR chronic oral MRL: 1.0 x 10^{-9} mg/kg/day EPA slope factor: 1.56 x 10^{5} per mg/kg/day
Blue catfish	0/1	ND		
Channel catfish	1/1	**4.080**		
Freshwater drum	1/1	0.005		
Largemouth bass	1/1	0.001		
Longnose gar	0/1	ND		
Smallmouth buffalo	1/1	1.463		
All fish combined	4/7	0.793±1.549 (ND-**4.080**)		
Site 10 Sam Rayburn Reservoir at Dam				
Black crappie	1/2	0.035±0.050 (ND-0.071)	2.33 3.49	ATSDR chronic oral MRL: 1.0 x 10^{-9} mg/kg/day EPA slope factor: 1.56 x 10^{5} per mg/kg/day
Blue catfish	0/1	ND		
Channel catfish	1/1	0.001		
Flathead catfish	2/6	**2.413**±3.788 (ND-**8.204**)		
Freshwater drum	1/2	0.010±0.014 (ND-0.020)		
Hybrid striped bass	1/2	0.0002±0.0002 (ND-0.0003)		
Largemouth bass	1/4	0.576±1.152 (ND-**2.304**)		
Longnose gar	1/1	0.246		
Smallmouth buffalo	1/1	**21.162**		

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

Table 5f. PCDDs/PCDFs toxicity equivalent (TEQ) concentrations (pg/g) in fish collected from Sam Rayburn Reservoir, 2010–2011.				
Species	**# Detected / # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (pg/g)**	**Basis for Comparison Value**
Site 10 Sam Rayburn Reservoir at Dam (cont.)				
Spotted bass	1/1	0.010	2.33 3.49	ATSDR chronic oral MRL: 1.0×10^{-9} mg/kg/day EPA slope factor: 1.56×10^{5} per mg/kg/day
White bass	1/1	0.004		
All fish combined	11/22	1.741±4.846 (ND-**21.162***)		
Site 11 Sam Rayburn Reservoir at Bear Creek				
Blue catfish	0/1	ND	2.33 3.49	ATSDR chronic oral MRL: 1.0×10^{-9} mg/kg/day EPA slope factor: 1.56×10^{5} per mg/kg/day
Channel catfish	2/2	1.574±0.608 (1.144-2.004)		
Flathead catfish	1/1	**3.553**		
Freshwater drum	1/1	0.012		
Largemouth bass	1/2	0.00005±0.00006 (ND-0.00009)		
Longnose gar	2/2	**3.839**±4.773 (0.464-**7.215**)		
Smallmouth buffalo	1/1	**20.400**		
White bass	2/2	0.508±0.629 (0.063-0.953)		
White crappie	0/1	ND		
All fish combined	10/13	**2.754**±5.691 (ND-**20.400**)		
Site 12 Sam Rayburn Reservoir at FM 83 Ayish Bayou				
Black crappie	1/1	0.0008	2.33 3.49	ATSDR chronic oral MRL: 1.0×10^{-9} mg/kg/day EPA slope factor: 1.56×10^{5} per mg/kg/day
Blue catfish	0/1	ND		
Channel catfish	0/1	ND		
Flathead catfish	1/1	0.003		
Freshwater drum	0/1	ND		
Largemouth bass	0/1	ND		

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

Table 5g. PCDDs/PCDFs toxicity equivalent (TEQ) concentrations (pg/g) in fish collected from Sam Rayburn Reservoir, 2010–2011.				
Species	**# Detected / # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (pg/g)**	**Basis for Comparison Value**
Site 12 Sam Rayburn Reservoir at FM 83 Ayish Bayou (cont.)				
Longnose gar	0/1	ND	2.33 3.49	ATSDR chronic oral MRL: 1.0 x 10^{-9} mg/kg/day EPA slope factor: 1.56 x 10^{5} per mg/kg/day
White bass	1/1	0.003		
All fish combined	3/8	0.0009±0.001 (ND-0.003)		
All Sites				
Black crappie	4/13	0.006±0.020 (ND-0.071)	2.33 3.49	ATSDR chronic oral MRL: 1.0 x 10^{-9} mg/kg/day EPA slope factor: 1.56 x 10^{5} per mg/kg/day
Blue catfish	8/20	0.515±2.193 (ND-**9.830**[*])		
Channel catfish	12/15	0.612±1.183 (ND-**4.080**)		
Flathead catfish	10/14	**4.517**±5.381 (ND-**16.240**)		
Freshwater drum	9/15	0.035±0.102 (ND-0.403)		
Hybrid striped bass	3/5	0.065±0.143 (ND-0.320)		
Largemouth bass	5/19	0.121±0.528 (ND-**2.304**)		
Longnose gar	10/14	1.273±2.470 (ND-**7.215**)		
Smallmouth buffalo	11/11	**6.112**±7.898 (0.039-**21.162**)		
Spotted bass	6/6	0.261±0.444 (0.0003-1.104)		
Hybrid striped bass	1/2	0.0002±0.0002 (ND-0.0003)		
White bass	15/20	0.460±1.003 (ND-**4.051**)		
White crappie	1/3	0.001±0.002 (ND-0.004)		
Crappie (black and white)	5/16	0.005±0.018 (ND-0.071)		
All fish combined	94/155	1.173±3.359 (ND-**21.162**)		

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

Table 6a. Hazard quotients (HQs) for mercury in fish collected from Sam Rayburn Reservoir in 2010–2011. Table 6a also provides suggested weekly eight-ounce meal consumption rates for 70-kg adults.[*]

Species	Number (N)	Hazard Quotient	Meals per Week
Sam Rayburn Reservoir All Sites			
Black crappie	61	0.35	2.7
Blue catfish	50	0.38	2.4
Bluegill	5	0.28	3.4
Channel catfish	50	0.20	4.5
Flathead catfish	23	0.74	1.2
Freshwater drum	70	0.58	1.6
Hybrid striped bass	6	**1.00**[†]	**0.9**[‡]
Largemouth bass	240	0.83	1.1
Longear sunfish	2	0.08	11.0
Longnose gar	24	0.67	1.4
Redear sunfish	9	0.20	4.7
Smallmouth buffalo	21	0.30	3.1
Spotted bass	15	0.40	2.3
Warmouth	8	0.75	1.2
White bass	72	0.61	1.5
White crappie	4	**1.18**	**0.8**
Crappie (black and white)	65	0.40	2.3
Sunfish spp.	24	0.39	2.4
All fish combined	660	0.61	1.5

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

Table 6b. Hazard quotients (HQs) for mercury in select largemouth bass by size class collected from Sam Rayburn Reservoir in 2010–2011. Table 6b also provides suggested weekly eight-ounce meal consumption rates for 70-kg adults.[*]			
Species	**Number (N)**	**Hazard Quotient**	**Meals per Week**
Sam Rayburn Reservoir All Sites			
Blue catfish < 30”	41	0.26	3.6
Blue catfish > 30”	9	**1.00**[†]	**0.9**[‡]
Flathead catfish < 27”	14	0.62	1.5
Flathead catfish > 27”	9	**1.00**	**0.9**
Largemouth bass < 14”	14	0.64	1.4
Largemouth bass ≥ 14”	226	0.84	1.1
Largemouth bass ≥ 16”	147	**1.00**	**0.9**

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

Table 7a. Hazard quotients (HQs) and hazard indices (HIs) for PCBs and/or PCDDs/PCDFs in fish collected from Sam Rayburn Reservoir in 2010–2011. Table 7a also provides suggested weekly eight-ounce meal consumption rates for 70-kg adults.*			
Contaminant/Species	**Number (N)**	**Hazard Quotient**	**Meals per Week**
Black crappie			
PCBs	5	0.20	4.7
PCDDs/PCDFs	13	0.003	unrestricted†
Hazard Index (meals per week)		0.20	4.6
Blue catfish			
PCBs	12	0.31	3.0
PCDDs/PCDFs	20	0.22	4.2
Hazard Index (meals per week)		0.53	1.7
Channel catfish			
PCBs	7	0.27	3.5
PCDDs/PCDFs	15	0.26	3.5
Hazard Index (meals per week)		0.53	1.8
Flathead catfish			
PCBs	7	0.58	1.6
PCDDs/PCDFs	14	**1.94**‡	**0.5**§
Hazard Index (meals per week)		**2.51**	**0.4**
Freshwater drum			
PCBs	7	0.36	2.5
PCDDs/PCDFs	15	0.02	unrestricted
Hazard Index (meals per week)		0.38	2.4

* *DSHS assumes that children under 12 years of age and/or those that weigh less than 35 kg eat four-ounce meals.*
† *Denotes that the allowable eight-ounce meals per week are > 21.0.*
‡ *Emboldened numbers denote that the HQ or HI is ≥ 1.0.*
§ *Emboldened numbers denote that the calculated allowable meals for an adult are ≤ one meal per week.*

Table 7b. Hazard quotients (HQs) and hazard indices (HIs) for PCBs and/or PCDDs/PCDFs in fish collected from Sam Rayburn Reservoir in 2010–2011. Table 7b also provides suggested weekly eight-ounce meal consumption rates for 70-kg adults.*

Contaminant/Species	Number (N)	Hazard Quotient	Meals per Week
Hybrid striped bass			
PCBs	5	0.38	2.5
PCDDs/PCDFs	5	0.03	unrestricted†
Hazard Index (meals per week)		0.40	2.3
Largemouth bass			
PCBs	12	0.17	5.5
PCDDs/PCDFs	19	0.05	17.8
Hazard Index (meals per week)		0.22	4.2
Longnose gar			
PCBs	7	0.65	1.4
PCDDs/PCDFs	14	0.55	1.7
Hazard Index (meals per week)		**1.20**‡	**0.8**§
Smallmouth buffalo			
PCDDs/PCDFs	11	**2.62**	**0.4**
Spotted bass			
PCDDs/PCDFs	6	0.11	8.3
White bass			
PCBs	7	0.28	3.3
PCDDs/PCDFs	20	0.20	4.7
Hazard Index (meals per week)		0.47	2.0

* *DSHS assumes that children under 12 years of age and/or those that weigh less than 35 kg eat four-ounce meals.*
† *Denotes that the allowable eight-ounce meals per week are > 21.0.*
‡ *Emboldened numbers denote that the HQ or HI is ≥ 1.0.*
§ *Emboldened numbers denote that the calculated allowable meals for an adult are ≤ one meal per week.*

Table 7c. Hazard quotients (HQs) and hazard indices (HIs) for PCBs and/or PCDDs/PCDFs in fish collected from Sam Rayburn Reservoir in 2010–2011. Table 7b also provides suggested weekly eight-ounce meal consumption rates for 70-kg adults.*

Contaminant/Species	Number (N)	Hazard Quotient	Meals per Week
White crappie			
PCBs	2	0.21	4.5
PCDDs/PCDFs	3	< 0.00	unrestricted†
Hazard Index (meals per week)		0.21	4.4
Crappie (black and white)			
PCBs	7	0.20	4.6
PCDDs/PCDFs	16	< 0.00	unrestricted
Hazard Index (meals per week)		0.20	4.5
All fish combined			
PCBs	71	0.34	2.7
PCDDs/PCDFs	155	0.50	1.8
Hazard Index (meals per week)		0.84	1.1

* *DSHS assumes that children under 12 years of age and/or those that weigh less than 35 kg eat four-ounce meals.*
† *Denotes that the allowable eight-ounce meals per week are > 21.0.*

Table 8a. Calculated theoretical lifetime excess cumulative cancer risk from consuming fish collected in 2010–2011 from Sam Rayburn Reservoir containing arsenic, DDE, PCBs, and PCDDs/PCDFs and suggested consumption rate (eight-ounce meals/week) for 70 kg adults who regularly eat fish from Sam Rayburn Reservoir over a 30-year period.[*]				
Species/Contaminant	**Number (N)**	**Theoretical Lifetime Excess Cancer Risk**		**Meals per Week**
		Risk	**1 excess cancer per number of people exposed**	
Black crappie				
PCBs	5	3.4 E-06	293,343	unrestricted[†]
PCDDs/PCDFs	13	1.8E-07	5,548,535	unrestricted
Cumulative Cancer Risk		3.6E-06	278,613	unrestricted
Blue catfish				
Arsenic	12	5.5E-07	1,814,815	unrestricted
4,4′-DDE	12	3.3E-07	3,025,902	unrestricted
PCBs	12	5.4E-06	186,709	17.2
PCDDs/PCDFs	20	1.5E-05	67,768	6.3
Cumulative Cancer Risk		2.1E-05	48,395	4.4
Channel catfish				
PCBs	7	4.6E-06	219,534	20.3
PCDDs/PCDFs	15	1.8E-05	57,027	5.3
Cumulative Cancer Risk		2.2E-05	45,268	4.2
Flathead catfish				
PCBs	7	9.9E-06	100,823	9.3
PCDDs/PCDFs	14	**1.3E-04**[‡]	**7,726**	**0.7**[§]
Cumulative Cancer Risk		**1.4E-04**	**7,176**	**0.7**

[*] *DSHS assumes that children under 12 years of age and/or those who weigh less than 35 kg eat 4-ounce meals.*
[†] *Denotes that the allowable eight-ounce meals per week are > 21.0.*
[‡] *Emboldened numbers denote calculated excess lifetime cancer risk after 30 years exposure is greater than 1.0E-04.*
[§] *Emboldened numbers denote that the calculated allowable meals for an adult are ≤ one meal per week.*

Table 8b. Calculated theoretical lifetime excess cumulative cancer risk from consuming fish collected in 2010–2011 from Sam Rayburn Reservoir containing arsenic, DDE, PCBs, and PCDDs/PCDFs and suggested consumption rate (eight-ounce meals/week) for 70 kg adults who regularly eat fish from Sam Rayburn Reservoir over a 30-year period.[*]

Species/Contaminant	Number (N)	Theoretical Lifetime Excess Cancer Risk		Meals per Week
		Risk	1 excess cancer per number of people exposed	
Freshwater drum				
PCBs	7	6.2E-06	160,131	14.8
PCDDs/PCDFs	15	1.0E-06	985,884	unrestricted[†]
Cumulative Cancer Risk		7.3E-06	137,756	12.7
Hybrid striped bass				
PCBs	5	6.5E-06	155,024	14.3
PCDDs/PCDFs	5	1.9E-06	536,927	unrestricted
Cumulative Cancer Risk		8.3E-06	120,293	11.1
Largemouth bass				
Arsenic	12	8.3E-07	1,209,877	unrestricted
4,4′-DDE	12	1.3E-07	7,907,690	unrestricted
PCBs	12	2.9E-06	345,460	unrestricted
PCDDs/PCDFs	19	3.5E-06	288,432	unrestricted
Cumulative Cancer Risk		7.2E-06	139,116	12.6
Longnose gar				
PCBs	7	1.1E-05	89,370	8.3
PCDDs/PCDFs	14	3.6E-05	27,416	2.5
Cumulative Cancer Risk		4.8E-05	20,980	1.9
Smallmouth buffalo				
PCDDs/PCDFs	11	**1.8E-04**[‡]	**5,710**	**0.5**[§]

[*] *DSHS assumes that children under 12 years of age and/or those who weigh less than 35 kg eat 4-ounce meals.*
[†] *Denotes that the allowable eight-ounce meals per week are > 21.0.*
[‡] *Emboldened numbers denote calculated excess lifetime cancer risk after 30 years exposure is greater than 1.0E-04.*
[§] *Emboldened numbers denote that the calculated allowable meals for an adult are ≤ one meal per week.*

Table 8c. Calculated theoretical lifetime excess cumulative cancer risk from consuming fish collected in 2010–2011 from Sam Rayburn Reservoir containing arsenic, DDE, PCBs, and PCDDs/PCDFs and suggested consumption rate (eight-ounce meals/week) for 70 kg adults who regularly eat fish from Sam Rayburn Reservoir over a 30-year period.*				
Species/Contaminant	**Number (N)**	**Theoretical Lifetime Excess Cancer Risk**		**Meals per Week**
		Risk	**1 excess cancer per number of people exposed**	
Spotted bass				
PCDDs/PCDFs	6	7.5E-06	133,718	12.4
White bass				
PCBs	7	4.7E-06	210,698	19.5
PCDDs/PCDFs	20	1.3E-05	75,870	7.0
Cumulative Cancer Risk		1.8E-05	55,783	5.2
White crappie				
PCBs	2	3.6E-06	280,641	unrestricted†
PCDDs/PCDFs	3	4.0E-08	24,928,775	unrestricted
Cumulative Cancer Risk		3.6E-06	277,517	unrestricted
Crappie (black and white)				
PCBs	**7**	3.5E-06	289,598	unrestricted
PCDDs/PCDFs	16	1.5E-07	6,499,122	unrestricted
Cumulative Cancer Risk		3.6E-06	277,244	unrestricted
All fish combined				
Arsenic	24	8.3E-07	1,209,877	unrestricted
4,4′-DDE	24	2.3E-07	4,377,548	unrestricted
PCBs	71	5.8E-06	172,293	15.9
PCDDs/PCDFs	155	3.4E-05	29,753	2.7
Cumulative Cancer Risk		4.0E-05	24,850	2.3

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

Table 9. 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 Sam Rayburn Reservoir in 2010–2011.

Species	Average	Minimum	Maximum
	Number of Eight-Ounce Meals		
Blue catfish	5.4	1.0	15.0
Channel catfish	1.2	0.4	2.6
Crappie	0.9	0.5	1.5
Flathead catfish	7.6	2.0	25.0
Freshwater drum	2.3	0.6	7.8
Hybrid striped bass	3.2	1.6	4.0
Largemouth bass	2.2	1.0	8.0
Longnose gar	8.7	0.8	22.2
Smallmouth buffalo	15.1	6.3	35.2
Spotted bass	0.8	0.3	1.2
Sunfish	0.3	0.1	0.4
White bass	1.5	0.8	2.3
All fish combined	4.1	0.1	35.2

Table 10. Recommended fish consumption advice by species for Sam Rayburn Reservoir 2010–2011.

Contaminants of Concern	Species	Women of childbearing age and children < 12	Women past childbearing age and adult men
Dioxins and mercury	Blue catfish > 30 inches	**DO NOT EAT**	2 meals/month
	Flathead catfish	**DO NOT EAT**	1 meal/month
	Gar (all species)	**DO NOT EAT**	2 meals/month
	Largemouth bass > 16 inches	**DO NOT EAT**	2 meals/month
	Smallmouth buffalo	**DO NOT EAT**	**DO NOT EAT**
	Spotted bass > 16 inches	**DO NOT EAT**	2 meals/month

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