Characterization of Potential Adverse Health Effects Associated with Consuming Fish from

B.A. Steinhagen Reservoir

Jasper and Tyler Counties, Texas

2012

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 B.A. Steinhagen Reservoir initiated in 2010 by the Texas Department of State Health Service (DSHS) Seafood and Aquatic Life Group (SALG). The SALG conducted this study to investigate potential polychlorinated dibenzo-*p*-dioxins and/or dibenzofurans (PCDDs/PCDFs) and polychlorinated biphenyls (PCBs) 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 B.A. Steinhagen 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 B.A. Steinhagen Reservoir and suggests actions to reduce potential adverse health outcomes.

History of the B.A. Steinhagen 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's (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 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, and PCBs, dioxins, and furans. 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 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 (hereinafter 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 B.A. Steinhagen Reservoir predator composite and the bottom-dweller composite from the NLFTS contained PBT chemical concentrations in excess of DSHS SVs. The predator composite (largemouth bass) contained a mercury concentration of 1.080 mg/kg that exceeded the mercury SV (0.525 mg/kg). The bottom dweller composite (blue catfish) contained a PCDF/PCDD concentration of 22.4 ng/kg (PCDF/PCDD SV = 1.74 ng/kg) and a PCB concentration of 0.031 mg/kg (PCB SV = 0.027 mg/kg). The DSHS selected B.A. Steinhagen Reservoir for *Tier 2 Study* based on these results and its ranking on the Tier 2 Study Ranking List.

Description of B.A. Steinhagen Reservoir

B.A. Steinhagen Reservoir is a 10,687-acre impoundment of the Angelina-Neches River basin located 14 miles west of Jasper, Texas.[10] The United States Army Corps of Engineers (USACE), reservoir-controlling authority, oversees B.A. Steinhagen Reservoir daily operation including regulation of intermittent power releases from Sam Rayburn Dam, generation of hydroelectric power, and diversion of water into a water supply canal.[11] The reservoir is very shallow with a mean depth of 4 feet; littoral habitat < 15 feet comprises 95% of the reservoir's surface area.[12] Due to its shallow characteristics, aquatic vegetation issues persist at B.A. Steinhagen Reservoir. The USACE and TPWD use lake drawdowns and herbicide treatments to manage nuisance aquatic plants. Angler access and recreational opportunities abound at B.A. Steinhagen Reservoir that includes boating, fishing, swimming, camping, trails, and hunting. The USACE maintains five parks and TPWD operates Martin Dies Jr. State Park on the shores of B.A. Steinhagen Reservoir.[10,13]

Demographics of Jasper and Tyler Counties Surrounding the Area of B.A. Steinhagen Reservoir

B.A. Steinhagen Reservoir is located in rural East Texas forming part of the Jasper and Tyler County boundary along the Neches River channel. The United States Census 2010 calculated the population of Jasper and Tyler Counties at 35,710 and 21,766 people, respectively.[14] Jasper, Texas, the largest city in Jasper County, the Jasper County seat and the closest city to B.A.

Steinhagen Reservoir registered a United States Census 2010 population at 7,318 people.[15,16] In the United States Census 2010, Tyler County's principal city and county seat, Woodville, Texas tallied a population 2,586 people.[15,17] Lufkin, Texas positioned approximately 50 miles north of B.A. Steinhagen Reservoir is the closest major metropolitan area (population ≥ 20,000 people) in East Texas.

Subsistence Fishing at B.A. Steinhagen 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.[18] 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.*[19] The SALG bases its sampling and analysis protocols, in part, on procedures recommended by the USEPA in that agency's *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories, Volume 1.*[20] Advice and direction are also received from the legislatively mandated *State of Texas Toxic Substances Coordinating Committee (TSCC) Fish Sampling Advisory Subcommittee (FSAS).*[21] Samples usually represent species, trophic levels, and legal-sized specimens available for consumption from a water body. When practical, the DSHS collects samples from two or more sites within a water body to better characterize geographical distributions of contaminants.

Fish Sampling Methods and Description of the B.A. Steinhagen Reservoir 2010 Sample Set

In May–June 2010, the SALG staff collected 400 fish samples from B.A. Steinhagen 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 eight sample sites to provide spatial coverage of the study area (Figure 1): Site 1 B. A Steinhagen Reservoir at dam, Site 2 B.A. Steinhagen Reservoir near Campers Cove Park, Site 3 B.A. Steinhagen Reservoir at Sandy Creek, Site 4 B.A. Steinhagen Reservoir at US Highway 190, Site 5 B.A. Steinhagen Reservoir near Walnut Ridge Unit, Site 6 B.A. Steinhagen Reservoir near Magnolia Ridge Park, Site 7 B. A. Steinhagen Reservoir at Neches River and Angelina River Confluence, and Site 8 Angelina River at Bevilport Boat Ramp. 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 400 fish collected from B.A. Steinhagen Reservoir in May–June 2010 represent all species targeted for collection from this water body (Table 1). The list below contains the number of each target species collected for this study listed in descending order: largemouth bass (88), freshwater drum (53), blue catfish (50), channel catfish (46), flathead catfish (34), sunfish spp. (33), crappie spp. (32), gar spp. (23), smallmouth buffalo (16), spotted bass (16), white bass (7), and striped bass (2).

The survey team set gill nets at sampling sites 1 through 8 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 also 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 spp., 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 B.A. Steinhagen 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 week following each collection trip, the SALG delivered the frozen fish tissue samples to the Geochemical and Environmental Research Group (GERG) Laboratory, Texas A&M University, College Station, Texas, for contaminant analysis.

Fish Age Estimation

The DSHS SALG staff removed sagittal otoliths from alligator gar, 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.[22] 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.[22, 23] Alligator gar otoliths were shipped via commercial carrier to the TPWD Heart of Hills Fisheries Science Center for age estimation.

Analytical Laboratory Information

Upon arrival of the fish samples at the laboratory, GERG personnel documented receipt of the 400 B.A. Steinhagen 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 B.A. Steinhagen 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 400 samples for mercury. A subset of the original 400 samples was assayed for the following contaminant groupings: 96 samples for PCDDs/PCDFs, 40 samples for PCBs, and 16 samples for metals, pesticides, SVOCs, and VOCs.[24]

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

<u>Arsenic</u>

The GERG laboratory analyzed 16 fish samples for total (inorganic arsenic + organic arsenic = total arsenic) arsenic. Although the proportions of each form of arsenic may differ among fish species, under different water conditions, and, perhaps, with other variables, the literature suggests that well over 90% of arsenic in fish is likely organic arsenic – a form of arsenic that is virtually non-toxic to humans.[25] The DSHS, taking a conservative approach, estimates 10% of the total arsenic in any fish is inorganic arsenic, deriving estimates of inorganic arsenic concentration in each fish by multiplying reported total arsenic concentration in the sample by a factor of 0.1.

Mercury

Nearly all mercury in upper trophic level fish three years of age or older is methylmercury.[26] Thus, the total mercury concentration in a fish of legal size for possession in Texas serves well as a surrogate for methylmercury concentration. Because methylmercury analyses are difficult to perform accurately and are more expensive than total mercury analyses, the USEPA recommends that states determine total mercury concentration in a fish and that – to protect human health – states conservatively assume that all reported mercury in fish or shellfish is methylmercury. The GERG laboratory thus analyzed fish tissues for total mercury. In its risk characterizations, The DSHS compares mercury concentrations in tissues to a comparison value derived from the Agency for Toxic Substances and Disease Registry's (ATSDR) minimal risk level (MRL) for methylmercury.[27] (In these risk characterizations, the DSHS may interchangeably utilize the terms "mercury," "methylmercury," or "organic mercury" to refer to methylmercury in fish).

Polychlorinated Biphenyls (PCBs)

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

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

(IRIS) database.[30] IRIS currently contains systemic toxicity information for five Aroclor® mixtures: Aroclors® 1016, 1242, 1248, 1254, and 1260. IRIS does not contain all information for all mixtures. For instance, only one other reference dose (RfD) occurs in IRIS – the one derived for Aroclor 1016, a commercial mixture produced in the latter years of commercial production of PCBs in the United States. Aroclor 1016 was a fraction of Aroclor 1254 that was supposedly devoid of dibenzofurans, in contrast to Aroclor 1254.[31] Systemic toxicity estimates in the present document reflect comparisons derived from the USEPA's RfD for Aroclor 1254 because Aroclor 1254 contains many of the 43 congeners selected by McFarland and Clark and NOAA. As of yet, IRIS does not contain information on the systemic toxicity of individual PCB congeners.

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

Calculation of Toxicity Equivalent Quotients (TEQs) for Dioxins

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

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

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.[35] People who regularly consume contaminated fish or shellfish conceivably suffer repeated low-dose exposures to contaminants in fish or shellfish over extended periods (episodic exposures to low doses). Such exposures are unlikely to result in acute toxicity but may increase risk of subtle, chronic, and/or delayed adverse health effects that may include cancer, benign tumors, birth defects, infertility, blood disorders, brain damage, peripheral nerve damage, lung disease, and kidney disease.[35]

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

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

> *An estimate of a daily oral exposure for a given duration to the human population (including susceptible subgroups) that is likely to be without an appreciable risk of adverse health effects over a lifetime.*[39]

The USEPA also states that the RfD

> *… is derived from a BMDL* (benchmark dose lower confidence limit)*, a NOAEL* (no observed adverse effect level)*, a LOAEL* (lowest observed adverse effect level)*, or another suitable point of departure, with uncertainty/variability factors applied to reflect limitations of the data used. [Durations include acute, short-term, subchronic, and chronic and are defined individually in this glossary]* and *RfDs are generally*

reserved for health effects thought to have a threshold or a low dose limit for producing effects.[39]

The ATSDR uses a similar technique to derive its MRLs.[38] The DSHS divides the estimated daily dose derived from the measured concentration in fish tissue by the contaminant's RfD or MRL to derive a hazard quotient (HQ). The USEPA defines 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).[40]

Note that, according to the USEPA, a linear increase in the HQ for a toxicant does not imply a linear increase in the likelihood or severity of systemic adverse effects. Thus, 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.[38]

In developing oral RfDs and MRLs, federal scientists review the extant literature to devise NOAELs, LOAELs, or benchmark doses (BMDs) from experimental studies. Uncertainty factors are then utilized to minimize potential systemic adverse health effects in people who are exposed through consumption of contaminated materials by accounting for certain conditions that may be undetermined by the experimental data. These include extrapolation from animals to humans (interspecies variability), intra-human variability, and use of a subchronic study rather than a chronic study to determine the NOAEL, LOAEL, or BMD, and database insufficiencies.[37,39] Vulnerable groups such as women who are pregnant or lactating, women who may become pregnant, infants, children, people with chronic illnesses, those with compromised immune systems, the elderly, or those who consume exceptionally large servings are considered sensitive populations by risk assessors and USEPA and also receive special consideration in calculation of a RfD.[39]

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

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

The USEPA states that

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

And

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

Thus,

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

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

The DSHS calculates cancer-risk comparison values (HAC_{ca}) from the USEPA's chemical-specific cancer potency factors (CPFs), also known as cancer slope factors (CSFs), derived through mathematical modeling from carcinogenicity studies. For carcinogenic outcomes, the DSHS calculates a theoretical lifetime excess risk of cancer for specific exposure scenarios for carcinogens, using a standard 70-kg body weight and assuming an adult consumes 30 grams of edible tissue per day. The SALG risk assessors incorporate two additional factors into determinations of theoretical lifetime excess cancer risk: (1) an acceptable lifetime risk level (ARL)[39] of one excess cancer case in 10,000 persons whose average daily exposure is equivalent and (2) daily exposure for 30 years, a modification of the 70-year lifetime exposure assumed by the USEPA. Comparison values used to assess the probability of cancer do not contain "uncertainty" factors. However, conclusions drawn from probability determinations infer substantial safety margins for all people by virtue of the models utilized to derive the slope factors (cancer potency factors) used in calculating the HAC_{ca}.

Because the calculated comparison values (HAC values) are conservative, exceeding a HAC value does not necessarily mean adverse health effects will occur. The perceived strict demarcation between acceptable and unacceptable exposures or risks is primarily a tool used by risk managers along with other information to make decisions about the degree of risk incurred by those who consume contaminated fish or shellfish. Moreover, comparison values for adverse health effects do not represent sharp dividing lines (obvious demarcations) between safe and unsafe exposures. For example, the DSHS considers it unacceptable when consumption of four or fewer meals per month of contaminated fish or shellfish would result in exposure to contaminant(s) in excess of a HAC value or other measure of risk. The DSHS also advises people who wish to minimize exposure to contaminants in fish or shellfish to eat a variety of fish and/or shellfish and to limit consumption of those species most likely to contain toxic contaminants. The DSHS aims to protect vulnerable subpopulations with its consumption advice, assuming that advice protective of vulnerable subgroups will also protect the general population from potential adverse health effects associated with consumption of contaminated fish or shellfish.

Children's Health Considerations

The DSHS recognizes that fetuses, infants, and children may be uniquely susceptible to the effects of toxic chemicals and suggests that exceptional susceptibilities demand special attention.[41, 42] Windows of special vulnerability (known as "critical developmental periods") exist during development. Critical periods occur particularly during early gestation (weeks 0 through 8) but can occur at any time during development (pregnancy, infancy, childhood, or adolescence) at times when toxicants can impair or alter the structure or function of susceptible systems.[43] Unique early sensitivities may exist after birth because organs and body systems are structurally or functionally immature at birth, continuing to develop throughout infancy, childhood, and adolescence. Developmental variables may influence the mechanisms or rates of absorption, metabolism, storage, or excretion of toxicants. Any of these factors could alter the concentration of biologically effective toxicant at the target organ(s) or could modulate target organ response to the toxicant. Children's exposures to toxicants may be more extensive than adults' exposures because children consume more food and liquids in proportion to their body weights than adults consume. Infants can ingest toxicants through breast milk, an exposure pathway that often goes unrecognized. Nonetheless, the advantages of breastfeeding outweigh the probability of significant exposure to infants through breast milk and women are encouraged to continue breastfeeding and to limit exposure of their infants by limiting intake of the contaminated foodstuff. Children may experience effects at a lower exposure dose than might adults because children's organs may be more sensitive to the effects of toxicants. Stated differently, children's systems could respond more extensively or with greater severity to a given dose than would an adult organ exposed to an equivalent dose of a toxicant. Children could be more prone to developing certain cancers from chemical exposures than are adults.[44]

In any case, if a chemical or a class of chemicals is observed to be, or is thought to be, more toxic to fetuses, infants, or children, the constants (e.g., RfD, MRL, or CPF) are usually modified further to assure the immature systems' potentially greater susceptibilities are not perturbed.[37] Additionally, in accordance with the ATSDR's *Child Health Initiative*[45] and the USEPA's *National Agenda to Protect Children's Health from Environmental Threats,*[46] the DSHS further seeks to protect children from the possible negative effects of toxicants in fish by suggesting that this potentially sensitive subgroup consume smaller quantities of contaminated fish or shellfish than adults consume. Thus, the DSHS recommends that children weighing 35 kg or less and/or who are 12 years of age or younger limit exposure to contaminants in fish or shellfish by eating no more than four-ounces per meal of the contaminated species. The DSHS also recommends that consumers spread these meals over time. For instance, if the DSHS issues consumption advice that recommends consumption of no more than two meals per month of a contaminated species, those children should eat no more than 24 meals of the contaminated fish or shellfish per year and should not eat such fish or shellfish more than twice per month.

Data Analysis and Statistical Methods

The SALG risk assessors imported Excel© files into SPSS® statistical software, version 13.0 installed on IBM-compatible microcomputers (Dell, Inc), using SPSS® to generate descriptive statistics (mean, standard deviation, median, minimum and maximum concentrations, and range) on measured compounds.[47] In computing descriptive statistics, SALG risk assessors utilized ½ the reporting limit (RL) for analytes designated as not detected (ND) or estimated (J-values)[*]. 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 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.

---

[*] *"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.*

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 did not perform sample site mercury concentration comparisons because channel catfish and smallmouth buffalo were the only species collected at all sample sites. For the species that were represented at all sample sites, sample size and size class distribution were inadequate at each sample site to perform reliable comparisons. The SALG risk assessors used a *t*-test to examine differences in mercury concentrations in largemouth bass by sampling event (1995 and 2010). 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 B.A. Steinhagen Reservoir.[48] When lead concentrations in fish or shellfish are high, SALG risk assessors may utilize the EPA's Interactive Environmental Uptake Bio-Kinetic (IEUBK) model to determine whether consumption of lead-contaminated fish could cause a child's blood lead (PbB) level to exceed the Centers for Disease Control and Prevention's (CDC) lead concentration of concern in children's blood (10 mcg/dL).[49,50]

RESULTS

The GERG laboratory completed analyses and electronically transmitted the results of the B.A. Steinhagen Reservoir samples collected in May–June 2010 to the SALG in August 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–2e presents the results of metals analyses. Table 3 contains summary results of beta-HCH, gamma-HCH, and Delta-HCH. Table 4 summarizes the PCB analyses, and table 5 summarizes PCDDs/PCDFs analyses. This paper does not display SVOC and VOC data because these contaminants were not present at concentrations of interest in fish collected from B.A. Steinhagen 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 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.[51]

Inorganic Contaminants

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

The GERG laboratory analyzed a subset 16 fish tissue samples for six inorganic contaminants and 400 samples for mercury. All fish tissue samples from B.A. Steinhagen Reservoir contained some concentration of arsenic, cadmium, copper, lead, mercury, selenium, and zinc (Tables 2a–2d).

Three of the metalloids analyzed are essential trace elements: copper, selenium, and zinc. All 16 fish tissue samples contained copper (Table 2b). The mean copper concentration in fish sampled from B.A. Steinhagen Reservoir was 0.186±0.085 mg/kg. Blue catfish had the highest average concentration of copper (0.217±0.106 mg/kg). All fish tissue samples contained selenium. The average selenium concentration in fish from B.A. Steinhagen Reservoir was 0.210 mg/kg with a standard deviation of ±0.071 mg/kg (Table 2b). Selenium in fish from B.A. Steinhagen Reservoir ranged from 0.115–0.353 mg/kg. All samples also contained zinc (Table 2c). The mean zinc concentration in fish tissue samples from B.A. Steinhagen Reservoir was 4.337±1.065 mg/kg.

The SALG evaluated three toxic metalloids having no known human physiological function (arsenic, cadmium, and lead) in the samples collected from B.A. Steinhagen Reservoir. All 16 fish assayed contained arsenic ranging from 0.431–1.104 mg/kg (Table 2a). Cadmium concentrations in fish ranged from BDL–0.086 mg/kg (Table 2b). All species of fish assayed had at least one sample that contained lead at concentrations greater than the RL (Table 2c). The average lead concentration in all fish combined was 0.070±0.040 mg/kg (Table 2b).

<u>Mercury</u>

All fish tissue samples evaluated from B.A. Steinhagen Reservoir contained mercury (Table 2d). Across all sample sites and species, mercury concentrations ranged from 0.066 mg/kg (channel catfish) to 1.855 mg/kg (longnose gar). The mean mercury concentration for the 400 fish tissue samples assayed was 0.341±0.244 mg/kg (Table 2d).

The relationships between mercury concentration and TL were positive and significant ($p < 0.05$) for seven of 14 species (Figures 2–21). The SALG risk assessors did not include four species (hybrid striped bass, longear sunfish, redbreast sunfish, and warmouth) in these analyses due to insufficient sample size. TL explained from 13 to 69% of the variation in mercury concentration (Figures 2–20). Correlations were strongest for blue catfish, white bass, and largemouth bass.

The relationships between mercury concentration and age were positive and significant ($p < 0.05$) for six of seven species (Figures 2–21). The SALG risk assessors did not include alligator gar in these analyses because all alligator gar were part of the same year-class. Age explained from 26 to 73% of the variation in mercury concentration (Figures 2–20). Correlations were strongest for largemouth bass, white crappie, and blue catfish.

Blue catfish

Fifty blue catfish ranging from 14.9 to 30.2 inches TL ($\bar{X}$ – 21.7 inches TL) and from three to 14 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).[52] Mercury concentrations ranged from 0.084 to 0.546 mg/kg with a mean of 0.245±0.118 and a median of 0.250 mg/kg (Table 2d). Mercury concentrations in blue catfish were positively related to TL and age (r^2 = 0.687, n = 50, p <0.0005; r^2 = 0.707, n = 48, p <0.0005; Figures 3–4).

Channel catfish

Forty-six channel catfish ranging from 13.2 to 30.3 in TL ($\bar{X}$ – 20.3 inches TL) and from three to 12 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).[52] Mercury concentrations ranged from 0.066 to 0.565 mg/kg with a mean of 0.235±0.124 and a median of 0.238 mg/kg (Table 2d). Mercury concentrations in channel catfish were positively related to TL and age (r^2 = 0.231, n = 46, p = 0.001; r^2 = 0.256, n = 46, p <0.0005; Figures 6–7).

Flathead catfish

Thirty-four flathead catfish ranging from 17.2 to 33.9 in TL ($\bar{X}$ – 22.6 inches TL) and from two to eight years of age were analyzed for mercury (Table 1; Figure 8). Ninety-four percent of the flathead catfish samples examined were of legal size (≥ 18 inches TL).[52] Mercury concentrations ranged from 0.117 to 0.708 mg/kg with a mean of 0.318±0.133 and a median of 0.296 mg/kg (Table 2d). Mercury concentrations in flathead catfish were positively related to TL and age (r^2= 0.128, n = 34, p = 0.037; r^2 = 0.363, n = 34, p <0.0005; Figures 9–10).

Freshwater drum

Fifty-three freshwater drum ranging from 11.9 to 23.1 inches TL ($\bar{X}$ – 15.8 inches TL) were analyzed for mercury (Table 1). Currently, there is no minimum length limit for freshwater drum in Texas waters.[52] Mercury concentrations ranged from 0.078 to 1.116 mg/kg with a mean of 0.272±0.245 and a median of 0.162 mg/kg (Table 2d). Mercury concentrations in freshwater drum were positively related to TL (r^2 = 0.421, n = 53, p <0.0005; Figure 11).

Gar

Three species of gar (alligator, longnose, and spotted) ranging from 23.9 to 52.3 inches TL ($\bar{X}$ – 34.7 inches TL) were analyzed for mercury (Table 1). Currently, there is no minimum length limit for gar in Texas waters.[52] The mean mercury concentrations for alligator, longnose, and spotted gar were 0.274±0.101, 0.672±0.449, and 0.371±0.207 mg/kg, respectively (Table 2d). Mercury concentrations ranged from 0.171 to 1.855 mg/kg. The SALG risk assessors computed a Pearson product-moment correlation coefficient to assess the relationship between mercury concentration and TL for each species. There was no correlation between the two variables for alligator, longnose, or spotted gar (r = -0.402, n = 6, p = 0.429; r = 0.587, n = 11, p = 0.057; r = -

0.016, n = 6, p = 0.976). All alligator gar samples were part of the same year-class and estimated at three years of age.

Largemouth bass

Eighty-eight largemouth bass ranging from 11.1 to 24.6 inches TL ($\overline{X}$ – 15.6 inches TL) and from two to 10 years of age were analyzed for mercury (Table 1; Figure 12). Seventy-five percent of the largemouth bass samples examined were of legal size (≥ 14 inches TL).[52] Mercury concentrations ranged from 0.126 to 1.644 mg/kg with a mean of 0.498±0.282 and a median of 0.450 mg/kg (Table 2d). The mean mercury concentrations for largemouth bass ≥14 inches, ≥16 inches, and ≥18 inches were 0.548±0.301, 0.700±0.377, and 0.860±0.396 mg/kg, respectively (Table 2e). Mercury concentrations in largemouth bass were positively related to TL and age (r^2 = 0.547, n = 88, p <0.0005; r^2 = 0.734, n = 86, p <0.0005; Figures 13–14). Evaluation of mercury concentrations in largemouth bass by sampling event indicate that the 1995 and 2010 data do not statistically differ by sampling event (1995, n = 36; 2010, n = 88; t [122] = 1.199, p = 0.233).

Smallmouth buffalo

Sixteen smallmouth buffalo ranging from 19.6 to 31.5 inches TL ($\overline{X}$ – 24.5 inches TL) were analyzed for mercury (Table 1). Currently, there is no minimum length limit for smallmouth buffalo in Texas waters.[52] Mercury concentrations ranged from 0.207 to 0.659 mg/kg with a mean of 0.439±0.142 and a median of 0.432 mg/kg (Table 2d). 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 = 0.100, n = 16, p = 0.972).

Spotted bass

Sixteen spotted bass ranging from 10.0 to 17.7 inches TL ($\overline{X}$ – 13.4 inches TL) and from two to 8 years of age were analyzed for mercury (Table 1; Figure 15). Currently, there is no minimum length limit for spotted bass in Texas waters.[52] Mercury concentrations ranged from 0.290 to 1.025 mg/kg with a mean of 0.527±0.214 and a median of 0.532 mg/kg (Table 2d). The mean mercury concentration for spotted bass ≥14 inches was 0.660±0.217 mg/kg. Mercury concentrations in spotted bass were positively related to TL and age (r^2 = 0.368, n = 16, p = 0.013; r^2 = 0.598, n = 16, p < 0.0005; Figures 16–17).

Sunfishes

Five species of sunfish or *panfish* (bluegill, longear sunfish, redbreast sunfish, redear sunfish, and warmouth) ranging from 6.3 to 9.6 inches TL ($\overline{X}$ – 7.4 in TL) were analyzed for mercury (Table 1). Mercury concentrations in all sunfish combined ranged from 0.089 to 0.286 mg/kg with a mean of 0.154±0.059 and a median of 0.139 mg/kg (Table 2d). 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 for all sunfish combined (r = 0.152, n = 33, p = 0.400). The SALG risk assessors also evaluated the relationship between mercury concentration and TL for bluegill and redear sunfish. There was no correlation between the two variables for bluegill and redear sunfish ($r = 0.494$, $n = 12$, $p = 0.102$; $r = -0.420$, $n = 14$, $p = 0.135$).

White bass

Seven white bass ranging from 14.4 to 18.1 inches TL ($\overline{X}$ – 16.6 inches TL) and from two to four years of age were analyzed for mercury (Table 1; Figure 18). One-hundred percent of the white bass samples examined were of legal size (≥ 10 inches TL).[52] Mercury concentrations ranged from 0.378 to 0.920 mg/kg with a mean of 0.696±0.193 and a median of 0.761 mg/kg (Table 2d). Mercury concentrations in white bass were positively related to TL ($r^2 = 0.572$, $n = 7$, $p = 0.049$; Figure 19).

White crappie

Thirty-two white crappie ranging from 8.9 to 13.5 inches TL ($\overline{X}$ – 11.4 inches TL) and from two to 8 years of age were analyzed for mercury (Table 1; Figure 20). Ninety-four percent of the white crappie samples examined were of legal size (≥ 10 inches TL).[52] Mercury concentrations ranged from 0.134 to 0.537 mg/kg with a mean of 0.234±0.083 and a median of 0.214 mg/kg (Table 2d). 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 ($r = 0.323$, $n = 32$, $p = 0.071$). Mercury concentrations in white crappie were positively related to age ($r^2 = 0.718$, $n = 31$, $p < 0.0005$; Figure 21).

Organic Contaminants

Pesticides

The GERG laboratory analyzed 16 fish for 34 pesticides. Fifteen of 16 samples examined contained concentrations of beta-hexachlorocyclohexane (HCH) and gamma-HCH (Table 3a). The mean beta-HCH and gamma-HCH concentrations were 0.003±0.0009 and 0.001±0.0006 mg/kg, respectively. Nine of 16 samples contained low concentrations of delta-HCH (ND-0.003 mg/kg). Trace to low concentrations of 4,4′-DDD, 4,4′-DDE, 2,4′-DDT, 4,4′-DDT, alachlor, and methoxychlor were present in one or more fish samples (data not presented).

PCBs

Thirty-seven of 40 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 0.103 mg/kg with a mean of 0.013±0.015 and a median of 0.010 mg/kg (Table 4). Longnose gar contained the highest mean concentration of PCBs (0.057±0.065 mg/kg).

PCDDs/PCDFs

The GERG laboratory analyzed a subset of 96 fish tissue samples for 17 of the 210 possible PCDF/PCDD (135 PCDFs + 75 PCDDs) congeners from B.A. Steinhagen 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.[53] 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. Table 5 contains summary statistics for PCDDs/PCDFs in fish collected from B.A. Steinhagen 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]). Sixty-nine of 96 fish tissue samples contained at least one of the 17 congeners ranging from ND–6.063 pg/g with a mean of 0.240±0.702 and a median of 0.064 pg/g (Table 5). No samples contained all 17 congeners (data not shown). Hybrid striped bass contained the highest mean TEQ concentration (1.896±0.643 pg/g; Table 5).

SVOCs

The GERG laboratory analyzed a subset of 16 B.A. Steinhagen Reservoir fish tissue samples for SVOCs. Trace concentrations of bis (2-ethylhexyl) phthalate and phenol were present in some fish samples assayed (data not presented). The laboratory detected no other SVOCs in fish from B.A. Steinhagen Reservoir.

VOCs

The GERG laboratory reported the 16 fish tissue samples selected for analysis from B.A. Steinhagen 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, and o-xylene (data not presented). Trace quantities of many VOCs were also present in one or more fish tissue samples assayed from B.A. Steinhagen 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.[37] Despite such limitations, risk assessors must calculate parameters to represent potential toxicity to humans who consume contaminants in fish and other environmental media. The DSHS calculated risk parameters for systemic and carcinogenic endpoints in those who would consume fish from B.A. Steinhagen 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 B.A. Steinhagen Reservoir

Mercury was observed in fish from B.A. Steinhagen Reservoir that equaled or exceeded its HAC_{nonca} (0.700 mg/kg; Tables 2d, 6a, and 6b). One (longnose gar) of 40 fish tissue samples evaluated contained PCBs exceeding the HAC_{nonca} for PCBs (0.047 mg/kg; Tables 4 and 7b). The mean PCB concentrations of the eight species evaluated and the all fish combined mean concentration did not exceed the PCB HAC_{nonca} nor did the HQs exceed 1.0. Two of 96 (hybrid striped bass and longnose gar) fish tissue samples assayed contained PCDDs/PCDFs exceeding the HAC_{nonca} for PCDDs/PCDFs (2.330 pg/g; Tables 5 and 7a–7b). The mean PCDD/PCDF concentrations of the nine species assessed and the all fish combined mean concentration did not exceed the PCDDs/PCDFs HAC_{nonca} nor did the HQs exceed 1.0. No species of fish collected contained any other inorganic or organic contaminants at concentrations that equaled or exceeded the DSHS guidelines for protection of human health or would likely cause systemic risk to human health from consumption of fish from B.A. Steinhagen Reservoir.

Mercury

Four-hundred of 400 fish collected from B.A. Steinhagen Reservoir in 2010 contained mercury (Table 2d). Nine percent of all samples (n = 400) 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: flathead catfish, freshwater drum, largemouth bass, longnose gar, smallmouth buffalo, spotted bass, spotted gar, and white bass. Longnose gar and white bass were the only species of fish that had an overall mean mercury concentration that equaled or exceeded the

HAC_{nonca} for mercury or an HQ of 1.0 (Table 6a). The consumption of longnose gar and white bass from B.A. Steinhagen Reservoir may pose potential systemic health risks.

Positive relationships between mercury concentration and TL and mercury concentration and age were observed in many fish from B.A. Steinhagen Reservoir, indicating that mercury concentrations increase as fish grow (Figures 2–21). Generally, fish age was a better predictor of fish mercury concentration than TL. The SALG risk assessors evaluated these relationships and corresponding regression equations to predict the TL by species at which the mercury concentration equaled or exceeded the HAC_{nonca} for mercury. Blue catfish, channel catfish flathead catfish, and white crappie regression analyses predicted that mercury concentrations equivalent to the HAC_{nonca} for mercury occurred in these species of fish at larger TLs or older ages than represented by the study data. Thus, the SALG risk assessors considered the use of mercury regression equations for catfish and white crappie inappropriate for recommending size class fish consumption advice. The linear regression model for freshwater drum indicated that freshwater drum > 22 inches TL contain mercury concentrations equivalent to the HAC_{nonca} for mercury (Figure 11). However, size category mean mercury concentration calculations indicate that freshwater drum ≥ 20 inches TL contain mercury concentrations equivalent to the HAC_{nonca} for mercury (Table 2e). The mercury–TL linear regression equation for largemouth bass estimated that largemouth bass > 18 inches TL contain mercury concentrations equivalent to the HAC_{nonca} for mercury (Figure 13). The mercury–age linear regression equation 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 bass show that largemouth bass ≥ 16 inches TL contain mercury concentrations equivalent to the HAC_{nonca} for mercury (Table 2e). The mercury–TL linear regression equation for spotted bass estimated that spotted bass > 15 inches TL contain mercury concentrations equivalent to the HAC_{nonca} for mercury (Figure 16). The mercury–age linear regression equation for spotted bass predicted that spotted bass ≥ 5 years of age contain mercury concentrations equivalent to the HAC_{nonca} for mercury (Figure 17). The calculation of size class mean mercury concentrations for spotted bass show that spotted bass ≥ 14 in TL contain mercury concentrations equivalent to the HAC_{nonca} for mercury (Table 2e). The linear regression model for white bass estimated that white bass > 16 inches TL contain mercury concentrations equivalent to the HAC_{nonca} for mercury (Figure 19).

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 B.A. Steinhagen 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 equation, or size class mean mercury concentration) by species. The SALG risk assessors estimated that healthy adults could consume 0.8 (eight-ounce) meals per week of freshwater drum ≥ 20 inches TL, 0.9 (eight-ounce) meals per week of largemouth bass ≥ 16 inches TL, 0.9 (eight-ounce) meal per week of longnose gar, 0.9 (eight-ounce) meals per week of spotted bass ≥ 14 inches TL, and 0.9 (eight-ounce) meals per week of white bass containing mercury. The SALG risk assessors suggest that fish from B.A. Steinhagen Reservoir contain mercury at concentrations that may pose potential systemic health risks and that people should limit their consumption of freshwater drum ≥ 20 inches TL, largemouth bass ≥ 16 inches

TL, longnose gar (all sizes), spotted bass ≥ 14, and white bass (all sizes) from B.A. Steinhagen 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.

Characterization of Theoretical Lifetime Excess Cancer Risk from Consumption of Fish from B.A. Steinhagen Reservoir

The USEPA classifies arsenic, most chlorinated pesticides, PCBs, and PCDDs/PCDFs as carcinogens. Although arsenic, chlorinated pesticides, PCBs, and PCDDs/PCDFs were present in fish samples from B.A. Steinhagen Reservoir, none of these contaminants evaluated singly by species, or all fish combined had mean contaminant concentrations that would be likely to increase the risk of cancer to exceed the DSHS guideline for protection of human health of one excess cancer in 10,000 equally exposed individuals (Tables 8a–8b).

Characterization of Calculated Cumulative Systemic Health Effects and of Cumulative Excess Lifetime Cancer Risk from Consumption of Fish from B.A. Steinhagen 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 B.A. Steinhagen Reservoir fish could have these properties, especially with respect to effects on the immune system. Multiple organic contaminants in the B.A. Steinhagen Reservoir samples did increase the likelihood of systemic adverse health outcomes from consuming hybrid striped bass and longnose gar from B.A. Steinhagen Reservoir (Tables 7a–7b). The combined toxicity of PCBs and PCDDs/PCDFs in hybrid striped bass and longnose gar exceeded a HI of 1.0. Consuming other fish from B.A. Steinhagen 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 B.A. Steinhagen Reservoir that healthy adults could consume without significant risk of adverse systemic effects (Tables 7a–7b). The SALG estimated this group could consume 0.9 (eight-ounce) meals per week of hybrid striped bass and 0.5 (eight-ounce) meals per week of longnose gar containing PCBs and PCDDs/PCDFs. The SALG risk assessor suggest that fish from B.A. Steinhagen Reservoir contain PCBs and PCDDs/PCDFs at concentrations that may pose potential systemic health risks and that people should limit their consumption of hybrid striped bass and longnose gar from B.A. Steinhagen Reservoir. The developing nervous system of the human fetus and young children may be especially susceptible to these effects.

The SALG also queried the probability of increasing lifetime excess cancer risk from consuming fish containing multiple inorganic and organic contaminants. In most assessments of cancer risk from environmental exposures to chemical mixtures, researchers have considered any increase in cancerous or benign growths in one or more organs as cumulative, no matter the mode or mechanism of action of the contaminant. In this assessment, risk assessors added the calculated carcinogenic effect of arsenic, chlorinated pesticides, PCBs, and PCDFs/PCDDs (all data not presented; Tables 8a–8b). 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 B.A. Steinhagen Reservoir

Notwithstanding, the 2010 B.A. Steinhagen 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 B.A. Steinhagen Reservoir only, as well as protect those who may consume fish from other waters within the same watershed (i.e. Neches River or Sam Rayburn Reservoir) 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.

Mercury concentrations in blue and flathead catfish from B.A. Steinhagen Reservoir indicate potential consumption risks associated with consuming larger size classes of these species not represented in the 2010 dataset. To better characterize the potential consumption risks associated with larger size classes of blue and flathead catfish, the DSHS SALG risk assessors combined blue and flathead catfish mercury data from the Neches River (2007), B.A. Steinhagen Reservoir, and Sam Rayburn Reservoir (2010–2011). One-hundred nine blue catfish contained mercury concentrations ranging from 0.031 to 1.332 mg/kg with a mean of 0.264±0.198 and a median of 0.224 mg/kg (Table 9). Mercury concentrations in blue catfish were positively related to TL ($r^2 = 0.446$, $n = 109$, $p < 0.0005$ Figure 22). The mercury–TL regression model for blue catfish estimated that blue catfish > 36 inches TL contain mercury concentrations equivalent to the HAC_{nonca} for mercury. The calculations of size class mean mercury concentrations for blue catfish indicate that blue catfish > 30 inches TL contain mercury concentrations equivalent to the HAC_{nonca} for mercury (Table 9). Sixty flathead catfish contained mercury concentrations ranging from 0.117 to 2.406 mg/kg with a mean of 0.439±0.334 and a median of 0.377 mg/kg (Table 9). Mercury concentrations in flathead catfish were positively related to TL ($r^2 = 0.379$, $n = 60$, $p < 0.0005$ Figure 23). The mercury–TL regression model for flathead catfish estimated that flathead catfish > 30 inches TL contain mercury concentrations equivalent to the HAC_{nonca} for mercury. The calculations of size class mean mercury concentrations for flathead catfish indicate that flathead catfish > 27 inches TL contain mercury concentrations equivalent to the HAC_{nonca} for mercury (Table 9).

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%.[54] 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 B.A. Steinhagen Reservoir in

2010 (Table 10). The recoveries and yields for an average fish of each species from B.A. Steinhagen Reservoir in 2010 ranged from 0.3–8.8 eight-ounce meals. Based on recoveries and yields ($\overline{X}$ – 38%) from whole fish to skin-off fillets for this project, the average B.A. Steinhagen fish yields 1.4 pounds of skin-off fillets or approximately three eight-ounce meals (Table 10). To illustrate the importance of potential exposure from large catfish, buffalo, or gar let us consider the flathead catfish mean mercury concentration (0.318 mg/kg) for this project. Based on a mean mercury concentration of 0.318 mg/kg, a person consuming eight eight-ounce meals per month would exceed the MRL. The maximum size flathead catfish (20.9 pounds) for this project yields 8.0 pounds of skin-off fillets, approximately 16 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 B.A. Steinhagen 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 B.A. Steinhagen Reservoir, located in Jasper and Tyler Counties, Texas. Risk assessors from the SALG conclude from the present characterization of potential adverse health effects from consuming fish from B.A. Steinhagen Reservoir that:

1. Alligator gar, blue catfish, flathead 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. Alligator gar, blue catfish, channel catfish, flathead catfish, largemouth bass, and white bass do not contain any PCB or PCDD/PCDF concentrations, either singly or in combination, that exceed the DSHS guidelines for protection of human health. Therefore, consumption of these species containing PCBs or PCDDs/PCDFs **poses no apparent risk to human health**.

3. Spotted gar do not contain any PCDD/PCDF concentrations that exceed the DSHS guidelines for protection of human health. Therefore, consumption of spotted gar containing PCDDs/PCDFs **poses no apparent risk to human health**.

4. Alligator gar, blue catfish, bluegill, channel catfish, hybrid striped bass, longear sunfish, redbreast sunfish, redear sunfish, warmouth, and white crappie do not contain any mercury concentrations that 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 blue catfish, flathead catfish, and gar not represented in the fish 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 blue catfish, flathead catfish, and gar from B.A. Steinhagen Reservoir as of **unknown significance to human health.**

6. Freshwater drum > 20 inches TL, largemouth bass > 16 inches TL, longnose gar, spotted bass > 14 inches TL, and white bass contain mercury at concentrations exceeding the DSHS guidelines for protection of human health. Regular or long-term consumption of these fishes may result in adverse systemic health effects. Therefore, consumption of these species from B.A. Steinhagen Reservoir **poses an apparent risk to human health**.

7. Evaluation of combined datasets from the Neches River, B.A. Steinhagen Reservoir, and Sam Rayburn Reservoir indicate that larger size classes of blue catfish and flathead catfish contain mercury at concentrations exceeding the DSHS guidelines for protection of human health. Regular or long-term consumption of blue catfish > 30 inches TL or flathead catfish > 27 inches TL may result in adverse systemic health effects. Therefore, consumption of larger size classes of blue and flathead catfish from B.A. Steinhagen Reservoir **poses an apparent risk to human health**.

8. One of two hybrid striped bass samples assayed contains PCDDs/PCDFs at a concentration exceeding the DSHS guidelines for protection of human health. Due to the small sample size of hybrid striped bass, the SALG risk assessors are unable to characterize adequately health risks associated with consuming PCDD/PCDF-contaminated hybrid striped bass from B.A. Steinhagen Reservoir. Therefore, the SALG characterizes the likelihood of adverse health effects from regular consumption of PCDD/PCDF-contaminated hybrid striped bass from B.A. Steinhagen Reservoir as of **unknown significance to human health.**

9. One of two longnose gar samples assayed contains PCBs at a concentration exceeding the DSHS guidelines for protection of human health and one of six longnose gar samples evaluated contains PCDDs/PCDFs at a concentration exceeding DSHS guidelines for protection of human health. Due to the small sample size of longnose gar and the variability of PCB and PCDD/PCDF concentrations observed in longnose gar samples, the SALG risk assessors are unable to characterize adequately health risks associated with consuming PCB and/or PCDD/PCDF-contaminated longnose gar from B.A. Steinhagen Reservoir. Therefore, the SALG characterizes the likelihood of adverse health effects from regular consumption of PCB and/or PCDD/PCDF-contaminated longnose gar from B.A. Steinhagen Reservoir as of **unknown significance to human health.**

10. Consumption of multiple organic contaminants in hybrid striped bass and longnose gar does increase the likelihood of systemic health risks. However, due to the small sample sizes of hybrid striped bass and longnose gar and variability of organic contaminant concentrations observed in hybrid striped bass and longnose gar samples, the SALG risk assessors are unable to characterize adequately health risks associated with consuming PCB and/or PCDD/PCDF-contaminated hybrid striped bass and longnose gar from B.A. Steinhagen Reservoir. Therefore, the SALG characterizes the likelihood of adverse health effects from regular consumption of PCB and/or PCDD/PCDF-contaminated hybrid striped bass and longnose gar from B.A. Steinhagen Reservoir as of **unknown significance to human health.**

11. Consumption of multiple inorganic or organic contaminants in fish does not significantly increase the likelihood of systemic or carcinogenic health risks observed in fish (excluding hybrid striped bass and longnose gar) from B.A. Steinhagen Reservoir. Therefore, SALG risk assessors conclude that consuming fish (excluding hybrid striped bass and longnose gar) containing multiple contaminants at concentrations near those observed in fish from B.A. Steinhagen 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 EPA.[20, 24, 55] 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).[56] Declarations of prohibited harvesting areas are enforceable under the Texas Health and Safety Code, Subchapter D, parts 436.091 and 436.101.[56] 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), largemouth bass, smallmouth buffalo, and/or spotted bass from B.A. Steinhagen Reservoir **poses an apparent hazard to public health.** Therefore, SALG risk assessors recommend that:

1. People should not consume smallmouth buffalo from B.A. Steinhagen 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 , and spotted bass > 16 inches TL from B.A. Steinhagen Reservoir (Table 11).

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 B.A. Steinhagen 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 B.A. Steinhagen Reservoir.

5. The continuation 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 from B.A. Steinhagen Reservoir in this study and the 1995 study are likely fish that escaped from Sam Rayburn Reservoir during water releases into the Angelina River–B.A. Steinhagen Reservoir. Stocking records from TPWD indicate that the stocking of hybrid striped bass has not occurred in B.A. Steinhagen Reservoir. 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 B.A. Steinhagen 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.[57]
- 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.[58] The SALG regularly updates this Web site.
- The DSHS also provides EPA (http://epa.gov/waterscience/fish/advisories/), the TCEQ (http://www.tceq.state.tx.us), and the TPWD (http://www.tpwd.state.tx.us) with information on all consumption advisories and possession bans. Each year, the TPWD informs the fishing and hunting public of consumption advisories and fishing bans on its Web site and in an official downloadable publication containing general hunting and fishing regulations available at http://www.tpwd.state.tx.us/publications/nonpwdpubs/media/cs_bk_k0700_284_2011_20

12.pdf [52] A booklet containing this information is available at all establishments selling Texas fishing licenses.[59]

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 EPA's IRIS Web site (http://www.epa.gov/iris/) contains information on environmental contaminants found in food and environmental media.
- The ATSDR, Division of Toxicology (888-42-ATSDR or 888-422-8737 or the ATSDR's Web site (http://www.atsdr.cdc.gov) supplies brief information via ToxFAQs.™ ToxFAQs™ are available on the ATSDR Web site in either English (http://www.atsdr.cdc.gov/toxfaq.html) or Spanish (http://www.atsdr.cdc.gov/es/toxfaqs/es _toxfaqs.html). The ATSDR also publishes more in-depth reviews of many toxic substances in its *Toxicological Profiles* (ToxProfiles™) 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. B.A. Steinhagen Reservoir Sample Sites

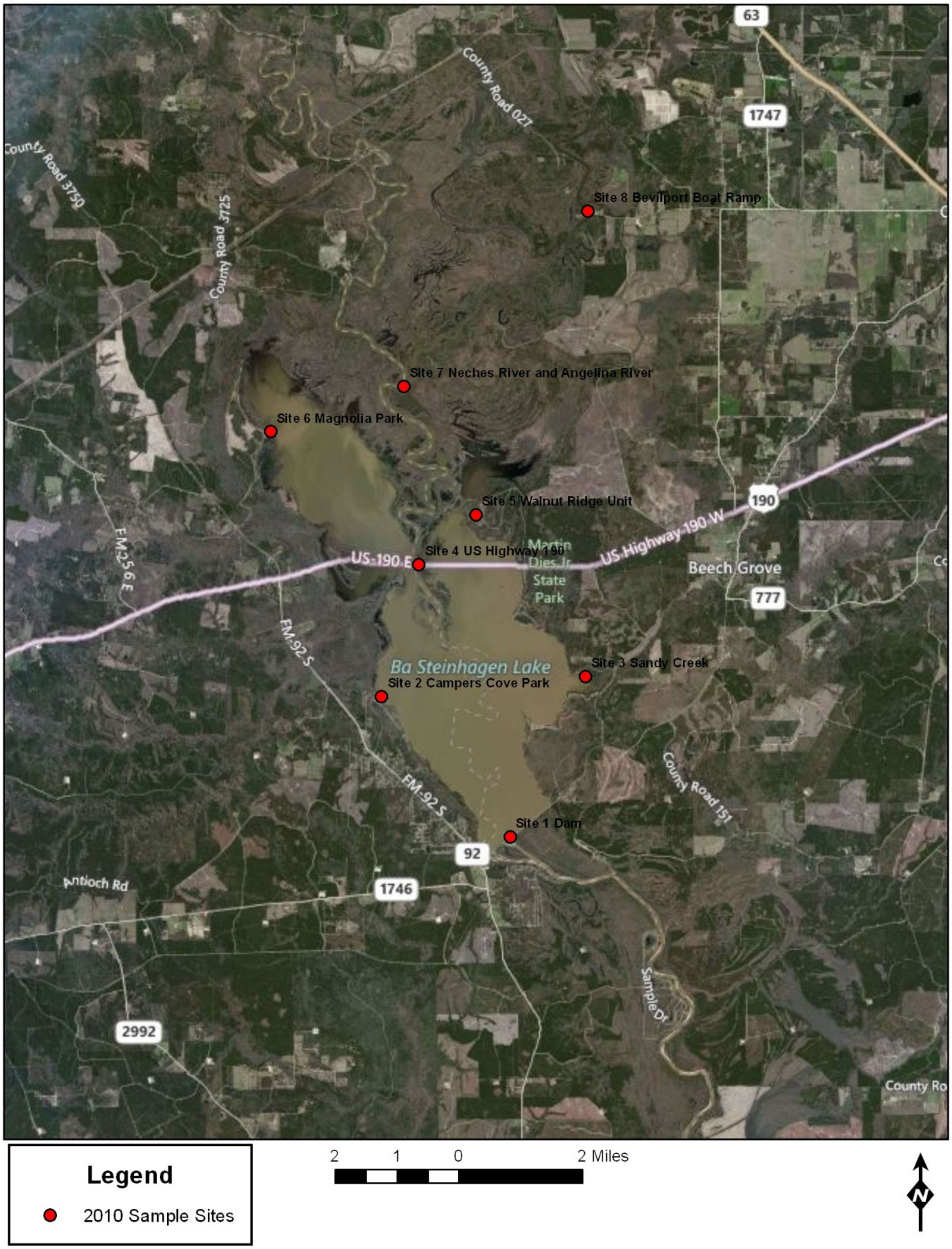


Figure 2. Length at age for blue catfish collected from B.A. Steinhagen Reservoir, Texas, 2010.

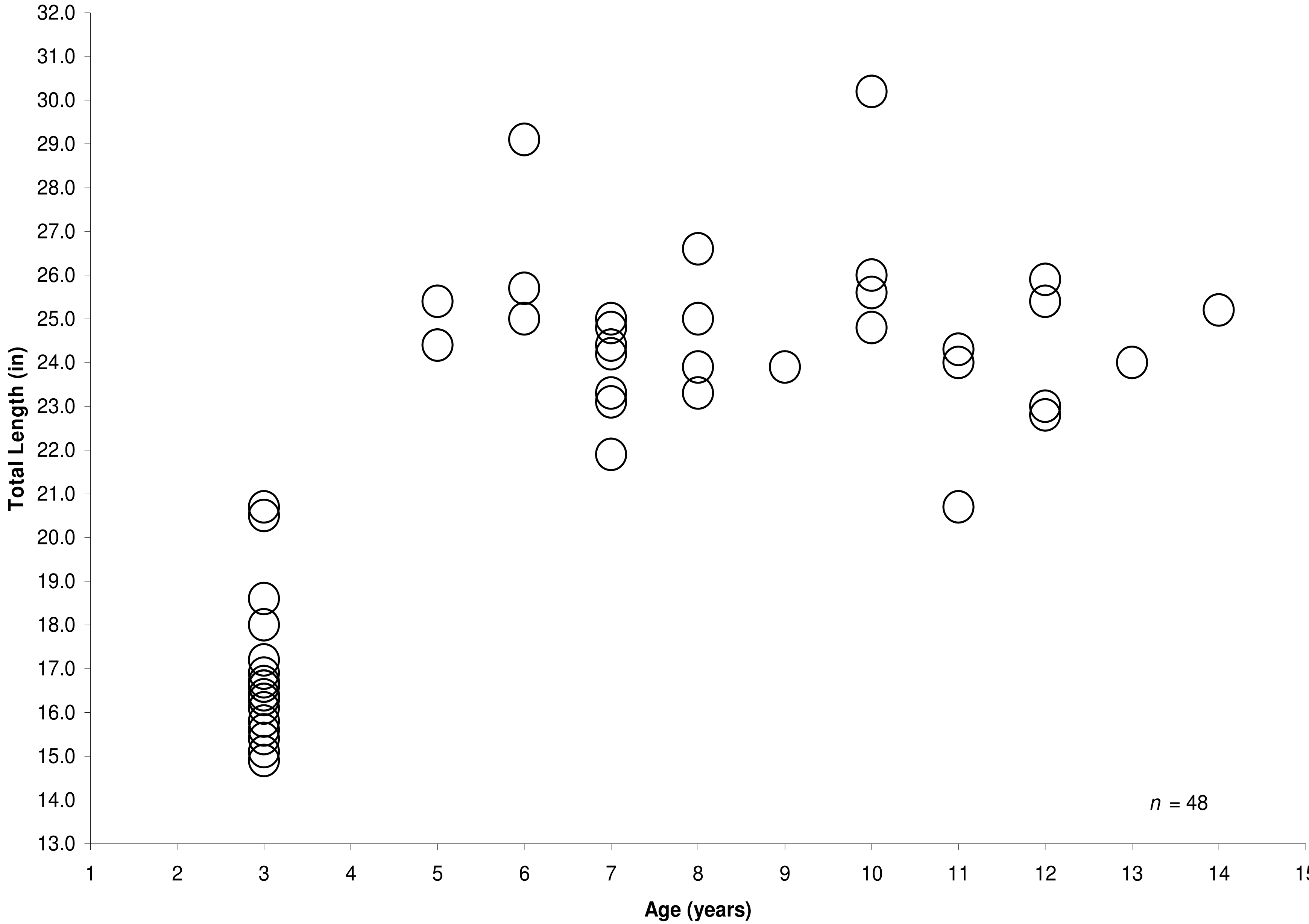


Figure 3. Relationship between mercury concentration and total length for blue catfish collected from B.A. Steinhagen Reservoir, Texas, 2010.

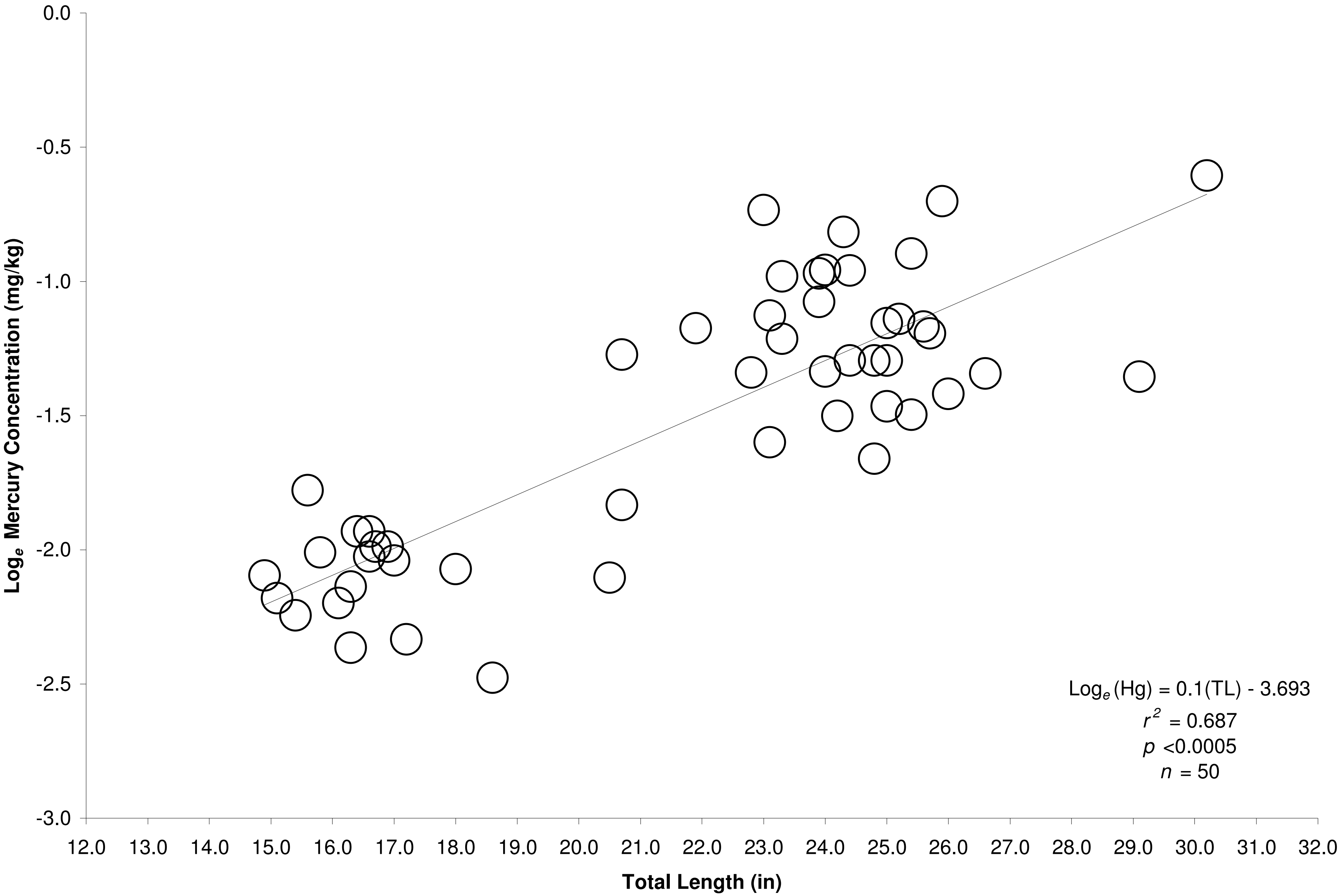


Figure 4. Relationship between mercury concentration and age for blue catfish collected from B.A. Steinhagen Reservoir, Texas, 2010.

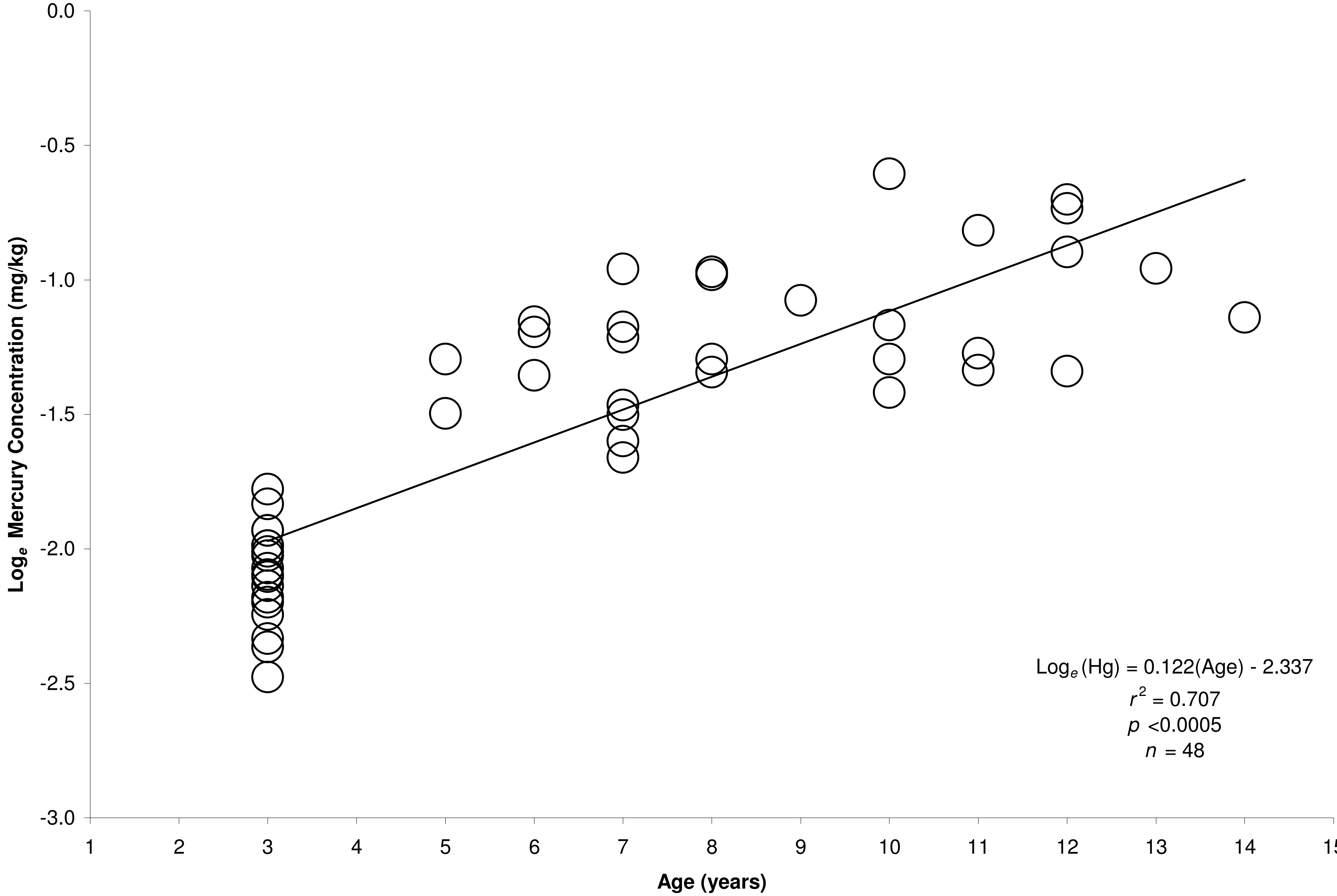


Figure 5. Length at age for channel catfish collected from B.A. Steinhagen Reservoir, Texas, 2010.

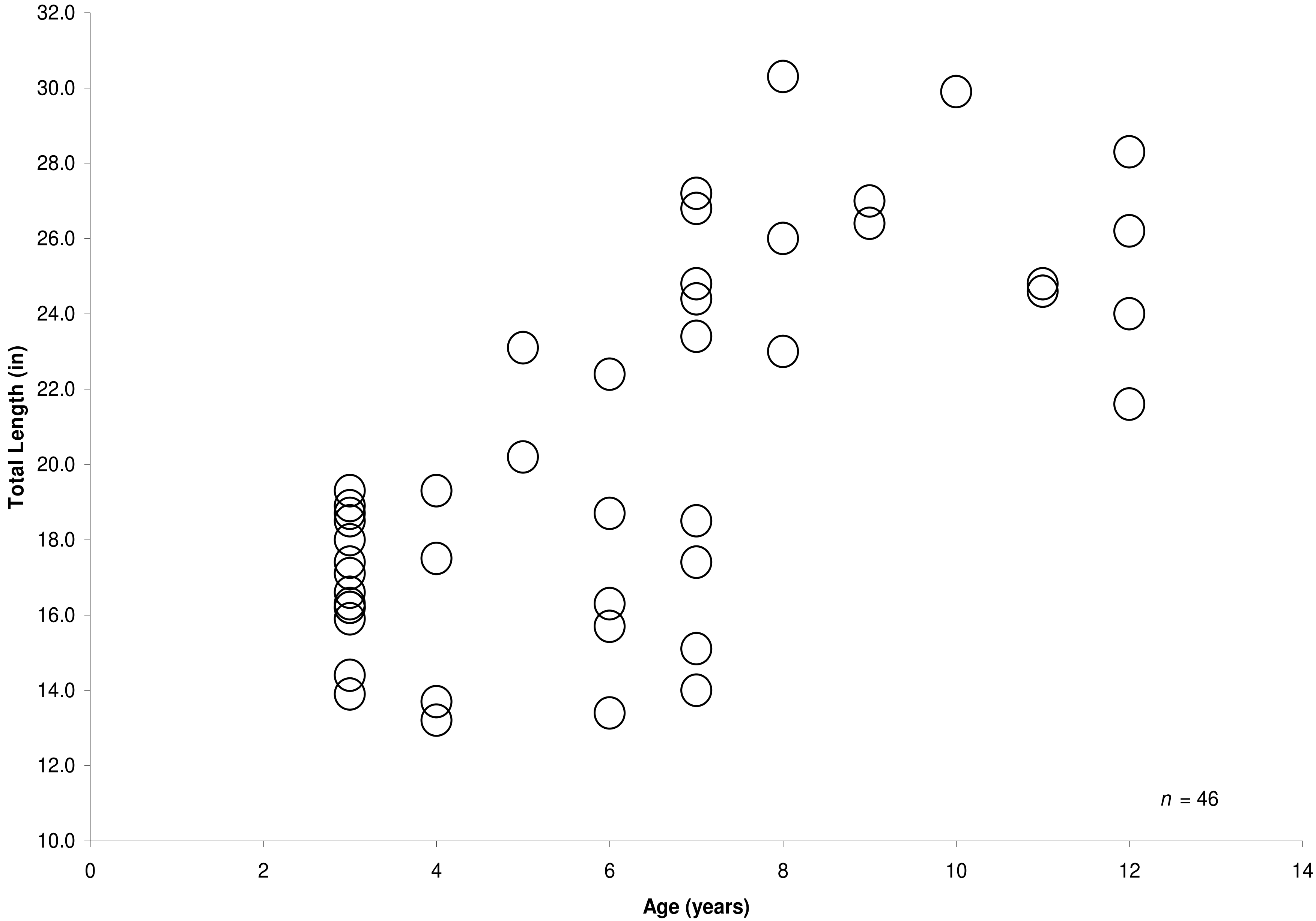


Figure 6. Relationship between mercury concentration and total length for channel catfish collected from B.A. Steinhagen Reservoir, Texas, 2010.

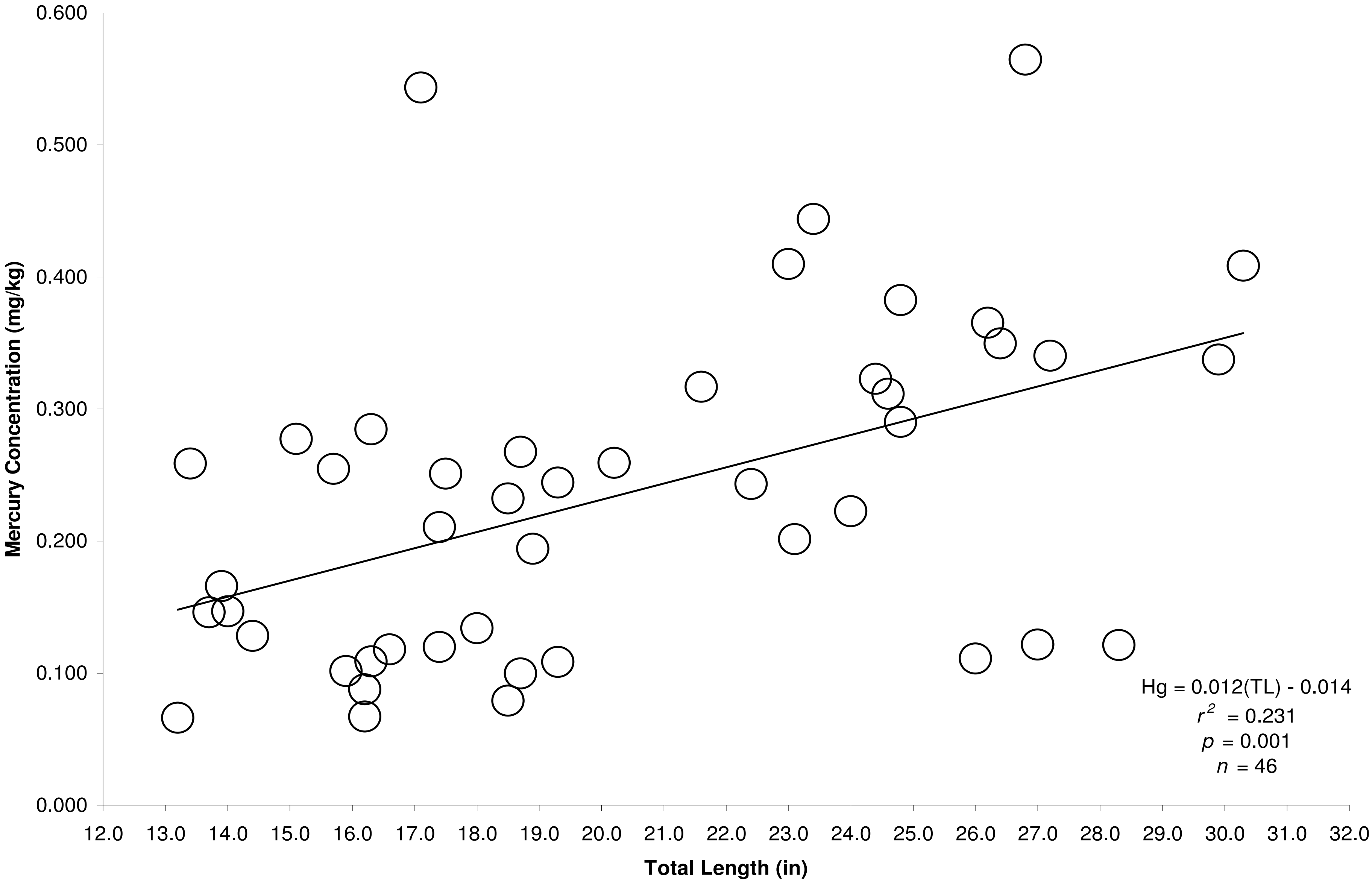


Figure 7. Relationship between mercury concentration and age for channel catfish collected from B.A. Steinhagen Reservoir, Texas, 2010.

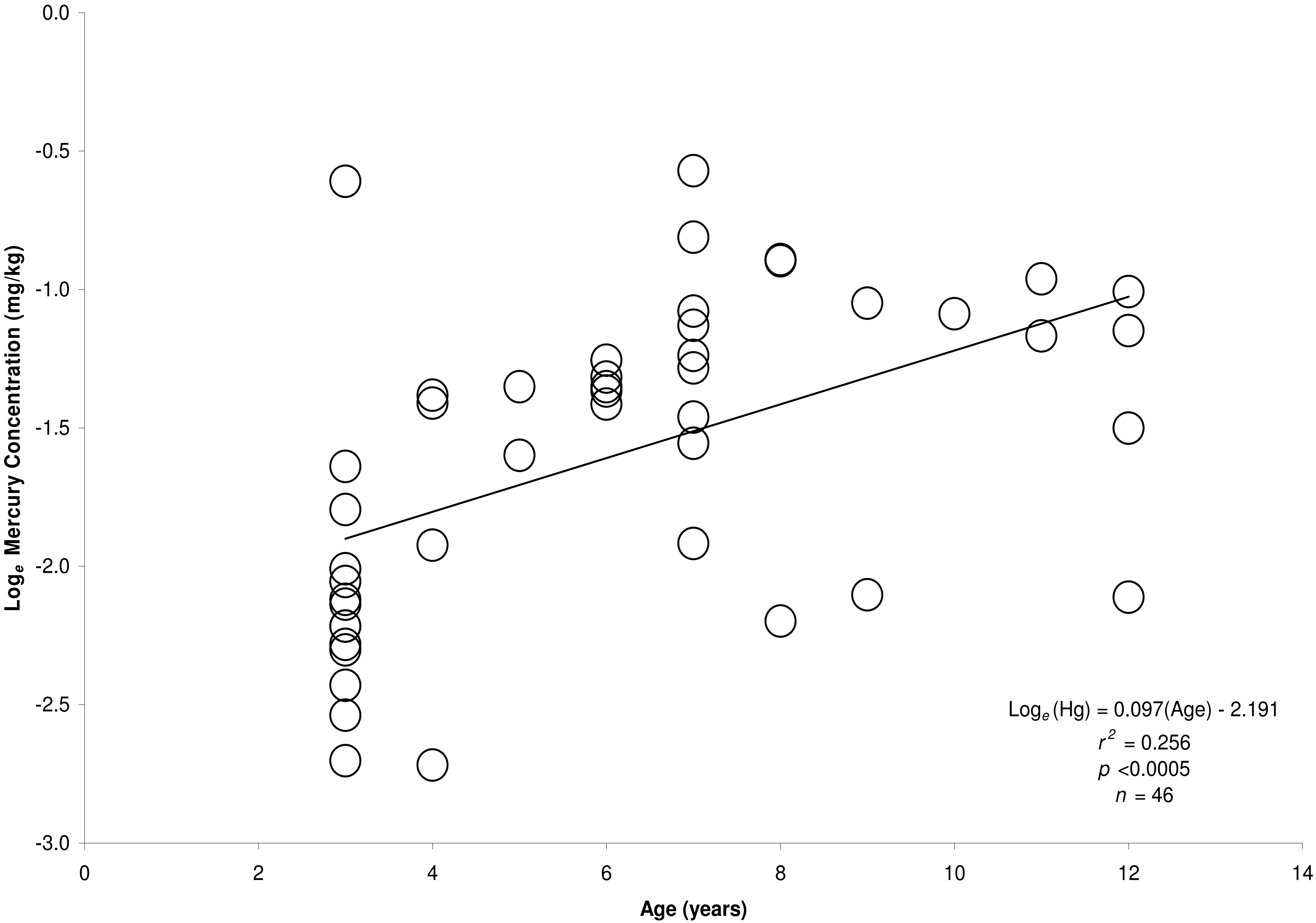


Figure 8. Length at age for flathead catfish collected from B.A. Steinhagen Reservoir, Texas, 2010.

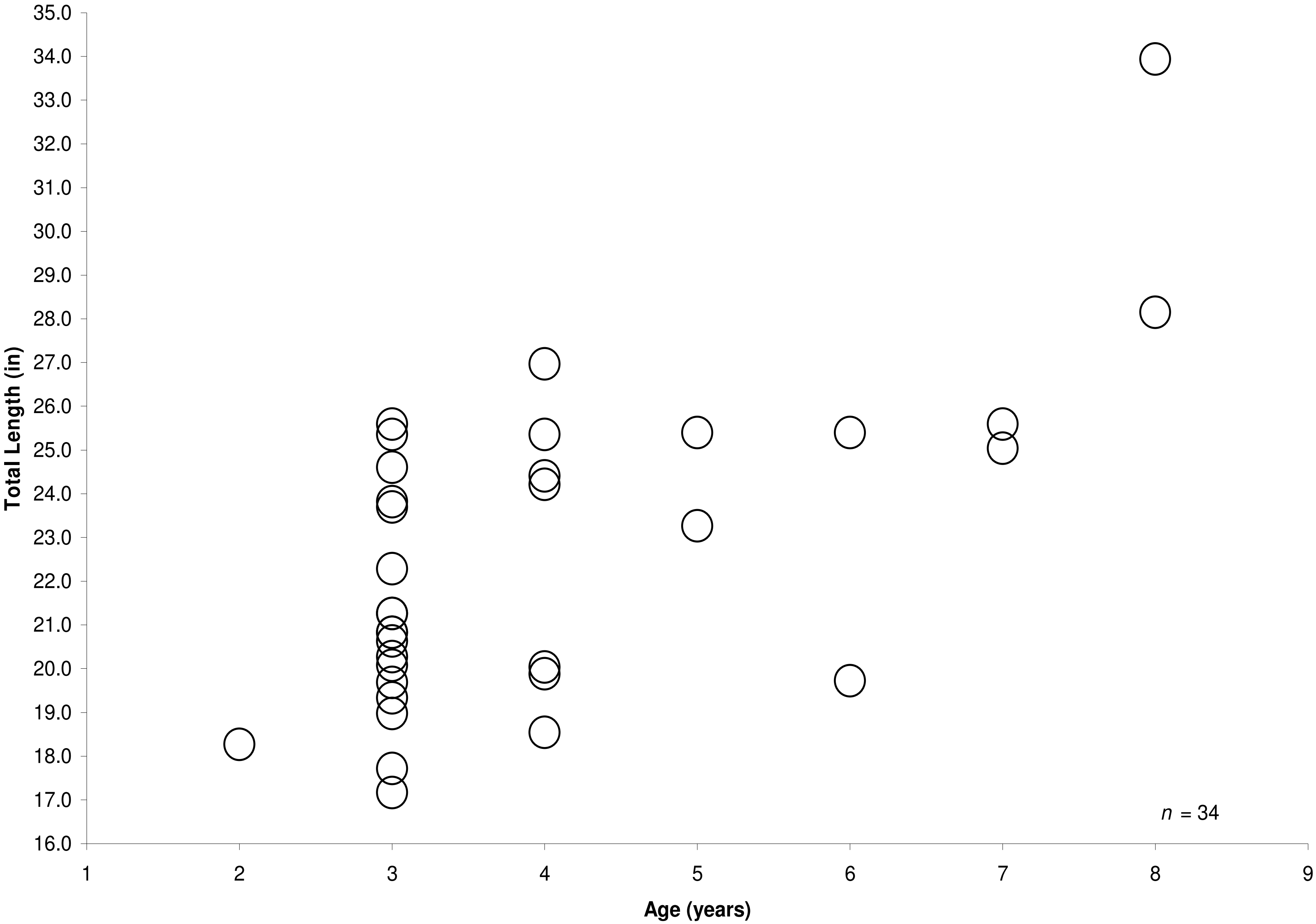


Figure 9. Relationship between mercury concentration and total length for flathead catfish collected from B.A. Steinhagen Reservoir, Texas, 2010.

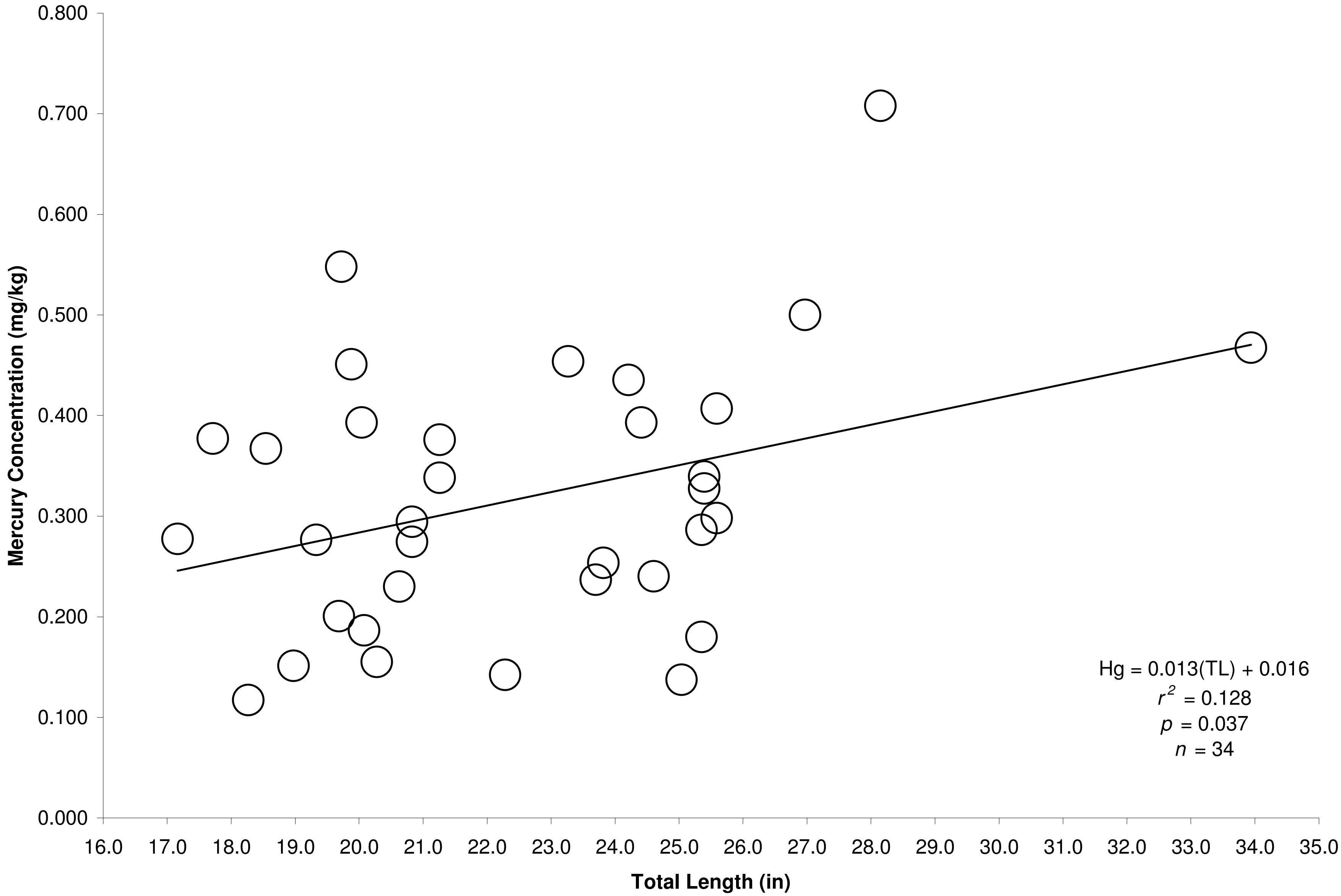


Figure 10. Relationship between mercury concentration and age for flathead catfish collected from B.A. Steinhagen Reservoir, Texas, 2010.

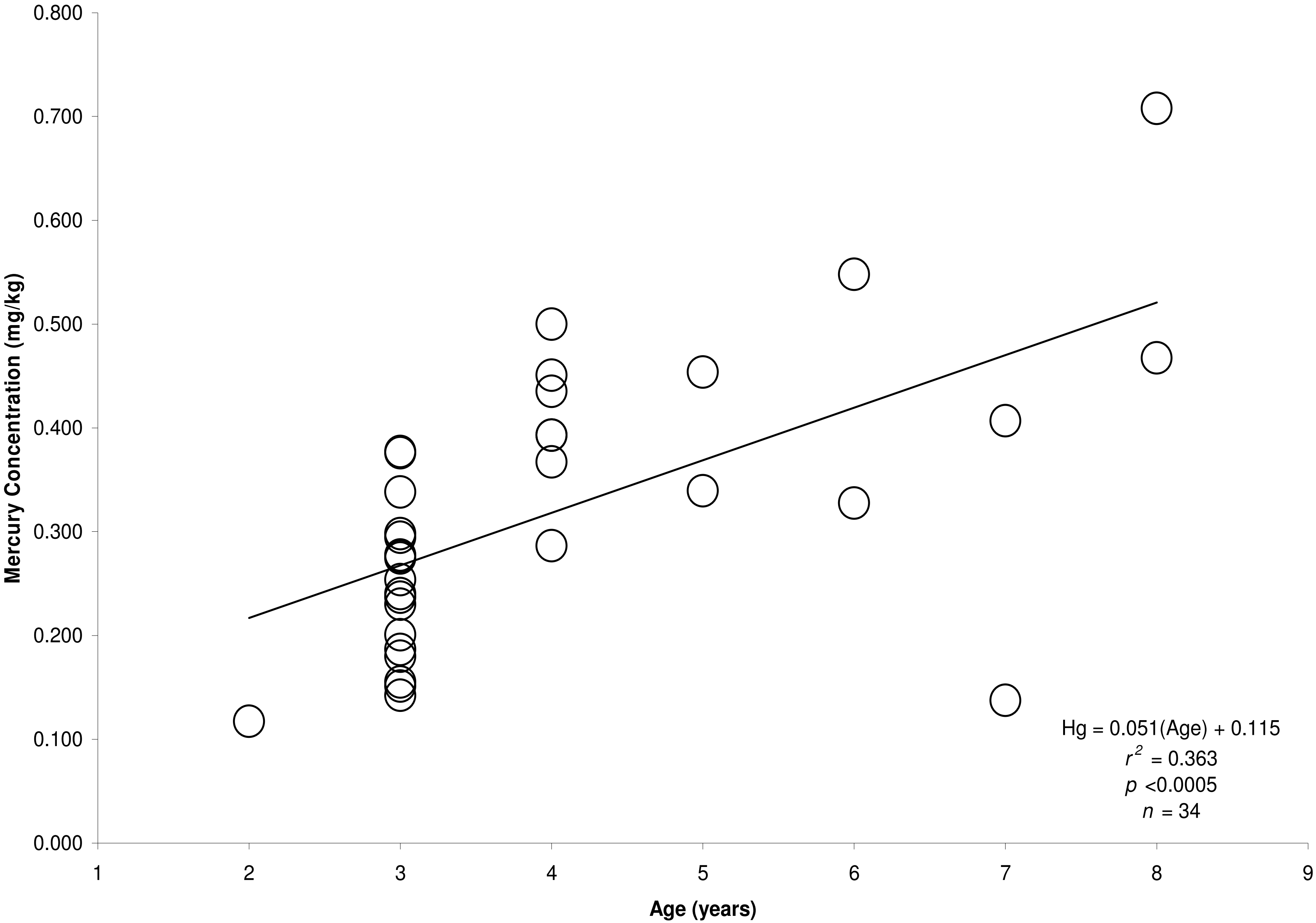


Figure 11. Relationship between mercury concentration and total length for freshwater drum collected from B.A. Steinhagen Reservoir, Texas, 2010.

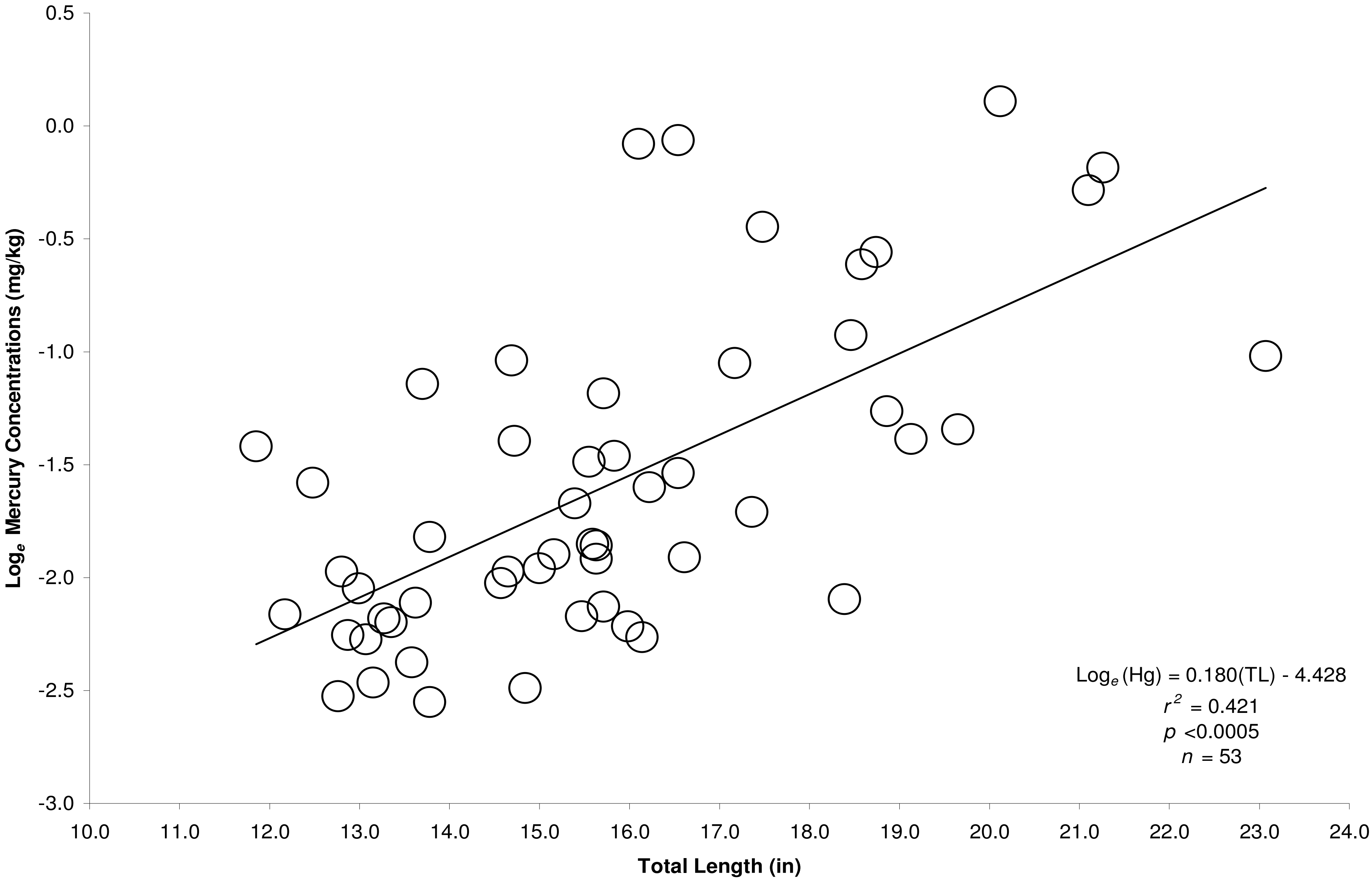


Figure 12. Length at age for largemouth bass collected from B.A. Steinhagen Reservoir, Texas, 2010.

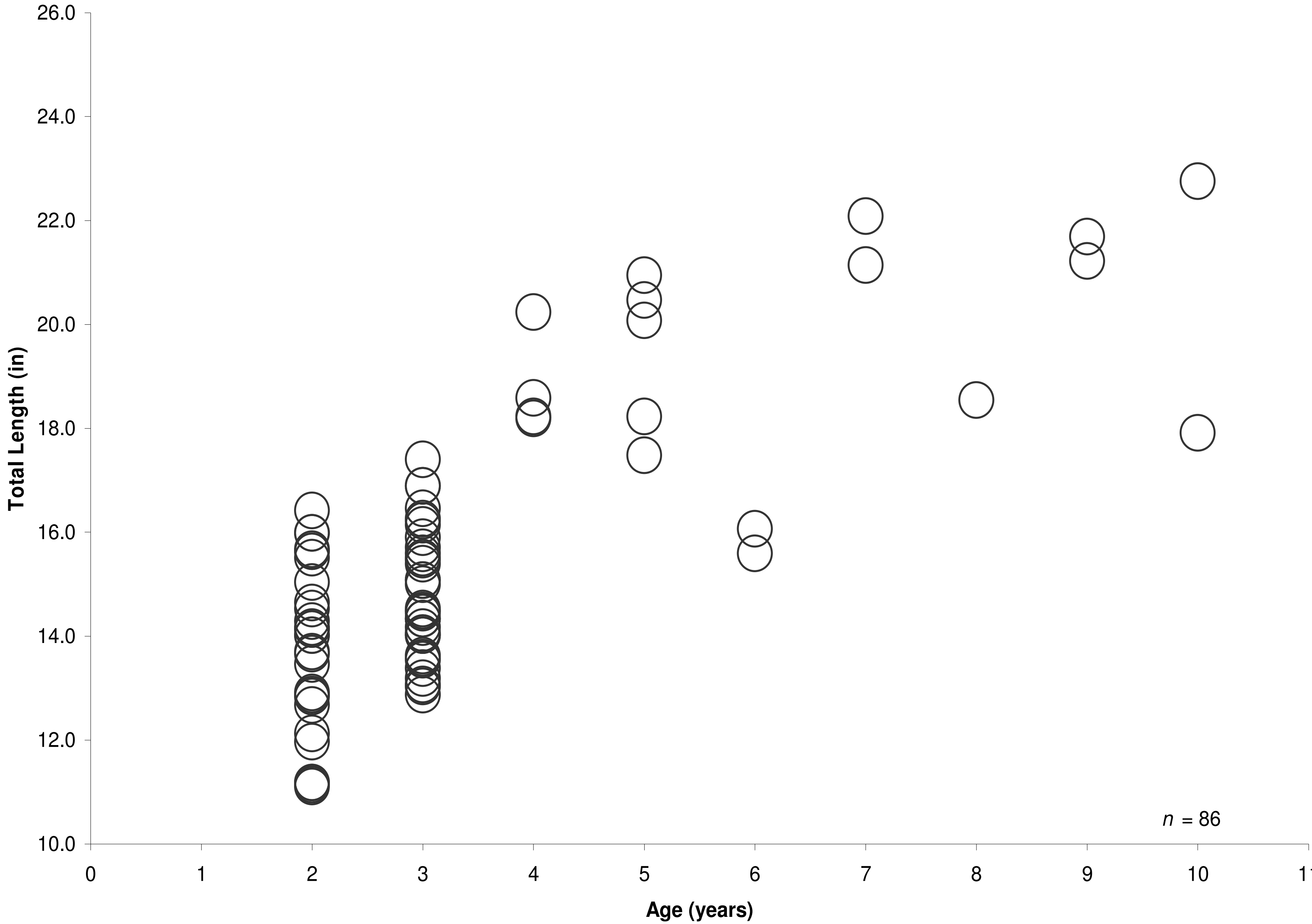


Figure 13. Relationship between mercury concentration and total length for largemouth bass collected from B.A. Steinhagen Reservoir, Texas, 2010.

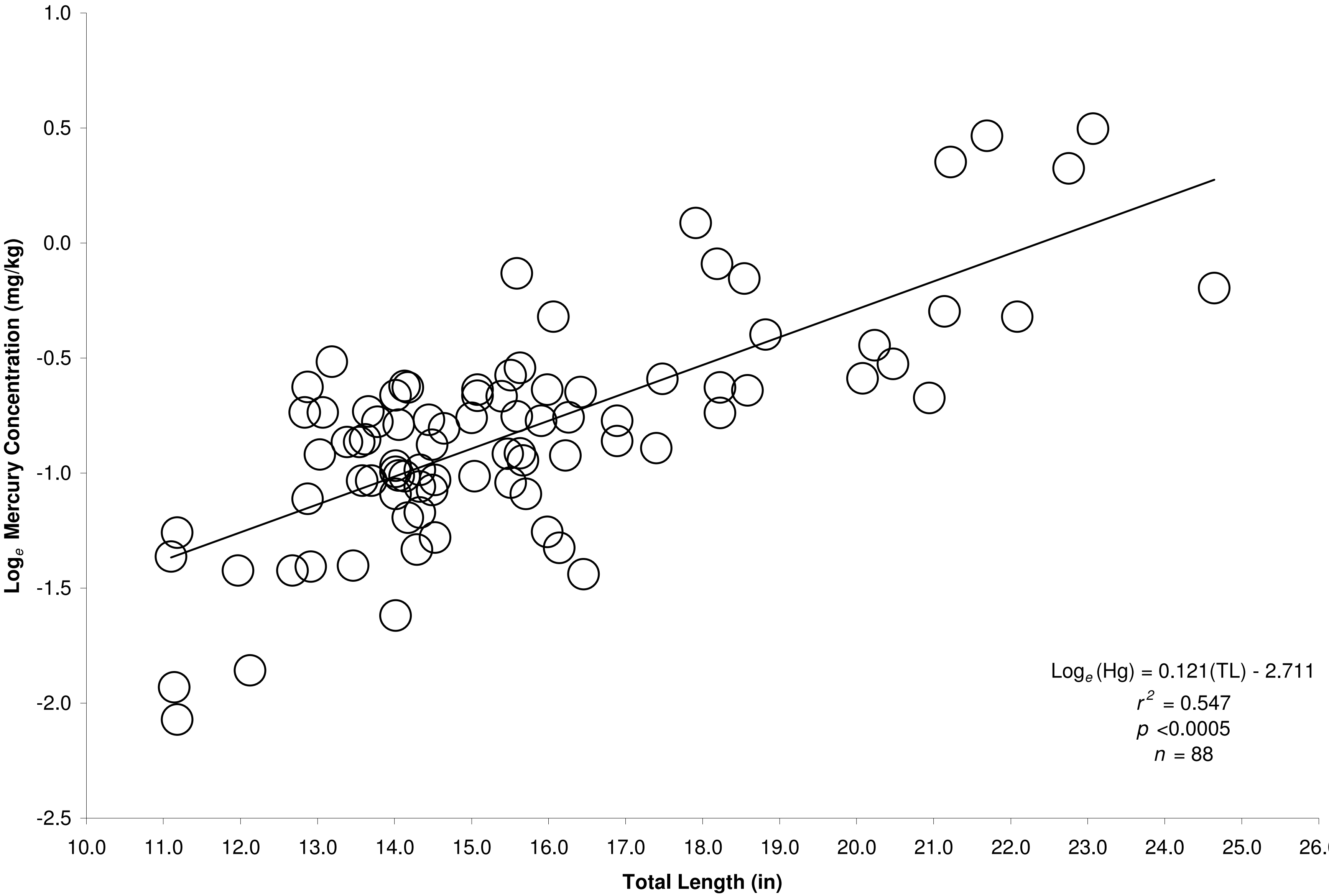


Figure 14. Relationship between mercury concentration and age for largemouth bass collected from B.A. Steinhagen Reservoir, Texas, 2010.

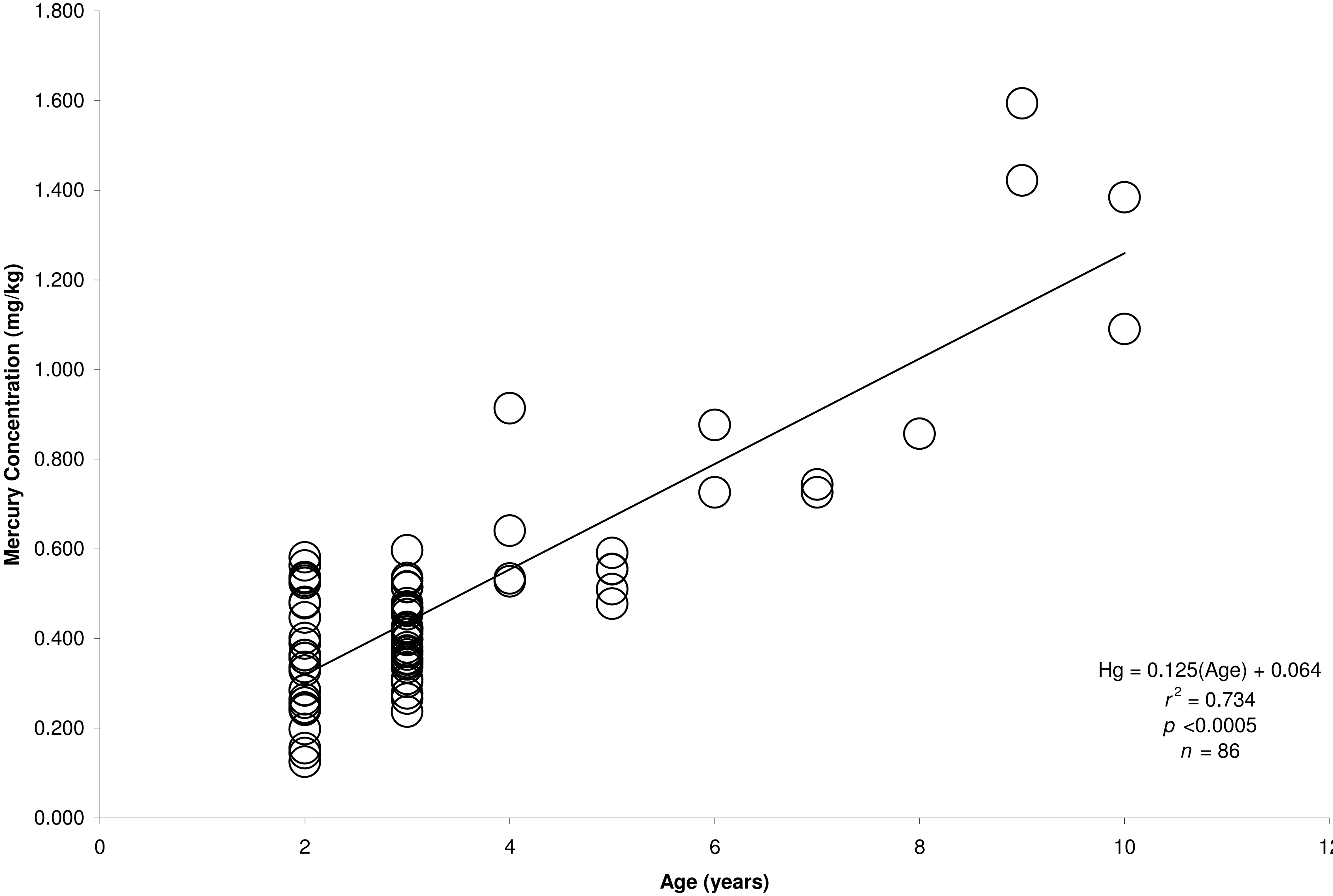


Figure 15. Length at age for spotted bass collected from B.A. Steinhagen Reservoir, Texas, 2010.

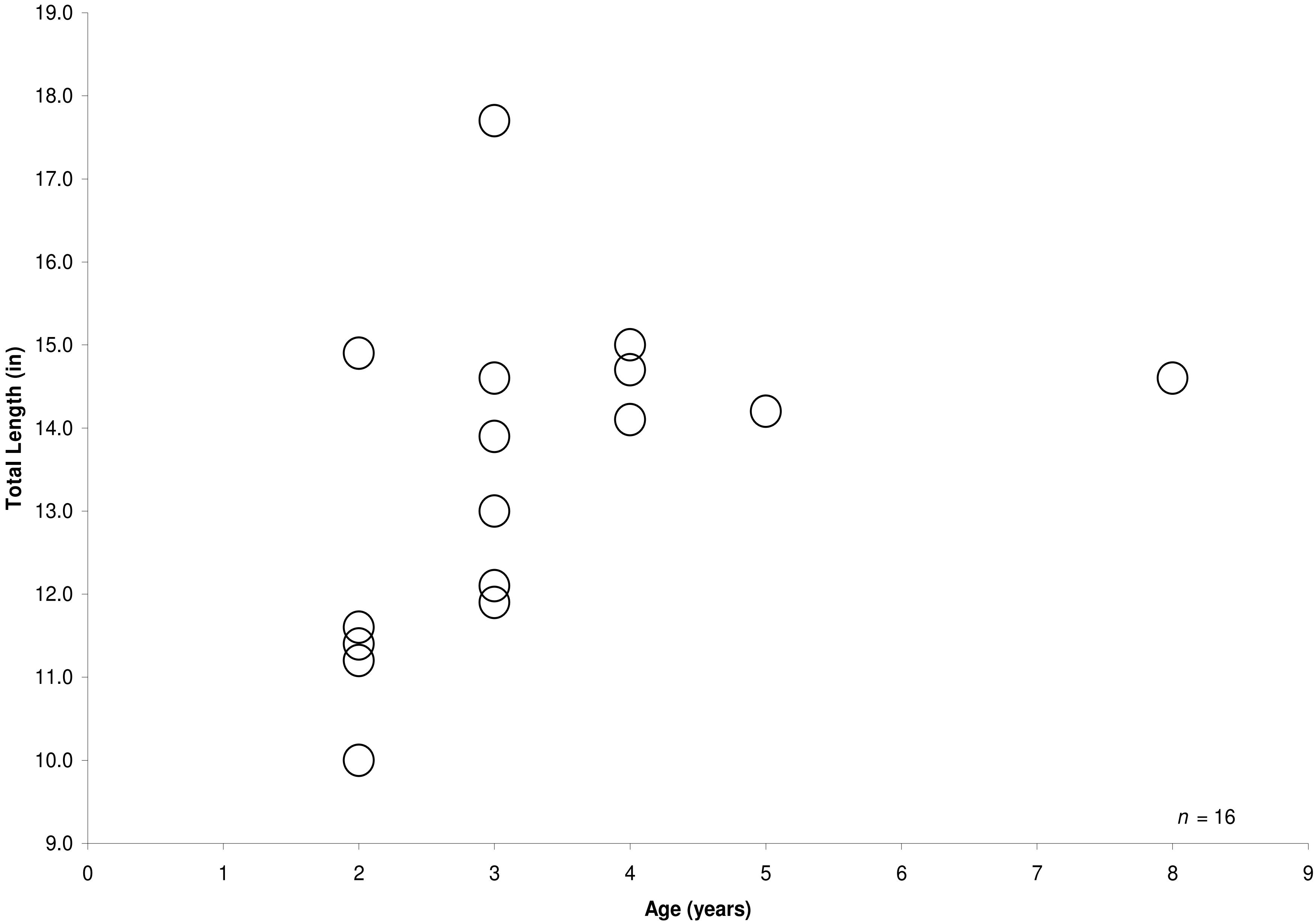


Figure 16. Relationship between mercury concentration and total length for spotted bass collected from B.A. Steinhagen Reservoir, Texas, 2010.

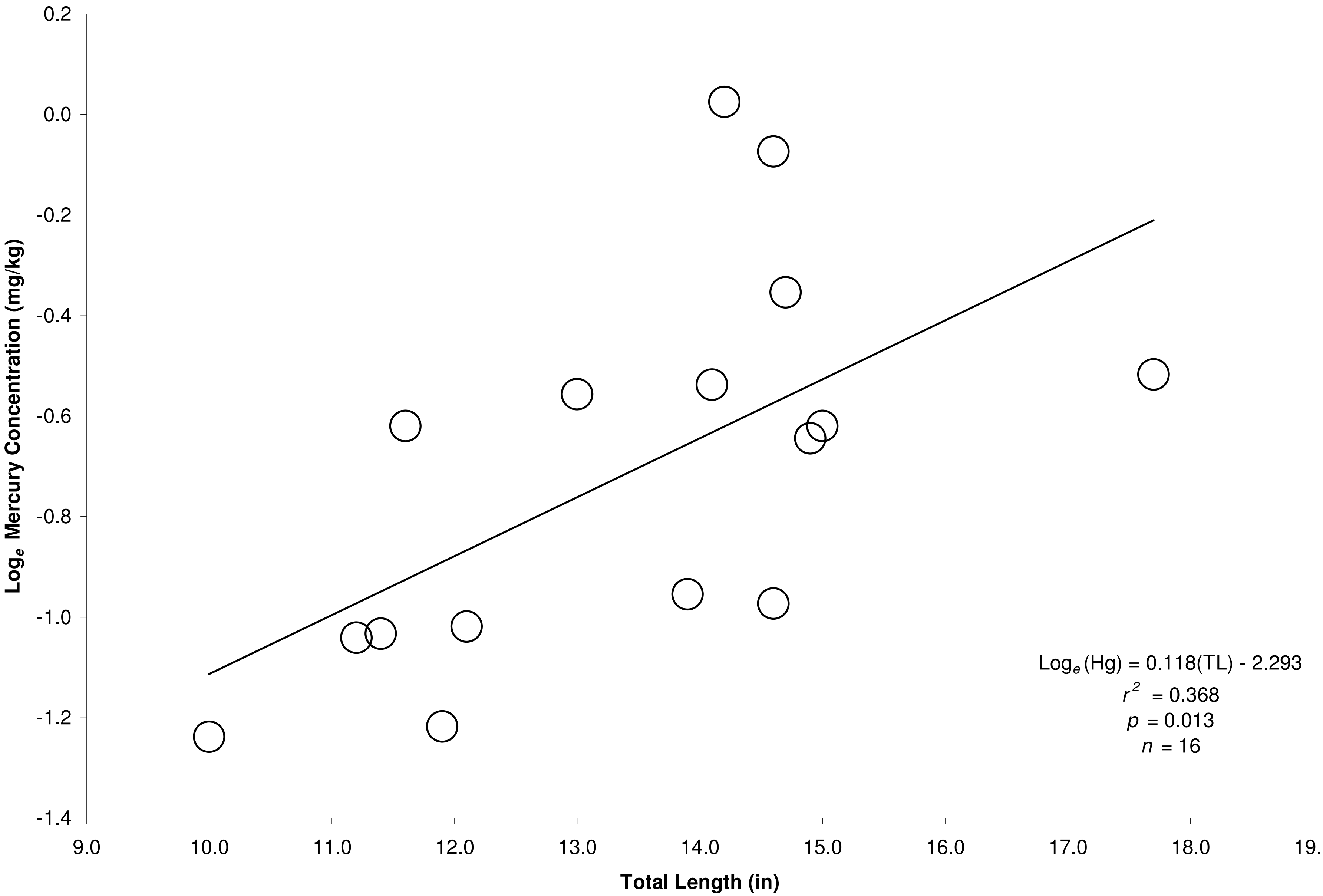


Figure 17. Relationship between mercury concentration and age for spotted bass collected from B.A. Steinhagen Reservoir, Texas, 2010.

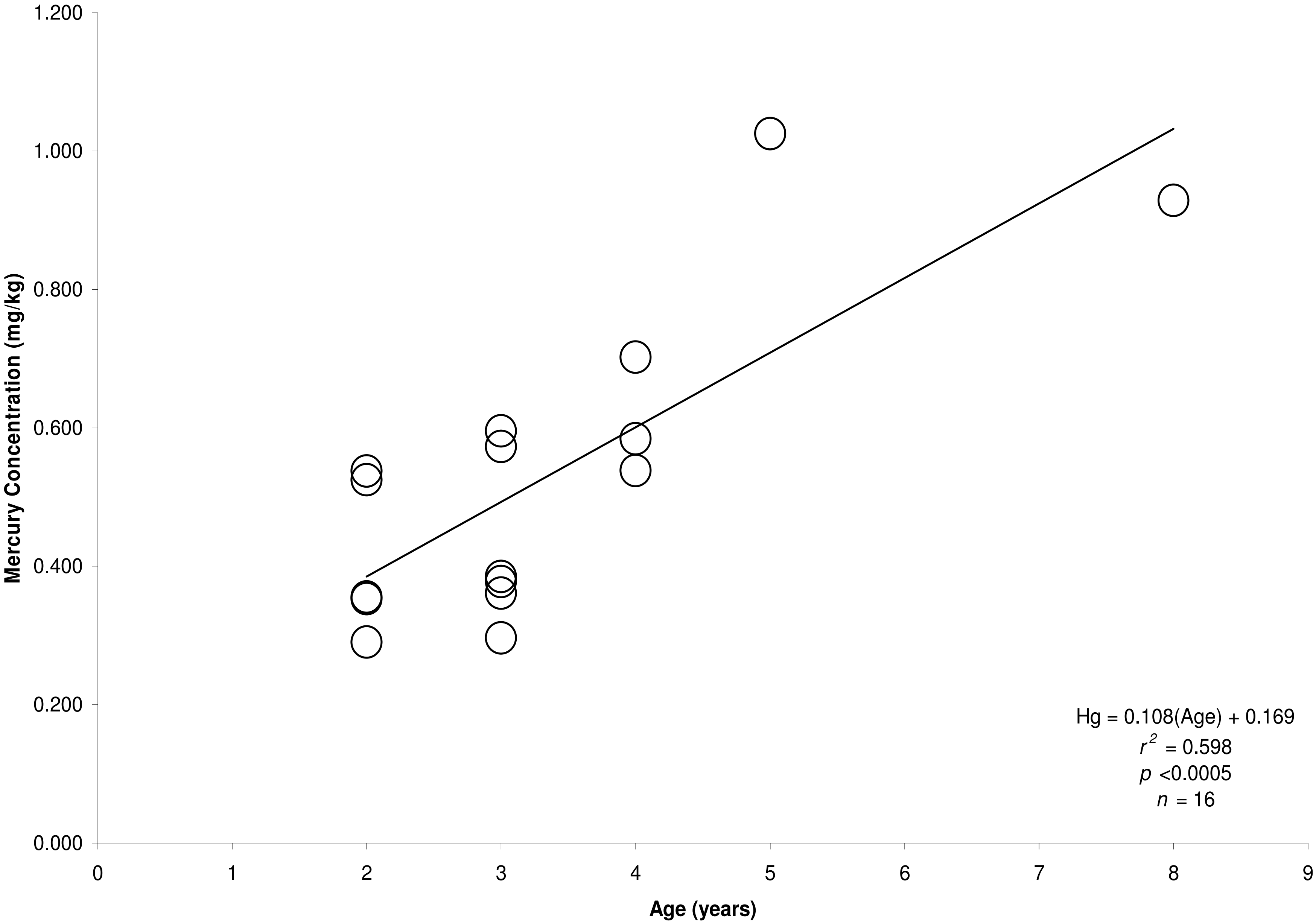


Figure 18. Length at age for white bass collected from B.A. Steinhagen Reservoir, Texas, 2010.

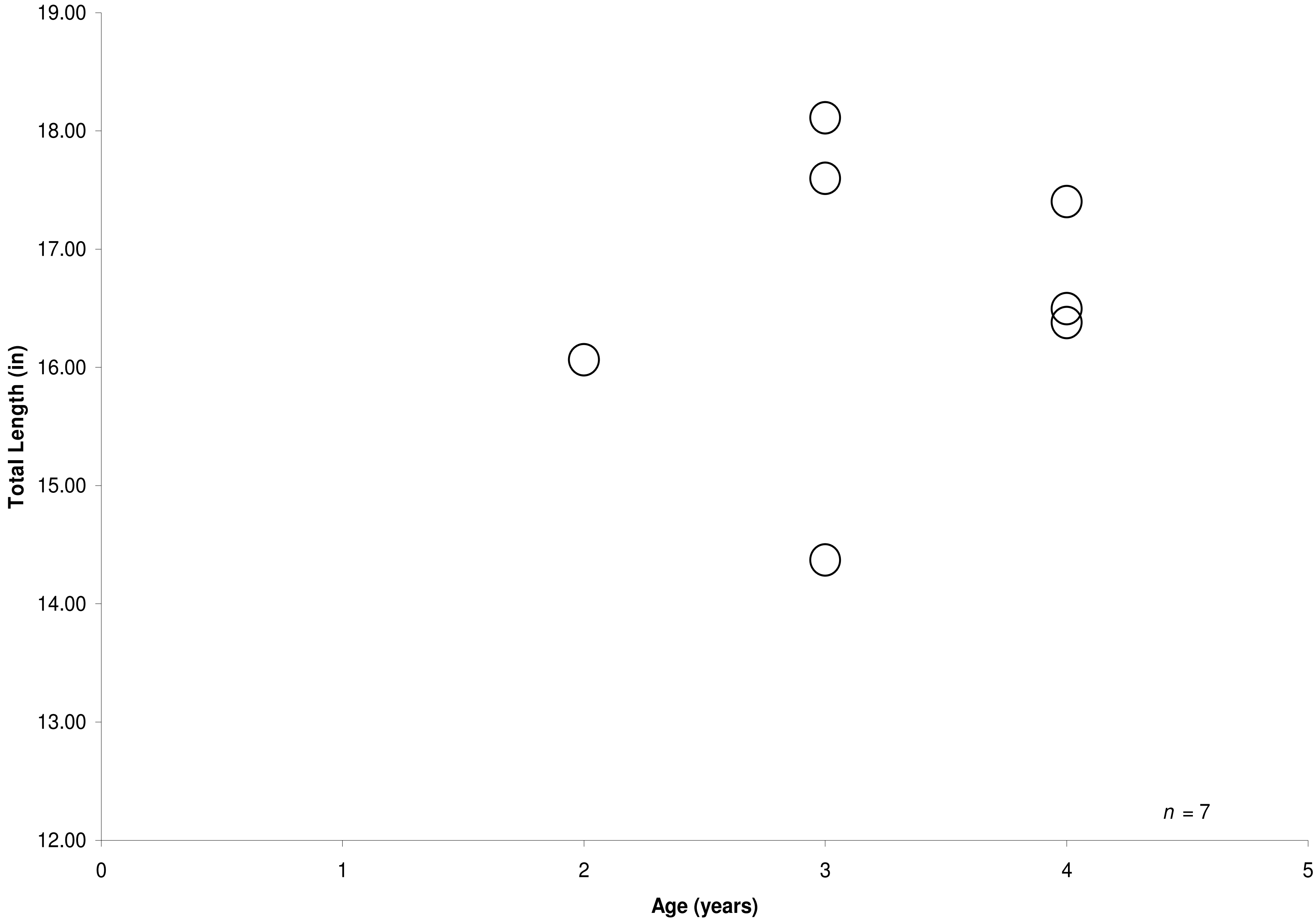


Figure 19. Relationship between mercury concentration and total length for white bass collected from B.A. Steinhagen Reservoir, Texas, 2010.

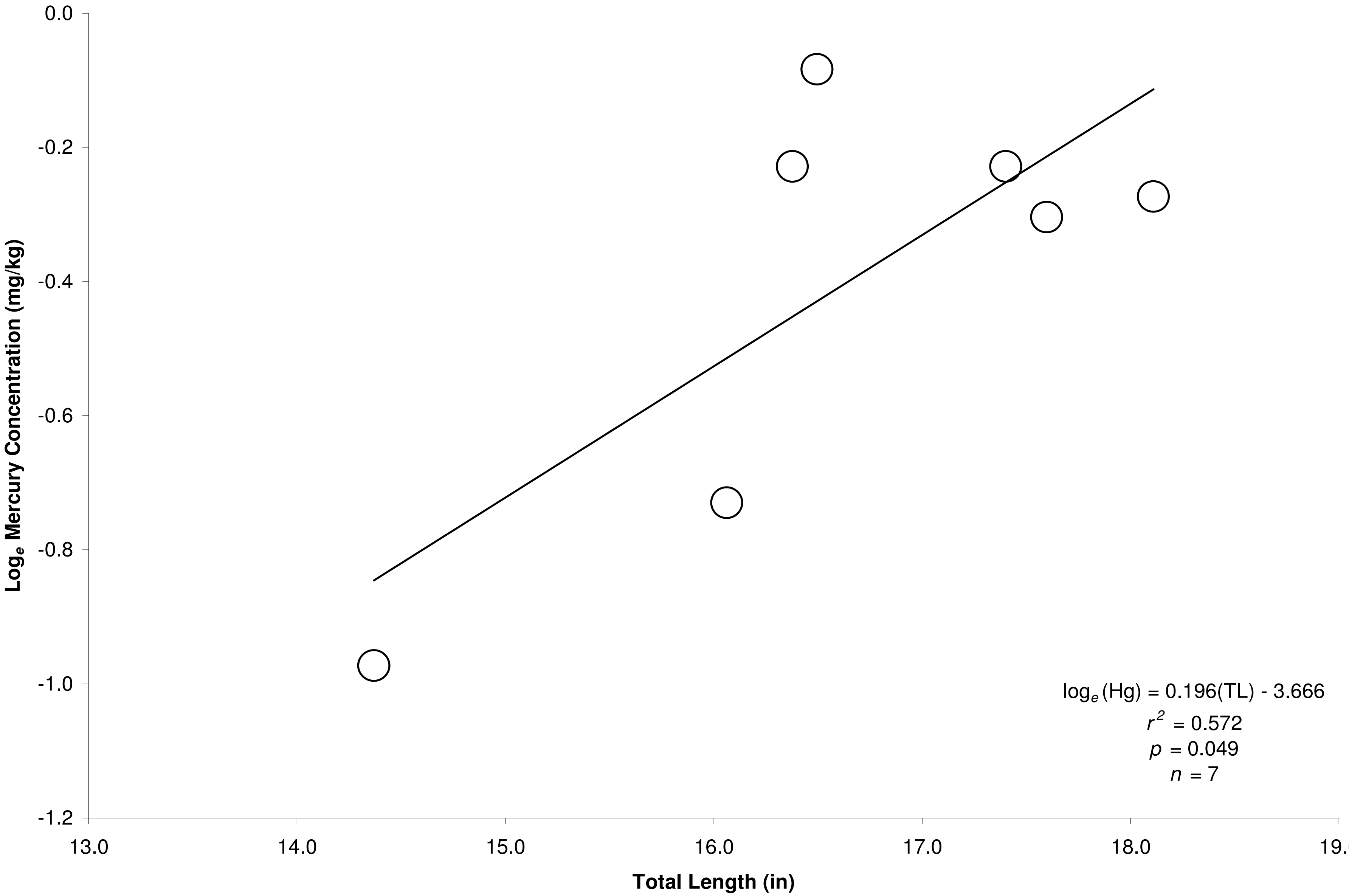


Figure 20. Length at age for white crappie collected from B.A. Steinhagen Reservoir, Texas, 2010.

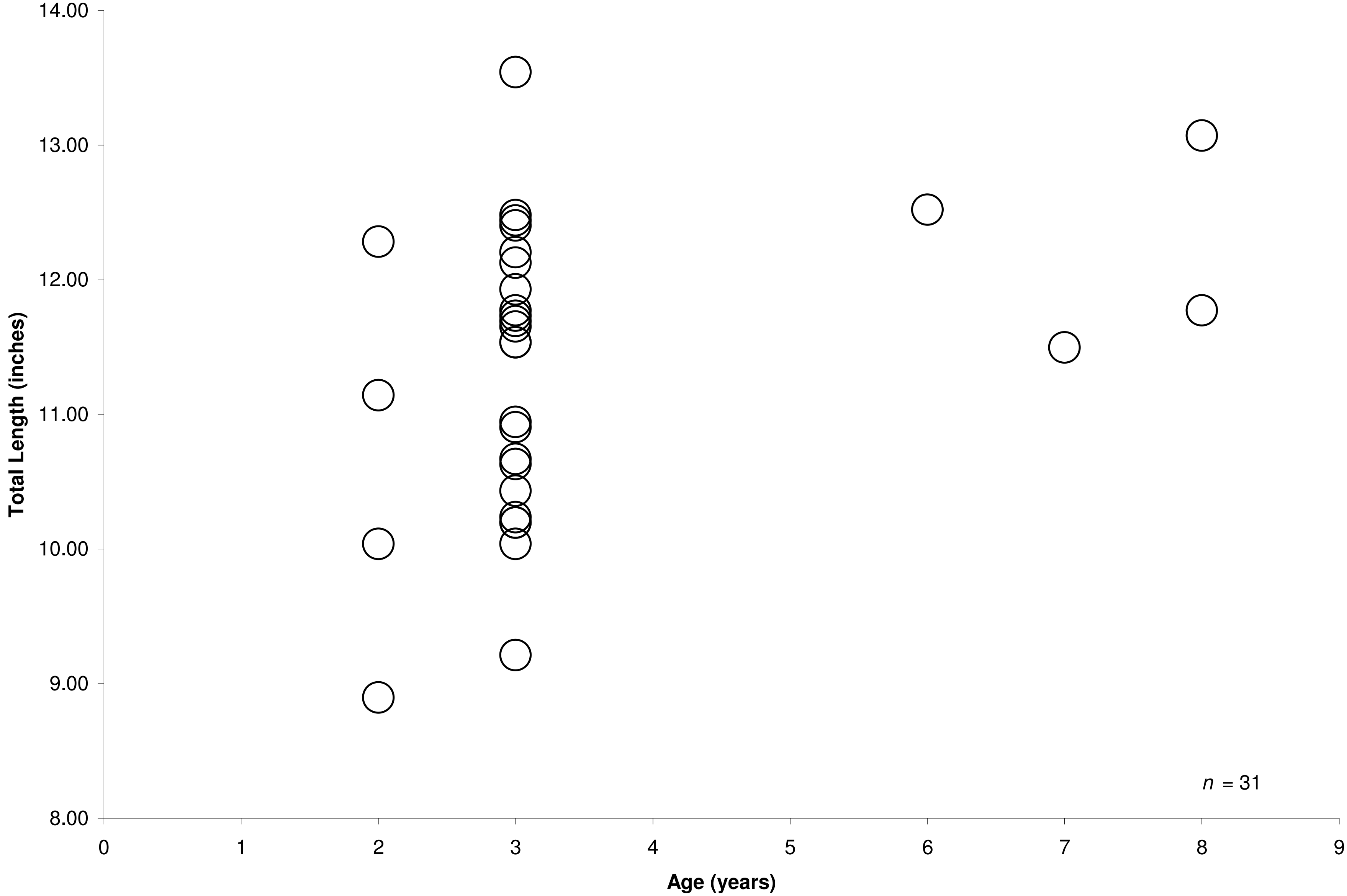


Figure 21. Relationship between mercury concentration and age for white crappie collected from B.A. Steinhagen Reservoir, Texas, 2010.

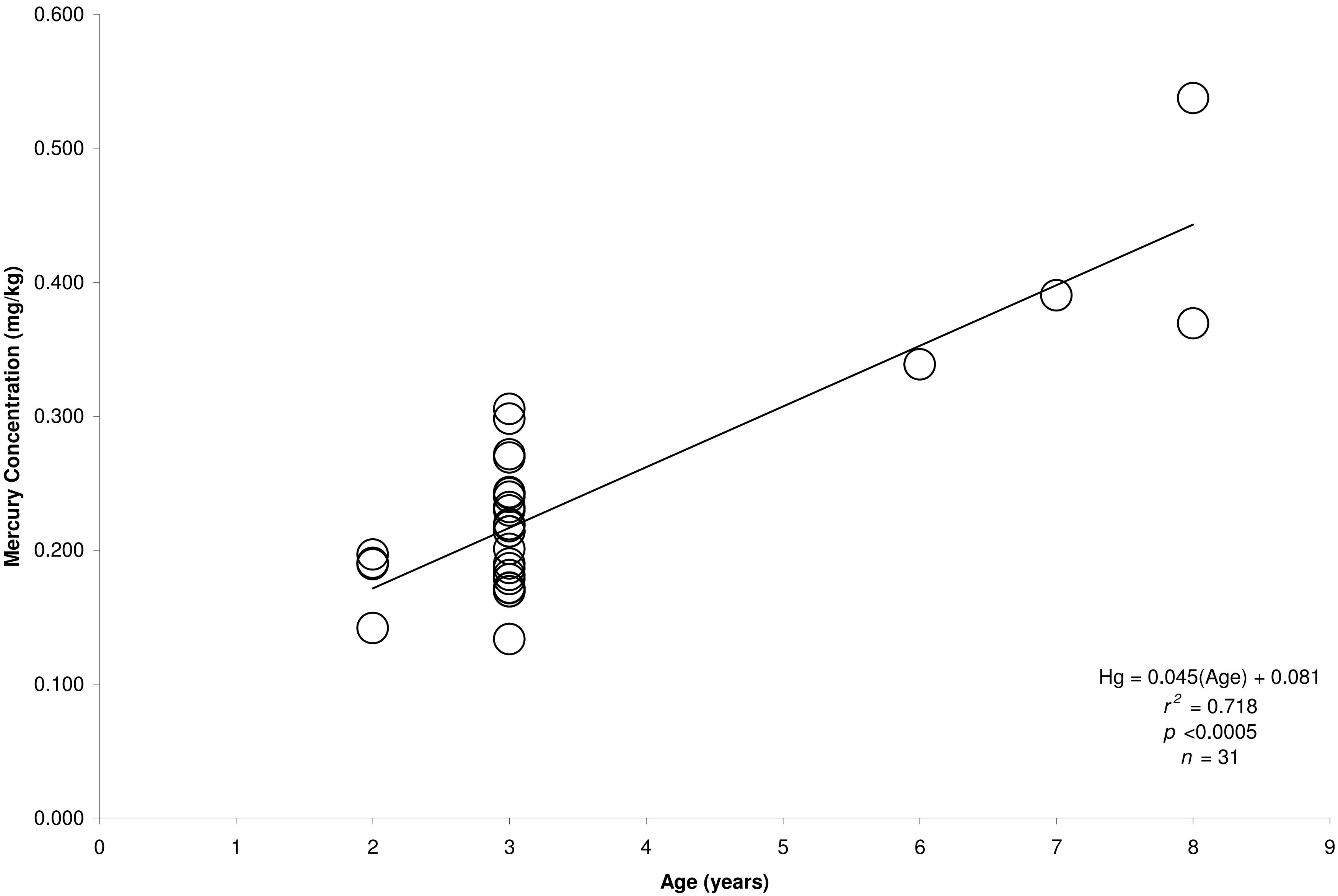


Figure 22. Relationship between mercury concentration and total length for blue catfish collected from the Neches River in 2007 and B.A. Steinhagen and Sam Rayburn Reservoirs, Texas in 2010–2011.

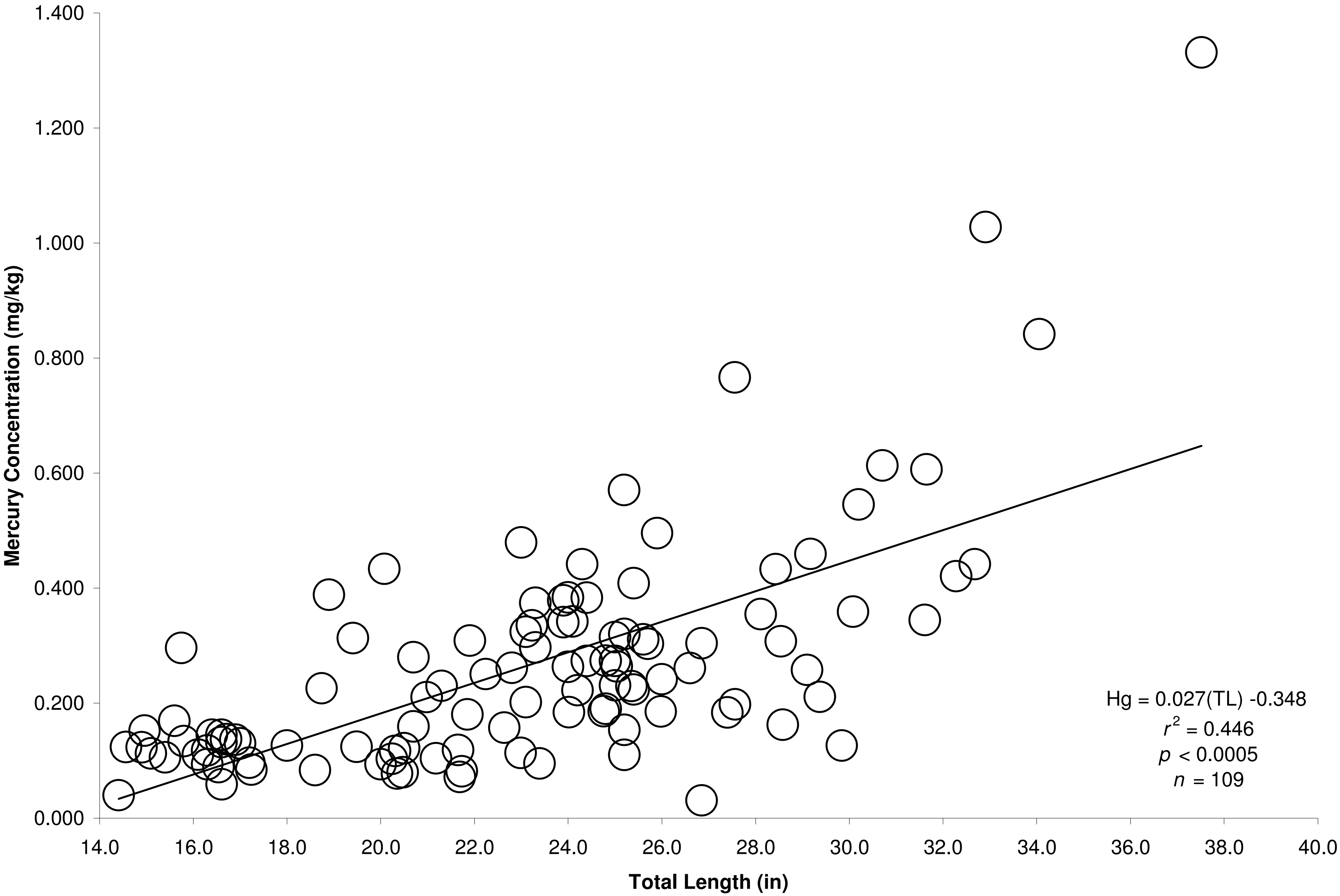
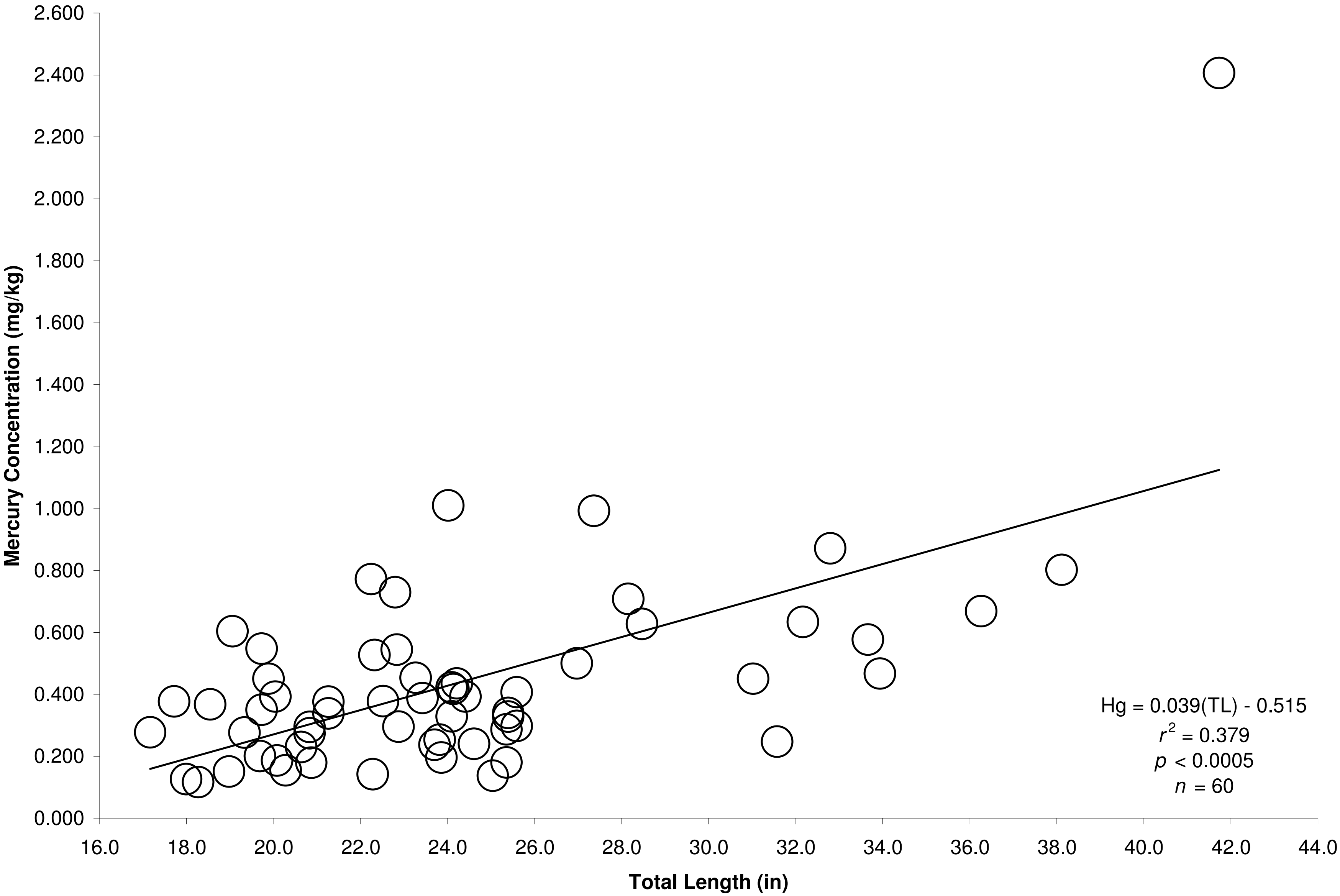


Figure 23. Relationship between mercury concentration and total length for flathead catfish collected from the Neches River in 2007 and B.A. Steinhagen and Sam Rayburn Reservoirs, Texas in 2010–2011.



TABLES

Table 1. Fish samples collected from B.A. Steinhagen Reservoir May–June 2010. Sample number, species, length, and weight recorded for each sample.

Sample Number	Species	Length (mm)	Weight (g)
Site 1 B.A. Steinhagen Reservoir at Dam			
BAS01	Smallmouth buffalo	590	3847
BAS02	Smallmouth buffalo	579	3407
BAS03	Freshwater drum	511	2464
BAS04	Freshwater drum	536	2767
BAS05	Freshwater drum	412	1286
BAS06	Freshwater drum	422	1171
BAS07	Freshwater drum	373	765
BAS08	Freshwater drum	409	1073
BAS09	Hybrid striped bass	490	1492
BAS10	Longnose gar	1115	4390
BAS11	Alligator gar	883	3497
BAS12	White crappie	296	313
BAS13	Blue catfish	527	1329
BAS14	Channel catfish	630	2991
BAS15	Channel catfish	625	3214
BAS16	Channel catfish	415	703
BAS17	Channel catfish	681	4147
BAS18	Channel catfish	759	5049
BAS19	Channel catfish	671	4000
BAS21	Channel catfish	621	3015
BAS22	Channel catfish	629	2795
BAS23	Channel catfish	489	1362
BAS24	White crappie	255	257
BAS25	Blue catfish	430	823
BAS26	Blue catfish	431	763
BAS27	Blue catfish	391	532
BAS28	Blue catfish	378	452
BAS29	Flathead catfish	482	1211
Site 2 B.A. Steinhagen Reservoir near Campers Cove Park			
BAS47	White crappie	312	412
BAS48	Freshwater drum	469	1802
BAS49	Freshwater drum	345	558
BAS50	Freshwater drum	420	1173
BAS51	Freshwater drum	350	589
BAS52	Freshwater drum	332	418
BAS54	Alligator gar	871	3840

Table 1 cont. Fish samples collected from B.A. Steinhagen Reservoir May–June 2010. Sample number, species, length, and weight recorded for each sample.			
Sample Number	**Species**	**Length (mm)**	**Weight (g)**
Site 2 B.A. Steinhagen Reservoir near Campers Cove Park (cont.)			
BAS55	Alligator gar	1029	5639
BAS56	Flathead catfish	515	1675
BAS57	Channel catfish	475	1146
BAS58	Channel catfish	665	3232
BAS59	Blue catfish	593	2345
BAS61	Blue catfish	620	2820
BAS62	Blue catfish	675	3681
BAS63	Blue catfish	634	2909
BAS64	Blue catfish	410	618
BAS65	Blue catfish	416	802
BAS66	Blue catfish	646	2579
BAS67	Blue catfish	631	2833
BAS68	Blue catfish	520	1404
BAS69	Blue catfish	740	4598
BAS70	White bass	442	1197
BAS71	Freshwater drum	309	389
BAS72	Freshwater drum	337	507
BAS73	Smallmouth buffalo	612	4971
BAS74	Smallmouth buffalo	660	5630
BAS75	Longnose gar	886	2211
BAS76	Longnose gar	826	1425
BAS77	Channel catfish	354	392
BAS78	Channel catfish	549	1797
BAS79	Freshwater drum	346	625
BAS80	Redear sunfish	176	103
BAS81	Redear sunfish	186	154
BAS82	Redear sunfish	164	107
BAS83	Blue catfish	641	3244
Site 3 B.A. Steinhagen Reservoir at Sandy Creek			
BAS30	Smallmouth buffalo	685	7277
BAS31	Smallmouth buffalo	542	3395
BAS32	Largemouth bass	369	766
BAS33	Largemouth bass	397	969
BAS34	Largemouth bass	406	1040
BAS35	Largemouth bass	394	1057
BAS36	Largemouth bass	397	949
BAS37	Bluegill	162	95

Table 1 cont. Fish samples collected from B.A. Steinhagen Reservoir May–June 2010. Sample number, species, length, and weight recorded for each sample.			
Sample Number	**Species**	**Length (mm)**	**Weight (g)**
Site 3 B.A. Steinhagen Reservoir at Sandy Creek (cont.)			
BAS38	Freshwater drum	472	1970
BAS39	Freshwater drum	399	965
BAS40	Freshwater drum	339	586
BAS41	Freshwater drum	327	488
BAS42	Freshwater drum	325	453
BAS43	Channel catfish	692	3857
BAS44	Channel catfish	595	2470
BAS45	Channel catfish	585	2404
BAS46	Channel catfish	422	674
BAS38	Freshwater drum	472	1970
BAS39	Freshwater drum	399	965
BAS40	Freshwater drum	339	586
BAS41	Freshwater drum	327	488
BAS42	Freshwater drum	325	453
BAS43	Channel catfish	692	3857
BAS44	Channel catfish	595	2470
BAS45	Channel catfish	585	2404
BAS46	Channel catfish	422	674
Site 4 B.A. Steinhagen Reservoir at U.S. Highway 190			
BAS86	Freshwater drum	540	2693
BAS87	Freshwater drum	397	926
BAS89	Freshwater drum	486	1883
BAS91	Freshwater drum	385	959
BAS93	Channel catfish	476	1182
BAS94	Channel catfish	471	1238
BAS95	Channel catfish	400	681
BAS96	Smallmouth buffalo	706	8072
BAS97	Alligator gar	1108	5523
BAS98	Blue catfish	415	645
BAS99	Blue catfish	609	2748
BAS100	Blue catfish	660	2942
BAS101	Blue catfish	650	3030
BAS102	Blue catfish	766	6100
BAS103	Blue catfish	607	2650
BAS104	Flathead catfish	644	3143
BAS105	Flathead catfish	510	1574
BAS106	Flathead catfish	529	1684

Table 1 cont. Fish samples collected from B.A. Steinhagen Reservoir May–June 2010. Sample number, species, length, and weight recorded for each sample.

Sample Number	Species	Length (mm)	Weight (g)
Site 4 B.A. Steinhagen Reservoir at U.S. Highway 190 (cont.)			
BAS107	White bass	408	926
BAS108	White bass	419	993
BAS109	White bass	365	622
BAS110	Hybrid striped bass	477	1859
BAS111	Freshwater drum	586	3856
BAS112	Channel catfish	489	1262
BAS113	Spotted gar	726	1665
BAS114	Spotted bass	450	1260
BAS115	Largemouth bass	360	660
BAS116	Largemouth bass	410	1447
BAS117	Freshwater drum	499	2297
BAS118	Freshwater drum	410	1057
BAS120	White crappie	283	379
BAS121	White crappie	317	399
BAS122	Spotted bass	373	812
BAS123	Smallmouth buffalo	556	3476
BAS124	White crappie	259	285
BAS125	Spotted bass	284	316
BAS126	Channel catfish	687	3925
BAS127	Channel catfish	610	3001
BAS128	Blue catfish	396	544
BAS129	Blue catfish	584	2294
BAS130	Channel catfish	443	832
BAS131	Redear sunfish	182	130
BAS132	Redear sunfish	190	135
BAS133	Redear sunfish	199	167
BAS134	Redear sunfish	176	138
BAS136	Bluegill	170	130
BAS138	Bluegill	176	116
BAS139	Longear sunfish	185	166
BAS367	Spotted gar	746	2104
BAS435	Largemouth bass	418	1047
BAS436	Freshwater drum	406	961
BAS437	Flathead catfish	500	1380

Table 1 cont. Fish samples collected from B.A. Steinhagen Reservoir May–June 2010. Sample number, species, length, and weight recorded for each sample.			
Sample Number	**Species**	**Length (mm)**	**Weight (g)**
Site 5 B.A. Steinhagen Reservoir near Walnut Ridge Unit			
BAS174	Alligator gar	1040	5959
BAS176	Freshwater drum	441	1363
BAS177	Freshwater drum	377	893
BAS178	Freshwater drum	391	1003
BAS180	Freshwater drum	396	1014
BAS181	Freshwater drum	370	734
BAS182	White bass	460	1393
BAS183	White bass	416	1191
BAS184	White bass	447	1211
BAS185	Spotted gar	670	1314
BAS186	Blue catfish	631	3106
BAS187	Blue catfish	635	2900
BAS188	Blue catfish	645	2724
BAS193	Blue catfish	652	2808
BAS194	Blue catfish	592	2495
BAS195	Blue catfish	456	931
BAS196	Blue catfish	383	447
BAS197	Channel catfish	435	737
BAS198	Channel catfish	512	1153
BAS199	Channel catfish	569	1518
BAS200	Channel catfish	405	659
BAS201	Channel catfish	480	927
BAS202	Channel catfish	471	930
BAS203	Channel catfish	456	910
BAS204	Channel catfish	366	399
BAS205	Blue catfish	579	1960
BAS206	Blue catfish	657	3106
BAS207	Channel catfish	443	815
BAS208	Flathead catfish	524	1480
BAS209	Freshwater drum	402	1010
BAS210	Freshwater drum	381	897
BAS212	Freshwater drum	334	565
BAS213	White crappie	303	382
BAS214	Smallmouth buffalo	682	6903
BAS215	Smallmouth buffalo	556	3436
BAS216	Spotted gar	607	730
BAS217	Largemouth bass	471	1605

Table 1 cont. Fish samples collected from B.A. Steinhagen Reservoir May–June 2010. Sample number, species, length, and weight recorded for each sample.			
Sample Number	**Species**	**Length (mm)**	**Weight (g)**
Site 5 B.A. Steinhagen Reservoir near Walnut Ridge Unit (cont.)			
BAS218	Largemouth bass	463	1835
BAS219	Largemouth bass	391	907
BAS220	Largemouth bass	356	626
BAS221	Largemouth bass	326	530
BAS222	Largemouth bass	304	400
BAS223	Largemouth bass	342	549
BAS224	Largemouth bass	322	452
BAS225	Spotted bass	371	881
BAS226	Spotted bass	378	842
BAS227	Spotted bass	353	579
BAS228	Warmouth	195	181
BAS229	Bluegill	175	134
BAS230	Bluegill	178	139
BAS231	Bluegill	167	96
BAS232	Bluegill	161	99
Site 6 B.A. Steinhagen Reservoir near Magnolia Ridge Park			
BAS140	Smallmouth buffalo	800	12701
BAS141	Smallmouth buffalo	576	4161
BAS142	Freshwater drum	467	1718
BAS143	Freshwater drum	397	930
BAS144	Freshwater drum	324	453
BAS145	Freshwater drum	350	585
BAS146	Freshwater drum	393	951
BAS147	Spotted gar	743	1465
BAS148	Spotted gar	725	1542
BAS149	Flathead catfish	650	3470
BAS150	Flathead catfish	464	1089
BAS151	Flathead catfish	566	2053
BAS152	Blue catfish	473	991
BAS153	Blue catfish	636	2915
BAS154	Blue catfish	555	1710
BAS155	Blue catfish	527	1583
BAS156	Blue catfish	436	713
BAS157	Blue catfish	415	644
BAS158	Channel catfish	661	3322
BAS159	Channel catfish	719	4631
BAS160	Channel catfish	587	2153

Table 1 cont. Fish samples collected from B.A. Steinhagen Reservoir May–June 2010. Sample number, species, length, and weight recorded for each sample.			
Sample Number	**Species**	**Length (mm)**	**Weight (g)**
Site 6 B.A. Steinhagen Reservoir near Magnolia Ridge Park (cont.)			
BAS161	Channel catfish	411	643
BAS162	White crappie	344	450
BAS163	Redear sunfish	186	133
BAS164	Redear sunfish	186	123
BAS165	Redear sunfish	186	139
BAS166	Largemouth bass	537	2644
BAS167	Largemouth bass	406	1042
BAS168	Largemouth bass	356	642
BAS169	Largemouth bass	399	877
BAS170	Largemouth bass	368	722
BAS171	Largemouth bass	284	344
BAS172	Largemouth bass	283	302
BAS173	Largemouth bass	308	419
Site 7 B.A. Steinhagen Reservoir at Neches River and Angelina River Confluence			
BAS284	Flathead catfish	636	2833
BAS285	Flathead catfish	471	1082
BAS286	Flathead catfish	450	902
BAS287	Largemouth bass	340	647
BAS288	Largemouth bass	335	528
BAS289	Largemouth bass	327	447
BAS290	White crappie	293	353
BAS291	White crappie	299	341
BAS292	Freshwater drum	399	829
BAS294	Freshwater drum	395	942
BAS296	Freshwater drum	476	1602
BAS299	Freshwater drum	444	1373
BAS300	Freshwater drum	420	932
BAS301	Freshwater drum	436	1165
BAS302	Longnose gar	1017	2873
BAS303	White crappie	316	423
BAS304	Blue catfish	615	2501
BAS305	Blue catfish	610	2240
BAS306	Blue catfish	620	2483
BAS307	Blue catfish	588	2445
BAS308	Blue catfish	617	2226
BAS309	Blue catfish	421	602
BAS310	Blue catfish	425	665

Table 1 cont. Fish samples collected from B.A. Steinhagen Reservoir May–June 2010. Sample number, species, length, and weight recorded for each sample.			
Sample Number	**Species**	**Length (mm)**	**Weight (g)**
Site 7 B.A. Steinhagen Reservoir at Neches River and Angelina River Confluence (cont.)			
BAS311	Flathead catfish	501	1304
BAS312	Channel catfish	412	630
BAS313	Spotted bass	361	734
BAS314	Longnose gar	750	1187
BAS315	Longnose gar	848	1646
BAS316	Smallmouth buffalo	697	6372
BAS317	Smallmouth buffalo	499	2981
BAS318	Largemouth bass	369	854
BAS319	Largemouth bass	396	992
BAS320	Largemouth bass	413	1081
BAS321	Largemouth bass	332	492
BAS322	Largemouth bass	327	512
BAS323	Largemouth bass	350	702
BAS324	Largemouth bass	284	300
BAS325	Largemouth bass	282	313
BAS326	Spotted bass	331	586
BAS327	Spotted bass	290	351
BAS331	Freshwater drum	374	799
BAS333	White crappie	278	250
BAS334	White crappie	234	194
BAS335	Channel catfish	445	939
BAS336	Flathead catfish	436	830
BAS337	Blue catfish	422	693
BAS338	Blue catfish	402	539
BAS339	Redear sunfish	180	133
BAS343	Warmouth	205	249
BAS345	Flathead catfish	529	1664
BAS346	Flathead catfish	625	2975
BAS347	Flathead catfish	715	4366
BAS348	Flathead catfish	602	2350
BAS349	Flathead catfish	540	1840
BAS350	Flathead catfish	540	1812
BAS351	Flathead catfish	644	2568
BAS352	Flathead catfish	509	1564
BAS353	Flathead catfish	491	1274
BAS354	Flathead catfish	615	2694
BAS355	Flathead catfish	645	3251

Table 1 cont. Fish samples collected from B.A. Steinhagen Reservoir May–June 2010. Sample number, species, length, and weight recorded for each sample.			
Sample Number	**Species**	**Length (mm)**	**Weight (g)**
Site 7 B.A. Steinhagen Reservoir at Neches River and Angelina River Confluence (cont.)			
BAS356	Flathead catfish	505	1411
BAS357	Flathead catfish	605	2343
BAS358	Flathead catfish	620	2581
BAS359	Flathead catfish	685	3866
BAS360	Flathead catfish	862	9500
BAS361	Blue catfish	606	2439
BAS362	Blue catfish	586	2015
BAS363	Freshwater drum	479	1571
BAS365	Largemouth bass	356	651
BAS366	Largemouth bass	357	790
BAS367	Spotted gar	746	2104
BAS368	Largemouth bass	532	2553
BAS369	Largemouth bass	520	2187
BAS370	Largemouth bass	539	2377
BAS371	Largemouth bass	412	1045
BAS372	Largemouth bass	561	2928
BAS373	Largemouth bass	382	858
BAS374	Largemouth bass	356	584
BAS375	Largemouth bass	363	706
BAS376	Largemouth bass	393	966
BAS377	Largemouth bass	331	620
BAS378	Largemouth bass	367	705
BAS379	Largemouth bass	364	732
BAS380	Largemouth bass	344	699
BAS381	Largemouth bass	359	648
BAS382	Largemouth bass	346	551
BAS383	White crappie	299	446
BAS384	White crappie	271	246
BAS385	White crappie	226	170
BAS386	White crappie	315	347
BAS387	Bluegill	234	353
BAS388	Bluegill	190	202
BAS391	Bluegill	200	210
BAS392	Bluegill	184	170
BAS394	Redear sunfish	197	166
BAS397	Warmouth	172	131
BAS399	Alligator gar	953	4124

Table 1 cont. Fish samples collected from B.A. Steinhagen Reservoir May–June 2010. Sample number, species, length, and weight recorded for each sample.			
Sample Number	**Species**	**Length (mm)**	**Weight (g)**
Site 7 B.A. Steinhagen Reservoir at Neches River and Angelina River Confluence (cont.)			
BAS400	Flathead catfish	650	2948
BAS401	Flathead catfish	591	2169
BAS402	Largemouth bass	429	1172
BAS403	Largemouth bass	442	1618
BAS404	Largemouth bass	381	938
BAS405	Largemouth bass	551	2639
BAS406	Largemouth bass	360	668
BAS407	Largemouth bass	364	771
BAS408	Largemouth bass	394	887
BAS409	Largemouth bass	368	784
BAS410	Largemouth bass	510	2252
BAS411	Largemouth bass	408	1027
BAS412	Largemouth bass	383	897
BAS413	Largemouth bass	463	2227
BAS414	Largemouth bass	356	698
BAS415	Largemouth bass	429	1247
BAS416	Largemouth bass	444	1491
BAS417	Spotted bass	381	821
BAS418	Spotted bass	358	781
BAS419	Spotted bass	372	694
BAS420	Spotted bass	295	362
BAS421	Spotted bass	307	362
BAS422	White crappie	296	401
BAS423	White crappie	297	317
BAS424	White crappie	298	416
BAS425	White crappie	265	271
BAS426	White crappie	318	529
BAS427	White crappie	332	541
BAS428	White crappie	310	419
BAS429	White crappie	292	442
BAS430	White crappie	270	345
BAS431	White crappie	308	497
BAS432	White crappie	260	308
BAS433	Flathead catfish	645	3077
BAS434	Largemouth bass	357	724

Table 1 cont. Fish samples collected from B.A. Steinhagen Reservoir May–June 2010. Sample number, species, length, and weight recorded for each sample..			
Sample Number	**Species**	**Length (mm)**	**Weight (g)**
Site 8 Angelina River at Bevilport Boat Ramp			
BAS233	Longnose gar	840	1580
BAS234	Longnose gar	1004	2687
BAS235	Longnose gar	770	1107
BAS236	Longnose gar	1329	8845
BAS237	Freshwater drum	372	851
BAS238	Freshwater drum	301	327
BAS239	Freshwater drum	317	436
BAS240	Freshwater drum	348	536
BAS241	Freshwater drum	330	442
BAS242	White crappie	277	284
BAS243	White crappie	255	207
BAS244	White crappie	259	282
BAS245	Largemouth bass	626	3766
BAS246	Largemouth bass	586	2876
BAS247	Largemouth bass	396	827
BAS248	Largemouth bass	417	1211
BAS249	Largemouth bass	455	1482
BAS250	Largemouth bass	478	1812
BAS251	Largemouth bass	364	682
BAS252	Largemouth bass	383	940
BAS253	Largemouth bass	359	619
BAS254	Largemouth bass	348	556
BAS255	Largemouth bass	347	535
BAS256	Largemouth bass	462	1578
BAS257	Largemouth bass	514	1913
BAS258	Largemouth bass	578	2670
BAS259	Largemouth bass	472	1574
BAS260	Largemouth bass	404	960
BAS261	Largemouth bass	372	764
BAS262	Largemouth bass	398	922
BAS263	Largemouth bass	345	559
BAS264	Largemouth bass	328	451
BAS265	Spotted bass	301	344
BAS266	Spotted bass	254	223
BAS267	White crappie	293	359
BAS268	Redbreast sunfish	244	278
BAS269	Redbreast sunfish	215	164

Table 1 cont. Fish samples collected from B.A. Steinhagen Reservoir May–June 2010. Sample number, species, length, and weight recorded for each sample.

Sample Number	Species	Length (mm)	Weight (g)
Site 8 Angelina River at Bevilport Boat Ramp (cont.)			
BAS270	Redbreast sunfish	193	137
BAS271	Bluegill	170	107
BAS272	Redear sunfish	228	226
BAS273	Redear sunfish	192	127
BAS274	Channel catfish	415	571
BAS275	Channel catfish	355	355
BAS276	Channel catfish	383	465
BAS277	Channel catfish	348	333
BAS278	Channel catfish	336	290
BAS279	Channel catfish	341	303
BAS280	Smallmouth buffalo	572	2795
BAS281	Smallmouth buffalo	630	4827
BAS282	Longnose gar	770	1020
BAS270	Redbreast sunfish	193	137
BAS271	Bluegill	170	107
BAS272	Redear sunfish	228	226
BAS273	Redear sunfish	192	127
BAS274	Channel catfish	415	571
BAS275	Channel catfish	355	355
BAS276	Channel catfish	383	465
BAS277	Channel catfish	348	333
BAS278	Channel catfish	336	290
BAS279	Channel catfish	341	303
BAS280	Smallmouth buffalo	572	2795
BAS281	Smallmouth buffalo	630	4827
BAS282	Longnose gar	770	1020

Table 2a. Arsenic (mg/kg) in fish collected from B.A. Steinhagen Reservoir, 2010.					
Species	**# Detected/ # Sampled**	**Total Arsenic Mean Concentration ± S.D. (Min-Max)**	**Inorganic Arsenic Mean Concentration***	**Health Assessment Comparison Value (mg/kg)†**	**Basis for Comparison Value**
Alligator gar	1/1	0.748	0.075	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
Blue catfish	8/8	0.756±0.203 (0.431-1.104)	0.076		
Flathead catfish	6/6	0.665±0.133 (0.461-0.819)	0.066		
Largemouth bass	1/1	0.923	0.092		
All fish combined	16/16	0.732±0.172 (0.431-1.104)	0.073		

* *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 $1x10^{-4}$.*

Table 2b. Inorganic contaminants (mg/kg) in fish collected from B.A. Steinhagen Reservoir, 2010.				
Species	**# Detected/ # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
Cadmium				
Alligator gar	1/1	0.060	0.47	ATSDR chronic oral MRL: 0.0002 mg/kg–day
Blue catfish	8/8	0.025±0.010 (BDL-0.043)		
Flathead catfish	6/6	0.040±0.027 (BDL-0.086)		
Largemouth bass	1/1	BDL		
All fish combined	16/16	0.032±0.020 (BDL-0.086)		
Copper				
Alligator gar	1/1	0.162	334	National Academy of Science Upper Limit: 0.143 mg/kg–day
Blue catfish	8/8	0.217±0.106 (0.144-0.471)		
Flathead catfish	6/6	0.156±0.053 (0.106-0.249)		
Largemouth bass	1/1	0.149		
All fish combined	16/16	0.186±0.085 (0.106-0.471)		
Lead				
Alligator gar	1/1	0.142	NA	EPA IEUBKwin32 Version 1.1 Build 9
Blue catfish	8/8	0.060±0.039 (BDL-0.129)		
Flathead catfish	6/6	0.070±0.039 (BDL-0.134)		
Largemouth bass	1/1	0.081		
All fish combined	16/16	0.070±0.040 (BDL-0.142)		
Selenium				
Alligator gar	1/1	0.215	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
Blue catfish	8/8	0.215±0.056 (0.155-0.334)		
Flathead catfish	6/6	0.187±0.093 (0.115-0.353)		
Largemouth bass	1/1	0.302		
All fish combined	16/16	0.210±0.071 (0.115-0.353)		

Table 2c. Zinc (mg/kg) in fish collected from B.A. Steinhagen Reservoir, 2010.				
Species	**# Detected/ # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
Zinc				
Alligator gar	1/1	4.448	700	EPA chronic oral RfD: 0.3 mg/kg–day
Blue catfish	8/8	4.303±0.735 (3.403-5.763)		
Flathead catfish	6/6	4.486±1.583 (3.478-7.648)		
Largemouth bass	1/1	3.599		
All fish combined	16/16	4.337±1.065 (3.403-7.648)		

Table 2d. Mercury (mg/kg) in fish collected from B.A. Steinhagen Reservoir, 2010.				
Species	**# Detected/ # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
Mercury				
Alligator gar	6/6	0.274±0.101 (0.177-0.430)	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg–day
Blue catfish	50/50	0.245±0.118 (0.084-0.546)		
Bluegill	12/12	0.150±0.061 (0.089-0.266)		
Channel catfish	46/46	0.235±0.124 (0.066-0.565)		
Flathead catfish	34/34	0.318±0.133 (0.117-**0.708**[*])		
Freshwater drum	53/53	0.272±0.245 (0.078-**1.116**)		
Hybrid striped bass	2/2	0.156±0.063 (0.111-0.200)		
Largemouth bass	88/88	0.498±0.282 (0.126-**1.644**)		
Longear sunfish	1/1	0.134		
Longnose gar	11/11	**0.672**±0.449 (0.171-**1.855**)		
Redbreast sunfish	3/3	0.158±0.098 (0.094-0.271)		
Redear sunfish	14/14	0.142±0.044 (0.095-0.246)		
Smallmouth buffalo	16/16	0.439±0.142 (0.207-**0.659**)		
Spotted bass	16/16	0.527±0.214 (0.290-**1.025**)		
Spotted gar	6/6	0.371±0.207 (0.212-**0.761**)		
Warmouth	3/3	0.229±0.055 (0.176-0.286)		
White bass	7/7	**0.696**±0.193 (0.378-**0.920**)		
White crappie	32/32	0.234±0.083 (0.134-0.537)		
Gar spp.	23/23	0.490±0.370 (0.171-**1.855**)		
Sunfish spp.	33/33	0.154±0.059 (0.089-0.286)		
All fish combined	400/400	0.341±0.244 (0.066-**1.855**)		

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

Table 2e. Mercury (mg/kg) in select fish by size class collected from B.A. Steinhagen Reservoir, 2010.				
Species	**# Detected/ # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
Mercury				
Freshwater drum ≥ 20”	4/4	**0.766**[*]±0.312 (0.361-**1.116**)	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg–day
Largemouth bass < 14”	22/22	0.349±0.132 (0.126-0.597)		
Largemouth bass ≥ 14”	66/66	0.548±0.301 (0.198-**1.644**)		
Largemouth bass ≥ 16”	30/30	**0.700**±0.377 (0.237-**1.644**)		
Largemouth bass ≥ 18”	17/17	**0.860**±0.396 (0.478-**1.644**)		
Largemouth bass ≥ 20”	11/11	**0.967**±0.446 (0.510-**1.644**)		
Largemouth bass ≥ 22”	4/4	**1.114**±0.442 (**0.726**-**1.644**)		
Spotted bass ≥ 14”	8/8	**0.660**±0.217 (0.378-**1.025**)		

[*] *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 B.A. Steinhagen Reservoir, 2010				
Species	**# Detected / # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
Beta-HCH				
Alligator gar	1/1	0.004	1.4 0.3	ATSDR intermediate oral MRL: 0.0006 mg/kg–day EPA slope factor: 1.8 per mg/kg–day
Blue catfish	7/8	0.003±0.001 (ND-0.004)		
Flathead catfish	6/6	0.003±0.0005 (0.002-0.004)		
Largemouth bass	1/1	0.004		
All fish combined	15/16	0.003±0.0009 (ND-0.004)		
Gamma-HCH				
Alligator gar	1/1	0.002	0.7	EPA chronic oral RfD: 0.0003 mg/kg–day
Blue catfish	7/8	0.001±0.0005 (ND-0.002)		
Flathead catfish	6/6	0.001±0.0008 (BDL-0.002)		
Largemouth bass	1/1	0.001		
All fish combined	15/16	0.001±0.0006 (ND-0.002)		
Delta-HCH				
Alligator gar	1/1	0.0009	N/A	N/A
Blue catfish	4/8	0.0009±0.0004 (ND-0.002)		
Flathead catfish	3/6	0.001±0.0005 (ND-0.002)		
Largemouth bass	1/1	0.003		
All fish combined	9/16	0.001±0.0006 (ND-0.003)		

Table 4. PCBs (mg/kg) in fish collected from B.A. Steinhagen Reservoir, 2010.

Species	# Detected / # Sampled	Mean Concentration ± S.D. (Min-Max)	Health Assessment Comparison Value (mg/kg)	Basis for Comparison Value
PCBs				
Alligator gar	4/6	0.010±0.0004 (ND-0.011)		
Blue catfish	8/8	0.010±0.001 (BDL-0.013)		
Channel catfish	7/7	0.011±0.001 (BDL-0.013)		
Flathead catfish	5/6	0.011±0.004 (ND-0.020)		
Hybrid striped bass	2/2	0.012±0.00007 (0.011-0.012)	0.047 0.272	EPA chronic oral RfD: 0.00002 mg/kg–day EPA slope factor: 2.0 per mg/kg–day
Largemouth bass	6/6	0.011±0.003 (BDL-0.017)		
Longnose gar	2/2	**0.057**[*]±0.065 (0.011-**0.103**)		
White bass	3/3	0.012±0.0006 (0.011-0.012)		
All fish combined	37/40	0.013±0.015 (ND-**0.103**)		

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

Table 5. PCDDs/PCDFs toxicity equivalent (TEQ) concentrations (pg/g) in fish collected from B.A. Steinhagen Reservoir, 2010.				
Species	**# Detected / # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (pg/g)**	**Basis for Comparison Value**
B.A. Steinhagen Reservoir All Sites				
Alligator gar	5/6	0.106±0.107 (ND-0.284)	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	17/18	0.128±0.124 (ND-0.443)		
Channel catfish	14/18	0.201±0.301 (ND-0.945)		
Flathead catfish	16/18	0.164±0.263 (ND-1.099)		
Hybrid Striped bass	2/2	1.896±0.643 (1.441-**2.351**[*])		
Largemouth bass	4/21	0.050±0.227 (ND-1.042)		
Longnose gar	5/6	1.353±2.365 (ND-**6.063**)		
Spotted gar	3/4	0.051±0.057 (ND-0.119)		
White bass	3/3	0.132±0.189 (0.018-0.350)		
All fish combined	69/96	0.240±0.702 (ND-**6.063**)		

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

Table 6a. Hazard quotients (HQs) for mercury in fish collected from B.A. Steinhagen Reservoir in 2010. Table 6a also provides suggested weekly eight-ounce meal consumption rates for 70-kg adults.*			
Species	**Number (N)**	**Hazard Quotient**	**Meals per Week**
B.A. Steinhagen Reservoir All Sites			
Alligator gar	6	0.39	2.4
Blue catfish	50	0.35	2.6
Bluegill	12	0.21	4.3
Channel catfish	46	0.34	2.8
Flathead catfish	34	0.45	2.0
Freshwater drum	53	0.39	2.4
Hybrid striped bass	2	0.22	4.2
Largemouth bass	88	0.71	1.3
Longear sunfish	1	0.19	4.8
Longnose gar	11	**0.96**†	**1.0**‡
Redbreast sunfish	3	0.23	4.1
Redear sunfish	14	0.20	4.6
Smallmouth buffalo	16	0.63	1.5
Spotted bass	16	0.75	1.2
Spotted gar	6	0.53	1.7
Warmouth	3	0.33	2.8
White bass	7	**0.99**	**0.9**
White crappie	32	0.33	2.8
Gar spp.	23	0.70	1.3
Sunfish spp.	33	0.22	4.2
All fish combined	400	0.49	1.9

* *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 6b. Hazard quotients (HQs) for mercury in select fish by size class collected from B.A. Steinhagen Reservoir in 2010. Table 6b also provides suggested weekly eight-ounce meal consumption rates for 70-kg adults.[*]

Species	Number (N)	Hazard Quotient	Meals per Week
B.A. Steinhagen Reservoir All Sites			
Freshwater drum ≥ 20”	4	**1.09**[†]	**0.8**[‡]
Largemouth bass < 14”	22	0.50	1.9
Largemouth bass ≥ 14”	66	0.78	1.2
Largemouth bass ≥ 16”	30	**1.00**	**0.9**
Largemouth bass ≥ 18”	17	**1.23**	**0.8**
Spotted bass ≥ 14”	8	**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 B.A. Steinhagen Reservoir in 2010. Table 7a also provides suggested weekly eight-ounce meal consumption rates for 70-kg adults.*			
Contaminant/Species	**Number (N)**	**Hazard Quotient**	**Meals per Week**
Alligator gar			
PCBs	6	0.21	4.3
PCDDs/PCDFs	6	0.05	20.4
Hazard Index (meals per week)		0.26	3.6
Blue catfish			
PCBs	8	0.21	4.3
PCDDs/PCDFs	18	0.05	16.9
Hazard Index (meals per week)		0.27	3.4
Channel catfish			
PCBs	7	0.24	3.9
PCDDs/PCDFs	18	0.09	10.7
Hazard Index (meals per week)		0.32	2.9
Flathead catfish			
PCBs	6	0.24	3.9
PCDDs/PCDFs	18	0.07	13.2
Hazard Index (meals per week)		0.31	3.0
Hybrid striped bass			
PCBs	2	0.26	3.6
PCDDs/PCDFs	2	0.81	1.1
Hazard Index (meals per week)		**1.07**†	**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 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 B.A. Steinhagen Reservoir in 2010. Table 7b also provides suggested weekly eight-ounce meal consumption rates for 70-kg adults.[*]			
Contaminant/Species	**Number (N)**	**Hazard Quotient**	**Meals per Week**
Largemouth bass			
PCBs	6	0.24	3.9
PCDDs/PCDFs	21	0.02	unrestricted[†]
Hazard Index (meals per week)		0.26	3.6
Longnose gar			
PCBs	2	**1.22**[‡]	**0.8**[§]
PCDDs/PCDFs	6	0.58	1.6
Hazard Index (meals per week)		**1.80**	**0.5**
Spotted gar			
PCDDs/PCDFs	4	0.02	unrestricted
White bass			
PCBs	3	0.26	3.6
PCDDs/PCDFs	3	0.06	16.4
Hazard Index (meals per week)		0.31	2.9
All fish combined			
PCBs	40	0.28	3.3
PCDDs/PCDFs	96	0.10	9.0
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.*
[†] *Emboldened numbers denote 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 8a. Calculated theoretical lifetime excess cumulative cancer risk from consuming fish containing Arsenic, PCBs, and PCDDs/PCDFs collected in 2010 from B.A. Steinhagen Reservoir and suggested consumption (eight-ounce meals/week) for 70 kg adults who regularly eat fish from B.A. Steinhagen 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**	
Alligator gar				
Arsenic	1	2.1E-05	48,395	4.5
PCBs	6	3.7E-06	272,222	unrestricted†
PCDDs/PCDFs	6	3.0E-06	329,248	unrestricted
Cumulative Cancer Risk		2.7E-05	36,531	3.4
Blue catfish				
Arsenic	8	2.1E-05	47,758	4.4
PCBs	8	3.7E-06	272,222	unrestricted
PCDDs/PCDFs	18	3.7E-06	272,658	unrestricted
Cumulative Cancer Risk		2.8E-05	35,361	3.3
Channel catfish				
PCBs	7	4.0E-06	247,475	unrestricted
PCDDs/PCDFs	18	5.8E-06	173,633	16.0
Cumulative Cancer Risk		9.8E-06	102,040	9.4
Flathead catfish				
Arsenic	6	1.8E-05	54,944	5.1
PCBs	6	4.0E-06	247,475	unrestricted
PCDDs/PCDFs	18	4.6E-06	218,127	20.2
Cumulative Cancer Risk		2.7E-05	37,301	3.4

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

Table 8b. Calculated theoretical lifetime excess cumulative cancer risk from consuming fish containing Arsenic, PCBs, and PCDDs/PCDFs collected in 2010 from B.A. Steinhagen Reservoir and suggested consumption (eight-ounce meals/week) for 70 kg adults who regularly eat fish from B.A. Steinhagen 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**	
Hybrid striped bass				
PCBs	2	4.4E-06	226,852	21.0
PCDDs/PCDFs	2	5.4E-05	18,369	1.7
Cumulative Cancer Risk		5.9E-05	16,993	1.6
Largemouth bass				
Arsenic	1	2.5E-05	39,452	3.6
PCBs	6	4.0E-06	247,475	unrestricted†
PCDDs/PCDFs	21	1.4E-06	698,006	unrestricted
Cumulative Cancer Risk		3.1E-05	32,446	3.0
Longnose gar				
PCBs	2	2.1E-05	47,758	4.4
PCDDs/PCDFs	6	3.9E-05	25,795	2.4
Cumulative Cancer Risk		6.0E-05	16,749	1.5
Spotted gar				
PCDDs/PCDFs	4	1.5E-06	684,319	unrestricted
All fish combined				
Arsenic	16	2.0E-05	49,721	4.6
PCBs	40	4.8E-06	209,402	19.3
PCDDs/PCDFs	96	6.9E-06	145,418	13.4
Cumulative Cancer Risk		3.2E-05	31,482	2.9

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

Table 9. Mercury (mg/kg) in blue and flathead catfish collected from the Neches River, 2007 and B.A. Steinhagen Reservoir and Sam Rayburn Reservoir, 2010.				
Species	**# Detected/ # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
Blue catfish				
All blue catfish	109/109	0.264±0.198 (0.031-**1.332**[*])	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg–day
Blue catfish < 30"	99/99	0.225±0.129 (0.031-**0.767**)		
Blue catfish > 30"	10/10	**0.653**±0.322 (0.345-**1.332**)		
Flathead catfish				
All flathead catfish	60/60	0.439±0.334 (0.117-**2.406**)	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg–day
Flathead catfish < 27"	48/48	0.352±0.178 (0.117-**1.010**)		
Flathead catfish > 27"	12/12	**0.788**±0.547 (0.247-**2.406**)		
Flathead catfish < 30"	51/51	0.377±0.203 (0.117-**1.010**)		
Flathead catfish > 30"	9/9	**0.791**±0.634 (0.247-**2.406**)		

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

Table 10. The number of eight-ounce meals assuming 38% yield from whole fish to skin-off fillets for an average, minimum, and maximum weight fish of each species collected from B.A. Steinhagen Reservoir in 2010.			
Species	**Average**	**Minimum**	**Maximum**
	Number of Eight-Ounce Meals		
Blue catfish	3.0	1.0	10.0
Channel catfish	3.0	0.5	9.5
Crappie	0.6	0.3	0.9
Flathead catfish	4.0	1.0	16.0
Freshwater drum	1.9	0.5	6.5
Gar	4.8	1.2	14.8
Largemouth bass	2.0	1.0	6.0
Smallmouth buffalo	8.8	4.7	21.3
Spotted bass	1.0	0.4	2.1
Sunfish	0.3	0.2	0.6
White bass	1.7	1.0	2.3
All fish combined	2.9	0.2	21.3

Table 11. Risk assessor recommended fish consumption advice by species for B.A. Steinhagen Reservoir, 2010.			
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**	1 meal/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

LITERATURE CITED

[1] U.S. Environmental Protection Agency (USEPA). 2009. The national study of chemical residues in lake fish tissue. EPA-823-R-09-006. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

[2] Texas Department of Health (TDH). 1995. Assessment of risk for consumption of fish taken from Caddo Lake. Texas Department of Health, Seafood Safety Division, Austin, Texas.

[3] Texas Department Health (TDH). 1995. Fish and shellfish consumption advisory 11 (ADV-11) all Texas waters of Caddo Lake. Texas Department of Health, Seafood Safety Division, Austin, Texas.

[4] Texas Parks and Wildlife Department (TPWD). 2010-2011 Texas parks and wildlife outdoor annual hunting and fishing regulations. Ed. J. Jefferson. Texas Monthly Custom Publishing, a division of Texas Monthly, Inc. 2010.

[5] Texas Department of Health (TDH), Seafood Safety Division. 1995. Assessment of risk for consumption of fish taken from B.A. Steinhagen Reservoir. Texas Department of Health, Seafood Safety Division, Austin, Texas.

[6] Texas Department of Health (TDH) Inter-Office Memorandum. October 17, 1995. Aggregate risk assessment for consumption of fish from East Texas lakes. Texas Department of Health, Seafood Safety Division, Austin, Texas.

[7] Texas Department Health (TDH). 1995. Fish and shellfish consumption advisory 12 (ADV-12) all waters of B.A. Steinhagen Reservoir, Big Cypress Creek, and Sam Rayburn Reservoir. All Texas waters of Caddo Lake and Toledo Bend Reservoir. Texas Department of Health, Seafood Safety Division, Austin, Texas.

[8] Texas Department of Health (TDH). 2003. Preliminary screening values for toxicants in fish or shellfish: statewide screening initiative.Texas Department of Health, Seafood Safety Division, Austin, Texas.

[9] Texas Department of State Health Service (DSHS). 2011. DSHS tier 2 fish tissue monitoring and human health risk assessment priority water body assessment ranking list. Texas Department of State Health Services, Seafood and Aquatic Life Group, Austin, Texas.

[10] Texas Parks and Wildlife Department (TPWD). 2011. B.A. Steinhagen Lake. Available: http://www.tpwd.state.tx.us/fishboat/fish/recreational/lakes/steinhagen/ (May 31, 2011).

[11] United States Army Corps of Engineers (USACE). 2011. History of Town Bluff Dam and B.A. Steinhagen Lake. Available: http://www.swf-wc.usace.army.mil/townbluff/Information/History.asp (May 31, 2011).

[12] Ashe, D., and T. Driscoll. 2010. Statewide freshwater fisheries monitoring and management program survey report for B.A. Steinhagen Reservoir, 2009. Texas Parks and Wildlife Department, Federal Aid Report F-30-R-35, Texas Parks and Wildlife Department (TPWD), Austin, Texas.

[13] United States Army Corps of Engineers (USACE). 2011. Town Bluff Dam and B.A. Steinhagen Reservoir map. Available: http://www.swf-wc.usace.army.mil/townbluff/PDF's/Town%20Bluff.pdf (May 31, 2011).

[14] United States Census Bureau (USCB). 2010. 2010 census data. Available: http://2010.census.gov/2010census/data/ (May 31, 2010.

[15] United States Census Bureau (USCB). 2010. American factfinder. Available: http://factfinder2.census.gov/main.html (June 1, 2011).

[16] Jasper County. 2011. Jasper County profile. Available: http://www.txcip.org/tac/census/profile.php?FIPS=48241 (June 1, 2011).

---

[17] Tyler County. 2011. Tyler County profile. Available: http://www.txcip.org/tac/census/profile.php?FIPS=48457 (June 1, 2011).

[18] United States Environmental Protection Agency (USEPA). 2002. Economic and benefits analysis for the proposed section 316(b) phase II existing facilities rule Available: http://www.epa.gov/waterscience/316b/phase2/econbenefits/toc.pdf (July 14, 2010).

[19] Texas Department of State Health Services (DSHS). 2007. Standard operating procedures and quality assurance/quality control manual. Seafood and Aquatic Life Group Survey Team, Austin, Texas.

[20] United States Environmental Protection Agency (USEPA). 2000. Guidance for assessing chemical contaminant data for use in fish advisories. vol. 1, fish sampling and analysis, 3rd ed. EPA-823-B-00-007. Office of Water, Washington, D.C.

[21] Toxic Substances Coordinating Committee (TSCC) Web site. Available: http://www.tscc.state.tx.us/dshs.htm (July 14, 2010).

[22] Gulf States Marine Fisheries Commission (GSMFC). 2009. Practical handbook for determining the ages of Gulf of Mexico fishes, 2nd Edition. GSMFC Publication Number 167. Ocean Springs, MS.

[23] Texas Parks and Wildlife Department (TPWD). 2009. Texas inland fishery assessment procedures, TPWD Inland Fisheries Division unpublished manual. Austin, TX.

[24] United States Environmental Protection Agency (USEPA). 2000. Guidance for assessing chemical contaminant data for use in fish advisories. vol. 2, risk assessment and fish consumption limits, 3rd ed. EPA-823-00-008. Office of Water, Washington, D.C.

[25] Agency for Toxic Substances and Disease Registry (ATSDR). 2007. Toxicological profile for arsenic. United States Department of Health & Human Services, Public Health Service Atlanta, GA.

[26] Clean Water Act (CWA). 33 USC 125 *et seq.* 40CFR part 131: Water Quality Standards.

[27] Agency for Toxic Substances and Disease Registry (ATSDR). 1999. Toxicological profile for mercury (update). United States Department of Health & Human Services, Public Health Service. Atlanta, GA.

[28] Lauenstein, G.G. & Cantillo, A.Y. 1993. Sampling and analytical methods of the national status and trends program national benthic surveillance and mussel watch projects 1984-1992: overview and summary of methods - Vol. I. NOAA Tech. Memo 71. NOAA/CMBAD/ORCA. Silver Spring, MD. 157pp. Available: http://www.ccma.nos.noaa.gov/publications/tm71v1.pdf (August 27, 2010).

[29] McFarland, V.A. & Clarke, J.U. 1989. Environmental occurrence, abundance, and potential toxicity of polychlorinated biphenyl congeners: considerations for a congener-specific analysis. Environmental Health Perspectives. 81:225-239.

[30] Integrated Risk Information System (IRIS). Polychlorinated biphenyls (PCBs) (CASRN 1336-36-3), Part II, B.3. United States Environmental Protection Agency. Available: http://www.epa.gov/iris/subst/0294.htm (August 27, 2010).

[31] Integrated Risk Information System (IRIS). Comparison of database information for RfDs on Aroclor® 1016, 1254, 1260. United States Environmental Protection Agency. Available: http://cfpub.epa.gov/ncea/iris/compare.cfm (August 27, 2010).

[32] Van den Berg, M., L. Birnbaum, ATC Bosveld et al. 1998. Toxic equivalency factors (TEFs) for PCBs, PCDDs, PCDFs for humans and wildlife. Environ. Health Perspect. 106(12):775-792.

[33] World Health Organization (WHO). 2005. Project for the re-evaluation of human and mammalian toxic equivalency factors (TEFs) of dioxins and dioxin-like compounds. Available: http://www.who.int/ipcs/assessment/tef_update/en/ (August 27, 2010).

[34] De Rosa, CT, D. Brown, R. Dhara et al. 1997. Dioxin and dioxin-like compounds in soil, part 1: ATSDR interim policy guideline. Toxicol. Ind. Health. 13(6):759-768. Available: http://www.atsdr.cdc.gov/substances/dioxin/policy/ (August 27, 2010).

[35] Klaassen C.D., editor. 2001. Casarett and Doull's toxicology: the basic science of poisons, 6th ed. McGraw-Hill Medical Publishing Division, New York, NY.

[36] Beauchamp, R. 1999. Personal Communication: Monte Carlo simulations in analysis of fish tissue contaminant concentrations and probability of toxicity. Department of State Health Services, Austin, TX.

[37] Integrated Risk Information System (IRIS). 1993. Reference dose (RfD): description and use in risk assessments. United States Environmental Protection Agency. Available: http://www.epa.gov/iris/rfd.htm (August 27, 2010).

[38] Agency for Toxic Substances and Disease Registry (ATSDR). 2009. Minimal risk levels for hazardous substances. United States Department of Health & Human Services. Public Health Service. Available: http://www.atsdr.cdc.gov/mrls/index.html (August 27, 2010).

[39] Integrated Risk Information System (IRIS). 2010. IRIS glossary/acronyms & abbreviations. United States Environmental Protection Agency. Available: http://www.epa.gov/NCEA/iris/help_gloss.htm (August 27, 2010).

[40] United States Environmental Protection Agency (USEPA). 1999. Glossary of key terms. Technology transfer network national-scale air toxics assessment. Available: http://www.epa.gov/ttn/atw/natamain/gloss1.html (August 27, 2010).

[41] Thompson, K.M. 2004. Changes in children's exposure as a function of age and the relevance of age definitions for exposure and health risk assessment. MedGenMed. 6(3), 2004. Available: http://www.medscape.com/viewarticle/480733. (February 24, 2009).

[42] University of Minnesota, Maternal and Child Health Program, School of Public Health. 2004. Children's special vulnerability to environmental health risks. Healthy Generations 4(3). Available: http://www.epi.umn.edu/mch/resources/hg/hg_enviro.pdf (August 27, 2010).

[43] Selevan, S.G., C.A. Kimmel, and P. Mendola. 2000. Identifying critical windows of exposure for children's health. Environmental Health Perspectives Volume 108, Supplement 3.

[44] Schmidt, C.W. 2003. Adjusting for youth: updated cancer risk guidelines. Environmental Health Perspectives. 111(13):A708-A710.

[45] Agency for Toxic Substances and Disease Registry (ATSDR). 1995. Child health initiative. United States Department of Health & Human Services. Public Health Service. ATSDR Office of Children's Health. Atlanta, GA.

[46] United States Environmental Protection Agency (USEPA). 2000. Strategy for research on environmental risks to children, Section 1 and 2. Office of Research and Development (ORD)Washington, D.C.

[47] SPSS 13 for Windows©. Release 13.0.1. 2004. Copyright SPSS, Inc., 1989-2004. Available: http://www.spss.com (August 29, 2006).

[48] Microsoft Corporation. Microsoft® Office Excel 2003. Copyright© Microsoft Corporation 1985-2003.

[49] Centers for Disease Control and Prevention (CDC). 2005. Preventing lead poisoning in young children. United States Department of Health & Human Services. Atlanta, GA. Available: http://www.cdc.gov/nceh/lead/publications/PrevLeadPoisoning.pdf (August 27, 2010).

[50] Centers for Disease Control and Prevention (CDC). 2007. Interpreting and managing blood lead levels <10 mcg/dL in children and reducing childhood exposures to lead. United States Department of Health & Human Services, CDC Advisory Committee on Childhood Lead Poisoning Prevention. Atlanta, GA. MMWR 56(RR08); 1-14; 16 Available: http://www.cdc.gov/mmwr/preview/mmwrhtml/rr5608a1.htm (August 27, 2010). ERRATUM MMWR November 30, 2007 / 56(47):1241-1242. Available: http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5647a4.htm (August 27, 2010).

[51] Corl, E., R. Owen, A. Pollack, S. Braunig, and M. Holden. 2002. Detection and reporting limit issues related to risk assessments. United States Navy. Available: http://web.ead.anl.gov/ecorisk/issue/pdf/Final_Detection_04_02.pdf (August 27, 2010).

[52] Texas Parks and Wildlife Department (TPWD). 2011. 2011-2012 Regulations Summary. Available: http://www.tpwd.state.tx.us/publications/nonpwdpubs/media/cs_bk_k0700_284_2011_2012.pdf (February 9, 2012).

[53] United States Environmental Protection Agency (USEPA). 2003. Exposure and human health reassessment of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) and related compounds. Part III: integrated summary and risk characterization for 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) and related compounds. National Center for Environmental Assessment, Research and Development, Washington, D.C. **DRAFT for PUBLIC REVIEW ONLY** Available: http://www.epa.gov/NCEA/pdfs/dioxin/nas-review/pdfs/part3/dioxin_pt3_full_oct2004.pdf (August 27, 2010).

[54] University of Alaska Fairbanks, Alaska Sea Grant College Program. 2004. Recoveries and yields of pacific fish and shellfish. Marine Advisory Bulletin No. 37. University of Alaska, Fairbanks, AK

[55] United States Environmental Protection Agency (USEPA). 1996. Guidance for assessing chemical contaminant data for use in fish advisories. vol. 3, overview of risk management. EPA-823-B-96-006. Office of Water, Washington, D.C.

[56] Texas Statutes: Health and Safety Code, Chapter 436, Subchapter D, §436.061and § 436.091.

[57] Department of State Health Services (DSHS). 2009. Guide to eating Texas fish and Crabs. Seafood and Aquatic Life Group. Austin, TX.

[58] Department of State Health Services (DSHS). 2012. Seafood and Aquatic Life Group Web site. Austin, TX. Available: http://www.dshs.state.tx.us/seafood/ (February 23, 2012).

[59] Texas Parks and Wildlife Department (TPWD). 2011-2012. Outdoor annual: hunting and fishing regulations. Ed. J. Jefferson. Texas Monthly Custom Publishing, a division of Texas Monthly, Inc. (valid September 1, 2011 through August 31, 2012).