Characterization of Potential Adverse Health Effects Associated with Consuming Fish from

B.A. Steinhagen Reservoir

Jasper and Tyler Counties, Texas

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

This document summarizes the results of a survey of 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. 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. 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. 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. 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. 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. 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. 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. The reservoir is very shallow with a mean depth of 4 feet; littoral habitat < 15 feet comprises 95% of the reservoir’s surface area. 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.

**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. 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.\textsuperscript{15,16} In the United States Census 2010, Tyler County’s principal city and county seat, Woodville, Texas tallied a population 2,586 people.\textsuperscript{15,17} Lufkin, Texas positioned approximately 50 miles north of B.A. Steinhagen Reservoir is the closest major metropolitan area (population \( \geq 20,000 \) 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.\textsuperscript{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*.\textsuperscript{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*.\textsuperscript{20} Advice and direction are also received from the legislatively mandated *State of Texas Toxic Substances Coordinating Committee (TSCC) Fish Sampling Advisory Subcommittee (FSAS)*.\textsuperscript{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°F Fahrenheit (-20°C) 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. 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. 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.

**Details of Some Analyses with Explanatory Notes**

**Arsenic**

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. 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. 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. (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. 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), from McFarland and Clarke, and from the USEPA’s guidance documents for assessing contaminants in fish and shellfish 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 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. 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.

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. 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.

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

CI = concentration of a given congener
TEF = toxicity equivalence factor for the given congener
\(n\) = \# of congeners
$i = \text{initial congener}$

$\sum = \text{sum}$

**Derivation and Application of Health-Based Assessment Comparison Values for Systemic Effects (HAC}_{\text{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. 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.

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. 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}_{\text{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 or the ATSDR’s chronic oral MRLs. 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.

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.\textsuperscript{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

\textit{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

\textit{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,

\textit{Concern should increase as the number of effect-specific HIs 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)\textsuperscript{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.\textsuperscript{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.\textsuperscript{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.\textsuperscript{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.\textsuperscript{37} Additionally, in accordance with the ATSDR’s \textit{Child Health Initiative}\textsuperscript{45} and the USEPA’s \textit{National Agenda to Protect Children’s Health from Environmental Threats},\textsuperscript{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.

\textbf{Data Analysis and Statistical Methods}

The SALG risk assessors imported Excel\textsuperscript{©} files into SPSS\textsuperscript{®} statistical software, version 13.0 installed on IBM-compatible microcomputers (Dell, Inc), using SPSS\textsuperscript{®} to generate descriptive statistics (mean, standard deviation, median, minimum and maximum concentrations, and range) on measured compounds.\textsuperscript{47} In computing descriptive statistics, SALG risk assessors utilized \(\frac{1}{2}\) the reporting limit (RL) for analytes designated as not detected (ND) or estimated (J-values).\textsuperscript{*} PCDDs/PCDFs descriptive statistics are calculated using estimated concentrations (J-values) and assuming zero for PCDDs/PCDFs designated as ND.\textsuperscript{†} The change in methodology for computing PCDDs/PCDFs descriptive statistics is due to the proximity of the reporting limits to the HAC value. Assuming \(\frac{1}{2}\) 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 \(\frac{1}{2}\) 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 loge-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. 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). 48

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**

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

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).

**Mercury**

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 (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). 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 (r² = 0.687, n = 50, p <0.0005; r² = 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 (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). 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 (r² = 0.231, n = 46, p = 0.001; r² = 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 (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). 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 (r² = 0.128, n = 34, p = 0.037; r² = 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 (X – 15.8 inches TL) were analyzed for mercury (Table 1). Currently, there is no minimum length limit for freshwater drum in Texas waters. 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 (r² = 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 (X – 34.7 inches TL) were analyzed for mercury (Table 1). Currently, there is no minimum length limit for gar in Texas waters. 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 (\( \bar{X} = 15.6 \) 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 (\( \geq 14 \) inches TL). Mercury concentrations ranged from 0.126 to 1.644 mg/kg with a mean of 0.498\( \pm \)0.282 and a median of 0.450 mg/kg (Table 2d). The mean mercury concentrations for largemouth bass \( \geq 14 \) inches, \( \geq 16 \) inches, and \( \geq 18 \) inches were 0.548\( \pm \)0.301, 0.700\( \pm \)0.377, and 0.860\( \pm \)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 (\( \bar{X} = 24.5 \) inches TL) were analyzed for mercury (Table 1). Currently, there is no minimum length limit for smallmouth buffalo in Texas waters. Mercury concentrations ranged from 0.207 to 0.659 mg/kg with a mean of 0.439\( \pm \)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 (\( \bar{X} = 13.4 \) 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. Mercury concentrations ranged from 0.290 to 1.025 mg/kg with a mean of 0.527\( \pm \)0.214 and a median of 0.532 mg/kg (Table 2d). The mean mercury concentration for spotted bass \( \geq 14 \) inches was 0.660\( \pm \)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 (\( \bar{X} = 7.4 \) 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\( \pm \)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 \( (\bar{X} = 16.6 \text{ inches TL}) \) 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 \( (\geq 10 \text{ inches TL}) \). 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 \( (r^2 = 0.572, n = 7, p = 0.049; \text{Figure 19}) \).

**White crappie**

Thirty-two white crappie ranging from 8.9 to 13.5 inches TL \( (\bar{X} = 11.4 \text{ inches TL}) \) 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 \( (\geq 10 \text{ inches TL}) \). 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 \( (r^2 = 0.718, n = 31, p <0.0005; \text{Figure 21}) \).

**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.\textsuperscript{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. 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\textsubscript{nonca} (0.700 mg/kg; Tables 2d, 6a, and 6b). One (longnose gar) of 40 fish tissue samples evaluated contained PCBs exceeding the HAC\textsubscript{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\textsubscript{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\textsubscript{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\textsubscript{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\textsubscript{nonca} for mercury (0.700 mg/kg). Mercury concentrations that equaled or exceeded the HAC\textsubscript{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 inches 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 \( (r^2 = 0.446, n = 109, p < 0.0005 \text{ Figure 22}) \). The mercury–TL regression model for blue catfish estimated that blue catfish > 36 inches TL contain mercury concentrations equivalent to the HAC\textsubscript{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\textsubscript{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 \( (r^2 = 0.379, n = 60, p < 0.0005 \text{ Figure 23}) \). The mercury–TL regression model for flathead catfish estimated that flathead catfish > 30 inches TL contain mercury concentrations equivalent to the HAC\textsubscript{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\textsubscript{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%.\textsuperscript{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. Steinheagen Reservoir in 2010 ranged from 0.3–8.8 eight-ounce meals. Based on recoveries and yields (\(\bar{X} = 38\%\)) from whole fish to skin-off fillets for this project, the average B.A. Steinheagen 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\textsubscript{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. Steinheagen 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. Steinheagen 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. Steinheagen 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, redbreast 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. 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). Declarations of prohibited harvesting areas are enforceable under the Texas Health and Safety Code, Subchapter D, parts 436.091 and 436.101. 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.
- 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. 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
A booklet containing this information is available at all establishments selling Texas fishing licenses. 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.

Log$_e$(Hg) = 0.1(TL) - 3.693

$r^2 = 0.687$
$p < 0.0005$
$n = 50$
Figure 4. Relationship between mercury concentration and age for blue catfish collected from B.A. Steinhagen Reservoir, Texas, 2010.

$\text{Log}_e(Hg) = 0.122(\text{Age}) - 2.337$

$r^2 = 0.707$

$p < 0.0005$

$n = 48$
Figure 5. Length at age for channel catfish collected from B.A. Steinhagen Reservoir, Texas, 2010.

$n = 46$
Figure 6. Relationship between mercury concentration and total length for channel catfish collected from B.A. Steinhagen Reservoir, Texas, 2010.

Hg = 0.012(TL) - 0.014

$r^2 = 0.231$

$p = 0.001$

$n = 46$
Figure 7. Relationship between mercury concentration and age for channel catfish collected from B.A. Steinhagen Reservoir, Texas, 2010.

\[
\log_e (Hg) = 0.097(Age) - 2.191
\]

\[ r^2 = 0.256 \]

\[ p < 0.0005 \]

\[ n = 46 \]
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.

\[ Hg = 0.013(TL) + 0.016 \]

\[ r^2 = 0.128 \]

\[ p = 0.037 \]

\[ n = 34 \]
Figure 10. Relationship between mercury concentration and age for flathead catfish collected from B.A. Steinhagen Reservoir, Texas, 2010.

\[ Hg = 0.051(Age) + 0.115 \]

\[ r^2 = 0.363 \]

\[ p < 0.0005 \]

\[ n = 34 \]
Figure 11. Relationship between mercury concentration and total length for freshwater drum collected from B.A. Steinhagen Reservoir, Texas, 2010.

\[
\log_e (Hg) = 0.180(TL) - 4.428 \\
\]

\[
r^2 = 0.421 \quad p < 0.0005
\]

- 3.0 -2.5 -2.0 -1.5 -1.0 -0.5 0.0 0.5 1.0 1.5 2.0 2.5 3.0

-3.0 -2.5 -2.0 -1.5 -1.0 -0.5 0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5

10.0 11.0 12.0 13.0 14.0 15.0 16.0 17.0 18.0 19.0 20.0 21.0 22.0 23.0 24.0

Total Length (in)
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.

\[
\log_e(Hg) = 0.121(TL) - 2.711
\]

\[r^2 = 0.547\]

\[p < 0.0005\]

\[n = 88\]
Figure 14. Relationship between mercury concentration and age for largemouth bass collected from B.A. Steinhagen Reservoir, Texas, 2010.

$Hg = 0.125(Age) + 0.064$

$r^2 = 0.734$

$p < 0.0005$

$n = 86$
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.

\[
\log_e(Hg) = 0.118(TL) - 2.293
\]

\[
r^2 = 0.368
\]

\[
p = 0.013
\]

\[
n = 16
\]
Figure 17. Relationship between mercury concentration and age for spotted bass collected from B.A. Steinhagen Reservoir, Texas, 2010.

Hg = 0.108(Age) + 0.169

$r^2 = 0.598$

$p < 0.0005$

$n = 16$
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.

\[
\log_e(Hg) = 0.196(TL) - 3.666
\]

\[r^2 = 0.572\]

\[p = 0.049\]

\[n = 7\]
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.

\[ Hg = 0.045(Age) + 0.081 \]

\[ r^2 = 0.718 \]

\[ p < 0.0005 \]

\[ n = 31 \]
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.

\[ Hg = 0.027(TL) - 0.348 \]

\[ r^2 = 0.446 \]

\[ p < 0.0005 \]

\[ n = 109 \]
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.

\[ \text{Hg} = 0.039(TL) - 0.515 \]

\[ r^2 = 0.379 \]

\[ p < 0.0005 \]

\[ n = 60 \]
Table 1. Fish samples collected from B.A. Steinhagen Reservoir May–June 2010. Sample number, species, length, and weight recorded for each sample.

<table>
<thead>
<tr>
<th>Sample Number</th>
<th>Species</th>
<th>Length (mm)</th>
<th>Weight (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BAS01</td>
<td>Smallmouth buffalo</td>
<td>590</td>
<td>3847</td>
</tr>
<tr>
<td>BAS02</td>
<td>Smallmouth buffalo</td>
<td>579</td>
<td>3407</td>
</tr>
<tr>
<td>BAS03</td>
<td>Freshwater drum</td>
<td>511</td>
<td>2464</td>
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<tr>
<td>BAS04</td>
<td>Freshwater drum</td>
<td>536</td>
<td>2767</td>
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<tr>
<td>BAS05</td>
<td>Freshwater drum</td>
<td>412</td>
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<td>BAS06</td>
<td>Freshwater drum</td>
<td>422</td>
<td>1171</td>
</tr>
<tr>
<td>BAS07</td>
<td>Freshwater drum</td>
<td>373</td>
<td>765</td>
</tr>
<tr>
<td>BAS08</td>
<td>Freshwater drum</td>
<td>409</td>
<td>1073</td>
</tr>
<tr>
<td>BAS09</td>
<td>Hybrid striped bass</td>
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<td>1492</td>
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<td>BAS10</td>
<td>Longnose striped bass</td>
<td>1115</td>
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</tr>
<tr>
<td>BAS11</td>
<td>Alligator gar</td>
<td>883</td>
<td>3497</td>
</tr>
<tr>
<td>BAS12</td>
<td>White crappie</td>
<td>296</td>
<td>313</td>
</tr>
<tr>
<td>BAS13</td>
<td>Blue catfish</td>
<td>527</td>
<td>1329</td>
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<td>Channel catfish</td>
<td>630</td>
<td>2991</td>
</tr>
<tr>
<td>BAS15</td>
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Site 1 B.A. Steinhagen Reservoir at Dam

Site 2 B.A. Steinhagen Reservoir near Campers Cove Park
Table 1 cont. Fish samples collected from B.A. Steinhagen Reservoir May–June 2010. Sample number, species, length, and weight recorded for each sample.

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<th>Length (mm)</th>
<th>Weight (g)</th>
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| Site 2 B.A. Steinhagen Reservoir near Campers Cove Park (cont.) |
|------------------|------------------|-----------|-----------|
| 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        |

| 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.

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<th>Weight (g)</th>
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Table 1 cont. Fish samples collected from B.A. Steinhagen Reservoir May–June 2010. Sample number, species, length, and weight recorded for each sample.

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

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Site 5 B.A. Steinhagen Reservoir near Walnut Ridge Unit
Table 1 cont. Fish samples collected from B.A. Steinhagen Reservoir May–June 2010. Sample number, species, length, and weight recorded for each sample.

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Site 6 B.A. Steinhagen Reservoir near Magnolia Ridge Park

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Site 7 B.A. Steinhagen Reservoir at Neches River and Angelina River Confluence

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

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

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<th>Weight (g)</th>
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Table 1 cont. Fish samples collected from B.A. Steinhagen Reservoir May–June 2010. Sample number, species, length, and weight recorded for each sample.

<table>
<thead>
<tr>
<th>Sample Number</th>
<th>Species</th>
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<th>Weight (g)</th>
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Table 2a. Arsenic (mg/kg) in fish collected from B.A. Steinhagen Reservoir, 2010.

<table>
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<tr>
<th>Species</th>
<th># Detected/# Sampled</th>
<th>Total Arsenic Mean Concentration ± S.D. (Min-Max)</th>
<th>Inorganic Arsenic Mean Concentration*</th>
<th>Health Assessment Comparison Value (mg/kg)†</th>
<th>Basis for Comparison Value</th>
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<tbody>
<tr>
<td>Alligator gar</td>
<td>1/1</td>
<td>0.748 ± 0.075 (0.700-0.363)</td>
<td>0.075</td>
<td>0.700</td>
<td>EPA chronic oral RfD for inorganic arsenic: 0.00003 mg/kg-day</td>
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<tr>
<td>Blue catfish</td>
<td>8/8</td>
<td>0.756 ± 0.203 (0.431-1.104)</td>
<td>0.076</td>
<td>0.363</td>
<td>EPA oral slope factor for inorganic arsenic: 1.5 per mg/kg-day</td>
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<td>Flathead catfish</td>
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<td>0.665 ± 0.133 (0.461-0.819)</td>
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<td></td>
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<tr>
<td>Largemouth bass</td>
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<td>0.923</td>
<td>0.092</td>
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</tr>
<tr>
<td>All fish combined</td>
<td>16/16</td>
<td>0.732 ± 0.172 (0.431-1.104)</td>
<td>0.073</td>
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* 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 1x10⁻⁶.
### Table 2b. Inorganic contaminants (mg/kg) in fish collected from B.A. Steinhagen Reservoir, 2010.

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<th># Detected/ # Sampled</th>
<th>Mean Concentration ± S.D. (Min-Max)</th>
<th>Health Assessment Comparison Value (mg/kg)</th>
<th>Basis for Comparison Value</th>
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<td>0.060</td>
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<tr>
<td>Blue catfish</td>
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<td>0.025±0.010 (BDL-0.043)</td>
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<tr>
<td>Flathead catfish</td>
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<td>0.040±0.027 (BDL-0.086)</td>
<td>0.47</td>
<td>ATSDR chronic oral MRL: 0.0002 mg/kg-day</td>
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<td>All fish combined</td>
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<td>0.032±0.020 (BDL-0.086)</td>
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<td>Alligator gar</td>
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<td>0.162</td>
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<td>Blue catfish</td>
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<td>0.217±0.106 (0.144-0.471)</td>
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<td>National Academy of Science Upper Limit: 0.143 mg/kg-day</td>
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<td>0.156±0.053 (0.106-0.249)</td>
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<td>0.186±0.085 (0.106-0.471)</td>
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<td>0.060±0.039 (BDL-0.129)</td>
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<td>EPA IEUBKwin32 Version 1.1 Build 9</td>
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<td>0.070±0.039 (BDL-0.134)</td>
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<td>0.081</td>
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<td>0.070±0.040 (BDL-0.142)</td>
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<td>8/8</td>
<td>0.215±0.056 (0.155-0.334)</td>
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<td>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</td>
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<td>0.187±0.093 (0.115-0.353)</td>
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</tr>
<tr>
<td>Largemouth bass</td>
<td>1/1</td>
<td>0.302</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All fish combined</td>
<td>16/16</td>
<td>0.210±0.071 (0.115-0.353)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Species</td>
<td># Detected/ # Sampled</td>
<td>Mean Concentration ± S.D. (Min-Max)</td>
<td>Health Assessment Comparison Value (mg/kg)</td>
<td>Basis for Comparison Value</td>
</tr>
<tr>
<td>------------------</td>
<td>-----------------------</td>
<td>------------------------------------</td>
<td>------------------------------------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>Zinc</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alligator gar</td>
<td>1/1</td>
<td>4.448</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blue catfish</td>
<td>8/8</td>
<td>4.303±0.735 (3.403-5.763)</td>
<td>700</td>
<td>EPA chronic oral RfD: 0.3 mg/kg-day</td>
</tr>
<tr>
<td>Flathead catfish</td>
<td>6/6</td>
<td>4.486±1.583 (3.478-7.648)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Largemouth bass</td>
<td>1/1</td>
<td>3.599</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All fish combined</td>
<td>16/16</td>
<td>4.337±1.065 (3.403-7.648)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Table 2d. Mercury (mg/kg) in fish collected from B.A. Steinhagen Reservoir, 2010.

<table>
<thead>
<tr>
<th>Species</th>
<th># Detected/ # Sampled</th>
<th>Mean Concentration ± S.D. (Min-Max)</th>
<th>Health Assessment Comparison Value (mg/kg)</th>
<th>Basis for Comparison Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alligator gar</td>
<td>6/6</td>
<td>0.274±0.101 (0.177-0.430)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blue catfish</td>
<td>50/50</td>
<td>0.245±0.118 (0.084-0.546)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bluegill</td>
<td>12/12</td>
<td>0.150±0.061 (0.089-0.266)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Channel catfish</td>
<td>46/46</td>
<td>0.235±0.124 (0.066-0.565)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flathead catfish</td>
<td>34/34</td>
<td>0.318±0.133 (0.117-0.708)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Freshwater drum</td>
<td>53/53</td>
<td>0.272±0.245 (0.078-1.116)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hybrid striped bass</td>
<td>2/2</td>
<td>0.156±0.063 (0.111-0.200)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Largemouth bass</td>
<td>88/88</td>
<td>0.498±0.282 (0.126-1.644)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Longear sunfish</td>
<td>1/1</td>
<td>0.134</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Longnose gar</td>
<td>11/11</td>
<td>0.672±0.449 (0.171-1.855)</td>
<td>0.7</td>
<td>ATSDR chronic oral MRL: 0.0003 mg/kg-day</td>
</tr>
<tr>
<td>Redbreast sunfish</td>
<td>3/3</td>
<td>0.158±0.098 (0.094-0.271)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Redear sunfish</td>
<td>14/14</td>
<td>0.142±0.044 (0.095-0.246)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smallmouth buffalo</td>
<td>16/16</td>
<td>0.439±0.142 (0.207-0.659)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spotted bass</td>
<td>16/16</td>
<td>0.527±0.214 (0.290-1.025)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spotted gar</td>
<td>6/6</td>
<td>0.371±0.207 (0.212-0.761)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Warmouth</td>
<td>3/3</td>
<td>0.229±0.055 (0.176-0.286)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White bass</td>
<td>7/7</td>
<td>0.696±0.319 (0.378-0.920)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White crappie</td>
<td>32/32</td>
<td>0.234±0.083 (0.134-0.537)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gar spp.</td>
<td>23/23</td>
<td>0.490±0.370 (0.171-1.855)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sunfish spp.</td>
<td>33/33</td>
<td>0.154±0.059 (0.089-0.286)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All fish combined</td>
<td>400/400</td>
<td>0.341±0.244 (0.066-1.855)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* 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.

<table>
<thead>
<tr>
<th>Species</th>
<th># Detected/ # Sampled</th>
<th>Mean Concentration ± S.D. (Min-Max)</th>
<th>Health Assessment Comparison Value (mg/kg)</th>
<th>Basis for Comparison Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury</td>
<td></td>
<td></td>
<td>0.7</td>
<td>ATSDR chronic oral MRL: 0.0003 mg/kg-day</td>
</tr>
<tr>
<td>Freshwater drum ≥ 20”</td>
<td>4/4</td>
<td>0.766 ±0.312 (0.361-1.116)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Largemouth bass &lt; 14”</td>
<td>22/22</td>
<td>0.349 ±0.132 (0.126-0.597)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Largemouth bass ≥ 14”</td>
<td>66/66</td>
<td>0.548 ±0.301 (0.198-1.644)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Largemouth bass ≥ 16”</td>
<td>30/30</td>
<td>0.700 ±0.377 (0.237-1.644)</td>
<td>0.7</td>
<td>ATSDR chronic oral MRL: 0.0003 mg/kg-day</td>
</tr>
<tr>
<td>Largemouth bass ≥ 18”</td>
<td>17/17</td>
<td>0.860 ±0.396 (0.478-1.644)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Largemouth bass ≥ 20”</td>
<td>11/11</td>
<td>0.967 ±0.446 (0.510-1.644)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Largemouth bass ≥ 22”</td>
<td>4/4</td>
<td>1.114 ±0.442 (0.726-1.644)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spotted bass ≥ 14”</td>
<td>8/8</td>
<td>0.660 ±0.217 (0.378-1.025)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Emboldened numbers denote that mercury concentrations equal and/or exceed the DSHS HAC value for mercury.
<table>
<thead>
<tr>
<th>Species</th>
<th># Detected / # Sampled</th>
<th>Mean Concentration ± S.D. (Min-Max)</th>
<th>Health Assessment Comparison Value (mg/kg)</th>
<th>Basis for Comparison Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Beta-HCH</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alligator gar</td>
<td>1/1</td>
<td>0.004</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blue catfish</td>
<td>7/8</td>
<td>0.003±0.001 (ND-0.004)</td>
<td>1.4</td>
<td>ATSDR intermediate oral MRL: 0.0006 mg/kg-day</td>
</tr>
<tr>
<td>Flathead catfish</td>
<td>6/6</td>
<td>0.003±0.0005 (0.002-0.004)</td>
<td>0.3</td>
<td>EPA slope factor: 1.8 per mg/kg-day</td>
</tr>
<tr>
<td>Largemouth bass</td>
<td>1/1</td>
<td>0.004</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All fish combined</td>
<td>15/16</td>
<td>0.003±0.0009 (ND-0.004)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Gamma-HCH</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alligator gar</td>
<td>1/1</td>
<td>0.002</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blue catfish</td>
<td>7/8</td>
<td>0.001±0.0005 (ND-0.002)</td>
<td>0.7</td>
<td>EPA chronic oral RfD: 0.0003 mg/kg-day</td>
</tr>
<tr>
<td>Flathead catfish</td>
<td>6/6</td>
<td>0.001±0.0008 (BDL-0.002)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Largemouth bass</td>
<td>1/1</td>
<td>0.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All fish combined</td>
<td>15/16</td>
<td>0.001±0.0006 (ND-0.002)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Delta-HCH</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alligator gar</td>
<td>1/1</td>
<td>0.0009</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blue catfish</td>
<td>4/8</td>
<td>0.0009±0.0004 (ND-0.002)</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Flathead catfish</td>
<td>3/6</td>
<td>0.001±0.0005 (ND-0.002)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Largemouth bass</td>
<td>1/1</td>
<td>0.003</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All fish combined</td>
<td>9/16</td>
<td>0.001±0.0006 (ND-0.003)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Species</td>
<td># Detected / # Sampled</td>
<td>Mean Concentration ± S.D. (Min-Max)</td>
<td>Health Assessment Comparison Value (mg/kg)</td>
<td>Basis for Comparison Value</td>
</tr>
<tr>
<td>----------------------</td>
<td>------------------------</td>
<td>--------------------------------------</td>
<td>--------------------------------------------</td>
<td>----------------------------</td>
</tr>
<tr>
<td>Alligator gar</td>
<td>4/6</td>
<td>0.010±0.0004 (ND-0.011)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blue catfish</td>
<td>8/8</td>
<td>0.010±0.001 (BDL-0.013)</td>
<td>0.047</td>
<td>EPA chronic oral RfD: 0.00002 mg/kg–day</td>
</tr>
<tr>
<td>Channel catfish</td>
<td>7/7</td>
<td>0.011±0.001 (BDL-0.013)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flathead catfish</td>
<td>5/6</td>
<td>0.011±0.004 (ND-0.020)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hybrid striped bass</td>
<td>2/2</td>
<td>0.012±0.0007 (0.011-0.012)</td>
<td>0.272</td>
<td>EPA slope factor: 2.0 per mg/kg–day</td>
</tr>
<tr>
<td>Largemouth bass</td>
<td>6/6</td>
<td>0.011±0.003 (BDL-0.017)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Longnose gar</td>
<td>2/2</td>
<td>0.057±0.065 (0.011-0.103)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White bass</td>
<td>3/3</td>
<td>0.012±0.0006 (0.011-0.012)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All fish combined</td>
<td>37/40</td>
<td>0.013±0.015 (ND-0.103)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*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.

<table>
<thead>
<tr>
<th>Species</th>
<th># Detected / # Sampled</th>
<th>Mean Concentration ± S.D. (Min-Max)</th>
<th>Health Assessment Comparison Value (pg/g)</th>
<th>Basis for Comparison Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>B.A. Steinhagen Reservoir All Sites</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alligator gar</td>
<td>5/6</td>
<td>0.106±0.107 (ND-0.284)</td>
<td>2.33</td>
<td>ATSDR chronic oral MRL: 1.0 x 10^-9 mg/kg/day</td>
</tr>
<tr>
<td>Blue catfish</td>
<td>17/18</td>
<td>0.128±0.124 (ND-0.443)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Channel catfish</td>
<td>14/18</td>
<td>0.201±0.301 (ND-0.945)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flathead catfish</td>
<td>16/18</td>
<td>0.164±0.263 (ND-1.099)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hybrid Striped bass</td>
<td>2/2</td>
<td>1.896±0.643 (1.441-2.351)</td>
<td>3.49</td>
<td>EPA slope factor: 1.56 x 10^5 per mg/kg/day</td>
</tr>
<tr>
<td>Largemouth bass</td>
<td>4/21</td>
<td>0.050±0.227 (ND-1.042)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Longnose gar</td>
<td>5/6</td>
<td>1.353±2.365 (ND-6.063)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spotted gar</td>
<td>3/4</td>
<td>0.051±0.057 (ND-0.119)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White bass</td>
<td>3/3</td>
<td>0.132±0.189 (0.018-0.350)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All fish combined</td>
<td>69/96</td>
<td>0.240±0.702 (ND-6.063)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* 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. *

<table>
<thead>
<tr>
<th>Species</th>
<th>Number (N)</th>
<th>Hazard Quotient</th>
<th>Meals per Week</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>B.A. Steinhagen Reservoir All Sites</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alligator gar</td>
<td>6</td>
<td>0.39</td>
<td>2.4</td>
</tr>
<tr>
<td>Blue catfish</td>
<td>50</td>
<td>0.35</td>
<td>2.6</td>
</tr>
<tr>
<td>Bluegill</td>
<td>12</td>
<td>0.21</td>
<td>4.3</td>
</tr>
<tr>
<td>Channel catfish</td>
<td>46</td>
<td>0.34</td>
<td>2.8</td>
</tr>
<tr>
<td>Flathead catfish</td>
<td>34</td>
<td>0.45</td>
<td>2.0</td>
</tr>
<tr>
<td>Freshwater drum</td>
<td>53</td>
<td>0.39</td>
<td>2.4</td>
</tr>
<tr>
<td>Hybrid striped bass</td>
<td>2</td>
<td>0.22</td>
<td>4.2</td>
</tr>
<tr>
<td>Largemouth bass</td>
<td>88</td>
<td>0.71</td>
<td>1.3</td>
</tr>
<tr>
<td>Longear sunfish</td>
<td>1</td>
<td>0.19</td>
<td>4.8</td>
</tr>
<tr>
<td>Longnose gar</td>
<td>11</td>
<td><strong>0.96</strong></td>
<td><strong>1.0</strong></td>
</tr>
<tr>
<td>Redbreast sunfish</td>
<td>3</td>
<td>0.23</td>
<td>4.1</td>
</tr>
<tr>
<td>Redear sunfish</td>
<td>14</td>
<td>0.20</td>
<td>4.6</td>
</tr>
<tr>
<td>Smallmouth buffalo</td>
<td>16</td>
<td>0.63</td>
<td>1.5</td>
</tr>
<tr>
<td>Spotted bass</td>
<td>16</td>
<td>0.75</td>
<td>1.2</td>
</tr>
<tr>
<td>Spotted gar</td>
<td>6</td>
<td>0.53</td>
<td>1.7</td>
</tr>
<tr>
<td>Warmouth</td>
<td>3</td>
<td>0.33</td>
<td>2.8</td>
</tr>
<tr>
<td>White bass</td>
<td>7</td>
<td><strong>0.99</strong></td>
<td><strong>0.9</strong></td>
</tr>
<tr>
<td>White crappie</td>
<td>32</td>
<td>0.33</td>
<td>2.8</td>
</tr>
<tr>
<td>Gar spp.</td>
<td>23</td>
<td>0.70</td>
<td>1.3</td>
</tr>
<tr>
<td>Sunfish spp.</td>
<td>33</td>
<td>0.22</td>
<td>4.2</td>
</tr>
<tr>
<td>All fish combined</td>
<td>400</td>
<td>0.49</td>
<td>1.9</td>
</tr>
</tbody>
</table>

* 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. *

<table>
<thead>
<tr>
<th>Species</th>
<th>Number (N)</th>
<th>Hazard Quotient</th>
<th>Meals per Week</th>
</tr>
</thead>
</table>
| 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.

<table>
<thead>
<tr>
<th>Contaminant/Species</th>
<th>Number (N)</th>
<th>Hazard Quotient</th>
<th>Meals per Week</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Alligator gar</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCBs</td>
<td>6</td>
<td>0.21</td>
<td>4.3</td>
</tr>
<tr>
<td>PCDDs/PCDFs</td>
<td>6</td>
<td>0.05</td>
<td>20.4</td>
</tr>
<tr>
<td>Hazard Index (meals per week)</td>
<td>0.26</td>
<td>3.6</td>
<td></td>
</tr>
<tr>
<td><strong>Blue catfish</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCBs</td>
<td>8</td>
<td>0.21</td>
<td>4.3</td>
</tr>
<tr>
<td>PCDDs/PCDFs</td>
<td>18</td>
<td>0.05</td>
<td>16.9</td>
</tr>
<tr>
<td>Hazard Index (meals per week)</td>
<td>0.27</td>
<td>3.4</td>
<td></td>
</tr>
<tr>
<td><strong>Channel catfish</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCBs</td>
<td>7</td>
<td>0.24</td>
<td>3.9</td>
</tr>
<tr>
<td>PCDDs/PCDFs</td>
<td>18</td>
<td>0.09</td>
<td>10.7</td>
</tr>
<tr>
<td>Hazard Index (meals per week)</td>
<td>0.32</td>
<td>2.9</td>
<td></td>
</tr>
<tr>
<td><strong>Flathead catfish</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCBs</td>
<td>6</td>
<td>0.24</td>
<td>3.9</td>
</tr>
<tr>
<td>PCDDs/PCDFs</td>
<td>18</td>
<td>0.07</td>
<td>13.2</td>
</tr>
<tr>
<td>Hazard Index (meals per week)</td>
<td>0.31</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td><strong>Hybrid striped bass</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCBs</td>
<td>2</td>
<td>0.26</td>
<td>3.6</td>
</tr>
<tr>
<td>PCDDs/PCDFs</td>
<td>2</td>
<td>0.81</td>
<td>1.1</td>
</tr>
<tr>
<td>Hazard Index (meals per week)</td>
<td><strong>1.07</strong>†</td>
<td><strong>0.9</strong>‡</td>
<td></td>
</tr>
</tbody>
</table>

* 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.  

<table>
<thead>
<tr>
<th>Contaminant/Species</th>
<th>Number (N)</th>
<th>Hazard Quotient</th>
<th>Meals per Week</th>
</tr>
</thead>
<tbody>
<tr>
<td>Largemouth bass</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCBs</td>
<td>6</td>
<td>0.24</td>
<td>3.9</td>
</tr>
<tr>
<td>PCDDs/PCDFs</td>
<td>21</td>
<td>0.02</td>
<td>unrestricted†</td>
</tr>
<tr>
<td>Hazard Index (meals per week)</td>
<td>0.26</td>
<td>3.6</td>
<td></td>
</tr>
<tr>
<td>Longnose gar</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCBs</td>
<td>2</td>
<td>1.22‡</td>
<td>0.8§</td>
</tr>
<tr>
<td>Hazard Index (meals per week)</td>
<td>1.80</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Spotted gar</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCDDs/PCDFs</td>
<td>4</td>
<td>0.02</td>
<td>unrestricted</td>
</tr>
<tr>
<td>White bass</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCBs</td>
<td>3</td>
<td>0.26</td>
<td>3.6</td>
</tr>
<tr>
<td>PCDDs/PCDFs</td>
<td>3</td>
<td>0.06</td>
<td>16.4</td>
</tr>
<tr>
<td>Hazard Index (meals per week)</td>
<td>0.31</td>
<td>2.9</td>
<td></td>
</tr>
<tr>
<td>All fish combined</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCBs</td>
<td>40</td>
<td>0.28</td>
<td>3.3</td>
</tr>
<tr>
<td>PCDDs/PCDFs</td>
<td>96</td>
<td>0.10</td>
<td>9.0</td>
</tr>
<tr>
<td>Hazard Index (meals per week)</td>
<td>0.38</td>
<td>2.4</td>
<td></td>
</tr>
</tbody>
</table>

* 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.

<table>
<thead>
<tr>
<th>Species/Contaminant</th>
<th>Number (N)</th>
<th>Theoretical Lifetime Excess Cancer Risk Risk</th>
<th>1 excess cancer per number of people exposed</th>
<th>Meals per Week</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Risk</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alligator gar</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arsenic</td>
<td>1</td>
<td>2.1E-05</td>
<td>48,395</td>
<td>4.5</td>
</tr>
<tr>
<td>PCBs</td>
<td>6</td>
<td>3.7E-06</td>
<td>272,222</td>
<td>unrestricted†</td>
</tr>
<tr>
<td>PCDDs/PCDFs</td>
<td>6</td>
<td>3.0E-06</td>
<td>329,248</td>
<td>unrestricted</td>
</tr>
<tr>
<td><strong>Cumulative Cancer Risk</strong></td>
<td></td>
<td>2.7E-05</td>
<td>36,531</td>
<td>3.4</td>
</tr>
<tr>
<td>Blue catfish</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arsenic</td>
<td>8</td>
<td>2.1E-05</td>
<td>47,758</td>
<td>4.4</td>
</tr>
<tr>
<td>PCBs</td>
<td>8</td>
<td>3.7E-06</td>
<td>272,222</td>
<td>unrestricted</td>
</tr>
<tr>
<td>PCDDs/PCDFs</td>
<td>18</td>
<td>3.7E-06</td>
<td>272,658</td>
<td>unrestricted</td>
</tr>
<tr>
<td><strong>Cumulative Cancer Risk</strong></td>
<td></td>
<td>2.8E-05</td>
<td>35,361</td>
<td>3.3</td>
</tr>
<tr>
<td>Channel catfish</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCBs</td>
<td>7</td>
<td>4.0E-06</td>
<td>247,475</td>
<td>unrestricted</td>
</tr>
<tr>
<td>PCDDs/PCDFs</td>
<td>18</td>
<td>5.8E-06</td>
<td>173,633</td>
<td>16.0</td>
</tr>
<tr>
<td><strong>Cumulative Cancer Risk</strong></td>
<td></td>
<td>9.8E-06</td>
<td>102,040</td>
<td>9.4</td>
</tr>
<tr>
<td>Flathead catfish</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arsenic</td>
<td>6</td>
<td>1.8E-05</td>
<td>54,944</td>
<td>5.1</td>
</tr>
<tr>
<td>PCBs</td>
<td>6</td>
<td>4.0E-06</td>
<td>247,475</td>
<td>unrestricted</td>
</tr>
<tr>
<td>PCDDs/PCDFs</td>
<td>18</td>
<td>4.6E-06</td>
<td>218,127</td>
<td>20.2</td>
</tr>
<tr>
<td><strong>Cumulative Cancer Risk</strong></td>
<td></td>
<td>2.7E-05</td>
<td>37,301</td>
<td>3.4</td>
</tr>
</tbody>
</table>

* 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.

<table>
<thead>
<tr>
<th>Species/Contaminant</th>
<th>Number (N)</th>
<th>Theoretical Lifetime Excess Cancer Risk</th>
<th>Meals per Week</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Risk</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 excess cancer per number of people</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>exposed</td>
<td></td>
</tr>
<tr>
<td>Hybrid striped bass</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCBs</td>
<td>2</td>
<td>4.4E-06</td>
<td>226,852</td>
</tr>
<tr>
<td>PCDDs/PCDFs</td>
<td>2</td>
<td>5.4E-05</td>
<td>18,369</td>
</tr>
<tr>
<td>Cumulative Cancer Risk</td>
<td></td>
<td>5.9E-05</td>
<td>16,993</td>
</tr>
<tr>
<td>Largemouth bass</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arsenic</td>
<td>1</td>
<td>2.5E-05</td>
<td>39,452</td>
</tr>
<tr>
<td>PCBs</td>
<td>6</td>
<td>4.0E-06</td>
<td>247,475</td>
</tr>
<tr>
<td>PCDDs/PCDFs</td>
<td>21</td>
<td>1.4E-06</td>
<td>698,006</td>
</tr>
<tr>
<td>Cumulative Cancer Risk</td>
<td></td>
<td>3.1E-05</td>
<td>32,446</td>
</tr>
<tr>
<td>Longnose gar</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCBs</td>
<td>2</td>
<td>2.1E-05</td>
<td>47,758</td>
</tr>
<tr>
<td>PCDDs/PCDFs</td>
<td>6</td>
<td>3.9E-05</td>
<td>25,795</td>
</tr>
<tr>
<td>Cumulative Cancer Risk</td>
<td></td>
<td>6.0E-05</td>
<td>16,749</td>
</tr>
<tr>
<td>Spotted gar</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCDDs/PCDFs</td>
<td>4</td>
<td>1.5E-06</td>
<td>684,319</td>
</tr>
<tr>
<td>All fish combined</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arsenic</td>
<td>16</td>
<td>2.0E-05</td>
<td>49,721</td>
</tr>
<tr>
<td>PCBs</td>
<td>40</td>
<td>4.8E-06</td>
<td>209,402</td>
</tr>
<tr>
<td>PCDDs/PCDFs</td>
<td>96</td>
<td>6.9E-06</td>
<td>145,418</td>
</tr>
<tr>
<td>Cumulative Cancer Risk</td>
<td></td>
<td>3.2E-05</td>
<td>31,482</td>
</tr>
</tbody>
</table>

* 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.

<table>
<thead>
<tr>
<th>Species</th>
<th># Detected/ # Sampled</th>
<th>Mean Concentration ± S.D. (Min-Max)</th>
<th>Health Assessment Comparison Value (mg/kg)</th>
<th>Basis for Comparison Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blue catfish</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All blue catfish</td>
<td>109/109</td>
<td>0.264±0.198 (0.031-1.332)</td>
<td>0.7</td>
<td>ATSDR chronic oral MRL: 0.0003 mg/kg–day</td>
</tr>
<tr>
<td>Blue catfish &lt; 30”</td>
<td>99/99</td>
<td>0.225±0.129 (0.031-0.767)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blue catfish &gt; 30”</td>
<td>10/10</td>
<td>0.653±0.322 (0.345-1.332)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flathead catfish</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All flathead catfish</td>
<td>60/60</td>
<td>0.439±0.334 (0.117-2.406)</td>
<td>0.7</td>
<td>ATSDR chronic oral MRL: 0.0003 mg/kg–day</td>
</tr>
<tr>
<td>Flathead catfish &lt; 27”</td>
<td>48/48</td>
<td>0.352±0.178 (0.117-1.010)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flathead catfish &gt; 27”</td>
<td>12/12</td>
<td>0.788±0.547 (0.247-2.406)</td>
<td>0.7</td>
<td>ATSDR chronic oral MRL: 0.0003 mg/kg–day</td>
</tr>
<tr>
<td>Flathead catfish &lt; 30”</td>
<td>51/51</td>
<td>0.377±0.203 (0.117-1.010)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flathead catfish &gt; 30”</td>
<td>9/9</td>
<td>0.791±0.634 (0.247-2.406)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*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.

<table>
<thead>
<tr>
<th>Species</th>
<th>Average</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blue catfish</td>
<td>3.0</td>
<td>1.0</td>
<td>10.0</td>
</tr>
<tr>
<td>Channel catfish</td>
<td>3.0</td>
<td>0.5</td>
<td>9.5</td>
</tr>
<tr>
<td>Crappie</td>
<td>0.6</td>
<td>0.3</td>
<td>0.9</td>
</tr>
<tr>
<td>Flathead catfish</td>
<td>4.0</td>
<td>1.0</td>
<td>16.0</td>
</tr>
<tr>
<td>Freshwater drum</td>
<td>1.9</td>
<td>0.5</td>
<td>6.5</td>
</tr>
<tr>
<td>Gar</td>
<td>4.8</td>
<td>1.2</td>
<td>14.8</td>
</tr>
<tr>
<td>Largemouth bass</td>
<td>2.0</td>
<td>1.0</td>
<td>6.0</td>
</tr>
<tr>
<td>Smallmouth buffalo</td>
<td>8.8</td>
<td>4.7</td>
<td>21.3</td>
</tr>
<tr>
<td>Spotted bass</td>
<td>1.0</td>
<td>0.4</td>
<td>2.1</td>
</tr>
<tr>
<td>Sunfish</td>
<td>0.3</td>
<td>0.2</td>
<td>0.6</td>
</tr>
<tr>
<td>White bass</td>
<td>1.7</td>
<td>1.0</td>
<td>2.3</td>
</tr>
<tr>
<td>All fish combined</td>
<td>2.9</td>
<td>0.2</td>
<td>21.3</td>
</tr>
</tbody>
</table>
Table 11. Risk assessor recommended fish consumption advice by species for B.A. Steinhagen Reservoir, 2010.

<table>
<thead>
<tr>
<th>Contaminants of Concern</th>
<th>Species</th>
<th>Women of childbearing age and children &lt; 12</th>
<th>Women past childbearing age and adult men</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dioxins and mercury</td>
<td>Blue catfish &gt; 30 inches</td>
<td>DO NOT EAT</td>
<td>2 meals/month</td>
</tr>
<tr>
<td></td>
<td>Flathead catfish</td>
<td>DO NOT EAT</td>
<td>1 meal/month</td>
</tr>
<tr>
<td></td>
<td>Gar (all species)</td>
<td>DO NOT EAT</td>
<td>1 meal/month</td>
</tr>
<tr>
<td></td>
<td>Largemouth bass &gt; 16 inches</td>
<td>DO NOT EAT</td>
<td>2 meals/month</td>
</tr>
<tr>
<td></td>
<td>Smallmouth buffalo</td>
<td>DO NOT EAT</td>
<td>DO NOT EAT</td>
</tr>
<tr>
<td></td>
<td>Spotted bass &gt; 16 inches</td>
<td>DO NOT EAT</td>
<td>2 meals/month</td>
</tr>
</tbody>
</table>
LITERATURE CITED


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