Characterization of Potential Adverse Health Effects Associated with Consuming Fish from Lower Leon Creek

Bexar County, Texas

2024

INTRODUCTION

This addendum report summarizes per- and polyfluoroalkyl substances (PFAS) found in fish collected in two sampling events from Lower Leon Creek, Bexar County, Texas. The first sampling event took place in December 2021 and January 2022, the results from which are summarized in *Lower Leon Creek Risk Characterization Addendum 2022* [DSHS 2022]. The second sampling event took place in November 2023. This report combines the results from the December 2021/January 2022 and November 2023 sampling events and replaces the 2022 addendum report. The current report addresses the public health implications of consuming contaminated fish with PFAS from Lower Leon Creek, individually and cumulatively, and suggests actions to protect humans from possible adverse health effects of consuming contaminated fish from this water body.

BACKGROUND

In the 1970s, air force firefighters were trained on air force bases to extinguish aircraft fires using aqueous film forming foam (AFFF) [Anderson 2016]. The AFFF contained PFAS and repeated use of the AFFF led to PFAS contaminants seeping into the groundwater. Because some of these military facilities are located adjacent to water bodies, it is possible that historic use of AFFF has contaminated surface water and fish with PFAS. In Texas, AFFF was used at several former and active military bases throughout the state and its use has resulted in PFAS contamination in soil and groundwater [Environmental Working Group 2018].

Lower Leon Creek is adjacent to both Lackland Air Force Base and the former Kelly Air Force Base (now collectively referred to as Joint Base San Antonio). The Department of Defense identified PFAS in groundwater at the Lackland Air Force Base but did not identify PFAS in samples collected from the surface drainage to Lower Leon Creek [OTIE 2017].

Per- and Polyfluoroalkyl Substances

Per- and polyfluoroalkyl substances (PFAS) are a group of environmental persistent and ubiquitous chemicals. Because their chemical structure produces an ability to repel both oil and water, these compounds have been

widely used for several decades in many consumer products, including non-stick cookware, clothing, and cosmetics, and to produce various materials, including aqueous film forming foam [Barzne-Hanson 2017, Lindstrom 2011].

Evidence from both animal and human studies demonstrate associations between PFAS exposure and a variety of adverse health effects, including high cholesterol, adverse reproductive and developmental effects, altered liver enzymes, thyroid disorders, and pregnancy hypertension [USEPA 2021]. Some PFAS chemicals have also been identified as possible human carcinogens [ATSDR 2020a].

People are primarily exposed to PFAS through their diet, and fish and other seafood often contain high concentrations. Several studies have confirmed that fish intake is associated with elevated levels of multiple PFAS compounds in the US population [Holzer 2020, Fujii 2015]. Although PFAS contamination in water bodies is pervasive and comes from a wide range of sources, water bodies located near military locations where AFFF was frequently used are potentially at risk for contamination. Previous studies have observed higher levels of PFAS in fish tissue collected adjacent to military sites with PFAS-contaminated soil and groundwater, compared with other locations where PFAS was not used [Goodrow 2020].

History of Lower Leon Creek Fish Consumption Advisory

Lower Leon Creek flows southeasterly through two military facilities. These facilities include Kelly Field (formerly Kelly Air Force Base) and Lackland Air Force Base. Past operations from these facilities have results in documented environmental contamination to Lower Leon Creek, the shallow groundwater and soil in and around the Kelly Field. Contaminants included organic solvents such as trichloroethylene and tetrachloroethylene, and other toxic substances [ATSDR 1999].

In July 2000, as part of routine monitoring of environmental conditions associated with air force bases, the U.S. Air Force (USAF) collected and analyzed samples of whole fish from the Lower Leon Creek. The assessment confirmed that whole fish samples from Lower Leon Creek contained polychlorinated biphenyls (PCBs) and organochlorine pesticides [ATSDR 1999]. In 2002, the Texas Department of Health (TDH), now Texas Department of State Health Services (DSHS), in collaboration with USAF conducted another fish survey to assess contamination in edible portions of fish and to characterize possible risks to human health from consuming fish from the creek [ATSDR 2003]. Based on the results of the second fish survey, TDH concluded that PCBs in fish are at levels that could potentially

result in adverse health effects in people who regularly eat fish from Lower Leon Creek. In August 2003, TDH issued Advisory 26 (ADV-26), which recommended that no one consume fish taken from Lower Leon Creek from State Highway 90 downstream to Military Drive [DSHS 2003].

In 2010, the TDH updated the fish survey at Lower Leon Creek and issued ADV-42, which expanded the geographic extent of the ADV-24 [DSHS 2010]. ADV-42 is based on the presence of PCBs in fish, including channel catfish, common carp, gar, and largemouth bass, collected downstream of Rodriquez Park. ADV-42 recommends that no one consume fish collected from the creek from State Highway 90 to Rodriquez Park.

In 2022, DSHS evaluated fish from Lower Leon Creek for PFAS. The results of the evaluation were summarized in *Lower Leon Creek Risk Characterization Addendum 2022* [DSHS 2022].

Lower Leon Creek, Texas

Leon Creek originates as a spring-fed stream in the Edwards Plateau region of south-central Texas. The creek is a 57-mile stream in the San Antonio River Basin that extends from its confluence with the Medina River to its headwaters in northern Bexar County. Lower Leon Creek makes up a 32-mile segment of Leon Creek. Lower Leon Creek drains a highly urbanized residential area, including Kelly Field and Lackland Air Base.

With its shallow banks, Lower Leon Creek is easily accessible through public parks and bridge crossings, increasing the possibility that people will fish and consume fish taken from its waters.

PURPOSE

The purpose of 2021/2022 and 2023 surveys was to 1) determine the presence of PFAS in fish from Lower Leon Creek; 2) determine the public health implications of consuming PFAS-contaminated fish, individually and cumulatively, and 3) suggest actions to protect humans from possible adverse health effects of consuming contaminated fish from this water body.

METHODS

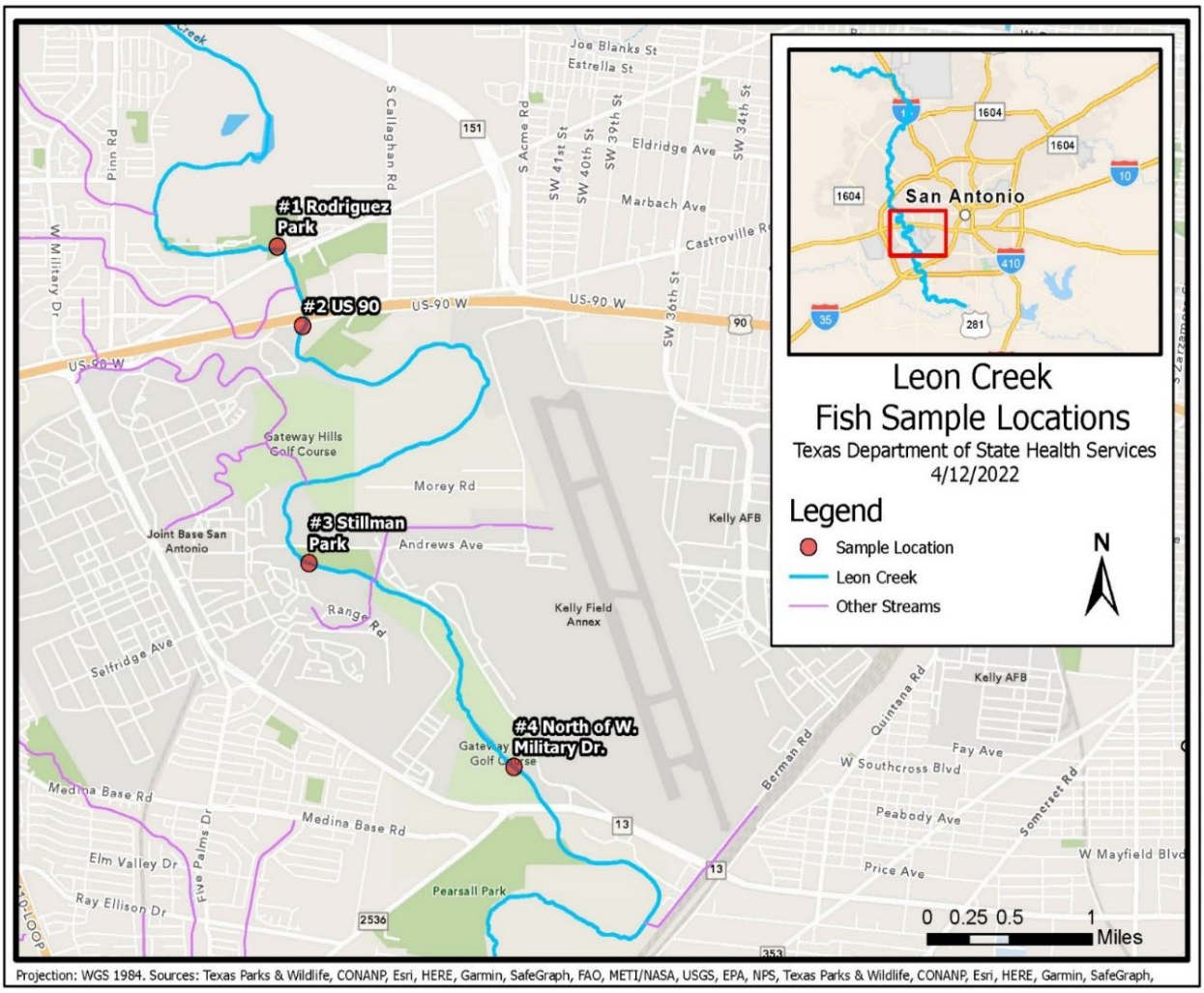
Fish Sampling and Preparation

For each sampling event, DSHS targeted a sample size of 60 samples based on power calculations using estimates from the New Jersey Department of Environmental Protection for safe amounts of specific PFAS compounds in fish for unlimited human consumption [NJDEPP 2019]. However, DSHS was only able to collect 52 fish samples in 2021/2022 and 35 in 2023 because of low water levels. DSHS determined 52 and 35 samples to be of adequate

power (almost 99% in both sample years) to detect differences between safe levels of PFAS and levels needing consumption advisories for each species of fish, should these differences truly exist.

Fish were collected from same locations as the 2010 DSHS fish survey event at Lower Leon Creek [DSHS 2010]. However, because of low water levels in December 2021/January 2022 fewer fish were collected from sites 1, 2, and 4 compared to site 3. Therefore, in 2023, DSHS focused its sampling efforts on sites 3 and 4. Site 4 is downstream from Kelly Air Force Base and the location of the highest PFAS concentrations in water based on 2021 sampling results.

Figure 1. Lower Leon Creek Sampling Sites



DSHS aimed to collect 5 different fish species at each sampling location to represent distinct ecological groups, capture a wide geographic distribution, include fish that are of local recreational fishing value, and include fish that are commonly consumed. Among these fish species, largemouth bass, white

crappie, channel and flathead catfish and white bass are the most popular among anglers at Leon Creek (TXPWD 2021).

DSHS stored fish on wet ice and processed fish at the Joint Base Camp Bullis (San Antonio, Texas) immediately after catching the fish during both sampling events. DSHS following standard operating procedures from the DSHS Seafood and Aquatic Life Unit survey team standard operating procedures and EPA quality assurance/quality control (QA/QC) manual (DSHS 2016, USEPA 2000a). All fish were weighed and measured, and two fish skin-off fillets were prepared. DSHS properly packaged and froze fish. All samples were hand-delivered to the Geochemical and Environmental Research Group (GERG) operating at the Texas A&M University Oceanography Department, College Station, Texas, for chemical analysis.

DSHS also collected a water and a sediment sample at each sampling location during the 2021 sampling and two water and two sediment samples from sites 3 and 4 during the 2023 sampling. The water samples were collected from the surface of the creek and the sediment samples were collected from the top few inches of sediment. Water and sediment samples were stored on ice or at 4^{o}C until extraction. Water and sediment samples were hand-delivered to GERG for chemical analysis.

DSHS removed sagittal otoliths from fish for age estimation following otolith extraction procedures recommended by the Gulf States Marine Fisheries Commission and Texas Parks and Wildlife Department [GSMFC 2009, TXPWD 2009].

Per- and Polyfluoroalkyl Substances (PFAS)

Twenty-eight analytes of PFAS compounds from the following seven groups of PFAS were evaluated:

- Perfluoroalkylcarboxilic acids (PFCAs)
- Perfluoroalkylsulfonates (PFASs)
- Perfluorooctanesulfonamides (PFOSAs)
- Telomer sulfonates
- Fluorotelomer carboxylic acids (FTCAs)
- Perfluorooctanesulfonamidoacetic acids
- Perfluoroether carboxylic acids (Gen X).

These seven categories of PFAS include 28 specific and common variations of PFAS analytes (Table 1). Among these compounds, perfluorohexanoic acid (PFHxA), a type of PFCA, and perfluorooctanesulfonic acid (PFOS), a type of PFAS, are both associated with AFFF substances [Houtz 2013]. Additionally, PFOS, PFHxA, perfluoro-n-nonanoic acid (PFNA), and perfluoro-n-octanoic acid (PFOA) have all been detected in other fish studies [NJDEPP 2018].

PFAS can be categorized by not only the terminal functional group, but by the chain length as well. Short-chain PFAS include those carboxylates with less than seven fluorinated carbon atoms (less than eight total carbons; PFHpA and shorter), and those sulfonates with less than six carbons (PFBS). The long-chain compounds tend to bioaccumulate and be toxic, while solubility in water is inversely proportional to the length of the carbon chain [Conder 2008, Prevedouros 2006]. Both short- and long-chain types of PFAS were evaluated in fish collected from Lower Leon Creek.

PFAS Analysis in Samples

GERG, operating in the Texas A&M University Oceanography Department laboratory, evaluated fish, water, and sediment samples for PFAS using established methods [van Leeuwen 2009, Powley 2008]. The samples were stored frozen until homogenized, then frozen again until extraction. For all samples and quality control samples were subsampled, weighed, spiked with surrogate standards, and extracted through dispersive solid phase extraction. The extracts were injected with injection standards then analyzed using liquid chromatography tandem mass spectrometry. DSHS conducted QA/QC on data following standard operating procedures and determined that data met QC/QC criteria as outlined in DSHS Seafood and Aquatic Life Unit survey team standard operating procedures and EPA quality control/assurance manual [DSHS 2016, USEPA 2000a].

Health-Based Assessment Comparison (HAC) Values

If diverse species of fish are available, DSHS assumed that people eat a variety of species from a water body. Further, DSHS assumed that most fish species are mobile. In this analysis, DSHS combine data from different fish species and/or sample sites within Lower Leon Creek to evaluate mean contaminant concentrations of PFAS in all samples. This approach intuitively reflects consumers' likely exposure over time to contaminants in fish from any water body but may not reflect the reality of exposure at a specific location within a water body or a single point in time.

DSHS evaluated PFAS in fish by comparing the mean concentration of a contaminant to its health-based assessment comparison (HAC) value for noncancer endpoints. HAC values are levels below which no adverse health effects are expected to occur following long-term and regular exposure. Chemical concentrations above HAC values do not necessarily mean there is a health concern, but rather suggests that further public health evaluation based on site-specific exposure conditions is needed. DSHS derived HAC values using reference doses (RfD) derived by the Texas Commission on Environmental Quality [TCEQ 2024] or other available health guidelines (Table 1). Health guidelines were not available for some PFAS compounds, including perfluoroundaconoic acid (PFUdA), perfluorononanesulfonic acid

(PFNS), perfluoroheptanesulfonic acid (PFHpS), perfluoropentanesulfonic acid (PFPeS), telomer sulfonates (8:2 FTS, 6:2 FTS, 4:2 FTS), fluorotelomer carboxylic acids (FTCAs), perfluorooctancesulfonamidoacetic acids, and perfluoro ether carboxylic acids (such as Gen X). If detected, compounds without health guidelines were evaluated cumulatively as part of total PFAS.

Table 1. Per- and polyfluoroalkyl substances (PFAS) analytes (abbreviations) analyzed and available reference doses (RfD)	
Perfluoroalkylcarboxilic Acids (PFCAs)	RfD (mg/kg/day)
Perfluorotetradecanoic acid (PFTeDA)	1.2E-05
Perfluorotridecanoic acid (PFTrDA)	1.2E-05
Perfluorododecanoic acid (PFDoA)	1.2E-05
Perfluoroundaconoic acid (PFUdA)	Not available
Perfluorodecanoic acid (PFDA)	1.5E-05
Perfluorononanoic acid (PFNA)	1.2E-05
Perfluorooctanoic acid (PFOA)	1.2E-05
Perfluoroheptanoic acid (PFHpA)	2.3E-05
Perfluorohexanoic acid (PFHxA)	5.0E-04
Perfluoropentanoic acid (PFPeA)	5.0E-04
Perfluorobutanoic acid (PFBA)	1.0E-03
Perfluoroalkylsulfonates (PFASs)	
Perfluorodecansulfonic acid (PFDS)	1.2E-05
Perfluorononanesulfonic acid (PFNS)	Not available
Perfluorooctanesulfonic acid (PFOS)	2.3E-05
Perfluoroheptanesulfonic acid (PFHpS)	Not available
Perfluorohexanesulfonic acid (PFHxS)	3.8E-06
Perfluoropentanesulfonic acid (PFPeS)	Not available
Perfluorobutanesulfonic acid (PFBS)	1.4E-03
Perfluorooctanesulfonamides (PFOSAs)	
Perfluoro-1-octanesulfonamide (FOSA-1)	1.2E-05
Telomer Sulfonates	
Sodium 1H,1H,2H,2H-perfluorodecane sulfonate (8:2 FTS)	Not available
Sodium 1H,1H,2H,2H-perfluorooctane sulfonate (6:2 FTS)	Not available
Sodium 1H,1H,2H,2H-perfluorohexane sulfonate (4:2 FTS)	Not available

Fluorotelomer carboxylic acids (FTCAs)	
2-Perfluorodecyl ethanoic acid (10:2 FTCA)	Not available
2-Perfluorooctyl ethanoic acid (8:2 FTCA)	Not available
2-Perfluorohexyl ethanoic acid (6:2 FTCA)	Not available
Perfluorooctancesulfonamidoacetic Acids	
N-ethylperfluoro-1-octanesulfonamidoacetic acid (N-EtFOSAA)	Not available
N-methylperfluoro-1-octanesulfonamidoacetic acid (N-MeFOSAA)	Not available
Perfluoro ether carboxylic acids	
Hexafluoropropylene oxide dimer acid (GenX)	Not available

Notes: mg/kg/day=milligrams per kilogram per day

The HAC values were determined as follows:

$$HAC = \frac{RfD \times BW \ x\, RSC}{IR}$$

Where:

- HAC = Health advisory concentration (ng/kg-day)
- RfD = Reference dose (ng/kg-day)
- BW = Body weight (kg)
- IR = Intake rate (kg/day)
- RSC = Relative source contribution (unitless)

DSHS used a relative source contribution of 1 for all HAC calculations assuming the majority of PFAS exposure is from fish consumption.

DSHS used standard exposure parameters for healthy adults, children (under 6 years) and subsistence fishers (Table 2) [USEPA 2000a]. DSHS assumed an adult weighs on average 70 kilograms (kg) and consumes 30 grams (g) of fish per day and a child weighs 15 kg and consumes 15 g per day. DSHS assumed a meal size of 227 g (about 8 ounces) and 113 g (about 4 ounces) for an adult and child, respectively. Taken together, these assumptions equal about one meal of fish per week (or 4 meals per month) for both adults and children. This is a health protective exposure estimate which is consistent with a full and unrestricted use of the fish resource. Instead of estimating health risks for women of childbearing age, the health risks for children were conservatively applied to women of childbearing age (below 50 years of age), including pregnant women, women who may become pregnant and women who are nursing infants. Subsistence fishers are those that rely on fishing to provide for basic needs. This group might be at greater risk of exposure to contaminants in fish due to higher

consumption rates. DSHS used a consumption rate of 142 g per day and meal size of 227 grams per meal for subsistence fishers [USEPA 2000a]. Using these exposure parameters, DSHS estimated that a subsistence fisher would eat about 4.6 meals per week (or about 19 meals per month).

Table 2. Exposure parameters for target populations

Target Population	Body Weight (kg)	Intake Rate (g/day)	Meal Size (g/meal)
Adults	70	30	227
Children (less than 6 years)	15	15	113
Subsistence Fishers	70	142	227

Abbreviations: kg=kilogram; g/day=grams per day; g/meal=grams per meal

Hazard Quotients and Hazard Indices

To calculate non-cancer health risks, DSHS calculated the hazard quotient (HQ). The HQ is the ratio of the estimated exposure to a chemical over the level at which no adverse effect is expected. The HQ is derived by dividing the mean contaminant concentration detected in fish by the HAC level. An HQ less than 1 means no adverse health effects are expected and an HQ greater than 1 means adverse health effects are possible. The HQ was determined as follows:

$$HQ = \frac{C}{HAC}$$

Where:

- HQ = Hazard quotient (unitless)
- C = Mean concentration in fish (ng/kg wet weight)
- HAC = Health advisory concentration (ng/kg)

DSHS calculated the hazard index (HI) to assess additive mixture toxicity. The HI is the sum of HQs for a group of chemicals that share a similar mode of action and target organ. An HI less than 1 means no adverse health effects are expected and an HI greater than 1 means adverse health effects are possible. The HI was determined as follows:

$$HI = \sum HQ$$

Where:

- HI = Hazard index (unitless)

- HQ = Hazard quotient (unitless)

Because PFAS compounds have similar and overlapping mode of actions and target organs, and to consider PFAS without health guidelines, HIs were determined for all PFAS substances detected. DSHS also calculated HIs by combining the mean concentrations of PFAS with contaminants, PCBs and PCDDs/PCDFs, previously detected in the 2010 Lower Leon Creek fish survey [DSHS 2010]. For this evaluation, DSHS assumed the mode of actions and target organs of PCBs and PCDDs/PCDFs were like PFAS [ATSDR 1998, ATSDR 2000].

Fish Consumption Advisory

Fish consumption advisories are not regulatory standards, but are recommendations intended to provide additional information to individuals consuming fish from Lower Leon Creek. DSHS develops risk-based fish consumption advisories following EPA guidance [USEPA 2000a; USEPA 2000b] and uses species-specific data on concentrations of individual contaminants to determine how often it is safe to eat a species of fish. A consumption advisory may be triggered when the HI is above 1 and/or if the calculated meals per week is below 1 meal per week (or 4 meals per month). DSHS calculated the maximum number of recommended meals of fish per month (MpM) using standard exposure parameters (Table 2), health guidelines (such as TCEQ's RfDs) and the measured mean concentration of contaminants using the equation below:

$$MpM = \frac{RfD * BW * ED}{MS * C}$$

Where:

- MpM = Meals per month (meals/month)
- RfD = Reference dose (mg/kg-day)
- BW = Body weight (kg)
- ED = Exposure duration = 30.44 days/month
- MS = Meal size (kg/meal)
- C = Mean concentration in fish (mg/kg wet weight)

DSHS also determined meals per month from ingestion of fish contaminated with multiple substances (MpMmixture) using the equation below:

$$MpM(mixture) = \sum_{i=1} (\frac{RfD_i}{C_i}) * \frac{BW * ED}{MS}$$

Where:

- MpM = Meals per month (meals/month)
- RfD_i = Reference dose for chemical i (mg/kg-day)
- C_i = Mean concentration in fish for chemical i (mg/kg wet weight)
- BW = Body weight (kg)
- ED = Exposure duration = 30.44 days/month
- MS = Meal size (kg/meal)

Statistics

DSHS used Kruskal-Wallis chi-squared test to determine statistical differences in total PFAS and PFOS levels among fish species and sampling location. A non-parametric analysis, Kendall's Tau, was also used to determine significant correlations between total PFAS and PFOS concentration for each fish species with fish length, weight, and age, as appropriate, where $p<.05$ (Appendix B, Figures B1-B3).

RESULTS and DISCUSSION

In 2021/2022 and 2023, DSHS collected a total of 87 fish from 4 different locations (Table 3). Nine different species of fish were collected including: 7 spotted gar, 49 common carp, 5 channel catfish, 4 longnose gar, 7 largemouth bass, 10 redbreast sunfish, 2 redear sunfish, 1 gizzard shad, and 2 grey redhorse.

The highest number of fish (62% in 2021/2022 and 97% in 2023) were collected from site 3 - Stillman Park. Less than 23% were collected from the other locations (14% site 1- Rodriquez Park; 8% from site 2 - US 90 and 2% from site 4 - North of West Military Drive). Because of low water levels at three of the sampling sites, most fish were collected from site 3 – Stillman Park.

A summary of the length, weight and age for fish samples collected is provided on Table 3. Sagittal otoliths for age estimation were not collected in common carp, longnose gar, and redear sunfish in 2021/2022 and not in any fish collected in 2023. Statistically significant correlations were not observed between mean Total PFAS and PFOS concentrations detected in channel catfish, redbreast sunfish, common carp, largemouth bass and spotted gar with length, weight, or age, respectively (Appendix B, Figure B2). Not enough fish samples were collected to conduct correlation analysis for redear sunfish, longnose gar, grey redhorse, and gizzard shad.

Table 3. Location, type and number of fish collected from Lower Leon Creek, Texas

Year	2021/2022	2023	2021/2022 and 2023

Table 3. Location, type and number of fish collected from Lower Leon Creek, Texas			
Species	Number of Fillets (% total)	Number of Fillets (% total)	Number of Fillets (% total)
Spotted Gar	2 (4)	5 (14)	7 (8)
Common Carp	34 (65)	15 (43)	49 (56)
Channel Catfish	3 (6)	2 (6)	5 (6)
Longnose Gar	2 (4)	2 (6)	4 (5)
Largemouth Bass	6 (12)	1 (3)	7 (8)
Redbreast Sunfish	3 (6)	7 (20)	10 (11)
Redear Sunfish	2 (4)	NS	2 (2)
Gizzard Shad	NS	1 (3)	1 (1)
Grey Redhorse	NS	2 (6)	2 (2)
Location	Number of Fillets (% total)	Number of Fillets (% total)	Number of Fillets (% total)
Rodriguez Park (site 1)	12 (23)	NS	12 (14)
US 90 (site 2)	7 (13)	NS	7 (8)
Stillman Park (site 3)	32 (62)	34 (97)	66 (76)
North of West Military Drive (site 4)	1 (2)	1 (3)	2 (2)
Species	Average length in millimeters (standard deviation)	Average length in millimeters (standard deviation)	Average length in millimeters (standard deviation)
Spotted Gar	582 (27)	559 (29)	566 (63)
Common Carp	515 (96)	575 (73)	534 (95)
Channel Catfish	544 (30)	497 (39)	526 (41)
Longnose Gar	695 (45)	584 (243)	639 (158)
Largemouth Bass	439 (77)	411	435 (77)
Redbreast Sunfish	205 (17)	191 (21)	195 (21)
Redear Sunfish	210 (11)	NS	210 (11)
Gizzard Shad	NS	437	437

Table 3. Location, type and number of fish collected from Lower Leon Creek, Texas			
Grey Redhorse	NS	451 (18)	451 (18)
Species	Average weight in grams (standard deviation)	Average weight in grams (standard deviation)	Average weight in grams (standard deviation)
Spotted Gar	732 (70)	663 (291)	683 (243)
Common Carp	2055 (1138)	2647 (759)	2249 (1085)
Channel Catfish	1384 (368)	1112 (330)	1275 (389)
Longnose Gar	742 (226)	1473 (636)	1107 (589)
Largemouth Bass	1345 (765)	952	1285 (781)
Redbreast Sunfish	134 (33)	117 (40)	122 (39)
Redear Sunfish	145 (18)	NS	145 (18)
Gizzard Shad	NS	110	110
Grey Redhorse	NS	900 (174)	900 (174)
Species	Average age in years (standard deviation)	Average age in years (standard deviation)	Average age in years (standard deviation)
Spotted Gar	Not analyzed	Not analyzed	Not analyzed
Common Carp	Not analyzed	Not analyzed	Not analyzed
Channel Catfish	4 (2)	Not analyzed	4 (2)
Longnose Gar	Not analyzed	Not analyzed	Not analyzed
Largemouth Bass	5 (2)	Not analyzed	5 (2)
Redbreast Sunfish	3 (1)	Not analyzed	3 (1)
Redear Sunfish	Not analyzed	Not analyzed	Not analyzed

PFAS Levels in Fish

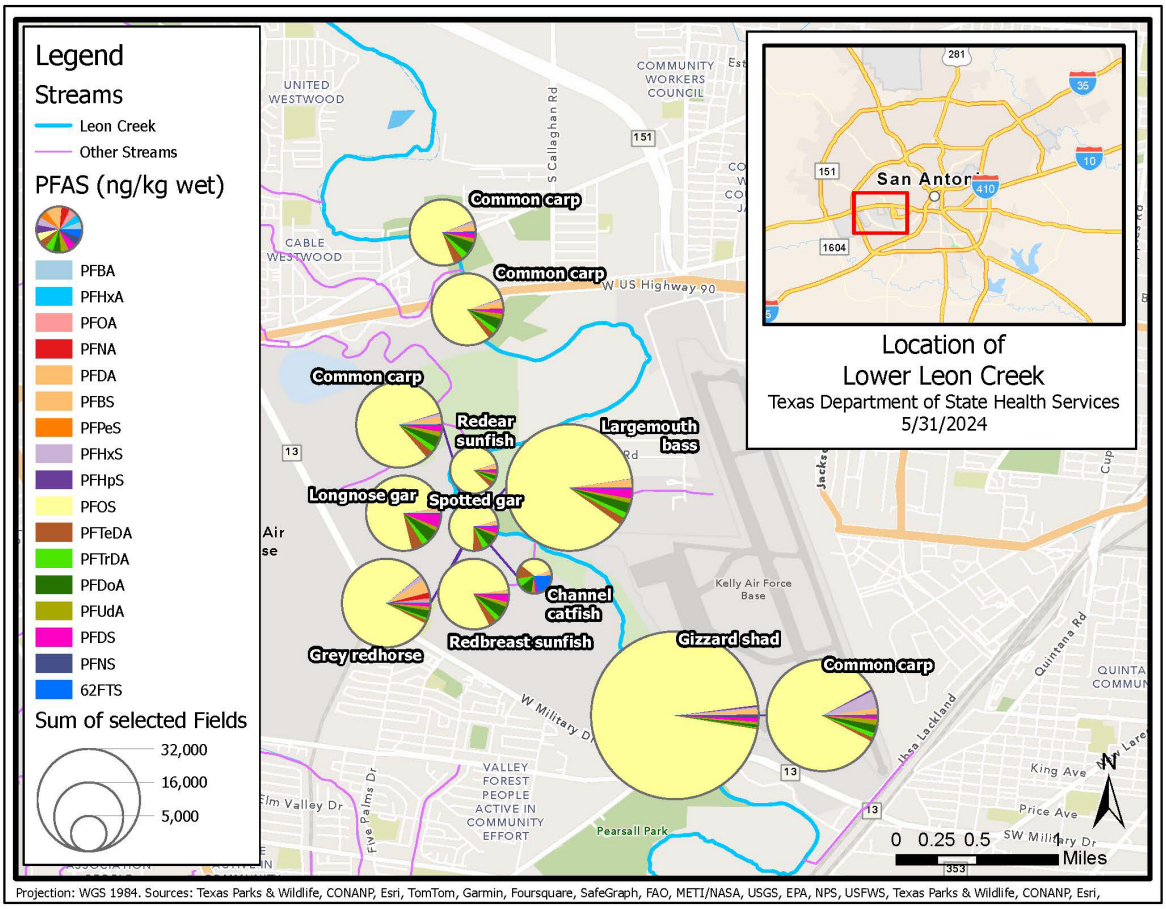
The overall summary of PFAS levels per fish species and location is provided in Table A1 (Appendix A). PFAS was detected in all fish species and at all locations. Of the 28 PFAS analytes included in the survey, 16 were detected in at least one fish fillet. These included: sodium 1H,1H,2H,2H-perfluorooctane sulfonate (6:2 FTS), perfluorobutanoic acid (PFBA), perfluorohexanoic acid (PFHxA), perfluorooctanoic acid (PFOA), perfluorononanoic acid (PFNA), perfluorodecanoic acid (PFDA),

perfluoropentanoic acid (PFPeA), perfluoroundaconoic acid (PFUdA), perfluorododecanoic acid (PFDoA), perfluorotridecanoic acid (PFTrDA), perfluorotetradecanoic acid (PFTeDA), perfluorohexanesulfonic acid (PFHxS), perfluoroheptanesulfonic acid (PFHpS), perfluorooctanesulfonic acid (PFOS), perfluorononanesulfonic acid (PFNS), and perfluorodecansulfonic acid (PFDS).

Combining the results from both sampling events, mean total PFAS levels were significantly different among the fish species analyzed (p-value<.05) (Appendix B, Figure B1). Individually, mean PFAS levels in common carp were significantly higher than mean PFAS in channel catfish, largemouth bass, and spotted gar (p-value <.05). Mean PFAS levels in channel catfish were also significantly different than redbreast sunfish (p-value <.05). DSHS did not detect any significant differences in mean PFAS levels among sampling locations (p-value >.05) (Appendix B, Figure B2). However, three of the sampling sites had so few samples collected that it may be the reason why no significant differences were found.

PFOS was detected at the highest levels in all fish sampled. The highest concentrations were detected in gizzard shad (72,195 ng/kg; only 1 sample collected) at site 4 – North of West Military Drive, in largemouth bass (range 12,947 – 66,947; mean = 40,512 ng/kg) at site 3 - Stillman Park, and in common carp (31,342 ng/kg; only 1 sample collected) at site 4 – North of West Military Drive. PFOS levels varied among species. Largemouth bass, common carp, longnose gar, grey redhorse, and gizzard shad generally contained higher levels of PFOS than redbreast sunfish, redear sunfish, spotted gar and channel catfish (Figure 2; Table A1).

Figure 2. Mean PFAS concentrations in fish collected from Lower Leon Creek in 2021, 2002 and 2023.



PFAS in Water and Sediment Samples

DSHS collected a water sample at each sampling location in 2021 and two sediment and water samples from sites 3 and 4 in 2023. Thirteen different PFAS compounds were detected in at least one water sample (Table 4). The total PFAS concentration in water samples ranged from 85.15 nanograms per liter (ng/L) to 399.45 ng/L. Highest total mean PFAS concentrations occurred at the most down-stream sampling location, site 4 - North of West Military Drive, and the lowest total PFAS concentrations occurred at the most upstream location sampled during each sampling event. Total PFAS concentrations in water were lower at sites 3 and 4 in 2023 compared to samples collected in 2021 and 2022. Among the individual PFAS compounds detected, PFHxS and PFOS were detected at the highest levels (141.45 ng/L and50.71 ng/L, respectively), and most frequently (35% and 13%) at the site 4 - North of West Military Drive location in 2021.

Table 4. PFAS concentrations (ng/L) in surface water samples collected from Lower Leon Creek, Texas						
Year	2021	2021	2021	2021	2023	2023
PFAS Type	Site 1 Rodriguez Park*	Site 2 US 90	Site 3 Stillman Park	Site 4 North of West Military Drive	Site 3 Stillman Park (mean n = 2)	Site 4 North of West Military Drive (mean n = 2)
PFBA	14.87	19.87	24.02	23.66	6.77	21.61
PFPeA	8.79	28.64	21.26	36.98	5.92	42.47
PFHxA	6.62	23.99	16.28	42.61	4.65	42.95
PFHpA	3.86	10.84	7.28	15.42	2.11	18.08
PFOA	9.76	15.83	14.31	21.06	8.64	24.03
PFNA	ND	1.68	0.75	1.36	0.41	2.02
PFDA	ND	1.58	ND	ND	ND	0.95
PFBS	31.01	30.19	36.54	39.65	23.12	17.19
PFPeS	3.43	6.58	6.85	11.57	2.69	9.91
PFHxS	17.53	22.47	23.96	141.45	20.76	76.67
PFHpS	ND	0.75	ND	2.46	ND	1.57
PFOS	7.03	22.03	8.66	50.71	10.08	41.50
6:2FTS	ND	ND	ND	12.52	ND	ND
Total PFAS	103.00	184.45	159.91	399.45	85.15	298.95

*Results are the average of duplicate samples collected. Abbreviations: ng/L=nanograms per liter; ND= not detected; PFAS= per- and polyfluoroalkyl substances; 6:2FTS= sodium 1H,1H,2H,2H-perfluorooctane sulfonate; PFBA= perfluorobutanoic acid; PFPeA= perfluoropentanoic acid; PFHxA= perfluorohexanoic acid; PFOA= perfluorooctanoic acid; PFNA= perfluorononanoic acid; PFBS= perfluorobutanesulfonic acid; PFPeS= perfluoropentanesulfonic acid; PFHxS= perfluoropentanesulfonic acid; PFOS= perfluorooctanesulfonic acid; PFHpS=perfluoroheptanesulfonic acid.

DSHS collected a sediment sample from each sampling location in 2021 and two sediment samples from sites 3 and 4 in 2023 (Table 5). Four different PFAS compounds were detected in at least one sediment sample, including PFHxA, PFOA, PFOS, and PFPeA. PFAS was detected at only two locations in 2021 (site 2 - US 90 and site 4 - North of West Military Drive). PFOS was detected at site 3 – Stillman Park in 2023 but not in 2021. Total PFAS concentrations ranged from 756.13 ng/kg to 1435.54 ng/kg. PFOS was detected at highest levels at each location where PFAS was detected.

Table 5. PFAS concentrations (ng/kg) in sediment samples collected from Lower Leon Creek, Texas

Year	2021	2021	2021	2021	2023	2023
PFAS Type	Site 1 Rodriguez Park	Site 2 US 90	Site 3 Stillman Park	Site 4 North of West Military Drive	Site 3 Stillman Park (mean n = 2)	Site 4 North of West Military Drive (mean n = 2)
PFHxA	ND	ND	ND	339.60	ND	127.33
PFOA	ND	222.07	ND	ND	ND	ND
PFOS	ND	715.54	ND	1095.94	756.13	961.07
PFPeA	ND	ND	ND	ND	ND	110.27
Total PFAS	-	937.61	-	1435.54	756.13	1088.40

Abbreviations: ng/kg = nanograms per kilogram; ND= not detected; PFHxA = perfluoropentanesulfonic acid; PFOA = perfluorooctanoic acid; PFOS= perfluorooctanesulfonic acid; PFPeA = Perfluoropentanoic acid

Fish Consumption/Risk Assessment

DSHS evaluated the contribution of fish consumption on human exposure to PFAS by comparing the mean level of a contaminant to its HAC value for noncancer endpoints. PFOS was the only PFAS type to be detected at levels in fish above HAC values. PFOS levels exceeded the HAC value (HQ>1) for

- adults in gizzard shad;
- subsistence fishers in common carp, largemouth bass, longnose gar, redbreast sunfish, gizzard shad, and grey redhorse; and,

- children in largemouth bass and gizzard shad (Table 6).

Table 6. Health assessment comparison (HAC) values and hazard quotients (HQ) for PFOS in Fish

		Subsistence Fisher		Adult		Children*	
PFAS Type	Species	HAC (ng/kg)	HQ	HAC (ng/kg)	HQ	HAC (ng/kg)	HQ
PFOS	Channel catfish	11,338	0.1	53,667	0.03	23,000	0.1
	Common carp	11,338	**1.5**	53,667	0.3	23,000	0.7
	Largemouth bass	11,338	**3.6**	53,667	0.8	23,000	**1.8**
	Longnose gar	11,338	**1.3**	53,667	0.3	23,000	0.6
	Redbreast sunfish	11,338	**1.2**	53,667	0.2	23,000	0.6
	Redear sunfish	11,338	0.6	53,667	0.1	23,000	0.3
	Spotted gar	11,338	0.6	53,667	0.1	23,000	0.3
	Gizzard shad	11,338	**6.4**	53,667	**1.3**	23,000	**3.1**
	Grey redhorse	11,338	**1.8**	53,667	0.4	23,000	0.9

Notes: *Instead of estimating health risks for women of childbearing age, the health risks for children were conservatively applied to women of childbearing age (below 50 years of age), including pregnant women, women who may become pregnant and women who are nursing infants. Abbreviations: HAC=health assessment comparison; HQ=hazard quotient; ng/kg=nanogram per kilogram; PFAS= per- and polyfluoroalkyl substances; PFOS= perfluorooctanesulfonic acid. Bold values indicate HQ greater than 1.

DSHS calculated the number of 8-ounce and 4-ounce meals of fish healthy adults, subsistence fishers, and children could consume without significant risk of PFAS-related adverse health effects (Table 7). The maximum allowable meals per week were greater than 1 for all fish except for

- gizzard shad for adults;

- common carp, largemouth bass, longnose gar, redbreast sunfish, gizzard shad, and grey redhorse for subsistence fishers; and,
- largemouth bass and gizzard shad for children.

Table 7. Estimated number of meals (per week and per month) of fish with PFOS					
		Adult/Subsistence Fishers		Children *	
PFAS Type	Fish Species	Meals/ Month	Meals/ Week	Meals/ Month	Meals/ Week
PFOS	Channel catfish	134.3	30.9	57.8	13.3
	Common carp	12.9	3.0	5.5	1.3
	Largemouth bass	5.3	1.2	2.3	0.5
	Longnose gar	15.2	3.5	6.5	1.5
	Redbreast sunfish	16.1	3.7	6.9	1.6
	Redear sunfish	31.4	7.2	13.5	3.1
	Spotted gar	34.3	7.9	14.8	3.4
	Gizzard shad	3.0	0.7	**1.3**	0.3
	Grey redhorse	10.7	2.5	4.6	1.1

Notes: * Instead of estimating health risks for women of childbearing age, the health risks for children were conservatively applied to women of childbearing age (below 50 years of age), including pregnant women, women who may become pregnant and women who are nursing infants. Abbreviation: PFOS= perfluorooctanesulfonic acid.

PFAS Mixture

DSHS evaluated how a potential additive mixture would affect the consumption results. DSHS assumed all detected PFAS have the same mode of action and target organ. The HI was greater than 1 (HI>1) for

- adults consuming gizzard shad;
- subsistence fishers consuming common carp, largemouth bass, longnose gar, redbreast sunfish, gizzard shad, and grey redhorse; and,
- children consuming largemouth bass and gizzard shad (Table 8).

The maximum allowable meals per month for adults and children was less than 4 for gizzard shard and largemouth bass and grey redhorse, respectively. The maximum allowable meals per month for subsistence fishers were less than 19 for common carp, largemouth bass, longnose gar, redbreast sunfish, gizzard shad, and grey redhorse.

Table 8. Potential additive mixture for total PFAS, hazard index and meals per month

	Hazard Index			Meals/Month Mixture	
Species	Subsistence Fishers	Adult	Children *	Adult/ Subsistence Fisher	Children*
Channel catfish	0.5	0.1	0.3	37	16
Common carp	**2.2**	0.5	**1.1**	9	4
Largemouth bass	**4.4**	0.9	**2.2**	4	2
Longnose gar	**2.0**	0.4	**1.0**	10	4
Redbreast sunfish	**1.7**	0.4	0.8	11	5
Redear sunfish	0.8	0.2	0.4	23	10
Spotted gar	**1.0**	0.2	0.5	19	8
Gizzard shad	**6.9**	**1.5**	**3.4**	3	1
Grey redhorse	**2.6**	0.6	**1.3**	7	3

Notes: * Instead of estimating health risks for women of childbearing age, the health risks for children were conservatively applied to women of childbearing age (below 50 years of age), including pregnant women, women who may become pregnant and women who are nursing infants. Abbreviation: PFOS= perfluorooctanesulfonic acid. Abbreviations: PFAS= per- and polyfluoroalkyl substances. Bold values indicated either an HI> 1.

The results from the 2010 fish survey from Lower Leon Creek determined consumption of PCBs and PCDDs/PCDFs in channel catfish, common carp, largemouth bass, redear sunfish and spotted gar increases the likelihood of noncancer health risks. DSHS implemented fish consumption advisories based on these results that recommends nobody consume fish collected from this area of Lower Leon Creek. To determine whether PFAS detected in

some fish species may affect existing fish consumption advisories, DSHS DSHS calculated HIs and meals per week/month for PCBs, PCDDs/PCDFs and PFOS combined. DSHS assumed that PFOS have a similar mode of action as PCBs and PCDDs/PCDFs and that would produce an additive mixture toxic effect.

Table 9 shows that the cumulative effect of PFOS, PCBs and PCDDs/PCDFs contamination does not change the existing estimated meals per week for all fish types evaluated from what was determined in 2010 for adults. While the meals per week for redbreast sunfish decreased slightly from 1.27 to 1.00 meals per week, the decrease is not enough to trigger a fish consumption advisory for this fish species. Additionally, the cumulative effect of PFOS, PCBs and PCDDs/PCDFs contamination does not change the existing estimated meals per week for fish species evaluated for children less than 6 years (Table 10). DSHS does not consider subsistence fishers for fish consumption advisories.

Table 9. Hazard quotient and meals per week for adult consumption of fish

	PCB and PCDD/PCDFs		PCB and PCDD/PCDFs added with PFOS	
Contaminant/Species	Hazard Quotient	Meals per Week	Hazard Quotient	Meals per Week
Channel catfish				
PCBs	**1.95**	**0.47**	**1.95**	**0.47**
PCDDs/PCDFs	0.48	1.95	0.48	1.95
PFOS	-	-	0.03	30.89
Hazard Index (meals per week)	**2.43**	**0.38**	**2.46**	**0.38**
Common carp				
PCBs	**4.67**	**0.20**	**4.67**	**0.20**
PCDDs/PCDFs	0.19	4.81	0.19	4.81
PFOS	-	-	0.31	2.96
Hazard Index (meals per week)	**4.86**	**0.19**	**5.18**	**0.18**
Largemouth bass				

Table 9. Hazard quotient and meals per week for adult consumption of fish				
	PCB and PCDD/PCDFs		PCB and PCDD/PCDFs added with PFOS	
Contaminant/Species	Hazard Quotient	Meals per Week	Hazard Quotient	Meals per Week
PCBs	**1.71**	**0.54**	**1.71**	**0.54**
PCDDs/PCDFs	>0.01	unrestricted	>0.01	unrestricted
PFOS	-	-	0.75	1.23
Hazard Index (meals per week)	**1.71**	**0.54**	**2.47**	**0.37**
Redbreast sunfish				
PCBs	0.73	1.27	0.73	1.27
PCDDs/PCDFs	>0.01	unrestricted	>0.01	unrestricted
PFOS	-	-	0.25	3.70
Hazard Index (meals per week)	0.73	1.27	0.98	1.00
Redear sunfish				
PCBs	0.49	1.88	0.49	1.88
PCDDs/PCDFs	>0.01	unrestricted	>0.01	unrestricted
PFOS	-	-	0.13	7.23
Hazard Index (meals per week)	0.49	1.88	0.62	1.49
Spotted gar				
PCBs	**3.99**	**0.23**	**3.99**	**0.23**
PCDDs/PCDFs	>0.01	unrestricted	>0.01	unrestricted
PFOS	**-**	**-**	0.12	7.89
Hazard Index (meals per week)	**3.99**	**0.23**	**4.11**	**0.23**

Notes: Bold values show HQ> 1 or meals per week < 1. Abbreviations: PCB= polychlorinated biphenyls; PCDD/PCDF= polychlorinated dibenzo-para-dioxins and polychlorinated dibenzofurans; PFOS= perfluorooctanesulfonic acid.

Table 10. Hazard quotient and meals per week for children's consumption of fish				
	PCB and PCDD/PCDFs		PCB and PCDD/PCDFs added with PFOS	
Contaminant/Species	Hazard Quotient	Meals per Week (child)	Hazard Quotient	Meals per Week (child)
Channel catfish				
PCBs	**4.55**	**0.20**	**4.55**	**0.20**
PCDDs/PCDFs	**1.13**	**0.83**	**1.13**	**0.83**
PFOS	-	**-**	0.07	13.30
Hazard Index (meals per week)	**5.67**	**0.16**	**5.74**	**0.16**
Common carp				
PCBs	**10.90**	**0.09**	**10.90**	**0.09**
PCDDs/PCDFs	0.45	2.07	0.45	2.07
PFOS			0.73	1.28
Hazard Index (meals per week)	**11.35**	**0.08**	**12.08**	**0.08**
Largemouth bass				
PCBs	**4.0**	**0.23**	4.0	0.23
PCDDs/PCDFs	>0.01	unrestricted	>0.01	unrestricted
PFOS	-	-	1.76	0.53
Hazard Index (meals per week)	**4.0**	**0.23**	**5.76**	**0.16**
Redbreast sunfish				
PCBs	**1.70**	**0.55**	**1.70**	**0.55**
PCDDs/PCDFs	>0.01	unrestricted	>0.01	unrestricted
PFOS	-	-	0.58	1.59
Hazard Index (meals per week)	**1.70**	**0.55**	**2.28**	**0.41**
Redear sunfish				

Table 10. Hazard quotient and meals per week for children's consumption of fish				
	PCB and PCDD/PCDFs		PCB and PCDD/PCDFs added with PFOS	
Contaminant/Species	Hazard Quotient	Meals per Week (child)	Hazard Quotient	Meals per Week (child)
PCBs	**1.15**	**0.81**	**1.15**	**0.81**
PCDDs/PCDFs	>0.01	unrestricted	>0.01	unrestricted
PFOS	-	-	0.30	3.11
Hazard Index (meals per week)	**1.15**	**0.81**	**1.45**	**0.64**
Spotted gar				
PCBs	**9.31**	**0.10**	**9.31**	**0.10**
PCDDs/PCDFs	>0.01	unrestricted	>0.01	unrestricted
PFOS	**-**	**-**	0.27	3.40
Hazard Index (meals per week)	**9.31**	**0.10**	**9.59**	**0.10**

Notes: Bold values show HQ> 1 or meals per week < 1. Abbreviations: PCB= polychlorinated biphenyls; PCDD/PCDF= polychlorinated dibenzo-para-dioxins and polychlorinated dibenzofurans; PFOS= perfluorooctanesulfonic acid.

CONCLUSIONS

This fish survey addresses the public health implications of consuming fish contaminated with PFAS, individually and cumulatively, from Lower Leon Creek, Texas. Confidence in the conclusions from several species of fish is limited by the small sample size for specific species (1 to 2 samples) and the limited sampling at some locations. Most fish were collected at site 3 because of low water levels at the other locations.

The results show that long-term and regular fish consumption of fish containing PFAS exceed DSHS guidelines for protection of human health and may pose noncancer risk to human health for adults, children less than 6 years, and subsistence fishers.

The results of the 2010 risk characterization from Lower Leon Creek showed that regular and long-term consumption of fish contained PCBs and

PCDDs/PCDFs at concentrations exceeding DSHS guidelines for protection of human health. Based on 2010 results, DSHS recommended all people (adults, women of childbearing age and children less than 6 years) should not consume any species of fish from Lower Leon Creek.

RECOMMENDATIONS

1. DSHS continue the consumption advisory (ADV-42) presently in place for fish from Lower Leon Creek until contaminants, such as PCBs, PCDDs/PCDFs, and PFAS, are shown to have decreased to levels that are unlikely to pose a risk to human health.
2. DSHS continue to regularly monitor fish from Lower Leon Creek for the presence and concentrations of PCBs, PCDDs/PCDFs, and PFAS.
3. DSHS replace addendum 01 with this addendum and include it to the 2010 Risk Characterization for Lower Leon Creek.

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APPENDICES

Appendix A

Table A1. Mean concentrations of PFAS in fish fillets from Lower Leon Creek, Texas, 2021/2022 and 2023

Location	Fish Species (number detected)	PFAS* mean concentration and (range) (ng/kg wet)															
		62FTS	PFBA	PFDA	PFDoA	PFDS	PFHpS	PFHxA	PFHxS	PFNA	PFNS	PFOA	PFOS	PFPeA	PFTeDA	PFTrDA	PFUdA
Site 1 Rodriquez Park	Common Carp (12)	ND	9.8 (ND - 113.7)	534.2 (339.1 - 854)	911.3 (606.7 - 1268)	398.7 (223.1 - 565.7)	41.4 (ND - 89.2)	2 (ND - 20.1)	208.7 (ND - 522.1)	67.6 (ND - 161.7)	3.1 (ND - 33.7)	45.9 (18.8 - 112.7)	11104.2 (7615.2 - 17151.2)	ND	703.1 (403 - 1142.6)	518.3 (316.4 - 848.3)	317.2 (248 - 406.5)
Site 2 Highway 90	Common Carp (6)	ND	ND	604.2 (332 - 1409.7)	840.6 (658.2 - 1151.8)	290.5 (170.4 - 375.2)	34.4 (ND - 116.6)	3.5 (ND - 19.5)	166.8 (51.9 - 367.8)	54.4 (37.6 - 88.6)	19.3 (ND - 113.9)	40.3 (29.8 - 51.6)	13799 (6444.9 - 40796.8)	ND	481.8 (245.1 - 695.6)	439.4 (274.8 - 709.7)	420.3 (242.5 - 806.3)
Site 3 Stillman Park	Channel catfish (5)	1022.9 (ND - 5101.6)	ND	212.8 (157.3 - 286.2)	561.8 (368.8 - 657.1)	145.8 (110.3 - 176.6)	ND	ND	47.5 (36.5 - 61.6)	31.8 (ND - 62.9)	ND	19.3 (ND - 31.9)	1607.5 (1013.7 - 2407.4)	20 (ND - 63)	636.2 (365.6 - 1044.9)	411.7 (243 - 616.7)	176.2 (104.1 - 212.8)
	Common Carp (29)	57.9 (ND - 841.1)	ND	736.1 (263.8 - 1547)	992.5 (515.4 - 1427)	523.1 (229.4 - 1208)	67 (ND - 769.6)	ND	230.3 (54.4 - 814.5)	45.1 (ND - 127)	23.4 (ND - 264.6)	34.2 (ND - 81.4)	19200.6 (4702.1 - 74606.9)	17.1 (ND - 55.2)	690.3 (339.4 - 1227.7)	495.2 (216.1 - 837)	446.9 (177.1 - 726.3)
	Grey redhorse (2)	ND	ND	1295.5 (1158 - 1433)	694 (526.2 - 861.8)	291 (223.7 - 358.3)	49.8 (48.7 - 51)	ND	409.8 (311.5 - 508.2)	527.5 (496 - 559)	ND	466.7 (322.6 - 610.8)	20173.5 (18199.6 - 22147.4)	16.2 (ND - 32)	307.6 (202.5 - 412.7)	210.4 (128.8 - 292)	366.6 (301.7 - 431.6)
	Largemouth bass (7)	ND	18.2 (ND - 125.6)	965.5 (673.8 - 1456)	1210.4 (966.3 - 1523.3)	1160.4 (425.1 - 1628)	29.9 (ND - 56.7)	ND	69 (ND - 328.7)	10.9 (ND - 50)	91.2 (ND - 237.8)	19.2 (ND - 29.8)	40511.6 (12946.1 - 66947.2)	ND	893.9 (531.5 - 1279.6)	681.2 (421 - 880.8)	551.2 (359.8 - 880.5)
	Longnose gar (4)	ND	ND	380.3 (304.3 - 506.3)	1040.7 (682.5 - 1438.5)	1097.8 (750.1 - 1481.7)	11 (ND - 24.2)	ND	50.6 (40.2 - 78.8)	ND	41.8 (26.9 - 50)	16.3 (ND - 24.2)	14203.1 (7574.3 - 19710.5)	14.6 (ND - 57.5)	975.3 (608.6 - 1510.3)	507.3 (344.3 - 713.3)	308 (235.2 - 402.4)
	Redbreast sunfish (10)	ND	8.4 (ND - 44.6)	307.6 (124 - 587.5)	910.2 (288.2 - 1774.7)	575.8 (209 - 1178.9)	2.3 (ND - 20.2)	ND	21.1 (ND - 184.6)	9.9 (ND - 60.1)	13.5 (ND - 83.3)	10.2 (ND - 43.8)	13415.6 (6822.6 - 25835)	32 (ND - 76.8)	625.3 (213.4 - 1188.3)	398.7 (106.2 - 600.5)	376.4 (111.8 - 622.4)
	Redear sunfish (2)	ND	ND	284 (237.7 - 330.4)	230.4 (177.7 - 283)	166.9 (152.7 - 181)	10.2 (ND - 20)	ND	41.9 (21.2 - 62.5)	32.8 (23.6 - 42)	ND	26.9 (23.8 - 30)	6864.8 (6346 - 7383.6)	ND	329.5 (302.9 - 356.1)	154.4 (150.5 - 158.4)	136.7 (114.8 - 158.5)
	Spotted gar (7)	ND	11 (ND - 74.8)	241.2 (117 - 466.8)	665.5 (498.8 - 997.5)	385.5 (189.3 - 1047.1)	4 (ND - 26)	ND	51.2 (ND - 77.2)	18 (ND - 24.9)	12.7 (ND - 65.5)	27.6 (ND - 48)	6295.7 (2191.2 - 17790.5)	70.3 (ND - 220.9)	587.1 (402.9 - 701.9)	386.1 (236 - 582.7)	200.6 (128.2 - 377.1)
Site 4	Common Carp (1)	ND	ND	679.3	879.2	292.2	220.1	ND	1912.8	70	82.2	50.5	31342.6	ND	428.3	522.8	641.9

Appendix A

Table A1. Mean concentrations of PFAS in fish fillets from Lower Leon Creek, Texas, 2021/2022 and 2023

Location	Fish Species (number detected)	PFAS* mean concentration and (range) (ng/kg wet)															
		62FTS	PFBA	PFDA	PFDoA	PFDS	PFHpS	PFHxA	PFHxS	PFNA	PFNS	PFOA	PFOS	PFPeA	PFTeDA	PFTrDA	PFUdA
North of West Military Drive	Gizzard shad (1)	ND	ND	857.6	391	567	260.9	ND	251.6	128.2	343.4	43	72194.5	22.6	149.1	117.4	397.7

Abbreviations: perfluorobutanoic acid (PFBA), perfluorohexanoic acid (PFHxA), perfluorooctanoic acid (PFOA), perfluorononanoic acid (PFNA), perfluorodecanoic acid (PFDA), perfluoroundaconoic acid (PFUdA), perfluorododecanoic acid (PFDoA), perfluorotridecanoic acid (PFTrDA), perfluorotetradecanoic acid (PFTeDA), perfluorohexanesulfonic acid (PFHxS), perfluoroheptanesulfonic acid (PFHpS), perfluorooctanesulfonic acid (PFOS), perfluorononanesulfonic acid (PFNS), and perfluorodecansulfonic acid (PFDS); ng/kg = nanogram per kilogram.

Appendix B

Figure B1. Comparison of total PFAS levels per fish species

Total PFAS levels in different fish species are significantly different from each other (Kruskal-Wallis chi-squared= 39.59, df=8, p-value=3.8E-6, α=0.05). Mean total PFAS levels in common carp are significantly different than levels in channel catfish (p=0.000025), largemouth bass (p=0.028), and spotted gar (p=0.020). Mean total PFAS levels in channel catfish are significantly different than levels in redbreast sunfish (p=0.023). Results were similar for PFOS by species (data not shown).

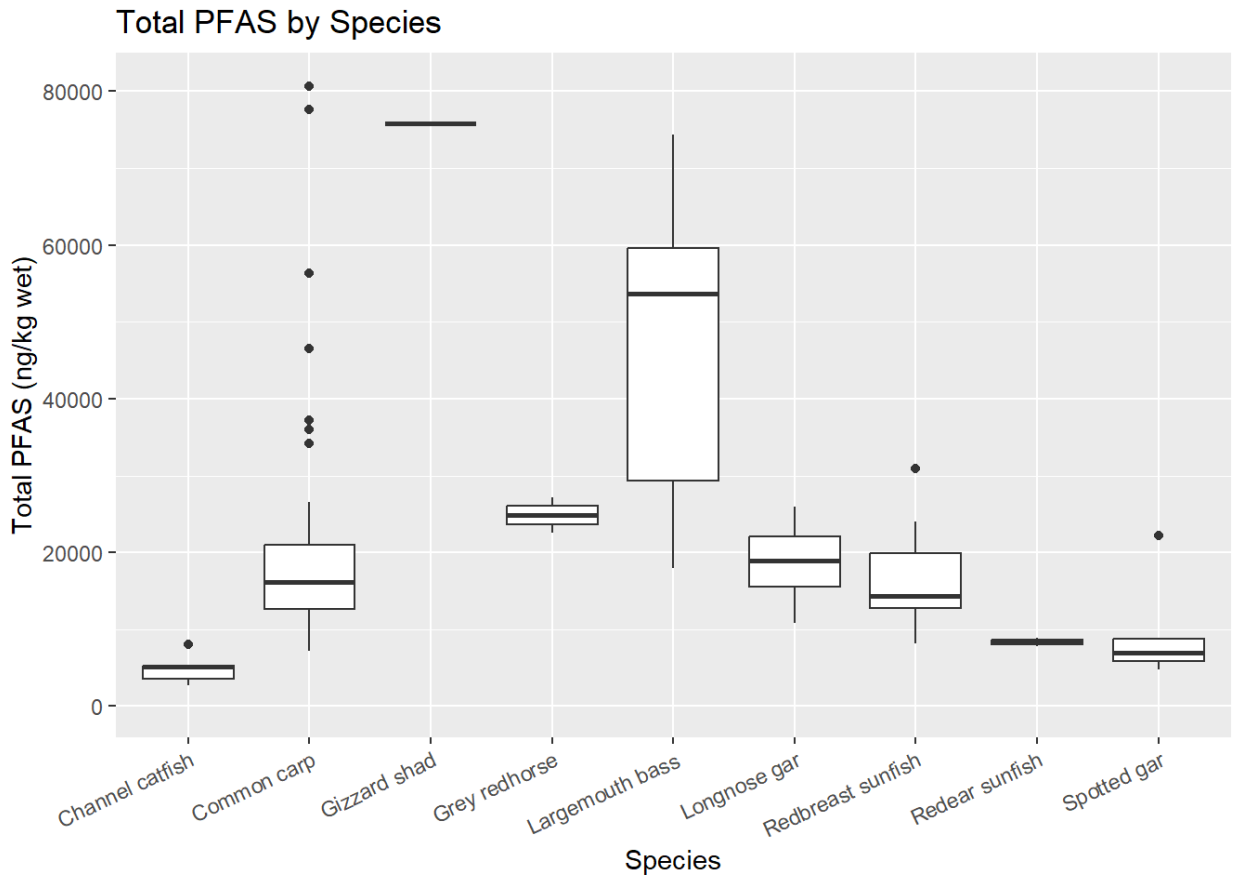


Figure B2. Comparison of total mean PFAS levels per sampling location.

No significant differences in total mean PFAS levels were identified among sampling locations (Kruskal-Wallis chi-squared= 6.16, df=3, p-value=0.10, α=0.05). Results were similar for PFOS by location (results not shown).

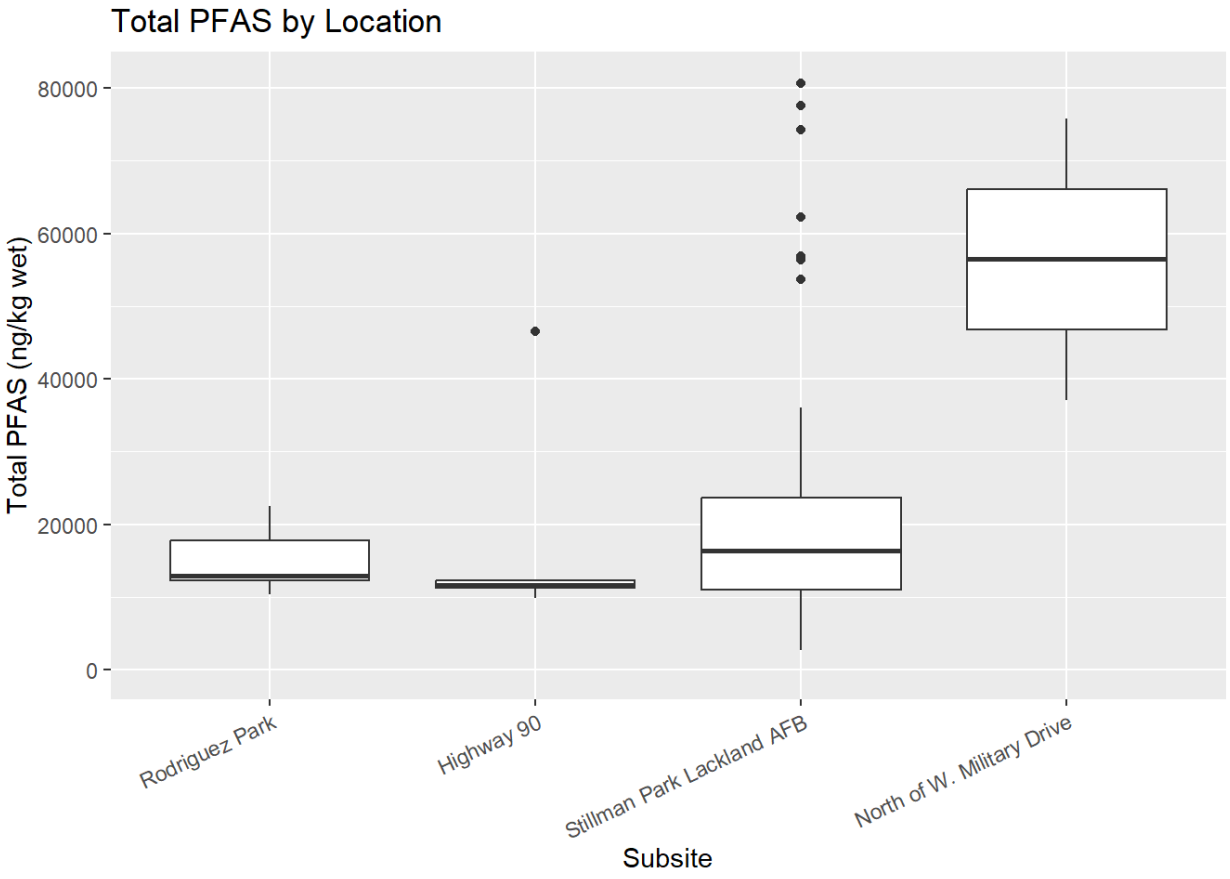
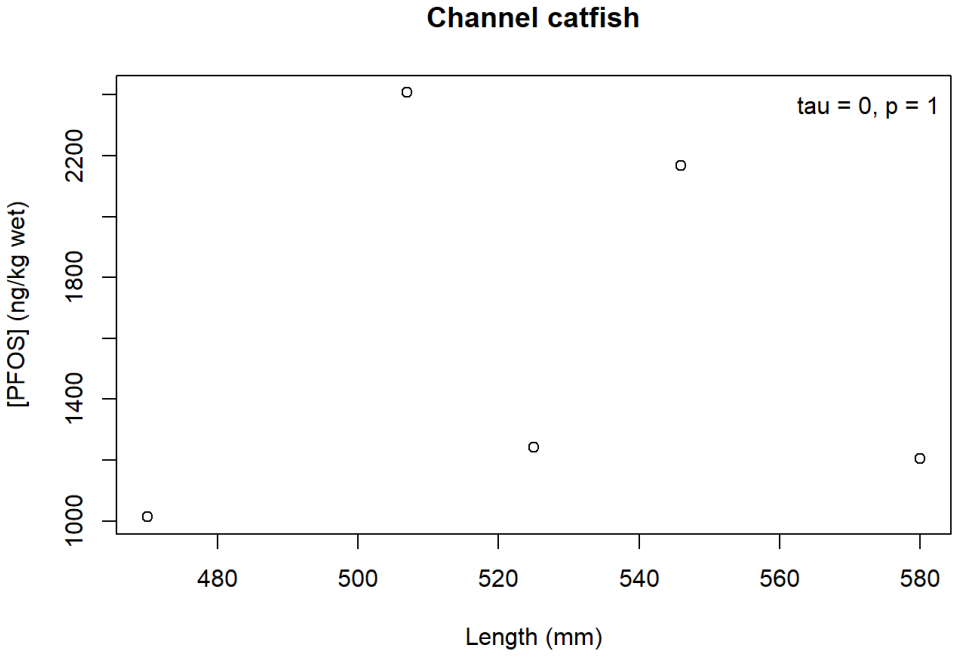
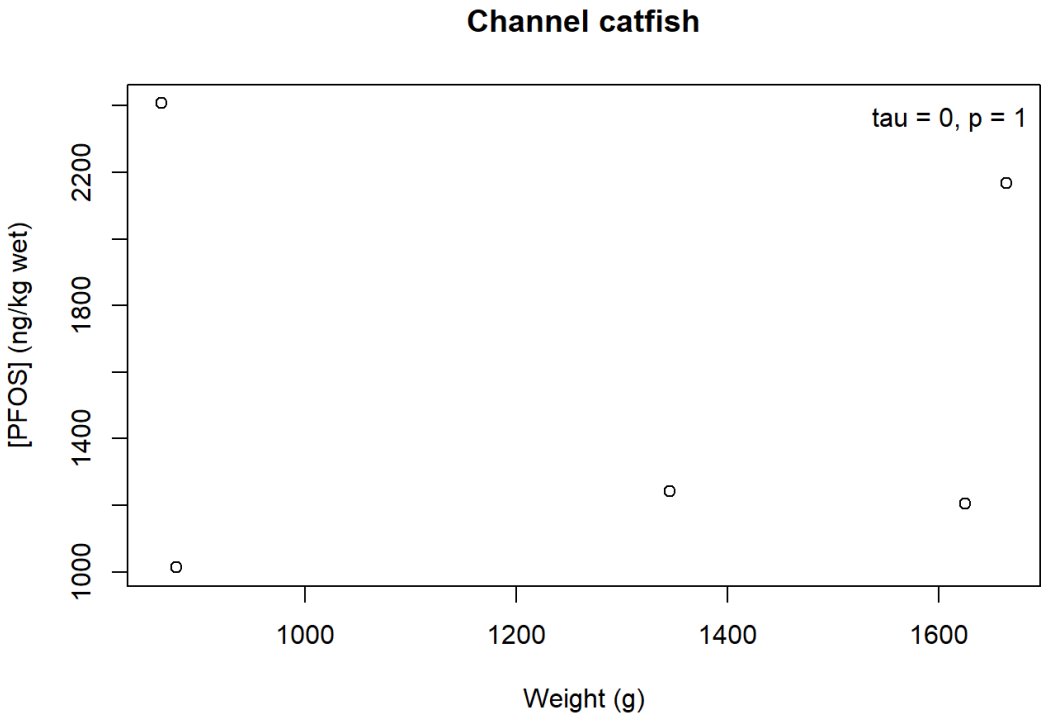


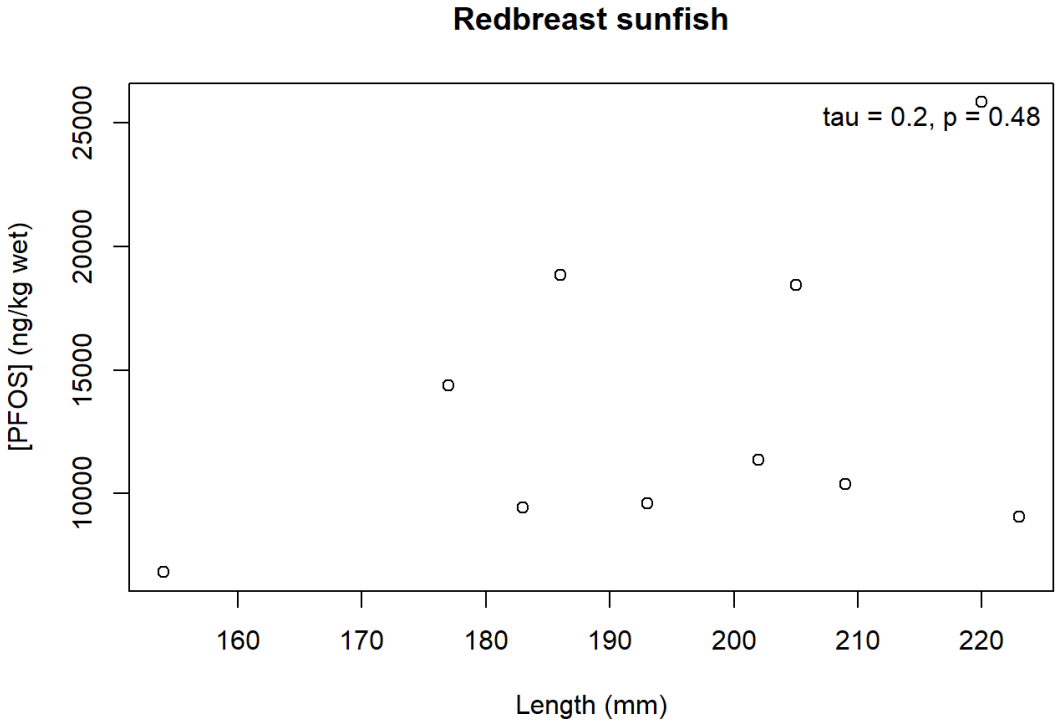
Figure B3. Comparing PFOS concentrations and length, weight and age in fish

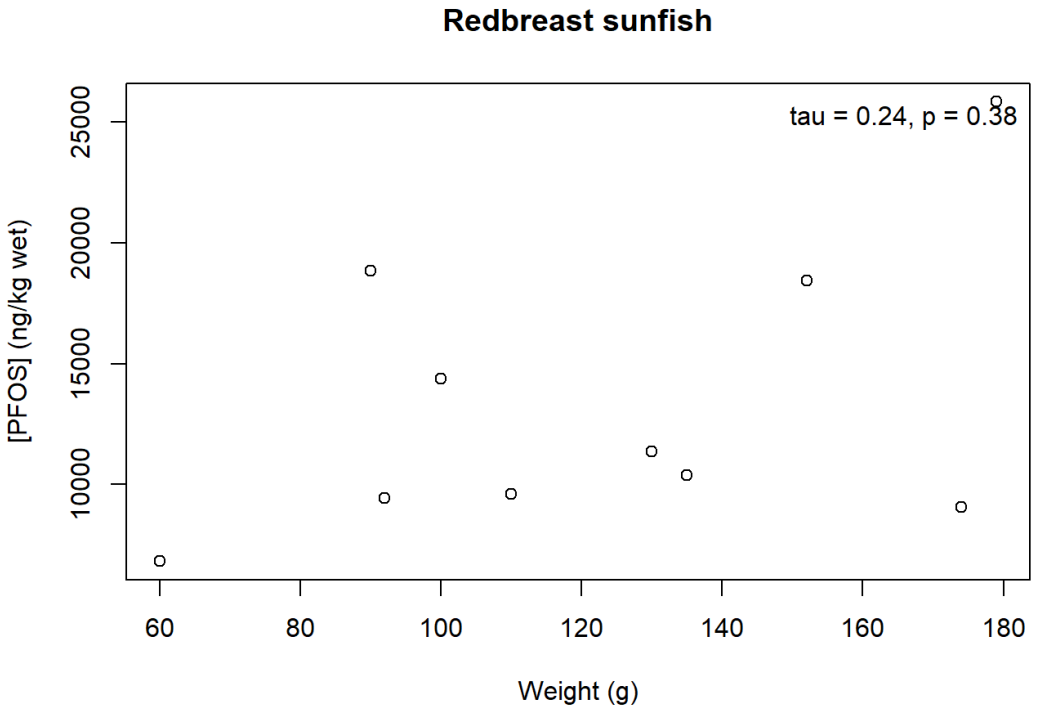
Correlation plots comparing total PFOS concentrations (ng/kg wet) in channel catfish, redbreast sunfish, common carp, largemouth bass and spotted gar with length (mm), weight (g), and age (years) (age only evaluated in 2021 largemouth bass samples). No significant correlations were identified using Kendall's tau (α=0.05).

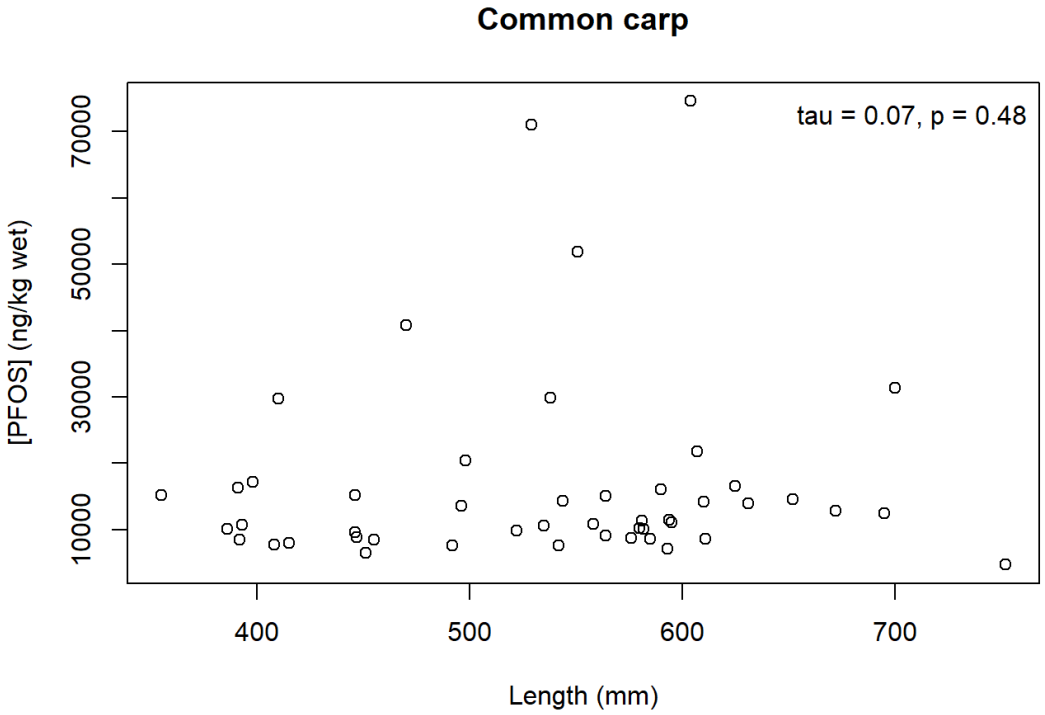
Not enough fish samples were collected to conduct correlation analysis for redear sunfish, longnose gar, grey redhorse, and gizzard shad. Results were similar for total PFAS (results not shown).

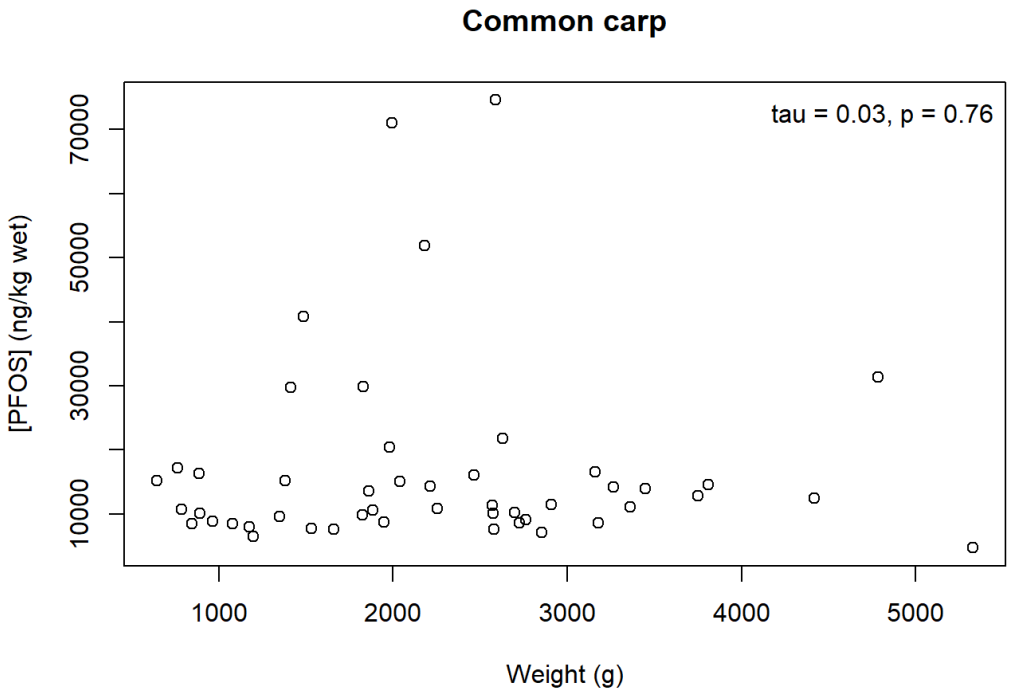


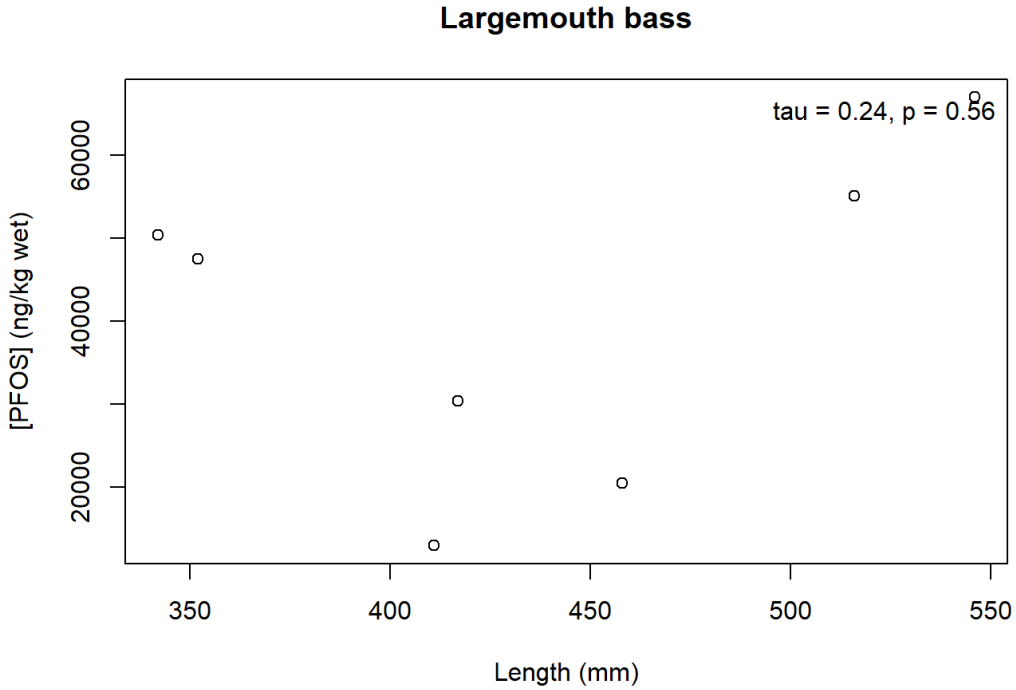

Channel catfish
tau = 0, p = 1
[PFOS] (ng/kg wet)
1000
1400
1800
2200
1000
1200
1400
1600
Weight (g)

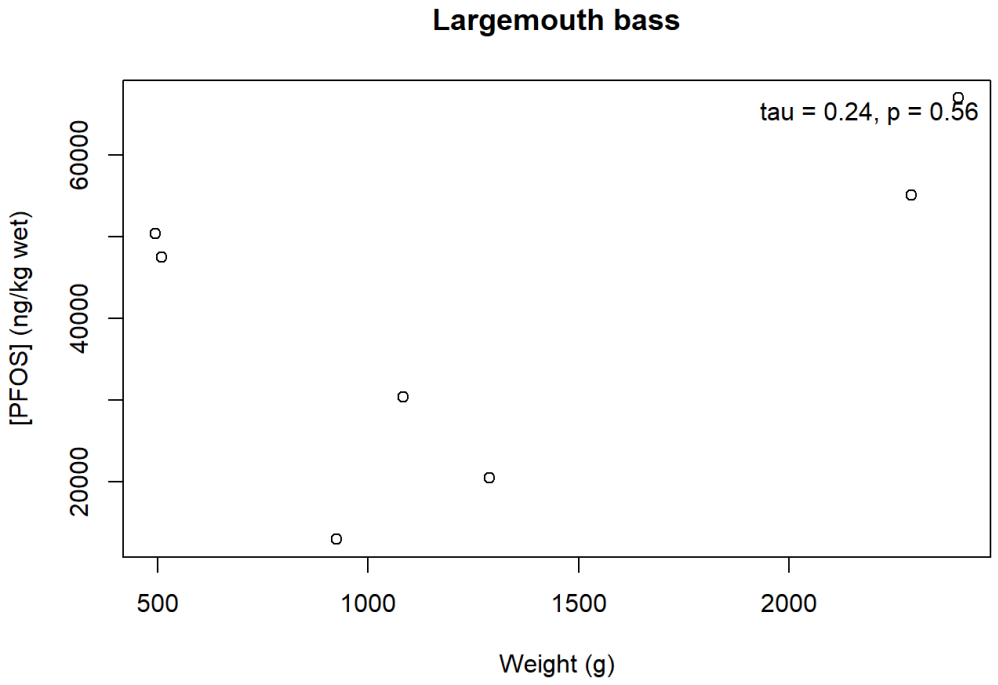

Redbreast sunfish
tau = 0.2, p = 0.48
[PFOS] (ng/kg wet)
10000
15000
20000
25000
160
170
180
190
200
210
220
Length (mm)


Redbreast sunfish
tau = 0.24, p = 0.38
[PFOS] (ng/kg wet)
10000
15000
20000
25000
60
80
100
120
140
160
180
Weight (g)

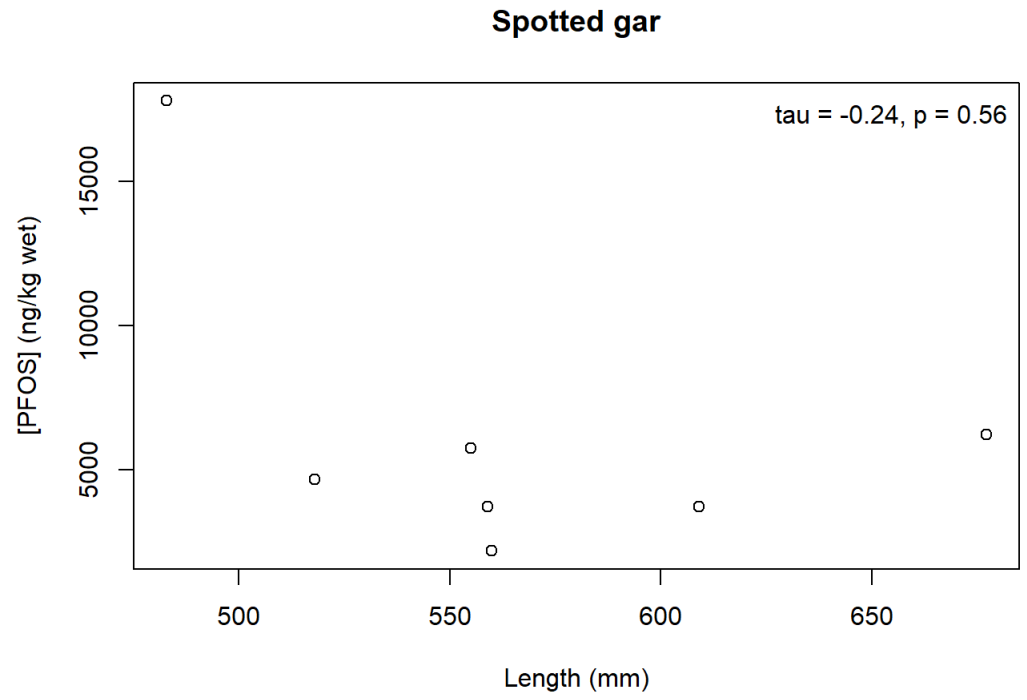

Common carp
tau = 0.07, p = 0.48
[PFOS] (ng/kg wet)
10000
30000
50000
70000
400
500
600
700
Length (mm)

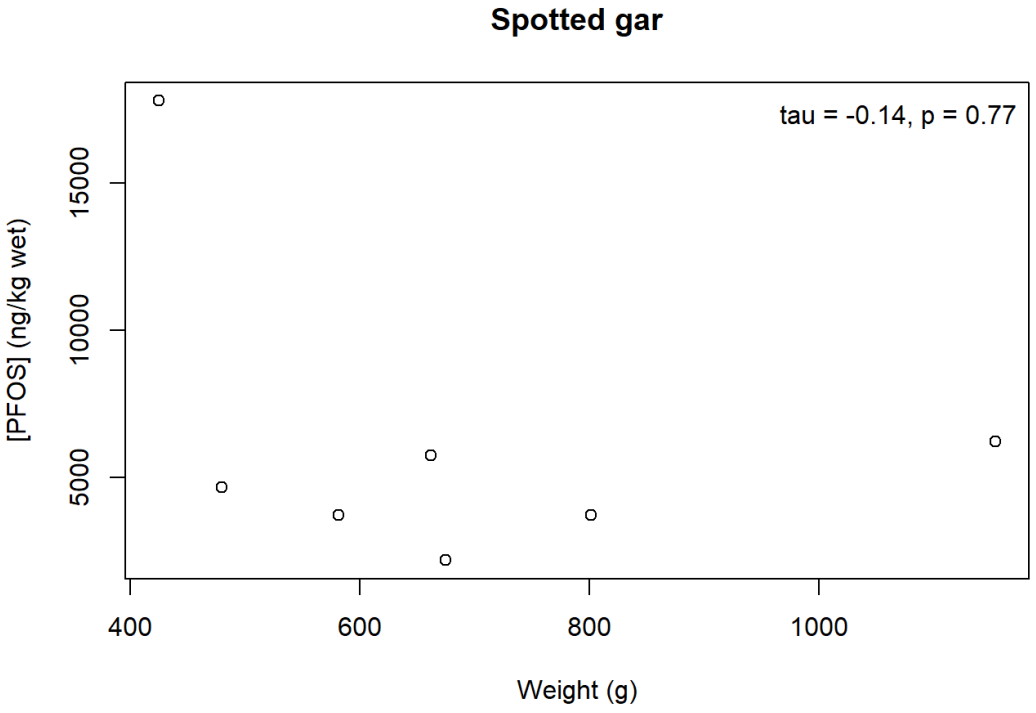

Common carp
tau = 0.03, p = 0.76
[PFOS] (ng/kg wet)
10000
30000
50000
70000
1000
2000
3000
4000
5000
Weight (g)


Largemouth bass
tau = 0.24, p = 0.56
[PFOS] (ng/kg wet)
20000
40000
60000
350
400
450
500
550
Length (mm)


Largemouth bass
tau = 0.24, p = 0.56
[PFOS] (ng/kg wet)
20000
40000
60000
500
1000
1500
2000
Weight (g)


Largemouth bass
tau = -0.07, p = 0.85
[PFOS] (ng/kg wet)
20000
30000
40000
50000
60000
3
4
5
6
7
8
Age (years)


Spotted gar
tau = -0.24, p = 0.56
[PFOS] (ng/kg wet)
5000
10000
15000
500
550
600
650
Length (mm)


Spotted gar
tau = -0.14, p = 0.77
[PFOS] (ng/kg wet)
5000
10000
15000
400
600
800
1000
Weight (g)