ADDENDUM 01

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

Bexar County, Texas

2022

INTRODUCTION

This addendum report summarizes per- and polyfluoroalkyl substances (PFAS) found in fish collected in December 2021 and January 2022 from Lower Leon Creek, Bexar County, Texas. The addendum report addresses 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 bases trained air force firefighters 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). Although not detected in surface runoff, it is possible PFAS has contaminated the creek and fish in the creek.

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, which included contamination of the shallow groundwater and soil in and around the Kelly Field with organic solvents, including 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, TDH concluded that PCBs in fish are at levels that could potentially result in adverse effects on

the health of 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 (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 from the creek downstream of Rodriquez Park.

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 consume fish taken from its waters.

PURPOSE

The purpose of the current fish survey 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

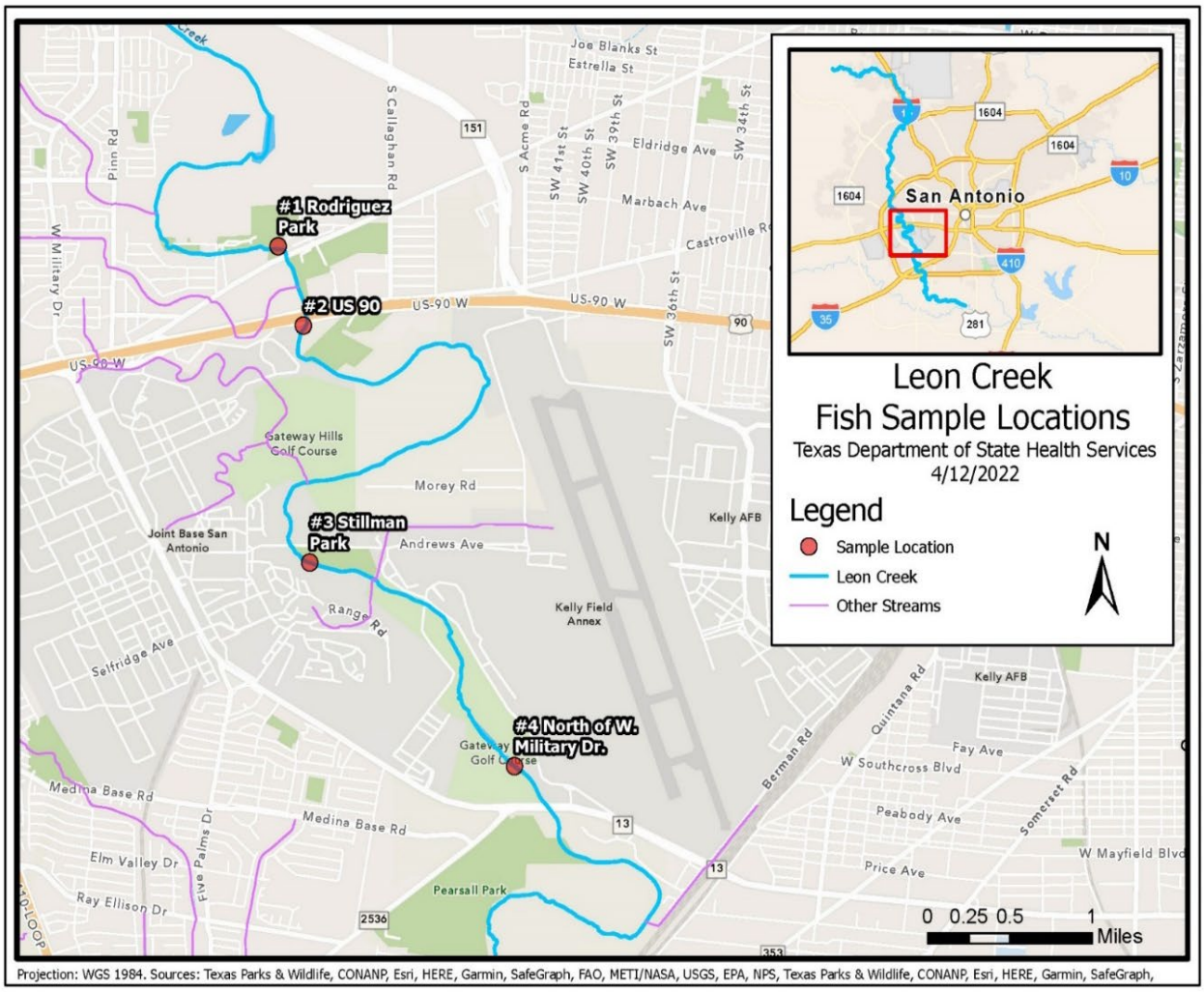
Fish Sampling and Preparation

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 from Lower Leon Creek because of low water levels. DSHS determined 52 samples to be of adequate power (almost 99%) to detect differences between safe levels of PFAS and levels needing consumption advisories for each species of fish, should these differences truly exist.

DSHS collected fish from Lower Leon Creek in December 2021 and in January 2022. Sampling locations included site 1 - Rodriquez Park, site 2 -

US 90, site 3 -Stillman Park and site 4 - North of West Military Drive (Figure 1). The sampling locations include upstream and downstream locations from the parts of the creek adjacent to the military facilities.

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. 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) Laboratory, Texas A&M University, College Station, Texas, for chemical analysis.

DSHS also collected a water and a sediment sample at each sampling location. 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°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

The GERG 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 non-cancer 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 2022) 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)	3.8E-06
Perfluoropentanoic acid (PFPeA)	3.8E-06
Perfluorobutanoic acid (PFBA)	2.9E-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 weight of 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 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)
- 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 of interest to high-risk groups. 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 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 contaminant 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)

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

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

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)
- 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 levels among fish species and sampling location. A non-parametric analysis, Kendall's Tau, was also used to determine significant correlations between total PFOS for each fish species and fish length, weight, and age, as appropriate, where $p>0.05$ (Appendix B, Figures B1-B3).

RESULTS and DISCUSSION

DSHS collected a total of 52 fish of 7 different species from 4 different locations from Lower Leon Creek (Table 3). Fish species collected included: 2 spotted gar, 34 common carp, 3 channel catfish, 2 longnose gar, 6 largemouth bass, 3 redbreast sunfish and 2 redear sunfish. Because of low water levels at three of the sampling sites, including site 1 - Rodriquez Park, site 2 - Highway 90, and site 4 - North of West Military Drive, only one type of fish, common carp, could be collected from these three locations.

Fish were collected from some of the same locations as the 2010 DSHS fish survey event at Lower Leon Creek (DSHS 2010). The highest number of fish (62%) were collected from site 3 - Stillman Park. At the other locations, 23% were collected from site 1- Rodriquez Park; 7% from site 2 - US 90 and 2% from site 4 - North of West Military Drive. Because low water levels at three of sampling sites, most fish were collected from site 3 – Stillman Park.

A summary of the length, weight and age for fish samples collected are provided on Table 3. Sagittal otoliths for age estimation could not be removed common carp, longnose gar, and redear sunfish. Statistically significant correlations were not observed between PFOS concentrations detected in common carp and largemouth bass and fish length, weight, or age, respectively (Appendix B, Figure B2). Not enough fish samples were collected to conduct correlation analysis for channel catfish, redbreast sunfish, redear sunfish, spotted gar and longnose gar.

Table 3. Location, type and number of fish collected from Lower Leon Creek, Texas, December 2021 and January 2022

Species	Number of Fillets* (n=52)

Table 3. Location, type and number of fish collected from Lower Leon Creek, Texas, December 2021 and January 2022	
Spotted Gar	2 (4)
Common Carp	34 (65)
Channel Catfish	3 (6)
Longnose Gar	2 (4)
Largemouth Bass	6 (12)
Redbreast Sunfish	3 (6)
Redear Sunfish	2 (4)
Location	Number of Fillets* (% total)
Rodriguez Park (site 1)	12 (23)
US 90 (site 2)	7 (13)
Stillman Park (site 3)	32 (62)
North of West Military Drive (site 4)	1 (2)
Species	Average length in millimeters (standard deviation)
Spotted Gar	582 (27)
Common Carp	515 (96)
Channel Catfish	544 (30)
Longnose Gar	695 (45)
Largemouth Bass	439 (77)
Redbreast Sunfish	205 (17)
Redear Sunfish	210 (8)
Species	Average weight in grams (standard deviation)
Spotted Gar	732 (70)
Common Carp	2055 (1138)
Channel Catfish	1384 (368)
Longnose Gar	742 (226)
Largemouth Bass	1345 (765)

Table 3. Location, type and number of fish collected from Lower Leon Creek, Texas, December 2021 and January 2022	
Redbreast Sunfish	134 (33)
Redear Sunfish	145 (13)
Species	Average age in years (standard deviation)
Spotted Gar	Not analyzed
Common Carp	Not analyzed
Channel Catfish	4 (2)
Longnose Gar	Not analyzed
Largemouth Bass	5 (2)
Redbreast Sunfish	3 (1)
Redear Sunfish	Not analyzed

PFAS Levels in Fish

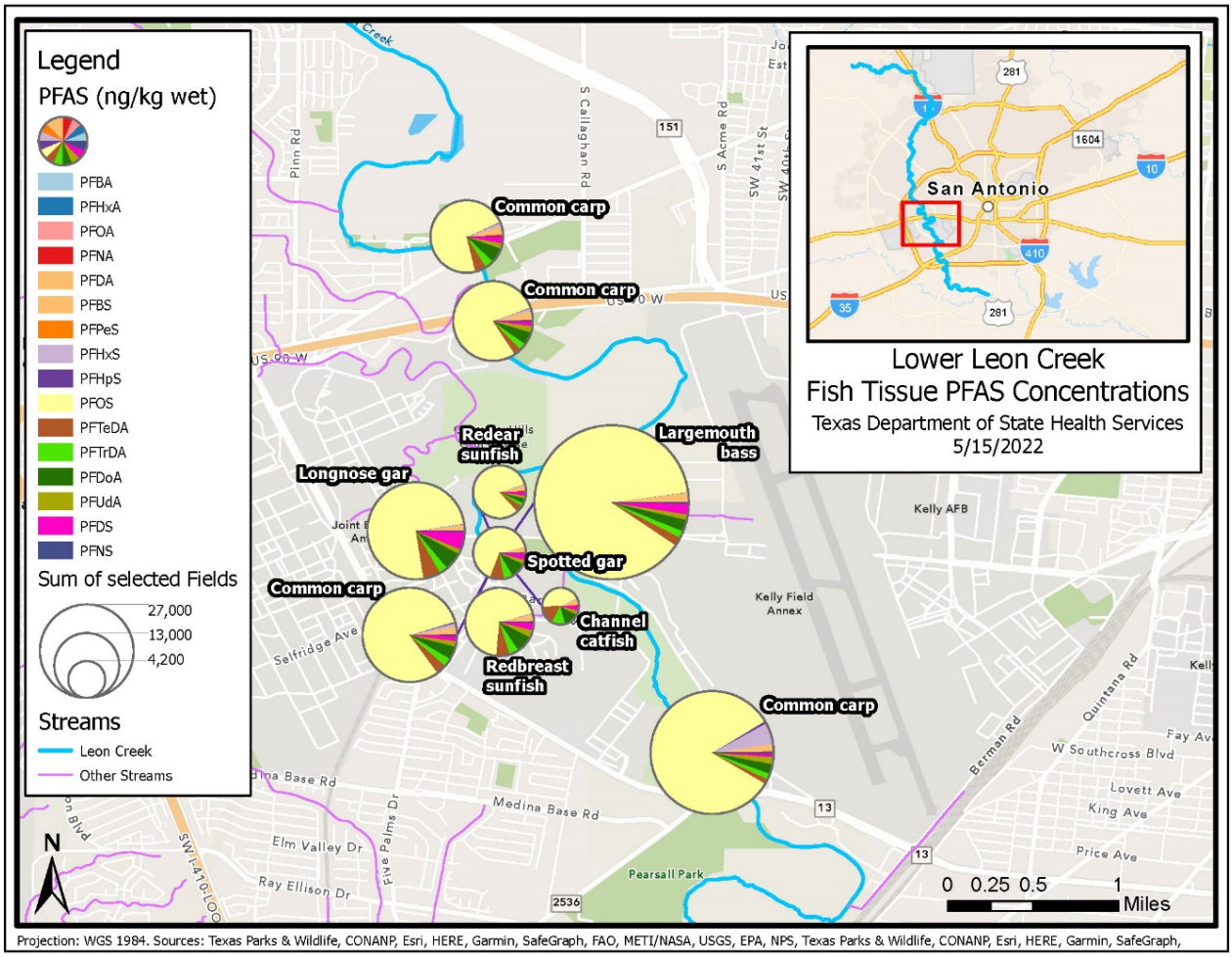
The overall summary of PFAS levels per fish species and location is provided in Table A1 (Appendix A). PFAS was detected in all fish species and at all locations. Of the 28 PFAS analytes included in the survey, 14 were detected in at least one fish fillet. These included: perfluorobutanoic acid (PFBA), 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).

Mean total PFAS levels were significantly different among the fish species analyzed (p-value=0.000125) (Appendix B, Figure B1). Additionally, mean total PFAS levels in common carp were significantly different than levels in channel catfish (p-value=0.0056) and in largemouth bass (p-value=0.0050). However, no significant differences in total mean PFAS levels were identified among sampling locations (p-value=0.37) (Appendix B, Figure B2).

PFOS was detected at the highest levels in all fish sampled. Highest concentrations were detected in largemouth bass (mean level of 45,104 ng/kg) at site 3 - Stillman Park and in common carp (mean level 31,342 ng/kg) at site 4 – North of West Military Drive. PFOS levels varied among

species. Largemouth bass, common carp and longnose gar generally contained higher levels of PFOS than redbreast sunfish, redear sunfish and spotted gar (Figure 2; Table A1).

Figure 2. Fish tissue PFAS Concentrations from Lower Leon Creek



PFAS in Water and Sediment Samples

DSHS collected a water sample at each sampling location. Thirteen different PFAS compounds were detected in at least one water sample (Table 4). The total PFAS concentration in water samples ranged from 103.00 nanograms per liter (ng/L) to 399.45 ng/L. Highest total 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, site 1 – Rodriquez Park. Among the individual PFAS compounds detected, PFHxS and PFOS were the most abundant types measured at greater than 35% (141.45 ng/L) and 13% (50.71 ng/L),

respectively, of total PFAS at the site 4 - North of West Military Drive location.

Table 4 PFAS concentrations (ng/L) in surface water samples collected from Lower Leon Creek, Bexar County, Texas, December 2021 and January 2022

PFAS Type	Site 1 Rodriguez Park*	Site 2 US 90	Site 3 Stillman Park	Site 4 North of West Military Drive
PFBA	14.87	19.87	24.02	23.66
PFPeA	8.79	28.64	21.26	36.98
PFHxA	6.62	23.99	16.28	42.61
PFHpA	3.86	10.84	7.28	15.42
PFOA	9.76	15.83	14.31	21.06
PFNA	ND	1.68	0.75	1.36
PFDA	ND	1.58	ND	ND
PFBS	31.01	30.19	36.54	39.65
PFPeS	3.43	6.58	6.85	11.57
PFHxS	17.53	22.47	23.96	141.45
PFHpS	ND	0.75	ND	2.46
PFOS	7.03	22.03	8.66	50.71
6:2FTS	ND	ND	ND	12.52
Total PFAS	103.00	184.45	159.91	399.45

*Results are the average of duplicate samples collected.
Abbreviations: ng/L=nanograms per liter; ND= not detected; PFAS= per- and polyfluoroalkyl substances; 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 (Table 5). Three different PFAS compounds were detected in at least one sediment sample, including PFHxA, PFOA and PFOS. PFAS was detected at only two locations, site 2 - US 90 and site 4 - North of West Military Drive. Total PFAS concentrations ranged from 937.61 ng/kg to 1435.54 ng/kg. PFOS was detected at highest levels at both locations.

Table 5. PFAS concentrations (ng/kg) in sediment samples collected from Lower Leon Creek, Bexar County, Texas, December 2021 and January 2022

PFAS Type	Site 1 Rodriguez Park	Site 2 US 90	Site 3 Stillman Park	Site 4 North of West Military Drive
PFHxA	ND	ND	ND	339.6
PFOA	ND	222.07	ND	ND
PFOS	ND	715.54	ND	1095.94
Total PFAS	-	937.61	-	1435.54

Abbreviations: ng/kg = nanograms per kilogram; ND= not detected; PFHxA = perfluoropentanesulfonic acid; PFOA = perfluorooctanoic acid; PFOS= perfluorooctanesulfonic 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 non-cancer endpoints. PFOS was the only PFAS type to be detected at levels in fish above HAC values. PFOS levels did not exceed the HAC value for adults but did exceed HAC levels (HQs greater than 1) in common carp, largemouth bass and longnose gar for subsistence fishers and in largemouth bass for women of childbearing age and children less than 6 years (Table 6).

Table 6. PFOS in fish and health assessment comparison (HAC) values and hazard quotients (HQ)							
		Subsistence Fisher		Adult		Children/Pregnant Women*	
PFAS Type	Species	HAC (ng/kg)	HQ	HAC (ng/kg)	HQ	HAC (ng/kg)	HQ
PFOS	Channel catfish	11,338	0.2	53,667	0.04	23,000	0.08
	Common carp	11,338	**1.4**	53,667	0.3	23,000	0.7
	Largemouth bass	11,338	**4.0**	53,667	0.8	23,000	**2.0**
	Longnose gar	11,338	**1.6**	53,667	0.3	23,000	0.8
	Redbreast sunfish	11,338	0.9	53,667	0.2	23,000	0.4
	Redear sunfish	11,338	0.6	53,667	0.1	23,000	0.3
	Spotted gar	11,338	0.4	53,667	0.09	23,000	0.2

Notes: *Women of childbearing age and children less than 6 years.
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, women of childbearing age, and children could consume without significant risk of PFAS-related adverse effects (Table 7). DSHS estimated that adults could consume 1 to 26 meals per week (4 to 112 meals per month) depending on the type of fish contaminated with PFOS and not experience any adverse health effects. However, the estimated meals per month are lower than what a subsistence fisher would expect to eat (19 meals per month) for common carp, largemouth bass, and longnose gar. Similarly, the estimated meals per month are lower than what women of childbearing age and children less than 6 years would expect to eat (4 meals per month) for largemouth bass.

Table 7. Estimated number of meals (per week and per month) for PFOS					
		Adult/Subsistence Fishers		Children/Pregnant Women*	
PFAS Type	Fish Species	Meals/ Month	Meals/Week	Meals/ Month	Meals/Week
PFOS	Channel catfish	112.0	25.8	48.2	11.1
	Common carp	14.0	3.2	6.0	1.4
	Largemouth bass	4.8	1.1	2.1	0.5
	Longnose gar	12.2	2.8	5.2	1.2
	Redbreast sunfish	22.4	5.2	9.7	2.2
	Redear sunfish	31.4	7.2	13.5	3.1
	Spotted gar	45.5	10.5	19.6	4.5

Notes: *Women of childbearing age and children less than 6 years.
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. For subsistence fishers the results show the HIs are above 1 for common carp, largemouth bass and longnose gar. For these fish, subsistence fishers could safely consume 4 to 13 meals per month (Table 8). For women of childbearing age and children less 6 years, the results show HIs above 1 for largemouth bass and longnose gar. For these fish species, women of childbearing age and children less than 6 years could safely consume 2 and 3 meals a month, respectively. For other adults (non-subsistence fishers and women not of childbearing age) the HIs were 1 and less. These adults can safely consume 4 or more meals per month of all fish species. Additionally, there are no limits on fish consumption of catfish, redbreast sunfish, redear sunfish and spotted gar for any of the exposure groups evaluated.

Table 8. Potential additive mixture for total PFAS, hazard index and meals per month					
	Subsistence Fishers	Adult	Children/ Pregnant Women*	Meals/Month Mixture	
Species	Hazard Index	Hazard Index	Hazard Index	Adult/ Subsistence Fisher	Children/ Pregnant Women*
Channel catfish	0.6	0.1	0.3	34	15
Common carp	**2.0**	0.4	1.0	9	4
Largemouth bass	**4.8**	1.0	**2.4**	4	2
Longnose gar	**2.5**	0.5	**1.2**	8	3
Redbreast sunfish	**1.4**	0.3	0.7	13	6
Redear sunfish	0.8	0.2	0.4	23	10
Spotted gar	0.8	0.2	0.4	23	10

Notes: *Women of childbearing age and children less than 6 years. 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 that consumption of PCBs and PCDDs/PCDFs, in channel catfish, common carp, largemouth bass, redear sunfish and spotted gar increases the likelihood of non-cancer health risks. Because there is potential that PFAS detected in some fish species may affect existing fish consumption advisories when treated as a mixture with other chemicals, 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 redear sunfish decreased slightly from 1.38 to 1.02 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 women of childbearing age and children less than 6 years (Table 10).

Table 9. Hazard quotient and meals per week for adult consumption of fish with combined contaminants				
	PCB and PCDD/PCDFs		PCB and PCDD/PCDFs added with PFOS	
Contaminant/Species	Hazard Quotient	Meals per Week (adult)	Hazard Quotient	Meals per Week (adult)
Channel catfish				
PCBs	**1.95**	**0.47**	**1.95**	**0.47**
PCDDs/PCDFs	0.48	1.95	0.48	1.95
PFOS			0.04	28.01
Hazard Index (meals per week)	**2.43**	**0.38**	**2.47**	**0.37**
Common carp				
PCBs	**4.67**	**0.20**	**4.67**	**0.20**
PCDDs/PCDFs	0.19	4.81	0.19	4.81
PFOS			0.29	3.51
Hazard Index (meals per week)	**4.86**	**0.19**	**5.15**	**0.18**
Largemouth bass				
PCBs	**1.71**	**0.54**	**1.71**	**0.54**
PCDDs/PCDFs	>0.01	unrestricted	>0.01	unrestricted
PFOS			0.84	1.20
Hazard Index (meals per week)	**1.71**	**0.54**	**2.55**	**0.36**
Redbreast sunfish				
PCBs	0.73	1.27	0.73	1.27
PCDDs/PCDFs	>0.01	unrestricted	>0.01	unrestricted
PFOS			0.18	5.60

Table 9. Hazard quotient and meals per week for adult consumption of fish with combined contaminants				
	PCB and PCDD/PCDFs		PCB and PCDD/PCDFs added with PFOS	
Contaminant/Species	Hazard Quotient	Meals per Week (adult)	Hazard Quotient	Meals per Week (adult)
Hazard Index (meals per week)	0.73	1.27	0.91	1.02
Redear sunfish				
PCBs	0.49	1.88	0.49	1.88
PCDDs/PCDFs	>0.01	unrestricted	>0.01	unrestricted
PFOS			0.13	7.86
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			0.09	11.38
Hazard Index (meals per week)	**3.99**	**0.23**	**4.08**	**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 consumption of fish with combined contaminants for women of childbearing age and children less than 6 years				
	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**

Table 10. Hazard quotient and meals per week consumption of fish with combined contaminants for women of childbearing age and children less than 6 years				
	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)
PCDDs/PCDFs	**1.13**	**0.83**	**1.13**	**0.83**
PFOS			0.08	12.06
Hazard Index (meals per week)	**5.67**	**0.16**	**5.76**	**0.16**
Common carp				
PCBs	**10.90**	**0.09**	**10.90**	**0.09**
PCDDs/PCDFs	0.45	2.07	0.45	2.07
PFOS			0.67	1.51
Hazard Index (meals per week)	**11.35**	**0.08**	**12.02**	**0.08**
Largemouth bass				
PCBs	**4.0**	**0.23**	4.0	0.23
PCDDs/PCDFs	>0.01	unrestricted	>0.01	unrestricted
PFOS			1.96	0.52
Hazard Index (meals per week)	**4.0**	**0.23**	**5.96**	**0.16**
Redbreast sunfish				
PCBs	**1.70**	**0.55**	**1.70**	**0.55**
PCDDs/PCDFs	>0.01	unrestricted	>0.01	unrestricted
PFOS			0.42	2.41
Hazard Index (meals per week)	**1.70**	**0.55**	**2.12**	**0.44**
Redear sunfish				
PCBs	**1.15**	**0.81**	**1.15**	**0.81**
PCDDs/PCDFs	>0.01	unrestricted	>0.01	unrestricted

Table 10. Hazard quotient and meals per week consumption of fish with combined contaminants for women of childbearing age and children less than 6 years				
	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)
PFOS			0.30	7.86
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			0.21	4.90
Hazard Index (meals per week)	**9.31**	**0.10**	**9.52**	**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 at three of the locations and one-time sampling event.

PFAS levels detected in fish, including common carp, channel catfish, largemouth bass, longnose gar, redbreast sunfish, redear sunfish, and spotted gar, do not exceed DSHS guidelines for protection of human health for adults. However, PFAS levels in common carp, largemouth bass, and longnose gar exceed DSHS guidelines for subsistence fishers and PFAS levels in largemouth bass exceed DSHS guidelines for women of childbearing age and children less than 6 years. Therefore, consumption of some fish species containing PFAS may pose non-cancer risk to human health for subsistence fishers and women of childbearing age and children less than 6 years.

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. The results of the current evaluation do not change these recommendations.

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 include this addendum 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 and 2022

Location	Fish Species (number detected)	PFAS* type (ng/kg wet)													
		PFBA	PFHxA	PFOA	PFNA	PFDA	PFUdA	PFDoA	PFTrDA	PFTeDA	PFHxS	PFHpS	PFOS	PFNS	PFDS
Site 1 Rodriquez Park	Common Carp (12)	9.8	2.0	45.9	67.6	534.2	317.2	911.3	518.3	703.1	208.7	41.4	11104.2	3.1	398.7
Site 2 Highway 90	Common Carp (6)	ND	3.5	40.3	54.4	604.2	420.3	840.6	439.4	481.8	166.8	34.4	13799.0	19.3	290.5
Site 3 Stillman Park	Channel catfish (3)	ND	ND	26.0	34.8	214.8	163.3	543.8	480.7	697.8	51.4	0.3	1926.8	ND	152.7
	Common Carp (14)	ND	ND	44.3	44.0	561.2	408.3	965.9	611.3	760.7	236.2	102.5	18604.1	46.7	386.2
	Largemouth bass (6)	21.2	ND	17.4	4.3	1008.8	562.4	1251.1	724.6	923.2	25.7	25.5	45105.8	106.4	1154.9
	Longnose gar (2)	ND	ND	21.2	ND	455.0	365.8	1352.5	628.1	1307.9	60.7	21.6	17750.4	46.3	1350.5
	Redbreast sunfish (3)	ND	ND	33.3	27.2	405.0	420.7	1003.9	540.6	792.2	61.7	6.9	9627.9	16.6	449.9
	Redear sunfish (2)	ND	ND	26.9	32.8	284.0	136.7	230.4	154.4	329.5	41.9	10.2	6864.8	ND	166.9

Appendix A

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

Location	Fish Species (number detected)	PFAS* type (ng/kg wet)													
		PFBA	PFHxA	PFOA	PFNA	PFDA	PFUdA	PFDoA	PFTrDA	PFTeDA	PFHxS	PFHpS	PFOS	PFNS	PFDS
	Spotted gar (2)	ND	ND	33.6	24.4	240.2	202.9	745.6	444.2	665.5	27.8	ND	4743.7	11.1	304.7
Site 4 North of West Military Drive	Common Carp (1)	ND	ND	50.5	70.0	679.3	641.9	879.2	522.8	428.3	1912.8	220.1	31342.6	82.2	292.2

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 = nanagram per kilogram.

Appendix B

Figure B1. Comparison of total mean PFAS levels per fish species

Mean total PFAS levels are significantly different from each other (Kruskal-Wallis chi-squared= 27.34, df=6, p-value=0.000125, α=0.05). Mean total PFASs levels in common carp are significantly different than levels in channel catfish (p=0.0056) and in largemouth bass (p=0.0050).

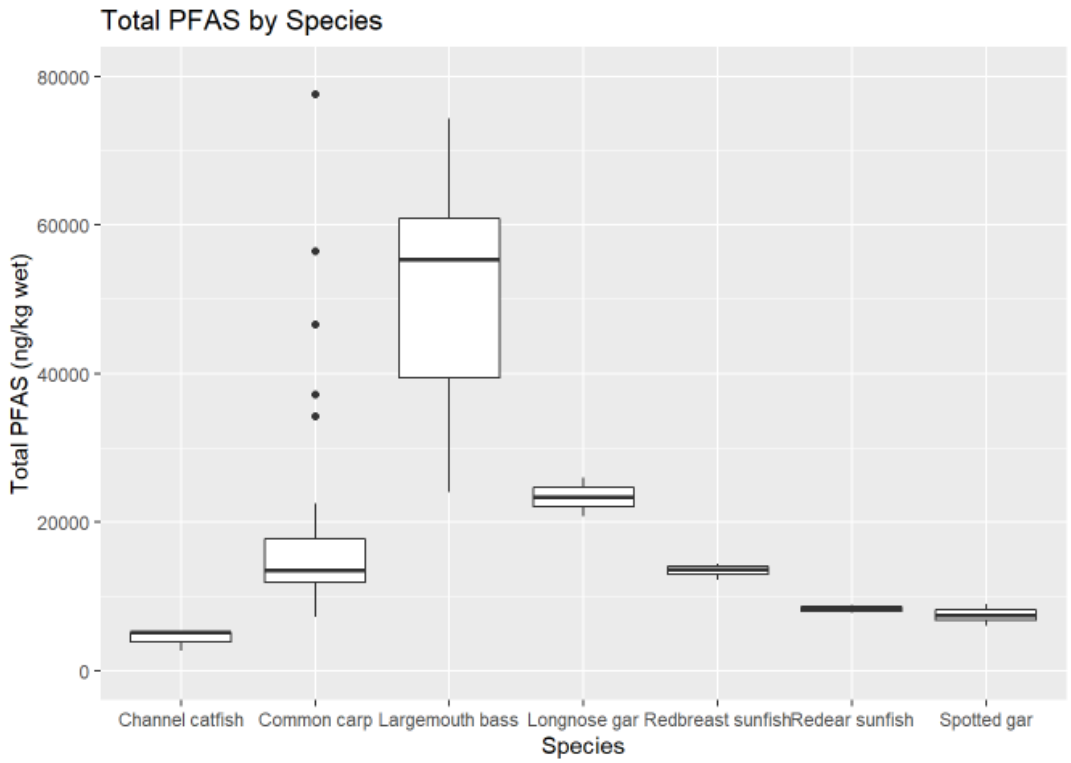


Figure B2. Comparison of total mean PFAS levels per sampling location.

No significant differences in total mean PFAS levels were identified among sampling locations (Kruskal-Wallis chi-squared= 3.14, df=3, p-value=0.37, α=0.05).

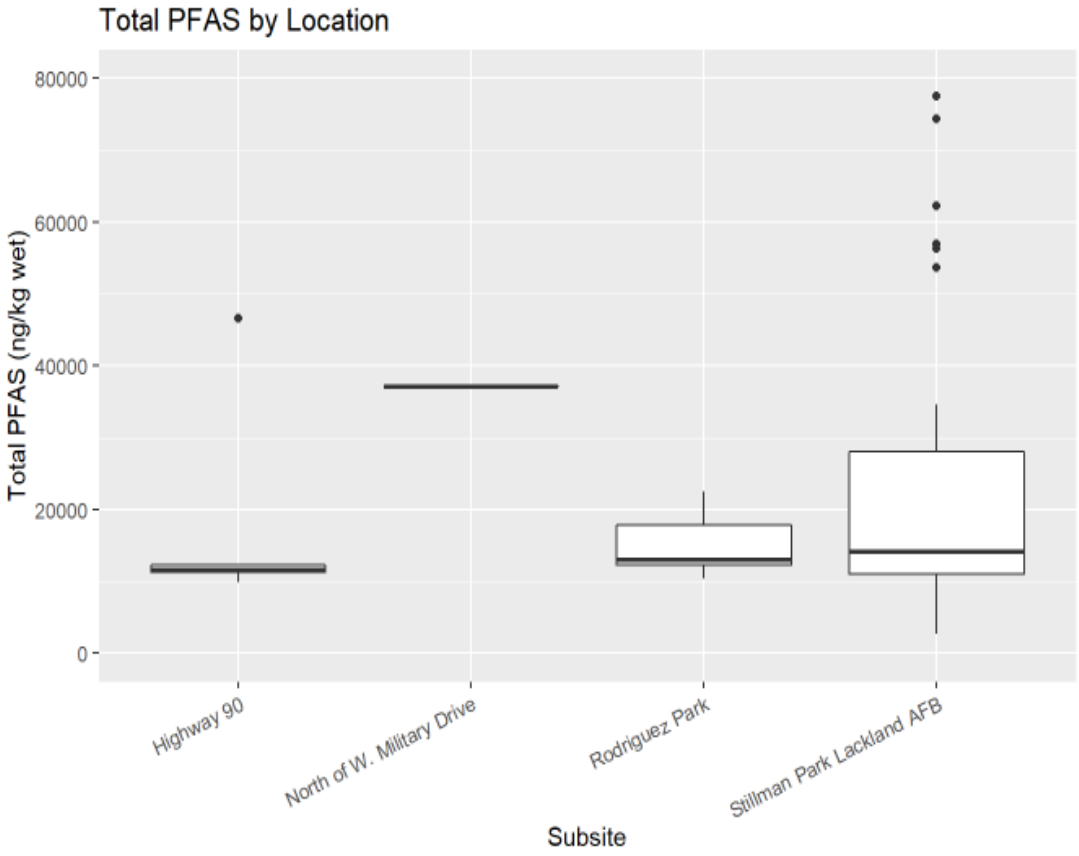
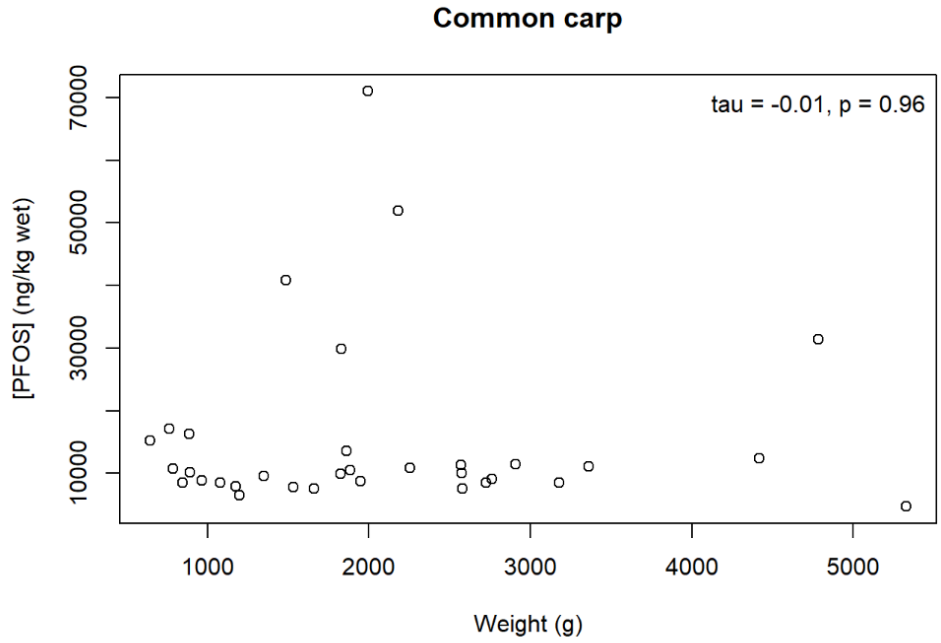
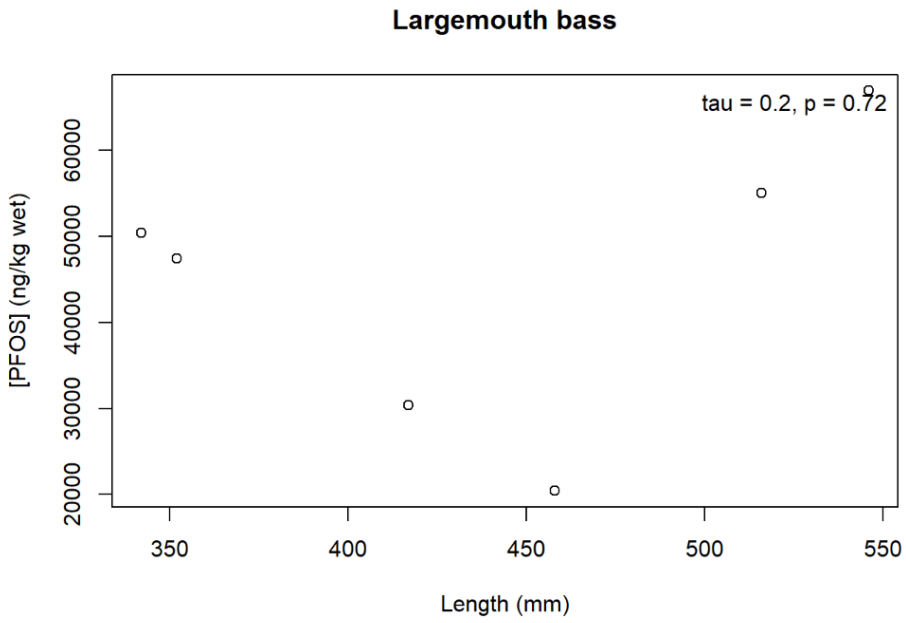
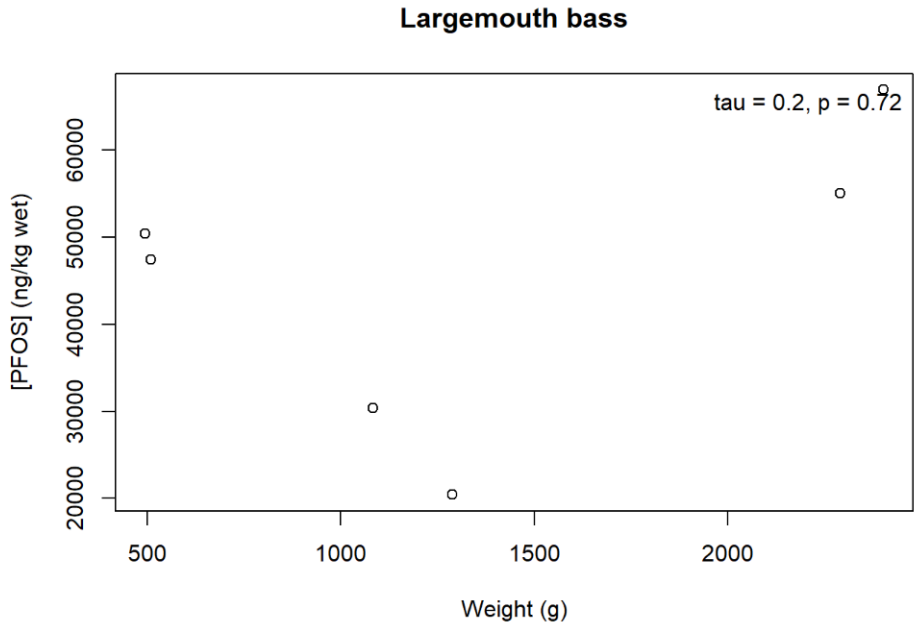


Figure B3. Correlation plots comparing total PFOS concentrations (ng/kg wet) in common carp and largemouth bass with length (mm), weight (g), and age (years) (age not evaluated in common carp). Not enough fish samples were collected to conduct correlation analysis for channel catfish, redbreast sunfish, redear sunfish, spotted gar and longnose gar.

No significant correlations were identified using Kendall's tau (α=0.05).




Largemouth bass
tau = 0.2, p = 0.72
[PFOS] (ng/kg wet)
20000
30000
40000
50000
60000
350
400
450
500
550
Length (mm)


Largemouth bass
tau = 0.2, p = 0.72
[PFOS] (ng/kg wet)
20000
30000
40000
50000
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)