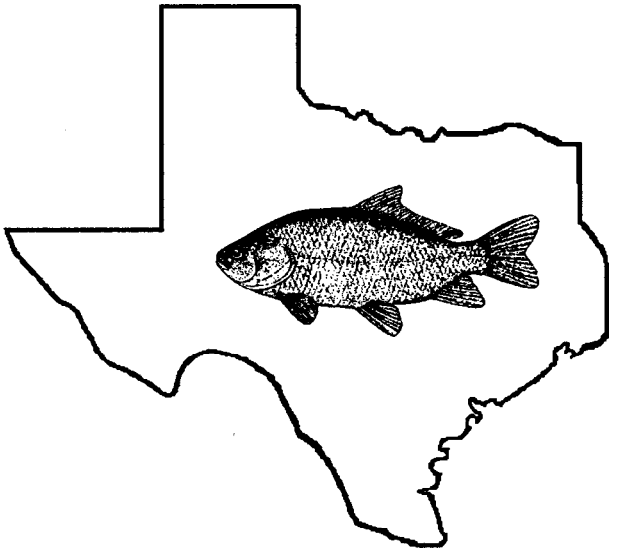
U.S. Fish and Wildlife Service
Region 2
Contaminants Program

CONTAMINANTS INVESTIGATION OF THE GUADALUPE AND SAN ANTONIO RIVERS OF TEXAS 1992

by

M. Clare Lee and Thomas W. Schultz



U.S Fish and Wildlife Service
Fish and Wildlife Enhancement
Corpus Christi Field Office
Campus Box 338, 6300 Ocean Drive
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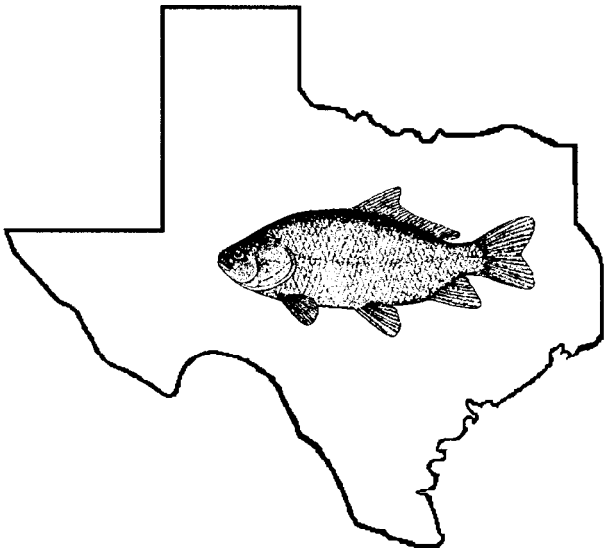

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Abstract

The Guadalupe and San Antonio River Basins drain a combined area of 26,547 km^2 (10,250 square miles), transporting wastewaters from agricultural, livestock, and mining operations, dumps, and urban, industrial, and domestic sources, ultimately discharging into the San Antonio Bay system. Due to a need for baseline studies to assess both current conditions and to provide data for future comparisons, five species of fish were collected from four sites on the San Antonio River and five sites on the Guadalupe River from August to October 1992. Predatory fish from the upper reaches of the San Antonio River had elevated tissue concentrations of mercury up to 2.5 times the U. S. Fish and Wildlife Service's (Service) National Contaminant Biomonitoring Program's (NCBP) 85^{th} percentile of 0.17 ppm. Concentrations in predatory fish also exceeded the NCBP geometric mean for PCB's (0.39 ppm) and DDE (0.19 ppm) by up to ten times and six times, respectively. At three sites on the San Antonio River, copper exceeded the NCBP geometric mean of 1 .O ppm. On the Guadalupe River, PCB's and DDE exceeded the NCBP geometric mean by four and two times, respectively. Mercury exceeded the NCBP 85^{th} percentile in predators at two sites and concentrations of copper in predators in the lower Guadalupe River were nearly twice the NCBP 85^{th} percentile. Chromium concentrations in fish were present at levels of concern at several locations in both rivers. It is recommended that further sampling be conducted to determine sources of PCB's, DDE, mercury, and chromium in the San Antonio River south of San Antonio, and PCB's, chromium, copper, and mercury in the Guadalupe River.

Project Number 21410-l 130-2F24

Introduction

The San Antonio River has four major tributaries, the Medina River, Leon Creek, Cibolo Creek, and Salado Creek, draining a 10,826 km^2 (4,180 square mile) area. The Guadalupe River, with two tributaries, the Blanco and San Marcos Rivers, drains 15,721 km^2 (6,070 square miles). After converging near the coast, the San Antonio and Guadalupe Rivers empty into Guadalupe Bay, a portion of the San Antonio Bay System. Both rivers receive agricultural runoff as well as numerous industrial and municipal outfalls. The study area includes U. S. Geological Survey (USGS) watershed classification system segments 1803 and 1804 of the Guadalupe River which receives a total 19 domestic and 17 industrial outfalls. San Antonio River USGS segments 190 1 and 1911 receive a total of 28 domestic and industrial outfalls. All segments are currently listed by the Texas Water Commission (TWC) as high quality aquatic habitat (TWC 1992). The river systems fall within the Fish and Wildlife Service's Edwards Plateau and Gulf Coast Ecoregions.

The areas' continued population growth and consequent agricultural, industrial, and urban expansion will place increasing pressure on the rivers and the bay system. The intent of this study is to provide baseline information on fish from two major Texas rivers and to locate any potential problem areas that may cause contaminant-related impacts to wildlife.

Study Area and Methods

The study area falls within the Fish and Wildlife Service's Edwards Plateau and Gulf Coast Ecoregions. From August 21-October 9, 1992, fish were collected from four sites on the San Antonio River and five sites on the Guadalupe River (Figure 1, Table 1). Abundant rainfall preceding and during this period resulted in the rivers being at or above normal flow levels. Three predatory species, the alligator gar (*Lepisosteus* spatula), the longnose gar (*L. osseus*), and the flathead catfish (*Pylodictis olivaris*), and two bottom-feeders, the smallmouth buffalo (*Ictiobus bubalus*), and the channel catfish (*Ictalurus punctatus*) were collected using gill nets, hoop nets, trotlines, or limblines. Hoop nets were baited with cottonseed cake, and hooks were baited with chicken liver, goldfish, or commercially prepared catfish bait. Fish samples were s measured, weighed, wrapped in aluminum foil and placed on ice prior to freezing and shipping to contract laboratories for analysis.

Lab analysis of whole body composites was conducted by Geochemical & Environmental Research Group at Texas A&M. For organic analysis, tissue was homogenized with a Teckmar Tissumizer, and purified by chromatography. Quantitative analyses were performed by capillary gas chromatography with a flame ionization detector for aliphatic hydrocarbons; CGC with electron capture detector for pesticides and PCB's; and a mass spectrometer detector in the SIM mode for aromatic hydrocarbons. Mercury was determined using cold vapor atomic absorption spectrometry; arsenic, selenium, cadmium, and lead were determined by graphite furnace AAS; and the remaining elements were quantified by atomic emission using an argon plasma. Chemical methodology and reports met or exceeded Patuxent Analytical control Facility Quality Assurance Quality Control standards (Moore 1990).

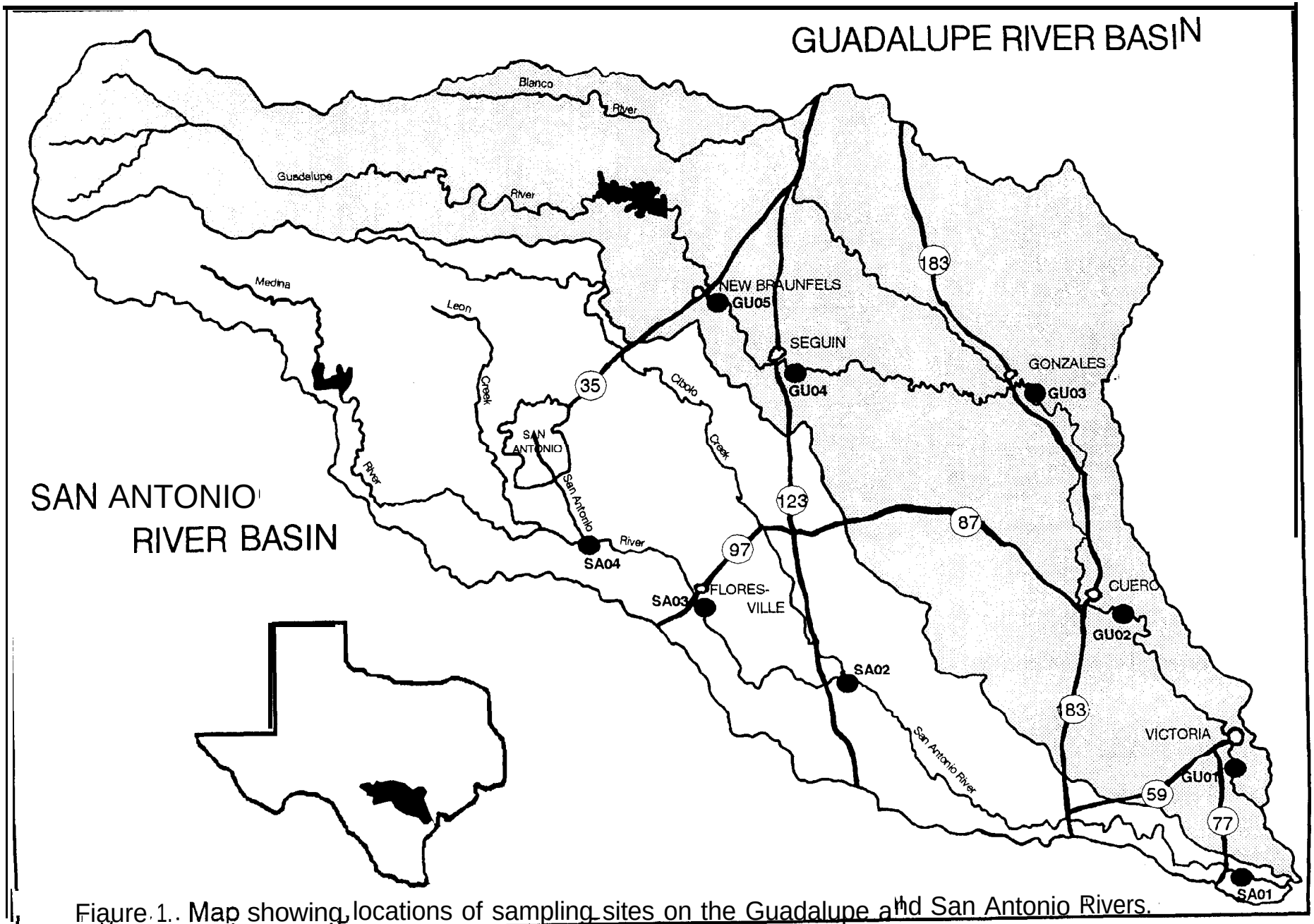

Figure 1.. Map showing locations of sampling sites on the Guadalupe and San Antonio Rivers.

Table 1. Location of sample collection sites on the Guadalupe and San Antonio Rivers, 1992.

Site Name	Site #	Species	Location
Guadalupe River			
New Braunfels	GU05	CC*	2 km South of I 35 bridge
Seguin	GU04	LG, CC	3.5 km upstream of the Hwy. 123 bypass to 2 km downstream of the Hwy. 123 bypass
Gonzales	GU03	BU	3.5 km East of Hwy 183
Cuero	GU02	LG, BU	4 km East of Junction 183/77A 5 km West of Hwy 236
Victoria	GUO1	AG, BU	2-3 km South of Hwy 175 bridge
San Antonio River			
San Antonio/Medina	SA04	LG, BU	At confluence of San Antonio and Medina Rivers and 1/4 km downstream Note: Many thousands of old tires dumped in the vicinity
Floresville	SA03	LG, BU	Near both sides of Hwy 97 bridge
Helena	SA02	LG, BU	From confluence of Cibolo Creek to 1.5 km downstream
McFaddin	SA01	AG, YC	Immediately downstream of Hwy 77 bridge Note: This site corresponds roughly to NCBP** site #113

*CC=channel catfish, LG=longnose gar, BU=smallmouth buffalo, AG=alligator gar, Y C=flathead catfish

**NCBP=National Contaminant Biomonitoring Program

Results and Discussion

Between 1976 and 1984, diverse species of freshwater fish were collected nationwide by the U.S. Fish and Wildlife Service's National Contaminant Biomonitoring Program (NCBP) and analyzed for organochlorine compounds and potentially toxic elements (Schmitt and Brumbaugh 1990, Schmitt et al. 1990). These whole body composite samples provide a useful benchmark for comparison. Results from the current study are presented in parts per million (ppm) wet weight (unless otherwise stated) for ease of comparison with the most recent NCBP data. Contaminants analyzed in fish are listed in Table 2 and detection limits are listed in Appendix l-l.

AROMATIC HYDROCARBONS

Concentrations of all aromatic hydrocarbons analyzed were below detection levels for all fish samples from both rivers with the exception of negligible levels of Cl-, C2-, C3-, and C4-naphthalenes as listed in Appendix l-2 and l-3.

ORGANOCHLORINES

Although banned from production in the United States since 1979, PCB levels in the environment continue to be a hazard to wildlife (Eisler 1986a). PCB's are dispersed primarily through contaminated sediments, atmospheric transport, and disposal sites, and were detected in all fish samples from both rivers, ranging from 0.02 to 2.13 ppm in the Guadalupe River (GR) and from 0.05 to 3.86 ppm in the San Antonio River (SAR). Total PCB's were elevated above the 1984 NCBP geometric mean of 0.39 (Schmitt et al. 1990) in two sites in each river (Figures 2 and 3). Longnose gar from Seguin (GR) had a level of 2.13 ppm. Floresville (SAR) had ten times the NCBP average in longnose gar (3.86 ppm), a concentration which exceeds the FDA action level of 2 ppm.

All but four samples were below the detection limit of 0.02 ppm for DDT isomers, ranging from 0.02 to 0.04 ppm. The only fish above the NCBP geometric mean were smallmouth buffalo from Floresville (SAR).

Levels of p,p' DDD equaled or exceeded NCBP average of 0.06 ppm in three samples from the San Antonio River, both longnose gar (0.08 ppm) and smallmouth buffalo (0.06 ppm) from Floresville and longnose gar (0.09 ppm) from the San Antonio/Medina site.

Four of sixteen samples exceeded the 1984 NCBP geometric mean of 0.19 ppm for p,p' DDE, the most persistent homolog of DDT (Figures 4 and 5). Tissue concentrations in fish from the San Antonio River varied from 0.22 ppm in smallmouth buffalo to 1.22 ppm in longnose gar from Floresville, and gar from the San Antonio/Medina site exceeded the NCBP mean by three-fold. Guadalupe River fish ranged from 0.3 ppm, 1.6 times the NCBP geometric mean at New Braunfels to 0.45 ppm, 2.4 times the NCBP average at Seguin. In another study, smallmouth

Table 2. Trace elements and compounds analyzed in biota from the San Antonio and Guadalupe Rivers, 1992.

Aromatic Hydrocarbons

1,2,5,6-dibenzanthracene
1,2-benzanthracene
1,6,7-Trimethyl-naphthalene
C 1 -Fluoranthenes & Pyrenes
C 1 -Phenanthrenes & Anthracenes
C2-Phenanthrenes & Anthracenes
C3-Phenanthrenes & Anthracenes
C4-Phenanthrenes & Anthracenes
C 1 -chrysenes
C2-chrysenes
C3-chrysenes
C4-chrysenes
C 1 -dibenzothiophenes
C2-dibenzothiophenes
C3-dibenzothiophenes
C 1 -fluorenes
C2-fluorenes
C3-fluorenes
C 1 -naphthalenes
C2-naphthalenes
C3-naphthalenes
C4-naphthalenes
acenaphthalene
acenaphthene
anthracene
benzo(a)pyrene
benzo(b)fluoranthene
benzo(e)pyrene
benzo(g,h,i)perylene
benzo(k)fluoranthene
chrysene
dibenzothiophene
fluoranthene
fluorene
indeno(1,2,3-cd)pyrene
naphthalene
perylene
phenanthrene
pyrene

Organochlorines

HCB
Heptachlor
PCB
Aldrin
alpha BHC
alpha chlordane
beta BHC
biphenyl
cis-nonachlor
delta BHC
dieldrin
endrin
gamma BHC
gamma chlordane
heptachlor epoxide
mirex
o,p'-DDD
o,p'-DDE
o,p'-DDT
oxychlordane
p,p'-DDD
p,p'-DDE
p,p'-DDT
toxaphene
trans-nonachlor

Trace Metals

Aluminum
Arsenic
Cadmium
Chromium
Copper
Iron
Lead
Mercury
Manganese
Nickel
Selenium
Zinc

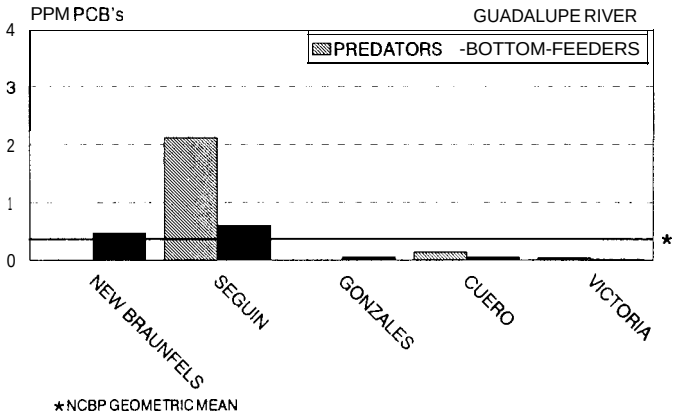

Figure 2. PCB concentrations in fish tissue from the Guadalupe River.

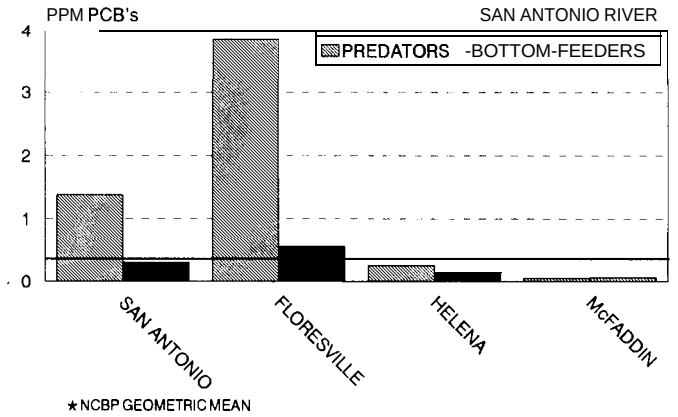

Figure 3. PCB concentrations in fish tissue from the San Antonio River

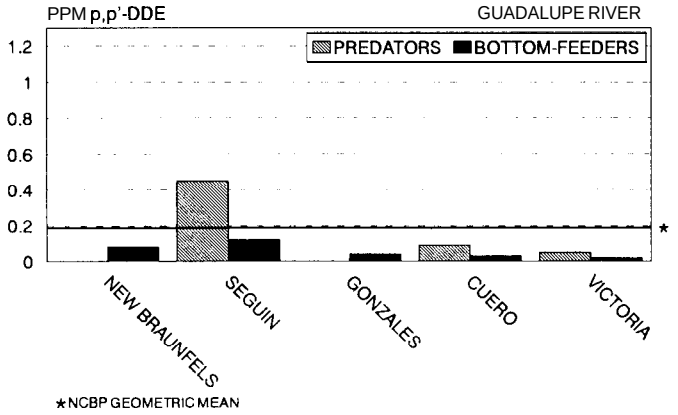

Figure 4. p,p'-DDE concentrations in fish tissue from the Guadalupe River.

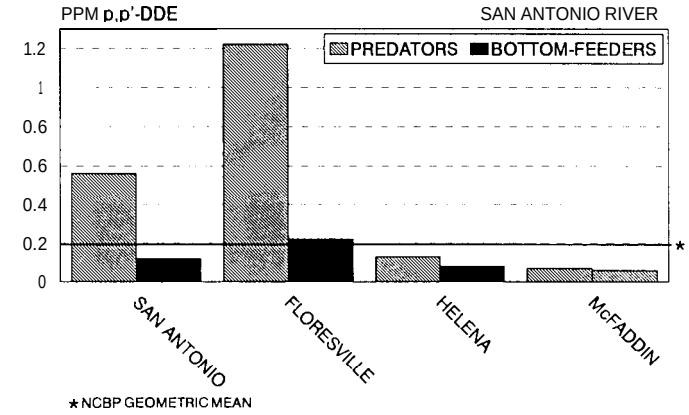

Figure 5. p,p'-DDE concentrations in fish tissue from the San Antonio River.

buffalo, longnose gar and carp from the Trinity River downstream from Dallas also exceeded the national average (Irwin 1988).

Cis-nonachlor exceeded the NCBP national geometric mean of 0.02 ppm in longnose gar (0.04 ppm) from Seguin (GR), smallmouth buffalo (0.03 ppm) from Floresville (SAR), and longnose gar (0.03 ppm) from the San Antonio/Medina site. In the Guadalupe River, *trans*-nonachlor was well above the national average of 0.03 ppm in longnose gar (0.09 ppm) and in channel catfish (0.05 ppm) from Seguin. Samples from the San Antonio River which exceeded the NCBP geometric mean include smallmouth buffalo (0.05 ppm) and longnose gar (0.09 ppm) from Floresville and smallmouth buffalo (0.09 ppm) from the San Antonio/Medina site.

TRACE METALS

Of the twelve elements analyzed in biota from the Guadalupe and San Antonio Rivers, all were above the detection limit in at least one site. Arsenic, copper, mercury, lead, selenium, and zinc were present above the NCBP geometric mean in more than one site; arsenic, copper, mercury, and lead exceeded the NCBP 85th percentile (Schmitt and Brumbaugh 1990). Raw data for these elements as well aluminum, iron, manganese and nickel are included in Appendix 1-2 and l-3.

Arsenic

Arsenic was detected in only one sample, an alligator gar from Victoria (GR) with a concentration of 0.27 ppm. Because the NCBP 85th percentile is 0.27 ppm and the detection limit in this study was 0.2 ppm, meaningful comparisons between these two studies were not possible. However, a longnose gar collected from the NCBP McFaddin site #113 in 1984 contained 0.49 ppm, the fifth highest in the nation (Schmitt et al. 1990). Currently, alligator gar from this site were below the 0.2 ppm detection limit, suggesting a decline in arsenic in the lower San Antonio River.

Cadmium

Only one sample, smallmouth buffalo from Helena (SAR) exceeded the NCBP mean of 0.03 ppm for cadmium. Cadmium, a nonessential heavy metal, is a known teratogen and carcinogen that can severely affect freshwater biota when present in sufficient concentrations (Eisler 1985).

Chromium

Chromium is an essential trace element in humans and some laboratory animals but data are incomplete for other groups of organisms. Biomagnification has not been observed, therefore, concentrations are usually highest at lower trophic levels. Tissue levels in excess of 4.0 ppm dry weight are indicative of chromium contamination as suggested by current evidence (Eisler 1986b). Most of the samples exceeded this level, ranging from 4.1 to 8.7 ppm dry weight (1.49-2.88 ppm wet wt.). In the Guadalupe River, smallmouth buffalo from Victoria had the highest chromium concentrations (8.7 ppm dry wt.), followed by fish of the same species from Gonzales with 6.8 ppm dry wt. (1.8 ppm wet wt.). In the San Antonio River, longnose gar from Floresville had the highest chromium levels (8.0 ppm dry wt.) followed by longnose gar from Helena (6.25 ppm dry wt.).

Copper

Although, copper is a minor essential trace element for aquatic life at low concentrations, it is toxic at higher concentrations (EPA 1985). Copper was detected in all samples from both rivers (Figures 6 and 7). In the Guadalupe River, concentrations ranged from 0.37 ppm to a high of 1.96 ppm in gar at Victoria, almost twice the NCBP 85th percentile (1.0 ppm). In a Texas Water Commission study, copper was <0.7 ppm for centrarchid species near the Guadalupe-Blanco River Authority Regional waste water treatment facility at Victoria (TWC 1991). Levels as high as detected by the current study warrant further investigation.

Three sites on the San Antonio River exceeded the 1984 NCBP geometric mean of 0.65 ppm. Smallmouth buffalo from Floresville and Helena contained 0.86 and 0.74 ppm of copper, respectively. McFaddin site #1 13 of the NCBP was reported to be 0.56 ppm in 1984 for longnose gar (Schmitt et al. 1990). Current results for alligator gar (0.95 ppm) approach the NCBP 85th percentile.

Lead

Lead is a nonessential and nonbeneficial element that can have severe effects on wildlife including reduced survival, reduced growth, and impaired reproduction (Eisler 1988). Lead concentrations in fish collected from the San Antonio River near San Antonio/Medina and Helena equalled or exceeded the NCBP 85"' percentile of 0.22. Also, fish collected from the Guadalupe River near Victoria equalled or exceeded the NCBP 85th percentile. Lead was also found to exceed the 85th percentile in Rio Grande perch in a downtown San Antonio site (TWC 1989).

Mercury

Mercury has no known biological function, is potentially hazardous to wildlife, biomagnities through the food chain, and is slow to depurate. Sublethal effects in aquatic organisms include reduced reproduction and growth, and adverse effects on behavior, metabolism and oxygen exchange (Eisler 1987). Mercury was detected in every sample from both rivers (Figures 8 and 9). At each site, mercury was higher in predatory fish than in bottom-feeders as would be expected (Eisler 1987). Levels ranged from 0.04 to 0.26 ppm in fish from Guadalupe River sites and from 0.08 to 0.42 ppm in fish from the San Antonio River. Five samples exceeded the 1984 NCBP 85th percentile for mercury of 0.10 ppm (Schmitt and Brumbaugh 1990). The San Antonio/Medina site exceeded the NCBP 85" percentile of 0.17 ppm by two-fold, with a distinctly declining trend in concentrations at further downstream sites. In all samples, concentrations were well below the FDA action level of 1.0 ppm (FDA 1986).

Longnose gar collected from McFaddin (SAR) contained slightly lower levels of mercury (0.14 ppm) than found in alligator gar collected there in 1984 (0.17 ppm). A TWC (1991) study conducted near the Guadalupe Blanco River Authority (GBRA) Regional wastewater treatment facility at Victoria found slightly lower levels of mercury in centrarchid species (0.08 ppm) than gar from the Victoria site (0.095 ppm) in this study. However, this disparity may be accounted for by the difference in trophic levels.

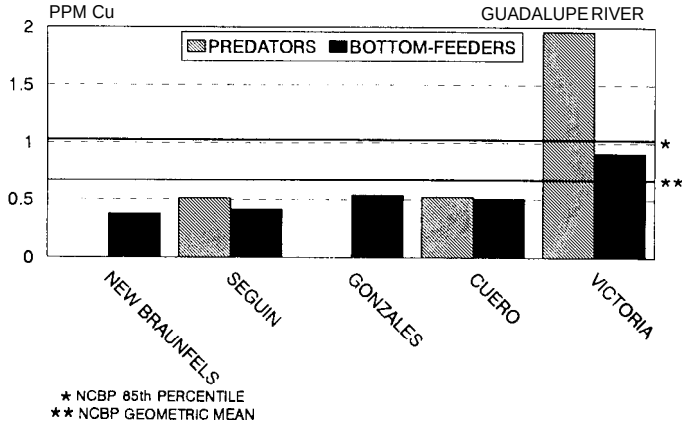

Figure 6. Copper concentrations in fish tissue from the Guadalupe River.

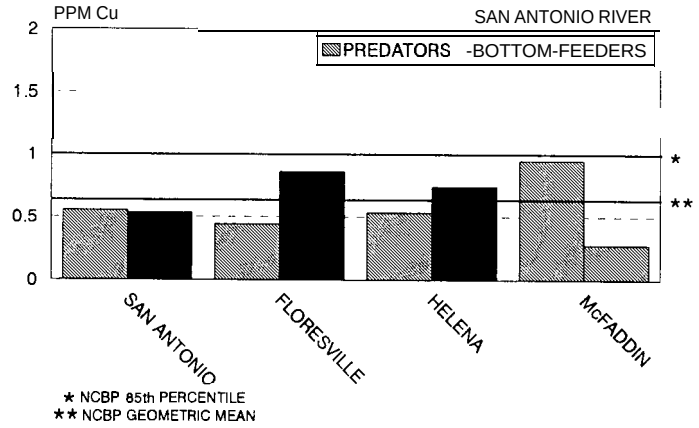

Figure 7. Copper concentrations in fish tissue from the San Antonio River.

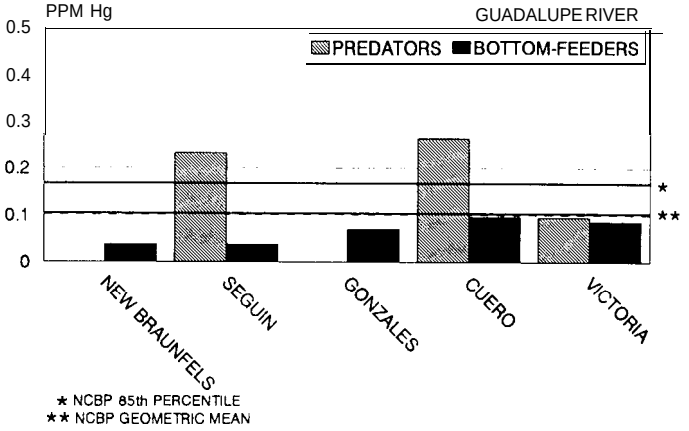

Figure 6. Mercury concentrations in fish tissue from the Guadalupe River.

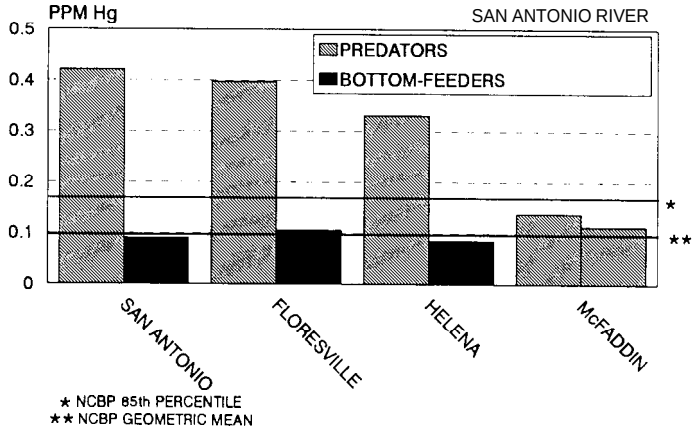

Figure 9. Mercury concentrations in fish tissue from the San Antonio River

Selenium

Although selenium is an essential element and although a deficiency can impact wildlife, an excess can also result in deleterious effects. The range between deficiency and poisoning is narrow (Eisler 1985). Seven samples exceeded the national geometric mean (0.42 ppm) for selenium in 1984, ranging from 0.45 to 0.58 ppm but none exceeded the 85" percentile. There were no major differences in concentrations between rivers or between species. In comparison, green sunfish *(Lepomis cyanellus)* and Rio Grande perch (*Cichlasoma cyanoguttata*) collected in 1987 from two sites on the Upper San Antonio River exceeded the NCBP 85th percentile (TWC 1989).

Zinc

Zinc is an essential trace element which can result in lethal or sublethal effects at excessive concentrations. Zinc was detected in all fish collected, with a range of 13.7-25.2 ppm. Five gar samples exceeded the NCBP geometric mean of 21.7 ppm. Two of these samples were from the Guadalupe River at Cuero and Seguin, and three were from the San Antonio River at Helena, Floresville, and San Antonio/Medina, ranging from 22.1-25.2 ppm. These concentrations were lower than those found in the Trinity River for the much smaller mosquitofish *(Gambusia affinis)*, in which 20 of 28 samples were greater than 28 ppm (Irwin 1988).

Summary and Recommendations

Although a majority of the organochlorines were below detection, PCB's and DDE in fish residues were elevated at the confluence of the Medina and San Antonio Rivers. Further downstream at Floresville, these concentrations peaked dramatically. Trace elements at levels of concern in the San Antonio River are chromium and mercury. Elevated levels of mercury, which decline downstream, indicate a source originating in the upper part of the river which warrants further investigation.

Contaminants in the Guadalupe River are generally lower in concentration than in the San Antonio River. At the Victoria site, however, copper is elevated in predators and chromium is elevated in bottom-feeders. The sources of these elements should be determined through additional sampling.

Acknowledgements

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Appendix l-l. Lower limit of detection used in analysis of fish samples collected from the Guadalupe and San Antonio Rivers, 1992.

CONTAMINANT	PPM (WET WT)	PPM (DRY WT)
Aromatic Hydrocarbons	.02	
Organochlorines	.02	
Al		11.1
As		0.5
Cd		0.1
Cr		4.02
c u		0.78
Fe		1.38
Hg		0.1
Mg		0.3
Ni		2.64
Pb		0.5
Se		0.5
Zn		1.2

Appendix l-2. Concentrations of organochlorines, aromatic hydrocarbons, and trace elements in composite whole body fish samples from the Guadalupe River (ppm wet wt.).

	GU01[a] (AG)[b]	GU01 (BU)	GU02 (LG)	GU02 (BU)	GUO3 (BU)	GU04 (LG)	GU04 (CC)	GUO5 (CC)
Sample Size (N=)	1	4	3	5	5	3	5	5
Total Weight (g)	4100	5100	6300	5600	6900	6000	5800	5100
% Moisture	60.3	62.9	59.1	68.4	65.4	59.0	70.5	73.4
% Lipid	11.9	5.1	4.4	2.6	3.8	7.7	3.7	3.0
C1-Naphthalenes	BDL[c]	BDL	BDL	BDL	BDL	BDL	BDL	.026
C3-Naphthalenes	BDL	BDL	BDL	BDL	.022	BDL	BDL	BDL
Total PCB's	.04	.02	.14	.06	.06	2.13	.60	.47
alpha chlordane	BDL	BDL	BDL	BDL	BDL	.03	.02	BDL
cis-nonachlor	BDL	BDL	BDL	BDL	BDL	.04	.02	BDL
trans-nonachlor	BDL	BDL	.02	BDL	BDL	.09	.05	.03
gamma chlordane	BDL	BDL	BDL	BDL	BDL	.02	.02	BDL
p,p'-DDD	BDL	BDL	BDL	BDL	BDL	.03	BDL	BDL
p,p'-DDE	.05	.02	.09	.03	.04	.45	.12	.08
TRACE ELEMENTS								
% Moisture	59.99	66.92	63.29	73.42	74.08	62.68	76.98	76.12
Al	17.26	238.90	5.16	21.25	14.01	<4.14	3.42	56.07
As	0.274	<.17	<.18	<.13	<.13	<.19	<.12	<.12
Cd	<.04	<.03	1.04	<.03	<.03	1.04	<.02	1.02
Cr	11.6	2.88	1.96	1.23	1.76	2.03	<.93	<.96
cu	1.96	.91	.52	.51	.54	.51	.41	.37
Fe	25.85	173.38	25.94	31.40	31.50	33.52	15.63	52.51
Hg	.095	.086	.262	.096	.074	.231	.037	.037
Mn	4.37	5.50	4.10	3.80	3.13	1.76	1.25	4.44
Ni	<1.06	1.92	<.97	<.70	1.68	<.99	<.61	<.63
Pb	<.20	.37	<.18	<.13	<.13	<.19	<.12	<.12
Se	<.20	.51	.35	.47	.52	.44	.29	.31
Zn	14.19	17.01	25.18	16.19	15.36	22.70	19.51	20.32

[a]Collection site: See Figure 1.
[b]Species: AG=alligator gar, BU=smallmouth buffalo, LG=longnose gar, CC=channel catfish
[c]Below Detection Limit

Appendix 1-3. Concentrations of organochlorines, aromatic hydrocarbons and trace elements in composite whole body fish samples from the San Antonio River (ppm wet wt.).

	SA01[a] (AG)[b]	SA01 (YC)	SA02 (LG)	SA02 (BU)	SAO3 (LG)	SA03 (BU)	SA04 (LG)	SAO4 (BU)
Sample Size (N=)	2	2	3	3	5	5	5	4
Total Weight (g)	6100	2100	3900	7100	4300	10100	5300	8500
% Moisture	60.7	73.1	54.0	61.8	59.5	61.5	56.9	63.1
% Lipid	8.9	2.4	6.6	5.7	4.1	7.8	4.2	7.5
C2-Naphthalenes	BDL[c]	BDL	BDL	BDL	BDL	.021	BDL	BDL
C3-Naphthalenes	BDL	BDL	BDL	BDL	BDL	BDL	BDL	.029
C4-Naphthalenes	BDL	BDL	BDL	BDL	BDL	BDL	BDL	.026
Total PCB's	.05	.06	.25	.14	3.86	.55	1.38	.3
alpha chlordane	BDL	BDL	BDL	BDL	.03	.04	.04	.03
cis-nonachlor	BDL	BDL	BDL	BDL	.02	.03	.03	BDL
trans-nonachlor	BDL	BDL	.02	.02	.09	.05	.09	.03
gamma chlordane	BDL	BDL	BDL	BDL	.02	.03	.02	.02
dieldrin	.02	BDL	BDL	.02	BDL	.03	.02	.02
o,p'-DDT	BDL	BDL	BDL	BDL	BDL	.02	BDL	.02
p,p'-DDT	BDL	BDL	BDL	BDL	.02	.04	.02	.02
p,p'-DDD	.02	BDL	.03	.02	.08	.06	.09	.04
p,p'-DDE	.07	.06	.13	.08	1.22	.22	.56	.12
TRACE ELEMENTS								
% Moisture	63.7	77.41	62.03	69.44	64.67	68.52	64.61	68.3
Al	10.58	6.74	8.46	17.46	8.6	58.68	7.83	5.35
As	<.18	<.11	<.19	<.15	<.18	<.16	<.18	<.16
Cd	<.04	<.02	<.04	.04	<.04	<.03	<.04	<.03
Cr	1.49	.91	2.37	<1.23	2.83	1.30	1.93	1.89
Cu	.95	.28	.53	.74	.44	.86	.55	.53
Fe	26.58	15.20	34.99	36.71	33.35	59.65	32.89	25.60
Hg	.138	.113	.332	.085	.397	.105	.421	.091
Mn	3.90	.55	2.29	2.52	2.93	4.55	1.80	2.86
Ni	<.96	<.60	<1.00	<.81	<.93	.90	<.93	<.84
Pb	<.18	<.11	<.19	.24	<.18	.19	<.18	.22
Se	<.18	.17	.34	.58	.49	.47	.39	.36
Zn	18.14	13.72	22.08	18.38	24.95	16.06	22.11	16.90

[a]Collection Site: See Figure 1.
[b]Species: AG=alligator gar, YC=flathead catfish, LG=longnose gar, BU-smallmouth buffalo
[c]Below Detection Limit