CONTAMINANT EVALUATION OF SHOVELNOSE STURGEON FROM THE ATCHAFALAYA RIVER, LOUISIANA

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PREFACE

This report documents the 1992-93 environmental contaminants evaluation of shovelnose sturgeon collected downstream of the Old River Control Structure Complex in east-central Louisiana. The study was conducted to determine baseline contaminant levels in shovelnose sturgeon; that species was selected as a surrogate to identify potential contaminant levels in the endangered pallid sturgeon, which also inhabits the study area.

This investigation was a cooperative effort between the Louisiana Department of Wildlife and Fisheries (LDWF) and the Lafayette, Louisiana Ecological Services Field Office of the U.S. Fish and Wildlife Service. The study was designed by both agencies and LDWF collected the samples. The Service arranged for analytical testing, interpreted the results, and prepared this report.

Questions, comments, and suggestions related to this report are encouraged and should be directed to the following address:

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ABSTRACT

Baseline contaminant levels in shovelnose sturgeon (*Scaphirynchus platorynchus*) collected from the outfall channel of the Old River Control Structure (ORCS), Concordia Parish, Louisiana, are discussed. Our investigation also complemented previous Missouri River and upper Mississippi River studies on the suitability of the shovelnose sturgeon as a surrogate species for assessing contaminants in the endangered pallid sturgeon (*Scaphirynchus albus*). Shovelnose sturgeon were analyzed as individual whole-body specimens for organochlorine pesticides, total polychlorinated biphenyls, polycyclic aromatic hydrocarbons, aliphatic hydrocarbons, and trace elements. Results are compared to data from other fish species that were previously collected downstream of the ORCS in the Atchafalaya Basin, to data from the National Contaminants Biomonitoring Program (NCBP), and to shovelnose and pallid sturgeon data from other areas (i.e., ORCS and the northern United States).

Shovelnose sturgeon collected from the ORCS contained higher organochlorine pesticide levels than were previously found in fishes collected from downstream sites. Those levels were comparable to the levels observed in NCBP fishes and in samples of shovelnose from the northern United States; however toxaphene and total organochlorines were elevated in all circumstances, except when compared to ORCS pallid sturgeon. Few polycyclic aromatic hydrocarbons were detected in the ORCS shovelnose sturgeon and all were at low levels. Our data also indicate that about half of the ORCS shovelnose sturgeon sampled were exposed to petrogenic aliphatic hydrocarbons. ORCS shovelnose trace element concentrations were lower than those documented in other fishes from the same general area, but were elevated in comparison to NCBP levels and, for the most part, to shovelnose sturgeon collected in the northern United States. The results of this study also corroborate previous investigations, i.e., that it may be the best available surrogate for contaminant studies on the pallid sturgeon.

KEYWORDS: Louisiana, shovelnose sturgeon, *Scaphirynchus platorynchus*, pallid sturgeon, *Scaphirynchus albus*, organochlorine pesticides, polychlorinated biphenyls, polycyclic aromatic hydrocarbons, aliphatic hydrocarbons, trace elements, endangered species.

INTRODUCTION

The pallid sturgeon (*Scaphirynchus albus*) was listed as an endangered species by the Fish and Wildlife Service on September 6, 1990, (55 FR 36641) pursuant to the Endangered Species Act (Act) of 1973 (87 Stat. 884; as amended, 16 U.S.C. 1531 et seq.). The Pallid Sturgeon Recovery Plan (Dryer and Sandvol 1993) states that pollution and contamination are likely threats to the species, and that additional information is required to determine the extent and sources of contaminant-related impacts on that species.

Contaminant investigations have been conducted on pallid sturgeon from the Missouri River in North Dakota, South Dakota, Nebraska, and Kansas (Allen and Wilson 1991, Ruelle and Keenlyne 1992, Ruelle and Henry 1994a, Welsh 1992, Welsh and Olson 1992). Ruelle and Henry (1994a) also completed an investigation on contaminants found in pallid sturgeon collected from the outfall channel of the Old River Control Structure (ORCS) Complex, located between the Mississippi and Atchafalaya Rivers in Concordia Parish, Louisiana. The U.S. Army Corps of Engineers is required to pass 30 percent of the combined Mississippi River and Red River flows through the ORCS into the Atchafalaya River. Operation of the ORCS and a hydropower plant located within that complex apparently attracts and concentrates sturgeon in the outfall channels. Over 120 pallid sturgeon have been caught and tagged at this location as the result of a population study initiated by the Louisiana Department of Wildlife and Fisheries (LDWF) in 1992.

The contaminant data presented in this report were obtained from samples taken in conjunction with the above-mentioned population study. Due to the apparent rarity of the pallid sturgeon and its endangered status, shovelnose sturgeon (*Scaphirynchus platyrhynchus*) were collected and submitted as surrogates for contaminant analyses. The shovelnose sturgeon, which hybridizes with the pallid sturgeon, has ranges and habitat preferences that are similar to those of the pallid sturgeon. Ruelle and Keenlyne (1994) examined the similarities and differences between those species and concluded that, while the shovelnose may not meet all the traits desired for a pallid surrogate, it may be the best available for contaminant studies.

METHODS AND MATERIALS

Ten shovelnose sturgeon were collected by biologists of the LDWF; six during November 1992 and four in May 1993. All samples were obtained from the ORCS outflow channels (Table 1). Five-centimeter mesh gill nets and four-centimeter mesh hoop nets were employed to obtain the samples. All fishes were immediately placed on wet ice. Those samples were weighed, measured, sexed, labeled, wrapped in aluminum foil, and frozen later that day. LDWF transported the frozen samples to the Service's Ecological Services Field Office in Lafayette, Louisiana, where they were

Table 1. Shovelnose sturgeon collected at the Old River Control Structure, Atchafalaya River, Louisiana, in 1992-93.

Sample Number	Collection Date	Collection Method	Sex	Field Measurements		Analytical Laboratory Measurements		
				Wt. (g)	Lgth.* (mm)	Wt. (g)	% H2O	% Lipid
1	Nov 17, 92	Hoop net 1.5"	Male	572	552	563	72.6	5.8
2	Nov 18, 92	Hoop net 1.5"	Female	680	574	689	69.8	10.3
3	Nov 17, 92	Hoop net 1.5"	Male	522	540	502	73.8	6.5
4	May 25, 93	Hoop net 1.5"	Female	575	622	537	65.4	18.4
5	May 25, 93	Hoop net 1.5"	Female	611	623	593	66.8	17.4
6	Nov 17, 92	Gill net 2.0"	Female	470	521	459	69.6	9.2
7	Nov 17, 92	Gill net 2.0"	Male	618	591	610	79.2	1.8
8	Nov 18, 92	Hoop net 1.5"	Male	470	561	451	80.8	2.4
9	May 25, 93	Hoop net 1.5"	Female	1334	725	1310	64.0	21.7
10	May 25, 93	Hoop net 1.5"	Female	1531	730	1520	62.4	18.9
	Geometric Mean			683.6	659.6	659.6	70.2	8.6
	Standard Error			1.14	1.04	1.14	1.03	1.31

* Total length

stored at -4°C until shipped on dry ice to the analytical laboratories at Mississippi State, Mississippi, and Research Triangle Park, North Carolina. All shovelnose sturgeon were screened for organochlorine pesticides (OCs), total polychlorinated biphenyls (ΣPCBs), polycyclic aromatic hydrocarbons (PAHs), aliphatic hydrocarbons (APHs), and trace elements. The Service's Patuxent Analytical Control Facility provided analytical and quality assurance/quality control (QA/QC) services for the laboratory phase of this study.

Quantitative organic analyses were conducted by Mississippi State Chemical Laboratory, Mississippi State, Mississippi, using packed or capillary column electron capture gas chromatography (GC) for pesticides and packed or megabore column electron capture GC for ΣPCBs. Capillary column flame ionization GC was used to quantify APHs, and capillary column flame ionization GC and fluorescent high pressure liquid chromatography (HPLC) were used to quantify PAHs. The detection limit for most organic compounds was 0.01 μg/g (0.05 μg/g for ΣPCBs and toxaphene).

Quantitative inorganic analyses were conducted by Research Triangle Institute, Research Triangle Park, North Carolina. Graphite furnace atomic absorption spectrophotometry was used for selenium and arsenic determinations and cold vapor atomic absorption spectrophotometry was employed for mercury determinations. Inductively-coupled plasma emission spectrophotometry was used for the remaining trace elements analyzed. The detection limit for most inorganics was 0.05 μg/g; however, the detection limit for beryllium, cadmium, and mercury was 0.1 μg/g; for strontium, 0.2 μg/g; manganese, 0.04 μg/g; aluminum, 5.0 μg/g; and for iron and magnesium, 10.0 μg/g.

Both laboratories performed standard QA/QC analyses of duplicate samples, spiked samples, standard reference materials, and procedural blanks. The accuracy of analyses, as measured by spike recovery, was generally acceptable. The precision, as measured by duplicate sample analyses, was acceptable for all analytes. All fishes were analyzed as individual whole-body samples. All concentrations are expressed on a fresh (or wet) weight (FW) basis, and inorganic concentrations are presented on both a dry weight (DW) and FW basis.

Statistical analysis was limited to determination of geometric means with standard errors indicated. In this report, use of the term "mean" refers to the geometric mean unless otherwise specified. In those instances when an analyte was not detected, a value of 75 percent of the detection limit was assigned to facilitate estimation of the mean.

RESULTS AND DISCUSSION

Organochlorines (OC's) Results for the OC analyses (pesticides and PCBs) of shovelnose sturgeon are presented in Table 2. For the purposes of discussion and comparison, the OC homologs for DDT and chlordane were combined as total DDT (ΣDDT) and total chlordane (ΣChlordane), and PCB isomers were analyzed as ΣPCBs.

The OC residues (pesticide, metabolite, or ΣPCB) were totaled, and are presented in the table as total organochlorines (ΣOCs) to provide an estimate of the cumulative body burden for each specimen.

All OC analytes were detected in at least one (and frequently in several) of the shovelnose sturgeon samples; frequency of occurrence ranged from 10 percent (i.e., one sturgeon) for mirex to 100 percent for toxaphene. The number of OC analytes identified in each shovelnose sturgeon ranged from a low of 7 compounds in specimen 7, to all compounds screened in specimen 10. The ΣOC body burden ranged from a low of 1.09 μg/g for specimen 8 to a high of 5.28 μg/g for specimen 9. Specimen 9 had the highest concentration for most of the OCs analyzed, resulting in an ΣOCs concentration 2.5 times that of the next highest concentration (i.e., 2.12 μg/g in specimen 1). The presence of all OC analytes in specimen 10 and the ΣOCs concentrations in specimen 9, both mature females, may be related to their greater apparent age. Although none of the specimens were aged, those two fishes were at least twice as large (by length and weight) as any of the others. OC concentrations (especially in specimen 10) may reduce the reproductive potential of sexually mature female sturgeons.

According to Winger and Andreasen (1985), OC residues (FW) of fish (whole-body composites) collected from the Atchafalaya River basin in 1981 consisted primarily of DDT and its metabolites, α-BHC, γ-BHC, dieldrin, toxaphene, and PCBs (Aroclors 1254 and 1260). Aldrin, heptachlor, malathion, and γ-chlordane were detected only occasionally. OC concentrations for most species in the Atchafalaya Basin were generally well below those observed in the shovelnose sturgeon at the ORCS, except for dieldrin (0.62 μg/g), ΣPCBs (1.04 μg/g), ΣDDT (1.79 μg/g), and ΣOCs (3.46 μg/g), all in a single spotted gar (*Lepisosteus oculatus*) taken at Raccourci Old River. Also, the mean toxaphene concentration in shovelnose (0.76 μg/g) approximated the maximum toxaphene concentration (0.80 μg/g) detected in a spotted gar composite sample collected at Little Bayou Pigeon (Winger and Andreasen 1985).

In the Bayou Courtableau area of the Atchafalaya Basin, Hern et al. (1979) recorded dieldrin, PCBs, and DDT in five species of fish (i.e., spotted gar, bowfin (*Amia calva*), bluegill (*Lepomis macrochirus*), redear (*Lepomis microlophus*), and largemouth bass

Table 2. Organochlorine concentrations* (ug/g, FW) detected in shovelnose sturgeon collected at the Old River Control Structure, Atchafalaya River, Louisiana, in 1992-93.

Sample Number	HCB	Total PCB	Deildrin	Endrin	Heptachlor epoxide	a-Chlor-dane	cis-Non-achlor	g-Chlor-dane	Oxychlor-dane	t-Nona-chlor
1	BDL	0.33	0.04	BDL	0.01	0.02	0.01	0.02	0.01	0.03
2	0.01	0.13	0.06	0.01	0.02	0.04	0.05	0.04	0.02	0.08
3	BDL	0.28	0.02	BDL	0.02	0.02	0.01	0.02	0.01	0.03
4	BDL	0.46	0.06	0.02	0.03	0.04	0.03	0.04	0.01	0.04
5	BDL	0.38	0.06	0.01	0.02	0.03	0.02	0.02	0.02	0.03
6	BDL	0.35	0.03	BDL	0.03	0.03	0.03	0.02	0.02	0.04
7	BDL	0.27	0.01	BDL	BDL	BDL	BDL	BDL	BDL	0.01
8	BDL	0.25	0.02	BDL	0.01	0.01	0.01	0.01	0.01	0.02
9	0.01	1.40	0.08	0.03	0.04	0.10	0.09	0.12	0.06	0.14
10	0.01	0.61	0.07	0.01	0.03	0.04	0.03	0.04	0.02	0.05
Geo. Mean	0.01	0.37	0.04	0.01	0.02	0.03	0.02	0.02	0.02	0.04
Std. Error	1.04	1.22	1.24	1.16	1.20	1.27	1.29	1.28	1.21	1.26

Sample Number	Toxa-phene	Mirex	o,p'-DDD	o,p'-DDE	o,p'-DDT	p,p'-DDD	p,p'-DDE	p,p'-DDT	Total DDT	Total OC
1	0.97	BDL	0.02	0.01	BDL	0.08	0.50	0.04	0.65	2.12
2	0.85	BDL	0.04	0.02	0.04	0.11	0.53	0.05	0.79	2.11
3	0.83	BDL	0.01	0.01	BDL	0.08	0.31	0.03	0.44	1.71
4	0.72	BDL	0.04	0.01	0.02	0.09	0.16	0.04	0.36	1.83
5	0.58	BDL	0.02	0.01	0.02	0.05	0.12	0.03	0.25	1.44
6	0.96	BDL	0.02	0.02	0.02	0.10	0.35	0.04	0.55	2.08
7	0.32	0.01	BDL	BDL	BDL	0.03	0.48	0.01	0.52	1.22
8	0.47	BDL	0.01	BDL	BDL	0.04	0.18	0.02	0.25	1.09
9	2.10	BDL	0.08	0.02	0.05	0.27	0.59	0.09	1.10	5.28
10	0.78	BDL	0.03	0.01	0.02	0.10	0.20	0.04	0.40	2.10
Geo. Mean	0.76	0.01	0.02	0.01	0.02	0.08	0.30	0.03	0.49	1.90
Std. Error	1.17	1.03	1.26	1.13	1.25	1.21	1.20	1.20	1.16	1.15

*Benzene hexachloride (BHC) was not detected.
BDL = Below detection limit.

(*Micropterus salmoides*). These were all analyzed as individual whole body samples. Mean concentrations calculated from their data were 0.01 μg/g dieldrin, 0.13 μg/g ΣPCBs, 0.09 μg/g *o,p'*-DDE, 0.03 μg/g *o,p'*-DDT, 0.04 μg/g *p,p'*-DDD, 0.25 μg/g *p,p'*-DDE, 0.03 μg/g *p,p'*-DDT, 0.28 μg/g ΣDDT, and 0.86 μg/g ΣOCs. Except for *o,p'*-DDE and *o,p'*-DDT, ORCS shovelnose exceeded those concentrations.

The OC concentrations in shovelnose sturgeon were also compared to National Contaminant Biomonitoring Program (NCBP) data. The most recent NCBP data for 23 OC analytes in composite whole body fish samples (3-5 adult specimens/sample) have been summarized by Schmidt and Brumbaugh (1990). Those data were obtained from 112 stations throughout the United States during 1984-85. A total of 321 composite fish samples were analyzed. Those samples represented 47 taxa; the most frequently collected taxa were common carp, (*Cyprinus carpio*), white sucker (*Catastosmus commersoni*), and largemouth bass and their respective families (Cyprinidae, Catastomidae, and Centrarchidae). NCBP geometric means and residue ranges provided in Table 3 correspond to those OCs results for this study.

Table 3. National Contaminant Biomonitoring Program (Schmidt and Brumbaugh 1990) ranges and geometric means (μg/g) for OCs that are common to those screened in this investigation.

Parameter	Range	Geo. Mean
HCB	ND-0.41	<0.01
Oxychlordane	ND-0.29	0.01
Heptachlor epoxide	ND-0.29	0.01
t-nonachlor	ND-1.00	0.03
Toxaphene	ND-8.20	0.14
α-Chlordane	ND-0.66	0.03
γ-Chlordane	ND-0.35	0.02
Dieldrin	ND-1.39	0.04
Endrin	ND-0.22	<0.01
cis-Nonachlor	ND-0.45	0.02
p,p'-DDE	ND-4.74	0.19
p,p'-DDD	ND-2.55	0.06
p,p'-DDT	ND-1.79	0.03
ΣDDT	ND-9.08	0.26
Mirex	ND-0.44	<0.01
ΣPCBs	ND-6.70	0.41

The shovelnose sturgeon mean OC concentrations generally mirrored the NCBP data. HCB, endrin, heptachlor epoxide, oxychlordane, *t*-nonachlor, mirex, *p,p'*-DDD, *p,p'*-DDE, and ΣDDT concentrations for shovelnose sturgeon from the ORCS only slightly exceeded the NCBP mean level for ORCS sturgeon. Toxaphene (0.76 μg/g) exceeded the NCBP mean five-fold, but was well below the NCBP maximum of 8.2 μg/g. Elevated toxaphene levels downstream of Louisiana's cotton-growing region are not uncommon (Winger 1989, Schultz 1991a, and Conzelmann et al. 1995). Toxaphene residues in excess of 0.4 to 0.6 μg/g (FW) may be hazardous to fish health and should be considered as presumptive evidence of significant environmental contamination (Cohen et al. 1982, Eisler 1985a). For toxaphene, 90 percent of the ORCS sturgeon samples exceeded 0.4 μg/g and 70 percent exceeded 0.6 μg/g.

Table 4 compares mean OC concentrations in shovelnose and pallid sturgeon extracted from Allen and Wilson (1991), Welsh (1992), Welsh and Olson (1992), and Ruelle and Henry (1994a), with the corresponding shovelnose data from this study. Some of the means were calculated from the raw data presented in those studies. Figure 1 illustrates the comparison of shovelnose sturgeon means from Table 4.

Allen and Wilson (1991) collected shovelnose sturgeon from several locations in the lower Missouri River (Nebraska and Missouri) that had elevated whole-body levels of Σchlordane, ΣDDT, and ΣOCs, as well as the highest observed concentration of ΣPCBs. At two stations, their analysis showed Aroclor 1254 to be the predominant PCB compound present. Welsh and Olson (1992) reported low levels of Aroclor 1254 and 1260, chlordane, *p,p'*-DDE, *p,p'*-DDD, and *o,p'*-DDT in the livers, gonads, and skinless filets (analyzed individually) of unaged shovelnose sturgeon taken near Bismarck, North Dakota on the upper Missouri River. Welsh (1992) reported on two 1988 shovelnose sturgeon whole-body composite samples (of five fish each) collected on the upper Missouri River at its confluence with the Yellowstone River. Those fish contained low levels of *p,p'*-DDE (0.05 and 0.08 μg/g) and ΣPCBs (0.14 and 0.29 μg/g). While those values may be comparable to the ORCS means (ΣPCBs 0.37 μg/g, ΣDDT 0.49 μg/g), ΣOC concentrations (0.19 and 0.37 μg/g), however, were considerably less than the mean of Louisiana samples (1.90 μg/g).

Ruelle and Henry (1994a) examined both whole-body and specific tissues (gonad, liver, and muscle) of shovelnose sturgeon from the Missouri River in South Dakota and Nebraska (Table 4). Most OC concentration were less than or equal to detection limits. ΣPCBs, ΣChlordane, ΣDDT, and ΣOCs were 0.22, 0.03, 0.12, and 0.39 μg/g, respectively, in whole-body shovelnose sturgeon. In tissues, the highest concentratoins of those compounds were found in gonads at 0.26, 0.09, 0.24, and 0.63 μg/g, respectively; those levels could potentially affect reproduction.

Figure 1. Organochlorines (ug/g, FW) detected in shovelnose sturgeon from the upper, middle, and lower Missouri River and the Old River Control Structure, Atchafalaya River.

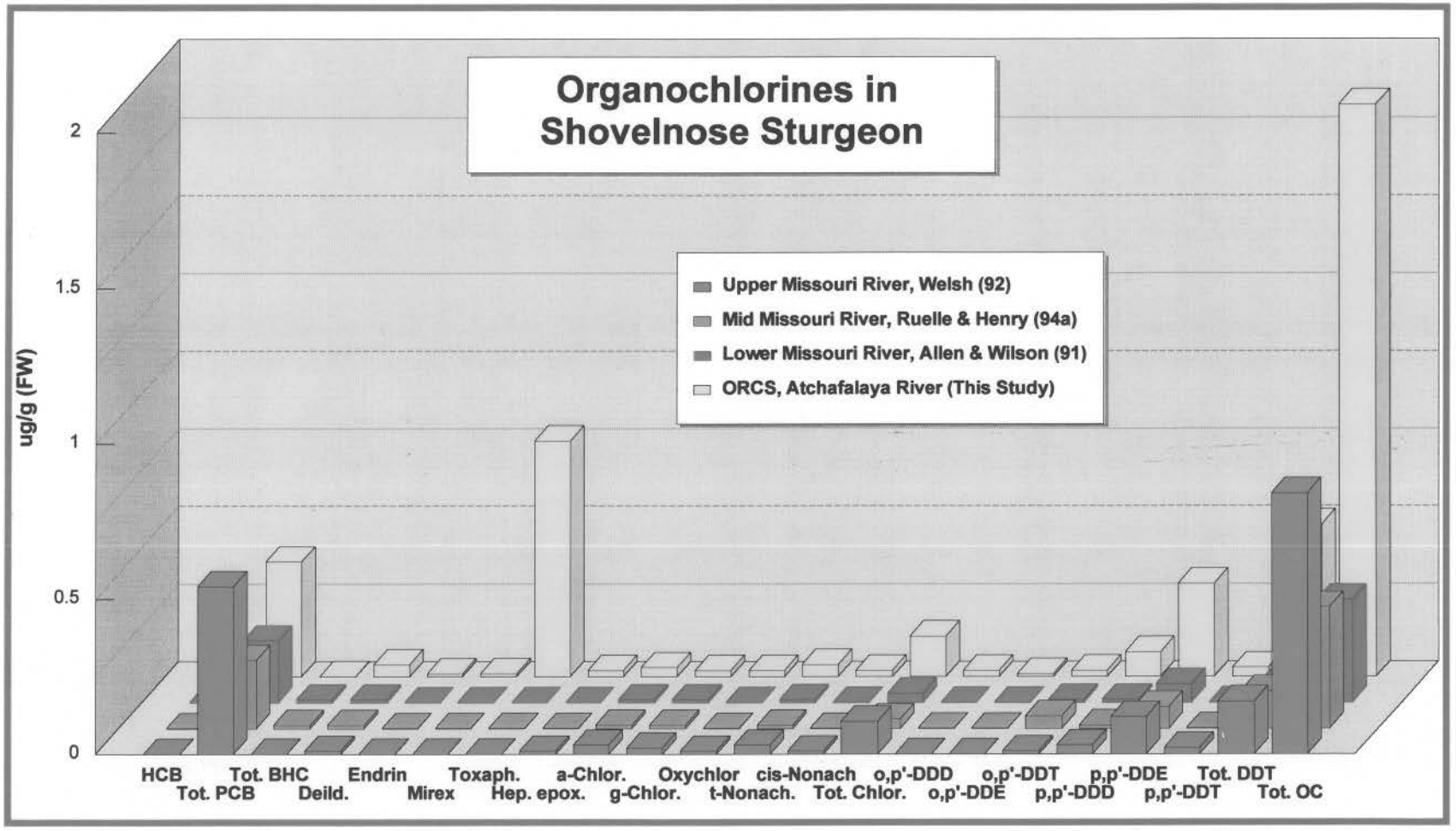


Table 4. Comparative geometric means of organochlorines (ug/g, FW) detected in shovelnose and pallid sturgeon from the Missouri River, upper Mississippi River, and ORCS.

Study	HCB	Aroclor 1242	Aroclor 1248	Aroclor 1254	Aroclor 1260	Total PCB	a-BHC	b-BHC	g-BHC	Total BHC	Deil-drin	Endrin	Mirex	Toxa-phene	Heptachlor epoxide
Shovelnose Sturgeon															
Allen and Wilson (1991; lower Missouri River)															
Whole-body	BDL	BDL	BDL	1.34	BDL	0.54	BDL	BDL	BDL	BDL	0.01	BDL	BDL	BDL	0.01
Welsh (1992; upper Missouri River)															
Whole-body	BDL	NA	NA	NA	NA	0.20	(0.01)	BDL	BDL	(0.01)	0.01	BDL	BDL	BDL	BDL
Welsh and Olson (1992; upper Missouri River)*															
Gonad	(0.01)	BDL	BDL	0.86	0.90	1.80	(0.02)	BDL	(0.01)	(0.03)	(0.05)	BDL	BDL	BDL	(0.03)
Liver	BDL	BDL	BDL	0.68	0.80	1.50	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Muscle	BDL	BDL	BDL	0.07	0.12	0.17	BDL	BDL	BDL	BDL	(0.01)	BDL	BDL	BDL	BDL
Ruelle and Henry (1994a; middle Missouri River)															
Gonad	BDL	NA	NA	NA	NA	0.26	BDL	BDL	BDL	BDL	0.02	0.01	BDL	BDL	0.01
Liver	BDL	NA	NA	NA	NA	0.02	BDL	BDL	BDL	BDL	0.01	0.01	BDL	BDL	BDL
Muscle	BDL	NA	NA	NA	NA	0.01	BDL	BDL	BDL	BDL	0.01	0.01	BDL	BDL	0.01
Whole-body	NA	NA	NA	NA	NA	0.22	0.01	BDL	BDL	0.01	0.01	BDL	BDL	BDL	NA
This study (1992-93; ORCS)															
Whole-body	0.01	NA	NA	NA	NA	0.37	BDL	BDL	BDL	BDL	0.04	0.01	0.01	0.76	0.02
Pallid Sturgeon															
Ruelle and Henry (1994b)															
Gonad															
Louisiana	0.03	0.21	0.21	3.32	3.12	6.98	0.02	0.02	0.02	0.06	0.45	0.04	0.08	1.08	0.09
Illinois	0.04	0.14	0.11	3.48	1.58	5.47	0.01	0.01	0.01	0.04	0.54	0.03	0.01	0.14	0.12
Missouri	0.01	NA	NA	NA	NA	NA	0.02	0.04	0.02	0.08	0.28	0.01	0.01	0.08	0.04
Liver															
Louisiana	0.02	0.11	0.15	1.82	1.48	3.65	0.02	0.01	0.01	0.04	0.28	0.03	0.06	0.67	0.06
Illinois	0.02	0.10	0.14	1.30	1.03	3.47	0.01	0.01	0.01	0.03	0.29	0.10	0.01	0.10	0.06
Missouri	0.01	NA	NA	NA	NA	NA	0.03	0.06	0.06	0.17	0.06	0.30	0.01	0.08	0.02
Muscle															
Louisiana	0.01	0.08	0.08	0.23	0.29	0.78	0.01	0.01	0.01	0.03	0.04	0.01	0.01	0.18	0.01
Illinois	0.01	0.08	0.11	0.46	0.49	1.40	0.01	0.01	0.01	0.02	0.15	0.01	0.01	0.08	0.03
Missouri	0.01	0.10	0.10	0.10	0.10	0.40	0.02	0.02	0.02	0.10	0.04	0.01	0.01	0.09	0.01

* Arithmetic means

( ) = maximum concentration, mean not calculated;

BDL - below detection limit;

NA - not analyzed.

Table 4 (contd). Comparative geometric means of organochlorines (ug/g, FW) detected in shovelnose and pallid sturgeon from the Missouri River, upper Mississippi River, and ORCS.

Study	a-Chlor-dane	g-Chlor-dane	Oxy-chlordane	t-Non-achlor	cis-Non-achlor	Total chlordane	*o,p'*-DDD	*o,p'*-DDE	*o,p'*-DDT	*p,p'*-DDD	*p,p'*-DDE	*p,p'*-DDT	Total DDT	Total OCs
						Shovelnose Sturgeon								
Allen and Wilson (1991; lower Missouri River)														
Whole-body	0.03	0.02	0.01	0.03	0.01	0.11	BDL	BDL	0.01	0.03	0.12	0.02	0.17	0.79
Welsh (1992; upper Missouri River)														
Whole-body	(0.01)	0.01	BDL	0.01	BDL	0.03	BDL	BDL	0.01	0.01	0.06	BDL	0.08	0.33
Welsh and Olson (1992; upper Missouri River)*														
Gonad	0.04	0.03	(0.02)	0.06	BDL	0.14	BDL	BDL	0.04	0.10	0.40	BDL	0.54	2.60
Liver	(0.05)	BDL	BDL	0.04	BDL	0.07	BDL	BDL	BDL	(0.08)	0.22	BDL	0.30	1.87
Muscle	BDL	BDL	BDL	0.01	BDL	0.02	BDL	BDL	BDL	0.01	0.05	BDL	0.06	0.24
Ruelle and Henry (1994a; middle Missouri River)														
Gonad	0.02	0.02	0.01	0.04	NA	0.09	BDL	BDL	BDL	BDL	0.22	0.02	0.24	0.63
Liver	0.01	0.01	BDL	0.02	NA	0.04	BDL	BDL	BDL	BDL	0.14	0.02	0.16	0.24
Muscle	0.01	0.01	0.01	0.01	NA	0.04	BDL	BDL	BDL	BDL	0.07	0.01	0.08	0.16
Whole-body	0.01	0.01	BDL	0.01	BDL	0.03	BDL	BDL	0.04	0.01	0.07	BDL	0.12	0.39
This study (1992-93; ORCS)														
Whole-body	0.03	0.02	0.02	0.04	0.02	0.13	0.02	0.01	0.02	0.08	0.30	0.03	0.49	1.90
						Pallid Sturgeon								
Ruelle and Henry (1994b)														
Gonad														
Louisiana	0.13	0.15	0.11	0.26	NA	0.66	0.06	0.02	0.03	0.70	2.29	0.30	3.60	14.55
Illinois	0.17	0.19	0.06	0.30	NA	0.73	0.07	0.01	0.05	0.18	0.55	0.03	0.94	8.16
Missouri	0.20	0.16	0.06	0.24	NA	0.66	0.10	0.02	0.27	0.91	2.56	0.24	4.16	6.73
Liver														
Louisiana	0.08	0.08	0.06	0.12	NA	0.37	0.06	0.01	0.02	0.38	1.42	0.15	2.12	7.90
Illinois	0.09	0.02	0.03	0.19	NA	0.35	0.03	0.02	0.04	0.10	0.33	0.02	0.54	5.12
Missouri	0.04	0.05	0.03	0.01	NA	0.21	0.06	0.03	0.11	0.65	3.27	0.11	4.47	5.10
Muscle														
Louisiana	0.02	0.02	0.01	0.02	NA	0.07	0.01	0.01	0.01	0.06	0.22	0.03	0.37	1.64
Illinois	0.05	0.04	0.02	0.10	NA	0.21	0.02	0.01	0.05	0.04	0.17	0.01	0.31	2.28
Missouri	0.01	0.03	0.03	0.05	NA	0.13	0.03	0.02	0.04	0.16	0.63	0.07	0.27	2.78

* Arithmetic means

( ) = maximum concentration, mean not calculated;

BDL - below detection limit;

NA - not analyzed.

Ruelle and Keenlyne (1992) reported on pallid sturgeon collected from the Missouri River in southeastern Nebraska (a 10-year-old female taken in 1988), in south central North Dakota (a 41-year-old female taken in 1983), and near the Missouri River-Yellowstone River confluence in northwestern North Dakota (a 37-year-old male taken in 1988). Tissues analyzed individually included ovary in the Nebraska sample; muscle, eggs, and liver in the Fort Rice sample; and muscle and liver in the sample collected from near the Yellowstone River-Missouri River confluence. Ruelle and Henry (1994b) included the three samples in a comparative study of pallid sturgeon from the Missouri River, Upper Mississippi River (Chester, Illinois) and Atchafalaya River (ORCS, Louisiana). (The latter area is the same location from which the shovelnose in this study were taken.) Direct comparison of data from the previous study is difficult because specific tissues were analyzed, whereas the ORCS shovelnose sturgeon analyses were conducted on a whole-body samples. Although those data are not directly comparable, they illustrate variation in tissue levels, highlight those OCs that were elevated in whole-body samples, and form a basis for comparison.

The tissues of the Missouri River pallid sturgeon were heavily contaminated with high levels of ΣDDT, ΣChlordane, and ΣPCBs (Ruelle and Keenlyne 1992). The 41-year-old female pallid sturgeon contained the greatest ΣDDT concentrations (i.e., eggs-2.62 μg/g, fillet-5.70 μg/g, and liver-5.93 μg/g). Other results for those tissues were Σchlordane - 0.13, 0.24, and 0.19 μg/g; ΣPCBs - 1.18, 2.41, and 1.72 μg/g; and ΣOCs - 4.35, 8.55, and 8.14 μg/g, respectively.

In reviewing the Ruelle and Henry (1994b) data, most OCs were detected in at least some of the tissues, except for BHC in the Upper Mississippi River pallids, mirex in Missouri River pallids, and toxaphene in Upper Mississippi River and Missouri River pallids. BHC and DDT metabolites were highest in the Missouri River samples; HCB, dieldrin, chlordane, and heptachlor epoxide levels were higher in the Upper Mississippi River samples; and ΣPCBs, mirex, and toxaphene levels were highest in Atchafalaya River (ORCS) samples. ΣOC body burdens in the Atchafalaya River samples were, however, about twice those of the northern samples.

Shovelnose sturgeon composite tissue data (arithmetic means) from near Bismarck, North Dakota, (Welsh and Olson 1992) were relatively uncontaminated, compared to the above described pallid sturgeon data. The highest concentrations occurred in the testes at 0.56 μg/g ΣDDT, 0.14 μg/g ΣChlordane, 1.8 μg/g ΣPCBs, and 2.52 μg/g ΣOCs. Welsh and Olson (1992) expressed uncertainty as to the toxicological significance of these contaminant levels in shovelnose or pallid sturgeon. However, ΣOCs of >41.0 μg/g (Ruelle and Keenlyne 1992) in an endangered species' gonads (ovary), compared to 4.67 μg/g (sum of maximum values) in shovelnose sturgeon gonads (testes) is cause for concern.

Comparison of shovelnose whole-body contaminant concentrations to pallid sturgeon tissue contaminant concentrations must, by definition, allow for a substantial margin of error. OC concentrations were the highest in pallid sturgeon gonads, lowest in muscle tissue, and were intermediate in the liver (Ruelle and Henry 1994b). Whole-body OC concentrations in ORCS shovelnose, compared to Missouri River pallid sturgeon, were generally less than or equal to pallid fillet mean concentrations; α-chlordane, heptachlor epoxide, and ΣDDT whole-body concentrations fell between the muscle and liver concentrations, HCB and mirex equaled all tissue means, and toxaphene exceeded all tissue concentrations.

ORCS shovelnose whole-body means were generally comparable to upper Mississippi River pallid sturgeon fillets; however, *p,p'*-DDD, *p,p'*-DDE, and ΣDDT in whole-body samples exceeded the fillet levels, *p,p'*-DDT in whole-body samples exceeded liver concentrations, and toxaphene in whole-body samples exceeded gonad concentrations (Table 4). ORCS shovelnose (whole-body) OC means averaged slightly higher, or were equal to, ORCS pallid fillets. Toxaphene was the only parameter in shovelnose that exceeded the pallid liver mean. Shovelnose concentrations were about equal to fillet concentrations for all OCs when compared to the means of the three areas combined.

Polycyclic Aromatic Hydrocarbons (PAHs) PAH results for ORCS shovelnose sturgeon whole-body samples are presented in Table 5. In addition to the PAHs listed in Table 5, those screened but not detected were 1,2,5,6-dibenzanthracene; 2,3,5-trimethylnaphthalene; C^1-fluoranthenes and pyrenes; C^1, C^2, C^3, and C^4-chrysenes; C^1, C^2, and C^3-dibenzothiophenes and fluorenes; C^2, C^3, and C^4-phenanthrenes; C^3 and C^4-naphthalenes; acenaphthalene; acenaphthene; and biphenyl. The mean concentration of those detected was at the detection limit, except for 2-methylnaphthalene (0.02 μg/g) and C^1-naphthalene (0.03 μg/g); the mean ΣPAHs was 0.04 μg/g. The two largest shovelnose sturgeon (oldest) had the lowest (0.35 μg/g) and the highest (0.52 μg/g) ΣPAH concentrations. PAHs in the two shovelnose composite samples of Welsh (1992) were both below the detection limit for all analytes listed.

Aliphatic Hydrocarbons (APHs) The aliphatic hydrocarbons that were detected as part of this study are presented in Table 6. APHs screened but not detected were *n*-decane, *n*-dotriacontane, *n*-hentriacontane, *n*-hexacosane, *n*-tetracosane, *n*-tetratriacontane, *n*-triacontane, and *n*-tritriacontane.

Table 5. Polycyclic aromatic hydrocarbon concentrations (ug/g, FW) detected in shovelnose sturgeon collected at the Old River Control Structure, Atchafalaya River, Louisiana, in 1992-93.

Sample Number	1,2-Benzan-thracene	1-Methy-naphthalene	1-Methyl-phenanthrene	2,6-Dimethyl-naphthalene	2-Methyl-naphthalene	C1-Naph-thalenes	C1-Phen-anthrenes	C2-Naph-thalenes
1	0.01	0.01	BDL	BDL	0.02	0.03	BDL	BDL
2	0.02	0.01	0.02	0.01	0.02	0.03	0.01	0.01
3	0.01	0.01	BDL	0.01	0.02	0.03	BDL	0.01
4	0.01	0.01	0.02	0.01	0.02	0.03	BDL	0.01
5	BDL	0.01	BDL	0.01	0.02	0.03	BDL	0.01
6	BDL	0.01	BDL	BDL	0.02	0.03	BDL	BDL
7	BDL	0.01	BDL	BDL	0.02	0.03	BDL	BDL
8	BDL	0.01	BDL	BDL	0.02	0.03	BDL	BDL
9	0.02	0.01	0.03	0.02	0.02	0.03	0.03	0.02
10	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01
Geo. mean	0.01	0.01	0.01	0.01	0.02	0.03	0.01	0.01
Std. Error	1.13	1.00	1.19	1.10	1.07	1.04	1.15	1.10

Sample Number	Acenaph-thalene	Anthra-cene	Benzo(a)-pyrene	Benzo(b)-fluoranthene	Benzo(e)-pyrene	Benzo(g,h,i)-perylene	Benzo(k)-fluoranthene	Dibenzo-thiophene
1	BDL	BDL	0.01	0.01	0.01	BDL	0.01	BDL
2	BDL	0.02	0.02	0.01	0.01	0.01	0.01	0.01
3	BDL	BDL	0.03	0.03	0.02	BDL	BDL	BDL
4	BDL	0.01	BDL	0.02	BDL	BDL	BDL	BDL
5	BDL	0.01	BDL	0.02	BDL	BDL	BDL	BDL
6	BDL	BDL	BDL	0.02	BDL	BDL	BDL	BDL
7	BDL	BDL	BDL	0.02	BDL	BDL	BDL	BDL
8	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
9	0.02	0.02	0.01	0.02	0.01	BDL	0.01	0.01
10	BDL	0.01	BDL	BDL	BDL	BDL	BDL	BDL
Geo. mean	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Std. Error	1.10	1.13	1.17	1.17	1.10	1.03	1.04	1.04

BDL - below detection limit

Table 5. (contd.) Polycyclic aromatic hydrocarbon concentrations (ug/g, FW) detected in shovelnose sturgeon collected at the Old River Control Structure, Atchafalaya River, Louisiana, in 1992-93.

Number	Fluor-anthene	Fluorene	Indeno(1,2,3-cd)pyrene	Naph-thalene	Perylene	Phen-anthrene	Pyrene	Total PAHs
1	BDL	BDL	BDL	0.01	0.01	0.01	BDL	0.37
2	0.02	0.01	0.01	0.01	0.02	0.03	0.02	0.36
3	0.01	BDL	BDL	0.01	0.01	BDL	BDL	0.48
4	BDL	BDL	BDL	0.01	BDL	0.01	BDL	0.42
5	BDL	BDL	BDL	0.01	BDL	0.01	0.01	0.39
6	BDL	BDL	BDL	0.01	BDL	BDL	BDL	0.38
7	BDL	BDL	BDL	0.01	BDL	BDL	BDL	0.37
8	BDL	BDL	BDL	0.01	BDL	BDL	BDL	0.37
9	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.35
10	0.01	BDL	BDL	0.01	BDL	0.01	0.01	0.52
Geo. Mean	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.40
Std. Error	1.10	1.04	1.04	1.00	1.10	1.16	1.10	1.04

BDL - below detection limit

Table 6. Aliphatic hydrocarbon conncentrations (ug/g, FW) detected in shovelnose sturgeon collected at the Old River Control Structure, Atchafalaya River, Louisiana, in 1992-93.

Sample Number	n-Do-cosane	n-Do-decane	n-Ei-cosane	n-Henei-cosane	n-Hepta-cosane	n-Hepta-decane	n-Hexa-decane	n-Nona-cosane	n-Nona-decane	n-Octa-cosane
1	BDL	0.03	0.02	0.19	BDL	0.36	0.06	BDL	0.06	BDL
2	BDL	0.03	0.03	0.20	0.04	0.13	0.06	0.04	0.02	BDL
3	BDL	0.02	BDL	0.35	0.06	0.42	0.14	BDL	BDL	BDL
4	BDL	0.01	BDL	0.14	BDL	0.52	0.05	BDL	0.09	BDL
5	0.03	0.02	BDL	0.14	BDL	0.27	0.12	BDL	BDL	BDL
6	0.03	0.02	0.07	0.15	BDL	2.00	0.05	BDL	BDL	0.03
7	BDL	0.02	0.06	0.10	BDL	1.90	0.12	0.06	BDL	0.01
8	0.04	BDL	BDL	0.07	0.03	0.17	0.05	BDL	BDL	BDL
9	BDL	BDL	BDL	0.12	BDL	0.32	0.04	BDL	0.04	BDL
10	0.08	0.08	BDL	0.54	0.75	0.48	0.43	BDL	0.78	BDL
Geo. Mean	0.01	0.02	0.01	0.17	0.02	0.44	0.08	0.01	0.02	0.01
Std. Error	1.34	1.25	1.34	1.21	1.62	1.33	1.26	1.29	1.64	1.15

Sample Number	n-Octa-decane	n-Penta-cosane	n-Penta-decane	n-Tetra-decane	n-Tri-cosane	n-Tri-decane	n-Unde-cane	Phytane	Pristane	Total APHs
1	0.03	BDL	0.11	0.22	BDL	0.03	0.04	0.06	0.07	1.39
2	BDL	0.10	0.25	1.10	0.02	0.15	0.14	0.23	0.32	2.94
3	0.06	0.15	0.24	1.60	0.05	0.12	0.08	0.38	0.61	4.38
4	0.04	BDL	0.12	0.29	BDL	0.05	0.14	0.14	0.17	1.87
5	BDL	0.08	0.44	2.70	0.03	0.50	0.09	0.36	0.12	5.01
6	0.15	0.09	0.25	0.56	0.06	0.15	0.12	0.44	0.59	4.84
7	0.14	BDL	0.24	0.55	BDL	0.13	0.11	0.41	0.54	4.49
8	BDL	BDL	0.09	0.25	BDL	0.03	0.02	0.08	0.07	1.02
9	0.03	BDL	0.09	0.17	BDL	0.04	0.16	0.07	0.08	1.28
10	0.09	0.40	0.67	5.70	0.18	0.40	0.14	0.01	1.20	12.01
Geo. Mean	0.03	0.03	0.20	0.68	0.02	0.10	0.10	0.14	0.24	2.99
Std. Error	1.45	1.65	1.24	1.45	1.44	1.38	1.23	1.46	1.39	1.28

BDL - below detection limit

Interpreting APH results in fish tissues can be problematic. Once petroleum hydrocarbons are ingested they are metabolized, tend to mix with similar compounds present in the organism, and are excreted, making the resulting analytical data difficult to interpret (Hall and Coon 1988). However, those authors presented guidelines that help to derive conclusions from seemingly incomprehensible APH data. Those guidelines involve consideration of the presence of PAHs, the concentration of total resolved hydrocarbons, dominance of high molecular weight compounds, pristane/phytane ratios, and dominance of odd-numbered hydrocarbons.

Those guidelines were applied to the APH data, and the results are tabulated in Table 7. None of the ORCS shovelnose sturgeon data were definitive as to whether the APH concentrations were of petroleum or biological origin, (i.e., all criteria indicating either petroleum or biological origin). Calculations for half of the shovelnose samples indicated hydrocarbons of petrogenic origin. Specimens 2 and 3 very strongly indicated, and specimens 5, 6, and 7 strongly indicated the presence of petrogenic hydrocarbons.

Although the shovelnose sturgeon were not aged, specimens 9 and 10 are presumed to be the oldest specimens; their length and weight measurements were twice that of the other 8 specimens. While it would seem intuitive that their potential for petroleum exposure was greater, results of the evaluation indicated only slight petrogenic exposure in those specimens. Of the nine APH evaluation criteria, the results for specimen 10 had the highest calculated values for six and the lowest for two, with four factors indicating biogenic origins of exposure, and five indicating petrogenic origins of exposure. Welsh (1992) questioned whether the guidelines were valid indicators for freshwater fishes, in that most of the guidelines for interpreting residues were for marine organisms, especially molluscs (Farrington et al. 1973). Welsh also suggested that laboratory bioassays with petroleum would help resolve some of this uncertainty; our results support that suggestion.

Table 8 compares APHs of Missouri River shovelnose sturgeon from North Dakota (Welsh 1992) and Nebraska and Kansas (Allen and Wilson 1991) with ORCS shovelnose sturgeon. Those data are illustrated in Figure 2. The ΣAPH concentrations presented in Table 8 were compiled for those APHs common to all three studies. ΣAPHs in ORCS shovelnose exceeded Missouri River shovelnose by about 1 μg/g, while the Missouri River shovelnose sturgeon ΣAPH concentrations were comparable to those from the ORCS samples.

In Louisiana, with its extensive oil and gas exploration and petrochemical industry, it is probable that sturgeon (both shovelnose and pallid) have experienced at least some petroleum

Table 7. Evaluation of aliphatic hydrocarbon criteria for determination of their biologic/petroleum origin in ORCS shovelnose sturgeon.

Sample Number	ΣPAHs[1]	Total Resolved Hydrocarbons[2]	Dominant Molecular Weight[3]		Pristane / Phytane Ratios[4,5]			Odd Number Dominance[6]	
			ΣLight/ C^{11}-C^{19}	ΣHeavy/ C^{20}-C^{31}	Pristane /Phytane	Pristane /n-C^{17}	Phytane /n-C^{18}	Odd No.	Even No.
1	0.37	1.66	0.43	0.66	0.86	0.19	2.0	0.89	0.44
2	0.36	3.30	1.67	0.80	0.72	2.46	28.8	1.41	1.47
3	0.48	4.86	2.06	1.63	0.62	1.45	6.3	2.10	2.22
4	0.42	2.29	0.61	1.02	0.82	0.33	3.5	1.26	0.55
5	0.39	5.40	3.75	0.89	3.00	0.44	45.0	1.69	3.25
6	0.38	5.22	1.10	3.31	0.74	0.30	2.93	3.43	1.35
7	0.37	4.86	1.05	3.18	0.76	0.28	2.93	3.11	1.32
8	0.37	1.39	0.40	0.39	1.14	0.41	10.0	0.51	0.45
9	0.35	1.63	0.47	0.59	0.88	0.25	2.33	0.88	0.43
10	0.52	12.52	6.99	3.00	0.01	2.50	0.11	5.55	6.41

Values double-underlined tend to indicate hydrocarbons of biologic origin, shadowed values tend to indicate petroleum contamination, and those redlined indicate hydrocarbons of questionable origin.

[1]Presence of PAHs indicative of petroleum exposure.

[2]Values >3.0 μg/g interpreted as indicative of petroleum exposure, values <1.0 μg/g of biologic origin, between 1 and 3 μg/g of questionable but probable petroleum exposure.

[3]Dominance of lower molecular weight compounds (n-C^{11} to n-C^{19}) over high molecular weight compounds (n-C^{20} to n-C^{31}) tends to be indicative of biologic origin.

[4]Low ratio of pristane to phytane may be indicative of petroleum exposure.

[5]High ratio of pristane to n-C^{17} and phytane to n-C^{18} may be indicative of petroleum exposure.

[6]Dominance of APHs with odd numbers of carbon atoms tends to be indicative of biologic origin, while when about equal in number indicative of petroleum exposure.

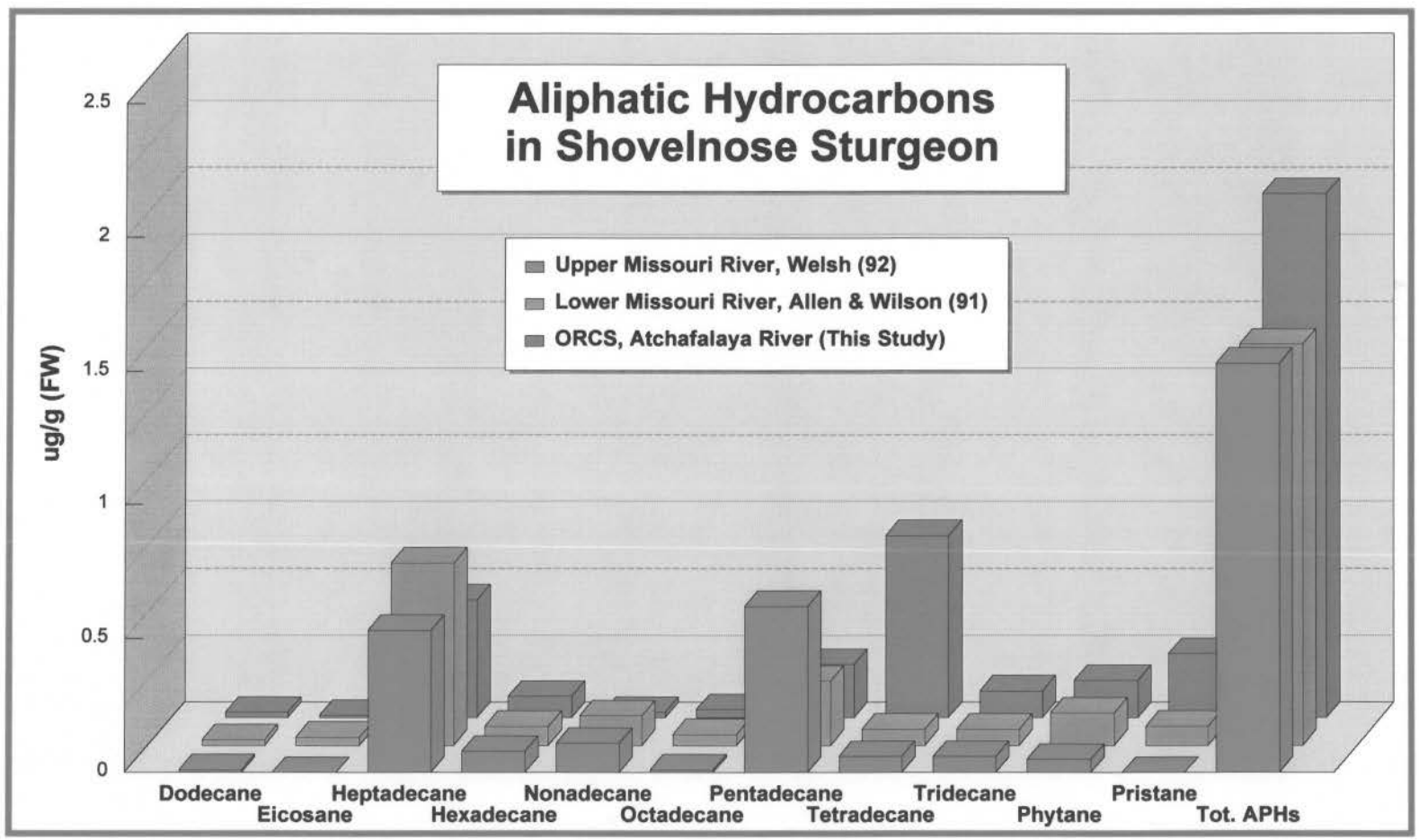
Table 8. Aliphatic hydrocarbon concentrations (ug/g, FW) detected in shovelnose sturgeon from the Missouri River, and Old River Control Structure, Atchafalaya River, Louisiana.

Study	n-Do-cosane	n-Dode-cane	n-Eico-sane	n-Henei-cosane	n-Hepta-cosane	n-Hepta-decane	n-Hexa-decane	Octylcyc-lohexane	Nonlycyc-hexane	n-Nona-cosane	n-Nona-decane
Allen and Wilson (1991)	NA	0.02	0.03	NA	NA	0.68	0.07	0.02	0.01	NA	0.11
Welsh (1992)	NA	0.01	BDL	NA	NA	0.53	0.08	NA	NA	NA	0.11
This study	0.01	0.02	0.01	0.17	0.02	0.44	0.08	NA	NA	0.01	0.02

Study	n-Octa-cosane	n-Octa-decane	n-Penta-cosane	n-Penta-decane	n-Tetra-decane	n-Tri-cosane	n-Tri-decane	n-Unde-cane	Phytane	Pristane	Total* APHs
Allen and Wilson (1991)	NA	0.04	NA	0.24	0.06	NA	0.06	NA	0.12	0.07	1.71
Welsh (1992)	NA	0.01	NA	0.62	0.06	NA	0.06	NA	0.05	BDL	1.72
This study	0.01	0.03	0.03	0.20	0.68	0.02	0.10	0.10	0.14	0.24	2.51

*Total APHs include only those aliphatics analyzed in all three studies.
NA = Not analyzed.
BDL = Below detection level.

Figure 2. Comparative geometric means of aliphatic hydrocarbons (ug/g, FW) detected in shovelnose sturgeon from the Missouri River and Old River Control Structure, Atchafalaya River.



contamination over their lifetime. While the origin of APH residues in ORCS shovelnose sturgeon tissues appears somewhat equivocal, those concentrations are elevated when compared to ΣAPH in fish tissues from the Missouri River (Allen and Wilson 1991, Welsh 1992), Louisiana National Wildlife Refuges (NWR) (Schultz and Schultz 1988, Schultz 1991b, and Conzelmann and Schultz 1993), and the Mississippi River and coastal marsh south of New Orleans (Conzelmann et al. 1996).

For comparison with Louisiana fish samples, only C^{12} (*n*-dodecane) through C^{20} (*n*-eiosane) APHs were used, since these were the only analytes common to the three National Wildlife Refuge (NWR) studies cited above. All APH concentrations are for whole-body fish, with 18 individuals representing 5 species from the Bogue Chitto NWR (Conzelmann and Schultz 1993), 23 individuals representing 5 species from the Sabine NWR (Schultz 1991b), and 24 individuals representing 6 species from the Bayou Sauvage NWR (Schultz and Schultz 1988). The lower Mississippi River and coastal marsh (Conzelmann et al. 1996) data are also from whole-body fish samples (8 individuals representing 4 species from the Mississippi River, and 26 individual fishes representing 6 species from the coastal marsh).

The ΣAPH geometric mean for fishes from the Bayou Sauvage NWR was 0.40 μg/g, 1.30 μg/g for Sabine NWR, and 1.94 μg/g for Bogue Chitto NWR. The ΣAPH geometric means were 3.12 μg/g and 3.07 μg/g for Mississippi River and coastal marsh fishes, respectively. The shovelnose sturgeon ΣAPH geometric mean of 2.43 μg/g was intermediate between samples from waters generally considered to be "clean" and samples from areas of extensive oil exploration and production (i.e., the coastal marsh) or from waters generally considered to be "polluted" (i.e., the Mississippi River).

Trace Elements The trace element analytical results for ORCS shovelnose sturgeon are presented in Tables 9 and 10 on a FW and DW basis, respectively. Both FW and DW data are presented for comparison because the literature provides either one or the other, but not both. Trace elements, except beryllium and molybdenum, which were below the detection limit) were present in most specimens. Specimen 8 carried the greatest body burden of trace elements detected, and it also had the highest concentrations for seven elements (i.e., barium, copper, magnesium, manganese, nickel, strontium, and zinc).

Shovelnose sturgeon trace element means (FW) were compared to means of fish samples from eight locations in the Atchafalaya basin (Winger and Andreasen 1985). Atchafalaya Basin fishes were analyzed for six trace elements: arsenic, cadmium, lead, mercury, selenium, and zinc. The shovelnose sturgeon arsenic mean (0.41.0 μg/g) exceeded the mean for all fishes from the Atchafalaya Basin, except for the gizzard shad (0.51 μg/g) collected at

Table 9. Trace element concentrations (ug/g, DW) detected in shovelnose sturgeon collected at the Old River Control Structure, Atchafalaya River, Louisiana, in 1992-93.

Sample No.	Al	As	B	Ba	Cd	Cr	Cu	Fe	Hg	Mg	Mn	Ni	Pb	Se	Sr	V	Zn
1	130	2.76	BDL	23.5	0.48	2.89	3.27	259	0.32	1433	11.4	7.38	0.38	2.09	49.6	BDL	69.9
2	108	1.77	BDL	33.8	0.90	4.08	9.03	394	0.28	1407	12.1	11.2	2.40	3.28	31.8	BDL	94.6
3	195	0.86	BDL	20.4	0.26	5.11	6.19	512	0.21	1524	15.8	18	1.11	3.34	41.5	BDL	72.2
4	255	1.93	BDL	8.4	BDL	4.96	4.45	687	0.08	974	17.1	15.7	1.11	6.34	8.9	0.78	38.2
5	354	0.98	BDL	23.0	0.10	3.61	3.21	555	BDL	1630	23.6	7.34	0.82	7.41	55.6	1.45	73.8
6	436	1.08	BDL	34.2	0.35	19.1	5.09	1238	0.26	2044	27.8	28.6	0.90	3.12	68.8	1.10	87.7
7	175	2.12	0.45	48.4	0.43	4.68	4.80	442	1.04	1700	16.7	6.98	0.78	2.45	79.9	0.71	90.5
8	253	1.15	BDL	33.5	0.58	5.32	8.78	666	0.25	2385	26.8	27.2	1.12	2.64	75.0	0.97	124.1
9	88	1.09	0.99	21.2	0.31	2.96	2.56	254	0.11	1257	11.6	3.41	1.99	2.14	34.6	BDL	72.5
10	347	1.29	BDL	14.6	BDL	5.05	3.51	726	0.10	1153	16.5	14.7	BDL	3.02	20.4	0.90	43.5
Geo. Mean	207	1.4	0.41	23.6	0.27	4.88	4.68	516	0.2	1502	17.1	11.7	0.94	3.27	39.6	0.66	72.8
Std. Error	1.19	1.13	1.1	1.17	1.32	1.18	1.14	1.17	1.27	1.09	1.11	1.24	1.21	1.14	1.24	1.18	1.12

Table 10. Trace element concentrations (ug/g, FW) detected in shovelnose sturgeon collected at the Old River Control Structure, Atchafalaya River, Louisiana, in 1992-93.

Sample No.	Al	As	B	Ba	Cd	Cr	Cu	Fe	Hg	Mg	Mn	Ni	Pb	Se	Sr	V	Zn
1	34.7	0.73	BDL	6.3	0.13	0.77	0.87	69	0.08	381	3.02	1.96	BDL	0.56	13.2	BDL	18.6
2	29.5	0.48	BDL	9.2	0.24	1.11	2.46	107	0.08	383	3.30	3.06	0.65	0.89	8.7	BDL	25.7
3	66.2	0.29	BDL	6.9	0.09	1.74	2.10	174	0.07	518	5.38	6.13	0.38	1.14	14.1	BDL	24.5
4	85.4	0.65	BDL	2.8	BDL	1.66	1.49	230	0.03	326	5.74	5.27	0.37	2.12	3.0	0.26	12.8
5	106.2	0.29	BDL	6.9	0.03	1.08	0.96	167	0.03	489	7.07	2.20	0.24	2.22	16.7	0.44	22.1
6	92.1	0.23	BDL	7.2	0.07	4.03	1.07	261	0.05	431	5.86	6.03	0.19	0.66	14.5	0.23	18.5
7	37.0	0.45	0.11	10.3	0.09	0.99	1.02	94	0.22	360	3.54	1.48	0.17	0.52	16.9	0.15	19.2
8	92.7	0.42	BDL	12.3	0.21	1.95	3.21	244	0.09	873	9.80	9.97	0.41	0.97	27.4	0.36	45.4
9	32.9	0.41	0.37	7.9	0.12	1.11	0.96	95	0.04	470	4.34	1.25	0.74	0.80	12.9	BDL	27.1
10	107.7	0.40	BDL	4.5	BDL	1.57	1.09	225	0.03	357	5.12	4.55	BDL	0.94	6.3	0.28	13.5
Geo. Mean	60.8	0.41	0.13	6.9	0.08	1.43	1.22	151	0.06	440	5.00	3.41	0.28	0.96	11.6	0.19	21.3
Std. Error	1.18	1.12	1.14	1.14	1.29	1.16	1.12	1.16	1.23	1.09	1.12	1.24	1.24	1.17	1.22	1.18	1.12

BDL = below detection limit.

Raccourci Old River. For cadmium (0.08 μg/g) and lead (0.28 μg/g), the shovelnose mean was exceeded by all Atchafalaya basin samples. The shovelnose sturgeon mercury mean (0.06 μg/g) equaled that of the lowest Atchafalaya Basin fish mean (range 0.06 to 0.79 μg/g at Bayou Petite Prairie in largemouth bass). The selenium mean for shovelnose sturgeon (0.96 μg/g) was elevated compared to a black crappie from Raccourci Old River (range 0.07 to 0.58 μg/g). Shovelnose sturgeon zinc means closely approximated those observed in Atchafalaya Basin fishes.

Trace element levels (FW) in shovelnose sturgeon were also compared to the NCBP data. Most recent NCBP data for trace elements in fish samples were summarized by Schmidt and Brumbaugh (1990). Those data were obtained from 109 stations from throughout the United States during 1984-85. A total of 315 composite whole-body fish samples (3-5 adult specimens/ sample) were analyzed for arsenic, cadmium, copper, lead, mercury, selenium, and zinc. NCBP mean concentrations, residue ranges, and the 85th percentile are provided in Table 11. The 85th percentile is an arbitrary value used to distinguish NCBP sites with elevated concentrations (May and McKinney 1981, Lowe et al. 1985).

Table 11. National Contaminant Biomonitoring Program (Schmidt and Brumbaugh, 1990) trace element ranges and geometric means (μg/g, FW) that are common to those in this investigation.

Parameter	Range	Geo. mean	85th %
Arsenic	0.01-1.50	0.14	0.27
Cadmium	0.01-0.22	0.03	0.05
Copper	0.06-23.1	0.65	1.00
Lead	ND-4.88	0.11	0.22
Mercury	0.01-0.37	0.10	0.17
Selenium	0.08-2.3	0.42	0.73
Zinc	9.6-118.4	21.7	34.2

ORCS shovelnose sturgeon means exceeded the NCBP 85th percentile for arsenic, cadmium, copper, lead and selenium. On an individual basis, all shovelnose sturgeon exceeded the arsenic 85th percentile concentration except specimen 6. Three ORCS shovelnose sturgeon equaled the NCBP cadmium mean and the remaining seven exceeded the 85th percentile, with one exceeding the NCBP maximum cadmium concentration. All ORCS sturgeon exceeded the copper NCBP mean, and seven exceeded the 85th percentile. Mercury in ORCS shovelnose sturgeon was present in the lowest concentrations relative to the NCBP mean, however,

specimen 7 exceeded the 85th percentile. For lead, all but one ORCS sturgeon exceeded the NCBP mean, and six exceeded the 85th percentile. Seven ORCS sturgeon exceeded the NCBP selenium 85th percentile, and two approached the NCBP maximum selenium concentration. Half of the ORCS sturgeon exceeded the NCBP zinc mean, and specimen 8 exceeded the NCBP 85th percentile zinc concentration.

Welsh (1992) indicated that shovelnose sturgeon from near the Missouri River-Yellowstone River confluence (upper Missouri River), had elevated lead concentrations (4.89 and 10.2 μg/g, FW) in 1988, but low concentrations in 1990; other trace elements were generally within background concentrations except for slightly elevated chromium concentrations. Welch and Olson (1992) recorded elevated concentrations of arsenic, cadmium, and selenium in livers of un-aged shovelnose sturgeon taken near Bismarck, North Dakota on the Missouri River.

Trace element concentrations in ORCS shovelnose sturgeon were generally higher than in shovelnose sturgeon from other areas (Table 12). Figures 3, 4, and 5 illustrate trace element means for the upper (Welsh 1992), middle (Ruelle and Henry 1994a), and lower (Allen and Wilson 1991) Missouri River and the ORCS. ORCS shovelnose sturgeon had elevated concentrations of arsenic, barium, chromium, copper, iron, magnesium, manganese, and nickel as compared to Missouri River shovelnose sturgeon (Welsh 1992 [individual and composite whole-body], Ruelle and Henry 1994a [individual whole-body and tissues]). The ORCS sturgeon mean concentrations for those parameters always exceeded Missouri River means, while selenium was also elevated in most instances. In contrast, trace elements in Missouri River shovelnose were elevated for cadmium, lead, strontium, and vanadium (Ruelle and Henry 1994a). Other trace element concentrations were comparable.

Ruelle and Keenlyne (1992) reported elevated concentrations of cadmium, selenium, and mercury in liver, gonad, and muscle tissues of pallid sturgeon from the upper Missouri River. The highest concentrations (DW) were 1.03 μg/g cadmium (in the kidney) and 5.28 μg/g selenium (in the liver) of Nebraska pallid sturgeon, and 16.0 μg/g mercury in a North Dakota pallid sturgeon liver. Ruelle and Henry (1994b) compared trace element concentrations in pallid sturgeon gonad, liver, and muscle tissues from the Missouri, upper Mississippi (Illinois), and Atchafalaya (ORCS) Rivers (Table 12). Figures 6, 7, and 8 illustrate their pallid sturgeon data for comparison with shovelnose data shown in Figures 3, 4, and 5. Lack of sensitivity in certain trace element analyses occasionally precluded comparison of Missouri River sturgeon with those from other areas. In general, however, the Missouri River and the upper Mississippi River pallid sturgeon had the highest trace element concentrations, regardless of tissue type. Trace

Table 12. Comparative trace element geometric means (ug/g, DW) detected in shovelnose and pallid sturgeon from the Missouri River, upper Mississippi River, and ORCS Atchafalaya River.

Study	Al	As	B	Ba	Be	Cd	Cr	Cu	Fe	Pb	Mg	Mn	Hg	Mo	Ni	Se	Sr	V	Zn
							Shovelnose		Sturgeon										
Allen and Wilson (199																			
Whole-body	86.3	0.51	NA	NA	0.01	0.48	0.96	3.2	283	0.58	NA	23.9	0.19	NA	0.92	1.4	NA	NA	73.7
Welsh (1992)-Wholebody																			
1988[1]	NA	0.71	2.00	19.6	BDL	0.83	0.97	2.9	NA	23.6	976	13.7	0.13	NA	1.05	3.0	NA	1.43	42.5
1990[2]	193.1	0.36	BDL	21.7	0.15	0.37	3.91	2.7	474	0.82	1445	14.8	0.21	3.28	6.27	2.3	111.4	2.14	85.5
Welsh and Olson (1992)																			
Gonad	BDL	0.45	BDL	0.5	NA	BDL	BDL	1.7	41	NA	358	2.2	0.12	NA	BDL	2.2	BDL	0.51	20.4
Liver	11.3	1.40	2.42	21.6	NA	8.17	BDL	35.8	2325	NA	204	2.0	0.83	NA	4.05	9.3	0.57	5.84	69.7
Muscle	BDL	0.57	BDL	6.6	NA	BDL	0.52	1.0	31	NA	1076	3.4	0.47	NA	BDL	3.3	9.64	BDL	33.4
Ruelle and Henry (1994a)																			
Whole-body[3]	18.2	1.02	BDL	20.3	BDL	0.35	3.15	2.2	194	1.72	1218	17.0	0.18	BDL	0.66	4.6	67.50	0.37	88.8
This study (ORCS)																			
Whole-body	207.3	1.40	0.41	23.6	BDL	0.27	4.88	4.7	516	0.94	1502	17.1	0.20	BDL	11.67	3.3	39.59	0.66	72.8
							Pallid		Sturgeon										
Ruelle and Henry (1994b)																			
Gonad																			
Louisiana	0.9	1.12	0.36	0.5	0.01	0.10	0.09	0.6	8	0.45	21	0.1	0.01	0.36	0.12	0.5	0.07	0.04	4.3
Illinois	1.5	0.48	0.43	0.9	0.02	0.07	0.44	1.4	35	0.55	123	0.7	0.05	0.43	0.18	2.2	0.12	0.21	15.5
Missouri	NA	0.44	NA	1.2	NA	NA	NA	3.7	46	NA	137	1.4	0.56	NA	NA	1.2	0.19	NA	15.6
Liver																			
Louisiana	3.4	0.83	NA	2.3	0.02	0.04	0.22	17.6	330	0.98	81	0.9	0.21	0.49	0.48	1.4	0.13	0.43	34.8
Illinois	9.5	1.23	NA	7.4	0.04	1.69	1.18	17.4	799	0.48	236	2.9	0.41	0.69	2.10	6.4	0.31	3.80	47.8
Missouri	55.5	0.64	NA	6.7	0.10	0.47	NA	2.6	733	NA	318	3.4	3.36	NA	NA	5.4	1.15	NA	35.2
Muscle																			
Louisiana	3.2	1.90	1.26	1.1	0.06	0.19	0.38	2.9	2	1.58	610	1.5	0.39	1.26	0.46	1.2	1.46	0.16	14.6
Illinois	2.9	1.92	1.17	2.0	0.06	0.18	0.88	1.7	27	1.46	736	1.8	0.32	1.17	0.42	4.0	1.27	0.18	25.5
Missouri	6.8	0.40	1.60	1.2	0.08	0.24	1.02	1.5	80	2.00	463	2.5	2.00	1.60	0.48	1.4	0.88	0.20	14.4

BDL - below detection limit; NA - not analyzed.

[1]Arithmetic means; Al, Sb, Fe, Ag, St, and Sn failed QA/QC and are not reported .

[2]Arithmetic means; Sn (10.24ug/g), Sb (BDL), Ag (BDL), and Tl (BDL) also analyzed.

[3]Sb, Co, Ag, and Sn also analyzed and below detection.

Figure 3. Trace element mean concentrations (ug/g, DW) detected in shovelnose sturgeon from the upper, (Welsh & Olsen 1992), middle (Ruelle & Henry 1994a), and lower (Allen & Wilson 1991) Missouri River, and on the Atchafalaya River (ORCS, this study).

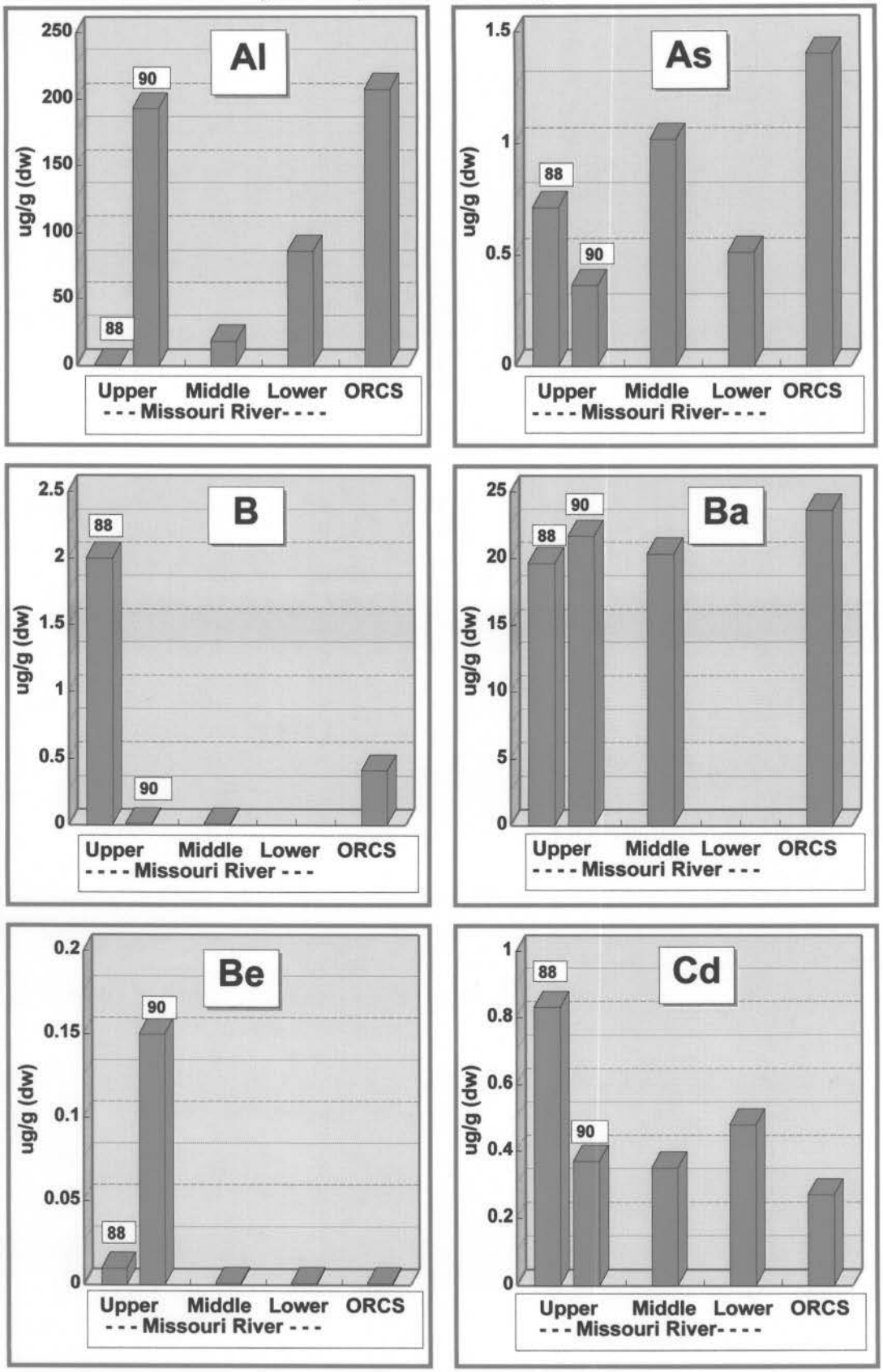


Figure 4. Trace element mean concentrations (ug/g, DW) detected in shovelnose sturgeon from the upper, (Welsh & Olsen 1992), middle (Ruelle & Henry 1994a), and lower (Allen & Wilson 1991) Missouri River, and on the Atchafalaya River (ORCS, this study).

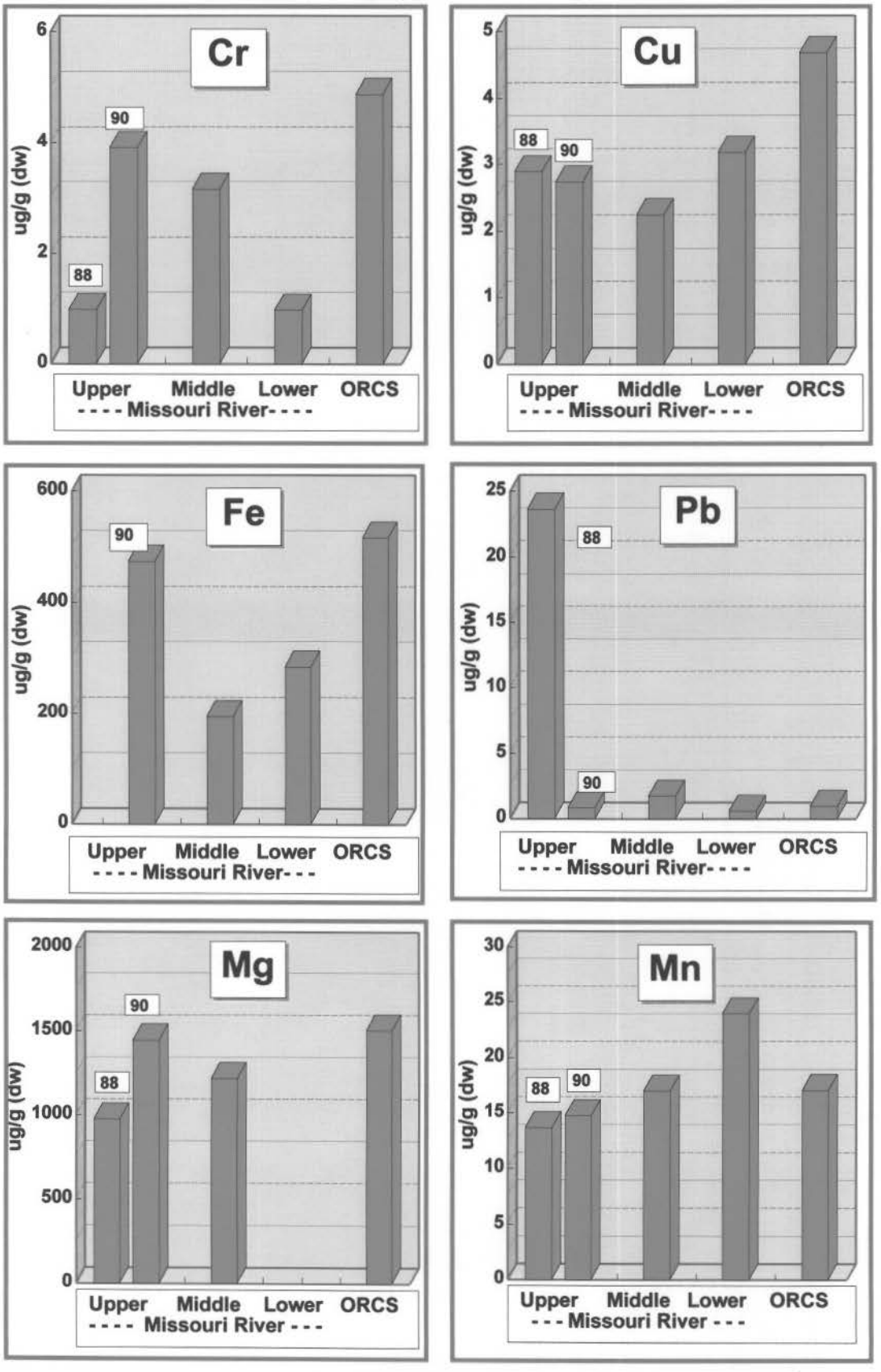
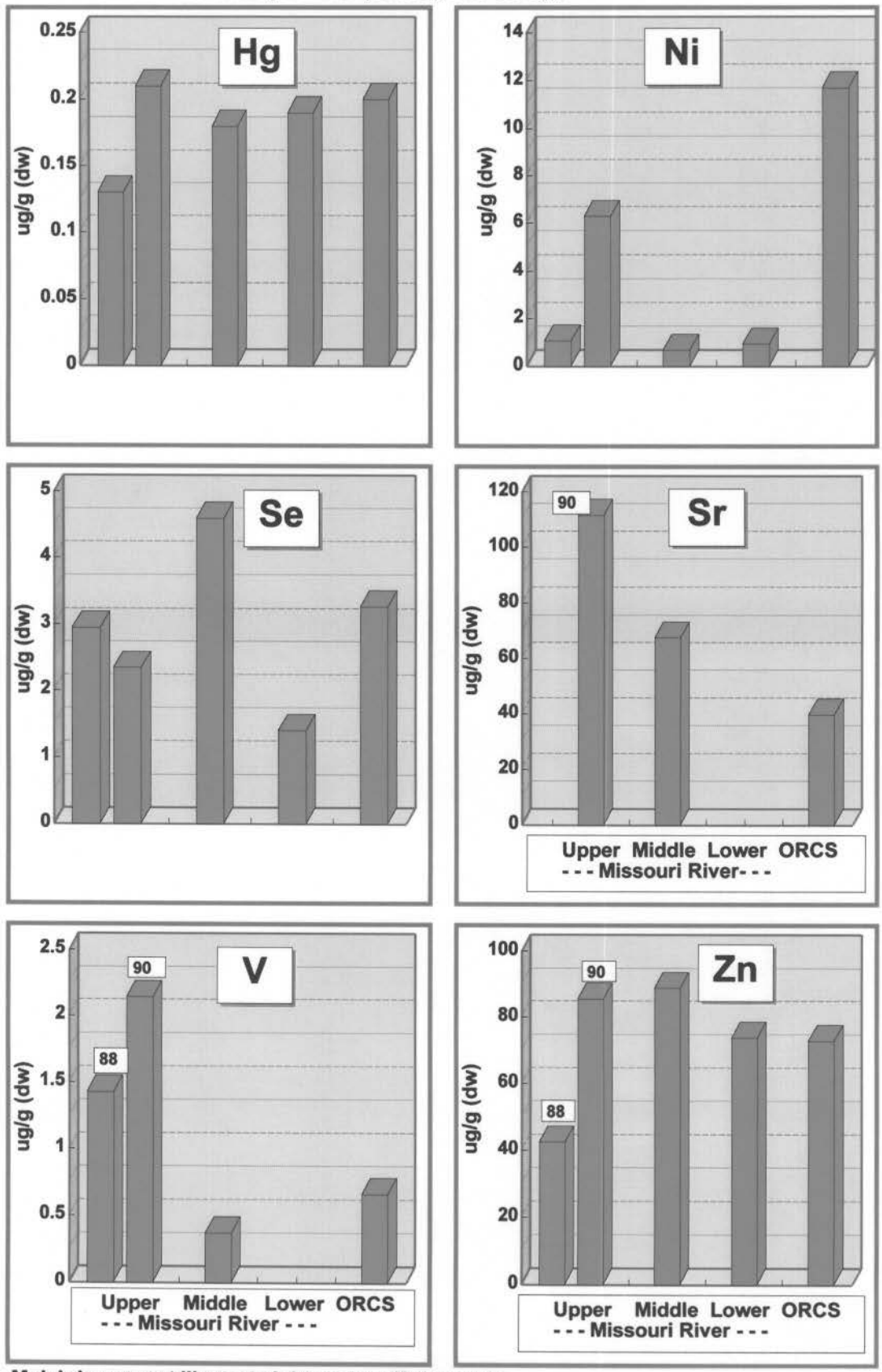
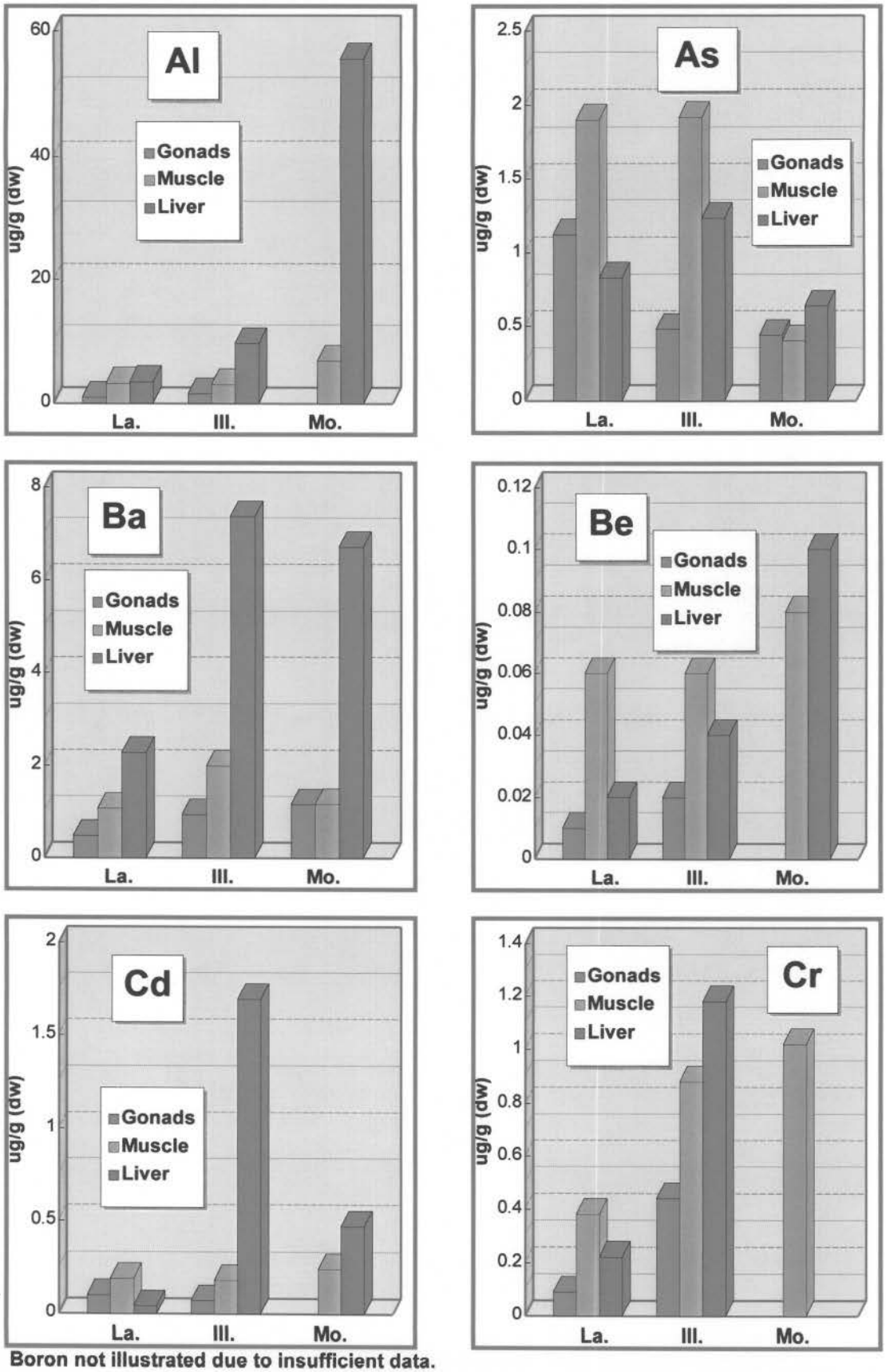


Figure 5. Trace element mean concentrations (ug/g, DW) detected in shovelnose sturgeon from the upper (Welsh & Olsen 1992), middle (Ruelle & Henry 1994a), and lower (Allen & Wilson 1991) Missouri River, and on the Atchafalaya River (ORCS, this study).



Molybdenum not illustrated due to insufficient data.

Figure 6. Trace element mean concentrations (ug/g, DW) detected in pallid sturgeon gonads, muscle, and liver (Ruelle and Henry 1994b) from the Missouri (Missouri), upper Mississippi (Illinois) and lower Mississippi (ORCS, Louisiana) Rivers.



Boron not illustrated due to insufficient data.

Figure 7. Trace element mean concentrations (ug/g, DW) detected in pallid sturgeon gonads, muscle, and liver (Ruelle and Henry 1994b) from the Missouri (Missouri), upper Mississippi (Illinois) and lower Mississippi (ORCS, Louisiana) Rivers.

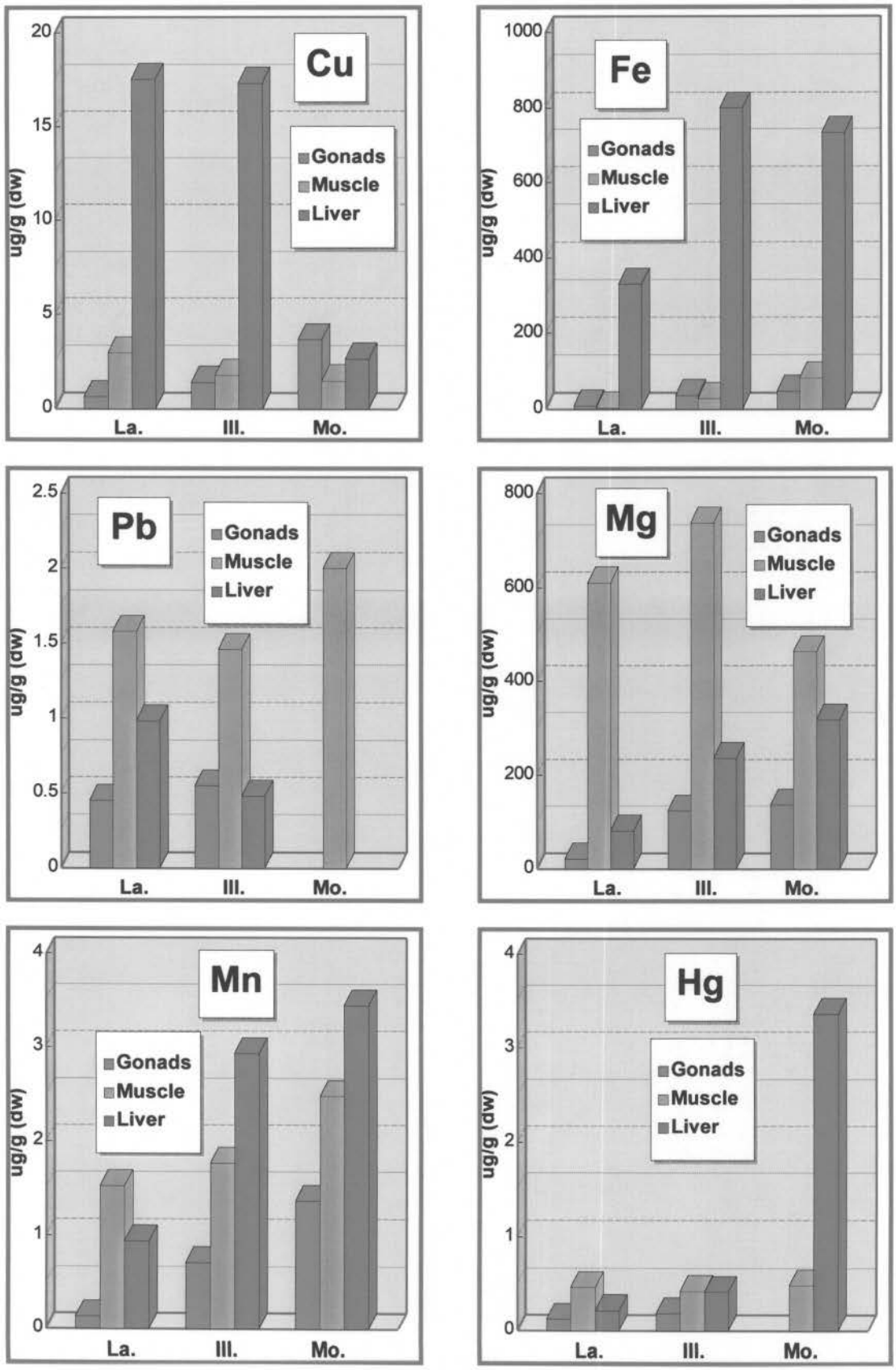
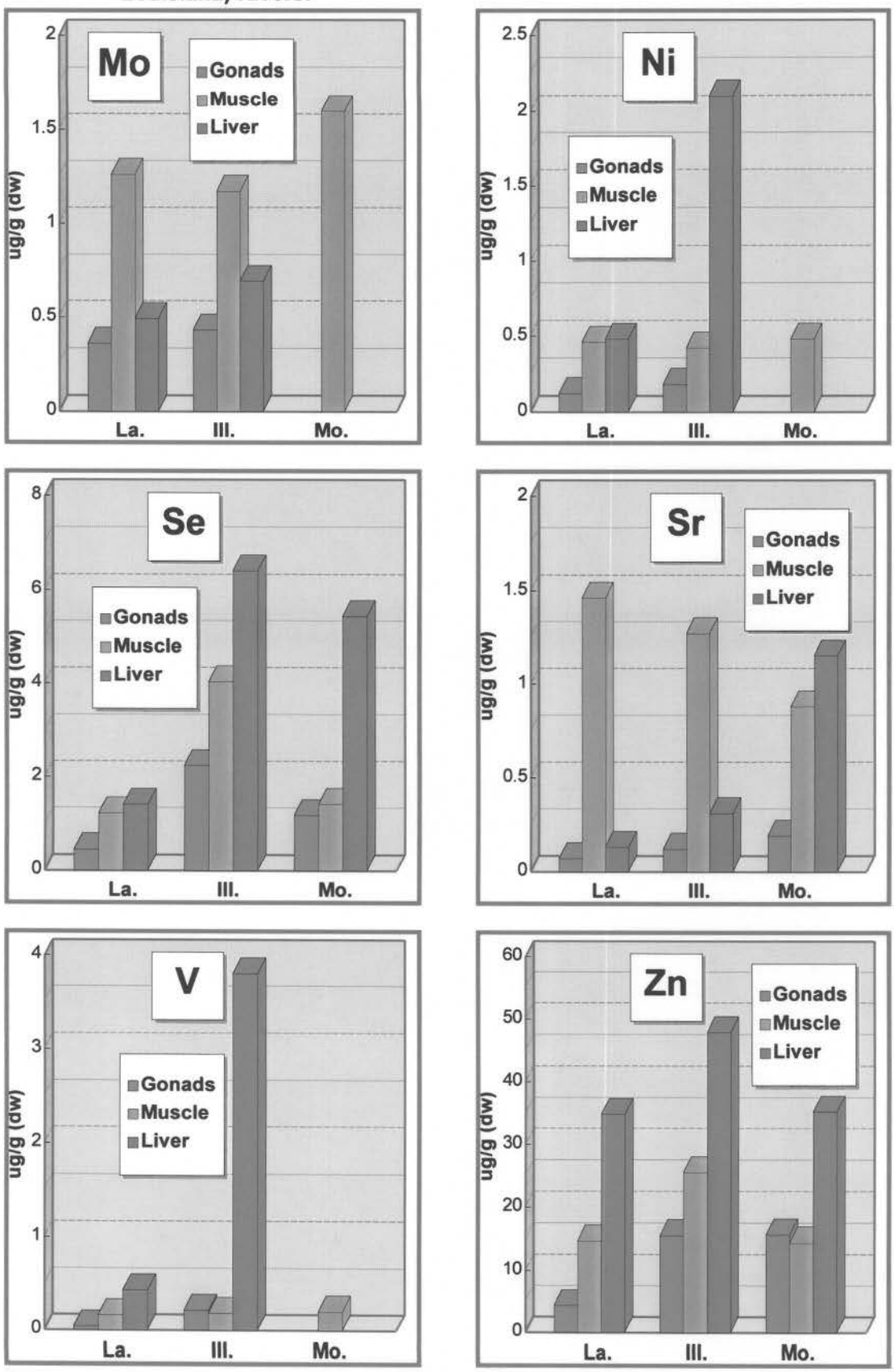


Figure 8. Trace element mean concentrations (ug/g, DW) detected in pallid sturgeon gonads, muscle, and liver (Ruelle and Henry 1994b) from the Missouri (Missouri), upper Mississippi (Illinois) and lower Mississippi (ORCS, Louisiana) Rivers.



element concentrations that were elevated in Atchafalaya River pallid sturgeon (as compared to those from the upper Mississippi and Missouri Rivers) were arsenic (1.12 μg/g) in gonads, lead (0.98 μg/g) in liver, and copper (17.56 μg/g) in muscle tissues.

Most trace element concentrations were unremarkable; however, cadmium, copper, lead, selenium, and arsenic concentrations were elevated and, except for the latter, warrants environmental concern. Selenium and copper are essential elements (Ganther 1974, Frieden 1972), however, the range between dietary requirement and toxic levels for selenium are relatively narrow (Ganther 1974). The shovelnose selenium mean equaled or exceeded maximum levels observed (Eisler 1985b) in various whole-body freshwater fish species. Ohlendorf (1989) indicated selenium will biomagnify and bioaccumulate. At elevated water levels (0.06 to 0.6 μg/g), inorganic selenium is toxic or can produce pathological changes in a variety of internal organs (Eisler 1985b) and may cause developmental abnormalities, embryo mortality, reduced growth, or reduced survival of young (Ohlendorf 1989). Copper concentrations in shovelnose exceeded those found in freshwater fishes from South Carolina and Georgia (Wiener and Giesy 1979, Winger et al. 1990). Elevated copper levels affect behavior and survival (Waiwood and Beamish 1978), and are synergistic with zinc.

Cadmium is a non-essential element that is carcinogenic, teratogenic, and a probable mutagen. It has been implicated as causing severe deleterious effects on fish and wildlife, and in combination with some metals has synergistic effects (Eisler 1985c). Lead is very toxic and is not required or beneficial to an animal's health. All lead-related effects on reproduction, metabolism, growth, development, behavior, and survival are adverse (Eisler 1988).

The appropriateness of an organism as an endangered species surrogate should be assessed based on similarity of various traits. The trace elements in ORCS shovelnose and pallids exhibited such a similarity when the tissue concentrations of Ruelle and Henry's (1994b) ORCS pallids are combined. ORCS shovelnose and pallids were comparable (i.e., having a differential of 1X to 3X between the two species' trace element concentrations) for cadmium, iron, lead, magnesium, mercury, selenium, strontium, vanadium, and zinc. They differed for aluminum, barium, chromium, manganese, and nickel which ranged from 6X (barium and manganese) to 27X (aluminum) greater in the shovelnose, and for arsenic, boron, and copper which ranged from 4X to 8X greater in the pallid.

Summation ORCS shovelnose sturgeon had higher OC levels than were found in other Atchafalaya Basin fishes. OC levels in ORCS shovelnose sturgeon were comparable to NCBP levels, except for the elevated toxaphene levels in the ORCS sturgeon. This was not remarkable because the Atchafalaya Basin is at the lower end

of the Louisiana cotton-growing region where, historically, toxaphene was used extensively. Generally, individual OC levels in ORCS shovelnose samples were comparable to those in Missouri River shovelnose sturgeon (Figure 1), but toxaphene, p,p'-DDE, and ΣOCs were elevated in the ORCS samples. ORCS APH concentrations were slightly elevated over Missouri River shovelnose (Figure 2), but were comparable to fishes from other areas of Louisiana. ORCS shovelnose trace element levels exceeded NCBP levels, but were lower than Atchafalaya fishes (except for arsenic and selenium). ORCS shovelnose sturgeon trace element levels in general were comparable or less than those in Missouri River shovelnose sturgeon, except for elevated levels of arsenic, copper, and nickel (Figures 3, 4, and 5).

ORCS shovelnose whole-body OCs were comparable to pallid sturgeon fillet concentrations. However, combined pallid sturgeon tissue concentrations, regardless of location, were elevated over ORCS shovelnose sturgeon, and concentrations of toxaphene in ORCS shovelnose sturgeon exceeded the combined-tissue values from Missouri and upper Mississippi River pallid sturgeon. Toxaphene concentrations in ORCS pallid sturgeon (tissues combined) were more than twice as high as ORCS shovelnose sturgeon concentrations. Regardless of location, pallid sturgeon combined tissues exhibited higher elemental concentrations than ORCS shovelnose, except for aluminum, barium, chromium, magnesium, manganese, nickel, and strontium.

The organic contaminant concentrations in the two larger (i.e., assumed to be older) shovelnose sturgeon (specimens 9 and 10) are problematic. It is generally assumed that the greater an animal's longevity, the higher the contaminant body burden that can be expected. However, in the case of ORCS shovelnose sturgeon this is not the case. Specimen 9 had the highest ΣOCs concentration, yet it also had the lowest ΣPAHs and ΣAPHs. Conversely, specimen 10 had the greatest ΣPAHs and ΣAPHs and one of the lowest ΣOC body burdens of all ORCS sturgeon. The trace element concentrations for these two specimens failed to demonstrate a similar dichotomy, probably resulting from variation in their lifetime exposure.

CONCLUSIONS

In general, contaminant concentrations in the shovelnose sturgeon were intermediate between the less-contaminated Atchafalaya Basin fishes (other than sturgeon) and the ORCS pallid sturgeon. ORCS shovelnose sturgeon (whole-body) carried body burdens of organic compounds (ΣOCs and ΣAPHs) twice those of shovelnose sturgeon from other areas. This trend generally held true for trace element concentrations as well.

The geographic difference in organic concentrations for pallids was similar to that of the shovelnose, with Louisiana pallids exhibiting higher ΣOCs and ΣAPHs than their northern

counterparts. The opposite was observed for trace elements, with pallids from the Missouri River and upper Mississippi River having higher inorganic body burdens than ORCS pallids.

The few PAHs detected (and at low levels) indicate no reason for concern. The APH evaluation indicated all specimens were exposed to petrogenic sources of hydrocarbons; half were highly exposed and the results for the remaining half were ambiguous.

Trace elements, many of which are essential for sustaining life, can adversely affect reproduction, development and ultimately may be lethal if concentrations are excessive. Most trace element levels were unremarkable; however, cadmium, copper, lead, and selenium concentrations were elevated in ORCS samples and may warrant concern.

OC concentrations are the main environmental concern in Louisiana's shovelnose sturgeon, and consequently, in the pallid sturgeon. Shovelnose OC concentrations were generally greater than were observed in fishes from other areas, and ORCS shovelnose sturgeon toxaphene levels (as well as ORCS pallid sturgeon) were elevated compared to the NCBP. Toxaphene concentrations at whole-body levels as low as 0.4 μg/g have been demonstrated to be lethal and/or cause chronic toxicosis to freshwater teleost fish (Cohen et al. 1982, Eisler 1985a). Toxaphene possesses known carcinogenic, teratogenic, xenotoxic, and mutagenic properties; can cause suppression of the immune system; and function as an endocrine system imitator, blocker, or disruptor (Colburn and Clements 1992). Those factors, in combination with the high ΣOCs, make toxaphene the greatest OC concern in ORCS shovelnose sturgeon and, by extension, the ORCS pallid sturgeon.

In examining the similarities and differences between shovelnose and pallid sturgeon, Ruelle and Keenlyne (1994) concluded that while the shovelnose may not meet all the traits desired for a surrogate, it may be the best available for contaminant studies. Dissimilarities are to be expected with two separate, valid species; however, it is doubtful a better surrogate exists. The information presented herein tends to corroborate this conclusion. In addition, the comparisons suggest that extrapolation of pallid contaminant levels from analyses of shovelnose sturgeon will require further evaluation, (e.g., analyses of ORCS shovelnose sturgeon tissues to fully validate that conclusion). This study indicates that shovelnose contaminant data should be interpreted as conservative estimates of expected pallid sturgeon contaminant body burdens.

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