Bull. Environ. Contam. Toxicol. (1993) 50:898–906

Bulletin of Environmental Contamination and Toxicology

Contaminants in Missouri River Pallid Sturgeon

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Pallid sturgeon (Scaphirhynchus albus) are large river fish which inhabit the main-stems and major tributaries of the lower Mississippi River and Missouri River. Pallid sturgeon habitat within our study area, the upper Missouri River, has been modified by a series of reservoirs created by large dams. Dams have eliminated spawning habitat, blocked fish passage, and have altered water quality.

Pallid sturgeon populations have declined in recent years. Pallid sturgeon, an endangered species, have not reproduced in the wild for over ten years (U.S. Fish and Wildlife Service 1990). Our study objective was to identify and quantify inorganic and organochlorine compounds in pallid sturgeon tissues from the upper Missouri River to assess whether contaminants could be associated with reduced reproduction.

MATERIALS AND METHODS

Tissues from only three of these rare fish could be obtained for contaminant analyses. One fish was collected in Nebraska and two in North Dakota which represented 1,685 km of pallid sturgeon range.

The Nebraska fish (NPS) was a ten-year-old immature female taken at river km 856 near Auburn, Nemaha County, Nebraska. A 41-year-old female (NDP) was collected below Garrison Dam and upriver of the Oahe Reservoir headwaters at river km 2039.4 near Fort Rice, Morton County, North Dakota. A 37-year-old male (GPP) was collected at the headwaters of Lake Sakakawea near the mouth of the Yellowstone River at river km 2524.8. Pertinent data on the fish are reported in Table 1.

Age estimates were obtained from sections of the leading pectoral fin viewed under a compound microscope. Annuli were interpreted by standard methods (Cuerrier 1951).

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Table 1. Vital statistics on Missouri River pallid sturgeon from which tissues were collected for analyses.

Sample I.D. Number	Percent Moisture	Tissue Analyzed	Collection Location & River km	Date Collected	Age	Sex	Weight Grams	Total Length mm	Fork Length mm
NPS-1	8.10	Ovary	Auburn, NE/856	April 4, 1988	10	F	2,239	959	864
NPS-2	64.60	Liver							
NPS-3	76.70	Kidney							
NPS-4	74.60	Muscle							
NDP-1	48.20	Muscle	Fort Rice, ND/ 2039.4	May 14, 1983	41	F	17,110	1,575	1,404
NDP-2	50.20	Eggs							
NDP-3	51.00	Liver							
NDP-4	54.50	Liver							
NDP-5	50.70	Eggs							
NDP-6	75.10	Kidney							
NDP-7	52.40	Muscle							
GPP-1	59.30	Muscle	McKenzie County, ND/2524.8	May 24, 1988	37	M	10,000	1,314	1,244
GPP-2	75.80	Kidney							
GPP-3	39.60	Testes							
GPP-4	64.80	Liver							
GPP-5	49.60	Liver							
GPP-6	51.30	Muscle							

Fish were weighed to the nearest gram, and length was recorded to the nearest mm.

Gonad, liver, kidney, and muscle tissues were surgically taken from each fish, frozen in chemically clean jars and shipped on dry ice to the analytical laboratory. The gas chromatograph/mass spectrometry method was used by Texas A & M Research Foundation, College Station, Texas to analyze for organic compounds. Atomic absorption methods were used by the Research Triangle Institute, Research Triangle Park, North Carolina to analyze for arsenic, mercury, and selenium. Other elements were analyzed by inductively coupled plasma emission spectroscopy (ICP) with preconcentration. Laboratory quality control was conducted by the Patuxent Analytical Control Facility of the U.S. Fish and Wildlife Service. Inorganic and organic analytical results are reported in mg/kg dry weight, and mg/kg wet weight respectively.

RESULTS AND DISCUSSION

Nothing is recorded in the literature on concentrations of contaminants in pallid sturgeon; therefore, we compared our data with contaminant concentrations reported in tissues of other fish. The spawning cycle for pallid sturgeon is unknown. Conte et al. (1988) indicate that most female sturgeon species do not mature until several years of age, and several years are required for eggs to mature between spawnings. Delayed maturation, coupled with multi-year egg development, would be a great disadvantage to fish that inhabit waters polluted with chemicals that concentrate in reproductive tissues. For example, organochlorine compounds (like PCB's) are lipophilic and known to concentrate in eggs (Vodicnik and Peterson 1985).

We identified several contaminants which may cause adverse impacts to pallid sturgeon. Pertinent data and analytical results are reported in Tables 1-2. Tissues varied in moisture content from 8.10 percent in testes to 76.70 percent in kidneys; therefore, moisture content of tissue samples are also reported (Table 1).

Bridges et al. (1963) determined the concentrations of DDT and metabolites in tissues from six black bullheads (Ictalurus melas) from a pond treated with DDT. DDT was not detected in muscle or liver 16 months after treatment, 0.1 mg/kg was detected in ovary tissue. DDE was detected at higher concentrations than DDD in all tissues with the highest concentration in muscle, and lower concentrations in liver and ovary respectively 16 months after treatment.

DDT was banned from use in the United States in 1974; however, metabolites of DDT (DDD and DDE) were found in all tissues we analyzed. Concentrations of p,p' DDT ranged between 0.08 mg/kg and 0.44 mg/kg with the highest concentration being detected in ovaries of the Nebraska fish. In eggs, DDE at 2.12 mg/kg was the most elevated DDT derivative with lower concentrations of DDD at

Table 2. Concentrations of organic contaminants (mg/kg wet weight) in pallid sturgeon tissues collected from North Dakota and Nebraska.

Sample I.D. Number	Tissue	Oxyclor-dane	Gamma-chlordane	Alpha-chlordane	C-Non-achlor	T-Non-achlor	Hept-achlor	Hepta-chlor epoxide	O,P'DDE	P,P'DDE	O,P'DDD	P,P'DDD	O,P'DDT	P,P'DDT
NPS-1	Ovary	0.34	1.30	1.27	0.74	1.98	<0.01	0.17	<0.01	3.10	0.17	1.11	0.41	0.44
NDP-1	Muscle	0.04	0.04	0.04	0.06	0.05	<0.01	<0.01	0.12	3.56	0.08	1.24	0.44	0.26
NDP-2	Eggs	0.01	0.02	0.03	0.03	0.03	<0.01	<0.01	0.07	2.12	0.06	0.06	0.18	0.13
NDP-3	Liver	0.02	0.03	0.03	0.04	0.06	<0.01	0.01	0.10	3.78	0.16	1.71	0.10	0.08
GPP-5	Liver	0.05	0.07	0.04	0.08	0.15	<0.01	0.03	<0.01	2.82	0.02	0.25	0.13	0.14
GPP-6	Muscle	0.07	0.07	<0.01	0.12	0.20	<0.01	<0.01	<0.01	3.67	0.03	0.30	0.10	0.15

Table 2. - Continued

Sample I.D. Number	Tissue	Total PCB's	Endrin	Dieldrin	Aldrin	Alpha BHC	Beta BHC	Gamma BHC	Delta BHC	Hexa-chloro-benzene	Total BHC's	Mirex	Toxa-phene
NPS-1	Ovary	28.52	<0.01	1.30	0.16	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	<0.01	<0.10
NDP-1	Muscle	2.41	<0.01	0.05	<0.01	0.10	<0.01	<0.01	<0.01	<0.01	0.10	<0.01	<0.10
NDP-2	Eggs	1.18	0.02	0.06	<0.01	0.08	0.16	0.05	<0.01	0.01	0.29	<0.01	<0.10
NDP-3	Liver	1.72	0.01	0.05	<0.01	0.09	0.03	0.06	<0.01	<0.01	0.19	<0.01	<0.10
GPP-5	Liver	20.51	0.09	0.08	<0.01	<0.01	0.11	0.05	<0.01	0.01	0.16	<0.01	<0.10
GPP-6	Muscle	25.36	0.02	0.14	<0.01	<0.01	0.15	0.09	<0.01	<0.01	0.18	<0.01	<0.10

0.06 mg/kg and DDT at 0.18 mg/kg being detected. The p,p' DDT found in all tissues in this study suggests that fish are being continually exposed to the parent compound.

Concentrations of p,p' DDD ranged between 0.06 mg/kg and 1.71 mg/kg with the highest concentration being detected in liver tissues. The p,p' DDE isomer was elevated in all tissues and ranged between 2.12 mg/kg and 3.78 mg/kg with the highest concentration being present in the liver of the Fort Rice fish. Organic analytical results are reported in Table 2.

DDT and its metabolites are highly persistent in the environment. It is common for DDT and its metabolites, DDD and DDE, to accumulate in fish (Kenaga and Goring 1980). Macek et al. (1979) indicated that fish likely accumulate DDE through their diet. The detection of DDT metabolites in our study suggests that the piscivorous pallid sturgeon were exposed to considerable dietary loads of DDT which were metabolized or that they received continued loading of DDT metabolites through the food chain.

The effects of DDT concentrations detected in this study on the reproductive health of pallid sturgeon are unknown. If not implicated directly, DDT and its metabolites can create physiological alterations to the balance of serum amino acids and thyroid activity which can affect the general ability of the animal to withstand stress (White et al. 1983). Although it is not possible to determine from the literature whether DDT or derivative compounds may cause reproductive failure, reduced survival of young, or population declines in pallid sturgeon, the concentrations are high enough to be of concern, especially in view of loading with other chemical insults like PCB's (Berlin et al. 1981).

PCB's are relatively stable compounds that are known to persist in the environment for 25 years or longer (U.S. Fish and Wildlife Service unpublished data). PCB toxicity varies among species and, when present in fish ovaries, reduces reproductive success. Wet weight PCB threshold values, beyond which reduced survival of developing eggs can be expected, can be as low as 0.12 mg/kg for Baltic flounder (Platichthys flesus) or as high as 24 mg/kg for cyprinid minnows (Phoxinus phoxinus) (Ernst 1984). Four samples had concentrations that exceeded the Food and Drug Administration's (FDA) action level of 2.0 mg/kg wet weight for PCB's in edible fish tissues. Several tissues contained elevated PCB concentrations: gonadal tissues from the Nebraska fish - 28.52 mg/kg (31.03 mg/kg dry weight), liver of the McKenzie County fish - 20.51 mg/kg (49.69 mg/kg dry weight), and muscle of the McKenzie County fish - 25.36 mg/kg (52.07 mg/kg dry weight). Therefore, PCB could be suspected of causing reproductive or other health related problems in pallid sturgeon.

Chlordane was commonly used in the past for termite control. Most termite treatment areas in the Missouri River basin are located downstream of Omaha, Nebraska. In 1978, the Environmental

Protection Agency placed use restrictions on chlordane and, in 1980, banned it for farm and agricultural use. Chlordane persists in the environment and concentrations in three samples analyzed exceeded the FDA action level of 0.3 mg/kg for fish. Chlordane was elevated in ovarian tissue of the Nebraska fish (highest concentrations being gamma chlordane at 1.30 mg/kg and alpha chlordane at 1.27 mg/kg). Ovarian tissues of this fish also had elevated concentrations of trans-nonachlor (1.98 mg/kg). Upper river fish exhibited low chlordane loads. Chlordane concentrations were equal to or less than 0.07 mg/kg in all tissues of the two North Dakota fish.

Dieldrin was banned in the United States in 1974. It, like chlordane, was used extensively in the past for subterranean termite treatment in urban areas, and so one might expect to find it in the lower study reach. Nebraska issued a dieldrin human health advisory for Missouri River fish in June 1991 after finding elevated concentrations in channel catfish (Ictalurus punctatus) and common carp (Cyprinus carpio). Grzenda et al. (1972) reported dieldrin concentrations of 0.089, 0.020, and 0.022 mg/kg wet weight in muscle tissue of three different groups of goldfish. All pallid sturgeon muscle tissue analyzed in this study contained dieldrin; however, none exceeded the FDA action level of 0.3 mg/kg for edible fish tissue. Grzenda et al. (1972) reported 0.057 mg/kg wet weight of dieldrin in goldfish ovary. The highest dieldrin concentration (1.3 mg/kg) was detected in the ovarian tissue of the Nebraska fish (Table 2).

Benoit et al. (1976) reported that kidney, liver and gill tissues accumulated the greatest amount of cadmium for brook trout (Salvelinus fontinalis). Mercury concentrations in livers of common carp from the upper Mississippi River ranged from 0.092 to 7.92 mg/kg dry weight (Wiener et al. 1984). They also reported selenium concentrations in common carp livers of 2.18 to 5.26 mg/kg. Elements in all our fish tissues were at background concentrations except for cadmium, mercury and selenium. In our study, highest cadmium concentrations were in kidney tissues and ranged from <0.50 mg/kg to 1.03 mg/kg. The FDA action level for mercury is 1.00 mg/kg wet weight. Mercury concentrations exceeded 1.00 mg/kg in 9 of 11 tissues analyzed. Highest mercury concentrations (16.00 mg/kg) and highest selenium concentrations (7.66 mg/kg) were detected in the liver of the McKenzie County fish. However, relatively low concentrations of selenium were noted in gonadal (0.58 mg/kg) and kidney (1.74 mg/kg) tissues from this male fish.

Some inorganics, especially selenium, are known to concentrate in eggs and can inhibit reproduction (Ohlendorf et al. 1981). Cadmium toxicity to fish can be represented as decreased standing crop, decreased growth, or inhibited reproduction (Eisler 1985). No literature sources suggest levels which may affect reproduction or other life functions for either cadmium or mercury, so our results only document that these elements have accumulated in pallid sturgeon at fairly high concentrations.

Selenium is a naturally occurring element found in high concentrations in glacial deposits and upper cretaceous formations. Selenium was found to be highest in liver tissue of all three fish with the highest concentration of 7.66 mg/kg being found in the McKenzie County fish. Cumbie and Van Horn (1978) reported that in Belews Lake, North Carolina, excessive selenium adversely impacted fish reproduction, induced fish mortality, and resulted in significant population declines. Ovaries in fish from this lake with selenium concentrations ranging from 1.57 mg/kg to 41.7 mg/kg wet weight exhibited numerous necrotic or ruptured egg follicles which contributed to reproductive failure (Sorensen et al. 1984). Eggs of the Fort Rice, North Dakota, fish had a selenium concentration of 2.39 mg/kg dry weight (1.18 mg/kg wet weight) which was below those concentrations where reproductive problems were noted.

No contaminant data exists in the literature on pallid sturgeon with which we can compare our data. And little data exists on the effects of multiple insults of contaminants on fish reproduction. However, several contaminants were found at concentrations high enough to suggest that contaminants can be affecting pallid sturgeon reproduction in the upper Missouri River. Contaminants of greatest concern would be several heavy metals (mercury, cadmium, and selenium) and organic compounds (PCB's, chlordane, dieldrin, and DDT and its isomers).

Acknowledgments. We thank Laura Jenkins, U.S. Fish and Wildlife Service, Panama City, Florida, for processing and reading pectoral fin sections, and Steve Hamilton, U.S. Fish and Wildlife Service, Yankton, South Dakota, for providing a technical and editorial review of the manuscript.

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Received March 10, 1992; accepted December 7, 1992.