

**A preliminary ecotoxicological assessment of Asian carp species in the
Mississippi and Illinois Rivers**

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Abstract

Asian carp were collected for a preliminary toxicological screen of some priority pollutants. One sample site was in the Illinois River near Havana, while the other two sites were in the Mississippi River, one in Pool 25 and one site in Pool 26 below the confluence of the Illinois River. Five bighead carp (*Hypophthalmichthys nobilis*) and 5 silver carp (*Hypophthalmichthys molitrix*) from each site were collected for muscle tissue analysis. Contaminants differed between species and among sites. Selenium and arsenic levels were higher in silver carp, with selenium levels higher in fish tissues at the Illinois site.

Introduction

Two species of carp native to Asia, the bighead carp (*Hypophthalmichthys nobilis*) and silver carp (*Hypophthalmichthys molitrix*), have recently established populations in the Illinois and Mississippi Rivers (Chick and Pegg 2001). Concerns about the impact of these two species on the native fish communities have typically focused on direct and indirect competition for food resources (e.g., Radke and Kahl. 2002, Schrank et al. 2003). There is great concern about the potential for these fish to become established within the Great Lakes. A lot of time and effort has been directed at preventing these Asian carps from becoming established in the Great Lakes. The perception is that the impacts in the Great Lakes could be significant given the impact of other filter-feeding non-native species (e.g., zebra mussels and quagga mussels) already established in most of the Great Lakes Basin. It is not likely that these carp can be eliminated from the Illinois and Mississippi rivers, but efforts to reduce their impact should be investigated.

One potential management mechanism for reducing bighead and silver carp populations in the Mississippi and Illinois rivers is to encourage commercial harvest of these species (Nuevo et al. 2004). Recent inquiries suggest that markets for these carps could be developed for both human and animal consumption. Another potential option is their use as a protein media for pharmaceuticals. A major roadblock to the development of these carps is a lack of knowledge of how safe the fish are for consumptive purposes. Specific concerns focus on the level of bioaccumulation of several known contaminants found in the Illinois and Mississippi river basins: total and methyl mercury, total PCBs, selective pesticides/herbicides (like Atrazine), and trace metals.

To address the concerns about potential contaminants in silver and bighead carp we conducted an initial ecotoxicological screen. Fish were collected from one site in the Illinois River and at two sites in the Mississippi River. Muscle tissue was analyzed for a variety of compounds in bighead and silver carp.

Methods

Fish collection

Bighead carp (*Hypophthalmichthys nobilis*) and silver carp (*Hypophthalmichthys molitrix*) were obtained from 3 sites (Figure 1), one in the Illinois River, and two sites

within the Mississippi River (Pool 25, 26). Fish were collected from the Illinois River at Havana, IL. The upper Mississippi River site is located above the Illinois River confluence (Pool 25) and the lower site is located downstream of the confluence (Pool 26). Five fish of each species were collected per site (30 total). Fish were collected by INHS personnel using trammel nets or obtained through commercial fishermen (upper Mississippi site). Upon collection, fish were immediately put on ice and later frozen.

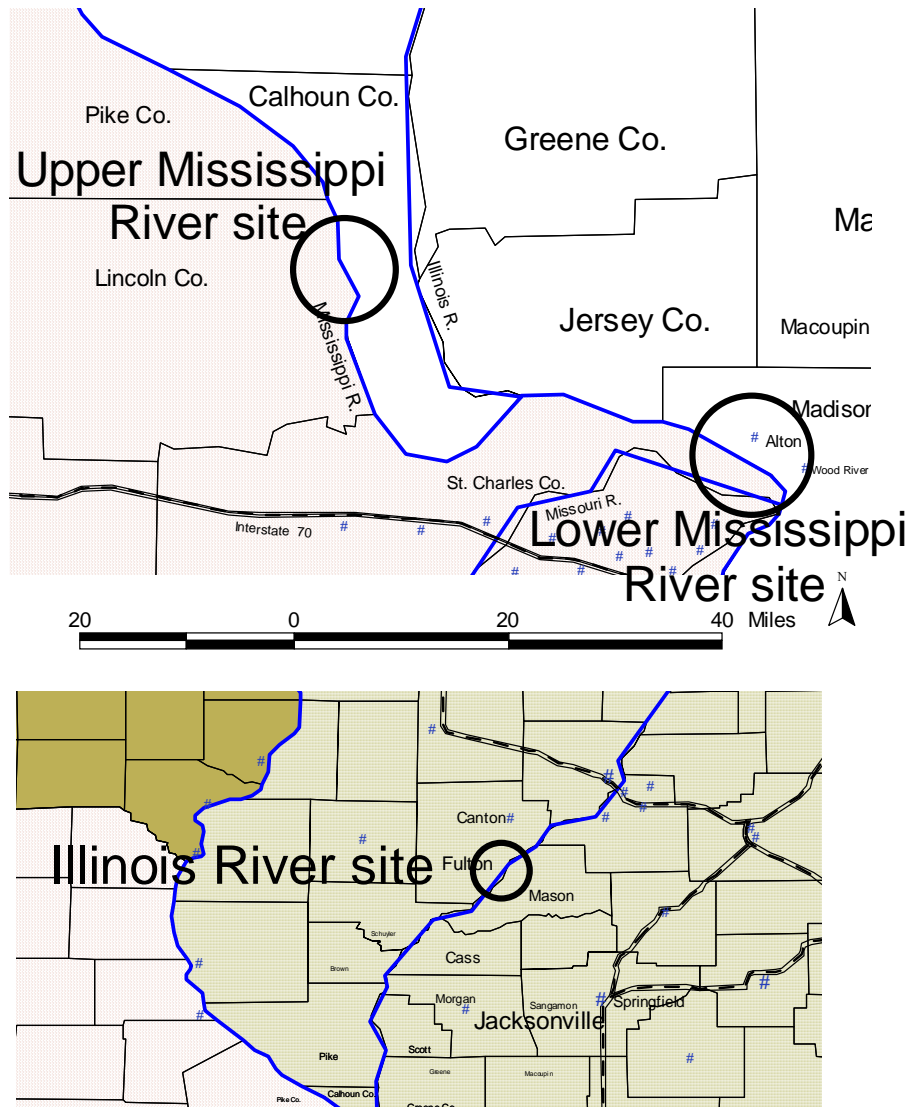


Figure 1. Asian carp sampling sites

Laboratory procedures

Fish were measured for total length to the nearest cm in the laboratory (tip of nose to end of the squeezed caudal fin). Two tissue samples were obtained from the left side of the

fish, at a location just below the dorsal fin and above the lateral line. A muscle fillet of about 10 x 6 x 4 cm was excised with a stainless steel knife. The skin was left intact. A smaller tissue sample of approximately 1 cm squared (skin intact) was also removed from the same area. Tissue samples were placed in separate Whirlpack® bags with identifying labels. Tissue samples were delivered to Carbon Dynamics Institute, LLC (Springfield, IL) for analyses. All fish were individually analyzed for organohalides, and selected elements (Cr, Ni, Cu, As, Se, Hg₂₀₀, Hg₂₀₂, Pb). For semi-volatile organic compound(s), base neutral acid extractable compounds (CDI SOP TA-TN-GMT-1625 Revision A) composite samples were used, meaning one composite sample (5 fish) per species was collected per site.

The samples were homogenized (without skin) and were partitioned in appropriate amounts that best represented the character of each sample submitted for each subsequent analysis to be performed. There were three analyte groups of interest for this investigation: organo-halide pesticides (including PCBs), base neutral acid extractable compounds (e.g. PAHs and phthalates) and nine elements (Cr, Ni, Cu, As, Se, Ag, Cd, Hg and Pb). Three specific methods were used to determine the presence of the Target Compound List analytes: organo-halide pesticides (CDI SOP TA-TN-1656 Revision A), certain base neutral acid extractable compounds (CDI SOP TA-TN-GMT-1625 Revision A) and for metals (CDI SOP TA-TN-IMQ Revision 0).

This section summarizes the method used to determine the presence of organo-halide pesticides, including PCBs, in accordance with CDI SOP TA-TN-1656, Revision A:

1. A measured volume of approximately 10 grams of sample was homogenized and dried with sodium sulfate, then extracted with a methylene chloride: hexane solution (1:1) in a Soxhlet extractor. The organic extract was concentrated to approximately 5 mL and subjected to GPC cleanup. The extract was re-constituted to 1 mL of hexane and analyzed by gas chromatography mass spectrometry with a negative chemical ionization source (GC/MS/NCI).
2. Qualitative identification of the parameters in the extract was performed using the retention time and relative abundance of two or more characteristic masses (m/z). Quantitative analysis was performed using internal standard techniques with a single characteristic m/z.
3. Non-target compounds are identified by comparing resultant mass spectra from the non-target compounds to mass spectra contained in the Mass Spectral Library. Non-target compounds are quantitated by comparing MS response from the reconstructed ion chromatogram for the non-target compound peaks to the MS response produced by the nearest internal standard using an assumed response factor of one.
4. The final report issued for each sample lists on the target compounds identified from the Target Compound List was provided by the Project Manager.

This section summarizes the method used to determine the presence of certain base neutral acid extractable compounds (semi-volatile organic compounds) in accordance with CDI SOP TA-TN-1625 Revision A:

1. A measured volume of homogenized sample, approximately ten (10) grams, was dried with sodium sulfate) and then extracted with an organic solvent mixture of Methylene Chloride: Acetone (1:1) in a Soxhlet extractor. The organic extract was concentrated to approximately 5 mL and subjected to GPC cleanup. The extract was re-constituted to 1 mL of methylene chloride and analyzed by gas chromatography mass spectrometry with an electron ionization source (GC/MS/EI).
2. Qualitative identification of the parameters in the extract was performed using the retention time and relative abundance of two or more characteristic masses (m/z). Quantitative analysis was performed using internal standard techniques with a single characteristic m/z.
3. Non-target compounds are identified by comparing resultant mass spectra from the non-target compounds to mass spectra contained in the Mass Spectral Library. Non-target compounds are quantitated by comparing MS response from the reconstructed ion chromatogram for the non-target compound peaks to the MS response produced by the nearest internal standard using an assumed response factor of one.
4. The final report issued for each sample lists on the target compounds identified from the Target Compound List was provided by the Project Manager.

This section summarizes the method used to determine the presence of certain elements in accordance with CDI SOP TA-TN-IMQ Revision 0:

1. A pre-measured volume of approximately one gram of tissue was acid digested with HNO₃ and H₂O₂ in accordance with the appropriate sample preparation methods described in EPA OSW Methods 3050B and 6020 prior to filtration. Interference check and quality control solutions were also prepared.
2. Multi-elemental determination of analytes is achieved by the measurement of ions produced by radio-frequency inductively coupled plasma where analyte species are nebulized and the resultant aerosol is transported by argon gas into the plasma torch. Ions produced in the plasma are sorted according to their mass-to-charge ratios and quantified with a channel electron multiplier. Appropriate internal standards were used in the analysis.
3. Qualitative identification of the parameters in the digest was performed using the most abundant isotopic characteristic masses (m/z). Quantitative analysis was performed using internal standard techniques with a single characteristic m/z.
4. The final report issued for each of the sample lists of the elements identified from the TCL was provided by the Project Manager.

Statistics

The vast majority of organic compounds analyzed were below the detection limit, as a result no comparisons among sites or between fish species were made of organic compounds. Most of the elements analyzed were detected in fish with the exception of silver and cadmium. As numerous elements in tissues are correlated with one another, differences between species and among sites were investigated with discriminant function

analyses. Mercury levels in two fish were below detection levels, to include these fish in the discriminant analyses half the detection level was used. Elemental levels were log transformed to approximate normality for analyses. In addition, samples were weighted by fish length, as fish length was correlated with a number of element concentrations. One-way analyses of variance (ANOVAs) were conducted on individual elements. This was restricted to elements that were identified as important in the discriminant analyses.

Results

Complete analytical results are listed in Appendix 1 and 2.

Organohalides

Organohalide levels in most fish muscle tissues were below detection limits. The few compounds detected were: chlordane, hexachlorobenzene, and one of the PCBs (Aroclor 1260).

Semi-volatile organic compounds (base neutral acid extractable compounds)

For most semi-volatile organic compounds, levels in fish muscle tissue were below detection limits with the exception of some of the phthalates (diethyl phthalate, di-n-butyl phthalate, butyl benzyl phthalate, and Bis(2-thyhexyl) phthalate).

Metals

A summary of fish metal concentrations in muscle tissue by site and fish species is presented in table 1. For some of the metals, fish length was correlated with concentration across sites and species. Selenium concentrations were negatively correlated with length for both species. Chromium and mercury (^{200}Hg , ^{202}Hg) were positively correlated with fish length in silver carp. Differences between the two species and among sites were investigated using discriminant function analyses. As a number of metals were correlated with fish length, discriminant analyses were weighted by fish length.

Table 1. Geometric mean metal concentration ($\mu\text{g}/\text{kg}$ wet weight) in muscle tissue by site and species.

Site	species	n	^{52}Cr	^{60}Ni	^{65}Cu	^{75}As	^{78}Se	^{109}Ag	^{111}Cd	^{200}Hg	^{208}Pb
IL	s	5	121	69.2	595	36.7	324	U	U	33.1	38.1
IL	bh	5	108	91.1	680	29.6	247	U	U	34.2	37.3
LM	s	5	135	75.6	692	40.5	262	U	U	20.4	64.6
LM	bh	5	117	88.8	670	18.6	205	U	U	82.3	35.5
UM	s	5	92	57.4	739	39.4	191	U	U	61.1	44.0
UM	bh	5	131	66.3	770	23.5	154	U	U	42.3	35.0

bh = bighead carp, s = silver carp, U = below detection limit

Species comparisons (metals)

In the discriminant analysis there was a significant difference in metals concentrations in muscle tissue between the two Asian carp species (Wilk's Lambda 0.3649, $F_{8,21} = 4.568$,

$p=0.0024$). Three fish were incorrectly classified, one bighead and two silver carps (Table 2). Only the first canonical axis was significant explaining 0.7969 percent of the variation in the model. Silver carp were differentiated from bighead carp by having a higher concentration of arsenic, lead, and selenium (Table 1).

Table 2. Discriminant function analysis classification matrix by species

		Predicted	
		Bighead carp	Silver carp
Actual	Bighead carp	13	2
	Silver carp	1	14

Site comparisons

Sample sites were adequately discriminated based on results of the metals analysis (Figure 2). The discriminant analysis was significant (Wilk's Lambda 0.166, $F_{16, 40} = 3.640$, $p=0.0005$). Six fish were misclassified. None of the fish from the upper Mississippi River sample site were misclassified; however, three fish from the lower Mississippi River were classified to the Illinois River site, and one fish was classified to the upper Mississippi River site (Table 3). Fish from the upper Mississippi River site had lower levels of selenium and nickel than fish at the other two sites.

Table 3. Discriminant function analysis classification matrix by site

		Predicted		
		Illinois	Lower Mississippi	Upper Mississippi
Actual	Illinois	8	2	0
	Lower Mississippi	3	6	1
	Upper Mississippi	0	0	10

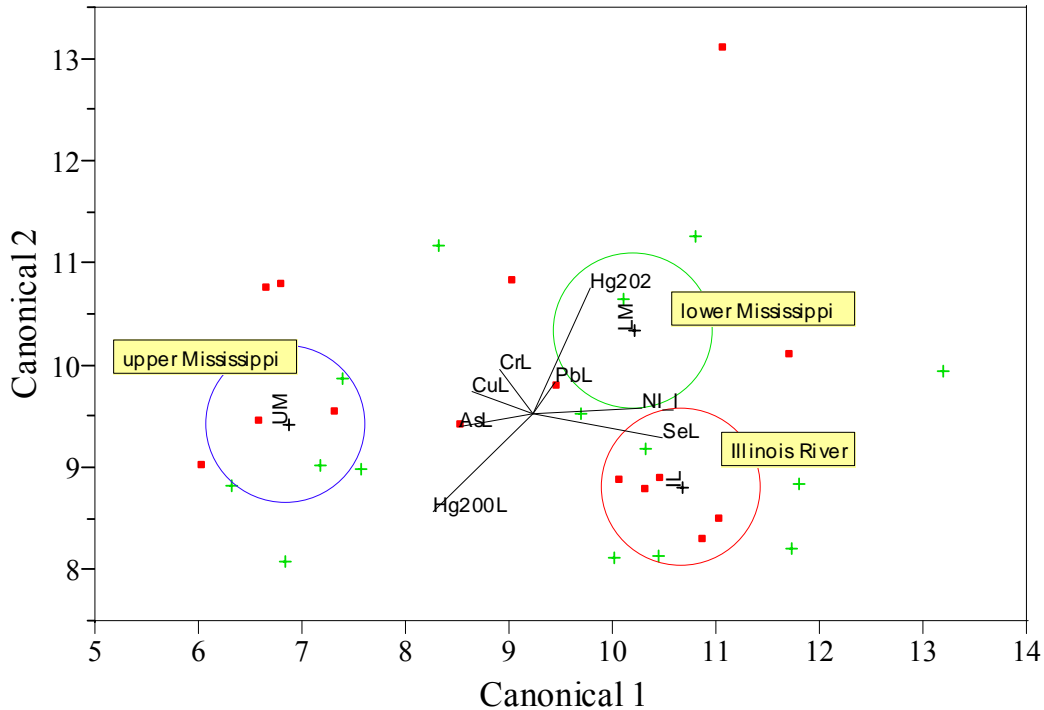


Figure 2. Biplot of a discriminant analysis of sample sites by levels of metals in bighead and silver carp muscle tissue. Non-overlapping circles are significantly different.

Analysis of variance

An analysis of variance was carried out for the three analytes (Se, As, Pb) shown to account for the differentiation between the two species in the discriminant analysis. Selenium and arsenic levels in muscle tissue were significantly different between the species ($p < 0.0001$), whereas only selenium was significantly different among sample sites. The interaction term was not significant for the three analytes (Table 4). Selenium levels were higher in silver carp and in fish collected from the Illinois River compared to bighead carp and the other sites (Figure 3 & 4).

Table 4. ANOVA results for selenium, arsenic and lead, data log-transformed, and weighted by fish length.

Selenium

Source	DF	Sum of Squares	Mean Square	F Ratio	P
Model	5	24.284495	4.85690	11.7200	<0.0001
Error	24	9.945848	0.41441		
C. Total	29	34.230343			

Source	Nparm	DF	Sum of Squares	F Ratio	P
species	1	1	6.325866	15.2647	0.0007
site	2	2	18.723345	22.5903	<0.0001
species*site	2	2	0.081620	0.0985	0.9066

Arsenic

Source	DF	Sum of Squares	Mean Square	F Ratio	P
Model	5	34.807724	6.96154	10.4888	<0.0001
Error	24	15.929158	0.66371		
C. Total	29	50.736882			

Source	Nparm	DF	Sum of Squares	F Ratio	P
species	1	1	25.579714	38.5402	<0.0001
site	2	2	2.281692	1.7189	0.2006
species*site	2	2	4.371923	3.2935	0.0545

Lead

Source	DF	Sum of Squares	Mean Square	F Ratio	P
Model	5	19.18402	3.83680	1.0529	0.4104
Error	24	87.45676	3.64403		
C. Total	29	106.64078			

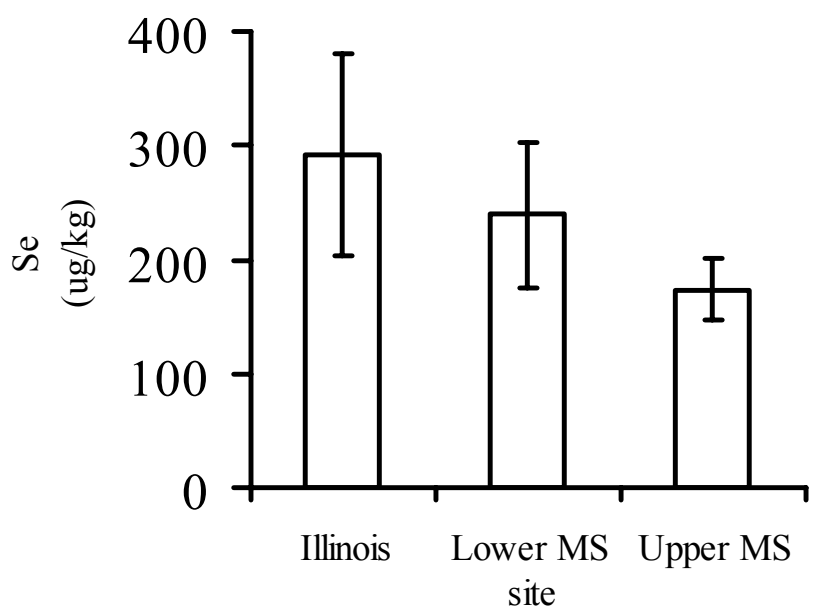


Figure 3. Mean selenium levels in Asian carp muscle by site. Error bars represent standard error.

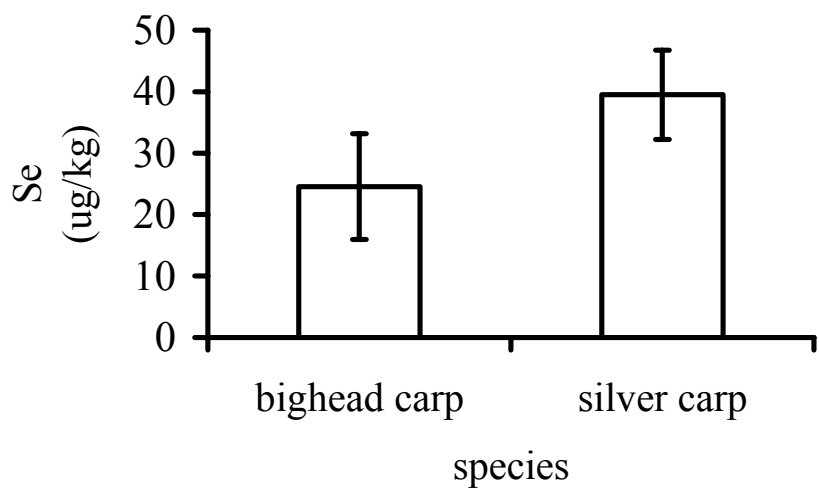


Figure 4. Mean selenium levels in Asian carp muscle by species. Error bars represent standard deviations.

Discussion

Fish contaminants are of high public interest as evidenced by a recent article in Science and the subsequent responses to the article (Hites et al. 2004). The authors present evidence that wild caught salmon are lower in contaminants than farmed salmon. Both farmed and wild caught salmon do not exceed United States Food and Drug Administration (FDA) levels for individual contaminants (U.S. FDA 2001). However, the authors also use the United States Environmental Protection Agencies (EPA) guidance for fish advisories (U.S. EPA 2000) and make fish consumption advisories based on those guidelines. We present the results of the Asian carp analyses with comparisons to listed advisories for individual contaminants.

Fish consumption advisories in the State of Illinois are based on elevated levels of three contaminants: PCBs, chlordane, and mercury. The two tables below give the consumption advisory levels for these chemicals in Illinois (per Thomas Hornshaw, IL – EPA). All Asian carp had PCB levels lower than any Illinois advisory levels and 8 fish had levels of mercury that women of childbearing age, and children less than 15, should restrict themselves to one meal/week (1 silver carp at the Illinois River site; 3 bighead carp at lower MS R.; 1 bighead and 2 silver carps at the upper MS R. site). One of those fish (bighead carp from the lower MS R. site) had a mercury level of 340 µg/kg, equating to an advisory of one meal a month.

Table 5. Illinois advisory structure for PCBs and mercury for women of childbearing age and children <15 (all values µg/kg).

Fish consumption advisory	Levels	Number of fish this study			
		PCB		Mercury	
		silver	bighead	silver	bighead
Unlimited	0 - 50	15	15	12	10
1 meal/week	60 - 220			3	4
1 meal/month	230 - 950				1
6 meals/year	960 - 1890				
Do not eat	≥ 1890				

Table 6. Illinois advisory structure for chlordane and mercury for women beyond childbearing age and adult men (all values µg/kg).

Fish consumption advisory	Levels	Number of fish this study			
		Chlordane		Mercury	
		silver	bighead	silver	bighead
Unlimited	0 - 150	15	15	15	14
1 meal/week	160 - 650				1
1 meal/month	660 - 2820				
6 meals/year	2830 - 5620				
Do not eat	≥ 5620				

Illinois EPA collected and analyzed composites (5 fish) of silver and bighead carp fillets (with skin intact) collected 11 of November 2003 from the Illinois River near Havana (Thomas Hornshaw, IL – EPA). All of the compounds detected in the Illinois EPA composite samples were greater than the maximum levels found in any of the fish we analyzed (Table 7). Some of the differences between our samples and the Illinois EPA samples can be attributed to differences in methods and analysis. Our samples were of individual fish not composites, and skin was removed from the muscle fillets prior to analyses. Fish skin has been shown to have higher levels of persistent organic pollutants (Zabik et al 1996, Bayen et al 2005). Lipid content of both skin and muscle varied along the length of Atlantic salmon (*Salmo salar*), as did levels of persistent organic pollutants including PCBs, which were highest (on a wet weight basis) towards the head with a peak in the central section (Bayen et al. 2005). Our tissue samples were collected from the central section of each fish. Variation in lipid content and contaminants in fish can also vary seasonally (Das et al 2002, Greenfield et al 2005).

Table 7. Illinois EPA Asian carp composite samples collected 11 November 2003 (all values µg/kg).

	Silver carp	Bighead carp
Avg. weight (lbs)	7.76	8.79
Avg. length (inches)	27.2	28.6
% lipid	5.9	1.7
Dieldrin	17	ND
Chlordane	22	ND
PCBs	230	110

ND = not detected

Comparisons of our Asian carp samples to Federal guidelines are listed in Table 8. Screening values are provided by the EPA,

“...to be used as guidance by States, authorized tribes, and EPA in establishing or updating water quality standards for waters of the United States.”(USEPA 2002).

The screening value for recreational fishers is based on the consumption of 0.0175 kg of fish per day (USEPA 2002). The median for silver carp (48.6 µg/kg) across all sites is close to the EPA’s screening value for subsistence fishers (49 µg/kg). At least one silver carp from each site exceeded the EPA screening value of subsistence fishers for mercury. None of the carp muscle tissue samples exceed the EPA screening value of mercury for recreational fishers.

Table 8. Federal action levels, tolerances and guidance levels for poisonous or deleterious substances in seafood (<http://www.cfsan.fda.gov/~ear/nss2-42d.html>), with median and maximum levels detected in Asian carp muscle tissues (all values µg/kg wet weight).

Chemical contaminant	FDA (2001)	EPA SV for		This study			
	Action level	recreational fishers	subsistence fishers	Silver carp		Bighead carp	
				Median values	Max. levels	Median values	Max. levels
Chlordane	300	114	14	< 0.10*	1.71	< 0.10*	3.05
Total DDT (DDT, DDE, TDE) ^a	5000	117	14	< 0.10*	3.68	< 0.10*	0.59
Aldrin/Dieldrin ^b	300	2.5	0.3	< 0.20*	9.76	< 0.20*	0.89
Heptachlor/Heptachlor epoxide ^c	300	4.4	0.54	< 0.10*	10.4	< 0.10*	3.37
Mercury	1000	400	49	48.6 ^d	105 ^d	39.1 ^d	340 ^d
Mirex	100	800	98	NA	NA		
	tolerance level						
PCBs	2000	20	2.5	1.96	11.7	0.66	3.25

SV = screening value

* = these values are the detection limits

a) The action level for DDT, TDE, and DDE are for residues of the pesticides individually or in combination. However, in adding amounts of DDT, TDE, and DDE do not count any of the three found below 0.2 ppm for fish.

b) The action level for aldrin and dieldrin are for residues of the pesticides individually or in combination. However, in adding amounts of aldrin and dieldrin do not count aldrin or dieldrin found at the level below 0.1 ppm for fish.

c) The action level for heptachlor and heptachlor epoxide are for the pesticides individually or in combination. However, do not count heptachlor or heptachlor epoxide found below 0.1 ppm.

d) ²⁰⁰Hg

The only semi-volatile organic compounds detected in fish muscle tissues were phthalates; we believe that this is a result of sample contamination. Plastics are a common source of phthalates (Bosnir et al. 2003), and as fish tissue samples were transported to the lab in plastic bags, it is believed that the bags are the source of phthalates detected in fish tissues (Ackman and Macpherson 1996). The phthalates detected in our Asian carp samples were the same as those detected in a study investigating the migration of phthalate plasticizers into fish wrapped in heavy plastic (Ackman and Macpherson 1996).

Levels of metals in the muscle tissue of bighead and silver carps were fairly low. The most interesting result was the difference in selenium and arsenic levels between the two species. Selenium levels were significantly higher in silver carp compared to bighead carp. Selenium levels are often related to trophic levels of the organism (Mason et al. 2000, Burger et al. 2001). This would suggest that phytoplankton make up a greater

percentage of silver carp diet than in bighead carp. In a stable isotope analysis comparing trophic levels of the silver and bighead carp in lakes, a greater percentage of the bighead carp diet was composed of zooplankton (Xu and Xie 2004). Selenium levels in fish are primarily driven by selenium levels in food that they ingest (Xu and Wang 2002, Hamilton 2004). In our study selenium levels were also linked to fish size, larger fish had lower levels of selenium. Larger fish generally feed on larger organisms, thus the negative correlation of selenium and fish length supports the idea that their diet is composed of more zooplankton than phytoplankton.

It has been reported that arsenic levels tend to be higher in planktivorous fish compared to piscivorous fish (Hunter et al. 1981, Schmitt and Brumbaugh 1990). However in our study arsenic levels in Asian carp (means for silver and bighead were 39.5 and 24.6 µg/kg respectively) were much lower compared to piscivorous fish in other studies where levels were generally a magnitude higher (Schmitt 2002, Watanabe et al. 2003). Canned tuna had a much higher level of arsenic, with a mean of 929 µg/kg (SD =326) in 39 samples (USDA 2004). In 2004 the EPA and FDA issued a fish advisory for women who might become pregnant, are pregnant, nursing mothers and young children, to avoid some fish and eat fish that are lower in mercury (U.S. EPA 2004). Canned light tuna was included in this advisory with a recommendation to eat up to 12 ounces (2 average meals) a week. Table 9 provides a comparison between contaminant levels in Asian carp with those found in canned tuna.

Table 9. Comparison of some priority pollutants found in tuna, canned in oil* (USFDA 2003, 2004) compared to Asian carp sampled in this study (Results in µg/kg).

Analyte	FDA Market Basket Study*		Asian carp this study			
	Canned tuna in oil		Silver carp		Bighead carp	
	N	Mean	N	Mean	N	Mean
DDE, p,p'	10	0.9	0	<0.20 [#]	0	<0.20 [#]
dieldrin	10	0.5	3	3.78	3	0.53
Hexachlorobenzene	1	0.5	14	2.48	12	1.30
PCBs	1	45.0	12	3.25	8	0.89
Arsenic	39	929	15	39.5	15	24.6
Cadmium	40	21	0	<0.90 [#]	0	<0.90 [#]
Copper	39	460	15	702	15	714
Lead	40	1	15	53.7	15	39.6
Selenium	39	711	15	267	15	203
Hg	40	163	15	48.8 ^a	15	70.0 ^a

*Only results of positive tests reported – sample size was generally 40.

[#] Detection level, levels were below detection level

a) ²⁰⁰Hg

Comparisons among sites were restricted to the metals, as most of the organic analytes in fish were below detection levels. The discriminant analysis conducted on metals by sites was significant, indicating that metal exposure and uptake differed among sites. Selenium levels drove most of the site differences. Selenium levels were higher in fish collected from the Illinois River, followed by the downstream Mississippi River site, with the fish from the upper Mississippi River site having the lowest selenium levels. This would suggest that the Illinois River is a major contributor of selenium to the Mississippi River. Although there were differences in selenium between sites, the levels were much lower than selenium levels found in canned tuna and other species of fish.

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Appendix 1. Results of organic analysis for Asian carp muscle tissue by species and site.

Analyte	detection limit	IL Silver 1	IL Silver 2	IL Silver 3	IL Silver 4	IL Silver 5	Mean IL Silver
Length (cm)		59	60	59	72	73	64.6
Aldrin	0.10 µg/kg	U	U	U	U	U	.
α-BHC	0.10 µg/kg	U	0.10	0.15	0.47	U	0.24
β-BHC	0.10 µg/kg	U	U	0.76	U	U	0.76
γ-BHC	0.10 µg/kg	U	U	0.25	0.32	U	0.29
δ-BHC	0.10 µg/kg	U	U	U	U	U	.
α-Chlordane	0.10 µg/kg	U	U	0.10	0.17	U	0.14
γ-Chlordane	0.10 µg/kg	U	U	U	0.10	U	0.10
4,4-DDD	0.20 µg/kg	U	U	U	U	U	.
4,4-DDE	0.20 µg/kg	U	U	U	U	U	.
4,4-DDT	0.20 µg/kg	U	U	U	U	U	.
Dieldrin	0.20 µg/kg	U	U	U	U	U	.
Endosulfan I	0.10 µg/kg	U	U	U	U	U	.
Endosulfan II	0.20 µg/kg	U	U	U	U	U	.
Endosulfan Sulfate	0.20 µg/kg	U	U	U	U	U	.
Endrin	0.20 µg/kg	U	U	U	U	U	.
Endrin aldehyde	0.50 µg/kg	U	U	U	U	U	.
Endrin ketone	0.20 µg/kg	U	U	U	U	U	.
Heptachlor	0.10 µg/kg	U	U	U	U	U	.
Heptachlor epoxide	0.10 µg/kg	U	U	U	U	U	.
Hexachlorobenzene	0.50 µg/kg	1.48	1.01	0.95	1.89	0.92	1.25
Methoxychlor	0.20 µg/kg	U	U	U	U	U	.
Toxaphene	2.00 µg/kg	U	U	U	U	U	.
Aroclor 1016	0.50 µg/kg	U	U	U	U	U	.
Aroclor 1221	0.50 µg/kg	U	U	U	U	U	.
Aroclor 1232	0.50 µg/kg	U	U	U	U	U	.
Aroclor 1242	0.50 µg/kg	U	U	U	U	U	.
Aroclor 1248	0.50 µg/kg	U	U	U	U	U	.
Aroclor 1254	0.50 µg/kg	3.35	1.56	U	U	U	2.46
Aroclor 1260	0.50 µg/kg	4.83	0.58	U	0.99	U	2.13
⁵² Cr	19.2 µg/kg	162.10	100.40	129.10	162.10	76.10	125.96
⁶⁰ Ni	1.50 µg/kg	129.70	64.00	64.60	52.80	56.10	73.44
⁶⁵ Cu	8.70 µg/kg	688.90	691.00	489.30	562.90	571.20	600.66
⁷⁵ As	2.70 µg/kg	42.80	36.00	22.80	44.30	42.60	37.70
⁷⁸ Se	1.50 µg/kg	246.40	340.90	302.90	521.50	268.60	336.06
¹⁰⁹ Ag	9.00 µg/kg	U	U	U	U	U	.
¹¹¹ Cd	0.90 µg/kg	U	U	U	U	U	.
²⁰⁰ Hg*	3.25 µg/kg	46.30	74.70	5.00	56.90	40.40	44.66
²⁰² Hg*	2.74 µg/kg	47.10	73.80	5.40	56.70	40.00	44.60
²⁰⁸ Pb**	0.60 µg/kg	35.00	26.20	48.10	24.60	74.00	41.58

U= undetected

Analyte	Detection limit	IL Bighead					Mean IL Bighead
		1	2	3	5	6	
Length (cm)		68	74	67	67	69	69.0
Aldrin	0.10 µg/kg	U	U	U	U	U	.
α-BHC	0.10 µg/kg	4.95	U	U	U	U	4.95
β-BHC	0.10 µg/kg	9.03	U	U	U	U	9.03
γ-BHC	0.10 µg/kg	5.17	U	U	U	U	5.17
δ-BHC	0.10 µg/kg	U	U	U	U	U	.
α-Chlordane	0.10 µg/kg	1.99	0.25	U	U	U	1.12
γ-Chlordane	0.10 ug/kg	1.06	0.12	U	U	U	0.59
4,4-DDD	0.20 µg/kg	U	U	U	U	U	.
4,4-DDE	0.20 µg/kg	U	U	U	U	U	.
4,4-DDT	0.20 µg/kg	U	U	U	U	U	.
Dieldrin	0.20 µg/kg	U	U	0.40	U	U	.
Endosulfan I	0.10 µg/kg	U	U	U	U	U	.
Endosulfan II	0.20 µg/kg	U	U	U	U	U	.
Endosulfan Sulfate	0.20 µg/kg	U	U	U	U	U	.
Endrin	0.20 µg/kg	U	U	U	U	U	.
Endrin aldehyde	0.50 µg/kg	U	U	U	U	U	.
Endrin ketone	0.20 µg/kg	U	U	U	U	U	.
Heptachlor	0.10 µg/kg	U	U	U	U	U	.
Heptachlor epoxide	0.10 µg/kg	U	U	U	U	U	.
Hexachlorobenzene	0.50 µg/kg	U	3.01	1.42	U	0.63	1.69
Methoxychlor	0.20 µg/kg	U	U	U	U	U	.
Toxaphene	2.00 µg/kg	U	U	U	U	U	.
Aroclor 1016	0.50 µg/kg	U	U	U	U	U	.
Aroclor 1221	0.50 µg/kg	U	U	U	U	U	.
Aroclor 1232	0.50 µg/kg	U	U	U	U	U	.
Aroclor 1242	0.50 µg/kg	U	U	U	U	U	.
Aroclor 1248	0.50 µg/kg	U	U	U	U	U	.
Aroclor 1254	0.50 µg/kg	U	U	U	U	U	.
Aroclor 1260	0.50 µg/kg	U	1.90	U	0.66	1.45	1.34
⁵² Cr	19.2 µg/kg	105.30	117.60	97.20	140.20	89.00	109.86
⁶⁰ Ni	1.50 µg/kg	81.00	84.30	115.90	78.10	101.50	92.16
⁶⁵ Cu	8.70 µg/kg	606.40	612.10	625.50	718.40	873.90	687.26
⁷⁵ As	2.70 µg/kg	31.60	27.40	50.40	21.70	24.00	31.02
⁷⁸ Se	1.50 µg/kg	283.10	247.70	270.20	221.80	219.70	248.50
¹⁰⁹ Ag	9.00 µg/kg	U	U	U	U	U	.
¹¹¹ Cd	0.90 µg/kg	U	U	U	U	U	.
²⁰⁰ Hg*	3.25 µg/kg	31.50	39.10	28.20	42.70	31.70	34.64
²⁰² Hg*	2.74 µg/kg	32.60	36.60	26.50	44.00	31.20	34.18
²⁰⁸ Pb**	0.60 µg/kg	34.60	33.10	35.70	50.10	35.40	37.78

U= undetected

Analyte	Detection limit	LMS Silver 1	LMS Silver 2	LMS Silver 3	LMS Silver 4	LMS Silver 5	Mean LMS Silver
Length (cm)		84	64	52	35	34	53.8
Aldrin	0.10 µg/kg	U	U	U	U	U	.
α-BHC	0.10 µg/kg	U	U	U	U	U	.
β-BHC	0.10 µg/kg	U	U	U	U	U	.
γ-BHC	0.10 µg/kg	U	U	0.27	U	U	0.27
δ-BHC	0.10 µg/kg	U	U	U	U	U	.
α-Chlordane	0.10 µg/kg	U	U	U	0.98	U	0.98
γ-Chlordane	0.10 µg/kg	U	U	U	0.73	U	0.73
4,4-DDD	0.20 µg/kg	1.50	0.99	0.48	U	U	0.99
4,4-DDE	0.20 µg/kg	U	U	U	U	U	.
4,4-DDT	0.20 µg/kg	U	U	U	U	U	.
Dieldrin	0.20 µg/kg	U	U	U	U	U	.
Endosulfan I	0.10 µg/kg	U	U	U	U	U	.
Endosulfan II	0.20 µg/kg	U	U	U	U	U	.
Endosulfan Sulfate	0.20 µg/kg	U	U	U	U	U	.
Endrin	0.20 µg/kg	U	U	U	U	U	.
Endrin aldehyde	0.50 µg/kg	U	U	U	U	U	.
Endrin ketone	0.20 µg/kg	U	U	U	U	U	.
Heptachlor	0.10 µg/kg	U	U	U	U	U	.
Heptachlor epoxide	0.10 µg/kg	U	U	U	U	U	.
Hexachlorobenzene	0.50 µg/kg	4.74	1.23	0.75	2.79	U	2.38
Methoxychlor	0.20 µg/kg	U	U	U	U	U	.
Toxaphene	2.00 µg/kg	U	U	U	U	U	.
Aroclor 1016	0.50 µg/kg	U	U	U	U	U	.
Aroclor 1221	0.50 µg/kg	U	U	U	U	U	.
Aroclor 1232	0.50 µg/kg	U	U	U	U	U	.
Aroclor 1242	0.50 µg/kg	U	U	U	U	U	.
Aroclor 1248	0.50 µg/kg	U	U	U	U	U	.
Aroclor 1254	0.50 µg/kg	U	U	U	U	1.24	1.24
Aroclor 1260	0.50 µg/kg	6.19	1.56	U	11.70	1.20	5.16
⁵² Cr	19.2 µg/kg	150.10	117.50	142.60	134.40	135.00	135.92
⁶⁰ Ni	1.50 µg/kg	197.60	86.60	81.00	34.60	51.50	90.26
⁶⁵ Cu	8.70 µg/kg	1062.90	751.90	533.30	410.50	906.70	733.06
⁷⁵ As	2.70 µg/kg	45.30	30.70	39.90	36.80	53.20	41.18
⁷⁸ Se	1.50 µg/kg	245.90	264.10	366.80	159.20	325.10	272.22
¹⁰⁹ Ag	9.00 µg/kg	U	U	U	U	U	.
¹¹¹ Cd	0.90 µg/kg	U	U	U	U	U	.
²⁰⁰ Hg*	3.25 µg/kg	54.10	30.30	50.30	2.10	U	34.20
²⁰² Hg*	2.74 µg/kg	52.90	28.90	48.50	U	3.70	33.50
²⁰⁸ Pb**	0.60 µg/kg	129.70	49.60	56.10	66.00	47.10	69.70

U= undetected

Analyte	Detection limit	LMS	LMS	LMS	LMS	LMS	Mean LMS
		Bighead 1	Bighead 2	Bighead 3	Bighead 4	Bighead 5	
Length (cm)		92	89	76	73	67	79.4
Aldrin	0.10 µg/kg	U	U	U	U	U	.
α-BHC	0.10 µg/kg	U	U	U	U	U	.
β-BHC	0.10 µg/kg	U	U	U	U	U	.
γ-BHC	0.10 µg/kg	U	U	U	U	U	.
δ-BHC	0.10 µg/kg	U	U	U	U	U	.
α-Chlordane	0.10 µg/kg	U	U	U	U	U	.
γ-Chlordane	0.10 µg/kg	U	U	U	U	U	.
4,4-DDD	0.20 µg/kg	0.59	U	U	U	U	0.59
4,4-DDE	0.20 µg/kg	U	U	U	U	U	.
4,4-DDT	0.20 µg/kg	U	U	U	U	U	.
Dieldrin	0.20 µg/kg	U	U	U	U	U	.
Endosulfan I	0.10 µg/kg	U	U	U	U	U	.
Endosulfan II	0.20 µg/kg	U	U	U	U	U	.
Endosulfan Sulfate	0.20 µg/kg	U	U	U	U	U	.
Endrin	0.20 µg/kg	U	U	U	U	U	.
Endrin aldehyde	0.50 µg/kg	U	U	U	U	U	.
Endrin ketone	0.20 µg/kg	U	U	U	U	U	.
Heptachlor	0.10 µg/kg	U	U	U	U	U	.
Heptachlor epoxide	0.10 µg/kg	U	U	U	U	U	.
Hexachlorobenzene	0.50 µg/kg	1.11	0.89	0.78	0.73	1.63	1.03
Methoxychlor	0.20 µg/kg	U	U	U	U	U	.
Toxaphene	2.00 µg/kg	U	U	U	U	U	.
Aroclor 1016	0.50 µg/kg	U	U	U	U	U	.
Aroclor 1221	0.50 µg/kg	U	U	U	U	U	.
Aroclor 1232	0.50 µg/kg	U	U	U	U	U	.
Aroclor 1242	0.50 µg/kg	U	U	U	U	U	.
Aroclor 1248	0.50 µg/kg	U	U	U	U	U	.
Aroclor 1254	0.50 µg/kg	U	U	U	U	U	.
Aroclor 1260	0.50 µg/kg	0.92	U	U	1.88	3.25	2.02
⁵² Cr	19.2 µg/kg	108.90	122.00	103.90	101.00	159.40	119.04
⁶⁰ Ni	1.50 µg/kg	91.20	56.70	78.30	67.00	204.10	99.46
⁶⁵ Cu	8.70 µg/kg	795.60	674.20	642.90	592.70	659.90	673.06
⁷⁵ As	2.70 µg/kg	20.30	19.80	17.00	15.40	21.20	18.74
⁷⁸ Se	1.50 µg/kg	181.10	221.20	216.80	207.40	202.20	205.74
¹⁰⁹ Ag	9.00 µg/kg	U	U	U	U	U	.
¹¹¹ Cd	0.90 µg/kg	U	U	U	U	U	.
²⁰⁰ Hg*	3.25 µg/kg	133.80	116.00	33.20	340.10	21.60	128.94
²⁰² Hg*	2.74 µg/kg	131.60	117.90	34.40	342.50	20.90	129.46
²⁰⁸ Pb**	0.60 µg/kg	91.20	17.50	29.00	34.60	35.30	41.52

U= undetected

Analyte	Detection limit	UMS Silver 1	UMS Silver 2	UMS Silver 3	UMS Silver 4	UMS Silver 5	Mean UMS Silver
Length (cm)		89	90	85	91	85	88.0
Aldrin	0.10 µg/kg	U	U	U	U	U	.
α-BHC	0.10 µg/kg	U	U	U	U	U	.
β-BHC	0.10 µg/kg	U	U	U	U	U	.
γ-BHC	0.10 µg/kg	U	U	U	U	U	.
δ-BHC	0.10 µg/kg	U	U	U	U	U	.
α-Chlordane	0.10 µg/kg	0.29	U	0.20	0.50	0.82	0.45
γ-Chlordane	0.10 ug/kg	0.23	U	0.20	0.32	0.74	0.37
4,4-DDD	0.20 µg/kg	U	U	1.90	2.01	3.68	2.53
4,4-DDE	0.20 µg/kg	U	U	U	U	U	.
4,4-DDT	0.20 µg/kg	U	U	U	U	U	.
Dieldrin	0.20 µg/kg	U	U	0.83	0.76	9.76	3.78
Endosulfan I	0.10 µg/kg	U	U	U	U	U	.
Endosulfan II	0.20 µg/kg	U	U	U	U	U	.
Endosulfan Sulfate	0.20 µg/kg	U	U	U	U	U	.
Endrin	0.20 µg/kg	U	U	U	U	U	.
Endrin aldehyde	0.50 µg/kg	U	U	U	U	U	.
Endrin ketone	0.20 µg/kg	U	U	U	U	U	.
Heptachlor	0.10 µg/kg	U	U	U	U	U	.
Heptachlor epoxide	0.10 µg/kg	0.93	U	0.29	0.58	1.98	0.95
Hexachlorobenzene	0.50 µg/kg	3.43	0.99	2.60	3.50	8.40	3.78
Methoxychlor	0.20 µg/kg	U	U	U	U	U	.
Toxaphene	2.00 µg/kg	U	U	U	U	U	.
Aroclor 1016	0.50 µg/kg	U	U	U	U	U	.
Aroclor 1221	0.50 µg/kg	U	U	U	U	U	.
Aroclor 1232	0.50 µg/kg	U	U	U	U	U	.
Aroclor 1242	0.50 µg/kg	U	U	U	U	U	.
Aroclor 1248	0.50 µg/kg	U	U	U	U	U	.
Aroclor 1254	0.50 µg/kg	U	U	U	U	U	.
Aroclor 1260	0.50 µg/kg	2.53	0.97	1.58	1.96	8.58	3.12
⁵² Cr	19.2 µg/kg	82.40	97.60	89.20	107.50	84.20	92.18
⁶⁰ Ni	1.50 µg/kg	46.60	41.60	54.70	92.80	63.20	59.78
⁶⁵ Cu	8.70 µg/kg	541.40	667.30	556.40	974.50	1123.90	772.70
⁷⁵ As	2.70 µg/kg	34.10	46.30	35.20	41.00	41.70	39.66
⁷⁸ Se	1.50 µg/kg	173.30	235.80	170.90	188.00	192.40	192.08
¹⁰⁹ Ag	9.00 µg/kg	U	U	U	U	U	.
¹¹¹ Cd	0.90 µg/kg	U	U	U	U	U	.
²⁰⁰ Hg*	3.25 µg/kg	105.30	68.80	48.60	59.10	41.10	64.58
²⁰² Hg*	2.74 µg/kg	107.90	69.80	48.70	61.80	43.70	66.38
²⁰⁸ Pb**	0.60 µg/kg	49.30	18.80	75.80	74.20	31.70	49.96

U= undetected

Analyte	Detection limit	UMS Bighead 1	UMS Bighead 2	UMS Bighead 3	UMS Bighead 4	UMS Bighead 5	Mean UMS Bighead
Length (cm)		81	88	82	85	83	83.8
Aldrin	0.10 µg/kg	U	U	U	U	U	.
α-BHC	0.10 µg/kg	U	U	U	U	U	.
β-BHC	0.10 µg/kg	U	U	U	U	U	.
γ-BHC	0.10 µg/kg	U	U	U	U	U	.
δ-BHC	0.10 µg/kg	U	U	U	U	U	.
α-Chlordane	0.10 µg/kg	U	U	U	U	0.28	0.28
γ-Chlordane	0.10 µg/kg	U	U	U	U	0.31	0.31
4,4-DDD	0.20 µg/kg	U	U	U	U	U	.
4,4-DDE	0.20 µg/kg	U	U	U	U	U	.
4,4-DDT	0.20 µg/kg	U	U	U	U	U	.
Dieldrin	0.20 µg/kg	U	U	U	0.17	0.89	0.53
Endosulfan I	0.10 µg/kg	U	U	U	U	U	.
Endosulfan II	0.20 µg/kg	U	U	U	U	U	.
Endosulfan Sulfate	0.20 µg/kg	U	U	U	U	U	.
Endrin	0.20 µg/kg	U	U	U	U	U	.
Endrin aldehyde	0.50 µg/kg	U	U	U	U	U	.
Endrin ketone	0.20 µg/kg	U	U	U	U	U	.
Heptachlor	0.10 µg/kg	U	U	U	U	U	.
Heptachlor epoxide	0.10 µg/kg	U	U	U	U	0.55	0.55
Hexachlorobenzene	0.50 µg/kg	0.98	U	0.74	0.86	2.82	1.35
Methoxychlor	0.20 µg/kg	U	U	U	U	U	.
Toxaphene	2.00 µg/kg	U	U	U	U	U	.
Aroclor 1016	0.50 µg/kg	U	U	U	U	U	.
Aroclor 1221	0.50 µg/kg	U	U	U	U	U	.
Aroclor 1232	0.50 µg/kg	U	U	U	U	U	.
Aroclor 1242	0.50 µg/kg	U	U	U	U	U	.
Aroclor 1248	0.50 µg/kg	U	U	U	U	U	.
Aroclor 1254	0.50 µg/kg	U	U	U	U	U	.
Aroclor 1260	0.50 µg/kg	U	U	2.20	U	1.06	1.63
⁵² Cr	19.2 µg/kg	126.90	137.10	119.60	177.50	106.20	133.46
⁶⁰ Ni	1.50 µg/kg	39.80	83.30	60.40	84.70	75.60	68.76
⁶⁵ Cu	8.70 µg/kg	564.70	885.60	716.70	872.60	867.60	781.44
⁷⁵ As	2.70 µg/kg	28.20	20.00	17.60	24.20	29.70	23.94
⁷⁸ Se	1.50 µg/kg	161.40	143.20	149.10	156.80	161.40	154.38
¹⁰⁹ Ag	9.00 µg/kg	U	U	U	U	U	.
¹¹¹ Cd	0.90 µg/kg	U	U	U	U	U	.
²⁰⁰ Hg*	3.25 µg/kg	31.20	72.60	21.90	42.80	63.60	46.42
²⁰² Hg*	2.74 µg/kg	31.00	70.20	21.00	43.90	66.60	46.54
²⁰⁸ Pb**	0.60 µg/kg	21.60	75.50	22.50	47.00	30.50	39.42

U= undetected

Appendix 2. Results of semi-volatile organic analysis for composite Asian carp by species and site.

Analyte	detection limit	Illinois River		Lower Mississippi R.		Upper Mississippi R.	
		silver	bighead	silver	bighead	silver	bighead
Phenol	5.00 µg/kg	U	U	U	U	U	U
1,2-Dichlorobenzene	1.00 µg/kg	U	U	U	U	U	U
1,3-Dichlorobenzene	1.00 µg/kg	U	U	U	U	U	U
1,4-Dichlorobenzene	1.00 µg/kg	U	U	U	U	U	U
Hexachlorobutadiene	1.00 ug/kg	U	U	U	U	U	U
m,p-cresol	1.00 ug/kg	U	U	U	U	U	U
2-nitrophenol	5.00 ug/kg	U	U	U	U	U	U
2,4-dimethylphenol	5.00 µg/kg	U	U	U	U	U	U
bis-(2-chloroethoxy)-methane	1.00 µg/kg	U	U	U	U	U	U
2,4-dichlorophenol	5.00 µg/kg	U	U	U	U	U	U
Naphthalene	1.00 µg/kg	U	U	U	U	U	U
2,6-dichlorophenol	5.00 µg/kg	U	U	U	U	U	U
4-chloro-3-methylphenol	5.00 µg/kg	U	U	U	U	U	U
2,4,6-trichlorophenol	5.00 µg/kg	U	U	U	U	U	U
2,4,5-trichlorophenol	5.00 µg/kg	U	U	U	U	U	U
Dimethyl phthalate	1.00 µg/kg	U	U	U	U	U	U
Acenaphthylene	1.00 µg/kg	U	U	U	U	U	U
Acenaphthene	1.00 µg/kg	U	U	U	U	U	U
2,4-dinitrophenol	5.00 µg/kg	U	U	U	U	U	U
4-nitrophenol	5.00 µg/kg	U	U	U	U	U	U
2,3,4,6-tetrachlorophenol	5.00 µg/kg	U	U	U	U	U	U
Diethyl phthalate	1.00 µg/kg	1.90	1.70	1.35	1.15	1.85	5.05
Fluorene	1.00 µg/kg	U	U	U	U	U	U
4-chlorophenyl phenylether	5.00 µg/kg	U	U	U	U	U	U
2-methyl-4,6-dinitrophenyl	5.00 µg/kg	U	U	U	U	U	U
4-bromophenyl phenylether	5.00 µg/kg	U	U	U	U	U	U
Pentachlorophenol	5.00 µg/kg	U	U	U	U	U	U
Phenanthrene	1.00 µg/kg	U	U	U	U	U	U
Anthracene	1.00 µg/kg	U	U	U	U	U	U
Dinoseb (DNBP)	1.00 µg/kg	U	U	U	U	U	U
Carbazole	1.00 µg/kg	U	U	U	U	U	U
Di-n-butyl phthalate	1.00 µg/kg	733	496	269	612	108	102
Fluoranthene	1.00 µg/kg	U	U	U	U	U	U
Pyrene	1.00 µg/kg	U	U	U	U	U	U
Butyl benzyl phthalate	1.00 µg/kg	53.0	22.0	U	U	U	U
Benzo (a) anthracene	1.00 µg/kg	U	U	U	U	U	U

U= undetected

Illinois River

Lower

Upper

Analyte	detection limit	Mississippi R.				Mississippi R.	
		silver	bighead	silver	bighead	silver	bighead
Chrysene	1.00 µg/kg	U	U	U	U	U	U
Bis (2-ethylexyl) phthalate	1.00 µg/kg	43.0	27.5	38.5	20.1	47.0	18.2
Di-n-octyl phthalate	1.00 µg/kg	U	U	U	U	U	U
Benzo (b) fluoranthene	1.00 µg/kg	U	U	U	U	U	U
Benzo (k) fluoranthene	1.00 µg/kg	U	U	U	U	U	U
Benzo (a) pyrene	1.00 µg/kg	U	U	U	U	U	U
Indeno (1,2,3-c,d) pyrene	1.00 µg/kg	U	U	U	U	U	U
Dibenzo (a,h) anthracene	1.00 µg/kg	U	U	U	U	U	U
Benzo (g,h,i) perylene	1.00 µg/kg	U	U	U	U	U	U
Alachlor	1.00 µg/kg	U	U	U	U	U	U
Ametryn	1.00 µg/kg	U	U	U	U	U	U
Atraton	1.00 µg/kg	U	U	U	U	U	U
Atrazine	1.00 µg/kg	U	U	U	U	U	U
Bromacil	1.00 µg/kg	U	U	U	U	U	U
Butachlor	1.00 µg/kg	U	U	U	U	U	U
Butylate	1.00 µg/kg	U	U	U	U	U	U
Chlorpropham	1.00 µg/kg	U	U	U	U	U	U
Chloropyrifos	1.00 µg/kg	U	U	U	U	U	U
Cycloate	1.00 µg/kg	U	U	U	U	U	U
Cyanazine	1.00 µg/kg	U	U	U	U	U	U
Dichlorvos	1.00 µg/kg	U	U	U	U	U	U
Dimethenamid	1.00 µg/kg	U	U	U	U	U	U
Diphenamid	1.00 µg/kg	U	U	U	U	U	U
EPTC	1.00 µg/kg	U	U	U	U	U	U
Ethroprop	1.00 µg/kg	U	U	U	U	U	U
Fenarimol	1.00 µg/kg	U	U	U	U	U	U
Hexazinone	1.00 µg/kg	U	U	U	U	U	U
Metolachlor	1.00 µg/kg	U	U	U	U	U	U
Mevinphos	1.00 µg/kg	U	U	U	U	U	U
Molinate	1.00 µg/kg	U	U	U	U	U	U
Napropamide	1.00 µg/kg	U	U	U	U	U	U
Norflurazon	1.00 µg/kg	U	U	U	U	U	U
Pebulate	1.00 µg/kg	U	U	U	U	U	U
Prometon	1.00 µg/kg	U	U	U	U	U	U

U= undetected

Analyte	detection limit	Illinois River		Lower Mississippi R.		Upper Mississippi R.	
		silver	bighead	silver	bighead	silver	bighead
Prometryn	1.00 µg/kg	U	U	U	U	U	U
Pronamide	1.00 µg/kg	U	U	U	U	U	U
Propachlor	1.00 µg/kg	U	U	U	U	U	U
Propazine	1.00 µg/kg	U	U	U	U	U	U
Simetryn	1.00 µg/kg	U	U	U	U	U	U
Stirofos	1.00 µg/kg	U	U	U	U	U	U
Tebuthiuron	1.00 µg/kg	U	U	U	U	U	U
Terbacil	1.00 µg/kg	U	U	U	U	U	U
Terbutryn	1.00 µg/kg	U	U	U	U	U	U
Triadimefon	1.00 µg/kg	U	U	U	U	U	U
Trifluralin	1.00 µg/kg	U	U	U	U	U	U
Vernolate	1.00 µg/kg	U	U	U	U	U	U

U= undetected