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Estimation of Whole-Fish Contaminant Concentrations from Fish Fillet Data

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DEPARTMENT OF ENERGY

See revised mercury eq. and new DDT eq. in revised Table 2 attached at back.
– MSB

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Estimation of Whole-Fish Contaminant Concentrations from Fish Fillet Data

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PREFACE

The purpose of this technical memorandum is to present the results of an investigation of the relationship between fillet and whole-fish contaminant concentrations and develop equations for the estimation of whole-fish concentrations for several analytes. Fish were collected from several sites in Tennessee and Ohio and analyzed for contaminants; analyses were conducted on fillet portions as well as the remaining carcasses of 31 bass and 10 catfish. This work was performed under Work Breakdown Structure 1.4.12.2.3.04.05.02 (Activity Data Sheet 8304). Publication of this document meets an Environmental Restoration Risk Assessment Program milestone for FY 96.

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EXECUTIVE SUMMARY

In aquatic systems, many contaminants accumulate in fish. To assess the risks that these contaminants may present to human consumers, fish are frequently collected, and the contaminant concentrations of the muscle portion (i.e., fillet) are determined. However, many consumers, including piscivorous animals and some human groups, consume the entire fish. For these cases, the use of fillet contaminant concentrations for risk assessment may be inadequate. Because of chemical-specific differences in assimilation rates and affinities for various tissue compartments, fillet concentrations may not accurately represent or predict concentrations in the whole body.

Use of fillet data to assess risks to piscivorous wildlife and to persons who consume whole fish requires methods to estimate whole-fish concentrations from fillet data. The objective of this report is to investigate the relationship between fillet and whole-fish contaminant concentrations and develop equations for estimating whole-fish concentrations for several analytes.

This report provides contaminant-specific equations to describe the relationship between fillet and whole-body contaminant concentrations. Transferability of these equations is limited by the range of contaminant concentrations, the number of species, and the fish sizes represented in the data presented herein. However, these conversion equations still provide an alternative that should be better than using fillet concentrations to represent whole body values.

1. INTRODUCTION

In aquatic systems, many contaminants accumulate in fish. To assess the risks that these contaminants may present to human consumers, fish are frequently collected, and the contaminant concentrations are analyzed. Because most people consume only the muscle portion of fish, the fillet portion of the fish is typically the only part analyzed to provide data for human health risk assessments. While fish fillet data may be suitable to assess risks to the majority of the human population, piscivorous animals, such as mink, otter, herons, and kingfishers, typically consume more than just muscle tissue and often consume the entire fish. Therefore, the use of fillet data may not accurately represent risks that contaminants in fish present to wildlife. In addition, not all people restrict themselves to consuming only fish fillets. Persons in some cultures and locations may catch, prepare, and consume whole fish. Whole-body contaminant information in fish is needed but is not readily available.

Fillet concentrations may not accurately represent or predict concentrations in the whole body because of chemical-specific differences in assimilation rates and affinities for various tissue compartments (Heit 1979, Ray et al. 1984, Goldstein et al. 1996). The greatest differences are expected for those substances that have high affinities for hard tissues (bones and scales). Bone seeking elements, such as calcium, strontium, and lead (Bowen 1979), would therefore be likely to be more abundant in whole fish than in muscle tissue only. Elements that bind to proteins, such as mercury, selenium, and cadmium (Bowen 1979), are enriched in muscle tissue and organs (i.e., the kidneys), but large differences between whole body and fillet concentrations are less likely because much of the whole fish that is not muscle is nevertheless proteinaceous soft tissue. Elements whose concentrations in soft tissue are to some extent homoeostatically controlled, such as potassium and zinc, might increase in hard tissues (and therefore whole fish) in response to increased exposure while muscle concentrations remain unchanged.

Fat soluble organic contaminants, such as dichlorodiphenyl-trichloroethane or polychlorinated biphenyls, accumulate in tissues rich in lipids. If lipid contents of fillets and whole fish are similar, concentrations of fat-soluble contaminants would be expected to be similar. However, species that store much of their lipid reserves within the abdominal cavity, rather than within muscle tissue, would likely exhibit higher whole-body than fillet concentrations.

Use of fillet data to assess risks to piscivorous wildlife and to persons who consume whole fish requires methods to estimate whole-fish concentrations from fillet data. The objective of this report is to investigate the relationship between fillet and whole-fish contaminant concentrations and develop equations for the estimation of whole-fish concentrations for several inorganics, polychlorinated biphenyls, and chlordane.

2. METHODS

Black bass (largemouth bass *Micropterus salmoides* and spotted bass *M. punctulatis*) and catfish (channel catfish *Ictalurus punctatus* and blue catfish *Ictalurus furcatus*) were collected from several sites in Tennessee and Ohio for contaminant analysis as part of the Clinch River Environmental Restoration Program at the U.S. Department of Energy's (DOE's) Oak Ridge Reservation (ESD-ORNL 1996) and a baseline risk assessment at DOE's Portsmouth Gaseous

Diffusion Plant (ORNL 1995). In addition to analyzing fillet portions (i.e., muscle tissue) for contaminants, the remaining carcasses (i.e., whole body minus the fillets) of 31 bass and 10 catfish were also analyzed for the same contaminants (Table 1). Catfish fillets were analyzed with the skin off, and bass samples were analyzed with skin on and scales removed. The sites sampled included those with a known history of contamination and those believed to be uncontaminated (i.e., background). For the statistical analysis, sites were combined to provide a wide range of contaminant concentrations.

Table 1. Data sources and ranges of key variables used in statistical analysis of fillet to whole-body contaminant relationships

Analyte	Number and Species	Sites	Weight range (g)	Length range (cm)
All metals	12 Black bass (largemouth and spotted)	Portsmouth , OH Hinds Creek, TN	162–603	24.5–34.5
PCBs*	31 Black bass (largemouth and spotted)	Portsmouth , OH Hinds Creek, TN Watts Bar Reservoir, TN Norris Reservoir, TN	162–2829	24.5–54.0
	10 catfish (channel and blue)	Watts Bar Reservoir, TN	350–996	35.9–48.2
Chlordane	20 Black bass (largemouth)	Watts Bar Reservoir, TN Norris Reservoir, TN	489–2829	24.5–54.0
	10 catfish (channel and blue)	Watts Bar Reservoir, TN	350–996	35.9–48.2

*PCBs=polychlorinated biphyenls

Samples were analyzed for either inorganic compounds (11 metals) or organic compounds (polychlorinated biphenyls and chlordane constituents) or both (Table 1). For the purpose of our analysis, total polychlorinated biphenyl concentration was calculated as the sum of Aroclor 1254 and Aroclor 1260 and total chlordane as the sum of five chlordane constituents (alpha-chlordane, gamma-chlordane, oxychlordane, cis-nonachlor, and trans-nonachlor). For all analytes, one half of the reported detection limit was used for results that were reported as non-detects (i.e., less than the detection limit).

Whole body concentration (C_{wb}) was calculated as

$$C_{wb} = (C_f \bullet W_f + C_c \bullet W_c)/(W_f + W_c) \tag{1}$$

where C_f and C_c are the contaminant concentration (mg/kg) in the fillet and carcass, and W_f and W_c are the weight (g) of the fillet (both sides) and carcass, respectively.

Throughout the analysis, the following underlying model was used to relate whole body contaminant concentrations (C_{wb}) and fillet concentrations (C_f):

$$C_{wb} = k' + k \bullet (C_f)^b \tag{2}$$

where $b>0$ and k' is assumed to be zero, resulting in a relationship that passes through the point $(C_{wb}, C_f)=(0, 0)$. For this reduced two-parameter model, taking logs on both sides of Eq. (2) changes the model to a standard linear regression model of $\ln(C_{wb})$ and $\ln(C_f)$. Therefore, all concentration values were natural log transformed for statistical analyses. For some applications, it might be reasonable to consider $k'>0$, in which case a nonlinear or weighted estimation method should be used to estimate the unknown parameters.

A logical progression of statistical tests was established to determine the most appropriate equation for the conversion of fillet concentration to whole body concentration for each contaminant (Fig. 1). This series of statistical tests was performed for each contaminant by species group. The first question addressed was whether the measured fillet concentration was different from the calculated whole-body concentration. A paired t-test was used to determine if the average difference of the transformed fillet and whole-body concentrations was different from zero ($P<0.05$ for all analyses). If no significant difference was found, it was concluded that the fillet concentration could be used as the whole body concentration. If the difference was significant, the analysis proceeded to the next step.

The second question addressed was whether the regression model

$$\ln(C_{wb}) = \ln(k) + b \bullet \ln(C_f) \tag{3}$$

produced a slope, b, which differed significantly from 0. If the slope was not different from zero, it was determined that the existing data were not adequate to derive a reasonable relationship for that contaminant. In this case, the average whole-body concentration was used to estimate the whole body concentration regardless of the fillet concentration (i.e., slope equals 0).

If the slope differed from 0, then evaluations determined whether it differed significantly from 1. If the slope did not differ from 1, then the following equation was used to define the relationship between whole body and fillet concentrations:

$$C_{wb} = k_d \bullet C_f \tag{4}$$

where k_d is the mean whole body-to-fillet ratio as estimated from the antilog of the mean difference (d) of the logs (Table 2); i.e.,

$$k_d = e^{-d} \tag{5}$$

where d is the mean difference of $\ln(C_f)$ minus $\ln(C_{wb})$ for each analyte by species combination.

If the regression analysis revealed that the slope was significantly different from 1, the estimated model was then used as shown in Eq. (3) to define the conversion equation. A stepwise regression analysis was also performed to determine if whole-body weight or fillet lipid content were significant explanatory variables in addition to the fillet concentration for predicting whole-body contaminant concentration. Both of these variables were natural log-transformed for the regression analysis. If the addition of either variable produced a significant regression model, this expanded model was included as an alternate conversion equation.

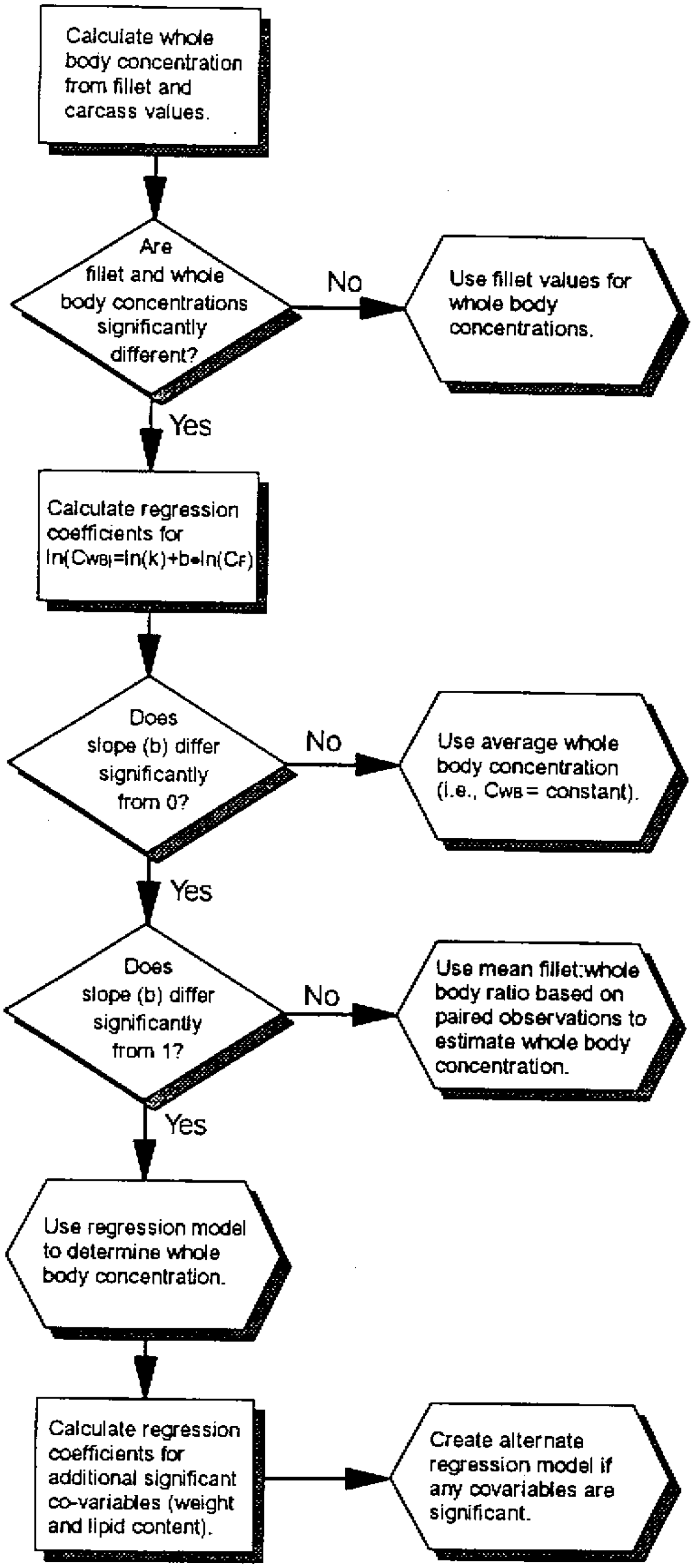

Fig. 1. Flow diagram describing statistical procedures used to determine equations for estimating whole-fish contaminant concentrations from fillet values.

(See revised Table 2 in back.)

Table 2. Results of statistical analysis evaluating the relationship between fillet and whole body contaminant concentrations, where d is the difference between $\ln(C_f)$ and $\ln(C_{wb})$, b is the slope of the equation describing the relationship, C_f is the contaminant concentration (mg/kg) in the fillet, C_{wb} is the contaminant concentration (mg/kg) in the whole body, W_{wb} is the weight (g) of the whole body, and L_f is the lipid content (percent by weight) of the fillet.

Contaminant	Species	Fillet concentration range	d, (e^{-d})	H_0:d=0 P value	H_0:b=0 P value	H_0:b=1 P value	Conversion equation {Alternate conversion equation}
Arsenic	Black bass	0.031–0.08	-0.330, (1.4)	<0.0001	<0.001	0.03	$C_{wb}=\exp[-0.72+0.65\cdot\ln(C_f)]$ or $\{C_{wb}=\exp[-1.41+0.77\cdot\ln(C_f)-0.18\cdot\ln(W_{wb})]\}$
Cadmium	Black bass	0.0008–0.077	-1.788, (5.9)	<0.01	0.28		$C_{wb}=0.086$
Chromium	Black bass	0.09–0.18	-0.187, (1.2)	<0.01	<0.01	0.16	$C_{wb}=1.2\cdot C_f$
Copper	Black bass	0.23–0.59	-1.055, (2.9)	<0.001	0.13		$C_{wb}=0.76$
Lead	Black bass	0.0005–0.048	-1.370, (3.9)	<0.01	0.18		$C_{wb}=0.28$
Mercury	Black bass	0.12–0.38	0.387, (0.7)	<0.0001	<0.001	<0.001	$C_{wb}=\exp[-0.84+0.74\cdot\ln(C_f)]$ or $\{C_{wb}=\exp[-0.81+0.75\cdot\ln(C_f)+0.009\cdot\ln(L_f)]\}$
Nickel	Black bass	0.024–0.102	-2.121, (8.3)	<0.0001	0.78		$C_{wb}=0.37$
Selenium	Black bass	0.27–0.46	-0.067, (1.1)	0.04	<0.001	0.02	$C_{wb}=\exp[-0.25+0.68\cdot\ln(C_f)]$
Uranium	Black bass	0.00025–0.048	-1.780, (5.9)	<0.0001	0.40		$C_{wb}=0.009$
Vanadium	Black bass	0.004–0.014	-1.795, (6.0)	<0.0001	0.26		$C_{wb}=0.059$
Zinc	Black bass	5.8–12.0	-0.890, (2.4)	<0.0001	0.54		$C_{wb}=18.5$
Total PCBs*	Catfish	0.36–2.0	-0.397, (1.5)	0.01	<0.001	0.03	$C_{wb}=\exp[0.21+0.81\cdot\ln(C_f)]$
Total PCBs	Black bass	0.04–2.34	-0.829, (2.3)	<0.0001	<0.001	0.79	$C_{wb}=2.3\cdot C_f$
Total chlordane	Catfish	0.027–0.115	-0.167, (1.2)	<0.01	<0.001	0.56	$C_{wb}=1.2\cdot C_f$
Total chlordane	Black bass	0.025–0.05	-0.520, (1.7)	<0.0001	0.01	0.45	$C_{wb}=1.7\cdot C_f$

*PCBs=polychlorinated

3. RESULTS

The analytical results and detailed sample information are presented in the Appendix to this report. The relationship between fillet and whole-body concentrations for each analyte is illustrated in Fig. 2. A one-to-one line (dotted line) is included as a reference to the expected distribution of points if fillet and whole body concentrations were equal. Paired t-tests revealed that whole body concentrations of all analytes were significantly different from fillet concentrations (Table 2). Only for mercury were concentrations higher in the fillet than in the whole body.

The regression of fillet concentration on whole body concentration revealed a slope not different from 0 for Cd, Cu, Pb, Ni, U, V, and Zn. For each of these metals, the analysis suggests that within the range of concentrations represented by the data, the concentration in the whole body was fairly constant regardless of the concentration in the fillet. For these contaminants, the best estimate for whole-body concentration is a constant value calculated as the mean whole body concentration of the data in the analysis. The relationship for each of these analytes is indicated as a horizontal dashed line in the appropriate panels of Fig. 2. The reader should note that the range of fillet concentrations used in this analysis is relatively narrow and that the concentrations represent background values that would be expected at an uncontaminated site.

For four cases (chromium, polychlorinated biphenyls for bass, and chlordane for both catfish and bass) the regression analysis determined that the slope was not significantly different from 1 (Table 2). For these analytes, the resulting conversion equation is a simple multiplier of the fillet concentration. The relationships described by the conversion equation for these analytes is indicated as dashed lines in the appropriate panels of Fig. 2.

For the remaining analytes (As, Hg, Se, and polychlorinated biphenyls for catfish) the slopes were significantly different from 1 (Table 2). For these analytes, the regression model (intercept and slope) as determined by the regression analysis is recommended for estimating whole body concentrations from fillet concentrations. The relationships described by this model are indicated as solid lines in Fig. 2. For analysis of the catfish polychlorinated biphenyl data, one outlier value (open circle in PCB-Catfish panel of Fig. 2) was removed. This point was determined to have a disproportionate effect on the regression, resulting in a relationship that falls below the 1:1 line at C_f>1.5 although none of the actual observations are below the 1:1 line.

For arsenic and mercury, the addition of a second explanatory variable significantly improved the predictive capabilities of each model which are offered as alternative conversion equations (Table 2). For arsenic, the inclusion of whole-body weight in the regression is recommended if the information is available. Likewise, for mercury, the inclusion of percent lipid content of the fillet also significantly improves the regression model.

4. DISCUSSION

Little information has been published that defines the relationship between fillet and whole-body contaminant concentrations for chemicals other than mercury. This assessment found that mercury levels were generally higher in muscle tissue than in the whole body for bass. A similar relationship was described by Goldstein et al. (1996) for channel catfish and carp *Cyprinus carpio*,

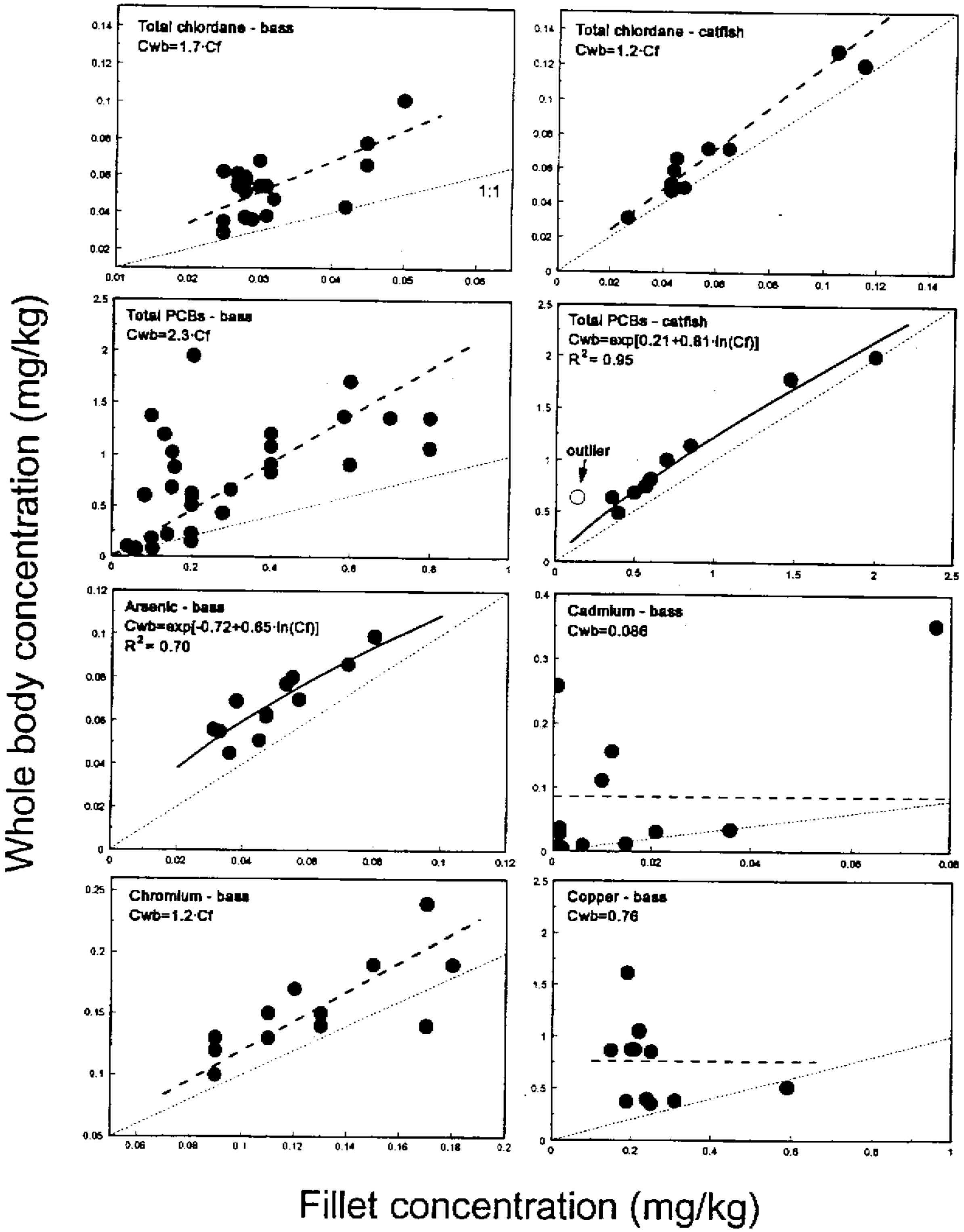

Fig. 2. Plots of fillet versus whole body contaminant concentrations for 2 organic and 11 inorganic chemicals. Conversion equations are represented by solid lines (determined with the basic regression model) and dashed lines (determined with the simple conversion factor or the mean whole body concentration). The dotted line represents a fillet:whole body relationship of 1:1. The mercury panel includes regression lines derived by Goldstein et al. (1996) for catfish and carp.

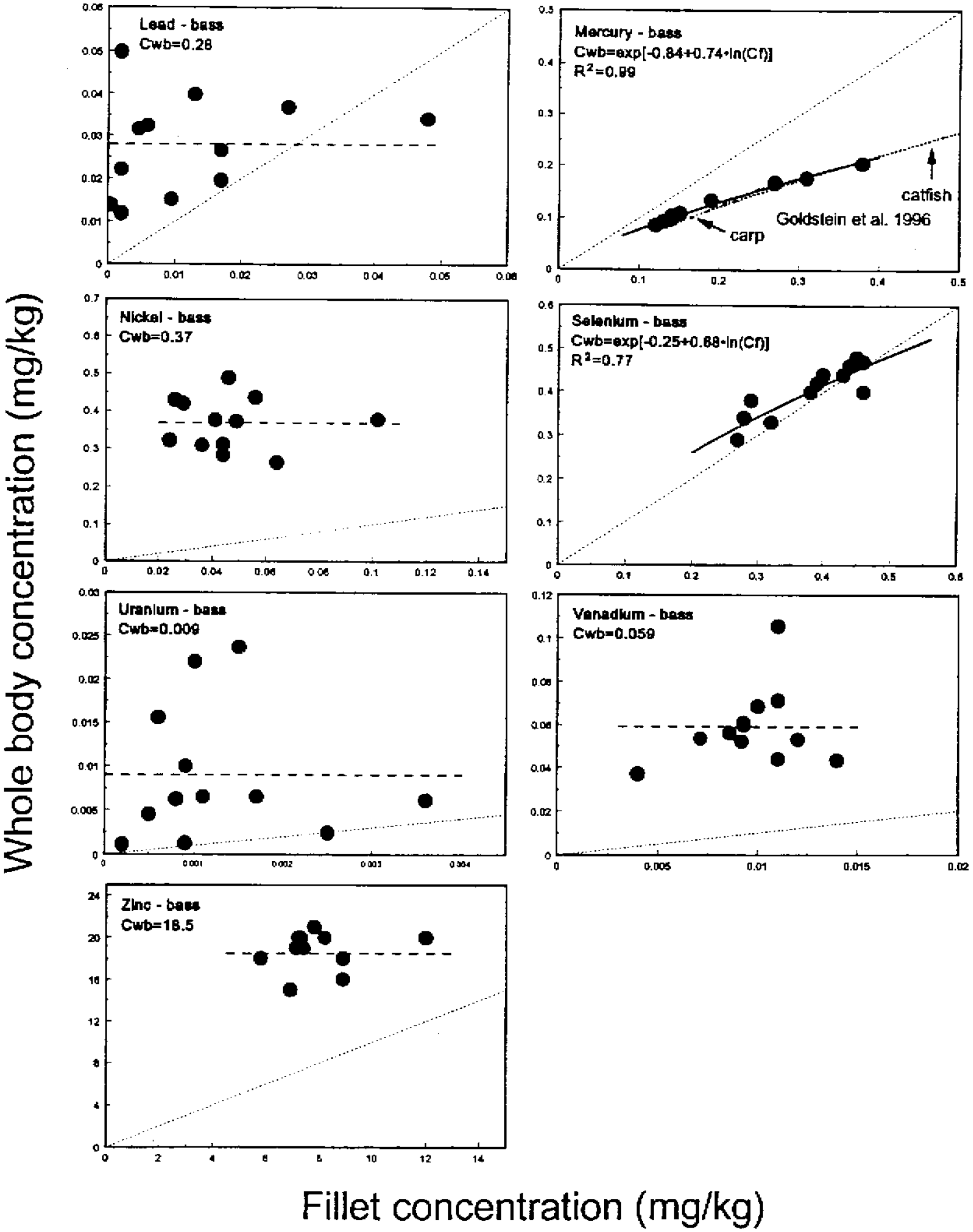

Fig. 2. (continued)

and their regression models were similar to the bass model herein (see mercury panel in Fig. 2). Ray et al. (1982) found similar results for mercury tissue compartments (concentrations in muscle≥liver>kidney>gonad) in striped bass *Morone saxatilis*. Becker and Bigham (unpublished data) found higher concentrations of methyl mercury in the fillets of bluegill sunfish *Lepomis macrochirus* than in the whole body, but no differences for white perch *Morone americana*, smallmouth bass *Micropterus dolomieu*, and gizzard shad *Dorosoma cepedianum*. However, in their study, fillet and whole body concentrations were not derived from the same fish. Phillips et al. (1987) concluded that fillet and whole body concentrations of mercury were not different for walleye *Stizostedion vitreum* and white crappie *Pomoxis annularis*, though they also did not have fillet and whole body data from the same individuals and also had small sample sizes (N=5 to 10).

Because this analysis was performed on a limited set of contaminant data, several limitations and uncertainties should be considered. All inferences from this analysis are constrained by the limited range of available data. Due to a relatively narrow range of contaminant concentrations in this study and the lack of related studies suggesting otherwise, this analysis was limited to a single model type where the y-intercept passes through the origin. This model included two forms: one linear (Fig. 3A) and the other curvilinear (Fig. 3B). However, it is possible that for some contaminants a different model form would be a better descriptor. For example, it may be the case for some chemicals that the y-intercept does not intersect the origin (Fig. 3C). A different model form would be required if whole body and fillet concentrations converge at high concentrations (Fig. 3D). The model given by Eq. 3 has the capability to handle these cases when $k'>0$. Additional data that represent a larger range of tissue concentrations are necessary to more accurately determine the most appropriate model form.

Other limitations of the conversion equations presented here include variations in within-body contaminant distribution among fish of different sizes and species. Although fish size was a significant co-variable in only one case (arsenic) in the analysis, it is possible that with data over a larger size range, this factor would have been found to improve the estimate of whole-body contaminant concentration for other contaminants. As fish grow, changes are expected in the proportion of the body made up of muscle, the distribution of lipids, and the apportionment of energy and contaminants to reproductive tissue (Ray et al. 1982). For similar reasons differences are expected among sexes, although this expectation was not tested in this analysis due to small sample sizes. Among-species differences exist in physiology, body structure, and lipid apportionment; therefore, differences in the fillet-to-whole-body contaminant relationships among species are possible. For example, the ratio of whole-body to fillet concentrations of hydrophobic contaminants (e.g., polychlorinated biphenyls and chlordane) would be expected to be higher in bass, which store much of their lipids in the peritoneal cavity, than in catfish, which store a greater proportion of lipids in muscle tissue. However, significant differences were not distinguishable between catfish and bass in regression models for polychlorinated biphenyls and chlordane, largely due to the high variation in the largemouth bass data.

Because of the limitations described previously, any extrapolation of the conversion equations presented here outside of the bounds within which these relationships were determined should be done with caution. These bounds include the species and size range of fish used and the range of contaminant concentrations. However, given the shortcomings of these conversion equations, they still provide an alternative that should be better than using fillet concentrations to represent whole body values.

Although the fillet concentrations differed significantly from whole body concentrations for all analytes, the differences for most were relatively small. For chromium, selenium, and chlordane (in catfish), fillet and whole-body concentrations differed by less than 20%. The largest differences were observed for Cd, Pb, Ni, U, and V, which were 4- to 8-fold higher in the whole body than in the fillet. Differences of similar magnitude will likely occur in the ecological risk calculations using these data. Because equations used to calculate the ecological risk to piscivorous animals are generally linear, a two-fold difference in contaminant concentration would result in a two-fold difference in risk.

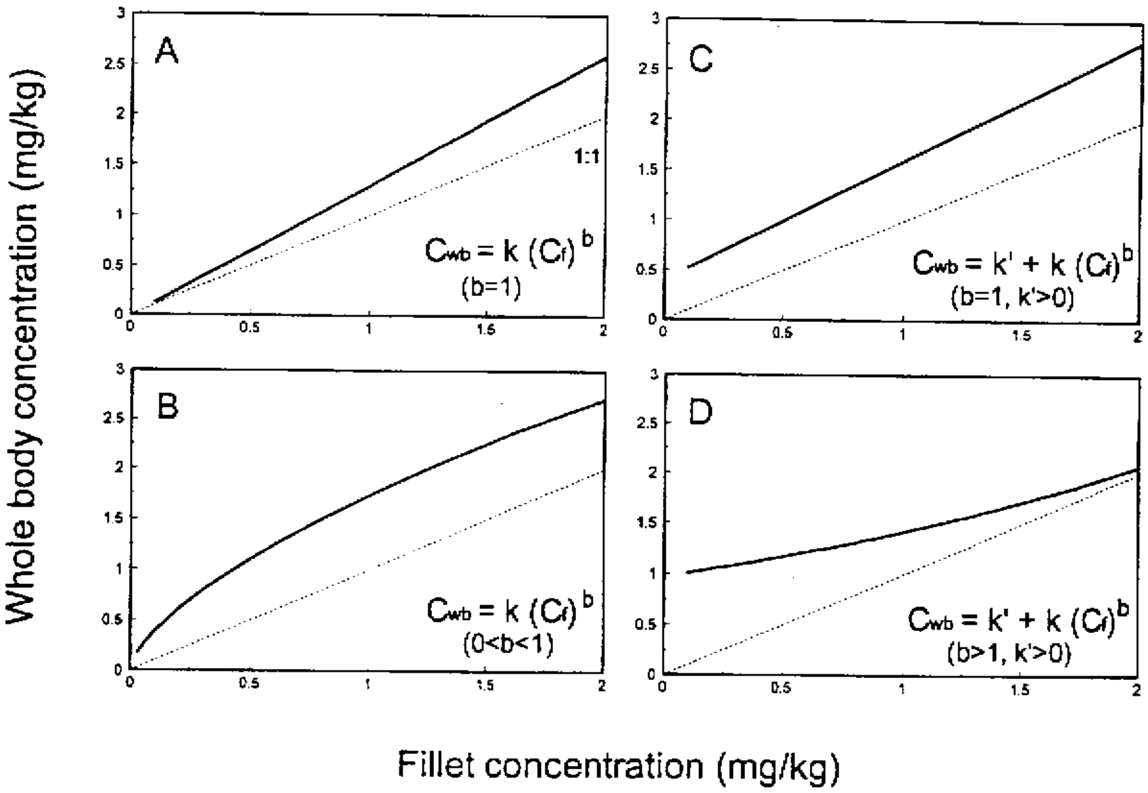

Fig. 3. Possible relationships between fillet and whole body concentrations of contaminants. Panels A and B represent the forms of the model used in this analysis while panels C and D are other potential model forms. The dotted line represents a fillet:whole body relationship of 1:1.

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APPENDIX

Table A.1. Sample information and organic contaminant concentrations in fillet portions and whole bodies for fish used in the analysis of the relationship between fillet and whole body contaminant concentrations.

Fish No.	Species	Site	Sex	Total Wgt. (g)	Lipid fillet (%)	Lipid whole (%)	Total PCB fillet (mg/kg)	Total PCB whole (mg/kg)	Chlordane fillet (mg/kg)	Chlordane whole (mg/kg)
2488	LMB	CRM10	M	572	1.7	4.3	0.15	0.68	0.030	0.054
2491	LMB	CRM10	M	778	2.1	3.8	0.80	1.36	0.042	0.043
2493	LMB	CRM10	M	1224	2.7	5.4	0.60	0.91	0.045	0.066
2496	LMB	CRM10	M	489	1.4	4.1	0.20	0.15	0.028	0.057
6752	LMB	CRM10	M	715	1.7	4.4	0.20	0.51	0.027	0.054
6753	LMB	CRM10	M	675	2.6	4.6	0.14	0.22	0.025	0.029
6754	LMB	CRM10	M	538	1.2	3.6	0.20	0.62	0.027	0.056
6755	LMB	CRM10	M	527	1.0	2.7	0.40	1.20	0.027	0.061
6768	LMB	CRM10	F	2829	1.0	2.5	0.40	1.08	0.031	0.054
6769	LMB	CRM10	M	510	1.4	3.0	0.28	0.43	0.029	0.036
C001B04	LMB	CRM1	F	1037	0.3	10.5	0.20	0.23	0.031	0.038
C001B10	LMB	CRM1	F	2163	1.0	4.3	0.40	0.91	0.032	0.047
C010C61	CAT	CRM10	F	554	8.6	12.4	0.60	0.81	0.057	0.072
C010C62	CAT	CRM10	M	524	1.1	1.7	0.14	0.63	0.027	0.031
C010C63	CAT	CRM10	F	402	3.5	6.7	0.70	1.00	0.045	0.066
C010C64	CAT	CRM10	F	484	6.7	9.9	0.40	0.48	0.043	0.051
C010C65	CAT	CRM10	F	350	1.1	1.6	0.50	0.68	0.043	0.047
C010C66	CAT	CRM10	F	512	6.3	8.4	2.00	2.01	0.105	0.128
C010C67	CAT	CRM10	M	444	4.1	5.9	0.85	1.14	0.065	0.072
C010C68	CAT	CRM10	F	410	4.1	6.1	0.57	0.74	0.048	0.049
C010C69	CAT	CRM10	F	418	4.3	4.7	0.36	0.63	0.044	0.059
C010C70	CAT	CRM10	M	996	8.5	11.0	1.47	1.79	0.115	0.120
P030B01	LMB	PRM30	F	1776	1.1	4.4	0.15	1.02	0.025	0.062
P030B02	LMB	PRM30	M	961	1.9	6.9	0.10	0.18	0.025	0.035
T530B01	LMB	TRM530	M	2176	2.3	11.8	0.40	0.83	0.028	0.059

Table A.1. (continued)

Fish No.	Species	Site	Sex	Total Wgt. (g)	Lipid fillet (%)	Lipid whole (%)	Total PCB fillet (mg/kg)	Total PCB whole (mg/kg)	Chlordane fillet (mg/kg)	Chlordane whole (mg/kg)
T530B10	LMB	TRM530	F	805	2.5	10.5	0.30	0.66	0.028	0.037
T561B01	LMB	TRM561	F	800	1.3	10.0	0.20	0.59	0.028	0.051
T561B06	LMB	TRM561	F	2382	4.0	8.8	0.70	1.36	0.050	0.101
T570B01	LMB	TRM570	F	2704	1.6	9.6	0.60	1.71	0.045	0.078
T570B07	LMB	TRM570	F	1287	3.2	7.9	0.80	1.07	0.030	0.068
4678	SPB	LBK5.0	F	248	0.5	0.4	0.20	1.95	0	0
4679	SPB	LBK5.0	F	356	4.0	4.6	0.58	1.37	0	0
8588	SPB	LBK5.0	F	345	0.0	2.8	0.04	0.10	0	0
8589	SPB	LBK5.0	M	401	1.1	2.6	0	0	0	0
4918	SPB	LBK2.4	F	309	0.4	2.9	0.08	0.60	0	0
4919	SPB	LBK2.4	F	517	0.0	1.4	0.16	0.88	0	0
8218	SPB	LBK2.4	F	231	0.5	3.8	0.13	1.19	0	0
8219	SPB	LBK2.4	F	211	0.5	2.7	0.10	1.37	0	0
8469	SPB	HindsCr	F	162	1.3	3.8	0.10	0.08	0	0
4860	LMB	HindsCr	F	450	2.3	2.2	0.06	0.04	0	0
4670	SPB	HindsCr	F	603	1.7	6.3	0.06	0.08	0	0
4839	LMB	HindsCr	M	314	1.2	2.2	0.06	0.05	0	0

*PCBs=polychlorinated

Table A.2. Inorganic contaminant concentrations in fillet portions and whole bodies for fish used in the analysis of the relationship between fillet and whole body contaminant concentrations. Sample information for these fish is found in Table A.1.

Fish No.	Arsenic fillet (mg/kg)	Arsenic whole (mg/kg)	Cadmium fillet (mg/kg)	Cadmium whole (mg/kg)	Chromium fillet (mg/kg)	Chromium whole (mg/kg)	Copper fillet (mg/kg)	Copper whole (mg/kg)	Lead fillet (mg/kg)	Lead whole (mg/kg)	Mercury fillet (mg/kg)	Mercury whole (mg/kg)
4678	0.072	0.086	0.010	0.111	0.17	0.24	0.19	1.61	0.013	0.040	0.15	0.11
4679	0.047	0.062	0.001	0.258	0.09	0.13	0.22	1.04	0.006	0.032	0.14	0.10
8588	0.057	0.070	0.002	0.035	0.12	0.17	0.19	0.37	0.002	0.022	0.14	0.10
8589	0.045	0.051	0.002	0.027	0.18	0.19	0.23	0.87	0.002	0.050	0.31	0.18
4918	0.055	0.080	0.036	0.034	0.11	0.13	0.59	0.51	0.048	0.034	0.14	0.10
4919	0.031	0.056	0.077	0.352	0.13	0.14	0.22	1.05	0.027	0.037	0.38	0.21
8218	0.080	0.099	0.021	0.031	0.09	0.12	0.25	0.85	0.017	0.020	0.12	0.09
8219	0.036	0.045	0.012	0.156	0.09	0.10	0.25	0.35	0.010	0.015	0.14	0.10
8469	0.047	0.063	0.002	0.005	0.17	0.14	0.24	0.39	0.017	0.027	0.13	0.09
4860	0.033	0.055	0.015	0.012	0.13	0.15	0.21	0.87	0.002	0.012	0.19	0.13
4670	0.038	0.069	0.006	0.009	0.15	0.19	0.15	0.86	0.001	0.014	0.27	0.17
4839	0.053	0.077	0.001	0.006	0.11	0.15	0.31	0.38	0.005	0.032	0.14	0.10

Fish No.	Nickel fillet (mg/kg)	Nickel whole (mg/kg)	Selenium fillet (mg/kg)	Selenium whole (mg/kg)	Uranium fillet (mg/kg)	Uranium whole (mg/kg)	Vanadium fillet (mg/kg)	Vanadium whole (mg/kg)	Zinc fillet (mg/kg)	Zinc whole (mg/kg)		
4678	0.04	0.38	0.43	0.44	0.0006	0.0156	0.010	0.068	7.4	19.2		
4679	0.04	0.31	0.39	0.42	0.0009	0.0100	0.009	0.052	5.8	17.8		
8588	0.02	0.32	0.38	0.40	0.0008	0.0062	0.012	0.053	7.1	18.9		
8589	0.06	0.44	0.46	0.40	0.0015	0.0237	0.009	0.061	7.8	21.2		
4918	0.10	0.38	0.40	0.44	0.0036	0.0061	0.011	0.044	12.0	20.2		
4919	0.05	0.49	0.44	0.46	0.0010	0.0220	0.011	0.071	7.2	19.6		
8218	0.05	0.37	0.46	0.47	0.0017	0.0065	0.004	0.037	5.8	18.0		
8219	0.04	0.31	0.45	0.48	0.0005	0.0045	0.009	0.056	7.3	19.6		
8469	0.06	0.27	0.29	0.38	0.0011	0.0065	0.014	0.043	8.2	19.5		
4860	0.03	0.42	0.27	0.29	0.0002	0.0011	0.009	0.060	8.9	15.7		
4670	0.03	0.43	0.28	0.34	0.0009	0.0012	0.011	0.106	8.9	17.8		
4839	0.04	0.28	0.32	0.33	0.0025	0.0024	0.007	0.054	6.9	14.6		

*PCBs=polychlorinated

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Table 2. Results of statistical analysis evaluating the relationship between fillet and whole body contaminant concentrations, where d is the difference between $\ln(C_f)$ and $\ln(C_{wb})$, b is the slope of the equation describing the relationship, C_f is the contaminant concentration (mg/kg) in the fillet, C_{wb} is the contaminant concentration (mg/kg) in the whole body, W_{wb} is the weight (g) of the whole body, and L_f is the lipid content (percent by weight) of the fillet.

Contaminant	Species	Fillet concentration range	d (e^{-d})	H_0:d=0 P value	H_0:b=0 P value	H_0:b=1 P value	Conversion equation {Alternate conversion equation}
Arsenic	Black bass	0.031–0.08	-0.330 (1.4)	<0.01	<0.001	0.03	$C_{wb}=\exp[-0.72+0.65\cdot\ln(C_f)]$ or $\{C_{wb}=\exp[-1.41+0.77\cdot\ln(C_f)-0.18\cdot\ln(W_{wb})]\}$
Cadmium	Black bass	0.0008–0.077	-1.788 (5.9)	<0.01	0.28		$C_{wb}=0.086$
Chromium	Black bass	0.09–0.18	-0.187 (1.2)	<0.01	<0.01	0.16	$C_{wb}=1.2\cdot C_f$
Copper	Black bass	0.23–0.59	-1.055 (2.9)	<0.01	0.13		$C_{wb}=0.76$
Lead	Black bass	0.0005–0.048	-1.370 (3.9)	<0.01	0.18		$C_{wb}=0.28$
Mercury	Centrarchid spp. [a]	0.12-2.12	0.392 (0.7)	<0.01	<0.01	0.06	$C_{wb}=0.7\cdot C_f$ $C_{wb}=\exp[-0.37+1.04\cdot\ln(C_f)]$
Nickel	Black bass	0.024–0.102	-2.121 (8.3)	<0.01	0.78		$C_{wb}=0.37$
Selenium	Black bass	0.27–0.46	-0.067 (1.1)	0.04	<0.001	0.02	$C_{wb}=\exp[-0.25+0.68\cdot\ln(C_f)]$
Uranium	Black bass	0.00025–0.048	-1.780 (5.9)	<0.01	0.40		$C_{wb}=0.009$
Vanadium	Black bass	0.004–0.014	-1.795 (6.0)	<0.01	0.26		$C_{wb}=0.059$
Zinc	Black bass	5.8–12.0	-0.890 (2.4)	<0.01	0.54		$C_{wb}=18.5$
Total PCBs	Catfish	0.36–2.0	-0.397 (1.5)	0.01	<0.001	0.03	$C_{wb}=\exp[0.21+0.81\cdot\ln(C_f)]$
Total PCBs	Black bass	0.04–2.34	-0.829 (2.3)	<0.01	<0.001	0.79	$C_{wb}=2.3\cdot C_f$
Total chlordane	Catfish	0.027–0.115	-0.167 (1.2)	<0.01	<0.001	0.56	$C_{wb}=1.2\cdot C_f$
Total chlordane	Black bass	0.025–0.05	-0.520 (1.7)	<0.01	0.01	0.45	$C_{wb}=1.7\cdot C_f$
Total DDT	Black bass	0.73-28	-2.922 (18.6)	<0.01	<0.01	<0.01	$C_{wb}=\exp[3.55+0.63\cdot\ln(C_f)]$ or $\{C_{wb}=\exp[3.28+0.70\cdot\ln(C_f)-0.16\cdot\ln(L_f)]\}$
Total DDT	Catfish	0.88-917	-1.809 (6.1)	<0.01	<0.01	<0.01	$C_{wb}=\exp[2.25+0.86\cdot\ln(C_f)]$ or $\{C_{wb}=\exp[2.15+0.90\cdot\ln(C_f)-0.27\cdot\ln(L_f)]\}$
Total DDT	Buffalo	0.75-521	-1.494 (4.5)	<0.01	<0.01	<0.01	$C_{wb}=\exp[2.34+0.69\cdot\ln(C_f)]$ or $\{C_{wb}=\exp[2.17+0.82\cdot\ln(C_f)-0.31\cdot\ln(L_f)]\}$
Total DDT	Carp	1.05-380	-2.543 (12.7)	<0.01	<0.01	<0.01	$C_{wb}=\exp[3.70+0.49\cdot\ln(C_f)]$ or $\{C_{wb}=\exp[2.94+0.65\cdot\ln(C_f)-0.34\cdot\ln(L_f)]\}$

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[a] [illegible]