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Projected Changes to the Trophodynamics of PCBs in the Western Lake Erie Ecosystem Attributed to the Presence of Zebra Mussels (*Dreissena polymorpha*)

HEATHER A. MORRISON,*,† FRANK A. P. C. GOBAS,‡ RODICA LAZAR,† D. MICHAEL WHITTLE,§ AND G. DOUGLAS HAFFNER†

Department of Biological Sciences, University of Windsor, Windsor, Ontario, N9B 3P4 Canada, School of Natural Resource and Environmental Management, Simon Fraser University, Burnaby, British Columbia, V5A 1S6 Canada, and Department of Fisheries and Oceans, Great Lakes Laboratory for Fisheries and Aquatic Sciences, 867 Lakeshore Road, Burlington, Ontario, L7R 4A6 Canada

A food web bioaccumulation model was used to hindcast PCB congener concentrations in aquatic biota from western Lake Erie in the years prior to the zebra mussel invasion, and these results were compared to post-mussel predicted concentrations that had been verified previously against measured data to estimate the effects of mussels on the trophodynamics of PCB congeners in western Lake Erie. Two hindcasting scenarios were compared to a third, previously verified, scenario to determine the changes in PCB congener concentrations in biota in response to (i) modifications to food web structure, before and after the introduction of mussels, and (ii) modifications to food web structure combined with a decline in particulate organic carbon (POC) concentrations resulting from removal of seston from the water column by mussel filtering activities. The reduction in the concentration of POC, attributed to the prodigious filter-feeding of large zebra mussel populations, was predicted to have caused increases in the freely dissolved concentrations of PCB congeners ranging from 2.9% to 9.3%. These increases in dissolved chemical were predicted by the model to cause small increases (range 0−7.3%) in the PCB congener burdens of many biota including zooplankton, prey fish species, and walleye. Other organisms, such as *Gammarus*, small white suckers, and freshwater drum, were predicted to have larger increases in their PCB body burdens (9.1−22.2%) as a result of the increase in freely dissolved chemical and a shift in diet. For crayfish, yellow perch, black crappie, white perch, large white suckers, gizzard shad, and largemouth bass, the increased exposure to chemical via water was offset by decreased chemical exposure via the diet, which resulted from shifts in diet toward less contaminated items brought about by the presense of zebra mussels. The results of this study are relevant to Lake Erie resource managers that are concerned about the potential of zebra mussels to alter PCB congener dynamics in the western basin.

Introduction

The effects of the zebra mussel (*Dreissena polymorpha*) on the dynamics of polychlorinated biphenyls (PCBs) in the western basin of Lake Erie are an important environmental concern (*1*). This concern exists because PCBs are persistent and hazardous chemicals that are prevalent in the basin, and changes in the transfer pathways of these contaminants could lead to increases in the chemical body burdens of aquatic biota. Furthermore, Lake Erie supports the most valuable commercial and recreational freshwater fishery in North America (*2*), and historically PCB and mercury contamination has restricted the use of this resource. The dynamics of PCBs are known to be intimately related to ecosystem dynamics (*3*). Since invading the western basin of Lake Erie, zebra mussels have dramatically changed the ecosystem structure of the basin (*4*, *5*). Hence, the effects of zebra mussels on contaminant transfer in the food web are potentially significant.

Since invading the western basin of Lake Erie in 1988, zebra mussels have had several documented effects on the ecology of the region. Marked declines in chlorophyll *a* concentrations (*5*), phytoplankton densities (*4*), and rotifer densities (*4*) as well as increased water clarity (*5*) have been attributed to the prodigious filtering capacity and indiscriminate scavenging of large populations of zebra mussels. Zebra mussels are capable of removing particles between 0.7 (*6*) and 750 μm (*7*) from the water column. Using a bioenergetics model, Madenjian (*8*) concluded that, in 1990, mussels removed 26 ± 10% of primary production from the western basin. Of the estimated 6.4 million ton of phytoplankton scavenged from the water column, it was predicted that 1.4 million ton was deposited on the lake bottom as pseudofeces.

By depositing nutrient-rich pseudofeces and increasing habitat complexity, zebra mussels benefit many macroinvertebrates (*9*). Macroinvertebrates such as chironomidae larvae and *Gammarus* sp. thrive on diets of pseudofeces (*10*, *11*). Dermott et al. (*9*) observed that abundances of tanytarsine chironomids, mayfly *Caenis* sp., leeches, gastropods, flatworms, and especially *Gammarus fasciatus* were elevated at sites colonized by zebra mussels as compared with uncolonized sites. These increases in population densities were attributed to increased habitat complexity and increased food availability provided by zebra mussels.

Mussels themselves are preyed upon by several species. To varying extents crayfish (*12*, *13*), freshwater drum (*14*), white perch (*15*), yellow perch (*15*), silver bass (*16*), and white suckers (*17*) have incorporated zebra mussels into their diets.

With respect to contaminant dynamics, zebra mussels have the potential to affect the ecosystem in several ways. First, by directly or indirectly influencing the diet compositions of other biota, zebra mussels may be changing the trophodynamics of PCB congeners. Second, by reducing the water column concentration of POC, equilibrium concentrations of freely dissolved chemical could increase. The objective of this paper was to estimate the effects of zebra mussels on the trophodynamics of PCBs through their effects on food web structure and POC levels. In the absense of field data describing PCB congener concentrations in biota

* Address correspondence to this author at her present address: Aqualink, 4936 Yonge St., Suite 507, Toronto, ON, M2N 6S3 Canada; e-mail: morrisonh@dfo-mpo.gc.ca.
† University of Windsor.
‡ Simon Fraser University.
§ Great Lakes Laboratory for Fisheries and Aquatic Sciences.

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TABLE 1. Definition of Symbols

parameter	units	definition
C_B, C_D	μg kg^{-1}	chemical concentration in biota and diet, respectively
C_W	μg L^{-1}	chemical concentration in water
G_W	L d^{-1}	rate of water ventilation across the respiratory surface
G_D	kg d^{-1}	ingestion rate of food
G_R	kg d^{-1}	growth rate
k_M	d^{-1}	metabolic rate
V_{SS}	kg L^{-1}	concentration of suspended solids in water column
E_W, E_D	fraction	efficiency of chemical transfer across the respiratory surface and the organism and between gut contents and the organism, respectively
σ	fraction	particle scavenging efficiency
K_{OW}, K_{OC}		chemical partition coefficient between octanol and water and organic carbon and water, respectively
M_B	kg	mass of organism
α	fraction	fraction of organic carbon or lipid in diet that is removed upon digestion
β	fraction	fraction of ingested diet absorbed by the organism
∅	fraction	fraction of lipid or organic carbon in a phase
ff		filter feeder

in the years prior to the mussel invasion, the food web model of Morrison et al. (*18*) was used to hindcast concentrations. These concentrations were compared to predicted chemical concentrations in western Lake Erie biota from the years since the mussel invasion that had been verified previously against measured data (*18*).

Experimental Section

Foodweb Bioaccumulation Model. The food web bioaccumulation model described by Morrison et al. (*18*) was used to hindcast PCB congener concentrations in aquatic biota from western Lake Erie at steady-state using conventional chemical, biological, and environmental data. The accuracy of the model for predicting PCB congener concentrations in western Lake Erie biota had been determined in Morrison et al. (*18*) and was within a factor of 2 for 95% of the data. The model predicts bioconcentration of persistent organic chemicals by phytoplankton using equilibrium partitioning between the phytoplankton's organic carbon and water. Predicted bioaccumulation of PCBs in all other species is based on the premise that the predominant routes of chemical uptake are directly from water and through consumption of contaminated food. Chemical loss is determined for elimination to water by fecal egestion and metabolic transformation. In addition, growth dilution is included in the model for fish. Assumptions of the model are discussed in Morrison (*18*). The following equations describe bioaccumulation of lipophilic (hydrophobic) chemicals in zooplankton, filter feeding and detritivorous benthic invertebrates, and fish. Definitions and units for each of the parameters in the equations are listed in Table 1.

Benthic Invertebrates, Zooplankton, and Fish.

$$C_B = \left[\frac{C_W G_W E_W + C_D G_D E_D}{\dfrac{E_W G_W}{\varnothing_B K_{OW}} + \dfrac{E_D(1-\alpha)(1-\beta)G_D\varnothing_D}{\varnothing_B} + G_R + M_B k_M}\right] \quad (1)$$

For filter-feeders, the ingestion rate (G_D) can be described as the product of the gill ventilation rate (G_W), the concentration of suspended solids in the water column (V_{SS}), and the particle scavenging efficiency (σ) as follows:

$$G_D = G_W V_{SS} \sigma \quad (2)$$

Four equations were added to the model to better describe the effect of zebra mussels on contaminant transfer. The first two equations describe the chemical concentration and organic carbon and/or lipid content in zebra mussel feces, and the second two equations describe the chemical concentration and organic carbon and/or lipid content in zebra mussel pseudofeces. The following equation describes the chemical concentration in zebra mussel feces ($C_{F,ZM}$):

$$C_{F,ZM} = (1 - E_F)(1 - \beta)C_D \quad (3)$$

where E_F is the efficiency of chemical transfer between the gut contents and the organism, β is the fraction of ingested diet absorbed by the organism, and C_D is the chemical concentration in the diet on a wet weight basis. In this study, E_F was assumed to be constant at 72%. The efficiency of chemical assimilation from food is shown to be dependent on the digestibility of the food and the properties of the chemical (*19*). Bruner et al. (*11*) measured the E_F of PCB 47 (log K_{OW} = 5.90) and PCB 153 (log K_{OW} = 6.90) from spiked algae by zebra mussels to be 77.6% (±5.5) and 68.6% (±2.9), respectively. Other researchers have found that E_F is not well described by K_{OW} (*19*). Because of the lack of data describing the E_F of zebra mussels for a variety of PCB congeners differing in K_{OW}, a single E_F value of 72% was used for all congeners. This value was the mean of all E_F values measured in benthic invertebrates (*20*). This may result in an underestimation of the concentration of the higher K_{OW} congeners and an overestimation of the lower K_{OW} congeners in zebra mussel feces.

The organic carbon and/or lipid content of the feces ($\varnothing_{F,ZM}$) is described as follows:

$$\varnothing_{F,ZM} = (1 - \alpha)\varnothing_D \quad (4)$$

where α is the fraction of organic carbon or lipid in the diet that is removed upon digestion and $\varnothing_D$ is the organic carbon or lipid content of the diet.

The next two equations describe the chemical concentration in zebra mussel pseudofeces ($C_{P,ZM}$) and the organic carbon and/or lipid content of pseudofeces ($\varnothing_{P,ZM}$):

$$C_{P,ZM} = 0.9C_D \quad (5)$$

and

$$\varnothing_{P,ZM} = 0.76\varnothing_D \quad (6)$$

where C_D describes the chemical concentration in the diet of zebra mussels and $\varnothing_D$ describes the organic carbon/lipid content of pseudofeces. These two equations are based on a study by Reeders and Bij de Vaate (*21*) that found that the chemical concentration of pseudofeces was approximately 90% of the chemical concentration in suspended matter and

TABLE 2. Diet Compositions (% vol) for Western Lake Erie Biota prior to and after the Arrival of Zebra Mussels[a]

species		A	B	C	D	E	F	G	H	I	J	K	L	ref[b]
Gammarus	pre	30			30	40								1
	post		50	50										1
crayfish	pre	46			38			2	9	5				2
	post		9	9	25		45	2		10				3
small w. sucker	pre	10				60		5	15	10				1
	post	10				40	15	5	15	15				4
black crappie	pre					75		5	10	10				1
	post					75				25				4
white perch	pre					70		2	20	3		5		1
	post					64	2	3		18		13		5
yellow perch	pre					60		2	25	3		10		1
	post					55	35	1		4		5		5
adult w. sucker	pre	5				60		10	15	10				1
	post	5				50	15	10	5	15				4
f. drum	pre	5				25		30	15	5		20		6
	post	5				5	35		9	16		25	5	7
gizzard shad	pre	10				55		10	20	5				1
	post	10				50	5		15	20				8

[a] A, sediment/detritus; B, zebra mussel pseudofeces; C, zebra mussel feces; D, phytoplankton; E, zooplankton; F, zebra mussels; G, caddisfly larvae; H, *Hexagenia limbata*; I, *Gammarus*; J, crayfish; K, YOY fish; L, emerald shiner; pre, pre-zebra mussel invasion; post, post-zebra mussel invasion; w. sucker, white sucker; f. drum, freshwater drum. [b] 1, estimated; 2, ref *27*; 3, estimates from refs *27*, *12*, and *13*; 4, ref *27*; 5, estimated from ref *15*; 6, estimated from ref *28*; 7, estimated from ref *14*; 8, estimated from refs *29* and *30*.

that the organic carbon content of the pseudofeces was a factor of 0.76 of the organic carbon content of the suspended matter.

Diets. Table 2 lists the pre- and post-zebra mussel diet information for those western Lake Erie biota whose diets have changed since the arrival of zebra mussels. Diets of all other biota are listed in Morrison et al. (*18*). Post-zebra mussel diet data were determined from observations of fish stomach contents carried out as part of this study and from the literature as described by Morrison et al. (*18*). Most of the pre-zebra mussel diet data were assembled from the literature (Table 2). When published data were not available, diets were estimated from post-zebra mussel observations while considering documented changes in prey availability attributed to zebra mussel colonization such as increased concentrations of *Gammarus* (*9*). Where necessary, diets were catagorized in terms of bottom sediment, resuspended sediment, phytoplankton, zooplankton, and the 19 benthic invertebrate and fish species included in the western Lake Erie food web.

Fraction of Chemical Freely Dissolved. To simulate the response of freely dissolved chemical concentrations to an increase in POC measured in the water column in the years prior to the invasion of the basin by zebra mussels, the follow equation was used:

$$F_{DW} = \frac{1}{1 + (\mathrm{POC} + \mathrm{DOC})K_{OC}} \tag{7}$$

where F_{DW} is the fraction of chemical freely dissolved, POC is the concentration of particulate organic carbon (kg of C L^{-1}), DOC is the concentration of dissolved organic carbon (kg of C L^{-1}), and K_{OC} (L kg^{-1}) is the organic carbon−water partitioning coefficient. A K_{OC} value equal to $0.41K_{OW}$ (*22*) was used because it was measured in sediments that contained POC and DOC and should take into account the low affinity of DOC for sorbing organic contaminants.

PCB congener concentrations that were measured in the water column of western Lake Erie after mussels had invaded in 1994 (Table 3) were used to hindcast the concentrations of these congeners in the years prior to the mussel invasion when measured POC levels were higher. The primary assumptions were that total PCB congener concentrations were the same before and after the mussel invasion and that the organic carbon in the water column was in thermodynamic equilibrium with the freely dissolved chemical. The change in measured POC concentrations takes into account changes in phytoplankton density.

Other Model Inputs. Mean POC concentrations in western Lake Erie between May and August 1994 were 0.54 mg of C L^{-1} (range 0.23−1.12) (*23*). Prior to the zebra mussel invasion, POC measurements were made between May and October 1981−1987 and tended to fluctuate around 0.80 mg of C L^{-1} (range 0.20−2.00) (*23*). Zebra mussels do not directly affect DOC concentrations (*24*). DOC concentrations measured in western Lake Erie in May 1986, July 1988, and May−October 1997 were essentially constant at 2.21, 2.13, and 2.50 mg of C L^{-1}, respectively (*23*). Other model input parameters, including lipid values for all of the biota, were obtained from the literature and are listed in Morrison et al. (*18*). Literature cited values for K_{OW} differ; hence, model sensitivity to K_{OW} was assessed. On average, a 10% change in K_{OW} resulted in a 15% change in model output.

Model Simulations. Two scenarios were simulated to assess the effects of zebra mussels on PCB congener concentrations in western Lake Erie. The two scenarios were selected to hindcast PCB congener concentrations in biota from the western basin of Lake Erie in the years prior to the zebra mussel invasion assuming (i) that freely dissolved chemical concentrations did not change pre- and post-mussel invasion but that the structure of the food web, characterized by documented changes in diet compositions, did change and (ii) that freely dissolved chemical concentrations did change in response to higher POC levels and the food web structure also changed. The results of these two scenarios were compared to a third scenario that represented chemical concentrations in biota from western Lake Erie collected in 1993−1994 when zebra mussels were prevalent. Data for the third scenario were predicted by the model and compared to measured data in Morrison et al. (*18*). All of the scenarios assume that the food web is in steady state with chemical concentrations in water and sediment. The three scenarios are summarized as follows:

Scenario 1: Pre-Zebra Mussel Invasion, No Change in POC Levels. In the first scenario, the food web contains no zebra mussels, the POC concentration is 0.54 mg of C L^{-1}, and the DOC concentration is 2.17 mg of C L^{-1}. The concentrations of PCB congeners in the freely dissolved phase are listed in Table 3.

TABLE 3. Freely Dissolved Chemical Concentration (C_W) from the Western Basin of Lake Erie since Zebra Mussels Arrived (Post-Zebra Mussel, POC = 0.54 mg of C/L), Calculated Total Chemical Concentration in the Water Column (C_{TW}), Fraction of Chemical in the Dissolved Phase (F_{DW}) before the Arrival of Zebra Mussels, and Freely Dissolved Chemical Concentration prior to the Arrival of Zebra Mussels (Pre-Zebra Mussels, POC = 0.80 mg of C/L)

chemical	log K_{OW}[a]	post-zebra mussel C_W (pg/L)[b]	calculated C_{TW} (pg/L)	pre-zebra mussel F_{DW}	pre-zebra mussel C_W (pg/L)
28/31	5.6	6.6	9.5	0.67	6.4
52	6.1	24.2	58.1	0.39	22.9
49	6.1	8.0	19.3	0.39	7.6
44	6	8.9	18.7	0.45	8.4
42	5.6	4.5	6.5	0.67	4.4
64	6.1	0.9	2.1	0.39	0.8
74	6.1	3.3	8.0	0.39	3.2
70	5.9	12.6	23.8	0.51	12.1
66/95	5.8	20.3	34.5	0.57	19.5
60	5.9	5.0	9.4	0.51	4.8
101	6.4	8.7	33.1	0.25	8.1
99	6.6	3.0	16.5	0.17	2.8
97	6.6	1.5	8.0	0.17	1.4
87	6.5	3.6	16.2	0.21	3.3
110	6.48	4.7	20.3	0.21	4.3
151	6.9	0.7	6.5	0.09	0.6
149	6.8	2.2	17.7	0.12	2.0
118	6.4	3.5	13.3	0.25	3.3
146	6.9	0.1	1.4	0.09	0.1
153	6.9	1.3	12.6	0.09	1.2
105	6.4	1.5	5.6	0.25	1.4
138	7	1.4	16.6	0.08	1.3
129	7.3	<0.05	0.7	0.04	<0.05
182/187	7.17	0.3	4.4	0.05	0.2
183	7	0.1	1.2	0.08	0.1
174	7	0.1	1.8	0.08	0.1
171	6.7	0.1	0.8	0.14	0.1
180	7.36	0.3	7.0	0.03	0.2
170/190	7.27	0.1	2.0	0.04	0.1
201	7.5	0.1	3.8	0.03	0.1
203	7.1	<0.05	0.7	0.06	<0.05
195	7.1	<0.05	0.7	0.06	<0.05
206	7.2	<0.05	0.9	0.05	<0.05

[a] All values are from ref *31* except for congeners 110, 182/187, 180, and 170/190, which are from ref *32*. [b] Data provided by Environment Canada (see refs *33* and *18*).

Scenario 2: Pre-Zebra Mussel Invasion, Higher POC Levels. In the second scenario, the food web contains no zebra mussels, the POC concentration is 0.80 mg of C L^{-1}, and the DOC concentration is 2.17 mg of C L^{-1}. The estimated concentrations of PCB congeners in the freely dissolved phase are listed in Table 3, and they are less that PCB congener concentrations measured in 1994.

Scenario 3: Post-Zebra Mussel Invasion. The food web contains zebra mussels, the POC concentration is 0.54 mg of C L^{-1}, and the DOC concentration continues to remain constant at 2.17 mg of C L^{-1}. The concentrations of chemicals in the freely dissolved phase when POC levels are 0.54 mg of C L^{-1} are listed in Table 3.

Results and Discussion

This model predicts that the introduction of zebra mussels into the western basin of Lake Erie has altered the trophodynamics of PCBs. The shifts in diet by biota between pre- and post-zebra mussel invasion scenarios 1 and 3, respectively (Table 4) had the largest effect on chemical concentrations in western Lake Erie biota. For example, changes in the diet compositions of crayfish, black crappie, white perch, and yellow perch were estimated to result in a decline in PCB congener burdens of 30%, 29%, 36%, and 49%, respectively. Yellow perch were predicted to exhibit a large decline in PCB burden despite the fact that the chemical concentration in all of their prey items increased between the pre- and post-zebra mussel scenarios. The shift in diet from very contaminated mayfly larvae to less contaminated zebra mussels resulted in a substantial decline in the chemical body burden of yellow perch.

TABLE 4. Predicted Mean % Change in PCB Congener Concentrations in Western Lake Erie Biota in Response to Scenario 1 (S1), Pre-Zebra Mussel Invasion and a POC Level of 0.54 mg of C L^{-1}, and to Scenario 2 (S2), Pre-Zebra Mussel Invasion and a POC Level of 0.80 mg of C L^{-1}, and Scenario 3 (S3), which Represented Post-Zebra Mussel Invasion Conditions[a]

	S2−S1		S3−S1		S3−S2	
species	mean	SD	mean	SD	mean	SD
phytoplankton	6.7	1.7	0.0	0.0	−6.7	1.7
zooplankton	7.3	2.0	0.0	0.0	−7.3	2.0
caddisfly larvae	2.3	1.3	0.0	0.0	−2.3	1.3
gammarus	2.2	1.3	6.7	18.8	−9.1	19.9
hexagenia	0.0	0.0	0.0	0.0	0.0	0.0
crayfish	2.9	1.6	−29.9	32.7	27.5	34.2
young-of-the-year	7.3	2.0	0.0	0.0	−7.3	2.0
emerald shiner	4.7	2.5	0.9	1.7	−5.7	3.8
alewife	5.2	2.6	0.5	2.1	−5.8	4.4
trout-perch	3.1	1.8	1.7	2.1	−4.9	3.4
smelt	5.4	2.7	−3.9	14.3	−1.6	16.4
small white sucker	1.6	1.0	20.2	10.4	−22.2	11.2
black crappie	3.9	2.1	−29.3	27.0	26.1	28.5
white perch	4.5	2.4	−36.0	29.6	32.4	31.8
yellow perch	3.8	1.9	−48.7	24.7	46.3	26.2
white sucker	2.4	1.5	−6.9	8.2	4.6	9.0
freshwater drum	3.1	1.9	13.9	11.5	−17.6	13.9
smallmouth bass	5.5	2.7	0.2	1.7	−5.8	4.1
gizzard shad	1.7	1.1	−0.7	3.4	−1.0	3.8
largemouth bass	4.0	2.1	−10.3	28.4	6.1	30.3
walleye	5.6	2.8	0.2	1.8	−5.8	4.2

[a] SD, = standard deviation.

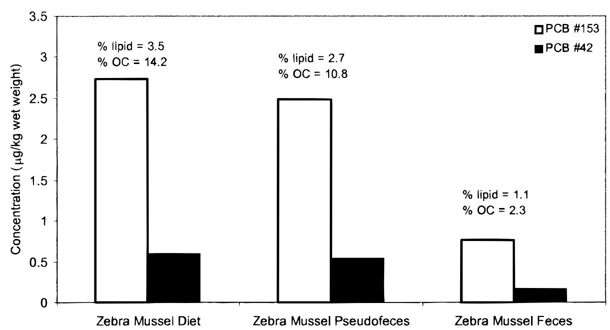

FIGURE 1. Concentration of PCB 42 and PCB 153 and the organic carbon and lipid content of zebra mussel diet, pseudofeces, and feces.

Additionally, shifts in the diets of *Gammarus*, small white sucker, and freshwater drum were estimated to cause increased chemical burdens of 7%, 20% and 14%, respectively (Table 4). In the case of *Gammarus*, the shift in diet from detritus and phytoplankton to feces and pseudofeces is predicted to contribute to increased contaminant exposure (Table 4). Figure 1 illustrates the change in concentration of two PCB congeners and the change in lipid and organic carbon content of zebra mussel diet, pseudofeces, and feces. On a wet-weight basis, the chemical concentration decreases from the diet to pseudofeces to feces as the chemical is accumulated by zebra mussels. On a lipid/organic carbon basis, the chemical concentration increases from the mussels' diet to pseudofeces to feces because the fraction of lipid and organic carbon is lower in these two phases. As

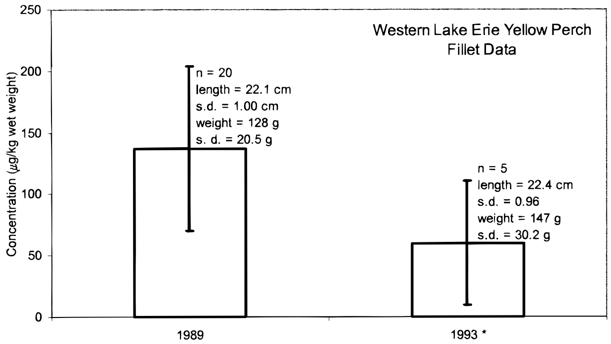

FIGURE 2. Concentration of total PCB (± standard deviation) in the fillet (skinless epaxial muscle) of yellow perch from the western basin of Lake Erie in 1989 (1 year after the invasion of the basin by zebra mussels) and in 1993. The data beside the bars indicate the sample size and size of the fish that were analyzed. Data were provided by ref 25. In 1993, five fish were analyzed for total PCBs. Of these fish, two fish had T-PCB levels below the detection limit. For the sake of graphing the results, it was assumed that the actual concentrations were half of the detection limit. The actual data for the five fish were (μg/kg): >20, >20, 120, 100, and 60.

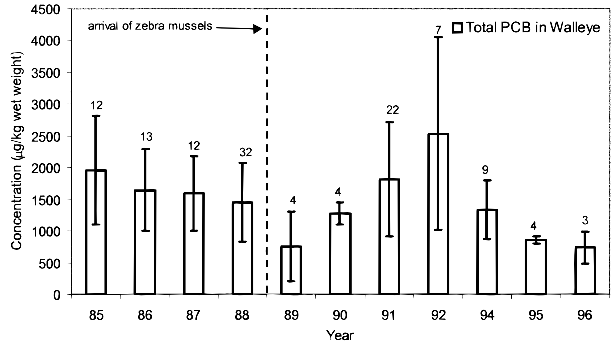

FIGURE 3. Concentration of total PCB (± standard deviation) in 5-year-old whole walleye from the western basin of Lake Erie prior to and since the invasion of zebra mussels. The numbers above the bars indicate the sample size. Data provided by ref 26.

Gammarus assimilate organic carbon from the pseudofeces and feces, they are exposed to relatively higher concentrations of the chemical as compared to when they foraged on detritus and phytoplankton on the surficial sediment.

The reduction in the concentration of POC attributed to large populations of zebra mussels is predicted to have caused increases in the freely dissolved concentrations of PCB congeners (Table 3). Increases in freely dissolved concentrations are predicted to cause increases in the body burdens of PCB congeners in all aquatic biota, including phytoplankton, ranging from <0.05 to 7.3% (S2−S1, Table 4). For many organisms, the increased exposure to chemical via water was offset by decreased chemical exposure via the diet that occurred when organisms shifted their diets toward less contaminated items (S3−S2, Table 4).

From a management perspective, it is of interest to know whether we will be able to detect these changes in contaminant concentrations in commercially valued fish such as walleye, yellow perch, and white perch. Trend data for total PCBs (T-PCB) were available for yellow perch and walleye from the western basin of Lake Erie. Figure 2 illustrates the measured concentrations of total PCBs in skinless dorsal muscle samples of yellow perch. This food web model predicts that PCB congener concentrations have decreased on average 46% since zebra mussels have arrived. If one considers the measured variablility in total PCB concentrations in yellow perch in 1989 (Figure 2), a sample size of 17 fish would be necessary to produce the required level of precision, with 95% confidence, to detect the predicted 46% change in total PCB levels before and after the arrival of zebra mussels with statistical significance. In 1993, five fish were collected. A decrease of approximately 56% in the measured concentration of T-PCB in yellow perch was observed over this time period. The sample size in 1993 was too small to determine if this difference was statistically significant, but these data do agree with the predictions of this food web modeling excerise.

Figure 3 illustrates the measured concentrations of total PCBs in whole fish samples of 5-year-old walleye. This food web model predicts that PCB congener concentrations in walleye have increased on average 5.8% since zebra mussels have arrived because of increased exposure to freely dissolved chemical and more contaminated prey items. If one considers the measured variability in total PCB concentrations in 5-year-old walleye in 1988 (Figure 3), a sample size of 990 5-year-old walleye would be necessary to produce the required level of precision, with 95% confidence, to detect the predicted 5.8% change in total PCB levels before and after the arrival of zebra mussels with statistical significance. There are not enough samples to determine whether the trend data for walleye support or refute the predictions of the model. This calculation was made with the intention of emphasizing the difficulty of statistically quantifying changes in contaminant levels in the environment.

While changing the ecosystem dynamics of the western basin of Lake Erie, zebra mussels are predicted to be concomitantly affecting PCB dynamics. The effects of mussels on the diets of other biota are predicted to have the greatest impact on PCB congener accumulation. The number of organisms whose chemical body burdens are predicted to have been affected by zebra mussels highlights the importance of benthos and benthic processes in determining chemical exposure by aquatic organisms in the western basin of Lake Erie. Furthermore, the effects of zebra mussels on PCB congener levels in western Lake Erie biota are not consistent but vary according to species and their diets.

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