Linking Habitat Use of Hudson River Striped Bass to Accumulation of Polychlorinated Biphenyl Congeners

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Since 1976, the commercial striped bass fishery in the Hudson River (NY) has been closed due to total polychlorinated biphenyl (t-PCB) concentrations that exceed the U.S. Food and Drug Administration's advisory level of 2 μg/g-wet weight. Extensive monitoring of Hudson River striped bass demonstrated much more variability in t-PCB levels among individual striped bass than could be explained by their age, sex, or lipid contents. To investigate the possible role of differential habit use among subpopulations of striped bass in controlling their PCB exposures, 70 fish collected throughout the Hudson River estuary and Long Island Sound in 1994−1995 were analyzed for PCB congeners, and their lifetime migration behaviors were estimated by otolith microchemistry. The mean salinity encountered during the fish's last growth season prior to capture was inversely correlated with the t-PCB body burden. Striped bass permanently residing in fresh and oligohaline portions of the estuary adjacent to known PCB sources had elevated t-PCB levels and congeneric patterns with higher proportions of di-, tri-, and tetrachlorobiphenyls. Conversely, fish spending the majority of their life in more saline waters of the estuary or migrating frequently throughout the salinity gradient contained lower PCB levels composed of more highly chlorinated congeners. The approach used in this study allows habitat use to be incorporated into exposure assessments for anadromous fish species such as striped bass.

Introduction

In estuaries and coastal embayments, the distribution of hydrophobic organic contaminants (HOCs) such as polychlorinated biphenyls (PCBs) is often spatially heterogeneous (*1*−*3*). The exposure and subsequent accumulation of these contaminants to aquatic organisms are influenced by their proximity to the contaminant inventories. For resident organisms such as bivalves and nonmigratory fishes, the body burdens of PCBs often accurately mirror contaminant levels in the organisms' habitat (*4*). However, for migratory species such as the Hudson River striped bass (*Morone saxatilis)*, the evaluation of HOC accumulation requires consideration of temporal variability in exposure.

The Hudson River estuary has enormous spatial variation in PCB contamination. From the mid 1940s to the mid 1970s, the Hudson River estuary received over 250 tonnes of PCBs, largely as a result of industrial discharges above the Troy Dam at Ft. Edward and Hudson Falls (*5*−*7*). PCB inventories in sediments revealed a considerable concentration gradient down-estuary due to advection, dispersion, and dilution (*8*, *9*). However, as a consequence of the decades of PCB release in the upper estuary, the commercial striped bass fishery in the entire Hudson River was closed, and consumption advisories for recreational anglers were issued in 1976. Although total PCB (t-PCB) concentrations in edible portions of striped bass have declined significantly after the termination of direct discharge in the upper estuary in 1978, annual averages still exceed the FDA action limit of 2 μg/g (*10*).

Hudson River striped bass are anadromous, migrating annually to freshwaters to spawn in the spring and returning to coastal and marine environments thereafter (*11*). The migration behavior of these and other anadromous fishes has recently been evaluated using otolith microchemistry analysis (*11*−*13*). In this technique, an electron microprobe is used to measure the molar concentrations of Ca and Sr in layers sequentially deposited within the otolith (the calcium carbonate "ear stone" responsible for hearing and equilibrium) during growth of the fish. Abundant in seawater, Sr is diluted in estuarine environments by freshwater input and, therefore, serves as a tracer of salinity (*14*). A fish's age-and season-specific habitat (salinity) history is determined from the ratio of Sr to Ca (Sr:Ca) to seasonal bands (annuli) within the otolith's microstructure (*15*).

Thomann et al. (*16*) modeled PCB contamination in the Hudson River striped bass by assuming that the entire population of fish began emigrating into coastal environments following sexual maturity. However, Secor and Piccoli (*13*) concluded that Hudson River striped bass migratory behavior is highly variable. To investigate the effect of habitat use on PCB concentrations, Zlokovitz and Secor (*17*) evaluated the lifetime salinity histories of a sample of striped bass collected along the Hudson River estuary and Long Island Sound during the fall and spring of 1994−1995 and related them to individual total PCB (t-PCB) levels in muscle tissue. t-PCB concentrations were inversely correlated with recent habitat use as measured by the mean salinity encountered during the last growth season prior to capture (*17*). Hudson River striped bass residing in fresh to oligohaline regions near the dominant PCB source had the highest contaminant body burdens while those inhabiting largely meso- to euhaline waters had significantly lower t-PCB concentrations. The observed relationship between recent habitat use and PCB body burden was independent of effects due to collection season, sex, or fish size.

Congener specific PCB profiles in surficial sediments collected along the Hudson River estuarine gradient revealed a shift from higher chlorinated patterns in areas of higher salinity to a more "unweathered" profile having more lower chlorinated congeners near the dominant PCB source (*18*). Resident fish utilizing the upper estuary might, therefore, have PCB congener patterns enriched in lower chlorinated congeners. Bush et al. (*7*) analyzed congener specific PCBs in striped bass and suggested that the presence of lower chlorinated congeners, specifically 2,2′- and 2,6-dichlorobiphenyl, indicated a recent exposure to the upper Hudson River PCB source. They also observed a subset of striped bass PCB patterns which were depleted in lower chlorinated congeners, suggesting that a contingent was either not exposed to the upper Hudson River PCB source or had depurated those less lipophilic congeners between the time of exposure and collection (*19*).

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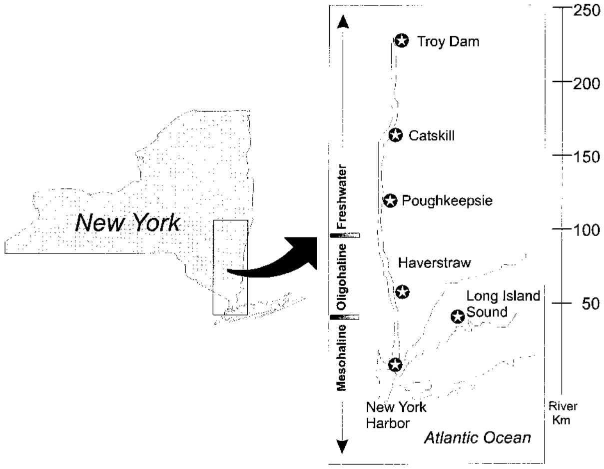

FIGURE 1. Map of the Hudson River Estuary and Long Island Sound showing zones of capture for those fish used in this study.

The objectives of this study were (1) to relate concentrations and patterns of PCB congeners in Hudson River striped bass to their habitat use, as determined by otolith microchemistry, and (2) to explore whether PCB congener patterns and habitat use can be used to identify other sources of PCBs to the Hudson River estuary. This is the first attempt to incorporate the individual variability in migration patterns among a population of anadromous fish into an assessment of PCB congener exposure in an estuary.

Methods

Sample Collection. Since 1976, the New York State Department of Environmental Conservation (NYDEC) has routinely monitored PCB concentrations in striped bass collected from the Hudson River, the south shore of Long Island, and the Long Island Sound to document spatial and temporal contaminant patterns for purposes of establishing consumption advisories and to assist in the management and regulation of the contaminated fishery. Striped bass samples are routinely collected by beach haul seine or angling (a small portion of the total catch), and the edible fillets are analyzed for t-PCBs using standard EPA analytical methods. In this study, we reanalyzed a subset of the striped bass that were collected by the NYDEC in the Fall 1994/Spring 1995 and analyzed for t-PCBs by Hazleton Environmental Services (Madison, WI) for PCB congeners using high-resolution capillary gas chromatography (*2, 20*) and for habitat use by otolith microchemistry (*13, 17*). The fish (33 males; 37 females) were chosen to include fish from five zones within the Hudson River (Troy, Catskill, Poughkeepsie, Haverstraw Bay, New York Harbor) and one zone incorporating sites from Long Island Sound (Figure 1).

PCB Congener Analysis. Whole striped bass fillets (skin-on) were homogenized. A 20 g subsample of the homogenate was extracted for 16 h with dichloromethane using a Soxhlet apparatus and analyzed for t-PCBs and lipid content by Hazleton Environmental Services (Madison, WI). Sample extracts were shipped from Hazleton to our laboratory for PCB congener analysis using laboratory and quantification methods previously published (*1, 2, 20, 21*). t-PCBs were calculated by summing those congeners detected above the detection limit.

Analytical Quality Assurance. To assess precision of the PCB analysis, two sample replicates were taken from each sample extraction test tube of seven randomly selected samples. The average percent difference between duplicate samples for total PCB concentrations was ca. 7%. Overall method recoveries determined by adding surrogate PCB congeners 14, 65, and 166 to the extracts prior to lipid separation averaged 76 ± 24%, 71 ± 18%, and 87 ± 26%, respectively. Masses of PCB congeners in the Hudson River striped bass extracts were generally much greater than those in laboratory matrix blanks (30 g of clean Na_2SO_4 analyzed using identical procedures). The method detection limit for each congener was calculated as the larger of three times the mass of analyte in the matrix blank or three times the instrumental detection limit. The t-PCB method detection limit was 27.0 ng/sample or 0.14 ng/g-wet weight. Concentrations of the vast majority of PCB congeners were well above detectable levels in these samples. Method accuracy for individual PCB congener analysis was within 15% of true values, as determined by analysis of NIST Standard Reference Material 1974a (Organics in Mussel Tissue).

Otolith Analysis. The habitat use of each fish was determined by tracing the salinity history by microchemical analysis of otoliths, as detailed in Zlokovitz and Secor (*17*). To determine salinity histories of each fish, electron probe otolith microanalysis of strontium and calcium was performed by X-ray wavelength dispersive spectrometry using a JEOL JXA-840A microprobe (Center for Microanalysis, University of Maryland, College Park, MD). Time series of Sr:Ca ratios were compiled for each striped bass. To convert Sr:Ca values to salinity, the logistic relationship developed by Secor et al. (*15*) was used. Based on residuals from the relationship, Sr:Ca typically predicted salinity habitation with a precision error less than 6 ppt.

Data Analysis. Principal component analysis (PCA) was performed on the concentrations of individual congeners to mathematically aid in discrimination of congeneric pattern differences/similarities. Our assumption underlying the use of this technique is that fish samples of common habitat use will tend to have similar patterns of PCB congeners, even though absolute concentrations may vary widely due to such factors as age, lipid content, and diet. To remove the effect of absolute concentration on the first principal component, individual PCB congener concentrations were normalized to t-PCB (*22, 23*). In some samples where several congener concentrations were below the instrumental detection limit, the detection limit was substituted such that those congeners could be used in the PCA (*24*). The first two principal component scores of a PCA were used to detect differences or similarities among individual PCB congener patterns. The resulting eigenvectors in the principal component equation were used to identify those specific congeners which varied the most between habitat types. Linear discriminant analysis (LDA) was used to classify individual congener patterns into distinct groups based on, in this case, salinity habitation (*25*). Because of the relatively small number of fish analyzed, the jackknifing method was used. This involved successively eliminating each individual and allocating it to a group based on a rule developed from the remaining individuals (*26*).

Results

Salinity (Migration) Profiles. Four distinct migratory patterns were discerned in the Hudson River striped bass analyzed (Figure 2a−d). The first pattern represents resident behavior at salinities less than 5 ppt and was found for all fish captured at Troy (Figure 2a). Individuals having this pattern had the highest average t-PCBs body burdens (3500 ± 900 ng/g wet weight) due to constant exposure to the highly contaminated upper freshwater portion of the estuary (*17*). The second and third patterns involved habitat shifts from either high to low (Figure 2b) or from low to high salinities (Figure 2c). Habitat shifts from saline waters to freshwaters often corresponded to t-PCB concentrations which were higher than the mean value for all fish throughout the estuary and Long Island (1300 ± 1200 ng/g wet wgt). Conversely, shifts from low to high salinity often coincided with lower t-PCB body burdens. However, exceptions were observed, such as

TABLE 1. Summary of Spring 1994 and Fall 1995 Collected Hudson River Striped Bass

location caught	river (km)	age (years)	weight (g)	length (mm)	lipid content (%)	mean salinity of last year (ppt)	t-PCBs (ng/g wet wgt)
Long Island Sound ($n = 5$)		5 ± 2	3100 ± 2200	640 ± 140	5 ± 3	23 ± 6	500 ± 400
New York Harbor ($n = 17$)	5	7 ± 4	3300 ± 2400	650 ± 160	6 ± 3	23 ± 7	1200 ± 1100
Haverstraw ($n = 17$)	60	6 ± 2	3500 ± 2300	660 ± 100	5 ± 2	22 ± 8	900 ± 900
Poughkeepsie ($n = 7$)	120	6 ± 2	3000 ± 700	640 ± 50	7 ± 3	20 ± 4	1000 ± 1000
Catskill ($n = 12$)	165	8 ± 3	4800 ± 2200	730 ± 110	5 ± 1	25 ± 8	700 ± 500
Troy ($n = 12$)	235	9 ± 3	3600 ± 2500	670 ± 140	4 ± 2	4 ± 2	4000 ± 1000

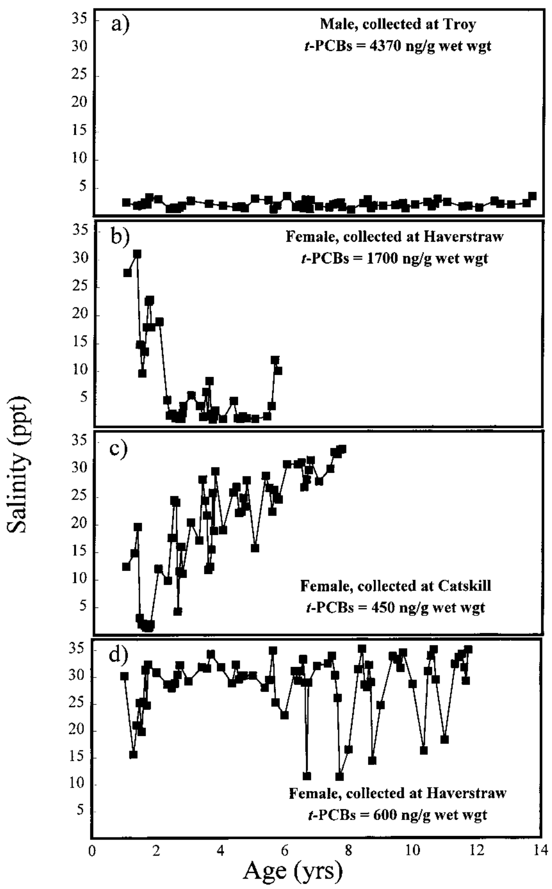

FIGURE 2. Representative time series of salinity habitation for individual fish displaying (a) resident behavior, (b) a shift from high to low salinity, (c) a shift from low salinity to high salinity, and (d) resident behavior in saline waters with annual migrations to fresher waters.

a female captured at Haverstraw (river km 65) with relatively high t-PCB concentrations (3000 ng/g wet wgt) that spent its early life in freshwater near the known source but inhabited meso- to polyhaline regions for most of the remainder of its lifetime. The final pattern determined through olotolith chemistry was one incorporating annual migrations from freshwater/oligohaline to marine habitats (Figure 2d), indicating possible spawning migrations (*13*).

Mean salinity during the last year of a fish's life has been used as an index of recent habitat use for Hudson River striped bass (*17*). Although all fish captured at Troy (river km 235) displayed resident behavior with an average mean salinity value of 4 ± 2 ppt, fish caught at the other locations generally had widely varying habitat uses (Table 1). For example, fish caught approximately 70 km down-estuary of Troy at Catskill (river km 175) had mean salinity values ranging from 3 to 35 ppt. Similarly, those fish captured at Haverstraw (river km 60) ranged in habitat use from 3 to 30 ppt (with an average mean salinity value of 22 ± 8 ppt). The wide ranges of habitat use arose from the fact that collections were made in both the fall and the spring. In the fall, fish collected up-estuary tended to be resident, while in the spring the collections consisted of both resident fish and those that traveled up-estuary into the spawning grounds. With the exception of three fish having mean salinity histories >11 ppt and one with a history near 35 ppt, those fish collected in the New York Harbor ($n = 17$) used habitats within the relatively small range of 20–29 ppt.

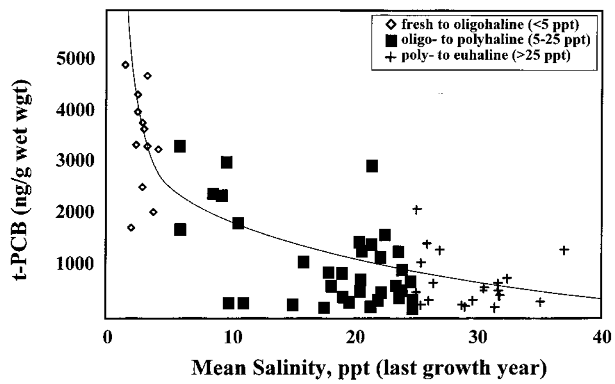

FIGURE 3. Mean salinity of last growth year versus t-PCB concentrations in Hudson River striped bass fillets as determined by congener specific analysis.

Using t-PCBs as determined by the Aroclor Method (Hazleton Environmental Services), Zlokovitz and Secor (*17*) found contaminant body burdens were strongly and inversely related to mean salinity of the last growth year ($r = -0.71$; $p < 0.001$). Using the sum of all quantified congeners in this study, t-PCB concentrations (expressed as mass/mass wet wgt) were similarly well correlated to habitat use as expressed by mean salinity of the last growth season (Figure 3; $r = -0.75$; $p < 0.001$). Other factors such as lipid content, length, age, sex, and weight were poorly correlated to t-PCB concentrations ($r < 0.2$; $p < 0.001$) suggesting habitat use as the major determinant of the magnitude of contaminant body burdens. Despite this, there was considerable scatter in data points reflecting the large variability in migration behavior of the sampled striped bass as well as in t-PCB body burdens (Figure 3).

PCB Congener Patterns. Four representative congener patterns corresponding to the individual fish with varying habitat use from Figure 2 are shown in Figure 4. Coeluting congeners 4+10 (2,2′- and 2,6-dichlorobiphenyl) are often present in larger relative proportions in fish with resident

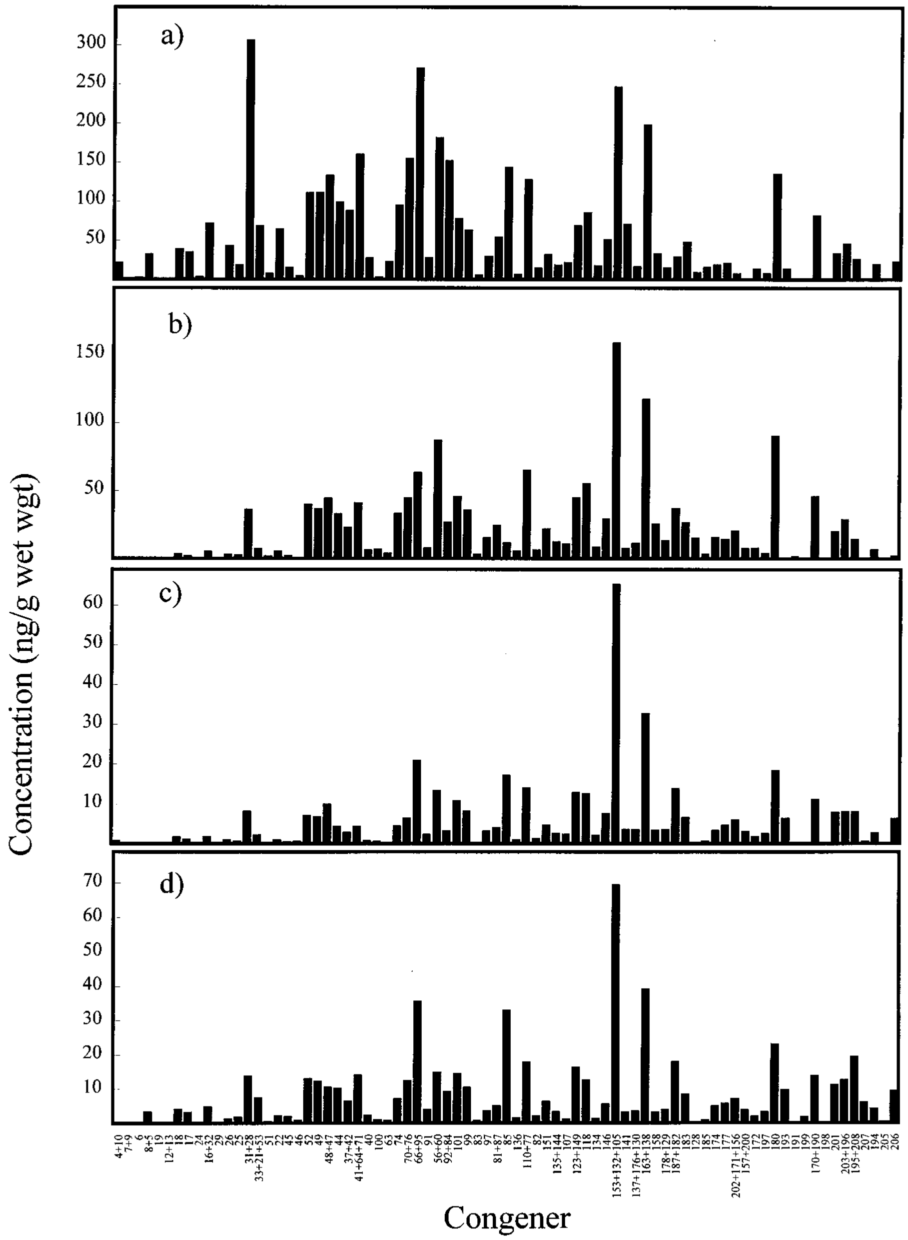

FIGURE 4. PCB congener concentrations displayed in chromatographic elution order for four Hudson River striped bass with time series of salinity habitation shown in Figure 2.

behavior (e.g., Figure 4a vs 4b−d). These congeners were also detected in sediment and prey fish samples from the upper estuary, suggesting a recent exposure to unweathered, near-source PCBs (*7*). Congeners 31+28, 66+95, 153+132+105, 163+138, and 180 were often the largest contributing peaks in the congener patterns in these fish. Those resident fish using habitats of mean salinity <5 ppt (e.g., Figure 2a) often, but not exclusively, had PCB congener patterns having a higher proportion of lower chlorinated congeners (di-, tri-, and tetrachlorobiphenyls) (Figure 4a) compared to those patterns (Figure 4b−d) obtained from fish exhibiting the three other migration behaviors (Figure 2b−d). In comparison, the majority of fish using habitats of mean salinity during the last growth year of >5 ppt had congeneric profiles having a larger proportion of the higher chlorinated congeners. However, there were several individuals that had lighter PCB congener patterns indicative of the up-river source that had not utilized the fresh or oligohaline portions of the Hudson.

Principal Component Analysis of PCB Congener Patterns. The first two principal components (PC1 and PC2) described 41% and 10% of the variability among the PCB congener patterns of all fish, respectively. Clustering of fish samples into distinct groups was not observed from a PCA crossplot (Figure 5). Based on mean salinity of the last growth year, each fish was grouped into one of three mean salinity groups: "fresh to oligohaline" (<5 ppt), "oligo- to polyhaline" (6−25 ppt), or "poly- to euhaline" (>25 ppt, Figure 5). As the distance among denoted salinity groups increases, the normalized congener patterns become more different among those groups. For example, the individual patterns observed for those resident fish utilizing fresh to oligohaline waters most greatly differed from those using habitats of mean salinities greater than 25 ppt as indicated by the largest separation of these two groups on the PCA crossplot (Figure 5). On average, as PC1 scores increase, the more saline the water the fish utilized during the last growth year. For PC1, coefficient (eigenvectors) weightings were by far highest for the coeluting congeners 31+28 and 153+132+105. As expected, PC1 and the ratio of the concentrations of the two coeluting congeners ([31+28] to [153+132+105]) were highly correlated ($r = 0.\text{-}88$; $p < 0.001$). Coupling the information

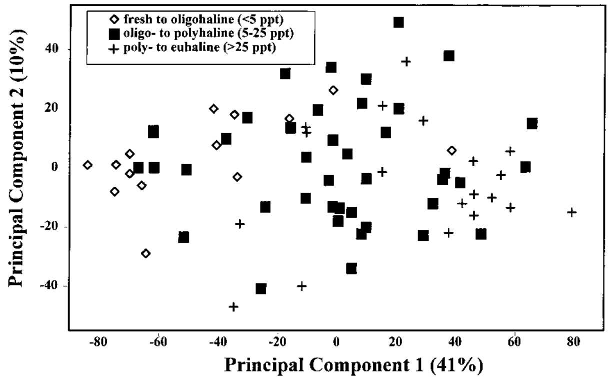

FIGURE 5. Cross-plot resulting from principal component analysis of normalized PCB congener concentrations in Hudson River striped bass. Individual fish are grouped according to mean salinity range of last growth year.

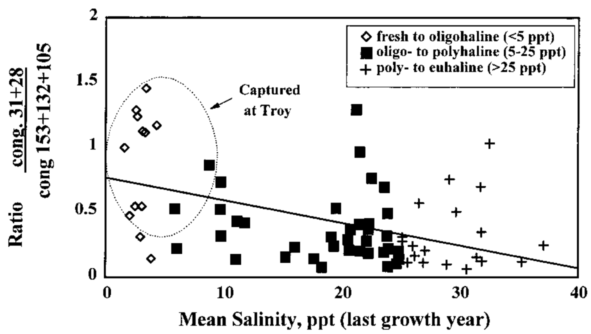

FIGURE 6. The ratio of the concentrations of coeluting congeners 31+28 to 153+132+105 in Hudson River striped bass versus mean salinity range for last growth year.

TABLE 2. Linear Discriminant Analysis under Jackknifing Method of PCB Congener Data Showing Allocation of Individual Striped Bass Patterns in Salinity Groups (Last Year Before Capture)

	assigned group		
allocated to	0−5 ppt	6−25 ppt	>25 ppt
0−5 ppt	81.8% ($n = 9$)	18.2% ($n = 2$)	0% ($n = 0$)
6−25 ppt	32.4% ($n = 12$)	51.4% ($n = 19$)	16.2% ($n = 6$)
>25 ppt	4.6% ($n = 1$)	13.6% ($n = 3$)	81.8% ($n = 18$)

gained by the PCA crossplot and the coefficients, the ratio also was negatively correlated to the mean salinity of the last growth year (Figure 6; $r = -0.50$; $p < 0.001$).

Linear Discriminant Analysis of PCB Congener Patterns. PCB patterns from individual striped bass were classified into three groups based on mean salinity of the last year before capture. A linear discriminant analysis using the jackknifing method was performed (Table 2). The jackknifed estimates indicate 82% of those striped bass assigned the 0−5 ppt salinity range could be correctly allocated to that salinity range. The same percentage of striped bass originally assigned to the >25 ppt range could be correctly allocated in that bin. A lower probability (52%) exists for those assigned to the 5−25 ppt range and allotted to the same range. Overall, linear discriminant analysis predicted 72% of the samples were correctly allocated to mean salinity range (last year before capture) on the basis of PCB congener pattern, suggesting a tight coupling between habitat use and PCB congener accumulation in the Hudson River striped bass population.

Discussion

The majority of Hudson River striped bass utilize the estuary only for portions of their lives. Age and sex greatly affect habitat choice. Typically, young of the year and yearlings reside in the estuary, while many older fish return to portions of the estuary only to overwinter and/or spawn. Salinity chronologies determined for the striped bass collected in the Fall 1994 and Spring 1995 affirm recent findings of tremendous variability in habitat use (as expressed by mean salinity of the last growth year) within the Hudson River population (Figure 2) (*13, 17*). Similarly, as others have reported (e.g., *6, 7, 10*), t-PCB body burdens of Hudson River and Long Island Sound striped bass vary widely as well (Table 1). Variability in PCB concentrations within a fish population not associated with the fishes' characteristics (% lipid, length, etc.) have also been observed in the lake trout of Lake Michigan. Using an individual-based model approach, Madenjian et al. (*27*) found that the variation in contaminant concentrations among individual fish could be explained by subjecting subsets of the population to different PCB concentrations in prey fish. In the Hudson River however, the variation in t-PCB body burdens is largely driven by the widely varying patterns of habitat use (Figure 3) in an estuary which is known to be dominated by a significant and localized source of contamination. Recently, Madenjian et al. (*28*) found that male walleye utilizing more contaminated environments of Saginaw Bay accumulated more PCBs than did females which migrated further from the major contaminant sources. The results presented here demonstrate that the findings of Madenjian et al. (*28*) are not unique to a single species or location.

Many striped bass permanently residing in fresh to oligohaline waters (e.g., Figure 4a) have higher proportions of lower chlorinated congeners (di-, tri-, and tetrachlorobiphenyls) compared to those utilizing other portions of the estuary (e.g., Figure 4b−d). However, as revealed by the ratio of coeluting congeners (31+28) to (153+132+105) (Figure 6), considerable variability in the patterns exist within a population of fish using similar salinity ranges. For example, the population of fish residing permanently in the fresh to oligohaline waters (0−5 ppt) of the upper estuary had patterns that exemplified both near-source (lower chlorinated) and further from known source (higher chlorinated) profiles. Of the 12 fish utilizing fresh to oligohaline waters (0−5 ppt) and displaying resident lifetime behaviors (e.g., Figure 2a), all but two were caught in the Troy Dam region (Figure 6). The Troy-caught fish may be considered truly resident. Two fish within this denoted salinity range having mean salinity levels of 3.0 and 3.9 ppt and 31+28 to 153+132+105 congener ratios of 0.30 and 0.15 (indicating patterns that were dominated by higher chlorinated PCB congeners, Figure 6) were caught at Catskill (river km 175) and Haverstraw (river km 60). Unlike those caught at Troy, these two fish migrated down the estuary to these areas and may have depurated lower chlorinated congeners between the time of exposure to the unweathered source around the Troy Dam and their capture. Similarly, a fish with mean salinity of 6 ppt and an equally low congener ratio of 0.23 was caught down-estuary at Haverstraw. These individual cases suggest that small differences in the salinity of habitat recently encountered can have large consequences to PCB exposure and accumulation.

On average, fish utilizing the 0−5 ppt salinity range had congener patterns that were statistically different from those utilizing down-estuary salinity ranges. Patterns dominated by lower chlorinated congeners were indicative of lifetime exposure to unweathered PCBs in the fresh to oligohaline waters of the upper estuary (Troy Dam), while patterns shifted to more higher chlorinated congeners down-estuary. Bush et al. (*7*) observed similar pattern differences when comparing individuals captured from the Hudson River to those captured

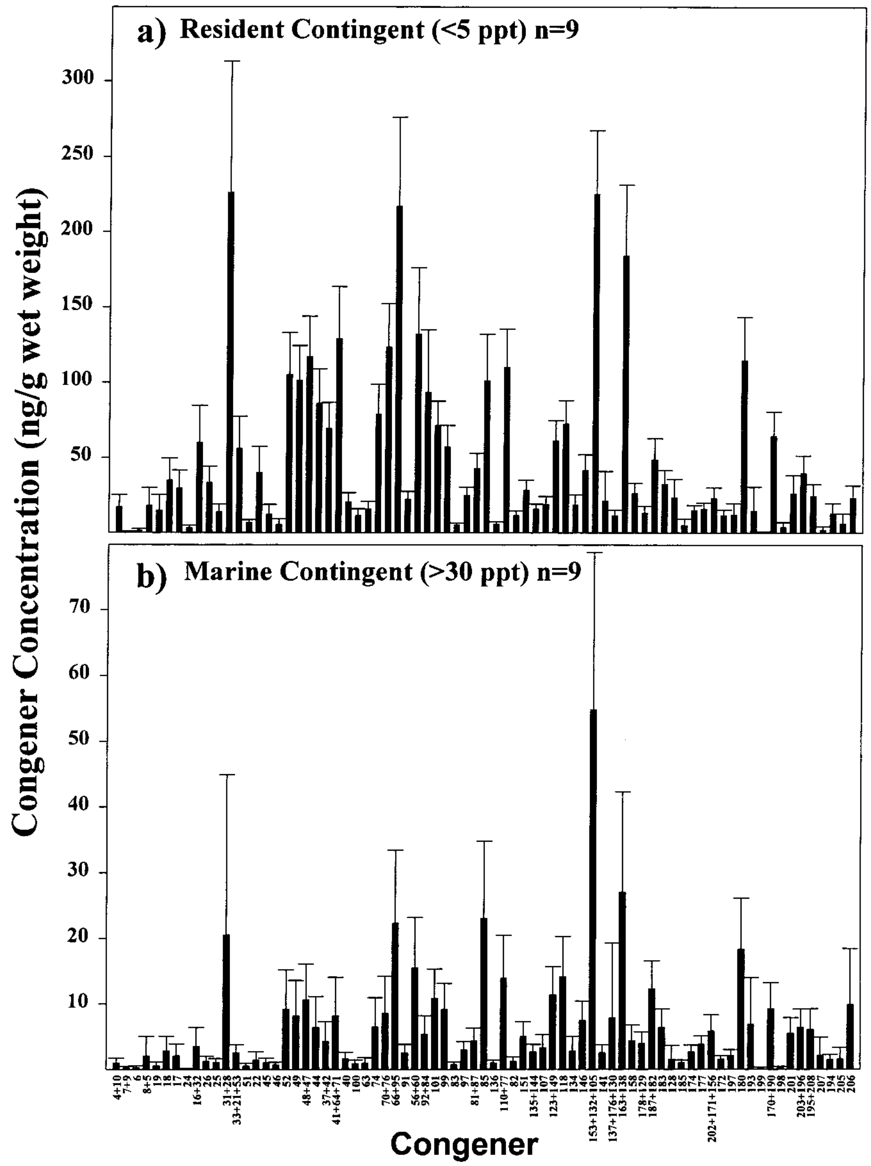

FIGURE 7. Average congener patterns showing absolute concentrations for (a) an "exposed" contingent residing near the known source in the upper Hudson River and (b) a "background" or marine contingent residing in waters > 30 ppt. Error bars represent the standard deviations of the means.

from the Long Island Sound area. They speculated that most of the fish from Long Island Sound were either not exposed to the Hudson River estuary or had been absent from the estuary for an extended time such that the less chlorinated congeners had a chance to depurate. According to tagging studies by Clark (*29*), most Long Island Sound striped bass do not utilize the Hudson River estuary or New York Harbor for growth. The salinity profiles of the fish utilizing salinities > 30 ppt and having low t-PCBs body burdens indicate little growth or PCB bioaccumulation occurring in freshwaters. The resulting average congeneric pattern from those fish can therefore be confidently labeled as representative of the "marine" contingent of bass having little to no interactions with the known source at in the Troy Dam area (Figure 7b), even though some of these fish had PCB congener patterns with low ratios of coeluting congeners 31+28 to 153+132+105 (Figure 6). Conversely, the average congeneric pattern from the resident, near-source contingent represents that expected under constant exposure from the upper estuary source (Figure 7a).

In the salinity range from 20 to 25 ppt, t-PCB levels in striped bass were highly variable, suggesting that a sub-population from this area may have been exposed to a large regional source of PCBs (e.g., New York Harbor). Moreover, within this salinity range, there were several fish that displayed Upper Hudson source-like patterns as indicated by the ratio of congeners 31+28 to 153+132+105 (Figure 6), even though their individual lifetime salinity chronologies suggested that they had not been in fresh to oligohaline (0−5 ppt) waters. To discriminate potential unique PCB signals from this area, average PCB congener patterns in fish with t-PCBs ≥ 1 ng/g wet weight were compared with those with t-PCBs < 1 ng/g wet weight from this salinity range (Figure 8). The resulting strong linear correlation suggests little difference in PCB congener patterns of the two groups. This consistency suggests either that the "hot" population has been exposed to the upper estuary source but had sufficient time to depurate the lower chlorinated congeners or that the patterns of the "hot" contingent with mean salinities of 20−25 ppt may reflect a local source with more chlorinated congeners than the up-river PCB source. It has been widely accepted that the upper Hudson River is a major source of PCB contamination to the lower estuary (*30*); however, elevated concentrations of PCBs in sediments from New York Harbor

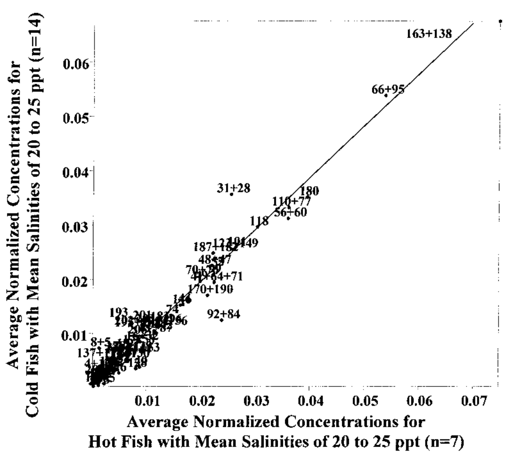

FIGURE 8. Scatter plot of the average normalized congener concentrations of "hot" (t-PCBs ≥ 1 ng/g wet wgt) versus "cold" (t-PCBs <1 ng/g wet wgt) contingents the salinity range of 20−25 ppt. The 1:1 line indicates the case where PCB patterns are identical.

have been reported (*9*). Recently, Durrel and Lizotte (*31*) estimated that 88 kg of PCB is annually discharged from New York and New Jersey wastewater treatment plants. Whether these inputs are significantly contributing to the inventories of PCBs in the sediment, water, and biota and are providing a unique congener pattern in fish utilizing the Harbor as primary habitat remains unclear. This is partly due to the limited resolution in pinpointing the usage of suspected contaminated areas such as New York Harbor using the salinity profiles derived from otolith analysis. Moreover, the numerous trophic transfers that PCB congeners undergo on their way to upper trophic levels may ultimately hamper our ability to use a top predator's congeneric pattern for source detection.

Contamination of PCBs in the upper Hudson River not only resulted in elevated body burdens of those striped bass permanently residing in the area but also imparted a characteristic congeneric pattern to the contingent, one that was dominated by lower chlorinated PCB congeners. Based on the congener patterns of sampled Hudson River and Long Island Sound striped bass, there was evidence to suggest other important sources within the estuary. However, due to the limited resolution in pinpointing exact locations with respect to mean salinities within the Hudson River, the source of these PCBs is unknown, but it is likely to be of urban origin (NY Harbor). Other more accurate techniques for evaluating lifetime habitat use such as biotelemetry should be investigated. This study demonstrates the need to adopt an individual-based approach when modeling both the magnitude and pattern of PCB accumulation in Hudson River striped bass such that consideration of the variability in habitat use may be incorporated. Furthermore, considering the influence of habitat use on PCB bioaccumulation in striped bass within the Hudson River, it is not suggested that this species be used as a sentinel species for precisely denoting contaminant sources along the estuary or as indicators of specific habitat quality. Although habitat use was observed to be a determinant of PCB exposure and accumulation in the Hudson River, other factors such as dietary differences down the estuarine gradient of the river and Long Island Sound (*29*), elimination by metabolic (e.g., ref *32*) or reproductive processes (e.g., ref *33*), and depuration kinetics for PCBs (e.g., ref *16, 19*) in striped bass may be important in the heterogeneously contaminated Hudson River.

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