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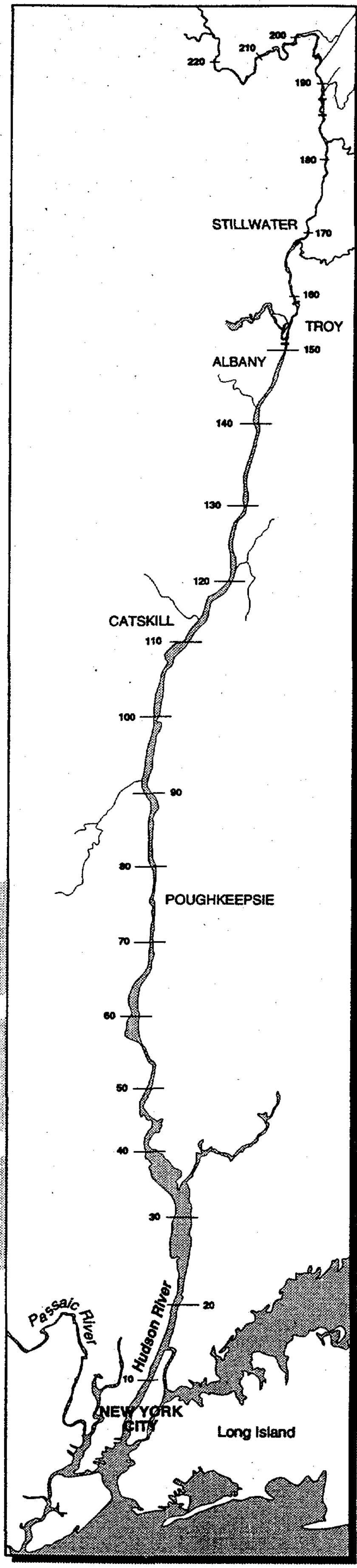
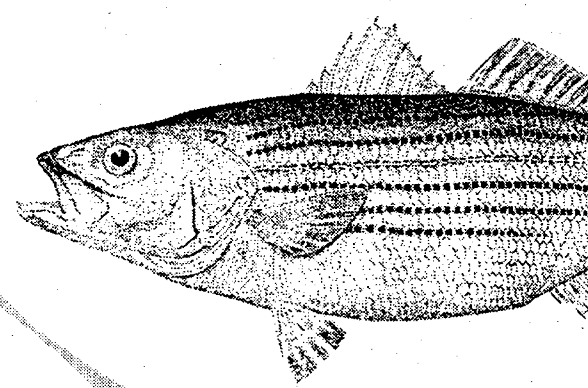
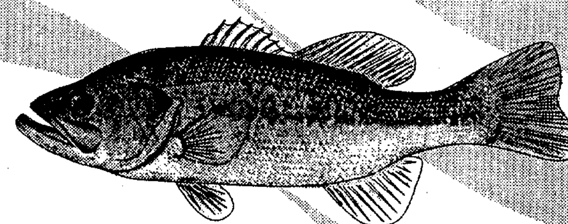


Hudson River
Congener-Specific Analysis

DATA SUMMARY AND ANALYSIS REPORT

JULY 1997





PREPARED FOR:

National Oceanic and Atmospheric Administration Damage Assessment Center
Silver Spring, Maryland

PREPARED BY:

ENVIRONMENT CONSULTANTS
Seattle, Washington

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Hudson River
Congener-Specific Analysis

DATA SUMMARY AND ANALYSIS REPORT

by

Susan E. McGroddy[2], Lorraine B. Read[2], L. Jay Field[1], Corinne G. Severn[2], and Robert N. Dexter[2]

Prepared for

[1]National Oceanic and Atmospheric Administration
Damage Assessment Center
Silver Spring, MD

William Conner, COTR

Prepared by

[2]EVS Environment Consultants, Inc.
200 West Mercer Street, Suite 403
Seattle, WA 98119

Under contract to

Industrial Economics, Incorporated
2067 Massachusetts Avenue
Cambridge, MA 02140

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LIST OF ACRONYMS

GC/ECD	gas chromatography with electron capture detection
GE	General Electric
NOAA	National Oceanic and Atmospheric Administration
NPL	National Priorities List
NYSDEC	New York State Department of Environmental Conservation
PCB	polychlorinated biphenyl
QA/QC	quality assurance/quality control
RI/FS	remedial investigation and feasibility study
RM	river mile
U.S. EPA	U.S. Environmental Protection Agency

EXECUTIVE SUMMARY

Approximately 200 miles of the Hudson River, from Hudson Falls to New York City, are collectively designated as a federal Superfund site because of polychlorinated biphenyl (PCB) contamination. The contamination is documented to be primarily the result of releases of PCBs to the river from two manufacturing facilities located at Hudson Falls and Fort Edward (Figures ES-1 through ES-3). This PCB contamination has resulted in closures of recreational and commercial fisheries along the river. The striped bass commercial fishery in the lower Hudson River has been closed since 1976 because of PCB contamination at concentrations that exceed the U.S. Food and Drug Administration advisory level for PCBs in fish.

Historical monitoring conducted primarily by the New York State Department of Environmental Conservation (NYSDEC) since 1978 has measured PCB concentrations on an Aroclor basis in striped bass and other fish species. Results have consistently shown that total PCB concentrations in fish decrease with increasing distance from the Thompson Island Pool. PCB congener data for resident fish species collected in 1993 as part of the Superfund Remedial Investigation showed a downstream decline in total PCB concentrations, similar to that seen in the historical data. The 1993 study also demonstrated that the PCB compositions in several resident fish species collected from multiple locations between the Thompson Island Pool and the Tappan Zee area were highly consistent both within and among species at a given location. Both the historical Aroclor data and the 1993 congener data showed that the lower-chlorinated di-, tri-, and tetrachlorobiphenyls decreased in concentration more rapidly along the downstream gradient than the higher-chlorinated penta-, hexa-, and heptachlorobiphenyls.

Adult striped bass may spend part of the year outside of the Hudson River, resulting in exposure to a variety of PCB sources in addition to those associated with the Hudson River, including releases into Long Island Sound from New York City and other coastal sources. The purpose of this study is to evaluate whether PCB contamination in striped bass is predominantly derived from the historical and ongoing releases of PCBs from the Upper Hudson River above the Thompson Island Dam or from other potential sources within or outside the Hudson River. PCB congener concentrations were measured in adult striped bass and resident fish species (yellow perch, largemouth bass, white perch, and juvenile striped bass) collected in 1995 from multiple locations throughout the river. The 1995 data, combined with the 1993 congener-specific data for resident fish species and the historical, Aroclor-based data, are used as a basis for evaluating the likely origin of PCB body burdens.

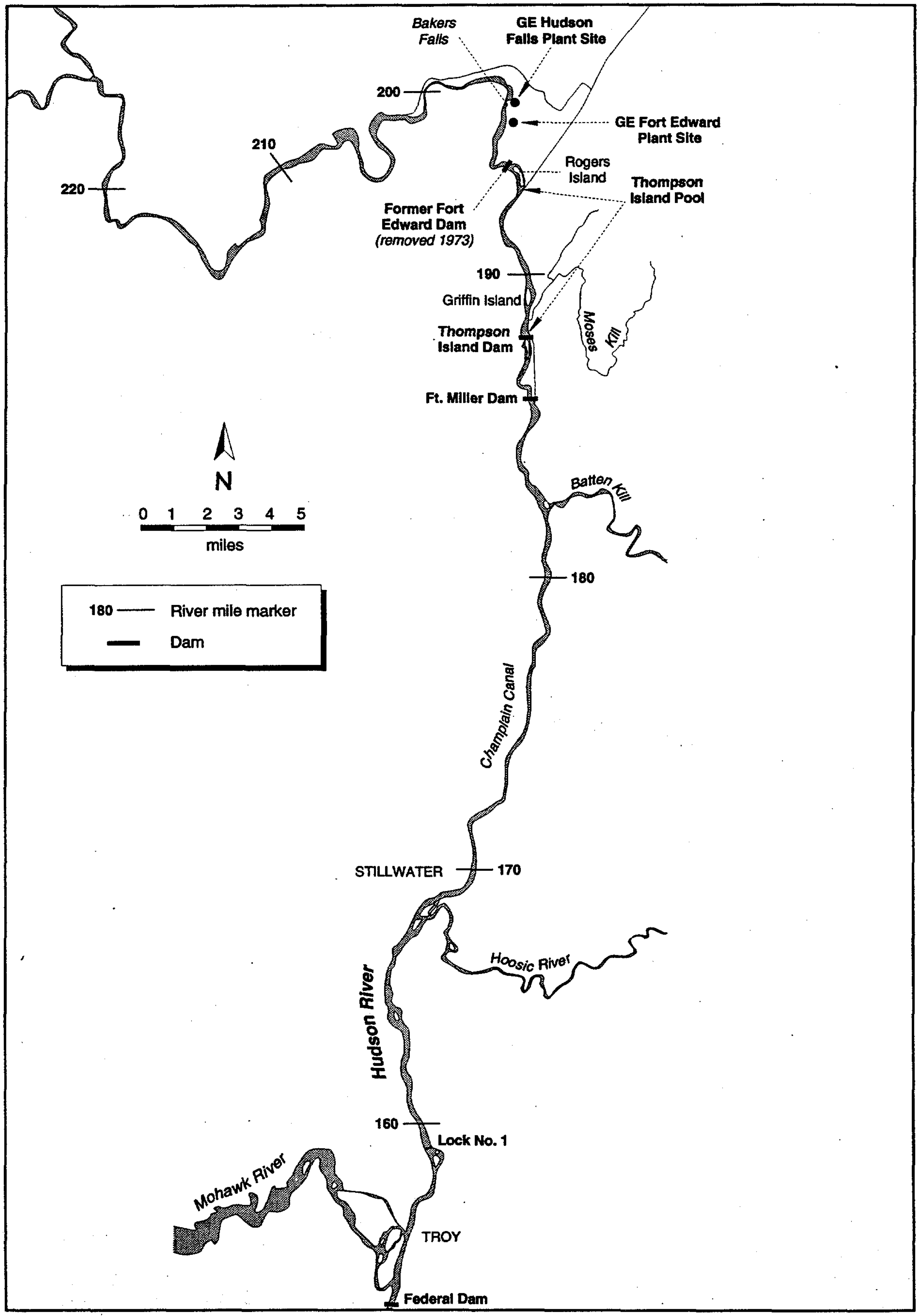

Figure ES-1. Upper Hudson River from River Mile 220 to the Federal Dam

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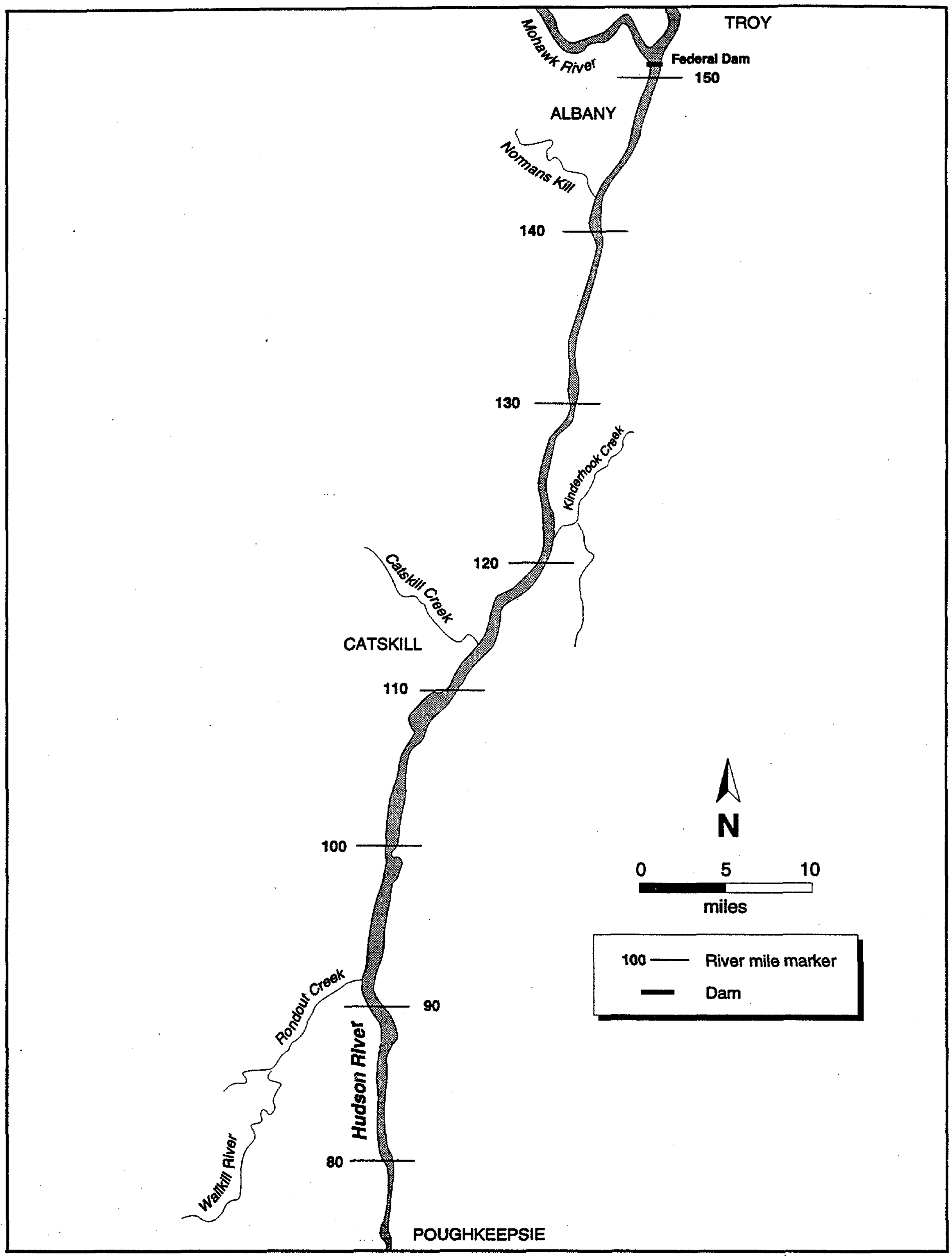

Figure ES-2. Lower Hudson River from the Federal Dam to Poughkeepsie

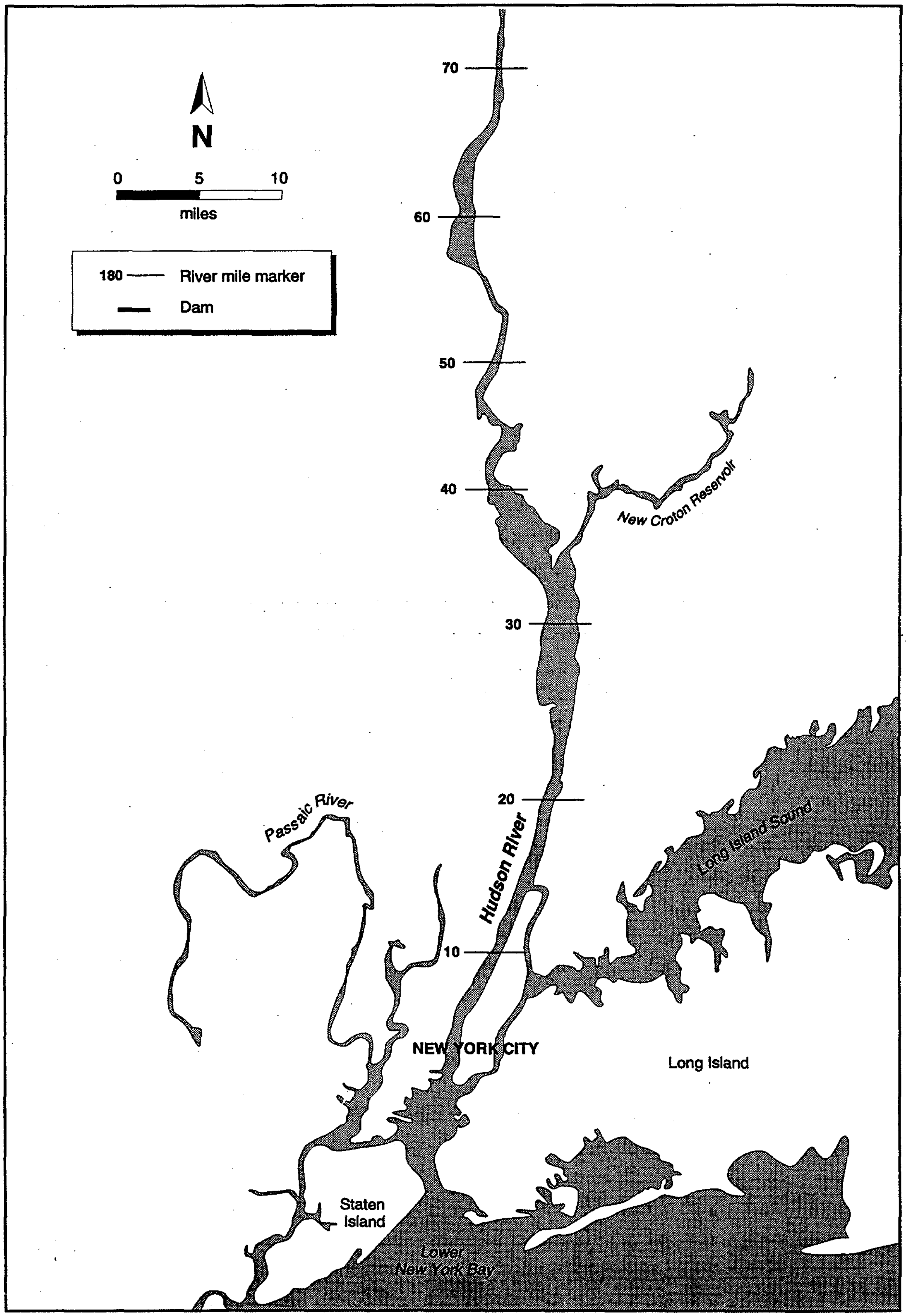

Figure ES-3. Lower Hudson River from River Mile 70 to the mouth

To test the hypothesis that PCB contamination in Hudson River striped bass results from upper Hudson River sources, comparisons were made of PCB congener concentrations and composition in several resident fish species and adult striped bass collected from the same sampling location. In addition, changes in PCB congener concentrations and composition measured in the striped bass and resident species were compared along the length of the Hudson River from the area just below the Federal Dam to the Tappan Zee area. Changes in PCB congener concentrations and composition over the river gradient were also compared with those reported in previous studies and the historical database.

In 1995, a total of 120 fish were sampled from multiple locations from the Thompson Island Pool (River Mile [RM] 190) to the Tappan Zee area (RM27). Resident fish species included yellow perch, largemouth bass, white perch, and juvenile striped bass. Adult and juvenile striped bass were collected from just below the Federal Dam (RM152) to the Tappan Zee area (RM27). All tissue samples were skin-on, scaled, muscle fillets with the exception of the juvenile striped bass samples, which were whole-body homogenates. At each location, five replicate fish samples were collected and analyzed individually. In addition to the spatial sampling, a limited effort was made to collect resident fish and striped bass in both spring and fall to evaluate possible seasonal differences. Both male and female adult striped bass were collected at one station to evaluate possible gender differences in the accumulation of PCBs.

Each individual fish sample was analyzed for 107 target PCB congeners using standard, dual-column gas chromatography with electron capture detection. Comparisons of the PCB concentrations and composition were based on a group of 46 PCB congeners that were selected based on their contribution to the total PCB concentration and frequency of detection. The sum of these congeners explained more than 99 percent of the variability in the total PCB concentration and represented a mean of 91 percent of the total PCBs.

A statistical method based on Euclidean distances calculated using the percent congener compositions provided an objective basis for quantifying the degree of similarity or difference in the congener profile within and between groups of samples.

The major findings from the analysis of the 1995 data set are summarized below:

- Total PCBs and individual congener concentrations in resident fish and striped bass decreased in a generally consistent manner downstream from the Thompson Island Pool to the Tappan Zee area.

- The largest changes in concentration occurred between fish collected from the upper river and the lower river. While no hydrologic data were evaluated in this report, the observed rates of change are believed to be consistent with the overall dilution caused by tributary flows, in particular the influx of the Mohawk River, which discharges just above the Federal Dam at RM154.

- These results are similar to the trends observed in the historical data, although the concentrations observed in 1995 were generally less than those observed in the same species collected at similar locations in 1993.

- Congener compositions for individual samples from the same species, location, and season showed a high degree of similarity. Based on the statistical comparisons, only 11 of the 120 samples were identified as being different in composition from other members of their group, where group was defined by species, location, season, life history stage (adult or juvenile), or sex (only determined for largemouth bass and adult striped bass).

- Within a specific sampling location and season, congener compositions in the resident fish species (yellow perch, largemouth bass, white perch, and juvenile striped bass) were more similar for different species collected at the same location than for fish of the same species collected from widely spaced locations.

- Congener concentrations and composition in resident fish species and striped bass changed in a similar way along the spatial gradient of the river. The contribution of higher-chlorinated penta-, hexa-, and heptachlorobiphenyls increased with distance from the Thompson Island Pool due to a more rapid decline in concentrations of the lower-chlorinated tri- and tetrachlorobiphenyls. These changes were consistent with the congener concentrations measured in resident fish in 1993 and compositional changes seen in the historical Aroclor-based data.

- The calculated Euclidean distances provided a quantitative measure of the similarities in PCB composition of the fish tissue concentrations. These distances indicated that the differences in the congeners accumulated by all resident species from the same locations were small, substantially less than the differences calculated between commercial Aroclor mixtures. This finding supports the hypothesis that fish in all locations were exposed to sources with similar PCB compositions. It was also apparent that, for the resident species, the differences in composition were not large even when comparisons were made between different species, seasons, and locations.

- The PCB composition in the adult striped bass generally contained a higher percentage of the higher-chlorinated PCBs compared to the composition of resident fish species collected from the same area in the lower river. However, the changes in concentrations and composition seen in resident species and striped bass were similar along the downstream gradient between the Albany area and the Tappan Zee area. The dominant congeners in the striped bass were the same as those found in resident fish, only the absolute and relative concentrations were different.

- Both spring and fall samples were collected for white perch, yellow perch, and adult striped bass from the Albany area and for adult striped bass from the Tappan Zee area. Seasonal differences in PCB congener concentrations and composition were observed in resident fish (white perch and yellow perch) and adult striped bass from the Albany area. For both the striped bass and resident species collected in the fall, the lower-chlorinated tri- and tetrachlorobiphenyls contributed a higher percentage of the total PCB composition than in the spring-collected fish. The seasonal differences in PCB composition are consistent with major seasonal changes in the nature of PCB loading.

- Male adult striped bass collected from the Catskill Creek area (RM 115) had higher PCB concentrations on a lipid-basis than female striped bass from that area, although the wet-weight PCB concentrations were similar. The congener compositions were nearly identical, which indicates that both male and female adult striped bass were exposed to the same sources of PCBs.

The results of the 1995 study confirm and extend the conclusion from the historical Aroclor database and the 1993 congener study of resident fish: the observed accumulation of PCBs by resident fish species in the Hudson River from RM190 to RM27 is consistent with a pathway of exposure from a source of PCBs that originated above the Thompson Island Dam and continues to be transported downstream. Similarly, a substantial portion of the PCB content of striped bass is attributed to their exposure to PCB along this pathway within the Hudson River.

1.0 INTRODUCTION

The Lower Hudson River, from below the Federal Dam at Troy, New York to the mouth of the river at New York City, is a tidal estuary that provides habitat to numerous estuarine and anadromous fish species under the trust jurisdiction of the National Oceanic and Atmospheric Administration (NOAA), the U.S. Department of the Interior, and the State of New York. The fish use the Lower Hudson River system for spawning; egg, larval, and juvenile development; and adult habitat. In addition, some species travel through the locks at the Federal Dam into the upper river. Important trust fish that use this system include striped bass, American shad, American eel, blueback herring, rainbow smelt, white perch, and shortnose and Atlantic sturgeon. The shortnose sturgeon is on the federal and State of New York endangered species lists.

Studies begun as early as 1969 found high concentrations of polychlorinated biphenyls (PCBs) in fish from the Hudson River from near River Mile (RM) 200 in the Upper Hudson River to the Battery in New York City (RM 0). In 1981, the U.S. Environmental Protection Agency (U.S. EPA) determined that the PCB contamination was sufficiently hazardous to place the Hudson River on the Superfund National Priorities List (NPL). The remedial process identified releases from two General Electric (GE) facilities located in the Upper Hudson River as the major sources of PCBs to the Hudson River. U.S. EPA is currently conducting a reassessment of the Hudson River site.

While many resources may have been injured by the PCB release, the striped bass fishery in the Lower Hudson River is of particular concern because it has traditionally been important both commercially and recreationally. The commercial fishery has been closed since 1976 because the striped bass contained PCBs in their edible tissue at concentrations that exceeded U.S. Food and Drug Administration tolerance levels for PCBs in fish.

Because of the migratory nature of the striped bass, these fish are potentially exposed to a variety of PCB sources, including releases into Long Island Sound from New York City and other coastal sources. Therefore, it is necessary to determine the extent to which the PCB concentrations in Hudson River striped bass are attributable to their exposure to PCB contamination within the Hudson River. However, previous studies have shown that the changes in PCB concentration and composition seen in striped bass collected throughout the Hudson River are consistent with the known sources of PCBs in the upper river (Sloan et al. 1995).

This study was initiated to explore using the PCB congener concentrations measured in resident fish and striped bass to further establish that the releases of PCBs to the Upper Hudson River have been, and continue to be, a substantial contributor to the contamination in the striped bass.

1.1 BACKGROUND

Beginning in the late 1940s, two GE capacitor manufacturing plants located near Fort Edward and Hudson Falls, New York discharged PCBs into the river (Figures 1-1a, b, and c). GE reportedly discharged between 227,000 and 500,000 kilograms of PCBs into the Hudson River between 1947 and 1977. Large quantities of PCBs were retained in sediments behind a dam at Fort Edward. Removal of the dam at Fort Edward in 1973, followed by major flooding in the region in 1974 and 1976, resulted in the downstream release of an estimated 0.9 million cubic meters of PCB-laden sediment. Industrial discharges of PCBs to the Hudson River ceased in July 1977, but by then the contamination had extended to all 200 miles of river sediment downstream of the GE facilities. In addition, more recent studies have identified substantial on-going releases from contaminated soil and groundwater sources at the Hudson Falls and Fort Edward plants (near RM197). An estimated 226,000 to 300,000 kilograms of PCBs remain in the river (U.S. EPA 1984; Brown et al. 1985).

The Hudson River flows southward from the site of the releases and is separated from the tidal Hudson River by the Federal Dam at RM154. South of the dam, the Hudson is a tidal river for approximately 150 miles, where it becomes a partially mixed estuary. The freshwater-to-saltwater interface is generally present during the low discharge months of summer between RM50 and RM60 (Chillrud 1996). The lowest freshwater discharges occur in the late summer and the highest discharges occur in the spring. Freshwater residence times are on the order of 6-12 weeks during low discharge months and 1-2 weeks during high runoff events (Clark et al. 1992).

PCBs were detected in fish collected in the river from the first measurement made in 1969. By 1975, the concentrations of PCBs in fish from the Hudson River were perceived as a serious human health problem. New York State Department of Environmental Conservation (NYSDEC) banned all fishing in the Upper Hudson River below Hudson Falls between 1975 and 1995 and New York State Department of Health issued specific health advisories for all fish from the Lower Hudson River, New York Bay, and the waters surrounding Long Island. The commercial striped bass fishery in the Lower Hudson River has been closed since 1976.

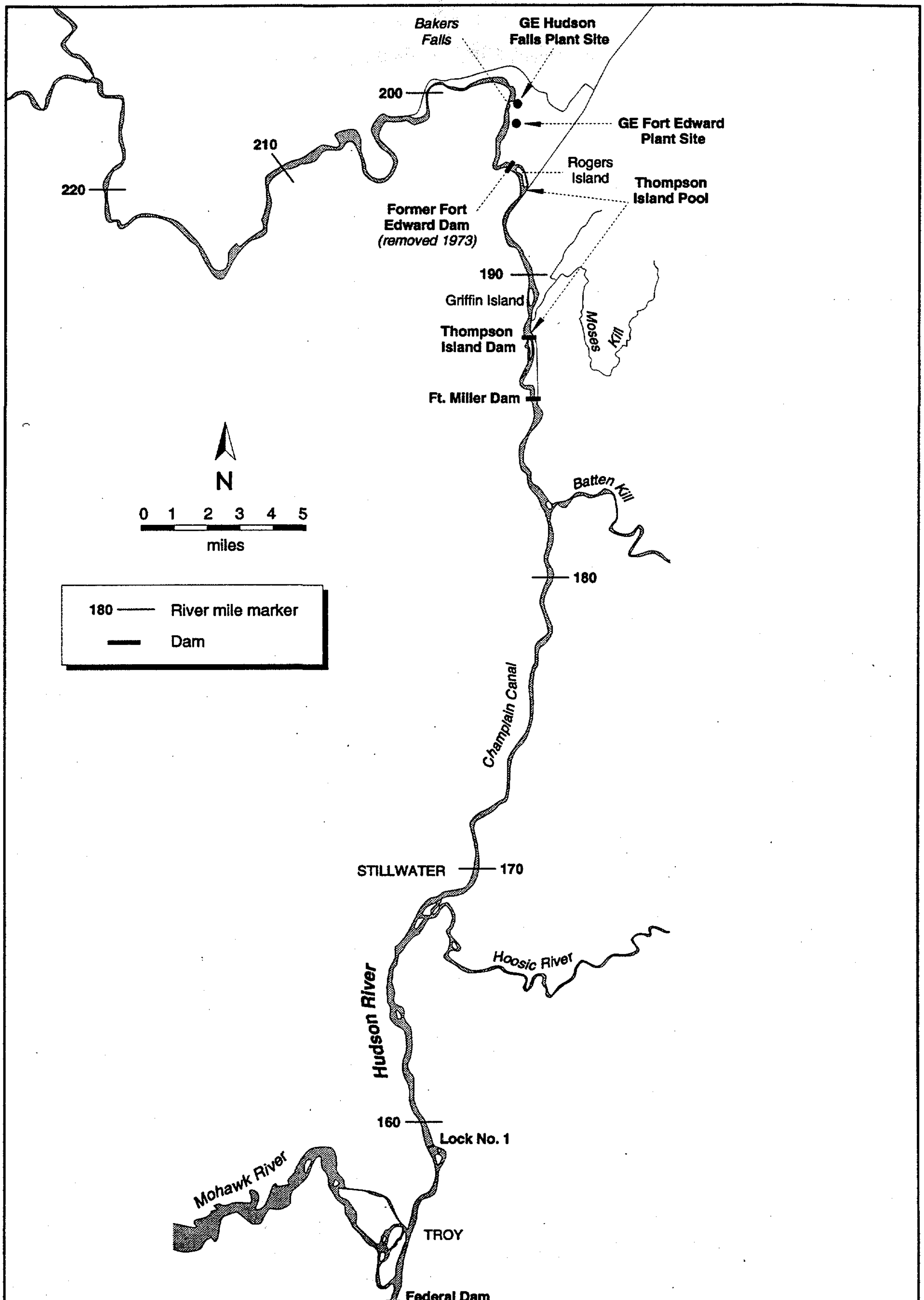

Figure 1-1a. Upper Hudson River from River Mile 220 to the Federal Dam

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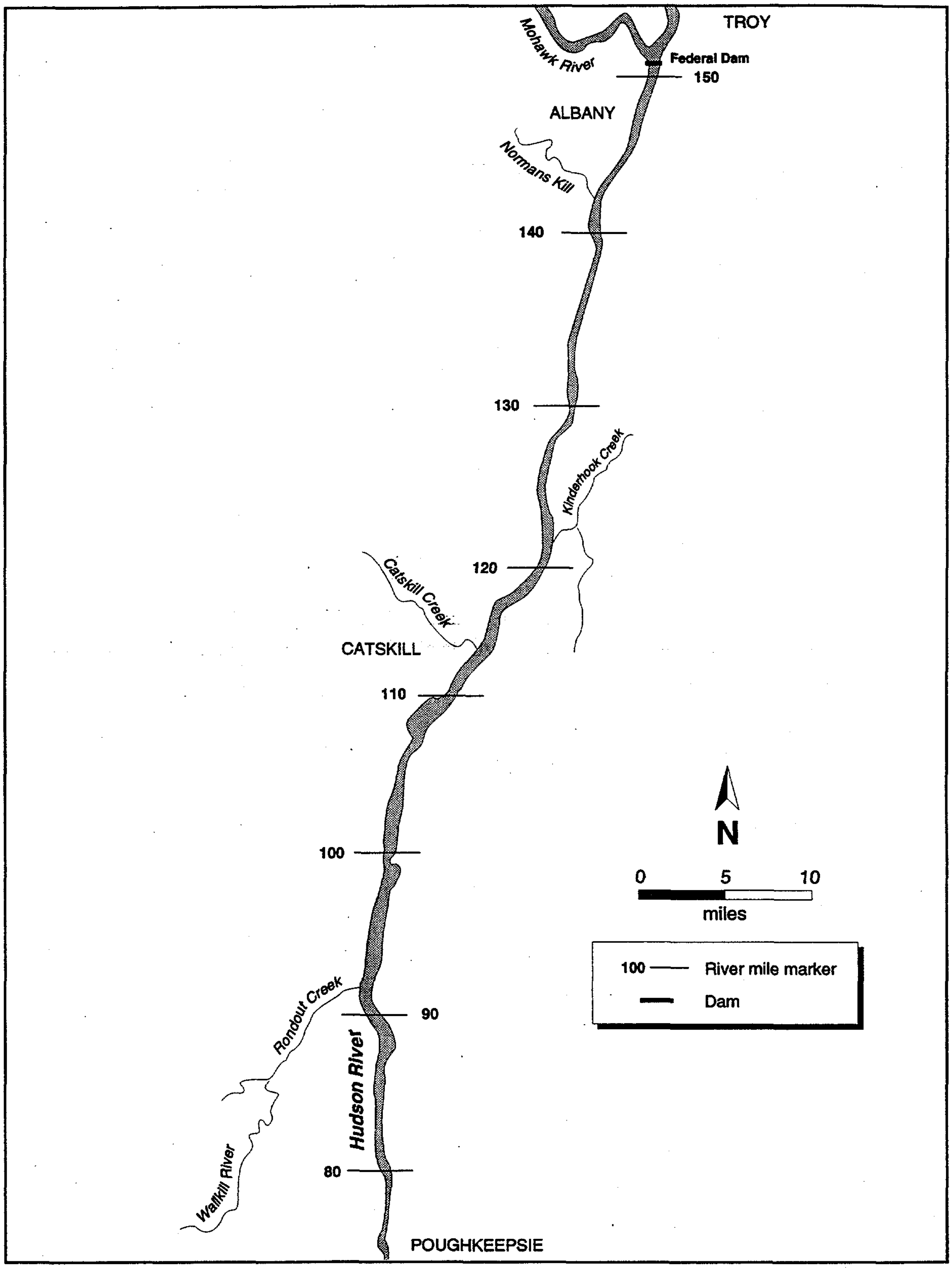

Figure 1-1b. Lower Hudson River from the Federal Dam to Poughkeepsie

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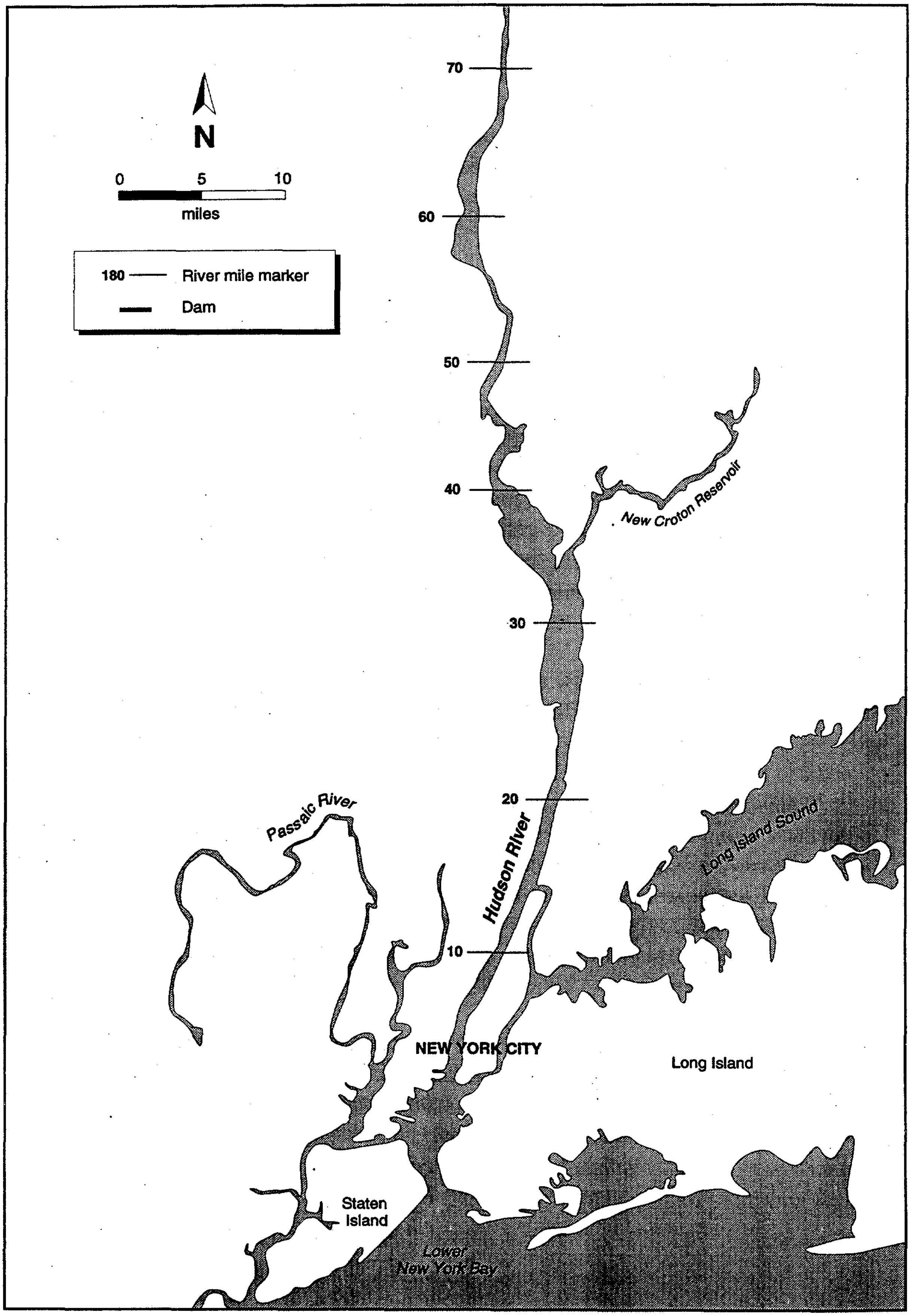

Figure 1-1c. Lower Hudson River from River Mile 70 to the mouth

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In 1981, the U.S. EPA determined that the PCB contamination in the Hudson River from Hudson Falls to the Battery in New York Harbor, a stretch of nearly 200 river miles, was sufficiently hazardous to place the site on the Superfund NPL. The remedial investigation and feasibility study (RI/FS) Record of Decision was issued in 1984; the remedy selected for the river segment of the site was "interim no action." In 1989, a reassessment of the decision was initiated.

The historical releases of PCBs from GE have primarily included Aroclors 1016, 1242, and 1254. These Aroclor releases have resulted in the accumulation of high concentrations of PCBs in the sediments, and continued releases to the water column that are dominated by trichlorobiphenyls (TAMS 1997). In addition, dechlorination of some congeners has been observed in the highly contaminated sediments of the Thompson Island Pool, resulting in the generation of mono- and dichlorobiphenyls at concentrations far exceeding their concentration in the PCBs originally released (TAMS 1997). These releases have resulted in sediment and water column PCB contamination dominated by di-, tri-, and tetrachlorobiphenyl congeners in the Upper Hudson River. The absolute and relative congener concentrations of the GE source are sufficiently characteristic that the contamination can be clearly traced in the sediments and water throughout the downstream portions of both the upper and lower river (TAMS 1997).

Historical monitoring of total PCB concentrations in Hudson River fish species has been conducted since 1978 by NYSDEC. In all of these years, a consistent spatial gradient has been observed characterized by dramatically higher total PCB concentrations in fish collected in the Thompson Island Pool (RM194 to RM188) compared to those collected above RM200, and decreasing concentrations with increasing distance downstream from the Thompson Island Pool (RM194 to RM188) to the Tappan Zee area (approximately RM27; Sloan et al. 1995). The typical trend is illustrated in Figure 1-2, in which the mean total PCB concentrations (lipid-based) measured in a range of resident species and striped bass between 1991 and 1995 are plotted against the locations (river mile) at which they were collected. A similar gradient has consistently been observed for striped bass, as illustrated by data collected in 1994 (Figure 1-3).

In addition to the observed decreases in total PCB concentrations measured in Hudson River fish with increasing distance downriver from the Thompson Island Pool, changes in congener composition have also been reported (Sloan et al. 1985, 1995). While the concentrations of all PCB congeners decreased downstream, the concentrations of the

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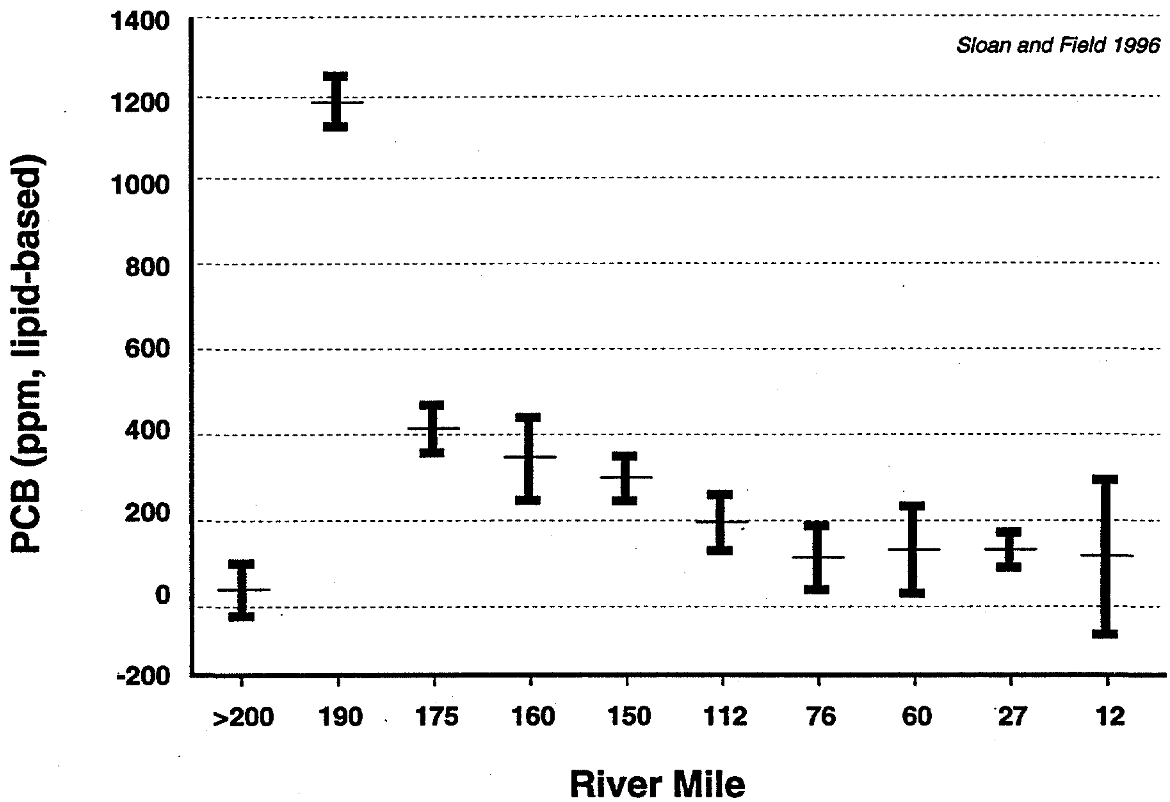

Error bars represent the 95% confidence limits from the analysis of variance

Figure 1-2. Mean total PCB concentration (lipid-based) in resident fish and striped bass (1991-1995)

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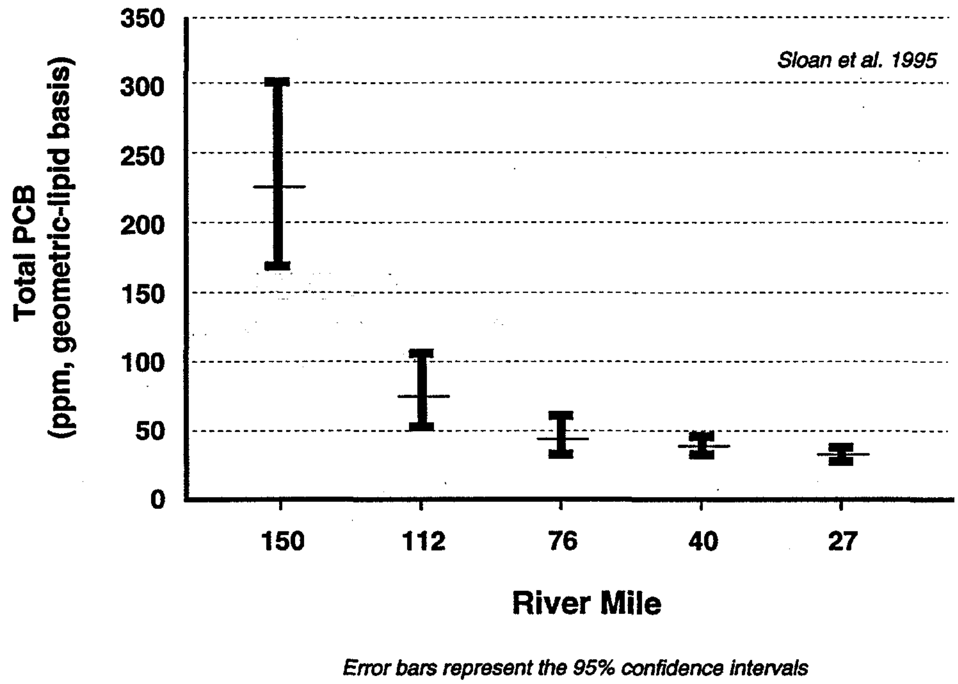

Figure 1-3. Mean total PCB concentration (lipid-based) in striped bass (1994)

lower-chlorinated congeners consistently decreased more rapidly compared to the concentrations of the more highly chlorinated congeners. These trends were consistent among all fish species measured and are illustrated in Figure 1-4, which presents the separate concentrations of higher-chlorinated congeners and lower-chlorinated congeners, as well as the total PCB concentrations, using the same data plotted in Figure 1-2.

These data were consistent with exposure of the fish along a pathway contaminated by releases from or just above the Thompson Island Pool, and previous studies have associated GE's releases with the PCB contamination of fish throughout the river below the Hudson Falls plant (TAMS/Gradient 1992). The changes in concentration are expected because of dilution, which occurs in the water column with the increase in river volume as tributaries such as the Mohawk, Hoosic, and Battenkill Rivers join the flow of the Hudson. The PCB concentration associated with sediment loads will also be diluted as the more contaminated sediment is transported downstream and becomes mixed with less contaminated materials. Changes in composition are related to specific chemical properties of the individual congeners as well as biological degradation processes, which tend to be specific to unique congeners. The apparent changes in congener composition are consistent with the known environmental chemistry of PCB congeners. Lower-chlorinated congeners are more easily removed from the system due to volatilization, water column transport out of the river, and biodegradation reactions. In contrast, more highly chlorinated congeners are less water soluble and tend to be associated with sediments. They also tend to be less easily biodegraded.

The PCB concentrations and composition in the historical database have been reported on an Aroclor basis. The lower-chlorinated PCBs were estimated as concentrations of Aroclors 1016, 1242, and 1248, while the higher-chlorinated PCBs were estimated as concentrations of Aroclors 1254 and 1260 (Sloan and Field 1996). Prior to 1992, quantitation of PCBs was based on the measurement of Aroclors 1016, 1221, and 1254. Since 1992, the range of Aroclors has been expanded to also include Aroclors 1242, 1248, and 1260.

Using Aroclors as the basis for comparisons has limitations because the procedure actually relies on the quantitation of only a few key congeners considered representative of a particular Aroclor. This approach is not precise in identifying the concentrations or the changes in concentrations of all congeners that may be present in a sample, and may also over- or underestimate the actual total PCB concentration, depending on how well the sample can be represented by a mix of Aroclors. Therefore, while these data provided evidence of an exposure pathway from the PCBs in the Upper Hudson River to the remainder of the downstream reaches, there was a need to more fully evaluate the exposure pathway based on congener-specific concentrations and composition.

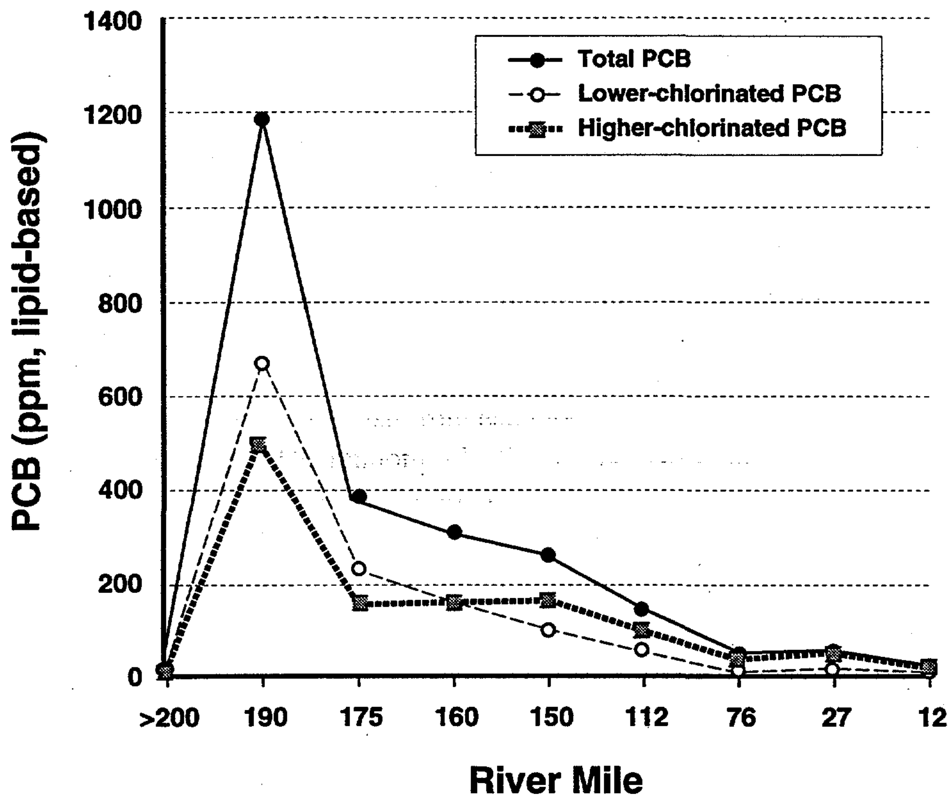

Figure 1-4. Total, higher-chlorinated, and lower-chlorinated PCB concentrations in resident fish and striped bass (1991-1995)

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As part of a 1993 study (Field et al. 1996), resident fish species and surficial sediments were collected in the late summer of 1993 from 15 locations in the Hudson River between RM197 and RM25 and analyzed for 145 PCB congeners. The spatial gradient in congener concentrations was consistent with the historical Aroclor database, with the total PCB concentrations decreasing exponentially with distance in the three resident species collected (spottail shiner, pumpkinseed, and yellow perch) between the Thompson Island Pool (RM194-190) and RM89 (Figure 1-5; Field et al. 1996).

Changes in the concentrations of the individual congeners in fish over the river gradient observed in the 1993 data confirmed the greater rate of decreasing concentrations of the lower-chlorinated PCBs in the Hudson River, and demonstrated that the change was primarily from a rapid decrease in the concentration of tri- and tetrachlorobiphenyl congeners. The higher-chlorinated congeners also decreased in concentration, but more slowly. Further, the comparability of congener concentrations and composition for both the sediment and fish appeared to reflect similar source material throughout the study area (Field et al. 1996). These data further support the argument that the PCB concentrations were the result of exposure along a pathway from the area of the Thompson Island Pool to all downstream reaches. However, the 1993 sampling did not include striped bass.

1.2 OBJECTIVE AND SCOPE OF THE CURRENT STUDY

The current (1995) study was designed to build on the congener data and the historical database for resident fish established in the 1993 study (Field et al. 1996). Congener concentrations were measured in resident fish and juvenile striped bass collected at the same locations along the river to provide a basis for establishing the pathway to the PCB concentrations measured in the migratory striped bass.

The following specific hypotheses were investigated:

- Spatial gradients in congener concentrations and composition in the adult striped bass are consistent with exposure to PCBs released from a source located in the Upper Hudson River above the Thompson Island Dam.

- The current (1995) spatial gradients in PCB congener concentrations and composition in the resident species and striped bass correspond to the historical database.

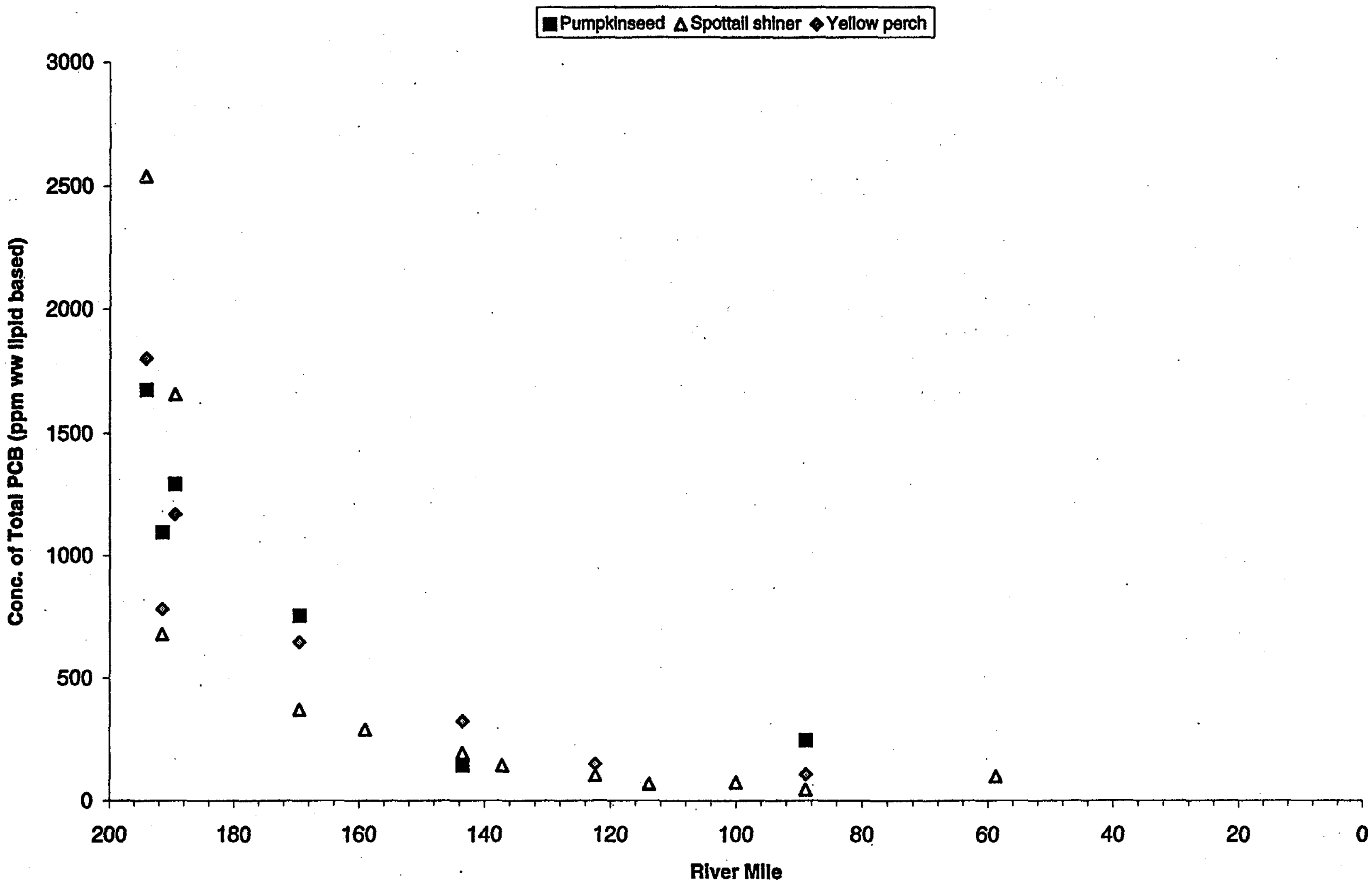

Figure 1-5. Average total PCB concentration (sum of 145 congeners) in resident species (1993)

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- For resident fish, local exposure condition, as indicated by sampling location, is more important than species as a factor controlling the observed PCB concentrations and composition.

- The congener concentrations and composition measured in juvenile striped bass are more similar to those in resident fish than in adult striped bass collected at the same location, further supporting the hypothesis that exposure conditions are more important than species as a factor controlling the observed PCB concentrations and composition.

- The congener compositions, described in terms of the relative contributions of each congener to the total PCB concentrations, are sufficiently similar among replicate fish of the same species collected at a specific location that statistical comparisons can be made to discriminate differences in PCBs among locations, times, and species.

Both adult and juvenile striped bass were selected for analysis. Juvenile striped bass were included because they remain in the river and estuarine areas where they were spawned; therefore, the exposure of juvenile striped bass was expected to be similar to that of the resident species to allow testing of interspecies differences among the three resident fish and the striped bass.

In addition to the striped bass, three resident species were collected: yellow perch, white perch, and largemouth bass. The yellow perch and white perch were selected because they had been collected in earlier studies and shown to demonstrate spatial trends consistent with the historical database (Field et al. 1996). The largemouth bass was selected because of its trophic level and size similarities to the striped bass.

1.3 LIFE HISTORIES OF FISH SPECIES

Detailed life history information for each of the species sampled is contained in Appendix A. A brief summary of several important aspects of the life histories of the resident species and striped bass follows. Two of the resident species, yellow perch and white perch, are medium-sized resident fish that are classified as opportunistic benthic feeders that consume insects, invertebrates, and fishes. Largemouth bass are large, resident, fish-eating predators whose food type varies with the fish's size from plankton to insects to crayfish, fish, and frogs. The home ranges of the largemouth bass and the yellow perch encompass the freshwater range of the river. The white perch home range extends into estuarine waters below the freshwater-to-saltwater interface. All of the resident species are potentially mobile within their home ranges; however, they are resident within the river throughout their life cycles.

The striped bass is a large anadromous fish. During spawning, adult striped bass enter the Hudson River between mid-May and mid-June (Fay et al. 1983). Movements of juveniles under the age of five years vary widely, but generally most juveniles remain in the river or estuarine areas where they were spawned for their first two years. Striped bass are voracious predators at a trophic level similar to that of the largemouth bass. Adult striped bass feed on a wide variety of fishes, squid (in marine areas), and crab.

1.4 ORGANIZATION OF REPORT

Section 2.0, *Methods*, describes the methods used for sample selection, chemical analysis, and statistical analysis. Section 3.0, *Results and Discussion*, presents the data generated and compares the PCB concentrations and composition over the spatial gradient of the Hudson River. In addition, the composition of the PCBs measured within each of the resident species and the striped bass (juveniles and adults) is compared and statistically evaluated. A summary of findings of this study is presented in Section 4.0, *Conclusions*.

2.0
METHODS

This section presents brief discussions of the sample selection, chemical analyses, quality assurance and quality control (QA/QC) procedures, and statistical analyses.

2.1 SELECTION OF SAMPLES FOR ANALYSIS

The fish tissue samples analyzed for this study were taken from fish that were collected and archived by NYSDEC. Fish were collected by NYSDEC from seven stations located throughout the Hudson River, from the Tappan Zee Bridge area at RM27 to the Thompson Island Pool at RM190. Two stations (RM175 and RM190) were located in the Upper Hudson River above the Federal Dam at RM154. The river mile designations used to identify the sampling locations are approximate. The sampling locations and species selected are shown in Figures 2-1 through 2-3 and are summarized in Table 2-1.

Yellow perch, white perch, and juvenile striped bass were randomly selected from the available fish, sorting only to obtain fish of similar size. All tissue samples were skin-on, scaled, muscle fillets with the exception of the juvenile striped bass samples, which were whole-body homogenates (Table 2-1).

Length, weight, lipid content, and total PCB concentrations (determined as Aroclors) were available for the adult striped bass and largemouth bass. These data were used to select a homogenous subset of tissue samples for the congener analyses to help ensure that extreme variability did not compromise our ability to develop reasonable data analysis and interpretive approaches. The following criteria were used to eliminate from selection individual fish samples from the sample pools at each location prior to selecting the five fish for congener analyses:

- Any fish sample with a total PCB concentration outside of the 95 percent probability interval for the distribution of the NYSDEC data for that species at that location

- Any fish whose reported lipid content or size (length, weight, or weight/length ratio) was substantially greater or less than that in the majority of fish of that species at that location

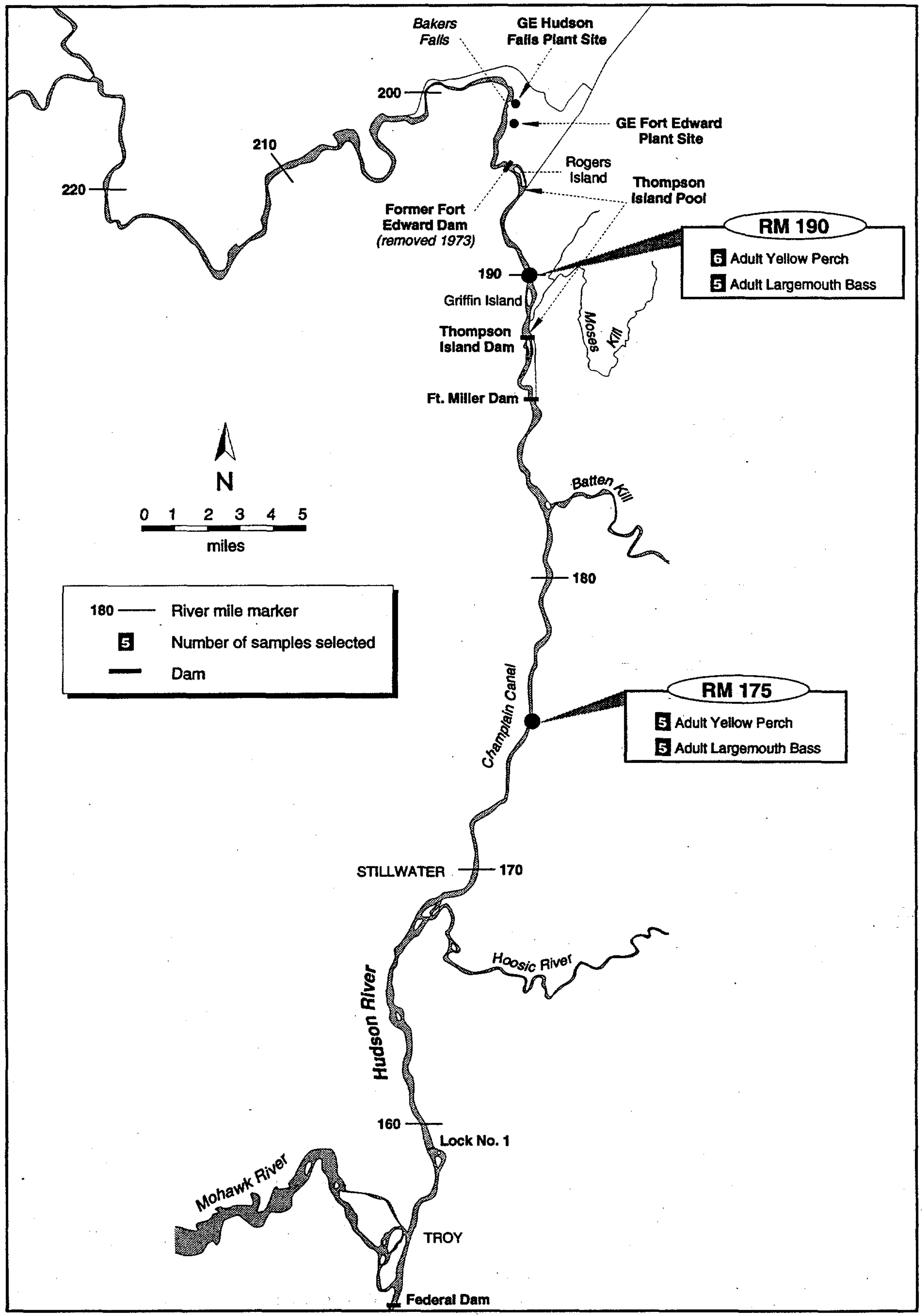

Figure 2-1. Sampling locations in upper Hudson River from River Mile 220 to the Federal Dam

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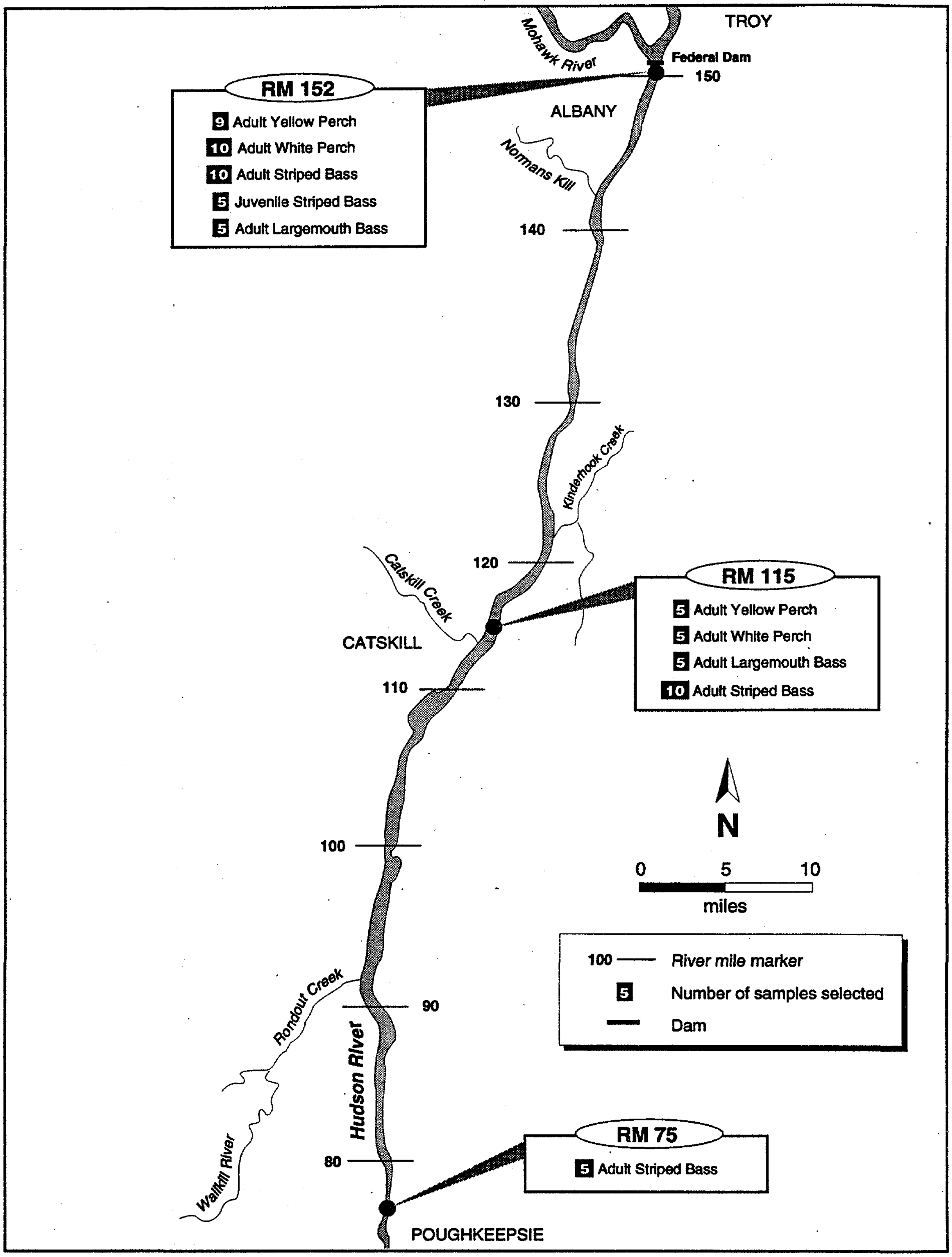

Figure 2-2. Sampling locations in lower Hudson River from the Federal Dam to Poughkeepsie

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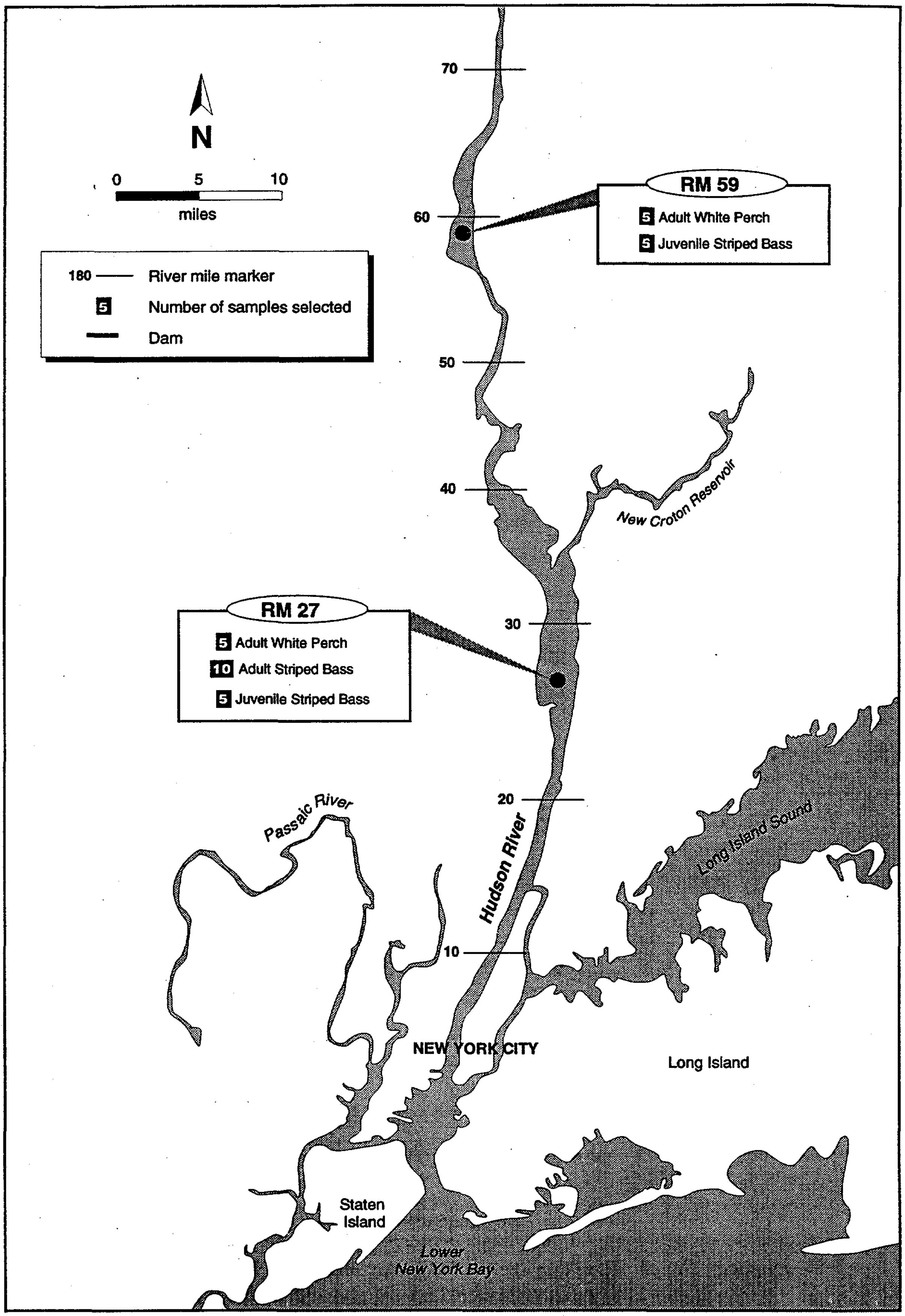

Figure 2-3. Sampling locations in lower Hudson River from River Mile 70 to the mouth

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Table 2-1. Summary of fish samples selected by species and river mile

Group	River Mile	Species	Age[a]	Sex[b]	Tissue[c]	Month	Season	Number of Fish Selected
1	190	Largemouth bass	A	M	f	May	Spring	5
2	190	Yellow perch	A	U	f	May	Spring	6[d]
3	175	Largemouth bass	A	M	f	May	Spring	5
4	175	Yellow perch	A	U	f	May	Spring	5
5	152	Largemouth bass	A	M	f	May	Spring	5
6	152	Yellow perch	A	U	f	May	Spring	4[d]
7	152	Yellow perch	A	U	f	August	Fall	5
8	152	Striped bass	J	U	w	August	Fall	5
9	152	Striped bass	A	M	f	June	Spring	5
10	152	Striped bass	A	M	f	August	Fall	5
11	152	White perch	A	U	f	May	Spring	5
12	152	White perch	A	U	f	August	Fall	5
13	115	Largemouth bass	A	M	f	May	Spring	5
14	115	Yellow perch	A	U	f	May	Spring	5
15	115	Striped bass	A	M	f	May	Spring	5
16	115	Striped bass	A	F	f	May	Spring	5
17	115	White perch	A	U	f	May	Spring	5
18	75	Striped bass	A	M	f	April	Spring	5
19	59	Striped bass	J	U	w	September	Fall	5
20	59	White perch	A	U	f	September	Fall	5
21	27	Striped bass	J	U	w	September	Fall	5
22	27	Striped bass	A	M	f	April	Spring	5
23	27	Striped bass	A	M	f	Nov./Dec.	Fall	5
24	27	White perch	A	U	f	August	Fall	5

[a] A - adult
J - juvenile

[b] F - female
M - male
U - gender not determined

[c] f - fillet sample
w - whole-body homogeneate

[d] Insufficient yellow perch samples could be collected during the spring collection at RM 152. An additional yellow perch sample was added to RM 190 to maintain the total number of samples.

The 95 percent probability interval for the total PCB concentrations was calculated as $X \pm t_{0.05(2), n-1} \times S_x$, where X, S_x, and n are the observed mean, standard deviation, and sample size, respectively, from each sampling location. The critical value of the *t*-distribution ($t_{0.05(2), n-1}$) was used to estimate the values encompassing 95 percent of the weight of a *t*-distribution with mean and variance equal to that observed in the sample. The *t*-distribution approximates a normal distribution, but is more conservative, and is more appropriate when the population parameters are estimated from the sampling data and the sample size is small (Zar 1996).

The distributions of the data were first reviewed to ensure symmetry and approximate normality. Based on this assessment, the 95 percent probability intervals were calculated and compared with the sample values to identify potential outliers.

The relationship between size and percent lipids is not well defined; however, fish that have an exceptionally high or low lipid content for their size may have a different accumulation of PCBs, based on the supposition that fish with dramatically different lipid content may well be physiologically different, and hence may have different PCB uptake than that of other fish.

From the pool of remaining fish, five fish from each location were randomly selected for subsequent congener analysis. The random selection of the fish samples minimized the introduction of bias resulting from the selection process.

2.2 CHEMICAL ANALYSIS METHODS

Tissue samples were analyzed for 107 PCB target congeners using dual-column (RTX-Apiexon L and RTX-5) gas chromatography with electron capture detection (GC/ECD). A subset of samples was analyzed by a gas chromatography/mass spectrometry method to verify the GC/ECD quantitation. The analyses were performed by Inchcape Laboratories in Colchester, Vermont. A detailed discussion of the analytical methods is contained in Appendix B.

2.3 QUALITY ASSURANCE/QUALITY CONTROL

Inchcape Laboratories submitted the data from both column measurements to EcoChem Inc., where the results were merged to form the final data set (Bailey 1996 pers. comm.). In addition, a quality assurance evaluation of the reported congener concentrations was performed by EcoChem. The overall assessment of the accuracy and precision determined that the data were acceptable for use as qualified. The data validation report submitted by EcoChem is contained in Appendix C.

An additional quality assurance evaluation was conducted by comparing the measured lipid content and total PCB concentrations in the adult striped bass and largemouth bass samples with the lipid content and total PCB concentrations reported for the same samples from the Aroclor analyses performed for NYSDEC by Hazleton Laboratories.

The lipid concentrations reported by Hazleton are plotted against the lipid content reported by Inchcape in Figure 2-4. The lipid concentrations reported by Hazleton were consistently higher than those reported by Inchcape for the same samples. Further investigation revealed that bias was attributable to the two laboratories using different solvents to extract the tissue samples and determine the lipid content of the samples. The lipid concentrations referred to in the remainder of this analysis are those reported by Inchcape.

Total PCB concentrations (ppm, wet weight-based) reported by both laboratories are compared in Figure 2-5. The total PCB concentrations reported by Hazleton are consistently higher than the total PCB concentrations reported for these samples by Inchcape. These differences are most likely due to differences in the quantitation methods used by the two laboratories (as Aroclors versus as individual congeners). The differences between the two reported total PCB concentrations does not appear to be related to the differences in the extraction solvents that may have affected the lipid analyses. The effectiveness of the Inchcape PCB extraction was demonstrated through multiple QA/QC measures, including recovery surrogates and standard reference materials (Appendix C).

2.4 STATISTICAL ANALYSES

The complete PCB data set consisting of 107 individual congeners was reduced to a subset of 46 principal congeners that represented the vast majority of the mass of the PCBs both within individual samples and across the entire data set. (See Section 3.1.1 for further discussion of the selection of the 46 principal congeners.)

The PCB composition of the samples, defined as the percentages that each of the 46 principal congeners contributed to the total PCB concentration, was used to calculate Euclidean distances. The Euclidean distance between two samples in multiple dimensions, in this case 46 dimensions, is an extension of the concept of distance between two points on a straight line. The Euclidean distances were used to develop a

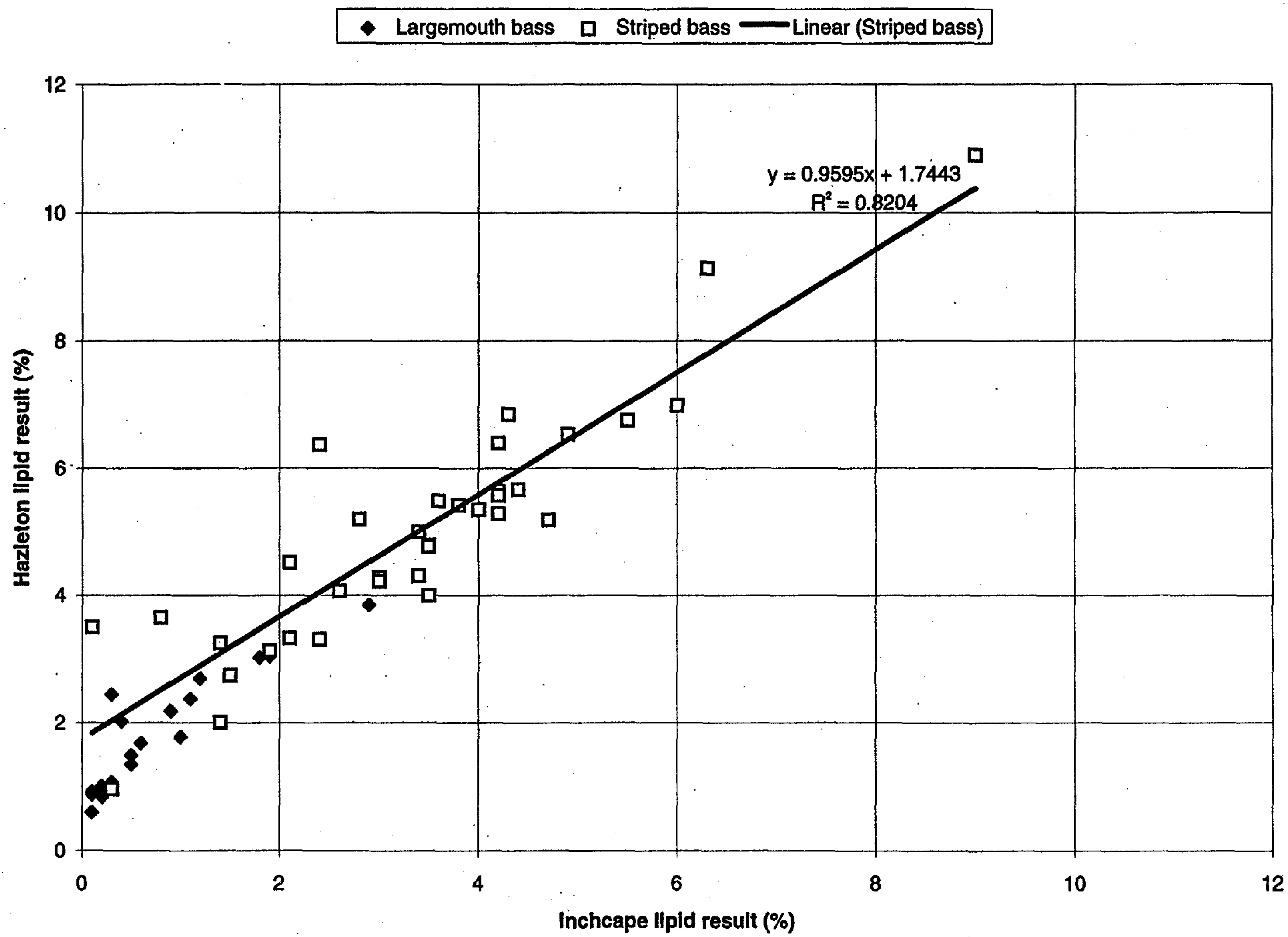

Figure 2-4. Comparison of Hazleton and Inchcape lipid results

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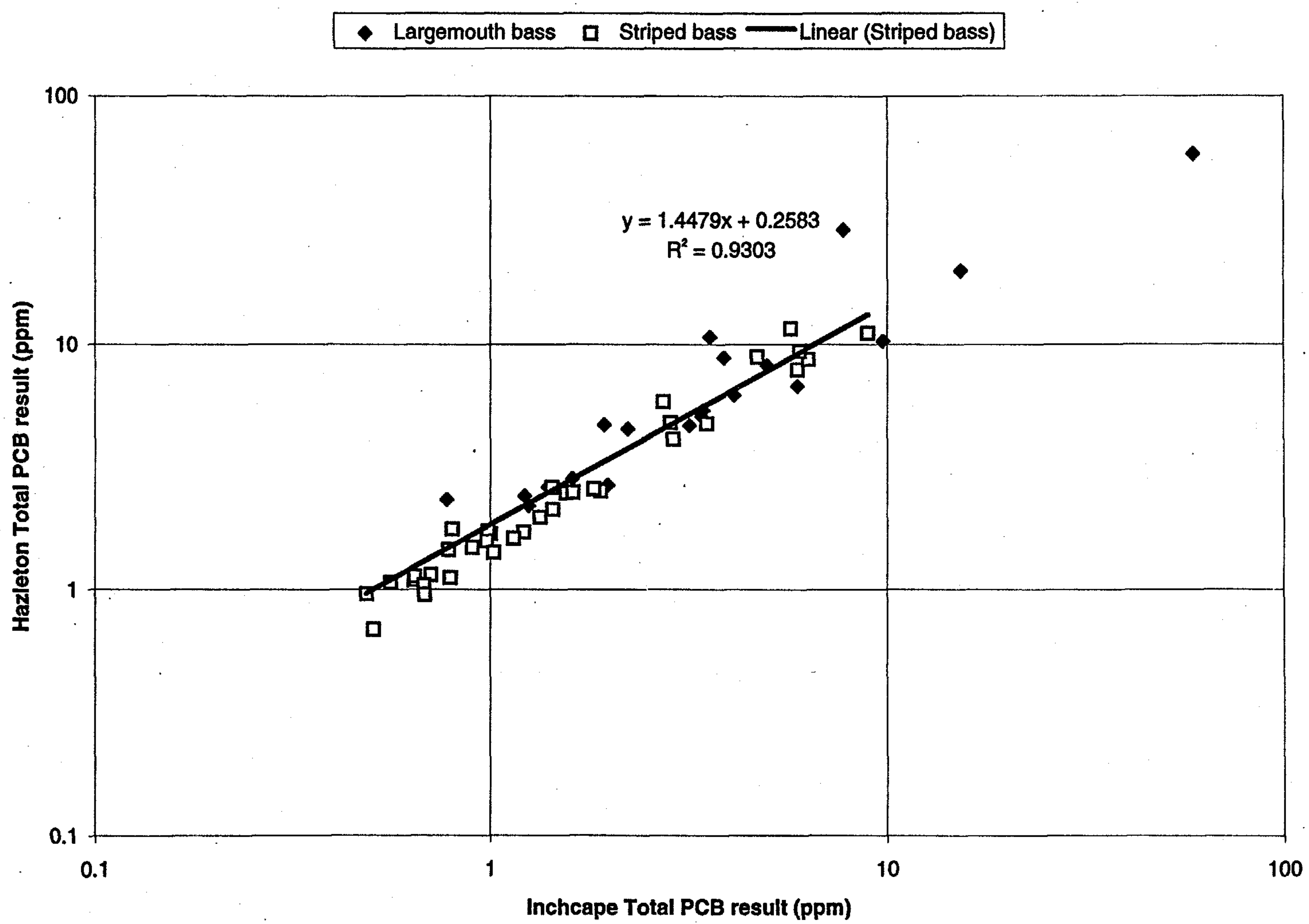

Figure 2-5. Comparison of Hazleton and Inchcape total PCB results

quantitative and objective measure of the similarity of the PCB compositions of individual fish within sample groups, as well as the similarities and differences between different sampling groups.

The method of comparing Euclidean distances provides an objective measure of the magnitude of change in composition across sampling locations and species. Euclidean distance is a common tool for describing the similarities between samples in exploratory multivariate techniques such as cluster analyses or multi-dimensional scaling (see for example, Johnson and Wichern 1992). In a similar study, Litten et al. (1993) used Euclidean distances to compare PCB homolog concentrations between locations in a river using PISCES samplers, a surrogate for chemical uptake in fish tissue.

The Euclidean distance was calculated between samples *a* and *b* using the following equation:

$$d_{ab} = \left[\sum_{i=1}^{46} (a_i - b_i)^2 \right]^{½}$$

where a_i and b_i are the percent compositions for congener *I*, (*I* = 1,2,...,46) in sample *a* and *b*, respectively. Two samples may generate a large distance value due to large-magnitude differences in one or two congeners, or due to smaller-magnitude differences in many congeners. While both of these situations would result in a large distance value, which type of deviation is present cannot be determined from that univariate distance value itself. Once two samples are identified as having a large distance value, the pattern differences and the principal congeners responsible for these differences must be identified from the congener profile plots.

Euclidean distance values were calculated on a "within-group" and "between-group" basis, as follows:

- The within-group distances were computed for all pairs of samples within a group where a "group" was defined by its *a priori* designation according to species, location, season, and gender. There were 24 *a priori* groups based on these four factors (Table 2-1). For example, for yellow perch at RM175 (n=5), 10 pairwise distances were computed.

- The between-group distances were computed for all possible pairs of fish from one *a priori* group to fish in another group. For example, for a comparison between yellow perch at RM175 (n=5) and yellow perch at RM190 (n=6), 30 pairwise distances were computed.

This test was used to demonstrate similarities or differences in the composition of the PCBs among groups by comparing the maximum distances observed "between-groups" to the maximum "within-group" distances. To investigate the effect of location on the congener compositions, Euclidean distances were calculated between river mile groups within each species. Similarly, between-group distances were calculated for each of the species groups collected at the same locations. The smaller the Euclidean distance calculated between individual samples within a group or between groups, the more similar the composition of the PCBs.

To provide a basis for evaluation of the distance value as a measure of similarity, distances were also calculated for standard Aroclor mixtures. The Aroclors were used for this purpose in part because most PCB researchers are familiar with the types and degrees of differences among these commercial mixtures, and because virtually all PCBs were used and released into the environment initially as one or more of these mixtures. Therefore, it was assumed that if the fish are exposed to releases of another type of PCBs, they would show Euclidean distances equal to or greater than those calculated among the Aroclor mixtures. The Aroclor distances were calculated from the percent compositions of the 46 principal congeners measured in duplicate analyses of the five major Aroclors (Table 2-2). The congener composition profiles for the five Aroclors are plotted in Figure 2-6.

Table 2-2. Mean Euclidean distances between commercial Aroclors

	AROCLOR 1016	AROCLOR 1242	AROCLOR 1248	AROCLOR 1254	AROCLOR 1260
Aroclor 1016	0	-	-	-	-
Aroclor 1242	0.116	0	-	-	-
Aroclor 1248	0.250	0.154	0	-	-
Aroclor 1254	0.388	0.318	0.234	0	-
Aroclor 1260	0.440	0.392	0.360	0.282	0

As would be expected, the largest distance value was calculated between Aroclor 1016 and Aroclor 1260. The congener composition profiles for these two Aroclors illustrate the large differences in composition between Aroclor 1016, with a high content of lower-chlorinated congeners, and Aroclor 1260, dominated by the higher-chlorinated hexa- and heptachlorinated biphenyl congeners. The smallest distance calculated was between Aroclor 1016 and Aroclor 1242.

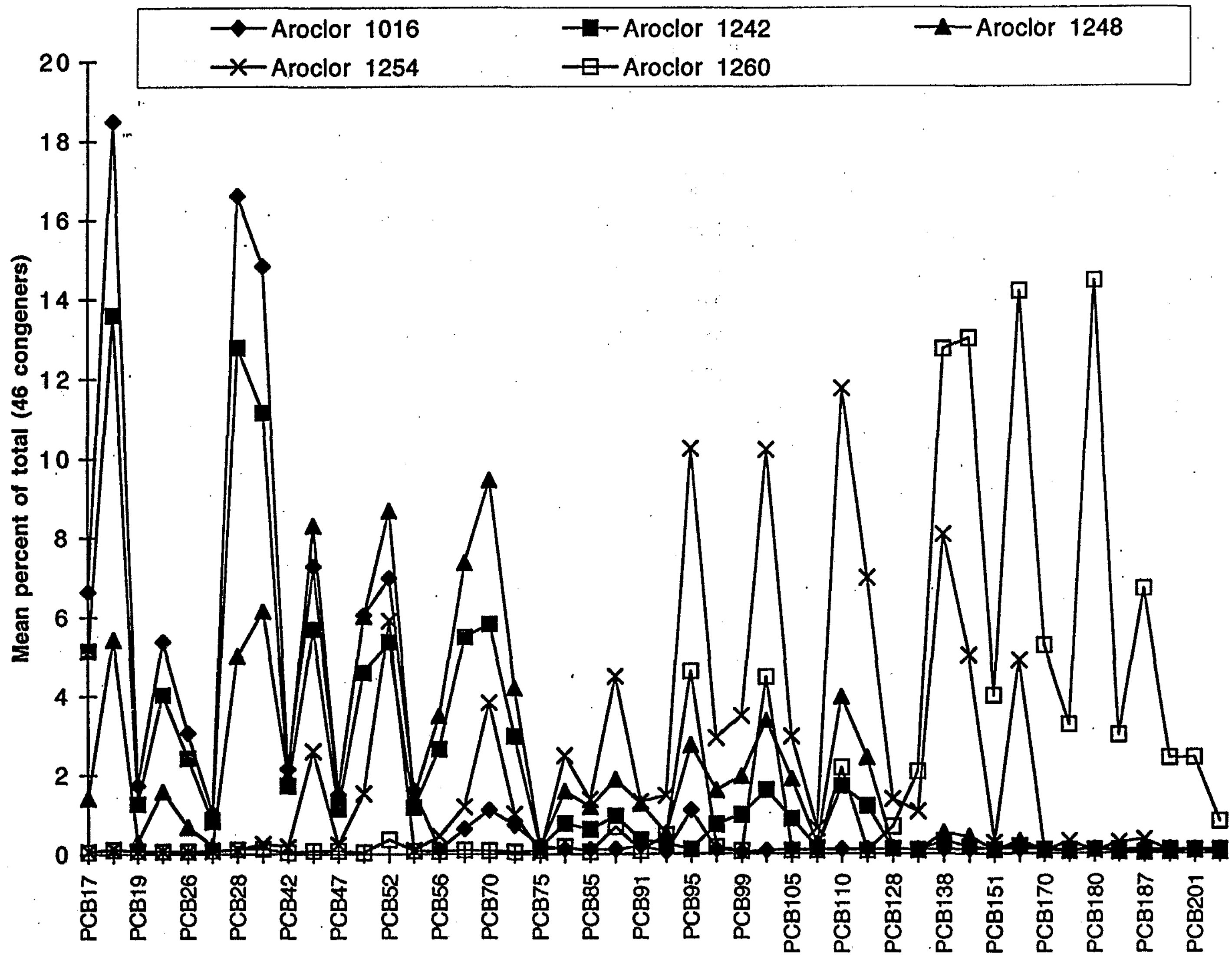

Figure 2-6. Congener composition profiles for various Aroclors

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In addition to investigating the differences among locations and species, limited study was made of differences in PCB composition associated with season and gender, based on the data for the species where separate male and female and spring and fall groups were collected (Table 2-1). If the congener patterns were found to be very similar between genders or seasons, then further comparisons were performed on the pooled data for the similar groups.

The Euclidean distances were used in this report in two ways. First, the distances were used as a measure of the degree of difference among the samples to provide an objective basis for statements of trends that could be observed visually in the tabular or plotted congener compositions. Second, the Euclidean distances were used to screen for distances that were so large that they would indicate that the fish yielding the large distance had been exposed to release of a different type of PCB (Aroclor).

3.0
RESULTS AND DISCUSSION

3.1 PRELIMINARY DATA EVALUATION

The database of complete analytical results for all measurements on individual fish is provided in electronic form on a diskette insert with this report. In the following discussions, total PCB concentrations were always calculated as the sum of all 107 congeners. For samples with congener concentrations that were below the detection limit, one-half the detection limit was used for all comparisons.

The congener compositions were calculated as the concentration of the individual congeners divided by the sum of the congeners. In the composition profiles presented below, the data reflect the congener concentrations of each of the congeners divided by the total of all 107 congeners in that sample. However, because the calculation of the Euclidean distances, based on the 46 principal congeners (discussed below), required that the sum of the components was equal to one, the Euclidean distance was calculated using congener composition data based on the sums of the 46 principal congeners.

3.1.1 Principal Congener Identification

Examination of the congener profiles for 107 congeners (Appendix D), revealed that the PCBs were dominated by about 20 major congeners in all of the fish from the Hudson River. Of the 107 congeners analyzed for in the 1995 fish samples, 5 congeners were never detected, and 21 were detected in 50 percent or fewer of the fish. Therefore, to provide a manageable data set for comparing the congener compositions and to limit the number of non-detected values in the data set used for statistical analyses, a subset of principal congeners was identified. This subset was defined as those target congeners that had a reasonably high frequency of detection (measured in ≥75 percent of all fish sampled) and made an important contribution (at least 1 percent of the mass) to the total PCBs in any individual fish tissue sample. A subset of 46 congeners was identified based on these criteria. These congeners were not selected because of their toxicological significance, but for the contribution of the congeners to the total concentration and the percent of the samples in which the congener was detected.

The individual principal congeners are listed in Table 3-1. The selected congeners represent a range of chlorination levels from trichlorobiphenyls to nonachlorobiphenyls.

Table 3-1. Subset of congeners identified as principal congeners in 1995

PCB Congener (BZ No.)	Chlorination Level	Max. Contribution to Total PCB Concentration (%)	Frequency of Detection (%)	Principal Congener in 1993
17	3	2.77	99.2	✓
18	3	3.53	96.7	✓
19	3	2.33	84.2	✓
22	3	1.16	95.8	✓
26	3	2.59	98.3	✓
27	3	2.22	95.8	✓
28	3	5.32	98.3	✓
31	3	6.92	86.7	✓
42	4	1.94	100	✓
44	4	4.00	100	✓
47	4	5.82	99.2	✓
49	4	8.61	100	✓
52	4	9.08	100	✓
53	4	1.70	98.3	✓
56	4	2.29	100	✓
66	4	8.09	100	✓
70	4	7.19	100	✓
74	4	6.32	100	✓
75	4	1.37	97.5	
84	5	1.42	87.5	✓
85	5	2.03	98.3	✓
87	5	2.58	100	✓
91	5	1.46	87.5	✓
92	5	1.87	100	✓
95	5	4.34	100	✓
97	5	2.36	100	✓
99	5	6.34	100	✓
101	5	7.73	100	✓
105	5	3.79	94.2	✓
107	5	2.33	100	
110	5	6.78	100	✓
118	5	8.46	100	✓
128	6	1.53	88.3	✓
135	6	1.16	97.5	
138	6	11.8	100	✓
149	6	5.09	100	✓
151	6	1.78	99.2	✓
153	6	13.1	100	✓
170	7	1.30	93.3	✓
177	7	1.04	100	
180	7	4.40	100	✓
183	7	1.56	100	✓
187	7	4.68	99.2	✓
194	8	1.35	100	
201	8	1.76	100	✓
206	9	1.57	89.2	

The majority of the congeners, and those contributing most to the total mass of PCBs, were tri-, tetra-, penta-, and hexachlorobiphenyls. This distribution is consistent with the PCB composition reported for fish tissues in the historical database (Sloan et al. 1995) and the congener-specific analyses of resident fish tissues collected in 1993 conducted by Field et al. (1996). These measured congener compositions are consistent with exposure to Aroclors 1016, 1242, 1254, and 1260, known to have been released from the GE facilities (TAMS 1997).

The sum of 46 principal congeners represented more than 99 percent of the variability in the total PCBs ($r^2 = 0.999$, $n = 120$) (Figure 3-1) and constituted between 82.2 and 94.0 percent (mean: 90.8 percent) of the total PCB concentrations in individual fish samples, which ranged from 0.3 to 55 ppm (wet weight) (Figure 3-2).

Forty congeners were identified as principal congeners in both the 1993 analysis of congener concentrations in resident fish (Field et al. 1996) and this 1995 study. These congeners are identified in Table 3-1.

3.1.2 Evaluation of the Euclidean Distance Approach

Using the PCB congener data, substantial evaluation of the Euclidean distance approach was performed, both to ensure that the method was sufficiently powerful and robust to be useful, and to ensure that the data used were appropriate for this effort. A more detailed discussion of the testing is included in Appendix E. These efforts indicated that the test was in fact delineating real differences among samples. In addition, careful scrutiny of the distribution of Euclidean distances among the samples within each of the 24 groups indicated that few samples had congener distributions that were substantially different from the remainder of the group.

This study was intentionally limited to a reasonably homogenous set of samples to allow testing the basic strengths of the approach. The decision was made to exclude from this first round of evaluations those fish samples whose within-group distances exceeded the 90 percent probability value for a lognormal distribution with mean and variance estimated from the within-group distance data. A detailed discussion of the exclusion analysis is included in Appendix E. Less than 10 percent of the total samples were excluded and the samples included representatives of all species. One fish was excluded from each of five groups, and two fish were excluded from each of three groups. The fish that were excluded are listed in Table 3-2.

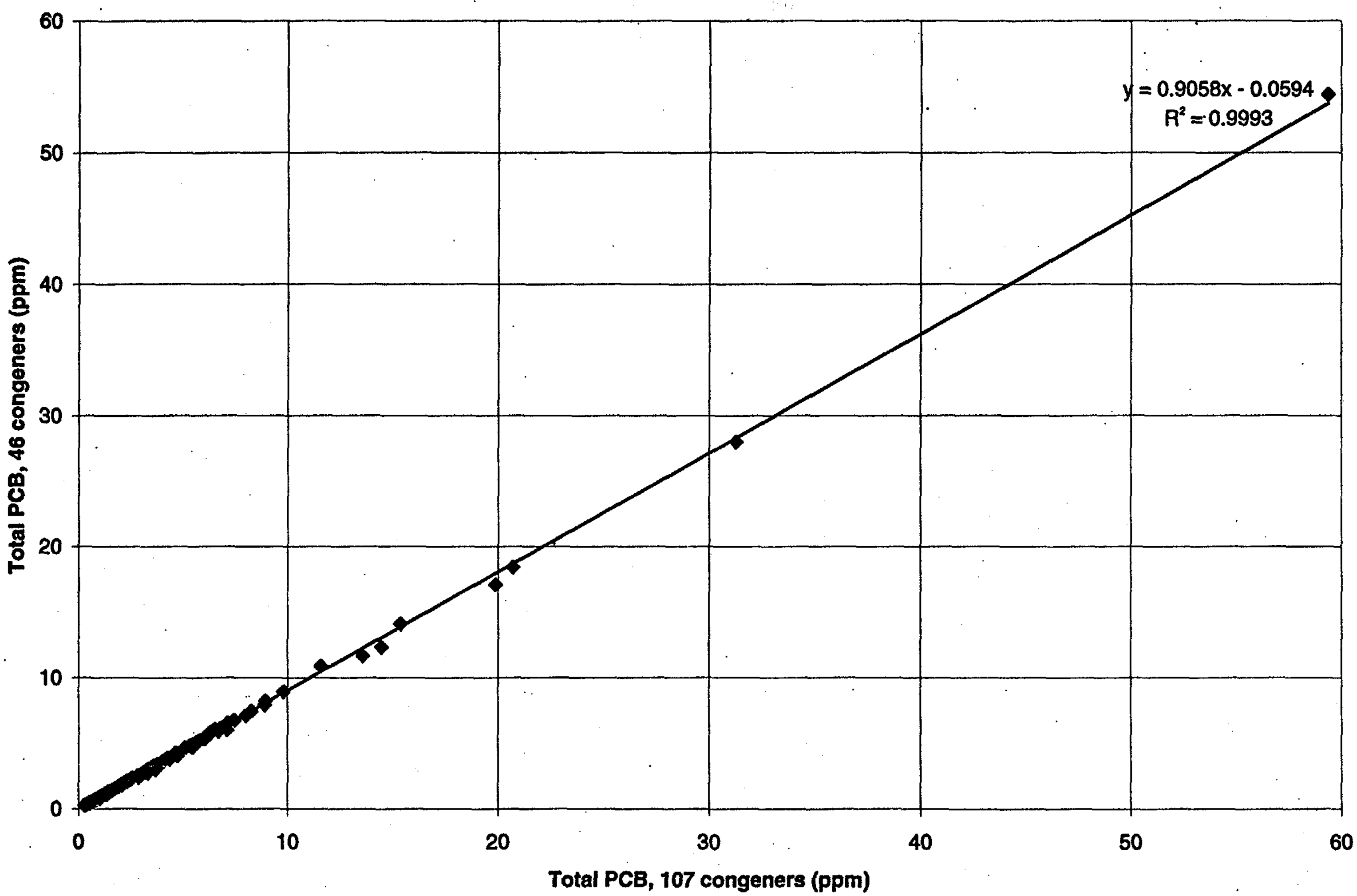

Figure 3-1. Comparison of total PCBs

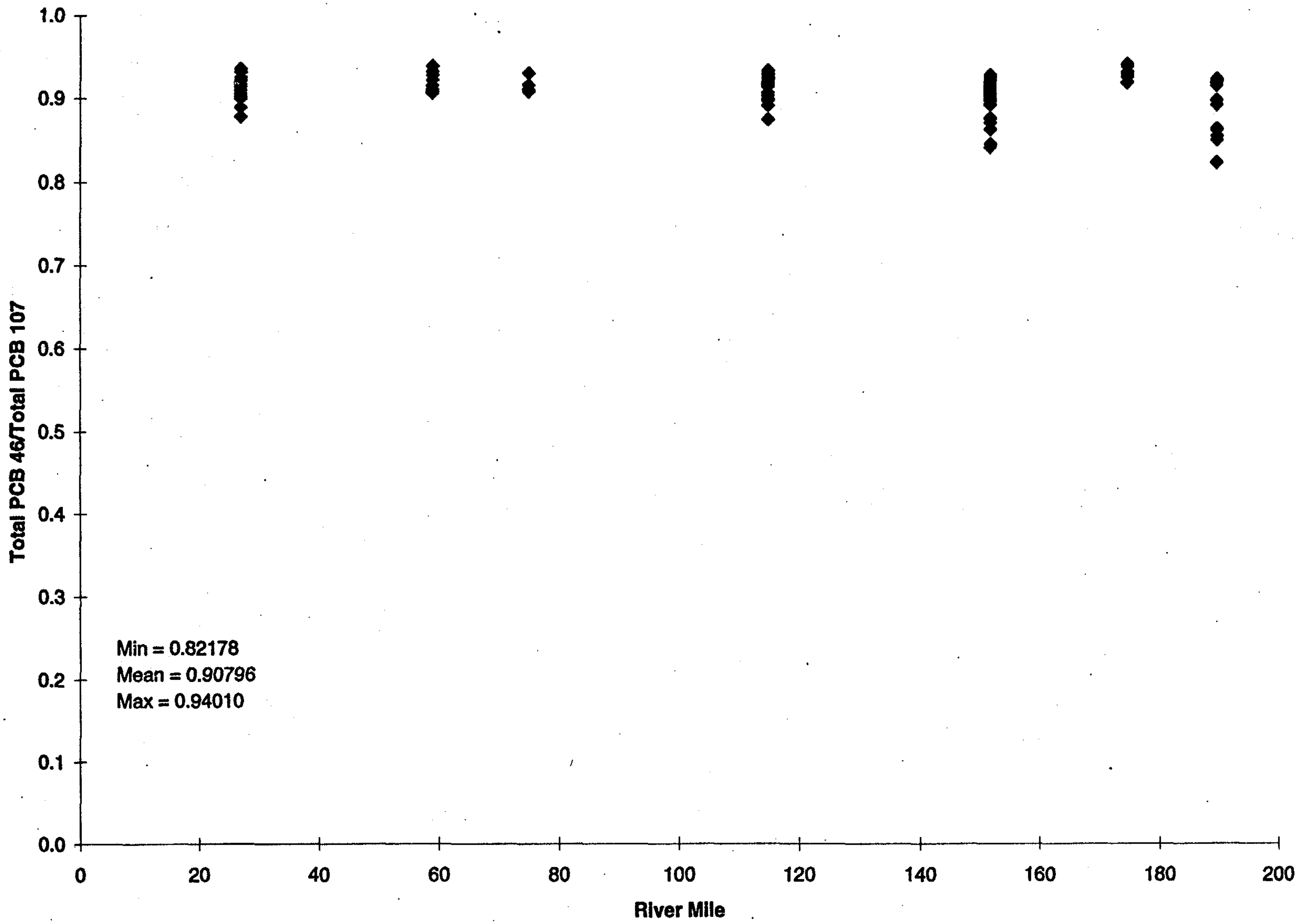

Figure 3-2. Percent total PCBs represented by the principal congeners by river mile

Table 3-2. Samples excluded from group analyses

Sample ID[a]	Species	River Mile	Season	Gender	Age	Maximum Distance Value
F309711R1	Largemouth bass	190	Spring	Male	Adult	0.088
F293919	Striped bass	75	Spring	Male	Adult	0.131
F293915	Striped bass	152	Spring	Male	Adult	0.081
F282166	White perch	27	Fall	Unknown	Adult	0.097
F282163	White perch	59	Fall	Unknown	Adult	0.099
F282165	White perch	59	Fall	Unknown	Adult	0.099
F283129	Yellow perch	115	Spring	Unknown	Adult	0.104
F284077	Yellow perch	190	Spring	Unknown	Adult	0.091
F284078	Yellow perch	190	Spring	Unknown	Adult	0.089
F284087	Striped bass	152	Fall	Unknown	Juvenile	0.103
F284089	Striped bass	152	Fall	Unknown	Juvenile	0.103

[a] These samples exceeded the 90 percent probability value of the lognormal distribution of within-group distances.

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3.2 PHYSICAL CHARACTERISTICS

Results of the physical measurements were used as a check of the overall comparability of samples collected at different times and locations. Length, weight, and percent lipid were measured for all of the fish samples, with the exception of the white and yellow perch collected in the fall of 1995 at RM152. No weight data were collected for those fish. The data for all of the samples are summarized in Table 3-3 and presented in Appendix F.

The reported percent lipids showed greater differences within species than the other physical characteristics and limited differences among the different species. Overall, largemouth bass were reported to have the lowest lipid content, particularly in the upper river samples. The juvenile striped bass and the yellow perch from RM115 had similar lipid contents to the lower river largemouth bass. The adult striped bass, the white perch, and the yellow perch from the other stations all had similar lipid contents. Finally, the adult striped bass and the white perch collected from RM27 appeared to have slightly higher lipid contents than most of the other specimens, but these differences were not tested statistically.

3.3 PCB CONCENTRATION AND COMPOSITION

3.3.1 Spatial Trends in Total PCB Concentrations

The sums of the measured concentrations of all 107 PCB congeners are presented for all species at all sampling locations in Figure 3-1. An exponential decline in concentration was seen with increasing distance downriver from RM190 when the total PCB concentrations were expressed as either a wet-weight (Figure 3-3a) or lipid-based concentrations (Figure 3-3b). The only exceptions to this trend of decreasing total PCB concentrations with distance from RM190 was seen at RM59, where white perch and juvenile striped bass had PCB concentrations higher than at RM115 on a wet-weight basis.

When the spatial trends of the lipid-based total PCB concentrations were examined for each species (Figure 3-4), the two species that were sampled both above and below the Federal Dam at RM154 (yellow perch and largemouth bass) both showed rapid decreases in PCB concentration between the sites above the dam (RM190, RM175) and the sampling locations below the dam (RM152, RM115). White perch and striped bass were collected from the stretch of the river from the Federal Dam to the Tappan Zee Bridge, RM152 to RM27. Declining PCB concentrations were seen in both juvenile and adult

Table 3-3. Summary of length, weight, and percent lipid measurements for groups of fish analyzed

Species	Season	Life History Stage[a]	Sex[b]	River Mile	Count	Length (mm) Min.	Max.	Average	Std. Dev.	Weight (g) Min.	Max.	Average	Std. Dev.	Percent Lipid Min.	Max.	Average	Std. Dev.
Largemouth bass	Spr	A	M	190	4	359	440	390.8	29.90	660	1540	964.5	345.40	0.30	2.90	1.03	1.08
Largemouth bass	Spr	A	M	175	5	353	411	385.6	19.70	640	1060	880	138.71	0.10	0.30	0.22	0.10
Largemouth bass	Spr	A	M	152	5	354	386	374.4	11.90	610	970	798	142.18	0.10	1.20	0.64	0.45
Largemouth bass	Spr	A	M	115	5	355	409	376	19.00	760	1210	894	162.68	0.50	1.90	1.22	0.54
Striped bass	Spr	A	M	152	4	496	691	597.3	73.10	1300	3710	2477.5	909.96	1.90	4.40	3.28	0.94
Striped bass	Spr	A	M	115	5	500	635	556.8	48.70	1300	2700	1886	526.48	0.10	6.30	2.58	2.35
Striped bass	Spr	A	M	75	4	592	665	637.3	28.20	2290	3380	2842.5	399.77	3.50	9.00	5.25	2.23
Striped bass	Spr	A	M	27	5	527	831	648.6	99.70	1790	7210	3506	1909.54	3.40	5.50	4.30	0.68
Striped bass	Spr	A	F	115	5	682	845	738.4	57.30	3330	8300	4772	1801.48	2.10	4.00	2.96	0.70
Striped bass	Fall	A	M	152	5	479	820	695	118.90	1080	5740	3596	1536.35	0.30	4.20	2.12	1.30
Striped bass	Fall	A	M	27	5	615	802	703.2	65.90	2960	5560	4088	921.62	1.50	6.00	3.60	1.60
Striped bass, juv.	Fall	J	U	152	3	68	77	71.3	4.00	2	5	3.33	1.25	0.60	0.60	0.60	0.00
Striped bass, juv.	Fall	J	U	59	5	60	83	70	7.90	2	5	2.8	1.17	0.70	1.10	0.92	0.13
Striped bass, juv.	Fall	J	U	27	5	63	79	73	5.30	3	7	4.8	1.33	0.60	1.10	0.82	0.20
White perch	Spr	A	U	152	5	178	192	186.2	5.10	80	100	94	8.00	2.70	5.60	3.88	1.08
White perch	Spr	A	U	115	5	160	190	170.4	10.40	60	90	78	11.22	2.00	4.40	2.98	0.88
White perch	Fall	A	U	152	5	0	212	165.4	82.80	0	0	0	3.60	2.30	4.80	3.38	0.87
White perch	Fall	A	U	59	3	164	178	171	5.70	62	96	79.33	13.89	2.80	6.60	5.30	1.77
White perch	Fall	A	U	27	4	191	237	212.3	16.70	165	335	249	60.45	6.90	10.80	9.00	1.44
Yellow perch	Spr	A	U	190	4	241	287	269	17.10	198	330	274	50.66	2.10	4.80	3.28	1.03
Yellow perch	Spr	A	U	175	5	204	327	241.6	43.60	75	435	178	130.22	0.70	3.10	2.22	0.89
Yellow perch	Spr	A	U	152	4	180	256	206.5	30.20	55	180	103.75	50.91	0.70	5.00	2.10	1.70
Yellow perch	Spr	A	U	115	4	186	251	219.8	23.90	80	200	130	45.83	0.60	2.80	1.53	0.86
Yellow perch	Fall	A	U	152	5	0	188	107	87.50	0	0	0	4.41	2.70	4.80	3.68	0.74

[a] A - adult; J - juvenile.
[b] M-male; F-female; U-unknown.

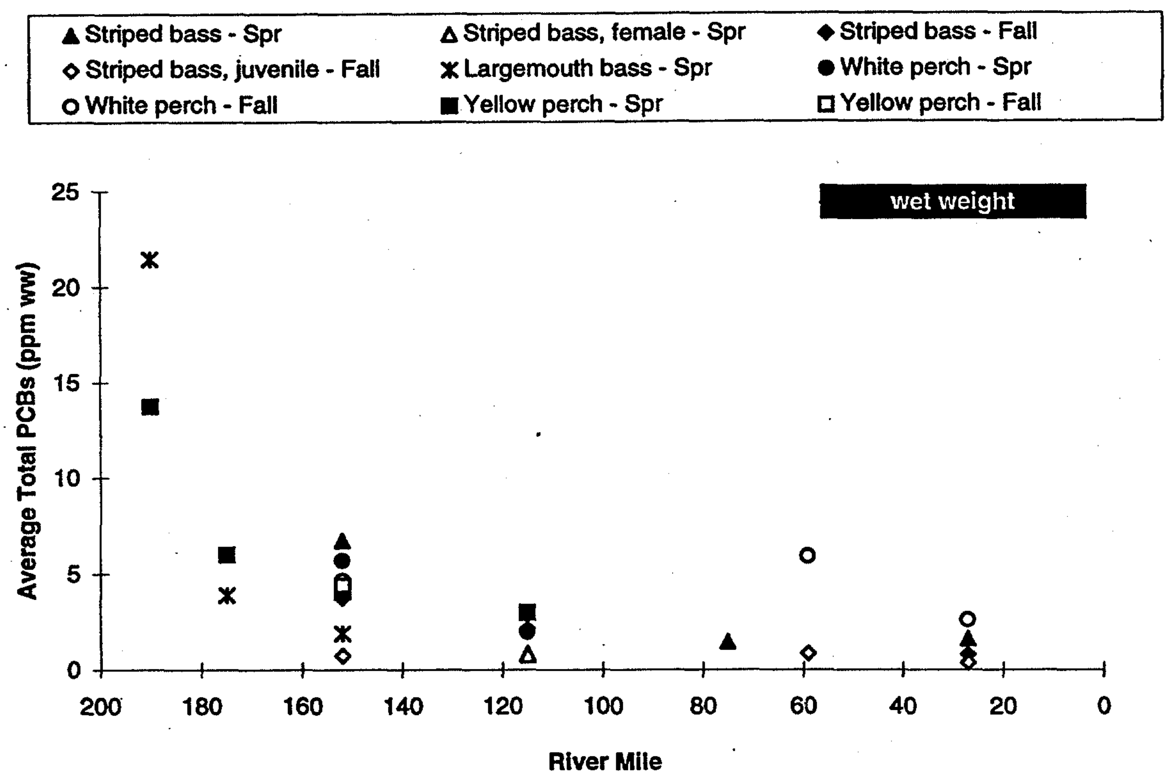

Figure 3-3a. Average total PCBs (wet weight)

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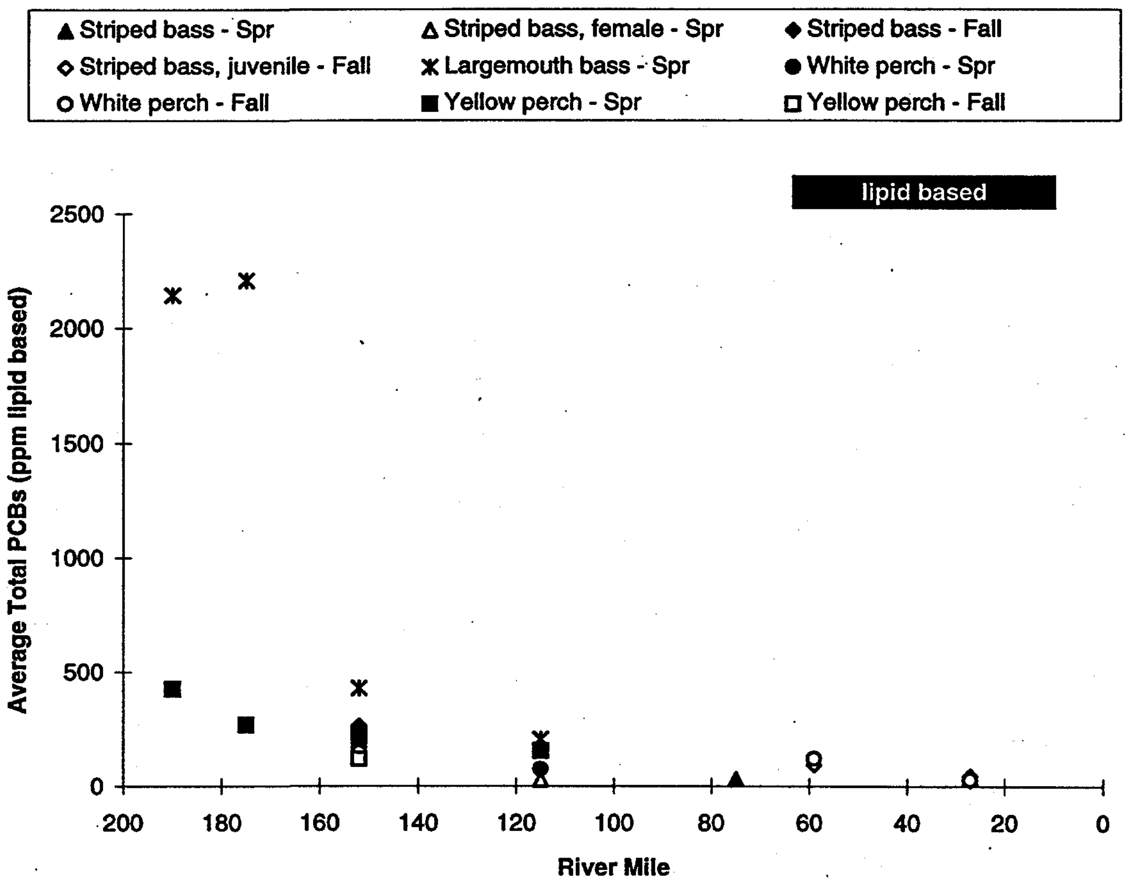

Figure 3-3b. Average total PCBs (lipid-based)

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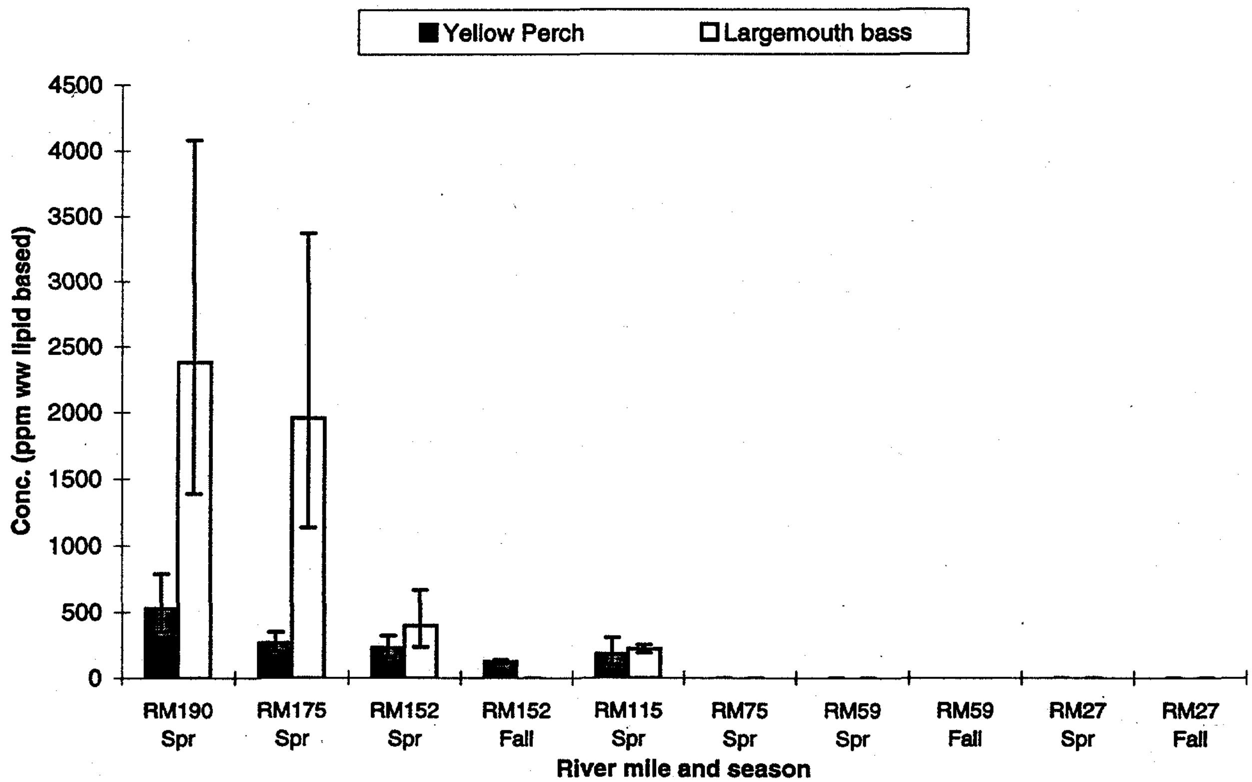

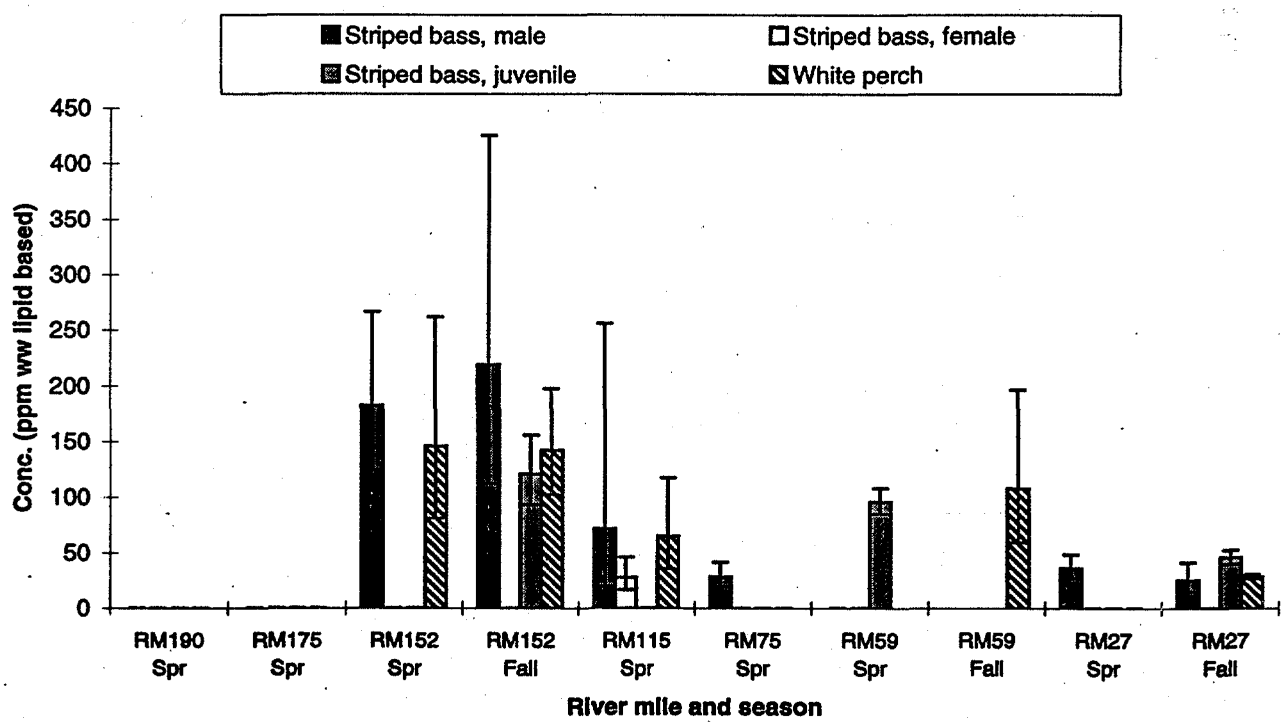

Figure 3-4. Geometric mean and 95% confidence interval for total PCB concentrations (lipid-based) by species

321190

striped bass with increasing distance downriver from the dam, with the exception of an increased PCB concentration measured in the juvenile striped bass collected from RM59.

The decline in total PCB concentrations with increasing distance downstream from the Thompson Island Pool is consistent with previous studies and the hypothesis that the principal source of PCBs to the Hudson River is located at or above the Thompson Island Pool. However, the total PCB concentrations are less stringent than measures of individual congener concentrations and composition in determining the relationships between PCBs measured in different locations and different species.

3.3.2 Spatial Trends in PCB Composition and Congener Concentration Within Resident Fish Species and Striped Bass

To identify changes in the congener concentration and composition between sampling locations, congener concentration and composition profiles were compared for each species. For this spatial comparison, the data are presented for sample groups defined by species, sampling location, season, and life stage (juvenile versus adult). Between-group comparisons were made between groups that differed only in terms of sampling location whenever possible. In the few instances where comparisons were made between fall- and spring-collected samples, these comparisons are clearly identified. The differences in congener composition were quantified by the calculation of the maximum between-group Euclidean distances using the statistical methods discussed in Section 2.4 of this report.

The analysis of spatial trends in PCB composition and concentration within resident fish species and striped bass was conducted in order to address two of our initial hypotheses:

- Spatial gradients in congener concentrations and composition in the adult striped bass are consistent with exposure to PCBs released from a source located in the Upper Hudson River above the Thompson Island Dam.

- The current (1995) spatial gradients in PCB congener concentrations and composition in the resident species and striped bass correspond to those reported in the historical database.

3.3.2.1 Section Overview

The spatial trends for all of the resident fish, including the juvenile striped bass, showed consistent decreases, with few exceptions, in the concentrations for all congeners with increasing distance downstream in the river. These changes were consistent with the changes in total PCB concentrations calculated for the same fish and with the trends in concentration changes in total PCBs observed in the historical data. In addition, the congener data identified specific differences in the rates of decrease in concentration among the congeners. Selected lower-chlorinated congeners decreased more rapidly in downriver stations compared to the higher-chlorinated congeners. These differences were also observed consistently among the resident fish. These differences can be used to identify the specific congeners responsible for compositional differences seen in the historical data.

It is important to note that, even though the concentrations and compositions of the PCBs change among locations, both the composition profiles and the Euclidean distances demonstrate that the changes in PCB composition between locations were limited. Only in comparisons between the PCB compositions observed in fish from the upper river and those of the lower river did the differences approach or exceed the differences seen between Aroclors 1016 and 1242.

The spatial trends observed in the PCB concentrations in the adult striped bass were similar to those of the resident fish, showing consistent decreases in concentration from fish caught near the Federal Dam to those collected nearer the mouth of the river. Changes in the adult striped bass PCB compositions among locations accompanied the changes in concentrations and overall were also similar to those of the resident fish. However, the magnitude of the compositional changes along the spatial gradient of the river was greater within resident species compared to adult striped bass.

3.3.2.2 Yellow Perch

The decline in the total PCB concentration that was seen between the upper river yellow perch samples (RM175 and RM190) and the lower river samples (RM152 and RM115) was reflected in the profiles of the mean congener concentrations (lipid-based) for each river mile (Figure 3-5a). The largest concentration decreases occurred in the concentrations of the lower-chlorinated congeners, specifically the trichlorobiphenyl congeners PCB28 and PCB31 and tetrachlorobiphenyl congeners PCB44, PCB47, PCB49, PCB52, PCB66, PCB70, and PCB74. The lowest concentrations were measured in the fall-collected fish from RM152. All other samples for this species were collected in the spring. The highest concentrations of the hexa- and heptachlorobiphenyl congeners PCB134, PCB153, PCB180, and PCB187 were measured in the spring-collected fish from RM152 and RM115. The differences in the lipid-normalized concentrations are driven, in part, by the fact that these groups of yellow perch had the lowest average percent lipid.

Changes in congener composition reflect the decrease in the trichlorobiphenyl and tetrachlorobiphenyl congeners seen in the concentration profiles, but the compositional changes are not as large between locations as the changes in concentration. The lower

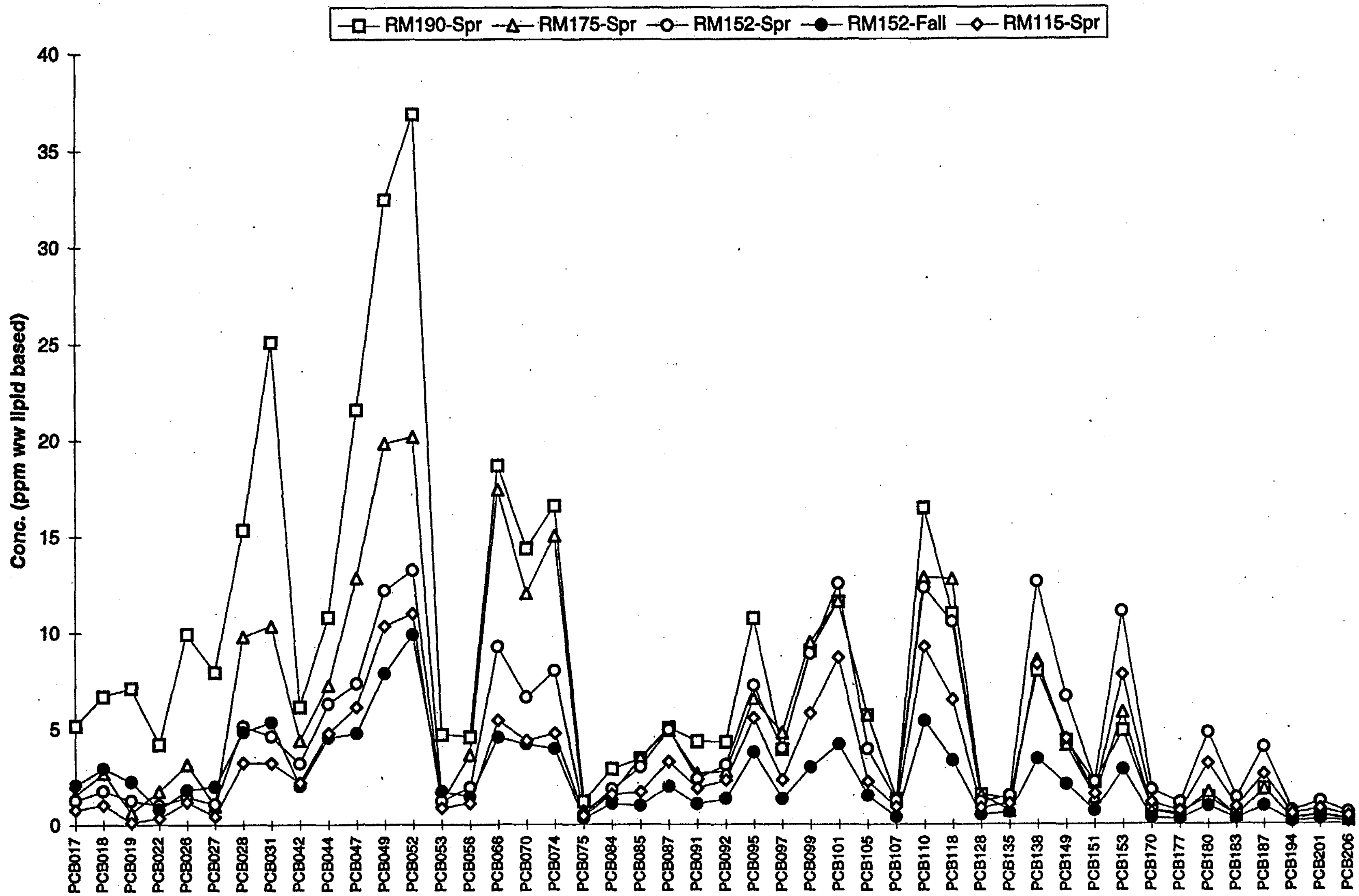

Figure 3-5a. PCB concentration profiles - yellow perch

river yellow perch had lower relative contributions from the lower-chlorinated congeners and higher contributions from the more highly chlorinated congeners compared to the upper river fish (Figure 3-5b).

Maximum between-group Euclidean distances for the sampling locations were calculated for the yellow perch (Table 3-4). The strong similarities between the PCB compositions in the groups collected at RM152 and RM115 that could be observed in the profiles in Figure 3-5b were reflected in the small Euclidean distances calculated between these groups (note that the distance between Aroclors 1016 and 1242 was 0.116). The distance values indicated that the degree of differences in composition were similar between RM190 and RM175 and between RM175 and the lower river groups. Only the distances between the yellow perch from RM190 and those from the lower river exceed the distances between the most similar Aroclors (1016 and 1242).

Table 3-4. Maximum between-group distances for the yellow perch between river miles

River Mile	RM190	RM175	RM152	RM115
RM190	0	-	-	-
RM175	0.098	0	-	-
RM152	0.14	0.097	0	-
RM115	0.136	0.097	0.06	0

3.3.2.3 Largemouth Bass

Largemouth bass were collected from the same locations as the yellow perch. All of the largemouth bass were collected in the spring. The lipid-based mean congener concentrations reflect the same decreases in concentrations between the upper river and lower river fish that were seen in the yellow perch (Figure 3-6a). Overall, the congener makeup of the PCBs in the largemouth bass was similar to that measured in the yellow perch. All congener concentrations appeared to decrease between the upper river (RM190, RM175) and the lower river (RM152, RM115), and the decrease appeared to be greatest for the tetrachlorobiphenyl congeners PCB66, PCB70, and PCB74 relative to the more highly chlorinated congeners PCB138 and PCB153.

The congener composition profiles of the largemouth bass samples are compared in Figure 3-6b. The upper river fish (RM190 and RM175) had relatively greater contributions from PCB66, PCB70, and PCB74 relative to the lower river largemouth bass. The lower river largemouth bass had relatively greater contributions from the more highly chlorinated congeners.

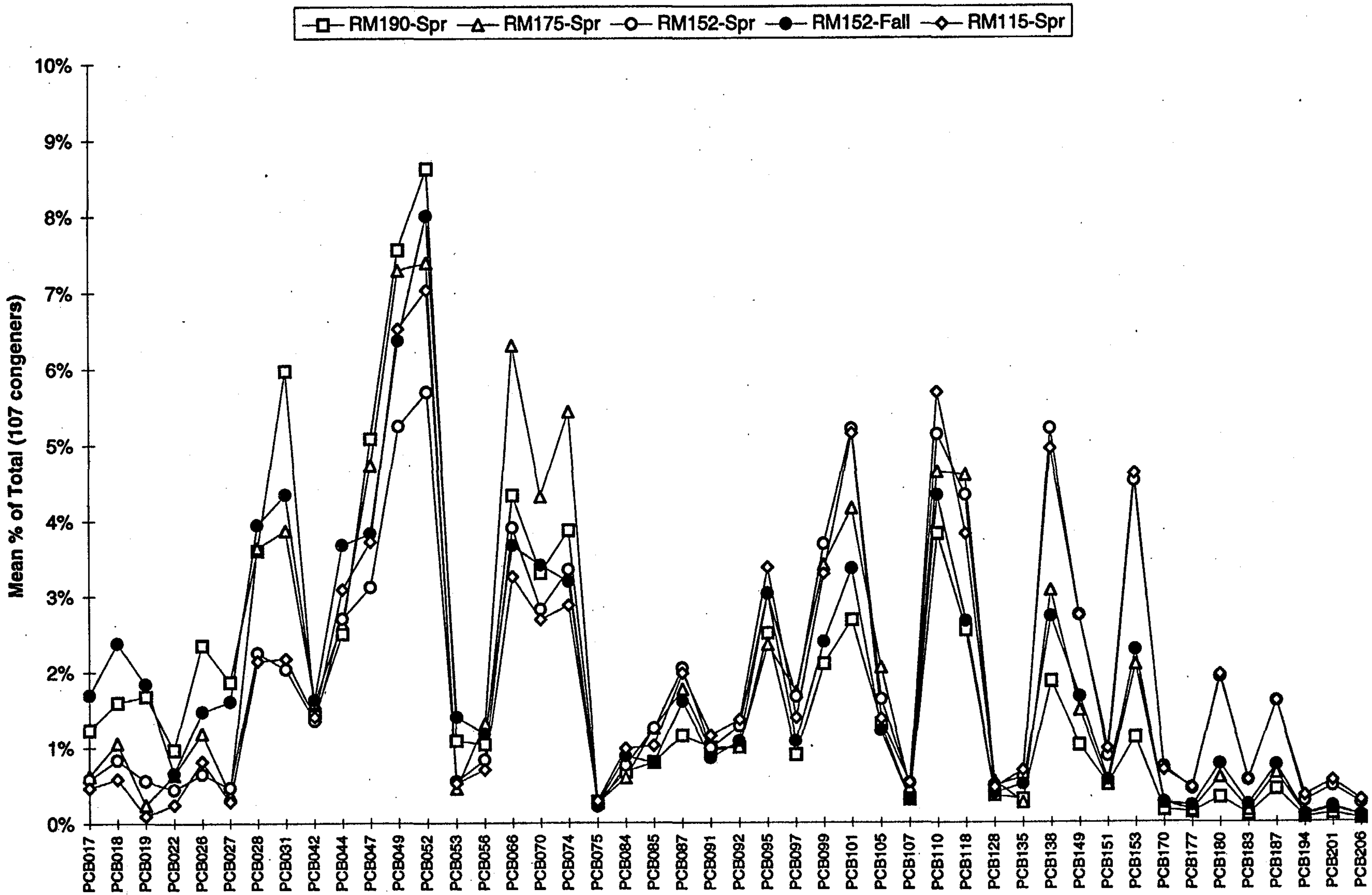

Figure 3-5b. PCB composition profiles - yellow perch

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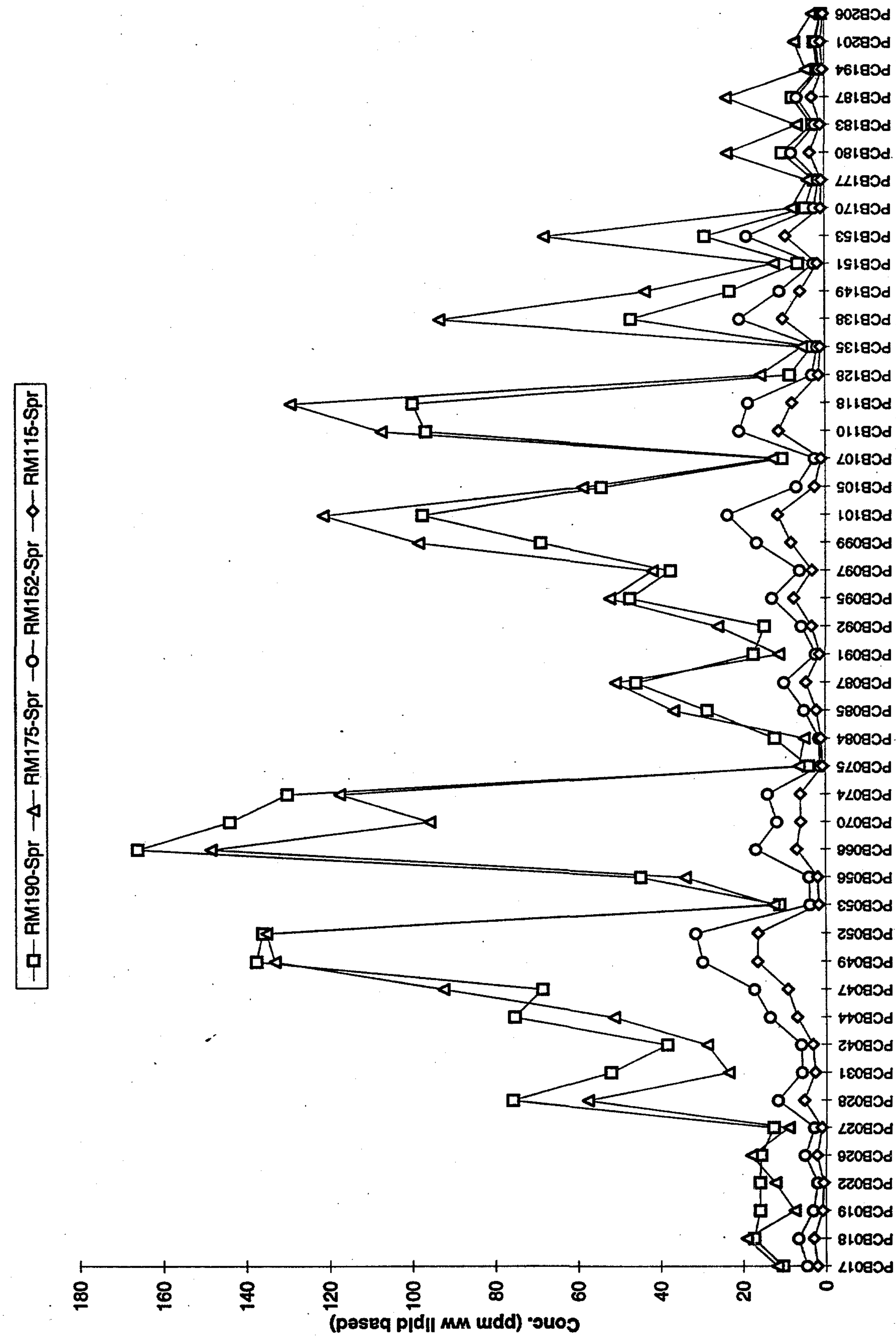

Figure 3-6a. PCB concentration profiles - largemouth bass

321196

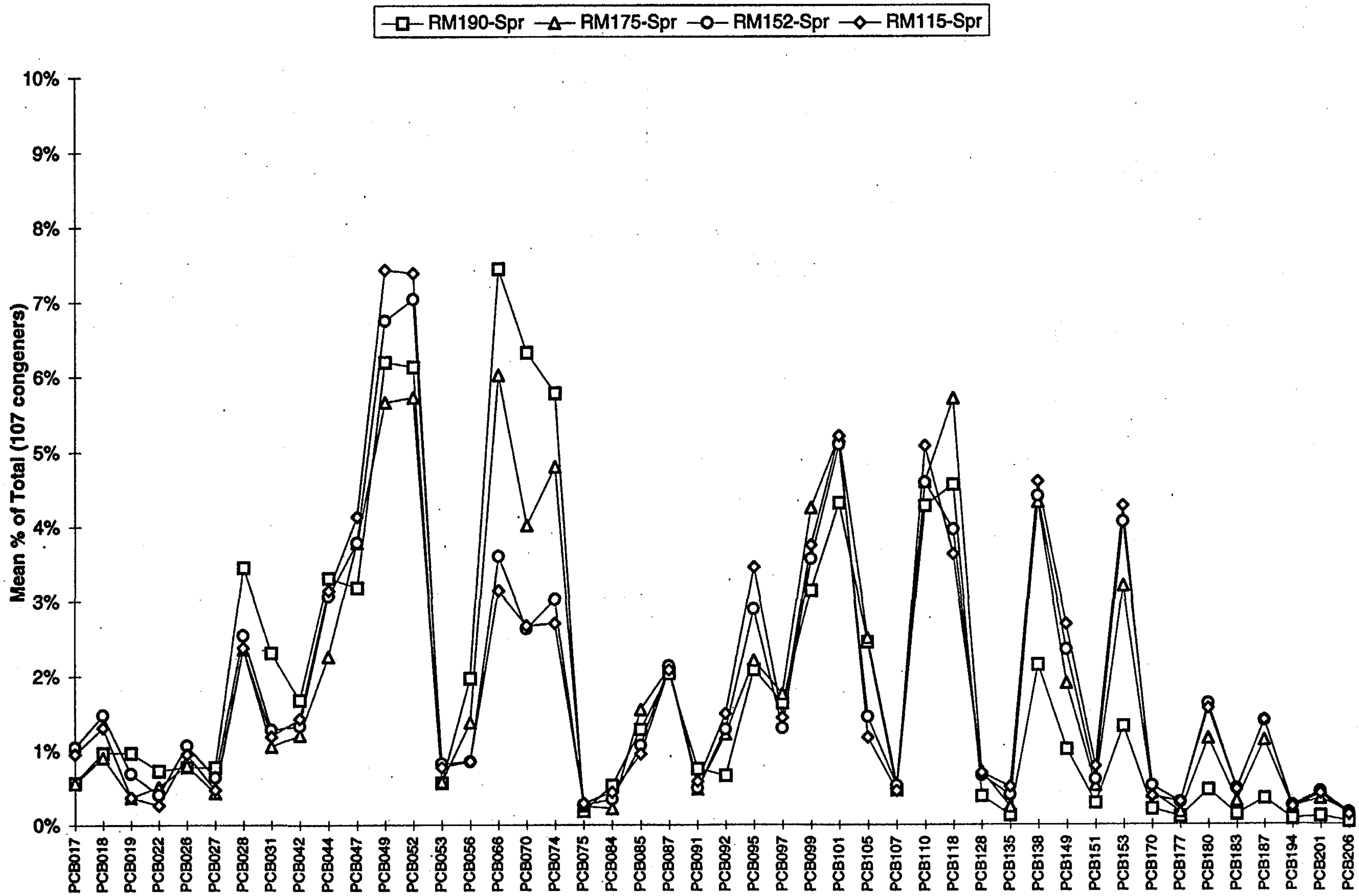

Figure 3-6b. PCB composition profiles - largemouth bass

The differences seen in the composition profiles for the upper and lower river largemouth bass are reflected in the calculated between-group distances shown in Table 3-5. As was the case with the yellow perch, the Euclidean distances also demonstrated that the composition of the PCBs changed to a limited extent among locations, and that the distances increased as the concentrations decreased in fish collected in downstream locations. The smallest distance was calculated between RM115 and RM152, indicating, as with the yellow perch, that the fish from the lower river had similar congener compositions that differed slightly from the upper river locations.

Table 3-5. Maximum between-group distances for largemouth bass between river miles

RIVER MILE	RM190	RM175	RM152	RM115
RM190	0	-	-	-
RM175	0.095	0	-	-
RM152	0.106	0.076	0	-
RM115	0.117	0.087	0.048	0

3.3.2.4 White Perch

White perch were collected only from the lower river, near RM152, RM115, RM59, and RM27. The concentration profiles reflect the same spatial trend seen for total PCB concentrations (Figure 3-7a; note the concentration scale is an order of magnitude less than that of Figure 3-6a). Congener concentrations decreased consistently with distance downstream within each season (spring: RM152 and RM115; and fall: RM152, RM59, and RM27), although the concentrations of some of the more highly chlorinated congeners were higher in the samples collected near RM59 in the fall, compared to those collected during the same season at RM152.

The changes in congener composition observed along the spatial gradient in the river were similar in the white perch to those observed in the yellow perch and largemouth bass (Figure 3-7b). The fish from RM115 and RM152 tended to have relatively greater contributions from PCB66, PCB70, and PCB74. The importance of considering both the composition and concentration profiles is seen in the profiles for RM27. The white perch from RM27 had the highest percent contribution of the highly chlorinated congeners PCB153, PCB180, PCB187, PCB190, PCB201, and PCB206, but the concentrations of these congeners in fish from RM27 were the lowest of all the white perch samples.

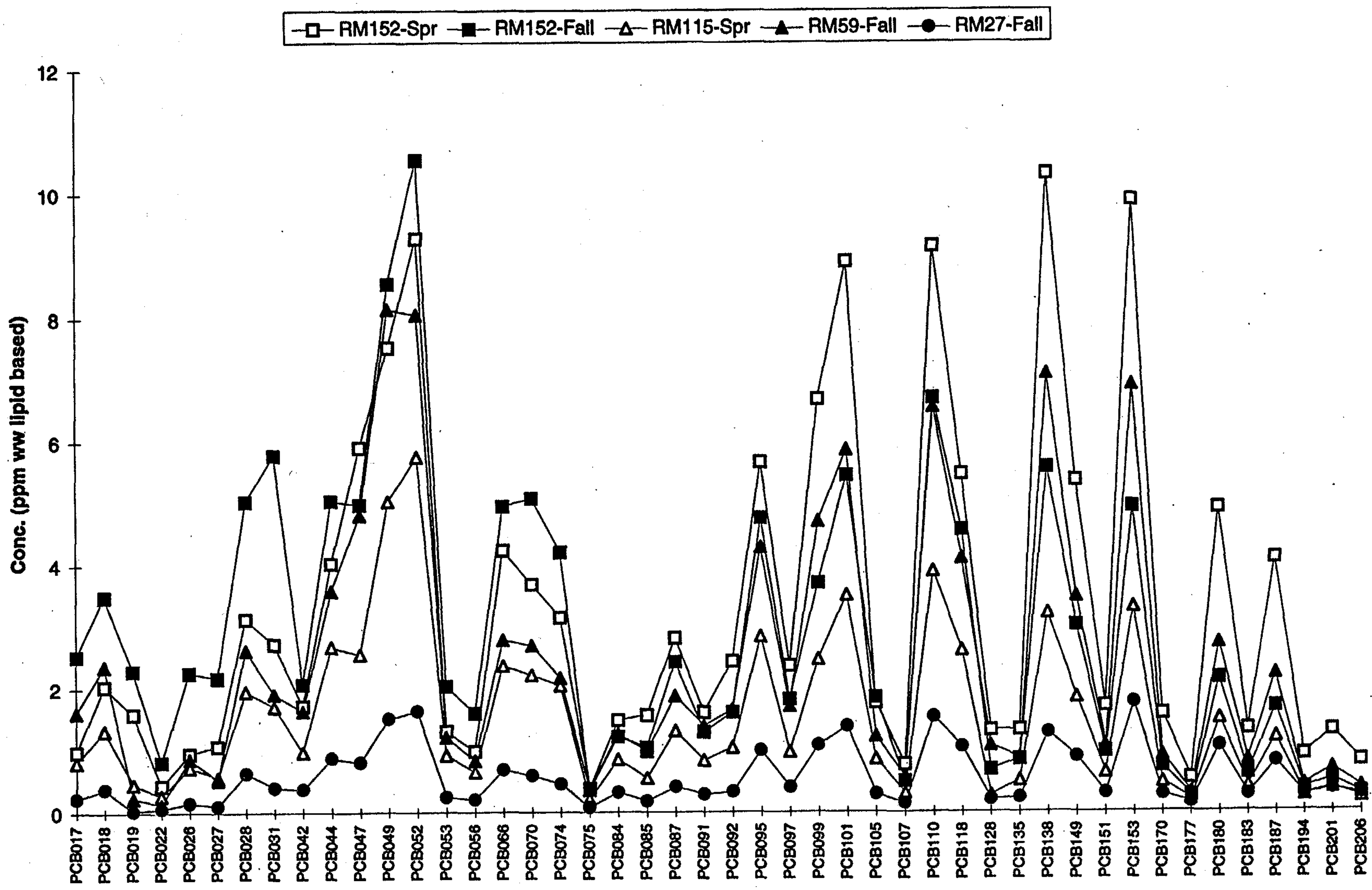

Figure 3-7a. PCB concentration profiles - white perch

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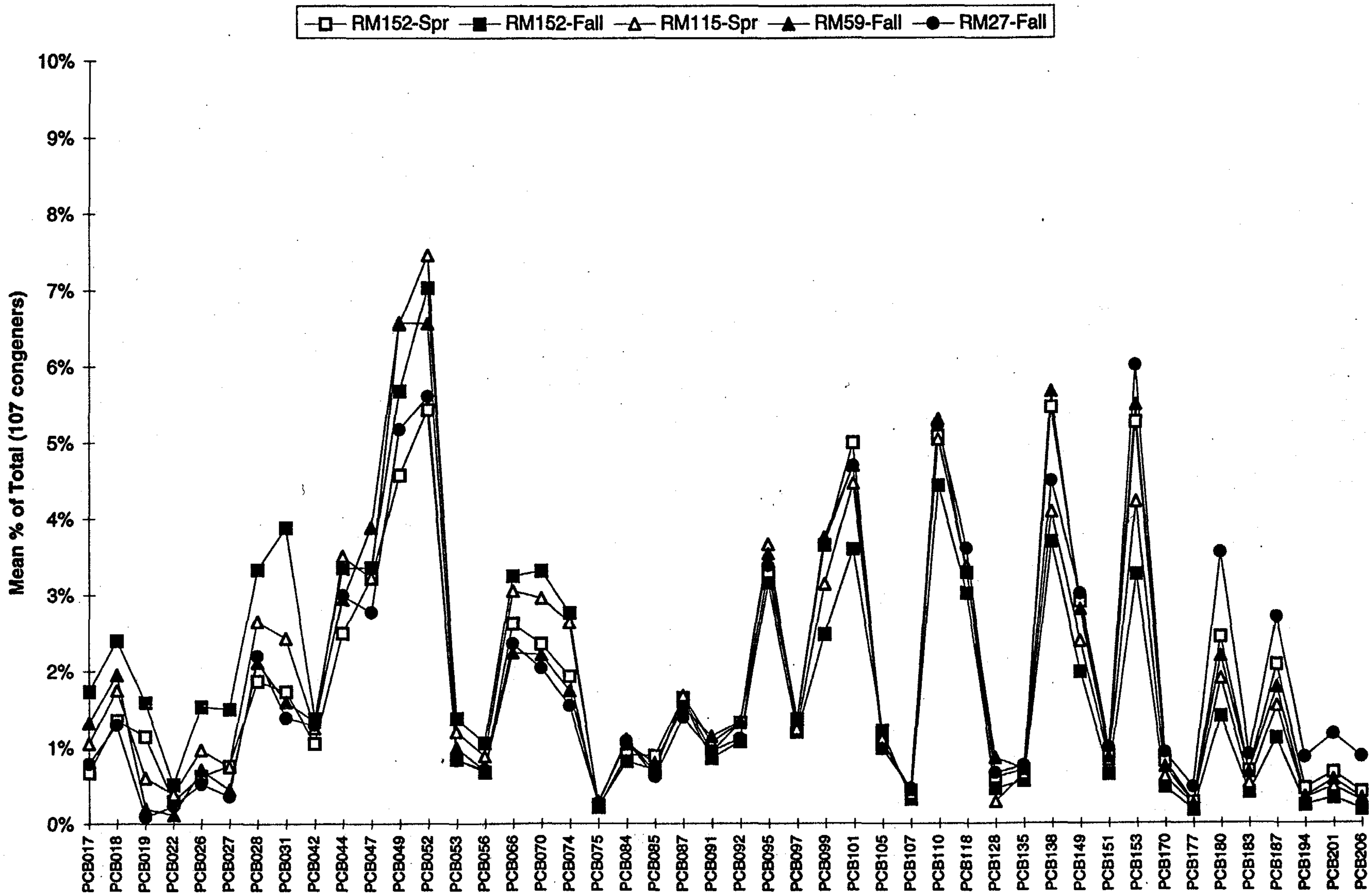

Figure 3-7b. PCB composition profiles - white perch

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As with the other resident species, the Euclidean distances increased with increased distance between locations. The largest distances were calculated for all locations compared with RM152, as well as between RM115 and RM27 (Table 3-6). The distances calculated between RM59 and RM115, as well as RM59 and RM27, were small. Therefore, the congener composition of PCBs in the white perch from RM59 was most similar to that of fish from adjacent locations.

Table 3-6. Maximum between-group distances for the white perch between river miles

River Mile	RM152	RM115	RM59	RM27
RM152	0	-	-	-
RM115	0.084	0	-	-
RM59	0.098	0.059[a]	0	-
RM27	0.119	0.082[a]	0.067	0

[a] Comparison of spring- to fall-collected fish.

3.3.2.5 Juvenile and Adult Striped Bass

Juvenile Striped Bass — Juvenile striped bass were collected in the fall at RM152, RM59, and RM27. Congener composition of the juvenile striped bass was similar to those of the resident fish, as discussed in more detail below. In general, the congener concentrations decreased with increasing distance downriver (Figure 3-8a). Most of the congeners showed consistent decreases in concentration with distance downriver; however, the tetrachlorobiphenyl congeners PCB42, PCB44, PCB47, PCB49, PCB52, and PCB53 had similar concentrations in the juvenile striped bass from RM59 and RM152.

The congener composition profiles for the juvenile striped bass (Figure 3-8b) appear to reflect the same compositional differences with distance downriver that were observed with the resident fish species (Figure 3-7b). Even though the concentrations of all of the congeners decreased, the percent contributions from PCB66, PCB70, and PCB74 were lower and the percent contributions of PCB138, PCB153, PCB180, and PCB187 were higher in the RM27 fish relative to the congener compositions at RM152. The percent contributions from the more highly chlorinated congeners in the juvenile striped bass samples from RM59 more closely resembled those for fish from RM152 than RM27, but the percent contributions from PCB66, PCB70, and PCB74 at RM59 were depleted relative to those at RM152 and were more similar to those at RM27. A different relationship is seen for tetrachlorobiphenyls PCB44, PCB47, PCB49, and PCB52, where the percent contributions at RM59 exceeded those seen at RM152.

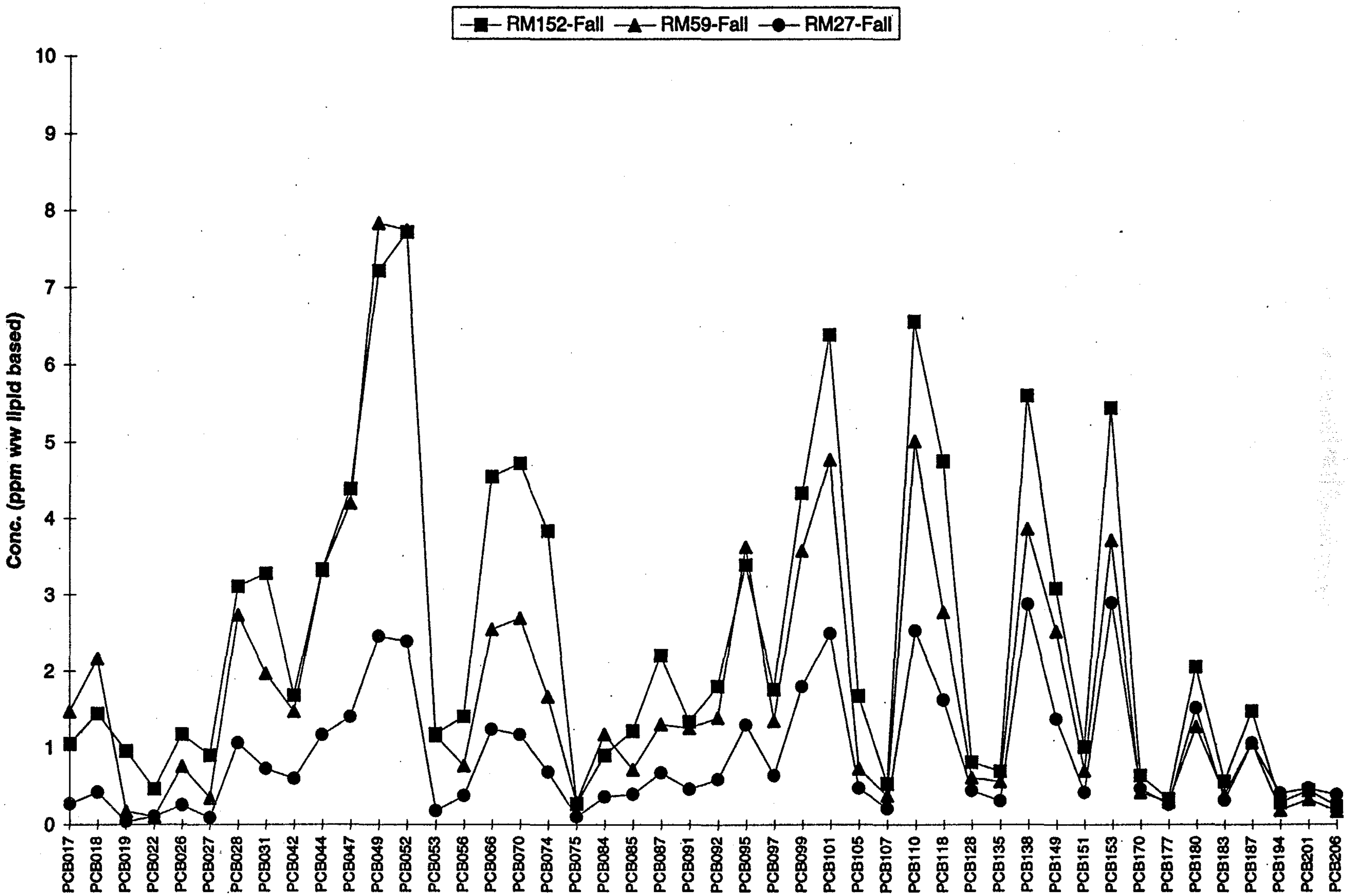

Figure 3-8a. PCB concentration profiles - juvenile striped bass

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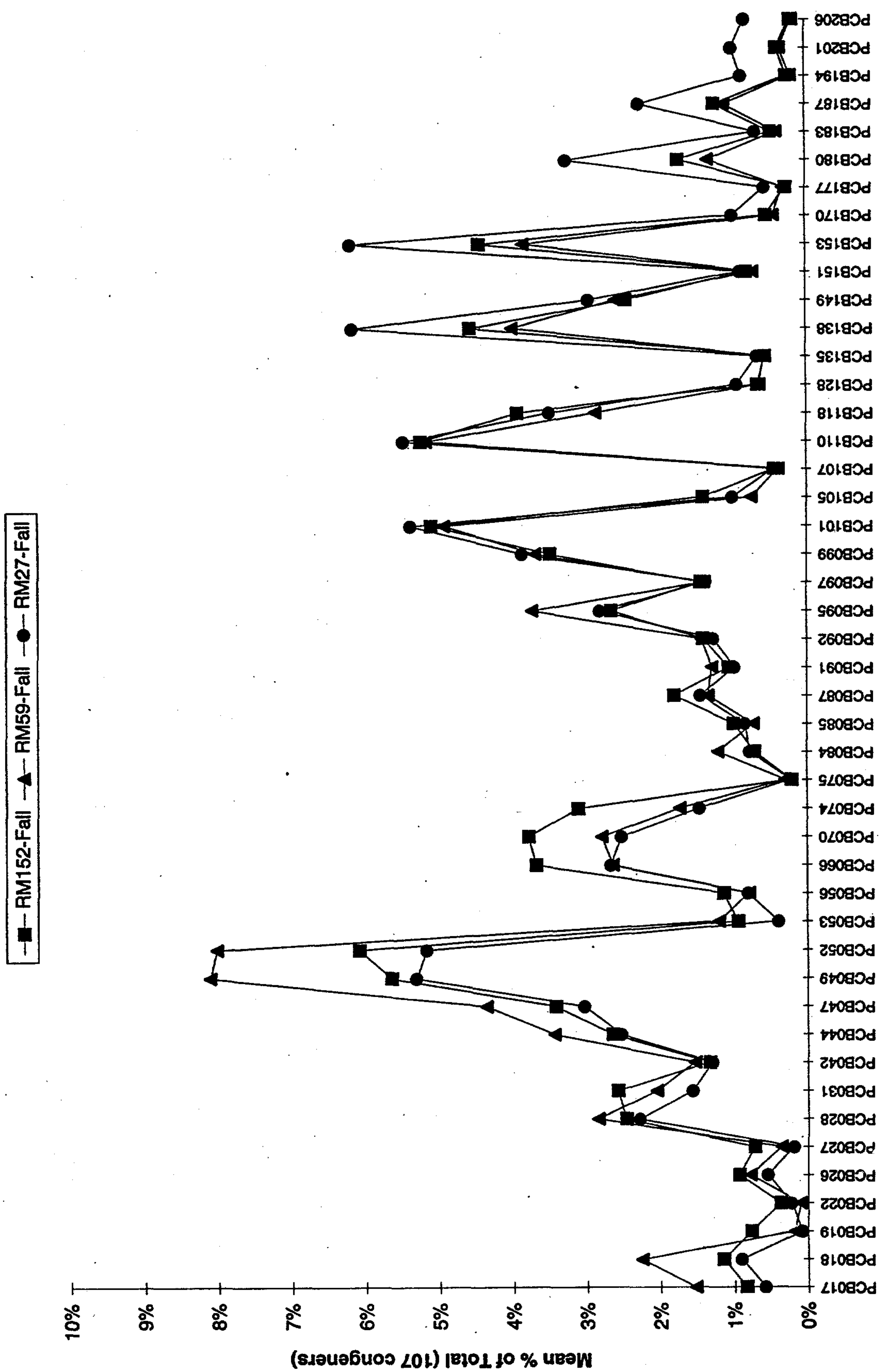

Figure 3-8b. PCB composition profiles - juvenile striped bass

321203

The calculated maximum between-group Euclidean distances calculated for the juvenile striped bass were similar, with the largest distance calculated between RM59 and RM27 (Table 3-7).

Table 3-7. Maximum between-group distances for the juvenile striped bass between river miles

River Mile	RM152	RM59	RM27
RM152	0	-	-
RM59	0.077	0	-
RM27	0.076	0.096	0

***Adult Striped Bass* —** The congener concentration profiles for the adult striped bass in general illustrate that there were differences compared to the resident fish, a result expected because of the different migratory and hence exposure history expected for these fish. These differences are discussed more fully below. The congener concentrations for the adult striped bass collected from RM152, RM115, RM75, and RM27 show that the congener concentrations decreased substantially between RM152 and the far downriver stations (Figure 3-9a) for fish caught during both the spring and fall collections, with the PCBs in the fish collected from RM115 (spring) being intermediate in concentration. These changes occurred fairly consistently for all of the 46 congeners.

Even though the congener concentrations decreased, the congener composition in the adult striped bass samples appeared to be more constant among locations than were compositions in the juvenile striped bass or white perch over the same range of locations (Figure 3-9b). The adult striped bass collected from RM152 had a relatively higher contribution from the tetrachlorobiphenyl congeners PCB47, PCB49, and PCB52 than did adult striped bass from the other locations.

The between-group Euclidean distances were similar between all locations and were similar in magnitude to those seen for the resident fish (Table 3-8). While the largest distance calculated was between adult striped bass from RM27 and RM152 (fall-collected fish), the between-location distances did not increase as consistently with increased downstream separation of the collection locations as observed for the resident fish.

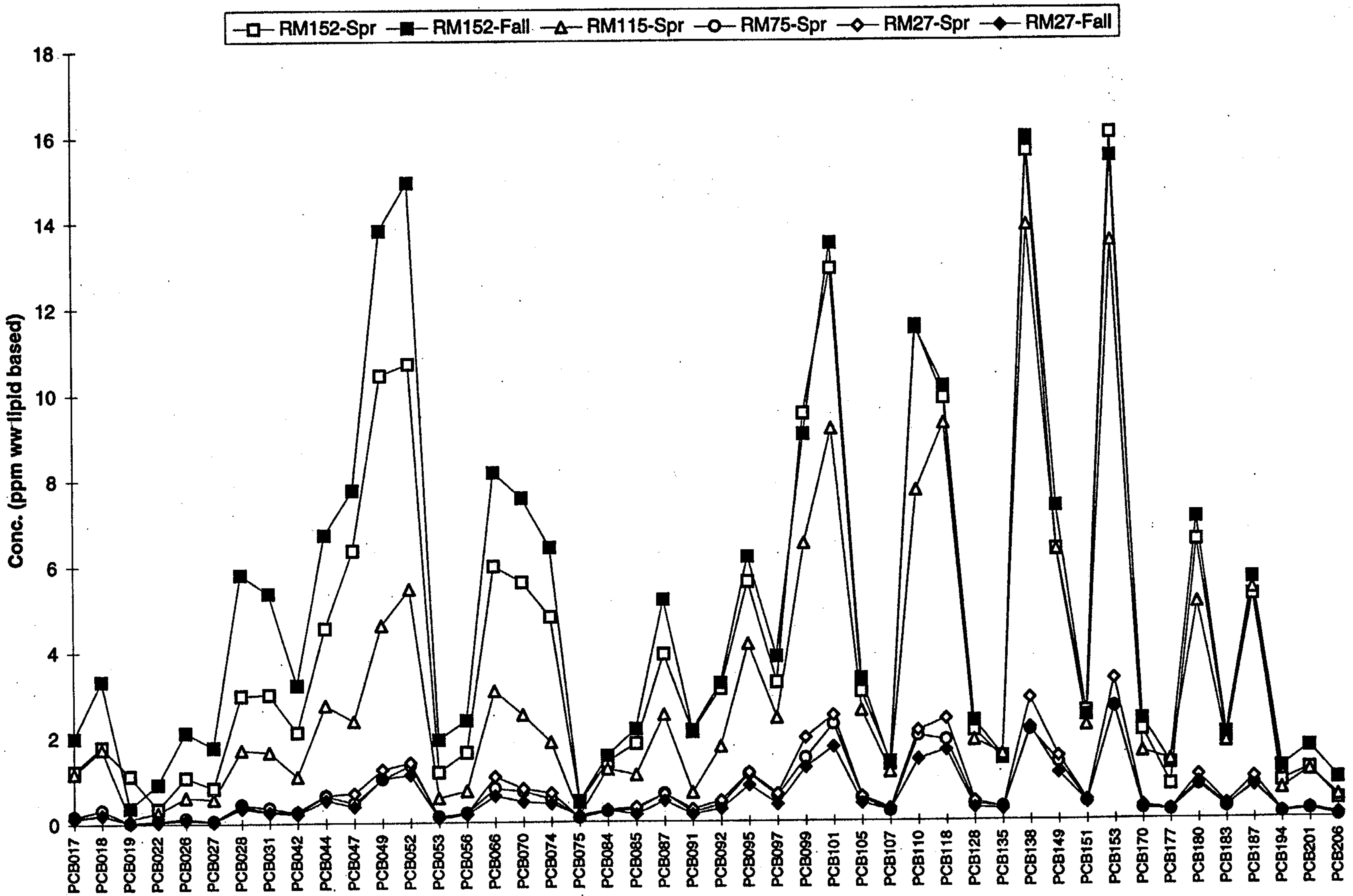

Figure 3-9a. PCB concentration profiles - adult striped bass

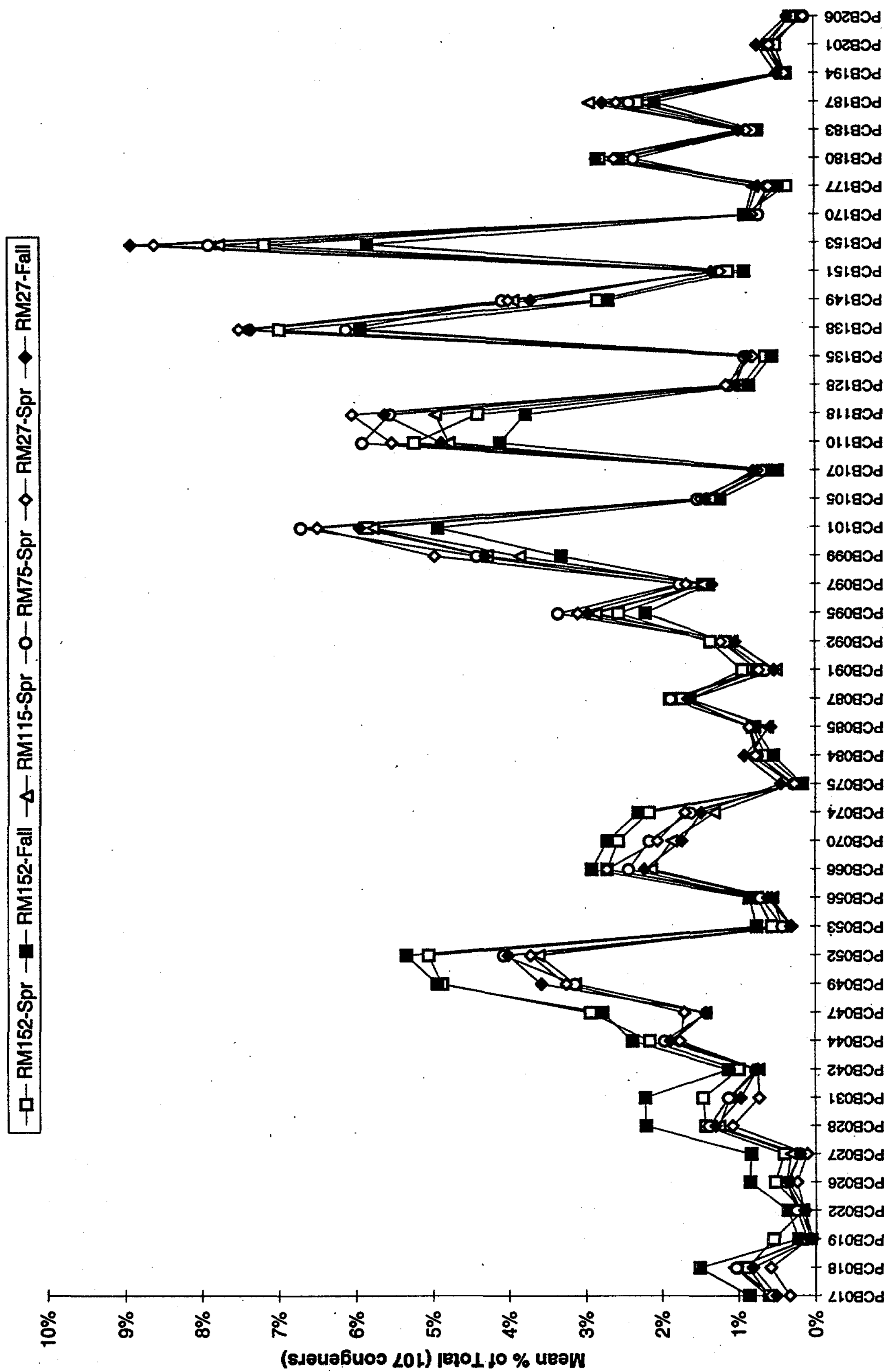

Figure 3-9b. PCB composition profiles - adult striped bass

321206

Table 3-8. Maximum between-group distances for the adult striped bass between river miles

River Mile	RM152	RM115	RM75	RM27
RM152	0	-	-	-
RM115	0.090[a]	0	-	-
RM75	0.082[a]	0.095[a]	0	-
RM27	0.103[b], 0.089[a]	0.070[a]	0.088[a]	0

[a] Comparison of spring-collected fish.
[b] Comparison of fall-collected fish.

3.3.3 Seasonal and Gender Differences in PCB Composition and Congener Concentration within Resident Fish Species and Striped Bass

Previous studies have reported differences in the PCB concentrations and compositions in resident species and striped bass that corresponded to differences in gender or sampling season (Sloan et al. 1995). The influences of gender and season on congener concentrations and compositions were investigated with a limited subset of the fish that could be grouped according to the season in which they were sampled and the gender of the fish, in addition to being grouped by species and sampling location. At RM152, white perch, yellow perch, and adult striped bass were collected in both spring and fall. In addition, adult striped bass were collected from RM27 in fall and spring. Gender differences were compared for male and female adult striped bass collected from RM115. All other fish collected were either male (largemouth bass and adult striped bass) or their gender was not determined (yellow perch, white perch, and juvenile striped bass).

3.3.3.1 Section Overview

Overall, the results indicated consistently higher PCB concentrations in spring-collected fish compared to fall-collected fish, with the one exception of higher concentrations in fall-collected adult striped bass at RM152. However, it should be noted that for all of the comparisons, the differences were not large (usually less than factors of two) and were not tested statistically. For many of the congeners for all of the species, the calculated standard deviations overlapped, indicating that many of the differences would not be considered significant. In addition, the database for these comparisons was small and only addressed a single pair of seasons.

3.3.3.2 Seasonal Differences in Resident Species of White Perch and Yellow Perch

The concentration profiles for the yellow perch collected in the spring (May 23, 1995) and fall (August 28, 1995) at RM152 are plotted in Figure 3-10a. The yellow perch collected in the spring contained higher concentrations of most of the 46 principal congeners than the fall-collected fish. While the same congeners dominated the PCBs in both seasons, the differences in the concentrations were largest for the more highly chlorinated congeners PCB101, PCB110, PCB118, PCB138, and PCB153. The concentrations were more similar for the tri- and tetrachlorobiphenyls PCB17, PCB18, PCB22, PCB26, PCB27, PCB28, PCB31, and PCB42. When the composition profiles for the fall- and spring-collected yellow perch are compared (Figure 3-10b), the PCB composition of the spring yellow perch had a larger percent contribution from the more highly chlorinated congeners relative to the lower-chlorinated congeners.

The differences in concentration and composition profiles for the white perch collected in the spring (May 23, 1995) and fall (August 28, 1995) at RM152 were similar to those for the yellow perch (Figure 3-11a and b). The concentration differences between the spring and fall white perch were not as dramatic as those seen in the yellow perch (Figure 3-11a). However, higher concentrations were measured in the spring-collected fish relative to the fall-collected fish. In addition, the concentration differences were larger for the penta- and hexachlorobiphenyl congeners PCB101, PCB110, PCB138, and PCB153 relative to the tetrachlorobiphenyls PCB47, PCB49, PCB52, PCB66, PCB70, and PCB74.

The seasonal differences in congener composition and concentration may reflect differences in exposure resulting from changes in ambient PCB concentrations associated with the river hydrology in the spring and fall. In addition, changes in water temperature and primary production in the water column may affect the bioavailability of PCBs, the physiology and feeding habitats of the fish, and may play a role in the observed seasonal differences.

One potential explanation for the observed seasonal differences in concentration and composition is based on the compositional differences seen between the PCBs in the sediment and those that have been observed in the water column. Sediment-associated PCBs have a higher percent contribution from higher-chlorinated congeners relative to PCBs in the water column (Bopp et al. 1981). The PCB composition in the spring-collected resident fish may reflect increased accumulation of sediment-associated PCBs by the resident fish because of the increased sediment transport associated with spring high flows. In the fall, slower river flow and increased water temperatures may result in higher water column PCB concentrations (TAMS 1997) and hence accumulation in fish

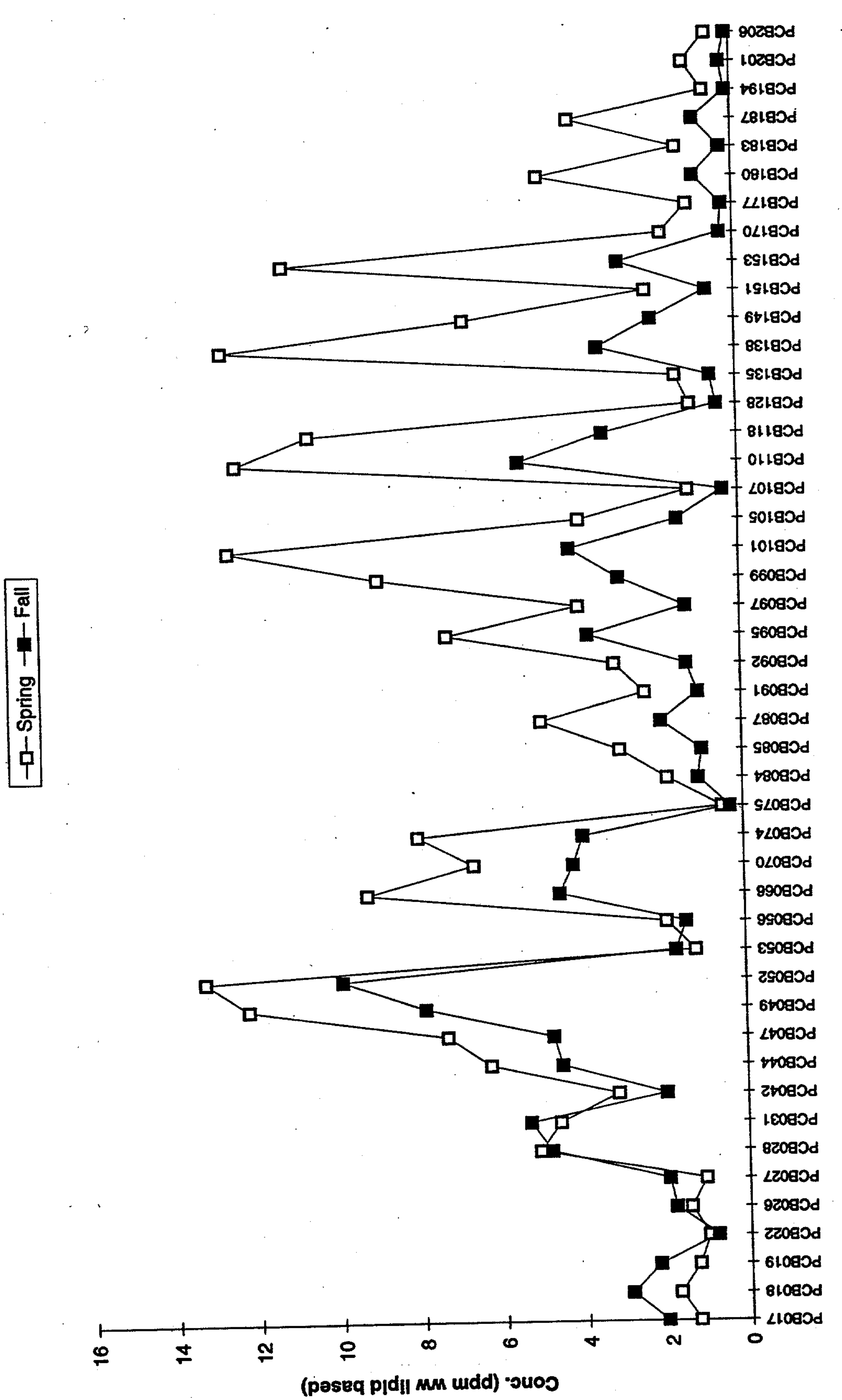

Figure 3-10a. Seasonal differences in PCB concentration - yellow perch at River Mile 152

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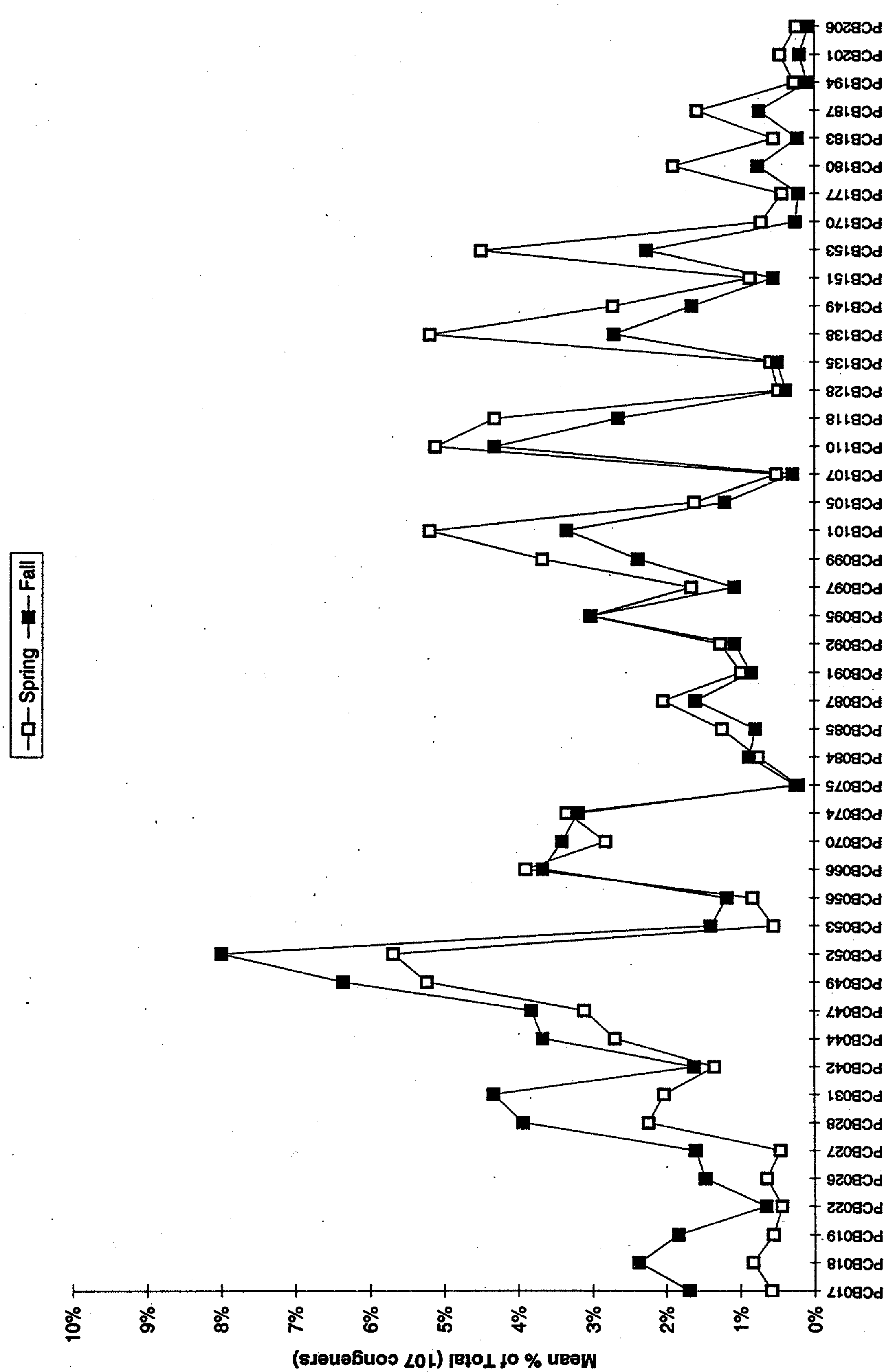

Figure 3-10b. Seasonal differences in PCB composition - yellow perch at River Mile 152

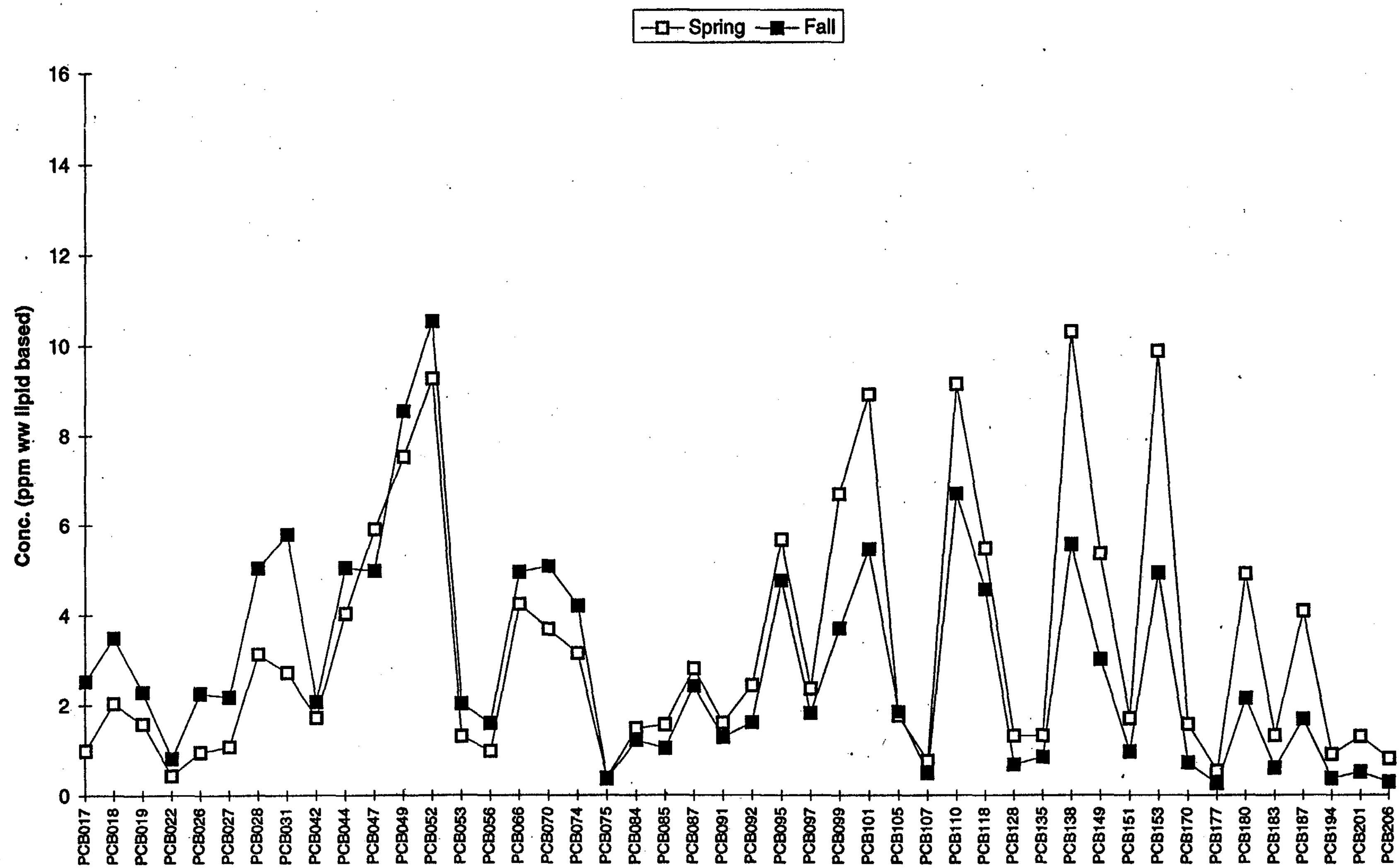

Figure 3-11a. Seasonal differences in PCB concentration - white perch at River Mile 152

321211

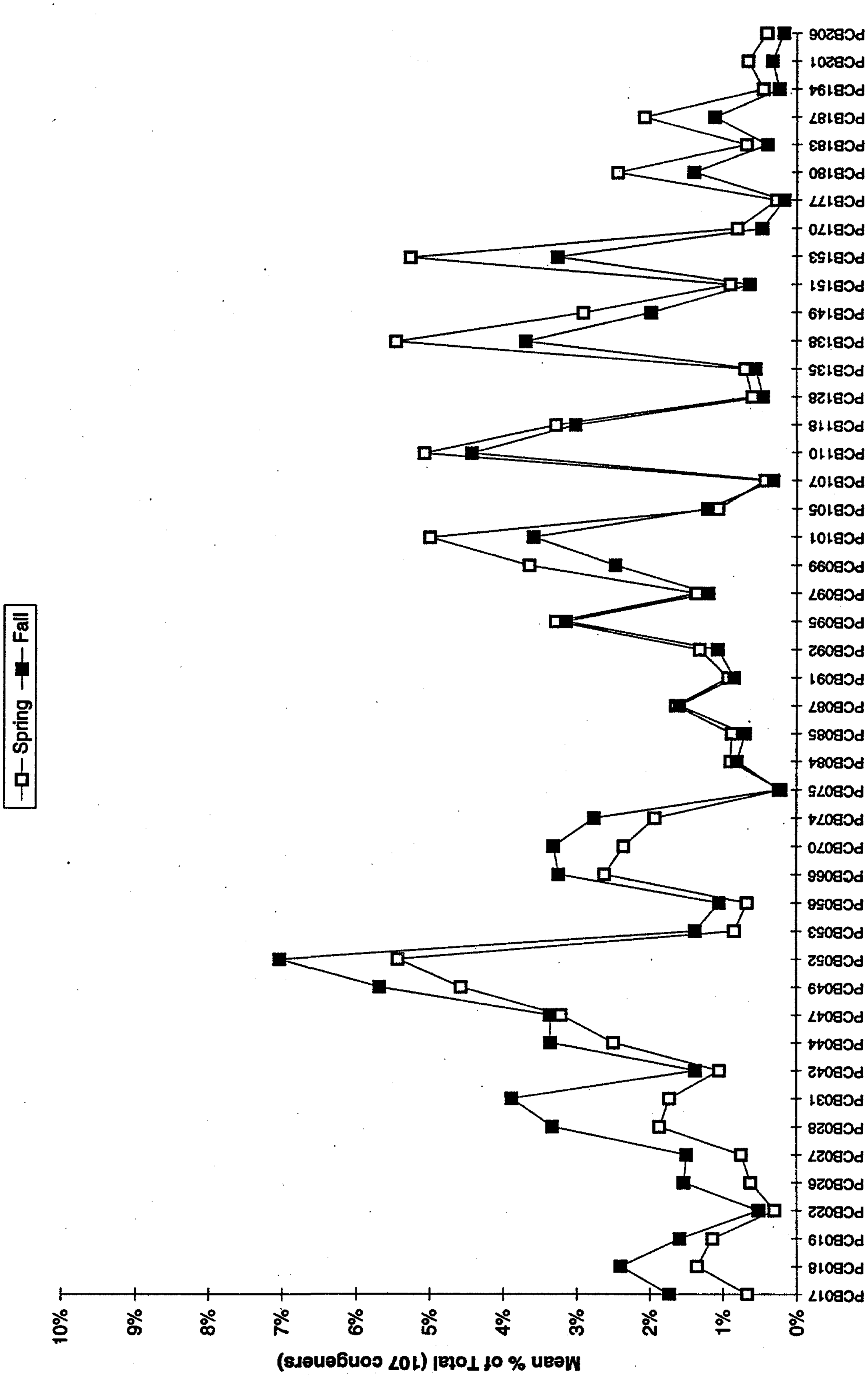

Figure 3-11b. Seasonal differences in PCB composition - white perch at River Mile 152

321212

of PCBs that more strongly reflect the water column composition. The observed seasonal differences in concentration cannot be explained in terms of differences in the lipid content of the spring- and fall-collected fish. No differences were seen between the seasons for this parameter.

Seasonal influences appear to be the important factors affecting the PCB congener concentrations and, to some extent, their composition in resident fish tissues.

3.3.3.3 Seasonal Differences in Adult Striped Bass

At stations RM152 and RM27, adult striped bass were collected in the spring and fall. The spring collection at RM152 occurred on June 21, 1995 and the spring collection at RM27 occurred on April 12, 1995. The timing of the collection relative to the spawning run of this species may be important. Spawning tends to occur from mid-May to mid-June. Therefore, the RM27 spring collection may have sampled adult striped bass prior to spawning and the RM152 spring collection sampled fish in the middle of their spawning season.

The congener concentrations of the adult striped bass collected at RM152 in the spring and fall (August 28, 1995) (Figure 3-12a) showed different seasonal differences from those seen in the resident species (Figures 3-10a and 3-11a) collected at this location. Overall the differences did not appear to be as great as for the resident fish, but the mean congener concentrations in the fall-collected fish were almost always greater than those in the spring-collected fish. The differences between the congener concentrations were largest for the lower-chlorinated tri- and tetrachlorobiphenyl congeners PCB28, PCB31, PCB44, PCB47, PCB49, PCB52, PCB66, PCB70, and PCB74. The concentrations of the more highly chlorinated congeners PCB138 and PCB153 were similar.

These differences in concentration are reflected in the composition profiles for these fish (Figure 3-12b), which show a slightly greater percent contribution of penta- and hexachlorobiphenyls in the spring-collected fish. This observation is consistent with previously reported differences in PCB composition in spring- and fall-collected Hudson River striped bass (Sloan et al. 1995). This pattern is also consistent with expected migratory behavior; if the spring-collected fish had more recently arrived at RM152 they would have had less time to respond to the local PCB exposure concentrations and compositions than the fall-collected fish that may have resided in the river over the summer.

The seasonal trends in PCB congener concentration and composition in the adult striped bass from RM27 are shown in Figures 3-13a and b. The spring sampling date for these fish (April) was earlier than the other spring sampling dates (May/June). The fall

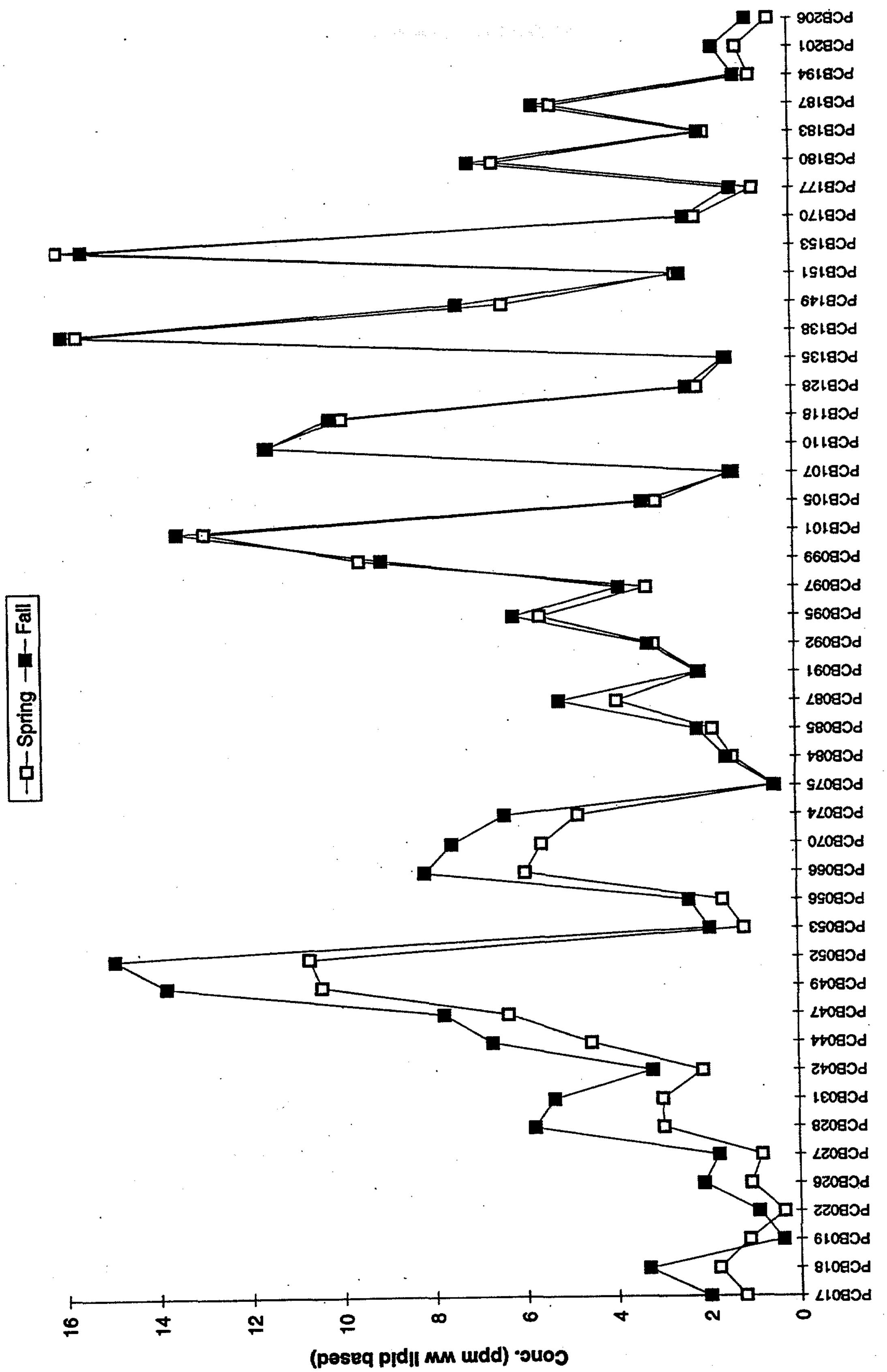

Figure 3-12a. Seasonal differences in PCB concentration - striped bass at River Mile 152

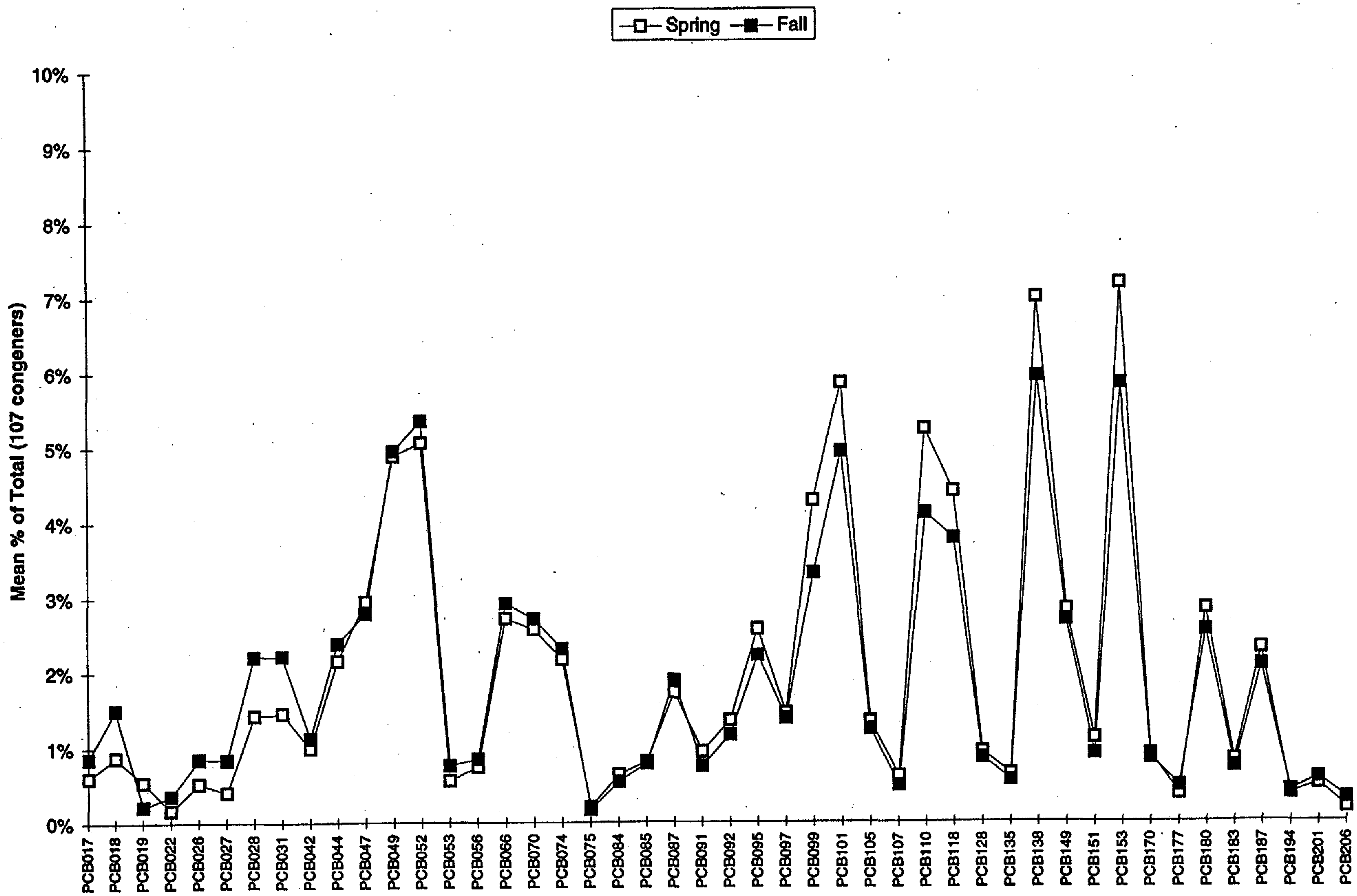

Figure 3-12b. Seasonal differences in PCB composition - striped bass at River Mile 152

321215

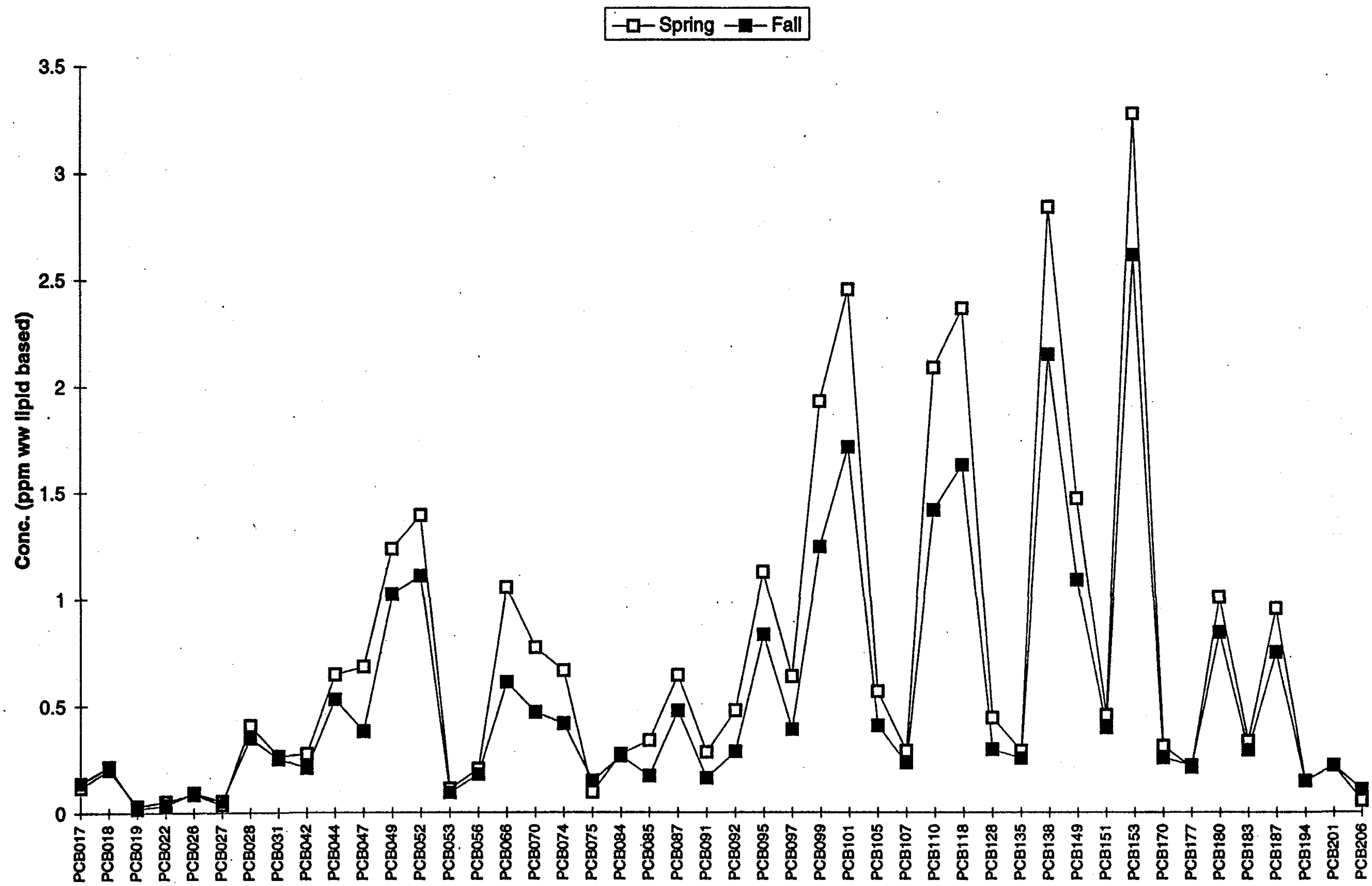

Figure 3-13a. Seasonal differences in PCB concentration - striped bass at River Mile 27

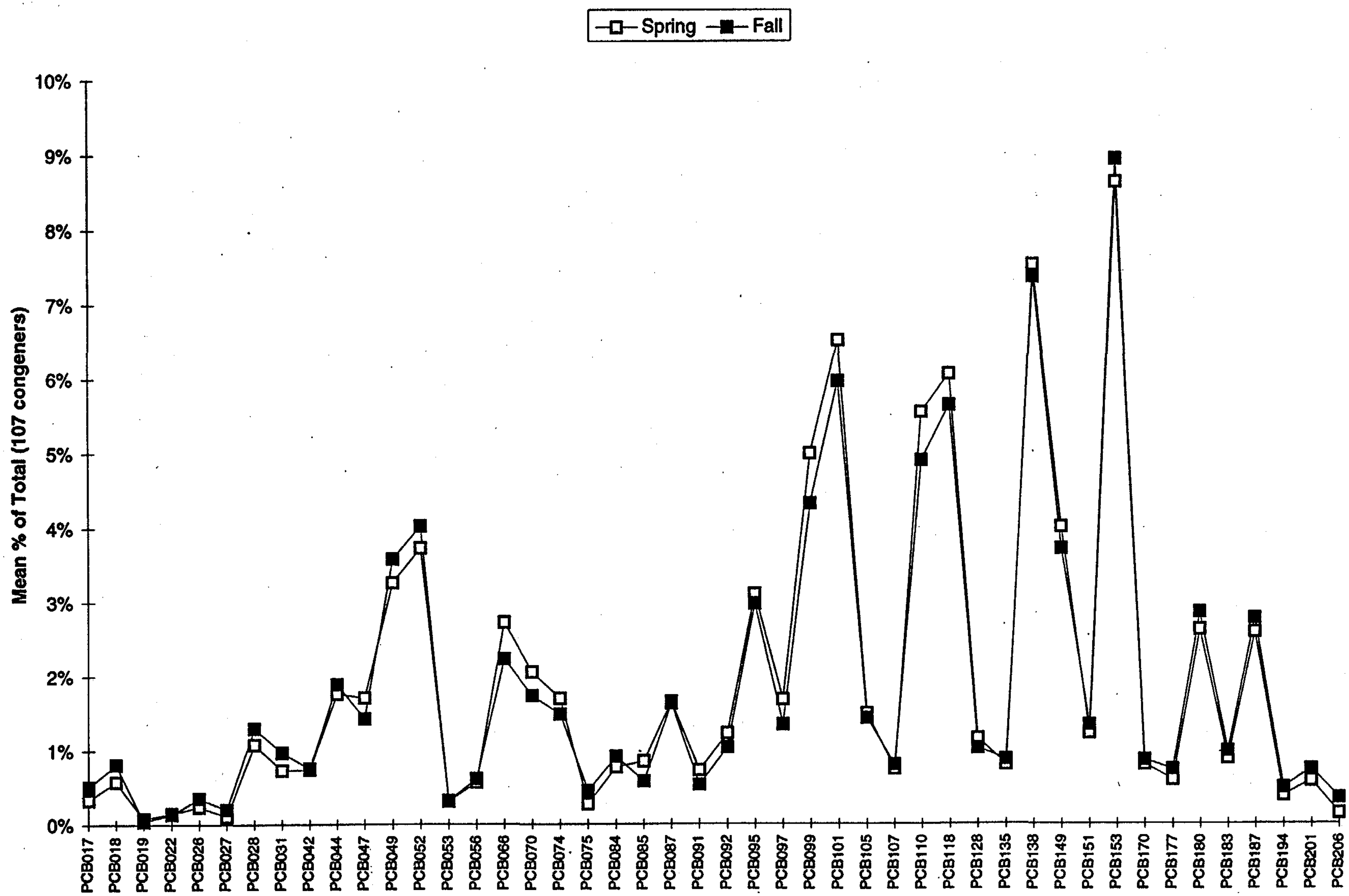

Figure 3-13b. Seasonal differences in PCB composition - striped bass at River Mile 27

sampling date for these fish (November/December) was later in the year than the other fall sampling dates (August/September). The late sampling date at RM27 may have resulted in the collection of striped bass that were overwintering in the river.

Similar to the resident fish, the spring-collected adult striped bass at RM27 had higher congener concentrations than those measured in the fall-collected fish (Figure 3-13a), but the congener composition profiles for the spring-and fall-collected fish were very similar with no evidence of compositional differences between the two groups (Figure 3-13b).

3.3.3.4 Gender Differences in PCB Concentration and Composition in Adult Striped Bass

The only sample groups that could be used to evaluate the influence of gender on the observed PCB concentrations and compositions were the adult striped bass collected at RM115. Five female and five male adult striped bass were collected in the spring at this location. The lipid-based mean congener concentrations in the male striped bass appeared to be higher than those measured in the female striped bass for all of the principal congeners (Figure 3-14a). These differences may reflect, in part, the differences in the average lipid content of these samples (males – 0.80 percent, females – 2.1 percent). When the concentrations were compared on a wet-weight basis, the concentrations measured in the males and females were similar (Figure 3-14b). The congener compositions in the male and female striped bass appeared to be similar (Figure 3-15).

Previous studies have reported higher lipid-based PCB concentrations in male striped bass compared to female striped bass (Sloan and Armstrong 1988). Sloan et al. (1995) reported that the observed gender differences were greater in spring-collected relative to fall-collected fish. In addition, the magnitude of the observed gender difference appeared to be correlated with total PCB concentrations. Striped bass in the upper river had the highest total PCB concentrations and the largest gender differences (Sloan et al. 1995) .

Gender did not appear to be an important factor affecting the congener composition in the striped bass from RM115; therefore, the male and female adult striped bass from RM115 were combined into one sample group in the other analyses of congener composition. However, all concentration comparisons were based on the concentrations measured only in the male striped bass because only males were collected at other locations, the largemouth bass were all male, and the genders of white perch and yellow perch were not determined.

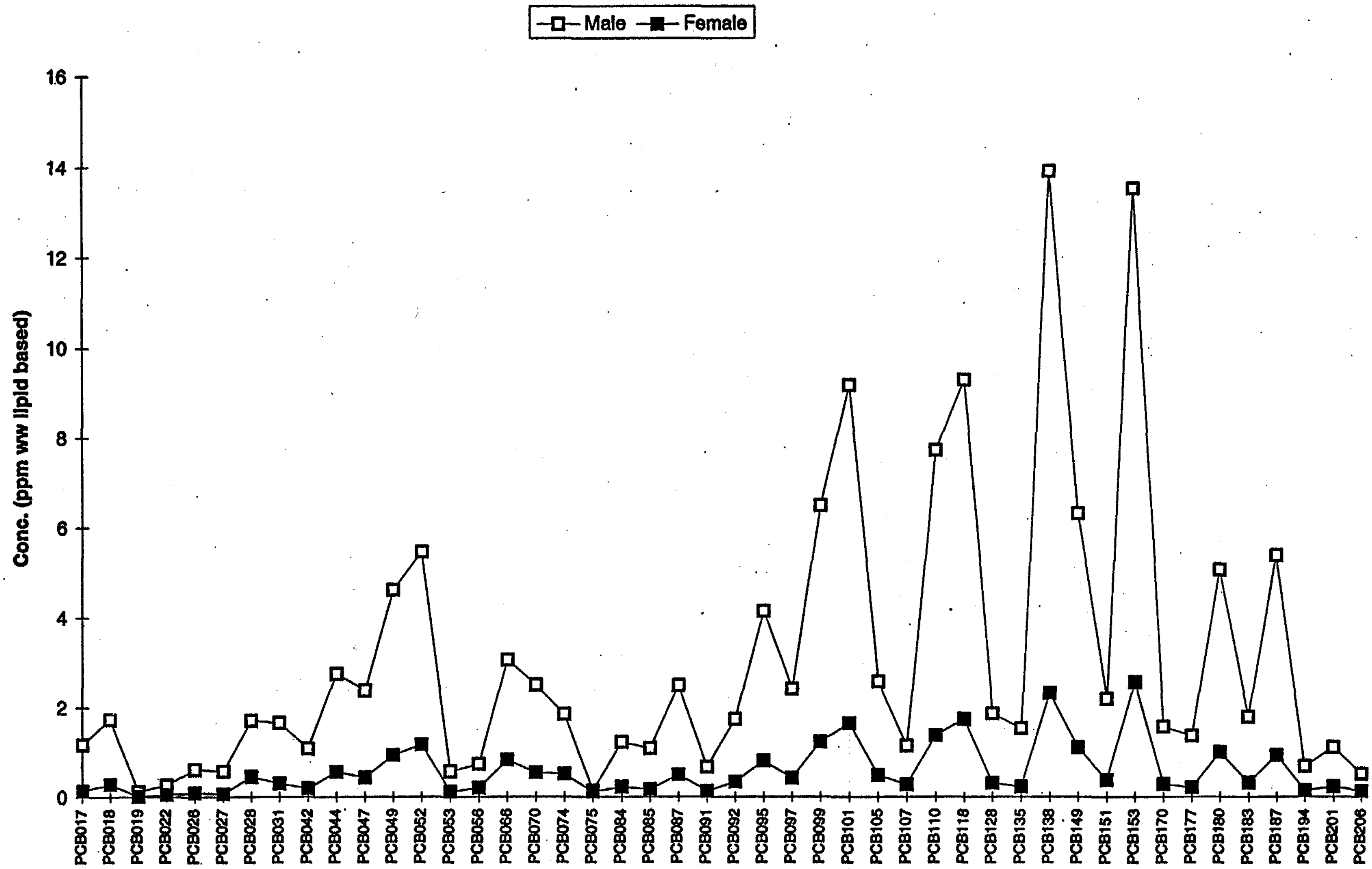

Figure 3-14a. Gender differences in PCB concentration (lipid-based) - striped bass at River Mile 115

321219

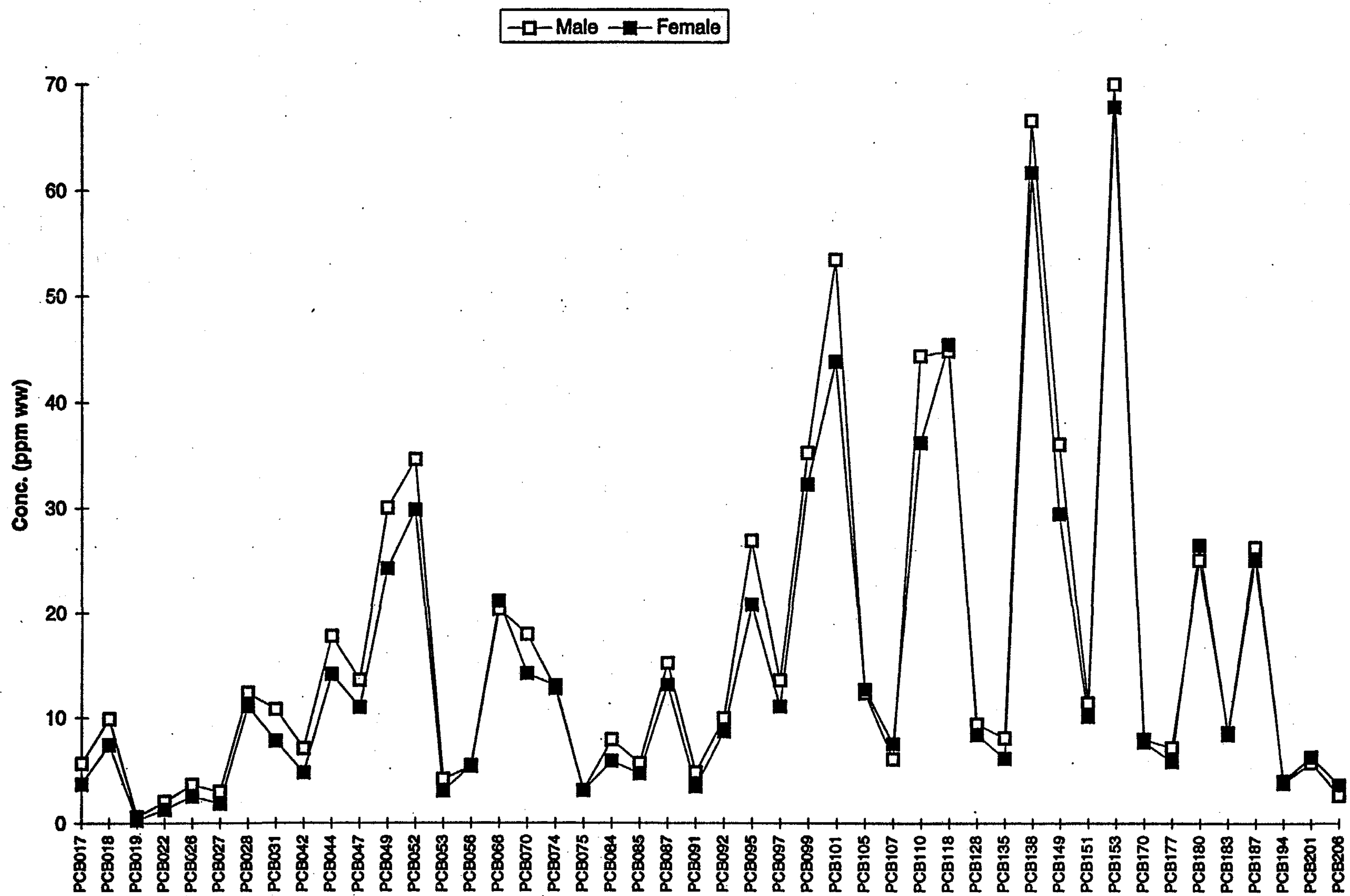

Figure3-14b. Gender differences in PCB concentration (wet weight) - striped bass at River Mile 115

321220

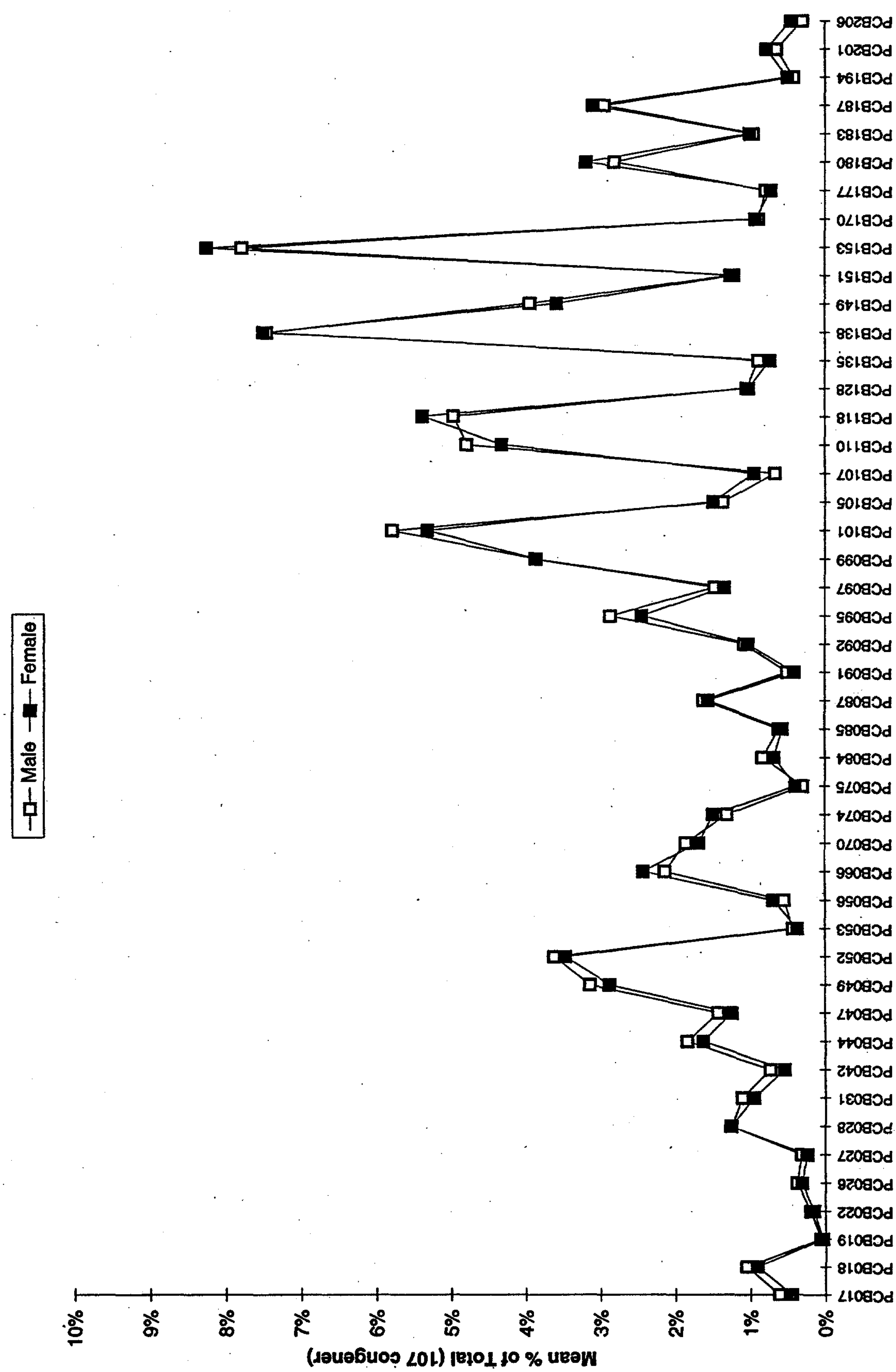

Figure 3-15. Gender differences in PCB composition - striped bass at River Mile 115

321221

3.3.4 Comparison of 1993 and 1995 Congener Concentration and Composition

3.3.4.1 Section Overview

Two resident species, yellow perch and white perch, were collected in 1993 and 1995. A comparison of the congener concentrations and composition measured in these species at similar locations, based on the subset of 40 congeners identified as principal congeners in both 1993 and 1995, indicates that there may have been some decreases in PCB congener concentrations between the 1993 and 1995 fish, particularly in the samples from the upper river. In the lower river samples, the differences among years was never large, and often appeared to be consistent with the observed seasonal changes discussed above in the data from 1995. Compositional changes were also observed that corresponded to changes in the congener concentrations, but the differences among samples and among years were small. The data available for this comparison were limited and the comparisons were not tested statistically.

3.3.4.2 Yellow Perch

Yellow perch were collected from three common locations in 1993 and 1995. In the upper river, perch were collected at RM190 and RM170 in 1993 and at RM190 and RM175 in 1995. In the lower river, fish were collected at RM 144, RM122, and RM89 in 1993 and at RM152 and RM115 in 1995. The congener concentration and composition profiles from yellow perch collected from the nearest locations in 1993 and 1995 are compared in the following sections. In addition to some differences in collection locations, also note that the fish from 1993 were collected in the fall, while many of the 1995 fish were collected in the spring. Finally, the results are compared on the basis of the 40 congeners that were identified as principal congeners in the data from both years (Table 3-1), and none of the differences have yet been tested statistically.

RM170, RM175, and RM190 — The mean principal congener concentrations observed in the yellow perch collected in the fall of 1993 from RM170 and RM190 are compared to the similar data collected in the spring of 1995 from RM175 and RM190 in Figure 3-16a. The congener concentrations measured in 1995 appeared lower than those measured in 1993 when data from corresponding sampling locations were compared, i.e., RM190:RM190 and RM170:RM175. This temporal difference is consistent with the results reported by Sloan and Field (1996), who reported PCB concentrations in fish in the upper river monitored by NYSDEC that increased substantially from 1992 through 1993, then decreased back to pre-1991 concentrations by 1995. The increase was associated with a documented release of several tons of PCBs into the river from an old abandoned mill structure located near RM198 in 1991 (Sloan and Field 1996). The

321222

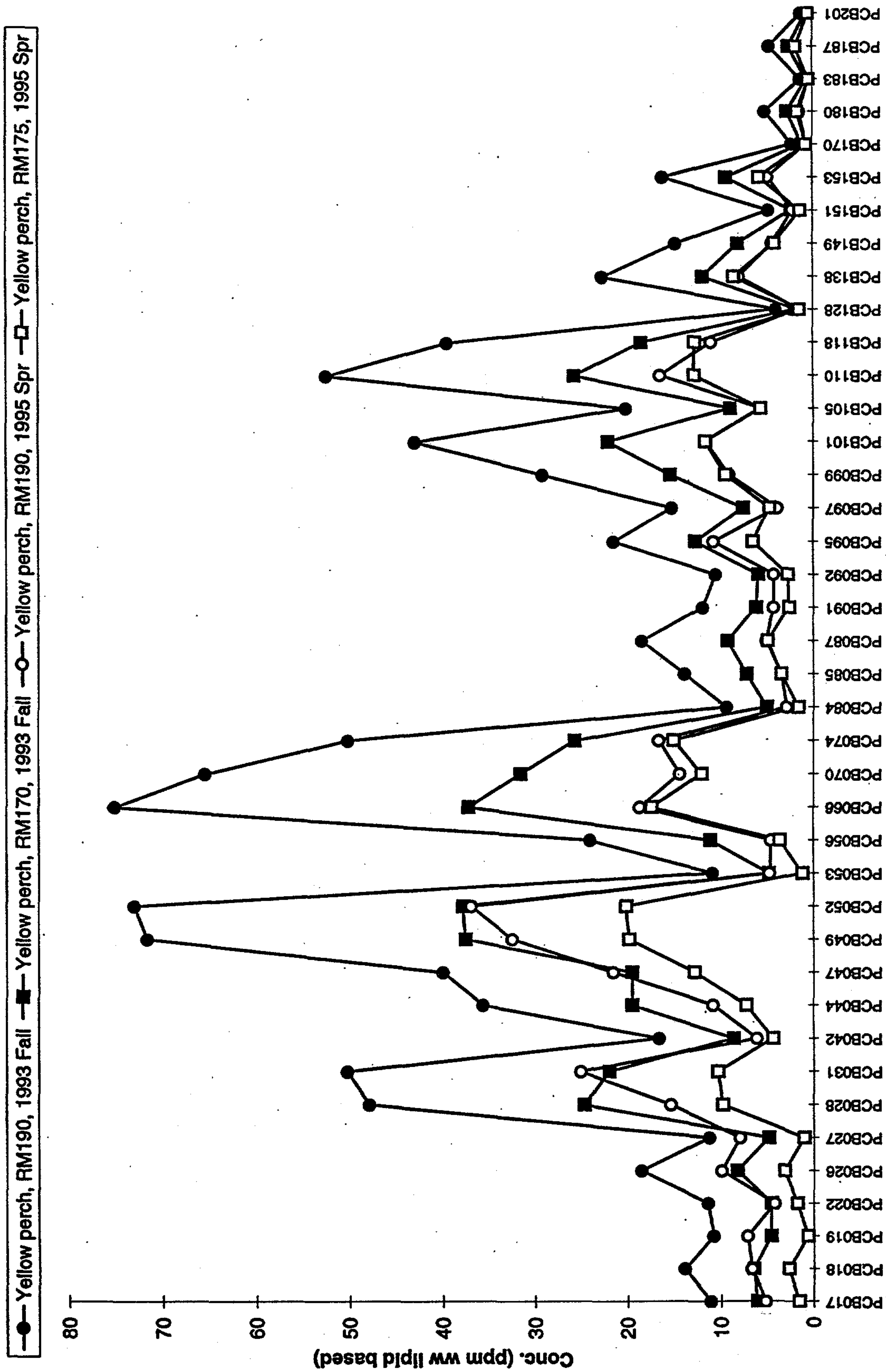

Figure 3-16a. PCB concentration profiles for yellow perch (RM190, RM175, RM170): 1993 vs. 1995

congener composition profiles are compared in Figure 3-16b. There appeared to be very few differences among the congener compositions measured in the 1993 and 1995 samples.

RM144 and RM152 — The congener concentration profiles for yellow perch collected from RM144 in 1993 were compared to those from fish collected at RM152 in 1995 (Figure 3-17a). The concentrations of the lower-chlorinated tri- and tetrachlorobiphenyl congeners PCB26, PCB28, PCB31, PCB44, PCB47, PCB49, PCB52, PCB66, PCB70, and PCB74 were apparently higher in the 1993 samples than in the 1995 samples, particularly when comparable seasons were compared, even though the samples were collected slightly farther downstream in the lower river. The concentrations of penta- and hexachlorobiphenyl congeners were similar for the fall-collected 1993 fish and the spring-collected 1995 fish. The congener concentrations measured in 1993 fall-collected yellow perch were higher than those in the 1995 fall-collected fish for the entire suite of principal congeners.

In general, the congener composition profiles showed differences that were similar to the seasonal differences discussed above, rather than clear differences between 1993 and 1995 (Figure 3-17b). The fall-collected yellow perch from 1993 and 1995 had similar compositions, with higher contributions from the lower-chlorinated congeners PCB28, PCB31, PCB44, PCB49, and PCB52 relative to the 1995 spring-collected yellow perch. The only apparent compositional difference between 1993 and 1995 which could be inferred from these data was in the percent composition calculated for PCB66, PCB70, and PCB74. The yellow perch collected in 1993 had higher percent contributions from these congeners than the 1995 yellow perch.

RM89, RM115, and RM122 — The congener concentrations measured in fish collected in the fall of 1993 at RM89 and RM122 are compared to those from fish collected in the spring of 1995 from RM115 (Figure 3-18a). In general, higher congener concentrations were observed in the 1995 spring-collected yellow perch from RM115. Concentrations of the principal trichlorobiphenyl congeners between PCB17 to PCB31 were highest in the 1993 fall-collected yellow perch from RM122. The largest differences in concentration were seen for the penta- and heptachlorobiphenyl congeners PCB110, PCB138, and PCB153. The differences observed in these fish samples were similar in magnitude to the differences observed between fall- and spring-collected yellow perch from RM152 in 1995 (Figure 3-10a).

The corresponding congener composition profiles also showed some evidence of seasonal differences, with higher contributions from the lower-chlorinated tri- and tetrachlorobiphenyls in the fall samples compared to the spring samples (Figure 3-18b).

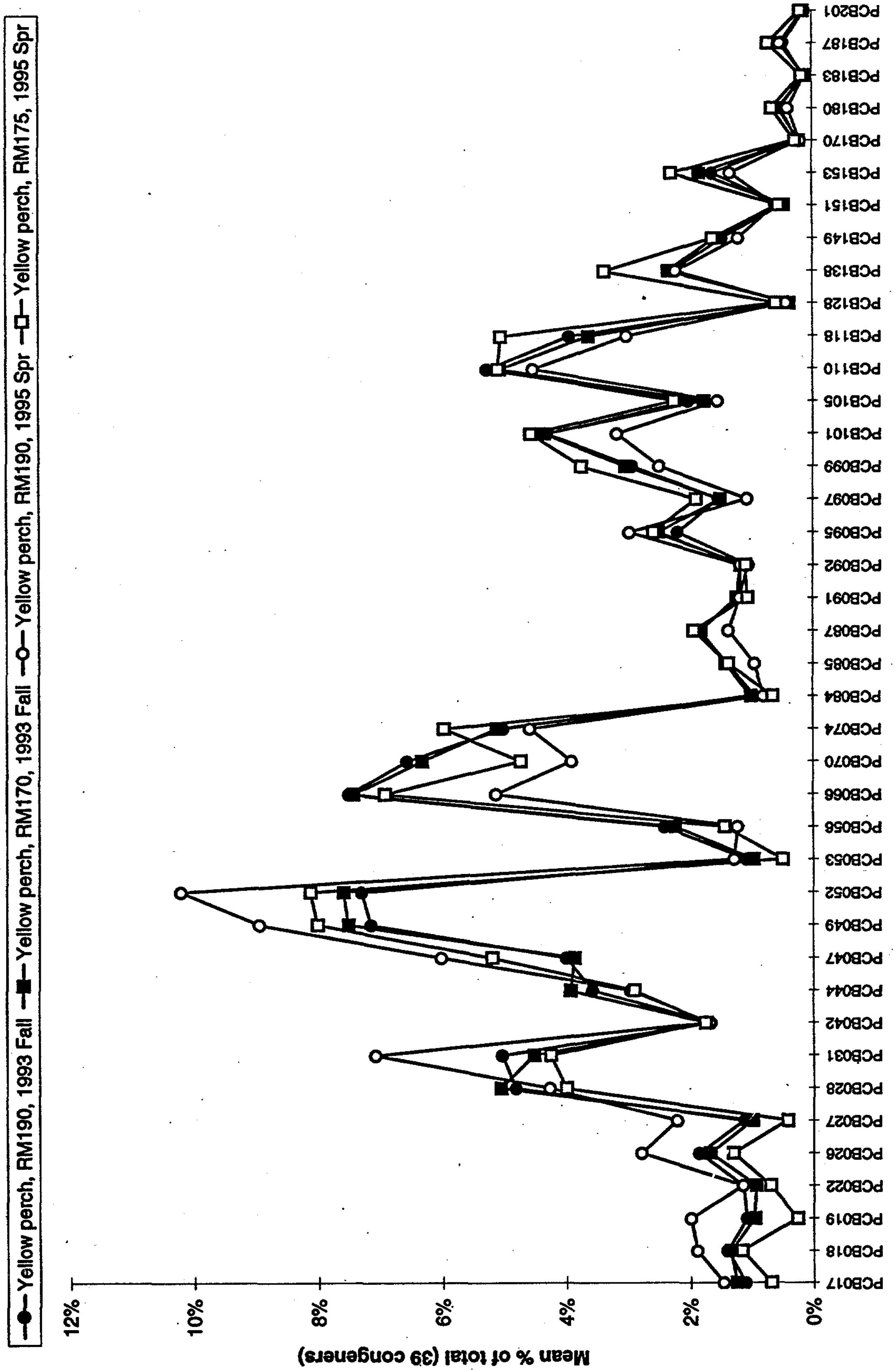

Figure 3-16b. PCB composition profiles for yellow perch (RM190, RM175, RM170): 1993 vs. 1995

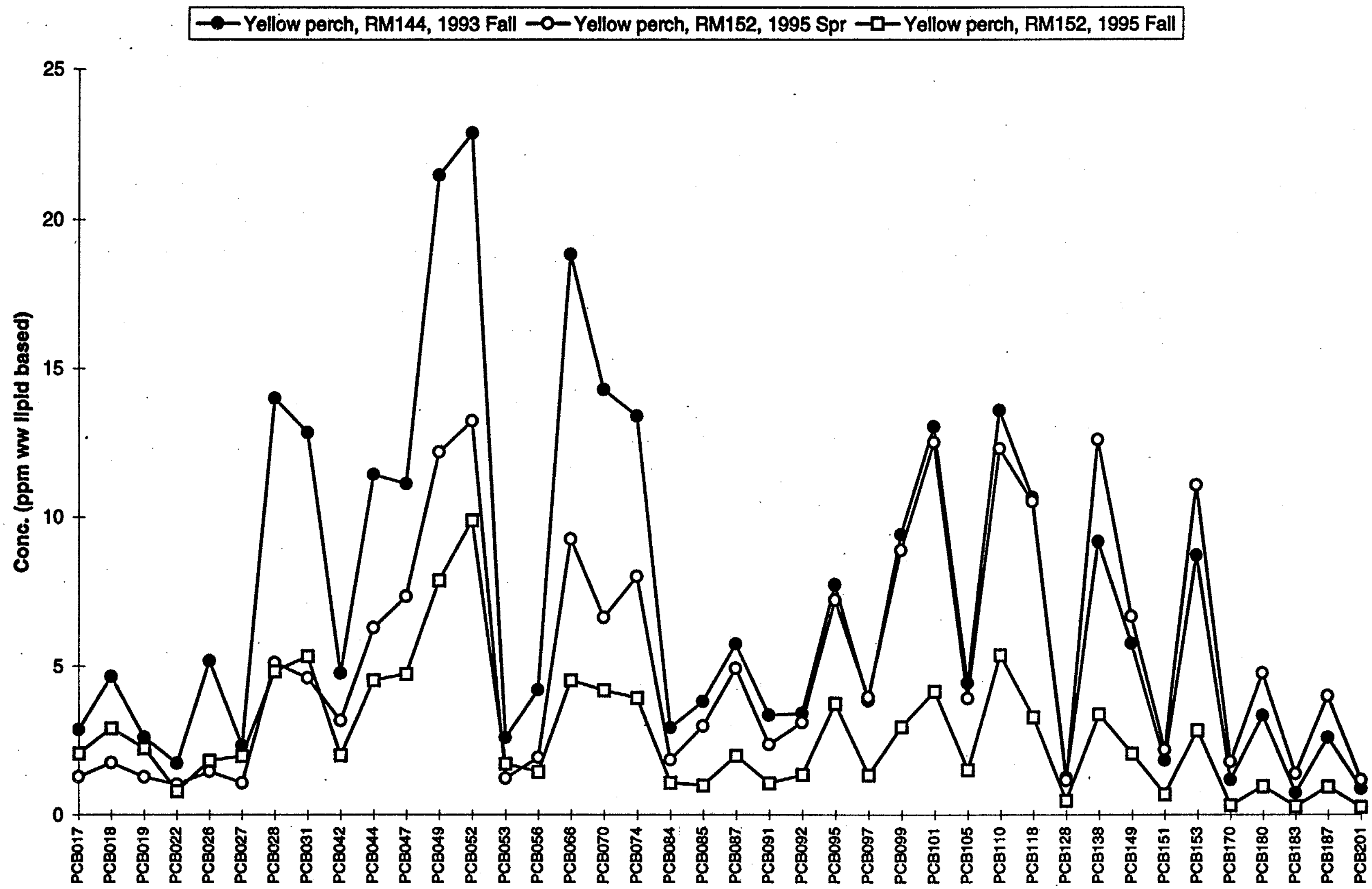

Figure 3-17a. PCB concentration profiles for yellow perch (RM152, RM144): 1993 vs. 1995

321226

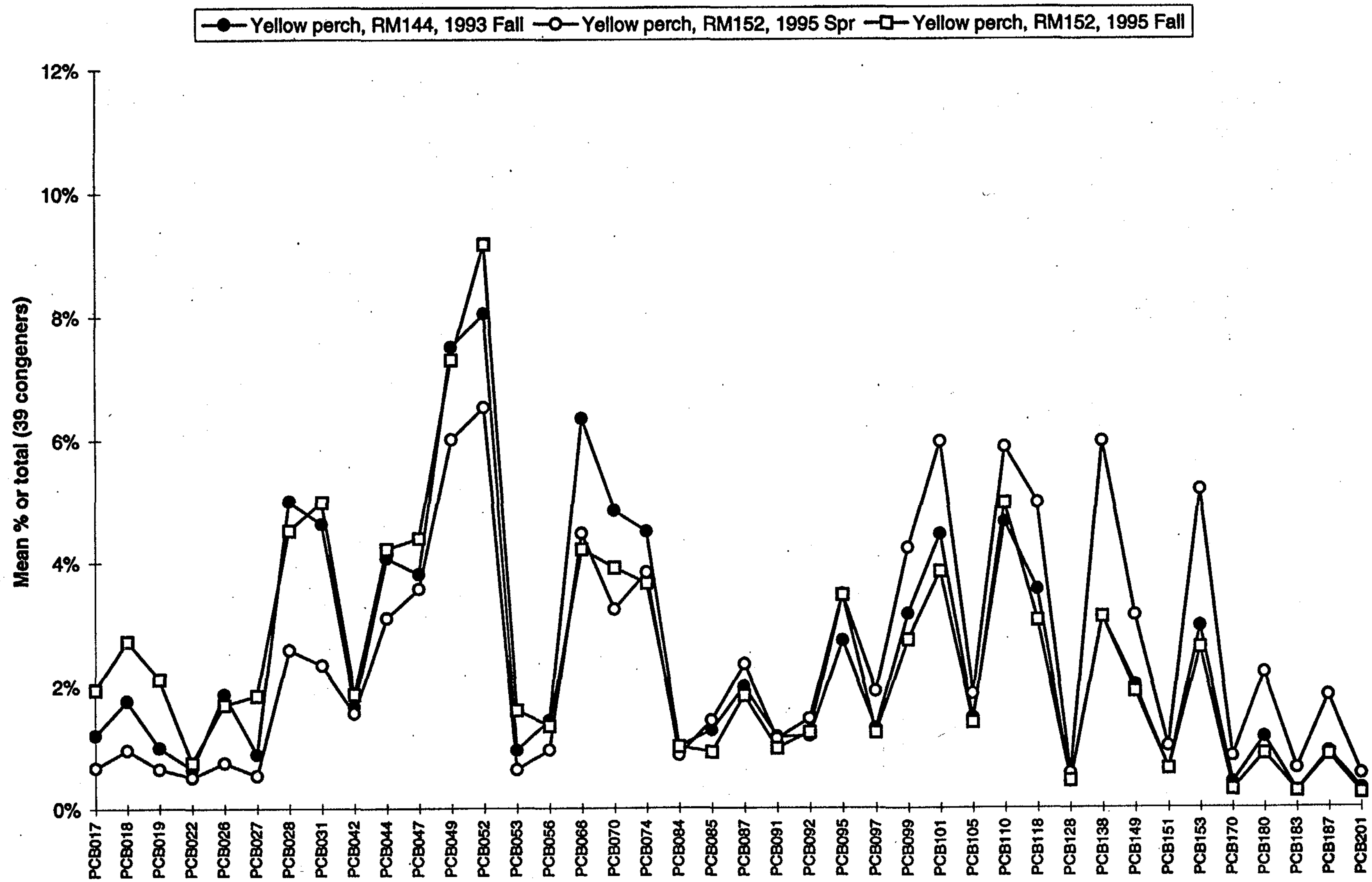

Figure 3-17b. PCB composition profiles for yellow perch (RM152, RM144): 1993 vs. 1995

321227

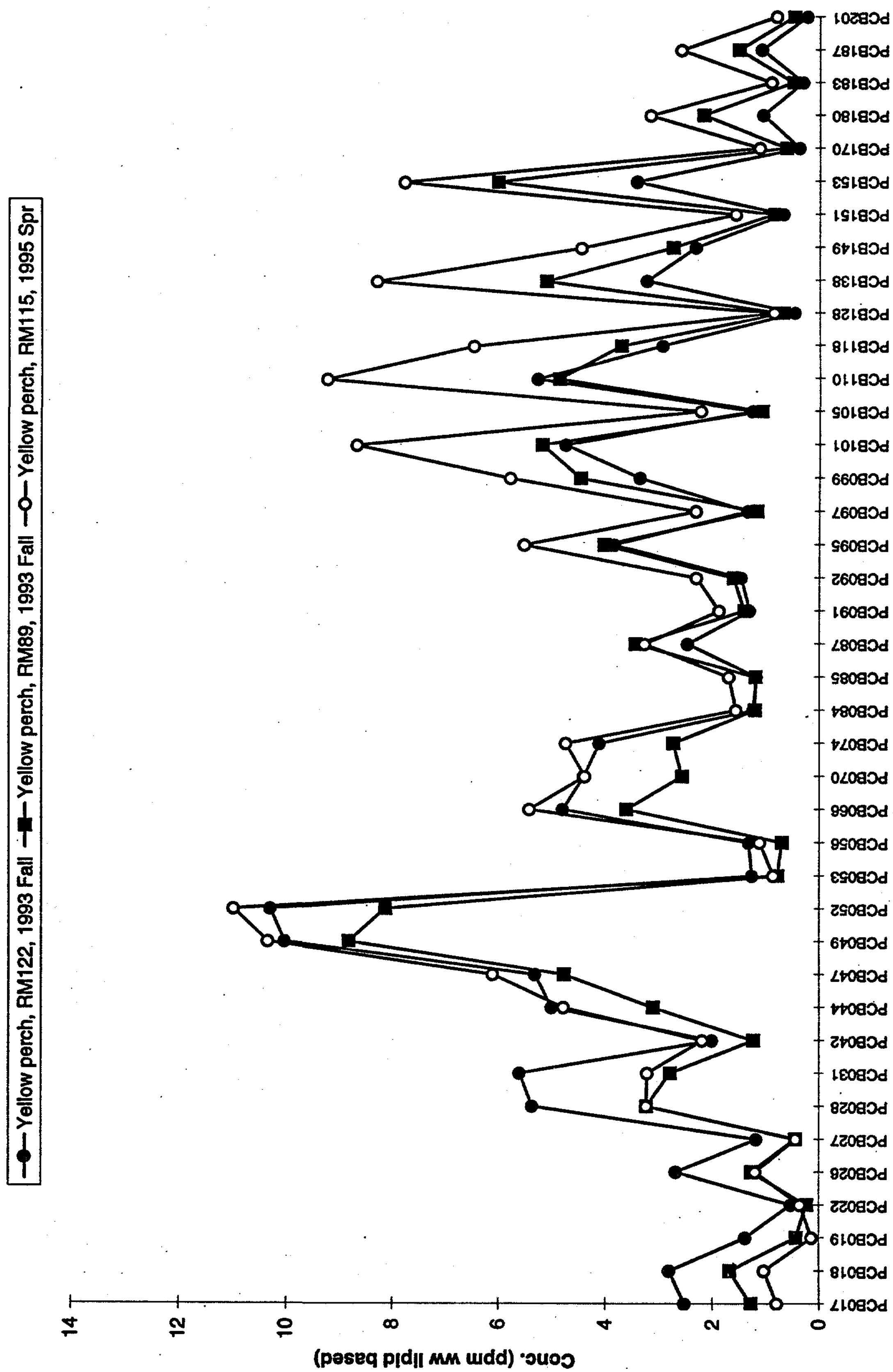

Figure 3-18a. PCB concentration profiles for yellow perch (RM122, RM115, RM 89): 1993 vs. 1995

321228

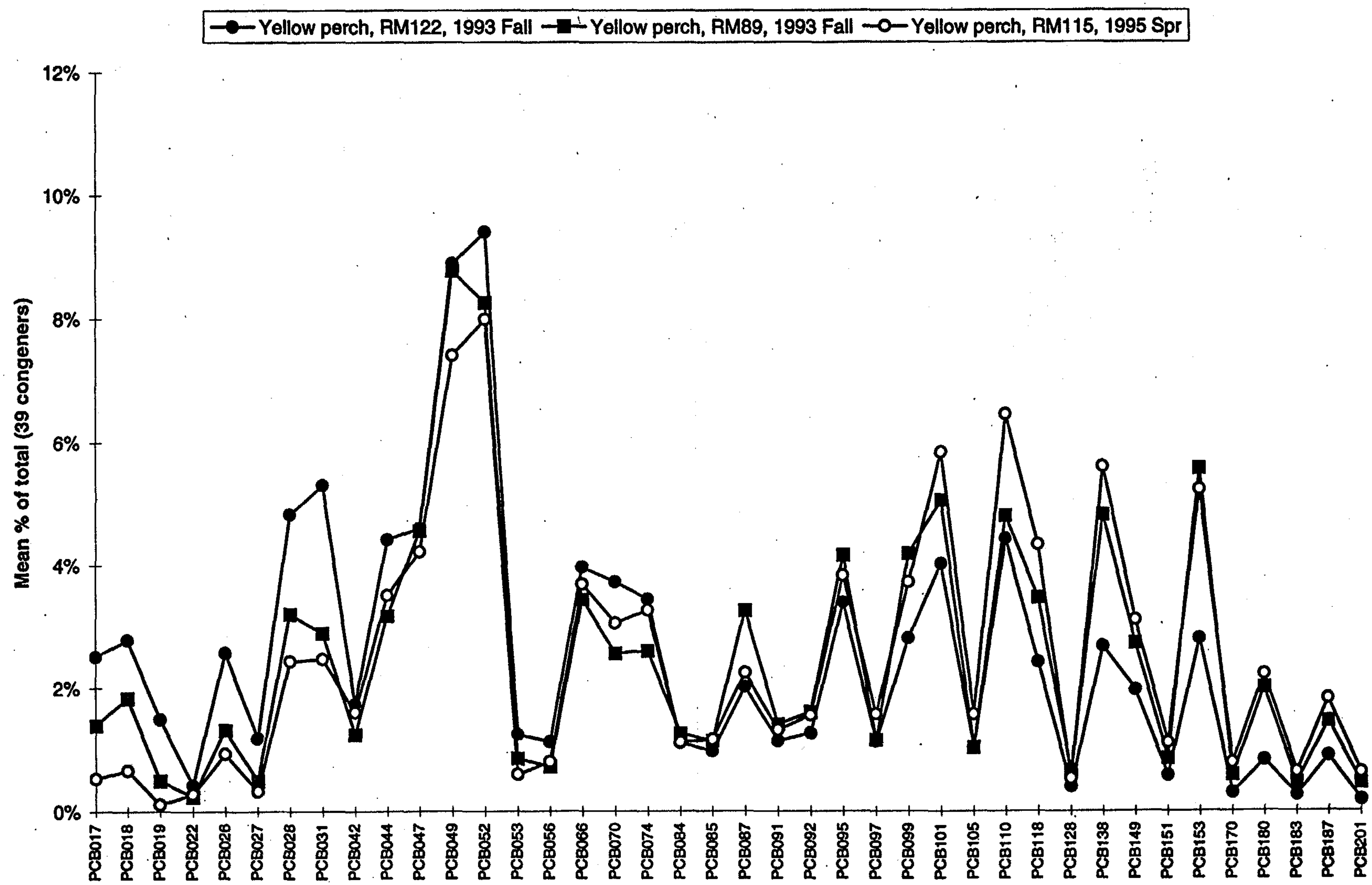

Figure 3-18b. PCB composition profiles for yellow perch (RM122, RM115, RM89): 1993 vs. 1995

321229

3.3.4.3 White Perch

White perch were also collected from common locations in both 1993 and 1995. The data from these collections are compared below in the same way that the yellow perch data were compared.

RM144 and RM152 — The congener concentration profiles for white perch collected from the Albany-Troy area in 1993 and 1995 are compared in Figure 3-19a. The white perch collected from RM144 in the fall of 1993 and from RM152 in the fall of 1995 had similar congener concentrations. The spring-collected white perch from 1995 (RM152) tended to have slightly lower concentrations of the lower-chlorinated tri- and tetrachlorobiphenyl congeners and higher concentrations of the higher-chlorinated congeners PCB99, PCB110, PCB138, PCB153, PCB180, and PCB187 than the fall-collected 1993 and 1995 white perch. Seasonal differences in congener concentrations at this location appeared to be greater than the differences between sampling years. The congener composition profiles reflect the seasonal differences observed in the concentration profiles (Figure 3-19b).

RM114 and RM115 — Congener concentrations measured in white perch collected in the fall of 1993 from RM114 were compared to those from white perch collected in the spring of 1995 at RM115 (Figure 3-20a). Higher congener concentrations were seen in the fall-collected 1993 samples, with the greatest differences seen for the tri- and tetrachlorinated congeners. The congener composition profiles for the 1993 and 1995 samples were similar (Figure 3-20b).

RM59 — The white perch collected at RM59 in 1993 and 1995 were collected in the fall. The congener concentration profiles for these two groups are plotted in Figure 3-21a. Higher congener concentrations were measured in the 1995 samples than the 1993 samples. The compositional profiles reflect the relatively larger contribution from PCB110, PCB115, PCB138, PCB153, PCB180, and PCB187 in 1995 relative to 1993 (Figure 3-21b). In addition to the temporal differences between the 1993 and 1995 collections, there was a difference in sampling locations. The 1993 white perch were collected from the west side of the river and the 1995 white perch were collected from the east side of the river.

RM26 and RM27 — The congener concentrations measured at RM26 and RM27 in both 1993 and 1995 were low relative to the concentrations in fish collected from upriver stations, and both the congener concentration and composition profiles for fall-collected samples of white perch collected in 1993 and 1995 appear to be similar (Figures 3-22a and b).

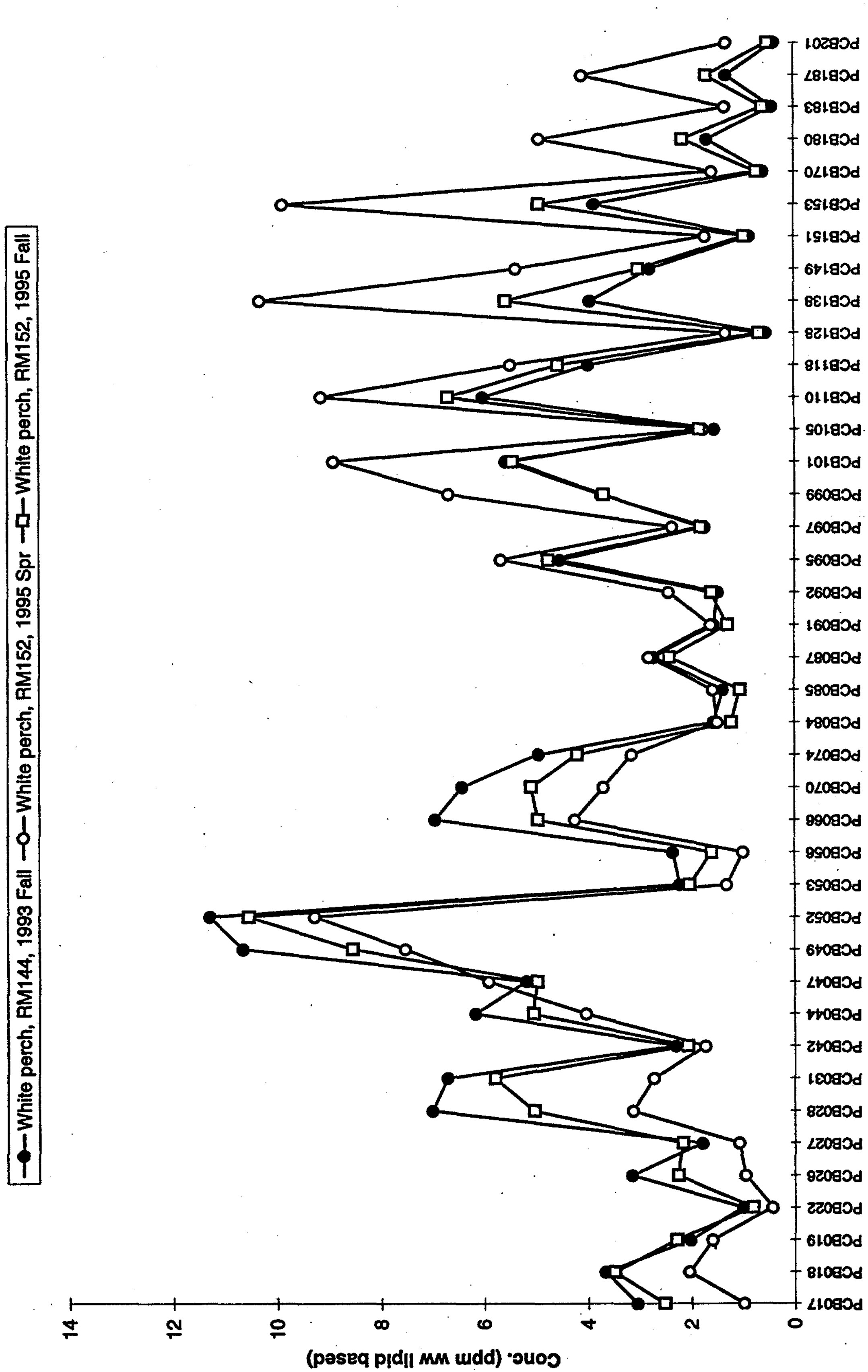

Figure 3-19a. PCB concentration profiles for white perch (RM152, RM144): 1993 vs. 1995

321231

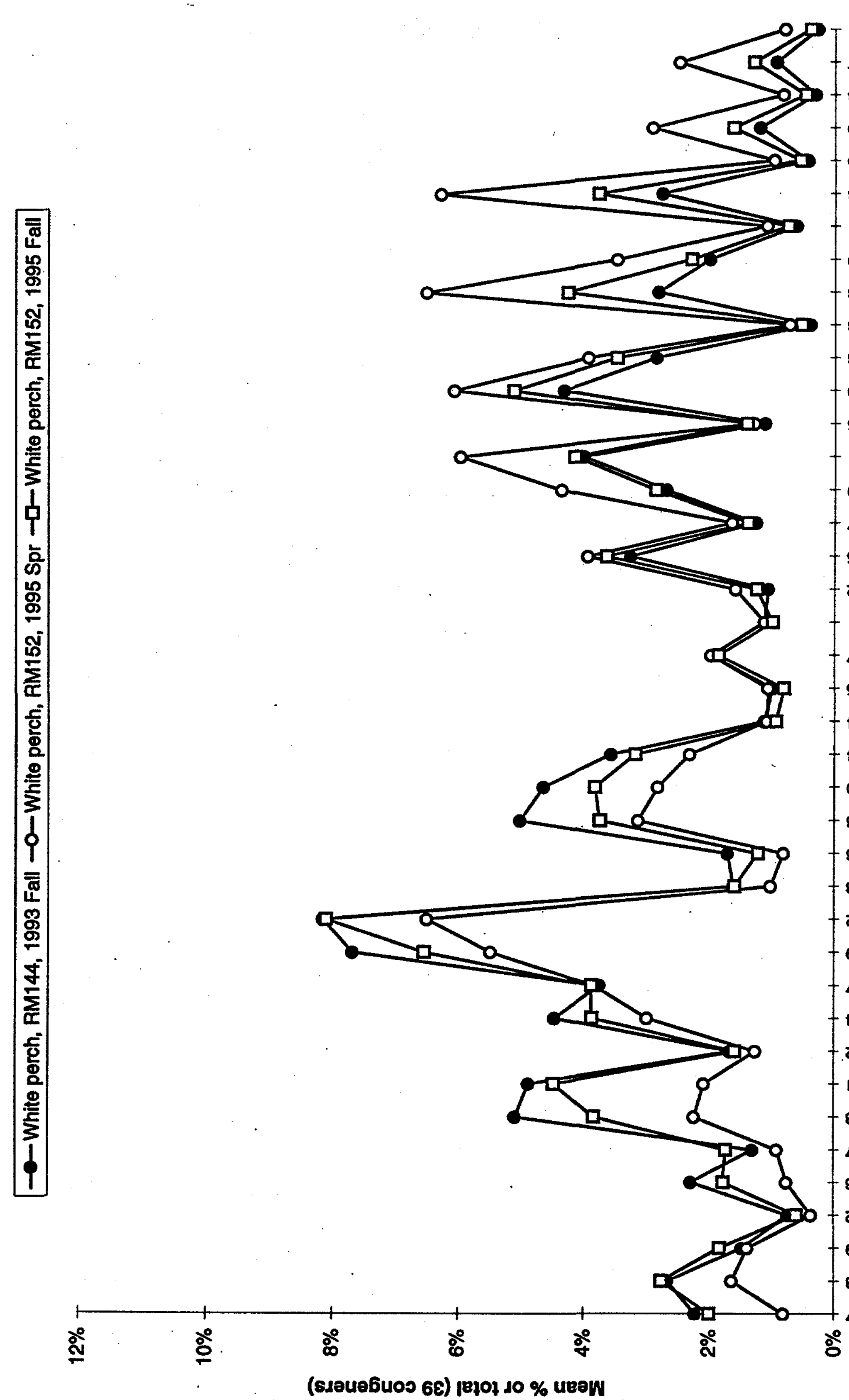

Figure 3-19b. PCB composition profiles for white perch (RM152, RM144): 1993 vs. 1995

321232

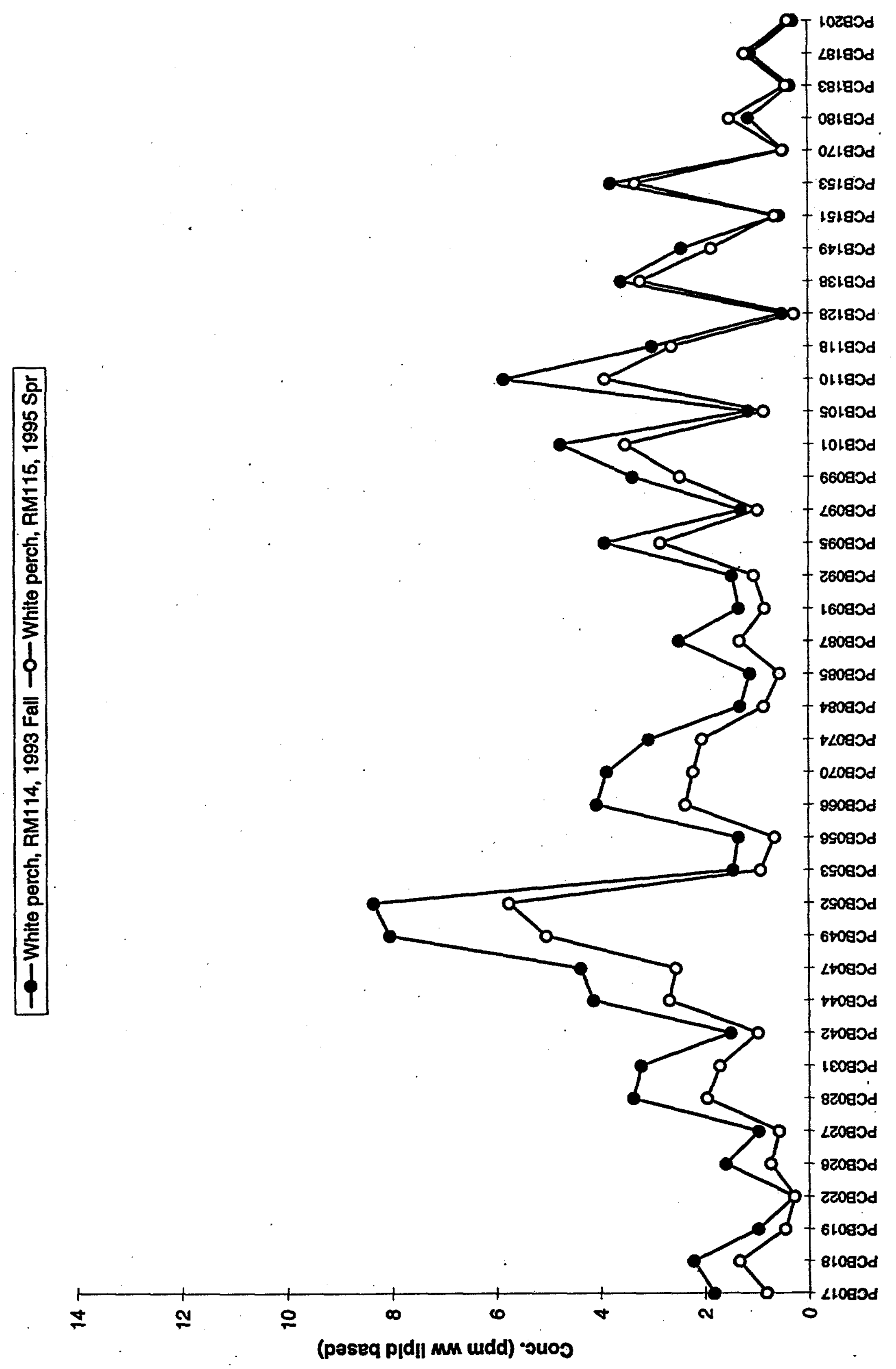

Figure 3-20a. PCB concentration profiles for white perch (RM115, RM114): 1993 vs. 1995

321233

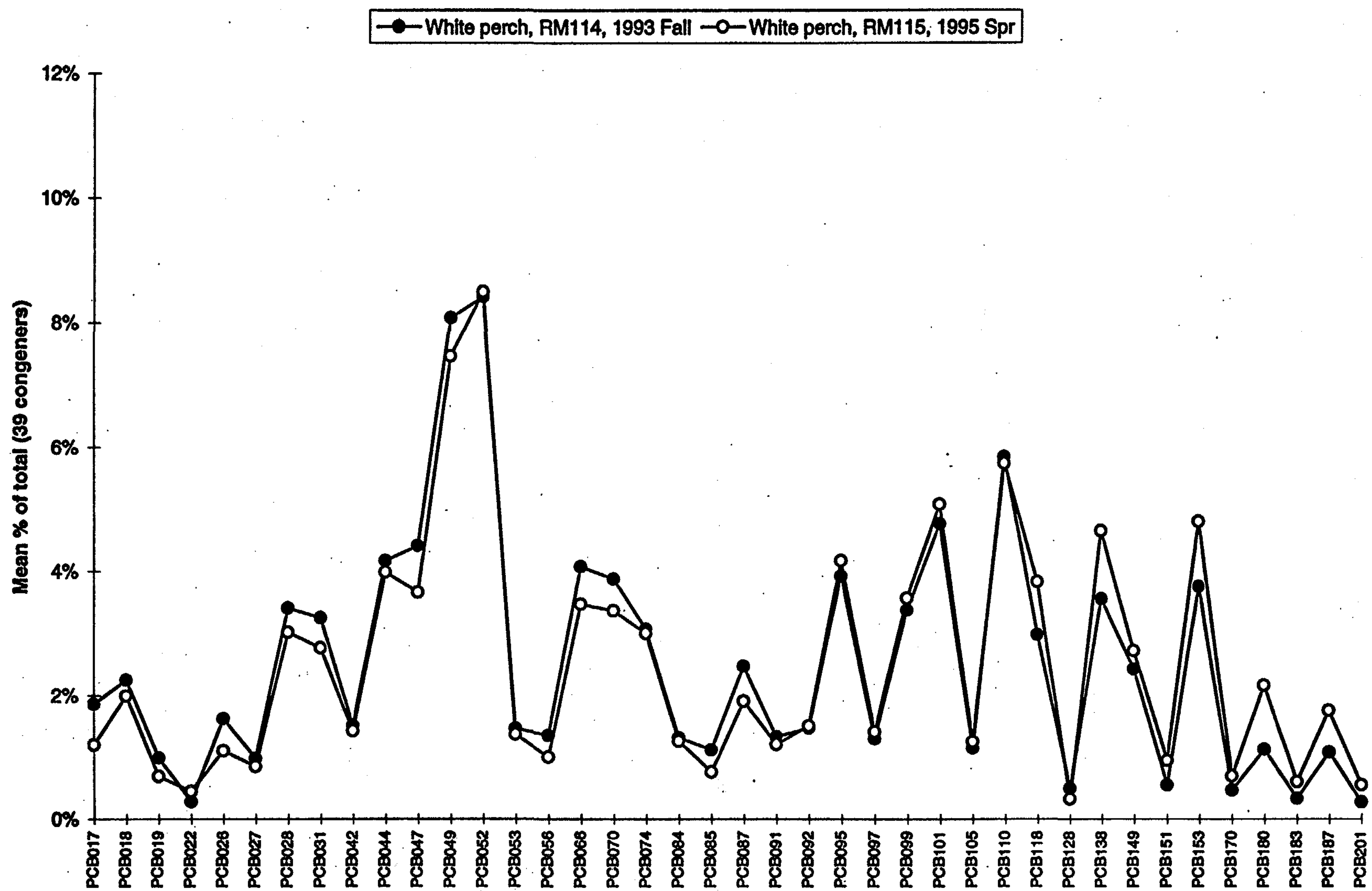

Figure 3-20b. PCB composition profiles for white perch (RM115, RM114): 1993 vs. 1995

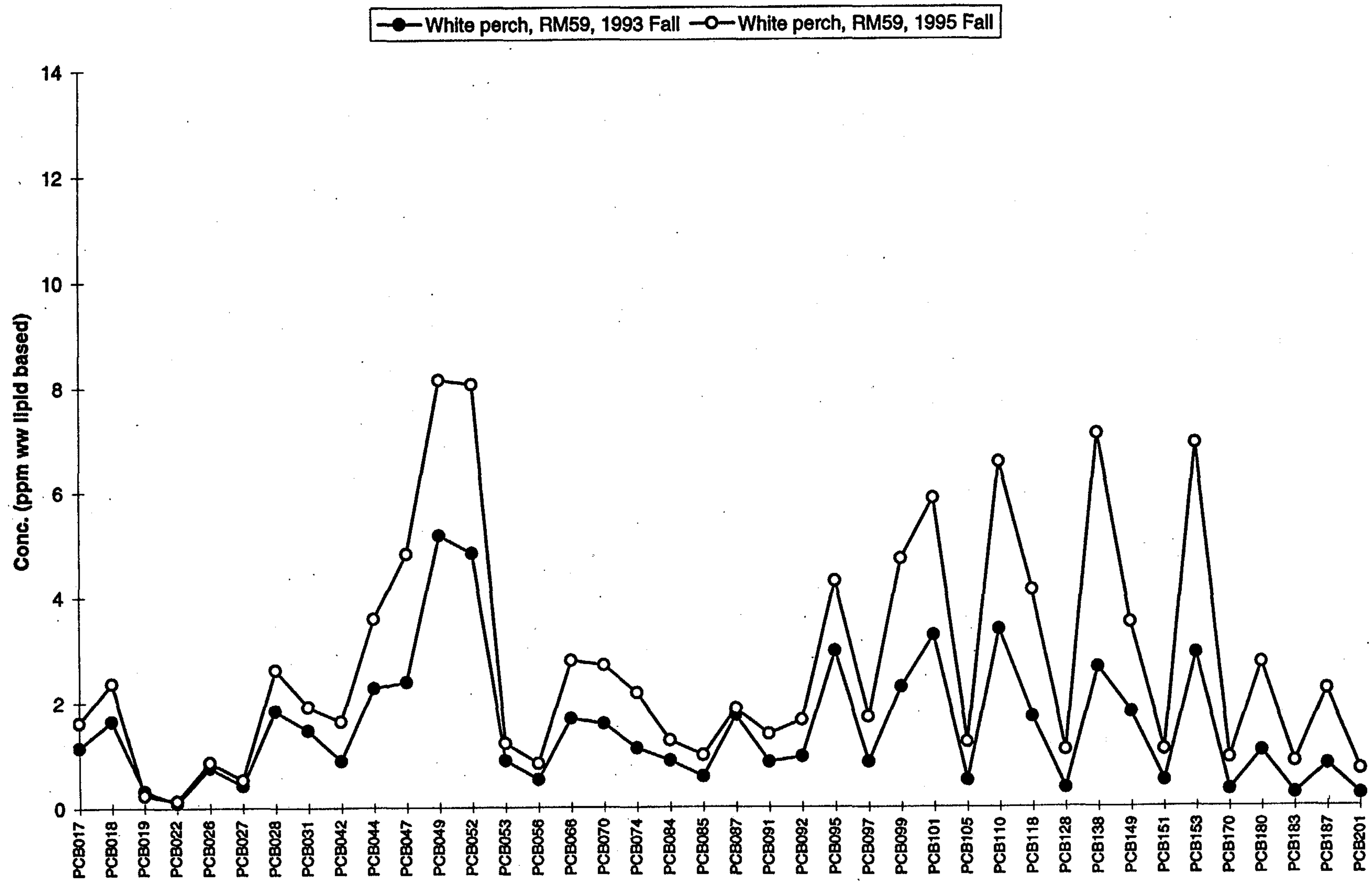

Figure 3-21a. PCB concentration profiles for white perch (RM59): 1993 vs. 1995

321235

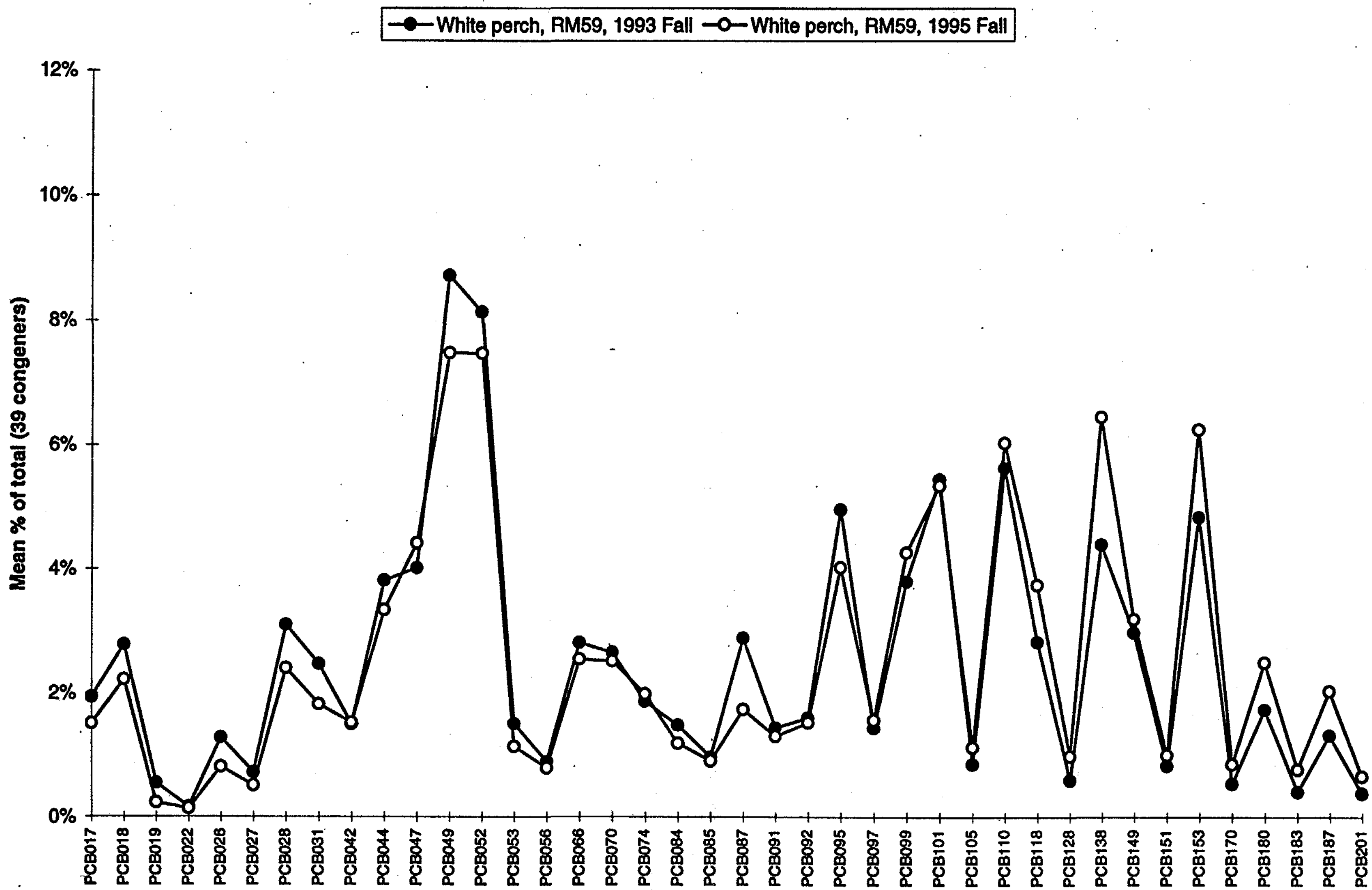

Figure 3-21b. PCB composition profiles for white perch (RM59): 1993 vs. 1995

321236

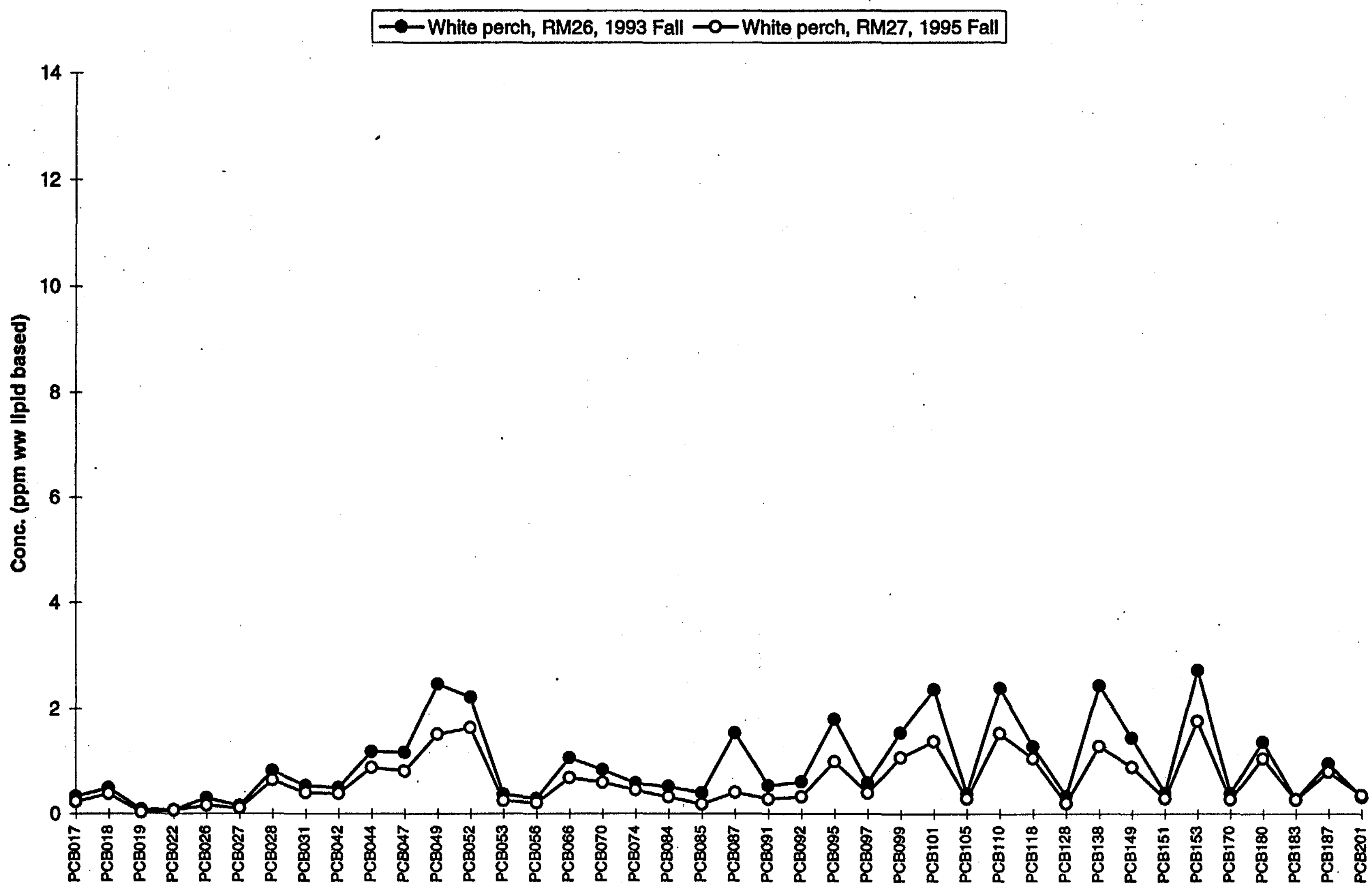

Figure 3-22a. PCB concentration profiles for white perch (RM27, RM26): 1993 vs. 1995

321237

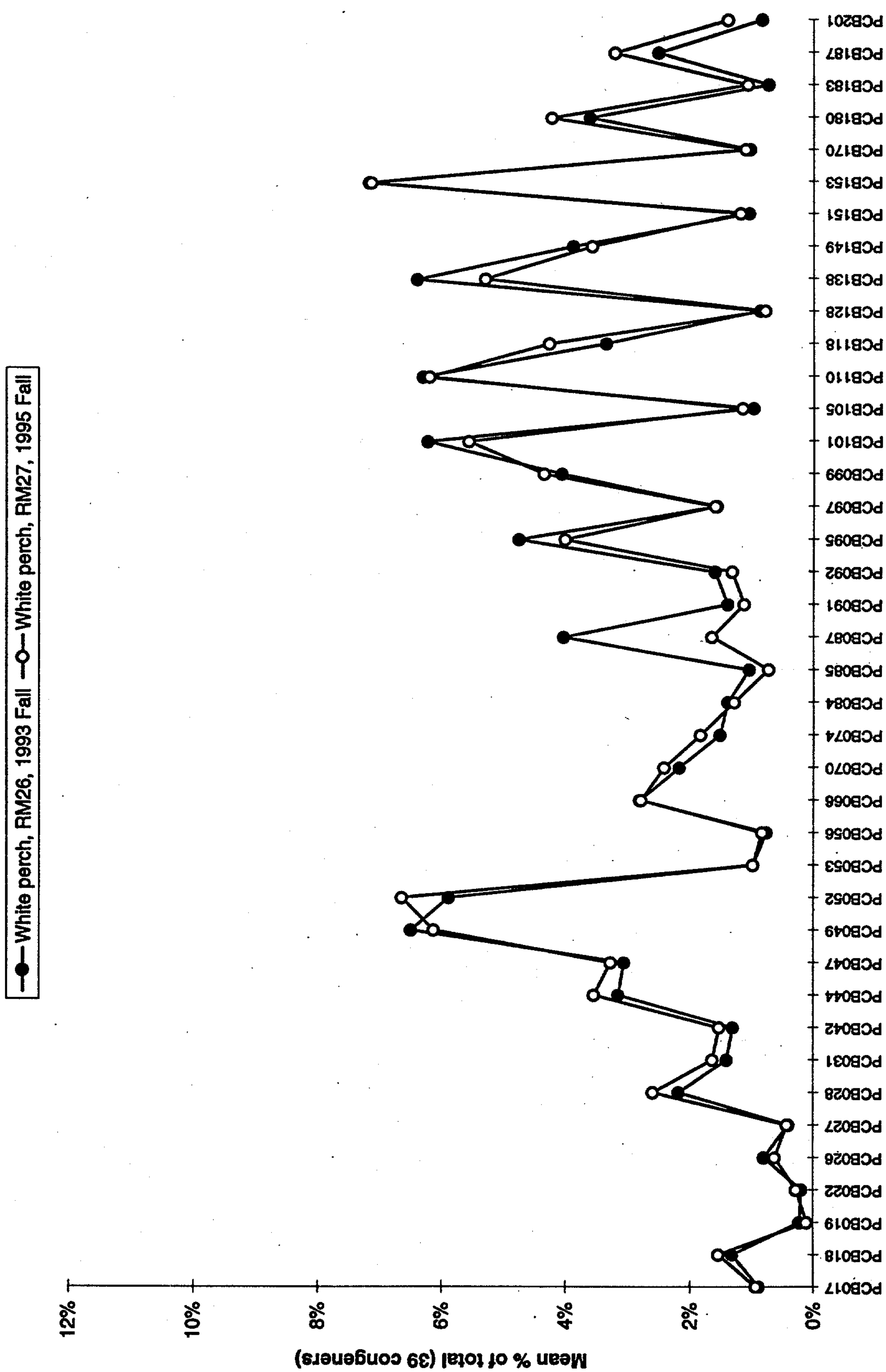

Figure 3-22b. PCB composition profiles for white perch (RM27, RM26): 1993 vs. 1995

321238

3.3.5 Comparison of PCB Composition and Concentration within Sampling Locations

Resident fish were collected at every sampling location from RM27 to RM190. However, no one species was collected at all locations. Yellow perch and largemouth bass were collected above the Federal Dam at RM175 and RM190. White perch and juvenile striped bass were collected in the lowest sections of the river at RM27 and RM59. All resident species were collected at RM152, and all resident species except the juvenile striped bass were collected at RM115. These data were used to determine whether there were differences in PCB compositions in different resident species collected at the same location.

This test was important because one of our initial hypotheses stated that the PCB content in the resident fish would reflect ambient concentrations at the location where they were sampled, and hence could be used to predict the exposure experienced by other fish at the same location. The strength of that predictability depends on our ability to demonstrate either that all fish respond in a similar fashion to the exposure, or that the differences were constant.

The comparisons of the mean congener compositions and concentrations for species collected at the same river mile locations are discussed below.

3.3.5.1 RM190

Two resident fish species — yellow perch and largemouth bass — were collected at RM190.

The lipid-based congener concentrations measured in largemouth bass were much higher than yellow perch concentrations (Figure 3-23a). These differences were driven in part by the low lipid content reported for the largemouth bass samples (average lipid = 0.86 percent) compared to the lipid content of the yellow perch (average lipid = 3.18 percent).

The PCB congener compositions for these fish are compared in Figure 3-23b. The PCBs in both species had major contributions from the lower-chlorinated congeners, but the relative contributions of different congeners were markedly different. The maximum between-group Euclidean distance calculated between yellow perch and largemouth bass at RM190 was 0.124, reflecting the substantial differences in the compositions of the PCBs in these two species at this location.

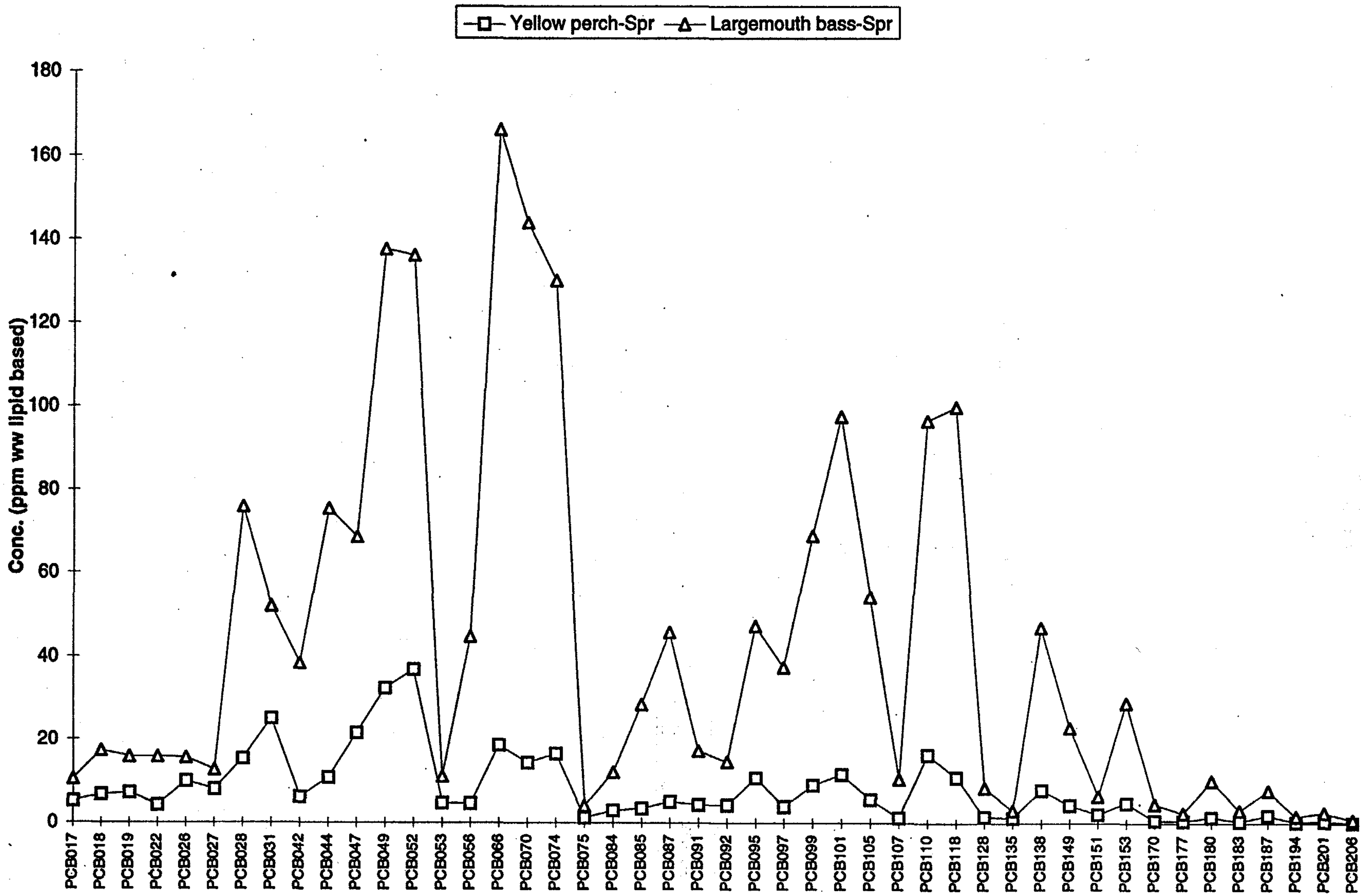

Figure 3-23a. PCB concentration profiles - River Mile 190

321240

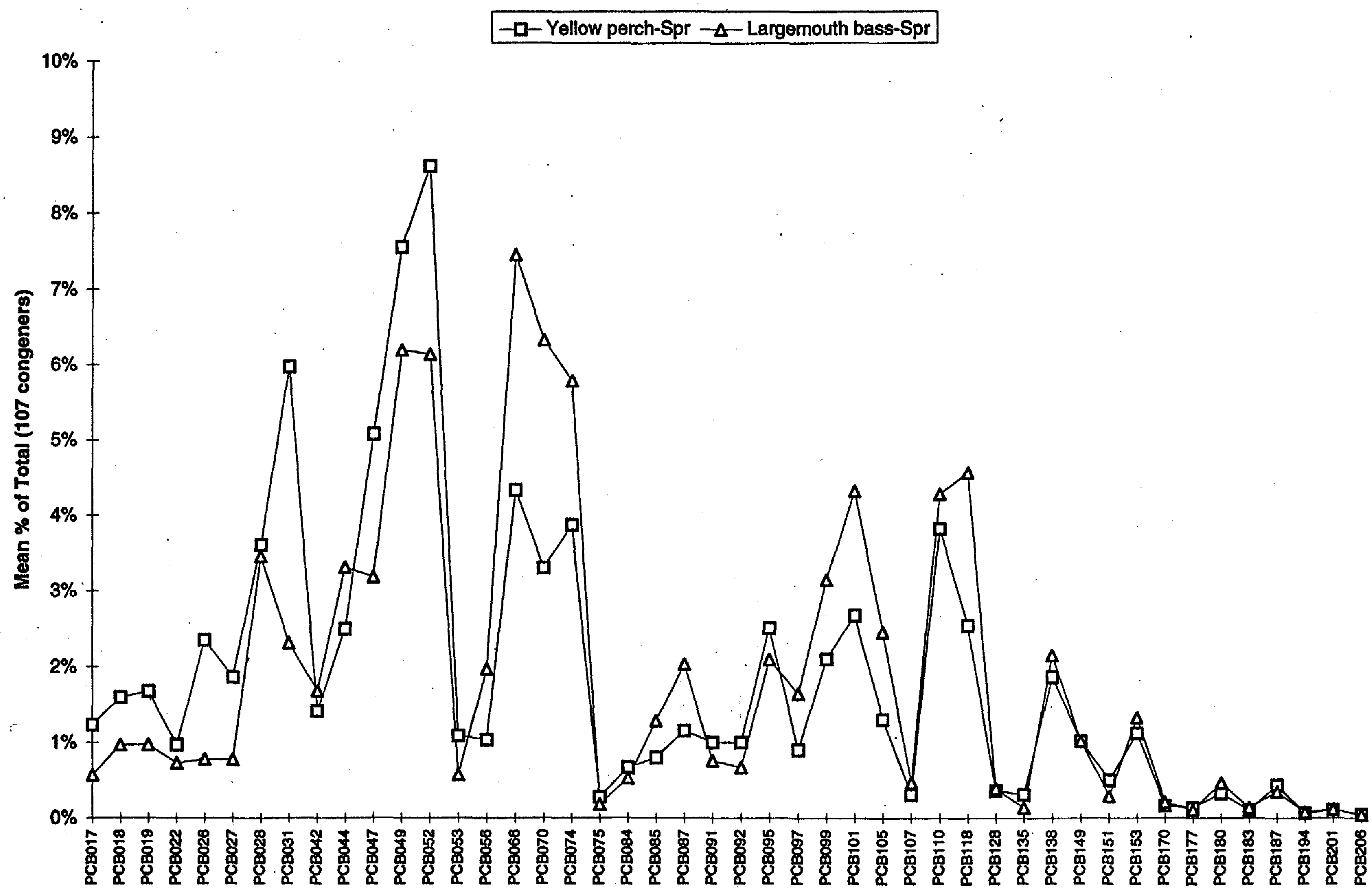

Figure 3-23b. PCB composition profiles - River Mile 190

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3.3.5.2 RM 175

The mean lipid-based congener concentration profiles for yellow perch and largemouth bass at RM175 were similar to those for RM190 (Figure 3-24a). The largemouth bass concentrations were much higher than those observed in the yellow perch, again related in part to the order-of-magnitude difference in the lipid content reported for these species (largemouth bass, average lipid = 0.22 percent; yellow perch, average lipid = 2.22 percent).

The composition profiles for the yellow perch and largemouth bass at RM175 were more similar than the composition profiles observed for these species at RM190 (Figure 3-24b). The maximum between-group pairwise distance calculated for these groups was 0.085. The calculated distance between yellow perch and largemouth bass at RM175 is less than that calculated for RM190, and is less than the distances observed within the species (Tables 3-4 and 3-5).

3.3.5.3 RM152

This sampling location was below the Federal Dam at RM154 and is the first station where both striped bass and resident fish species were collected. Both juvenile and adult striped bass samples were collected. Substantial seasonal differences were seen in the congener concentrations and composition for the yellow perch, white perch, and striped bass collected at this location (Section 3.3.3). Therefore, the spring-collected and fall-collected fish were considered separately. The differences between the resident species yellow perch, white perch, and largemouth bass and the striped bass are discussed in Section 3.3.7. However, the relationships between resident species are the focus of the following discussion.

RM152 - Spring-Collected Fish — The lipid-based congener concentration profiles for spring-collected fish from RM152 are compared in Figure 3-25a. The highest concentrations were measured in the largemouth bass and the lowest concentrations were measured in the white perch. Even though there were substantial differences in the concentrations, the congener composition profiles were similar for all the spring-collected resident species (Figure 3-25b).

The maximum between-group Euclidean distances calculated for the spring-collected fish are presented in Table 3-9. The largest distances were calculated between the adult striped bass and the resident fish, with smaller distances among the resident species.

321242

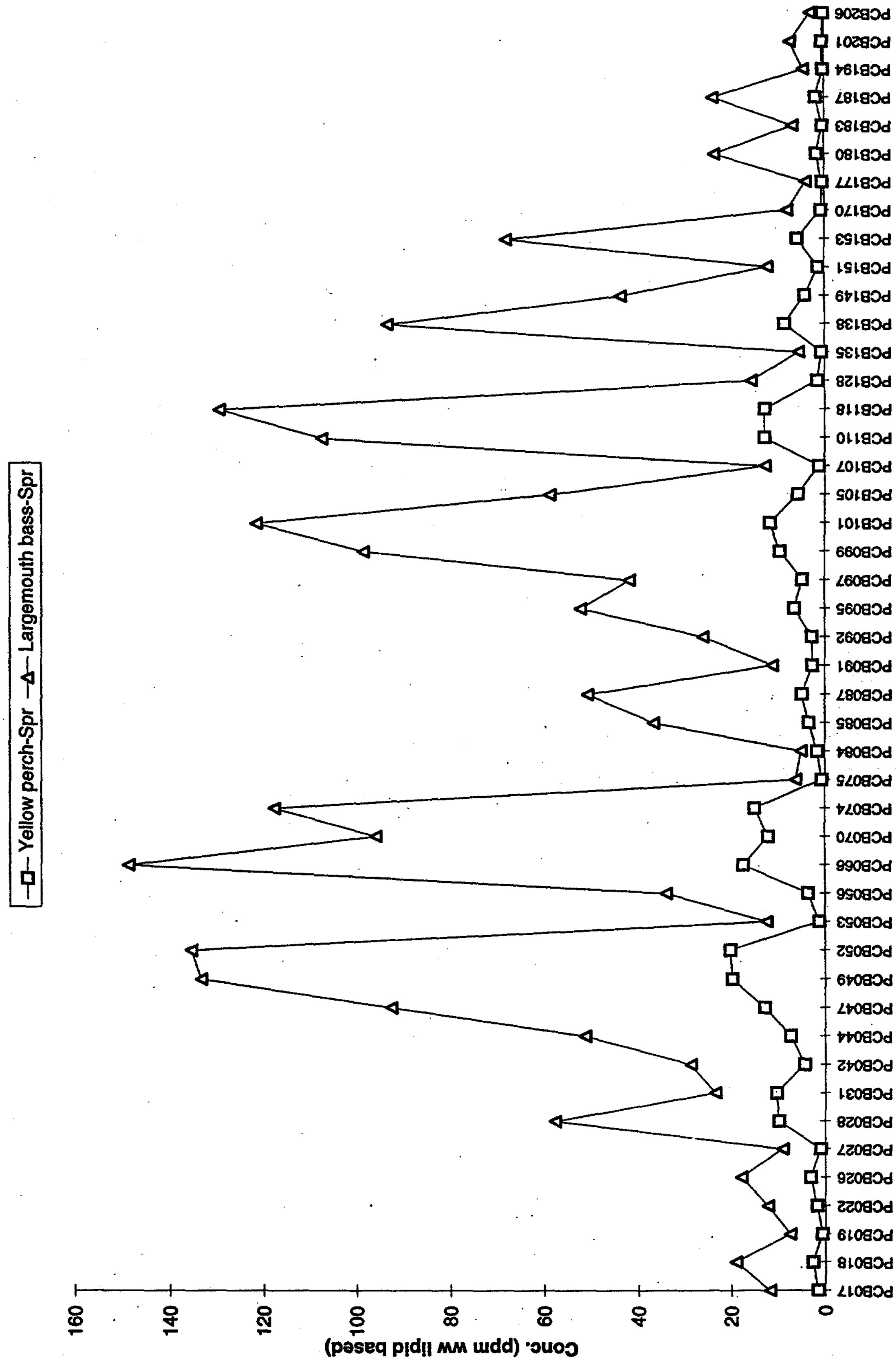

Figure 3-24a. PCB concentration profiles - River Mile 175

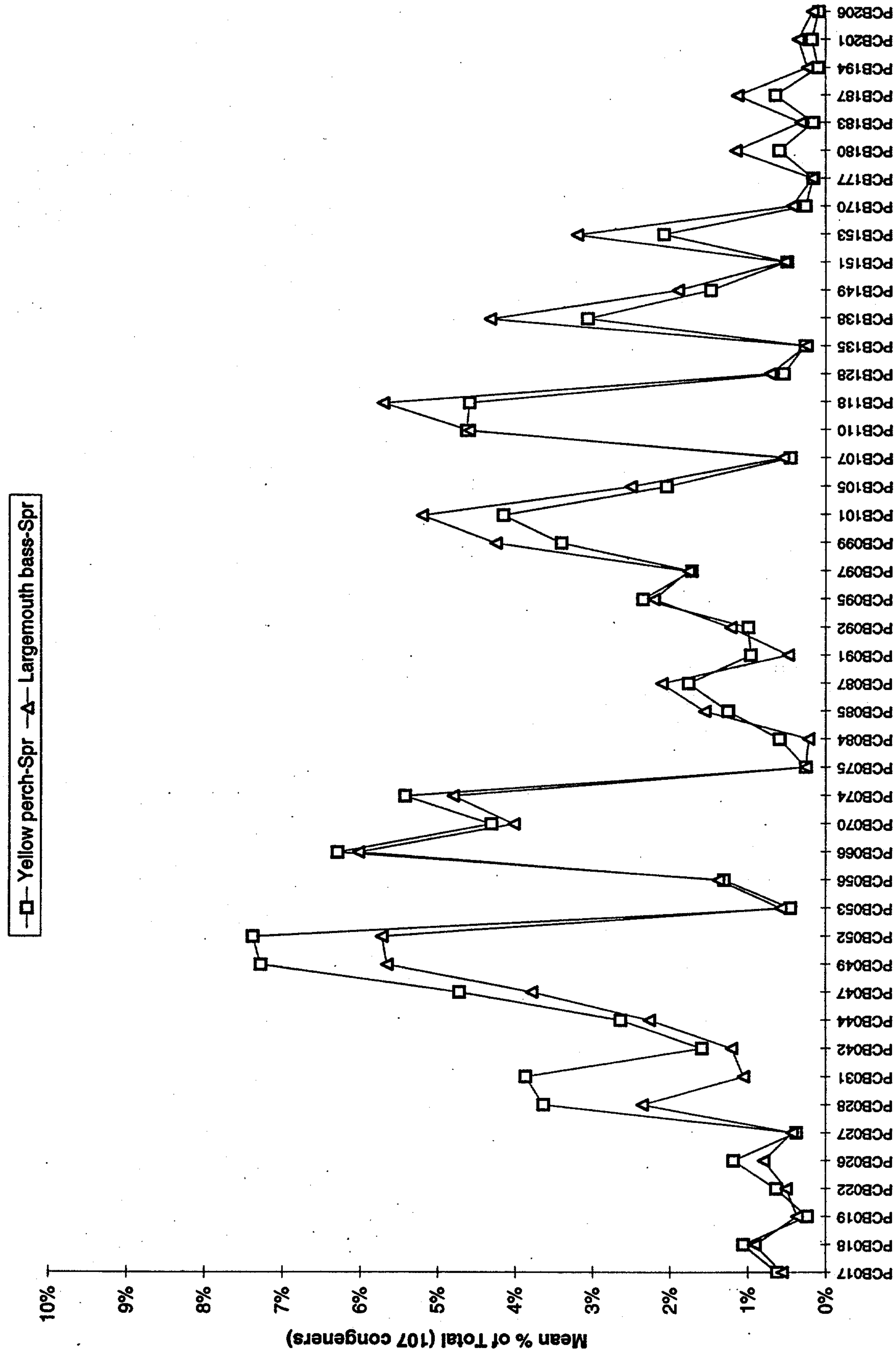

Figure 3-24b. PCB composition profiles - River Mile 175

321244

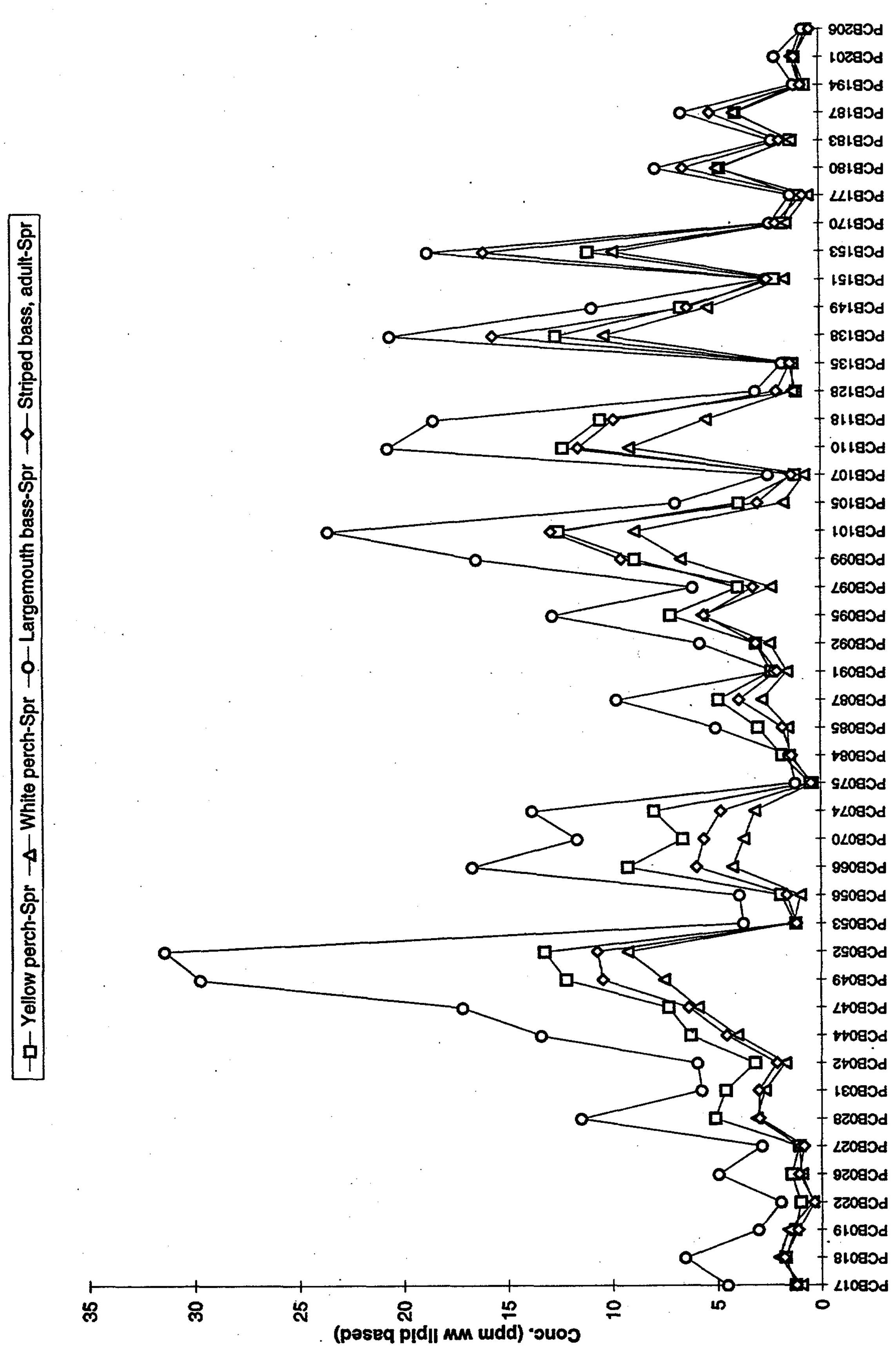

Figure 3-25a. PCB concentration profiles (Spring)- River Mile 152

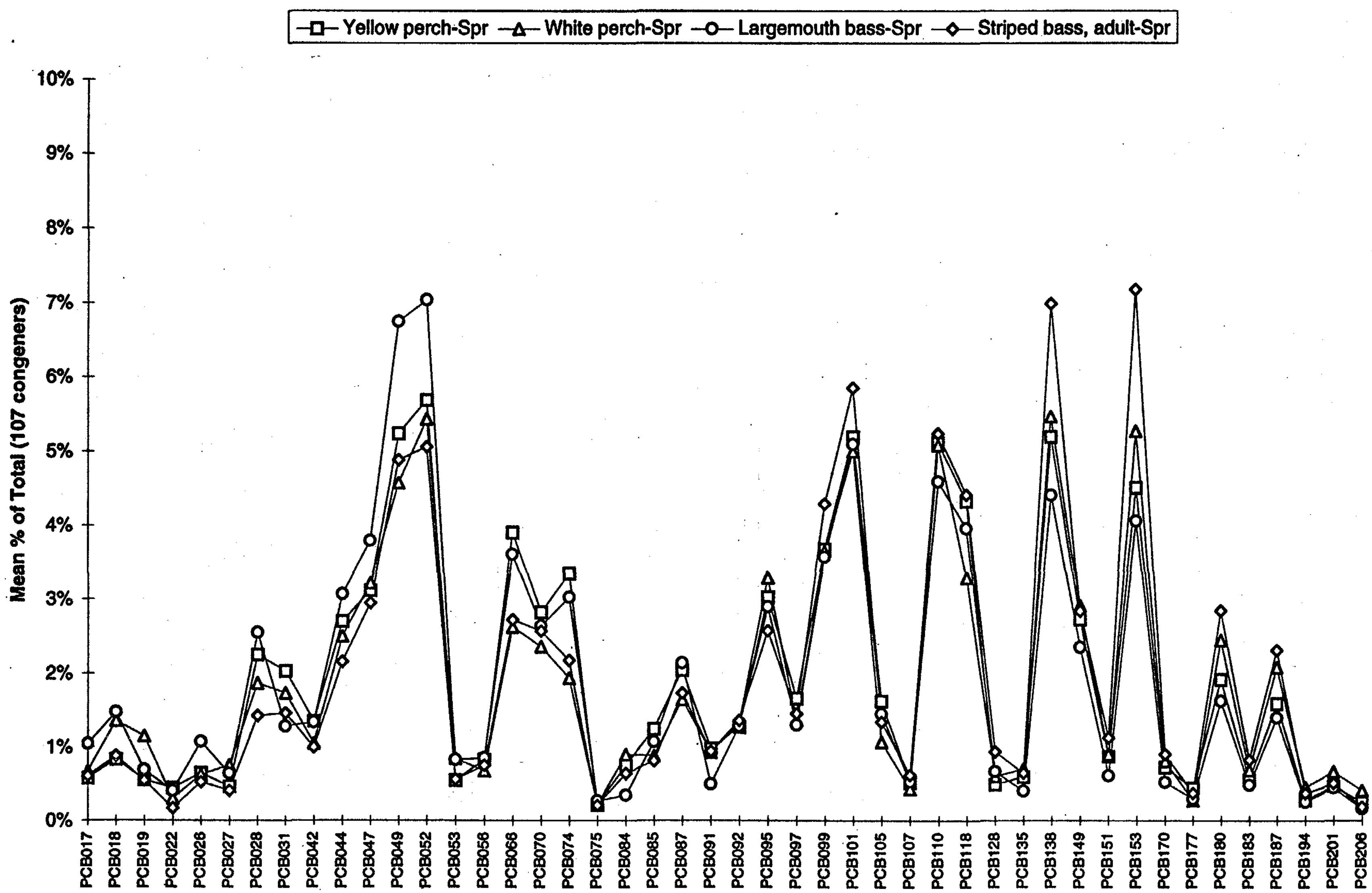

Figure 3-25b. PCB composition profiles (Spring) - River Mile 152

Table 3-9. Maximum between-group pairwise distances calculated for RM152 - spring

	STRIPED BASS - ADULT	STRIPED BASS - JUVENILE	YELLOW PERCH	WHITE PERCH	LARGEMOUTH BASS
Striped Bass -adult	0	-	-	-	-
Striped Bass -juv.	-	0	-	-	-
Yellow Perch	0.092	-	0	-	-
White Perch	0.096	-	0.066	0	-
Largemouth Bass	0.115	0.065[a]	0.07	0.088	0

[a] Cross-season comparison

RM152 - Fall-Collected Fish — The congener concentration profiles for the fall-collected fish from RM152 are compared in Figure 3-25c. The adult striped bass had the highest lipid-based congener concentrations. The white perch, yellow perch and juvenile striped bass had similar congener concentrations. The congener composition profiles showed dominant similarities for all fish (Figure3-25d). As was the case for the spring-collected fish, the largest maximum between-group distances were calculated between adult striped bass and the resident fish, yellow and white perch (Table 3-10).

Table 3-10. Maximum between-group pairwise distances calculated for RM152 - fall

	STRIPED BASS - ADULT	STRIPED BASS - JUVENILE	YELLOW PERCH	WHITE PERCH	LARGEMOUTH BASS
Striped Bass -adult	0	-	-	-	-
Striped Bass -juv.	0.058	0	-	-	-
Yellow Perch	0.135	0.082	0	-	-
White Perch	0.13	0.098	0.088	0	-
Largemouth Bass	-	0.065[a]	-	-	0

[a] Cross-season comparison

3.3.5.4 RM115

The differences in congener concentration among species collected in the spring at RM115 (Figure 3-26a) were similar to those observed for fish caught in the spring at RM152 (Figure 3-25a). The congener compositions observed in the yellow perch, white perch, largemouth bass, and striped bass collected at RM115 (Figure 3-26b) were also similar to those seen at RM152 (Figure 3-25b). All the groups collected at this location were collected in the spring; therefore, there are no seasonal differences to consider. The between-group Euclidean distances calculated for the resident species at this location are presented in Table 3-11 and demonstrate the same trend of substantial similarities in the

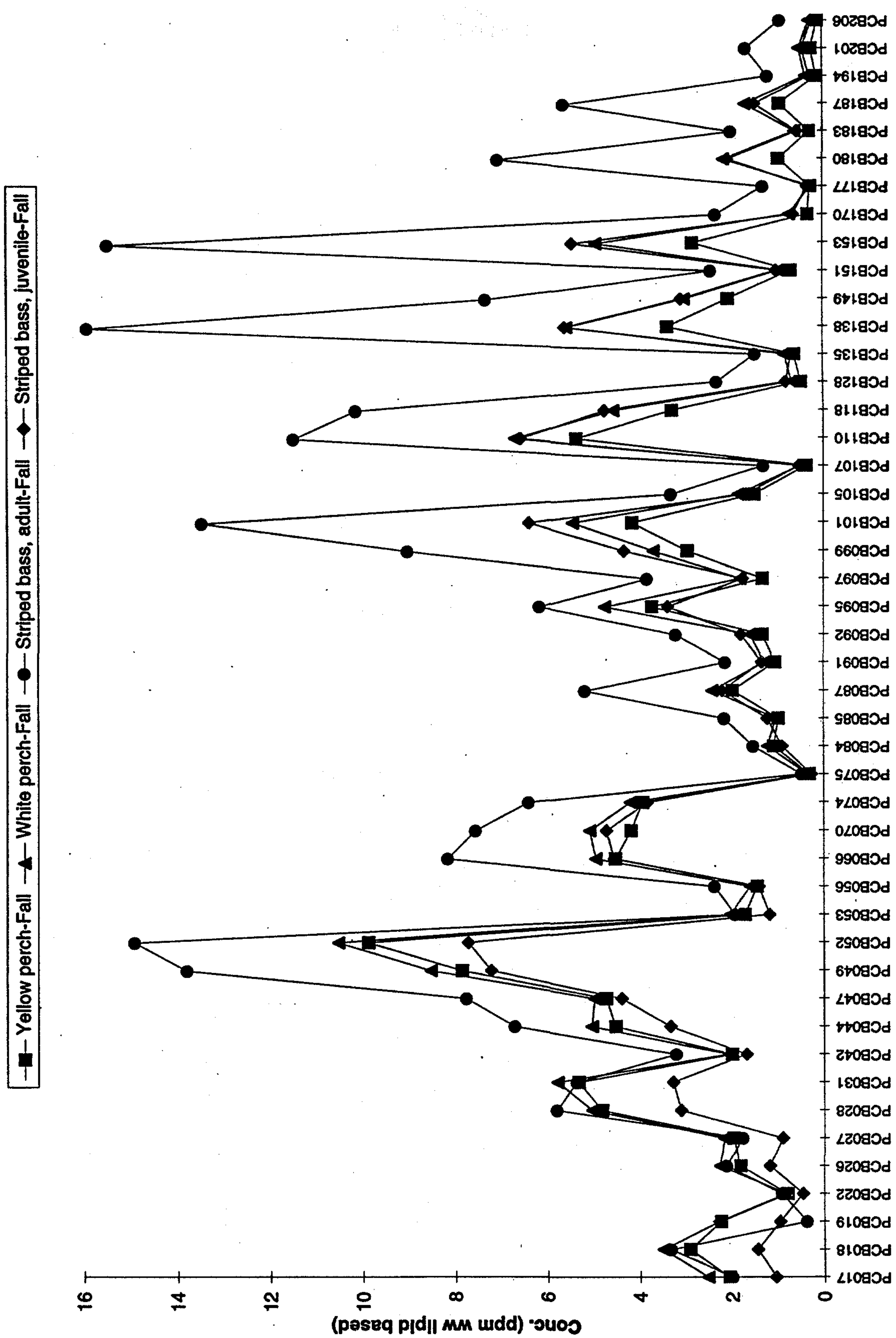

Figure 3-25c. PCB concentration profiles (Fall)- River Mile 152

321248

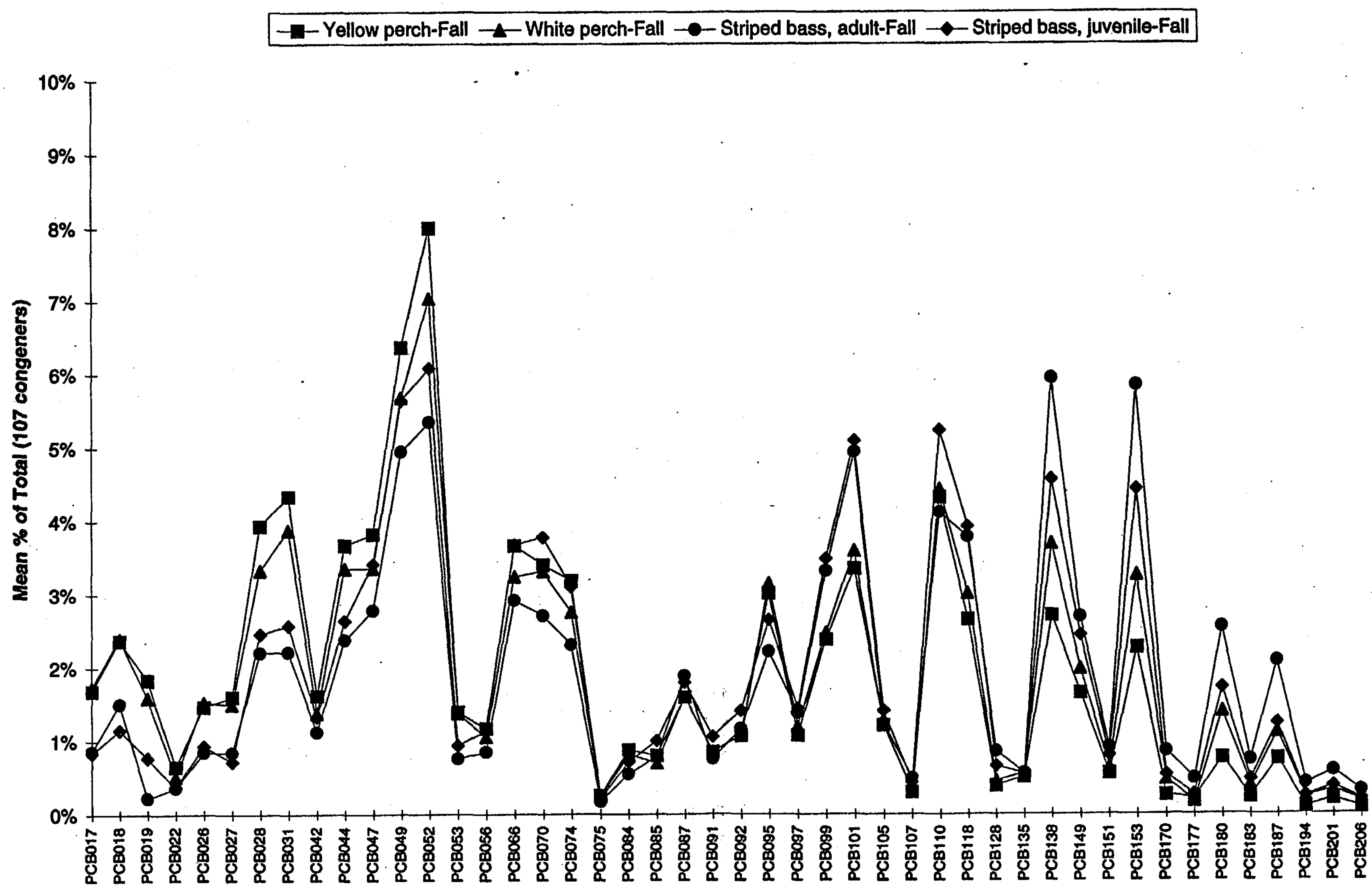

Figure 3-25d. PCB composition profiles (Fall) - River Mile 152

321249

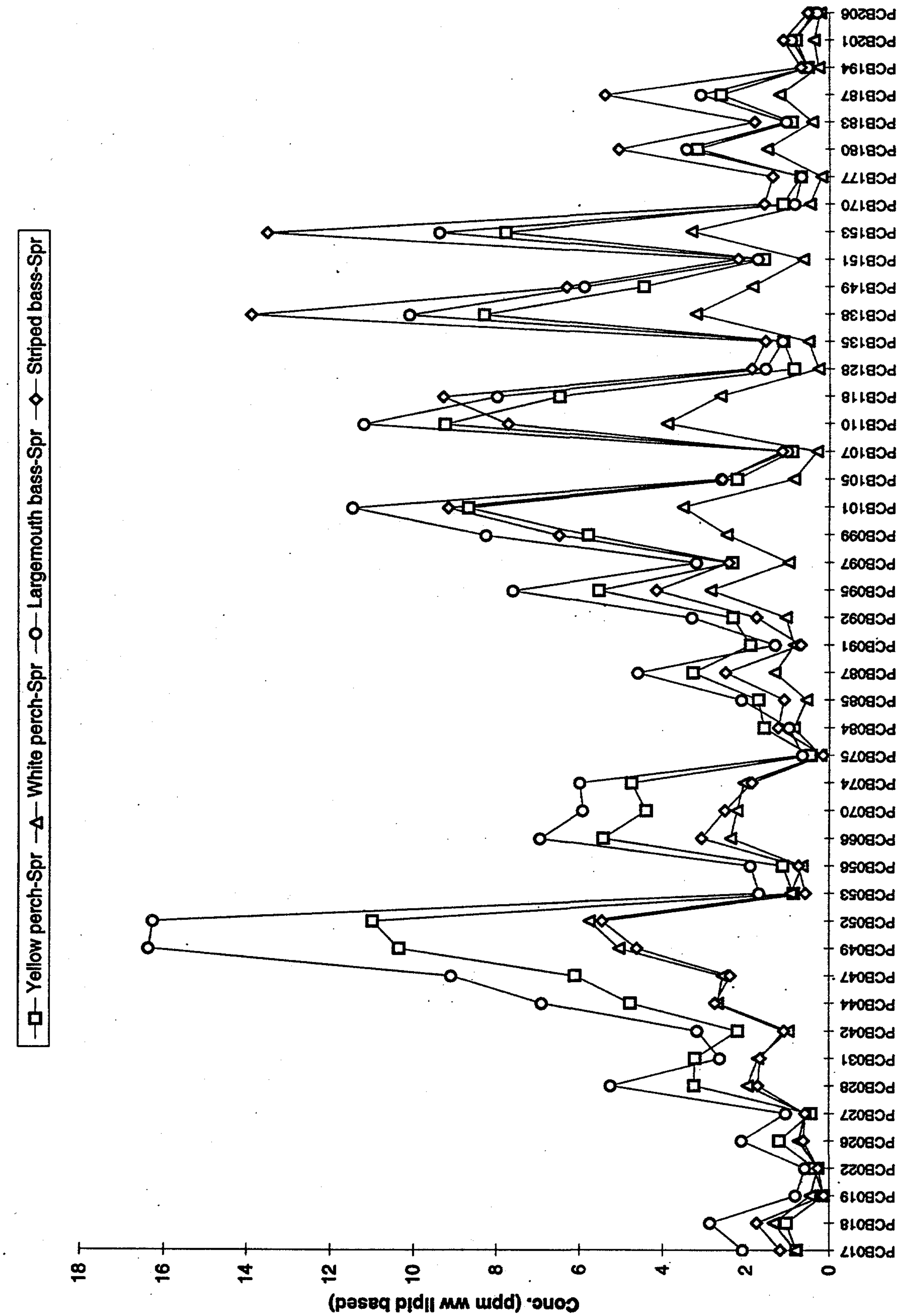

Figure 3-26a. PCB concentration profiles - River Mile 115

321250

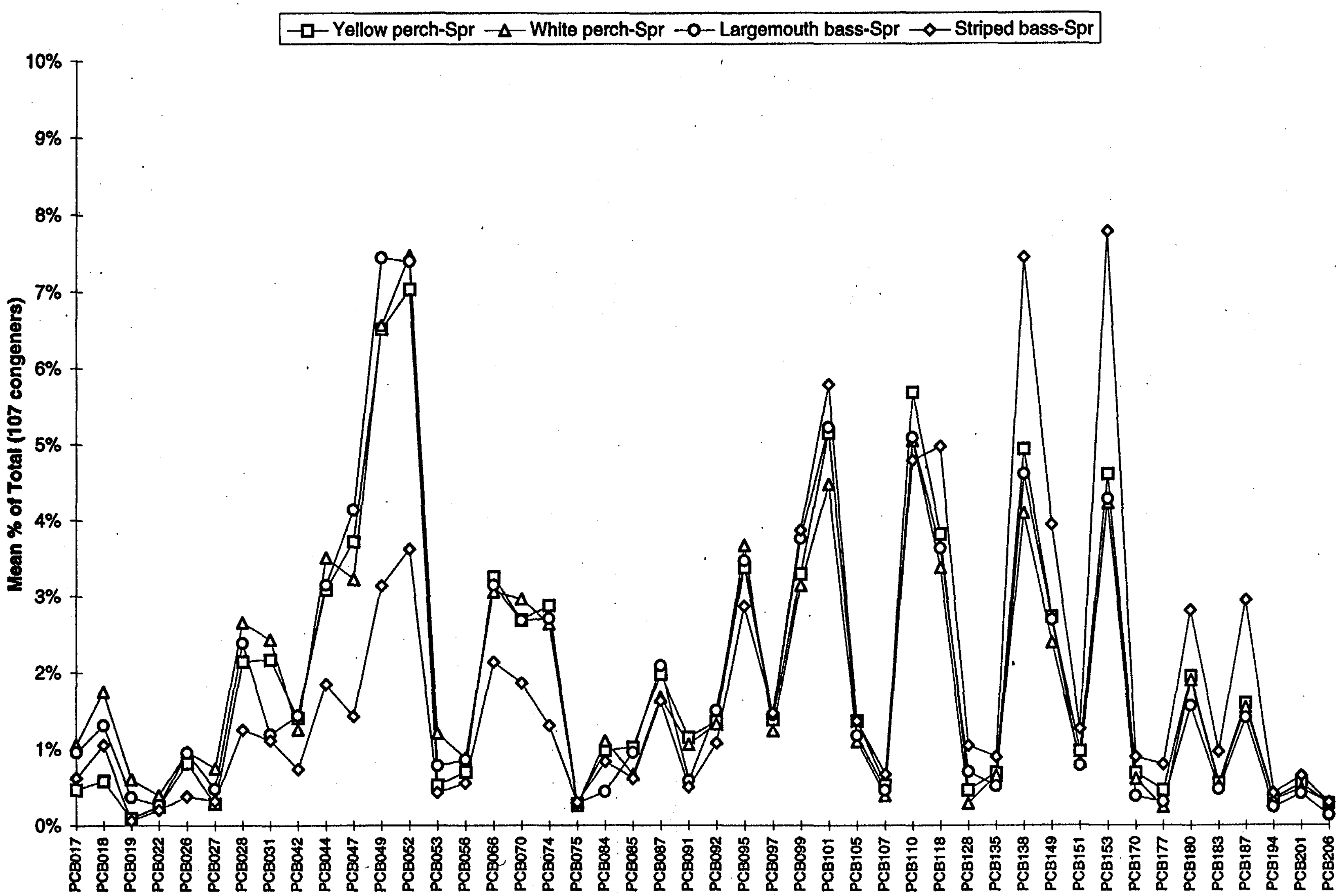

Figure 3-26b. PCB composition profiles - River Mile 115

321251

composition of the PCBs in resident fish, with the composition in the adult striped bass being less similar.

Table 3-11. Maximum between-group pairwise distances calculated for RM115

	Striped Bass - Adult	Yellow Perch	White Perch	Largemouth Bass
Striped Bass -adult	0	-	-	-
Yellow Perch	0.14	0	-	-
White Perch	0.144	0.067	0	-
Largemouth Bass	0.149	0.056	0.054	0

3.3.6 PCB Characteristics of Resident Fish as Indicators of Location-specific Exposure

The foregoing analyses showed that, within each sampling location, there were reasonably consistent differences in the congener concentrations among the species. Of more importance, however, was the fact that the congener compositions of the resident fish species were similar. In most instances, the congener compositions were more similar among species at a location than they were to the congener compositions among the same species collected from other sampling locations.

These data demonstrated that sampling location was more important than the identity of the specific species in governing the observed congener compositions and, to a less precise extent, the congener concentrations in the resident species. This finding is consistent with the hypothesis that the resident fish are responding to, and can be used as indicators of, general fish accumulation responses to local exposures. Therefore, the range of resident species collected from RM27 to RM190 can be used to identify "resident" compositions throughout the length of the river.

The principal differences between the resident PCB congener compositions at RM190 and the resident PCB congener compositions at RM27 are due to changes in the relative contributions from the following congeners: PCB66, PCB70, PCB74, PCB138, PCB149, and PCB153. The upper river samples (RM190 and RM175) had larger contributions to their total PCB concentrations from PCB66, PCB70, and PCB74 relative to PCB138, PCB149, and PCB153. It is important to note that the changes in concentration and composition in all resident species were related, and both changed in consistent and predictable fashion in comparing data from fish collected along the length of the river, with the possible exception of some data from fish collected near RM59.

The total PCB concentrations in the resident fish decreased with increasing distance below the Thompson Island Pool. Congener concentration profiles demonstrated that the rate of loss of the congeners was more rapid for the lower-chlorinated congeners PCB66, PCB70, and PCB74 relative to the more highly chlorinated congeners PCB138, PCB149, and PCB153. These changes are consistent with historical data describing changes in the composition of PCBs in the fish from the Hudson River with distance downriver from the Thompson Island Pool, and are consistent with the original hypothesis that the changes in concentrations and patterns observed in the resident species among locations (particularly between the upper and lower river) reflect the dilution and weathering of the PCBs from the source during transport downriver.

3.3.7 Comparison of PCB Characteristics of Resident Fish and Striped Bass

3.3.7.1 Section Overview

Consistent differences were seen between the congener compositions in the adult striped bass and the resident fish collected at the same sampling locations. The congener compositions of the adult striped bass were lower in PCB66, PCB70, and PCB74 and they received higher contributions from PCB138 and PCB153 relative to the resident fish collected at the same locations. The striped bass congener composition did not vary as much between sampling locations as was observed with the resident species, but did begin to resemble the resident species profiles as concentrations increased with distance upstream in the lower river and with increased residence time (Sloan 1997 pers. comm.), as indicated by comparing the data from fall-collected adult striped bass with the spring-collected adult striped bass at RM152.

The juvenile striped bass at RM59 and RM27 had congener concentrations and compositions similar to the resident fish, again reinforcing the hypothesis that the PCBs in these fish reflect their ambient exposure, and the uptake by the juvenile striped bass is not substantially different than that occurring in other resident fish.

In addition, the congener composition seen in the juvenile striped bass was more similar to the composition of the resident species than the composition of the adult striped bass collected at the same location. The only exception to this observation was seen at RM152, where the distance between the adult and juvenile striped bass was less than the distance between the juvenile striped bass and the resident species. The calculated distance at this river mile is a result, in part, of the exclusion of two samples from the juvenile striped bass sample as outliers.

Adult striped bass were collected from RM152, RM115, RM75, and RM27. In addition, juvenile striped bass were collected from RM152, RM59, and RM27. The concentrations and composition of PCBs in the striped bass and resident species are compared for each of these sampling locations in the following discussions.

3.3.7.2 RM152

The congener composition and concentration profiles for the striped bass and resident species collected at RM152 are compared in Figures 3-25a, b, c, and d. The congener concentration profiles are presented in Figures 3-25a and c. The PCB concentrations in the adult striped bass were comparable to, but lower than, those observed in the resident fish in the spring collection. In the fall, the concentrations of virtually all of the congeners were higher in the adult striped bass than in any resident fish. The concentrations in the juvenile striped bass collected in the fall were comparable to those of the resident fish, except for lower concentrations of the lower-chlorinated congeners.

The congener compositions of the adult striped bass and the juvenile striped bass were overall quite similar to those of the resident fish. Small differences in congener contributions indicated that the PCBs in the striped bass were more similar to those seen in the spring-collected white perch and yellow perch than the fall-collected white perch and yellow perch. The adult striped bass had relatively low percent contributions from the tetrachlorobiphenyls PCB44, PCB47, PCB49, PCB52, PCB66, PCB70, and PCB74 and corresponding high percent contributions from the more highly chlorinated congeners PCB138 and PCB153 compared to the resident fish.

The maximum between-group distances calculated for all species collected at RM152 are presented in Tables 3-9 and 3-10. The differences between the congener composition of the striped bass and the resident fish yielded Euclidean distances that were larger than the distances among resident fish, but were still less than or comparable to the distance calculated between Aroclors 1016 and 1242. The Euclidean distance calculated between the juvenile and adult striped bass was small. As a secondary check on this similarity, the distance was recalculated including the two juvenile striped bass samples that had usually been excluded (Section 3.1.2). If the entire group of juvenile striped bass was compared with the fall-collected adult striped bass, a relatively large maximum distance of 0.135 was calculated. The relatively small distance between the groups calculated without the outliers is driven in large part by one juvenile striped bass with low congener concentrations and a relatively low contribution from the lower-chlorinated congeners. If all of the juveniles are included, the mean composition is richer in lower-chlorinated congeners and is more similar to the composition of the resident fish.

The compositional differences that were seen between the fall-collected juvenile striped bass and the fall-collected yellow perch and white perch are reflected in the relatively large distances calculated between these groups. The juvenile striped bass composition appeared to be more similar to that seen in the spring-collected yellow perch and white perch. Relatively small distances were calculated for the juvenile striped bass and the largemouth bass, as well as the spring-collected yellow perch/white perch and yellow perch/largemouth bass pairs. In general, the resident fish were more similar to one another than to the adult striped bass. However, the juvenile striped bass appeared to be more similar to the spring-collected white perch and yellow perch rather than the fall-collected white perch and yellow perch, again based on comparisons that excluded the two juvenile striped bass samples.

3.3.7.3 RM115

The congener concentration profiles compared for all species collected at RM115 are presented in Figure 3-26a. The lowest concentrations of the tetrachlorobiphenyl congeners PCB44, PCB47, PCB49, PCB52, PCB66, PCB70, and PCB74 were seen in the striped bass. Concentrations of the hexachlorobiphenyls PCB138 and PCB153 in the striped bass were similar to those seen in the yellow perch and largemouth bass, with the lowest concentrations measured in the white perch.

The differences between the congener composition in the striped bass and the resident species were substantial (Figure 3-26b). A comparison of the composition observed in the striped bass relative to the resident species revealed a lower contribution from the tetrachlorobiphenyl congeners PCB44, PCB47, PCB49, PCB52, PCB66, PCB70, and PCB74 to the striped bass relative to the resident species.

The Euclidean distances calculated between the adult striped bass and the resident species pairs were among the largest calculated in this study (Table 3-11).

3.3.7.4 RM75 and RM59

White perch and juvenile striped bass were collected at RM59. The concentration and composition profiles for these two species were compared to the profiles for the adult striped bass collected from RM75 in Figures 3-27a and b. The concentration profiles (Figure 3-27a) reflect the high total PCB concentrations that were seen at RM59 relative to RM75. Both the juvenile striped bass and the white perch at RM59 had higher congener concentrations than the adult striped bass collected at RM75. The differences in concentrations were greatest for the lower-chlorinated tri-and tetrachlorobiphenyl congeners. Concentrations of the more highly chlorinated hexa- and heptachlorobiphenyls were similar.

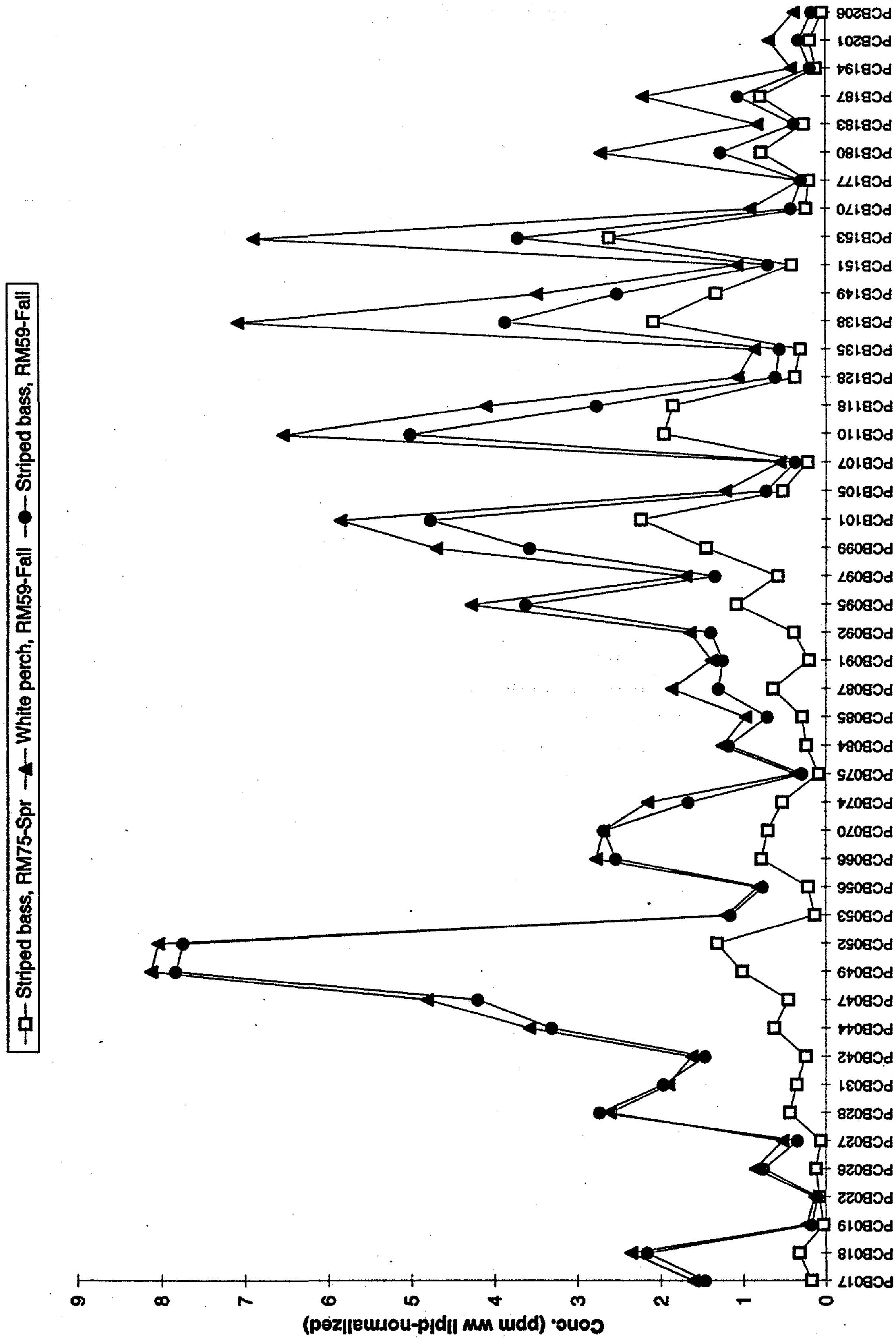

Figure 3-27a. PCB concentration profiles - River Mile 75, River Mile 59

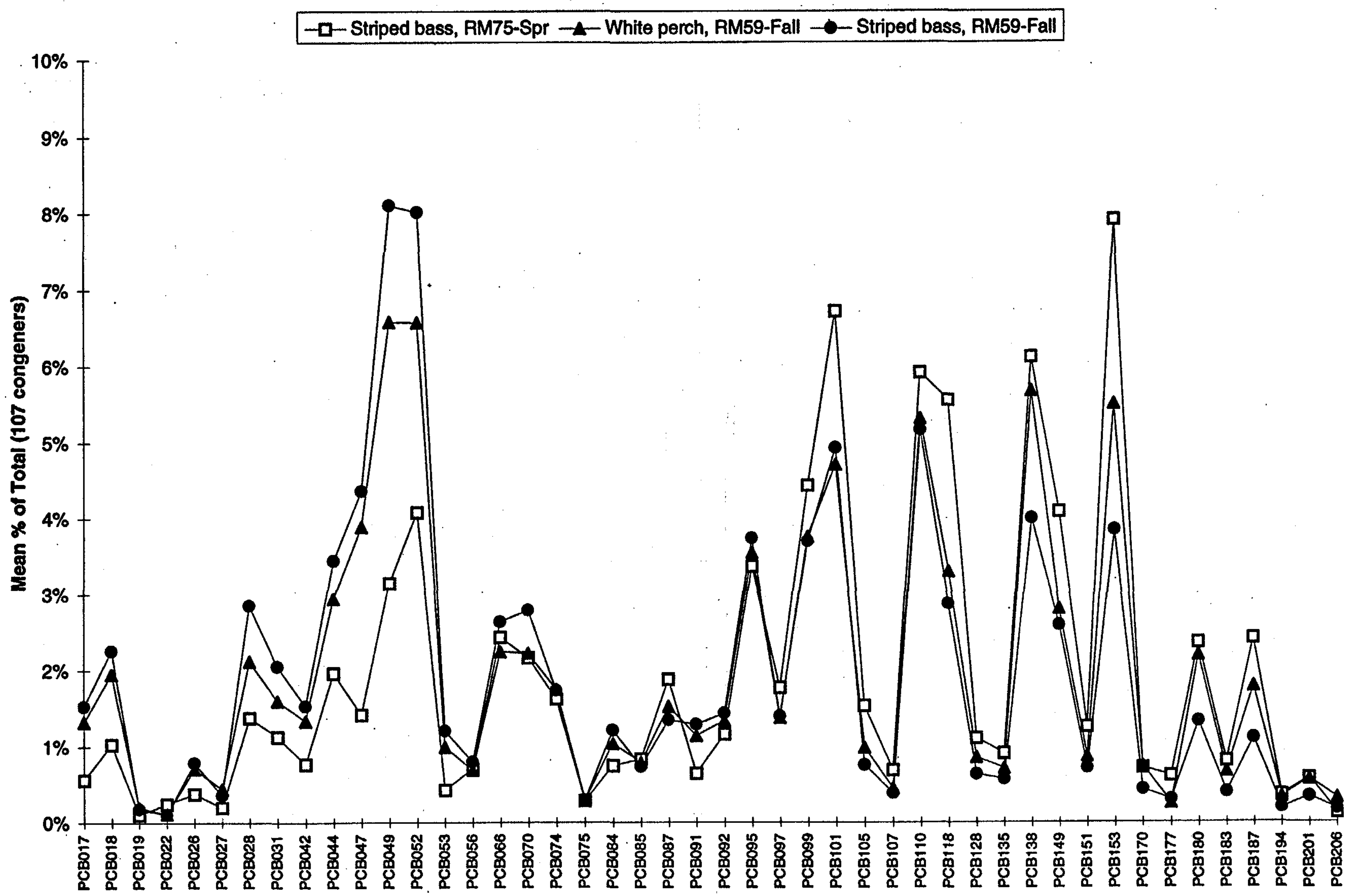

Figure 3-27b. PCB composition profiles - River Mile 75, River Mile 59

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The congener patterns observed in the adult striped bass collected from RM75 were similar to the congener patterns seen in the other adult striped bass samples, with a relative enrichment of the more highly chlorinated congeners. Congener composition profiles for the white perch and juvenile striped bass from RM59 were similar, and the between-group Euclidean distance calculated for these species (d = 0.057) was small.

3.3.7.5 RM27

The congener concentration and composition profiles for juvenile and adult striped bass and white perch at RM27 are shown in Figures 3-28a and b. The concentrations of all congeners in all species were low. The concentrations in the spring striped bass were lower than observed in the other fish species for most of the congeners, but the overall distribution of major congeners was similar.

The percent contributions of some of the lower-chlorinated tri- and tetrachlorobiphenyl congeners PCB28, PCB31, PCB42, PCB44, PCB47, PCB49, and PCB52 were higher in the white perch and juvenile striped bass than in the adult striped bass. The adult striped bass had relatively higher percent contributions from the hexachlorobiphenyls PCB138 and PCB153. In general, the congener compositions observed in all the fish collected at this location were quite similar.

The adult striped bass composition profile was similar to those seen at other sampling locations and somewhat different from the juvenile striped bass and the white perch, while the congener compositions of the juvenile striped bass and white perch were similar to each other. These differences are reflected in the calculated between-group Euclidean distances (Table 3-12).

Table 3-12. Maximum between-group pairwise distances calculated for RM27

	STRIPED BASS - ADULT	STRIPED BASS -JUVENILE	WHITE PERCH
Striped Bass - adult	0	-	-
Striped Bass - juv.	0.102[a]	0	-
White Perch	0.101[a]	0.065	0

[a] Comparison of fall-collected fish.

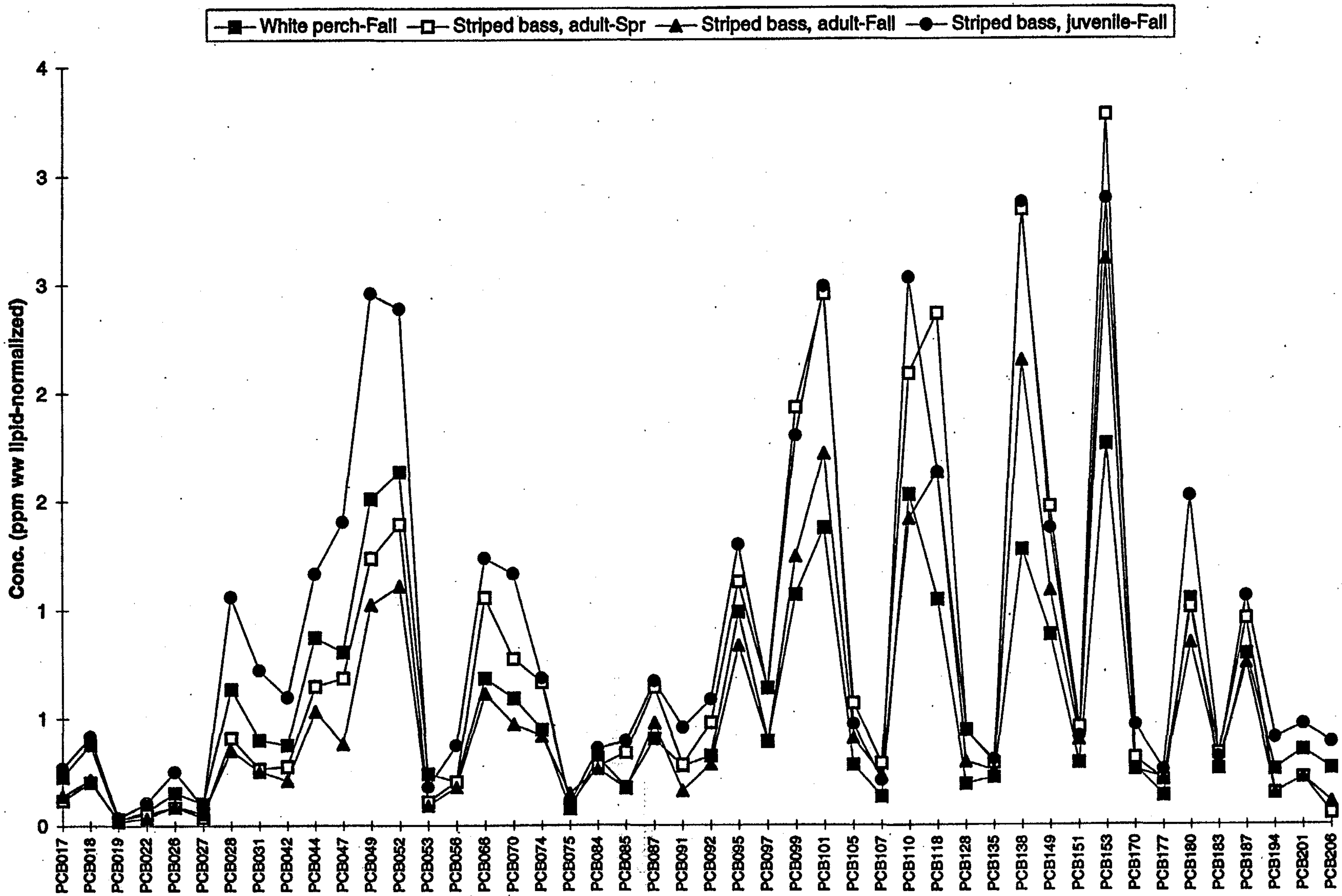

Figure 3-28a. PCB concentration profiles - River Mile 27

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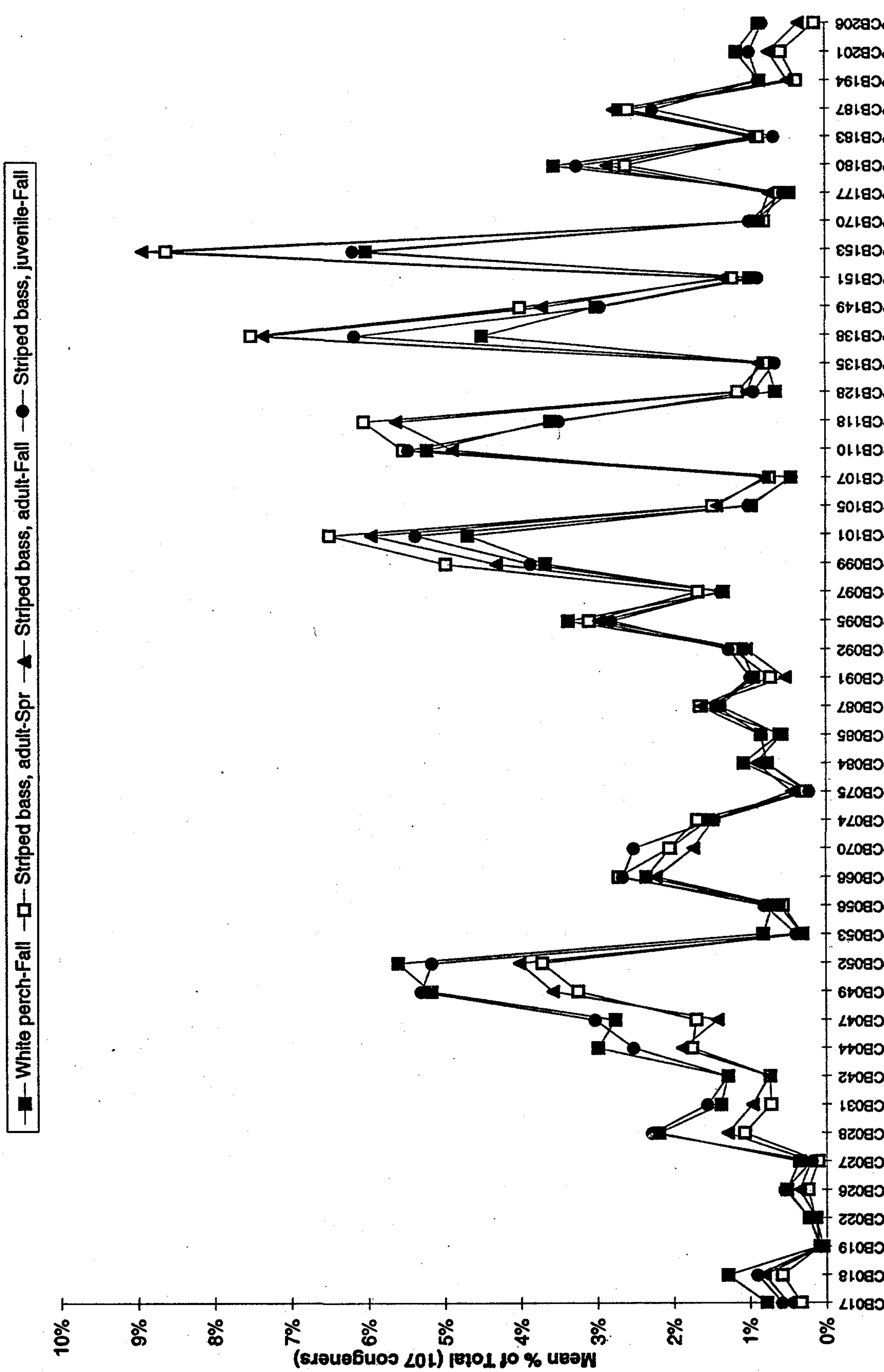

Figure 3-28b. PCB composition profiles - River Mile 27

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3.4 GENERAL DISCUSSION

The PCB congener concentrations and composition measured in resident fish species and adult striped bass, combined with the results of the 1993 congener study of resident fish and the historical Aroclor-based data, demonstrate that the observed PCB congener concentrations and composition in resident fish change in a regular and predictable fashion consistent with exposure to PCBs that were released in the Upper Hudson River and diluted and "weathered" during transport downstream.

Major factors that support this conclusion were:

- The total PCB and individual congener concentrations decreased in resident species with increasing distance downstream from the Thompson Island Pool, except in samples of white perch and juvenile striped bass collected from RM59. The largest changes in concentration occurred between fish collected from the upper river and the lower river, while the decreases in concentration were more gradual in the lower river. While data on tributary flow were not presented in this report, the observed rate of change is believed to be consistent with the effects of dilution from tributary flows, in particular the influx of the Mohawk River, which discharges just above the Federal Dam.

- The relatively high congener concentrations that were measured in white perch and juvenile striped bass at RM59 may reflect a local source. In the 1993 study, congener concentrations in spottail shiner collected from this location were higher than expected, whereas congener concentrations in white perch were not. There are several potential local sources of PCBs in the Newburgh area. Additionally, the presence of the freshwater-to-saltwater interface (salt front) in this area during the summer will result in flocculation and sedimentation of colloidal and dissolved organic matter. These processes have the potential to affect the transport and bioavailability of PCBs in this area. The elevated concentrations measured at this location do not reflect upstream transport from downriver sources because there is no evidence of an upstream concentration gradient between RM27 and RM59 in either the 1993 or the 1995 data sets.

- Congener concentrations and composition in resident fish species and striped bass changed in a similar way along the spatial gradient of the river. The contribution of higher-chlorinated penta-, hexa-, and heptachlorobiphenyls increased with distance from the Thompson Island Pool due to a more rapid decline in the concentrations of the lower-chlorinated tri- and tetrachlorobiphenyls. These changes were consistent with the congener

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concentrations measured in resident fish in 1993 and compositional changes seen in the historical Aroclor-based data.

- The calculated Euclidean distances provided a quantitative measure of the similarities in PCB composition of the fish tissue concentrations. These distances indicated that the differences in the congeners accumulated by all resident species from the same locations were small, substantially less than the differences calculated between commercial Aroclor mixtures, which supports the hypothesis that fish in all locations were exposed to sources with similar PCB compositions. It was also apparent that, for the resident species, the differences in composition were not large even when comparisons were made between different species, seasons, and locations.

- As expected, the juvenile striped bass, a comparatively small and resident (premigratory) fish, did appear to accumulate PCBs at concentrations and compositions that were generally similar to those in the resident fish collected at the same locations. The one apparent exception to this observation was the juvenile striped bass collected at RM152. The samples collected at this location were extremely variable. This variability resulted in the exclusion of several fish from this group and reduced our ability to draw clear conclusions from the data for the group.

- The PCB composition in the adult striped bass generally contained a higher percentage of the higher-chlorinated PCBs compared to the composition of resident fish species collected from the same area in the lower river. However, the changes in concentrations and composition seen in resident species and striped bass were similar along the downstream gradient between the Albany and the Tappan Zee areas. The dominant congeners in the striped bass were the same as those found in resident fish, only the absolute and relative concentrations were different.

  The differences in congener composition between the adult striped bass and the resident fish may result from differences in exposure due to the migration of the adult striped bass. Resident fish are only exposed to ambient river conditions. In contrast, adult striped bass leave the river to feed in estuarine waters where the PCB concentrations in the ambient environment and the food supply are lower than the concentrations in the river. Losses of PCBs due to depuration would be expected to be more significant for the more soluble, lower-chlorinated congeners and would result in higher contributions from the more persistent, higher-chlorinated congeners. The differences in composition that were observed between the adult striped bass and the resident fish are consistent with compositional changes that would be predicted as a result of depuration. Another difference between the adult striped bass and the resident fish that has the potential to affect the observed PCB composition is the difference in trophic level. Adult striped bass are higher on the food chain and biomagnification tends to result in an enrichment in the more highly chlorinated congeners.

- Both spring and fall samples were collected for white perch, yellow perch, and striped bass from the Albany area and for striped bass from the Tappan Zee area. Seasonal differences in PCB congener concentrations and composition were observed in resident fish (white perch and yellow perch) and adult striped bass from the Albany area. For both the striped bass and resident species collected in the fall, the lower-chlorinated tri- and tetrachlorobiphenyls contributed a higher percentage of the total PCB composition than in the spring-collected fish. The seasonal differences in PCB composition are consistent with major seasonal changes in the nature of the PCB loading. In the early spring, PCB loading is dominated by the suspended particulates transported during the high-flow period in the river (April). During the low-flow, warm water period from summer to fall, PCB loading is mostly in the dissolved phase (TAMS 1997). The composition of PCBs associated with suspended sediments generally will have a higher percentage of higher-chlorinated congeners than PCBs in the dissolved phase, even if the PCBs were derived from the same source. The congener patterns in the spring-collected fish suggest a more sediment-dominated pathway compared to the fall-collected samples. The observed seasonal differences suggest that the fish respond rapidly to changes in the ambient environment.

- Male adult striped bass collected from the Catskill Creek area (RM 115) had higher PCB concentrations on a lipid-basis than female striped bass from that area, although the wet-weight PCB concentrations were similar. Therefore, the differences observed in the lipid-based concentrations are due to gender differences in lipid content. The congener compositions were nearly identical, which indicates that both male and female adult striped bass are exposed to the same sources of PCBs.

- Comparing the congener concentrations and composition, both within the separate groups of species and among species within each location where multiple species were sampled, indicated that fish exposed to PCBs at the same location accumulated congeners in the same way regardless of species. Demonstrating the role of location in controlling the observed congener composition is important because it allows the composition measured in

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resident fish to be used more reliably as an indicator of the expected accumulation in other fish exposed to the ambient PCB concentrations.

The results of the 1995 study confirm and extend the conclusion from the historical Aroclor database and the 1993 congener study of resident fish that the observed accumulation of PCBs by resident fish species in the Hudson River from RM190 to RM27 is consistent with a pathway of exposure from a source of PCBs that originated above the Thompson Island Dam and continues to be transported downstream. Similarly, a substantial portion of the PCB content of striped bass could be attributed to their exposure to PCB along this pathway within the Hudson River.

4.0
CONCLUSIONS

The following conclusions were drawn from the analysis of the congener concentrations and composition measured in resident species and striped bass from the Hudson River.

- The PCB measurements in resident fish demonstrated that:

  - In general, concentrations decreased in all species in a manner consistent with the effects of dilution and weathering at each location downstream from the Thompson Island Pool.

  - Congener compositions overall were similar at all locations and among all species, but changed in significant ways together with the changes in PCB concentrations in the resident fish. The contributions from the lower-chlorinated congeners were higher in the fish collected from the upper river and decreased more rapidly with increasing distance downstream than did the contributions from the more highly chlorinated congeners. These changes in PCB composition in the fish are consistent with changes expected to result from a greater rate of loss of the lower-chlorinated congeners during downstream transport from the source.

  - These results are consistent with the hypothesis that the pathway of exposure to resident fish consists of historical and ongoing releases of PCBs from the Upper Hudson River at or above the Thompson Island Dam.

- The PCB measurements of adult striped bass demonstrated that:

  - Concentrations increased with increasing distance upstream, consistent with the exposure to higher ambient concentrations demonstrated in the resident fish collected from upstream locations.

  - The percent contribution from lower-chlorinated congeners increased with increased total PCB concentrations, also consistent with the accumulation patterns observed in resident species.

Both of these observations are consistent with the accumulation of PCBs in adult striped bass as a result of exposure to ambient PCB concentrations within the river, thus establishing a pathway link between past and ongoing PCB releases in the Upper Hudson River and PCB contamination in the adult striped bass in the Lower Hudson River.

Additional conclusions were:

- The calculation of Euclidean distances provided an objective basis for defining differences in the spatial and temporal distribution of patterns of PCB congeners in fish tissue.

- Congener patterns in resident fish within a sampling location were more similar to one another than to patterns in fish of the same species collected at distant sampling locations.

- Juvenile striped bass had congener concentrations and compositions that were similar to those seen in resident fish, indicating that the striped bass and resident fish respond to ambient exposures in the same way.

In summary, this study developed objective analyses that, together with data from the 1993 congener-specific study and the historical Aroclor-based data, demonstrate that the observed accumulation of PCBs by resident fish in the Hudson River from RM190 to RM27 is consistent with a pathway of exposure consisting of a source of PCBs originating in or above the Thompson Island Pool, with water column and sediment transport processes conveying that release to the remainder of the river downstream. Similarly, for adult striped bass, a substantial portion of their PCB content could be attributed to their exposure to PCBs along this pathway within the Hudson River.

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