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A Brief Report on PCB in Hudson River Striped Bass

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A BRIEF REPORT

ON PCB

IN HUDSON RIVER STRIPED BASS

by

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TABLE OF CONTENTS

ABSTRACT

Monitoring PCB concentrations in striped bass (Morone saxatilis) from the Hudson River since 1978 through 1993 generally reflects decreasing levels of contamination. The traditional spring fishery during the spawning migration in the lower portion of the estuary (below rivermile 80) has received the most scrutiny. Additional sampling has occurred, particularly in recent years, in the upper estuary during summer months after the fish arrive in the Albany/Troy area and in the late fall/early winter for bass presumably overwintering in the Haverstraw Bay/Tappan Zee areas.

Spring collections in 1992 of 144 fish from the lower estuary had the lowest concentrations (average of 1.84 ppm total PCB on a wet weight basis) of any time over the duration of the long-term monitoring of this species. However, PCB concentrations in 1993 increased to 2.34 ppm. Log_{10}-transformations of lipid-based total PCB data to better satisfy statistical constraints indicated there were no statistically significant changes in striped bass PCB levels since 1987. This lack of change may relate to the documented source conditions ongoing at Hudson Falls (RM 197) and Ft. Edward (RM 194).

Fall samples from Haverstraw Bay and Tappan Zee in 1992 and 1993 respectively averaged 5.70 ppm and 3.61 ppm. These results whether transformed or expressed in wet weight terms

statistically show little change since 1987. The lowest concentrations occurred in 1984 when fall sampling was initiated on a regular basis.

In the Albany/Troy area concentrations either on a wet weight basis or $\log_{10}$-transformed lipid-basis had exhibited some evidence for declines between 1985 and 1990. In 1992 both types of statistical analysis showed significant increases over 1990 results with the 1993 concentrations abating somewhat. The wet weight averages in 1992 and 1993 were 17.16 ppm and 12.39 ppm, respectively. The increase in 1992 over the 1990 average of 6.90 ppm is consistent with observations of recently discovered PCB releases above RM 194 at the General Electric Company plant sites at Ft. Edward and Hudson Falls and was also consistent with changes in PCB concentrations in other fish species.

The downstream PCB gradient is still evident in the 1992 and 1993 data although it is not as consistent as it was in 1990 and 1988.

Although fall collections of striped bass exhibited significant changes in PCB concentrations between years, a decline is not evident probably due to relatively small sample sizes coupled with highly variable behavioral patterns of the striped bass population in the river. Thermal changes in the river necessary for establishing suitable conditions for overwintering of the fish in the lower estuary (i.e. Haverstraw Bay and Tappan Zee areas) also may alter their movements contributing to variable PCB exposure conditions.

Correlations between size (length) of striped bass and PCB concentrations were significant in only five of the 14 sampling years. Since 1984, only 1990 and 1993 indicated a significant size-PCB relationship. In these years the correlations between length and PCB showed negative association.

Ratios of lower-chlorinated to higher-chlorinated PCB have not changed substantially since 1983 in the spring sampling periods. Differences are evident in the downstream gradient with lower-chlorinated PCB in greater evidence near the Federal Dam at Troy (RM 153) although the higher-chlorinated materials still predominate. In lower portions of the estuary, the higher chlorinated PCB compounds comprise about 85 percent of the total PCB at present.

INTRODUCTION

Since much of the background information is provided or referenced in a previous report (Sloan and Hattala 1991), the purpose of this brief report is to update the database for PCB contamination of Hudson River striped bass without lengthy introduction, discussion and statistical analysis. This paper includes summaries for the years 1992 and 1993 in addition to the trends in PCB levels observed since 1978.

METHODS

Over the years, sampling for striped bass has concentrated on the lower estuary from River Mile 76 (RM 76) near Poughkeepsie, New York south to the George Washington Bridge in New York City at RM 12 (Figure 1). Sampling occurs during April and May, but sometimes as early as March and as late as June, depending upon availability and characteristics of the spring migrations. This reach and season of year comprises the traditional commercial fishery on striped bass, hence the focus on this portion of the fishery. However, striped bass also enter the upper part of the estuary above Catskill and during the summer months are found near the Troy Dam (RM 153). This reach of the river, therefore, is also sampled, although not on a routine basis. Some sampling also now occurs in the fall months in the Haverstraw Bay and Tappan Zee areas (about RM 27 to RM 40).

The principal method for collection entails the use of gill nets operated by several commercial fishermen in pursuit of American shad. Fish are obtained from them by New York State Department of Environmental Conservation (DEC) personnel in the Hudson River Unit of the Bureau of Fisheries, Region 3, New Paltz, New York. In the upper estuary, hook and line and electroshocking methods supplement collection efforts. The traditional minimum size limit is 18 inches (457 mm) total length

(TL). Thus, sampling is confined largely to fish 18 inches total length and greater. Starting in 1987, in order to stratify sampling across a wider array of sizes, 10 percent of the collection effort in the spring in the lower estuary was also to feature striped bass 33 inches or greater TL.

All fish were handled according to standard protocols to maintain chain-of-custody and to ensure sample identity through tagging and completion of collection records. All fish were prepared for shipment to a contract analytical laboratory by the Region 3 New Paltz office of DEC. Frozen standard fillets were shipped priority air express (12 to 24 hour delivery) to Hazleton Laboratories America, Inc. (HLA), Madison, WI for PCB and lipid analyses. Details on analytical methodology utilizing gas chromatographs equipped with electron-capture detectors are described in Sloan and Horn (1986).

In 1992 the environmental analysis portion of HLA was purchased by the newly formed Hazleton Environmental Services, Inc. (HES) which was the successful bidder on the 1993-1996 analytical contract for the Division of Fish and Wildlife. The methodology utilized by HES remains similar to that used by HLA. There was a shift , however, in the inclusion of other PCB mixtures in the characterization of total PCB. Prior to 1992 the emphasis was on three mixtures of PCB to reflect degrees of chlorination as if they represented the Monsanto commercial PCB products of Aroclor 1221, Aroclor 1016, and Aroclor 1254. The spread of PCB congeners represented by these Aroclor mixtures, in

lieu of having congener specific data, ranged from mono-chloro- through hepta-chlorobiphenyl substitutions. Starting with 1992 the chromatograms are quantified on the basis of apparent pattern corresponding to best matches with Aroclors 1016, 1221, 1242, 1248, 1254 or 1260. Since the recent data reported herein still utilize packed column GC-EC methods, the presentation, rather than providing an "Aroclor" estimate, focuses on the spread of PCB homologues or congeners represented as two categories of lesser-chlorinated (fewer chlorines per biphenyl molecule) versus higher-chlorinated (more chlorines per biphenyl molecule) PCB. The least chlorinated forms or Aroclor 1221 were not apparent in the striped bass in 1992 and 1993 and therefore are not part of the PCB totals.

Data analyses for temporal trends are generally restricted to striped bass from the lower estuary (below RM 76) during the months of March through June at total lengths (TL) greater than 416 mm (about 16.5 inches). These restrictions were utilized in an attempt to minimize effects from long-term residency in the river. For example, fish in February may have overwintered in the Hudson River and would be exposed to PCB contamination over a longer period. Above RM 80 the magnitude of contamination was presumably greater and availability of samples was not as reliable. Striped bass less than 416 mm TL may represent younger age classes. Many of these individuals may not have left the river yet as part of the normal life cycle.

RESULTS AND DISCUSSION

Most Recent Sampling Years - 1992 and 1993

PCB Summary Results

Summary results from the most recent collection years, 1992 and 1993, are presented in Tables 1 and 2, respectively. These tables include fall striped bass samples as well as those collected in the spring spawning months.

In 1992 and for the first time, the spring collections from Poughkeepsie and on downstream through the George Washington Bridge averaged less than 2 ppm (Table 1). The 144 fish sampled in 1992 produced a mean concentration of 1.81 ppm ranging from 0.23 ppm to 26.5 ppm on a wet weight basis in standard fillets. Some locations, the Croton Point and Tappan Zee areas, during April averaged greater than 2 ppm at 3.25 ppm and 2.31 ppm, respectively. Fish from the Catskill and Albany/Troy areas were considerably higher on average at 3.29 ppm and 17.16 ppm, respectively. Likewise, fall collections from the fishery in the Haverstraw Bay and Tappan Zee locations were also higher in PCB levels than the spring samples at 5.70 ppm.

In the 1993 spring collection from the lower estuary the concentrations rose above what they were in 1992 and averaged 2.32 ppm in 124 fish (Table 2). Values for total PCB on a wet weight basis ranged from 0.42 ppm to 25.2 ppm. Upstream samples, at Catskill and Troy, were also higher averaging 3.74 ppm and

12.39 ppm, respectively. Similarly, fall 1993 samples from the Haverstraw Bay area were higher than they were for spring samples and averaged 3.61 ppm.

Results from other years are summarized in earlier reports (e.g. Sloan and Hattala 1991).

PCB Decreases with Distance Downstream

The existence of the downstream PCB gradient in spring samples, although not as pronounced or as consistent as it was in 1990, was still evident for 1992 and 1993 in that average concentrations generally decrease with distance downstream (Table 3). As indicated in Sloan and Hattala (1990), the influence and proximity to presumed source conditions is still apparent. A simplified presentation of this gradient for striped bass collected in 1992 and 1993 shows that the highest averages for the two years occurred at Albany/Troy (17.16 ppm and 12.39 ppm, respectively) and average concentrations generally decline from there through the estuary reaching 1.31 ppm at the George Washington Bridge, RM 12, for both years.

PCB Comparisons between Years

As in previous years, samples of striped bass were evaluated for statistical normality by calculating coefficients of skewness and kurtosis. Log_{10}-transformations of data have proven useful in reducing skewness and kurtosis (Sloan and Hattala 1991, Sloan et al. 1988, 1991). Transformations, therefore, were also applied to

the 1992 and 1993 data. The results on the effect of transformations and presentation of data on a lipid basis toward producing normally distributed data are presented in Table 4 comparing skewness and kurtosis coefficients calculated from transformed (geometric) versus untransformed (arithmetic) data. As these coefficients approach zero, a better approximation of the normal distribution is achieved.

The principal reason for attempting to approximate the normal distribution is so that the statistical analyses conducted are sufficiently powerful to discern real differences between groups. In the case of the striped bass, it is desirable to determine whether or not there are reliable significant differences between years of collections. On the other hand, the untransformed data more closely represent the actual dosages to which a consumer is exposed. Transformed data are not used in developing health risk assessments by the New York State Department of Health since they do not reflect contaminant dosage and exposure. Therefore, it is necessary to analyze the data under several regimes, and the reader is cautioned in interpreting the transformed (geometric) means.

Expressing the data as PCB concentrations in the fat or lipid material may also reduce variability. Since PCB is lipophilic, presumably there should be a strong positive association between PCB concentrations and fat (lipid) content. For migratory species such as striped bass, however, the correlation may not be particularly strong (Sloan and Armstrong

1988, Armstrong and Sloan 1988). Indeed, the correlations between PCB and lipid content have not been consistent across years (Table 5). Of the 14 data-years, five were not significantly correlated ($P > 0.05$). A basic transformation to a lipid based concentration also does not improve coefficients for skewness and kurtosis (Table 4). Based on the skewness and kurtosis coefficients, a lipid-based $\log_{10}$-transformation provided the best approximation to a normal distribution of the various methods used to express PCB in striped bass. Hence, in order to simplify the presentation in this update on PCB contamination , only two separate analyses are presented: 1) wet weight untransformed (arithmetic), and 2) lipid-based $\log_{10}$-transformed data. Earlier reports had included $\log_{10}$-transformed wet weight (geometric) and lipid-based untransformed analyses (Sloan and Hattala 1991).

In the 14 years of monitoring PCB in striped bass, only three years produced significant positive correlations between length and PCB concentrations for the spring collections from the lower estuary. Like most years, the correlations in 1992 were not significant whether data were transformed or untransformed (Table 5). In 1993, as in 1990, however, the relationship between length and PCB was significantly negatively correlated meaning that the larger size fish tended to have lower PCB concentrations.

Since striped bass monitoring focused on the spring fishery, particularly in the lower estuary (below RM 80), the evaluation of trend information principally features this spatial aspect for the 16-year period (1978-1993). Table 5 provides an overview of

the response by spring collected striped bass from the lower estuary to the PCB contamination of the Hudson River with respect to time.

Spring Lower Estuary (below Poughkeepsie)

Total PCB -untransformed and log_{10}-transformed lipid-based

Since the correlations between length and total PCB were not significant for most years, the trend information and summary data (Table 5) include some sub-legal sized striped bass (i.e. fish < 18 inches TL). However, in some years, exceptionally small fish were collected and since these animals could be resident in the river at these ages and sizes, a cutoff for the trend analyses of 416 mm total length (16.4 inches) minimum was used. Table 5 provides the specific correlation coefficients between length and PCB content for each year.

Analysis of variance exhibited significant differences between years for PCB in spring collected striped bass from the lower estuary (below RM 76) on a wet weight basis (Table 6). Declines were significant with 1978 having the highest average concentration. Multiple comparisons among the means (Table 7), and plots of the 95 percent confidence intervals (Figure 2), however, reflect statistically insignificant declines since 1986. Of interest though, note that 1992 levels were lower than they were in 1990 on the average. For the first time since this particular striped bass PCB monitoring project began (1978), average values in the lower estuary spring fishery were less than 2 ppm. Unfortunately, the average concentration rose again above

2 ppm to 2.34 ppm in 1993.

Analysis of the $\log_{10}$-transformed lipid-based data provides a similar (Table 6), but slightly different perspective. Concentrations generally declined from 1978 through 1986 but then increased from 1986 to 1987 (Table 7). Values dropped again the following year (1988) to the 1986 level and in the next three data years the average remained virtually unchanged (Figure 3) ranging between 32.4 ppm and 35.15 ppm in the lipid.

Composition changes

In the lower estuary for the spring collection, the composition of lower chlorinated versus higher chlorinated PCB shifted from nearly a 1:1 ratio to less than 0.2:1 by 1983 (Table 8). Since then, any additional shifts were relatively minor and for the most part the PCB concentrations observed were composed of 80 percent to 85 percent higher chlorinated congeners of PCB (Table 9, Figure 4).

Interestingly, in 1992 and 1993 with a change in the contract analytical laboratory, the PCB characterization for striped bass shifted from an Aroclor 1016 and Aroclor 1242 estimate for the lower chlorinated form of PCB to Aroclor 1248. Similarly, the former Aroclor 1254 representation for the higher chlorinated PCB shifted to an Aroclor 1254/Aroclor 1260 combination. To better evaluate this analytical change in how chemical composition is characterized, an evaluation of selected chromatograms across all the years is warranted. How this review

could be accommodated and what information and insights with respect to the temporal and spatial variation it might provide is largely speculative at the moment. However, there should be more than a passing academic interest since it might allow a better estimation for the rate of the river's recovery from the contamination caused by PCB.

Changes at Albany/Troy

Total PCB

Changes in total PCB on a wet weight basis were apparent in the span of years from 1984 to 1993 (Table 10). However, a clear trend is not inherent in the data since, for example, the 1992 and 1985 samples do not differ in total PCB content (Table 11, Figure 5).

Expressing the data on a $\log_{10}$-transformed lipid-based scale did provide some clarity with the highest averages for 1992 and 1993 being significantly ($P < 0.05$) different from the low average years of 1984, 1987 and 1988 (Tables 10 and 11, Figure 6). Unfortunately, the evidence would indicate increases in PCB rather than decreases. Increases between 1990 and 1992/1993 are consistent with analyses of resident species where 2.5 to 3-fold increases were seen between 1991 and 1992 in the Albany/Troy area and at several locations above the Federal Dam at Troy to the Thompson Island pool located below the Village of Ft. Edward (Sloan, unpublished data).

Composition changes

The influence of the source condition(s) is perhaps most noticeable by the changes in composition from one year or group of years compared to another year. In 1992 the ratio of lower- to higher-chlorinated PCB reached its maximum average since 1984 at 0.87. It dropped in 1993 to 0.60 but that average is still significantly above ($P < 0.05$) the 0.38 observed in 1986 (Tables 12 and 13, Figure 7). The expected data from the 1994 sampling at the Albany/Troy location, since it is closest to the major source areas as they are now known (O'Brien & Gere 1994a and 1994b, TAMS and Gradient 1991, 1992) are of interest to determine if control activities in 1993 at PCB sources in Ft. Edward and Hudson Falls were effective and to what degree.

Fall Haverstraw Bay/Tappan Zee

Total PCB

Fall collections which began in 1984 on a more systematic basis for the overwintering area of Haverstraw Bay and the Tappan Zee reached a hiatus in 1985 when they averaged 9.66 ppm. This was an increase over levels in 1984 when the striped bass averaged 2.42 ppm. Since 1985 there were declines on a wet weight basis but the concentrations on average never returned to the 1984 level (Tables 14 and 15, Figure 8). In 1992 and 1993, the fall averages were 5.70 ppm and 3.61 ppm, respectively.

For $\log_{10}$-transformed lipid-based concentrations, there was also an increase in 1985. Since then average values have remained

above or are at least comparable (e.g. 1987) to the 1984 low (Tables 14 and 15, Figure 9). At the least the concentrations have not increased appreciably since 1987.

Composition changes

On the other hand, the ratio between lower-chlorinated versus higher-chlorinated forms of PCB significantly shifted ($P < 0.05$) (Tables 16 and 17, Figure 10) toward the lesser chlorinated forms of PCB. In 1984 the average ratio was 0.13 but in 1990 the average increased to 0.29. Since that year the ratio has decreased to about 0.20. Changes in the ratio implies that bioaccumulation source conditions in the river have changed through the years and since the lesser-chlorinated forms are more sensitive to environmental alterations and are less persistent the ratio should mirror short-term perturbations in bioavailability.

PCB Comparisons between Rivermiles (1986,90,92,93)

In presenting information on the downstream gradients (i.e. by rivermiles), the format is changed from discussing results on total PCB and compositions as separate items in each topic. Rather, they will be presented within the context of pattern similarities among four selected data years - 1986, 1990, 1992 and 1993. These years were chosen for illustration to put temporal bounds around specific events or periods. The year 1986 was at a time of relative stability of PCB in the Hudson River

system in that concentrations were not reflecting major saltatory perturbations (See Figure 2.). In both 1988 and 1990, a smooth continuum in the spring data was noted (Sloan and Hattala 1991) and the gradient was consistent across collection periods and locations. For this analysis 1990 was specifically selected since it preceded the major apparent documented PCB release(s) from the Hudson Falls plant site (O'Brien & Gere 1994a). Two data years, 1992 and 1993, for PCB in striped bass were subsequent to the PCB releases to the river as recorded via the General Electric Company water monitoring data.

For these four selected years, all 12 analyses of variance were significant which like the analyses presented earlier in this report included wet weight total PCB, $\log_{10}$-transformed lipid-based total PCB, and composition ratios of lesser-:higher-chlorinated PCB (Tables 18, 19 and 20, respectively). Mean comparisons between rivermiles (Tables 21, 22 and 23) and the graphs associated with them (Figures 11, 12 and 13) have a similar pattern in that they have the appearance of a first order or exponential decline with distance downstream. Although there are some notable exceptions to this pattern, overall it is remarkably consistent with the furthest upstream point (Albany/Troy) being always higher on average than the downstream locations.

For 1986 the composition ratios are not as straightforward and consistent as they were in later years, but the ratios were at a minimum or near minimum that year and any shift in

composition at any rivermile (RM) location would result in divergence from the overall pattern. The small sample size of eight fish at RM 91 may also have contributed to discrepancies for total PCB and composition assessments.

For 1990, composition provided a consistent pattern over distance. Discontinuities in the total PCB averages over the gradient were not of statistical significance. Likewise, breaks in the continua were not significant ($P > 0.05$) in 1992 for the total PCB averages and composition. For 1993, the composition gradient was again consistent. Breaks in the gradient for the two types of total PCB averages were not significant ($P > 0.05$).

PCB Comparisons between Seasons (1992/1993 combined)

Total PCB concentrations on a wet weight basis did differ significantly ($P < 0.05$) between months as did the $\log_{10}$-transformed lipid-based data (Table 24). November collected fish from the lower portion of the estuary (i.e. below RM 70 and corresponding to the collection locations for the fall sampling efforts) had the highest average concentrations (Table 25). If the data were examined as spring versus fall there does not appear to be a clear distinction (Figures 14a and 14b).

There was a significant shift in the composition of PCB as shown by the ratio of lower to higher-chlorinated PCB in the spring months (April and May) compared to November (Tables 24 and 25). The spring collected fish did not differ from those in December (Figure 14c).

In other years differences between months were also apparent (Sloan and Hattala 1991) which were thought to reflect on behavioral aspects of the fish related to changes in exposure regimes and environmental (thermal) conditions for overwintering in the Haverstraw Bay/Tappan Zee area. In the 1992 and 1993 monthly comparisons, the November samples may represent striped bass that moved downstream from upstream locations where they would have had opportunity to accumulate proportionally more of the lesser chlorinated types of PCB as is reflected in the ratio of 0.23 versus the April and May ratios of 0.13 and 0.12, respectively. In December, these fish may be coming into the estuary from other coastal locations to overwinter. Hence, they are afforded the opportunity to accumulate relatively more of the higher-chlorinated forms of PCB. They then mix with fish from upstream areas that summered in the river or spent time in several locales (i.e. the December fish experienced variable exposure regimes.).

In Closing

With the finding and better elucidation of source conditions and their eventual remediation or elimination, it is presumed that a reduction of PCB impact on the fishery resource, including striped bass, will occur. Since a number of actions have occurred in recent months at the GE capacitor plant sites at Hudson Falls and Ft. Edward, the interpretation of the 1994 striped bass and the other long-term trend species from 1993 and 1994 is eagerly

anticipated. The inclusion of these results will continue to shed light on the issues associated with ongoing source conditions. For the moment, one can only suppose that conditions observed in the striped bass are related in some manner to ongoing inputs to the system from upstream location(s).

CONCLUSIONS

For the spring striped bass collections in the lower Hudson River estuary significant declines in PCB contamination have occurred. In recent years, however, the concentrations have stabilized especially when levels are expressed on $\log_{10}$-transformed lipid basis. PCB concentrations in the 1993 striped bass samples on a wet weight basis averaged above 2 ppm regardless of season and location of collection. Some samples by month and location in the lower reaches did average less than 2 ppm.

The lesser chlorinated component, although diminished in magnitude, is still present and does bioaccumulate, particularly the further upstream the fish occur. This aspect of the contamination is most likely indicative of greater source conditions being more readily manifested due to their closer proximity.

As in previous years and consistent with other species, a downstream gradient of PCB concentrations in the flesh of striped bass is apparent. Concentrations were highest in striped bass from the Troy area. Concentrations at Troy increased in 1992 and 1993 compared to 1990 in the same fashion as did resident species between 1991 and 1992.

Evaluation of upcoming results on 1994 striped bass collections and resident long-term trend monitoring species are critical in determining the river's future particularly in light

of upriver source(s) issues and the ongoing USEPA Superfund Reassessment.

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In keeping with the brevity of this report, acknowledgements contained in earlier Hudson River PCB reports are pertinent to this document. Most appreciated, however, was the understanding shown by all interested parties who patiently awaited this release. Lawrence Skinner provided a timely review of the draft document.

This report is dedicated to my son, Mack, for sacrificing his 4th of July weekend to compile the figures.

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Table 1. PCB concentrations in striped bass from the Hudson River in 1992.

Location	Month Collected	No. of Fish	Length (mm) Ave.	Length (mm) Min.-Max.	Weight (g) Ave.	Weight (g) Min.-Max.	Lipid (%) Ave.	Lipid (%) Min.-Max.	Lower-Cl (ppm) Ave.	Lower-Cl (ppm) Min.-Max.	Higher-Cl (ppm) Ave.	Higher-Cl (ppm) Min.-Max.	Total PCB (ppm) Ave.	Total PCB (ppm) Min.-Max.
Albany/Troy (RM 153)	June	10	644	497 - 789	3224	1700 - 5340	5.57	2.37 - 9.47	7.46	3.50 -11.00	9.74	4.62-16.50	17.16	8.66 -24.70
Catskill (RM 112)	May	20	653	480 - 948	3833	1150 -10,900	2.85	0.96 - 8.98	0.74	<0.05 - 4.10	2.54	0.24-10.50	3.29	0.26 -14.60
Poughkeepsie (RM 76)	April	20	609	550 - 750	2546	1720 - 4700	4.13	1.56 - 8.22	0.31	<0.05 - 2.20	1.60	0.30- 5.13	1.91	0.32 - 6.81
	May	20	625	537 - 790	2803	1720 - 5240	4.36	1.30 -12.90	0.40	<0.05 - 0.95	1.17	0.46- 2.72	1.57	0.66 - 3.69
	All Dates	40	616	537 - 790	2676	1720 - 5240	4.24	1.30 -12.90	0.35	<0.05 - 2.20	1.38	0.30- 5.13	1.74	0.32 - 6.82
Croton Pt. (RM 40)	April	21	636	521 - 885	3157	1620 - 7660	5.50	1.82 - 7.79	0.48	<0.05 - 4.80	2.83	0.84-21.70	3.31	0.86 -26.50
	May	22	660	525 - 918	3389	1880 - 8840	3.71	0.72 - 6.58	0.13	<0.05 - 0.39	0.74	0.18- 1.32	0.87	0.23 - 1.60
	All Dates	43	649	521 - 918	3273	1620 - 8840	4.59	0.72 - 7.79	0.30	<0.05 - 4.80	1.76	0.18-21.70	2.06	0.23 -26.50
Tappan Zee Bridge (RM 27)	April	20	654	504 - 996	3710	1360 - 8620	5.57	1.15 -11.00	0.26	<0.05 - 2.00	2.06	0.54- 9.40	2.31	0.56 -10.15
	May	21	653	536 - 902	3255	1600 - 9080	4.67	1.36 - 8.89	0.04	<0.05 - 0.24	1.52	0.82- 3.36	1.56	0.85 - 3.38
	All Dates	41	653	504 - 902	3477	1360 - 9080	5.11	1.15 -11.00	0.15	<0.05 - 2.00	1.78	0.54- 9.40	1.93	0.56 -10.15
George Washington Bridge(RM12)	April	20	670	554 - 970	3496	1980 - 7820	4.74	1.30 -10.00	0.11	<0.05 - 0.85	1.21	0.50- 3.27	1.32	0.54 - 4.12
Lower Estuary (RM 12-76)	Spring	144	644	504 - 970	3195	1360 - 9080	4.66	0.72 -12.90	0.25	<0.05 - 4.80	1.58	0.18-21.70	1.83	0.23 -26.50
Haverstraw Bay/Tappan Zee(RM27-33)	November	26	636	525 - 790	3165	1480 - 6520	5.23	1.06 -10.30	1.39	<0.05 -11.00	4.93	0.43-31.00	6.32	0.49 -38.50
	December	7	626	521 - 720	2540	1460 - 3620	4.50	2.73 - 7.97	1.18	<0.05 - 7.70	2.21	0.27-10.90	3.39	0.29 -18.60
	All Dates	33	634	634 - 790	3054	1460 - 6520	5.07	1.06 -10.30	1.35	<0.05 -11.00	4.36	0.27-31.00	5.70	0.29 -38.50

Table 2. PCB concentrations in striped bass from the Hudson River in 1993.

Location	Month Collected	No. of Fish	Length (mm) Ave.	Length (mm) Min.-Max.	Weight (g) Ave.	Weight (g) Min.-Max.	Lipid (%) Ave.	Lipid (%) Min.-Max.	Lower-Cl (ppm) Ave.	Lower-Cl (ppm) Min.-Max.	Higher-Cl (ppm) Ave.	Higher-Cl (ppm) Min.-Max.	Total PCB (ppm) Ave.	Total PCB (ppm) Min.-Max.
Albany/Troy	June	7	734	576 - 819	4486	1860 - 6760	4.04	0.97 - 8.61	3.57	1.20 - 6.00	9.41	3.18-14.80	12.99	4.38 -18.10
(RM 153)	July	1	652	--	3090	--	8.17	--	6.40	--	6.22	--	12.62	--
	October	10	625	535 - 697	2850	1820 - 3940	5.99	3.60 - 8.84	4.63	1.30 - 6.40	7.32	2.72-16.00	11.95	4.02 -21.80
	All Dates	18	669	535 - 819	3494	1820 - 1760	5.35	0.97 - 8.84	4.32	1.20 - 6.40	8.07	2.72-16.00	12.39	4.82 -21.80
Catskill (RM 112)	May	20	731	519 - 999	4756	1240 -11,460	3.66	0.94 - 6.28	0.94	0.22 - 3.10	2.79	0.58- 5.20	3.74	0.80 - 8.10
Poughkeepsie	April	17	730	608 -1117	4849	2560 -17,900	4.64	1.27 - 8.83	0.39	<0.05 - 1.10	1.62	0.89- 3.40	2.00	0.92 - 4.15
(RM 76)	May	28	680	580 - 836	3526	2240 - 6040	5.35	1.16 - 8.27	0.82	<0.05 - 6.20	3.02	0.64-21.20	3.84	0.66 -25.10
	All Dates	45	699	580 -1117	4037	1720 -17,900	5.09	1.16 - 8.83	0.66	<0.05 - 6.20	2.49	0.64-21.20	3.14	0.66 -25.10
Croton Pt. (RM 40)	April	20	643	553 - 960	3179	1960 - 9960	5.44	1.39 - 8.07	0.21	<0.05 - 0.49	1.38	0.60- 2.16	1.59	0.70 - 2.38
Tappan Zee	April	20	643	536 - 923	3417	1880 - 9600	5.81	3.25 - 9.15	0.82	<0.05 -11.00	2.29	0.61-11.30	3.11	0.64 -22.30
Bridge	May	26	697	530 - 912	3938	1740 - 9040	5.08	3.55 - 7.48	0.15	<0.05 - 0.75	1.30	0.39- 3.90	1.46	0.42 - 4.65
(RM 27)	All Dates	46	674	530 - 923	3712	1740 - 9600	5.40	3.25 - 9.15	0.44	<0.05 -11.00	1.73	0.39-11.30	2.18	0.42 -22.30
George Washington Bridge(RM12)	May	13	766	556 -1004	5455	1760 - 9530	5.43	2.18 - 8.62	0.19	<0.05 - 1.10	1.13	0.49- 4.08	1.32	0.52 - 5.15
Lower Estuary (RM 12-76)	Spring	124	687	530 -1117	3913	1740 -17,900	5.29	1.16 - 9.15	0.46	<0.05 -11.00	1.89	0.39-21.20	2.34	0.42 -25.10
Haverstraw	October													
Bay/Tappan	November	30	693	521 - 820	4085	1600 - 9200	7.40	3.54 -15.70	1.00	<0.05 - 7.40	3.23	0.65-20.20	4.23	0.68 -26.20
Zee(RM27-33)	December	30	710	624 - 856	3934	2740 - 6860	5.72	1.58 - 8.43	0.48	<0.05 - 4.70	2.51	0.46-18.40	3.00	0.54 -23.10
	All Dates	60		521 - 856		1600 - 6860		1.58 -15.70		<0.05 - 7.40		0.46-20.20		0.54 -26.20

Table 3. Average concentrations of PCB (ppm - wet weight basis) in striped bass collected in the spring of 1992 and 1993 from several rivermile (RM) locations in the Hudson River.

Location	1992 - Total PCB (ppm)				1993 - Total PCB (ppm)			
	No. of fish	Ave.	Min.	Max.	No. of fish	Ave.	Min.	Max.
Albany/Troy* RM 153	10	17.16	8.66	24.70	18	12.39	4.82	21.80
Catskill RM 112	20	3.29	0.26	14.60	20	3.74	0.80	8.10
Poughkeepsie RM 76	40	1.74	0.32	6.82	45	3.14	0.66	25.10
Croton Pt. RM 40	43	2.06	0.23	26.50	20	1.59	0.70	2.38
Tappan Zee Bridge RM 27	41	1.93	0.56	10.15	46	2.18	0.42	22.30
George Wash. Bridge RM12	20	1.32	0.54	4.12	13	1.32	0.52	5.18

* Striped bass are usually not available in this section of the Hudson River until late spring or early summer.

Table 4. Influence of several transformations and expressions of data on skewness and kurtosis coefficients for total PCB concentrations in spring collected striped bass (1978-1993) in the lower Hudson River estuary. Underlined values indicate a significant ($P < 0.05$) departure from data indicative of a normal distribution.

	Skewness				Kurtosis			
	Arithmetic		Geometric		Arithmetic		Geometric	
Year	wet weight	lipid based	wet weight	lipid based	wet weight	lipid based	wet weight	lipid based
1978	4.6	4.7	1.4	0.87	25.8	28.7	2.21	0.59
1979	0.80	1.6	0.28	0.87	-0.44	1.42	-1.24	.0001
1980	3.6	1.9	0.72	-0.82	15.7	5.28	1.14	0.43
1981	3.0	3.2	0.67	0.16	11.2	14.2	0.15	-0.28
1982	2.8	6.3	1.1	0.61	7.5	53.4	0.89	0 63
1983	3.8	2.2	1.3	0.30	17.6	6.3	2.3	-0.35
1984	4.7	2.9	1.5	0.41	27.5	9.9	3.6	0.09
1985	3.1	2.1	1.2	0.21	11.0	5.6	1.6	-0.41
1986	3.6	2.9	1.2	0.43	16.7	9.2	1.7	0.17
1987	3.4	2.1	1.3	0.14	12.4	4.8	2.3	-0.17
1988	2.9	3.7	1.1	0.55	9.3	17.3	1.1	0.47
1990	2.9	2.7	1.1	0.52	10.1	9.1	1.0	-0.07
1992	7.2	6.5	2.1	1.0	64.8	57.3	7.3	2.1
1993	5.5	6.4	1.1	1.2	33.8	50.0	3.0	3.1

Table 6. Analyses of variance for untransformed wet weight based and log_{10}-transformed lipid-based total PCB in spring collected striped bass from the lower Hudson River estuary (below RM 80) for 1978-1993.

Source of Variation	Sum of squares	d.f.	Mean square	F-ratio	Observed Significance Level
Untransformed wet weight					
Between years	63624.5	13	4894.2	33.1	<0.001
Within years	347030.1	2346	147.9		
Total (corrected)	410654.6	2359			
Log_{10}-transformed lipid-based					
Between years	138.5	13	10.65	81.2	<0.001
Within years	307.9	2347	0.13		
Total (corrected)	446.4	2360			

Table 5. PCB concentrations and correlations with length and lipid for Hudson River striped bass taken in the spring from the lower estuary (RM 76-12). The 95% CL refers to 95% confidence limits from analyses of variance conducted across all years (1978 - 1993).

	1978	1979	1980	1981	1982	1983	1984
Number of fish	375	14	185	164	153	137	167
Average length(mm)	587	456	545	523	544	570	577
Total PCB (ppm)							
Mean	18.05	5.17	6.08	4.65	5.54	4.91	4.72
95% CL	16.82 - 19.28	-1.21-11.54	4.33 - 7.83	2.79 - 6.51	3.62-7.47	2.87 - 6.95	2.87 - 6.56
Geometric mean	11.62	4.63	4.28	3.10	3.68	4.08	3.69
95% CL	10.85 - 13.44	3.07 - 6.78	3.83 - 4.77	2.73 - 3.51	3.24 - 4.16	3.58 - 4.63	3.27 - 4.15
Higher Cl-ed PCB[a]							
Mean	7.70	3.96	4.26	3.45	4.10	4.10	3.84
95% CL	7.16 - 8.23	1.18 - 6.75	3.50 - 5.03	2.63 - 4.26	3.26 - 4.95	3.21 - 4.99	3.03 - 4.64
Geometric mean	5.44	3.56	3.10	2.46	2.86	3.44	3.11
95% CL	5.08 - 5.82	2.39 - 5.14	2.78 - 3.45	2.17 - 2.77	2.53 - 3.22	3.04 - 3.88	2.77 - 3.47
Lower Cl-ed PCB[b]							
Mean	9.64	1.20	1.69	1.07	1.19	0.73	0.88
95% CL	8.88 - 10.39	-2.70 - 5.11	0.61 - 2.76	-0.07 - 2.21	0.01 - 2.37	-0.52 - 1.98	-0.25 - 2.01
Geometric mean	5.43	1.10	1.11	0.68	0.75	0.61	0.65
95% CL	5.11 - 5.76	0.62 - 1.73	0.97 - 1.27	0.56 - 0.81	0.62 - 0.90	0.48 - 0.75	0.53 - 0.78
Correlation between length and PCB							
-arithmetic	0.08[ns]	-0.32[ns]	0.11[ns]	0.42[**]	0.37[**]	-0.07[ns]	0.26[**]
-geometric	0.07[ns]	-0.42[ns]	0.07[ns]	0.53[**]	0.39[**]	-0.03[ns]	0.25[**]
Correlation between lipid and PCB							
-arithmetic	0.09[ns]	0.13[ns]	0.21[**]	0.56[**]	0.34[**]	0.05[ns]	0.17[*]
-geometric	0.09[ns]	0.25[ns]	0.15[**]	0.60[**]	0.40[**]	0.02[ns]	0.18[*]
Lipid-based total PCB							
mean	269.8	101.1	160.5	162.5	118.3	73.9	89.3
95% CL	250.6 - 289.1	1.54 - 200.8	133.1 - 187.9	133.4 - 191.6	88.2-148.4	42.1 - 105.8	60.5 - 118.1
geometric mean	160.2	87.0	107.3	111.1	76.1	55.6	66.2
95% CL	147.2 - 174.3	56.2 - 134.7	95.1 - 121.0	97.8 - 126.2	66.7 - 86.8	48.4 - 64.0	58.4 - 75.2

Table 5. (cont.)

	1985	1986	1987	1988	1990	1992	1993
Number of fish	213	204	147	170	164	144	124
Average length(mm)	599	614	640	667	667	644	687
Total PCB (ppm)							
Mean	4.60	3.93	3.61	3.97	2.77	1.84	2.34
95% CL	2.96 - 6.23	2.26 - 5.60	1.64 - 5.58	2.14 - 5.80	0.90-4.63	-0.16 - 3.83	0.20 - 4.49
Geometric mean	3.59	3.07	2.79	3.04	2.15	1.47	1.84
95% CL	3.23 - 3.99	2.74 - 3.43	2.43 - 3.19	2.68 - 3.44	1.86 - 2.46	1.23 - 1.73	1.55 - 2.17
Higher Cl-ed PCB[a]							
Mean	3.74	3.34	2.97	3.41	2.31	1.58	1.89
95% CL	3.03 - 4.46	2.61 - 4.07	2.11 - 3.82	2.61 - 4.20	1.50 - 3.12	0.72 - 2.45	0.95 - 2.82
Geometric mean	3.03	2.67	2.35	2.69	1.84	1.30	1.57
95% CL	2.74 - 3.35	2.39 - 2.96	2.05 - 2.67	2.39 - 3.02	1.61 - 2.10	1.10 - 1.52	1.32 - 1.84
Lower Cl-ed PCB[b]							
Mean	0.83	0.57	0.64	0.56	0.45	0.25	0.46
95% CL	-0.17 - 1.83	-0.45 - 1.60	-0.56 - 1.85	-0.56 - 1.68	-0.69- 1.59	-0.97 - 1.46	-0.86 - 1.77
Geometric mean	0.61	0.44	0.52	0.44	0.37	0.19	0.32
95% CL	0.54 - 0.73	0.35 - 0.54	0.40 - 0.65	0.34 - 0.55	0.27 - 0.48	0.10 - 0.29	0.21 - 0.44
Correlation between length and PCB							
-arithmetic	0.02[ns]	0.04[ns]	- 0.01[ns]	0.06[ns]	-0.16[*]	0.12[ns]	-0.09[ns]
-geometric	0.03[ns]	0.09[ns]	- 0.03[ns]	0.06[ns]	-0.22[**]	0.11[ns]	-0.22[*]
Correlation between lipid and PCB							
-arithmetic	0.15[*]	-0.05[ns]	0.29[**]	0.10[ns]	0.18[*]	0.28[**]	0.19[*]
-geometric	0.11[ns]	-0.05[ns]	0.26[**]	0.12[ns]	0.22[**]	0.52[**]	0.21[*]
Lipid-based total PCB							
mean	74.6	53.7	65.9	57.1	51.1	41.2	49.4
95% CL	49.1 - 100.2	27.6 - 79.8	35.1 - 96.6	28.5 - 85.7	22.0- 80.2	10.2 - 72.3	16.0 - 82.9
geometric mean	55.0	36.5	47.3	36.4	35.2	32.4	34.3
95% CL	49.1 - 61.5	32.5 - 40.9	41.3 - 54.1	32.2 - 41.3	30.9 - 39.9	28.3 - 37.1	29.6 - 39.7

[ns] -- not significant (P > 0.05)
[*] -- P < 0.05
[**] -- P < 0.01
[a] Represents more highly chlorinated types of PCB (penta-, hexa- and higher-chlorinated forms).
[b] Represents lesser chlorinated types of PCB, principally tri- and tetrachlorinated biphenyls.

Table 7. Comparisons among means of years for untransformed wet weight- and log_{10}-transformed lipid-based total PCB concentrations in striped bass collected in the spring from the lower Hudson River estuary (below RM 80) from 1978-1993 at $\alpha = 0.05$.

Year	N	Mean	95% Confidence Interval	Group Comparisons
Untransformed (Arithmetic)				
1992	143	1.84	-0.16 - 3.83	X
1993	124	2.34	0.20 - 4.49	XX
1990	164	2.77	0.90 - 4.63	XX
1987	147	3.61	1.64 - 5.58	XXX
1986	204	3.93	2.26 - 5.60	XXX
1988	170	3.97	2.14 - 5.80	XXX
1985	213	4.60	2.96 - 6.23	XX
1981	164	4.65	2.79 - 6.51	XX
1984	167	4.72	2.87 - 6.56	XX
1983	137	4.91	2.87 - 6.95	XX
1979	14	5.17	-1.20 -11.54	XXX
1982	153	5.54	3.62 - 7.47	X
1980	185	6.08	4.33 - 7.83	X
1978	375	18.05	16.82 -19.28	X
Log_{10}-transformed lipid-based (Geometric)				
1992	144	32.4	28.3 - 37.1	X
1993	124	34.3	29.6 - 39.7	X
1990	164	35.2	30.9 - 39.9	X
1988	170	36.4	32.2 - 41.3	X
1986	204	36.5	32.5 - 40.9	X
1987	147	47.3	41.3 - 54.1	X
1985	213	55.0	49.1 - 61.5	X
1983	137	55.6	48.4 - 64.0	XX
1984	167	66.2	58.4 - 75.2	XX
1982	153	76.1	66.7 - 86.8	X
1979	14	87.0	56.2 -134.7	XXX
1980	185	107.3	95.1 -121.0	X
1981	164	111.1	97.8 -126.2	X
1978	375	160.2	147.2 -174.3	X

Table 8. Analyses of variance for lower- : higher-chlorinated PCB ratios in spring collected striped bass from the lower Hudson River estuary (below RM 80) for 1978-1993.

Source of Variation	Sum of squares	d.f.	Mean square	F-ratio	Observed Significance Level
Between years	241.79	13	18.60	287.5	<0.001
Within years	151.76	2346	0.065		
Total (corrected)	393.55	2359			

Table 9. Comparisons among means of years for lower- : higher-chlorinated PCB ratios in spring collected striped bass from the lower Hudson River estuary (below RM 80) from 1978-1993 at $\alpha = 0.05$.

Year	N	Mean Ratio	95% Confidence Interval	Group Comparisons
1988	170	0.13	0.10 - 0.17	X
1992	143	0.14	0.10 - 0.19	XX
1990	164	0.17	0.13 - 0.21	XX
1986	204	0.17	0.13 - 0.20	XX
1983	137	0.17	0.13 - 0.21	XXX
1993	124	0.18	0.14 - 0.23	XXXX
1985	213	0.18	0.15 - 0.22	XXXX
1984	167	0.20	0.16 - 0.24	XXX
1987	147	0.20	0.16 - 0.24	XXXX
1982	153	0.23	0.19 - 0.27	XX
1981	164	0.25	0.21 - 0.29	X
1979	14	0.31	0.18 - 0.44	XXXX
1980	185	0.36	0.33 - 0.40	X
1978	375	1.06	1.04 - 1.09	X

Table 10. Analyses of variance for untransformed wet weight based and log_{10}-transformed lipid-based total PCB in striped bass collected from the Hudson River at Albany/Troy (RM 153) for 1984-1993.

Source of Variation	Sum of squares	d.f.	Mean square	F-ratio	Observed Significance Level
Untransformed wet weight					
Between years	2170.6	7	310.1	5.8	<0.001
Within years	7119.9	133	53.5		
Total (corrected)	9290.4	140			
Log_{10}-transformed lipid-based					
Between years	3.77	7	0.539	5.32	<0.001
Within years	13.47	133	0.101		
Total (corrected)	17.25	140			

Table 11. Comparisons among means of years for untransformed wet weight- and log_{10}-transformed lipid-based total PCB concentrations in striped bass collected from Albany/Troy in the Hudson River (RM 153) from 1984-1993 at $\alpha = 0.05$.

Year	N	Mean	95% Confidence Interval	Group Comparisons
Untransformed (Arithmetic)				
1990	13	6.90	2.89 -10.92	X
1984	6	8.60	2.69 -14.51	XX
1987	30	10.03	7.39 -12.67	XX
1988	8	10.32	5.20 -15.44	XXX
1993	18	12.39	8.98 -15.80	XXX
1986	36	16.40	13.99 -18.82	XX
1992	10	17.16	12.58 -21.73	XXX
1985	20	18.80	15.57 -22.04	X
Log_{10}-transformed lipid-based (Geometric)				
1984	6	93.8	51.9 -169.6	X
1987	30	97.6	74.9 -127.1	XX
1988	8	99.8	59.8 -166.6	XXX
1990	13	116.0	77.6 -173.4	XXXX
1986	36	144.8	113.7 -184.4	X XX
1985	20	191.8	138.7 -265.2	XX
1993	18	247.5	175.9 -348.4	X
1992	10	309.1	195.4 -488.9	X

Table 12. Analyses of variance for lower- : higher-chlorinated PCB ratios in striped bass collected from the Hudson River at Albany/Troy (RM 153) for 1984-1993.

Source of Variation	Sum of squares	d.f.	Mean square	F-ratio	Observed Significance Level
Between years	2.336	7	0.334	6.85	<0.001
Within years	6.477	133	0.049		
Total (corrected)	8.813	140			

Table 13. Comparisons among means of years for lower- : higher-chlorinated PCB ratios in striped bass collected from the Hudson River at Albany/Troy (RM 153) from 1984-1993 at $\alpha = 0.05$.

Year	N	Mean Ratio	95% Confidence Interval	Group Comparisons
1986	36	0.38	0.30 - 0.45	X
1988	8	0.39	0.23 - 0.54	XX
1985	20	0.41	0.32 - 0.51	XX
1984	6	0.44	0.26 - 0.62	XXX
1990	13	0.49	0.37 - 0.61	XXX
1987	30	0.50	0.42 - 0.58	XX
1993	18	0.60	0.50 - 0.71	X
1992	10	0.87	0.73 - 1.00	X

Table 14. Analyses of variance for untransformed wet weight based and log_{10}-transformed lipid-based total PCB in striped bass collected in the fall from the Hudson River in Haverstraw Bay/Tappan Zee (below RM 40) for 31984-1993.

Source of Variation	Sum of squares	d.f.	Mean square	F-ratio	Observed Significance Level
Untransformed wet weight					
Between years	2060.1	7	294.3	6.79	<0.001
Within years	14424.5	333	43.3		
Total (corrected)	16484.7	340			
Log_{10}-transformed lipid-based					
Between years	5.75	7	0.822	5.25	<0.001
Within years	52.15	333	0.157		
Total (corrected)	57.91	340			

Table 15. Comparisons among means of years for untransformed wet weight- and log_{10}-transformed lipid-based total PCB concentrations in striped bass collected in the fall from Haverstraw Bay/Tappan Zee in the Hudson River (below RM 40) from 1984-1993 at $\alpha = 0.05$.

Year	N	Mean	95% Confidence Interval	Group Comparisons
Untransformed (Arithmetic)				
1984	52	2.42	0.63 - 4.22	X
1987	39	2.91	0.84 - 4.98	XX
1993	60	3.61	1.94 - 5.28	XX
1990	20	3.89	0.99 - 6.78	XXX
1988	23	4.28	1.58 - 6.98	XXX
1992	33	5.70	3.45 - 7.96	XX
1986	54	6.16	4.40 - 7.92	X
1985	60	9.66	7.99 -11.34	X
Log_{10}-transformed lipid-based (Geometric)				
1984	52	26.3	20.5 - 33.7	X
1993	60	37.0	29.3 - 46.6	X
1987	39	37.8	28.4 - 50.4	XX
1992	33	42.1	30.8 - 57.5	XX
1988	23	42.3	29.1 - 61.5	XXX
1990	20	46.0	30.8 - 68.6	XXX
1986	54	59.1	46.3 - 75.4	XX
1985	60	65.1	51.7 - 82.1	X

Table 16. Analyses of variance for lower- : higher-chlorinated PCB ratios in striped bass collected in the fall from Haverstraw Bay/Tappan Zee in the Hudson River (below RM 40) for 1984-1993.

Source of Variation	Sum of squares	d.f.	Mean square	F-ratio	Observed Significance Level
Between years	0.549	7	0.078	2.12	0.041
Within years	12.344	333	0.037		
Total (corrected)	12.893	340			

Table 17. Comparisons among means of years for lower- : higher-chlorinated PCB ratios in striped bass collected in the fall from the Hudson River in Haverstraw Bay/Tappan Zee (below RM 40) from 1984-1993 at $\alpha = 0.05$.

Year	N	Mean Ratio	95% Confidence Interval	Group Comparisons
1984	52	0.13	0.08 - 0.18	X
1986	54	0.19	0.14 - 0.24	XX
1993	60	0.19	0.15 - 0.24	XXX
1988	23	0.21	0.13 - 0.29	XXX
1992	33	0.21	0.14 - 0.27	XXX
1985	60	0.23	0.18 - 0.28	XX
1987	39	0.24	0.18 - 0.31	XX
1990	20	0.29	0.21 - 0.38	X

Table 18. Analyses of variance for untransformed wet weight based total PCB in striped bass collected from several rivermile (RM) locations in the Hudson River for selected years - 1986, 1990, 1992 and 1993.

Source of Variation	Sum of Squares	d.f.	Mean Square	F-ratio	Observed Signific. Level
1986					
Between RMs	4535.7	6	755.95	19.7	<0.001
Within RMs	9775.3	255	38.33		
Total-correc.	14311.0	261			
1990					
Between RMs	310.9	5	62.18	8.02	<0.001
Within RMs	1481.5	191	.76		
Total-correc.	1792.4	196			
1992					
Between RMs	2204.3	5	440.86	53.1	<0.001
Within RMs	1385.7	167	8.30		
Total-correc.	3590.0	172			
1993					
Between RMs	1641.0	5	328.2	30.3	<0.001
Within RMs	1687.6	156	10.8		
Total-correc.	3328.7	161			

Table 19. Analyses of variance for log_{10}-transformed lipid-based total PCB in striped bass collected from several rivermile (RM) locations in the Hudson River for selected years - 1986, 1990, 1992 and 1993.

Source of Variation	Sum of Squares	d.f.	Mean Square	F-ratio	Observed Signific. Level
1986					
Between RMs	14.426	6	2.404	18.4	<0.001
Within RMs	33.397	255	0.131		
Total-correc.	47.824	261			
1990					
Between RMs	7.690	5	1.538	14.2	<0.001
Within RMs	20.745	191	0.109		
Total-correc.	28.745	196			
1992					
Between RMs	12.047	5	2.409	31.0	<0.001
Within RMs	12.971	167	0.078		
Total-correc.	25.019	172			
1993					
Between RMs	15.667	5	3.133	37.9	<0.001
Within RMs	12.894	156	0.083		
Total-correc.	28.562	161			

Table 20. Analyses of variance for lower- : higher-chlorinated PCB ratios in striped bass collected from several rivermile (RM) locations in the Hudson River for selected years - 1986, 1990, 1992 and 1993.

Source of Variation	Sum of Squares	d.f.	Mean Square	F-ratio	Observed Signific. Level
1986					
Between RMs	1.596	6	0.266	16.1	<0.001
Within RMs	4.223	255	0.017		
Total-correc.	5.819	261			
1990					
Between RMs	1.517	5	0.303	35.4	<0.001
Within RMs	1.637	191	0.009		
Total-correc.	3.154	196			
1992					
Between RMs	5.918	5	1.184	48.5	<0.001
Within RMs	4.072	167	0.024		
Total-correc.	9.990	172			
1993					
Between RMs	3.239	5	0.648	21.2	<0.001
Within RMs	4.762	156	0.031		
Total-correc.	8.001	161			

Table 21. Comparisons among means of rivermiles (RM) for untransformed wet weight-based total PCB concentrations in striped bass collected in spring/summer from the Hudson River for select years - 1986, 1990, 1992 and 1993 at $\alpha = 0.05$.

RM	N	Mean	95% Confidence Interval	Group Comparisons
1986				
27	59	3.05	1.46 - 4.64	X
36	30	3.15	0.93 - 5.38	X
73	58	4.49	2.89 - 6.09	X
12	57	4.67	3.05 - 6.28	X
91	8	7.10	2.79 -11.42	XX
111	20	9.59	6.86 -12.32	X
153	30	16.46	14.23 -18.69	X
1990				
12	37	1.91	1.00 - 2.81	X
27	43	2.08	1.24 - 2.91	XX
40	35	3.15	2.22 - 4.07	XXX
113	20	3.56	2.33 - 4.79	XX
74	49	3.75	2.97 - 4.54	X
153	13	6.90	5.38 - 8.43	X
1992				
12	20	1.32	0.05 - 2.60	X
73	39	1.77	0.86 - 2.68	XX
27	41	1.93	1.04 - 2.82	XX
38	43	2.06	1.19 - 2.93	XX
115	20	3.29	2.01 - 4.56	X
153	10	17.16	15.36 -18.95	X
1993				
12	13	1.32	-0.49 - 3.12	X
38	20	1.59	0.14 - 3.05	X
27	46	2.18	1.22 - 3.13	XX
73	45	3.14	2.18 - 4.11	XX
115	20	3.74	2.29 - 5.19	X
153	18	12.39	10.86 -13.92	X

Table 22. Comparisons among means of rivermiles (RM) for log_{10}-transformed lipid-based total PCB concentrations in striped bass collected in spring/summer from the Hudson River for select years - 1986, 1990, 1992 and 1993 at $\alpha = 0.05$.

RM	N	Mean	95% Confidence Interval	Group Comparisons
1986				
36	30	27.9	20.7 - 37.7	X
27	59	28.8	23.2 - 35.6	X
73	58	38.9	31.3 - 48.2	XX
12	57	50.4	40.5 - 62.6	X
111	20	92.5	64.1 -133.6	X
91	8	124.4	69.7 -222.3	X
153	30	138.3	102.5 -186.7	X
1990				
27	43	28.0	22.2 - 35.1	X
12	37	28.3	22.2 - 36.2	X
40	35	32.1	24.9 - 41.4	X
74	49	54.0	43.6 - 66.8	X
113	20	81.9	56.6 -114.5	X
153	13	116.0	76.6 -175.7	X
1992				
12	20	26.6	20.0 - 35.3	X
38	43	30.7	25.3 - 37.3	X
27	41	34.3	28.2 - 41.8	X
73	39	36.2	29.6 - 44.4	X
115	20	94.4	71.1 -125.4	X
153	10	309.1	207.0 -461.1	X
1993				
12	13	21.5	15.0 - 30.9	X
38	20	29.2	21.8 - 39.1	X
27	46	29.6	24.4 - 36.0	X
73	45	49.0	40.3 - 59.5	X
115	20	99.6	74.3 -133.4	X
153	18	247.5	181.9 -336.9	X

Table 23. Comparisons among means of rivermiles (RM) for lower- : higher-chlorinated PCB ratios in striped bass collected in spring/summer from the Hudson River for select years - 1986, 1990, 1992 and 1993 at $\alpha = 0.05$.

RM	N	Mean	95% Confidence Interval	Group Comparisons
1986				
36	30	0.08	0.03 - 0.12	X
73	58	0.14	0.11 - 0.18	X
111	20	0.16	0.10 - 0.22	XX
12	57	0.19	0.16 - 0.22	XX
27	59	0.21	0.18 - 0.24	X
91	8	0.34	0.25 - 0.43	X
153	30	0.36	0.32 - 0.41	X
1990				
12	37	0.13	0.10 - 0.16	X
27	43	0.16	0.13 - 0.19	XX
40	35	0.17	0.14 - 0.20	XX
74	49	0.19	0.17 - 0.22	X
113	20	0.28	0.24 - 0.32	X
153	13	0.49	0.44 - 0.54	X
1992				
27	41	0.06	0.02 - 0.11	X
12	20	0.09	0.02 - 0.16	XX
38	43	0.15	0.10 - 0.19	X
73	39	0.25	0.20 - 0.30	X
115	20	0.32	0.25 - 0.39	X
153	10	0.87	0.77 - 0.96	X
1993				
12	13	0.13	0.04 - 0.23	X
27	46	0.15	0.10 - 0.20	XX
38	20	0.16	0.08 - 0.24	XXX
73	45	0.24	0.19 - 0.29	X X
115	20	0.34	0.26 - 0.42	X
153	18	0.60	0.52 - 0.69	X

Table 24. Analyses of variance for untransformed wet weight based total PCB, log_{10}-transformed lipid-based total PCB and lower- : higher-chlorinated PCB ratios in striped bass collected below RM 60 in the Hudson River compared across four months -April, May, November and December- in combined years 1992 and 1993.

Source of Variation	Sum of Squares	d.f.	Mean Square	F-ratio	Observed Signific. Level
Untransformed wet weight					
B/w months	528.4	3	176.12	7.8	<0.001
W/in months	6147.5	272	22.60		
Total-correc.	6675.8	275			
Log_{10}-transformed lipid-based					
B/w months	1.39	3	0.464	4.00	0.008
W/in months	31.53	272	0.116		
Total-correc.	32.92	275			
Lower- : higher-chlorinated PCB					
B/w months	0.473	3	0.158	7.6	<0.001
W/in months	5.634	272	0.021		
Total-correc.	6.107	275			

Table 25. Comparisons among means of four months -April, May, November and December- for 1992 and 1993 combined for untransformed wet weight based total PCB, log_{10} transformed lipid-based total PCB and lower- : higher-chlorinated PCB ratios for striped bass collected below RM 60 at $\alpha = 0.05$.

Month	N	Mean	95% Confidence Interval	Group Comparisons
Untransformed wet weight				
5	82	1.30	0.27 - 2.34	X
4	101	2.34	1.41 - 3.27	X
12	37	3.07	1.53 - 4.61	X
11	56	5.20	3.95 - 6.45	X
Log_{10}-transformed lipid-based				
5	82	26.3	22.2 - 31.1	X
4	101	33.0	28.3 - 38.5	XX
12	37	34.6	26.8 - 44.6	XX
11	56	41.7	33.9 - 51.3	X
Lower- : higher-chlorinated PCB				
5	82	0.12	0.08 - 0.15	X
4	101	0.13	0.10 - 0.16	X
12	37	0.16	0.11 - 0.20	X
11	56	0.23	0.19 - 0.27	X

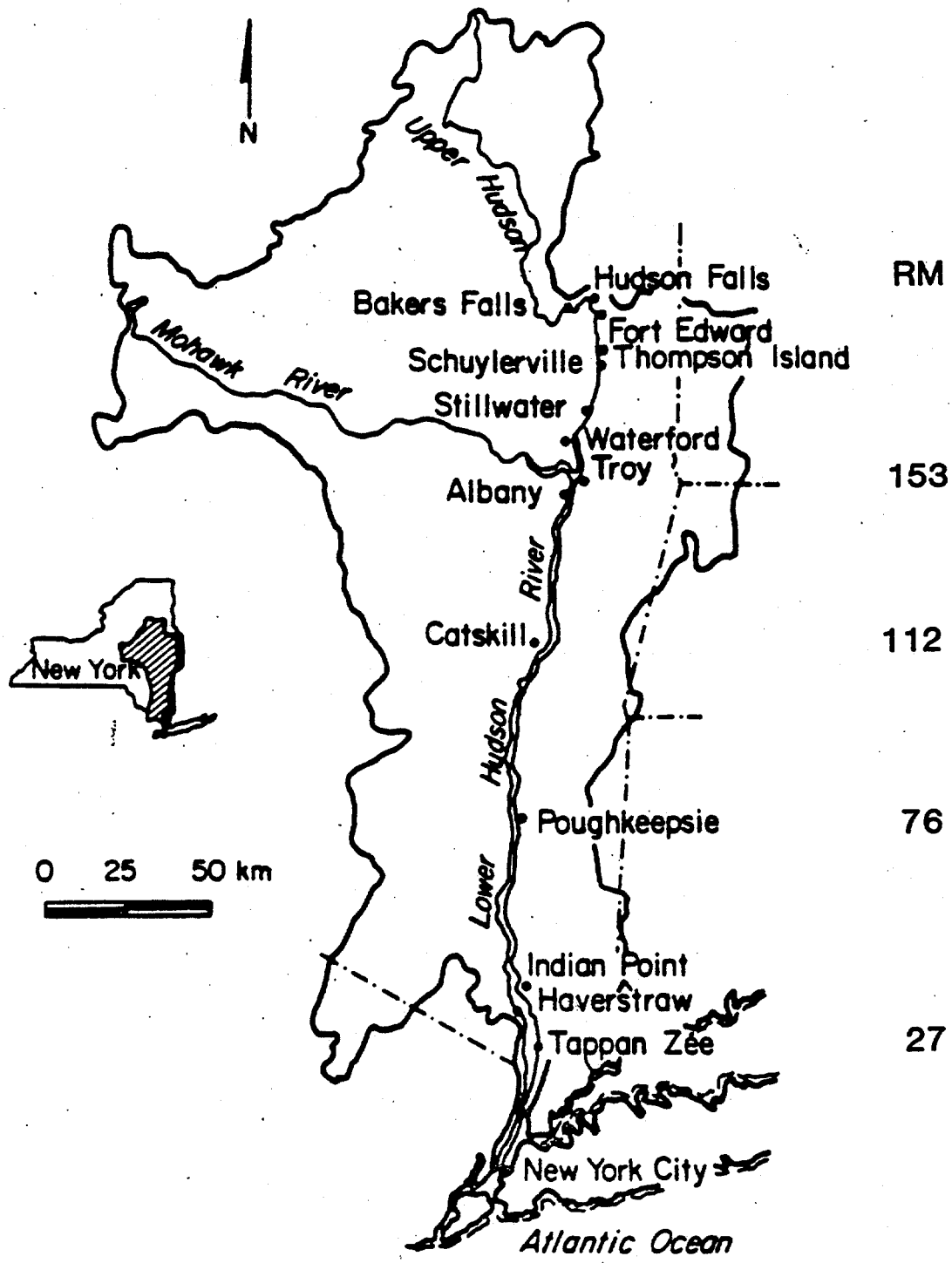

Figure 1. Outline map of features of the Hudson River watershed. River Mile index (RM) is calculated from the Battery on Manhattan Island.

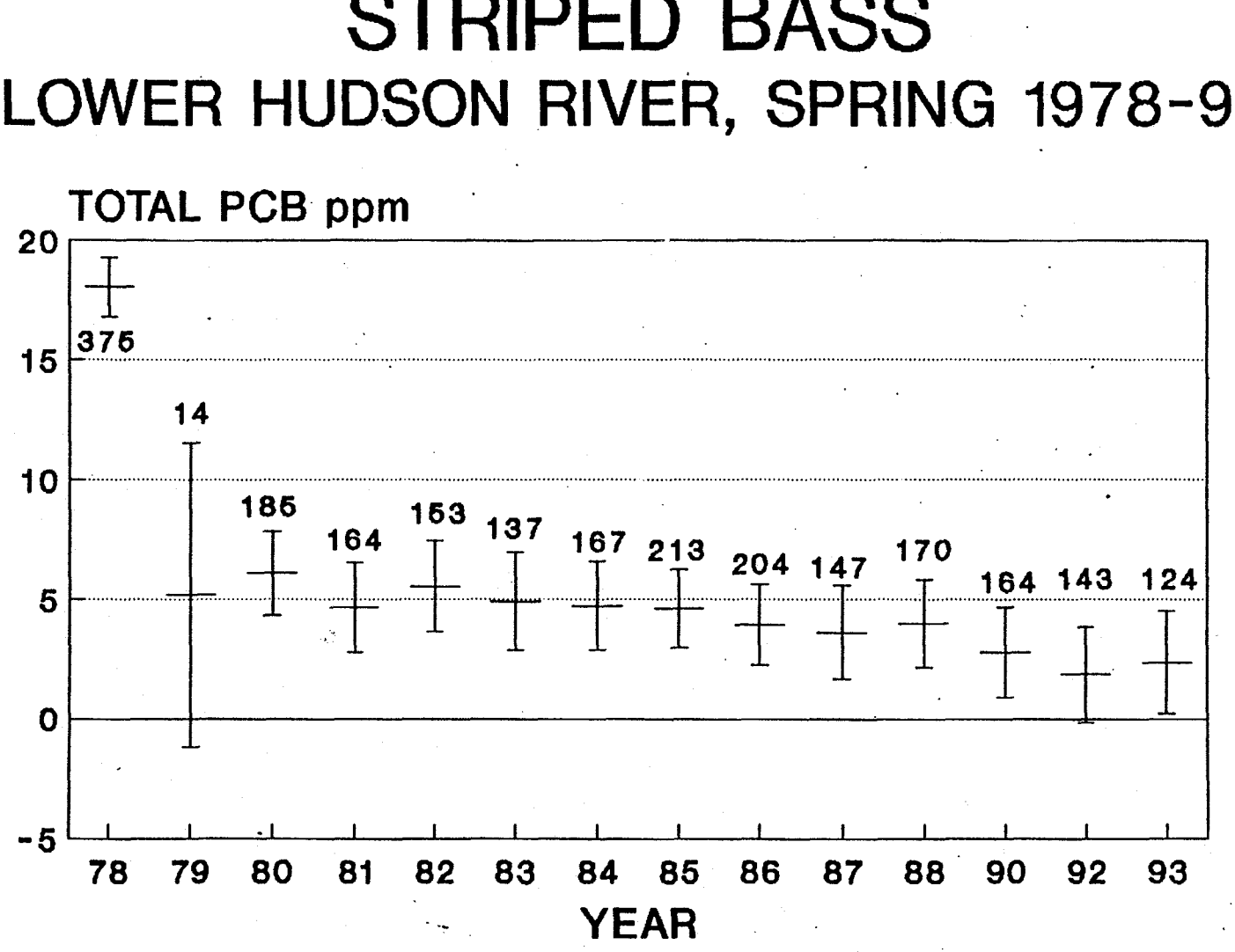

Figure 2. **Arithmetic** means and 95 percent confidence intervals for **total PCB** Concentrations in striped bass from the Hudson River collected in the spring **(1978-1993)** from the lower estuary (below RM 80).

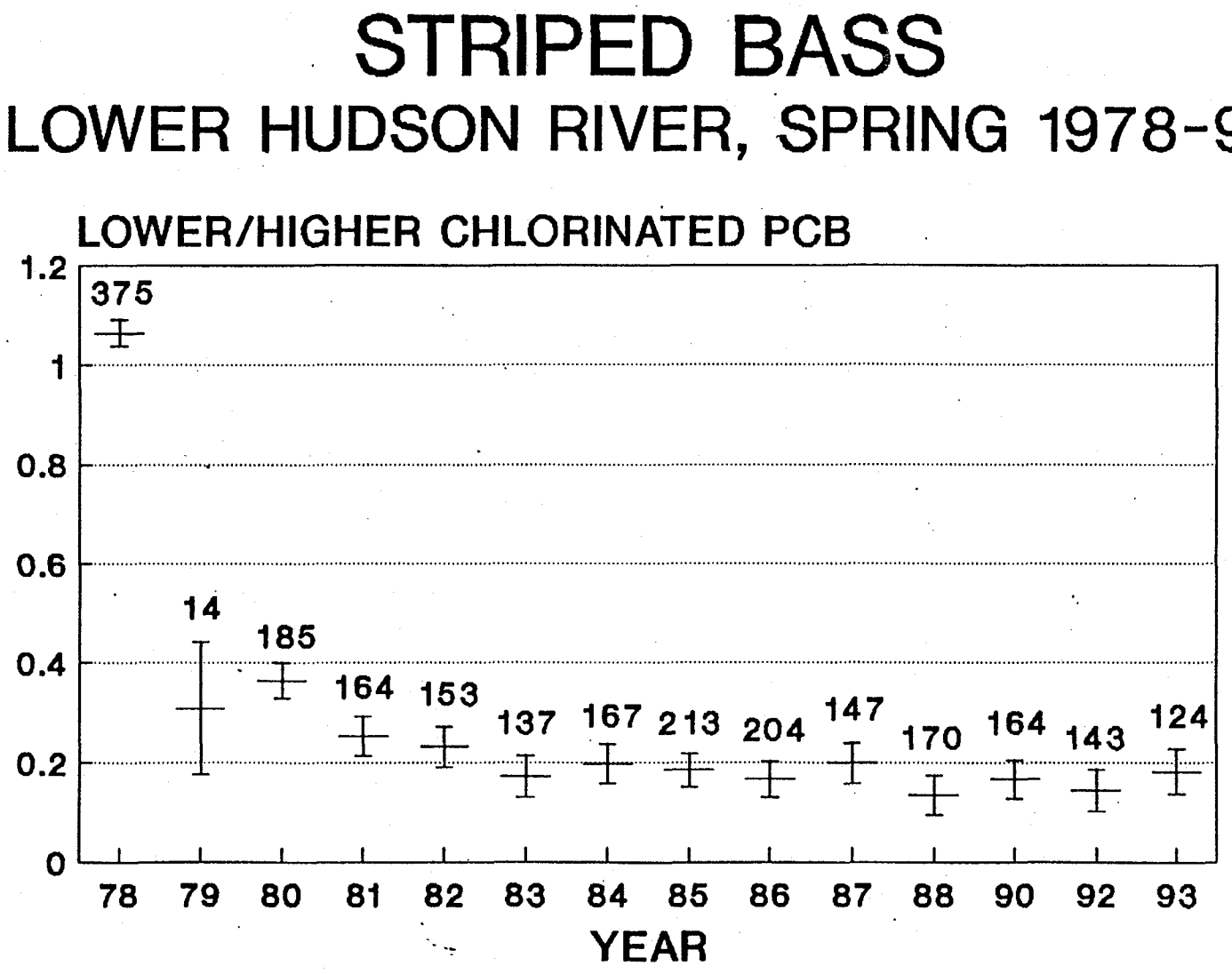

Figure 3. **Lipid-based Geometric** means and 95 percent confidence intervals for **total PCB** concentrations in striped bass from the Hudson River collected in the spring **(1978- 1993)**from the lower estuary (below RM 80).

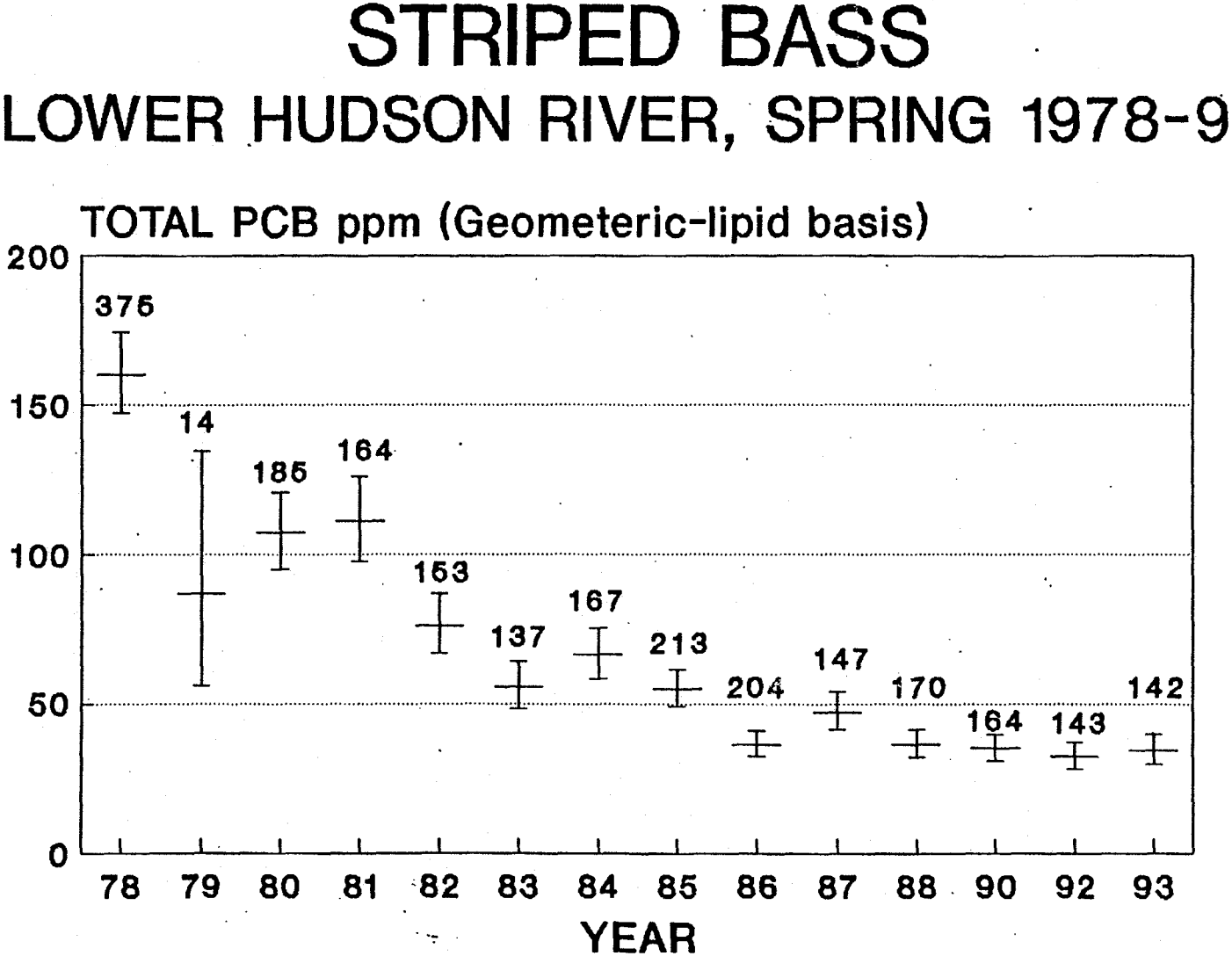

Figure 4. Mean ratios of lower /higher chlorinated PCB and 95 percent confidence intervals in striped bass from the Hudson River collected in the spring (1978-1993) from the lower estuary (belowRM 80).

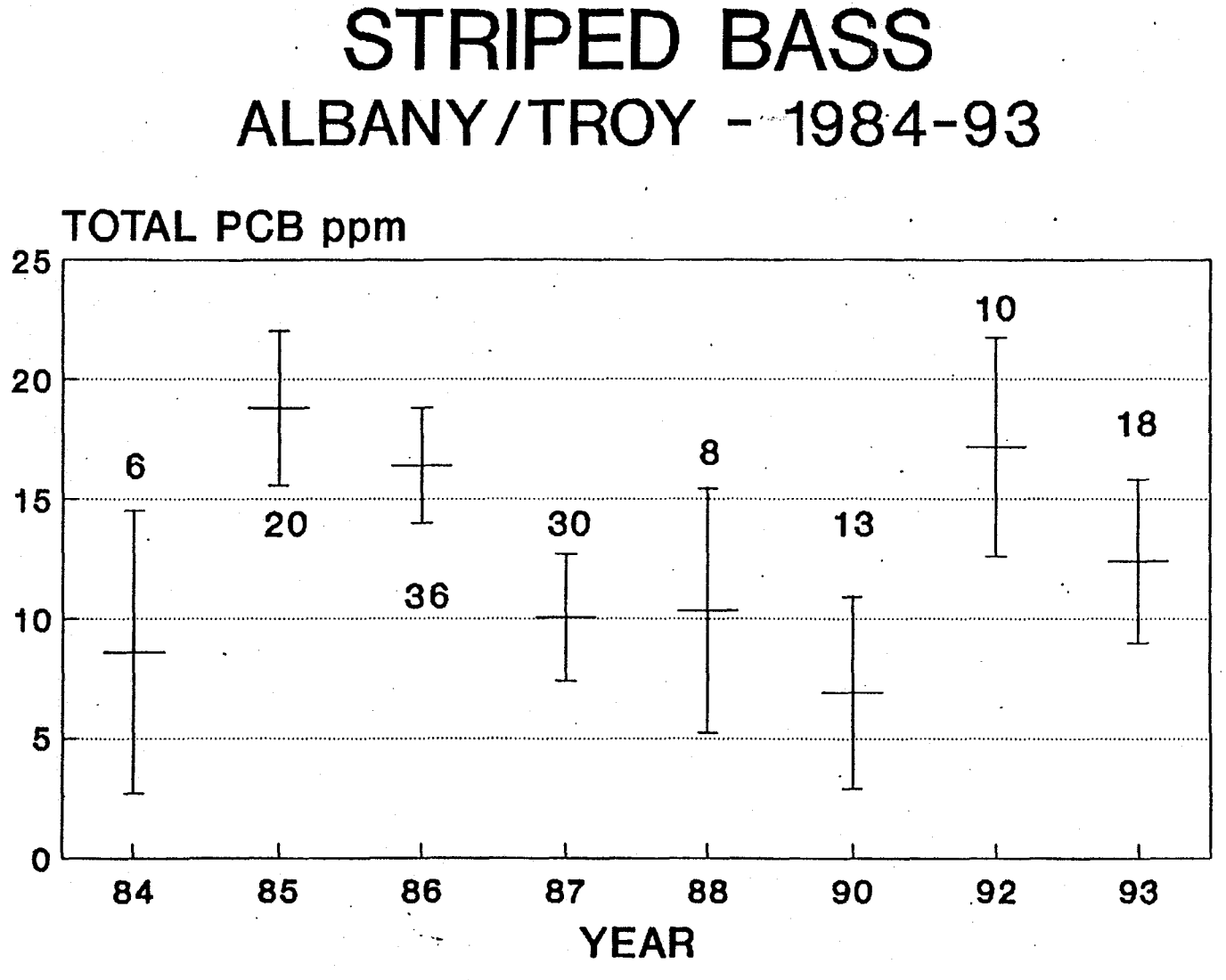

Figure 5. Arithmetic means and 95 percent confidence intervals for total PCB concentrations in striped bass from the Hudson River collected at Albany/Troy (RM 153) from 1984-1993.

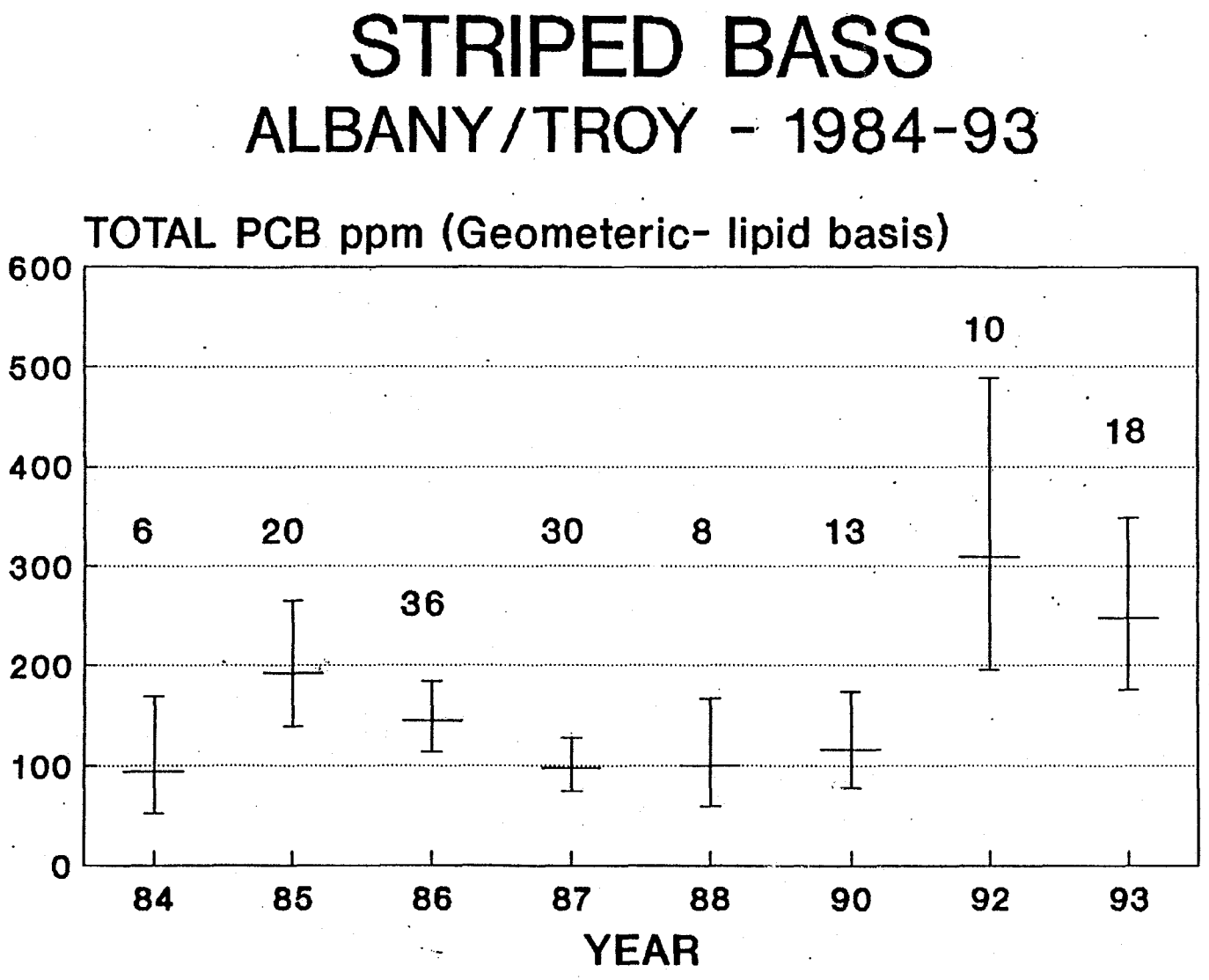

Figure 6: **Lipid-based Geometric** means and 95 percent confidence intervals for **total PCB** concentrations in striped bass from the Hudson River collected at **Albany/Troy** (RM 153) from **1984-1993**.

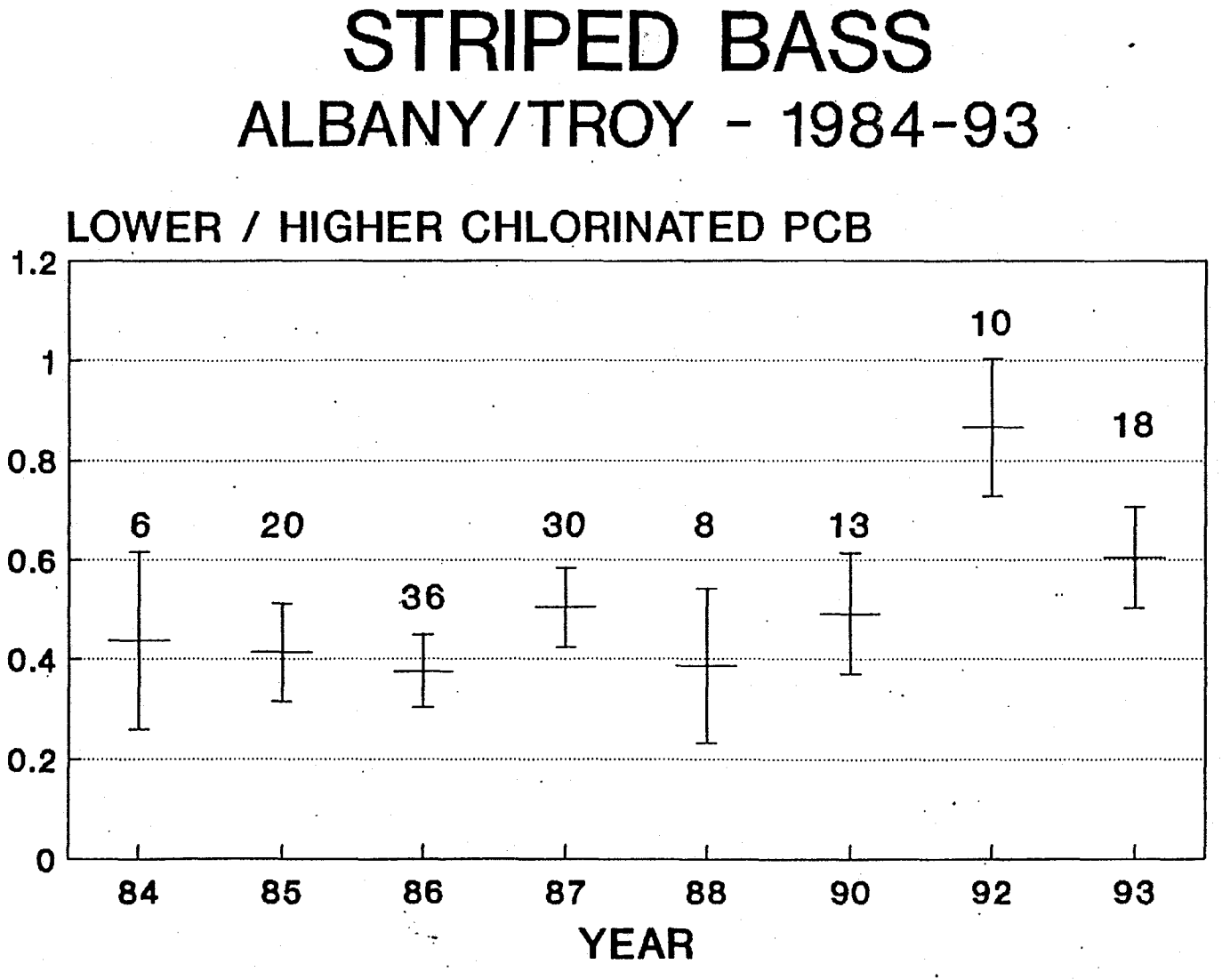

Figure 7. Mean ratios of lower /higher chlorinated PCB and 95 percent confidence intervals in striped bass from the Hudson River collected at Albany/Troy (RM 153) from 1984-1993.

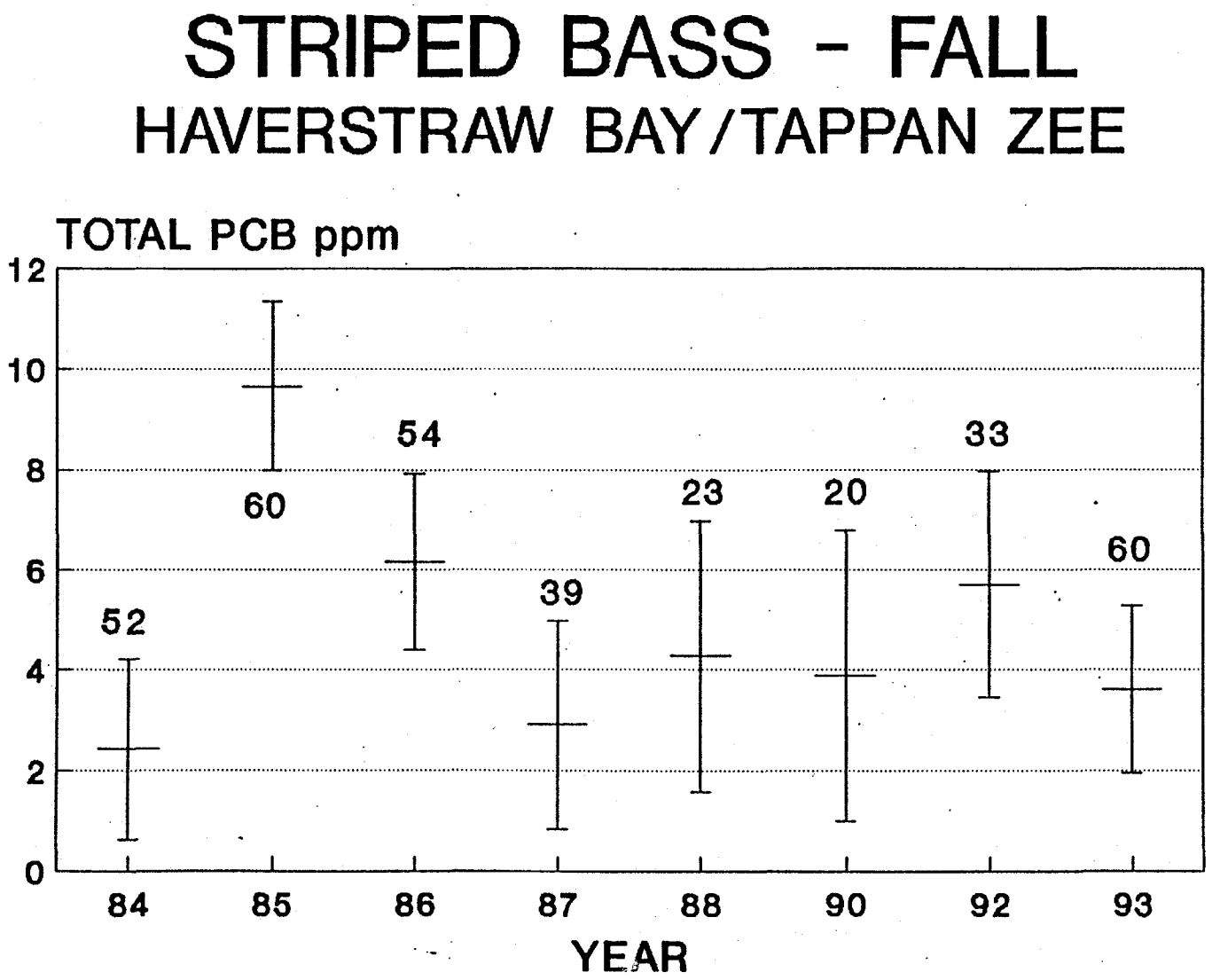

Figure 8. Arithmetic means and 95 percent confidence intervals for **total PCB** concentrations in striped bass from the Hudson River collected in the **fall (1984-1993)** from the **Haverstraw Bay/Tappan Zee** area.

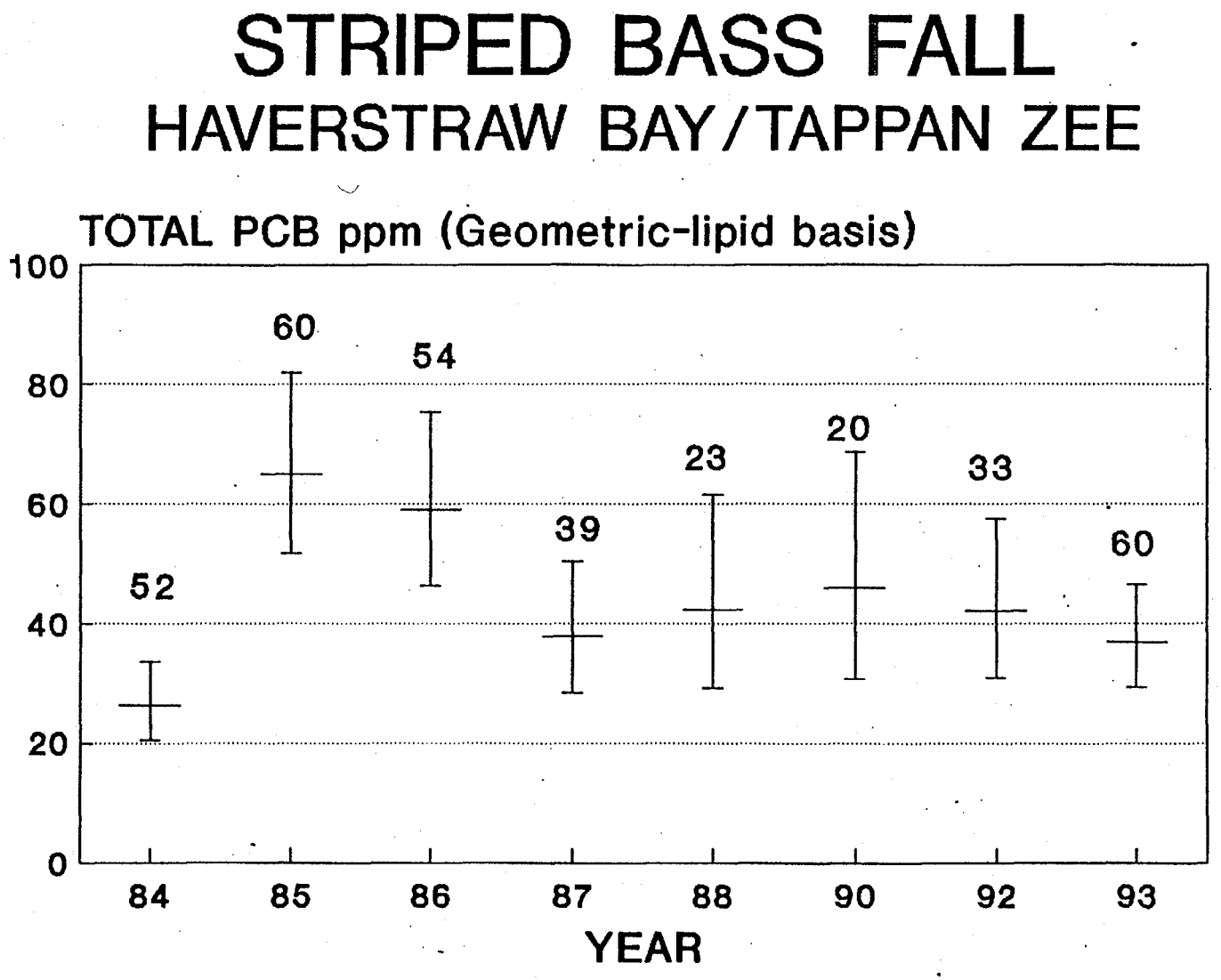

Figure 9. **Lipid-based geometric** means and 95 percent confidence intervals for **total PCB** concentrations in striped bass from the Hudson River collected in the **fall (1984-1993)** from the **Haverstraw Bay/Tappan Zee** area.

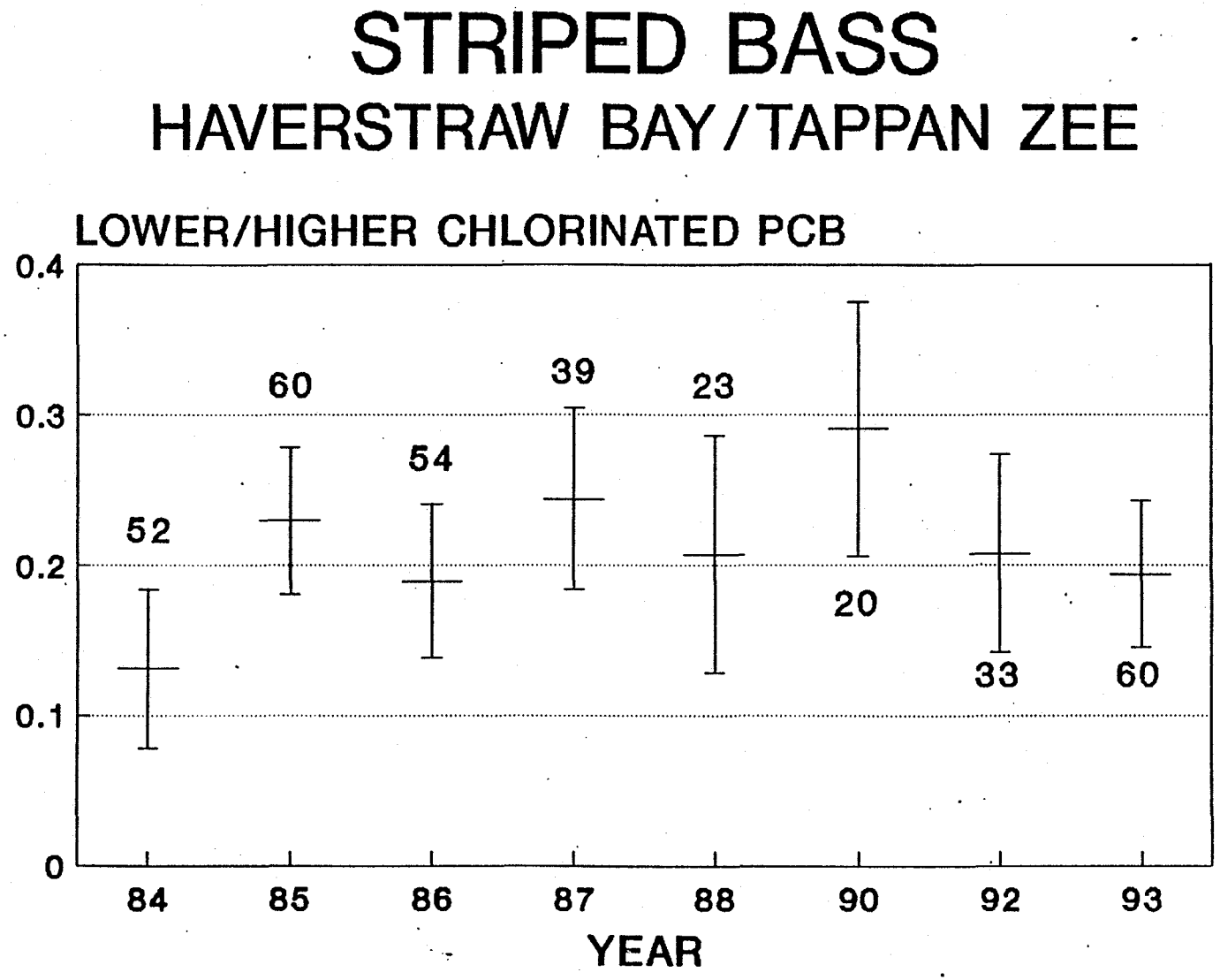

Figure 10. Mean ratios of lower /higher chlorinated PCB and 95 percent confidence intervals in striped bass from the Hudson River collected in the fall (1984-1993) from the Haverstraw Bay/Tappan Zee area.

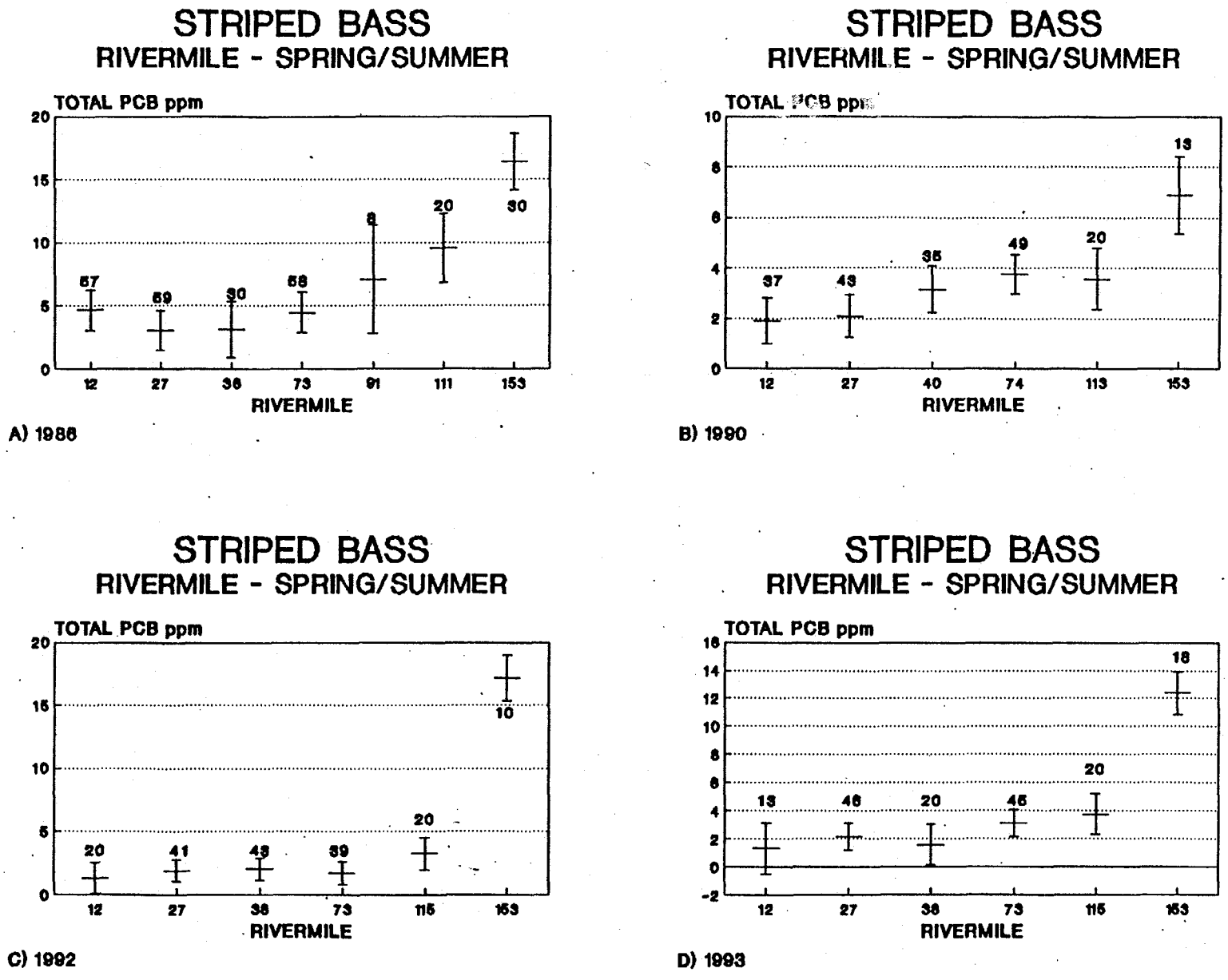

Figure 11. Arithmetic means and 95 percent confidence intervals for total PCB concentrations in striped bass collected from several rivermile locations in the Hudson River during spring/summe for select years. A) 1986, B) 1990, C) 1992 and D) 1993

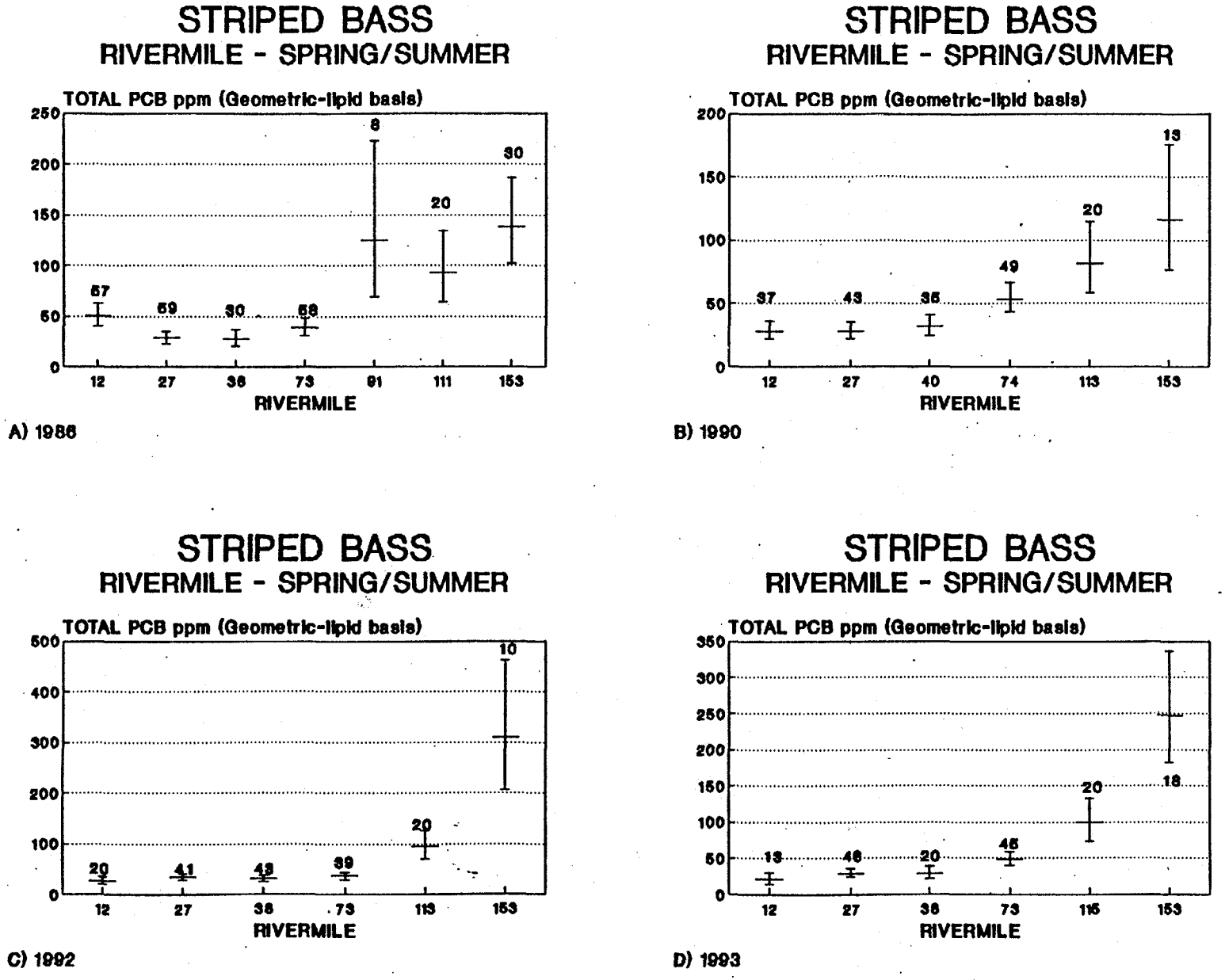

Figure 12. **Lipid-based geometric** means and 95 percent confidence intervals for **total PCB** concentrations in striped bass collected from **several rivermile** locations in the Hudson River

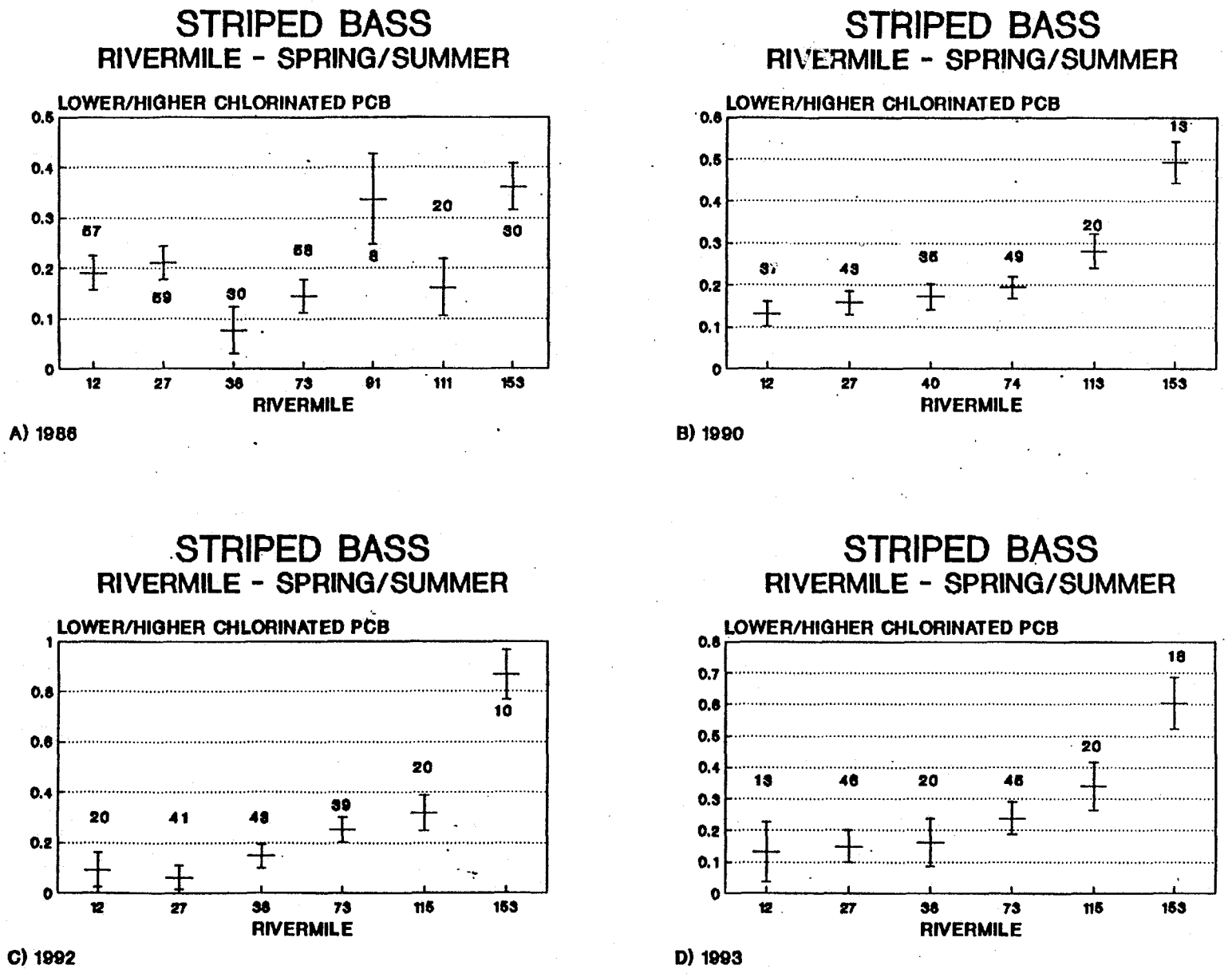

Figure 13. Mean ratios of lower /higher chlorinated PCB and 95 percent confidence intervals in striped bass collected from several riv nile locations in the Hudson River during spring/summer for select years. A) 19 B) 1990 C) 1992 and D) 1993

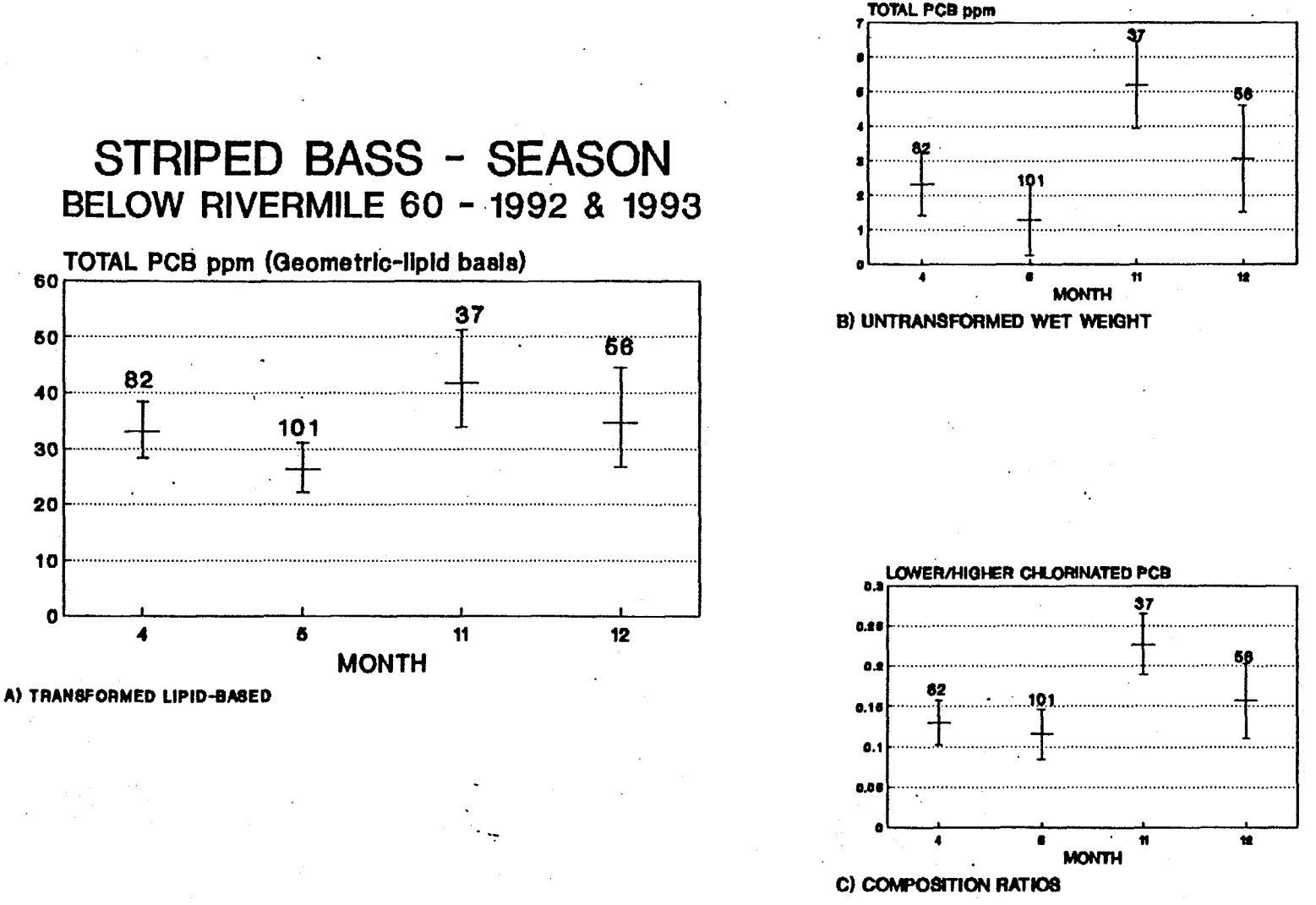

Figure 14. Means and 95 percent confidence intervals for **A) Lipid-based geometric, B) Untransformed wet weight and C) Composition ratio** variables for stripd bass collected from the Hudson River **below RM 60** compared across four months - **April, May, November and December** for 1992 - 1993 sampling