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Bioaccumulation Modeling of PCBs in the Hudson Estuary: A Review and Update

Robert V. Thomann and Kevin J. Farley
Manhattan College, Environmental Engineering Department, Riverdale, New York

Introduction

The issue of polychlorinated biphenyl (PCB) accumulation in the striped bass of the Hudson estuary has been a matter of concern for several decades. Early discharges of PCBs to the estuary resulted in total PCB concentrations in the striped bass during 1978 to 1982 of 5 to 10 times the U.S. Food and Drug Administration (FDA) action level of 2 µg/g(wet). The fishery has been closed to commercial harvesting since the mid-1970s.

Bioaccumulation Model

A linked homolog-specific, physicochemical bioaccumulation model was constructed (Thomann et al., 1989, 1991) to help address questions of the effectiveness of upstream controls on PCBs in reducing the PCB concentration in the striped bass or, if no action is taken, the time it would take to reach acceptable levels in the fish. Model calibration was accomplished with striped bass data from 1978 through 1987 and indicated that more than 90 percent of the observed PCB concentration was due to food web transfer. Projections were made of the expected decrease in PCB concentration in the striped bass from 1987 to 2010. The projections were based on a PCB homolog-specific modeling framework that included a time-variable, age-dependent striped bass bioaccumulation model. Those results indicated that under a no-action scenario, the average PCB concentration in the striped bass in the mid to lower estuary would decline below the FDA action level of 2 µg/g(wet) by about 1994 to 1995.

Model Post-Audit

Data obtained by the New York State Department of Environmental Conservation (as stored in TAMS, 1996) are now available to check the projections up through 1994. Observed mean total PCB concentrations in 2- to 5-year-old striped bass in the mid-lower estuary (designated SB2 group) declined from about 3.5 µg/g(wet) in 1988 to about 1.6 µg/g(wet) in 1994. A correction of the original projection was necessary due to a numerical error in exposure concentration in Food Web Region #4, the Long Island Sound and New York Bight area. This correction resulted in a reduction of less than about 0.5 µg/g(wet) from the original projection. Using the original input load projections, the comparison to the observed data for SB2 is shown in Figure 1 and indicates that the model underestimated the mean in 1989 and 1990 but adequately reproduced the means in 1992 and 1994. The variability in the data is large with 5 to 95 percentile

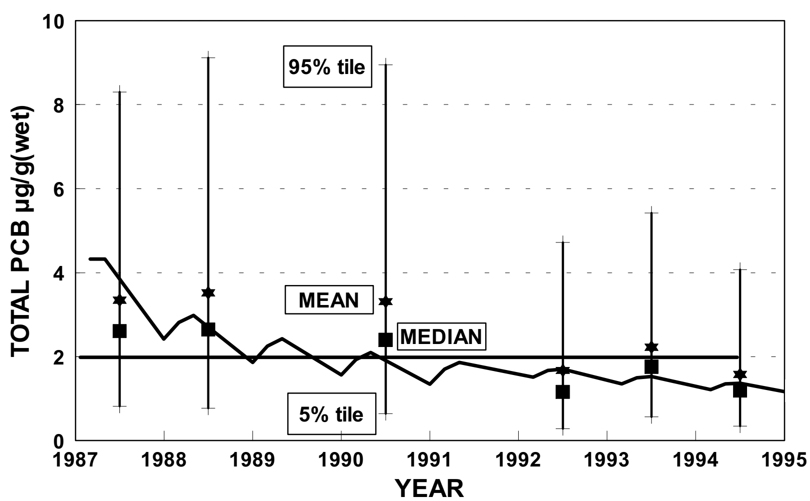

Figure 1. Comparison of original (as corrected) model projection (solid line) made in 1987 to observed data of striped bass (2-5 yr old), Food Web Region #2.

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range in individual samples of about an order of magnitude distributed approximately lognormally. Projections of the percent frequency of samples below a target level mean of 2 µg/g(wet) were also made, and comparison to observed data (Figure 2) indicated that the original model overestimated the frequency =< 2 µg/g(wet) in 1990 but tracked the general trend in the data of an increasing frequency=<2 µg/g(wet) in the years 1992 to 1994.

The model has been updated in two areas: assessment of the effect on striped bass from a temporary increase in upriver loading and an evaluation of a varying migration pattern of the striped bass. To assess the effect of the increase in loading, a fivefold increase over the originally projected load from the upper river was added for the one year of 1991. Preliminary results indicate a calculated increase of total PCB concentration of about 0.4 to 0.8 µg/g(wet) for 1992 to 1994 in the SB2 group. The effects of the increased load are dissipated in about 5 years in the mid-lower estuary.

For the effect of varying migration, recent research by Secor and Piccoli (1996), who estimated the exposed salinity regime in striped bass from measurements of the strontium/calcium (Sr/Ca) in the otolith, has indicated that some male striped bass remain in the mid to upper estuary and do not migrate to the ocean. Figure 3 shows a comparison of female and male SB2 total PCB concentrations from the data base. The higher median concentration in the males is observed, as well as considerably higher extreme concentrations in the male SB2 over the female SB2 group. The model results for nonmigratory behavior, shown in Figure 4, indicate an approximate doubling of the concentration in the striped bass and help explain the elevated concentrations that have been observed.

Projections to Year 2010

Revised long-term projections based on varying bass migration patterns and the original load projections are shown in Figure 5 for the mean and Figure 6 for the estimated frequency of occurrence =< 2 µg/g(wet). The revised projections indicate that by the year 2000, the mean total PCB concentration is estimated to be between 0.8 and 1.8 µg/g(wet) with an estimated 75 to 95 percent of the total PCB concentrations in the SB2 group = < 2 µg/g(wet). However, for the mid-upper estuary, calculated mean total PCB concentration is about 2.1 µg/g(wet) for 2- to 5- year-old bass, indicating that this region can be expected to have elevated concentrations over a longer a period of time than the mid estuary region.

Conclusions

For this work, which is still in progress, it is concluded that the original model generally tracked the observed decline in mean total PCB concentrations in the striped bass for the mid to lower estuary although there are year-to-year variations in the mean that are not captured by the model. A simulation of a 1-year "pulse" load of five times the estimated load in 1991 indicated that such an input persists in the SB2 group for about a 5-year period. Migration behavior is particularly significant and contributes to the observed variability in the SB2 data. The revised projections estimate that SB2 total PCB concentrations will continue to decline to levels below the FDA action level. It should be noted, however, that such projections are strictly related to the projections of the load and, of course, the model itself. Reevaluation of the loading using contemporary estimates and model recalibration are currently under way. There is a continual need to monitor the input PCB loads and the concentration in the striped bass and couple such monitoring with periodic model post-audits and updates.

References

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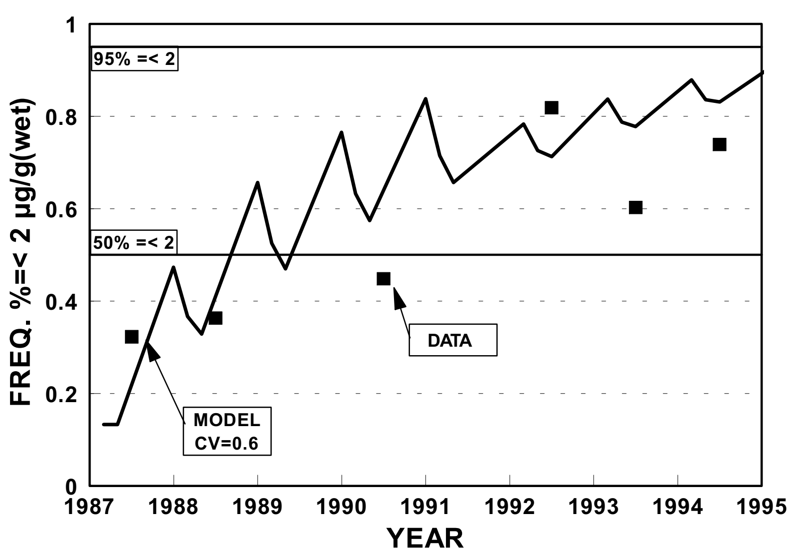

Figure 2. Comparison of observed vs. model exceedance frequencies (%=< 2 µg/g). Striped bass (2-5 yr old), Food Web Region #2.

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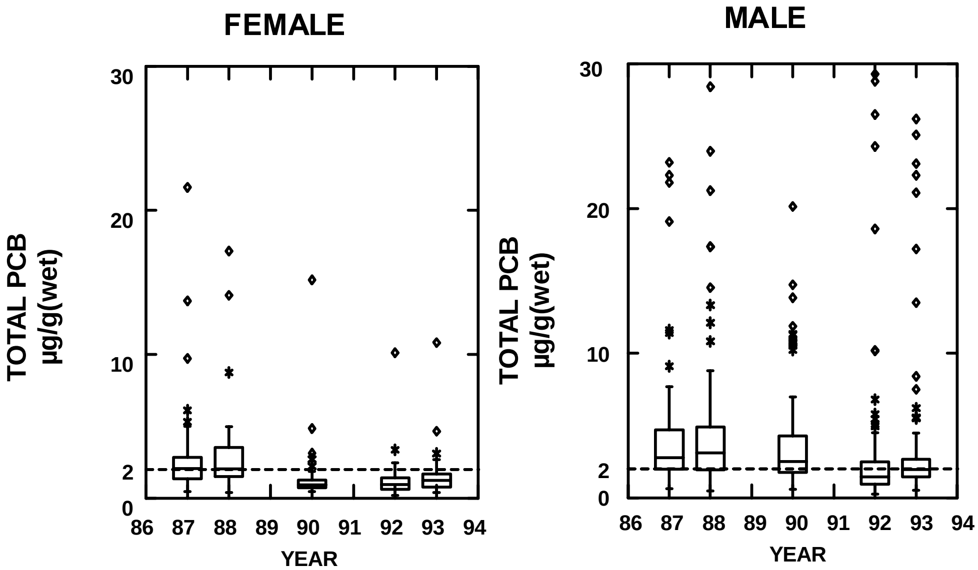

Figure 3. Variation in total PCB concentration in striped bass (2-5 yr old), Food Web Region #2. Line in box = 50th %tile, box boundaries = 25th and 75th %tile, symbols = outliers.

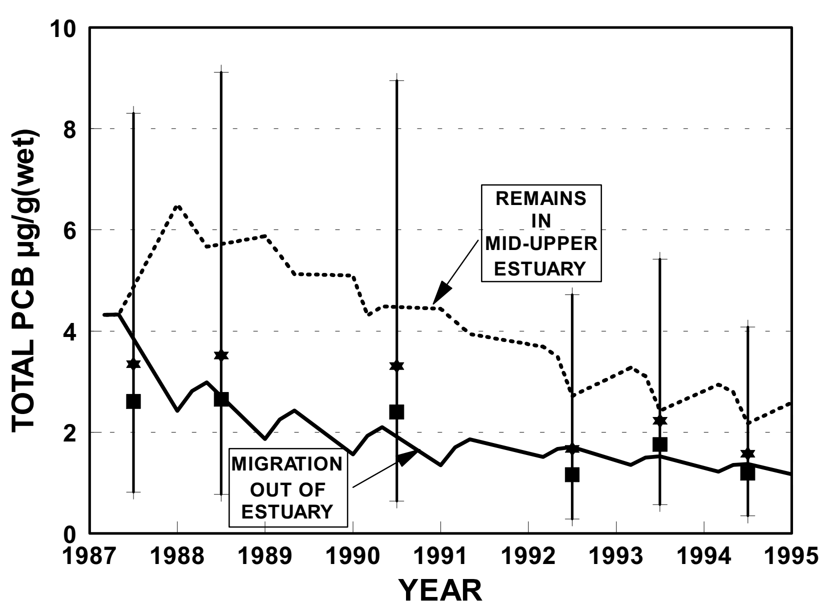

Figure 4. Calculated effect of varying migration of striped bass (2-5 yr old), Food Web Region #2.

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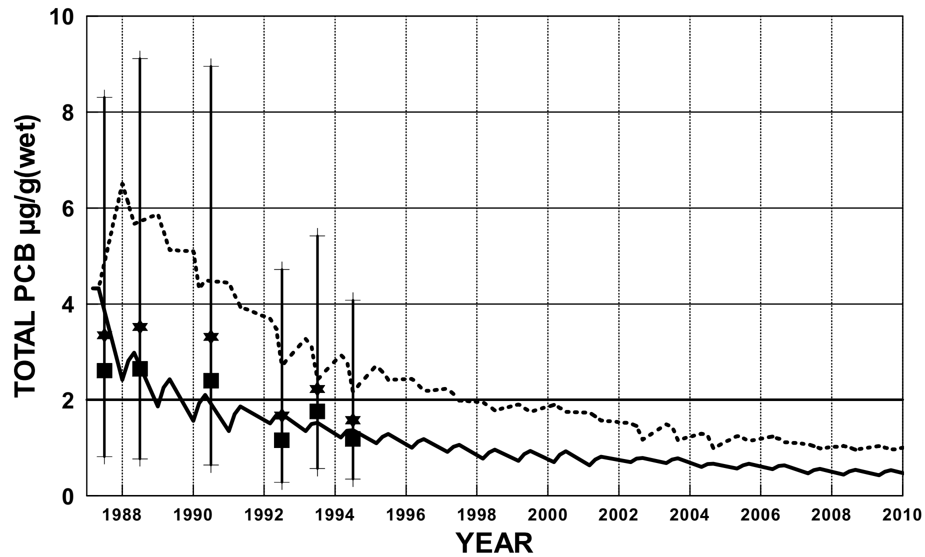

Figure 5. Long term model projection using original (1987) load projections with varying migration by striped bass. Solid line: striped bass migrates out of estuary; dashed line: fish remains in estuary. Striped bass (2-5 yr old), Food Web Region #2.

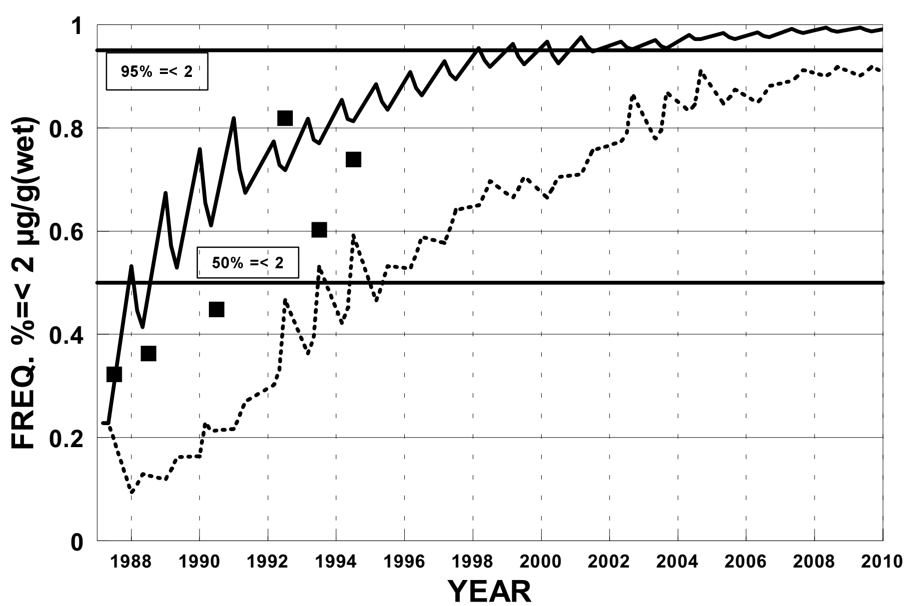

Figure 6. Long term model projection of frequency of striped bass =< 2µg/g with varying migration by striped bass. Solid line: striped bass migrates out of estuary; dashed line: fish remains in estuary. Striped bass (2-5 yr old), Food Web Region #2.

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