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Effects of Parental and Dietary PCBs on Survival, Growth, and Body Burdens of Larval Striped Bass

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The striped bass, Morone saxatilis (Walbaum), is a commercially and recreationally important anadromous fish native to the Atlantic Coast of North America. Its major spawning areas are in the heavily industrialized rivers of the Chesapeake Bay and the Hudson River. Although the commercial catch of striped bass has increased over tenfold in the past 40 years, year-to-year landings have varied markedly and reflect the "dominant year-class phenomenon." Recent landings have declined steadily from an all time peak in 1972 which was the result of a very successful spawning season in 1970. Some of this decline in landings can be attributed to the closing of the fishery in the Hudson River in 1976 due to polychlorinated biphenyl (PCB) contamination (BOPP et al. 1981; HORN et al. 1979). In addition to effects of pollution in spawning and nursery areas, overfishing and natural cycling have been suggested to explain the current decline in the Atlantic Coast stocks.

The extensive research on the striped bass done in recent years has been reviewed by ROGERS et al. (1980) and SETZLER et al. (1980). It is still, however, unknown why some year-classes of striped bass are stronger than others. It is generally agreed that year-class strength is determined during the first month of life. During this period the larva develops from a newly hatched yolk sac larva (prolarva) incapable of exogenous feeding to a metamorphosed young-of-the-year bass. Larvae could encounter potentially dangerous pollutants during this period from three sources: parental, dietary after initiation of feeding, and contact with waterborne pollutants. The last source was discussed by CALIFANO et al. (1980).

This study was designed to investigate the relative contribution of parental and dietary sources of PCBs to the survival and growth of striped bass larvae during their first month of life. To assess the effects of dietary PCBs upon these striped bass larvae, larvae having a known body burden of PCB were fed following yolk absorption and the initiation of feeding for 20 days on Artemia diets containing relatively high and low PCB contamination levels.

MATERIALS AND METHODS

Egg samples were obtained from five separate Hudson River females (Table 1) spawned in the spring of 1980, courtesy of the

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Table 1. Source of striped bass eggs used in this study and survival and growth of resulting larvae fed on two diets beginning after yolk absorption.

Hudson River Females			Larvae After 20 Days Feeding			
Hatchery Roe #	Weight (kg)	Length (cm TL)	Diet	% Survival	Dry Weight (mg)	Standard Length (mm)
539	4.5	73.5	B[a]	53,34	1.14 (0.63-1.73)[b]	8.7 (7.7-9.8)[b]
			S	27,43	0.91 (0.57-1.65)	8.6 (7.5-9.9)
721	8.7	88.4	not sampled due to small initial number of eggs			
527	10.0	88.7	B	44	ND[d]	9.3 (8.6-10.1)
			S	42	ND	9.1 (8.3-9.8)
553	11.0	94.4	B	0[c],0[c]	ND	8.8 (7.7-9.9)
			S	32,51	ND	9.1 (7.5-9.9)
566	19.0	112.0	not sampled due to small initial number of eggs			

[a] B=Brazilian Artemia; S=San Pablo Bay Artemia.

[b] Mean (range of 10 larvae).

[c] Aeration failure.

[d] ND=not determined; only larval lengths determined, then added to pooled frozen sample for analysis.

Consolidated Edison Company of New York's hatchery operation at Verplank, NY. Groups of live fertilized eggs or newly hatched larvae resulting from these spawnings were sent to Rhode Island. All of the samples for later organochlorine residue analysis were frozen (-10C) in acetone-rinsed glass vials with foil-cap liners. All organic solvent reagents used were pesticide analysis grade.

Larval culture. The groups of live fertilized eggs of pro-larvae obtained from the Hudson River females were stocked upon arrival at the laboratory into 4-L glass jars filled with reconstituted deionized water (LENNON & WALKER 1964) at 18C, with aeration. At yolk absorption 100 larvae were stocked into duplicate glass (4-L) rearing beakers at 18C and placed in constant temperature rearing baths. These beakers were filled initially with reconstituted deionized water. This was raised to 5 o/oo salinity with the addition of 5 µm filtered seawater to each beaker. The larvae were held in these aerated rearing containers throughout the course of the feeding portion of this study. At least two water changes per beaker were made per week. A more detailed description of the stocking and rearing procedures may be found in ROGERS & WESTIN (1981).

The diets fed to these striped bass larvae from the time of yolk absorption (initiation of first feeding) were brine shrimp (Artemia, spp.) nauplii reared from eggs of two geographical areas. Brazilian (Companhia Industrial do Rio Grande do Norte, CIRNE-Brand, harvested 1978) Artemia spp. served as the control, having low PCB residue levels, while the San Pablo Bay (Living World, San Francisco Bay Brand, Inc., lot #1628) Artemia spp. were high in PCBs (OLNEY et al. 1980). The larvae were fed to satiation twice daily on their Artemia spp. diet for 20 days at which time the larvae were 30 days old. Larval bass groups from each of three females were monitored daily for mortalities as was an unfed group. Samples were taken at stocking, and after 10 and 20 days of feeding on each diet type from other duplicate groups for measurements of length, dry weight (ROGERS & WESTIN 1981) and PCB residues.

Analysis for PCB residues. Frozen samples of eggs or pro-larvae, post yolk sac larvae, larvae fed 10 and 20 days and their respective diets were thawed in groups of six and extracted for organochlorine residue analysis. All samples contained enough individual larvae for at least 0.40 g wet weight, except for three which contained 0.10, 0.22, and 0.33 g. The extraction methods perfected and described by McLEAN (1980) for Artemia spp. and fish samples of less than one gram wet weight were used. Briefly, this procedure involved extraction of the larvae in acetonitrile with a Polytron Sonicator/Homogenizer (Brinkmann Instruments) in three grindings, followed by partitioning of the extracted lipid into petroleum ether (PE). The organochlorine compounds were separated from the remainder of the lipid fraction by chromatographing the lipid sample (in 1 mL PE) on 3 g of Woelm Alumina (activity grade 3) with 2% dichloromethane (DCM) in PE as the eluting solvent. The lipids were retained on the alumina while the organochlorine compounds were collected in the eluting solvent. DCM was removed

from the sample by evaporating over a steam bath; the organochlorine compounds were transferred into hexane. PCBs were then separated from other organochlorine compounds using silicic acid chromatography as described by BIDLEMAN et al. (1978) with the following modifications. The amount of silicic acid used was 2.5 g; 0.1 mL distilled water was added to attain the desired moisture content. The first fraction collected was 6 mL PE, the second was 25 mL PE, and the third was 12 mL DCM.

PCB identification and quantitation were performed by dual column electron-capture gas chromatography. A Tracor MT-220 gas chromatograph was used, employing Ni-63 detectors, 180 x 0.4 cm glass columns packed with 1.5% OV-17/1.95% QF-1 or 4% SE-30/6% QF-1 on 100/120 mesh Supelcon AW-DCMS (OLNEY et al. 1980). The PCB peaks were identified by retention time and quantitated using peak heights as compared with a standard (equal parts Aroclor 1016, 1254 and 1260) that closely resembled most sample chromatograms. Peaks corresponding to these Aroclors were summed to give total PCBs. Values reported are the average from dual column injection less reagent blank (negligible) of each sample extracted, unless otherwise stated. Recovery of the PCB standard using extraction procedures described ranged from 91-112%.

RESULTS AND DISCUSSION

The percentage survival of groups of striped bass larvae fed on their respective Artemia spp. diets for 20 days (Table 1) were not significantly different (Duncan's multiple range test). The percent survival observed among these larvae is similar to those recorded in other laboratory studies for larvae first fed 18-20 days after hatching (ROGERS & WESTIN 1981) or fed reduced rations (ELDRIDGE et al. 1981). The larvae in the present study were not fed to allow for complete yolk utilization until 8-10 days after hatching which may have contributed to the mortality and initial slow growth. For example, larvae from Roe 539 grew only 20% of their total body dry weight during the first ten days of feeding. The 50% mortality for an unfed group of these larvae occurred 15 days after hatching. This is five days earlier than that observed among other laboratory reared Hudson River larvae at 18C (ROGERS & WESTIN 1981), but three days later than similar estimates from field collections (DEY 1981).

The growth observed after 20 days among these larval striped bass (Table 1) is similar to that reported for earlier laboratory studies involving this species at this temperature. The lengths and dry weights for larvae fed on the Artemia spp. diets for 20 days are equivalent to those reported for "well-fed" (ELDRIDGE et al. 1981) or "first fed 8-14 days after hatching" (ROGERS & WESTIN 1981) larvae of earlier studies. This suggests that the PCB concentrations (parental and dietary) in this study had no effect on larval growth. Of ten previous studies of the effects of PCB on fish growth summarized by BERLIN et al. (1981), no effect was observed in seven. BERLIN et al. (1981) reported that the growth of lake trout fry was not significantly affected by any of the PCB

and/or DDT exposures they studied.

The result of residue analysis of striped bass eggs and larvae throughout their first month of life (Table 2) showed a consistent reduction in PCB concentrations (µg/g) over time regardless of the PCB level in the diet. This pattern is similar to the reduction observed by BERLIN et al. (1981) for lake trout fry exposed to PCB concentrations 1x that of southeastern Lake Michigan water (20 ng/L) and plankton (1 µg/g) for 176 days, although fry exposed to 5x and 25x these levels of PCB showed increased body burden of the contaminants. The lack of observable dietary effect in striped bass until perhaps the last 10-day period can probably be attributed to the very high initial PCB concentrations in the eggs and larvae. The values in Table 2 found in striped bass eggs fall between the PCB egg concentrations of 120 ng/g (ppb) and 7.0 µg/g (ppm) reported to adversely affect larval survival in flounder (VON WESTERHAGEN et al. 1980) and sheepshead minnows (HANSEN et al. 1974), respectively.

Larvae from four females lost 78 to 97% of their initial (fertilized egg) PCB concentrations after being fed 20 days on either Aretmia spp. diet (Table 2). For all of the larvae fed the Brazilian Artemia spp., the loss exceeded 83% by the end of their first month of life. Losses during yolk absorption (first 8 days after hatching at 18C, ROGERS et al. 1980) were variable. However, once the larvae began feeding, the loss of PCB appeared to increase rapidly on a µg/g basis, especially during the second 10-day feeding period. This was the period during which larvae from Roe 539 grew 80% of their total dry weight growth of the 20-day feeding period. The decrease was far less dramatic when calculated on a per larva basis (Table 3), although most notable during the second 10-day period. The individual PCB burdens in Table 3 were calculated using the average of the dry weights for the three life stages measured during this study (i.e., post yolk sac, 10 day, and 20 day larvae). These were adjusted to wet weight using the value of 80% water for striped bass larvae of this size (ROGERS et al. 1980). No egg weights were determined in this study. The value used for egg weight in the calculations was that determined for other Hudson River striped bass eggs containing 85% water (ROGERS & WESTIN 1981). The PCB concentrations given in Table 2 were then adjusted by these wet weight estimates for each stage to give PCB body burdens. A reduction in PCB concentration and body burden following yolk absorption was also observed in lake trout (MAC & SEELYE 1981).

Striped bass larvae have an oil globule in addition to their yolk sac. Prior to hatching, the oil accounts for 52-55% of an egg's dry weight, while yolk accounts for about 37%. Although the yolk is fully utilized during the larva's first 8 days, the oil globule remains apparently unchanged in size during starvation although the larvae lose dry weight (ELDRIDGE et al. 1981; ROGERS & WESTIN 1981). Sufficient numbers of starved larvae were available for residue analysis from among larvae of only one spawning (Roe 553). The increase in PCB (3.5 vs 2.1 ppm) noted in these

Table 2. Total PCB concentrations of striped bass eggs and larval stages fed on two diets. Values are in µg/g wet weight.

Female Roe#	Fertilized eggs or prolarvae	Post yolk sac larvae	Larvae fed 10 days		Larvae fed 20 days	
			Brazil[a]	San Pablo[a]	Brazil[a]	San Pablo[a]
539	8.1[b]	9.5	4.5	4.4	1.4	1.8
721	2.0	1.6	0.7	0.7	0.2	0.2
527	3.3	0.9	ND[c]	ND	0.3	0.3
553	3.3[b]	2.1	1.3	1.4	0.1	0.1
566	1.1	1.4	ND	ND	ND	ND

[a]Analysis of diet Artemia spp. showed 14[b] ng/g PCB in Brazilian diet and 127[b] ng/g PCB in San Pablo Bay diet.

[b]Average of two sample extractions. [c]ND=not determined.

Table 3. Total PCB burdens of striped bass eggs and larvae fed on two diets. Values are in ng per individual bass.

Female Roe#	Fertilized eggs or prolarvae	Post yolk sac larvae	Larvae fed 10 days		Larvae fed 20 days	
			Brazil	San Pablo	Brazil	San Pablo
539	16.2	9.5	8.6	8.3	6.8	8.8
721	4.0	1.7	1.4	1.3	0.8	0.9
527	6.7	0.8	---	---	1.4	1.9
553	6.7	1.9	2.5	2.6	0.5	0.7

larvae starved six days after yolk absorption (i.e., 15 days after hatching) is felt to be attributable to loss of larval weight (tissues), leaving the PCB in the oil globule and/or utlized yolk intact. The decrease in PCB concentrations among fed larvae is most likely simply the addition of relatively PCB-free tissues to the bass during this very rapid growth period. This dilution due to growth has been suggested for larval lake trout (BERLIN et al. 1981) and male and female fathead minnows (DEFOE et al. 1978).

If the PCB concentrations found in the fertilized egg samples (Table 2) were indicative primarily of the female ovarian burden, then the smallest female (Roe 539) had levels over seven times that of the largest (Roe 566) female sampled. This is contrary to observed correlations of increasing PCB levels with increasing length (JESSOP & DOUBLEDAY 1976) and weight (JESSOP & VITHAYASIA 1979) of striped bass adults from Canadian rivers. From the lengths of the females sampled here, their ages are most likely VII-VIII (ROGERS et al. 1980) or VII (McLAREN et al. 1981) for the smallest and over XIII for the largest. This would mean that, given the age at first maturity as 5 years (ROGERS et al. 1980) or VI (McLAREN et al. 1981) for the Hudson River stocks, the females could have spawned from 2 to 8 times. That is, the largest female had spawned at least two and probably three more times than the smallest. Analysis of females 79 and 102 cm FL held under culture conditions for 5 years without spawning showed PCB concentrations in ripe ovarian tissue of 19 and 23 ppm (ROGERS et al. 1980). The skeletal muscle levels of PCB from these females were high (0.5 and 2.8 ppm), when compared to muscle samples from wild bass of the same size (<0.2 ppm). Thus, spawning probably enhances depuration or elimination of PCB from adult striped bass as has been shown for rainbow trout (GUINEY et al. 1979).

The results of this preliminary laboratory study of possible effects of PCBs on larval survival and growth show that the inherited and dietary concentrations encountered had no effect on survival and growth after yolk absorption. The dramatic reduction in total PCBs (µg/g wet weight) reflects dilution of PCB from parental sources by the accretion relatively uncontaminated tissue during this period of rapid larval growth. Further, among mature female striped bass, the act of spawning apparently serves to eliminate PCBs from their body tissues.

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