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Effect of PCBs and Other Organochlorine Compounds on the Hatchability of Atlantic Salmon *(Salmo salar)* Eggs

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This paper reports the levels of PCB's, hexachlorobenzene, and several organochlorine pesticides in Atlantic salmon (*Salmo salar*) eggs used in the genetics program of the North American Salmon Research Center. An attempt is made to relate these levels to hatchability under normal hatchery conditions.

The effects of PCB's and organochlorine pesticides on reproduction in Atlantic salmon were reviewed by ELSON et al. (1973). In 1971, levels of PCB's, DDT and metabolites, and dieldrin in the eggs were compared with concentrations associated with effects on hatchability and survival. It was indicated that only levels of PCB's were close to those reported to affect hatchability and survival. PCB levels of 7.7 and 34 μg/g lipid resulted in 34 and 100% mortality of Atlantic salmon fry, respectively (JENSEN et al. 1970). PCB's (Aroclor 1242) at 2.7 μg/g, corresponding to about 41 μg/g lipid resulted in a 75% mortality of rainbow trout (*Salmo gairdneri*) fry by 30 days after hatching with 60-70% of the fry deformed (HOGAN and BRAUHN 1975). Mortality of 10-28% occurred in batches of eggs containing 0.39 μg/g (6 μg/g lipid) of Aroclor 1254.

EXPERIMENTAL

Egg Collection

In 1975, a pooled sample of eggs of Big Salmon, Saint John and Magaguadavic Rivers and of Rocky Brook origin was collected from hatchery stocks. In 1976, eggs from the same rivers were sampled separately. Figure 1 shows the locations of these New Brunswick rivers.

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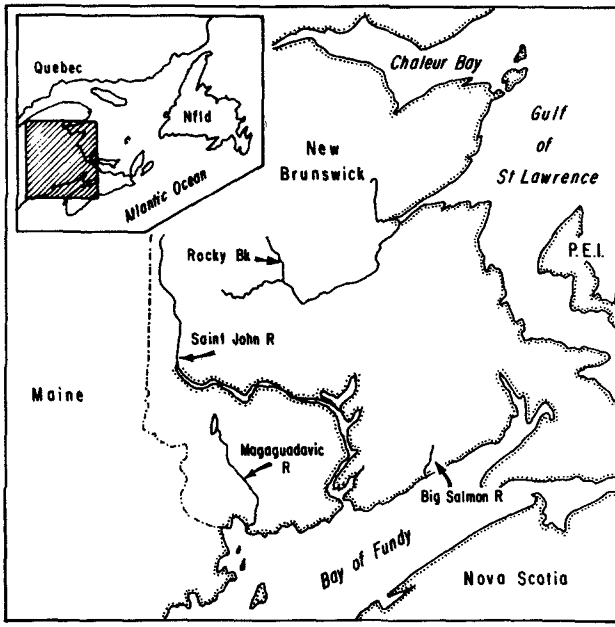

Fig. 1. Map of New Brunswick showing locations of rivers from which egg samples were studied for organochlorine compounds content.

Analysis

Approximately 3-10 g of eggs were taken at random from each of the four stocks. The eggs taken were the dead ones normally removed during incubation. Dead eggs regularly appear during incubation and are recognized by their white opaque appearance in contrast with red-orange viable eggs. Dead eggs may result from non-fertilization or from death of the embryo. There is no reason to believe that hydrocarbon levels should differ among the eggs produced by a given female. Eggs were freezedried, homogenized with anhydrous sodium sulfate and extracted with hexane in Soxhlet extractors. Aliquots of extracts were cleaned by column chromatography on alumina and silica and analyzed by gas chromatography. Details of the analytical procedure are described in ZITKO et al. 1974. The accuracy of the analyses, established in intercalibration programs, is normally ±10-20%.

Extracts of Magaguadavic and Rocky Brook eggs were cleaned on preparative alumina columns (40 g alumina/g lipid) and analyzed by gas chromatography-mass spectrometry (GCMS) to confirm the identity of the reported chlorinated compounds. A Finnigan 1015D mass spectrometer with a Model 6100 Data System was used. Samples were injected on a 5 ft x ¼ inch glass column containing 3% OV-1 on HP-Chromosorb W 80/100 at 100°C. The solvent was vented for 30 sec and, subsequently, the temperature was increased at a rate of 8°C/min to a final temperature of 270°C. Electron ionization mass spectra were scanned from 100 to 500 daltons in 5-sec intervals.

RESULTS AND DISCUSSION

Organochlorine compounds

The levels of PCB's and p,p'-DDE were lower in 1975 and 1976 than those reported by ELSON et al. (1973) for 1971, while the levels of p,p'-DDT and p,p'-DDD remained practically constant (Table 1). The

TABLE 1

PCB's and other chlorinated hydrocrabons (μg/g lipid) in Atlantic salmon (*Salmo salar*) eggs

Year and source	PCB's (Aroclor 1254)	Hexachlorbenzene (C_6Cl_6)	DDE	p,p'-DDD	DDT	Dieldrin	*trans*-Nonachlor
1971[a]	13.70	[b]	2.09	0.35	0.62	0.19	
1975	3.57	0.086	0.36	0.46	0.37	0.21	ND[c]
1976							
Big Salmon	6.48	0.086	0.48	0.45	0.40	[d]	0.21
Magaguadavic	2.88	0.132	0.39	0.34	0.41	[d]	
Saint John	2.44	0.142	0.16	0.20	0.35	[d]	
Rocky Brook	1.88	0.159	0.19	0.32	0.34	[d]	0.13

[a]Data of ELSON et al. (1973)

[b]Present, but not reported, probably <0.04

[c]Not detectable, <0.03

[d]Present, but not quantitated due to overlap with an interfering peak.

levels of dieldrin also have not changed very much between 1971 and 1976. On the other hand, the levels of hexachlorobenzene appear to be increasing. *Trans*-nonachlor, a component of technical chlordane, was detected for the first time in the 1976 samples. In the analytical procedure used, *trans*-nonachlor is detectable only by GCMS ($C\ell_8$ cluster, m/e = 405, Fig. 2), due to an interference by PCB's. It was present

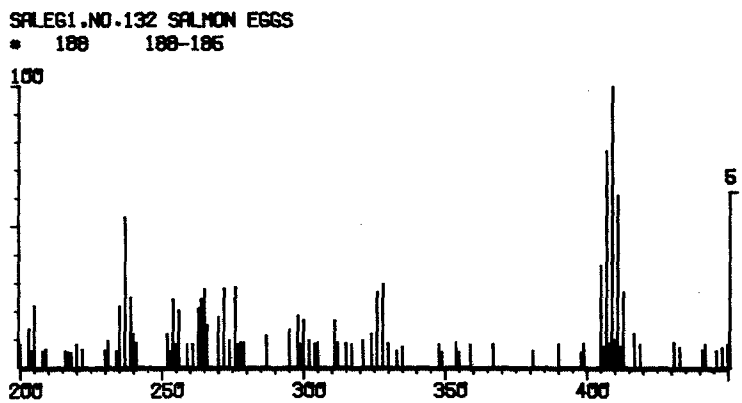

Fig. 2. Mass spectrum of *trans*-nonachlor in Big Salmon River eggs.

in both samples examined by this technique and it is likely that the remaining two 1976 samples, which could not be analyzed by GCMS because of lack of material, contained comparable levels of *trans*-nonachlor. The 1971 sample was not analyzed by GCMS, but *trans*-nonachlor was not detectable in the 1975 sample, examined by GCMS.

The 1976 samples also contained *cis*-nonachlor and *trans*- and *cis*-chlordane. These were not quantitated since the respective standards are not available. The relative areas under peaks on limited ion (m/e = 409 for nonachlors, m/e = 375 for chlordanes) gas chromatograms were 1.00, 0.30, 0.14, and 0.58, respectively. In a technical chlordane preparation, the corresponding values are 1, 0.24, 1.35, and 0.92.

The appearance of chlordane components in environmental samples may be due to its increased usage, started in 1970 (NRC, no date), although they may not have been detected in older samples, not examined by GCMS.

Except for dieldrin, the presence of all the reported compounds was confirmed by GCMS. This technique indicated that the PCB's ranged from tri- to heptachlorobiphenyls.

Hatchability

There were no apparent correlations between levels of organochlorine compounds and hatchabilities of the four salmon stocks studied (Table 2). There was little

TABLE 2

Hatching success of Atlantic salmon eggs from four wild, New Brunswick stocks; mean hatchability, variance, and number of families (matings) represented

	Big Salmon R.	Magaguadavic R.	Saint John R.	Rocky Brook
X	91.4	87.7	89.4	79.8
S	6.9	9.7	11.7	13.3
n	39	47	36	48

difference in hatching success among Magaguadavic, Saint John, and Big Salmon River eggs in spite of some differences in respective hydrocarbon levels. Although the eggs from Rocky Brook salmon had the poorest hatchability, their hydrocarbon levels, except hexachlorobenzene, were lower than for the other three stocks. This lower hatching success of Rocky Brook eggs was probably owing to some females being overripe; natural spawning of Rocky Brook salmon is slightly earlier than in the other three stocks. Although PCB's (Aroclor 1254) in eggs from Big Salmon River fish were 6.48 μg/g lipid, there was not an increased mortality rate. We conclude that the hydrocarbon levels reported here were not high enough singly or in combination to affect hatchability.

Possible source of Organochlorine Compounds

It is likely that organochlorine compounds are taken up by the fish while at sea rather than in fresh water. Salmon returning from the sea weigh from 30 to 70 times or more than they did on entering the sea as smolts. Certainly, the greater part of the lipid deposited in the body and mobilized during development of the eggs is derived from food taken at sea. Eggs from Big Salmon River fish, which are believed to spend their sea lives in the Bay of Fundy (SAUNDERS 1977), have the highest levels of all but hexachlorobenzene in marked contrast with Rocky Brook fish which, like other Miramichi stocks (SAUNDERS 1969), enter the Gulf of St. Lawrence and probably migrate to Newfoundland and Greenland. The Saint John River fish are known to contribute to Newfoundland and Greenland fisheries. Our limited data suggest that accumulation of PCB's and perhaps the organochlorine pesticides is related to migratory behavior at sea. Long residence in the Bay of Fundy may result in higher levels of PCB than migration to Newfoundland and Greenland. From data in Table 1, the Magaguadavic River fish appear to have a migration pattern similar to the Saint John River fish.

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