



Comment on Linking the Sex Difference in PCB Concentrations of Fish to Release of Eggs at Spawning: Time to Jettison the Dogma



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Opinion

For the past 20 years or so, a commonly used explanation in the scientific literature for higher polychlorinated biphenyl (PCB) concentrations in male fish than in female fish has been that females lose a high proportion of their PCB body burden by releasing eggs at spawning time, and therefore the females undergo a substantial decrease in their PCB concentration immediately after spawning due to shedding of their eggs [1]. Indeed, this explanation can be viewed as the conventional wisdom used by toxicologists to account for differences in PCB concentrations between the sexes of fish. On the surface, this explanation seems plausible. PCBs are lipid soluble, and eggs are thought to be relatively high in lipid concentration. If a sufficiently high proportion of the PCB body burden within a female fish is transferred to the eggs, then the release of eggs at spawning would be expected to result in a dramatic decrease in the PCB concentration of the female.

During the past 10 years, compelling evidence has emerged to show that higher PCB concentrations in male fish compared with female fish are not attributable to a dramatic decrease in PCB concentrations of females due to release of eggs at spawning [1]. Rather, this sex difference in PCB concentrations of fish appears to be primarily driven by males expending energy at a higher rate than females. Males exhibit greater swimming activity than females, and the resting metabolic rate (or standard metabolic rate, SMR) of males exceeds that of females, based on results from the few studies that have compared these rates between the sexes of fish [1-7]. These differences in activity rates and SMRs between the sexes contribute to a higher rate of energy expenditure in males than in females. For a given size of fish, this difference in energy expenditure rates between the sexes results in males consuming food at a higher rate than females. Given that nearly all of the PCBs entering the fish's body enter via food intake, this higher rate of food consumption by males than by females translates into males accumulating PCBs at a higher rate than females. Madenjian et al. [1] tested several hypotheses used to explain the higher whole-fish PCB concentrations in

males compared with females, and they concluded that the most likely primary driver of this observed difference in whole-fish PCB concentrations between the sexes is a higher rate of energy expenditure in males than in females.

Two key pieces of evidence have indicated that the higher whole-fish PCB concentrations in males compared with females are not attributable to females undergoing a drastic decrease in their PCB concentrations due to shedding of eggs at spawning [1]. First, coho salmon (*Oncorhynchus kisutch*) and sea lamprey (*Petromyzon marinus*) are semelparous species in that they spawn only once during their lifetime and die soon thereafter, yet PCB determinations of these fish caught prior to spawning indicated that males were significantly higher in PCB concentration than females. Mature male coho salmon, caught in Lake Michigan and its tributaries prior to their spawning, had 19% higher PCB concentrations, on average, than mature female coho salmon caught in Lake Michigan and its tributaries prior to their spawning [8]. Similarly, mature male sea lampreys caught in the Cheboygan River, a tributary to Lake Huron, prior to their spawning had 17% higher PCB concentrations, on average, than mature female sea lampreys caught in the Cheboygan River prior to their spawning [7]. These observed sex differences in PCB concentrations could not possibly be attributable to females experiencing a substantial decrease in their PCB concentrations due to shedding of eggs at spawning, because none of the fish used in these two studies had spawned during their lifetimes. Second, determinations of PCB concentrations in both the somatic tissue and eggs of mature female fish with ripe ovaries have indicated that, in most fish populations, PCB concentration of female fish is expected to increase, rather than decrease, immediately after spawning due to release of eggs [1]. If the PCB concentration in the somatic tissue of the female is greater than the PCB concentration in her eggs, then the proportion of her weight lost by releasing her eggs would exceed the proportion of her PCB body burden lost by releasing her eggs. Consequently, the PCB concentration of the female would increase immediately after spawning due to shedding of her eggs. Of the 12 fish populations

in which PCB concentrations of both somatic tissue and eggs of female fish with ripe ovaries have been determined, PCB concentration of females was expected to increase immediately after spawning due to egg release in 8 of those populations [9-15]. Specifically, female PCB concentration was estimated to increase by 9.1% in both rainbow trout (*Oncorhynchus mykiss*) and white suckers (*Catostomus commersoni*) from Lake Ontario [9], by 4.5% in walleye (*Sander vitreus*) from Saginaw Bay of Lake Huron [10], 5.4% in walleye from South Manistique Lake (Michigan) [11], 13.5% in lake trout (*Salvelinus namaycush*) from Lake Michigan [12], 4.2% in ciscoes (*Coregonus artedii*) from Lake Superior [13], 2.5% in lake whitefish (*Coregonus clupeaformis*) from Lake Huron [14], and 0.6% in summer flounder (*Paralichthys dentatus*) from the New Jersey coast (Atlantic Ocean) [15]. Because female PCB concentration is expected to increase immediately after spawning due to release of eggs, this increase in female PCB concentration could not possibly contribute to the observed higher PCB concentrations in males compared with females [1].

Despite the compelling evidence showing that the observed higher whole-fish PCB concentrations in males compared with females are not due to females exhibiting a substantial decrease in their PCB concentration immediately after spawning due to shedding of eggs, this explanation continues to be used by researchers today to account for males exceeding females in PCB concentration. Apparently, some toxicologists are reluctant to move past this traditional explanation.

I think that the time has come to jettison the dogma that females undergoing a major decrease in their PCB concentration due to egg release at spawning is the primary underlying cause for males exceeding females in whole-fish PCB concentration. The evidence against this dogmatic explanation is overwhelming [1]. Nevertheless, as the field of sex differences in contaminant concentrations of fish advances, toxicologists should continue to be aware of the possibility that, in a relatively few fish populations, females may actually experience a dramatic decrease in their PCB concentrations due to shedding of eggs at spawning time, and this large decrease may actually contribute to males exceeding females in whole-fish PCB concentration. Thus, toxicologists should continue to determine PCB concentrations in both somatic tissue and eggs of female fish with ripe ovaries to document any unusual cases. Although the likelihood of encountering them seems to be very low, cases in which females actually undergo a drastic decrease in their PCB concentrations owing to shedding of eggs at spawning should provide unique learning opportunities. However, unless evidence to the contrary emerges, toxicologists should consider the leading cause for males having higher whole-fish PCB concentrations than females to be males expending energy at a higher rate than females. This explanation does need to be further tested. Laboratory respirometry could be used to determine whether SMR for males is higher than SMR for females in fish species that have not yet been tested. Moreover, when feasible, telemetry

could be used to determine whether swimming activity by males exceeds that by females in fish populations that have not yet been examined. Finally, work on surveying fish populations from around the world should continue to better quantify the pervasiveness of the characteristic of mature males exceeding mature females in whole-fish PCB concentration.

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