Table 1. Mean concentrations (ng/g) of total polychlorinated biphenyls in tissue of nestling tree swallows along the Upper Hudson River and from the reference site in Saukville (WI, USA) in 1998. Data from previous studies provided for comparison

Location	ng/g	Reference
Upper Hudson River, New York, USA		
Remnant Deposit 4	7,900	This study
Special Area 13	9,950	
Saukville (WI, USA)	49	This study
Lower Fox River (WI, USA)	2,500	[38]
Lake Huron (ON, Canada)	10	[39]
Lake Ontario (ON, Canada)	750	[39]
Saginaw River (MI, USA)	1,000	[40]

1998 reference site was at the University of Wisconsin–Milwaukee Field Station (Saukville, WI, USA; 438239N, 888019W). We also included reference site data from our previous DNA fingerprinting studies of populations of tree swallows in Ontario (448349N, 768209W) and Alberta (538389N, 1128369W) in 1990 and 1991 [14–16]. Chemical analyses of tree swallows in other areas have indicated much lower levels of PCB contamination than along the upper Hudson River (Table 1; see also fig. 3 in [13]). None of the reference sites was near industrial activity, and thus we presumed these sites were less contaminated than the New York sites. In the case of the Wisconsin site, we provide data here to support this assumption. All nests were checked every 2 d to monitor stage of reproduction. Adults were captured in the nest boxes.

PCB analyses

Polychlorinated biphenyl concentration in tree swallow nestlings (14 d old) was estimated at the two Hudson River sites and in Wisconsin in 1998, similar to our previous studies [13]. For PCB analysis we collected two nestlings from each of four nests at each of the two Hudson River study sites (16 nestlings) and one nestling from each of two nests in Wisconsin (two nestlings). Nestlings were euthanized using carbon dioxide and approved techniques ([17]; see Acknowledgement for permits). All nestling samples were stored in chemically clean containers and kept frozen until analysis. Polychlorinated biphenyl congener analysis of tree swallow nestlings was performed by the Columbia Environmental Research Center (Biological Resource Division, U.S. Geological Survey, Columbia, MO) using capillary gas chromatography/electron capture detection. All gas chromatography/electron capture detection analyses were performed using a Hewlett-Packard 5890 Series II gas chromatograph (Hewlett-Packard, Palo Alto, CA, USA) with cool on-column capillary injection systems. Total PCB concentrations for these samples were determined by summing the concentrations of the PCB congeners [18].

DNA fingerprinting

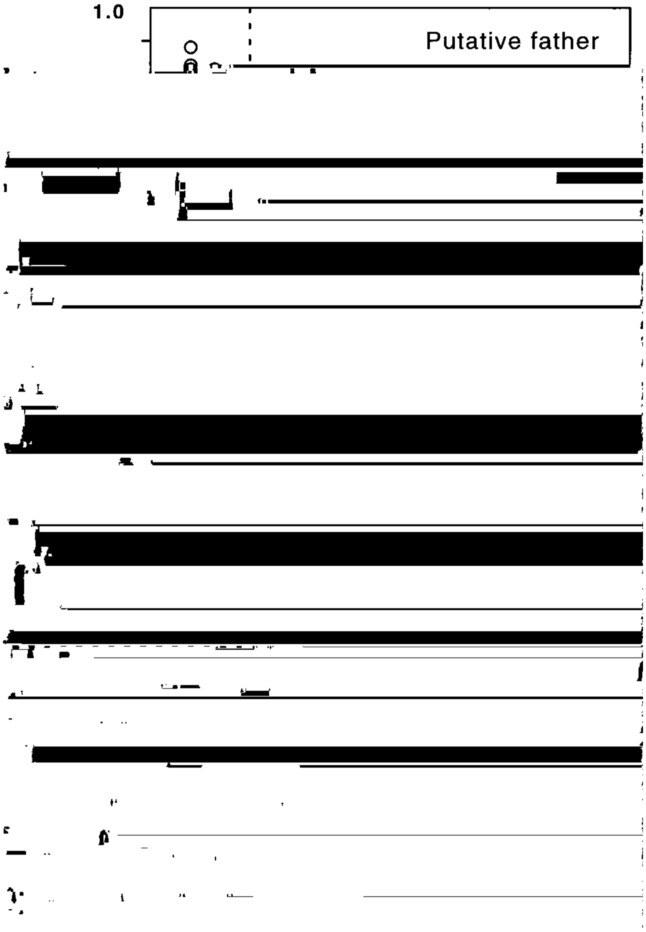

Fig. 1. Band-sharing coefficients and novel fragments of each offspring with their putative father (top panel) or mother (bottom panel). Data are from 178 nestlings sampled along the upper Hudson River,

per thousand fragments [3]. If such a high mutation rate occurred in tree swallows, then we should have found 37 novel fragments in the more contaminated sites (based on the number of fragments scored); however, we found just 18 novel fragments. Our pooled sample sizes (including all reference sites) were sufficient to detect a difference in mutation rate of about 0.5 times, which is smaller than the differences reported elsewhere. For example, the mutation rate of herring gulls was two times higher in contaminated than reference sites [3], and mutation rates of barn swallows from Chornobyl were 2 to 10 times higher than birds from reference sites [2].

Our results contrast with a recent study that found a higher rate of mutation in laboratory mice injected with PCB (Aroclor 1254) [12]. Hedenskog et al. [12] found six mutations among 51 alleles in their PCB treatment group (0.118), which was significantly greater than the control group (0 mutations among 43 alleles). However, in their study, mutations were found at only one of the two loci examined, suggesting that if PCBs do indeed cause mutations, the effect is variable. Hedenskog et al. [12] suggested that Aroclor 1254 was genotoxic because it interfered with recombination. Similarly, germ-line mutations in human minisatellites are thought to occur as a consequence of unequal sister chromatid exchange, gene conversions, or replication slippage [29,30].

A number of explanations exist for why our results differ from those of Hedenskog et al. [12]. First, differences may have existed in exposure to PCBs. The mice studied by Hedenskog et al. [12] had at least 10 times the concentration of PCBs observed in tree swallows. In this study the highest mean level of contamination in tree swallow nestlings was 12,000 ng total PCB/g body mass, while Hedenskog et al. [12] injected mice twice with 100,000 ng Aroclor 1254/g body mass over a period of approximately 12 d. The route of exposure also differed, as mice were injected with PCBs while swallows were exposed through their diet. Also, the PCB congener composition may have differed between studies. Substantial variability exists in the toxicological mode of action and the severity of effects among PCB congeners [31]. Lastly, it is well known that the effects of PCB contamination vary among species [31]. Even different strains of laboratory mice differ in mutation rate for the same minisatellite locus [12]. In birds, for example, PCB contamination has a wide range of physiological effects on reproduction and behavior, depending on the species [32,33]. In fact, it appears that tree swallows are able to tolerate higher levels of PCB exposure than other species. Tree swallows nesting along the upper Hudson River valley do not appear to have some of the extreme morphological deformities seen in other contaminated species [34], although they do have abnormal plumage development [35]. Additionally, tree swallows in this population have higher rates of nest abandonment [36] and make poorer-quality nests [37].

In summary, we found no effect of PCB contamination on the mutation rate of minisatellite DNA of tree swallows. It is apparent that DNA fingerprinting is a useful technique for testing effects of contaminants on wildlife, as minisatellite DNA has relatively high rates of mutation, and many loci (at least 10 in this study) can be surveyed simultaneously, thus reducing the need for large sample sizes. Contrasting results from different studies suggest the effects of PCB contamination are complex. Further studies are necessary to elucidate the effects of high concentrations of PCBs on mutation rates in both laboratory and wild vertebrates.

Acknowledgement

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