Assessment of Effects of PCB-Contaminated Sediments and Floodplain Soils on Reproduction and Community Structure of Insectivorous Song Birds

Miranda H. Henning, Ellen S. Ebert, Elizabeth R. Algeo, and Russell E. Keenan
ChemRisk® Division, McLaren/Hart Environmental Engineering
1685 Congress Street, Portland, Maine 04102 USA

1. Introduction

From the 1930s through the late 1970s, polychlorinated biphenyls (PCBs) were used as insulating liquids in electric transformers at a manufacturing facility in Massachusetts. While use of PCBs was discontinued in 1977, inadvertent releases prior to 1977 were conveyed to an adjacent river and deposited in river sediments downstream of the facility. During periodic flooding, river sediments containing PCBs were deposited on soils of the 10-year floodplain within an area managed for wildlife conservation. Concentrations of PCBs in floodplain soils in this area range from 0.5 to 32 ppm, while levels in sediments adjacent to this area range from 6 to 200 ppm.

As one component of a multiphase ecological risk assessment, population and reproductive studies were conducted on insectivorous passerine birds inhabiting the floodplain. Species were selected based on feeding behaviors and habitat preferences that could potentially result in high exposures to PCBs in the river sediments and floodplain soils. The diversity, density, community composition, and reproductive success of avian populations living within the floodplain (target population) were compared to those of reference populations.

2. Methods

Eight passerine species were selected for evaluation, based on their potential for exposure to PCBs, particularly with respect to feeding habits, home range, and trophic level. The species evaluated have home ranges smaller than the 10-year floodplain, ensuring that the majority of the area where they forage is within the study area, and are secondary consumers (primarily insectivorous species) that may be exposed to PCBs through food web transfers and directly from contact or ingestion of soils during foraging and preening. For all species selected, the spatial and temporal scales of their primary activities (foraging, reproducing, incubating, preening, and sleeping) coincide with the presence and potential availability of PCBs in the flood plain soils and sediments.

The susceptibility of birds to the toxicological effects of PCBs influenced the choice of assessment and measurement endpoints. Since the first reports in 1966[1,2] of reproductive problems in herring gulls and other species inhabiting the Great Lakes, substantial research has focused on the effects of PCBs on a variety of wild and domestic avian species. The past two decades of research on toxicity of PCBs to birds have focused on sublethal, chronic endpoints. While effects on numerous organs and systems have been observed in the laboratory at high PCB doses, the most prevalent effect observed in the field is reproductive impairment, including embryotoxicity and aberrant parental incubation behavior[3-13].

Assessment endpoints selected for evaluation in this study included: (a) adverse changes in community structure and (b) reproductive impairment. The following measurement endpoints were studied in the

field to evaluate these assessment endpoints: (a) diversity of avian species in the floodplain forest; (b) density of avian populations in the floodplain forest; (c) clutch sizes; and (d) number of young hatched.

Avian community structure was assessed by conducting censuses in the floodplain forest target area using a modified version of the plot census technique outlined by Svensson[14]. As six 1-hectare (ha) plots were traversed, the common name, sex, and location within the plots of all birds visually or aurally observed were recorded. Individual observations were plotted on species-specific composite maps. The numbers of individuals and breeding pairs of each species in the study area were extrapolated to the number of individuals and pairs per 40 ha of habitat. Species diversity was evaluated using Hill's[15] diversity numbers (designated N0, N1, and N2), a series of indices that accounts for both the number of species and the equitability or evenness of allotment of individuals among the species:

$$N0 = S$$
$$N1 = e^{H'} \text{ and}$$
$$N2 = 1/\lambda$$

where:

S	=	the total number of species (unitless)
e	=	the inverse of natural logarithm (unitless)
H′	=	Shannon's Index
λ	=	Simpson's Index

Shannon's Index:

$$H' = -\left[\sum_{i=1}^{s} p_i * \ln(p_i)\right]$$

Simpson's Index:

$$\lambda = \sum_{i=1}^{s} p_i^2$$

where:

p_i =	n_i/N (unitless)
n_i =	the number of individuals of the ith species (unitless)
N =	the total number of individuals for all S species in the population (unitless)

Because suitable local reference areas were not available for the community structure analysis, the avian community structure of the floodplain forest was compared to community structure recorded over the past decade for reference floodplain forests in Maryland and North Carolina.

To assess reproductive success, approximately 300 natural nests were monitored for the number of eggs laid and the number of young hatched. Observations were entered into a database listing each nest's species, number of eggs laid, number of eggs hatched, and location with respect to PCB contamination (i.e., target vs. reference area). Data were analyzed for significant differences in number of eggs laid and young hatched (by species) between target and reference nests. Significance was measured using the Student t-test and Mann-Whitney U-test.

3. Results

Of 23 species observed in the target area, American redstart was dominant, occupying 20% of the breeding territories, followed by veery (14%), and red-eyed vireo (11%). Density data for the target area and the two reference areas are presented in Figure 1. The density of breeding birds in the Massachusetts target area (424 territories/ha) was greater than the mean densities since 1981 for either the Maryland or North Carolina reference areas (365 and 289 territories/40 ha, respectively). As is depicted in Figure 2, avian diversity in the Massachusetts target area was lower than the average for either reference site since 1981.

A sufficient number of nests were located and monitored to allow analysis of the reproductive success of 8 species. Figure 3 summarizes clutch sizes for the 8 species (n=120) in target and reference areas. While clutch sizes for American redstart, red-winged blackbird, wood thrush, and yellow warbler were greater in the target areas than in reference areas, and clutch sizes for American robin and barn swallow in reference areas were greater than in the target area, none of these differences were statistically significant.

The results of the study of the numbers of young hatched (Figure 4) parallel those of the clutch size study. Several bird species, including the American redstart, American robin, red-winged blackbird, and wood thrush, had greater numbers of young hatched for the target groups than for the reference groups. The numbers of reference young hatched were greater than the numbers of target young hatched for the barn swallow and Eastern phoebe. Samples sizes were too small to test for significance for the American redstart and Eastern phoebe. Of the species for which adequate data were available to test for significance (barn swallow, American robin, and red-winged blackbird), none of the differences in numbers of eggs laid or young hatched for target and reference groups were significant (Figures 3 and 4).

Because clutch size and number of young hatched vary substantially among different species, it was necessary to segregate species for the preceding analyses. In contrast, hatching success (the ratio of young hatched to eggs laid for a given nest) was assumed not to vary among species and, therefore, analysis of hatching success was performed irrespective of species. Hatching success of reference nests was 88.4% (n=45) and hatching success of target nests was 87.4% (n=60). This difference is not statistically significant (p=0.77).

4. Discussion and Conclusions

While the density of nesting territories in the study area was equal to or greater than that in the reference areas, diversity in the target area was lower than the average for either reference site. This difference could be the result of several factors. First, the Massachusetts target area is smaller (5.8 ha) than the Maryland (6 ha) or North Carolina (12.6 ha) reference areas. Total time spent censusing avian species was also lower for the Massachusetts site (17.5 hr) than for the Maryland and North Carolina sites (avg = 52.6 and 19.8 hr, respectively). Third, bird species diversity generally decreases dramatically as one proceeds north from the equator[16-18]. Finally, breeding densities of birds may be substantially affected by resources (such as food and nest sites) or natural enemies (such as predators and parasites)[19]. Hence, the differences in avian community structure within the target and reference areas are inconclusive with respect to potential effects caused by the presence of PCBs in the floodplain soils.

The number of eggs laid and young hatched were not significantly different between target and reference nests. The results of the reproductive study, in terms of power and in levels of significance, were particularly strong for the red-winged blackbirds, which, due to nest locations and feeding behavior, would be expected to have particularly high levels of exposure. Hence, it appears that reproductive recruitment of young birds to the community has not been adversely affected by the presence of PCBs in flood plain soils or sediments. The embryonic bird is especially sensitive to PCBs and represents the life stage in which PCB effects would be expected to be most easily manifested[20]; hence, the finding of normal hatchability in nests located in territories with PCB contamination is of particular significance. In conclusion, when the health of the avian community inhabiting the PCB-contaminated floodplain was

evaluated relative to that of communities inhabiting reference sites and relative to normal ranges provided in scientific literature, the weight-of evidence indicated the absence of significant adverse effects on these communities.

5. References

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Figure 1. Avian Population Study: Density

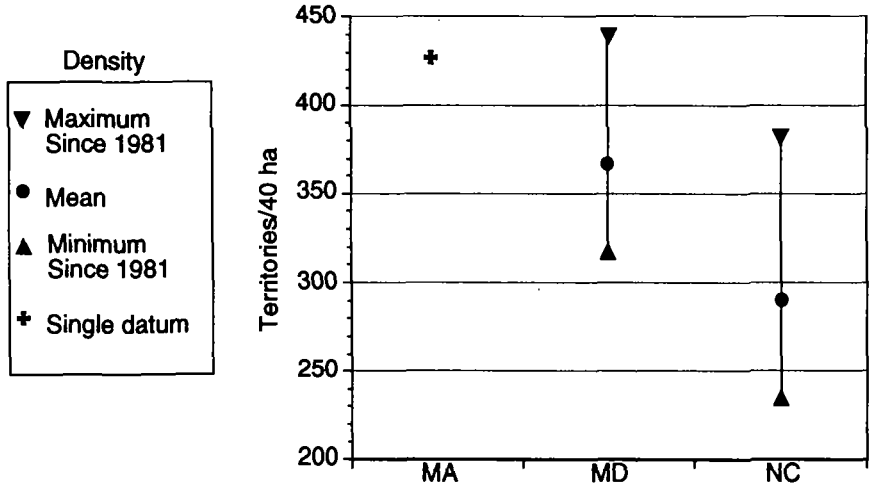

Figure 2. Avian Population Study: Diversity

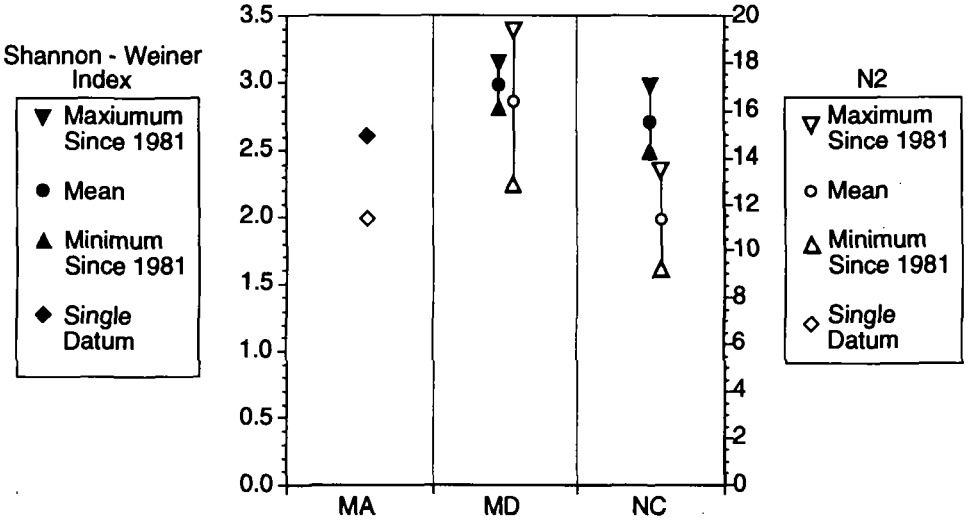

Figure 3. Avian Reproduction Evaluation: Clutch Size

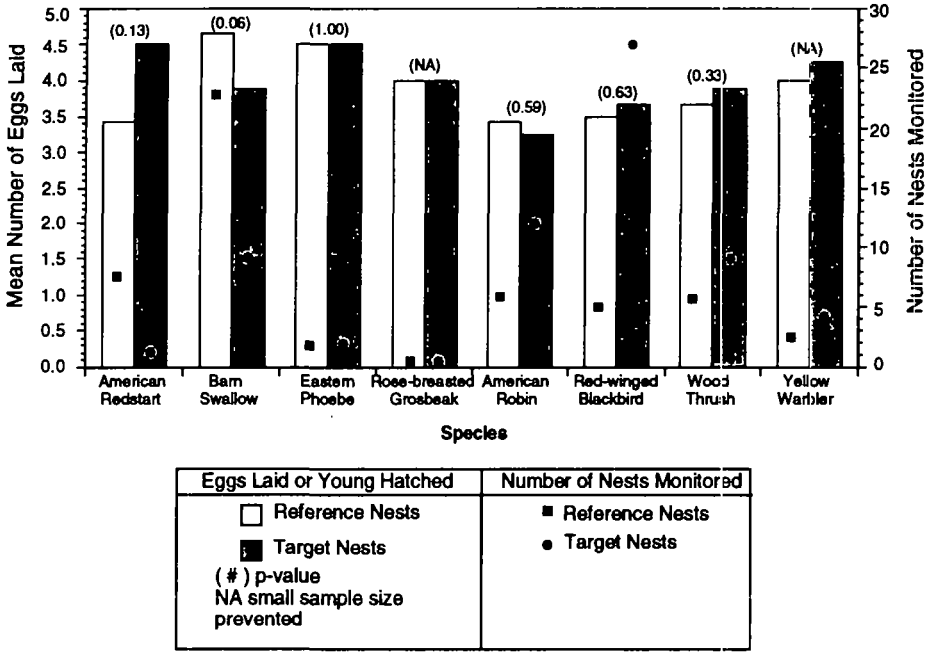

Figure 4. Avian Reproduction Evaluation: Young Hatched