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Polychlorinated biphenyl exposure and fish recruitment from 1988 to 2002 in the upper Hudson River, New York, USA

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ABSTRACT

Starting in the late 1940s, fish in the upper Hudson River, New York, USA, were exposed to polychlorinated biphenyls (PCBs) from discharges from two manufacturing plants. These discharges greatly decreased in 1976, and PCB concentrations in fish generally declined between 1980 and 1991, increased in 1992–1994 due to a failure in 1991 of a structure that contained PCBs, and then decreased after 1994. To assess the impact of PCBs on fish reproductive success and recruitment, we collected yellow perch (*Perca flavescens*), largemouth bass (*Micropterus salmoides*), and brown bullhead (*Ameiurus nebulosus*) from 2002 to 2006 at two sites just downstream of these PCB sources. A subsample of these fish were aged; ages of remaining fish were assigned using a length:age key, and linear catch curves [$\log_e$ (Number-at-age) = age] were computed. Maximum ages ranged from 11 to 16 years across species, and residual values generated from these catch-curve regressions represented relative year-class abundances produced from the late 1980s to the early 2000s. Wet-weight muscle tissue PCB concentrations in adults varied from average highs of 18–30 μg/g in the late 1980s-mid 1990s to lows of 3–9 μg/g by 2002 at the site nearest to the PCB sources. PCB concentrations in adult fish were unrelated to the formation of weak or strong year-classes in all three fish species. Although PCB concentrations were 2 to 8 times higher at the site nearest the PCB sources compared to a downstream site, natural mortality rates (fish harvest prohibited) derived from catch-curves were similar between sites for all three species. Thus, longevity and production of older year classes were consistent between sites. For these three species, we did not detect any PCB-mediated effect on fish recruitment at the population level at adult PCB concentrations (18–30 μg/g).

1. Introduction

Although the production and use of polychlorinated biphenyls (PCBs) ceased in the USA over 35 years ago and a world-wide ban was called for in 2001, extensive research continues to be published on wild fauna to document PCB uptake and to measure and predict any chronic effects of PCBs. Many studies were conducted from the 1970s to the present that either indicated or suggested PCBs to be a possible cause of fish reproductive failure through either direct toxicity effects on eggs, embryos, or larvae or indirect chronic effects via endocrine disruption (Kime, 1998; Wenning et al., 2011). Nearly all studies were completed in laboratory environments; less research has examined population-level effects of PCBs on wild fish collected from exposed aquatic systems (reviewed by Henry, 2015).

By 1976, two General Electric (GE) manufacturing plants in Fort Edward and Hudson Falls, New York, USA (Fig. 1), halted use of PCBs and discharge into the upper Hudson River. In the mid-1980s, total wet-weight PCBs in muscle tissue (3% lipid) ranged from 30 to 50 μg/g in fish collected downstream of these PCB sources and these concentrations appear to have generally declined until 1991 (Sloan et al., 2005). In late 1991, a wooden gate collapsed in a tunnel within the abandoned Allen Mill which was located next to the river bank near the Hudson Falls plant. Oil-phase PCBs that had migrated to the tunnel water via subsurface bedrock cracks had previously been prevented from entering the river by the gate (http://www.epa.gov/hudson/actions.htm). Concentrations of total wet-weight PCBs in fish increased to 40–100 μg/g (3% lipid) in 1992 and these concentrations persisted for a few years before decreasing after 1994 (Sloan et al., 2005).

Since the 1970s, fish inhabiting the Hudson River have been extensively sampled to record PCB concentrations in fish (Sloan et al., 1984; Fabrizio et al., 1991; Butcher et al., 1997; Sloan et al., 2005; Baldigo et al., 2006). In a review of published papers, Monosson (1999) speculated that PCBs concentrations in fish

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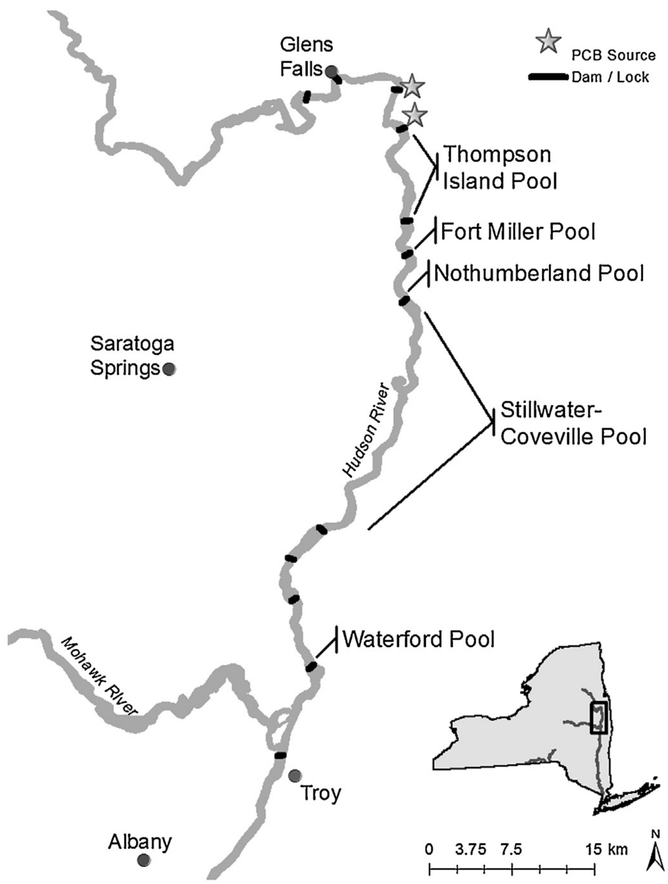

Fig. 1. Map of the upper Hudson River, New York, USA, that show the locations of the PCB sources, the Thompson Island, Northumberland, Fort Miller, Stillwater–Coveville, and Waterford pools.

inhabiting the upper Hudson River in the early to mid-1990s were high enough to cause reproductive endocrine disruption and affect subsequent reproduction, survival, and growth of young fish. In addition, using data collected in 1998, Baldigo et al. (2006) hypothesized that PCBs, mercury, or other contaminants may have been related to alterations in endocrine biomarkers which affect reproduction of black bass including largemouth bass (*Micropterus salmoides*) and smallmouth bass (*M. dolomieu*) in the upper Hudson River. However, Maceina and Sammons (2013) found no relation between reproductive success measured by electrofishing catch rates of age-1 fish and total wet-weight PCBs of 1–3 μg/g in muscle tissue of adult wild largemouth bass, smallmouth bass, and yellow perch (*Perca flavescens*) from 2003 to 2009 in the same areas sampled in the upper Hudson River by Baldigo et al. (2006).

In 1984, the upper Hudson River from Ft. Edward to Troy, New York, USA was designated by the U. S. Environmental Protection Agency (USEPA) as a Superfund Site, and in 2002, the USEPA selected sediment removal as a method to reduce PCBs in the system (http://www.epa.gov/hudson). The New York State Department of Environmental Conservation banned fishing from the upper Hudson River from 1976 to 1995 and has permitted only catch-and-release fishing since 1996. Maceina and Sammons (2013) noticed many of the adult fish sampled in 2003–2004 were 10 to 15 years old. Thus, these older fish were hatched in the late 1980s and early 1990s, when PCB concentrations were about an order of magnitude higher than PCB concentrations in fish collected in 2003–2009 (see Fig. 2 in Maceina and Sammons, 2013).

The presence of older fish and the ban on fish harvest since 1976, combined with the spike in fish PCB concentrations in the early to mid-1990s due to the “Allen Mill event”, afforded us a unique opportunity to examine the relation between historical fluctuations in PCBs and fish recruitment in the upper Hudson River. We compared observed to expected rates of cohort abundance of fish hatched from the late 1980s until 2002 and used age-structure data that tracked the decrease in abundance-at-age due to natural mortality as fishing mortality was absent. Deviations from expected changes of abundance-at-age over time (i.e. residuals) using catch-curve regressions infer either reduced or increased recruitment success (Maceina, 1997). These residuals were compared to variation in fish PCBs. From catch-curve analyses, we also computed and compared long-term survival rates between two sites on the upper Hudson River that had disparate levels of PCBs in fish. For these analyses, we examined wild populations of largemouth bass, yellow perch, and brown bullhead (*Ameiurus nebulosus*).

2. Materials and methods

2.1. Study sites

Data were analyzed from two sites (river pools), separated by dams and locks, in the upper Hudson River (Fig. 1). Major PCB sources to the upper Hudson River were two GE industrial plants located at river kilometer (RK) 317 and RK 319. The Thompson Island Pool was located just downstream of these plants (RK 303–314), whereas the Stillwater–Coveville Pool was further downstream (RK 271–295). In 1997–1998, total PCB concentrations in the surficial sediments (15–20 cm deep) averaged 2480 μg/g in the Thompson Island Pool which were about three times greater than in the Stillwater–Coveville Pool (Baldigo et al., 2006). Fish migration between these two pools was unlikely due to locks and dams which hindered upstream and downstream movement (Skinner, 2011; Maceina and Sammons, 2013). In addition, these three fish species are non-migratory and typically exhibit limited movements (Sammons and Maceina, 2005; Radabaugh et al., 2010; Brewer and Orth, 2015). Fish PCB data from three additional pools (Fort Miller, Northumberland, and Waterford; Fig. 1) were also obtained to predict yellow perch PCB concentrations from largemouth bass for five years when yellow perch were not collected for PCB analysis at our two sites.

2.2. Historic PCB data and analyses

Total wet-weight PCB concentrations (μg/g) in muscle tissue (filet) and percent lipid concentrations of largemouth bass, yellow perch, and brown bullhead were assembled into a single data base by Anchor/QEA (Montvale, NJ, USA) from the data collected by Sloan et al. (2005; http://www.dec.ny.gov/docs/wildlife_pdf/hrpcbtrend.pdf) and unpublished data collected by Law Environmental, Inc. (Kennesaw, Georgia, USA) in 1990. The skin on the fish filets was retained and also included the belly flap and rib (Sloan et al., 2005). The skin of brown bullhead was difficult to homogenize for PCB analysis, hence the skin was removed from the filet of these fish. A total of 1135 fish (Appendix Table A1) were collected for PCB analysis between 1985 and 2002 using DC electrofishing from 6 and 3 locations within the Thompson Island and Stillwater–Coveville pools, respectively. Most fish were collected in May and June, the rest were collected between July and November. Approximately 90–95% of the fish in the database were considered to be adults, based on the criteria of Sloan et al. (2005): largemouth bass >30 cm, yellow perch >17 cm, and brown bullheads >20 cm.

Upon collection, fish weights and lengths were recorded, and a unique identifying tag was given to each fish. Fish were placed in PCB-free plastic bags then frozen until shipped to an analytical laboratory for PCB analyses. At the contract laboratories, tissue