PCB CONTAMINATION OF THE HUDSON RIVER ECOSYSTEM

COMPILATION OF CONTAMINATION DATA THROUGH 2008

HUDSON RIVER NATURAL RESOURCE DAMAGE ASSESSMENT

HUDSON RIVER NATURAL RESOURCE TRUSTEES

STATE OF NEW YORK

U.S. DEPARTMENT OF COMMERCE

U.S. DEPARTMET OF THE INTERIOR

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HUDSON RIVER

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EXECUTIVE SUMMARY

The Hudson River Natural Resource Trustees are conducting a natural resource damage assessment (NRDA) to investigate natural resource injuries that may have occurred due to the release of polychlorinated biphenyls (PCBs) from General Electric (GE) facilities at Hudson Falls and Fort Edward, NY. This report summarizes available information on PCB contamination in the Hudson River ecosystem, including historic information, but focusing particularly on data collected and analyzed between 2002 and 2008 as part of ongoing NRDA activities. The Hudson River, for greater than 200 miles below Hudson Falls, NY, is extensively contaminated with PCBs. Surface waters, sediments, floodplain soils, fish, birds, wildlife, and other biota are all contaminated with PCBs. PCB concentrations are generally highest in those areas that are closer to the GE facilities, which are responsible for the majority of the area's PCB contamination. PCB concentrations tend to decrease with increasing distance downstream from these facilities. PCB concentrations upstream of the plant sites are substantially lower than the levels downstream.

This report also compares PCB concentrations in environmental media to regulatory standards and guidance criteria as well as to effects thresholds from the scientific literature. The more frequently these levels are exceeded, and the greater the magnitude of the exceedance, the more likely it is that PCBs have injured the natural resource(s) in question. Examples of exceedances described in this report include, but are not limited to:

- In water, exceedances of water quality standards and criteria;
- In sediments, exceedances of adverse effects levels for benthic organisms;
- In fish, exceedances of the U.S. Food and Drug Administration's (FDA) tolerance level for edible portions of fish;
- In mink, exceedances of levels associated with reproductive impairment;
- In snapping turtles, exceedances of levels associated with the latent mortality in juveniles;
- In bullfrogs, exceedances of levels associated with ecologically significant adverse effects (metamorph malformations and altered sex ratios); and
- In birds, exceedances of levels associated with reproductive impairment.

The frequency and severity of these exceedances varies by location and date; however, there are numerous instances in which the measured PCB concentrations exceed the selected benchmark by a factor of 10, 100, or more.

The information in this report demonstrates that high levels of PCB contamination have existed for decades in the Hudson River ecosystem. The data also suggest that PCBs are likely to be causing serious adverse effects to the area's biota.

The Hudson River Natural Resource Trustees' (HRNRT) natural resource damage assessment (NRDA) for the Hudson River ecosystem is ongoing. Additional information about the NRDA can be found on the following websites:

http://www.darp.noaa.gov/northeast/hudson/index.html

http://www.dec.ny.gov/lands/25609.html

http://www.fws.gov/contaminants/restorationplans/HudsonRiver/index.html

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ACRONYMS AND ABBREVIATIONS

DOI	U.S. Department of the Interior
EPA	U.S. Environmental Protection Agency
FWS	U.S. Fish and Wildlife Service
fww	Fresh wet weight
GE	General Electric Company
HRNRT	Hudson River Natural Resource Trustees
NOAA	National Oceanic and Atmospheric Administration
NRDA	Natural Resource Damage Assessment
NYDEC	New York State Department of Environmental Conservation
PCBS	Polychlorinated biphenyls
ppb	Parts per billion (for example, one microgram per kilogram, or µg/kg)
ppm	Parts per million (for example, one milligram per kilogram, or mg/kg)
pptr	Parts per trillion (for example, one nanogram per kilogram, or ng/kg)
tPCBs	Total polychlorinated biphenyls
USGS	U.S. Geological Survey
ww	Wet weight

CHAPTER 1: INTRODUCTION

The Hudson River ecosystem below Hudson Falls, NY is extensively contaminated with PCBs. Federal and State Trustees are investigating injuries to living organisms and other natural resources that may have been caused by PCBs present in the Hudson River and surrounding environment.

The Trustee agencies are the U.S. Department of Commerce (DOC), the U.S. Department of the Interior (DOI), and the State of New York. These entities have each designated representatives that possess the technical knowledge and authority to perform natural resource damage assessments (NRDAs). For the Hudson River, the designees are the National Oceanic and Atmospheric Administration (NOAA), which represents the U.S. Department of Commerce, the U.S. Fish and Wildlife Service (FWS), which represents the concerned DOI bureaus (FWS and the National Park Service), and the New York State Department of Environmental Conservation (NYSDEC), which represents the State of New York.

This report provides an overview of PCB contamination of the Hudson River ecosystem including some historical information, but focusing particularly on data collected and analyzed between 2002 and 2008 as part of the ongoing natural resource damage assessment (NRDA). (Post-2008 data may be presented in an update to this report.) The Hudson River Natural Resource Trustees (HRNRT) are using this information together with the results of ongoing and future studies to assess injury to natural resources, and to determine the amount and type of restoration necessary to compensate the public for natural resource injuries and associated lost services.

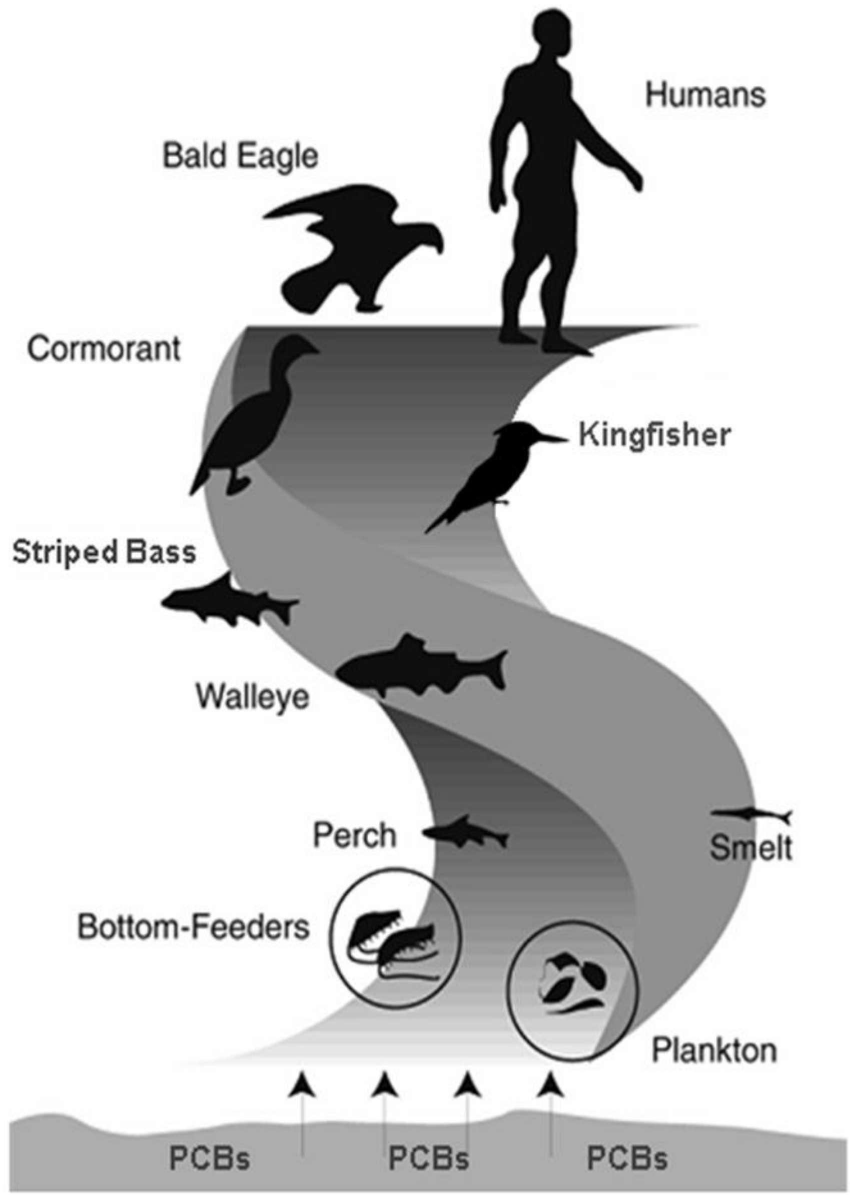
PCBs, or polychlorinated biphenyls, are a group of highly toxic compounds that are known to cause cancer, birth defects, reproductive dysfunction, growth impairment, behavioral changes, hormonal imbalances, damage to the developing brain, and increased susceptibility to disease in animals (HRTC 2002).

PCBs accumulate in living organisms (Exhibit 1). They are transmitted from animal to animal via the food chain, and from parent to offspring in eggs. PCBs are stored in body fat, and the PCBs that have accumulated in a mother's body can be passed to early life stages via eggs (e.g., Kelly et al. 2008), and through placental and lactational exposures (e.g., Bleavins et al. 1981). PCBs can also contaminate the air, entering organisms via the lungs or gills, and are absorbed through the skin, such as from contact with contaminated soil (ATSDR 2000).

PCB concentration measurements in sediments, soils, water, and biota are frequently reported in units of parts per million (ppm), parts per billion (ppb), or even parts per trillion (pptr), depending on the material measured and on the amount of PCBs present in the material. A PCB concentration of one part per million (or billion, or trillion) for a sample means that the sample contains one part of PCBs per million (or billion, or trillion) parts of whatever is being analyzed (sediments, soil, water, animal tissue or other material).

Two General Electric facilities (Exhibit 2) have been identified as the predominant historical sources of PCBs to the Hudson River. EPA has estimated that these plants released up to 1,300,000 pounds of PCBs to the Hudson River between the 1940s and 1977 (EPA 2002). After 1977, seepage of PCBs from the bedrock beneath these General Electric facilities, combined with erosion of remnant deposits and contaminated banks, continued to release PCBs to the river for some time (EPA 2000a). In more recent years, the amount of PCBs released from seepage has been markedly reduced due to the continuing performance of remedial measures at these facilities (NYSDEC 2004).

EXHIBIT 1: BIOACCUMULATION OF PCBS



Source: Adapted from Wisconsin Department of Natural Resources. Used with permission.
http://dnr.wi.gov/org/water/wm/foxriver/whatarepcbs.html.

EXHIBIT 2: THE GENERAL ELECTRIC HUDSON FALLS PLANT ON THE HUDSON RIVER

Source: http://www.fws.gov/contaminants/images/gehudsonriverepaimage.jpg (EPA photo)

The General Electric Hudson Falls plant used PCBs for manufacturing operations beginning in 1947. The abandoned Allen Mill structure situated just below the Hudson Falls Plant failed in 1991, leading to a temporary spike in outflow of PCBs to the Hudson River.

In general, PCB concentrations in the Hudson River ecosystem have been highest immediately downstream of the General Electric (GE) facilities. The GE facilities are located in Hudson Falls and Fort Edward (Exhibit 3), upstream of the Thompson Island Pool also known as River Section 1. River Section 1 is about six miles long, extending from the location of the former Fort Edward Dam downstream to the Thompson Island Dam.

The adjacent downstream portion of the river is River Section 2, consisting of the Fort Miller Pool immediately below the Thompson Island Dam and the Northumberland Pool, which is connected to the Thompson Island Pool by the land cut. River Section 2 is about five miles long and extends from the Thompson Island Dam to Northumberland Dam. River Section 3 is much larger – about 29 miles long—and extends from the Northumberland Dam downstream to the Federal Dam at Troy and is comprised of several pools separated by a series of locks. Collectively, these three river sections, approximately 40 miles in combined length, comprise the Upper Hudson. The Lower Hudson consists of the portion of the river south of the Federal Dam downstream to the Battery in New York City. This section of the river is tidally influenced and is over 150 miles long.

The Hudson River at and below Hudson Falls, New York, has been contaminated extensively by PCBs from GE facilities. The PCBs present a serious and long-term threat to the health of the Hudson River ecosystem and pose a potential health threat to people who eat fish or who eat other organisms that inhabit the river and the surrounding area. Numerous studies have documented PCB contamination in the surface water, groundwater, sediments and floodplain soils of the Hudson River, as well as in living resources at every level of the Hudson's aquatic, terrestrial, and wetland-based food chains.

Exhibit 3: Hudson River Below Corinth, New York

CHAPTER 2: PCB CONTAMINATION IN THE HUDSON RIVER

RIVER WATER

Water sampling has occurred throughout the river south of Hudson Falls; however the large majority of samples were taken from the Upper Hudson. Since PCB measurements of Hudson River water began in the 1970s, PCB levels in the river below Hudson Falls have routinely exceeded state and Federal water quality criteria developed to protect living organisms. Over 80 percent of over 6,000 water samples tested since 1975, from Hudson Falls to the Battery in Manhattan have contained PCBs at levels 10 to 10,000 times higher than that deemed safe for aquatic life, fish-eating wildlife and human consumers of fish (HRNRT 2008d*,* see Exhibits 4 and 5). Furthermore, this percentage very likely underestimates the extent of past contamination in the Hudson because early tests for PCBs were not as sensitive as more modern methods.

PCB levels in the river have also exceeded the current drinking water standard (0.09 ppb) in about two percent of samples taken from applicable locations (HRNRT 2008d). This standard was promulgated on March 12, 1998. The previous drinking water standard, promulgated in 1985, was 0.01 ppb, and nearly 80 percent of samples in applicable locations exceeded that value. Of note, drinking water standards apply only to portions of the river with certain designated water classes, which are located approximately between river miles 162 and 156 (the confluence with the Mohawk River to the Lock 2 Dam), and between river miles 129 to 65 (Chelsea to Houghtaling Island) (HRNRT 2008d*)*.

TOXICITY OF PCBs

PCBs are highly toxic—even very small amounts are considered hazardous. The New York State water quality standard for protection of human consumers of fish is 0.001 parts per trillion, or just 1/1,000th of a drop of PCBs in one trillion (1,000,000,000,000) drops of water.

The U.S. Environmental Protection Agency (EPA) issued the first regulatory standard for PCB levels in surface water in 1977, determining that PCBs in water at levels as low as 1 part per trillion (pptr) pose an unacceptable risk to humans and aquatic organisms. As scientific understanding of PCBs grew and the ability to measure PCB concentrations improved, EPA and the State of New York established criteria for PCBs in surface water to protect specific groups of organisms. The current criteria set levels for protection of salt water aquatic life (30 pptr on a total PCB basis) and freshwater aquatic life (14 pptr on a total PCB basis). Current regulatory standards are also in place for fish-eating wildlife (0.12 pptr on a total PCB basis). and human consumers of fish (0.001 pptr on a total PCB basis). PCB levels in the Hudson have far exceeded these amounts in the vast majority of water samples tested since the 1970s, with levels detected ranging to over 38,000 parts per trillion in the Upper Hudson. In 2008, the Trustees determined that the Hudson River's surface water has been, and continues to be, injured as a consequence of PCB exposure (HRNRT 2008d).

EXHIBIT 4: PCBS IN HUDSON RIVER SURFACE WATERS, 1975-2007

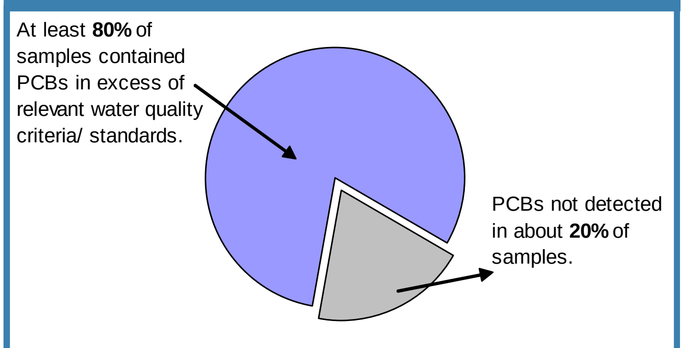
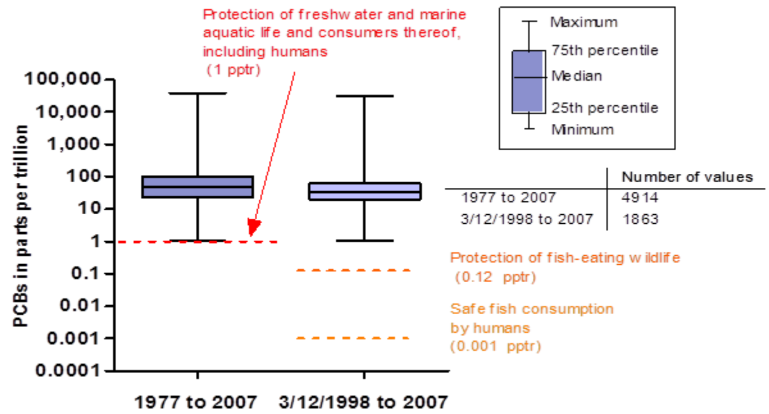


EXHIBIT 5: PCBs IN HUDSON RIVER SURFACE WATERS, ALL LOCATIONS, 1975-2007



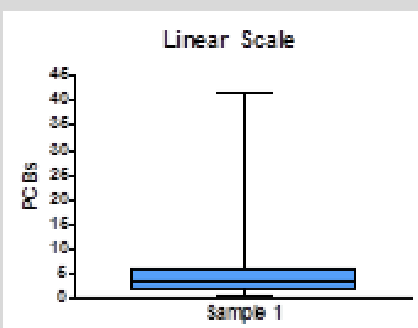
Data sources: Measurements taken by the U.S. Geological Survey, which in 1975 initiated regular monitoring of PCBs in the water column at Waterford and then expanded its monitoring program to a total of seven stations, all within the Upper Hudson. Additional data sources include measurements taken by GE, whose sampling program began in 1989, and which encompasses 124 locations, 120 of which are located in the Upper River, and smaller datasets provided by EPA (2000b), Litten (2003), and Bopp et al. (1985), all three of which included some sampling in both the Lower and Upper Hudson.

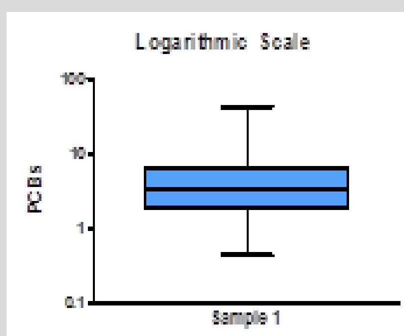
Notes: Data are shown for all years (1977-2007) and for the period after 3/12/1998 to 2007. The depicted 1 pptr EPA guidance criterion was established in 1976, while the 0.12 pptr and 0.001 pptr New York State water quality standards were promulgated on 3/12/1998. Because water quality criteria apply only after their issuance, only measurements taken after availability of the relevant criteria are included in this figure. The presented data also reflect only those samples in which PCBs were detected (about 80% of all measurements).

ABOUT THE GRAPHS IN THIS REPORT

Graphs in this report generally are presented in two styles. Where data are relatively few, individual measurements are shown. Where data are more numerous, a box-and-whisker style is used to illustrate the general distribution of the values. The whiskers represent the minimum and maximum values. The top and bottom of the colored box represent the 75th and 25th percentiles, respectively, and the central line represents the median value.

In addition, because of the wide range in PCB concentrations depicted in many of the graphs in this report, the information is shown in logarithmic scale to allow all the data to appear visible on the same graph. On a logarithmic scale, every ten-fold difference (such as between 1 and 10, or between 10 and 100) is depicted as an equally-sized interval. The sample figures below illustrate the visual difference between the same sample dataset plotted on both a linear and a logarithmic scale.





It is not possible to show values of zero on a logarithmic scale; therefore, samples in which PCBs are not detected (and which are assumed for purposes of this report to contain no PCBs) are discussed in the figure legends.

SEDIMENTS

Over the past 60 years, large quantities of PCBs from the Hudson River have settled out into the riverbed over a distance spanning more than 200 miles downstream of Hudson Falls to New York Harbor and beyond. Surface sediment (considered for purposes of this report to be sediments 12 or fewer inches deep) PCB concentrations are significantly higher in the Upper Hudson than the Lower Hudson. While surface concentrations in River Sections 1 and 2 are similar, concentrations decline in River Section 3, and decline further in the estuary. Through 2008 (the time period that is the focus of this report), PCB measurements in surface sediments of the Upper Hudson and some parts of the Lower Hudson have been well in excess of levels associated with toxic impacts (Exhibit 6).

PCBs in the riverbed continue to contaminate aquatic insects, mussels and other invertebrates that live in the sediment. During sampling conducted by GE in the Upper Hudson between 2002 and 2007, PCBs were detected at levels as high as 1,650 ppm in surficial sediments (top 12 inches), and this particular value was measured within the top two inches. This level of contamination creates a hazardous environment for exposed biota: for instance, NYSDEC (1999) developed sediment-based PCB screening criteria of 0.042 ppm for wildlife bioaccumulation, 0.58 ppm for chronic benthic effects, and 83 ppm for acute benthic effects.[1] Sediments with concentrations above these levels "are considered to be contaminated, and [are] potentially causing harmful impacts to marine and aquatic ecosystems" (ibid.). Approximately 99% of surficial (≤ 12 inches deep) remedial design samples exceed the NYSDEC 0.042 ppm criterion, while about 97% and 17% of these samples exceed the 0.58 ppm and the 83 ppm criteria, respectively.[2]

In addition, EPA determined that sediment concentrations in excess of 3 ppm pose a risk to amphibians in the Housatonic River,[3] another site that has been contaminated with PCBs from GE facilities (Weston Solutions 2003). This level is exceeded in over 70% of the Hudson River surficial sediment samples collected as part of the remedial design sampling. Follow-up studies on sediment are currently underway (HRNRT 2008b).

GROUNDWATER

Groundwater in the vicinity of GE's Hudson Falls and Fort Edward plants is heavily contaminated with PCBs, along with high concentrations of volatile and semi-volatile organic compounds. When the extent of contaminated groundwater in this area was discovered in the 1980s, the Town of Fort Edward issued bonds to pay for construction of a water system to serve Fort Edward Water District No. 1.

In the early 1990s, New York State determined that the releases of PCBs from the GE Hudson Falls and Fort Edward plant sites, including the migration of contaminated groundwater from beneath the Hudson Falls plant, represented a significant ongoing source of PCBs to the Hudson River. Implementation of remedial actions at both the Hudson Falls and Fort Edward capacitor plant sites since the early 1990s has resulted in marked reductions of PCBs released to the river from the plant sites. Remedial work is continuing at both plant sites.[4]

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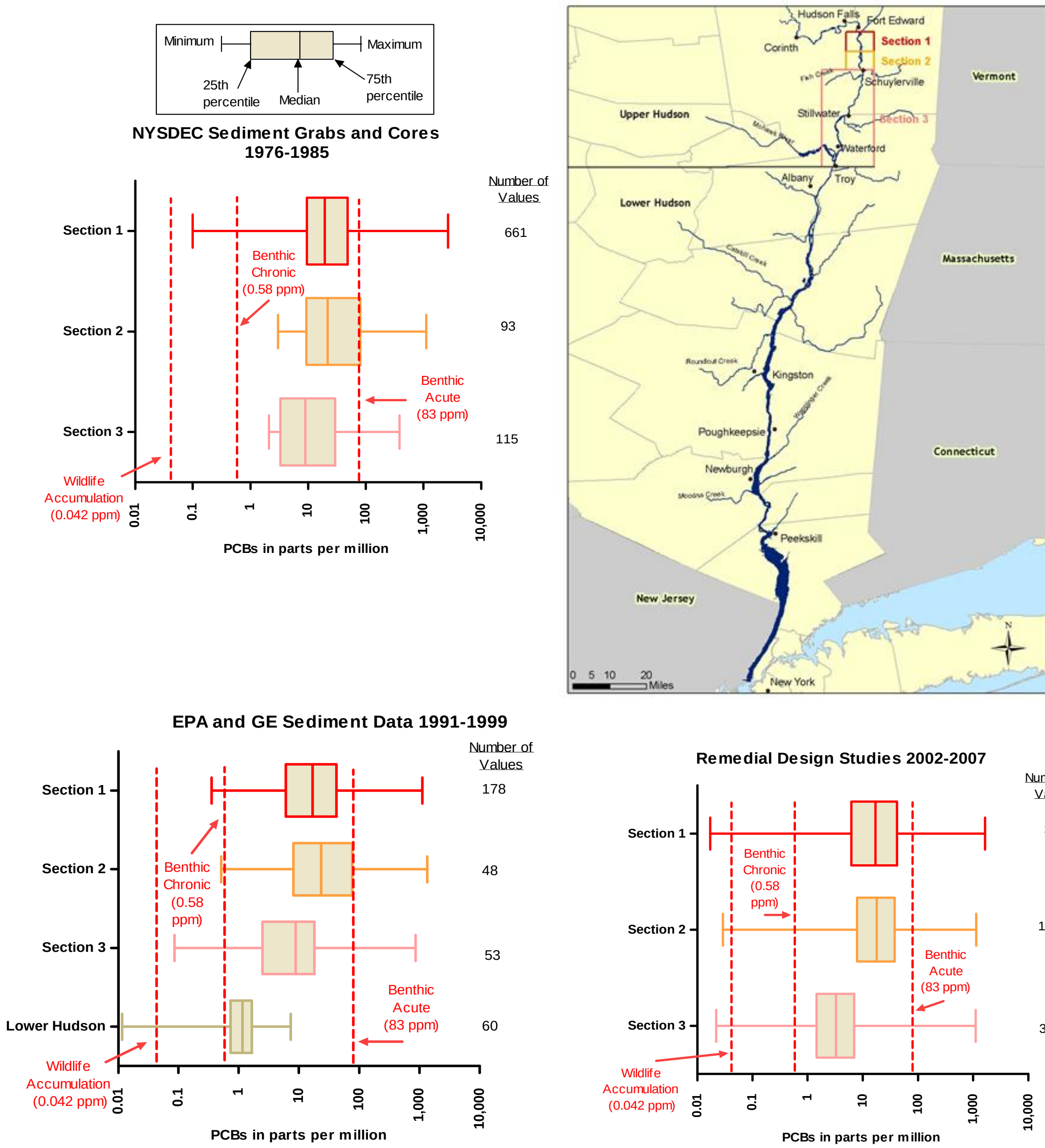
1 NYSDEC (1999) presents values on a μg/g organic carbon (OC) basis (i.e., 1.4 μg/g OC, 19.3 μg/g OC, and 2760.8 μg/g OC). The presented criteria have been converted into a mg/kg dry weight basis assuming that sediments contain 3% organic carbon, the average value for the Hudson River.

2 The presented percent exceedance figures are calculated comparing the original threshold values (in μg/g OC) to sediment concentration values expressed in the same units. Samples lacking an organic carbon measurement are not included in these calculations.

3 This value was selected as the "maximum acceptable threshold concentration" although adverse effects (including high mortality and developmental delays) were exhibited by leopard frog larvae exposed to all Housatonic site sediments. These sediments had PCB concentrations as low as 0.15 ppm (Weston Solutions 2003).

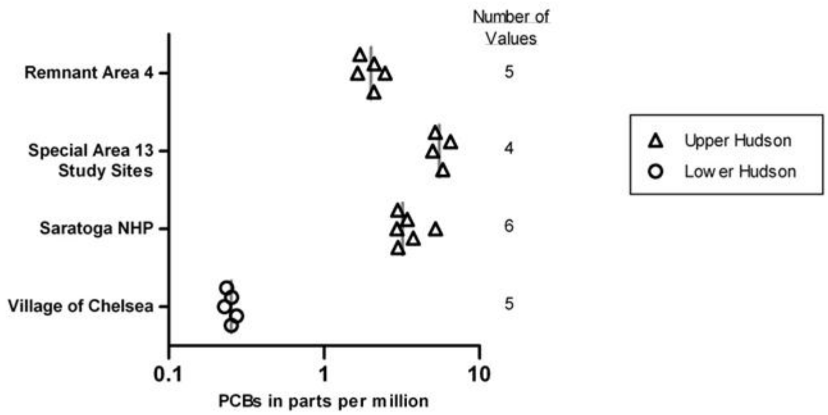
Exhibit 6: PCB Concentrations in Hudson River Mainstem Surface (≤ 12 inches) Sediments by River Section, 1975-2007



Data source: NOAA (2010).

Sediment data are grouped by data-generation project. This roughly approximates time periods and also reflects the different sampling strategies employed. Non-detects (less than 1% of the samples) are not included in this analysis and lab/field duplicates have also been removed, as have samples not taken in the river's mainstem. Surface sediments samples are defined as those that begin at the surface and have a lower depth of 12 inches or less. NYSDEC (1999) developed the depicted criteria for wildlife accumulation (1.4 μg/g OC), chronic benthic toxicity (19.3 μg/g OC), and acute benthic toxicity (2760.8 μg/g OC). Assuming 3% organic carbon in sediments (average for the Hudson River), these values become 0.042, 0.58, and 83 mg/kg sediment.

EXHIBIT 7: PCBS IN INSECTS EMERGING FROM THE HUDSON RIVER, 1998



Data source: HRNRT (2009a), NOAA (2010).
Notes: These insects inhabit the Hudson riverbed during their larval stage. As adults, they can fly and thereby provide a potential pathway for contamination of the floodplain food web. All samples contained detectable concentrations of PCBs. Each value represents a composite sample.

The New York Department of Health determined that the Village of Stillwater Well Field, in Saratoga County, is a groundwater resource that is under the influence of the surface water of the Hudson River. Results of sampling of several of the wells in the Stillwater Well Field shows that these groundwater resources exceed New York State's PCB standard of 0.09 ppm in fresh groundwater (Malcolm Pirnie 2009). As a result, the Village of Stillwater recently has paid for construction of a pipeline in order to change its water source to the Saratoga County Water Authority (Cignoll 2012).

ADULT AQUATIC INSECTS

Hudson River fish, birds, and wildlife can also become contaminated with PCBs through consumption of aquatic insects such as dragonflies, mosquitoes and mayflies, which live in or on the river's bottom as larvae but emerge from the river as flying insects in their adult forms. A 1998 study found PCB levels in these emerging adult insects along the banks of the Upper Hudson to be as high as 6.3 ppm (HRNRT 2009a). The study also found that PCB levels in insects captured in the Upper Hudson were over ten-fold higher than levels in insects captured in the Lower Hudson, about 90 miles downstream of the Troy Dam (Exhibit 7).

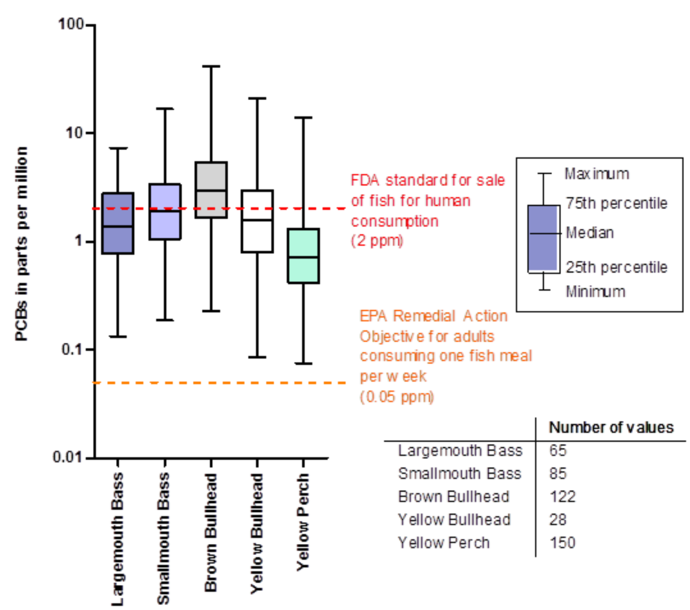
FISH

Hudson River fish downstream of the GE plants have been contaminated by PCBs. Fish not only absorb PCBs directly from the river water but are also exposed through the ingestion of contaminated prey, such as insects, crayfish, and smaller fish. In addition, fish, especially eggs, can be exposed to contaminants through river sediments. Contaminated fish can, in turn, be eaten by birds, wildlife or even humans, and can serve to expose these groups to PCBs as well.

In the 1970s, several Hudson River largemouth bass fillets were contaminated at levels in excess of 2,000 ppm (NOAA 2010). After 1977, when GE stopped direct discharges of PCBs to the river, PCB levels in Hudson River fish dropped considerably but since the early 1980s have generally remained stable[5] at relatively high levels. Sampling results indicate that PCB concentrations in fish tend to be highest in the Upper Hudson downstream of the GE plants at Hudson Falls and Fort Edward, and generally decline with increasing distance down the river, with a less pronounced gradient in the Lower Hudson.

PCBs in Hudson River fish may pose significant health risks to human consumers of fish. The U.S. Food and Drug Administration does not allow the commercial sale of fish for consumption by humans where PCB levels exceed 2 ppm, and the Environmental Protection Agency's remedial action objective (RAO) for the protection of human health is 0.05 ppm in fish fillets, based on an adult consumption rate of one half pound meal per week (EPA 2000a). In fish collected since 2000 in the Upper Hudson, this level was exceeded in approximately 75-90% of largemouth bass, smallmouth bass, brown bullhead, and yellow perch fillet samples, depending on the species. In fact, about 40-70% of these fillets (depending on species) exceeded this level by a factor of ten or more. (See Exhibit 8 for a subset of these data.) In striped bass and white perch fillets collected in the Lower Hudson over the same time period, EPA's 0.05 ppm RAO was exceeded in over 95% of samples, and about 65% of these samples exceeded this level by a factor of ten or more.

EXHIBIT 8: TOTAL PCBS (PPM) IN FILLETS OF FISH CAUGHT IN THE THOMPSON ISLAND POOL (RIVER SECTION 1) BETWEEN 2004 AND 2008



Data source: NOAA (2010).

Notes: Selected data represent fillet measurements in fish caught from the indicated location by General Electric between 2004 and 2008. Apparent lab/field duplicates have been eliminated from the analysis. All samples contained detectable concentrations of PCBs.

5 One exception to the relative stability of PCB levels in fish in the Hudson was the spike in levels that occurred in 1992 and 1993 following a release of PCBs resulting from the collapse of a structure at the Allen Mill, an abandoned industrial building adjacent to GE's plant at Hudson Falls. Concentrations dropped through the 1980s until the Allen Mill event, increased, then decreased after the spike. The rate of decline was generally greater prior to, rather than after the Allen Mill event. After recovery from the event, the rate of decline remained relatively stable, especially for sampling locations nearest the plant sites (Sloan et al. 2005).

Because of excessive levels of PCBs in Hudson River fish, New York State sharply limited fishing in the Hudson in 1976, closing most of the river's commercial fisheries, issuing an "eat none" advisory and prohibiting all recreational angling throughout the 40 miles of the Upper Hudson downstream of Bakers Falls. Most of the commercial closures remain in place to this day. The "eat none" advisory and the restriction on taking fish for this section of the Upper Hudson has been in place for 36 years. The ban on recreational angling in the Upper Hudson remained in place until 1995, when the State modified the regulations to permit catch and release fishing within that reach. Consumption advisories have also been established throughout the Lower Hudson River; these have varied over time by species and location.

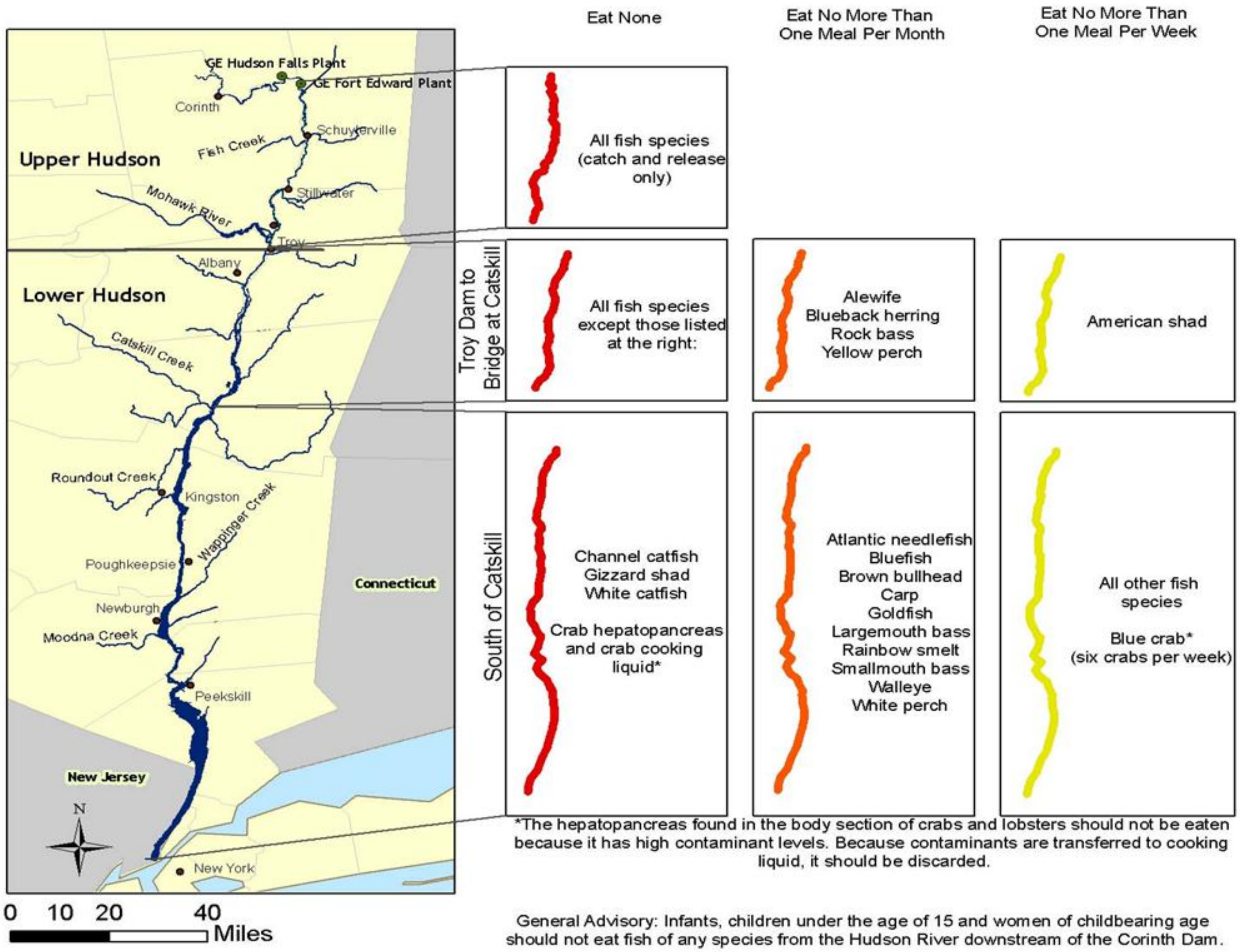
The 2008-2009 advisories (Exhibit 9)[6] include a "no consumption" advisory for all fish taken from the river between South Glens Falls (upstream of Hudson Falls) and the Troy Dam. "No consumption" advisories also exist for the general population for most species of fish from the Hudson River below the Troy Dam as far as Catskill, and advisories are in place restricting consumption to one meal per month for many species between Catskill and the Battery. In addition, women of childbearing age and children under age 15 are advised not to eat fish or crabs taken from the length of the river from Hudson Falls to the Battery.

Beyond the risks to human consumers of fish, studies at other contaminated sites and extensive laboratory testing have shown that PCBs can cause a wide range of toxic effects to the fish themselves. These include increased susceptibility to disease, feminization of males, growth of cancerous tumors, reduced egg survival rates, and impairment and death of newly hatched fish. Skeletal deformities and organ hemorrhaging have also been found in fish exposed to PCBs, as well as hormonal disturbances and biochemical changes (HRTC 2002).

Sampling in the Upper Hudson River between 2000 and 2008 found PCB levels in whole fish up to 470 ppm, with the maximum value from earlier years reaching 571 ppm (Exhibit 10). For comparison, the scientific literature documents biochemical changes in fish with PCB levels less than 1 ppm (Niimi 1996). Also, research has found that PCBs can severely affect reproduction in the barbel, a species of fish in the same biological family as Hudson River carp and minnows. Barbels with whole body PCB levels of approximately 0.8 ppm wet weight (ww) experienced an excess egg mortality of 20% (Hugla and Thomé 1999). Follow-up studies on fish are currently underway (HRNRT 2001, 2009b).

[6] These advisories are referenced because of the focus of this report on data through 2008. Current advisories are available in NYSDOH (2011).

Exhibit 9: Hudson River Fish Consumption Advisories for 2008-2009

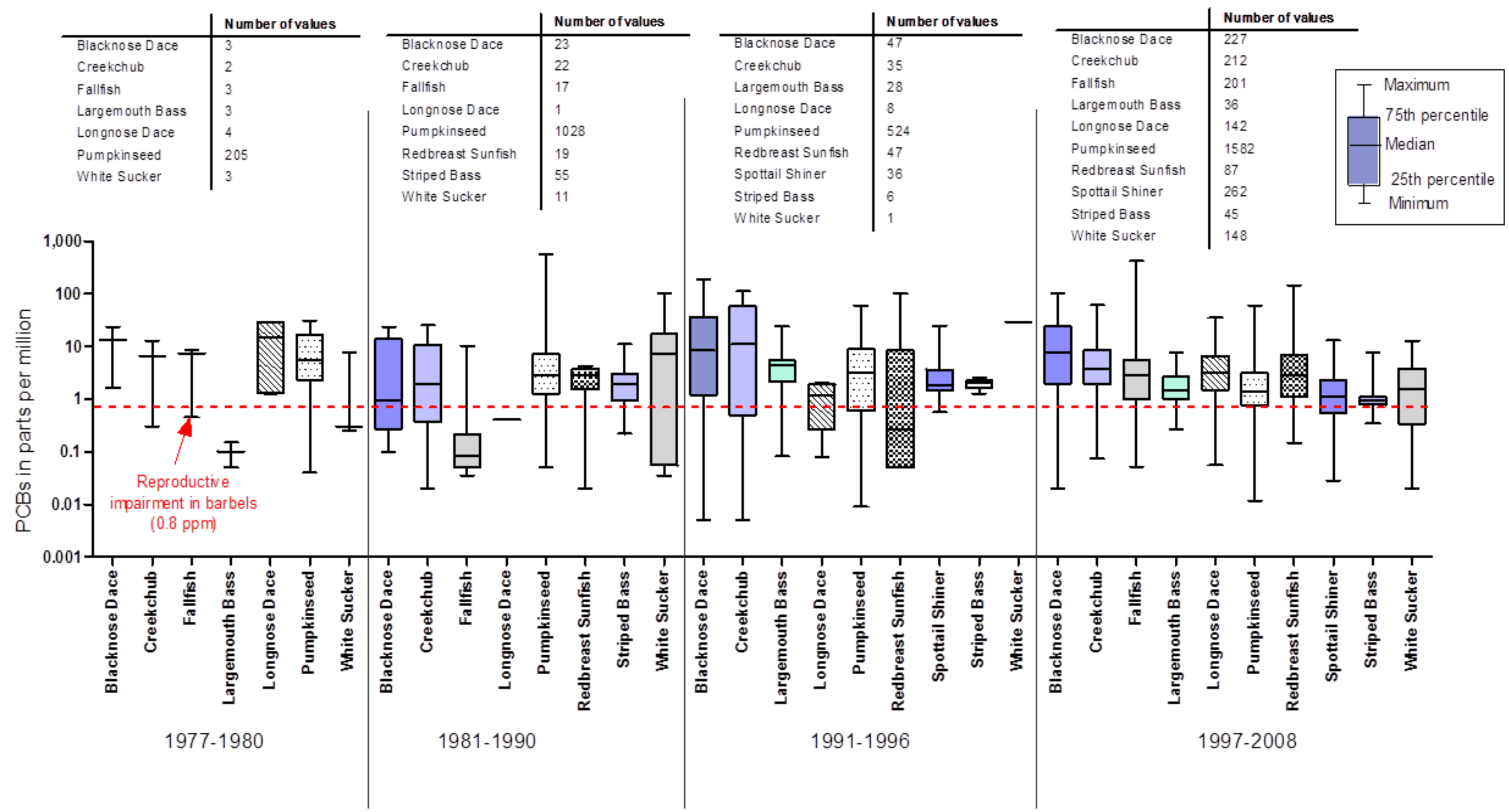


*The hepatopancreas found in the body section of crabs and lobsters should not be eaten because it has high contaminant levels. Because contaminants are transferred to cooking liquid, it should be discarded.

General Advisory: Infants, children under the age of 15 and women of childbearing age should not eat fish of any species from the Hudson River downstream of the Corinth Dam.

Data Source: NYSDOH (2008).

Exhibit 10: Total PCBs (ppm) in Whole Fish Caught South of the General Electric Plants, 1977-2008



Data Source: NOAA (2010)

Notes: Data are presented for the 10 species of Hudson River fish with the highest number of whole body samples. Samples identified as duplicates and non-detects (less than 2%) are not included in the analysis. Some records represent composites of multiple fish such that the listed number of values is less than the number of fish caught and analyzed. Fish data are broken into the following time periods: 1977-1980; 1981-1990 (passage of CERCLA through just before the Allen Mill event); 1991-1996 (representing the immediate post-Allen Mill period); 1997-2008 (up through the time just before Phase 1 dredging began). Data are compared to the level at which egg mortality has been observed to increase by 20% over control levels in barbels (a fish in the same family as Hudson River carp and minnows, Hugla and Thomé 1999). The 0.8 ppm wet weight value reflects the paper's 0.40 µg/g dry weight egg threshold converted into whole body wet weight using an egg-to-adult PCB dry weight ratio (calculated from Table 2 in the Hugla and Thomé 1999), assuming 80 percent moisture. Note: additional data for fish fillets is available, but is not depicted in the exhibit above.

FLOODPLAIN SOILS

The Hudson River floodplain is periodically inundated with water and sediments from the river (Exhibit 11). This inundation can result in the deposition of PCBs onto the river's banks as well as onto the adjoining wetlands and forested floodplain. This contaminated material is ingested by small animals such as insects and worms, which are a source of food for other animals. Because PCBs accumulate in the fatty tissues of animals, each time an animal is exposed to PCBs, the PCB level in its body can rise, leading to increased potential for toxic effects. As animals higher on the food chain consume other animals, PCBs can become more concentrated, potentially leading to very high levels of these toxic chemicals in larger animals such as mammals, birds, and humans.

EXHIBIT 11 : HUDSON RIVER FLOODPLAIN

Source: Joseph Steinbacher, Versar, Inc.

Several studies have measured PCB concentrations in the Upper Hudson floodplain soils. Concentrations in surficial soils (considered for purposes of this report to be soils six or fewer inches deep) range up to 1,040 ppm in River Section 1, up to 358 ppm in River Section 2, and up to 63 ppm in River Section 3 (NOAA 2010). Some studies found that PCB concentrations in floodplain soils tend to be highest in soils closer to the river (SEA 2002, Weston Solutions 2005), and closer to the GE plants, with concentrations decreasing downstream (SEA 2002). Exhibit 12 presents distributional information on PCB concentrations in surficial (≤ 6 inches deep) soils, grouped first by study source and secondarily by river section. Of note, the data presented represent a range of distances from the river and have their origin in collection efforts that utilized different sampling strategies.

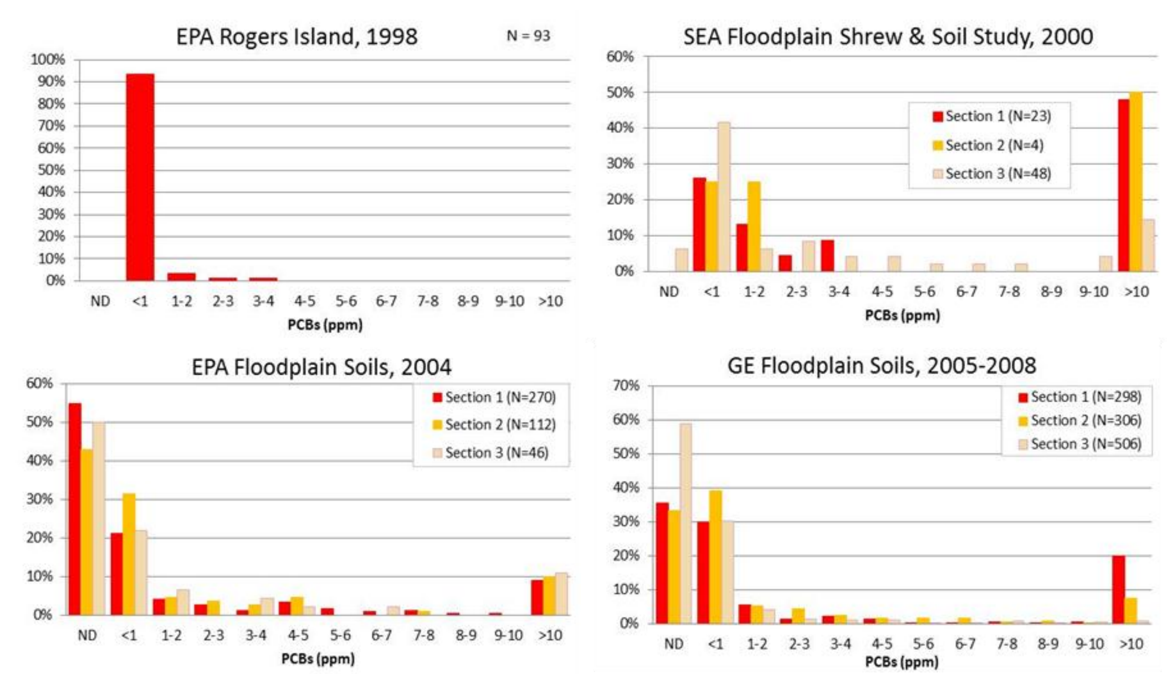
For comparison, Efroymson et al. (1997) developed a preliminary remediation goal (PRG) for total PCBs (tPCBs) in soils of 0.371 ppm. This level generally "correspond[s] to small effects on individual organisms which would be expected to cause minimal effects on populations and communities" of wildlife. The PRGs may not be sufficiently protective of species of special concern which are based on effects on individual organisms and should be based on no-observed adverse- effects levels." Of the datasets shown in Exhibit 12, over a third of samples in River Sections 1 and 2 exceed this value, and approximately a fifth of samples in River Section 3 exceed this value.

SMALL TERRESTRIAL MAMMALS AND THEIR PREY

PCBs from contaminated floodplain soils along the Hudson River have entered the terrestrial food chain. Earthworms collected in 2000 from the Upper Hudson River floodplain contained PCBs at levels averaging 7.7 ppm and as high as 23.9 ppm (Exhibit 13).

Shrews, mice, and meadow voles are important prey items for larger animals such as mink and raptors. Their contamination levels suggest that these small mammals may be an important pathway for PCB exposure to their predators.

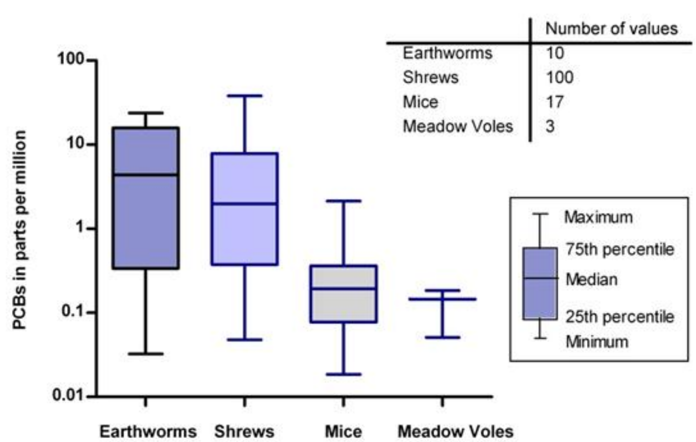
EXHIBIT 12: PERCENT OF SAMPLES BY PCB RANGE (PPM) IN SURFICIAL (≤ 6 INCHES DEEP) SOILS ASSOCIATED WITH THE UPPER HUDSON RIVER, 1998-2008



Data source: NOAA (2010)

Notes: ND = non-detect. Samples identified as duplicates and apparent field replicates have been eliminated from the analysis. Samples have a lower depth of not more than 6 inches. Results are grouped by study effort(s). Of note, Efroymson et al. (1997) developed a PRG for total PCBs of 0.371ppm, a level that generally "correspond[s] to small effects on individual organisms which would be expected to cause minimal effects on populations and communities."

EXHIBIT 13: PCBS (PPM) IN EARTHWORMS AND SMALL MAMMALS FROM THE UPPER HUDSON FLOODPLAIN, 2000-2001



Data sources: SEA (2002), HRNRT (2010), NOAA (2010). All samples contained detectable concentrations of PCBs. The mouse and vole values each represent composites of four to five animals, whereas the shrew data represent individual animals.

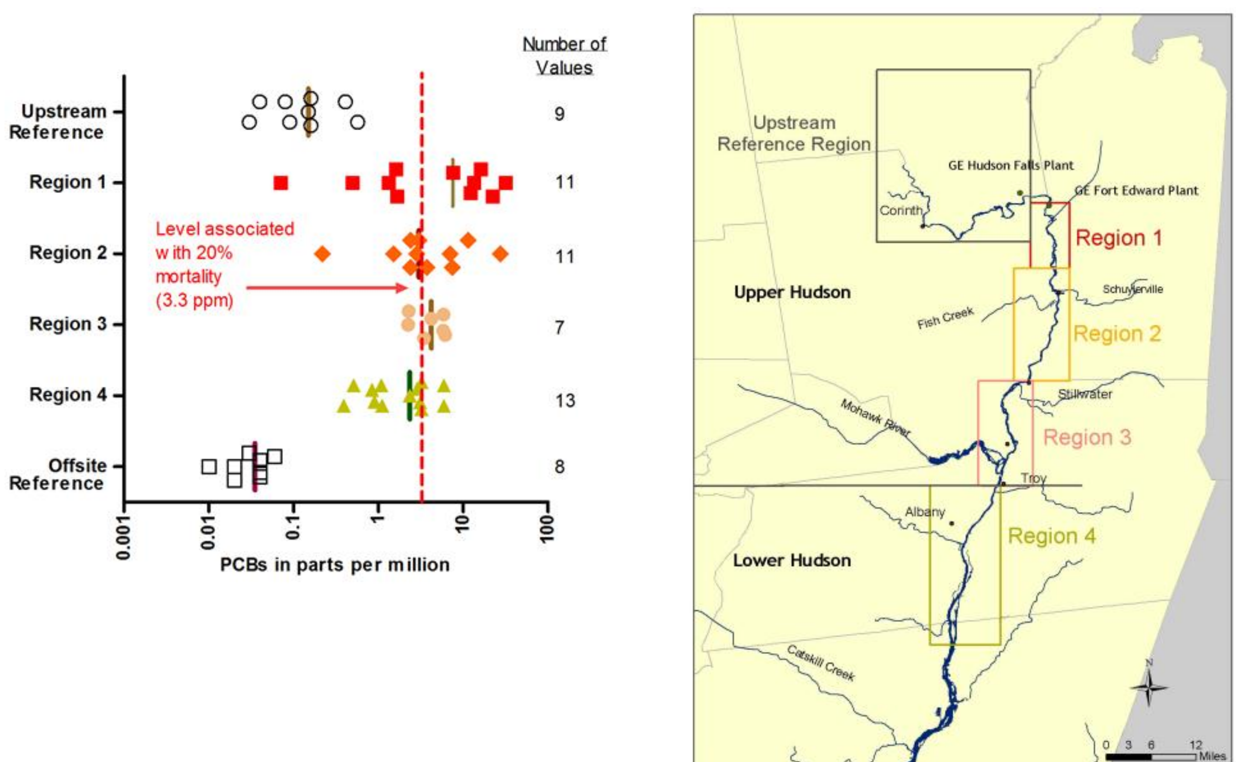
TURTLES AND FROGS

Reptiles from the Hudson River are also contaminated with PCBs. Snapping turtles collected in 1998 and 2000 contained very high levels of PCBs, ranging to over 3,000 parts per million in fat (NOAA 2010).

PCBs have been associated with behavioral abnormalities and changes to biochemistry in adult snapping turtles (HRNRT 2002), and PCBs are also passed from adult female turtles to their eggs. Snapping turtle eggs collected in 2002 contained elevated PCB levels, ranging up to 31.8 ppm (HRNRT 2005a, Exhibit 14). PCBs in snapping turtle eggs have also been linked to latent mortality: Eisenreich et al. (2009) found that snapping turtles hatched from Upper Hudson River PCBs eggs suffered a 60 percent mortality rate through 14 months of age, compared with a 10 percent rate for animals hatched from reference area eggs. Furthermore, the mortality rate was correlated with total PCBs in the collected eggs: the authors calculated a relationship between PCB egg concentrations and mortality, which suggests that levels of approximately 3.3 ppm decrease survival to about 80% of what it would have been absent PCB exposure (Eisenreich et al. 2009). Turtle eggs are also a pathway for PCB contamination to animals that consume these eggs, such as other reptiles, birds, and mammals, and potentially humans.

New York State has a long-standing statewide health advisory recommending no consumption of snapping turtles (or soups made with their meat) by women of childbearing age and children under the age of 15. The advisory further recommends that all others carefully trim all fat, and discard fat, liver, and eggs prior to cooking, to reduce exposure to contaminants. In 1993-1994, the advisory was clarified to explain that PCBs represent the chemical of concern (NYSDOH 1993). Concern about PCBs in turtles predates this clarification, however: since 1979, the elevated levels of PCBs in turtles—including Hudson River turtles—have been a driving concern in the state's warnings to citizens to avoid consumption of these animals (Funiciello 1979).

EXHIBIT 14: PCBs IN SNAPPING TURTLE EGGS FROM THE HUDSON RIVER VICINITY, 2002

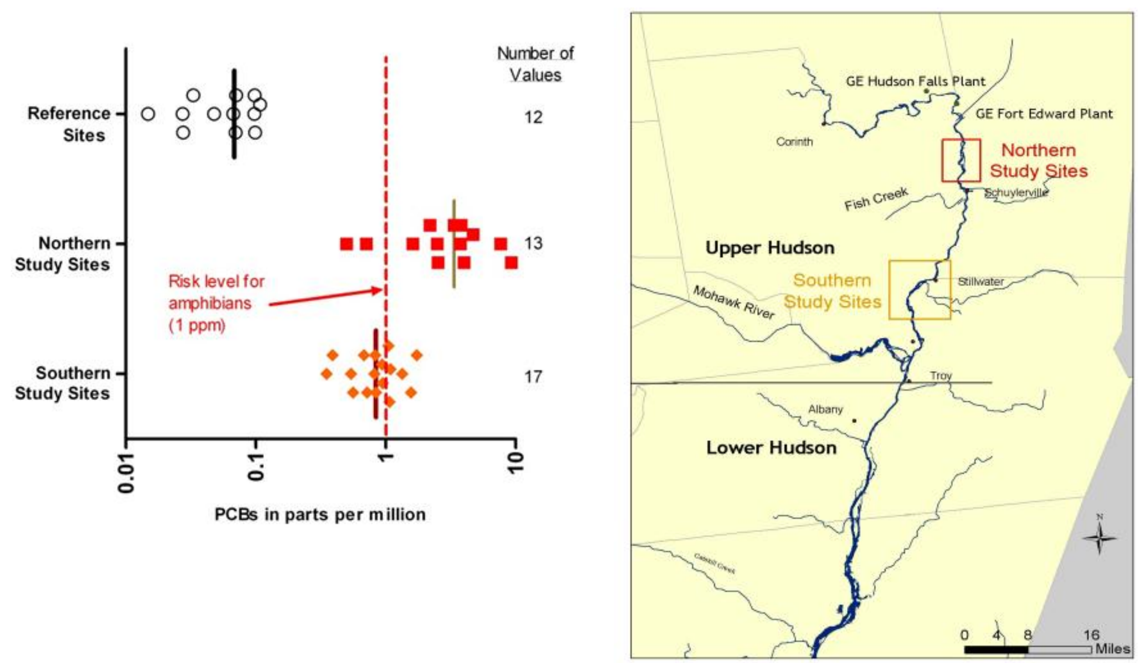


Data sources: HRNRT (2005a) and NOAA (2010).

Notes: PCBs were detected in all samples. Each sample represents a composite of three to five eggs. "Regions" are defined as shown in this figure (from HRNRT (2005a)); these regions differ from the "river sections" discussed elsewhere in this report. The vertical lines within the sampling data represent median values. The 3.3 ppm value associated with 20% mortality is derived from Eisenreich et al. (2009).

Amphibians from the Hudson River are also contaminated with PCBs. Bullfrog tadpoles collected in 2003 had levels as high as 9.3 parts per million (HRNRT 2007b; also see Exhibit 15). For comparison, in the Housatonic River (another PCB-contaminated site), EPA determined that PCB concentrations of 1 ppm in wood frogs is the level at which "significant adverse effects begin to occur, and response became frequent and more severe at approximately 10 mg/kg" (Weston Solutions 2003). These responses include the frequency of malformations in metamorphs and male:female sex ratios of 0.7 or less.

EXHIBIT 15: PCBS IN BULLFROG TADPOLES FROM THE UPPER HUDSON RIVER, 2003



Data source: HRNRT (2007b), NOAA (2010).

Notes: PCBs were detected in all samples. Each sample represents a composite of one to 12 tadpoles (most commonly, two to six tadpoles) at a similar developmental stage. The "risk level" is the value determined by EPA to pose a significant risk to amphibians (Weston Solutions 2003). The vertical lines within the sampling data represent median values. The reference site locations are varied and are not depicted on the map.

In the Hudson, the levels and specific types of PCBs detected in bullfrog tadpoles closely mirror those found in the sediments where the tadpoles were living. This suggests that in addition to receiving a burden of PCBs from their parents in the egg, these tadpoles are acquiring PCBs from the river environment they inhabit. Furthermore, PCB levels in sediments from known amphibian breeding areas of the Hudson River are at ecologically significant levels, suggesting the potential for injury to these organisms (HRNRT 2008a). The Trustees are investigating additional options to assess amphibian injury (HRNRT 2008c).

BIRDS

Birds in the vicinity of the Hudson River have been exposed to PCBs from the fish, insects, and other animals in their diet, as well as through the soil they ingest while feeding. In studies at other locations and in the laboratory, PCBs have been linked to a wide range of adverse impacts to birds, including disease, behavioral abnormalities, genetic mutations, physical deformities, changes in brain chemistry, reduced hatching rates, mortality of embryos, and death of adult and juvenile birds (HRTC 2002). In addition, PCB-contaminated birds and bird eggs are a source of PCB contamination for the animals that consume them, such as reptiles, mammals, and other birds.

More than 150 species of birds inhabit the Hudson River region at various times of the year, including waterfowl, wading birds, shorebirds, songbirds, and raptors. Birds are an integral part of the ecosystem, playing a number of important ecological roles, including seed distribution, plant pollination, and insect control. Some birds are also important prey items for other animals.

Several studies have confirmed that birds and their eggs in the Hudson River region are contaminated with PCBs (Exhibit 16). Tree swallows, which eat insects that inhabit the river bottom as larvae, are particularly likely to accumulate PCBs. In the mid-1990s, tree swallows were found to contain extremely high levels of PCBs, ranging up to 62 parts per million in nestlings (McCarty and Secord 1999a) and 190 parts per million in adult swallows (HRNRT 2011b). These are among the highest PCB levels ever reported in tree swallows from any location (McCarty and Secord 1999a). Tree swallow eggs were also found to be highly contaminated with PCBs, containing levels up to 77 ppm (McCarty and Secord 1999a).[7] In addition, studies conducted on tree swallows along the Upper Hudson during the 1990s found indications of disrupted reproductive functioning, including high incidence of nest abandonment (McCarty and Secord 1999a), inability to build normal nests (McCarty and Secord 1999b), and abnormal appearance of younger females during the breeding season (McCarty and Secord 2000). Similar signs have been associated with the effects of PCBs on hormone levels in other species (McCarty and Secord 1999b).

Elevated PCB levels were found in other birds in the vicinity of the Hudson during the mid- to late 1990s, including up to 78 ppm in eastern bluebird nestlings (HRNRT 2011b), 220 ppm in the fat of great blue heron nestlings (HRNRT 2011d), and 85.8 ppm in the fat of a bald eagle (HRNRT 2011b). Bald eagle eggs that failed to hatch were collected from the Lower Hudson in 1998-1999 and 2003 and 2004; these eggs were found to be highly contaminated with PCBs (HRNRT 2011c,d,e,f,g).

In 2002-2003, the eggs from several species of birds were collected from areas adjacent to the Hudson River (HNRTC 2005b,c). PCB levels as high as 56 ppm were detected, with the highest levels of contamination found in kingfisher and spotted sandpiper eggs (HRNRT 2005b). Harris and Elliott (2011) reviewed the effects of PCBs on wild birds and note that species exhibit varying sensitivity to PCBs. Among wild birds of "intermediate" (or possibly intermediate) sensitivity, critical egg thresholds for reproduction have ranged from 6 ppm to 50 ppm (Table 14.8, Harris and Elliott 2011). The lower level of 6 ppm has been exceeded in some eggs of many species of Hudson River birds, including the American robin, red-winged blackbird, common grackle, spotted sandpiper, Eastern phoebe, northern rough-winged swallow, tree swallow, Eastern screech owl, and belted kingfisher (Exhibit 16). Hudson River peregrine falcon eggs have also been shown to contain elevated levels of PCBs (HRNRT 2004a).

Additional reports have continued to confirm the presence of PCBs in Hudson River bird eggs of insectivorous, omnivorous and piscivorous bird species. Tree swallow eggs collected in 2004 contained an average of 6.8 ppm fww (Custer et al. 2010a); belted kingfisher eggs collected in 2004 contained an average 10.6 ppm fww (Custer et al. 2010c), and spotted sandpiper eggs collected in 2004 contained an average of 9.1 ppm fww (Custer et al. 2010b).[8] Additional studies are currently underway to investigate the effect of PCBs on birds in the Hudson River region (HRNRT 2004b, 2005d, 2006b, 2007a and d, 2008e, 2009c).

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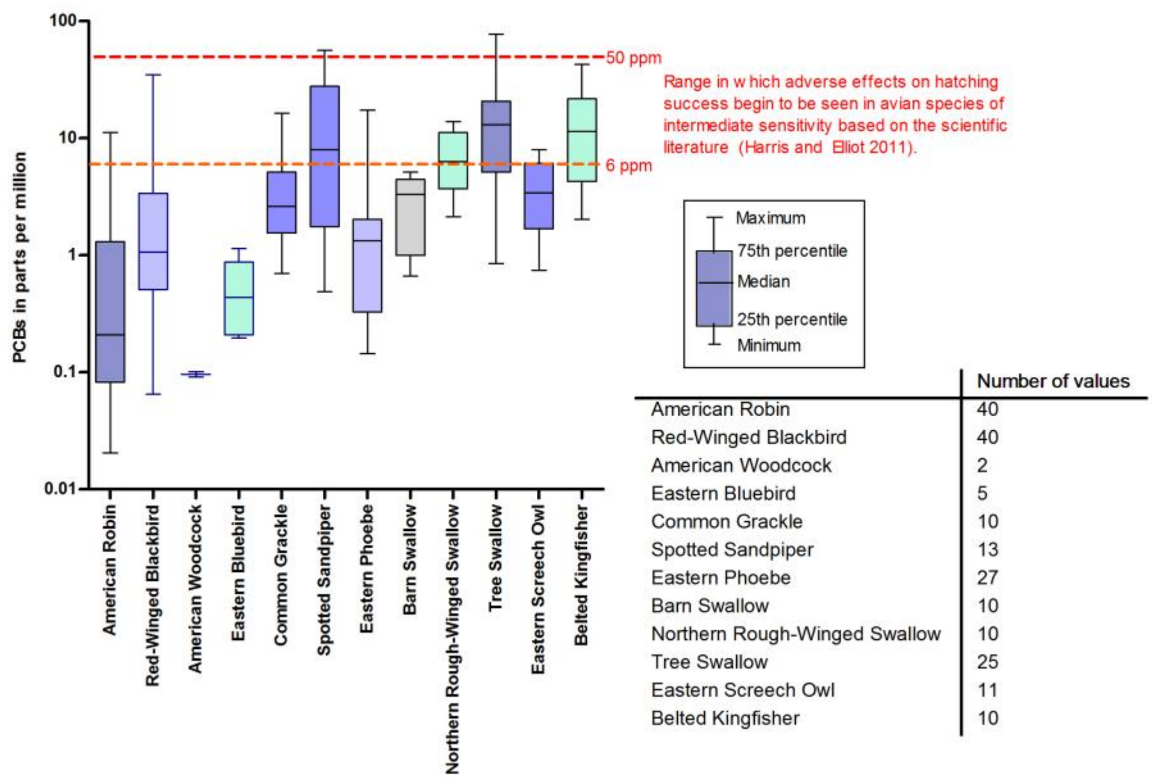
7 Where available, the presented concentrations in eggs are fresh wet weight values (i.e., the values have been corrected to account for the duration of incubation). Where not available, values are in wet weight.

8 These publications report geometric rather than arithmetic means. Arithmetic means would likely be higher.

EXHIBIT 16: PCBS IN BIRD EGGS COLLECTED NEAR THE HUDSON RIVER, 1994-2003



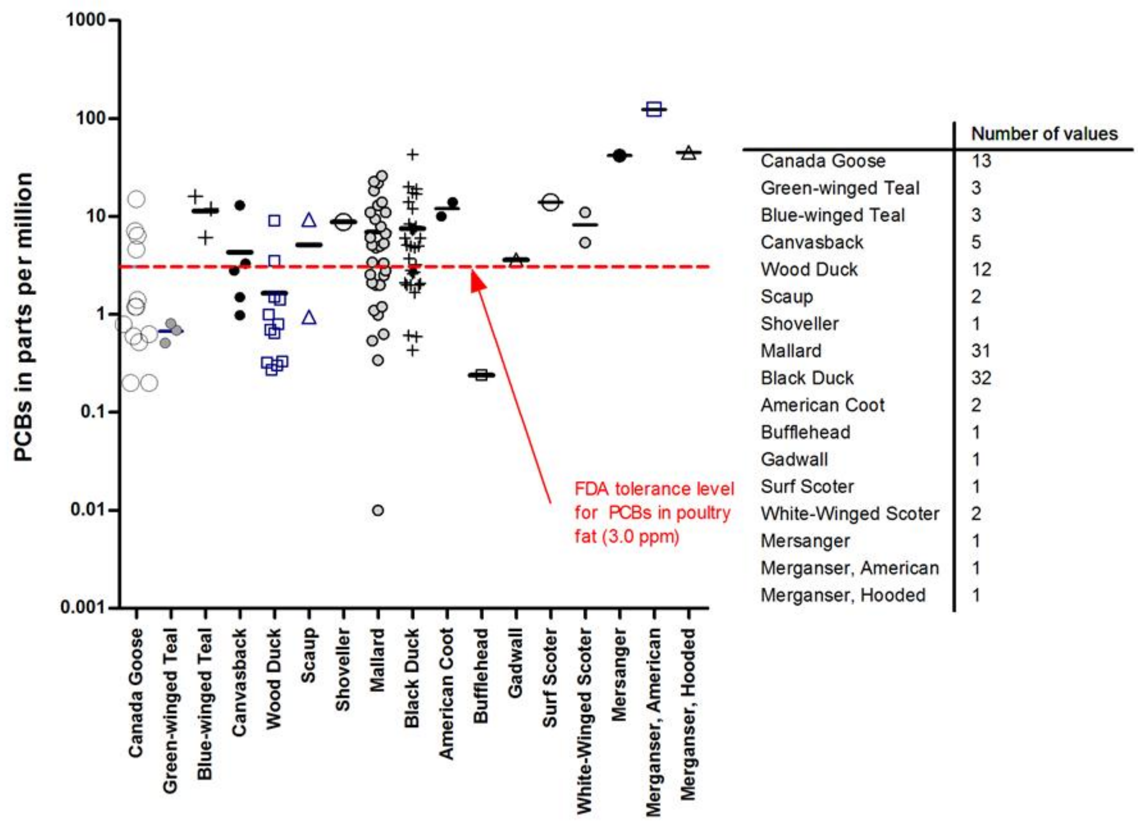
	Number of values
American Robin	40
Red-Winged Blackbird	40
American Woodcock	2
Eastern Bluebird	5
Common Grackle	10
Spotted Sandpiper	13
Eastern Phoebe	27
Barn Swallow	10
Northern Rough-Winged Swallow	10
Tree Swallow	25
Eastern Screech Owl	11
Belted Kingfisher	10

Data sources: HRNRT (2005b,c), HRNRT (2011a), Secord and McCarty (1997).

Notes: All data shown are from 2002 and/or 2003 Trustee collections, except for tree swallow eggs, which were collected in 1994 and1995. PCB values are in parts per million fresh wet weight. PCBs were detected in all samples. The presented critical threshold range is from Harris and Elliot (2011).

PCBs were also measured in waterfowl collected from hunters in New York State during the early 1980s (Kim et al. 1984, Kim et al. 1985). As shown in Exhibit 17, PCBs in the fat of a number of species of waterfowl have exceeded the 3 ppm U.S. Food and Drug Administration marketplace tolerance level for poultry (21 CFR 109.30). PCB concentrations ranged up to 22.7 parts per million in the fat of mallards, 124 ppm in a merganser, and 43 ppm in black ducks. These and other data showing similar patterns of contamination led the New York State Department of Health to issue a statewide waterfowl consumption advisory to protect human health. Further, limited data for mallards collected in 2000 confirm that PCB levels in these birds remain elevated, with up to 7.8 ppm found in fat (NOAA 2010). Further investigations of the level of PCBs in Hudson River waterfowl are underway (HRNRT 2008f).

Exhibit 17: PCBs in Hudson River Waterfowl Fat, 1981-1984



Data sources: Kim et al. (1985), Kim et al. (1984) and unpublished data (R. Foley, U.S. Fish and Wildlife Service).
Notes: PCB concentrations in the fatty tissue of Hudson River waterfowl are compared to the FDA tolerance level for poultry (3 ppm in fat, 21 CFR 109.30). The graph combines results of three studies, one conducted in 1979-1980, one conducted in 1981-82 and one conducted in 1983-84. Waterfowl are listed in the graph according to their diets: those on the left side of the graph are primarily vegetarian, those in the middle eat a mix of plants and small organisms, while the mergansers (on the right side of the graph) are fish-eaters. The horizontal lines within the sampling data represent median values. Non-detect samples (nine Canada geese and one wood duck) are not depicted.

BATS

Hudson River bats, which consume insects from both the floodplain and the aquatic ecosystem, also contain elevated levels of PCBs. A study conducted in 2001 and 2002 showed levels up to 0.64 ppm in the brains of big brown bats, and as high as 2.4 ppm in the brains of little brown bats (HRNRT 2007c).

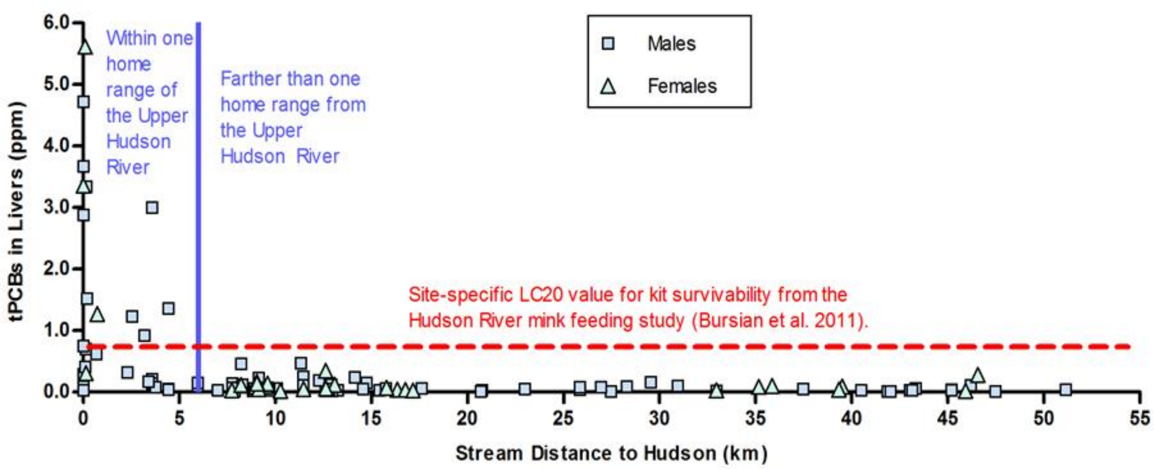
MINK AND OTTER

Mink and otter of the Hudson River inhabit both the river and riverside habitats, coming into contact with (and ingesting) contaminated water, sediment, and soil as they build dens and forage for food. Mink and otter have also been exposed to PCBs through the fish, invertebrates, small mammals, and other prey they eat.

Mink are known to be sensitive to the effects of PCBs: jaw lesions in wild mink have been linked to PCB contamination at the Kalamazoo River Superfund Site (Beckett et al. 2005). These lesions have also been seen in captive mink kits fed diets containing 1 ppm PCBs (Bursian et al. 2006). PCBs can also have toxic effects on mink reproduction, causing reduced growth and increased mortality of offspring. Previous studies have found reduced kit growth and/or survival at dietary PCB concentrations of 1 ppm or less (Restum et al. 1998, Heaton et al. 1995), and a recent study using Hudson River fish found a dietary LC20 concentration[9] for 6-week kit survivability, to be 0.34 ppm PCBs (Bursian et al. 2011). Given these data, the PCB contamination in the Hudson River environment appears to pose a high risk for mink: mink consume small mammals, fish, amphibians, reptiles, and birds, and as described previously, these organisms (see Exhibits 8, 10, 13,14, 15, 16) have frequently contained PCB levels in substantial excess of this level.

Measured concentrations of PCBs in Hudson River mink livers also suggest past and ongoing risks to mink (Exhibit 18). PCB levels in mink livers from the Hudson River watershed ranged up to 5.6 ppm, while Heaton et al. (1995) found PCB levels in livers of about 2 ppm to be sufficient to impair reproduction. Eight of the 33 mink (about 24%) caught within approximately one home range[10] (6 km) of the Hudson River between 1998 and 2002 had liver PCB concentrations that exceeded this value.

EXHIBIT 18: PCBS (PPM) IN MINK LIVERS AS A FUNCTION OF STREAM DISTANCE FROM THE UPPER HUDSON RIVER, 1989-2002



Data source: D. Mayack, New York State Department of Environmental Conservation. A subset of these data is available in NOAA (2010). Notes: The vast majority of mink were caught adjacent to streams. Stream distance to the Hudson is calculated as the stream length (not the straight-line distance) between the collection location and the Hudson River. Except for three samples, all data depicted represent animals collected between 1998 and 2000. This figure uses an estimated home range for mink of 6 km (D. Mayack, personal communication). PCBs were detected in all samples. The liver threshold of 0.8 ppm represents a site-specific LC20 value for kit survivability from the Hudson River mink feeding study (Bursian et al. 2011).

[9] The LC20 refers to the lethal concentration (LC) of a substance that is associated with a 20 percent mortality rate.

[10] The term "home range" refers to the area that an animal normally uses throughout its life.

Data from the early 1980s, while few, suggest that mink exposure to PCBs was of a similar magnitude: total PCBs measured in seven mink livers from the upper Hudson River watershed ranged up to 1.7 ppm, with a median value of 0.5 ppm (Foley et al. 1988, R. Foley, personal communication). In the 1998-2002 collection of 33 mink caught within a home range of the Upper Hudson, liver concentrations of PCBs ranged up to 5.6 ppm, with a median value of 0.41 ppm.

A trapping study in the Upper Hudson floodplain during 1999 and 2000 found evidence of lower numbers of mink in areas closer to the Hudson, trapping an average of only 3.5 mink per 1,000 trap nights, compared to an average of 26.2 mink trapped in the same amount of time in upstream and distant sites (Mayack and Loukmas 2001). Together with extensive data from both laboratory tests and field studies at other contaminated sites linking PCBs to failed reproduction, these numbers suggest that elevated PCB levels in Hudson floodplain mink may be affecting survival and/or reproduction. Follow-up studies are currently underway (HRNRT 2006a, HRNRT 2011h, 2011i).

Otters may also be at risk from elevated PCB concentrations in the Hudson River watershed. Concentrations of PCBs in the livers of 31 otters caught within a home range (30 km) of the Hudson River between 1997 and 2002 ranged up to 22.5 ppm, with a median value of about 1.2 ppm.[11] Levels of about 0.63 ppm are believed to be deleterious to liver functioning in this species (Smit et al. 1996).[12]

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[11] Data from D. Mayack, New York State Department of Environmental Conservation. A subset of these data are available in NOAA (2010).

[12] Above this concentration, Smit et al. (1996) estimate that 90 percent of animals would have reduced vitamin A levels in the liver. The 0.63 ppm value reflects the paper's estimated 21 µg/g lipid converted into the wet weight equivalent, assuming 3 percent lipids.

CHAPTER 3: CONCLUSIONS

The Hudson River, at and below Hudson Falls, New York, has been contaminated extensively by PCBs from GE facilities. Further, the resulting high levels of PCB contamination have existed for decades, and continue to exist, in the Hudson River ecosystem.

PCBs have contaminated the surface water, groundwater, sediments and floodplain soils of the Hudson River. Concentrations of PCBs in these environmental media exceed regulatory standards and criteria for their quality and use. Such exceedances include the following:

- Criteria for surface water quality are exceeded. The Hudson River's surface water has been, and continues to be, injured from PCB exposure. Additionally, groundwater around the GE facilities is heavily contaminated with PCBs and high concentrations of volatile and semi-volatile organic compounds.
- Edible portions of fish exceed the U.S. Food and Drug Administration's (FDA) tolerance level for PCBs, and there are advisories on fish consumption due to PCBs throughout the Upper and Lower Hudson Rivers.
- Consumption advisories are also in place for waterfowl and snapping turtles due to PCBs.

Services these natural resources provide to humans have been lost. For example, recreational fishing has been impaired by restrictions on taking fish from certain areas of the Hudson River. Further, PCB contamination in the Hudson River is a potential health threat to people who eat fish or who eat other organisms that inhabit the river and the surrounding area.

Living resources at every level of the Hudson's aquatic, terrestrial, and wetland-based food chains are contaminated with PCBs. PCB contamination is found in invertebrates, amphibians, reptiles, birds, and mammals such as mink, otter, bats, mice, shrews, and voles. PCB concentrations in wildlife exceed effects thresholds from the scientific literature. Such exceedances include the following:

- In sediments, PCBs are present at levels potentially causing harmful impacts to aquatic ecosystems.
- In fish, PCB levels associated with biochemical changes and adverse reproductive effects are exceeded.
- In mink, PCB levels associated with reproductive impairment are exceeded.
- In snapping turtles, PCB levels associated with the latent mortality in juveniles are exceeded.
- In bullfrogs, PCB levels associated with significant risk for various adverse effects in amphibians, including physical malformations, are exceeded.
- In birds, PCB levels associated with reproductive impairment are exceeded.

Serious adverse effects are likely to be occurring to these, and potentially other, living organisms exposed to the PCB contamination in the Hudson River region. To elucidate those effects, further studies on natural resources of the Hudson River, including fish, mink, sediment, birds, and waterfowl, are currently underway.

In conclusion, PCBs released from GE facilities on the Upper Hudson River present a serious and long-term threat to the health of the entire Hudson River ecosystem that *warrants continued study and further action to restore and compensate* for the injured natural resources and the services that have been lost. Because of concerns about the contamination and its potential impact, the Hudson River Natural Resource Trustees are continuing to assess the Hudson River ecosystem. The Trustees will use the information they collect during this assessment to document injuries to natural resources and determine the amount and type of restoration needed to compensate the public for these injuries.

FURTHER INFORMATION

Further information on the Hudson River natural resource damage assessment (NRDA) can be found at the following websites:

http://www.darp.noaa.gov/northeast/hudson/index.html

http://www.dec.ny.gov/lands/25609.html

http://www.fws.gov/contaminants/restorationplans/HudsonRiver/index.html

To add yourself to the Hudson-NRDA listserv:

1. Send a message to: requests@willamette.nos.noaa.gov
2. Write in the subject: Subscribe hudsonnrda

If you have questions about natural resource damages, please contact one of the individuals listed below:

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1305 East West Highway SSMC4, Room 10219
Silver Spring, MD 20910
301-713-3038 x186
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