Polychlorinated Biphenyl Contamination of Tree Swallows in the Upper Hudson River Valley, New York.

Effects on Breeding Biology and Implications for Other Bird Species

New York Field Office
U. S. Fish and Wildlife Service
Cortland, New York

March, 1997

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Executive Summary

The Hudson River, from Hudson Falls to New York City, New York, is highly contaminated with polychlorinated biphenyls (PCBs), largely as a result of PCB releases from two capacitor manufacturing plants in Hudson Falls and Fort Edward, New York. The U.S. Fish and Wildlife Service determined to evaluate the effects of Hudson River PCBs on migratory birds, selecting the tree swallow (*Tachycineta bicolor*) as a sentinel species. In 1994, we monitored three tree swallow nesting colonies along the upper Hudson River and one reference colony along the upstream Champlain Canal. Chemical parameters evaluated included total PCBs, congener specific and planar PCBs, metals, dioxins, dibenzofurans, and organochlorine pesticides. We also measured various indicators of reproductive success, as well as nestling growth and development.

Mean PCB concentrations in tree swallow eggs and nestlings from the Hudson River ranged from 377 nanograms per gram (ng/g) in reference area nestlings to 55,800 ng/g in Hudson River nestlings. PCB concentrations in tree swallows were generally correlated with PCB concentrations in sediment from adjacent riverine sediments. Hudson River tree swallow PCB concentrations were the highest ever reported for this species. At the two most contaminated sites, PCB accumulation in nestlings was significant enough to mask the effects of growth dilution. The PCB concentrations were of the same order of magnitude as PCB concentrations in aquatic insects, yellow perch, and cyprinid species from adjacent reaches of the Hudson River.

There was considerable consistency in the PCB congener patterns within and among sites, suggesting that a similar source of PCB contamination provided the strongest influence to PCB body burdens. The congener patterns in tree swallows also resembled the patterns found in upper Hudson River surface water, sediment, fish, and benthic invertebrates and were consistent with a PCB mixture predominated by Aroclor 1242, but amended with a small percentage of more highly chlorinated congeners.

PCB contamination of tree swallows was highly significant as it pertained to dioxin equivalency. The avian based toxic equivalency quotients in Hudson River tree swallows ranged from 1,260 picograms per gram (pg/g) to 11,100 pg/g, compared with 36 pg/g in reference site tree swallows. These toxic equivalency quotients are well above levels associated with adverse impacts in other bird species, such as the common tern (*Sterna hirundo*), Caspian tern (*Sterna caspia*), Forster's tern (*Sterna forsteri*), double-crested cormorant (*Phalacrocorax auritus*), and bald eagle (*Haliaeetus leucocephalus*).

Nestling mass at hatching was lower for Hudson River tree swallows than tree swallows from Ithaca, New York. This warrants further study since reduced mass at hatching has been associated with PCBs and other planar chlorinated hydrocarbons (PCHs) in other bird species. Clutch size, nestling survival, and nestling growth and development were all normal in the Hudson River tree swallows. Feeding studies conducted for this investigation found that tree

swallows nesting adjacent to the Hudson River consumed predominantly insects that develop from benthic aquatic larvae.

Plumage color is associated with several aspects of the social behavior of tree swallows. There were possible abnormalities in the plumage coloration of sub-adult females that warrant further attention. Our data suggest that a larger than normal percentage of sub-adult females in our study population had prematurely developed adult plumage. PCB exposure is one possible cause of altered plumage development.

A large number of nests were observed to be of poor quality in this population, in terms of the thickness of the grass cup, as well as the number of feathers lining the nest. Nest quality can influence reproductive success, particularly during adverse weather conditions, when nestlings depend on the protection provided by a well constructed and well feathered nest. Although nest building behavior in birds has not been shown to be influenced by PCBs, other reproductive behaviors in birds have been linked with PCB contamination.

Tree swallows breeding along the Hudson River in 1994 had lower reproductive success than tree swallows from an uncontaminated site. The primary sources of the lowered reproductive success were a reduced rate of hatchability and a high level of abandonment of eggs during the incubation stage. This lower reproductive success cannot be explained by adverse weather conditions, predation, unusual disturbance, or other contaminants, but is consistent with reduced reproductive success observed in other birds exposed to high concentrations of PCBs. Although this population had a high proportion of sub-adult females, that can be less successful at breeding than adult females, the Hudson River tree swallows still had lower reproductive success when compared to a population of tree swallows near Ithaca, New York, that also consisted of a large proportion of sub-adult females.

The PCB concentrations and toxic equivalency quotients we detected in tree swallows have significant implications for migratory birds, in general, that breed or migrate along the Hudson River. We estimate that if bald eagles, Forster's terns, common terns, Caspian terns, and double-crested cormorants were to nest along the Hudson River, at least between Hudson Falls and Saratoga National Historical Park, they would likely accumulate concentrations of PCBs which generally exceed concentrations associated with severe reproductive and developmental effects. Of these species, only the bald eagle is currently attempting to nest along the Hudson River. There are numerous other Hudson River bird species with feeding strategies that predispose them to high PCB exposures. PCB dose-response data are limited or nonexistent for these species, making it difficult to accurately predict PCB-induced risk to other Hudson River birds.

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1.0 INTRODUCTION

Between 1946 and 1977, an estimated 150,000 - 600,000 kilograms (kg) of polychlorinated biphenyls (PCBs) were released into the upper Hudson River by two capacitor manufacturing plants located in the Towns of Fort Edward and Hudson Falls, New York, making the Hudson River one of the most highly PCB contaminated ecosystems in North America (Horn et al. 1979, Sanders 1989). In 1992 and 1993, it was discovered that residual PCB in the form of dense non-aqueous phase liquid (DNAPL) underlies the Hudson Falls plant site. It was further discovered that this PCB is entering the Hudson River and may be contributing significantly to on-going Hudson River PCB loading (U.S. Environmental Protection Agency (USEPA) 1995).

The entire stretch of the Hudson River between Hudson Falls and the Battery in New York City, a distance of approximately 320 kilometers (km), has been designated as a superfund site by the USEPA as a result of PCB contamination (Figure 1.0). The most severe sediment contamination occurs between Hudson Falls and Troy, New York (just north of Albany), with approximately 40 sediment "hot spots" in which average PCB concentrations exceed 50 micrograms per gram (*ug*/g). Since 1976, various restrictions have been placed on fishing in the Hudson River due to the PCB contamination, including a complete ban on all fishing between Hudson Falls to the Troy Dam that lasted from 1976 until 1995. Although recreational fishing is now allowed in this upper Hudson River stretch, it is a strictly enforced catch and release fishery.

Although PCBs have been entering the Hudson River since at least the mid-1950's, significant quantities from the Fort Edward and Hudson Falls facilities were sequestered in sediments and woody debris within the pool formed by the Fort Edward Dam. In 1973, the Fort Edward Dam was removed, allowing a mass flux of PCB contaminated material downstream. Sediments scoured from behind the Fort Edward Dam settled initially in the east and west channels at Rogers Island and were subsequently removed by the New York State Department of Transportation (NYSDOT) to several nearby disposal areas. Periodic maintenance dredging of additional river sections has resulted in the formation of other disposal areas adjacent to the river. PCBs related to manufacturing processes at the Hudson Falls and Fort Edward plants are also believed to exist at a number of local landfills (Malcolm Pirnie Inc. 1978, Weston 1978).

PCBs were marketed in the United States predominantly under the commercial name Aroclor, with individual Aroclors distinguished by the percentage of chlorine by weight. The Fort Edward and Hudson Falls plants began to use PCBs in 1946 and stopped their use in 1977, primarily using Aroclors 1016 and 1242 from 1955 through 1977 with significant use of Aroclor 1254 prior to 1955 (Brown et al. 1984, as cited in TAMS/Gradient 1991).

Between 1966 and 1977, the Fort Edward and Hudson Falls plants purchased approximately 35,000 metric tons of PCBs, or approximately 15% - 25% of the PCBs manufactured in the United States during that period (Horn et al. 1979, Ayres et al. 1988, as cited in Chillrud 1996).

The Hudson River provides valuable habitat for nesting and migrating birds, with at least 143 species known to breed in the Hudson River corridor (Andrle and Carroll 1988). Yet very little information exists on PCB concentrations in migratory birds along the Hudson River. A study by the New York State Department of Environmental Conservation (NYSDEC) in 1983/1984 evaluated the contaminant loads of various waterfowl species collected by hunters in five areas of the state. In general, birds from Long Island exhibited the highest PCB concentrations, followed by birds from the Lake Champlain-Hudson River area. The highest concentration of PCB was 43 *ug*/g detected in the fat of a black duck (*Anas rubripes*) from the Hudson River area (Foley unpub.). Stone and Okoniewski (1983) reported a great horned owl (*Bubo virginianus*) from the Hudson River that was exhibiting tremors, food regurgitation, and general physical decline. The bird's brain tissue was later determined to contain 357 *ug*/g PCB. Although avian laboratory and field studies suggest that PCBs in the Hudson River aquatic environment may pose risks to certain bird species, to date, no systematic studies of the effects of contamination on breeding birds in the Hudson River valley have been done.

1.1 PCBs in Hudson River Matrices

There is considerable variability in the concentrations of PCBs in Hudson River surface water, sediment, and biota, depending on the location and time of sample collection. The USEPA performed an ecological field investigation as part of the remedial investigation of this superfund site. Their investigation involved the collection of fish, benthic invertebrates, and sediments from 20 sites located throughout the Hudson River (Table 1.1). These data provide one snapshot of PCB contamination in the Hudson River. The average PCB concentrations of Table 1.1 do not represent a comprehensive analysis of PCB contamination of the river, but do illustrate: (1) considerable variability in PCB concentrations in sediment samples collected within a few miles of one another, (2) a general trend of decreasing PCB concentrations in sediment, invertebrates, and fish with increasing distance downriver from Fort Edward and Hudson Falls, (3) the most contaminated reach of the river is between Hudson Falls (river mile 197) and the Thompson Island Dam (river mile 187), in an area known as the Thompson Island Pool, and (4) PCB concentrations in fish and invertebrates are generally within the same order of magnitude as PCB concentrations in co-located sediment.

1.2 Objectives

This study was initiated to explore the uptake of PCBs by migratory birds along the Hudson River and their possible effects on the biology of these birds. We also considered the tree swallow to be an appropriate sentinel species for PCB uptake and planned to use data from this study to estimate the PCB associated risk to other Hudson River bird species. During 1994 we studied breeding tree swallows at three sites along the upper Hudson River and one site along the Champlain Canal. This report summarizes the findings of the 1994 tree swallow breeding season.

The objectives of this study were to:

I. Determine whether tree swallows nesting along the upper Hudson River were accumulating PCBs from the Hudson River.

II. Determine whether PCBs were affecting reproductive success or nestling growth and development of tree swallows nesting along the upper Hudson River.

III. Based on the above results, hypothesize the risk to other migratory birds from Hudson River PCB contamination.

1.3 PCB Toxicity

PCBs include 209 congeners that differ in the number and position of chlorine atoms attached to the biphenyl ring structure. Studies of the mechanisms of PCB toxicity indicate that toxicity is related to the types and concentrations of the various congeners. PCB congeners that lack chlorine atoms in the *ortho* positions of the biphenyl ring structure are termed non-*ortho*-chloro substituted (non-*ortho*). These PCB congeners attain a planar configuration and are generally the most toxic to the developing embryos of fish and wildlife. These are also the congeners that most closely resemble the highly toxic 2,3,7,8 tetrachlorodibenzo-*p*-dioxin (2,3,7,8 TCDD).

Planar PCBs, polychlorinated dibenzo-*p*-dioxins (PCDDs), and polychlorinated dibenzofurans (PCDFs) are included in a group of compounds collectively termed planar chlorinated hydrocarbons (PCHs). Many of these compounds are believed to exert their toxicity through a similar mechanism, initiated through binding of the PCH molecule to the aryl hydrocarbon receptor (AhR), a ligand activated transcription factor found in most vertebrates. 2,3,7,8 TCDD has the greatest affinity for the AhR and is also generally regarded as the most toxic of the PCHs. The non-*ortho* PCBs have the greatest binding affinity to the AhR of the PCB congeners, followed by the mono-*ortho*-chloro substituted (mono-*ortho*) PCB congeners. There may also be some toxic responses of PCBs that are independent of the AhR and, therefore, not associated with the planar congeners (Safe 1990, Barron et al. 1995).

1.4 Physiological Effects of PCBs on Birds

PCBs have been implicated in behavioral abnormalities, reduced embryo survival, biochemical abnormalities, immune suppression, wasting syndrome, high levels of deformities, and adult mortality in a number of bird species. Each of these effects will be addressed in the following paragraphs.

1.4.1 Acute Toxicity

Adults of most bird species require a substantial dose of PCBs in the diet to cause acute toxicity. Median lethal concentrations (LC_{50}) in 5-day feeding trials with Aroclor 1254 were 604 *ug*/g for northern bobwhites (*Colinus virgianus*), 1,091 *ug*/g for ring-necked pheasants (*Phasianus colchicus*), and 2,697 *ug*/g for mallards (*Anas platyrhynchos*) (Heath et al. 1972, as cited in Hoffman et al. 1996). Clinical signs of acute PCB toxicity reported in birds included tremors, leg paralysis, hemorrhages, myocarditis, kidney and liver necrosis, enlarged kidneys, and blackish fluid in the gastrointestinal tract (Hoffman et al. 1996).

Several studies point to the value of determining brain concentrations of PCBs in assessing acute toxicity (Sileo et al. 1977, Stone and Okoniewski 1983, Stickel et al. 1984, Hoffman et al. 1996). Controlled feeding experiments with common grackles (*Quiscalus quiscula*), red-winged blackbirds (*Agelaius phoeniceus*), brown-headed cowbirds (*Molothrus ater*), and European starlings (*Sturnus vulgaris*) concluded that a PCB brain residue of 310 *ug*/g was an appropriate threshold for PCB induced mortality in these birds (Stickel et al. 1984). PCBs were the likely cause of mortality among wild ring-billed gulls (*Larus delawarensis*) in Ontario, Canada in the late 1960s and early 1970s. A brain concentration of 300 *ug*/g PCB was suggested as a threshold lethal level (Sileo et al. 1977). As noted earlier, a great horned owl from the Hudson River that was exhibiting tremors, food regurgitation, and general physical decline was found to contain 357 *ug*/g PCB in its brain (Stone and Okoniewski 1983).

Due to the extreme rarity of observing PCB-induced mortality in the field, we did not anticipate evaluating acute toxicity as part of this study. However, we were alert for the previously documented manifestations of PCB toxicosis.

1.4.2 Early Life Stage Effects

Based on controlled studies, bird embryos are more sensitive to the toxic effects of PCBs than are adults. Direct embryo mortality has been induced by PCBs in birds such as the double-crested cormorant (*Phalacrocorax auritus*), mallard, common goldeneye (*Bucephala clangula*), ring-necked pheasant, herring gull (*Larus argentatus*), and domestic chicken (*Gallus gallus*) (Barron et al. 1995). Of all the species studied thus far, chicken embryos are among the most sensitive to PCBs. Brunstrom (1989, as cited in Barron et al.) reported an LD_{50} for Aroclor 1248 in chicken embryos of 5 *ug*/g egg.

PCBs have reduced the hatchability of domestic chicken eggs when hens were given feed containing as little as 10 *ug*/g PCB. The corresponding whole egg concentrations were as low as 1.3 *ug*/g PCB (Sotherland and Rahn 1987, as cited in Hoffman et al. 1996). Concentrations in domestic chicken eggs greater than 15 *ug*/g produced high embryotoxicity, edema, and growth retardation (McLaughlin et al. 1963, Platonow and Reinhart 1973, Tumasonis et al. 1973, Cecil et al. 1974, as cited in Kubiak et al. 1989). Platonow and Funnell (1971, as cited in Barron et al. 1995) observed that domestic chickens fed 250 *ug*/g Aroclor 1254 experienced a significant reduction in comb and testicle weight. Other species, including the mallard and Atlantic puffin (*Fratercula arctica*), have not been shown to elicit as strong a reproductive response to PCB exposure as the domestic chicken in controlled studies (Hoffman et al. 1996).

In wild Forster's terns (*Sterna forsteri*) exposed to PCBs in Green Bay, Michigan, Kubiak et al. (1989) reported edema of embryos, as well as lower body weights and increased liver weight to body weight of newly hatched chicks. Total PCBs in the eggs ranged from 6 to 26 *ug*/g (median concentration of 23 *ug*/g PCB). Hoffman et al. (1987) reported shorter femur lengths in these same Forster's tern chicks. Harris et al. (1993) reported that some Forster's tern chicks from Green Bay exhibited a "wasting syndrome." This was characterized by chicks appearing to gain weight normally until about the 14th to 20th day after hatching, but then rapidly losing weight until dying.

Caspian terns (*Sterna caspia*) at a Saginaw Bay colony experienced reduced egg viability and fledging rates, as well as a "wasting syndrome" among the chicks following a 1986 flood event which mobilized PCB contaminated sediments (Ludwig et al. 1993). The average PCB concentrations reported in Caspian tern eggs collected in 1988 were 8 *ug*/g in first clutch nests and 18 *ug*/g in second clutch nests.

As part of this study, we quantified hatching success and determined whether unhatched eggs were infertile or showed any embryonic development. A more rigorous evaluation of embryos was not performed. All eggs were measured and weighed. We evaluated each nestling for overt signs of edema, and we monitored nestling growth (mass, wing length, tarsus length) from hatching until day 14 to assess growth rates.

1.4.3 Teratogenic Effects

PCBs and other PCHs are strongly associated with congenital malformations in birds. Studies with domestic chickens have demonstrated a link between PCB exposure and malformations of the beak, brain, and leg (Flick et al. 1965). Concentrations of PCBs in chicken eggs greater than 15 *ug*/g were associated with deformities of the leg, toe, beak, and neck of chicks (Tumasonis et al. 1973, as cited in Kubiak et al. 1989). Summer et al.

(1996) observed that chickens fed PCB-contaminated fish produced embryos and chicks with various deformities, including head and neck edema and hemorrhage, abdominal edema and hemorrhage, foot and leg deformities, skull and brain deformities, and yolk-sac deformities.

Congenital deformities have been reported in the embryos and hatchlings of wild herring gulls, ring-billed gulls, common terns, Caspian terns, Forster's terns, double-crested cormorants, black-crowned night herons (*Nycticorax nycticorax*), and bald eagles (*Haliaeetus leucocephalus*) from the Great Lakes (Gilbertson et al. 1976, Fox 1993). PCB concentrations in Lake Ontario common terns were as high as 463 *ug*/g (dry weight) and a high number of deformities, including crossed bills, extra and deformed toes, and small eyes, were observed (Gilbertson et al. 1976). It is believed that congenital deformities are extremely rare in wild bird populations and Fox et al. (1991) hypothesized that these and other congenital deformities observed in fish-eating birds from the Great Lakes were caused by aryl hydrocarbon hydroxylase (AHH) active persistent halogenated aromatic hydrocarbons (PHAHs), such as PCBs.

A sharp increase in abnormalities of common terns (*Sterna hirundo*) and roseate terns (*Sterna dougallii*) on Long Island Sound was reported in 1970, and was attributed to PCDD contamination. The most common abnormalities were feather loss among juveniles and deformities of the eye, beak, and feet of nestlings (Hays and Risebrough 1972 and Gochfield 1975, as cited in Hoffman 1994).

The Saginaw Bay Caspian tern chicks described above exhibited a 20% frequency of deformities, corresponding to 8 *ug*/g total PCB in first clutch nests and 18 *ug*/g in second clutch nests. These deformities included scoliosis, clubbed feet, and gastroschisis/unresorbed yolk sacs (Ludwig et al. 1993).

Forster's terns sampled at Green Bay, Wisconsin, in 1983 exhibited 14% hatchling deformities and 18% embryo deformities, associated with a median total PCB concentration in the eggs of 23 *ug*/g. The documented deformities included crossed beak, shortened lower beak, poorly ossified foot, and abnormal ossification of the ilium. By contrast, reference area Forster's terns containing a median PCB concentration of 3.2 *ug*/g total PCB exhibited no deformities (Hoffman et al. 1987; Kubiak et al. 1989).

We examined all tree swallow nestlings, as well as captured adults, for externally visible abnormalities. Particular attention was paid to the beaks, feet, eyes, wings, and feather development of nestlings.

1.4.4 Behavioral Effects

There is evidence that PCBs alter normal reproductive behavior in some birds. Peakall and Peakall (1973) attributed reduced reproductive success in ring doves (*Streptopelia* *risoria*) to decreased parental attentiveness caused by 10 *ug*/g PCB in the diet. The mean PCB concentration in the ring dove eggs was 16 *ug*/g. Mourning doves (*Zanaida macroura carolinensis*) fed 10 - 40 *ug*/g PCBs for 6 weeks went through prolonged courtship and, at the highest experimental doses, failed to nest (Tori and Peterle, 1983).

The poor reproductive success of Lake Ontario herring gulls in the 1960s and 1970s was attributed to PCH-induced poor parental attentiveness, as manifest by less aggressive response to human intruders, less heat applied to the eggs, and increased time that eggs were left exposed. These gulls were heavily contaminated with PCBs and other organochlorines (Fox et al. 1978). Kubiak et al. (1989) in their study of Forster's terns at Green Bay noted decreased parental attentiveness, as well as increased incubation period, nest abandonment, and egg disappearance among Green Bay terns versus reference area terns. PCBs appeared to be the only contaminant present in sufficient concentrations (23 *ug*/g median total PCB) to produce the observed effects.

For this study, we evaluated parental behavior indirectly by quantifying reproductive success. We recorded any instances of nest abandonment and recorded qualitative measurements of nest construction.

1.4.5 Other Physiological/Biochemical Aberrations

A number of other biomarkers are associated with PCB exposure, but were not explored as part of this study. Since these biomarkers may be more sensitive measures of PCB exposure than endpoints such as reproductive success or teratogenesis, they may be useful tools for future avian studies along the Hudson River. A few of these biomarkers are discussed here.

Porphyria is a general term which refers to an alteration of the type or amount of enzymes involved in heme biosynthesis. It has been observed in herring gulls from areas of the Great Lakes which are contaminated with PHAHs, including PCBs (Fox 1993). Elevated levels of highly carboxylated porphyrins in the liver appear to be a useful biomarker for PHAHs (Fox et al. 1988, as cited in Fox 1993).

Dietary exposure to PCBs has also been documented to accelerate vitamin A metabolism, resulting in a depletion of vitamin A from the body. It has been hypothesized that PCBs may exert some of their effects on avian reproduction and immune function by interfering with vitamin A homeostasis. Evidence supporting this comes from studies of herring gulls from contaminated areas of the Great Lakes (Fox 1993) and great blue herons (*Ardea herodias*) along the St. Lawrence River in Canada (Boily et al. 1994).

Evidence exists which indicates that PCBs and other PHAHs alter thyroid function, causing thyroid enlargement (goiter) in Great Lakes herring gulls. The thyroid plays an important role in many physiological processes, particularly metabolism, development, differentiation, and growth (Fox 1993).

2.0 STUDY SITES AND METHODS

2.1 The Tree Swallow as a Sentinel Species

The tree swallow is a common breeding passerine throughout the northern half of North America, where it is frequently found in association with bodies of water. As an aerial insectivore, the tree swallow feeds primarily on flying insects during the breeding season. It is a cavity nester and can be easily induced to nest in colonies of artificial nest-boxes. Its use of nest-boxes for breeding, combined with its tendency to feed on insects emerging from bodies of water located near the nest site, make the tree swallow an excellent candidate for the monitoring of aquatic contaminants (Hebert et al. 1993). Anthropogenic sources of environmental contamination, such as acid deposition and radiation, have been shown to influence the reproductive success of tree swallows (Blancher and McNicol 1988, Zach and Mayoh 1984, 1986). Tree swallows have also been used as biomonitors of heavy metal, pesticide, dioxin, and PCB contamination, and are known to accumulate and concentrate these substances (Ankley et al. 1993, Bishop et al. 1992, Bishop et al. 1995, DeWeese et al. 1985, Jones et al. 1993, Kraus 1989, Nichols et al. 1995, St. Louis et al. 1993, Shaw 1983). The biological implications of PCB contamination for tree swallows are not known.

2.2 Study Sites

Four tree swallow breeding sites, consisting of a total of 128 nest-boxes, were established in late March and early April of 1994. Three of these sites were located along the Hudson River in Saratoga County, New York, and the fourth site was located along the Champlain Canal in Washington County, New York (Figure 2.0). Nest-boxes were constructed of cedar, with floor area approximately 12 centimeters (cm) x 12 cm, a depth of 21 cm, and a 3.5 cm diameter entrance hole. Each box was mounted on a length of metal conduit at a height approximately 1.5 meters above the ground and was equipped with a 50 cm diameter conical predator guard located below the box. Boxes were located approximately 20 meters apart except at the site on the Champlain Canal where spacing was reduced to 10 - 15 meters due to limited area available.

Remnant Deposit 4 (43°16'N, 73°36'W) is located 0.75 km upstream from the former Fort Edward Dam on the west bank of the Hudson River, at approximately river mile 195. Five Remnant Deposit Sites are located in the Hudson River between Hudson Falls and Fort Edward. These sites consist of deposits of sediment and woody debris that were exposed after the Fort Edward Dam was removed in 1973. All five sites are highly contaminated with PCBs and were capped as part of early river remedial efforts. Thirty nest-boxes were located on the approximately nine hectare (ha) open field created by the capping of Remnant Deposit 4. This open field is surrounded by mature forest on three sides and by the Hudson River on the fourth side. All nest-boxes at this site were located between 10 and 50 meters from the river. Although the remnant sites are capped, this section of the river is known to be contaminated with PCBs due to residual substrate (sediment, woody debris) contamination and PCBs that are known to be still entering the river from the Hudson Falls plant. High resolution coring sediment data from 1994 exist for river mile 197.1, Bakers Falls, located about 1.6 km upstream of Remnant Site 4. Concentrations of total PCBs were 179 *u*g/g in surficial sediments and increased to 228 *u*g/g in the 4 to 6 cm depth (TAMS/Gradient 1996:PHASE2/HRCORES). In 1986, General Electric conducted sediment sampling in the vicinity of the remnant deposits prior to capping. PCB concentrations near Remnant Site 4 ranged from 0.2 to 22.8 *u*g/g in surface sediment (data from J. Haggard/GE Spreadsheet file:lhrsed.wk1).

Special Area 13 (SA 13) (43°15'N, 73°35'W) is a capped deposit of contaminated dredged river sediment which is owned by the New York State Thruway Authority (NYSTA) and located two km downstream of the former Fort Edward Dam site. This site is located at approximately river mile 193. Thirty-six nest-boxes were located on this site, surrounded by active and abandoned farm fields, and some secondary forest, with the Hudson River bordering the site on the east. All nest-boxes were located in the approximately two ha open field and were 50 - 100 meters from the river. The Hudson River adjacent to the SA 13 site is highly contaminated with PCBs. Sediment samples collected near river mile 193 in 1991 contained PCB concentrations ranging from non-detect to 656 *u*g/g (TAMS/Gradient 1996/PHASE2/SEDIMENT, TAMS/Gradient 1996/GE, J. Haggard/GE H-7 Survey/Spreadsheet file h7data.wk1).

Saratoga National Historical Park (43°00'N, 73°36'W) borders the west bank of the Hudson River in the town of Stillwater, approximately 40 km down-river from the former Fort Edward Dam. Nest-boxes were placed on the floodplain in an open area of approximately five ha, surrounded on three sides by forest. The Hudson River borders the site on the east side and U.S. Highway 4 runs along the west side. Thirty-five nest-boxes were located at this site, between 10 and 50 meters of the river. The Saratoga site lies at approximately river mile 173. Surface high resolution core sediment samples collected in 1994 from river miles 166.3 and 177.8 contained 1 and 6 *u*g/g PCB, respectively (TAMS/Gradient 1996:PHASE 2/HRCORES). Sediment sampling performed by General Electric in 1991 at approximately river miles 173-174 detected between non-detect and 20.5 *u*g/g total PCB (TAMS/Gradient 1996/GE).

The Lock 9 site was located on the Champlain Canal (43°21'N, 73°30'W) approximately 15 km northeast from its confluence with the Hudson River at Fort Edward. Twenty-seven nest-boxes were placed approximately 15 meters from the canal along the brushy border of the lock site. The approximately one ha open area around the lock is surrounded by secondary forest and agricultural fields. Although PCBs are suspected to have entered the Champlain Canal from sites to both the north and south of Lock 9, sediment testing performed just downstream of Lock 9 in 1994 determined that sediment PCB concentrations were generally at concentrations below 1 *u*g/g (J. Dergosits, NYSTA, pers. comm.). Lock 9 was established as a reference site.

2.3 Monitoring of Reproductive Success and Nestling Growth

Tree swallows have been the subject of a large number of ecological and behavioral studies and have proven to be extremely tolerant of human disturbance. The protocol followed for monitoring of reproductive success has been used at other sites in New York State since 1987, and no adverse effects on parental care have been observed (Winkler 1991 & 1993, McCarty 1995).

Nest-boxes were checked for activity beginning at the end of April. Visits were made every three to four days until egg laying began. If adults were in the box, data collection was deferred until later in the day or the following day. During egg laying, nests were visited in the afternoon (to avoid the morning egg laying period) at one to three day intervals and new eggs were marked using a #2 pencil. Egg length and width were measured to 0.1 millimeter (mm) using dial calipers and eggs were weighed to the nearest 0.05 gram (g) with an electronic balance (O'Haus model C151). Eggs were first weighed within two to three days of laying (most within one day) to minimize error due to evaporative water loss. Eggs were weighed again before hatching to determine the rate of mass loss. Egg volume was calculated from length and width measurements using the equation: $\text{volume} = 0.077(\text{egg length}) + 0.007(\text{egg width})^2 - 1.020$, as presented by Winkler (1991). Nests were checked for incubation at one to three day intervals. As nests approached their expected hatch date they were checked daily to determine the exact date of hatching. If eggs failed to hatch, they were classified according to the degree of embryonic development.

The date on which at least half the eggs hatched was considered the hatch day for that nest. Nestlings present on the nest hatch day (= day 1) were weighed to the nearest 0.5 g. Nests were visited on subsequent days to determine the total number of nestlings hatched. Nestlings were weighed on subsequent days as time allowed. We attempted to weigh all nestlings on days 8, 10, 12, and 14. In addition, the wing chord and length of the ninth primary were measured on these days. All nestlings were banded with numbered U.S. Fish and Wildlife Service (USFWS) bands on day 10. Nests were not checked after nestlings reached 14 days of age to avoid causing premature fledging. Nestlings that were present on day 14 were presumed to have successfully fledged unless they were found dead in the nest-box during a post-fledging box inspection.

2.4 Determination of Nest Quality

Observations of the size and condition of the nest and the number of feathers present in the nest were recorded during both the incubation and nestling phases. Nests were given a qualitative rating of 1 - 3, with #1 being a poorly feathered nest with a small amount of grass, #2 being a nest deficient in either grass or feathers, and #3 being a high quality nest. Feathers were counted at some point during incubation and also at some point during the nestling phase of the nest.

2.5 Collection of Samples for Chemical Analysis

Samples for chemical analysis were collected throughout May and June of 1994. Three eggs were collected from nests during the first three days of incubation. Nests were chosen based on several criteria: the earliest nests were chosen provided that clutch size was at least five eggs, six-egg nests were chosen over five-egg nests, and nests of females with full adult plumage were chosen over those of sub-adult females. Eggs were collected from six nests at each of the Hudson River sites, and from all five nests available at the Lock 9 Reference Site. Eggs had been marked as they were laid and eggs collected came from the first four eggs laid. Egg dimensions and mass were measured before the contents were collected. Contents were removed by cutting the shell around the equator using a sterile scalpel blade. When the shell was cracked, the contents were emptied into a contaminant-free sample jar (I-Chem Superfund-Analyzed) and the mass of contents recorded. Contents of eggs from each nest were pooled in a single sample and kept frozen using dry-ice until transfer to the laboratory freezer. Egg shell halves were rinsed and dried.

Since the intended reference site on the Champlain Canal lacked sufficient nests to determine reproductive success, we also collected eggs from a colony of tree swallows near Ithaca, New York, to enable us to use reproductive success and growth data from that area. Six sets of eggs were collected from the Ithaca site, but were not submitted for chemical analysis as part of this year's project.

Two nestlings were collected on day 14 from the nests where eggs had been collected. Nestlings were euthanized using CO_2 asphyxiation, weighed and measured, transferred to contaminant-free sample jars (I-Chem Superfund-Analyzed), and kept frozen on dry-ice until transfer to the laboratory freezer. We obtained nestling samples for chemical analysis from six nests at the Remnant site, seven nests from SA 13, five nests from Saratoga, four nests from Lock 9, and two nests from the Ithaca site.

2.6 Chemical Analyses

One sample from each site was submitted for chemical analysis for metals and organochlorines. Each sample consisted of three eggs from a single nest. The metals analysis was performed by Hazleton Laboratories America, Inc. (Hazleton). Arsenic and selenium were determined by graphite furnace atomic absorption, mercury by cold vapor atomic absorption, and all other elemental analysis by inductively coupled plasma spectroscopy. Organochlorine analysis was performed using capillary gas chromatography by Hazleton.

PCB analysis was performed by two laboratories. Total PCBs were determined in one egg composite from each site by Hazleton as part of the organochlorine analysis described above. Three egg composites (three eggs each) and one nestling composite (two nestlings each) from each site were analyzed by the Midwest Science Center of the Biological Resource Division of the U.S. Geological Survey (MSC) for congener specific PCBs by capillary gas chromatography/electron capture detection (GC/ECD). Total PCBs (cPCBs) were determined by summing the congener concentrations. One nestling composite from each site was analyzed for congener specific, non-*ortho* and mono-*ortho* PCBs by GC/ECD. Total PCBs (cPCBs) were determined in these samples by summing the congener concentrations.

2.7 Measurement of Egg Shells

Egg shell halves from collected eggs were dried at room temperature for 5 weeks. Shells were weighed to the nearest 0.0001 gm (O'Haus GA110). Shell halves were divided in half along the long axis and the thickness was measured near the center of each quarter to the nearest 0.001 mm using a Mitutoya micrometer (no. 2050-08). The mean of the four thickness measures was used for all analyses of thickness. An index of shell thickness was calculated using the equation: shell index = shell mass x $(\text{shell length x shell width})^{-1}$ (DeWeese et al. 1985, Ratcliffe 1967).

2.8 Capture of Adults and Collection of Diet Samples

Adult tree swallows were captured while feeding nestlings. Parents typically feed nestlings food boluses consisting of 1 to 50+ individual insects (Blancher et al. 1987, McCarty 1995). When an adult was captured with one of these food boluses in its mouth, the insects were removed and stored in 75% ethyl alcohol. Insects were identified to order (suborder in the case of Diptera and Odonata). Diets were determined based on the number of each insect variety, as well as on the mass of each insect variety. Mass was obtained by measuring the length of each item and then converting length to dry mass using conversion factors from McCarty (1995).

Sex of adult swallows was determined by the presence or absence of a vascularized brood patch, which is found only on females. Female plumage color was recorded and photographs taken of females with sub-adult plumage. Adults were measured, banded with a numbered USFWS band and one colored plastic band characteristic of the sample site, and released.

2.9 Statistical Analyses

Comparisons among contaminated and uncontaminated sites were made using standard statistical tests. Parametric analysis of variance (ANOVA) was used to test for differences among the sites in reproductive success variables. When the overall ANOVA was found to be significant, differences between pairs of sites were evaluated using a post-hoc test (Fisher's Protected Least Significant Difference: Lentner and Bishop 1986).

Because of the small sample sizes for data on contamination levels, the nonparametric Kruskal-Wallis test was used to evaluate differences among sites (Conover 1980). Unless noted, all comparisons were two-tailed, with $\alpha = 0.05$. PCB congener concentrations were compared within and among sample sites using the Correlation Coefficient function of EXCEL 4.0. Correlation coefficients were calculated by dividing the covariance of two data sets by the product of their standard deviations.

3.0 RESULTS AND DISCUSSION

3.1 Arrival Dates and Nest-box Occupancy

The Hudson River Valley appears to be a major migration route for tree swallows. Large numbers of migrating tree swallows were observed foraging over the river beginning on March 25, 1994, and hundreds of migrating tree swallows, barn swallows (*Hirundo rustica*), bank swallows (*Riparia riparia*), cliff swallows (*Hirundo pyrrhonota*), and northern rough-winged swallows (*Stelgidopteryx serripennis*) were observed foraging along the river throughout April and early May. By April 28, tree swallows had begun defending nest-boxes and gathering nest material at all of the Hudson River sites. The first completed nests were found on May 5 and egg laying had begun at all sites by May 9. The mean date of clutch initiation was earliest at SA 13 (May 15), followed by Saratoga (May 18), Remnant 4 (May 20), and Lock 9 (May 21) (Table 3.1). Nest-box occupancy was high at all river sites, with virtually all nests showing some activity, and 70 - 95% of nest-boxes reaching the egg stage (Table 3.1).

The nesting site at Champlain Canal Lock 9 provided the poorest physical habitat for tree swallows. Swallows arrived and nested later at this site and in smaller numbers. Clutch initiation dates (mean = May 21) were later at this site than at any of the river sites (Table 3.1). The late arrival may have been due, in part, to the fact that this section of the canal system was partially drained and frozen when the swallows first arrived and only filled with water during April. Nest-box occupancy was low compared to the river sites (Table 3.1). This may have been due to a number of factors. The canal system itself was probably less attractive to swallows than the Hudson River due to the less reliable source of food during adverse weather found along the canal. In addition, the nest-boxes at Lock 9 were placed much closer to brush and trees than at the river sites. Tree swallows are known to prefer nest sites further from tall vegetation and this undoubtedly reduced occupancy at Lock 9 (Rendell and Robertson 1990).

3.2 Chemical Analysis of Samples

3.2.1 Metals and Organochlorines

There were anthropogenic sources of metal enrichment in the upper Hudson River, including a pigment manufacturer in Glens Falls. Brown et al. (1988) as cited in TAMS/Gradient (1991) reported mean metals concentrations in Thompson Island Pool sediments of 21.6 *ug*/g cadmium, 475 *ug*/g chromium, 217 *ug*/g lead, and 1.96 *ug*/g mercury. Surface sediment collected in 1983 at river mile 188.5 contained 17.1 *ug*/g cadmium, 47.2 *ug*/g copper, 898 *ug*/g chromium, 278 *ug*/g lead, and 199 *ug*/g zinc, (Chillrud 1996). More recently, sediment collected between river miles 194.1 and 188.5 in 1993 contained up to 12.3 *ug*/g cadmium, 234 *ug*/g chromium, 264 *ug*/g lead, 2.5 *ug*/g mercury, and 421 *ug*/g zinc (TAMs/Gradient 1996/Phase2/ECO/NonPCBs).

The concentrations of metals detected in tree swallow eggs from the four sample sites show little variation among sites (Table 3.2.1). A discussion of the metals most frequently associated with toxicity in birds follows.

Mercury was present in all four tree swallow egg samples at concentrations at or slightly above the detection limit of 0.05 *ug*/g. At high doses, mercury can impair reproduction and hatchling survival in birds (Thompson 1996). The concentrations of mercury detected in Hudson River tree swallow eggs are one to two orders of magnitude less than egg concentrations of mercury associated with adverse effects in other bird species (Thompson 1996).

Lead was not detected in tree swallow eggs at greater than the detection limit of about one ug/g. Signs of lead poisoning in birds include anemia, microscopic lesions in tissues, weight loss, muscular incoordination, green diarrhea, anorexia, and death (Franson 1996).

Cadmium was not detected in tree swallow eggs at greater than the detection limits of 0.14 - 0.15 *ug*/g. Cadmium has been identified as causing bone damage, reduced egg production, egg shell thinning, kidney damage, testicular damage, anemia, embryo deformities, and altered avoidance behavior in clinical experiments with birds (Furness 1996).

Any future Hudson River investigations into lead and cadmium in birds should consider sampling tissues that are more useful for assessing lead and cadmium exposure. These tissues include blood, liver, kidney, and bone (Franson 1996, Furness 1996).

With the exception of PCBs, no organochlorines were detected at greater than the detection limits (Table 3.2.1).

3.2.2 Polychlorinated Dibenzo-*p*-dioxins and Polychlorinated Dibenzofurans

The results of this PCDD and PCDF analysis are presented in Table 3.2.2. In general, the concentrations of PCDDs in Hudson River tree swallow nestlings were an order of magnitude less than concentrations reported in tree swallow nestlings from the Fox River, Green Bay, Wisconsin (Ankley et al. 1993).

It is more difficult to compare PCDF concentrations in tree swallows between the Fox River and Hudson River because of differences in analytical detection limits and co-elution of congeners. Concentrations of PCDFs detected in Hudson River tree swallows were typically below the corresponding Green Bay detection limits and below the values presented for the qualified (due to co-elution) PCDF concentrations. PCDDs and PCDFs will be addressed later in this report in terms of their contribution to total dioxin equivalency.

3.2.3 Total PCBs

Concentrations of PCBs detected in the various samples are presented in Table 3.2.3 A. In general, eggs from SA 13 were the most highly contaminated, with a mean wet weight PCB concentration of 42,100 nanograms per gram (ng/g). Egg samples from the Saratoga site and Remnant 4 site were contaminated at similar levels to one another, with mean PCB concentrations of 12,400 ng/g and 11,700 ng/g, respectively. The lowest PCB concentrations were detected at the Lock 9 site, where the mean PCB concentration was 6,280 ng/g. Differences in PCB concentrations in tree swallow eggs collected from all sample sites were statistically significant (Kruskal-Wallis, $p=0.044$).

Nestlings collected from SA 13 were the most highly contaminated of all nestling samples, with a mean concentration of 55,800 ng/g PCB. Nestlings from the Remnant 4 site contained a mean concentration of 29,100 ng/g PCB, followed by a mean of 5,250 ng/g PCB in nestlings from Saratoga, and a mean of 377 ng/g PCB in nestlings from Lock 9. Between site differences in PCB concentrations in tree swallow nestlings were not statistically significant (Kruskal-Wallis, $p=0.083$).

Data from other investigations of PCBs in tree swallows are presented in Table 3.2.3 B and Figure 3.2.3. A study reported in Nichols et al. (1995) evaluated four colonies of tree swallows in the Saginaw River watershed, Michigan. Mean PCB residues in tree swallow eggs ranged from 563 ng/g to 1,373 ng/g, and were believed to correspond to increasing levels of sediment PCB contamination. Corresponding PCB concentrations in 15-day old nestlings ranged from 171 to 1,027 ng/g.

Bishop et al. (1995) collected tree swallow eggs and 16 - 17-day old nestlings, as well as sediment samples, from 12 wetland sites in the Great Lakes watershed. Mean PCB concentrations in tree swallow eggs ranged from 255 ng/g at Wye Marsh (Lake Huron, Ontario, Canada) to 1,020 ng/g at Cootes Paradise (Lake Ontario, Ontario, Canada) to 4,008 ng/g at *Akwesasne* in the St. Lawrence River at Massena, New York (Table 3.2.3 B). The nestlings showed concentrations ranging from 11.2 ng/g PCB at Wye Marsh to 754 ng/g PCB at Cootes Paradise. No nestlings were sampled at *Akwesasne*.

PCB uptake by tree swallows has also been evaluated at a confined disposal facility (CDF) near the mouth of the Fox River and along the lower Fox River, Green Bay, Wisconsin (Ankley et al. 1993). A pooled egg sample from the lower Fox River was found to contain 4,120 ng/g total PCB. A pooled sample of 4, 8, and 16-day old nestlings from the lower Fox River contained 2,490 ng/g total PCB, while a pooled sample of 9, 13, and 17-day old nestlings from the CDF contained 2,970 ng/g total PCB.

Tree swallows sampled for this study contained much greater concentrations of PCBs than have been detected in tree swallows from even the most contaminated sites in the Great Lakes. Tree swallow eggs collected at SA 13, the most contaminated site in this study, were about ten times more contaminated with PCBs than any previously documented tree swallow eggs. At the Lock 9 site, where local PCB contamination was believed to be minimal, the mean PCB concentration in eggs (6,280 ng/g) exceeded the mean PCB concentration of 4,120 ng/g detected in a pooled egg sample from the Fox River, the most PCB contaminated tree swallow samples for which data have been published.

We hypothesize that at least some of the females nesting at the Lock 9 site accumulated PCBs prior to arriving at the nest site, since no significant PCB sources exist in the vicinity of Lock 9. The 16,000 ng/g PCB detected in the eggs at one of the nests at Lock 9 most likely reflects prior and not local exposure. This hypothesis is supported by the low concentrations of PCBs in nestling composites from this site (0.24 and 0.38 *u*g/g), as well as calculated PCB accumulation/loss rates among 14-day old Lock 9 nestlings of 0.32 and - 0.22 *u*g/day. PCB accumulation rates will be discussed further in Section 3.2.5.

Tree swallows collected from the Remnant site (river mile 195) and SA 13 (river mile 194) in 1994 contained similar concentrations of PCBs as chironomids collected at nearby river locations in 1993. Chironomids collected at river mile 191.5 contained 7,161 ng/g; chironomids from river mile 189.5 contained 76,338 ng/g. Benthic invertebrates, in general appeared to concentrate PCBs within the same order of magnitude as tree swallow nestlings (Table 1.1). This is reasonably consistent with the data of Nichols et al. 1995, in which the PCB concentration in tree swallow nestlings was about three times the concentration found in concurrently collected emergent insects. A concurrent collection of Hudson River tree swallows and benthic invertebrates would be needed to draw more definitive conclusions about the relationship between PCB concentrations in tree swallows as compared with their prey.

3.2.4 Congener Specific PCB Analysis

The results of the congener specific PCB analysis are presented in Appendix A.

In general, the congeners present at the highest concentrations in tree swallow egg and nestling samples (of those which eluted separately) were PCB 52 and PCB 28, followed by PCB 47, PCB 74, PCB 42, PCB 99, and PCB 118. There is no published comprehensive PCB congener data for tree swallows, although PCB congener analysis has been performed in other studies and partially published (Nichols et al. 1995, Bishop et al. 1995, Ankley et al. 1993).

A study of piscivorous/predatory birds from the British Isles found that PCB 138, PCB 153, and PCB 180 predominated (Boumphrey et al. 1993). PCB 118, PCB 180, PCB 101, PCB 153, PCB 138, and PCB 170 were the most dominant in insectivorous Eurasian dippers (*Cinclus cinclus*) and grey wagtails (*Motacilla cinerea*) (Ormerod and Tyler 1992). The relative dominance of the more highly chlorinated PCB congeners (within homologue groups penta-, hexa-, and hepta-) in piscivorous/predatory birds is a pattern that has also been demonstrated in piscivorous birds from North America (Turle et al. 1991 and Elliott et al. 1989, as cited in Boumphrey et al. 1993).

It appears that Hudson River tree swallows were dominated by proportionally more of the lower chlorinated (within homologue groups tetra- and penta-) congeners than many other bird species for which congener data are published. The apparent differences in congener dominance in Hudson River tree swallows as compared to other birds most likely reflect primarily a differential PCB congener exposure and metabolism by the tree swallow as compared with other species. This will be discussed further in the subsequent section on PCB homologue groups.

We plotted the PCB congener distributions in egg and nestling samples from our four sample sites. PCB congeners which were not detected were given the value of half the detection limit. The PCB congener patterns for eggs and nestlings from SA 13 are representative of Hudson River tree swallows sampled for this study (Figures 3.2.4 A and B).

The PCB congener patterns for Hudson River tree swallow eggs and nestlings appeared similar within and among sites. In an effort to quantify this similarity, correlation coefficients were calculated to compare individual PCB congener concentrations within and among sites (Table 3.2.4 A). Correlation coefficients within and among sites were all greater than 0.77, and generally greater than 0.90, suggesting a high degree of correlation among the various PCB congener concentrations. This is consistent with the hypothesis that most of the PCB body burden of tree swallows in our study area came from a single source, presumably the upper Hudson River.

PCB congener concentrations of samples from Lock 9 had lower correlation coefficients both within Lock 9 and between Lock 9 and other sites (Table 3.2.4 A). This suggests that PCB congener patterns in swallows at the Lock 9 site exhibited somewhat greater variability than PCB congener patterns at the Hudson River sites, possibly because of less consistency in the PCB congener patterns in the local food source. The relative contribution of PCBs from areas other than the immediate breeding area may also have been greater in these birds and contributed to the observed lower consistency in the PCB congener pattern.

Nichols et al. (1995) hypothesized that insects fed to tree swallow nestlings should contribute relatively more to final PCB concentrations in nestlings at the more contaminated sites versus the less contaminated sites. At the less contaminated sites, "inherited residues" should contribute relatively more to final nestling residues. The same argument may pertain to congener patterns. We hypothesize that the congener pattern or fingerprint of upper Hudson River PCBs generally overwhelmed patterns of other congener mixtures consumed by tree swallows prior to their arrival at the Hudson River breeding areas. This will be supported in the following section.

PCB Homologue Groups An evaluation of PCB homologue groups in upper Hudson River tree swallow samples illustrated that the PCB homologue distribution at all sites, in both eggs and nestlings, peaked with the tetra-chlorinated PCB congeners (Table 3.2.4 B and Figure 3.2.4 C). Between 87 - 93% of the total cPCB in eggs consisted of tri-, tetra-, and penta-chlorobiphenyls. Between 88 - 94% of total cPCB in nestlings consisted of these three PCB homologue groups. PCB homologue distribution was somewhat different in tree swallows from the Saginaw River, with proportionally more of the more highly chlorinated congeners present in these birds. Greater than 70% of the PCBs in both nestlings and eggs from the Saginaw study were tetra-, penta-, hexa-, and hepta-chlorobiphenyls (Nichols et al. 1995).

The predominant Aroclors used at Hudson Falls and Fort Edward between 1955 and 1977 were 1016 and 1242, with some recent use and significant pre-1955 use of Aroclor 1254 (Brown, Jr. et al. 1984, as cited in TAMS/Gradient 1991). Approximately 82% of Aroclor 1242 and 79% of Aroclor 1016 consists of tri-, tetra-, and penta-chlorobiphenyls (PCB congeners 16 - 127) (USEPA 1983, as cited in TAMS/Gradient 1991). On the other hand, Aroclor 1248 was the dominant Aroclor disposed in Saginaw Bay (Kubiak, USFWS, pers. comm.). Aroclor 1248 also contains predominantly tri-, tetra-, and penta-chlorobiphenyls (97%), but the homologue distribution peaks with the tetra-chlorinated biphenyls instead of the tri-chlorinated biphenyls, like Aroclors 1016 and 1242.

The possible influence of Aroclor source on PCB homologue patterns in tree swallows is illustrated in Figure 3.2.4 D. This figure illustrates that the PCB homologue pattern in Saginaw River tree swallows is shifted to the right (toward a higher overall degree of chlorination) of the PCB homologue pattern for Hudson River tree swallows. The PCB homologue pattern for Aroclor 1248 is shifted to the right of the PCB homologue pattern for Aroclor 1016, mirroring the shift in PCB homologue patterns for the two tree swallow populations.

The histograms illustrating PCB homologue patterns in tree swallows resemble histograms generated from upper Hudson River sediment and chironomids, as well as the histogram for unaltered Aroclor 1016. This is illustrated by comparing relative PCB homologue concentrations in tree swallows from SA 13 and the Remnant 4 site with relative PCB homologue concentrations in surficial sediment and chironomids collected within five miles of those sample sites (Figure 3.2.4 E). The PCB homologue patterns observed in tree swallows from the upper Hudson River were consistent with the PCB homologue patterns of Aroclors 1016 and 1242, the dominant recent PCB source in the Hudson River, with some apparent enrichment of the mid-range (mostly tetra-chlorinated) PCB congeners and dilution of the lower chlorinated PCB congeners.

The tree swallow homologue patterns are not inconsistent with the fact that Aroclor 1254 was also disposed in the Hudson River at Fort Edward and Hudson Falls. The presence of the more highly chlorinated PCB congeners (penta-, hexa-, and hepta-chlorinated) in Hudson River tree swallows may reflect both a source of these congeners in the upper Hudson River and the tree swallow's limited ability to metabolize the more highly chlorinated congeners. It is not possible to determine the level of significance of each of these contributing factors.

Planar PCBs We analyzed one nestling sample per site for planar (non-*ortho* and mono-*ortho)* PCB congeners. The most prominent of these congeners are presented in Table 3.2.4 B. Of these congeners, at all four of our sample sites, the mono-*ortho* PCB 118 was present at the highest concentrations, followed by mono-*ortho* PCB 105, and the non-*ortho* PCB 77.

At the Saginaw River watershed sites, Nichols et al. (1995) reported a planar PCB congener distribution in tree swallows similar to what we observed along the Hudson River. PCB congener 118 was the most abundant planar congener in all tree swallow samples, followed by PCBs 77, 81, and 167. PCBs 126, 169, and 189 were present in very small quantities or were not detected, and PCB 105 was not examined because it co-eluted with other congeners.

The PCB 77 concentrations detected in tree swallow nestlings from the Remnant site and SA 13 (370 and 530 ng/g, respectively) appear to be the highest ever documented in tree swallows. Green Bay and Saginaw Bay tree swallow nestlings contained up to 41.2 ng/g and 5.8 ng/g of PCB 77, respectively (Ankley et al. 1993, Nichols et al. 1995).

Since PCB 77 is often regarded as the second most toxic PCB congener to birds in terms of its dioxin-like potency, the extremely high concentrations of this PCB congener in Hudson River tree swallow nestlings warrant further discussion. Evidence from Green Bay indicated that tree swallows accumulated proportionally more PCB 77 than the common tern, Forster's tern, or red-winged blackbird, indicating that feeding strategies and/or metabolic processes of the tree swallow may lead to a high level of exposure to this congener (Jones et al. 1993).

An evaluation of the USEPA ecological sampling data (TAMs/Gradient 1996) showed that in 1992 surficial sediment samples from river miles 189.3, 194.1, and 194.2, between 0.22% and 0.89% of the total PCB concentration was PCB 77, with an average PCB 77 contribution of 0.64%. Among chironomids collected from river miles 189.5 and 191.5 in 1993, between 0.20% and 0.39% of the total PCB concentration was PCB 77, with an average of 0.33% PCB 77. The percentage of total PCB represented by PCB 77 in yellow perch and cyprinid species from river mile 194.1 was 0.11% and 0.51% PCB 77, with an average of 0.40% PCB 77. PCB 77 contributed 0.9% and 1.3% of the total PCB concentrations in tree swallow nestlings from the Remnant site and SA 13, respectively.

Based on these data, chironomids, yellow perch, and cyprinids contain proportionally less PCB 77 than the surficial sediments, probably reflecting many factors, including metabolic processes of the organisms, as well as a contribution of water-borne PCBs to body burdens in these species. If we make the assumption that chironomids are representative of insects consumed by Hudson River tree swallows, it appears that tree swallows enhanced dietary PCB 77 by about a factor of 3. A more rigorous evaluation in concurrently collected tree swallows and diet samples is needed to confirm this initial observation.

We conclude that there may be particular risk to bird species like the tree swallow that biomagnify PCB 77 to a significant extent. The risk may be especially great to birds feeding in ecosystems in which Aroclors 1242 or 1248 were the primary PCB disposal products, since PCB 77 is proportionally more abundant in Aroclors 1242 (0.5%) and 1248 (0.61%) than Aroclors 1016 (0%), 1254 (0.06%), or 1260 (0.03%) (Safe 1994, Kannan et al. 1987, as cited in Jones et al. 1993).

There is considerable variability in how species respond to congener 77, but chicken embryos are generally more sensitive than many other species (Safe 1994, Brunstrom 1988, as cited in Hoffman et al. 1996). An LD_{50} of 2.6 ng/g was derived from PCB 77 injections into chicken egg air cells at day 4 of development (Hoffman et al. 1995, as cited in Hoffman et al. 1996). 1,000 ng/g of PCB 77 injected into pheasant eggs caused complete mortality (Brunstrom and Reutergardh 1986, as cited in Hoffman et al. 1996), but 5,000 ng/g injected into mallard and goldeneye eggs had no effects (Brunstrom 1988, as cited in Hoffman et al. 1996). Further investigation into the concentrations of congener 77 in tree swallows and other birds along the Hudson River, in conjunction with additional dose-response studies, are needed to clarify the threats to birds from this potentially toxic PCB congener.

3.2.5 PCB Accumulation Rates

We calculated the daily PCB accumulation rates for tree swallow nestlings by subtracting the average mass of PCB in the eggs from the average mass of PCB in the nestlings and dividing by the nestling age (14 days) (Table 3.2.5, Figure 3.2.5). The mean accumulation rates were 0.05 *u*g/day (Lock 9), 46.8 *u*g/day (Remnant 4), 82.2 *u*g/day (SA 13), and 7.3 *u*g/day (Saratoga). Tree swallows nesting at Green Bay accumulated 2.3 *u*g/day PCB in 1988 (Ankley et al. 1993) and 6.3 *u*g/day in 1994 (C. Custer, UMSC, pers. comm.) By comparison, Ankley et al. (1993) determined that Forster's tern nestlings at Green Bay in 1988 accumulated 15 *u*g total PCBs/day.

All of the PCB mass in newly hatched tree swallow nestlings is derived directly from the parents, in that it is the PCB mass initially deposited in the egg. After hatching, the PCB concentration in any nestling is influenced by this parental "inherited" residue, the PCB mass in the nestling's diet, and the metabolic processes of the nestling which alter or eliminate PCBs. In other studies evaluating PCBs in tree swallows, the concentrations in the nestlings were typically less than PCB concentrations in the eggs (Ankley et al. 1993; Bishop et al. 1995; Nichols et al. 1995). This is attributed to a growth dilution effect, in which the body mass of the growing nestling increased more rapidly than the nestling's net dietary accumulation of PCBs. Nichols et al. (1995) noted a "general trend toward decreased growth dilution with increasing degree of site contamination."

Like Nichols et al. (1995), we also observed that the effect of growth dilution was inversely proportional to the presumed degree of site PCB contamination. At both the Remnant site and the SA 13 site, the sites with the greatest river sediment PCB concentrations, mean PCB concentrations in the nestlings exceeded mean PCB concentrations in the eggs, indicating PCB uptake significant enough to overwhelm the effect of growth dilution.

The daily PCB accumulation rates were highly consistent within the Remnant site (mean = 46.8 *u*g/day, standard deviation = 3.3) and SA 13 site (mean = 82.2 *u*g/day, standard deviation = 2.7). This suggests that different birds at these two sites were consuming consistently similar concentrations of total PCB. By contrast, daily PCB accumulation rates at the Saratoga site were more variable (mean = 7.3 ug/day, standard deviation = 11.5). We believe this can be explained by taking a close look at the feeding habitat available to adult tree swallows at these three sites.

The significance of aquatically reared insects to the tree swallow diet was described earlier in this report and verified as part of this study (Section 3.3). At both the Remnant site and SA 13 site, the Hudson River was the only source of aquatic insects within 500 meters or more or the nesting colony. At the Saratoga site, there were several wetlands within 100 meters of the Saratoga nesting colony, including a wet meadow in the center of the colony in which swallows were often seen feeding. These Saratoga site wetlands are not directly connected to the Hudson River (although some of them may occasionally receive floodwater from the Hudson River) and may have been a source of less contaminated insect prey. This possible variability in PCB contamination of prey may account for the variability in daily PCB accumulation rates among tree swallows at the Saratoga site.

We conclude that tree swallows at the Remnant site and SA 13 received extremely high levels of PCBs in their diet. This is consistent with our knowledge that sediments in this section of river are highly contaminated with PCBs and that these swallows were feeding their young a diet rich in insects which develop in association with riverine water and sediments (see Section 3.3). Tree swallows nesting at the Saratoga site accumulated PCBs at a similar rate to tree swallows at Green Bay and consistent with the moderate PCB concentrations in riverine sediments and floodplain soils in that stretch of river. Tree swallows nesting at Lock 9 accumulated (or lost) PCBs at a rate suggesting little PCB contamination of their local environment.

3.2.6 TCDD Equivalency

The toxicity of PCB congener mixtures can be evaluated by determining the TCDD equivalency of the mixture. TCDD-equivalency estimates how toxic the mixture is compared to 2,3,7,8-TCDD, generally considered the most toxic PCH. A number of methods have been developed to assess TCDD equivalency. Some methods are based on the derivation of "toxic equivalency factors" (TEFs) for individual planar chlorinated hydrocarbon congeners. These factors estimate the potency of a congener when compared with 2,3,7,8-TCDD. TEF values can be derived from experimental studies that measure acute, reproductive, or carcinogenic effects or biochemical responses, such as enzyme induction (Safe 1990). Other methods for determining TCDD equivalency expose a cell culture (like the H4IIE rat hepatoma culture) to a sample extract and measure the induction of enzymes known to respond to PHHs.

TEFs have been developed for those planar chlorinated hydrocarbons determined to be the strongest Ah receptor agonists. TEFs exist for many of the 2,3,7,8-PCDDs, 2,3,7,8-PCDFs, non-*ortho* and mono-*ortho* planar PCBs. We calculated the TCDD-equivalency (TEQ) of a tree swallow nestling composite from each site using three sets of TEFs. The first set of TEFs used in these calculations was based on chicken egg injection studies, and for the purposes of this discussion will be termed C-TEFs (Hoffman et al. 1996 and Bosveld et al. 1992). The C-TEFs for the planar PCB congeners that are presented in Hoffman et al. (1996) were based on LD_{50} values from chicken egg injection studies taken from the literature. The C-TEFs derived by Bosveld et al. (1992) for dioxin and furan congeners were based on enzyme induction potency in chicken eggs. The TCDD equivalencies determined using the C-TEFs are termed C-TEQs. Our calculated C-TEQs were 36 pg/g for the Lock 9 site, 7,770 pg/g for the Remnant site, 11,100 pg/g for the SA 13 site, and 1,260 pg/g for the Saratoga site (Table 3.2.6 A).

S-TEQs were developed using S-TEFs from Safe (1990) (Table 3.2.6 B). S-TEFs were based on a number of studies with mice, rats, and chickens evaluating toxic or biochemical responses. Our calculated S-TEQs were 48 pg/g for the Lock 9 site, 6,660 pg/g for the Remnant site, 9,060 pg/g for the SA 13 site, and 1,590 pg/g for the Saratoga site.

Finally, TEQs were calculated using a set of international TEFs (I-TEFs) that are commonly used for risk assessment (Ahlborg et al. 1992 and 1994). These TEQs are referred to as I-TEQs. Our calculated I-TEQs were 13 pg/g for the Lock 9 site, 981 pg/g for the Remnant site, 1,390 pg/g for the SA 13 site, and 289 pg/g for the Saratoga site (Table 3.2.6 C).

The TEQs we calculated from the various methods are presented in Table 3.2.6 D. For comparison purposes, we also present TEQs calculated from tree swallow data from Green Bay (Jones et al. 1993). Although our TEQs are variable depending on the TEFs used, the relative TEQ magnitude is consistent among Hudson River sites. That is, the SA 13 tree swallow sample elicits the highest TEQ of all Hudson River samples, regardless of which TEFs are used, followed by the Remnant site, Saratoga site, and Lock 9 site.

The TEQs calculated for Hudson River tree swallow nestlings are very high when compared with Green Bay tree swallow TEQs. S-TEQs for Hudson River tree swallow nestlings ranged from 48 pg/g at Lock 9 to 9,060 pg/g at SA 13. This compares with 430 to 552 pg/g for Green Bay tree swallow nestlings (Jones et al. 1993). We calculated C-TEQs for Green Bay CDF and Fox River tree swallow nestlings using PCB, PCDD, and PCDF congener concentrations presented in Ankley et al. (1993). The total C-TEQs for Green Bay tree swallow nestlings were calculated to be 525 pg/g and 878 pg/g, with 98% attributable to PCB congeners 77, 105, 126, and 169.

The concentrations of TEQ in tree swallows in the upper Hudson River generally exceed TEQs associated with adverse effects in other bird species from the Great Lakes, although comparisons are complicated by the use of various methods for estimating TEQ. (It is important to note that H4IIE derived TCDD-EQs are always lower than TEQs derived mathematically by multiplying the TEF by the PCB or PCDD/PCDF congener concentration and summing the resulting products). In a study of Great Lakes double-crested cormorants, H4IIE derived TCDD-EQs of 100 - 300 pg/g were associated with egg mortalities of 8 - 39% (Tillitt et al. 1992).

An H4IIE derived TCDD-EQ of 214.5 pg/g was associated with an 8% hatch rate of Green Bay Forster's tern eggs, compared with an 83% hatch rate at a reference colony where the TCDD-EQ was 23.4 pg/g (Tillitt et al. 1993). The average S-TEQ calculated for these Green Bay Forster's terns was 626 pg/g (Jones et al. 1993). Using the congener data presented in Ankley et al. (1993), we calculated a mean C-TEQ for these Forster's tern eggs of 270 pg/g.

Caspian terns at Saginaw Bay in 1988 had S-TEQs of 1,604 pg/g in unincubated first clutch eggs and 2,686 pg/g in unincubated second clutch eggs. Over 98% of the S-TEQ was attributed to PCB congeners. The hatch rates of the first and second clutch eggs were 52% and 40%, respectively. Fledging rates for first and second clutch eggs were 53% and 0%, respectively. In other words, an S-TEQ of 2,686 pg/g among Caspian terns was associated with total reproductive failure (Ludwig et al. 1993).

Giesy et al. (1994) summarized avian H4IIE derived TEQs from various embryotoxicity studies. LD_{50} values for chicken embryos, double-crested cormorant embryos, Caspian tern embryos, and pheasant embryos were associated with TEQs of of 115 - 147 pg/g, 460 pg/g, 750 pg/g, and 2,200 pg/g, respectively.

The TEQs found in upper Hudson River tree swallows indicate that Hudson River tree swallows are exposed to a PCB congener mixture of much greater toxic potential than has been reported in tree swallows, red-winged blackbirds, common terns, Forster's terns, Caspian terns, and double-crested cormorants from Green Bay, Wisconsin, and other Great Lakes sites (Jones et al. 1993, Ludwig et al. 1993, Tillitt et al. 1993). Tree swallow C-TEQs from all three Hudson River sites could be anticipated to exceed the LD_{50} values for laboratory reared chicken, double-crested cormorant, and Caspian terns embryos, and approach or exceed the LD_{50} for pheasant embryos (Giesy et al. 1994).

It is not possible to draw definitive conclusions about the actual toxicity of the PCB mixture to which Hudson River tree swallows are exposed due to the limitations of the TEQ approach for ecological risk assessment. Laboratory studies have shown that TEQs do not always accurately predict toxic responses across species and endpoints. A number of reasons have been suggested for this, including that PCB, PCDD, and PCDF congeners may act synergistically or antagonistically (Safe 1994). Also, the TEFs used in this report are not specific to the tree swallow, but were developed based on scientific evidence from domestic chickens or numerous other species. An ideal TEF would be based on scientific evidence from the target species.

The contribution of each congener to the overall TEQ for a sample varied depending on which set of TEFs were used (Tables 3.2.6 E - G). PCB 77 contributed the most to C-TEQ at all sites (70 - 95%). PCB 77 contributed the most to S-TEQ at the Remnant site (57%) and SA 13 site (60%) and equaled that of PCB 118 (37%) at the Saratoga site.

Congener 118 contributed the most to S-TEQ at the Lock 9 site (35%). Congener 126 was the most significant contributor to I-TEQ at all 4 sites (53 - 57%). This is because the I-TEF for congener 126 is much greater than the I-TEFs for PCBs 77 or 118.

The two most important congeners in this study in terms of their contribution to TEQ were PCB 77 and PCB 126. They accounted for 80 - 99% of total C-TEQ, 77 - 88% of S-TEQ, and 71 - 90% of I-TEQ. The significance of these two congeners was also noted among tree swallows at Green Bay. PCB congeners 77 and 126 accounted for 80% of the S-TEQs in Green Bay tree swallows (Jones et al. 1993). PCB congeners 77 and 126 accounted for 97% of the C-TEQs that we calculated for Green Bay tree swallows, based on congener concentrations presented in Ankley et al. (1993).

Congener 77 was apparently a significant congener in Hudson River tree swallows in terms of its total concentration in nestlings (Table 3.2.4 B) and its significant contribution to dioxin equivalency as determined by C-TEFs and S-TEFs (Tables 3.2.6 E - F). Jones et al. (1993) found congener 77 to be a more important contributor to S-TEQ in tree swallows than either Forster's terns, common terns, or red-winged blackbirds. In that study, approximately 50% of the S-TEQ in tree swallows was attributable to congener 77, versus approximately 15% in red-winged blackbirds, 35% in common terns, and 10% in Forster's terns.

Regardless of which TEFs were used, the 2,3,7,8-substituted dibenzo-p-dioxins and 2,3,7,8-substituted dibenzofurans were minor contributors to TEQ, except at the Lock 9 site (Tables 3.2.6 E - G). Dioxins and furans, while not more abundant in Lock 9 tree swallows, contributed more on a relative basis to TEQ there than they did in upper Hudson River tree swallows.

3.3 Diets

Insect boluses were collected from 22 nests (Table 3.3). Based on the number of insects observed in these samples, the majority of insects in the diet of nestling tree swallows were adults of species that spend most of their lives as larvae in the Hudson River. These groups included species in the orders Odonata (both Zygoptera and Anisoptera), Plecoptera, Trichoptera, Diptera (suborder Nematocera, especially Chironomidae and Tipulidae), and Ephemeroptera. Non-aquatic insects that contributed to tree swallow diets include species in the orders Homoptera, Hemiptera, Hymenoptera, Diptera (suborder Brachycera), and Coleoptera. The importance of aquatic species was even greater when based on mass of insects delivered to the nestlings (Table 3.3). This reliance on aquatic insects has been found in other studies of tree swallow diets (Blancher et al. 1987, Holroyd 1983, McCarty 1995, Quinney and Ankney 1985, St. Louis et al. 1990).

Aquatic insect larvae, in general, bioconcentrate PCBs to levels on the order of 10^3 to 10^5 times the concentration found in water (Bush et al. 1985, Mayer et al. 1977, Sanders and

Chandler 1972). Concentrations of PCBs found in caddisfly larvae (Insecta: Trichoptera: Hydropsychidae) from the Hudson River ranged from 6,000 to 66,000 ng/g wet weight throughout the area covered by this study (Bush et al. 1985, Novak et al. 1988). Given the evidence regarding the tree swallow's diet at our study areas and in other studies, we believe that the bulk of PCBs accumulated by tree swallow nestlings came from the Hudson River. In addition, the use of the Hudson River as a food source for large numbers of migrating swallows in the spring suggests that the PCBs may be affecting swallows breeding across a wider geographic range.

3.4 Nests

Tree swallow nests consist of a dry grass cup lined with feathers. The size of the grass cup and the number of feathers vary widely among nests, and the quality of the nest has been found to be positively correlated with nesting success (Sheppard 1977, Winkler 1993). The number of feathers in nests increased throughout the nesting cycle (Table 3.4). All measures of nest quality suggest that nests were of highest quality at Lock 9, followed by SA 13, Remnant 4, and the Saratoga site (Table 3.4). Of the measures of nest quality, only the differences in the numbers of feathers found during the nestling stage were statistically significant (Table 3.4).

Prior experience with tree swallows breeding in central New York, as well as preliminary results from our 1995 Hudson River nest evaluation, lead us to believe that Hudson River nests were of lower quality than at some other sites. This lower quality was assessed according to the quality of the grass cup and the number of feathers used in nest construction.

Winkler (1993) reported an average of five feathers in the nest at clutch initiation, and that only 3 of 56 nests (5%) had zero feathers at initiation. While SA 13 and the Saratoga site had an average of 6.5 and 5.7 feathers, respectively, during egg laying, nests at the Remnant site had fewer than five feathers, on average. For all the Hudson River sites combined, 8 out of 63 nests (13%) lacked feathers completely at the time of laying, and of those nests with feathers, 12 of 55 (21%) had only one feather. At the time of hatching, Winkler (1993) found only 5 of 39 nests (13%) had ten or fewer feathers, while along the Hudson River, 17 of 65 nests (26%) had ten or fewer feathers during the nestling period.

Sheppard (1977) reported that tree swallow nests from Shackleton Point, New York, usually contained 25 - 50 feathers (range 0 - 150). Sheppard also categorized nests into four qualitative categories. Of 84 nests, Sheppard found seven corresponding to our ranking of #1 (low quality), ten corresponding to our ranking of #2 (moderate quality), and 67 corresponding to our ranking of #3 (high quality).

Although these results suggest that nest construction at the Hudson River sites was deficient, further quantitative data on nest construction will be needed to draw stronger conclusions about any relationship between PCB concentrations and nest building behavior.

3.5 Egg Shell Thickness

There was not a clear relationship between egg shell thickness and PCB contamination of the Hudson River (Table 3.5.1). All measures of thickness, including shell mass, shell thickness, and the shell index were similar for the Hudson River sites, the Lock 9 site, and the Ithaca site. There was a highly significant correlation between the shell index and shell thickness ($R^2 = 0.56$, $p < 0.001$). DeWeese et al. (1985) found similar results with a population of tree swallows in Colorado. The mean mass of egg shells from New York was greater than those collected in Colorado, as was the shell index (Table 3.5.2). DeWeese et al. (1985) also present data for tree swallow eggs collected prior to the widespread use of DDT (Table 3.5.2). New York eggs were again heavier and had a larger shell index than pre-DDT eggs, indicating that no significant shell thinning has occurred. The results from this study are consistent with a recent report which concluded that PCBs do not appear to cause eggshell thinning at environmentally realistic doses (Peakall and Lincer 1996).

3.6 Egg Size and Mass

The volumes of tree swallow eggs from the Hudson River sites were slightly higher than the volume of eggs from Ithaca, New York (Table 3.6). However, eggs obtained from the reference site at Lock 9 had higher volume and mass than the Hudson River sites. Masses of eggs from several other studies (Table 3.6) also suggest that egg mass at the Hudson River sites may have been low. Egg volume and mass were highly correlated ($R^2 = 0.87$, $p < 0.001$).

3.7 Nestling Growth and Development and Reproductive Success

Reproductive success, nestling growth, and nestling development data from Hudson River tree swallows were compared with similarly collected data from a presumably uncontaminated tree swallow colony near Ithaca (McCarty 1995 and unpub.). Ithaca site growth and development data from 1990 - 1993 were used. Reproductive success data from Ithaca breeding seasons 1990 and 1991 were used. These years were chosen because they were the first two years that the Ithaca site was occupied and there were high proportions of sub-adult females breeding at the site (Ithaca 1990 = 67% sub-adult females, Hudson River = 65% sub-adult females). Disturbance due to adverse weather and experimental procedures were also low in these years. Nests at this Ithaca site were not equipped with predator guards in 1990 and 1991, and some losses due to pole-climbing predators did occur. Predation losses were easily identifiable and were not included in the calculation of reproductive success. Predation (by the house wren) was only a factor at two nests along the Hudson River.

3.7.1 Growth of Nestlings

Nestling tree swallow mass at hatching (day 1) was lower for the Hudson River sites than for nestlings from Ithaca (Table 3.7.1; $p < 0.01$). We note that PCBs and other PCHs have been associated with reduced mass of newly hatched birds in other studies (Kubiak et al. 1989; Flick et al. 1965, 1973). Differences in nestling mass at hatching among Hudson River sites were not significantly different (ANOVA $p = 0.31$). By nestling day 8, average nestling size was smaller at the Ithaca site than at any of the Hudson River sites (Table 3.7.2). Mass and size on nestling day 8 were highest at SA 13, while the Remnant site and Saratoga site nestlings were slightly smaller (Table 3.7.2). Nestling mass and size followed the same pattern on nestling day 10 (Table 3.7.3), day 12 (Table 3.7.4), and day 14 (Table 3.7.5). The fact that nestling growth was faster on the Hudson River in 1994 than the average of the 1990 - 1993 seasons at Ithaca suggests that Hudson River environmental conditions such as temperature and food supply were adequate in 1994.

When growth of Hudson River swallows is compared to other published studies of tree swallow growth, it is clear that Hudson River swallows were well within the range of variation observed at other sites (Figure 3.7). This leads us to hypothesize that PCB contamination may not have a negative impact on the rate of nestling growth and development of tree swallows, at least not during seasons with favorable environmental conditions.

3.7.2 Possible Abnormalities

No gross morphological defects were observed at the Hudson River sites, however, nestlings at four nests were noted as having unusually large abdomens. It is unclear at this time whether this represented a case of chick edema disease (Gilbertson et al. 1991). In one case, unusual spots were observed under the skin of a nestling, which appeared to be the result of internal swelling. At four additional nests, nestlings younger than eight days were observed to have an unusual orange to orange-yellow color instead of the normal pink color of young nestlings. It is possible that these represented cases of jaundice due to impairment of liver function, as described by Gilbertson et al. (1991).

3.7.3 Clutch Size

Clutch size at the three Hudson River sites was within the range expected for tree swallows (Table 3.7.6). Individual clutches were within the normal range, except for one nest at the Saratoga site where a clutch consisted of ten eggs. This supernormal clutch is thought to be the product of a single female. Predation was extremely low at all the sites; eggs were lost from two nests and no nestlings were lost to predation.

3.7.4 Reproductive Success

Abandonment of nests during the incubation stage was common at both the Remnant site (23%) and the Saratoga site (26%) (Table 3.7.7). This abandonment was not likely to be the result of investigator disturbance since using the same methods at the Ithaca, New York site in 1990 and 1991 resulted in no abandonments (Table 3.7.7). Little published data on egg abandonment in tree swallows exists, however, the two studies that provided information on abandonment reported 0% (Burtt and Tuttle 1983) and 6% (Blancher and McNicol 1988). Reduced parental attentiveness and abandonment of eggs have been linked to PCB contamination in the herring gull (Fox et al. 1978) and Forster's tern (Kubiak et al. 1989).

Between 64% and 79% of eggs laid at the three Hudson River sites hatched, compared with a 93% hatch rate (hatchability) at Ithaca. Hatchability at other North American sites ranged from 77% to 95%. The lowest hatch rate reported (77%) was at Green Bay, Wisconsin, a site that is also contaminated with PCBs (Table 3.7.7). PCBs have been associated with reduced hatchability in chickens (Sotherland and Rahn 1987, as cited in Hoffman 1996), common terns (Hoffman et al 1993), Caspian terns (Ludwig et al. 1993), and double-crested cormorants (Tillitt et al. 1992).

The combination of abandonment and poor hatchability resulted in reproductive success rates (defined as the percent of eggs laid that resulted in fledged individuals) that ranged from 51% to 74% at the three Hudson River sites. This compares with a reproductive success rate of 88% at Ithaca. Reproductive success among tree swallows nesting at Sudbury, Ontario was only 60%, but the authors noted that reproductive difficulties may have been associated with rainy weather and the location of some nests in low pH wetlands (Blancher and McNicol 1988).

There are many factors that may influence reproductive success in tree swallows. Two of the most significant factors are weather and food supply. At all of the Hudson River sites in 1994, we observed that weather was mild, with no temperature or rainfall extremes, throughout the egg laying and nestling rearing period. We also believe that food supply was adequate, as evidenced by the normal growth rates of Hudson River tree swallow nestlings. Given that PCBs have been associated with reduced hatchability and nest abandonment in other bird species, we conclude that PCB exposure may have contributed to the observed poor reproductive success among Hudson River tree swallows.

3.7.5 Incubation Period

The length of the incubation period averaged 14.1 days (s.d. = 1.1, range = 12 to 18 days) for the Hudson River sites. There were no significant differences in incubation period among the sites (ANOVA $p = 0.31$), and the 14.1 days was well within the normal range for incubation in tree swallows (Robertson et al. 1992). Similarly, the length of the nestling period was normal, mean day of fledging = 21.2 (s.d. = 1.2, range = 18 - 24), and there were no significant differences among sites (ANOVA $p = 0.35$).

3.7.6 Unhatched Eggs

We were able to classify 49 unhatched eggs from 21 nests along the Hudson River as being either infertile (no observable embryonic development) or as having some embryonic development and having died before hatching. Sixteen eggs (33%) had some embryonic development when they died, and the remaining 33 eggs (67%) had no embryonic development, and were presumed to be infertile. We know of no published records of the cause of hatching failure in tree swallows, so it is unclear if these levels of apparent infertility and embryo mortality are unusual.

3.8 Adult Tree Swallows

Seventy-seven adult tree swallows were captured during 1994. Of these, 22 were males and 55 were females. These results do not reflect the actual sex ratio of the population, which is estimated to be near 1:1, but reflect the difficulty of capturing males and the increased effort devoted to capturing females. Female tree swallows have a distinct, brownish, sub-adult plumage during their first breeding season, before obtaining a male-like blue-green plumage during their second pre-basic molt (Hussell 1983, Robertson et al. 1992). Of the females captured, 19 had full adult plumage, and 36 were females with sub-adult plumage.

The plumage of sub-adult female tree swallows often includes a highly variable amount of green or blue feathers (Hussell 1983). Based on prior experience with tree swallows, the plumage of sub-adult females on the Hudson River included unusually high proportions of blue and green feathers. Hussell (1983) classified 9 of 73 (12%) known sub-adult females from southern Ontario as having more than 50% blue or blue-green plumage. We used Hussell's method to classify 31 sub-adult females from the Hudson River sites. We classified 19 sub-adult females (61%) as having less than 50% blue or blue-green feathers on their backs and 8 sub-adult females (25%) as having more than 50% blue or blue-green feathers on their back. An additional 4 sub-adult females (13%) were intermediate or had extensive green color that prevented us from confidently placing them in either category.

These results suggest that sub-adult female plumage may be unusual in the Hudson River population. Since plumage dimorphisms such as found in tree swallows are under the control of estrogen (Sturkie 1976, Owens and Short 1995), it is plausible that the estrogenic effects of PCBs may be causing the shift toward advanced plumage maturation in young females. Several females were salvaged or collected from this population and are preserved as voucher specimens in the Cornell University vertebrate collections.

Male tree swallows on the Hudson River tended to be heavier and larger than females (Table 3.8). In addition, females with sub-adult plumage were slightly smaller and lighter than females with full adult plumage. Both the size and mass of adults and the pattern of variation with sex and age were similar to those found in other populations of tree swallows (Table 3.8).

4.0 ESTIMATED RISK TO OTHER BIRD SPECIES

Numerous bird species for which laboratory and field PCB investigations have been conducted would be adversely affected by the PCB concentrations we found in tree swallows along the Hudson River. The average PCB concentrations detected in tree swallow eggs from all three Hudson River sites (12,000 - 42,000 ng/g) would cause total embryo mortality in the domestic chicken (Barron et al. 1995, Hoffman et al. 1996). Ringed turtle dove eggs containing 16,000 ng/g PCB were less likely to hatch (largely due to poor parental attentiveness), and the embryos had an increased level of chromosomal aberrations (Peakall and Peakall 1973, as cited in Hoffman et al. 1996).

Caspian tern chicks in Saginaw Bay exhibited a 20% frequency of deformities, corresponding to 8,000 ng/g total PCB in first clutch eggs and 18,000 ng/g in second clutch eggs. An S-TEQ of 1,604 pg/g was associated with a 52% hatch rate among first clutch Caspian terns in 1988. The hatch rate in 1986 (prior to the flood which re-distributed PCB laden sediment) at this same colony was 82%. An S-TEQ of 2,686 pg/g among Caspian terns in 1988 was associated with total reproductive failure (Ludwig et al. 1993). S-TEQS among Hudson River tree swallows were 6,660 at the Remnant site, 9,060 pg/g at the SA 13 site, and 1,590 pg/g at the Saratoga site. If we conservatively assume that Caspian terns would experience at least the same PCB exposure as tree swallows, Caspian terns nesting at the SA 13 and Remnant sites would be expected to suffer complete reproductive failure.

The concentrations of PCB congener 77 detected at the Remnant and SA 13 sites (370 - 530 ng/g nestling) were similar to the concentrations (200-1000 ng/g egg) causing 17 - 60 % mortality in domestic turkeys (Brunstrom and Lund 1988, as cited in Hoffman et al. 1996). Species such as the mallard, Atlantic puffin, and screech owl do not appear to be as sensitive to the effects of PCBs as the above species.

We have conducted a more detailed risk assessment for four additional bird species which are known to be sensitive to the effects of PCBs. These species are the bald eagle, Forster's tern, common tern, and double-crested cormorant.

4.1 Bald Eagle The bald eagle is a Federally listed threatened species and New York State listed endangered species that has been increasing in numbers along the Hudson River over the last decade. A well known wintering ground exists in the lower Hudson River at Iona Island, but there has been no successful Hudson River breeding in approximately one hundred years. A pair of bald eagles has been attempting to nest at a location south of Albany since 1992, but has never successfully fledged young. A second pair established a territory near the first pair in 1995, but has also been unsuccessful at producing young (Peter Nye, NYSDEC, pers. comm).

Studies conducted on bald eagles from the Great Lakes have concluded that PCBs are one of the primary factors impairing reproduction. They are probably the single most important environmental toxicant contributing to reduced productivity in the bald eagle (Kubiak and Best 1991, Bowerman et al. 1995). It has been estimated that bald eagle eggs should contain less than 4 - 6 ug/g total PCB if healthy rates of productivity (> 1.0 eaglets fledged per occupied breeding area) are to be maintained (Weimeyer et al. 1984, Kubiak and Best 1991, Bowerman et al. 1995). Total concentrations of PCBs in bald eagle eggs have been inversely correlated with productivity, and the following equation has been developed from that data (Kubiak and Best 1991):

$$y = -0.177 \ln x + 1.317$$

where,
y = number of eaglets fledged per occupied breeding area
x = total PCB residue in addled eggs

There has not been an investigation into PCB concentrations in bald eagles along the Hudson River and no eggs have been available to sample. However, we can estimate bald eagle productivity by calculating the PCB concentration likely to accumulate in the eggs of eagles that consume forage of known PCB concentration. A biomagnification factor (BMF) of 28 has been recommended to predict bald eagle egg PCB concentrations based on the PCB concentration in the forage (Giesy et al. 1995).

Using the above equation and a BMF of 28 yields the following eagle productivities (# eaglets per occupied breeding area) for eagles consuming forage with the specified average PCB concentration:

PCB Concentration in Forage (ng/g)	Predicted Productivity (# eaglets/occupied breeding area)
1,000	0.70
2,000	0.58
5,000	0.42
10,000	0.30
20,000	0.17
30,000	0.10
40,000	0.05
50,000	0.01
60,000	0

We have not studied the dietary habits of nesting bald eagles on the Hudson River, but information is available which allows us to estimate PCB concentrations in their prey. Bald eagles overwintering at Iona Island were determined to be feeding on prey that was presumed to be bullhead (*Ameiurus sp.*), white catfish (*Ictalurus eatus*), striped bass (*Morone saxatilis*), white perch (*Morone americana*), goldfish (*Carassius aurutus*), common carp (*Cyprinus carpio*), common merganser (*Mergus merganser*), mallard, ring-billed gull, white-tailed deer (*Odocoileus virginianus*), and cottontail rabbit (*Sylvilagus floridanus*) (Nye et al. 1993). A study conducted on an inland river in Maine found that 65% of the bald eagles' summer diet consisted of brown bullhead (*Ameiurus nebulosus*), white sucker (*Catostomus commersoni*), and chain pickerel (*Esox niger*) (Todd et al. 1982).

We calculated Hudson River bald eagle productivity based on the average fish concentrations (across all species at each station) of total PCB from the USEPA Phase 2 Ecological sampling data (Table 1.1). Although we know that these fish species are not representative of a typical bald eagle diet, we believe these average PCB concentrations approximate what Hudson River bald eagles may receive in their diet.

River Mile	Average Fish Concentration (*ug*/g)	Predicted Productivity (# eaglets/occupied breeding area)
203.3-204.7	0.23	0.99
196.9	7.25	0.38
194.1	28.28	0.14
191.5	3.64	0.50
190.3-189.6	19.34	0.20
169.5-169.2	10.46	0.31
159	1.67	0.64
143.5	4.54	0.46
137.2-136.7	3.90	0.49
122.7-122.4	2.91	0.54
113.8	3.66	0.50
100	0.68	0.80
89.4-88.7	3.88	0.49
58.7	2.68	0.55
47.3	1.30	0.68
25.8	2.46	0.57

It is apparent from this data, as well as Figure 4.1, that bald eagles that attempt to nest between river mile 197 (Hudson Falls) and at least river mile 26 (Nyack) may be exposed to concentrations of total PCB in their forage that are associated with reduced productivity in Great Lakes breeding eagles. We estimate that productivity, as measured by the number of eaglets per occupied breeding area, would range from 0.14 to 0.80 among eagles nesting along this Hudson River reach and feeding on predominantly Hudson River fish. An average of at least one eaglet per occupied breeding area is indicative of a healthy subpopulation. We also hypothesize that eagles overwintering along the Hudson River and feeding on Hudson River fish may accumulate concentrations of PCBs that may reduce their subsequent productivity.

4.2 Forster's Tern The Forster's tern has never been known to nest along the Hudson River, but it has recently been expanding its range along the east coast, spreading north from the mid-Atlantic states. It prefers to nest in saltmarsh islands, extensive freshwater marshes, or along marshy lake shores (Andrle and Carroll 1988).

A 1983 Study of Forster's terns from Green Bay, Wisconsin, associated 23,000 ng/g total PCBs in eggs with numerous reproductive difficulties (Kubiak et al. 1989). Green Bay hatching success was 52% of the Lake Poygan reference colony hatching success, where the average PCB concentration was 3,200 ng/g. Green Bay hatchlings weighed less, and had an increased ratio of liver weight to body weight, shorter femur length, edema, and malformations. Nest abandonment and egg disappearance among Green Bay Forster's terns were 30% and 12%, respectively. No abandonment or egg disappearance was documented at the Lake Poygan colony.

A 1988 follow-up study found a median PCB residue of 7,300 ng/g in eggs and improved hatching success; however 42% of chicks monitored died before fledging following a wasting syndrome (Harris et al. 1993).

We can estimate the risk to Forster's terns nesting along the Hudson River by using data from a 1988 study in which Forster's terns were collected concurrently with tree swallows at a CDF called Renard Island (Ankley et al. 1993). A composite of tree swallow nestlings, aged 9, 13, and 17 days contained 2,970 ng/g PCB; the average PCB concentration of Forster's tern nestlings aged 3, 13, 15, and 17 days was 3,975 ng/g. The Forster's tern nestlings were approximately 1.34 times as contaminated as the tree swallow nestlings. Forster's tern egg PCB concentrations corresponding to the above nestling PCB concentrations averaged 7,766 ng/g. Consequently, Forster's tern eggs were about 1.95 times as contaminated as the nestlings.

Our Hudson River 14-day old nestlings contained the following concentrations of PCBs, which would correspond with the estimated concentration in co-located Forster's terns.

Site	Tree Swallow Nestling PCB (ng/g)	Predicted Forster's Tern Nestling PCB (ng/g)	Predicted Forster's Tern Egg PCB (ng/g)
Lock 9	377	504	983
Remnant	29,100	38,900	75,900
SA 13	56,800	76,000	148,000
Saratoga	5,250	7,030	13,700

We conclude from this analysis that Forster's terns nesting at all of our study sites, except the reference site, would be likely to accumulate concentrations of total PCBs that exceed by 2 - 21 times the concentration (7,300 ng/g) that was associated with 42% nestling mortality at Green Bay, Wisconsin, in 1988. Forster's terns nesting at the Remnant site and SA 13 site would be likely to accumulate concentrations of total PCBs that exceed by 3 - 6 times the concentration (23,000 ng/g) associated with 48% reduced hatching, 30% abandonment, and 12% egg disappearance at Green Bay, Wisconsin, in 1983. We hypothesize that if Forster's terns were to nest at any of these three Hudson River sites or similarly contaminated sites along the river between these sites, reproductive success would be significantly lower than expected from a healthy, uncontaminated subpopulation.

4.3 Common Tern The common tern is a New York State listed threatened species. There is no known breeding along the Hudson River, but this species does breed on Long Island, Lake Ontario, Lake Champlain, Lake Erie, the St. Lawrence River, and the Finger Lakes. The common tern prefers to nest on small islands or structures, habitat that is available along the Hudson River (Andrle and Carroll 1988). In a study conducted in 1984 and 1985 at Green Bay, a hatching success of 71% corresponded to an average PCB egg concentration of 10,000 ng/g. The reference terns contained 4,700 ng/g PCB, corresponding with 85% hatching success (Hoffman et al. 1993).

Common tern nestlings (aged 5 and 16 days) collected at the Green Bay CDF in 1988 contained an average of 5,960 ng/g total PCB (Ankley et al. 1993). The eggs from the same nests contained an average of 11,200 ng/g total PCB, or 1.88 times as much as the nestlings. These common tern nestlings contained two times as much total PCB as concurrently collected tree swallows. Consequently, we would estimate that common terns nesting at our Hudson River sample sites would accumulate the following total PCB concentrations (on average) by a nestling age of 5 - 16 days.

Site	Tree Swallow Nestling PCB (ng/g)	Predicted Common Tern Nestling PCB (ng/g)	Predicted Common Tern Egg PCB (ng/g)
Lock 9	377	754	1,420
Remnant	29,100	58,200	109,000
SA 13	56,800	114,000	214,000
Saratoga	5,250	10,500	19,700

Common terns nesting at all of our Hudson River sites would be predicted to accumulate greater than 10,000 ng/g total PCB in eggs, which corresponds to levels of PCBs which were associated with a 16% reduction in hatching success among common terns nesting at Green Bay, Wisconsin, vs. reference colonies.

4.4 Double-Crested Cormorant The double-crested cormorant is a colonial nester that may breed at a few locations along the Hudson River (Andrle and Carroll 1988). This bird subsists on a diet almost exclusively consisting of fish. PCB concentrations of 7,300 ng/g in eggs from Green Bay and Beaver Islands on Lake Michigan in 1988 were associated with a frequency of deformed, live embryos of 6 - 7%. On Tahquamenon Island on Lake Superior, the deformity frequency was 2% and the corresponding PCB concentration was 3,600 ng/g (Yamashita et al. 1993). An analysis of Green Bay cormorants showed that total PCB concentrations in eggs of 7,000 to 9,000 ng/g were associated with 25% embryo mortality (Tillitt et al. 1992).

We conservatively estimate that double-crested cormorants nesting along the Hudson River would accumulate approximately the same concentrations of PCB as Forster's terns (a species which may consume large quantities of insects and other prey less contaminated than fish). Based on this assumption, double-crested cormorant eggs at Lock 9 would contain an average of 980 ng/g of total PCB, those at the Remnant site 76,000 ng/g, those at the SA 13 site 148,000 ng/g, and those at Saratoga 14,000 ng/g. Concentrations predicted in double-crested cormorants nesting at all but the Lock 9 site would exceed by 2 - 16 times the concentrations associated with 25% embryo mortality and a 6 - 7% frequency of deformed, live embryos in Green Bay.

6.0 CONCLUSIONS AND RECOMMENDATIONS

The following major conclusions can be made based on the results of this study:

1. Tree swallows are good indicators of exposure to aquatically distributed PCBs, particularly when the PCB source of interest is the primary aquatic habitat within a reasonable feeding radius. While the tree swallow is a good indicator of PCB exposure, it appears to be much more resistant to the effects of PCBs than many other birds for which studies on the effects of PCBs have been conducted.

2. Hudson River tree swallows were up to ten times more contaminated with PCBs than tree swallows from the Great Lakes. Accumulation rates of PCBs were extremely high in tree swallow nestlings at the two most contaminated sites on the Hudson River. The rates were 20-30 times greater than those found in tree swallows at two of the most PCB contaminated locations in the upper Great Lakes.

3. Tree swallows at the three Hudson River sites were exposed to a PCB congener mixture of much greater toxic potential (as expressed by dioxin equivalency) than has been reported in tree swallows from the Green Bay area.

4. PCB congener 77 was highly significant in Hudson River tree swallows, both in terms of its absolute concentrations, which may be the highest ever reported for any bird species, and its contribution to dioxin equivalency. This PCB congener is, by most accounts, the second most toxic congener in terms of its dioxin-like potency.

5. A high degree of nest abandonment, reduced hatchability, low quality nest construction, and possible plumage abnormalities are not fully explained, but may be a

result of PCB exposure. PCBs have been shown to cause similar effects in other bird species.

6. Based on the PCB concentrations we found in tree swallows, we predict that if birds such as the bald eagle, Forster's tern, common tern, Caspian tern, and double-crested cormorant were to nest along sections of the Hudson River, they would be exposed to PCB concentrations that would cause significant reductions in reproductive success and increased levels of nestling deformities. Of these species, only the bald eagle, and possibly the double-crested cormorant, currently nest along the Hudson River. The implications are unknown for other similarly sensitive species for which data currently do not exist.

We recommend that at least one additional year of investigation into PCBs and tree swallows be completed to address uncertainties from this study. The focus should remain on measures of reproductive vigor, including hatching success, fledging success, and parental behavior. Nest-box liners should be inserted into nest boxes so that nest mass can be used as a measure of nest quality, and feathers lining the nest should be counted at pre-established times during incubation and brood-rearing.

Plumage coloration should be evaluated, with a focus on quantifying the percent blue-green feathers on females of known age. Return rates of previously banded birds should be determined to preliminarily assess whether PCBs might affect normal winter survival or migratory patterns.

Chemical analysis of concurrently collected tree swallows and their prey should be performed to clarify pathways of PCB uptake. This chemical analysis should include non-*ortho*-chloro substituted and mono-*ortho*-chloro substituted PCB congeners to develop our understanding of the potential toxicity of Hudson River PCBs to tree swallows and other bird species.

Finally, work should continue to assess the risks posed to other birds from Hudson River PCBs, particularly birds that frequent the Hudson River and are known to be sensitive to the effects of planar PCBs and other Ah-active PCHs. These birds include the bald eagle, double-crested cormorant, wood duck (*Aix sponsa*), and great blue heron. Dozens of other piscivorous and insectivorous birds are exposed to high concentrations of PCBs if they feed along the upper Hudson River. There currently is no information on the effects of PCBs on most of these highly exposed bird species.

7.0 ACKNOWLEDGEMENTS

We are very indebted to Don Tillitt of the Midwest Science Center for his extensive contributions to the study design, chemical analyses of samples, interpretation of data, and review of this report. Thanks also go to other Midwest Science Center collaborators, including Kathy Echols, Robert Gale, John Meadows, Paul Peterman, and Ted Schwartz. Gratitude is extended to Mark Barash (USDOI), Jay Field (NOAA), John Hickey (USFWS), Tim Kubiak (USFWS), Bill Ports (NYSDEC), and Ron Sloan (NYSDEC), who provided very insightful comments on this report. MaryEllen VanDonsel is credited for her thorough editorial review.

This project would not have been possible without the cooperation of several organizations that allowed us to establish tree swallow colonies on their land. We extend our thanks to John Haggard and General Electric for providing access to Remnant Site 4 and David Hayes, Chris Martin, and Jim Schaberl of the National Park Service for allowing us to establish a colony at Saratoga National Historical Park and assisting in data collection. We also thank Dan Culligan, John Dergosits, and John King of the Thruway Authority for allowing access to and assisting at the Lock 9 and SA 13 sites. Finally, we wish to extend appreciation to David Winkler for allowing us to collect eggs and nestlings from his swallow colony and L. LaReesa Wolfenbarger for providing assistance in the field.

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Tables

Table 1.1 PCB Concentrations in Hudson River Matrices Derived from USEPA Ecological Sampling Data

Ecological Sampling Station	Location[1]	Sediment[2] (ug/g)	Benthic Invertebrates[3] (ug/g)	Fish[4] (ug/g)
Station 1	RM 203.3 - 204.7 (above Glens Falls)	0.07	NA	0.23
Station 20	RM 196.9 (Bakers Falls)	0.92	NA	7.25
Station 2	RM 194.1 (Ft. Edward)	20.19	NA	28.28
Station 3	RM 191.5 (Thompson Island Pool)	9.29	10.32	3.64
Station 4	RM 190.3 - 189.6 (Thompson Island Pool	10.49	23.85	19.34
Station 5	RM 189 (Thompson Island Pool)	29.35	42.37	NA
Station 6	RM 188.7 (Thompson Island Pool)	14.33	15.75	NA
Station 7	RM 188.5 (Thompson Island Pool)	18.51	16.20	NA
Station 8	RM 169.5 - 169.2 (Stillwater)	41.59	NA	10.46
Station 9	RM 159 (Waterford)	4.80	NA	1.67
Station 10	RM 143.5 (Albany/Norman Kill)	1.03	NA	4.54
Station 11	RM 137.2 - 136.7 (Castleton-on-Hudson, Shad & Schermerhorn Islands)	1.38	NA	3.90
Station 12	RM 122.7 - 122.4 (Coxsackie & Kinderhook Creek)	1.19	0.81	2.91
Station 13	RM 113.8 (Catskill & Rogers Island)	0.88	NA	3.66
Station 14	RM 100 (Kingston & Tivoli)	0.37	0.47	0.68
Station 15	RM 89.4 88-7 (Kingston & Esopus Meadows)	0.87	0.21	3.88
Station 16	RM 58.7 (Newburgh & Moodna Creek)	0.30	NA	2.68
Station 17	RM 47.3 (Peekskill & Iona Marsh)	1.31	0.83	1.30
Station 18	RM 25.8 (Nyack & Piermont Marsh)	0.48	0.22	2.46

Notes:

1 In order of increasing downstream distance from Ft. Edward. River Mile (RM) locations are approximate.

2 Concentrations represent averages from five samples.

3 Concentrations represent averages across all species at each station. Invertebrates sampled include amphipods, bivalves, chironomids, gastropods, isopods, odonata, and oligochaetes.

4 Concentrations represent averages across all species at each station. Fish sampled include Atlantic silverside, brown bullhead, brook silverside, cyprinid species (carp and minnow), longnose dace, rock bass, sucker species, smallmouth bass, spottail shiner, tesselated darter, white perch, and yellow perch.

Source: USFWS analysis of data from TAMs/Gradient 1996:Phase 2/ECO

Table 3.1. Nest box occupancy, egg dates, and female age in 1994.

Site	# Boxes	Percent Occupied	First Egg Date	Adult Females	Sub-Adult Females	Fem: Age Unknown
Lock 9	27	18.5	21.2 +/- 7.1	2	3	0
Remnant	30	70.0	19.6 +/- 9.6	5	16	0
SA13	36	94.4	15.3 +/- 10.1	12	18	4
Saratoga	35	74.3	18.0 +/- 11.9	8	14	4

Number of boxes is the number of nest boxes available at each site; percent occupied is the percent of those boxes that reached the egg stage. First egg date gives the mean date (+/- standard deviation) that the first egg was laid for first nests only. Mean dates were all in May 1994. Female age was based on both observations and capture data. Multiple clutches of eggs in the same nest box were assumed to be the product of a single female. Differences among sites in mean first egg date were significant (Kruskal-Wallis, H=10.9, p=0.013).

Table 3.2.1. Inorganic and organochlorine constituents detected in tree swallow eggs from the upper Hudson River - 1994. Each value represents one freshly laid three egg composite from a single nest.

Analyte	Concentration (ug/g wet weight)			
	Lock 9	Remnant	SA13	Saratoga
Al	<2.3	<2.46	<2.37	<2.44
As	0.55	0.82	0.75	0.66
B	2.04	<.98	2.55	1.52
Ba	0.5	<.49	<.47	0.87
Be	<.05	<.05	<.05	<.05
Cd	<.14	<.15	<.14	<.15
Cr	<.23	<.25	<.24	<.24
Cu	0.48	0.47	0.44	0.45
Fe	24.1	25.9	23.6	16.9
Hg	0.095	0.051	<.05	0.066
Mg	72.3	72.6	71.7	71.6
Mn	0.89	0.7	1.35	0.63
Mo	<.92	<.98	<.95	<.98
Ni	<.28	<.3	<.29	<.29
Pb	<1.15	<1.23	<1.19	<1.22
Se	NA	NA	NA	NA
Sr	1.83	1.1	1.08	1.48
V	<.11	<.12	<.12	<.12
Zn	14.6	15.3	15.6	15.3
HCB	<.043	<.052	<.057	<.052
PCB-Total	16	4.6	44	13
alpha BHC	<.043	<.052	<.057	<.052
alpha chlordane	<.27	<.077	<.58	<.24
beta BHC	<.043	<.052	<.057	<.052
dieldrin	<.043	<.052	<.057	<.052
endrin	<.043	<.052	<.057	<.052
gamma BHC	<.043	<.052	<.057	<.052
gamma chlordane	<.043	<.052	<.057	<.052
heptachlor epoxide	<.043	<.052	<.057	<.052
mirex	<.043	<.08	<.057	<.052
o,p'-DDD	<.043	<.052	<.057	<.052
o,p'-DDE	<.043	<.052	<.057	<.052
o,p'-DDT	<.11	<.052	<.057	<.052
oxychlordane	<.33	<.052	<.057	<.052
p,p'-DDD	<.043	<.052	<.057	<.052
p,p'-DDE	<.54	<.052	<.86	<.052
p,p'-DDT	<.05	<.052	<.057	<.052
toxaphene	<.22	<.26	<.29	<.26
trans-nonachlor	<.067	<.052	<.057	<.052

NA Not available;data rejected

Table 3.2.2. 2,3,7,8-substituted polychlorinated dibenzo-p-dioxins (PCDDs) and dibenzofurans (PCDFs) in tree swallows from the upper Hudson River - 1994. Each value from two, 14-day old nestlings from a single nest.

	Concentration (pg/g wet weight)			
	Lock 9	Remn	SA13	Sara
DIOXINS				
2,3,7,8-Tetra	0.2	0.3	0.4	0.4
1,2,3,7,8-Penta	0.9	0.7	1.0	0.8
1,2,4,7,8-Penta	0.4	0.2	0.3	0.3
1,2,3,4,7,8-Hexa	1.0	1.0	1.5	0.8
1,2,3,6,7,8-Hexa	1.8	2.0	3.5	2.7
1,2,3,7,8,9-Hexa	0.8	0.6NQ	0.6	0.4
1,2,3,4,6,7,8-Hepta	5.7	7.0	9.0	4.6
Octachloro	15.0	13.0	38.0	12.0
FURANS				
2,3,7,8-Tetra	4.6	9.1	16.0	29.0
1,2,3,7,8-Penta	0.2	0.9	1.5	1.0
2,3,4,7,8-Penta	0.6	3.5	6.7	3.3
1,2,3,4,7,8-Hexa	0.2NQ	1.1	2.1	0.7
1,2,3,6,7,8-Hexa	0.2	0.6	0.9	0.5
1,2,3,7,8,9-Hexa	0.07NQ	0.08NQ	0.1NQ	0.1ND
2,3,4,6,7,8-Hexa	0.2	0.5	0.7	0.5
1,2,3,4,6,7,8-Hepta	0.5	1.0	1.3	0.6
1,2,3,4,7,8,9-Hepta	0.2NQ	0.1ND	0.2NQ	0.1ND
Octachloro	3.5	4.2	4.6	3.3

ND = not detected at specified detection limit.
NQ = not quantitated at specified average concentration due to inaccurate ion ratio.

Table 3.2.3 A. Concentrations of PCBs in tree swallow eggs and nestlings from the upper Hudson River - 1994.

Matrix	PCB Concentration (ng/g wet weight)			
	Lock 9	Remnant	SA13	Saratoga
Eggs	852	6,550	29,600	18,500
	2,570	22,900	77,300	2,370
	5,720	12,900	17,600	15,700
	16,000*	4,600*	44,000*	13,000*
Egg Average	6280	11,700	42,100	12,400
Nestlings	510	31,100	54,800	9,780
	244	27,100	56,800	721
Nestlg Average	377	29,100	55,800	5,250

Each value represents one, three egg composite or two nestling composite from a single nest (Kruskal-Wallis: eggs p=.044, H=8.10; nestlings p=.083, H=6.67).

* values represent total PCB as part of an organochlorine scan; all other data values represent cPCB, which is total PCB concentration determined by summing the congener concentrations.

Table 3.2.3 B. Concentrations of PCBs in tree swallows from other studies.

Site	Year	Concentration (ng/g)	
		Eggs	Nestlings
Lower Fox River *	1988	4,120	2,490
Fox River CDF*	1988		2,970
Wye Marsh**	1991	255	11
Mud Creek**	1991	380	163
Pt. Rowan Sewage Lag.	1991	489	280
Long Point Tip**	1991	695	428
Cootes Paradise**	1991	1,020	754
Akwesasne**	1991	4,008	
Saginaw - CROW***	1991	563	171
Saginaw - AIRP***	1991	1,144	616
Saginaw - CHIP***	1991	836	330
Saginaw COPO***	1991	1,373	1,027

* Ankley et al. 1993
** Bishop et al. 1995
*** Nichols et al. 1995

Table 3.2.4 A. Average within site and among site correlation coefficients for concentrations of individual PCB congeners in tree swallow eggs and nestlings from the upper Hudson River 1994.

EGGS	Lock 9	Remn	SA13	Sara
Lock 9	0.89	0.91	0.90	0.93
Remn		0.99	0.97	0.96
SA13			0.98	0.94
Sara				0.97
NESTLINGS	Lock 9	Remn	SA13	Sara
Lock 9	0.82	0.84	0.84	0.92
Remn		0.96	0.97	0.94
SA13			0.99	0.93
Sara				0.98

PCB congener concentrations for each sample were compared as arrays using the correlation function of EXCEL 4.0.

Table 3.2.4 B. Concentrations of selected PCB congeners (ng/g wet weight) in tree swallows from various studies.

			PCB Congener IUPAC Number						
Source	**Site**	**Life Stage**	**77**	**105**	**118**	**126**	**156**		**Total PCB**
Ankley et al. 1993	Fox CDF	Nestling	22.5	66.9		1.2			**2,970**
	Fox River		41.2	47.2		0.8			**2,490**
Nichols et al. 1995	Saginaw CROW		1.1		5.7	0.1			**171**
	Saginaw AIRP		2.1		18.4	0.2			**616**
	Saginaw CHIP		0.4		8.1	0.1			**330**
	Saginaw COPO		5.9		36.2	516.0			**1,027**
This Study	Hudson Lk9		1.2	7.1	16.1	0.1	0.3		**377**
	Hudson Remn		370.0	794.6	1489.1	5.0	42.8		**29,100**
	Hudson SA13		530.0	961.6	1815.4	7.5	54.8		**55,800**
	Hudson Sara		56.0	234.3	560.2	1.5	7.5		**5,250**
Nichols et al. 1995	Saginaw CROW	Egg	1.7		14.8	0.3			**563**
	Saginaw AIRP		3.1		31.1	0.5			**1,144**
	Saginaw CHIP		3.4		20.1	0.5			**836**
	Saginaw COPO		4.6		37.4	0.7			**1,373**
Ankley et al. 1993	Fox River		42.5	116.0		1.1			**4,120**

Table 3.2.5. Daily rate of PCB accumulation by tree swallow nestlings in the upper Hudson River - 1994.

Box #	Egg Mass (g)	Mean Egg Mass (g)	PCB Conc. (ug/g)	PCB Mass (ug)	Chick Mass (g)	Mean Chick Mass (g)	PCB Conc. (ug/g)	PCB Mass (ug)	**Accum/Day* ug/day**
101	1.45	1.57	0.85	1.33	23.95	23.70	0.24	5.78	**0.32**
	1.55				23.45				
	1.70								
113	2.00	2.12	5.72	12.13	24.00	24.15	0.38	9.1	**-0.22**
	2.15				24.30				
	2.20								
206	2.05	1.98	6.55	12.97	22.35	22.50	31.12	700.2	**49.09**
	1.95				22.65				
	1.95								
221	2.00	1.93	12.92	24.94	24.75	23.93	27.06	647.62	**44.48**
	1.95				23.10				
	1.85								
327	1.95	1.85	77.35	143.10	23.90	23.10	54.83	1266.57	**80.25**
	1.85				22.30				
	1.75								
332	1.90	1.97	17.59	34.65	20.60	21.35	56.77	1212.04	**84.1**
	2.05				22.10				
	1.95								
418	1.85	1.77	2.37	4.19	21.80	22.48	9.78	219.83	**15.4**
	1.70				23.15				
	1.75								
419	1.70	1.82	15.68	28.53	22.60	22.70	0.72	16.37	**-0.87**
	1.80				22.80				
	1.95								

* Accumulation rate = ug PCB accumulated per day =
{(ug in average nestling - ug in average egg) / 14 days}.

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Table 3.2.6 A. 1994 Hudson River tree swallow C-TEQs calculated from avian based values derived from chicken egg injection studies (All concentrations and C-TEQs in ng/g, unless otherwise specified)

PCB CONGENER	C-TEF	Lk9 Conc.	Lk9 TEQ	Remn Conc	Remn TEQ	SA13 Conc	SA13 TEQ	Sara Conc	Sara TEQ
123	NA	0.35	NA	25.31	NA	31.61	NA	9.17	NA
118	0.00003	16.06	0.0004818	1489.07	0.0446721	1815.42	0.0544626	560.15	0.0168045
114	NA	0.75	NA	66.71	NA	85.23	NA	22.88	NA
105	0.00007	7.07	0.0004949	794.56	0.0556192	961.56	0.0673092	234.27	0.0163989
167	NA	0.71	NA	21.06	NA	28.62	NA	13.31	NA
156	0.0001	0.92	0.000092	42.75	0.004275	54.75	0.005475	22.82	0.002282
157	NA	0.29	NA	12.13	NA	17.1	NA	7.49	NA
189	NA	ND	ND	1.53	NA	2.17	NA	1.26	NA
81	NA	0.115	NA	16	NA	24.8	NA	4.29	NA
77	0.02	1.24	0.0248	370	7.4	530	10.6	56	1.12
126	0.05	0.067	0.00335	5	0.25	7.53	0.3765	1.48	0.074
169	0.001	0.003	0.000003	0.011	0.000011	0.017	0.000017	0.011	0.000011
	C-TEQ PCBs		0.0292217		7.7545773		11.1037638		1.2294964
	% total PCBs		82.00%		99.82%		99.78%		97.49%
DIOXINS									
2,3,7,8-Tetra	1	0.0002	0.0002	0.0003	0.0003	0.0004	0.0004	0.0004	0.0004
1,2,3,7,8-Penta	1.2	0.0009	0.00108	0.0007	0.00084	0.001	0.0012	0.0008	0.00096
1,2,4,7,8-Penta	NA	0.0004	NA	0.0002	NA	0.0003	NA	0.0003	NA
1,2,3,4,7,8-Hexa	0.05	0.001	0.00005	0.001	0.00005	0.0015	0.000075	0.0008	0.00004
1,2,3,6,7,8-Hexa	0.01	0.0018	0.000018	0.002	0.00002	0.0035	0.000035	0.0027	0.000027
1,2,3,7,8,9-Hexa	0.1	0.0008	0.00008	.0006NQ	ND	0.0006	0.00006	0.0004	0.00004
1,2,3,4,6,7,8-Hepta	0.001	0.057	0.000057	0.007	0.000007	0.009	0.000009	0.0046	0.0000046
Octachloro	NA	0.015	NA	0.013	NA	0.038	NA	0.012	NA
FURANS									
2,3,7,8-Tetra	0.9	0.0046	0.00414	0.0091	0.00819	0.016	0.0144	0.029	0.0261
1,2,3,7,8-Penta	0.3	0.0002	0.00006	0.0009	0.00027	0.0015	0.00045	0.001	0.0003
2,3,4,7,8-Penta	1.1	0.0006	0.00066	0.0035	0.00385	0.0067	0.00737	0.0033	0.00363
1,2,3,4,7,8-Hexa	0.01	.0002NQ	ND	0.0011	0.000011	0.0021	0.000021	0.0007	0.000007
1,2,3,6,7,8-Hexa	0.4	0.0002	0.00008	0.0006	0.00024	0.0009	0.00036	0.0005	0.0002
1,2,3,7,8,9-Hexa	NA	.00007NQ	ND	.00008NQ	ND	.0001NQ	ND	.0001ND	ND
2,3,4,6,7,8-Hexa	NA	0.0002	NA	0.0005	NA	0.0007	NA	0.0005	NA
1,2,3,4,6,7,8-Hepta	NA	0.0005	NA	0.001	NA	0.0013	NA	0.0006	NA
1,2,3,4,7,8,9-Hepta	NA	.0002NQ	ND	.0001ND	ND	.0002NQ	ND	.0001ND	ND
Octachloro	NA	0.0035	NA	0.0042	NA	0.0046	NA	0.0033	NA
	C-TEQ PCDDs/PCDFs		0.006425		0.013778		0.02438		0.0317086
	% total PCDDs/PCDFs		18.00%		0.08%		0.22%		2.51%
	TOTAL TEQ (pg/g)		**36**		**7,770**		**11,100**		**1,260**

C-TEFs for PCB congeners from Kubiak 1991, cited in Hoffman et al. 1996; PCDDs and PCDFs from Bosveld et al. 1992. *U.S. Fish and Wildlife Service*

Table 3.2.6 B. 1994 Hudson River tree swallow S-TEQs calculated from Safe (1990) TEFs (All concentrations and S-TEQs in ng/g, unless otherwise specified).

PCB CONGENER	S-TEF	Lk9 Conc	Lk9 TEQ	Remn Conc	Remn TEQ	SA13 Conc	SA13 TEQ	Sara Conc	Sara TEQ
123	0.001	0.35	0.00035	25.31	0.02531	31.61	0.03161	9.17	0.00917
118	0.001	16.06	0.01606	1489.07	1.48907	1815.42	1.81542	560.15	0.56015
114	0.001	0.75	0.00075	66.71	0.06671	85.23	0.08523	22.88	0.02288
105	0.001	7.07	0.00707	794.56	0.79456	961.56	0.96156	234.27	0.23427
167	0.001	0.71	0.00071	21.06	0.02106	28.62	0.02862	13.31	0.01331
156	0.001	0.92	0.00092	42.75	0.04275	54.75	0.05475	22.82	0.02282
157	0.001	0.29	0.00029	12.13	0.01213	17.1	0.0171	7.49	0.00749
189	0.001	ND	ND	1.53	0.00153	2.17	0.00217	1.26	0.00126
81	NA	0.115	NA	16	NA	24.8	NA	4.29	NA
77	0.01	1.24	0.0124	370	3.7	530	5.3	56	0.56
126	0.1	0.067	0.0067	5	0.5	7.53	0.753	1.48	0.148
169	0.05	0.003	0.00015	0.011	0.00055	0.017	0.00085	0.011	0.00055
	S-TEQ PCBs		0.0454		6.65367		9.05031		1.5799
	% total PCBs		94.98%		99.94%		99.92%		99.62%
DIOXINS									
2,3,7,8-Tetra	1	0.0002	0.0002	0.0003	0.0003	0.0004	0.0004	0.0004	0.0004
1,2,3,7,8-Penta	0.5	0.0009	0.00045	0.0007	0.00035	0.001	0.0005	0.0008	0.0004
1,2,4,7,8-Penta	NA	0.0004	NA	0.0002	NA	0.0003	NA	0.0003	NA
1,2,3,4,7,8-Hexa	0.1	0.001	0.0001	0.001	0.0001	0.0015	0.00015	0.0008	0.00008
1,2,3,6,7,8-Hexa	0.1	0.0018	0.00018	0.002	0.0002	0.0035	0.00035	0.0027	0.00027
1,2,3,7,8,9-Hexa	0.1	0.0008	0.00008	.0006NQ	ND	0.0006	0.00006	0.0004	0.00004
1,2,3,4,6,7,8-Hepta	0.01	0.057	0.00057	0.007	0.00007	0.009	0.00009	0.0046	0.000046
Octachloro	0.001	0.015	0.000015	0.013	0.000013	0.038	0.000038	0.012	0.000012
FURANS									
2,3,7,8-Tetra	0.1	0.0046	0.00046	0.0091	0.00091	0.016	0.0016	0.029	0.0029
1,2,3,7,8-Penta	0.1	0.0002	0.00002	0.0009	0.00009	0.0015	0.00015	0.001	0.0001
2,3,4,7,8-Penta	0.5	0.0006	0.0003	0.0035	0.00175	0.0067	0.00335	0.0033	0.00165
1,2,3,4,7,8-Hexa	0.1	.0002NQ	ND	0.0011	0.00011	0.0021	0.00021	0.0007	0.00007
1,2,3,6,7,8-Hexa	0.1	0.0002	0.00002	0.0006	0.00006	0.0009	0.00009	0.0005	0.00005
1,2,3,7,8,9-Hexa	0.1	.00007NQ	ND	.00008NQ	ND	.0001NQ	ND	.0001ND	ND
2,3,4,6,7,8-Hexa	0.1	0.0002	0.00002	0.0005	0.00005	0.0007	0.00007	0.0005	0.00005
1,2,3,4,6,7,8-Hepta	0.01	0.0005	0.000005	0.001	0.00001	0.0013	0.000013	0.0006	0.000006
1,2,3,4,7,8,9-Hepta	0.1	.0002NQ	ND	.0001ND	ND	.0002NQ	ND	.0001ND	ND
Octachloro	0.001	0.0035	0.0000035	0.0042	0.0000042	0.0046	0.0000046	0.0033	0.0000033
	S-TEQ PCDDs/PCDFs		0.0024235		0.0040172		0.0070756		0.0060773
	% total PCDDs/PCDFs		5.00%		0.06%		0.08%		0.38%
	TOTAL TEQ (pg/g)		**48**		**6,660**		**9,060**		**1,590**

S-TEF values for all congeners from Safe (1990).

Table 3.2.6 C. 1994 Hudson River I-TEQs calculated from I-TEFs (All concentrations and I-TEQs in ng/g, unless otherwise specified).

PCB CONGENER	I-TEF	Lk9 Conc	Lk9 TEQ	Remn Conc	Remn TEQ	SA13 Conc	SA13 TEQ	Sara Conc	Sara TEQ
123	0.0001	0.35	0.000035	25.31	0.002531	31.61	0.003161	9.17	0.000917
118	0.0001	16.06	0.001606	1489.07	0.148907	1815.42	0.181542	560.15	0.056015
114	0.0005	0.75	0.000375	66.71	0.033355	85.23	0.042615	22.88	0.01144
105	0.0001	7.07	0.000707	794.56	0.079456	961.56	0.096156	234.27	0.023427
167	0.00001	0.71	0.0000071	21.06	0.0002106	28.62	0.0002862	13.31	0.0001331
156	0.0005	0.92	0.00046	42.75	0.021375	54.75	0.027375	22.82	0.01141
157	0.0005	0.29	0.000145	12.13	0.006065	17.1	0.00855	7.49	0.003745
189	0.0001	ND	ND	1.53	0.000153	2.17	0.000217	1.26	0.000126
81	NA	0.115	NA	16	NA	24.8	NA	4.29	NA
77	0.0005	1.24	0.00062	370	0.185	530	0.265	56	0.028
126	0.1	0.067	0.0067	5	0.5	7.53	0.753	1.48	0.148
169	0.01	0.003	0.00003	0.011	0.00011	0.017	0.00017	0.011	0.00011
	I-TEQ PCBs		0.0106851		0.9771626		1.3780722		0.2833231
	% total PCBs		82.00%		99.59%		99.50%		97.90%
DIOXINS									
2,3,7,8-Tetra	1	0.0002	0.0002	0.0003	0.0003	0.0004	0.0004	0.0004	0.0004
1,2,3,7,8-Penta	0.5	0.0009	0.00045	0.0007	0.00035	0.001	0.0005	0.0008	0.0004
1,2,4,7,8-Penta	NA	0.0004	NA	0.0002	NA	0.0003	NA	0.0003	NA
1,2,3,4,7,8-Hexa	0.1	0.001	0.0001	0.001	0.0001	0.0015	0.00015	0.0008	0.00008
1,2,3,6,7,8-Hexa	0.1	0.0018	0.00018	0.002	0.0002	0.0035	0.00035	0.0027	0.00027
1,2,3,7,8,9-Hexa	0.1	0.0008	0.00008	.0006NQ	ND	0.0006	0.00006	0.0004	0.00004
1,2,3,4,6,7,8-Hepta	0.01	0.057	0.00057	0.007	0.00007	0.009	0.00009	0.0046	0.000046
Octachloro	0.001	0.015	0.000015	0.013	0.000013	0.038	0.000038	0.012	0.000012
FURANS									
2,3,7,8-Tetra	0.1	0.0046	0.00046	0.0091	0.00091	0.016	0.0016	0.029	0.0029
1,2,3,7,8-Penta	0.05	0.0002	0.00001	0.0009	0.000045	0.0015	0.000075	0.001	0.00005
2,3,4,7,8-Penta	0.5	0.0006	0.0003	0.0035	0.00175	0.0067	0.00335	0.0033	0.00165
1,2,3,4,7,8-Hexa	0.1	.0002NQ	ND	0.0011	0.00011	0.0021	0.00021	0.0007	0.00007
1,2,3,6,7,8-Hexa	0.1	0.0002	0.00002	0.0006	0.00006	0.0009	0.00009	0.0005	0.00005
1,2,3,7,8,9-Hexa	0.1	.00007NQ	ND	.00008NQ	ND	.0001NQ	ND	.0001ND	ND
2,3,4,6,7,8-Hexa	0.1	0.0002	0.00002	0.0005	0.00005	0.0007	0.00007	0.0005	0.00005
1,2,3,4,6,7,8-Hepta	0.01	0.0005	0.000005	0.001	0.00001	0.0013	0.000013	0.0006	0.000006
1,2,3,4,7,8,9-Hepta	0.01	.0002NQ	ND	.0001ND	ND	.0002NQ	ND	.0001ND	ND
Octachloro	0.001	0.0035	0.0000035	0.0042	0.0000042	0.0046	0.0000046	0.0033	0.0000033
	I-TEQ PCDDs/PCDFs		0.0024135		0.0039722		0.0070006		0.0060273
	% total PCDDs/PCDFs		18.00%		0.41%		0.50%		2.10%
	TOTAL TEQ (pg/g)		13		981		1,390		289

I-TEF values for all congeners from Ahlborg et al. 1994 and 1992.

Table 3.2.6 D. Comparison of TEQs in tree swallows calculated using various toxic equivalency factors (TEFs): 1994 upper Hudson River and 1988 Green Bay, Wisconsin.

Source	Life Stage	Site	Total PCB (ng/g)	C-TEQ (pg/g)	S-TEQ (pg/g)	I-TEQ (pg/g)
This study	14 day chick	Lock 9	244	36	48	13
"	"	Remnant	31,100	7,770	6,660	981
"	"	SA13	54,800	11,100	9,060	1,390
"	"	Saratoga	9,780	1,260	1,590	289
Jones et al. 1993	chick comp.		2,970	525	430	
& Ankley et al. 1993	16 day chick		2,490	878	552	

Avian based TEQs (C-TEQs) based on TEFs from Kubiak 1991 and Bosveld et al. 1992; S-TEQs based on TEFs from Safe 1990; International TEQs (I-TEQs) based on International TEFs from Ahlborg et al. 1994.

Table 3.2.6 E. Relative contribution of non-ortho and mono-ortho-chloro substituted PCBs, and 2,3,7,8-substituted PCDDs/PCDFs to C-TEQ in tree swallows from the upper Hudson River -1994.

Constituent	Lock 9		Remnant		SA13		Saratoga	
	TEQ (pg/g)	*% of total*	TEQ (pg/g)	*% of total*	TEQ (pg/g)	*% of total*	TEQ (pg/g)	% of total
PCB 77	24.8	***69.6***	7400.0	***95.3***	10600.0	***95.3***	1120.0	***88.8***
PCB 105	0.5	*1.4*	55.6	*0.7*	67.3	*0.6*	16.4	*1.3*
PCB 118	0.5	*1.3*	44.7	*0.6*	54.5	*0.5*	16.8	*1.3*
PCB 126	3.4	*9.4*	250.0	*3.2*	376.5	*3.4*	74.0	*5.9*
PCB 156	0.1	*0.3*	4.3	*0.1*	5.5	*0.0*	2.3	*0.2*
PCB 169	0.0	*0.0*	0.0	*0.0*	0.0	*0.0*	0.0	*0.0*
Sum PCBs	29.2	*82.0*	7754.6	*99.8*	11103.8	*99.8*	1229.5	*97.5*
PCDDs/PCDFs	6.4	*18.0*	13.8	*0.2*	24.4	*0.2*	31.7	*2.5*
Total C-TEQ	**35.6**		**7768.4**		**11128.2**		**1261.2**	

Table 3.2.6 F. Relative contribution of non-ortho and mono-ortho-chloro substituted PCBs, and 2,3,7,8-substituted PCDDs and PCDFs to S-TEQ in tree swallows from the upper Hudson River - 1994.

Constituent	Lock 9		Remnant		SA13		Saratoga	
	TEQ (pg/g)	*% of total*	TEQ (pg/g)	*% of total*	TEQ (pg/g)	*% of total*	TEQ (pg/g)	% of total
PCB 77	12.4	*27.1*	3700.0	***56.7***	5300.0	***59.6***	560.0	**36.6**
PCB105	7.1	*15.5*	795.0	*12.2*	962.0	*10.8*	234.0	*15.3*
PCB 118	16.1	***35.1***	1489.0	*22.7*	1815.0	*20.4*	560.0	***36.6***
PCB 126	6.7	*14.7*	500.0	*7.6*	753.0	*8.5*	148.0	*9.7*
PCB 156	0.9	*2.0*	42.7	*0.7*	54.7	*0.6*	22.8	*1.5*
PCB 169	0.2	*0.3*	0.6	*0.0*	0.8	*0.0*	0.6	*0.0*
Sum PCBs	43.4	*94.8*	6527.3	*100.0*	8885.5	*100*	1525.4	*99.6*
PCDDs/PCDFs	2.4	*5.2*	4.0	*0.0*	7.1	*0.0*	6.1	*0.2*
Total S-TEQ	**45.8**		**6531.2**		**8892.6**		**1531.5**	

Table 3.2.6 G. Relative contribution of non-ortho and mono-ortho-chloro substituted PCBs, and 2,3,7,8-substituted PCDDs and PCDFs to I-TEQ in tree swallows from the upper Hudson River - 1994.

	Lock 9		Remnant		SA13		Saratoga	
Constituent	TEQ (pg/g)	*% of total*	TEQ (pg/g)	*% of total*	TEQ (pg/g)	*% of total*	TEQ (pg/g)	*% of total*
PCB 77	0.6	*4.8*	185.0	*19.7*	265.0	*19.9*	28.0	*10.3*
PCB 105	0.7	*5.6*	79.5	*8.5*	96.2	*7.2*	23.4	*8.6*
PCB 118	1.6	*12.8*	148.9	*15.9*	181.6	*13.7*	56.0	*20.5*
PCB 126	6.7	***53.6***	500.0	***53.2***	753.0	***56.6***	148.0	***54.2***
PCB 156	0.5	*4.0*	21.4	*2.3*	27.4	*2.1*	11.4	*4.2*
PCB 169	0.0	*0.0*	0.1	*0.0*	0.2	*0.0*	0.1	*0.0*
Sum PCBs	10.1	*80.8*	934.9	*99.6*	1323.4	*99.5*	266.9	*97.8*
PCDDs/PCDFs	2.4	*19.2*	4.0	*0.4*	7.0	*0.5*	6.0	*2.2*
TOTAL I-TEQ	12.5		938.9		1330.4		272.9	

Table 3.3. Occurrence of insects with aquatic larvae in the diets of tree swallows breeding along the upper Hudson River - 1994.

Site	% Number	% Mass	Items	n
Lock 9	50	82	16	1
Remnant	97.8 +/- 2.7	99.2 +/- 0.9	147	4
SA13	78.4 +/- 32.4	83.6 +/-29.5	194	12
Saratoga	64.2 +/- 23.4	68.2 +/- 25.3	66	4

% Number = the percent of each sample composed of aquatic insects, with all items in each sample weighted equally. % Mass = the percent of each sample composed of insects based on the mass of aquatic insects in each sample. Items = the number of individual insects collected from each site. n = number of samples from each site. Values are means (+/- standard deviation).

Table 3.4. Tree swallow nest construction along the upper Hudson River - 1994.

	Lock 9	Remnant	SA13	Saratoga
Feathers at Eggs	1.3 +/- 1.9	3.7 +/- 4.5	6.5 +/- 6.7	5.7 +/- 4.2
Feathers at Chicks	40	23.4 +/- 15.8	30.7 +/- 10.9	17.9 +/- 13.2
Grade	3	2.2 +/- 0.8	2.4 +/- 0.6	2.1 +/- 0.7
#1's	0	4	1	4
#2's	0	5	14	10
#3's	1	7	14	5

Feathers at eggs = number of feathers lining nest counted during the egg laying period; feathers at chicks = number of feathers lining nest counted during the nestling period. Grade (see text for definition) = mean grade of the nest (+/- standard deviation). #1's = number of nests receiving a grade of 1, #2's = number of nests receiving a grade of 2, #3's = number of nests receiving a grade of 3. Differences among sites in feathers at eggs are not significant (Kruskal-Wallis H=7.3, p=0.063), nor are there significant differences among nest grades (Kruskal-Wallis H=4.8, p=0.188); the differences in feathers during the nestling stage are significant (Kruskal-Wallis H=10.9, p=0.012).

Table 3.5.1. Thickness and mass of tree swallow egg shells from the upper Hudson River and Ithaca sites in New York.

	Shell Thickness (mm)	Shell Mass (g)	Shell Index	n
Lock 9	0.091 +/- 0.006	0.110 +/- 0.012	0.040 +/- 0.003	15
Remnant	0.092 +/- 0.007	0.107 +/- 0.008	0.042 +/- 0.003	19
SA13	0.092 +/- 0.005	0.112 +/- 0.008	0.043 +/- 0.002	18
Saratoga	0.091 +/- 0.005	0.104 +/- 0.008	0.043 +/- 0.002	17
Ithaca	0.091 +/- 0.009	0.105 +/- 0.008	0.043 +/- 0.003	15
F value	0.09	2.25	0.78	
p value	0.990	0.071	0.541	

Means are given for each site (+/- standard deviation). Shell Index = shell mass * $(\text{length} * \text{width})^{-1}$ (DeWeese et al. 1985, Ratcliffe 1967). n = number of eggs measured from each site. P-values are from ANOVA.

Table 3.5.2. Tree swallow egg shell size and thickness - 1994 upper Hudson River compared with other studies.

Parameter	Hudson River	Ithaca	Colorado	Pre-DDT
Length (mm)	18.95 +/- 1.17	18.36 +/- 0.79	18.82 +/- 0.08	18.67 +/- 0.51
Width (mm)	13.40 +/- 0.45	13.39 +/- 0.40	13.37 +/- 0.21	13.28 +/- 0.33
Mass (g)	0.108 +/- 0.009	0.091 +/- 0.025	0.100 +/- 0.004	0.097 +/- 0.009
Index (g/cm^2)	0.043 +/- 0.003	0.043 +/- 0.010	0.040 +/- 0.002	0.039 +/- 0.002

Hudson River data are values for all four sites pooled, while Colorado and pre-DDT data are from DeWeese et al. (1988). Mass = mass of dried egg shell. Length and width are of intact eggs. Index = shell mass * $(\text{length} * \text{width})^{-1}$ (DeWeese et al. 1985, Ratcliffe 1967). Means are given for each site (+/- standard deviation). The masses of shells from the Hudson River (n=69) are significantly greater than the mean for Colorado (t-test, t=7.23, p,0.001) and pre-DDT North America (t=9.95, p,0.001). The shell index for Hudson River eggs is significantly larger than the means for Colorado (t=8.48, p,0.001) and pre-DDT North America (t=11.81, p,0.001).

Table 3.6 Volume and mass of fresh tree swallow eggs from 1994 upper Hudson River and other North American sites.

Site	Volume (ml)	n	Mass (g)	n
Lock 9	1.744 +/- 0.153	27	1.87 =/- 0.16	27
Remnant	1.690 +/- 0.098	122	1.82 +/- 0.14	121
SA13	1.703 +/- 0.123	198	1.84 +/- 0.16	192
Saratoga	1.677 +/- 0.141	164	1.81 +/- 0.18	162
Ithaca[1]	1.650 +/- 0.118	73		
MI[2]			1.94 +/- 0.10	13
Ontario[3]			1.85 +/- 0.03	29
Ontario[4]			1.93 +/- 0.01	121
B.C[5]			1.80 +/- 0.16	956

Means are given for each site (+/- standard deviation). n = number of eggs measured at each site. The differences in volume among the Hudson River and Ithaca samples are significant (ANOVA F = 4.15, p = 0.003), while the differences in mass among the Hudson River sites are not significant (ANOVA F = 1.53, p = 0.21).

[1] 1990 and 1994 data combined.
[2] Beaver and Lederle 1988.
[3] DeSteven 1978 sub-adults only.
[4] DeSteven 1978 adults only.
[5] Wiggins 1990.

Table 3.7.1. Mass of nestling tree swallows on the day of hatch - 1994 upper Hudson River (mean +/- standard deviation).

Site	Mass (g)	n
Remnant	1.65 +/- 0.21	17
SA13	1.69 +/- 0.29	26
Saratoga	1.56 +/- 0.22	22
Ithaca	1.80 +/- 0.34	

Mass is based on mean mass of nestlings in a brood; n = number of broods. Differences among Hudson River sites are not significant (ANOVA $F = 1.77$, $p = 0.179$). The mean mass of nestlings from all of the Hudson River sites combined (mean = 1.64 g) is significantly less than the mean mass of nestlings from Ithaca (t-test, $t = 5.30$, $p < 0.001$).

Table 3.7.2. Mass and wing length of nestling tree swallows on day 8 - 1994 upper Hudson River.

Site	Mass (g)	Wing Chord (mm)	9th Primary (mm)	n
Lock 9	16.6	28.7	3.7	1
Remnant	16.2 +/- 2.5	26.5 +/- 4.0	2.4 +/- 1.3	15
SA13	16.6 +/- 2.0	27.7 +/- 3.1	2.9 +/- 1.3	30
Saratoga	16.1 +/- 2.6	26.6 +/- 3.6	2.4 +/- 1.2	21
Ithaca	15.2 +/- 3.0	22.6 +/- 5.1	2.3 +/- 1.8	99

Mean and standard deviation for each site based on means of broods of nestlings; n = number of broods. Ithaca data from 1990 - 1993. Data from all other sites from 1994 season. Differences in mean mass and size among Hudson River sites are not significant (ANOVA, $F = 0.38$, $p > 0.685$; $F = 0.81$, $p > 0.452$; $F = 0.95$, $p > 0.392$ for mass, wing chord, and 9th primary, respectively). Hudson River nestlings are significantly heavier and have larger wings and 9th primaries than the means from Ithaca (t-test, $t = 3.95$, $p < 0.001$; $t = 10.35$, $p < 0.001$; $t = 1.98$, $p = 0.055$, respectively).

Table 3.7.3. Mass and wing length of nestling tree swallows on day 10 - 1994 upper Hudson River.

Site	Mass (g)	Wing Chord (mm)	9th Primary (mm)	n
Lock 9	21.1 +/- 1.2	36.8 +/- 4.9	8.1 +/- 3.2	3
Remnant	19.9 +/- 2.6	38.3 +/- 4.8	10.1 +/- 3.5	17
SA13	20.4 +/- 2.2	39.2 +/- 3.9	10.7 +/- 3.4	27
Saratoga	19.5 +/- 3.2	37.5 +/- 5.3	9.8 +/- 3.5	20
Ithaca	19.1 +/- 2.7	36.2 +/- 5.9	8.7 +/- 4.3	124

Mean and standard deviation for each site based on means of broods of nestlings; n = number of broods. Ithaca data from 1990 - 1993. Data from all other sites from 1994 season. Differences among Hudson River sites in mass, wing chord, and 9th primary are not significant (ANOVA, $F = 0.58$, $p > 0.630$; $F = 0.67$, $p > 0.572$; $F = 0.65$, $p > 0.584$, respectively). Hudson River nestlings are heavier and have larger wings and 9th primaries than the mean of Ithaca nestlings (t-test, $t = 2.94$, $p = 0.005$; $t = 3.82$, $p < 0.001$; $t = 3.47$, $p < 0.001$, respectively).

Table 3.7.4. Mass and wing length of nestling tree swallows on day 12 - 1994 upper Hudson River.

Site	Mass (g)	Wing Chord (mm)	9th Primary (mm)	n
Lock 9	25.5	53.3	23	1
Remnant	21.5 +/- 2.2	50.6 +/- 5.8	22.0 +/- 5.5	15
SA13	22.7 +/- 1.2	52.1 +/- 4.0	23.9 +/- 3.7	27
Saratoga	21.2 +/- 3.0	49.8 +/- 6.3	21.5 +/- 5.6	18
Ithaca	21.2 +/- 2.6	47.7 +/- 6.1	19.8 +/- 5.8	116

Mean and standard deviation for each site based on means of broods of nestlings; n = number of broods. Ithaca data from 1990 - 1993. Data from all other sites from 1994 season. Differences among Hudson River sites in mass, wing chord, and 9th primary are not significant (ANOVA, $F = 3.09$, $p = 0.053$; $F = 1.12$, $p = 0.333$; $F = 1.63$, $p = 0.205$, respectively). Hudson River nestlings are heavier and have larger wings and 9th primaries than the mean of Ithaca nestlings (t-test, $t = 2.59$, $p = 0.012$; $t = 4.99$, $p < 0.001$; $t = 4.66$, $p < 0.001$, respectively).

Table 3.7.5. Mass and wing length of nestling tree swallows on day 14 - 1994 upper Hudson River.

Site	Mass (g)	Wing Chord (mm)	9th Primary (mm)	n
Lock 9	24.3 +/- 0.9	60.6 +/- 5.3	31.4 +/- 4.0	4
Remnant	22.1 +/- 1.5	63.4 +/- 4.0	35.4 +/- 4.1	14
SA13	22.3 +/- 1.5	63.6 +/- 4.1	35.7 +/- 4.6	26
Saratoga	21.0 +/- 1.8	59.6 +/- 9.0	32.1 +/- 8.1	18
Ithaca	20.7 +/- 1.8	56.3 +/- 6.4	32.2 +/- 4.5	46

Mean and standard deviation for each site based on means of broods of nestlings; n = number of broods. Ithaca data from 1990 - 1993. Data from all other sites from 1994 season. Nestlings from Lock 9 are significantly heavier than those from other Hudson River sites (ANOVA, $F = 4.02$, $p = 0.011$), while differences in wing length and 9th primary are not significant ($F = 1.87$, $p = 0.144$ and $F = 1.90$, $p = 0.139$, respectively). Hudson River nestlings are significantly heavier and have larger wings and 9th primaries than the mean for Ithaca (t-test, $t = 5.07$, $p < 0.001$; $t = 7.70$, $p < 0.001$; $t = 2.77$, $p = 0.007$, respectively).

Table 3.7.6 Clutch size of tree swallows in New York and across North America.

Clutch Size	Abbreviation	Location	Reference
4.8	Remn	Remnant #4	This Study
5.7	SA13	Special Area 13	This Study
5.2	Sara	Saratoga NHP	This Study
5.5	Ith90	Ithaca, NY	McCarty, unpub.
5.5	Ith91	Ithaca, NY	McCarty, unpub.
5.8	Shak	Shackleton Pt., NY	Sheppard 1977
5.5	BNA	North America	Robertson et al. 1992
5.3	MI	Upper Peninsula, MI	Beaver and Lederle 1988
5.3	WI	Green Bay, WI	Beaver and Lederle 1988
4.6	Ohio	Delaware, Ohio	Burtt and Tuttle 1983
5.3	Sudbury	Sudbury, Ontario	Blancher and McNicol 1988

Table 3.7.7. Reproductive success of tree swallows. Comparison of success at upper Hudson River to results from other studies of tree swallow reproduction from across North America. See Table 3.7.6 for sources of information.

	Remn	SA13	Sara	Ithaca[1]	Shack	BNA[2]	MI	WI	Ohio[3]	Sudbury[4]
Hatchability	70	79	64	93	91	87-95	90	77	87	90
Reproductive Success	62	74	51	88						60
% Aband (egg stage)	23	3	26	0					0	6
Sample Size	17	29	26(27)[5]	23(15)[6]						

Hatchability = % of all eggs laid that hatched (ANOVA $F_{3,91}$=3.17, p=0.028).
Reproductive Success = % of all eggs laid that resulted in fledged individuals (ANOVA $F_{3,83}$=3.97, p=0.011).
% Aband = percent of nests with eggs abandoned by females before the expected hatch date.
[1]Ithaca data exclude losses due to predation.
[2]Robertson et al. 1992 note that hatching success should approach 95% in nests not affected by abnormal weather or other disturbances.
[3]Includes only females that were unbanded prior to hatching.
[4]Includes nests abandoned during periods of inclement weather and nests in low pH wetlands.
[5]N=27 for calculation of abandonment; n=26 for calculation of hatchability & reproductive success.
[6]N=23 for calculation of hatchability and abandonment; n=15 for calculation of reproductive success.

Table 3.8. Mass and wing length of adult tree swallows from the upper Hudson River (1994) compared with other North American data.

	Mass (g)	Wing Chord (mm)	9th Primary (mm)	n
Sub-adult Females	20.4 +/- 1.2	114.5 +/- 2.7	88.3 +/- 2.6	37
Adult Females	20.6 +/- 1.5	116.2 +/- 2.3	89.9 +/- 2.3	18
Males	21.0 +/- 1.6	118.7 +/- 3.0	91.8 +/- 2.9	22
Ithaca Adults[1]		117.4 +/- 3.6	92.2 +/- 2.9	10
Ontario Sub-adult Females[2]	20.4 +/- 1.5	112.8 +/- 2.3		86/94
Ontario Adult Females[2]	21.5 +/- 1.7	115.3 +/- 2.6		134/99
Ontario Males[2]	21.3 +/- 1.4	119.3 +/- 2.6		85/61

Means are given for each site (+/- standard deviation). n = number of individuals measured.

[1] McCarty unpub. data.
[2] Robertson et al. 1992: number of individuals measured for mass/number measured for wing chord.

Figures

Hudson River Watershed

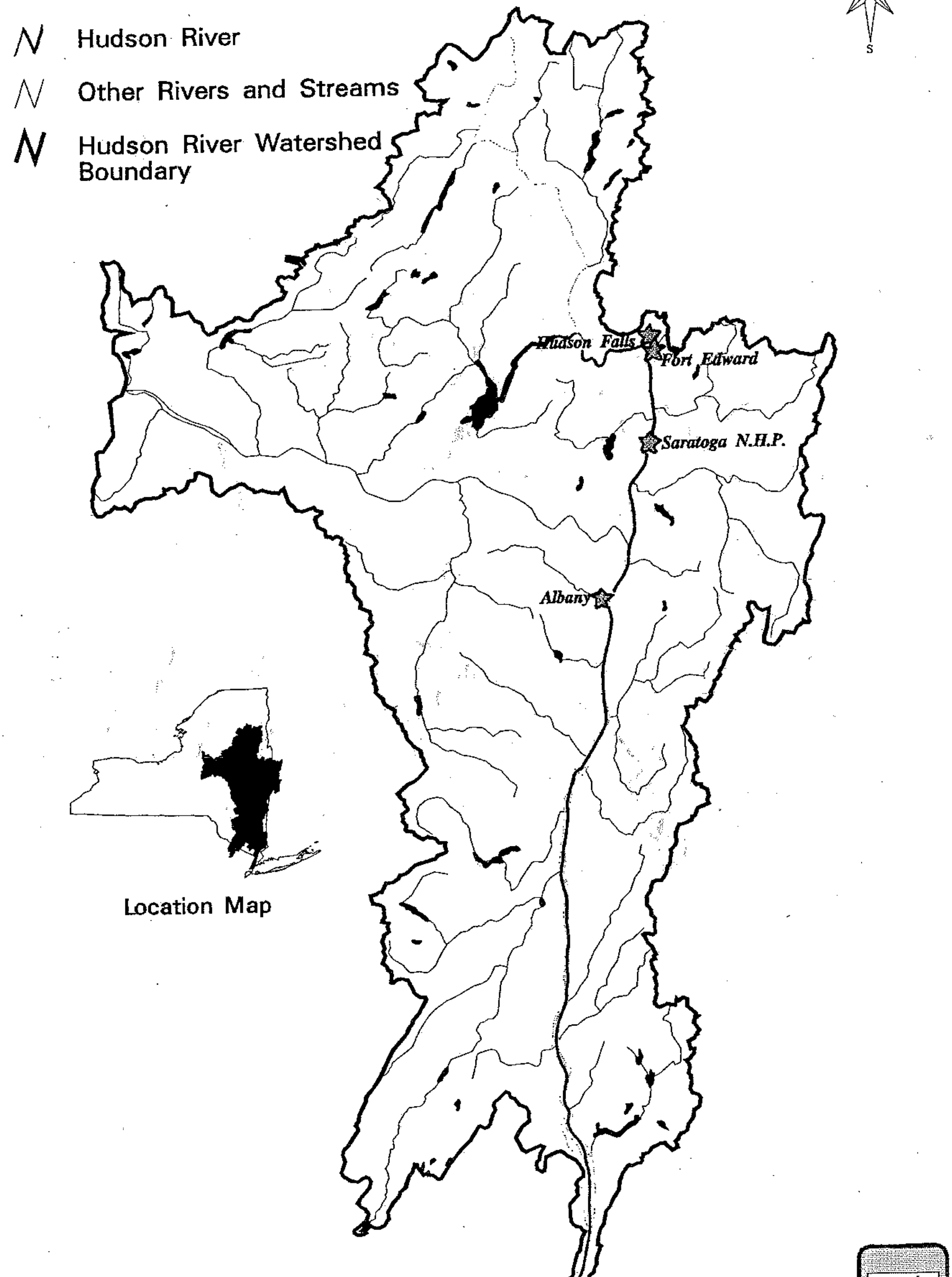


Figure 1.0. Overview of the Hudson River.

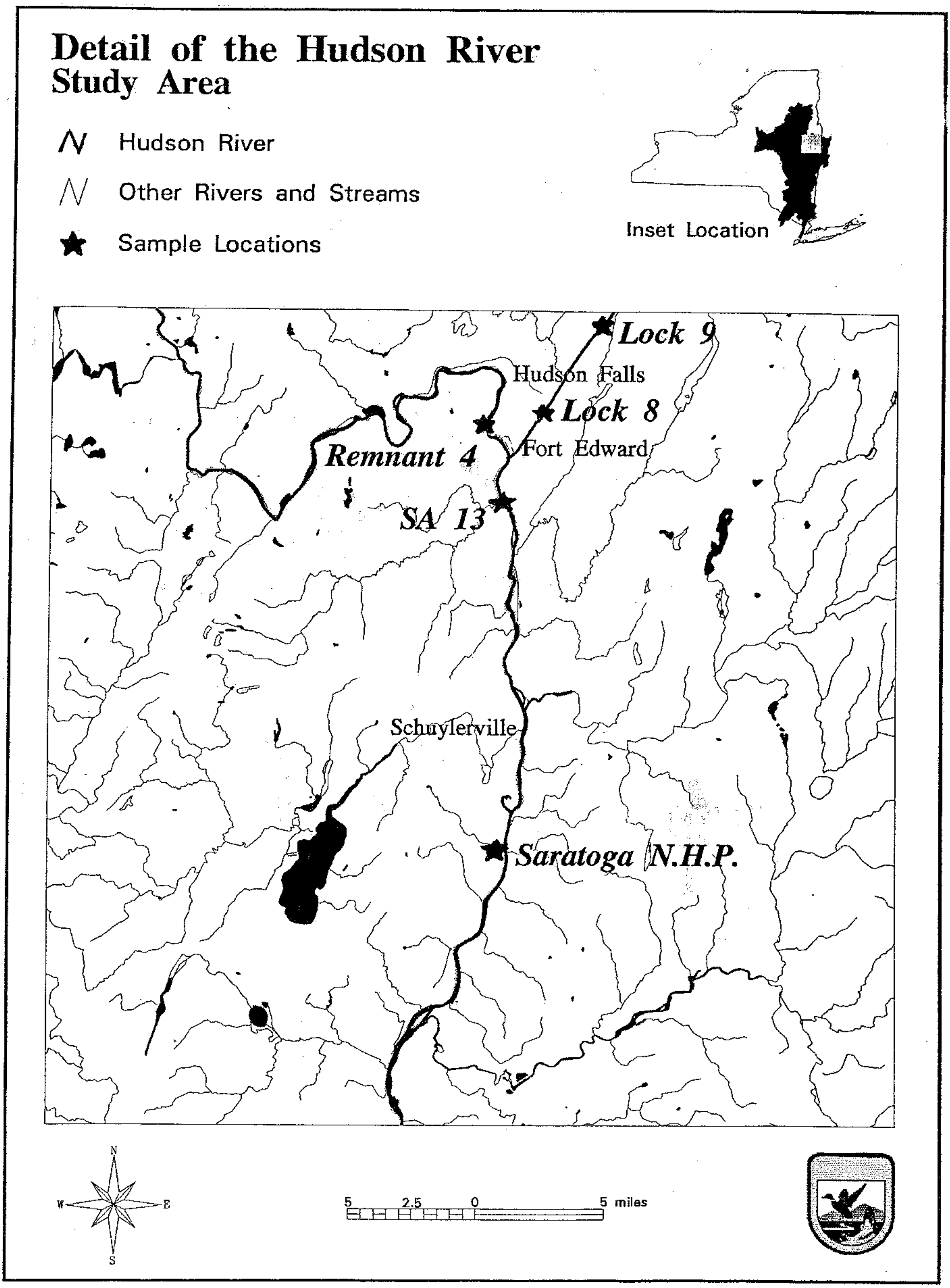
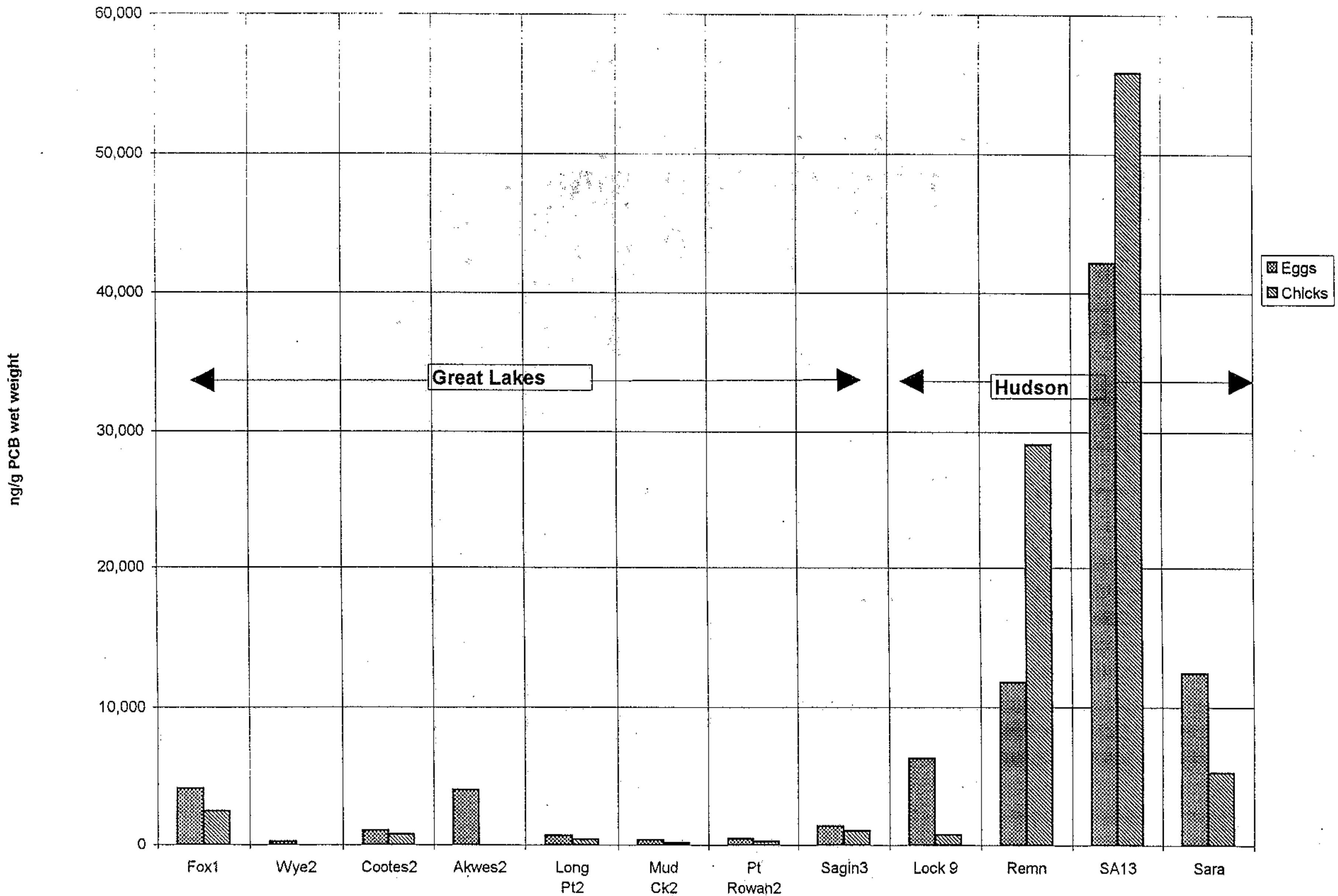


Figure 2.0. 1994 tree swallow sample sites along the upper Hudson River, New York.

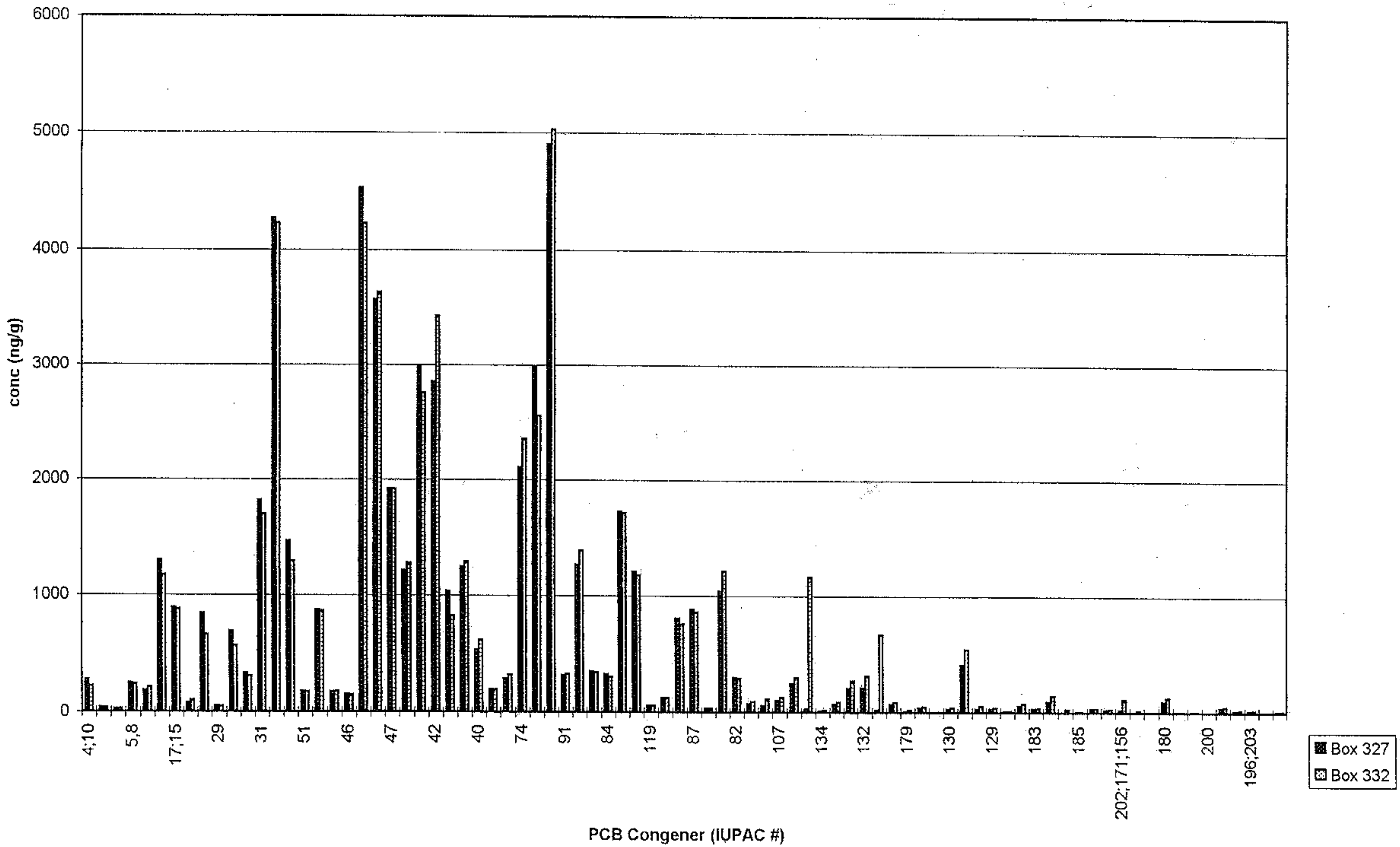
Figure 3.2.3. PCB concentration in tree swallows from the upper Hudson River and Great Lakes ecosystem.



1 Ankley et al. 1993
2 Bishop et al. 1995
3 Nichols et al. 1995

U.S. Fish and Wildlife Service

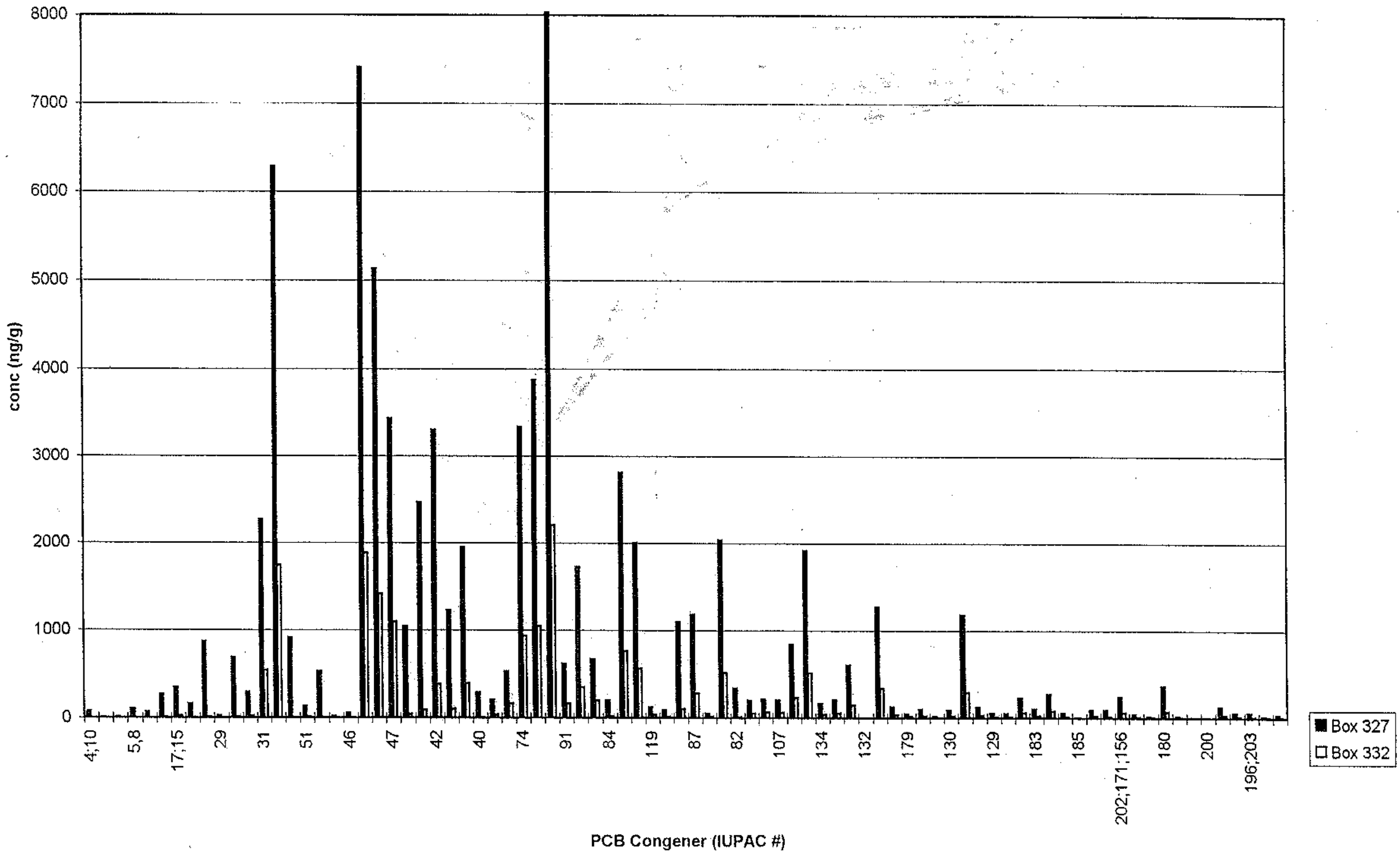
Figure 3.2.4 A. PCB congener distribution in tree swallow nestlings from the SA13 Site - upper Hudson River - 1994.



Each bar represents the concentration of a PCB congener(s) in a two-nestling composite from a single nest.

U.S. Fish and Wildlife Service

Figure 3.2.4 B. PCB congener distribution in tree swallow eggs from the SA13 Site - upper Hudson River - 1994.



U.S. Fish and Wildlife Service

Each bar represents the concentration of a PCB congener(s) in a three-egg composite from a single nest.

Figure 3.2.4 C. Average percent contribution of PCB homologues in tree swallow eggs and nestlings from the upper Hudson River - 1994.

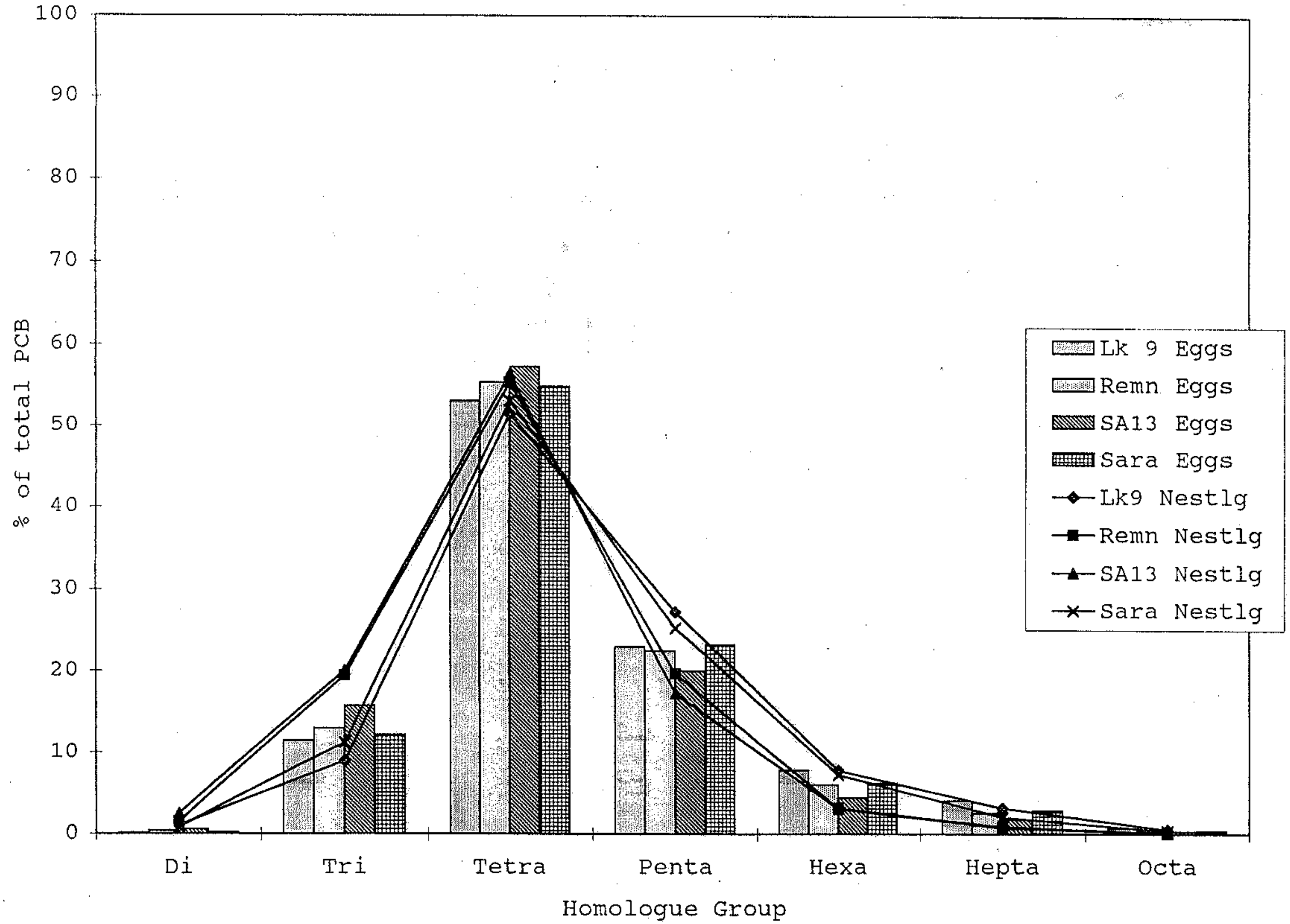
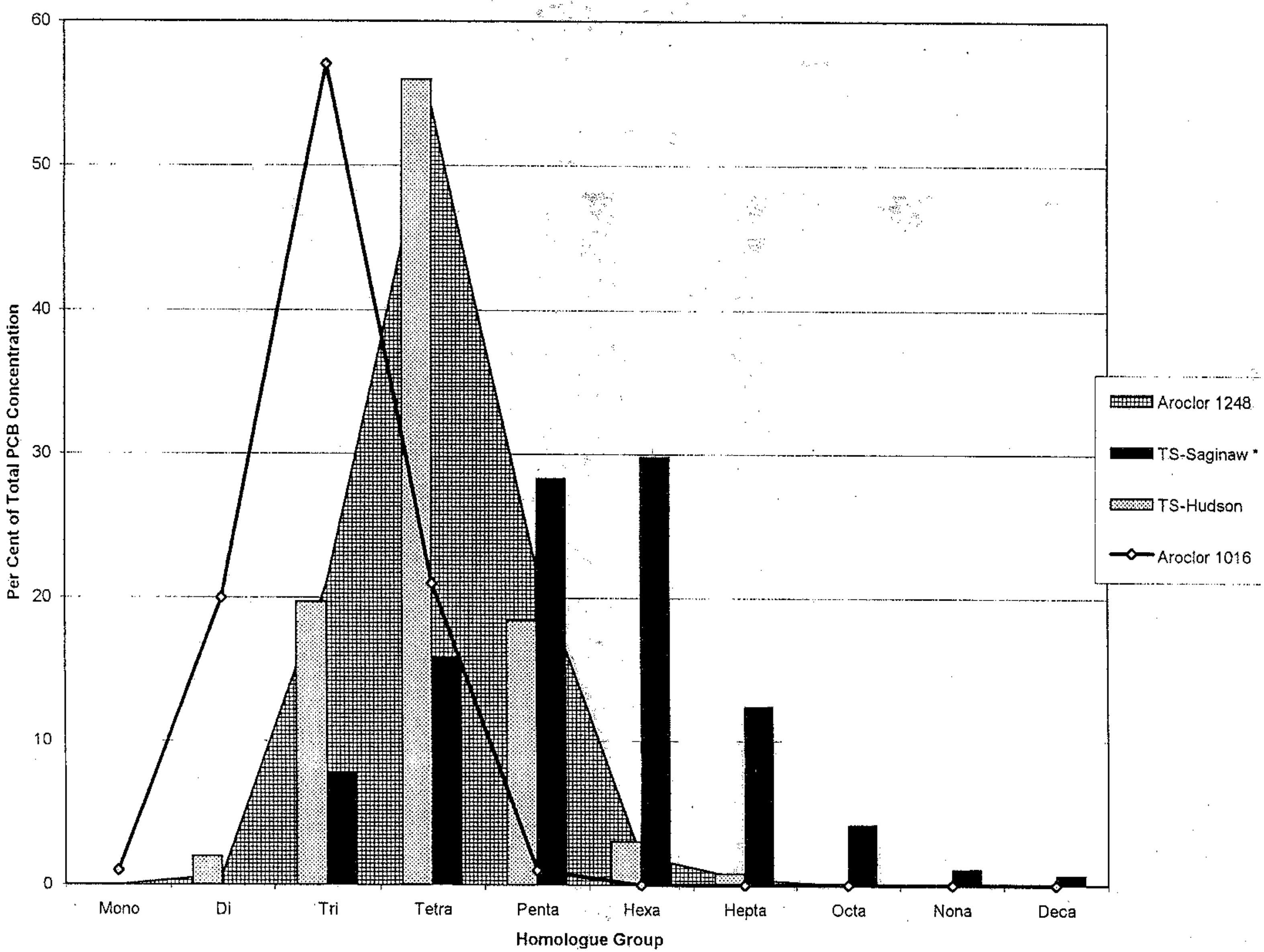
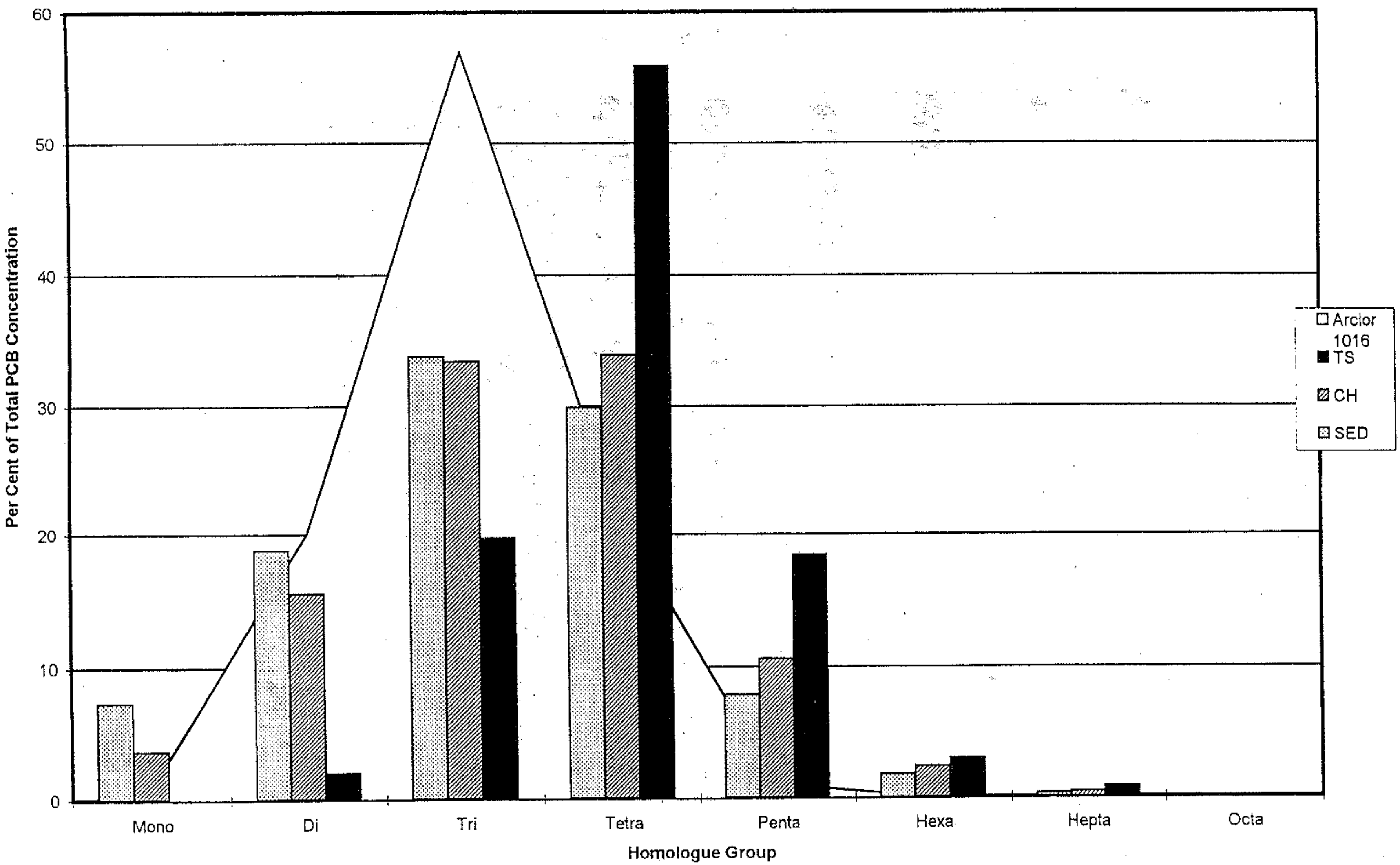


Figure 3.2.4 D. Average Per Cent Contribution of PCB Homologues to Aroclor 1016, Aroclor 1248, and Tree Swallow Nestlings from the Hudson and Saginaw Rivers.



* Saginaw River tree swallow data from Nichols et al. 1995

Figure 3.2.4 E. PCB Homologues in Surficial Sediment, Chironomids, and Nestling Tree Swallows from the Vicinity of Fort Edward, New York



SED: average of 6, 1993 sediment samples - RM 191.5 and 189.5 (Source:TAMS/1996/Phase 2/Eco)
CH: average of 3, 1993 chironomid samples - RM 189.5 and 191.5 (Source: ibid.)
TS: average of 4, 1994 tree swallow samples - Remnant (RM 195) and SA13 (RM 193)

Appendix A

Figure 3.2.5. Mean daily mass of PCBs accumulated by tree swallow nestlings on the upper Hudson River - 1994.

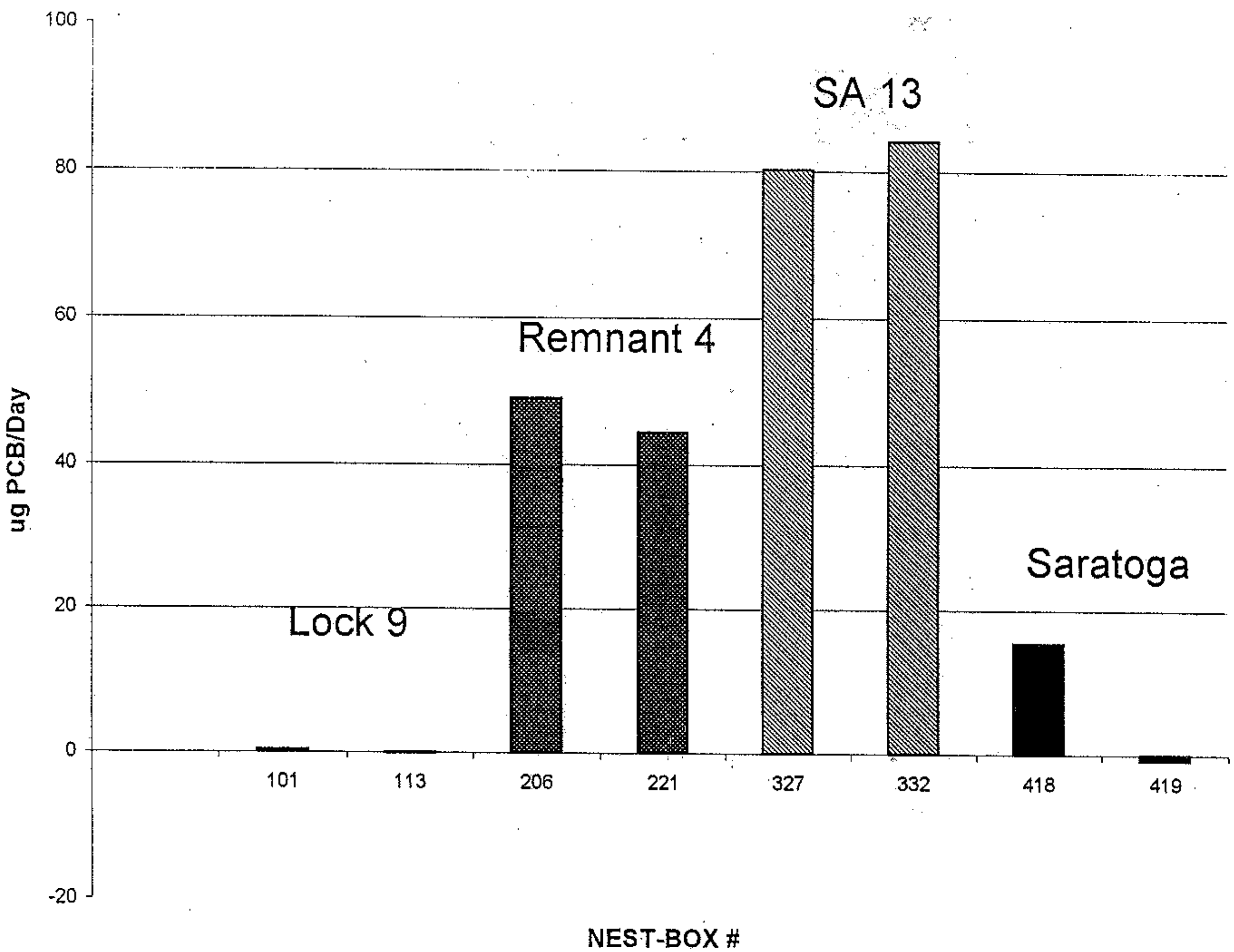
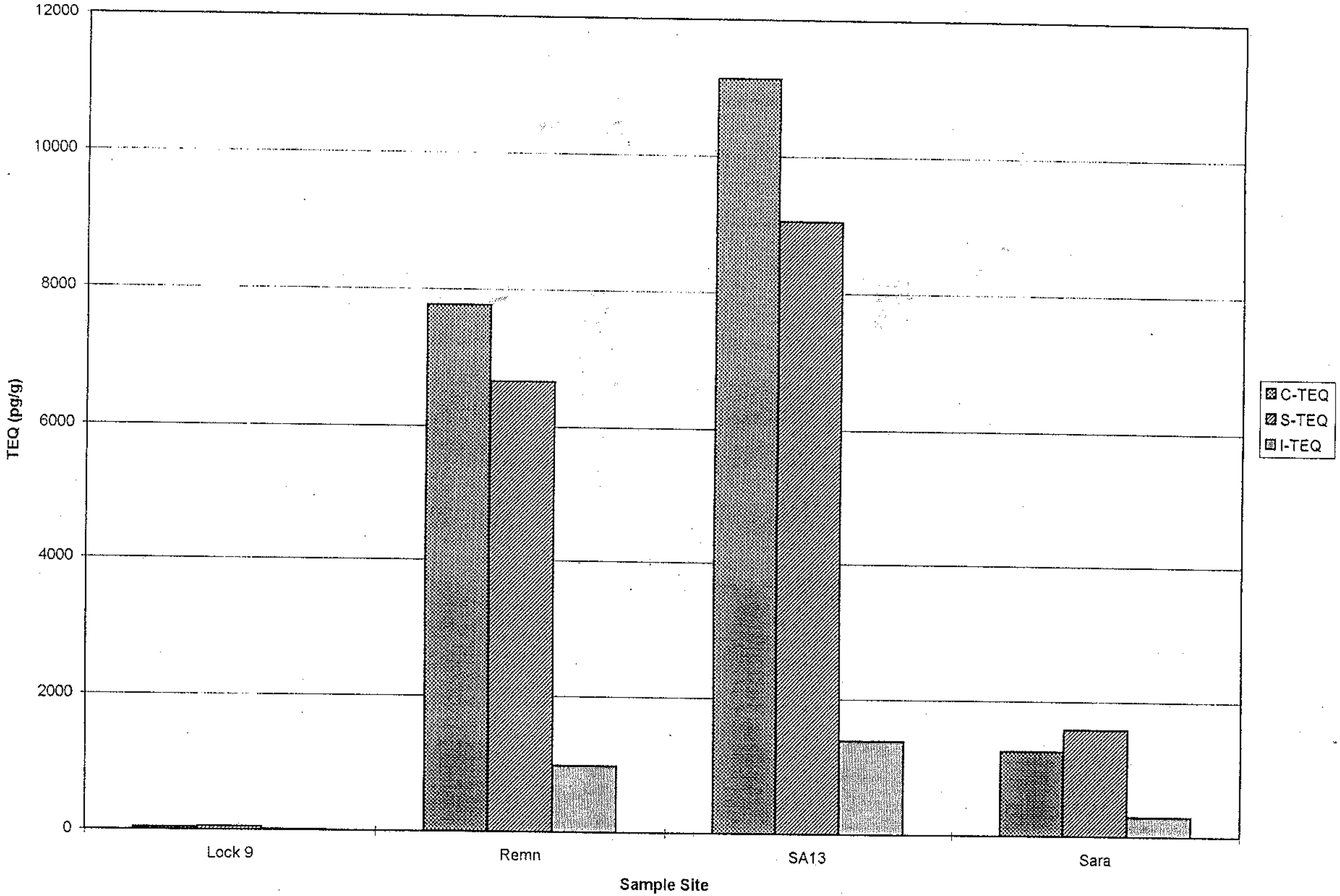


Figure 3.2.6. Comparison of TEQs in tree swallows from the Hudson River (1994) calculated from C-TEFs, S-TEFs, and I-TEFs.



C-TEQs calculated from C-TEFs developed by Kubiak (1991) and Bosveld et al. 1992; S-TEQs developed from S-TEFs (Safe 1990); I-TEQs from Ahlborg et al. 1994 and 1992.

U.S. Fish and Wildlife Service

Figure 3.7. Comparison of nestling tree swallow growth from sites along the upper Hudson River to other studies of nestling tree swallow growth.

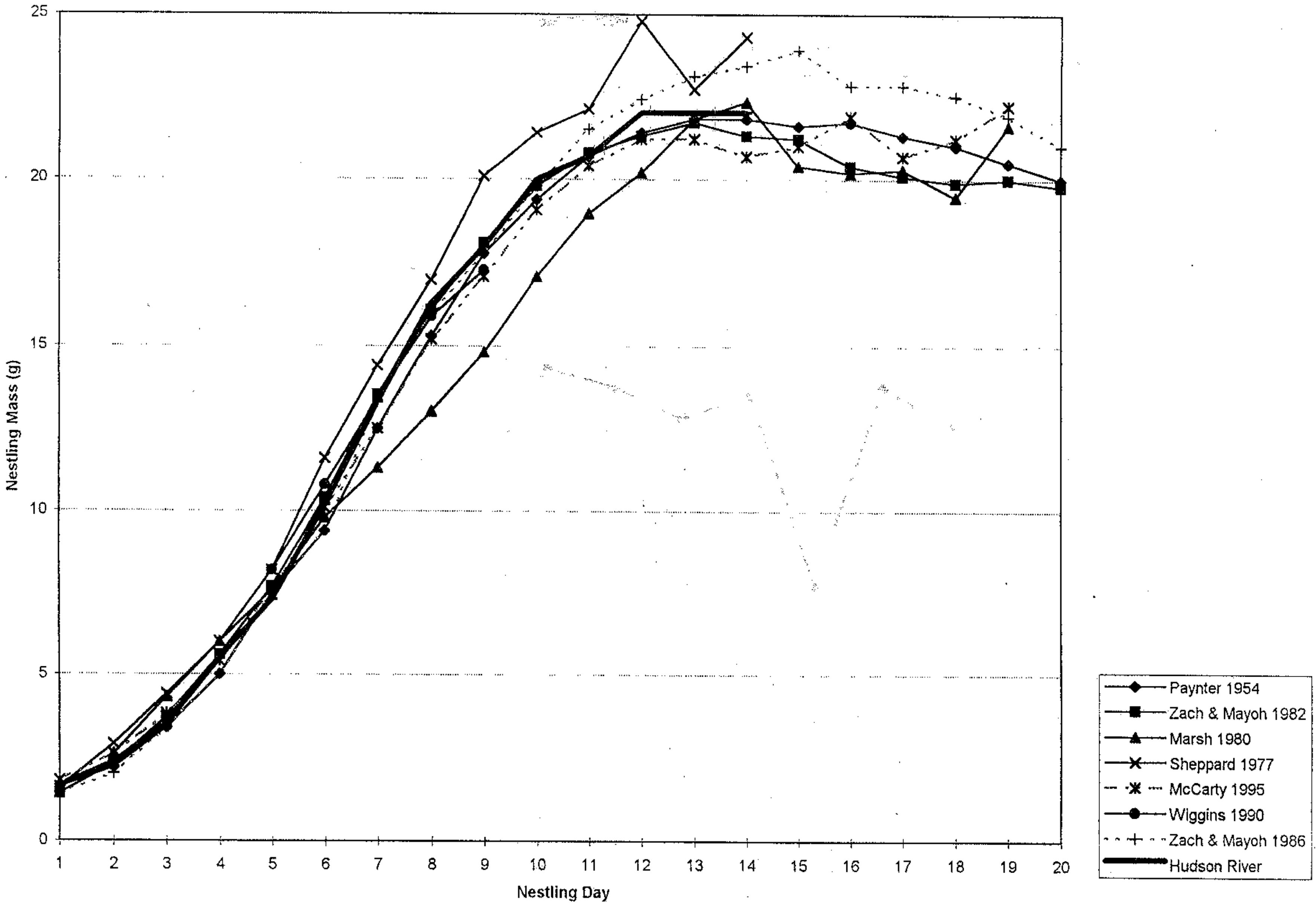
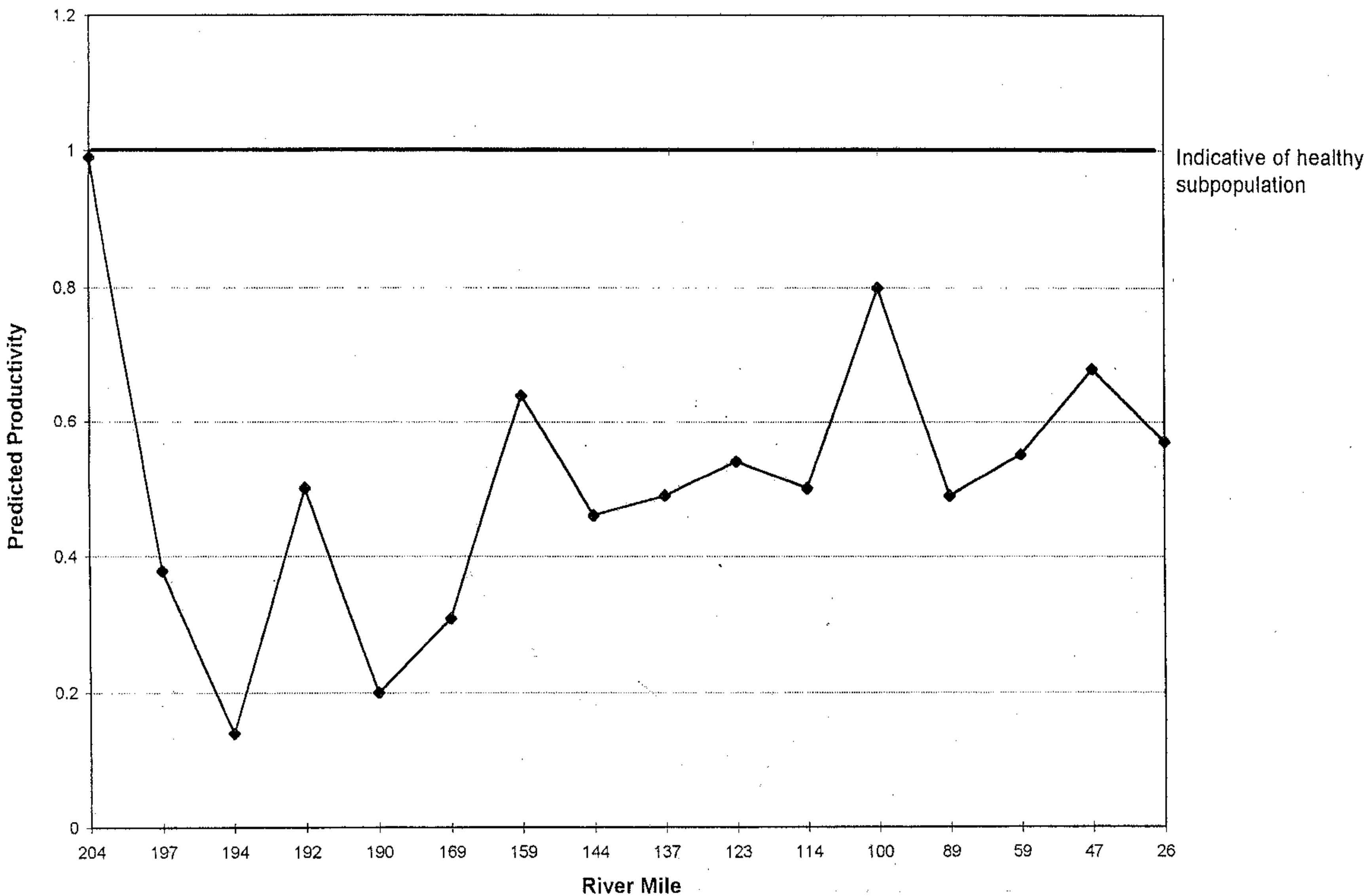


Figure 4.1. Bald eagle productivity, as measured by the # of eaglets per occupied breeding area, predicted for the Hudson River based on the likely PCB contamination of eagle forage.



Appendix A

Appendix A. Results of Congener Specific PCB Analysis of Tree Swallow Eggs and Nestlings - 1994 Upper Hudson River.

River

MSC CHEMISTRY DATABASE #'s	FIELD ID	Nest #	% Lipid	004,010	007,009	006	005,008	019	018	017,015	024,027
11090	Tree Swallow Egg NYFD/E1	419	8.1	< 0.4	< 0.4	< 0.4	< 1.2	2.8	7.2	23.4	10.3
11091	Tree Swallow Egg NYFD/E3	406	8.2	< 1.2	< 0.4	< 0.4	< 1.2	1.2	3.6	30.8	4.7
11092	Tree Swallow Egg NYFD/E6	325	7.1	14.9	< 1.2	1.9	11.9	25.0	85.1	96.7	46.4
11093*	Tree Swallow Egg NYFD/E7	327	7.1	77.5	3.0	10.8	99.8	64.2	270	344	157
11094	Tree Swallow Egg NYFD/E10	418	8.0	< 1.2	< 0.4	< 0.4	< 1.2	< 1.2	4.0	9.8	< 1.2
11095	Tree Swallow Egg NYFD/E12	332	7.7	< 1.2	< 0.4	< 0.4	< 1.2	< 1.2	4.7	24.6	4.0
11096	Tree Swallow Egg NYFD/E13	206	7.4	< 1.2	< 0.4	< 0.4	1.8	1.3	13.5	23.8	1.6
11097	Tree Swallow Egg NYFD/E16	113	7.3	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	6.7	< 0.4
11098	Tree Swallow Egg NYFD/E18	208	6.3	2.1	< 1.2	< 1.2	8.6	5.4	56.3	39.5	3.5
11099	Tree Swallow Egg NYFD/E19	221	6.6	17.7	< 1.2	1.3	12.8	5.8	39.3	50.1	3.3
11100	Tree Swallow Egg NYFD/E23	108	5.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 1.2	1.9	< 0.4
11101	Tree Swallow Egg NYFD/E29	101	8.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 1.2	1.4	< 0.4
11102	Tree Swallow Chick NYFD/C1	419	6.6	4.6	< 0.4	< 0.4	1.3	2.7	5.4	6.4	2.7
11103	Tree Swallow Chick NYFD/C12	332	9.3	221.1	34.0	28.1	239	215	1168	872	101
11104-A	Tree Swallow Chick NYFD/C15	221	8.5	26.2	10.1	4.1	48.0	51.2	559	298	24.0
11104-B	Tree Swallow Chick NYFD/C15	221	8.4	24.3	9.3	3.5	49.9	54.5	614	332	25.7
11104-C	Tree Swallow Chick NYFD/C15	221	8.4	24.6	9.2	3.4	47.0	52.3	575	308	24.4
11105-A	Tree Swallow Chick NYFD/C20	113	8.0	< 1.2	< 0.4	< 0.4	< 0.4	< 1.2	2.0	2.8	< 1.2
11105-B	Tree Swallow Chick NYFD/C20	113	7.9	< 1.2	< 0.4	< 0.4	< 0.4	< 1.2	1.7	2.6	< 1.2
11105-C	Tree Swallow Chick NYFD/C20	113	7.6	< 1.2	< 0.4	< 0.4	< 0.4	< 1.2	1.6	2.5	< 1.2

*Average of GC Replicates Note: These samples were not fractionated on carbon.
MDL = 0.4 ng/g
MQL = 1.2 ng/g

Appendix A. Results of Congener Specific PCB Analysis of Tree Swallow Eggs and Nestlings - 1994 Upper Hudson River (continued).

ver

MSC CHEMISTRY DATABASE #'s	016,032	029	026	025	031	028	020,033,053	051	022	045	046	052	049,043
11090	25.4	2.6	28.3	26.0	432	1188	90.4	15.2	8.2	< 1.2	2.3	1622	1256
11091	7.7	2.9	12.2	20.3	534	1666	101	13.6	3.0	< 1.2	1.3	2019	1543
11092	155	9.9	139	105	1267	2722	279	54.3	39.0	8.4	23.0	2907	2031
11093*	872	21.7	689	293	2270	6288	909	128	530	18.2	50.5	7412	5137
11094	4.0	< 1.2	4.5	8.6	50.7	160	7.7	1.2	4.2	< 1.2	< 1.2	161	134
11095	11.9	2.6	12.9	22.9	544	1742	< 1.2	13.1	4.2	< 1.2	2.0	1881	1412
11096	10.1	< 1.2	7.4	8.9	217	637	37.1	5.8	4.8	1.8	2.5	703	507
11097	< 1.2	< 1.2	< 1.2	2.1	151	558	21.9	1.7	< 0.4	< 0.4	2.1	657	436
11098	33.2	2.9	20.8	15.9	442	2144	102	9.5	16.7	6.4	7.1	2492	1798
11099	39.2	1.8	23.9	16.9	234	1224	54.7	7.5	20.2	3.5	4.2	1434	980
11100	< 0.4	< 0.4	< 0.4	1.4	28.5	223	< 1.2	< 0.4	< 0.4	< 0.4	< 0.4	260	161
11101	1.5	< 0.4	< 1.2	1.7	5.1	37.0	1.6	< 0.4	< 1.2	< 0.4	< 0.4	60.3	33.3
11102	9.6	< 0.4	9.5	3.7	17.4	33.5	9.2	3.5	3.7	< 1.2	< 1.2	61.6	51.9
11103	661	47.9	566	308	1702	4231	1291	175	862	178	145	4227	3634
11104–A	258	20.3	239	124	1091	2173	444	75.2	180	64.0	59.2	2330	1954
11104–B	284	20.4	256	134	1129	2545	481	81.8	192	66.5	60.6	2649	2205
11104–C	266	19.3	240	124	1116	2243	452	78.3	178	66.7	61.0	2465	2049
11105–A	1.5	< 0.4	< 1.2	1.6	5.0	31.4	4.6	< 1.2	< 1.2	< 1.2	< 1.2	53.9	37.5
11105–B	1.3	< 0.4	< 1.2	1.4	4.6	29.6	4.4	< 1.2	< 1.2	< 1.2	< 1.2	52.0	36.1
11105–C	1.3	< 0.4	< 1.2	1.4	4.0	27.9	4.2	< 1.2	< 1.2	< 1.2	< 1.2	49.4	34.1

*Average of GC Replicates
MDL = 0.4 ng/g
MQL = 1.2 ng/g

Appendix A. Results of Congener Specific PCB Analysis of Tree Swallow Eggs and Nestlings - 1994 Upper Hudson River (continued).

ìiver

MSC CHEMISTRY DATABASE #'s	047	048	044	042	041	064	040	067	063	074	070,076	066,095,088	091
11090	929	125	129	351	105	312	7.1	41.0	149.2	768	789	1849	179
11091	1283	38.7	76.6	34.9	110	374	3.7	45.7	190.8	949	983	2268	217
11092	1265	320	680	853	504	780	47.0	94.8	240.2	1401	1949	3303	226
11093*	3427	1040	2462	3294	1219	1944	287	204	530	3332	3866	8045	621
11094	126	16.6	16.0	48.0	9.5	20.7	2.6	7.2	28.1	116	100	228	16.8
11095	1094	38.3	86.2	383	102	390	4.4	35.3	161.8	937	1044	2204	162
11096	265	27.1	50.5	195	40.5	129	4.8	13.1	51.6	323	427	801	50.5
11097	281	26.3	7.9	116	20.1	111	3.5	6.5	49.5	296	353	758	48.5
11098	1252	152	106	363	86.2	370	12.5	28.3	224.0	1280	1004	3043	221.6
11099	628	89.1	75.7	152	39.8	178	10.5	17.7	125.7	705	582	1671	116.7
11100	121	9.7	1.3	45.9	46.2	2.9	< 0.4	1.7	28.2	137	87.7	346	23.3
11101	19.0	3.8	4.1	12.4	2.2	5.9	< 1.2	1.4	5.7	23.0	28.4	74.9	6.2
11102	34.1	9.9	23.9	26.3	12.2	14.1	3.5	2.8	4.6	25.1	32.4	63.2	8.2
11103	1919	1273	2756	3426	820	1289	613	196	323	2354	2554	5031	329
11104–A	942	451	1011	1198	320	603	106	101	151	1190	1638	2662	196
11104–B	1075	485	1127	1395	368	682	113	104	162	1334	1842	3118	201
11104–C	997	443	1049	1171	360	603	107	100	148	1212	1680	2842	173
11105–A	22.0	7.9	12.5	15.0	5.4	8.1	1.8	1.3	4.6	22.2	19.7	60.5	4.7
11105–B	21.9	6.4	11.8	14.6	4.9	7.6	1.7	1.3	4.2	21.2	18.1	57.1	4.6
11105–C	20.1	6.8	11.1	14.9	4.7	7.1	1.6	< 1.2	4.4	20.1	17.1	54.2	4.3

*Average of GC Replicates
MDL = 0.4 ng/g
MQL = 1.2 ng/g

Appendix A. Results of Congener Specific PCB Analysis of Tree Swallow Eggs and Nestlings - 1994 Upper Hudson River (continued).

River

MSC CHEMISTRY DATABASE #'s	056,060	092	084	101,090	099	119	083	097	087	136	110	082	151
11090	285	198	16.6	711	525	36.1	8.7	131	279	17.8	449	17.2	67.9
11091	350	235	27.8	841	642	43.7	9.1	109	317	24.9	530	9.4	76.1
11092	606	260	76.4	1069	773	48.6	48.4	339	487	19.2	835	71.3	76.6
11093*	1726	672	196	2812	2002	119	89.1	1092	1182	45.4	2034	337	201
11094	41.0	31.1	1.9	107	96.5	6.7	1.8	17.3	30.5	6.5	50.6	5.2	12.2
11095	353	198	17.3	764	565	36.3	9.1	102	283	19.0	514	10.6	52.1
11096	137	64.5	4.1	281	188	9.6	3.6	40.0	111	6.9	176	5.3	17.1
11097	125	64.9	1.4	260	176	10.1	< 1.2	22.9	98.3	5.1	174	1.2	15.9
11098	513	257	21.6	1066	776	49.9	10.0	51.9	368	14.5	599	9.2	70.6
11099	292	157	14.2	639	445	23.8	5.0	34.7	184	7.9	324	9.0	38.5
11100	63.7	31.1	6.4	133	93.3	5.9	< 0.4	1.5	31.3	4.8	55.0	< 1.2	7.9
11101	13.6	8.7	< 0.4	44.2	23.8	1.4	< 0.4	6.9	12.5	7.4	18.1	2.2	3.6
11102	12.1	8.3	4.9	29.4	19.4	1.4	1.8	9.7	11.9	2.0	18.9	3.0	4.2
11103	1393	343	302	1720	1172	59.5	124	754	654	37.4	1206	288	94.7
11104-A	580	176	130	906	597	29.2	55.8	320	440	23.3	605	87.1	44.1
11104-B	628	199	146	999	655	31.2	61.5	351	472	23.0	656	92.3	48.4
11104-C	571	185	136	939	606	29.1	55.9	324	444	24.1	599	86.0	44.8
11105-A	11.4	6.2	2.4	29.3	17.8	< 1.2	< 1.2	6.8	10.7	< 1.2	16.4	1.8	2.0
11105-B	10.8	6.4	2.5	28.6	17.4	< 1.2	< 1.2	6.6	10.2	< 1.2	14.9	1.8	2.0
11105-C	10.2	6.0	2.3	27.1	16.5	< 1.2	< 1.2	6.2	9.7	< 1.2	13.3	1.7	1.9

*Average of GC Replicates
MDL = 0.4 ng/g
MQL = 1.2 ng/g

Appendix A. Results of Congener Specific PCB Analysis of Tree Swallow Eggs and Nestlings - 1994 Upper Hudson River (continued).

River

MSC CHEMISTRY DATABASE #'s	135,144,124	107	123,149	118	134	146	153	132	105	141	179	137	176
11090	71.1	58.0	271	459	5.0	59.6	161	< 0.4	331	46.8	28.9	28.6	5.0
11091	80.6	69.8	303	541	3.4	69.2	181	< 0.4	375	50.0	12.4	29.4	6.3
11092	96.2	79.5	278	735	3.5	71.4	201	< 0.4	542	60.5	5.4	39.7	8.2
11093*	208	199	841	1916	163	205	607	< 0.4	1269	125	45.4	101.9	19.6
11094	12.9	14.1	50.7	94.1	< 0.4	20.0	55.8	< 0.4	59.5	11.5	1.8	6.8	< 0.4
11095	62.8	60.6	230	515	42.7	54.2	149	< 0.4	341	35.3	14.8	25.1	6.1
11096	24.5	19.9	64.1	196	16.9	21.0	65.1	< 0.4	129	15.6	4.7	9.9	1.5
11097	21.0	21.1	80.4	186	15.3	19.3	58.7	< 0.4	123	13.2	3.6	9.3	< 0.4
11098	86.3	91.4	346	774	6.7	88.3	245	< 0.4	565	59.2	13.6	46.8	3.9
11099	51.0	49.1	195	464	40.3	50.1	146	< 0.4	305	32.1	9.4	24.1	5.0
11100	11.2	12.9	46.5	109	10.2	16.5	43.3	< 0.4	74.6	< 1.2	< 0.4	8.0	< 0.4
11101	4.5	4.7	20.1	40.2	< 0.4	12.9	34.2	< 0.4	23.3	4.4	< 1.2	4.3	< 1.2
11102	3.4	2.3	12.4	17.9	< 0.4	3.0	8.5	< 0.4	10.6	2.1	< 1.2	< 1.2	< 0.4
11103	116	128	299	1158	16.3	87.8	274	314	669	88.1	20.2	47.6	5.5
11104–A	68.5	66.0	205	618	5.5	44.2	147	< 0.4	415	48.6	10.0	26.5	6.6
11104–B	72.7	70.8	229	676	5.8	48.2	165	< 0.4	438	48.1	9.2	27.9	5.1
11104–C	67.2	64.2	207	592	5.7	43.8	148	< 0.4	395	43.7	11.9	24.9	5.3
11105–A	2.3	2.6	9.3	19.4	< 1.2	2.6	8.0	< 0.4	12.6	1.9	< 0.4	1.2	< 0.4
11105–B	2.2	2.2	8.7	18.2	< 1.2	2.5	7.6	< 0.4	11.4	1.9	< 1.2	< 1.2	< 0.4
11105–C	2.1	2.2	8.1	17.8	< 1.2	2.4	7.4	< 0.4	11.2	1.8	< 1.2	< 1.2	< 0.4

*Average of GC Replicates
MDL = 0.4 ng/g
MQL = 1.2 ng/g

Appendix A. Results of Congener Specific PCB Analysis of Tree Swallow Eggs and Nestlings - 1994 Upper Hudson River (continued).

MSC CHEMISTRY DATABASE #'s	130	138	158	129	178	182,187	183	128	167	185	174	177	202,171,156
11090	30.8	331	30.6	14.8	15.6	73.5	26.1	80.1	13.3	2.6	29.6	26.3	67.0
11091	26.7	360	33.9	13.5	17.8	81.8	28.4	88.7	14.6	2.9	33.3	29.4	74.2
11092	37.1	414	45.9	23.0	15.3	73.6	32.0	107	20.1	2.7	31.8	28.1	89.3
11093*	85.8	1181	117	55.0	45.0	227	98.8	270	50.8	5.8	86.6	85.0	241
11094	7.9	91.3	8.6	2.6	6.5	31.8	12.6	19.1	4.2	< 1.2	9.6	10.0	22.9
11095	25.0	294	30.3	12.8	12.6	56.3	22.8	75.5	12.3	2.1	23.4	18.5	58.3
11096	7.9	122	11.6	4.1	4.8	26.3	10.7	28.7	5.3	< 1.2	11.5	8.1	25.0
11097	9.7	111	10.1	3.0	4.1	22.7	9.0	28.8	5.0	< 1.2	8.3	7.2	21.4
11098	45.2	478	58.6	12.3	20.7	99.1	43.8	123	24.3	3.1	37.7	33.7	113
11099	22.2	284	26.7	4.2	12.2	63.1	24.4	70.6	13.4	1.6	21.1	21.5	59.1
11100	7.0	78.9	9.3	< 1.2	3.8	20.2	9.1	21.0	5.4	< 1.2	6.9	5.0	21.3
11101	3.7	52.1	6.1	< 1.2	4.5	26.1	8.1	10.9	4.4	< 1.2	4.1	5.3	16.1
11102	1.2	14.3	< 1.2	< 1.2	< 1.2	4.1	< 1.2	3.4	< 1.2	< 0.4	1.7	1.3	2.6
11103	38.0	544	55.0	41.3	13.2	73.8	36.5	144	26.1	4.6	36.5	27.0	111
11104–A	22.9	330	31.4	19.4	6.9	41.4	20.7	73.1	12.3	2.3	22.0	14.9	62.0
11104–B	23.9	316	33.6	19.1	7.8	45.8	22.1	77.3	12.4	2.1	23.5	15.7	63.0
11104–C	18.9	297	31.3	18.2	7.1	40.4	20.2	70.6	11.2	2.2	21.7	14.8	57.8
11105–A	< 1.2	13.3	1.2	< 1.2	1.5	2.9	< 0.4	3.5	< 1.2	< 0.4	< 1.2	< 1.2	3.0
11105–B	< 1.2	12.8	1.2	< 1.2	< 1.2	2.5	< 1.2	3.2	< 1.2	< 0.4	< 1.2	< 1.2	2.7
11105–C	< 1.2	12.0	< 1.2	< 1.2	< 1.2	2.5	< 1.2	3.1	< 1.2	< 0.4	< 1.2	< 1.2	2.6

*Average of GC Replicates
MDL = 0.4 ng/g
MQL = 1.2 ng/g

Appendix A. Results of Congener Specific PCB Analysis of Tree Swallow Eggs and Nestlings - 1994 Upper Hudson River (continued).

MSC CHEMISTRY DATABASE #'s	157,201	172	180	193	191	200	170,190	199	196,203	208,195	194	Total-cPCBs
11090	15.9	4.4	91.3	3.8	1.8	1.6	31.4	16.8	13.7	5.4	8.1	15678
11091	16.0	5.1	92.9	5.9	3.0	1.6	35.6	19.7	16.0	5.8	9.4	18493
11092	19.8	5.2	106	4.4	2.8	1.2	43.5	15.9	16.1	5.3	10.6	29635
11093*	41.5	14.9	360	15.0	7.1	3.2	123	53.1	51.8	17.9	33.2	77346
11094	5.1	2.4	58.2	3.1	2.3	< 1.2	15.7	9.7	8.6	3.1	6.0	2370
11095	12.5	3.9	69.4	3.8	2.3	< 1.2	27.6	12.8	11.0	3.9	7.4	17591
11096	5.5	1.8	37.9	1.8	< 1.2	< 1.2	12.1	6.7	6.0	2.1	3.9	6548
11097	4.0	1.5	30.6	1.4	< 1.2	< 0.4	10.6	4.8	4.4	1.6	2.8	5724
11098	26.2	7.7	142	6.5	3.8	1.5	58.4	24.6	22.7	7.3	14.3	22888
11099	12.2	3.9	79.9	4.0	1.8	< 1.2	29.9	15.4	13.3	4.9	9.5	12923
11100	4.8	2.0	39.2	2.4	1.6	< 0.4	12.4	5.8	5.7	1.8	4.1	2566
11101	3.9	2.1	37.3	3.5	1.4	< 0.4	11.7	7.7	6.1	2.5	4.6	852
11102	< 1.2	< 0.4	3.8	< 0.4	< 0.4	< 0.4	1.5	< 1.2	< 1.2	< 0.4	< 1.2	721
11103	17.9	6.3	126	5.0	2.8	< 1.2	47.8	16.3	17.8	4.8	13.1	56770
11104-A	13.1	3.2	70.8	2.6	1.4	< 1.2	26.7	10.5	9.8	2.7	6.6	27063
11104-B	10.9	3.3	75.6	2.7	1.4	< 1.2	26.6	9.7	10.4	2.8	6.9	30195
11104-C	11.0	3.1	68.9	2.5	1.4	< 1.2	24.3	9.0	9.6	2.7	6.6	27691
11105-A	< 1.2	< 0.4	4.6	< 0.4	< 0.4	< 0.4	1.5	< 1.2	< 1.2	< 0.4	< 1.2	531
11105-B	< 1.2	< 0.4	4.2	< 0.4	< 0.4	< 0.4	1.4	< 1.2	< 1.2	< 0.4	< 0.4	512
11105-C	< 1.2	< 0.4	4.1	< 0.4	< 0.4	< 0.4	1.3	< 1.2	< 1.2	< 0.4	< 0.4	487

*Average of GC Replicates
MDL = 0.4 ng/g
MQL = 1.2 ng/g