Final Report to U.S. Environmental Protection Agency

Exposure and effects of chemical contaminants on tree swallows nesting along the Housatonic River, Berkshire Co., Massachusetts, 1998 – 2000.

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July 8, 2002

INTRODUCTION

The Housatonic River near Pittsfield, Massachusetts has been contaminated with polychlorinated biphenyls (PCBs). The construction and repair of electrical transformers, which contained mixtures of Aroclors 1254 and 1260, occurred between 1932 and 1977 at a facility on the Housatonic River in Pittsfield, Massachusetts (Beach et al. 2000). Releases of PCBs, including the rupture of a 1,000-gallon PCB storage tank in the late 1960s, reached riverbank soil and the Housatonic River. The current extent of PCB contamination in the flood plain coincides roughly with the 5-year flood plain of the Housatonic River (Beach et al. 2000).

In 1993, the nest success of eight passerine species, within and outside the 10-year flood plain of the Housatonic River, was monitored (Henning et al. 1997). Henning et al (1997) found no difference in clutch size, hatching rate and fledging success between birds nesting within and outside the 10-year flood plain ($N < 10$ nests for 10 of 12 species/locations). They concluded that PCBs were not affecting reproduction in songbirds although statistical power was low in that study because of small sample size. No data, however, on PCB concentrations in bird tissues or their food were collected during that study. Additionally, of the eight species studied, only the barn swallow (*Hirundo rustica*) is an aquatic insectivore. The other species studied feed on terrestrial insects that are less likely to be exposed to contamination from contaminated sediments (Ankley et al. 1993).

Swallows, especially tree swallows (*Tachycineta bicolor*) are now being widely used as indicators of local sediment contamination (Shaw 1983; DeWeese et al. 1985;

Kraus 1989; Ankley et al. 1993; King et al. 1994; Bishop et al. 1995; Nichols et al. 1995; Custer, C. M. et al. 1998, 2000, 2002; Secord et al. 1999; Custer, T.W. et al 2002). Tree swallows will readily use nest boxes, so study sites can be established at specific sites of interest. They feed near their nest box (approx. 300 - 400 m, Quinney and Ankney 1985; Dunn and Hannon 1992) primarily on emergent aquatic insects (Blancher and McNicol 1991) so residues in their tissues reflect local sediment contamination for those chemicals that transfer into the insect biota (Fairchild et al. 1992). They also will nest relatively densely so that adequate sample sizes can be obtained. Data for tree swallows are now available on PCB contaminant levels at a number of locations across the U. S. and Canada (Bishop et al. 1995, 1999; Custer et al. 1998, 2000; Custer, T.W. et al 2002; McCarty and Secord 1999; Secord et al. 1999), other organochlorines (Shaw 1983; DeWeese et al. 1985; Elliott et al. 1994), dioxins (Custer, T.W. et al. 2002), trace elements (Kraus 1989; King et al. 1994; Custer et al. 2001; Custer, C.M. et al. 2002), and polycyclic aromatic hydrocarbons (Custer et al. 2001).

Two studies of tree swallows at other PCB-contaminated sites in the U.S. (Custer et al. 1998) and Canada (Bishop et al. 1995, 1999) reported no effects of PCBs on hatching success. A study along the Hudson River in New York, however, which is heavily contaminated with PCBs (Bopp et al. 1981), suggested effects on reproduction in one of two years (McCarty and Secord 1999). The objectives of this study were to determine the exposure of tree swallows to PCBs and other chemicals in the Housatonic River Valley and to determine whether hatching success was related to chemical exposure.

METHODS

Overview

Nest boxes were erected at sites along the main stem and tributaries of the Housatonic River, as well as, at an in-basin reference location in 1998, 1999, and 2000. Number of eggs laid and hatching success were monitored throughout the spring and summer. For all three years, samples of eggs, nestlings, and diet were collected at appropriate times and analyzed for a suite of organochlorine chemicals including total PCBs and PCB congeners. Trace elements, dioxin and furans, and petroleum hydrocarbons were analyzed in only a subset of tissues and years. Accumulation rates of total PCBs in nestlings were calculated and compared among years. Concentrations of organochlorine chemicals were compared among sites and years using standard statistical analyses. The relationship between organochlorine chemicals and hatching success was tested using logistic regression techniques.

Field collections

Nest boxes, at least 30 boxes per site, were deployed and sampled in 1998 from four sites along the Housatonic River and its tributaries in Berkshire Co., Massachusetts (Fig. 1, Table 1). Three sites were located along the main stem of the Housatonic River, and from upstream to downstream, were designated as Canoe Meadows, Lenox Road, and Roaring Brook. One upstream tributary site, West Branch, was also sampled (Fig. 1). In 1999, a second upstream, tributary site was added (Taconic Valley), as well as, a reference site (Threemile Pond). Threemile Pond is not on the Housatonic River, but is in the Housatonic River basin. Additional nest boxes were also added at most of the

original four sites in 1999 and at Threemile Pond in 2000. All six sites were monitored and sampled in 2000.

Nest boxes were deployed in early April each year and nest box monitoring began during the first part of May and continued approximately weekly until the majority of young reached 12 days of age. Monitoring was stopped at this point so as not to cause premature fledging of young. Boxes were checked daily around the expected hatching date so that the fate of all eggs could be determined and samples collected for chemical analysis on that date (see below). During each nest check the number of eggs and/or young in each nest were counted.

Samples of eggs or just hatched young (hereafter together termed pippers) were collected for organochlorine contaminant analyses from all clutches as they pipped, and from clutches that failed to hatch if they persisted past the anticipated hatching date. Two pippers/nest (from 5-egg clutches) or three pippers/nest (from 6-egg or larger clutches) were collected on the day that the clutch hatched. One 12-day-old nestling was collected from between five and eight of these clutches per site to quantify chemical concentration and accumulation rates in nestlings (Custer and Custer 1995). An additional 12-day-old nestling was collected from a sample of these same nests to assay for hepatic ethoxyresorufin-O-dealkylase (EROD) activity (see methods below). The boxes from which nestlings were collected were boxes from which a sibling pipper sample had been collected. Food samples were collected from the stomachs of just-hatched and 12-day-old nestlings for chemical analyses. These diet samples were pooled by site because of the small sample mass, except in 1999 when two pools per site were made; one from

pippers and one from 12-day-old nestlings. In 1998 and 2000 only one food sample/site was chemically analyzed.

Sample processing

After being removed from a nest, pipper samples were weighed and if it was an egg, the contents were emptied into a chemically-clean jar provided by a commercial source. If the pipper was a just-hatched young, the young was weighed and then decapitated. The contents of the stomach were removed, and the carcass remainder, including the decapitated head, were placed in a chemically-clean jar. Two - three pippers from a nest were pooled into one sample to provide adequate mass for the analytical laboratory. Twelve-day old nestlings (± 1 day of age) were processed similarly. Immediately after death by decapitation, a small sample of liver was removed and snap-frozen in liquid nitrogen for EROD analysis (1999 and 2000 only). The stomach contents were removed as well. The 12-day old nestling samples consisted of the total carcass plus decapitated head minus a small piece of liver (approx. 0.3 g) and the stomach contents.

Chemistry

Organochlorine pesticides (N = 26), total PCBs, and PCB congeners (N > 90), were analyzed in pipper and nestling samples using standard methodology (see specifics in the following paragraph). In 1999 and 2000, but not in 1998, 5 Aroclors, 1242, 1248, 1254, 1260, 1268 were included in the chemical analyses. Polychlorinated dibenzo-*p*-dioxins (dioxins) and polychlorinated dibenzofurans (furans) (N = 16) were analyzed in one pooled pipper and one pooled nestling sample per site in 1998. Dioxins and furans were analyzed in individual pipper samples in 1999 and 2000 and in individual nestling

samples in 1999 as well. Polycyclic aromatic (PAH, N = 39) and aliphatic (AH, N = 27) hydrocarbons were analyzed in nestling carcasses in 2000. Trace elements (N = 19) were analyzed in nestling carcasses in 1998 and in pipper samples in 2000 . All samples, except pipper samples for trace elements in 2000, were analyzed by Geochemical & Environmental Research Group (GERG), Texas A&M University, College Station, TX. Trace element analyses in 2000 pipper samples were analyzed by Research Triangle Institute (RTI), Research Triangle Park, NC.

The following organochlorine contaminants were analyzed: aldrin; α-, β-, γ- and δ-benzene hexachloride (BHC); α- and γ-chlordane; chlorpyrifos (1999, 2000); *cis*-nonachlor; *trans*-nonachlor; dieldrin; endosulfan II; endrin; heptachlor; heptachlor epoxide; hexachlorobenzene (HCB); mirex; oxychlordane; *o, p'*-DDD; *o, p'*-DDE; *o, p'*-DDT; *p, p'*-DDD; *p, p'*-DDE; *p, p'*-DDT; pentachloro-anisole (1999, 2000); and toxaphene. Average levels of detection were 0.003 μg/g wet wt. (pippers), 0.001 (nestlings), and 0.002 (diet). Also analyzed were total PCBs and PCB congeners with the following IUPAC numbers: 1, 7 (1998), 8 (1998), 8/5 (1999, 2000), 7/9 (1999, 2000), 15, 16/32, 18 (1998), 18/17 (1999, 2000), 22 (1998), 22/51 (1999, 2000), 24 (1998), 24/27 (1999, 2000) 25, 26, 28, 29, 30 (1999, 2000), 31, 33 (1998), 33/20 (1999, 2000), 39, 40, 41/64, 42/59/37 (1999, 2000), 44, 45, 46, 47/48 (1998), 47/75 (1999, 2000), 48, 49, 52, 53, 60/56, 63, 66, 67, 69, 70, 72, 74 (1998), 74/61 (1999, 2000), 77, 81, 82, 83, 84, 85, 87 (1998), 87/115 (1999, 2000), 92, 95/80, 97, 99, 101 (1998), 101/90 (1999, 2000) 105, 107/108/144 (1998), 107 (1999, 2000), 110, 114, 118/108/149 (1998), 118 (1999, 2000) 119, 126, 128, 129, 130, 135, 136, 138 (1998), 138/160 (1999, 2000), 141 (1998), 141/179 (1999, 2000), 146, 149 (1998), 149/123 (1999, 2000), 151, 153 (1998), 153/132

(1999, 2000), 156/171/202 (1998), 156 (1999, 2000), 158, 166, 167, 169, 170 (1998), 170/190 (1999, 2000), 171/202, 172, 174, 175, 176/137 (1999, 2000), 177, 178, 180, 183, 185, 187/182/159 (1998), 187 (1999, 2000), 189, 191, 193, 194, 195 (1998), 195/208 (1999, 2000), 196 (1998), 196/203 (1999), 197, 199, 200, 201, 205, 206, 207, and 209. Congeners separated by a slash coeluted and are reported as that mixture. Congeners followed by a year designation were only analyzed in that year. Congeners not followed by a year designation were analyzed in all three years. Average detection limits for total PCBs were 0.06 μg/g wet wt. for pippers and diet, and 0.02 for nestlings. Detection limits for PCB congeners were between 0.2 - 0.4 ng/g wet wt. for pippers and diet, and 0.05 - 0.1 ng/g for nestlings. Detection limits for all Aroclors, except 1268 in nestlings, were 0.05 μg/g wet wt. for pippers and diet, and 0.01 μg/g for nestlings. Detection limit for 1268 in nestlings was 0.02 μg/g. For the above organic chemicals, tissues were homogenized and extracted with Na^2SO^4 and methylene chloride, and then purified by silica/alumina column chromatography and HPLC (MacLeod et al. 1985; Brooks et al. 1989; Wade et al. 1988). Quantitative analyses were performed by capillary gas chromatography with electron capture detector for pesticides and PCBs, with a flame ionization detector for aliphatic hydrocarbons, and a mass spectrometer detector for aromatic hydrocarbons (Wade et al. 1988).

The following dioxins and furans were analyzed: 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (CDD); 1,2,3,7,8-pentaCDD; 1,2,3,4,7,8-hexaCDD; 1,2,3,7,8,9-hexaCDD; 1,2,3,4,6,7,8-heptaCDD; octaCDD; 2,3,7,8-tetraclorodibenzofuran (CDF); 1,2,3,7,8-pentaCDF; 2,3,4,7,8-pentaCDF; 1,2,3,4,7,8-hexaCDF; 1,2,3,6,7,8-hexaCDF; 1,2,3,7,8,9-hexaCDF; 2,3,4,6,7,8-hexaCDF; 1,2,3,4,6,7,8-heptaCDF; 1,2,3,4,7,8,9-heptaCDF;

octaCDF. Average detection limits for dioxins and furans were 0.05 - 0.06 ng/g wet wt. for pippers and diet, and 0.004 ng/g for nestlings except for octaCDD and octaCDF which averaged 0.1 and 0.01 ng/g for pipper, diet, and nestlings; tetraCDD and tetraCDF averaged 0.01 and 0.001 ng/g for pipper, diet, and nestlings. The procedure used matrix-specific extraction, analyte-specific cleanup, and high-resolution gas chromatography/high resolution mass spectrometry (HRGC/HRMS) analysis techniques by a method of internal standard quantitation using [$^{13}C_{12}$]PCDD surrogates (Tondeur 1990; U.S. Environmental Protection Agency 1990).

Polycyclic aromatic analytes included: acenaphthalene; acenaphthene; anthracene; benzo(a)anthracene; dibenz(a,h)anthracene; benzo(a)pyrene; benzo(b)fluoranthene; benzo(e)pyrene; benzo(g,h,i)perylene; benzo(k)fluoranthene; biphenyl; chrysene; C1, C2, C3 & C4-chrysenes; dibenzothiophene; C1, C2 & C3-dibenzothiophenes; fluoranthene; C1-fluoranthenes & pyrenes; C1, C2, C3 & C4-phenanthrenes & anthracenes; fluorene; C1, C2 & C3-fluorenes; indeno(1,2,3-cd)pyrene; naphthalene; C1, C2, C3 & C4-naphthalenes; 1-methylnaphthalene; 1-methylphenanthrene; 2,6-dimethylnapthalene; 1,6,7-trimethyl-napthalene; perylene; phenanthrene; and pyrene. Also analyzed were 1,2,3,4-tetrachlorobenzene and 1,2,4,5-tetrachlorobenzene. Average detection limit was 0.02 µg/g wet wt. Aliphatic hydrocarbon analytes included: n-decane; n-docosane; n-dodecane; n-dotriacontane; n-eicosane; n-heneicosane; n-hentriacontane; n-heptacosane; n-heptadecane; n-hexacosane; n-hexadecane; n-nonacosane; n-nonadecane; n-octacosane; n-octadecane; n-pentacosane; n-pentadecane; n-tetracosane; n-tetradecane; n-tetratriacontane; n-triacontane; n-tricosane; n-tridecane; n-tritriacontane; n-undecane;

phytane, and pristine. Average detection limit was 0.05 µg/g wet wt. See analytical methods for organics above.

Trace elements analyzed, with detection limits in parentheses on a µg/g dry wt. basis, were aluminum (5), arsenic (0.5), boron (2), barium (1), beryllium (0.1), cadmium (0.1), chromium (0.5), copper (0.5), iron (5), magnesium (5), manganese (1), mercury (0.2), molybdenum (2), nickel (0.5), lead (0.5), selenium (0.5), strontium (0.5), vanadium (0.5), and zinc (1). Tissue samples were homogenized and then digested in the presence of nitric acid. Inductively coupled plasma - atomic emission spectrophotometry (ICP) was used by RTI for all elements, except mercury and selenium. Graphite furnace atomic absorption (GFAA) was used by GERG for all elements, except mercury. Mercury was determined with cold vapor atomic absorption by both laboratories. Research Triangle institute used GFAA for selenium.

Blanks, duplicates and spikes were run on at least 5% of the total number of samples. Reference material was used and 5% of samples were confirmed by gas chromatography mass spectrometry. Concentrations were not corrected for percent recovery. Blanks, duplicates, and spikes met quality assurance standards. Concentrations of trace elements are reported on a dry mass basis; all other concentrations are reported on a wet mass basis.

Toxic Equivalents (TEQs)

Toxic equivalent values were calculated using Kennedy's (Kennedy et al. 1996) toxic equivalent factors (TEFs) and the WHO-consensus TEFs (Van den Berg et al. 1998). These two TEQ systems were used because they were developed using avian endpoints. To calculate TEQs, the TEF coefficient was multiplied by the concentration

for each congener in each sample and then summed together. Samples that were below the detection limit were given a zero value for the TEQ calculation. This resulted in conservative TEQs. The TEQs reported here are for PCB, dioxin, and furan congeners combined, as well as, individually for PCBs congeners and for the dioxin/furan congeners. TEQs for 1998 are only for PCBs because dioxins and furans were not analyzed in individual pipper samples in 1998. The proportion that the PCB congeners comprised of the total TEQs is also calculated and reported. Four congeners, which were used in TEQ calculations, congener 118, 138, 156 and 170, co-eluted with other congeners during at least one year of the study. Congeners 118 and 156 only co-eluted in 1998, whereas, congener 138 and 170 co-eluted in both 1999 and 2000. Concentrations were used without correction because the concentration in the year(s) with co-elution was not statistically different than at least one other year. Additionally, these congeners, except for 138 comprised < 7% of the total TEQ value, so correction was deemed unnecessary and are, in fact, probably impossible.

Ethoxyresorufin-O-dealkylase Activity

Ethoxyresorufin-*O*-dealkylase (EROD) activity was assayed in 12-day-old liver microsomes (Custer et al. 1998) by USGS, Patuxent Wildlife Research Center personnel. EROD activity is presented as picomoles of product per minute per gram of liver tissue. Tree swallows nesting along the upper Mississippi River, Houston Co., MN were used as an out-of-basin reference site.

Statistics

Concentration data were statistically analyzed in a step-wise manner using analysis of variance (ANOVA) for those chemicals detected in > 50% of the samples.

Half the detection limit was used in the analyses when including samples, which were below the detection limit. Data were log transformed to satisfy the homogeneity of variance assumptions of ANOVAs and to be consistent with previously published data. Geometric means (antilog of mean log values) and 95% confidence intervals (CI) are presented in the tables and text. An initial series of 2-way ANOVAs were done to test for year, location, and interaction (year*location) effects for total PCBs and o,p'-DDE. These 2-way ANOVAs were run on pipper and nestling samples separately. Only the four sites with data from all three years were analyzed in this initial 2-way ANOVA. Because the interaction term was significant in those 2-way ANOVAs, except for o,p'-DDE in pippers, and because two new sites were added in 1999, 1-way ANOVAs were then run to determine which year/site combinations differed from other year/sites. There were a total of 16 year/site combinations. Means were separated using the Bonferroni mean separation test and were different if $P < 0.05$.

Dioxin and furan concentration data in pippers from 1999 and 2000 were also analyzed with 1-way ANOVA on log-transformed data comparing among the 12 year/site combinations. Only pooled data from pippers was available in 1998, so these data were not statistically compared to the other two years, but are presented in the tables. Trace elements and the petroleum hydrocarbons were compared among sites using 1-way ANOVA.

Accumulation rates of total PCBs and p,p'-DDE were calculated by subtracting the mass of the chemical in the pipper sample from the mass in the 12-day-old nestling and dividing by the age of the nestling (Custer and Custer 1995). Accumulation rates for these two chemicals were calculated because they were the two most prevalent

organochlorine chemicals present in pippers and nestlings. Accumulation rates are expressed as μg of the chemical accumulated per day. Because nestlings are only fed from the local area, and because the contaminant mass in the egg is subtracted out, the accumulation rate represents what the nestling is exposed to and assimilates, on an average daily basis. Accumulation rate effectively factors out what the female may have been exposed to prior to the nesting season. Average accumulation rates were compared using 1-ANOVAs, as above.

Pearson Correlation Coefficients were calculated for a series of correlations. Correlations included: (1) average accumulation rates with contaminant concentrations in diet, pipper, and 12-day-old nestling samples. Average accumulation rates for each site were correlated with concentration in diet because diet sample were pooled by site. (2) Concentrations in all samples with concentrations above the detection limit for total PCBs, Aroclor 1254, Aroclor 1260, and Kennedy's and WHO-consensus TEQs. We also correlated concentrations of total PCBs, total dioxin/furans, and the two most frequently detected furans, 2,3,7,8- PCDF and 1,2,3,7,8-pentaCDF.

Reproductive data were compiled using Mayfield's estimate of daily egg survival (Mayfield 1961, 1975) and compared among sites using methods outlined in Hensler and Nichols (1981). Contrasts (Sauer and Williams 1989) were used to make comparisons among sites within each year separately. Nests that were lost to predators or flooding were not included in the reproductive success analyses. Age of female, based on plumage color, was not included in hatching success analyses because female age has not been shown to affect hatching success (Kuerzi 1940-41; De Steven 1978; Blancher and McNicol 1988; Stutchbury and Robertson 1988; Dunn and Hannon 1992; but see St.

Louis and Barlow 1993). Because time of egg laying also does not affect hatching success (Stutchbury and Robertson 1988), it was not considered in the analyses either.

Logistic regressions were used to determine the relationship between percent hatching (dependent variable) and concentrations in pipper samples of total PCBs, total dioxin/furans, and TEQs calculated using both Kennedy and WHO-consensus methods (Hosmer and Lemeshow 1989; Custer et al. 1999). Other organochlorine chemicals were not regressed against percent hatching because all were below levels known to affect hatching success in other bird species (Blus 1996; Peakall 1996). Logistic models are commonly used to model binomial outcomes, i.e. an egg can either hatch or not hatch. Single-variable logistic regressions (hatching success vs total PCBs) were used on data from 1998, 1999, and 2000. Single- and multiple-variable logistic regressions (total PCBs and total dioxin/furans or the associated TEQs with both these chemical groups) were run on 1999 data only. Dioxin/furan data for individual pipper samples was not available in 1998; 2000 data had weather issues (see discussion for details) that precluded their use. Multiple variables in logistic models were used to assess the relative contribution of the two chemical groups, total PCBs or dioxins/furans, to reduced hatching success. We estimated extrabinomial variation by a scale parameter, which was Pearson Chi-square divided by its degrees of freedom. Standard errors were adjusted by the square root of this parameter. The Hosmer and Lemeshow goodness-of-fit test was used to determine whether the data adequately fit the logistic function; a P value > 0.05 was used to indicate an adequate fit. Additionally, 2-way ANOVAs, followed by Bonferroni mean separation tests, were used to assess whether mean concentrations of total PCBs varied by hatching success category. Two hatching success categories were

used: clutches that hatched normally or clutches that had hatching problems. Hatching problems were defined as a clutch that either contained dead embryos and/or had ≥ 2 infertile eggs.

EROD activity was compared among sites with 1-way ANOVA for each year separately. EROD activity was correlated with total PCB concentrations in 12-day-old nestling carcasses only for sites along the Housatonic River. Total PCBs concentration data were not available for nestling collected from the upper Mississippi River, Minnesota.

Samples sizes varied for the various summarizations. Sample sizes varied because we used all available data for each type of analysis; not all data were appropriate for each type of analysis, however. For example, nests that were depredated were used in clutch size summaries, but were not used in Mayfield analyses of egg success.

Climatological data were obtained from the National Weather Service for Pittsfield, MA. Data were available for 1999 and 2000, but not in 1998. Climatological data were collected to assess potential impacts of weather on hatching success.

RESULTS

Tree swallows nested at all study sites in the Housatonic River Basin, Berkshire Co., Massachusetts. Nest attempts ranged from five attempts at Canoe Meadows in 1998 to 40 at Roaring Brook at 1999 (Table 2). Percent of boxes occupied generally increased between the first and second year of the study at all sites.

Total PCBs and Aroclors

Total PCBs varied among sites in tree swallow pippers (Table 3 with sample

sizes; Table 4), and were generally higher in pippers from sites along the main stem of the Housatonic River as compared to sites on upstream tributaries, Taconic Valley or West Branch, or the reference location (Threemile Pond). Geometric mean concentrations ranged from 32 to 101 µg/g wet wt. along the main stem of the river and between 6 and 19 µg/g wet wt. at the upstream tributary and reference sites. Concentrations of total PCBs were generally consistent among years at each site, although Roaring Brook had pipper concentrations significantly higher in 1999 than in 1998. West Branch had lower total PCB concentrations in 2000 than in the earlier two years. Maximum concentrations of total PCBs in pippers exceed 100 µg/g wet wt. at Canoe Meadows (N = 2 pippers), Lenox Road (N = 2), and Roaring Brook (N = 18). Maximum concentrations did not exceed 100 µg/g wet wt. at the upstream or reference sites.

Total PCBs in 12-day old nestlings (N = 5 nestlings/site/year) were higher at sites along the main stem of the Housatonic River compared to upstream or reference sites (Table 5). Concentrations ranged from 21 to 45 µg/g wet wt. at main stem sites and between 2 and 4 µg/g wet wt. at upstream sites. At Threemile Pond concentrations in nestlings averaged 1 µg/g wet wt. Concentrations were similar among years at all sites.

Accumulation rates of total PCBs in 12-day old nestlings (Table 6) were significantly higher at sites along the main stem of the Housatonic River compared to upstream tributaries or the reference location. Accumulation rates varied between 34 - 76 µg/day of total PCBs at main stem sites, between 3 and 6 µg/day at upstream tributaries, and between -0.3 and 1 µg/day at the reference site. Two nest boxes had accumulation

rates in excess of 100 μg/day. These boxes were located at Canoe Meadows (1998) and Roaring Brook (1998), both main stem sites. Total PCBs in diet (Table 7) seemed to be higher at main stem sites than elsewhere, but because samples were pooled by site no statistical analyses were possible. Total PCB concentrations in diet, pipper, and nestlings, and accumulation rate in nestlings were all significantly and highly correlated (Table 8).

Only Aroclor 1254 and 1260 were reported as above the detection limit in > 50% of tree swallow samples (Table 4 and 5). Aroclor 1242 and 1268 were not reported in any sample. Aroclor 1248 was reported in 20 of 177 pippers, 8 of 64 nestlings, and 2 of 18 diet samples. Aroclor 1254 and 1260 were highly correlated with one another ($P < 0.001$; $R = 0.94$; $N = 230$) and with total PCBs ($R = 0.98$ [1254] and $R = 0.99$ [1260]).

Other organochlorine chemicals

Other organochlorine chemicals in pippers were present at low concentrations (Table 4). Those organochlorine chemicals that had an overall average of ≤ 0.01 μg/g wet wt. included dieldrin, HCB, heptachlor epoxide, mirex, o,p'-DDD and p,p'-DDT (Table 4). Chemicals that had overall averages between 0.01 and 0.05 μg/g wet wt. were cis-nonachlor, endosulfan II, oxychlordane, p,p'-DDD, and trans-nonachlor. Ortho-para DDT was present at 0.1 μg/g wet wt. See Table 4 for year or location differences for these chemicals. Concentration of p,p'- DDE ranged between 0.3 and 0.5 μg/g wet wt. and were generally similar among the nesting sites. Only Canoe Meadows in 1999 (0.54 μg/g wet wt.) differed from Canoe Meadows (0.27 μg/g wet wt.) and Lenox Road (0.26 μg/g wet wt.) in 2000. All sites were similar to one another. Concentrations were similar among years except as noted for Canoe Meadows above.

In 12-day old nestling samples, average concentrations of cis-nonachlor, dieldrin, endosulfan II, HCB, heptahchlor epoxide, mirex, oxychlordane, p,p'-DDD, p,p'-DDT, and trans-nonachlor were $\leq$0.01 µg/g wet wt. (Table 5). O,p'-DDD and o,p'-DDT, averaged between 0.01 and 0.05 µg/g wet wt., and p,p'-DDE averaged 0.1 µg/g wet wt. Year or location effects are given in Table 5.

Dioxins and furans

Dioxins and furans were detected in relatively few samples (Table 9). Four furans (2,3,7,8-TCDF, 1,2,3,7,8-PeCDF, 2,3,4,7,8-PeCDF and 1,2,3,4,6,7,8-HpCDF) had >50% of samples above the detection limit and were tested for year/location differences. The other 13 congeners were detected in too few samples to statistically analyze. Generally there was no difference in concentrations between 1999 and 2000 at a site except for Threemile Pond and West Branch (Table 10). At Threemile Pond and West Branch 2,3,4,7,8-PeCDF was not detected in 1999, but was detected in 2000. There were some location differences for the 4 individual furans (Table 10). Roaring Brook often had higher pipper concentrations than Threemile Pond (5 of 8 comparisons [2 years*4 congeners]), West Branch (6 of 8 comparisons), or Taconic Valley (4 of 8 comparisons). The other main channel sites (Lenox Road and Canoe Meadows) generally did not differ from Roaring Brook or from each other. The overall average concentrations of 2,3,7,8-TCDF, 1,2,3,7,8-PeCDF, 2,3,4,7,8-PeCDF and 1,2,3,4,6,7,8-HpCDF were 0.190, 0.460, 0.058 and 0.079 ng/g wet wt. respectively.

There was high correlation in pippers between concentrations of total PCBs and total dioxin/furans ($P < 0.001$, $R = 0.783$, $N = 84$), and between total PCBs and the two most commonly detected furans, 2,3,7,8-TCDF ($P < 0.001$, $R = 0.857$, $N = 74$) and

1,2,3,7,8-PeCDF ($P < 0.001$, $R = 0.753$, $N = 76$).

Toxic equivalents (TEQs)

Congener data for PCBs will be covered in depth elsewhere (EVS final report), however, the PCB congener profile was similar among all of the sites and total PCBs in pippers and nestlings were highly correlated with total TEQs as calculated using Kennedy's TEFs (Kennedy et al. 1996) ($P < 0.001$; $R = 0.97$ $N = 311$) and the WHO-consensus TEFs for birds (Van den Berg et al. 1998) ($P < 0.001$; $R = 0.65$, $N = 311$). The proportion of TEQs that were derived from PCBs averaged 93.4% $\pm$ 1.3 (SE) for Kennedy and 86.8% $\pm$ 1.4 for WHO-consensus and did not differ among the 16 year/location combinations ($P = 0.99$; df = 15,316 for Kennedy's TEQs and $P = 0.90$; df = 15,316 for WHO-consensus). Finally, mean TEQs differed among sites with main stem sites, except for Canoe Meadows and Lenox Road in 2000, being higher than Threemile Pond. Roaring Brook was generally higher than upstream tributary sites as well (Table 11).

Polycyclic aromatic and aliphatic hydrocarbons

None of the 43 polycyclic aromatic hydrocarbons were detected in the 29 tree swallow carcasses collected and analyzed in 2000. Twenty-five of the 27 aliphatic hydrocarbons were detected in > 50% of the samples (Table 12). N-dodecane and pristane were detected in < 50% of samples. Only 4 aliphatic hydrocarbons varied among sites: n-hexacosane (West Branch > Lenox road), n-nonacosane (Canoe Meadows > Taconic Valley), n-tetratriacontane (Threemile Pond = Taconic Valley = West Branch = Roaring Brook > Canoe Meadow = Lenox Road), and n-tritriacontane (Threemile Pond = Taconic Valley = West Branch > Canoe Meadow = Lenox Road). The ratio of pristine

to n-heptadecane did not differ among sites and averaged < 1.0 at all sites. There was generally a pronounced difference between the concentrations of odd-numbered aliphatic hydrocarbons (number of carbons in the n-alkane chain) and the even-numbered aliphatics (Fig. 2).

Trace elements

Trace elements were analyzed in two matrices, pippers (N = 10, in 2000) and nestling carcasses (N = 20, in 1998). Eleven of 19 trace elements were detected in > 50% of pipper samples (Table 13). There were no differences in concentrations among sites except for strontium. Threemile Pond had less strontium than Lenox Road, but the same amount as Roaring Brook. Arsenic, beryllium, cadmium, molybdenum, nickel, and lead were not detected; aluminum and chromium were detected in 1 pipper each. Ten trace elements were detected in nestling carcasses (Table 14). Concentrations of only one element, mercury, varied among the sites. Mercury concentrations were higher at Lenox Road compared with West Branch and Canoe Meadows. Arsenic, boron, beryllium, and lead were not detected. Aluminum was detected in 7 of 20 carcasses, cadmium in 8, nickel in 1, and vanadium in 9 carcasses.

Reproduction

The number of nest attempts generally increased from the first to second year that the boxes were present and then stabilized thereafter (Table 2). Some nest attempts were destroyed by predators, flooding, etc. (Table 15) and are not included in the reproductive success measures that follow; they are included in the clutch size summaries, however, if the clutch was completed prior to their destruction. The modal clutch size for tree swallows in the Housatonic River Valley was five in 1999 and six in 1998 and 2000 (Fig.

3). Average clutch sizes for the three years respectively were 5.43, 5.37, and 5.46. The daily probability of egg survival varied by location (Table 16). The lowest probability of hatching tended to be at Roaring Brook in 1998 and 1999, and was the lowest at Taconic Valley in 2000.

There was a negative relationship between total PCBs and hatching success in 1998 and 1999 combined ($P = 0.049$, Fig. 4), but not when 2000 was added to the model ($P = 0.273$). As total PCBs increased the proportion of eggs hatching decreased. The fit of the model however was poor (Hosmer and Lemeshow $P = 0.028$). In 1998 and 1999, clutches that contained dead embryos had significantly higher concentrations of total PCBs than nests that hatched normally ($P < 0.001$, df = 5,201, Fig. 5). The average concentration in clutches that experienced reduced hatching averaged 62.8 µg/g wet wt. (1998) and 69.1 (1999). In 2000, concentrations of total PCBs were significantly less than in 1998 or 1999 ($P < 0.001$) and did not differ between the two hatching-success categories. The total dioxin/furan concentrations did not differ between years (1999 and 2000) or between hatching success categories ($P = 0.598$), however, the mean concentrations followed the pattern established by total PCBs. Mean total dioxin/furan concentrations in 1999 and 2000 for nests with and without hatching problems were 0.451 and 0.233 in 1999, 0.398 and 0.332 ng/g wet wt. in 2000 for the two hatching category groups respectively.

A series of single-variable and multiple-variable logistic regressions were run on 1999 pipper concentration data to delineate the relative contribution of total PCBs and total dioxins/furans, including the TEQs associated with these two chemical groups (Table 17). Total PCBs and total dioxin/furans were significant variables when entered

individually into the logistic model, neither variable, however, was significant when entered simultaneously into the model. TEQs associated with the dioxins and furans, using both Kennedy and WHO-consensus values, were significant when entered independently, but either marginally not-significant (P = 0.072, Kennedy) or significant (0.035, WHO-consensus) when entered simultaneously with TEQs associated with PCBs. TEQs associated with PCBs were not significant whether entered in single- or multiple-variable models.

In 2000 there were three periods with unusual egg and nestling mortality (Fig. 6). These periods of egg and nestling mortality were associated with days when the maximum temperatures were < 16 °C. At main stem sites, 3 of 9 clutches that had dead embryos or ≥ 2 infertile eggs had these losses occur during these three periods, whereas, at upstream tributaries and reference sites 7 of 9 losses occurred during these periods of inclement weather.

EROD activity

EROD activity differed among sites (Table 18), with sites along the main stem of the Housatonic River having significantly induced EROD activity when compared to Threemile Pond or the out-of basin Upper Mississippi River site. There was a significant correlation between EROD activity and concentrations of total PCBs in 12-day-old nestling carcasses in 1999 (P < 0.001 R = 0.789), but not in 2000 (P = 0.281).

DISCUSSION

Total PCBS - exposure

Average concentrations of total PCBs (means ranged from 31.5 to 100.9 µg/g wet

wt.) in tree swallow eggs from along the Housatonic River, Massachusetts are the highest reported anywhere for tree swallows and even for most piscivorous birds (see review in Bosveld and Van den Berg 1994). In the Great Lakes average concentrations in tree swallow eggs ranged between 0.5 and 1.4 μg/g wet wt. in Saginaw Bay, Lake Michigan (Nichols et al. 1995); 3.2 - 4.2 μg/g wet wt. in lower Green Bay, Lake Michigan (Ankley et al. 1993; Custer et al. 1998); and 0.3 - 11.1 μg/g wet wt. in coastal areas of Lakes Erie and Ontario and the St. Lawrence River (Bishop et al. 1995; 1999). Along the upper Hudson River, New York tree swallow egg concentrations averaged 5.9 - 29.5 μg/g wet wt. (Secord et al. 1999; McCarty and Secord 1999). Concentrations in tree swallow eggs in non-industrialized areas of British Columbia were 0.18 μg/g wet wt. (Elliott et al. 1994).

PCBs in bird tissues from the Housatonic River were accumulated from local sources. Twelve-day old nestling tree swallows accumulated an average of between 34 and 76 μg of total PCBs per day along the main stem of the Housatonic River which compared to between only 3 - 6 μg/day at sites along upstream tributaries and < 1 μg/day at Threemile Pond reference area. These PCBs were accumulated from the local environment because the young were only fed insects from the local environment and the quantity of contaminant in the egg was subtracted off as part of the accumulation rate calculations. These average accumulation rates do not imply a constant daily intake rate of PCBs; PCB content of each meal probably varied. Accumulation rates on the Housatonic River are quite high compared to other areas. In Green Bay, Lake Michigan tree swallows accumulated on average between 1.3 and 6.7 μg/day (Custer et al. 1998). Along the Hudson River in New York, however, individual accumulation rates varied

between 3.5 and 158 µg/day (N = 13 - 14) with 67% of those accumulation rates being < 50 µg/day (Secord et al. 1999). The maximum individual rate along the Housatonic River was 104 µg/day.

The drop in apparent exposure to total PCBs in 2000 is noteworthy. The drop was consistent across three endpoints. Although the differences between 2000 and the other two years were not statistically significant, either for concentration in pippers or accumulation rate in 12-day old nestlings, for each site individually both values were qualitatively lower in 2000 compared to the other two years in 85% of the comparisons (17 of 20 possible comparisons). Additionally, concentration in diet samples tended to be less in 2000 compared to the other years. It is unknown why concentrations in pippers, diet, and accumulation rate dropped in 2000. Perhaps flooding and scouring events in 1999 moved contaminated sediments out of the system, or else existing contaminated sediments were covered with cleaner material from upstream.

There was high correlation ($R \geq 0.80$) between total PCB concentrations in diet and the accumulation rate of total PCBs in 12-day-old nestlings. This supports our argument that PCBs in nestlings came from food they consumed. There was also a significant correlation between total PCBs in diet and concentrations in pipper samples, indicating that concentrations of total PCBs in pippers probably also came from the local area. Because 70% of dietary items of tree swallows from the Housatonic River were aquatic insects (unpubl. data), it is clear that the major source of PCBs were the contaminated sediments that the aquatic insects emerged from.

Total PCBS - effects on tree swallows

We documented a small but statistically significant effect of total PCBs on

hatching success of tree swallows along the Housatonic River. By visual inspection, reproduction became more adversely affected at about 50 µg/g wet wt. and above in eggs (Fig. 4). Average concentrations in eggs with hatching problems contained 63 and 69 µg/g wet wt. of total PCBs. This relationship of PCBs to reduced hatching success has not been convincingly demonstrated in tree swallows elsewhere probably because concentrations of total PCBs in these other studies were probably below effect levels or sample size was insufficient to detect these small effects. Custer et al. (1998) found no effects on percent of eggs hatching in southern Green Bay, Lake Michigan where average total PCB egg concentration ranged between 1.9 and 3.3 µg/g wet wt., nor did Bishop et al. (1999) in Lakes Erie and Ontario and the St. Lawrence River with egg concentrations between 0.9 and 11.2 µg/g wet wt. There were also no effects on reproductive endpoints in tree swallows nesting downstream of pulp mills in Alberta, Saskatchewan, or British Columbia compared to upstream sites (Wayland et al. 1998; Harris and Elliott 2000). The contaminants of concern in those two studies were PCBs, as well as, dioxins and furans. Data on tree swallow hatching success from the Hudson River, New York in 1994 and 1995 are purported to demonstrate reduced hatching success due to total PCBs in one of two years (McCarty and Secord 1999). It is problematic in that study, however, that the reference data, which were the basis for those conclusions, were collected from a study area >230 km away three years earlier (1990 - 1991). It is well known that there can be differences among years in hatching success (Chapman 1955; Lederle 1995), so comparing success to values from other years could be misleading. Additionally, the most contaminated site along the Hudson River, Special Area #13 (29 µg/g wet wt. in tree swallow eggs) consistently had the highest hatching success (78% in 1994 and 90%

in 1995) compared to other less contaminated sites nearby (9.3 μg/g wet wt. and 75% and 82% hatching and 15 μg/g wet wt. with 70% and 89% hatching). Hatching success values reported above are interpolated from Fig. 2 in McCarty and Secord (1999).

The lack of an effect of PCBs on hatching success in 2000 along the Housatonic River is consistent with the lower exposure to PCBs in that year. In 1998 and 1999, clutches with hatching problems average > 60 μg/g wet wt. in pippers (Fig 5). In 2000, average concentrations was < 20 μg/g wet wt. for the two hatching success categories. The lower exposure to PCBs also explains as well why the logistic regression was not significant in 2000.

Concentration of total PCBs was a significant factor in the logistic regressions, but when TEQs associated with total PCBs was used as the independent variable the models were not significant. This may imply that other PCB congeners, besides those commonly used to calculate TEQs, may be contributing to the toxicity of the total PCB mixture. Another explanation might be that the TEF weighting factors were not applicable to hatching success. Most TEF weighting factors were established for biochemical endpoints, not hatching success (Kennedy et al. 1996;Van den Berg et al. 1998). Additionally, *in vitro* studies may not adequately account for the toxico-kenetics of different mixtures of compounds.

The total dioxin/furan concentrations, as well as, the TEQs associated with dioxin/furans were significant variables in the models. This may indicate that the dioxins and furans could be contributing to reduced hatching success. The lack of a significant effect, when both total PCBs and total dioxin/furans were entered simultaneously into the model, even though both were significant when entered individually, probably resulted

because colinearity can lead to inflated standard errors and contribute to non-significance. These results should be interpreted cautiously, however, because of the high degree of correlation between concentrations of total PCBs and the dioxins/furans. The only way to definitively address the relative risks associated with total PCBs and dioxin/furans is through exposure of eggs to these contaminants in a controlled factorial experiment.

Concentrations of other organochlorine chemicals were not regressed against hatching success because concentrations were too low to be a factor. For example, 13 organochlorine chemicals were not detected and another 11 chemicals averaged ≤ 0.05 µg/g wet wt. Only p,p'-DDE (means 0.3 - 0.5 µg/g) might warrant further consideration. Concentrations of DDE, however, were at least ten times lower than any published effects levels (Blus 1996). For example, the threshold for adverse effects on hatching success in brown pelican (*Pelecanus occidentalis*) eggs is 3 µg/g wet wt. (Blus 1996) and in white-faced ibis the threshold value is > 4 µg/g wet wt. (Henny and Herron 1989). Hatching success of double crested-cormorant (*Phalacrocorax auritus*) also was adversely affected beginning at approximately 4 µg/g wet wt. (Custer et al. 1999). These three species are recognized as some of the most sensitive to effects of DDE (Blus 1995). The cyclodiene pesticides, such as aldrin and endrin were either not detected or were present at low levels (all dieldrin means < 0.05 µg/g wet wt.). Reproductive processes of birds are not particularly sensitive to dieldrin (Peakall 1996). For example, hatching success of Japanese quail (*Coturnix coturnix japonica*) was reduced beginning at > 10 µg/g wet wt. in eggs (Walker et al. 1969). Trace elements were also not regressed against hatching success again because concentrations were also too low. Of the three elements that can cause reproductive problems in birds, cadmium was not detected and selenium

was within normal limits (Heinz 1996). Although mercury was slightly elevated in pippers, concentrations were 3 - 4 times lower than the 2.5 μg/g dry wgt that has been found to be detrimental to reproduction in birds (Thompson 1996).

Total PCBs - other passerine species and laboratory studies

Other field studies on insectivorous birds have generally not found effects of PCBs on hatching success probably because concentrations were too low. Dippers (*Cinclus cinclus*), another aquatic insectivore, demonstrated no effects of PCBs on hatching success in Wales, United Kingdom. Concentrations ranged between 0.1 and 0.5 μg/g wet wt. in eggs (Ormerod et al. 2000). At Crab Orchard National Wildlife Refuge, Illinois European starlings (*Sturnus vulgaris*), a terrestrial insectivore, had no reduction in hatching success with elevated concentrations of Aroclor 1242 (mean concentrations = 52 μg/g wet wt in 15-day old nestlings), similar to levels of total PCBs present in Housatonic River nestlings. Along the Housatonic River, Berkshire Co., Massachusetts reproductive effects on passerine birds were studied within and outside the 10-year flood plain (Henning et al. 1997). No effects on hatching success were found, however, no contaminant concentration data to verify actual exposure were collected and the sample sizes were small (N = 1 - 17 nests/species/location compared). Additionally, using the 10-yr floodplain, instead of the 5-yr floodplain (Beach et al. 2000), may have combined highly exposed with less exposed birds and thus masked any affect.

The field data that report an association of hatching problems with PCB exposure has, in many cases, probably been confounded by the presence of DDE. The effects of these two chemicals, that are usually highly correlated, have not been separated out except in a few cases (Custer et al. 1999). In that instance, and others (Dykstra et al.

2001), DDE was sufficiently high to account for the reduced hatching success. No effects of high PCB concentrations were found in a field dosing experiment with puffins (*Fratercula arctica*). Puffins dosed subcutaneously with Aroclor 1242 to produce concentrations in eggs between 9.6 and 81.3 μg/g, similar to what we found on the Housatonic River, had no effect on average number of young produced per dosed pair (Harris and Osborn 1981). Small sample size could have contributed to the lack of effect, especially at the higher exposure levels.

The amount of PCBs needed to adversely affect hatching success in laboratory studies are mostly consistent with the tree swallow data from the Housatonic River, that is, that relatively high concentrations are needed to reduce hatching success. Powell et al. (1997) injected cormorant eggs with PCB 126 and 2,3,7,8-TCDD. She estimated the LD_{50} to be 5,000 - 26,000 pg/g TEQs. This LD_{50} is above most of the TEQs on the Housatonic River and is therefore consistent with our data, which demonstrated a small but measurable effect on hatching success beginning at approximately 8,000 - 1400 pg/g TEQs. Two laboratory studies of hatching success of mallard eggs (*Anas platyrhynchos*) found no difference in average number of infertile or dead embryos in eggs with a mean concentration of 23.3 or 105 μg/g wet wt. resulting from being fed Aroclor 1242 (Haseltine and Prouty 1980; Custer and Heinz 1980). Injected herring gull (*Larus argentatus*) eggs, which results in a concentrations of $\geq$ 96 μg/g wet wgt, did not have reduced hatching success when compared to sham injected eggs; all eggs were naturally incubated (Gilman et al. 1978). Peakall and Peakall (1973), however, found that 16 μg/g wet wt. in ring dove (*Streptopelia risoria*) eggs had a 50% reduction in hatching. Ring doves, a member of the Columbidae family, may be more similar to chickens (*Gallus*

domesticus) in their sensitivity to PCBs (see review in Hoffman et al. 1996). Without laboratory studies, however, is difficult to determine differential species sensitivities to various chemical classes.

Other contaminants

Other organochlorine chemical contaminants in tree swallow tissues were at low or background concentrations and not at levels known to affecting hatching success in other bird species. For example, most organochlorine chemicals, such as dieldrin and DDT derivatives were present at $\leq$ 0.05 µg/g wet wt. Even p,p'-DDE, which averaged between 0.3 and 0.5 µg/g wet wt., was well below the 3 - 5 µg/g wet wgt associated with reproductive problems in the most sensitive species (Blus 1996).

Fewer than 25% of pipper samples had detectable concentrations of thirteen of the 17 dioxins and furans. The average overall concentrations of the 4 furan congeners that were detected in > 50% of samples from the 4 main stem sites averaged 0.190, 0.460, 0.058 and 0.079 ng/g wet wt. for 2,3,7,8-TCDF, 1,2,3,7,8-PeCDF, 2,3,4,7,8-PeCDF and 1,2,3,4,6,7,8-HpCDF respectively. This was higher than the average of 0.006 ng/g 2,3,7,8-TCDF in tree swallows along the Wisconsin River, an area with past dioxin contamination (Custer. T.W. et al. 2002), but similar to the 0.14 - 0.22 ng/g in Pool 15 of the Mississippi River near Davenport, IA and Rock Island, IL (Custer 2000). Concentrations in tree swallows eggs were similar to concentrations of 2,3,7,8-TCDF in three merganser species (0.11 - 0.27 ng/g wet wt.), which feed at a higher trophic levels than tree swallows; merganser eggs were collected at a site in Canada downstream of pulp mills (Champoux 1996). At other pulp mill locations in British Columbia 2,3,7,8-TCDF concentrations in tree swallow eggs averaged between 0.001 and 0.003 ng/g.

(Harris and Elliott 2000). 2,3,7,8-TCDD, one of the most toxic of the dioxin and furan congeners, was detected in only 1 of 8 pipper samples (12.5%) on the Wisconsin River, which is similar to 12 of 95 (12.6%) with detectable concentrations along the Housatonic River. Few field studies have quantified effects of furans on reproduction in birds.

The petroleum hydrocarbon contaminants were also at background concentrations along the Housatonic River. None of 43 polycyclic aromatic hydrocarbons (PAHs) were detected in tree swallow carcasses from the Housatonic River indicating a lack of petroleum contamination in the system. These contrasts with an area of know petroleum contamination where PAHs were detected in tree swallow carcasses (Custer et al. 2001). Additionally, the profile of aliphatic hydrocarbons, with a preponderance of odd-numbered compared to adjacent even-numbered aliphatic hydrocarbons, also indicates that nestlings were not chronically exposed to oil pollution. If nestlings were exposed to petroleum or pyrogenic hydrocarbon compounds, the ratio of odd to even aliphatics would be more equal (Voudrias and Smith 1986).

Trace element concentrations in eggs and/or carcasses tissues were at background or no-effect levels. Of the three trace elements that have known-effects on birds, cadmium was not detected in any of the pipper samples and selenium was within the normal range and similar to concentrations found in tree swallows in Wyoming and Colorado (Custer et al. 2001; Custer et al. 2002). Mercury (averages ranged between 0.59 and 0.77 μg/g dry wt.) was slightly elevated in Housatonic River tree swallow pipper samples compared with concentrations found in tree swallow eggs from Colorado (0.16 - 0.18 μg/g dry wgt) or Wyoming (0.3 μg/g dry wgt). Mercury concentrations were 3.5 times less, however, than the 2.5 μg/g dry wgt that has been found to be detrimental

to reproduction in birds (Thompson 1996). The essential trace elements, such as copper, magnesium etc. were all at comparable levels to tree swallows nesting elsewhere (Custer et al. 2001; Custer e al. 2002)

EROD activity was significantly induced in 12-day old nestling livers at sites along the main stem of the Housatonic River. Inductions levels were correlated with concentrations in nestling carcasses in 1999, but not in 2000. This lack of correlation in 2000 may have been due to the lower concentrations of total PCBs in 12-day old nestlings. The apparently lower EROD induction level in 2000 compared to 1999 probably reflects the lower exposure to total PCBs in 2000 compared to 1999.

Although we don't statistically analyzed clutch size data, mean clutch size along the Housatonic River in 1998 - 2000 was similar to or slightly higher than the 4.8 - 5.3 eggs/clutch present in central Massachusetts over a 22-year period (Chapman 1955). The modal clutch size of 5 eggs, with 6 eggs being the second most frequent clutch size in Connecticut (Kuerzi 1941), was similar to the modal data from our study sites along the Housatonic River.

Other Factors

Poor hatching success at all sites in 2000, which was probably due to weather conditions is an uncommon, but not unknown phenomenon in tree swallows. In 1940, several cold rainy periods in late May and early June reduced hatching success of tree swallows in Massachusetts to 44.7% (Chapman 1955). The cold rainy periods reduced hatching success probably because of the shortage of insects for the adults to feed on. Glick (1939) found a positive, linear, relationship between the number of flying insects collected and temperature between 2 °C and 24 °C. Fewer than half the numbers of

insects were caught when temperatures were 10° - 13 °C compared to numbers caught when temperatures were 24 °C. Feeding by swifts in Finland ceased when the average daily temperature dropped to 12° C (Koskimies 1950). The daily high temperature in Pittsfield during the three incidences of abnormal egg mortality was 13 °C or less, and was probably the cause of overall poor hatching in 2000 at the less contaminated sites.

SUMMARY

Concentrations of total PCBs in tree swallow pippers and nestlings collected from the Housatonic River near Pittsfield, Massachusetts were some of the highest ever reported in birds. Total PCBs, along with total dioxin and furans, were negatively correlated with hatching success in 1998 and 1999. The correlation was statistically significant, but weak. Hatching success was not correlated with these contaminants in 2000, probably because concentrations were reduced in 2000 and because cold, rainy weather contributed to poor hatching at all sites regardless of contaminant levels. Concentrations of other organochlorine chemicals, trace elements, and petroleum hydrocarbons were at background or no-effect levels.

Positive accumulation rates of total PCBs indicated local exposure. Accumulation rates varied between 30 and 75 µg /day of total PCBs at main stem Housatonic River sites, and indicated substantial exposure. This result is corroborated by concentrations of total PCBs in food items taken from the stomachs of nestling tree swallows, which varied between 2 and 19 µg/g wet wt. total PCBs. Because tree swallows fee primarily on emergent aquatic insects, our results support the conclusion that PCB and dioxin/furan contamination in tree swallow tissues originated from

contaminated sediments in the Housatonic River.

Acknowledgements - We thank Massachusetts Division of Fisheries and Wildlife, Weiner Broadcasting, Taconic Valley Trucking, Inc., Mr. Kenneth Nash, and Mr. And Mrs. Donald Brigham for access to their properties. We thank Richard Zoppel and other Roy F. Weston personnel for logistical support, John Lortie and other Woodlot Alternative personnel for field assistance, Paul Dummer for help with data management and statistical analyses, and Tod DeLong, John Elliott, Brian Grey, Dwayne Moore, and Miguel Mora for helpful comments on the manuscript.

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Table 1. Number of nest boxes at tree swallows study sites along the Housatonic River Valley, Berkshire Co., Massachusetts in 1998, 1999, and 2000.

	Study Site					
Year	Canoe Meadows	Lenox Road	Roaring Brook	Threemile Pond	Taconic Valley	West Branch
1998	31	31	31	-- [1]	-- [1]	35
1999	31	54	53	18	20	38
2000	31	52	53	38	20	32

[1] -- nest boxes not present at this location in1998

Table 2. Number of nest attempts by tree swallows in the Housatonic River Valley, Berkshire Co., Massachusetts in 1998, 1999, and 2000.

	Study Site					
Year	Canoe Meadows	Lenox Road	Roaring Brook	Threemile Pond	Taconic Valley	West Branch
1998	5	18	18	-- [1]	-- [1]	11
1999	11	26	40	15	9	16
2000	12	32	37	25	16	15

[1] -- nest boxes not present at this site in1998

Table 3. Number of pipper samples analyzed for organochlorine chemicals, including total PCBs, from tree swallows nesting in the Housatonic River Valley, Berkshire Co., Massachusetts in 1998, 1999, and 2000. Aroclors were only quantified in 1999 and 2000.

	Study Site					
Year	Canoe Meadows	Lenox Road	Roaring Brook	Threemile Pond	Taconic Valley	West Branch
1998	5	16	16	-- [1]	-- [1]	10
1999	10	20	29	12	9	13
2000	7	14	14	15	8	12

[1] -- location not present in1998

Table 4. Geometric mean (µg/g wet wt.) and 95% Confidence Intervals, by year and site, for organochlorine chemicals in tree swallow pipper samples collected in the Housatonic River Valley, Berkshire Co., Massachusetts in 1998, 1999, and 2000.

Chemical	Year	Study Site					
		Canoe Meadow	Lenox Road	Roaring Brook	Threemile Pond	Taconic Valley	West Branch
Total PCBs P < 0.0001 df = 15, 194	1998	49.15 ab[1] (44.08-54.80)	56.43 ab (53.39-59.66)	41.71 bcd (34.13-50.97)	---- [2]	---- [2]	18.06 def (13.70-23.80)
	1999	59.89 ab (52.27-68.62)	61.50 ab (57.13-66.21)	100.88 a (94.01-108.3)	9.52 fgh (7.37-12.31)	14.71 efg (13.10-16.52)	18.69 cdef (14.57-23.97)
	2000	31.52 bcde (27.57-36.04)	44.90 abc (38.99-51.71)	67.54 ab (61.27-74.45)	6.04 h (5.02-7.28)	16.18 ef (13.32-19.64)	6.33 gh (5.29-7.56)
Minimum - maximum values		20.8 - 138	12.2 - 111	3.1 - 190	1.6 - 62.9	8.3 - 49.4	2.1 - 92.4
PCB-1254 P < 0.0001 df = 11, 51	1999	20.04 a (17.17-23.38)	20.29 a (18.48-22.27)	38.23 a (35.57-41.08)	2.97 bcd (2.15-4.09)	2.99 bcd (1.75-5.11)	3.25 bcd (2.07-5.10)
	2000	9.46 abc (8.16-10.98)	12.43 ab (10.28-15.03)	20.86 a (18.60-23.40)	1.00 d (0.73-1.36)	2.74 cd (1.38-5.42)	0.76 d (0.46-1.25)

Table 4 cont.

Chemical	Year	Study Site					
		Canoe Meadow	Lenox Road	Roaring Brook	Threemile Pond	Taconic Valley	West Branch
PCB-1260 P < 0.0001 df = 11, 15	1999	39.35 ab (34.34-45.08)	40.78 ab (37.98-43.78)	60.38 a (56.29-64.76)	6.12 de (4.691-7.98)	9.74 cde (8.59-11.04)	13.09 cd (10.07-17.01)
	2000	21.76 bc (18.91-25.05)	31.73 ab (27.71-36.34)	45.42 ab (41.18-50.08)	4.66 e (3.82-5.68)	11.49 cd (9.50-13.90)	4.90 e (4.06-5.92)
cis-nonachlor P < 0.0001 df = 15, 194	1998	0.010 de (0.006-0.015)	0.007 defgh (0.006-0.008)	0.008 defgh (0.006-0.010)	----	----	0.012 cd (0.009-0.016)
	1999	0.046 ab (0.041-0.051)	0.030 abc (0.026-0.035)	0.085 a (0.078-0.092)	0.003 h (0.002-0.004)	0.006 defgh (0.005-0.007)	0.009 def (0.007-0.011)
	2000	0.017 bcd (0.014-0.020)	0.008 defgh (0.006-0.010)	0.003 efgh (0.003-0.004)	0.003 gh (0.0029-0.0031)	0.009 defg (0.006-0.013)	0.003 fgh (0.003-0.004)

Table 4 cont.

Chemical	Year	Study Site					
		Canoe Meadow	Lenox Road	Roaring Brook	Threemile Pond	Taconic Valley	West Branch
dieldrin P < 0.0001 df = 15, 194	1998	0.007 bcd (0.006-0.009)	0.007 bcd (0.005-0.009)	0.010 bcd (0.007-0.013)	----	----	0.009 bcd (0.007-0.011)
	1999	0.004 de (0.003-0.004)	0.004 de (0.003-0.004)	0.007 bcd (0.006-0.007)	0.001 ef (0.001-0.002)	0.002 ef (0.0015-0.0019)	0.001 f (0.001-0.002)
	2000	0.042 a (0.036-0.048)	0.016 ab (0.012-0.021)	0.005 cd (0.005-0.006)	0.010 bcd (0.008-0.012)	0.035 a (0.028-0.045)	0.012 bc (0.010-0.015)
endosulfan II P < 0.0001 df = 15, 194	1998	0.011 bcd (0.008-0.014)	0.004 cde (0.002-0.006)	0.001 f (0.0005-0.001)	----	----	0.001 f (na) [3]
	1999	0.060 a (0.051-0.070)	0.052 a (0.047-0.058)	0.072 a (0.066-0.078)	0.008 bcde (0.006-0.010)	0.011 bc (0.010-0.013)	0.010 bcd (0.008-0.012)
	2000	0.012 b (0.008-0.018)	0.007 bcde (0.005-0.009)	0.003 e (na)	0.003 de (0.0030-0.0034)	0.012 bc (0.008-0.016)	0.005 bcde (0.004-0.006)

Table 4 cont.

Chemical	Year	Study Site					
		Canoe Meadow	Lenox Road	Roaring Brook	Threemile Pond	Taconic Valley	West Branch
HCB P < 0.0001 df = 15, 194	1998	0.005 cdef (0.005-0.007)	0.006 bcde (0.006-0.007)	0.008 bcd (0.006-0.010)	----	----	0.022 a (0.017-0.029)
	1999	0.008 bcd (0.007-0.008)	0.007 bcd (0.007-0.008)	0.013 ab (0.012-0.014)	0.003 ef (0.003-0.004)	0.004 def (0.004-0.005)	0.004 def (0.004-0.005)
	2000	0.003 ef (0.0029-0.0033)	0.006 cdef (0.005-0.007)	0.011 abc (0.010-0.013)	0.003 f (na)	0.003 ef (0.003-0.004)	0.003 f (na)
heptachlor epoxide P < 0.0001 df = 15, 194	1998	0.017 abc (0.009-0.033)	0.008 abcde (0.007-0.010)	0.007 abcde (0.006-0.010)	----	----	0.027 a (0.021-0.033)
	1999	0.026 ab (0.022-0.031)	0.007 abcde (0.006-0.008)	0.008 abcde (0.006-0.011)	0.006 bcde (0.005-0.008)	0.009 abcde (0.007-0.012)	0.012 abcde (0.010-0.015)
	2000	0.012 abcde (0.009-0.017)	0.005 cde (0.004-0.006)	0.019 abc (0.015-0.024)	0.003 e (na)	0.016 abcd (0.012-0.022)	0.004 de (0.003-0.004)

Table 4 cont.

Chemical	Year	Study Site					
		Canoe Meadow	Lenox Road	Roaring Brook	Threemile Pond	Taconic Valley	West Branch
mirex P = 0.0228 df = 15, 194	1998	0.005 ab (0.004-0.007)	0.009 ab (0.007-0.011)	0.009 ab (0.007-0.011)	----	----	0.009 ab (0.007-0.011)
	1999	0.006 ab (0.005-0.008)	0.010 ab (0.008-0.011)	0.015 a (0.013-0.017)	0.014 ab (0.012-0.016)	0.013 ab (0.010-0.017)	0.011 ab (0.009-0.013)
	2000	0.004 b (0.003-0.005)	0.008 ab (0.006-0.011)	0.009 ab (0.007-0.010)	0.008 ab (0.007-0.011)	0.006 ab (0.004-0.009)	0.012 ab (0.009-0.016)
o,p'-DDD P < 0.0001 df = 15, 194	1998	0.001 h (na)	0.002 g (0.001-0.004)	0.010 f (0.006-0.016)	----	----	0.001 gh (0.0005-0.0008)
	1999	0.202 ab (0.178-0.229)	0.212 ab (0.196-0.229)	0.319 a (0.298-0.340)	0.028 def (0.022-0.037)	0.043 cde (0.036-0.051)	0.052 bcde (0.039-0.069)
	2000	0.103 abcd (0.089-0.119)	0.145 abc (0.123-0.171)	0.301 a (0.270-0.336)	0.021 ef (0.016-0.027)	0.071 bcde (0.055-0.092)	0.021 ef (0.016-0.027)

Table 4 cont.

Chemical	Year	Study Site					
		Canoe Meadow	Lenox Road	Roaring Brook	Threemile Pond	Taconic Valley	West Branch
o,p'-DDT P < 0.0001 df = 15, 194	1998	0.001 h (0.0006-0.001)	0.005 g (0.004-0.008)	0.013 fg (0.009-0.019)	----	----	0.001 h (0.0005-0.0007)
	1999	0.232 ab (0.203-0.265)	0.227 ab (0.211-0.244)	0.347 a (0.326-0.369)	0.037 def (0.029-0.048)	0.039 def (0.030-0.051)	0.065 cde (0.051-0.083)
	2000	0.119 abcd (0.105-0.136)	0.194 abc (0.164-0.228)	0.346 a (0.319-0.376)	0.030 ef (0.025-0.038)	0.086 bcde (0.068-0.110)	0.030 ef (0.025-0.037)
oxychlordane P < 0.0001 df = 15, 194	1998	0.036 ab (0.025-0.053)	0.020 bc (0.015-0.027)	0.024 abc (0.022-0.027)	----	----	0.037 ab (0.032-0.042)
	1999	0.051 a (0.046-0.057)	0.032 abc (0.030-0.035)	0.035 ab (0.032-0.038)	0.025 abc (0.022-0.028)	0.023 abc (0.020-0.026)	0.030 abc (0.026-0.034)
	2000	0.019 bc (0.016-0.023)	0.015 c (0.013-0.018)	0.024 abc (0.023-0.025)	0.021 bc (0.018-0.025)	0.039 ab (0.033-0.047)	0.022 bc (0.019-0.026)

Table 4 cont.

Chemical	Year	Study Site					
		Canoe Meadow	Lenox Road	Roaring Brook	Threemile Pond	Taconic Valley	West Branch
p,p'-DDD P < 0.0001 df = 15, 194	1998	0.012 bcde (0.008-0.016)	0.011 bcde (0.008-0.013)	0.010 cde (0.008-0.011)	----	----	0.005 efg (0.003-0.008)
	1999	0.024 abc (0.020-0.028)	0.027 ab (0.025-0.030)	0.051 a (0.047-0.055)	0.003 fg (0.003-0.004)	0.009 def (0.008-0.010)	0.010 bcde (0.009-0.012)
	2000	0.011 bcde (0.009-0.014)	0.015 bcd (0.013-0.018)	0.040 a (0.036-0.045)	0.003 g (0.0029-0.0031)	0.008 def (0.006-0.012)	0.006 efg (0.005-0.007)
p,p'-DDE P < 0.0001 df = 15, 194	1998	0.315 ab (0.261-0.379)	0.297 ab (0.271-0.325)	0.359 ab (0.302-0.427)	----	----	0.418 ab (0.362-0.481)
	1999	0.537 a (0.459-0.628)	0.387 ab (0.356-0.421)	0.492 ab (0.466-0.520)	0.402 ab (0.361-0.447)	0.319 ab (0.290-0.351)	0.458 ab (0.416-0.503)
	2000	0.266 b (0.219-0.323)	0.256 b (0.216-0.303)	0.468 ab (0.428-0.511)	0.354 ab (0.325-0.385)	0.298 ab (0.253-0.349)	0.350 ab (0.286-0.429)

Table 4 cont.

Chemical	Year	Study Site: Canoe Meadow	Lenox Road	Roaring Brook	Threemile Pond	Taconic Valley	West Branch
p,p'-DDT P < 0.0001 df = 15, 194	1998	0.007 a (0.005-0.010)	0.004 ab (0.003-0.005)	0.001 bc (0.001-0.002)	----	----	0.003 abc (0.002-0.004)
	1999	0.003 ab (0.003-0.004)	0.002 bc (0.0018-0.0024)	0.003 ab (0.003-0.004)	0.001 c (0.0008-0.001)	0.002 bc (0.002-0.003)	0.002 bc (0.002-0.003)
	2000	0.004 ab (0.003-0.004)	0.003 ab (0.0029-0.0033)	0.003 ab (0.003-0.004)	0.003 abc (na)	0.003 ab (0.003-0.004)	0.003 abc (na)
trans-nonachlor P < 0.0001 df = 15, 194	1998	0.030 abc (0.019-0.050)	0.012 cdef (0.009-0.015)	0.014 bcdef (0.012-0.016)	----	----	0.035 ab (0.027-0.047)
	1999	0.048 a (0.041-0.056)	0.015 bcde (0.013-0.016)	0.015 bcde (0.014-0.016)	0.007 efg (0.006-0.009)	0.011 def (0.009-0.012)	0.020 abcd (0.016-0.024)
	2000	0.016 bcde (0.011-0.023)	0.007 efg (0.006-0.008)	0.018 abcde (0.016-0.020)	0.004 g (0.003-0.004)	0.017 bcde (0.011-0.025)	0.005 fg (0.005-0.006)

[1] For each chemical, means sharing the same letter are not significantly different among site/year means.
[2] Sites not sampled in 1998.
[3] na = no variance calculated because all values were below the detection limit.

Table 5. Geometric mean (μg/g wet wt.) and 95% Confidence Intervals, by year and site, for organochlorine chemicals in tree swallow 12-day old nestling samples (N = 5/site) collected in the Housatonic River Valley, Berkshire Co., Massachusetts, 1998, 1999 and 2000.

		Study Site					
Chemical	Year	Canoe Meadow	Lenox Road	Roaring Brook	Threemile Pond	Taconic Valley	West Branch
Total PCBs P < 0.0001 df = 15, 64	1998	22.78 a[1] (18.10-28.67)	40.55 a (37.91-43.38)	44.66 a (40.97-48.68)	---- [2]	---- [2]	2.12 bc (1.85-2.43)
	1999	34.08 a (31.64-36.71)	32.25 a (29.79-34.92)	37.26 a (33.80-41.06)	1.22 c (0.93-1.61)	4.04 b (3.44-4.74)	4.06 b (3.45-4.78)
	2000	21.36 a (19.49-23.40)	23.50 a (22.64-24.39)	22.95 a (19.74-26.68)	0.81 c (0.67-0.97)	1.84 bc (1.01-3.33)	2.22 bc (2.09-2.35)
Minimum - maximum values		10.8 - 52.5	20.7 - 52.1	14.4 - 60.9	0.56 - 3.12	0.17 - 6.29	1.64 - 6.95
PCB-1254 P < 0.0001 df = 11, 48	1999	9.86 a (9.285-10.47)	9.67 a (8.929-10.48)	11.54 a (10.43-12.75)	0.25 d (0.204-0.300)	1.41 b (1.207-1.658)	1.26 b (1.104-1.442)
	2000	7.68 a (6.862-8.590)	9.41 a (9.057-9.768)	8.93 a (7.805-10.21)	0.27 cd (0.216-0.342)	0.71 bc (0.405-1.251)	0.99 b (0.915-1.081)

Table 5 cont.

Chemical	Year	Study Site					
		Canoe Meadow	Lenox Road	Roaring Brook	Threemile Pond	Taconic Valley	West Branch
PCB-1260 P < 0.0001 df = 11, 48	1999	24.21 a (22.29-26.29)	22.56 a (20.83-24.43)	25.71 a (23.28-28.40)	0.95 bc (0.69-1.29)	2.63 b (2.24-3.08)	2.70 b (2.18-3.34)
	2000	13.67 a (12.63-14.79)	14.08 a (13.56-14.62)	13.51 a (11.41-15.99)	0.53 c (0.45-0.63)	0.97 bc (0.54-1.73)	1.17 bc (1.13-1.23)
cis-nonachlor P < 0.0001 df = 15, 64	1998	0.004 cde (0.003-0.005)	0.002 cdef (0.002-0.003)	0.002 ef (0.001-0.002)	----	----	0.002 def (0.001-0.003)
	1999	0.034 a (0.032-0.036)	0.034 a (0.029-0.039)	0.029 a (0.023-0.035)	0.001 f (0.001-0.002)	0.006 bc (0.005-0.008)	0.003 cdef (0.003-0.004)
	2000	0.016 ab (0.013-0.018)	0.024 a (0.020-0.028)	0.041 a (0.032-0.052)	0.006 bcd (na) [3]	0.006 bcd (0.005-0.006)	0.002 cdef (0.002-0.003)

Table 5 cont.

Chemical	Year	Study Site					
		Canoe Meadow	Lenox Road	Roaring Brook	Threemile Pond	Taconic Valley	West Branch
dieldrin P < 0.0001 df = 15, 64	1998	0.004 ab (0.0039-0.0044)	0.006 ab (0.006-0.007)	0.005 ab (0.004-0.005)	----	----	0.002 bc (0.001-0.004)
	1999	0.003 abc (0.002-0.004)	0.002 bcd (0.0019-0.0022)	0.002 bcd (0.001-0.003)	0.0002 e (0.0002-0.0003)	0.0003 de (0.0003-0.0004)	0.0005 cde (0.0004-0.0006)
	2000	0.002 bcd (0.002-0.003)	0.005 ab (0.003-0.009)	0.016 a (0.010-0.024)	0.004 ab (0.0036-0.0044)	0.002 bcd (0.002-0.003)	0.010 ab (0.008-0.013)
endosulfan II P < 0.0001 df = 15, 64	1998	0.0002 e (na)	0.0002 e (na)	0.0002 e (na)	----	----	0.0003 e (0.0002-0.0005)
	1999	0.029 a (0.027-0.032)	0.023 a (0.019-0.028)	0.028 a (0.024-0.032)	0.001 d (0.001-0.001)	0.002 cd (0.002-0.003)	0.003 c (0.003-0.004)
	2000	0.016 a (0.015-0.018)	0.014 ab (0.011-0.017)	0.022 a (0.018-0.027)	0.006 bc (na)	0.005 c (0.004-0.005)	0.004 c (0.004-0.005)

Table 5 cont.

Chemical	Year	Study Site					
		Canoe Meadow	Lenox Road	Roaring Brook	Threemile Pond	Taconic Valley	West Branch
HCB P < 0.0001 df = 15, 64	1998	0.009 a (0.007-0.012)	0.003 abcd (0.003-0.004)	0.003 abcd (0.0028-0.0035)	----	----	0.001 d (0.0011-0.0012)
	1999	0.005 ab (0.004-0.005)	0.001 d (0.001-0.002)	0.003 bcd (0.002-0.003)	0.0002 e (0.0002-0.0002)	0.0003 e (0.0002-0.0005)	0.0013 cd (0.001-0.002)
	2000	0.004 abcd (0.003-0.004)	0.003 abcd (0.0028-0.0033)	0.004 abc (0.003-0.005)	0.004 ab (0.003-0.006)	0.002 bcd (0.001-0.003)	0.004 abc (0.003-0.006)
heptachlor epoxide P < 0.0001 df = 15, 64	1998	0.004 a (0.003-0.006)	0.001 ab (0.001-0.002)	0.001 ab (0.001-0.001)	----	----	0.002 a (0.002-0.003)
	1999	0.005 a (0.002-0.011)	0.002 a (0.001-0.003)	0.002 a (0.0016-0.0022)	0.0003 b (0.0002-0.0004)	0.001 ab (0.001-0.002)	0.002 ab (0.001-0.002)
	2000	0.004 a (0.003-0.005)	0.006 a (na)	0.004 a (0.003-0.005)	0.006 a (na)	0.004 a (0.003-0.005)	0.003 a (0.002-0.004)

Table 5 cont.

Chemical	Year	Study Site					
		Canoe Meadow	Lenox Road	Roaring Brook	Threemile Pond	Taconic Valley	West Branch
mirex P < 0.0001 df = 15, 64	1998	0.0002 ef (0.0002-0.0003)	0.0002 ef (0.0002-0.0003)	0.0002 f (na)	----	----	0.0008 cde (0.0007-0.0009)
	1999	0.0004 def (0.0003-0.0007)	0.0006 def (0.0004-0.0008)	0.0011 bcd (0.0008-0.0014)	0.0005 def (0.0004-0.0008)	0.0007 cde (0.0005-0.0009)	0.0011 bcd (0.0009-0.0013)
	2000	0.0058 a (na)	0.0058 a (na)	0.0033 ab (0.002-0.005)	0.0040 ab (0.003-0.005)	0.0051 a (0.005-0.006)	0.0025 abc (0.002-0.004)
o,p'-DDD P < 0.0001 df = 15, 64	1998	0.002 ef (0.0016-0.0023)	0.002 ef (0.002-0.003)	0.001 fg (0.0003-0.0016)	----	----	0.0002 g (0.00015-0.00024)
	1999	0.106 a (0.101-0.112)	0.080 a (0.076-0.085)	0.097 a (0.085-0.111)	0.006 cde (0.005-0.006)	0.011 c (0.009-0.013)	0.010 cd (0.009-0.012)
	2000	0.069 ab (0.066-0.072)	0.080 a (0.073-0.088)	0.073 ab (0.065-0.082)	0.003 de (0.002-0.004)	0.019 bc (0.014-0.027)	0.014 c (0.013-0.015)

Table 5 cont.

Chemical	Year	Study Site					
		Canoe Meadow	Lenox Road	Roaring Brook	Threemile Pond	Taconic Valley	West Branch
o,p'-DDT P < 0.0001 df = 15, 64	1998	0.001 gh (0.001-0.002)	0.002 g (0.002-0.003)	0.002 g (0.001-0.003)	----	----	0.0004 h (0.0002-0.0006)
	1999	0.091 a (0.082-0.100)	0.086 ab (0.081-0.091)	0.110 a (0.098-0.122)	0.004 efg (0.003-0.006)	0.012 def (0.010-0.014)	0.010 def (0.009-0.011)
	2000	0.063 abc (0.061-0.064)	0.077 ab (0.071-0.083)	0.080 ab (0.072-0.088)	0.004 fg (0.003-0.004)	0.020 bcd (0.014-0.028)	0.016 cde (0.015-0.017)
oxychlordane P < 0.0001 df = 15, 64	1998	0.013 ab (0.011-0.015)	0.006 abcd (0.006-0.007)	0.005 bcd (0.004-0.005)	----	----	0.003 cd (0.001-0.006)
	1999	0.015 a (0.013-0.019)	0.009 abcd (0.007-0.010)	0.014 ab (0.012-0.016)	0.003 d (0.002-0.003)	0.008 abcd (0.007-0.009)	0.007 abcd (0.006-0.008)
	2000	0.012 ab (0.010-0.014)	0.008 abcd (0.0077-0.0085)	0.016 a (0.013-0.020)	0.004 bcd (0.0039-0.0042)	0.011 ab (0.009-0.013)	0.009 abc (0.007-0.011)

Table 5 cont.

Chemical	Year	Study Site					
		Canoe Meadow	Lenox Road	Roaring Brook	Threemile Pond	Taconic Valley	West Branch
p,p'-DDD P < 0.0001 df = 15, 64	1998	0.009 ab (0.008-0.011)	0.008 ab (0.008-0.009)	0.007 abc (0.006-0.008)	----	----	0.002 cd (0.001-0.005)
	1999	0.014 ab (0.012-0.015)	0.008 ab (0.008-0.009)	0.016 a (0.014-0.019)	0.004 bcd (0.003-0.005)	0.008 abc (0.007-0.009)	0.007 abc (0.005-0.010)
	2000	0.009 ab (0.008-0.010)	0.007 abc (0.007-0.008)	0.015 a (0.011-0.019)	0.002 d (0.002-0.002)	0.008 ab (0.007-0.010)	0.009 ab (0.007-0.011)
p,p'-DDE P < 0.0001 df = 15, 64	1998	0.119 abc (0.108-0.131)	0.086 abcde (0.082-0.091)	0.145 ab (0.135-0.157)	----	----	0.106 abcd (0.093-0.119)
	1999	0.168 a (0.154-0.184)	0.088 abcde (0.080-0.096)	0.113 abcd (0.105-0.121)	0.056 def (0.052-0.060)	0.076 bcdef (0.070-0.083)	0.108 abcd (0.095-0.123)
	2000	0.087 abcde (0.078-0.097)	0.063 cdef (0.059-0.067)	0.064 cdef (0.059-0.070)	0.047 ef (0.045-0.049)	0.040 f (0.026-0.061)	0.055 def (0.049-0.061)

Table 5 cont.

Chemical	Year	Study Site					
		Canoe Meadow	Lenox Road	Roaring Brook	Threemile Pond	Taconic Valley	West Branch
p,p'-DDT P < 0.0001 df = 15, 64	1998	0.002 abcd (0.002-0.003)	0.002 abcd (0.0018-0.0022)	0.001 cde (0.0007-0.0010)	----	----	0.002 abcd (0.0016-0.0023)
	1999	0.003 abc (0.002-0.003)	0.001 bcd (0.001-0.002)	0.0003 ef (0.0002-0.0004)	0.0002 f (0.0002-0.0003)	0.0007 def (0.0006-0.0009)	0.0008 cde (0.0007-0.0010)
	2000	0.003 abcd (0.002-0.004)	0.002 abcd (0.002-0.003)	0.005 ab (0.003-0.006)	0.006 a (na)	0.003 ab (0.002-0.005)	0.003 abc (0.002-0.005)
trans-nonachlor P < 0.0001 df = 15, 64	1998	0.016 ab (0.012-0.021)	0.007 abc (0.007-0.008)	0.004 cd (0.003-0.005)	----	----	0.004 cd (0.003-0.006)
	1999	0.020 a (0.016-0.025)	0.005 bcd (0.004-0.007)	0.003 cd (0.003-0.004)	0.0003 e (0.0002-0.0004)	0.009 abc (0.007-0.011)	0.007 abc (0.007-0.008)
	2000	0.010 abc (0.008-0.012)	0.005 bcd (0.004-0.006)	0.006 abcd (0.004-0.008)	0.002 d (0.0017-0.0019)	0.011 abc (0.009-0.013)	0.008 abc (0.007-0.010)

[1] For each chemical, means sharing the same letter are not significantly different among each site/year mean.
[2] Site not sampled in 1998.
[3] na = no variance calculated because all values were below the detection limit.

Table 6. Summary of accumulation rates, by year and site, for tree swallows nesting along the Housatonic River Valley, Berkshire Co., Massachusetts in 1998, 1999, 2000. Means and standard errors (SE) are provided. N = 5 except N = 4 for West Branch in 1998 and Taconic Valley in 2000.

	Accumulation rate (ug/day)					
Year	Canoe Meadows	Lenox Road	Roaring Brook	Threemile Pond	Taconic Valley	West Branch
Total PCBs						
1998	43.0 ± 15.3 bc	66.5 ± 5.14 ab	75.9 ± 7.40 a	----	----	3.03 ± 0.36 e
1999	54.8 ± 5.14 abc	51.4 ± 5.05 abc	52.3 ± 4.97 abc	-0.3 ± 0.32 e	5.95 ± 1.30 de	3.93 ± 0.77 e
2000	33.7 ± 5.05 cd	38.0 ± 2.46 bc	39.1 ± 6.45 bc	0.7 ± 0.31 e	2.98 ± 0.98 e	2.63 ± 0.17 e
p,p' DDE						
1998	0.19 ± 0.03 abc	0.12 ± 0.01 bcd	0.21 ± 0.03 ab	----	----	0.18 ± 0.01 abc
1999	0.22 ± 0.02 a	0.09 ± 0.01 cd	0.13 ± 0.01 abcd	0.05 ± 0.004 de	0.10 ± 0.01 cd	0.12 ± 0.02 bcd
2000	0.11 ± 0.01 bcd	0.09 ± 0.01 cde	0.07 ± 0.01 de	0.04 ± 0.01 de	0.06 ± 0.03 de	-0.01 ± 0.04 e

[1] For each chemical, means sharing same letter are not significantly different. $P < 0.001$, df = 15,62 for total PCBs and p,p'DDE.

Table 7. Summary of total PCB concentrations in pooled diet samples, by year and site, for tree swallows nesting along the Housatonic River Valley, Berkshire Co., Massachusetts in 1998, 1999, 2000. One pooled diet sample per site in 1998 and 2000. Two samples pooled per site in 1999.

	Diet (μg/g wet wgt.)					
Year	Canoe Meadows	Lenox Road	Roaring Brook	Threemile Pond	Taconic Valley	West Branch
1998	1.92	15.5	18.8	----	----	0.96
1999	17.3	5.97	8.21	0.81	10.0	0.58
2000	3.7	7.13	5.63	0.07	0.17	0.11

Table 8. Correlation matrix of total PCB concentrations in diet, pippers, nestlings, and accumulation rate of total PCBs in 12-day old nestlings (N = 16) from Berkshire, Co., Massachusetts in 1998, 1999 and 2000. R-value on first line and P-value on second line.

	Diet	Pippers	Nestlings	Accum. rate
Diet	1.00 0.0	0.51 0.0416	0.80 0.0002	0.80 0.0002
Pippers	0.51 0.0416	1.00 0.0	0.83 0.0001	0.79 0.0002
Nestlings	0.80 0.0002	0.83 0.0001	1.00 0.0	0.99 0.0001
Accum. rate	0.80 0.0002	0.79 0.0002	0.99 0.0001	1.00 0.0

Table 9. Number of samples with dioxin or furan concentrations above the detection limit for tree swallow pipper samples collected along the Housatonic River Valley, Berkshire Co., Massachusetts 1998, 1999, and 2000.

Chemical	Study Site					
	Canoe Meadow (N = 11) [1]	Lenox Road (N = 18)	Roaring Brook (N = 21)	Threemile Pond (N = 17)	Taconic Valley (N = 13)	West Branch (N = 15)
Dioxins						
2,3,7,8-TCDD	1	1	6	3	1	0
1,2,3,7,8-PeCDD	0	1	4	1	2	1
1,2,3,4,7,8-HxCDD	0	0	2	1	0	1
1,2,3,6,7,8-HxCDD	0	0	7	4	4	4
1,2,3,7,8,9-HxCDD	0	0	1	0	0	0
1,2,3,4,6,7,8-HpCDD	3	6	15	6	6	8
OCDD	2	4	9	4	6	7
Furans						
2,3,7,8-TCDF	8	13	21	13	13	11

Table 9 cont

Chemical	Study Site					
	Canoe Meadow	Lenox Road	Roaring Brook	Threemile Pond	Taconic Valley	West Branch
1,2,3,7,8-PeCDF	11	16	21	12	10	10
2,3,4,7,8-PeCDF	6	9	17	6	6	4
1,23,4,7,8-HxCDF	0	2	1	3	4	4
1,2,3,6,7,8-HxCDF	1	1	1	0	0	1
1,2,3,7,8,9-HxCDF	0	0	0	0	0	0
2,3,4,6,7,8-HxCDF	0	0	3	0	1	1
1,2,3,4,6,7,8-HpCDF	4	9	16	8	8	7
1,2,3,4,7,8,9-HpCDF	0	0	0	0	0	0
OCDF	0	0	0	0	1	0

[1] Total number of samples analyzed. This total includes 1 pooled sample each from Canoe Meadow, Lenox Road, Roaring Brook and West Branch in 1998.

Table 10. Geometric mean (ng/g wet wt.) and 95% Confidence Intervals, by year and site, for dioxins and furans in tree swallow pipper samples collected along the Housatonic River Valley, Berkshire Co., Massachusetts in 1998, 1999, and 2000.

Chemical [1]	Year	Study Site					
		Canoe Meadow	Lenox Road	Roaring Brook	Threemile Pond	Taconic Valley	West Branch
TCDF P < 0.0001 df = 11, 79	1998	0.30 (na) [2]	0.32 (na)	0.50 (na)	---- [3]	---- [3]	0.05 (na)
	1999	0.05 bc[4] (0.02-0.09)	0.07 abc (0.04-0.1)	0.55 a (0.5-0.6)	0.09 abc (0.05-0.1)	0.05 bc (0.04-0.05)	0.04 bc (0.03-0.07)
	2000	0.21 ab (0.19-0.24)	0.12 abc (0.06-0.2)	0.38 ab (0.3-0.4)	0.02 c (0.01-0.03)	0.08 abc (0.06-0.1)	0.02 c (0.01-0.03)
PeCDF1 P < 0.0001 df = 11, 79	1998	0.04 (na)	0.05 (na)	0.05 (na)	----	----	0.01 (na)
	1999	0.63 ab (0.5-0.8)	0.36 abcd (0.3-0.5)	1.01 a (0.9-1.2)	0.12 cdef (0.1-0.2)	0.13 bcdef (0.1-0.2)	0.11 def (0.08-0.14)
	2000	0.35 abcd (0.3-0.4)	0.16 bcde (0.1-0.3)	0.59 abc (0.5-0.7)	0.03 f (0.02-0.04)	0.10 def (0.07-0.1)	0.06 ef (0.05-0.08)

Table 10 cont.

Chemical	Year	Study Site					
		Canoe Meadow	Lenox Road	Roaring Brook	Threemile Pond	Taconic Valley	West Branch
PeCDF2 P < 0.0001 df = 11, 79	1998	0.08 (na)	0.09 (na)	0.09 (na)	----	----	0.01 (na)
	1999	0.08 ab (0.06-0.1)	0.07 ab (0.07-0.08)	0.11 a (0.09-0.12)	0.06 ab (7 nd) [4]	0.06 ab (6 nd)	0.06 ab (7 nd)
	2000	0.03 abc (0.02-0.06)	0.02 bc (0.01-0.03)	0.07 ab (0.05-0.1)	0.01 c (0.007-0.01)	0.02 bc (0.01-0.02)	0.01 c (0.01-0.02)
HpCDF P < 0.0001 df = 11, 79	1998	0.01 (na)	0.01 (na)	0.01 (na)	----	----	0.01 (na)
	1999	0.07 ab (0.06-0.09)	0.08 ab (0.07-0.09)	0.1 ab (0.09-0.1)	0.06 abc (7 nd)	0.07 ab (0.06-0.08)	0.06 abc (7 nd)
	2000	0.03 bc (0.01-0.06)	0.04 bc (0.02-0.07)	0.23 a (0.2-0.3)	0.01 c (0.01-0.02)	0.04 bc (0.03-0.06)	0.04 bc (0.03-0.05)

[1] Chemical abbreviations are TCDF = 2,3,7,8-TCDF; PeCDF1 = 1,2,3,7,8-PeCDF; PeCDF2 = 2,3,4,7,8-PeCDF; HpCDF = 1,2,3,4,6,7,8-HpCDF.
[2] na = no variance estimate available because samples were pooled in 1998.
[3] Means sharing the same letter are not significantly different. ANOVA only on 1999 and 2000 data. Pooled samples in 1998 were not statistically compared to the other years.

[4] Number before nd is number not detected.

Table 11. Mean toxic equivalents (ng/g, TEQs) ± 1 standard error for pipper samples collected along the Housatonic River, Berkshire Co., Massachusetts 1998-2000. Kennedy's TEQs and WHO-consensus values are reported.

		Study Site					
Chemical	Year	Canoe Meadows	Lenox Road	Roaring Brook	Threemile Pond	Taconic Valley	West Branch
Kennedy [1] P < 0.0001	1998	18.00 + 2.55 ab [2]	15.18 + 0.74 bc	13.91 + 1.43 bcde	---- [3]	---- [3]	6.43 + 1.58 defg
	1999	14.34 + 2.16 bcd	13.39 + 0.81 bcde	25.41 + 1.81 a	4.04 + 1.39 fg	4.14 + 0.49 fg	5.51 + 1.27 efg
	2000	8.03 + 1.12 cdefg	11.97 + 1.36 bcdef	20.42 + 2.19 ab	2.15 + 0.30 g	5.56 + 1.30 egf	2.27 + 0.33 g
WHO [4] P < 0.0001	1998	4.3 + 0.90 a	1.97 + 0.25 bc	1.49 + 0.30 bcde	----	----	0.46 + 0.14 def
	1999	1.51 + 0.25 bcd	1.19 + 0.10 def	1.98 + 0.13 bc	0.35 + 0.12 def	0.30 + 0.04 ef	0.30 + 0.07 def
	2000	0.67 + 0.10 def	1.22 + 0.20 cdef	2.56 + 0.41 b	0.23 + 0.03 f	0.64 + 0.17 def	0.31 + 0.07 def

[1] Kennedy's (Kennedy et al. 1996) TEQs

[2] Means sharing the same letter are not significantly different. See P values above, df = 15, 194.

[3] ---- Sites not sampled in 1998.

[4] WHO-consensus (Van den Burg et al. 1998) TEQs.

Table 12. Geometric mean (µg/g wet wt.) and 95% Confidence Intervals for aliphatic hydrocarbons in tree swallow nestling samples collected along the Housatonic River Valley, Berkshire Co., Massachusetts in 2000.

	Study Site					
Chemical	Canoe Meadows	Lenox Road	Roaring Brook	Threemile Pond	Taconic Valley	West Branch
n-decane P = 0.0882	0.07 (0.04-.012)	0.07 (0.05-0.09)	0.18 (0.12-0.25)	0.22 (0.19-0.25)	0.15 (0.10-0.21)	0.07 (0.51-0.09)
n-docosane P = 0.3066	0.22 (0.15-0.30)	0.18 (0.14-0.24)	0.24 (0.22-0.27)	0.37 (0.27-0.50)	0.22 (0.19-0.25)	0.33 (0.29-0.38)
n-dotriacontane P = 0.6186	3.73 (1.65-8.44)	1.60 (1.37-1.86)	1.56 (1.09-2.25)	1.77 (1.35-2.32)	1.54 (1.38-1.72)	1.41 (0.98-2.04)
n-eicosane P = 0.2793	1.57 (1.10-2.24)	1.11 (0.81-1.53)	0.86 (0.73-1.03)	0.65 (0.57-0.74)	0.78 (0.55-1.19)	1.19 (0.91-1.57)
n-heneicosane P = 0.0969	15.32 (9.17-25.60)	9.14 (5.21-16.03)	8.28 (5.37-12.77)	8.72 (4.23-18.01)	8.40 (6.49-10.88)	1.41 (0.70-2.80)
n-hentriacontane P = 0.4475	1.70 (1.42-2.03)	1.94 (1.73-2.17)	1.43 (1.14-1.80)	1.49 (1.35-1.65)	1.22 (1.06-1.42)	1.68 (1.48-1.89)
n-heptacosane P = 0.0985	1.84 (1.51-2.25)	1.12 (0.89-1.42)	1.51 (1.22-1.86)	2.51 (2.35-2.68)	1.03 (0.99-1.06)	2.11 (1.39-3.20)
n-heptadecane P = 0.2752	0.52 (0.46-0.76)	0.60 (0.65-1.08)	0.84 (0.70-1.25)	0.93 (0.40-0.45)	0.42 (0.45-0.80)	0.60 (0.41-0.65)
n-hexacosane P = 0.0311	0.22 ab[1] (0.19-0.25)	0.21 b (0.17-0.24)	0.37 ab (0.32-0.42)	0.26 ab (0.22-0.30)	0.36 ab (0.28-0.46)	0.45 a (0.36-0.57)
n-hexadecane P = 0.2874	0.15 (0.11-0.21)	0.13 (0.10-0.17)	0.10 (0.07-0.14)	0.08 (0.06-0.09)	0.06 (0.04-0.09)	0.09 (0.08-0.11)
n-nonacosane P = 0.0348	1.81 a (1.46-2.24)	1.01 ab (0.87-1.18)	1.04 ab (0.78-1.39)	0.82 ab (0.75-0.90)	0.65 b (0.62-0.69)	1.21 ab (0.95-1.53)
n-nonadecane P = 0.1082	1.56 (0.98-2.48)	1.16 (0.71-1.89)	1.38 (0.92-2.09)	0.67 (0.40-1.12)	0.99 (0.9-1.24)	0.27 (0.17-1.24)
n-octacosane P = 0.1176	0.08 (0.06-0.09)	0.04 (0.03-0.06)	0.06 (0.05-0.09)	0.07 (0.05-0.09)	0.06 (0.05-0.07)	0.12 (0.10-0.16)

Table 12 cont.

Chemical	Study Site					
	Canoe Meadows	Lenox Road	Roaring Brook	Threemile Pond	Taconic Valley	West Branch
n-octadecane P = 0.1598	0.23 (0.16-0.35)	0.19 (0.15-0.24)	0.11 (0.08-0.13)	0.14 (0.08-0.26)	0.06 (0.40-0.11)	0.07 (0.05-0.10)
n-pentacosane P = 0.7293	1.75 (1.38-2.21)	1.40 (1.12-1.74)	1.58 (1.26-1.99)	1.52 (1.34-1.74)	1.21 (1.09-1.35)	2.05 (1.43-2.92)
n-pentadecane P = 0.0993	0.26 (0.22-0.31)	0.20 (0.15-0.27)	0.32 (0.28-0.38)	0.15 (0.13-0.16)	0.13 (0.11-0.16)	0.19 (0.14-0.27)
n-tetracosane P = 0.9430	0.12 (0.10-0.14)	0.15 (0.11-0.19)	0.15 (0.11-0.20)	0.12 (0.20-0.15)	0.15 (0.13-0.17)	0.15 (0.11-0.19)
n-tetradecane P = 0.6836	0.05 (0.04-0.07)	0.04 (0.03-0.05)	0.05 (0.03-0.06)	0.06 (0.04-0.07)	0.04 (0.03-0.05)	0.06 (0.06-0.07)
n-tetratriacontane P < 0.0001	0.54 b (0.45-0.65)	0.38 b (0.31-0.46)	1.40 a (1.07-1.84)	2.99 a (2.47-3.61)	2.65 a (2.24-3.12)	2.96 a (2.65-3.30)
n-triacontane P = 0.2398	0.43 (0.35-0.53)	0.63 (0.52-0.77)	0.55 (0.51-0.60)	0.46 (0.43-0.50)	0.31 (0.29-0.34)	0.38 (0.26-0.54)
n-tricosane P = 0.1591	1.17 (0.93-1.47)	1.32 (1.08-1.62)	2.65 (2.22-3.15)	1.07 (0.94-1.23)	1.61 (1.33-1.95)	1.95 (1.22-3.10)
n-tridecane P = 0.2493	0.30 (0.13-0.67)	0.16 (0.09-0.27)	0.08 (0.04-0.15)	0.59 (0.52-0.68)	0.37 (0.24-0.58)	0.37 (0.17-0.79)
n-tritriacontane P < 0.0001	1.2771 b (1.06-1.54)	1.4770 b (1.33-1.64)	3.2587 ab (2.24-4.73)	6.2405 a (5.52-7.06)	4.7478 a (3.92-5.75)	5.2263 a (4.57-5.97)
n-undecane P = 0.5597	0.20 (0.14-0.29)	0.13 (0.08-0.21)	0.08 (0.05-0.12)	0.24 (0.19-0.30)	0.08 (0.05-0.13)	0.18 (0.07-0.44)
phytane P = 0.5823	0.10 (0.05-0.20)	0.07 (0.03-0.14)	0.08 (0.05-0.14)	0.10 (0.07-0.17)	0.16 (0.13-0.19)	0.04 (0.03-0.06)
phristane:n-hepta- decane P = 0.2230	0.453	0.571	0.136	0.061	0.120	0.099

[1] Means sharing the same letter are not significantly different among sites. Means without letters did not differ significantly. See P-values above in table, df = 5, 23.

Table 13. Geometric mean (µg/g dry wt.) and 95% Confidence Intervals for trace elements in tree swallow pipper samples collected in 2000 along the Housatonic River Valley, Massachusetts.

Chemical	Study Site		
	Lenox Road (N = 2)	Roaring Brook (N = 3)	Threemile Pond (N = 5)
Boron P = 0.178	45.4 (45.00-45.90)	26.0 (20.25-33.46)	40.2 (34.98-46.10)
Barium P = 0.235	1.75 (1.74-1.75)	1.88 (1.69-2.08)	2.58 (2.19-3.04)
Copper P = 0.843	3.78 (3.37-4.23)	4.04 (3.71-4.39)	4.40 (3.66-5.30)
Iron P = 0.706	118 (106.0-132.0)	124 (117.5-130.8)	110 (99.2-122.3)
Mercury P = 0.153	0.77 (0.71-0.84)	0.64 (0.60-0.68)	0.59 (0.55-0.63)
Magnesium P = 0.714	865 (809.0-924.0)	911 (879.1-943.1)	786 (680.2-907.2)
Manganese P = 0.652	6.09 (4.59-8.08)	6.18 (4.78-7.99)	4.57 (3.61-5.79)
Selenium P = 0.059	2.90 (2.85-2.95)	2.10 (1.92-2.29)	2.50 (2.37-2.63)
Strontium P = 0.018	18.90 a[1] (15.80-22.60)	16.41 ab (12.74-21.14)	7.99 b (7.13-8.94)
Vanadium P = 0.955	1.24 (1.18-1.31)	1.18 (1.16-1.21)	1.14 (0.92-1.40)
Zinc P = 0.766	90.2 (81.70-99.50)	85.7 (83.76-87.67)	92.5 (85.71-99.77)

[1] Means sharing the same letter are not significantly different among sites. See P values above, df = 2, 7. Means without letters did not differ significantly from one another.

Table 14. Geometric mean (μg/g dry wt.) and 95% Confidence Intervals for trace elements in tree swallow nestling carcass samples collected in 1998 along the Housatonic River, Massachusetts.

	Study Site			
Chemical	Canoe Meadow (N = 5)	Lenox Road (N = 5)	Roaring Brook (N = 5)	West Branch (N = 5)
Barium P = 0.383	0.86 (0.68-1.07)	1.06 (0.86-1.31)	0.59 (0.50-0.69)	0.84 (0.61-1.15)
Chromium P = 0.093	0.75 (0.55-1.02)	0.59 (0.47-0.74)	0.44 (0.35-0.56)	1.04 (0.97-1.10)
Copper P = 0.402	7.32 (7.02-7.63)	7.93 (7.33-8.59)	7.28 (6.95-7.63)	8.39 (7.68-9.16)
Iron P = 0.078	220 (197.9-244.6)	220 (210.5-229.1)	228 (206.6-250.5)	170 (160.0-181.5)
Mercury P = 0.0004	0.27 bc[1] (0.25-0.29)	0.46 a (0.44-0.48)	0.35 ab (0.32-0.38)	0.20 c (0.17-0.24)
Magnesium P = 0.051	784 (721.3-851.2)	955 (895.5-1017.6)	734 (687.6-784.4)	922 (861.9-985.5)
Manganese P = 0.992	3.15 (2.45-4.05)	3.05 (2.37-3.92)	2.87 (2.41-3.42)	2.99 (2.58-3.47)
Selenium P = 0.780	2.44 (2.18-2.73)	2.23 (2.09-2.38)	2.16 (1.95-2.39)	2.41 (2.16-2.68)
Strontium P = 0.501	3.92 (2.71-5.66)	5.23 (4.03-6.80)	2.67 (2.08-3.42)	3.65 (2.64-5.05)
Zinc P = 0.273	92.9 (86.9-99.4)	104.7 (101.3-108.3)	93.2 (86.6-100.2)	106.1 (99.8-112.7)

[1] Means sharing the same letter are not significantly different among sites. See P values above, df = 3, 16. Means without letters did not differ significantly from one another.

Table 15. Number of nest attempts lost to predation, flooding, or human-related causes for tree swallows nesting in the Housatonic River Valley, Massachusetts in 1998, 1999, and 2000.

	Study Site					
Year	Canoe Meadows	Lenox Road	Roaring Brooke	Threemile Pond	Taconic Valley	West Branch
1998	0	3	2	-- [1]	-- [1]	2
1999	1	6	1	1	0	2
2000	3	2	0	1	3	1

[1] -- site not present in1998

Table 16. Summary of Mayfield egg survival estimates, by year and location, for tree swallows nesting along the Housatonic River Valley, Berkshire Co., Massachusetts in 1998, 1999, 2000. Means, 95% Confidence Intervals in parentheses, and sample size are provided

	Daily Survival						
Year	Canoe Meadows	Lenox Road	Roaring Brook	Threemile Pond	Taconic Valley	West Branch	P-value
1998	0.9863 ab[1] (0.9744-9983) 5	0.9992 a (0.9978-1.001) 15	0.9866 b (0.9803-0.9930) 16	----[2]	----	0.9904 ab (0.9827-0.9981) 9	< 0.001
1999	0.9977 a (0.9945-1.001) 11	0.9955 ab (0.9922-0.9988) 21	0.9886 b (0.9848-0.9924) 42	0.9930 ab (0.9874-0.9986) 14	0.9956 ab (0.9906-1.001) 9	0.9898 ab (0.9831-0.9965) 14	0.009
2000	0.9852 a (0.9755-0.9948) 9	0.9943 a (0.9912-0.9973) 30	0.9950 a (0.9925-0.9974) 37	0.9895 a (0.9847-0.9944) 24	0.9430 b (0.9251-0.9610) 15	0.9906 a (0.9847-0.9964) 14	< 0.001

[1] Means sharing same letter are not significantly different among sites. Each year analyzed separately.

[2] --- Site not sampled in 1998.

Table 17. P-values for single-variable and multiple-variable logistic regressions (hatching success vs contaminant concentration) for pipper data for tree swallows nesting along the Housatonic River, Berkshire Co., Massachusetts in 1999.

Independent Variable	P-values	
Two-variable models with	Total PCBs	Dioxins/furans
Total PCBs and total dioxin/furans	0.528	0.448
TEQs (Kennedy)	0.974	0.072
TEQs (WHO-consensus)	0.675	0.035
Single variable models with only	For each variable	
Total PCBs	0.044	
Total dioxins/furans	0.027	
TEQs for PCBs (Kennedy)	0.102	
TEQs for PCBs (WHO-consensus)	0.413	
TEQs for dioxins/furans (Kennedy)	0.009	
TEQs for dioxins/furans (WHO-consensus)	0.009	

Table 18. Summary of EROD activity, by year and site, for tree swallows nesting along the Housatonic River Valley, Berkshire Co., Massachusetts and in Houston Co., Minnesota in 1999 and 2000. Means ± 1 Standard Error and sample sizes are provided.

	EROD activity (pmoles/min/mg)						
Year	Canoe Meadows	Lenox Road	Roaring Brook	Taconic Valley	West Branch	Threemile Pond	Upper Miss. River
1999	--- [1]	147.8 ab[2] ± 40.51	249.9 a ± 39.11	---	71.5 b ± 13.19	20.3 b ± 6.10	43.3 b ± 8.16
		8	8		8	2	5
2000	47.1 a ± 4.20	47.3 a ± 5.65	44.5 ab ± 6.98	36.4 ab ± 2.05	30.4 ab ± 10.08	20.6 b ± 1.99	20.9 b ± 1.94
	5	8	8	3	6	7	20

[1] --- Location not sampled in 1999.

[2] Each year analyzed separately. Means sharing same letter are not significantly different among sites. 1999 with $P < 0.001$, df = 4,26; 2000 with $P < 0.001$, df = 6,50.

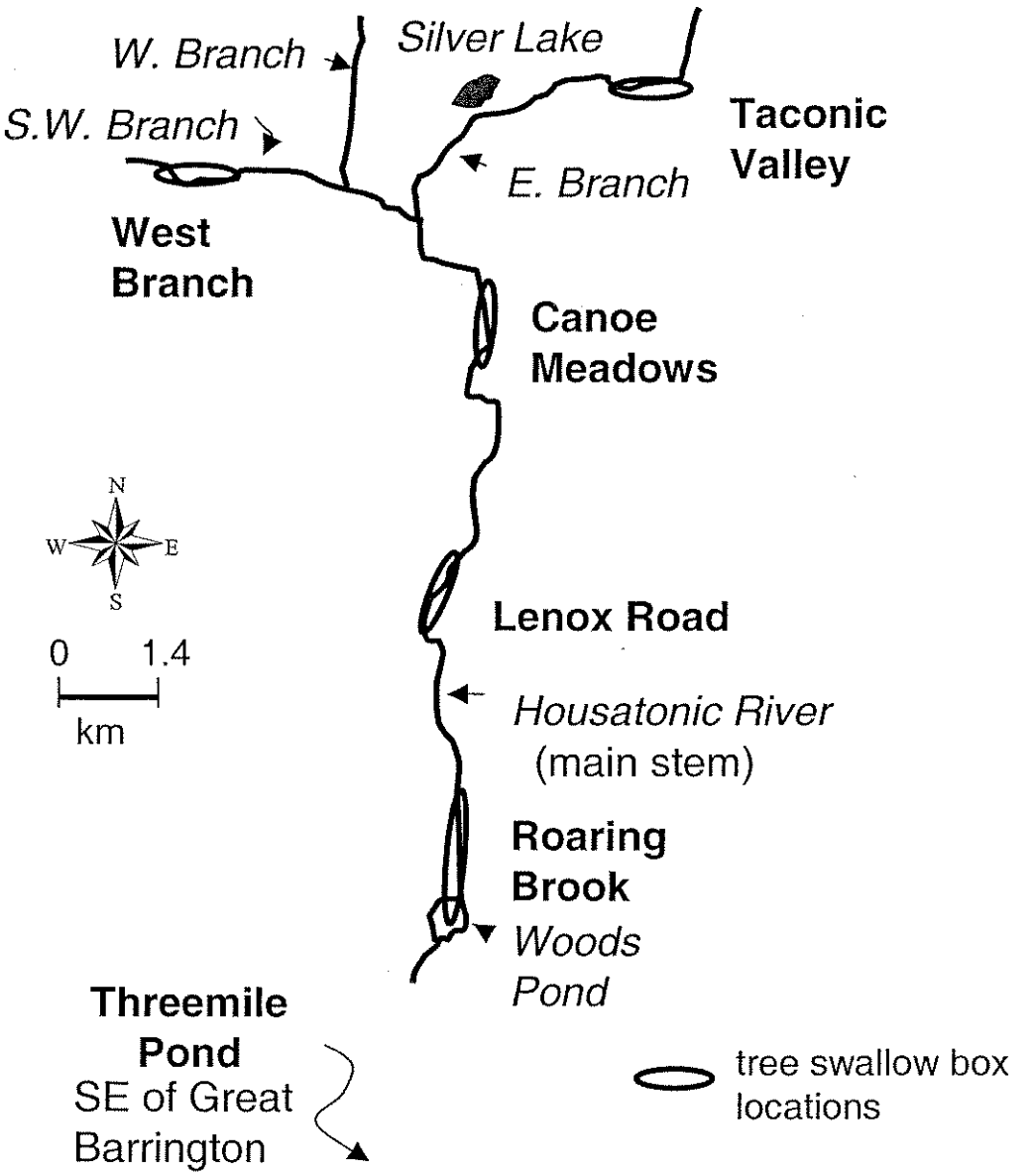

Figure 1. Tree swallow study sites in the Housatonic River Valley in 1998, 1999, and 2000, Berkshire Co., Massachusetts.

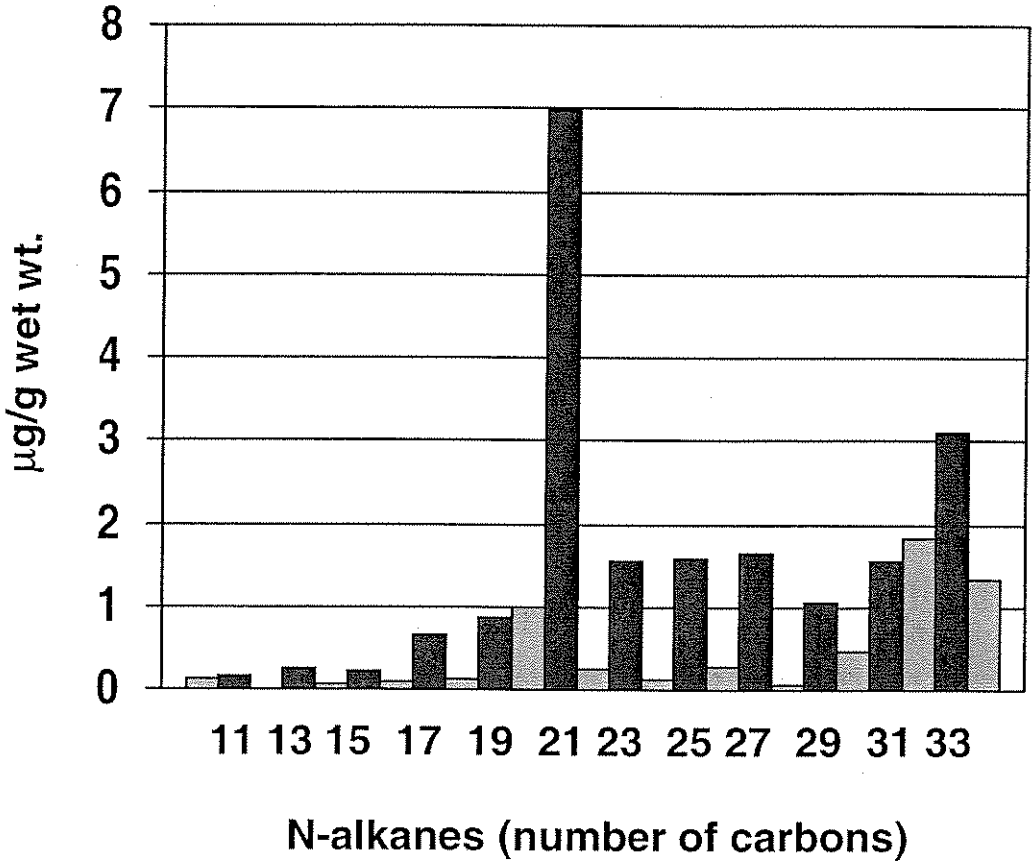

Figure 2. Concentrations of the aliphatic hydrocarbons (n-alkanes) in tree swallow carcasses from the Housatonic River Valley, Berkshire Co., Massachusetts in 2000.

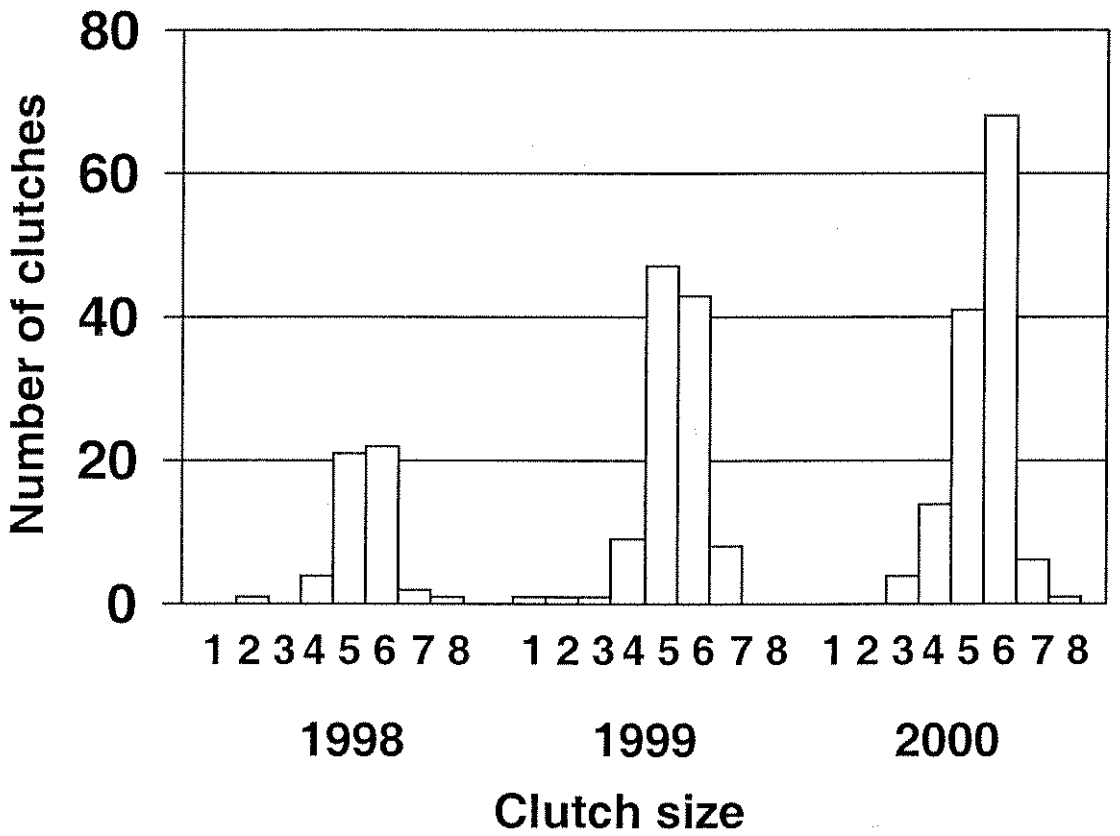

Figure 3. Frequency distribution of tree swallow clutches sizes for birds nesting in the Housatonic River Valley, Berkshire Co., Massachusetts in 1998, 1999, and 2000.

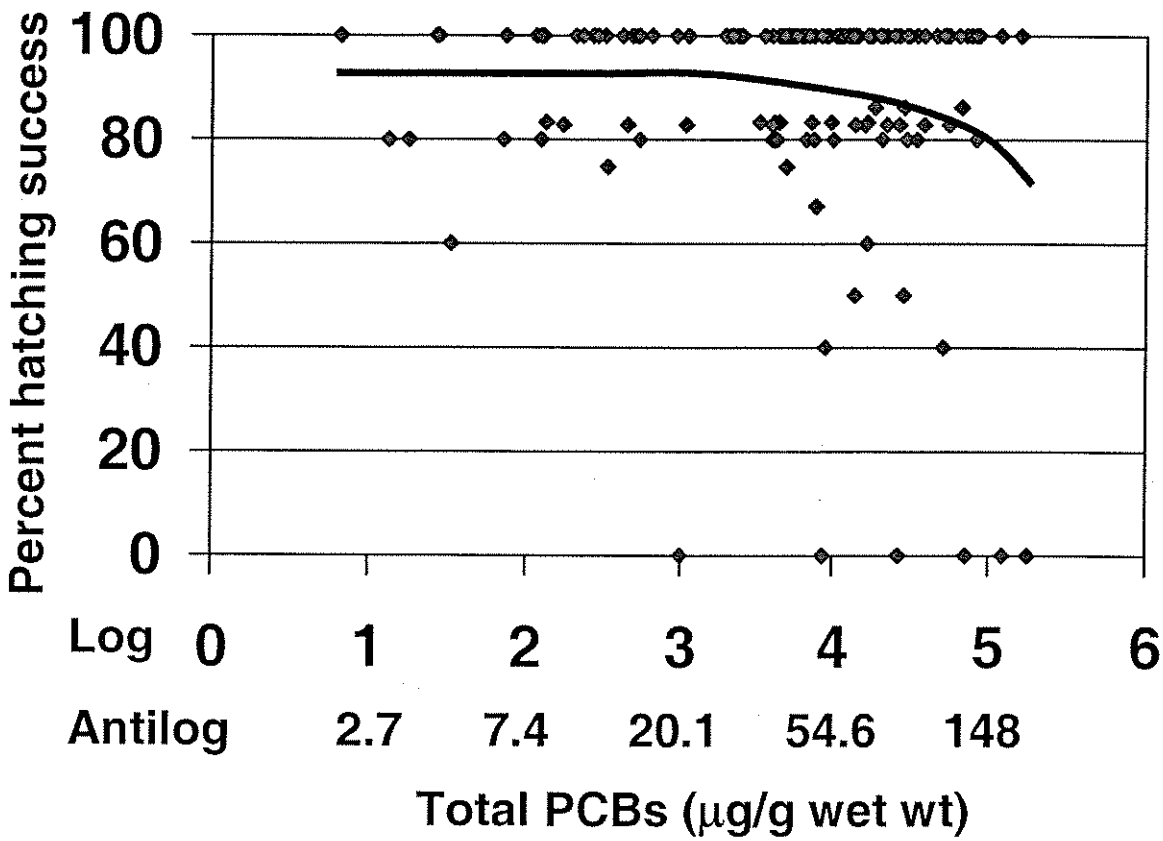

Figure 4. Logistic regression of percent hatching and natural log total PCBs in tree swallow pipper samples from the Housatonic River Valley, Berkshire Co., Massachusetts in 1998 and 1999.

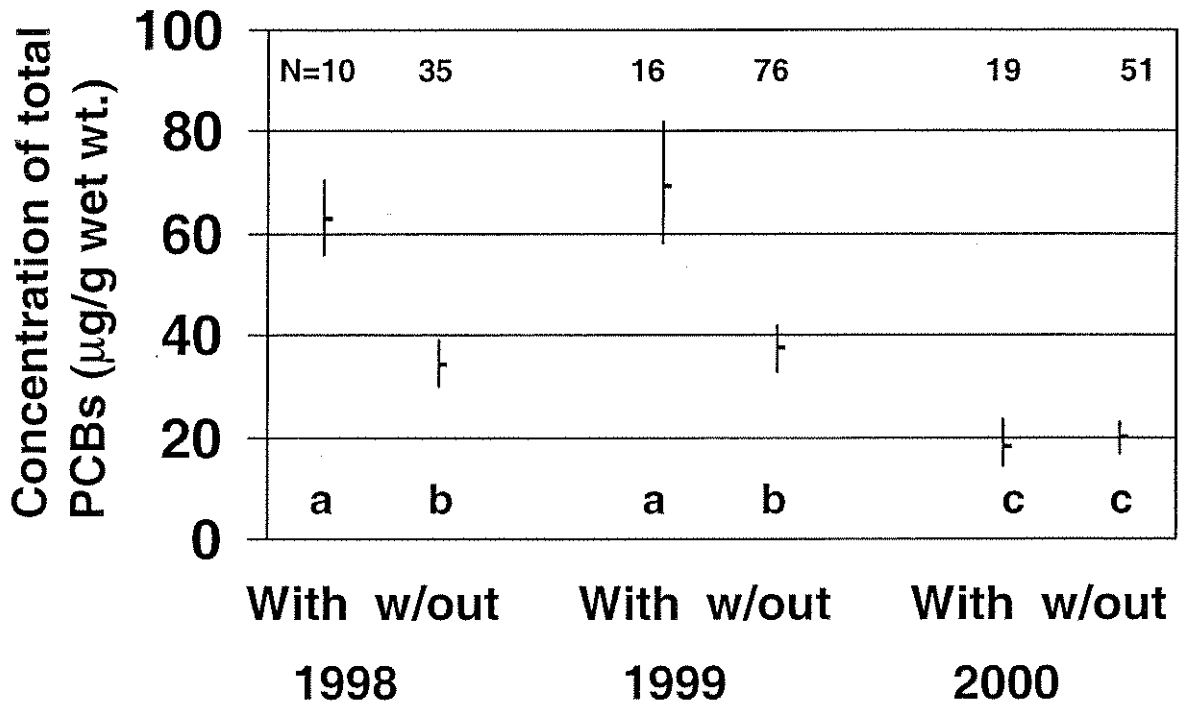

Figure 5. Concentration of total PCBs (geometric mean ± 95% Confidence Intervals) in tree swallows nesting in the Housatonic River Valley in 1998, 1999, and 2000, Berkshire Co., Massachusetts. Nests are categorized as having or not having hatching problems. Means sharing same letter are not significantly different.

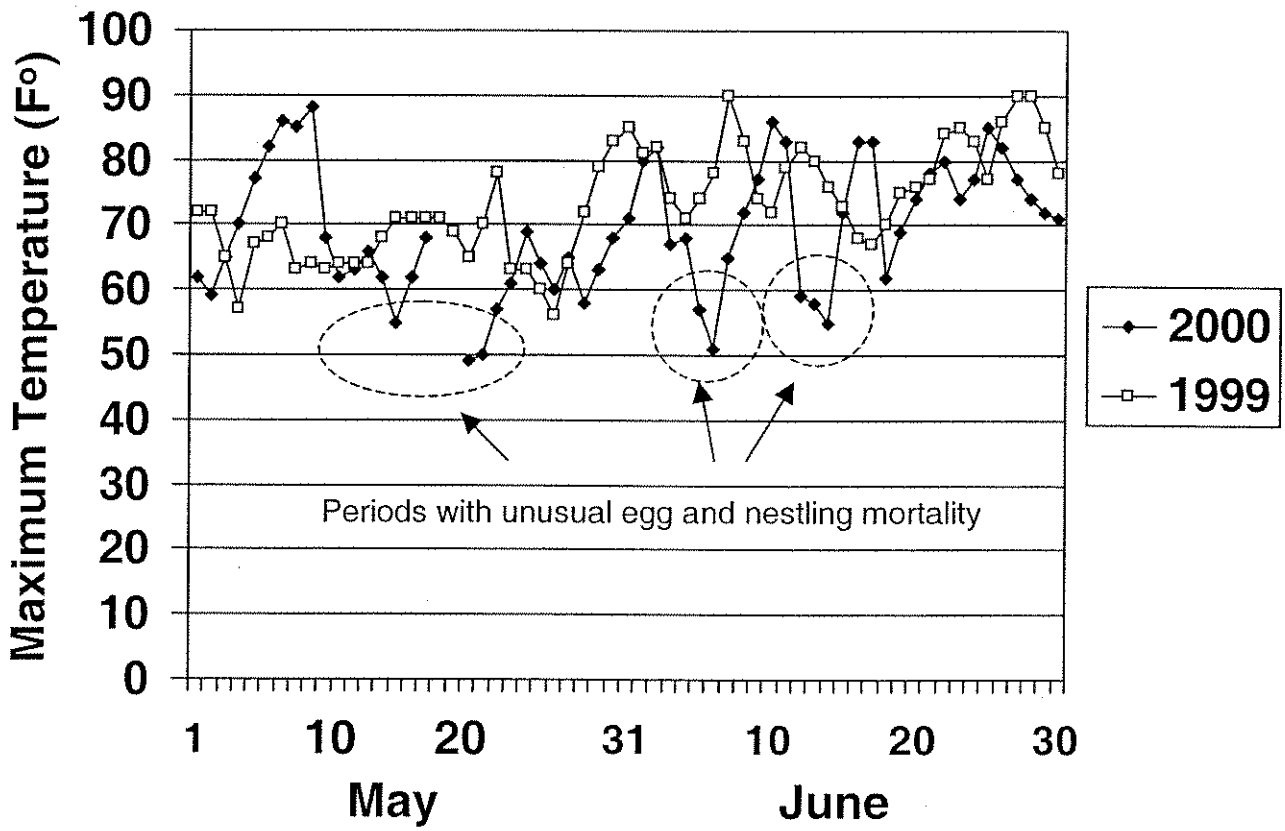

Figure 6. Maximum daily temperatures (°F) at Pittsfield, Massachusetts in 1999 and 2000. Temperature data were not available in 1998.