7.0 Summary, Conclusions and Recommendations

The broad goals of the Connecticut River Fish Tissue Contaminant Study (2000) were to establish a baseline of contaminant levels in Connecticut River fish of different trophic levels for future trend analysis and current statistical comparison, providing a baseline for ecological and human health risk screening, in support of consistent State fish advisories.

The current study provides a methodologically consistent characterization of total mercury, coplanar PCB and dioxin TEQs for humans/mammals, fish and birds, and chlorinated organic pesticides contaminant levels in Connecticut River smallmouth bass, yellow perch and white suckers. This was one of the first such studies of fish tissue contamination in the mainstem of a large, multi-state river in the United States. Samples were collected and analyzed by Reach. Statistical significant differences and relationships were observed in contaminant patters between species and Reaches. Exceedances of human health and ecological risk screening criteria were observed.

Key Findings

1. Total mercury concentrations in all three species were significantly higher in upstream Reaches than in downstream Reaches. Mercury poses a risk to recreational and subsistence fishers and to fish-eating wildlife.

2. Coplanar PCB TEQ risk (a standardized measure of toxicity) was generally lower in upstream Reaches than in downstream Reaches, although this varied by fish species and receptors (humans/mammals; fish-eating birds; or fish-eating fish). Coplanar PCBs pose a risk to recreational and subsistence fishers and to fish-eating mammals and fish-eating birds.

3. Dioxin contributed a highly variable percentage of total TEQ risk but constituted a risk to both subsistence and recreational fishers and fish-eating wildlife, even when coplanar PCB TEQs were not included in the risk calculations. Since risk associated with dioxin is not available for the remainder of the coplanar PCBs TEQ calculations, they underestimate human health and ecological risk from consumption of Connecticut River fish.

4. DDT homologs (chemical, physical and biological breakdown products of the parent compound) pose a risk to human subsistence fishers and to fish-eating birds.

7.1 Total Mercury

This chapter discussed mercury sources, cycling, biaccumulation, bioconcentration, ecological risks, human health screening, and the current state of the science in the Northeast. Observed levels of total mercury were compared by Reach with ecological and human health screening criteria and statistically between Reaches. Total mercury concentrations in smallmouth bass, yellow perch and white suckers were significantly higher in upstream Reaches than in downstream Reaches. Mercury poses a risk to recreational and subsistence fishers and to fish-eating wildlife.

7.1.1 Total Mercury Human Health and Eco-risk Screening Summary by Reach

In Reach 1 all three species for both fillets and whole fish did not exceed EPA's recreational fisher SV. However, all exceeded EPA's SV for subsistence fishers. EPA's Water Quality Criterion was not exceeded by any species.

All three species in Reach 1 exceeded the eco-risk SV for fish-eating birds. Similarly all smallmouth bass exceeded the eco-risk SV for fish-eating mammals. However, no yellow perch exceeded the mammalian eco-risk SV and only a single white sucker exceeded it.

In Reach 2 only a single smallmouth bass fillet exceeded EPA's recreational fisher SV. However, all samples exceeded EPA's subsistence fisher SV. Only two smallmouth bass fillets and single whole smallmouth bass exceeded EPA's water quality criterion.

All three species in Reach 2 exceeded the bird SV. All smallmouth bass, three yellow perch and two white suckers exceeded the mammalian SV.

In Reach 3 only two smallmouth bass fillets exceeded EPA's recreational fisher SV. However, all smallmouth bass, yellow perch and white sucker fillets and whole fish exceeded EPA's subsistence fisher SV. Two whole brown bullheads exceeded this value. Only a single shad fillet exceeded this value. All striped bass fillets and whole fish exceeded EPA's subsistence fisher SV. Three smallmouth bass fillets and two striped bass fillets exceeded EPA's water quality criterion. No whole fish in Reach 5 exceeded this value.

All samples from all species in Reach 3 exceeded the bird SV. Similarly, all smallmouth bass and striped bass exceeded the mammalian SV. Only two yellow perch and white suckers and no brown bullheads or shad exceeded this value.

Only a single smallmouth bass fillet in Reach 4 exceeded EPA's recreational fisher SV. However, all fillets and whole fish in all species exceeded EPA's subsistence fisher SV. Only 3 smallmouth bass fillets and a single whole fish exceeded EPA's water quality criterion.

All samples for all species in Reach 4 exceeded the bird SV. All but one white sucker exceeded the mammalian SV.

In Reach 5 no fillets or whole fish in any species exceeded EPA's recreational SV. However, all fillets and whole fish in all species exceeded EPA's subsistence SV. Only a single white sucker fillet exceeded EPA's water quality criterion.

All whole fish of all species exceeded the bird SV in Reach 5. Also all smallmouth bass, all white suckers, and only one yellow perch exceeded the mammalian SV.

In Reach 6 only two white sucker fillets exceeded EPA's recreational fisher SV. However, all fillets and whole fish in all species exceeded EPA's subsistence fisher SV. Three smallmouth bass fillets, one yellow perch fillet, and all five white sucker fillets exceeded EPA's water quality criterion. Only two whole white suckers exceeded EPA's water quality criterion

In Reach 6 all whole fish in all species exceeded the bird SV and all but one yellow perch exceeded the mammalian SV.

In Reach 7 all smallmouth bass and yellow perch fillets and three white sucker fillets exceeded EPA's recreational fisher SV. All fillets and whole fish in all species exceeded EPA's subsistence fisher SV. All smallmouth bass fillets and whole fish exceeded EPA's water quality criterion. All five yellow perch fillets and four whole fish exceeded this value. Four white sucker fillets and three whole white suckers exceeded this value.

In Reach 7 all whole fish in all species exceeded both bird and mammalian SVs.

Neither white sucker fillet from Reach 8 exceeded EPA's recreational fisher SV. However, both exceeded EPA's subsistence fisher SV. Only one fillet and no whole fish exceeded EPA's water quality criterion.

Both whole white suckers from Reach 8 exceeded the bird and mammalian SV.

Only two of the whole brook trout (control fish) raised in a Connecticut fish hatchery exceeded EPA's subsistence fisher SV, and none exceeded EPA's recreational fisher SV. These brook trout also only posed an eco-risk to fish-eating birds, not mammals.

7.1.2 Total Mercury Statistical Summary

Smallmouth bass, yellow perch and white suckers had significantly higher levels of total mercury in fillets and whole fish in Reaches 6 and 7 than in most lower Reaches. For smallmouth bass this may reflect the older relative age of fish sampled in Reach 7. No age information is available for smallmouth bass in Reach 6 or for yellow perch and white suckers in any Reaches. The pattern of total mercury in fillets and whole fish differed by species but were highly correlated within species.

In smallmouth bass fillets and whole fish total mercury in Reach 7 was significantly higher than all other Reaches. Reaches 3 and 4 were significantly higher than Reaches 1, 2, and 5 for both fillets and whole fish in smallmouth bass.

In yellow perch fillets and whole fish were significantly higher in Reach 4 than in Reaches 1 and 3. Reach 6, for both fillets and whole fish was significantly higher than all Reaches, except Reach 4. Reach 7 for both fillets and whole fish was significantly higher than all other Reaches.

In white sucker fillets and whole fish Reach 5 was significantly higher than Reach 1. Reach 4, in whole fish, was also higher than Reach 1. Reaches 6 and 7 were significantly higher than Reaches 1-5 in both fillets and whole fish. Reach 8, in white sucker fillets, had a very small sample[53], however, it was still significantly higher than Reaches 1, 2, and 3. For Reach 8 whole white suckers were significantly higher than Reaches 1 and 2 and lower than Reaches 6 and 7. In whole white suckers Reaches 4 and 5 were significantly higher than Reach 1.

7.1.3 Total Mercury Conclusions

7.1.3.1 Total Mercury Eco-Risk Screening

All whole smallmouth bass, yellow perch and white suckers exceeded the eco-risk screening value for fish-eating birds. All whole smallmouth bass, 39% of whole yellow perch, and 71% of whole white suckers exceeded the eco-risk screening value for fish-eating mammals.

Fish-eating birds are at risk from smallmouth bass, yellow perch and white suckers from all Reaches. Mammals are also at risk, however, this risk appears to increase from Reaches 4 through 8.

7.1.3.2 Total Mercury Human Health Risk Screening

All smallmouth bass, yellow perch, and white suckers fillets exceeded the EPA Hg subsistence fisher screening value. 46% of smallmouth bass, 17% of yellow perch, and 31% of white suckers fillets exceeded the EPA Hg Water Quality Criterion. 26% of SMB, 13% of yellow perch, and 14% of white suckers fillets exceeded the EPA Hg recreational fisher screening value.

[53] The Reach 8 sample consisted of only five white suckers divided into two composites.

All whole smallmouth bass, whole yellow perch, and 97% of whole white suckers exceeded the EPA Hg subsistence fisher screening value. 26% of whole smallmouth bass, 12% of whole yellow perch, and 14% of whole white suckers exceeded the EPA Water Quality Criterion. 11% of whole smallmouth bass, no whole yellow perch, and only 3% of whole white suckers exceeded the EPA Hg recreational fisher screening value.

The risk to recreational fishers does not appear to increase until Reach 7. Clearly subsistence fishers are at much greater risk than recreational fishers, from fillets or whole fish, from all Reaches. EPA's water quality criterion is exceeded more for smallmouth bass fillets in both Reach 3 and 4, than Reaches 1, 2, or 5. Reaches 6 and 7 also exceed this criterion more than other Reaches.

One possible cause of higher mercury levels in upstream Reaches is the degree of impoundment and water level fluctuation (Kamman, pers. comm. 2006). Sorensen and others (2005) in a study of manipulated and natural lakes in the region of Voyager National Park in Minnesota considered it likely that annual water-level fluctuations have a significant influence on mercury levels in young-of-year yellow perch, particularly if the water manipulations are early in the growing year. Other studies in North American and European reservoirs have found that methyl mercury increases initially with reservoir creation declining to background levels from 5 years to decades (TetraTech 2004; Porvari 1998). The effect of reservoir creation depends on water quality, such as organic matter, ph and other parameters associated with mercury methylation and with water level manipulation.

However, Adair Mulligan, Conservation Director of the CT River Joint Commissions (pers. comm. 2006), notes that, in Reach 7 "...only 11.2 miles of the 88 mile reach are subject to significant water level fluctuations". Other Reaches are also subject to water level manipulations, although the relative extent of this is unknown, particularly with respect to where fish were sampled in the current study.

Mailman and others (2005) review a number of management techniques to reduce mercury methylation, bioaccumulation and biomagnification in reservoirs. Techniques reviewed include limiting the flooded area, particularly wetlands areas. Run-of-the-river reservoirs many have lower MeHg concentrations by exporting it downstream.

Reservoirs also can export methyl mercury, primarily as dissolved and particulate matter, comprising 64% and 33% of the total. Schetagne and others (2000) concluded "however, zooplankton is the major component by which methylmercury is directly transferred to non-piscivorous fish downstream."

The techniques Mailman and others (2005) review include "selecting a site to minimize impacts, intensive fishing, adding selenium, adding lime to acidic systems, burning before flooding, removing standing trees, adding phosphorus, demethylating MeHg by ultraviolet light, capping and dredging bottom sediment, aerating anoxic bottom sediment and waters, and water level management." They conclude any management techniques must be acceptable to all stakeholders.

7.2 Dioxins, Furans and Dioxin-like (Coplanar) PCBs Human Health and Eco-Risk Screening Summary

This chapter discusses dioxin, furan and dioxin-like (coplanar) PCB sources, cycling, ecological and human health risks, the number of river miles under fish advisory for various contaminants and the total lake and river acres under advisory, the emerging issue of PBDEs, Toxic Equivalent Factors and Toxic Equivalences, and human health and ecological risk screening criteria. Observed levels of dioxins and furans and coplanar PCBs are compared by Reach with ecological and human health screening criteria and, for coplanar PCBs, statistically between Reaches.

Dioxin toxicity, in the twelve fillet composites analyzed, posed a varying risk to both subsistence and recreational fishers and fish-eating wildlife, even when dioxin-like PCB TEQs (a standardized measure of dioxin toxicity) were not included in the risk calculations. Since risk associated with dioxin is not available for the remainder of the fish samples, these PCB TEQs underestimate human health and ecological risk from consumption of Connecticut River fish.

Risk from dioxin-like (coplanar) PCBs was generally lower in upstream Reaches than in downstream Reaches; although this varied by fish species and was different for the humans/mammals, birds or fish that eat them. Dioxin-like PCBs pose a risk to recreational and subsistence fishers and to fish-eating mammals and fish-eating birds.

7.2.1 Dioxins, Furans and Coplanar PCBs Human Health Risk Screening Summary

All twelve fish fillets analyzed for both dioxin and coplanar PCB TEQs exceeded both human health recreational and subsistence fisher carcinogenic screening values (CSVs), many by several orders of magnitude. In all but one yellow perch fillet composite from Reach 7, in which no dioxins were detected, from 90.1% to 99.9% of the total human health risk and is provided by dioxin TEQs. If dioxin TEQs were available for the remainder of the whole fish samples, clearly a much greater eco-risk to mammals would have been calculated.

7.2.2 Coplanar PCB TEQ Human Health and Eco-Risk Screening Summary

Coplanar PCB TEQs in all whole Connecticut River fish pose a potential carcinogenic health risk to subsistence fishers. 98% of whole smallmouth bass, 80% of whole yellow perch and 86% of whole white suckers pose a potential carcinogenic health risk to recreational fishers.

Coplanar PCB TEQs in all smallmouth bass and white sucker fillets and 86.5% of yellow perch fillets pose a potential carcinogenic health risk to subsistence fishers. 51.4% of smallmouth bass fillets, 29.4% of yellow perch fillets and 73% of white sucker fillets pose a potential carcinogenic health risk to recreational fishers.
Clear differences were observed between species in levels of fish-eating (piscivorous) bird receptor coplanar PCB TEQs. Whole yellow perch contained the highest levels of fish-eating (piscivorous) bird receptor coplanar PCB TEQs and white suckers the lowest. A single sample from Reach 4 accounts for the observed “upturn” in the distribution of of human/mammalian or fish receptor TEQs for white suckers.

A similar pattern was observed with piscivorous fish receptor coplanar PCB TEQs. Whole yellow perch contained the highest levels of piscivorous fish receptor coplanar PCB TEQs and whole white suckers the lowest.

However, coplanar PCB TEQs in whole fish do not appear to pose an eco-risk to fish-eating mammals, birds or fish.

No statistically significant correlations were observed between whole fish composite total weight and coplanar PCB TEQs.

7.2.3 Human/Mammalian Coplanar PCB TEQs Statistical Summary

A factorial ANOVA found a marginally significant effect (p=0.04) in human/mammalian coplanar PCB TEQs in whole fish by species and Reach. However, a factorial ANOVA found no significant effect (p=0.70) in human/mammalian coplanar PCB TEQs in filleted fish by species and Reach.

A one-way ANOVA found a marginally significant effect for Reach (p=0.04) in human/mammalian coplanar PCB TEQs in whole smallmouth bass. Whole smallmouth bass had significantly higher levels of PCB TEQs in Reach 4 than all Reaches, except Reach 1.

A one-way ANOVA found a highly significant effect for Reach (p=9.54E-04) in human/mammalian coplanar PCB TEQs in filleted smallmouth bass. However, in filleted smallmouth bass only Reach 1 had significantly higher levels of PCB TEQs than other Reaches.

A one-way ANOVA found a significant effect for Reach (p=0.02) in human/mammalian coplanar PCB TEQs in whole yellow perch. Whole yellow perch had significantly higher levels of PCB TEQs in Reach 1 than all other Reaches.

A one-way ANOVA found no significant effect for Reach (p=0.12) in human/mammalian coplanar PCB TEQs in yellow perch fillets. Filleted yellow perch had a similar pattern to whole yellow perch.

A one-way ANOVA found a significant effect for Reach (p=0.01) in human/mammalian coplanar PCB TEQs in whole white suckers. Whole white suckers had significantly lower levels of PCB TEQs in Reaches 7 and 8 than in many other Reaches. Reach 1 was also significantly higher than Reach 5.

A one-way ANOVA found a significant effect for Reach (p=4.05E-04) in human/mammalian coplanar PCB TEQs in filleted white suckers. Filleted white suckers had significantly higher levels of PCB TEQs in Reach 1. Also Reach 4 was significantly higher than Reaches 7 and 8.

It is possible higher levels in Reach 1 reflect the increasing effects of urbanization in the lower watershed. This could be explored in subsequent analyses. However, any such analysis must also attempt to account for the interspecific differences in contaminant loads by Reach.

7.2.4 Piscivorous (Fish-eating) Bird Coplanar PCB TEQs Statistical Summary

A factorial ANOVA found no significant effect (p=0.71) in fish-eating bird coplanar PCB TEQs in whole fish by species and Reach. While significant differences were observed among Reaches and species, no clear geographic patterns were found.

A one-way ANOVA found a significant effect for Reach (p=0.03) in fish-eating bird coplanar PCB TEQs in whole smallmouth bass. In whole smallmouth bass fish-eating bird coplanar PCB TEQs in Reaches 2 and 4 were significantly higher than Reaches 5, 6 and 7. Reach 2 was also significantly higher than Reach 3.

A one-way ANOVA found no significant effect for Reach (p=0.17) in fish-eating coplanar PCB TEQs in whole smallmouth bass. In whole yellow perch fish-eating bird coplanar PCB TEQs in Reach 4 were significantly higher than Reaches 3, 5, 6, and 7.

A one-way ANOVA found no significant effect for Reach (p=0.27) in fish-eating coplanar PCB TEQs in whole white suckers. However, fish-eating bird coplanar PCB TEQs in Reach 4 in whole white suckers were significantly higher than Reaches 5, 6, and 7.

7.2.5 Piscivorous (Fish-eating) Fish Coplanar PCB TEQs Statistical Summary

A factorial ANOVA found a significant effect (p=0.02) in piscivorous (fish-eating) fish coplanar PCB TEQs in whole fish by species and Reach. Reach 4 in smallmouth bass was significantly higher than all other combinations of Reaches and species. Significant differences were also found between Reach 1 in yellow perch with Reaches 3, 5, 6, and 7 in yellow perch. Reach 1 in yellow perch was also significantly different than smallmouth bass in Reaches 6 and 7 and white suckers in Reach 7.

A one-way ANOVA found a significant effect for Reach (p=0.02) in piscivorous (fisheating) fish coplanar PCB TEQs in whole smallmouth bass. In whole smallmouth bass piscivorous fish coplanar PCB TEQs in Reach 4 were significantly higher than all other Reaches.
A one-way ANOVA found a significant effect for Reach (p=0.04) in piscivorous (fisheating) fish coplanar PCB TEQs in whole yellow perch. Reach 1 was significantly higher than all other Reaches.

A one-way ANOVA found a significant effect for Reach (p=0.02) in piscivorous (fisheating) fish coplanar PCB TEQs in whole white suckers. Reach 1 was significantly higher than Reaches 5, 7, and 8. Reach 3 was significantly higher than Reaches 7 and 8. Reach 4 was significantly higher than Reaches 5, 6, 7, and 8.

7.2.6 Dioxin, Furan, and Coplanar PCB TEQs Conclusions

Coplanar PCB TEQ risk, when dioxin TEQ toxicity was not included, appears to substantially underestimate human health risk from consumption of CT River smallmouth bass, yellow perch and white suckers. Total dioxin and coplanar PCB TEQ risk substantially exceeds both subsistence and recreational fisher human health carcinogenic screening levels, in all of the twelve samples analyzed for dioxins. Most observed PCB TEQs in these twelve samples exceeded these levels by orders of magnitude.

Coplanar PCB TEQs exceeded EPA's carcinogenic screening levels (CSV) for subsistence fisher in all samples of smallmouth bass fillets and whole fish, all whole yellow perch, and all fillets and whole white suckers. Over 86% of yellow perch fillets exceeded this CSV. The recreational fisher CSV was exceeded in over 51% of smallmouth bass fillets and 98% of whole smallmouth bass. Over 29% of yellow perch fillets and 80% of yellow perch whole fish samples exceeded the recreational fisher CSV. In white suckers 73% of fillets and 86% of whole fish exceeded the recreational fisher CSV.

Coplanar PCB TEQs in whole fish do not appear to pose an eco-risk to fish-eating mammals, birds or fish. However, if dioxin TEQs were available for the remainder of the whole fish samples, likely a much greater eco-risk to mammals would have been calculated. In the absence of the actual dioxin data in whole fish this conclusion is qualified by the widely divergent correlations observed between coplanar PCB TEQs for humans/mammalians, piscivorous fish, and piscivorous birds in whole and filleted fish in all three species.

7.3 Organochlorine Pesticides

This chapter described the human health and ecological risk screening criteria organochlorine pesticides and a number of internet sources of additional information. Observed levels of organochlorine pesticides in Connecticut River fish were compared with human health and ecological screening benchmarks by Reach. DDT breakdown products were statistically compared between Reaches. DDT and related breakdown products from chemical, physical and biological weathering, pose a risk to human subsistence fishers and to fish-eating birds, but not to recreational fishers or fish-eating mammals.

7.3.1 Organochlorine Pesticide Human Health and Eco-Risk Screening Summary

No fillets of smallmouth bass, yellow perch or white suckers exceeded either the recreational fisher non-cancer or cancer screening values. Similarly no fillets of these species exceeded the subsistence fisher non-cancer screening value. However, 37% of smallmouth bass fillets, 9% of yellow perch fillets, and 84% of white sucker fillets exceeded the subsistence fisher cancer screening value.

No whole smallmouth bass or yellow perch, and only 3% of whole white suckers, exceeded the subsistence fisher non-cancer screening value. However, 89% of whole smallmouth bass, 71% of whole yellow perch, and 94% of whole white suckers exceeded the subsistence fisher whole fish cancer screening value. No whole fish of any of these species exceeded the whole fish river otter eco-risk screening value. However, 97% of whole smallmouth bass, 91% of whole yellow perch, and 97% of whole white suckers exceeded the belted kingfisher eco-risk screening value.

7.3.2 Total DDT Homolog Human Health and Eco-risk Screening Summary by Reach

In Reach 1 four smallmouth bass fillets, no yellow perch fillets, and all five white sucker fillets exceeded the subsistence fisher cancer screening value for DDT. Only 1 whole white sucker exceeded the subsistence fisher non-cancer screening value. However, four whole smallmouth bass, five whole yellow perch and five whole white suckers exceeded the subsistence fisher cancer screening value. All five whole fish of the three species exceeded the belted kingfisher eco-risk screening value.

In Reach 2 four smallmouth bass fillets, two yellow perch fillets, and four white sucker fillets exceeded the subsistence fisher cancer screening value. No whole fish of these species exceeded the subsistence fisher non-cancer screening value for whole fish. However, four whole smallmouth bass, five whole yellow perch and five whole white suckers exceeded the subsistence fisher cancer screening value. All five whole fish of the three species exceeded the belted kingfisher eco-risk screening value.

In Reach 3 five smallmouth bass fillets, one yellow perch fillet, and five white sucker fillets exceeded the subsistence fisher cancer screening value. No whole fish of these species exceeded the subsistence fisher non-cancer screening value for whole fish. However, all five whole fish of all three species exceeded the subsistence fisher cancer screening value. All five whole fish of the three species exceeded the belted kingfisher eco-risk screening value.

In Reach 4 no smallmouth bass or yellow perch fillets and four white sucker fillets exceeded the subsistence fisher cancer screening value. No whole fish of these species exceeded the subsistence fisher non-cancer screening value for whole fish. However, four whole fish of all three species exceeded the subsistence fisher cancer screening value. Four whole fish of the three species exceeded the belted kingfisher eco-risk screening value.

In Reach 5 no smallmouth bass or yellow perch fillets and four white sucker fillets exceeded the subsistence fisher cancer screening value. No whole fish of these species exceeded the subsistence fisher non-cancer screening value for whole fish. However, four whole smallmouth bass, one whole yellow perch, and five whole white suckers exceeded the subsistence fisher cancer screening value. Four whole fish of smallmouth bass and yellow perch and five whole white suckers exceeded the belted kingfisher eco-risk screening value.

In Reach 6 no smallmouth bass or yellow perch fillets and four white sucker fillets exceeded the subsistence fisher cancer screening value. No whole fish of these species exceeded the subsistence fisher non-cancer screening value for whole fish. However, one whole smallmouth bass and yellow perch and four whole white suckers exceeded the subsistence fisher cancer screening value. Four whole fish of the three species exceeded the belted kingfisher eco-risk screening value.

In Reach 7 no smallmouth bass or yellow perch fillets and all five white sucker fillets exceeded the subsistence fisher cancer screening value. No whole fish of these species exceeded the subsistence fisher non-cancer screening value for whole fish. However, four whole smallmouth bass and yellow perch and all five whole white suckers exceeded the subsistence fisher cancer screening value. All five whole fish of the three species exceeded the belted kingfisher eco-risk screening value.

In Reach 8 no white suckers fillets exceeded any recreational or subsistence fisher human health screening value. Only one whole white sucker exceeded the subsistence fisher cancer screening value. Only one white sucker exceeded the belted kingfisher eco-risk screening value.

No human health SVs were exceeded by either hatchery raised brook trout filets or whole brook trout. Four whole brook trout exceeded the NOAEL for belted kingfisher exposure to DDT homologs.

7.3.3 Organochlorine Pesticides - Statistical Summary by Species

7.3.3.1 Smallmouth Bass

Total DDT homologs in smallmouth bass fillets in Reach 3 were significantly higher than all other Reaches. Reach 2 was also significantly higher than Reaches 4-6. Total DDT homologs in smallmouth bass fillets in Reaches 2 and 3 were significantly higher than brook trout controls.

Significantly higher levels of organochlorine pesticides were observed in whole smallmouth bass than in fillets. Total DDT homologs in whole smallmouth bass were significantly higher in Reach 1 than in Reaches 4-7. Reach 2 was signficantly lower than Reach 3 and higher than Reaches 4-7. Reaches 1, 2, 3, and 7 were significantly higher than brook trout controls.

7.3.3.2 Yellow Perch

Total DDT homologs in yellow perch fillets were significantly higher in Reach 1 than Reaches 5 and 6. Reach 2 was significantly higher than Reaches 4-7. Reach 3 was also significantly higher than Reaches 4-7. Reaches 2 and 3 were significantly higher than brook trout controls.

Whole yellow perch had significantly higher levels of chlorinated pesticides than yellow perch fillets. Total DDT homologs in whole yellow perch were significantly higher in Reach 2 than all other Reaches. Reach 3 was significantly higher than Reaches 4-7. Reaches 2 and 3 were significantly higher than brook trout controls.

7.3.3.3 White Suckers

The highest levels of organochlorine pesticides were observed in Reach 1. Total DDT homologs in Reach 1 were significantly higher than Reaches 5, 6 and 8. Reach 8 was significantly lower than Reaches 1, 2, 3, 4, and 7. Brook trout controls were significantly lower than Reaches 1, 2, 3, 4, and 7.

Whole white suckers had significantly higher levels of chlorinated pesticides than yellow perch fillets. Total DDT homologs in whole white suckers were significantly higher in Reach 1 than Reaches 2, 6 and 8. Reaches 3 and 5 were significantly higher than brook trout controls.

7.3.4 Organochlorine Pesticide Conclusions

Consumption of organochlorine pesticides, particularly DDT homologs, in all studied CT river fish fillets, except for hatchery raised brook trout, pose a potential carcinogenic health risk to subsistence fishers. White sucker fillets posed greater carcinogenic health risk than smallmouth or yellow perch. Yellow perch fillets appeared' to pose little carcinogenic or other human health risk.

DDT homologs in whole fish of all three studied wild species posed a much greater carcinogenic health risk to subsistence fishers than fillets. Whole fish also posed a carcinogenic health risk to recreational fishers.

Belted kingfisher appears to only be at risk from exposure to DDT homologs, however, this contamination is extremely persistent and ubiquitous. Otter appear to have no risk posed by CT river wild fish consumption, based on exposure to organochlorine pesticides.

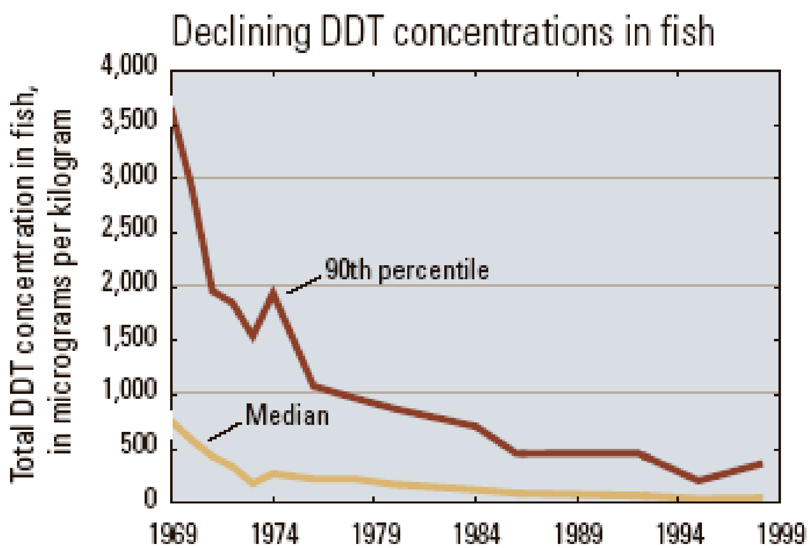

Figure 191. Declining DDT concentration in whole fish from nation-wide rivers and streams in mixed land use watersheds. Note the rapid decline from the 1960s through the 1970s and the slower rate of decline during the 1980s and 1990s (Source: Gilliom and others 2006).

A recent USGS study (Gilliom and others 2006) (Figure 191) summarized the first decade of nation-wide pesticide studies in NAWQA study units, including the Connecticut, Thames and Housatonic basin, provides a context for the findings in the current study. They conclude that additional assessments needs to include complex mixtures of pesticides. This study only considers organochlorine pesticides, which is a limitation.

Gilliom and others (2006) note that "Organochlorine pesticides (such as DDT) and their degradates and by-products were found in fish or bed-sediment samples from most streams in agricultural, urban, and mixed-land-use settings—and in more than half the fish samples from streams draining undeveloped watersheds. Most organochlorine pesticides had not been used in the United States for a number of years prior to the study period, but the continued occurrence of some historically used organochlorine pesticide compounds demonstrates their persistence in the environment."

Gilliom and others (2006) further observed that DDT, "...was detected in fish from about 30 percent of agricultural streams sampled by NAWQA, whereas DDE, a more stable degradate of DDT, was detected in fish from 90 percent of sampled agricultural streams." The most common pesticides observed in NAWQA studies exceeding wildlife benchmarks in agricultural watersheds were DDT homologs and dieldrin and in urban watersheds DDT homologs, chlordane and dieldrin. These were the pesticides also observed most frequently exceeding wildlife NOAELs in the current study.

7.4 Weight, Length and Condition Factor Summary

This chapter discusses the derivation and interpretation of condition factors.
Fish weight, length and “condition” were compared statistically by Reach and with total mercury. In yellow perch condition was significantly negatively correlated with total mercury.

The condition factor (condition) (K-Total Length) was calculated for all individual smallmouth bass, yellow perch, and white suckers. K-TL (condition) has been used by fisheries biologists as a measure of health or “well-being” of fish. A number of factors including diet, disease, reproductive status, season and site-specific factors influence K-TL (condition). However, condition (K-TL) can be affected by chemical exposure. The condition factor (K-TL) can be used as another source of information for a weight-of-evidence determination of impairment or health.

Weight and length were found to be highly statistically significantly correlated for smallmouth bass, yellow perch and white suckers. A highly statistically significant correlation ($p=0.001$) was observed between individual smallmouth bass condition and whole weight. No significant relationship was found between individual smallmouth bass length and condition. Highly statistically significant positive correlations were observed between yellow perch length, whole weight, composite total weight and condition. No significant relationship was observed between white sucker whole weight or length and condition.

A non-significant negative correlation ($r=-.30$; $p=0.08$) was found between total mercury in whole smallmouth bass and condition. A statistically significant negative correlation ($r=-.39$; $p=0.02$) was found between total mercury in whole yellow perch and condition. No significant relationship was found between total mercury in whole white suckers and condition.

A one-way ANOVA found a highly significant effect for Reach ($p=1.74E-07$) in individual smallmouth bass condition (K-TL). Reaches 1, 3, 4, and 7 were significantly lower than Reach 2. Reach 5 was significantly higher than all other Reaches. Reach 6 was significantly higher than Reaches 3. Although significantly older smallmouth bass were sampled in Reach 7, their condition scores did not reflect this, perhaps because of higher mercury exposure.

A one-way ANOVA found a highly significant effect for Reach ($p<0.0E-17$) in individual yellow perch condition (K-TL). Reach 3 was significantly lower than Reaches 2, 5, 6, and higher than Reach 7. Reaches 5 and 6 were significantly higher than Reaches 1, 2, 3, and 4. Reach 7 was significantly lower than all other Reaches.

A one-way ANOVA found a non-significant effect for Reach (p=0.46) in individual white sucker condition (K-TL). Only Reach 3 was marginally significantly different than Reaches 7 and 8, likely a result of chance.

No clear geographic pattern in condition was observed in any species, although inter-Reach differences were observed, particularly in smallmouth bass and yellow perch. Yellow perch appeared to have significantly lower condition with higher total mercury, although we can not know if any causal relationship is present.

7.5 Smallmouth Age

This chapter graphically and statistically analysed smallmouth bass age in Reaches 1, 2, 3, 5 and 7. Smallmouth bass age was negatively statistically correlated with Reach, total mercury, and PCB TEQs for human/mammalian, bird and fish receptors.

7.5.1 SMB Reconciled Age, Reach and Total Mercury Non-Parametric Correlations

Reconciled age, Reach and total mercury in filleted and whole smallmouth bass were found to be extremely significantly positively correlated. Thus higher concentrations of mercury in smallmouth bass in upper Reaches may be reflective of greater age of sampled fish. Coplanar PCB TEQs in human/mammalian, fish-eating bird, and fish-eating fish receptors were significantly negatively correlated with age in whole smallmouth bass. The possible cause of lower PCB TEQs in older smallmouth bass is unclear. One possibility is that young fish intake relatively larger body burdens of PCB TEQs that depurate as they age.

7.5.2 Reconciled Age by Reach - ANOVA Summary

A one-way ANOVA of reconciled age in individual smallmouth bass found a significant effect for Reach. Smallmouth bass sampled in Reach 3 were significantly older than those in Reach 1. Individual smallmouth bass sampled in Reach 7 were significantly older than smallmouth bass sampled in Reaches 1, 2, and 5.

7.5.3 Total Mercury and Age of Smallmouth Bass - Summary

Reach 1 was fairly even aged, with relatively similar mercury levels in all whole smallmouth bass composites. Reach 2 was more variably aged than Reach 1 and also displayed a much wider range of total mercury values in whole smallmouth bass composites. Reach 3 had the most widely aged composites of all five sampled Reaches. Reach 3 also displayed the most widely varying total mercury levels in whole smallmouth bass, with Composites 3 and 4 having nearly three times the total mercury in Composite 5. Reach 5 had heterogeneously aged Composites but displayed very similar total mercury values. Reach 7 had both the oldest aged composites of all five Reaches, but also the highest total mercury level with fairly similar values in all five

Composites. Age would appear to be a factor in the significantly higher mercury observed in Reach 7 and possibly other Reaches. Given the high correlation between total mercury in whole and filleted smallmouth bass very similar patterns were observed between age and total mercury. Age and total mercury in smallmouth bass fillets and whole fish were statistically significantly positively correlated: total mercury in smallmouth bass fillets (Spearman R=0.61; p=7.76E-09) and total mercury in whole smallmouth bass (Spearman R=0.62; p=3.08E-09).

7.5.4 Coplanar PCB TEQs and Whole Smallmouth Bass Age

Although no consistent graphical relationship between smallmouth bass age and human/mammalian, fish or bird receptor coplanar PCB TEQs was observable, a statistically significant negative correlation was observed in all three. The observed variability in coplanar PCB TEQs suggests that individual fish exposure to specific coplanar PCBs, in addition to age, are predictors of whole smallmouth bass TEQ burden.

7.6 Recommendations

1. Subsequent fish sampling should utilize Global Positioning Systems technology, ideally recording the GPS coordinates of all fish collection and shock boat paths. The date when fish are sampled should also be recorded as time of year has been shown to significantly affect mercury levels in fish.

2. Subsequent fish tissue analysis should attempt to use single fish and not composites in the analysis. Composites inevitably combine multi-aged fish and tend to statistically moderate extreme values.

3. The laboratories performing fish tissue analyses should be pre-qualified by having them provide Performance Evaluation samples for all of the methods they will be utilizing.

4. Future fish tissue contaminant studies should consider using the analyte list developed by the EPA National Study of Chemical Residues in Lake Fish Tissue, particularly focusing on emerging contaminants such as PDBEs.

5. Water quality parameters, including Total Organic Carbon (TOC), Dissolved Organic Carbon, (DOC), sulfates, Acid Neutralizing Capacity (ANC, and phytoplankton biomass should be collected concurrently with fish sampling. These parameters potentially affect mercury methylation and bioaccumulation.

6. Observed geographic gradients and patterns in mercury, dioxin and organo-chlorine pesticides should be studied further, including possible effects of water level impoundment manipulations on mercury methylation and demethylation.

This might include targeted sampling of “paired” impounded and non-impounded sections of the river.

7. Reach 8, the approximately 36 mile long, cold water portion of the Connecticut River, requires additional fish sampling and analysis to determine human health and eco-risks of contaminant loads, likely focusing on other native species than those used in the current study. Reach 8 is the “...high elevation, most pristine Reach of river, a famed sport fishery that has very, very significant economic importance to the region” (Mulligan pers. comm. 2006).

8. As noted in Chapter 1 no statistical comparison was made between land use/land cover, population demographics or other ancillary data and the contaminants found in Connecticut River smallmouth bass, yellow perch and white suckers. Further statistical exploration of these relationships would likely further explain the observed patterns of contaminant loads.

9. Use of the Reach concept in future studies should be re-assessed given the extremely small samples taken for long stretches of river. It has been shown in many studies that fish contaminant loads can vary over considerably smaller spatial scales than the Reaches used in the current study.

10. Knowledgeable individuals may provide further insight into the observed data. For example, Dr. Jane Rose of MADEP (pers. comm. 2005) noted in commenting on an earlier draft of this report that,

    “Fish PCBs spike below the confluence of Connecticut and the Millers and Otter Rivers. One of the earliest fish advisories in Massachusetts was issued for the Millers River and Otter River, where fish were found to be contaminated with PCBs. The joining of the two river systems may influence the presence of PCB contamination beginning at the northern end of reach 3.”

11. Further studies should build upon the collaborative example provided by the current study.