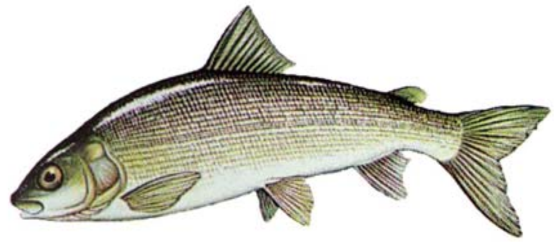

Lower Okanogan River Basin DDT and PCB Total Maximum Daily Load

Water Quality Effectiveness Monitoring Report

DEPARTMENT OF ECOLOGY
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Cover photo: Drawings of mountain whitefish (top), smallmouth bass (middle), and common carp (lower).

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Water Quality
Effectiveness Monitoring Report

by
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Abstract

This study monitors the effectiveness of the Lower Okanogan River Total Maximum Daily Load (TMDL) for the legacy contaminants DDT and PCB. The study compares contaminant concentrations in composite fish tissue samples collected in 2001 against a similar data set collected in 2008. Three species were sampled: smallmouth bass (*Micropterus dolomieui*), mountain whitefish (*Prosopium williamsoni*) and common carp (*Cyprinus carpio*). Samples were collected from three reaches of the Okanogan River along a span of 79 river miles.

The number of samples not meeting (exceeding) National Toxics Rule criteria is similar between the 2001 and 2008 studies. No carp specimens were obtained from the lower reach in 2001 due to unavailability. However, large specimens of carp collected from this reach in 2008 had elevated concentrations of total DDT. A fish consumption advisory for carp is likely to be issued by the Washington State Department of Health based, in part, on these 2008 samples.

Comparability between the two studies was difficult due to small sample size. No significant changes were found in median total DDT concentrations between the two studies. A decrease in lipid-normalized median total PCB concentration was found for common carp, significant at the 90% level. No other significant changes were found in median total PCB concentrations.

Mountain whitefish from the lower reach show slightly lower levels of contamination than in the other two reaches. Otherwise, overall contamination in fish is similar among the three reaches.

As a result of this study, the Department of Ecology recommends:

- Continued effectiveness monitoring every five years, as scheduled.
- Increasing sample size from 9 to at least 15 composite samples per fish species for the next monitoring event.
- Discontinuing the analysis for PCBs in smallmouth bass samples due to low concentrations.

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Background

What is a TMDL?

The federal Clean Water Act established a process to identify and clean up polluted waters. Under the Clean Water Act, every state has its own water quality standards designed to protect, restore, and preserve water quality. Every two years, states are required to prepare a list of waterbodies – lakes, rivers, streams, or marine waters – that do not meet water quality standards. This list is called the 303(d) list or Water Quality Assessment. To develop the list, the Washington State Department of Ecology (Ecology) compiles its own water quality data along with data submitted by local, state, and federal governments, tribes, industries, and citizen monitoring groups. All data are reviewed to ensure that they were collected using appropriate scientific methods before they are used to develop the 303(d) list.

The Clean Water Act requires that a Total Maximum Daily Load (TMDL) be developed for each of the waterbodies on the 303(d) list. A TMDL identifies how much pollution needs to be reduced or eliminated to achieve clean water. The local community then works with Ecology to develop a strategy to control the pollution and a monitoring plan to assess the effectiveness of the water quality improvement activities.

What Is Effectiveness Monitoring?

An effectiveness monitoring evaluation determines if the interim TMDL targets and water quality standards have been met. This is an essential component of any restoration or implementation activity since it measures to what extent the work performed or recommended has attained the watershed restoration objectives or goals.

The benefits of effectiveness evaluation include:

- More efficient allocation of funding.
- Optimization in planning/decision-making (i.e., program benefits).
- Watershed recovery status (i.e., how much restoration has been achieved, how much more effort is required).
- Adaptive management or technical feedback to refine restoration treatment design and implementation.

The effectiveness evaluation addresses four fundamental questions with respect to restoration or implementation activity:

1. Is the restoration or implementation work achieving the desired objectives or goals (significant improvement)?
2. How can restoration or implementation techniques be improved?
3. Is the improvement sustainable?
4. How can the cost-effectiveness of the work be improved?

Pollutants Addressed By This TMDL

This TMDL addresses the legacy pesticide DDT (dichloro-diphenyl-trichloroethane) and PCBs (polychlorinated biphenyls). The pesticide DDT also includes the breakdown products DDD and DDE. For consistency with the Technical Assessment, the summed concentrations of 4,4'-DDT, 4,4'-DDE, and 4,4'-DDD is termed *total DDT* or *t-DDT*.

Historic DDT use in the Okanogan Basin, primarily on orchard and other agricultural lands, has resulted in contamination of the aquatic environment. Although banned in the U.S. as a pesticide in 1972, DDT and its breakdown products have persisted, accumulating at high concentrations in lower Okanogan River and Lake Osoyoos fish as shown in the TMDL assessment study and other investigations (e.g., Johnson and Norton, 1990; Davis and Serdar, 1996; Serdar et al., 1998; Serdar, 2003).

PCBs have a similar history in the U.S. and Canada: beginning in 1929, PCBs were used in many industrial applications where their flame resistance and thermal stability were particularly useful. The most common usage of PCBs was in electrical equipment, though PCBs were put to a wide variety of uses including some consumer goods. The U.S. and Canada banned the manufacture and most non-electrical uses of PCBs by 1979, with the last uses of PCBs scheduled to be phased out through equipment maintenance and replacement. PCBs are now a ubiquitous environmental contaminant. They persist in the aquatic environment and continue to accumulate in fish tissue even though PCB production ended more than 30 years ago. The sum of Aroclor concentrations is referred to as *total PCB* or *t-PCB* in this report.

To be brief and clear in this report, the use of the term *DDT* will mean DDT and its breakdown products DDD and DDE, and the use of the term *PCBs* will mean all the forms of PCBs found in the Okanogan watershed.

Okanogan River TMDL Summary

The Okanogan River and several tributaries were listed under section 303(d) by Washington State for non-attainment of the (1) U.S. Environmental Protection Agency (EPA) human health criteria for DDT and PCBs in edible fish tissue and (2) Washington State chronic criteria for DDT in water.

During 2001 Ecology conducted a TMDL study for the portion of the river that flows through Washington State, as required by the Clean Water Act. The Technical Assessment (Serdar, 2003) determined that the source of these contaminants appears to be the legacy from historic agricultural and industrial activities throughout the Okanogan River watershed.

The chemical characteristics of DDT and PCBs cause them to be classified as persistent, bioaccumulative toxins. These contaminants are a legacy of past activities as their use has been banned in both the United States and Canada for more than 30 years. Due to the legacy nature of the contamination, substantial attenuation of the DDT and PCB contamination, both directly and indirectly, has already occurred in the Okanogan basin. Direct actions include the banning of these materials from use. Indirect actions include irrigation improvements that have reduced the loss of agricultural topsoil that potentially could carry pesticide residues to the Okanogan River and associated waterbodies. The presence of DDT and PCBs in the lower Okanogan River basin continues to prompt community actions to reduce contamination.

Although DDT and PCBs continue to persist in the environment, their effective levels are reduced over time through degradation and by natural attenuation through dilution and burial. The natural processes lowering exposure of aquatic life to these contaminants will play a major role in the success of this TMDL. Monitoring fish tissue concentrations of these contaminants was identified as the most effective means to judge the progress of environmental improvement.

Toxics Criteria

Washington State applies toxics criteria (e.g., for arsenic, mercury, chromium, lead, ammonia) to waters of the state to protect aquatic life and human health. In some cases, the state designs criteria to protect wildlife that are drinking water and eating fish contaminated with the toxins.

Aquatic Life Criteria

Criteria in Chapter 173-201A Washington Administrative Code (WAC) are designed to protect aquatic life from both short-term (acute) and long-term (chronic) effects. The state designs aquatic life criteria primarily to avoid direct lethality to fish and other aquatic life within the exposure periods specified for the specific criteria. The exposure periods assigned to the acute criteria are expressed as: (1) instantaneous concentrations not to be exceeded at any time, or (2) a 1-hour average concentration not to be exceeded more than once every three years on the average. The exposure periods assigned to the chronic criteria are expressed as either: (1) a 24-hour average not to be exceeded at any time, or (2) a 4-day average concentration not to be exceeded more than once every three years on the average.

Human Health Criteria

Criteria for the protection of human health are applied to Washington State through the federal National Toxics Rule [40 CFR 131.36(14)]. In fresh waters, human health criteria take into account the combined exposure of both drinking the water and eating fish that lived in the water. In marine (salt) waters, human health criteria only consider the effect of eating fish that lived in the water.

Washington State established criteria to protect against non-carcinogenic illness and to keep the excess risk of developing cancer to a pre-specified level. In Washington, the cancer risk is set such that no more than 1 in 1,000,000 people with full exposure would be likely to develop cancer in response to that exposure. Full exposure is defined by set assumptions on body size, fish, and water consumption, and the number of years exposed. For example, the risk is correlated to an average-sized man consuming 6.5 grams per day of fish (approximately 5 pounds per year), drinking 2 liters of water (if a fresh waterbody), and continuing this pattern for 70 years. People with higher or lower exposure patterns would face higher or lower risks. This basic exposure pattern is the same for both cancer-causing and non-cancer-causing chemicals.

Table 1 presents criteria used in developing the *Lower Okanogan River DDT and PCB TMDL*.

Table 1. Water Quality Criteria for DDT and PCBs for the Protection of Human Health and Aquatic Life.

Parameter	Human Health[a]		Aquatic Life[b]
	Water (ng/L)	Tissue (ug/kg)	Water (ng/L)
4,4'-DDE	0.59	32	1
4,4'-DDD	0.83	45	1
4,4'-DDT	0.59	32	1
t-DDT	ne	ne	1
PCB Aroclors	0.17	5.3	14
t-PCB	0.17	5.3	14

[a]National Toxics Rule (NTR) (40 CFR 131), for consumption of organisms and water.
[b]Chapter 201-173A WAC, chronic criteria.
ne: not established.

Recommendations for Prioritizing PCB 303(d) Listings

A recent report documents background t-PCB levels in fish tissue collected at relatively pristine areas of Washington State, where contamination sources are considered unlikely (Johnson et al., 2010). Contamination in these areas can occur due to atmospheric deposition of PCBs, which are sufficiently volatile to evaporate and then deposit in cooler regions. Recommendations were made in this report for prioritizing 303(d) listings based on t-PCB levels (Table 2).

Table 2. Recommendations for Prioritizing 303(d) Freshwater Fish Tissue Listings for PCBs (Johnson et al., 2010).

Total PCBs (ug/kg)	Recommendation	Rationale
< 10	No further action	• Fish from most background waterbodies have less than 10 ug/kg. • EPA screening level for non-carcinogenic effects for subsistence fishers is 9.8 ug/kg.
10-20	Low priority for TMDL	• Concentrations sometimes encountered in background waterbodies. • EPA screening level for recreational fishers for carcinogenic effects is 20 ug/kg.
20-100	Medium priority for TMDL	• Concentrations sometimes encountered in background waterbodies. • WDOH non-carcinogenic screening level is 23 ug/kg. • Concentrations above 53 ug/kg exceed Washington human health criteria by a factor of 10 (10-5 risk level). • EPA screening level for recreational fishers for non-carcinogenic effects is 80 ug/kg.
> 100	High priority for TMDL	• Exceeds maximum concentration encountered in background waterbodies. • WDOH considers > 100 ug/kg as indicating strong possibility of need for fish consumption advisory.

WDOH: Washington State Department of Health.

Fish Consumption Advisories

The Washington State Department of Health (WDOH) uses a different set of criteria called *screening values* to determine if chemical contaminants in edible fish tissue warrant further assessment, possibly leading to a fish consumption advisory. When screening values are not met (exceeded), concentrations are then compared to background levels, concentrations in other foods, reductions from cleaning and cooking techniques, and known benefits from fish consumption. Because of this different approach, National Toxics Rule (NTR) criteria can often be exceeded without prompting a fish consumption advisory.

It appears likely that WDOH will issue a fish consumption advisory in the near future for at least some species in at least one section of the Okanogan River, based on their review of Ecology's 2008 TMDL Effectiveness Monitoring data and accepted consumption models (McBride, 2010). This advisory is likely due in part to the elevated DDT concentrations found in large carp collected from the lower reach of the Okanogan River, described in this study. Carp from this reach were not found in the previous TMDL Technical Assessment (Serdar, 2003). WDOH had previously determined that a fish consumption advisory for the Okanogan River was not warranted based on their review of data from the Technical Assessment and accepted consumption models.

EPA is currently conducting a food consumption survey with the Colville Confederated Tribes to determine if current consumption models are appropriate. It is a large survey including thousands of interviews. Interviewing will continue through the end of March 2011, and the report may be ready later in 2011 (Stifelman, 2010).

Study Area

The Okanogan River flows from its headwaters in British Columbia (B.C.), Canada through north-central Washington where it discharges into the Columbia River near the town of Brewster. Most of the Okanogan River basin lies north of the Canadian border (Figure 1), where its flow is regulated by four lakes along the river's mainstem. Three of these lakes are located in Canada, while the 14,150-acre Lake Osoyoos straddles the border. The lower Okanogan River flows out of Lake Osoyoos (elevation 915') at the city of Oroville and flows 79 miles southward to its confluence with the Columbia River (779').

The largest tributary is the Similkameen River, originating in the Cascade Mountains along the U.S.-Canada border and joining the Okanogan River five miles below Lake Osoyoos. Fed by mountain snow pack, the Similkameen River contributes approximately three quarters of the flow in the Okanogan River below the confluence. Other tributaries to the Okanogan River are typically small or intermittent due to the semi-arid climate of the river basin. These other tributaries contribute little to the overall flow of the lower Okanogan River.

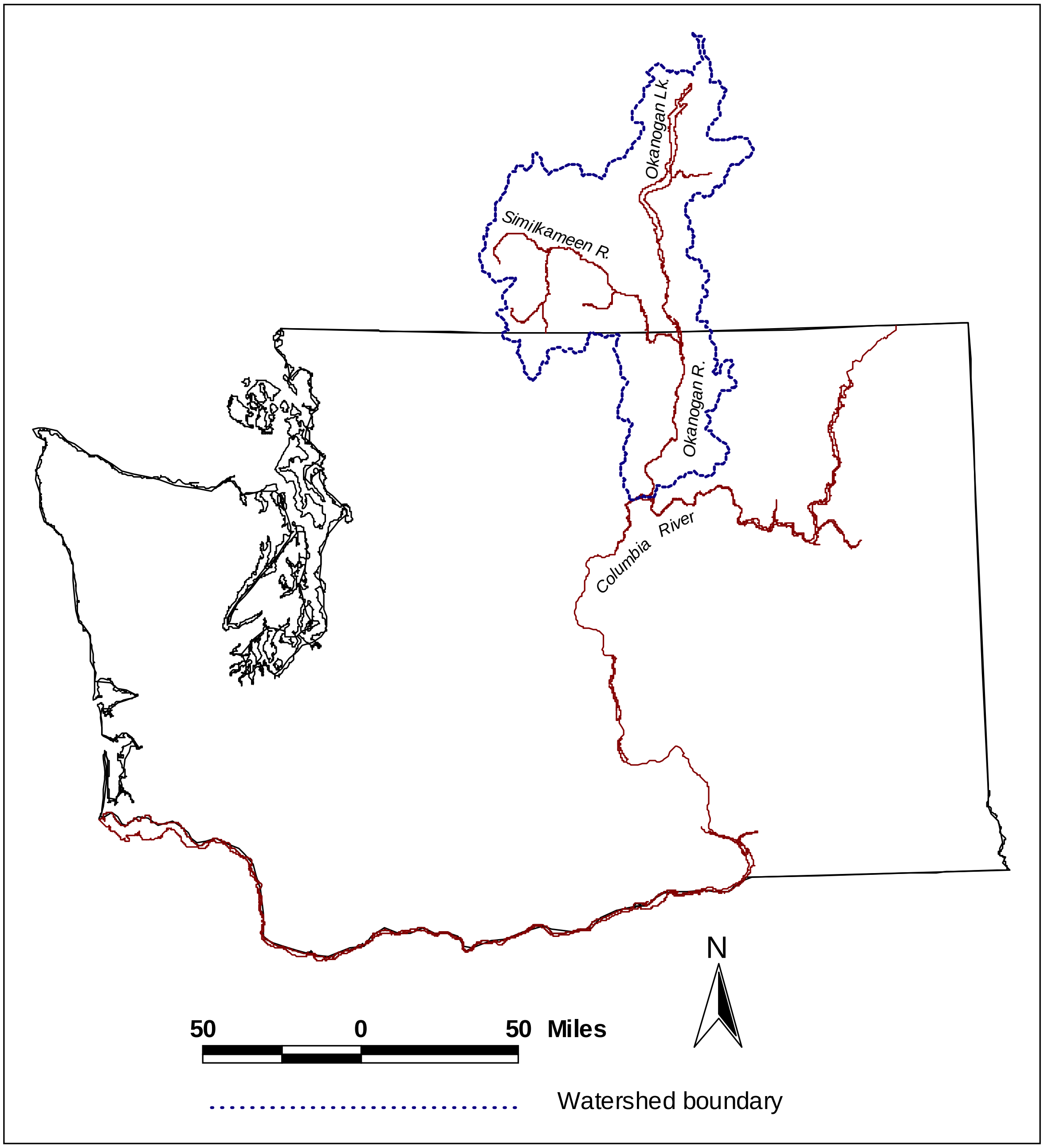


Figure 1. Okanogan River Watershed.

Land cover in the Okanogan watershed is primarily forest and rangeland, especially in the uplands. Near the valley bottom, orchards and pasture/hay are the primary agricultural uses. Fruit orchards have a long history in the Okanogan valley, with the first planted in 1857. By 1916, there were approximately 12,000 acres of irrigated orchards in the lower Okanogan River valley. Orchards presently comprise about 2% or approximately 37,000 acres of the land area. The upper Okanogan River basin (north of the Canadian border) has a similar composition of orchard lands, providing over 99% of the tree fruit grown in British Columbia (Sinclair and Elliott, 1993).

The Okanogan basin in Washington is sparingly populated, with 40,552 people in Okanogan County according to the 2009 census estimate. The cities of Omak and Okanogan have a combined population of approximately 7,000. Other population centers include the cities of Oroville (≈ 1,700), and Tonasket (≈ 1,000).

The lower Okanogan River marks the western boundary of the Colville Confederated Tribes (CCT), from the mouth to river mile 38.6 near Omak. The Okanogan River Basin, in both Canada and the United States, is traditional hunting and fishing grounds for the CCT. Many members of the CCT live near and along the river and regularly consume fish taken from its waters. The CCT is concerned about the presence and concentrations of PCBs and DDT found in the river and the effect that these pollutants may have on the biological resources in the river and, especially, on the health of people using the river's resources as a food source.

Historical Data Review

Early Studies

Beginning in the early 1970s, Canadian investigators began documenting high DDT levels in fish collected from lakes in British Columbia along the mainstem Okanogan River (Northcote et al., 1972). In 1983, Ecology collected data which revealed DDT and PCB contamination in fish from the lower Okanogan River below the Canada border (Hopkins et al., 1985). Since then, a number of Ecology surveys have verified DDT and PCB contamination in the basin (Johnson and Norton, 1990; Davis and Serdar, 1996; Johnson et al., 1997; Serdar et al., 1998).

Data from 1984 and 1994 (Hopkins et al., 1985; Davis and Serdar, 1996) found total DDT (t-DDT) concentrations in several fish species from the lower Okanogan River among the highest ever recorded in Washington State (1,700 – 3,200 µg/Kg). Concentrations in Lake Osoyoos fish showed more moderate levels of t-DDT (Serdar et al., 1998), but concentrations were generally elevated above the NTR criteria for DDT (32 µg/Kg for 4,4-DDT and 4,4'-DDE, 45 µg/Kg for 4,4'-DDD).

PCBs were found in some Okanogan River and Lake Osoyoos fish (Hopkins et al., 1985; Davis and Serdar, 1996; Serdar et al., 1998). Concentrations of total PCBs (t-PCBs, sum of Aroclors) in muscle tissues were relatively low (20 – 40 µg/Kg) in fish from the lower reaches of the mainstem Okanogan River. Lake Osoyoos fish had no detectable PCBs in muscle tissues, but detectable concentrations in whole fish indicate that PCBs are present in the lake.

Summaries of early historical DDT and PCB concentrations in fish tissue are presented in Appendix B (Tables B-1 and B-2).

Ecology's TMDL Technical Assessment

Ecology conducted a Technical Assessment of DDT and PCBs in the lower Okanogan River basin, including Lake Osoyoos (Serdar, 2003). Samples were collected during 2001-2002 to examine DDT and PCB concentrations in the water column of the main stem Okanogan River, water in tributary streams, sewage treatment plant (STP) effluent and sludge, and cores of bottom sediments. Composite samples of three species of fish also were analyzed for DDT and PCBs. Data from these samples were used in conjunction with historical data to develop the TMDLs.

Results suggested that only small loads of DDT and PCBs were being delivered to Lake Osoyoos and the lower Okanogan River through tributary streams and STPs. Combined, measurable DDT and PCB loads from tributaries and STPs averaged approximately 200 mg t-DDT/day and 3 mg t-PCB/day, respectively. This contrasted sharply with the measured loads in several reaches of the lower Okanogan River (1,500 – 4,300 mg t-DDT/day; no measurable PCBs), the assimilative capacities of the river (1,300 – 6,700 mg t-DDT/day; 230 – 1,100 mg t-PCB/day), and theoretical loads based on fish tissue concentrations (13,000 – 32,000 mg t-DDT/day; 0 – 6,500 mg t-PCB/day). The loading analysis showed that the bulk of loading was internal, presumably through bottom sediments. Load allocations and waste load allocations were developed for tributaries, STPs, and sediments.

DDT and PCB Concentrations in Fish Tissue

Ecology collected carp, mountain whitefish, and smallmouth bass from three locations on the lower Okanogan River during 2001, except for carp which were not found in the lower reach. The reaches were named for nearby towns: Oroville (upper reach), Riverside-Omak (middle reach), and Monse (lower reach).

Samples at each location were sorted by size to assess this as a factor affecting contaminant accumulation. Samples were analyzed for DDT, PCBs, and lipid content in fillet. Results for t-DDT and t-PCB from the Technical Assessment (Serdar, 2003) are presented in Appendix C (Tables C-3 and C-4).

Concentrations of t-DDT ranged from 30 to 600 ug/kg, while t-PCB concentrations were much lower, ranging from 2 ug/kg or less to 40 ug/kg. Mountain whitefish and carp generally had much higher DDT and PCB concentrations than smallmouth bass.

All tissue samples except one were reported to not meet (exceed) the NTR criterion (32 ug/kg) for 4,4'-DDE, the exception being a smallmouth bass sample from the middle reach near Omak. Only one sample exceeded the NTR criterion (45 ug/kg) for 4,4'-DDD, a carp sample from the middle reach near Omak. None of the samples exceeded the 4,4'-DDT criterion (32 ug/kg).

Concentrations of t-PCBs were reported above the NTR criterion (5.3 ug/kg) for all tissue samples for carp and mountain whitefish. Only one of the nine smallmouth bass samples exceeded the criterion for t-PCB. The most frequently detected Aroclor was PCB-1254, followed by PCB-1260 and PCB-1248.

The 2001-02 Technical Assessment graphed lipid-normalized fish tissue data (Figures 2 and 3). Lipid normalization is normally performed when a strong relationship exists between fish tissue concentrations and lipid content. (Normalized concentrations are calculated by dividing wet-weight concentrations by lipid percentage.) In these figures, fish were grouped into size classes to compare against other fish of similar size at a particular location. Note that size class is relative within each location and cannot be compared between locations.

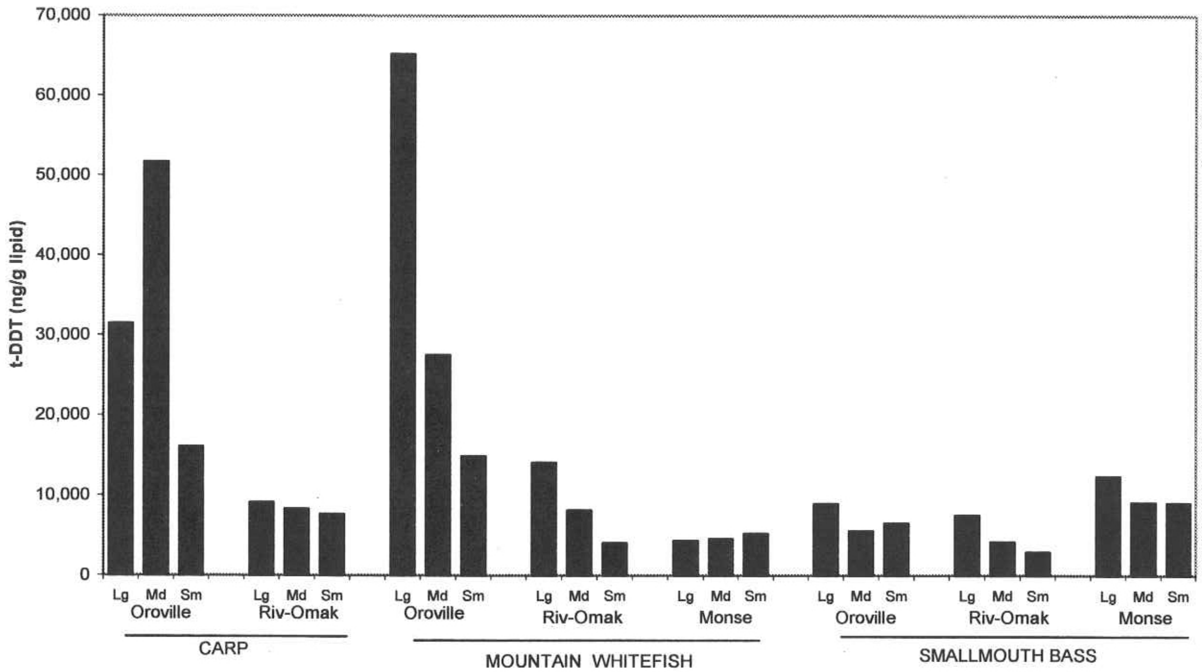


Figure 2. Lipid-Normalized t-DDT in Tissue from the Technical Assessment (Serdar, 2003).

Ordered by mean length of fish in each composite (Lg=large, Md=medium, Sm=small) and location for each species.

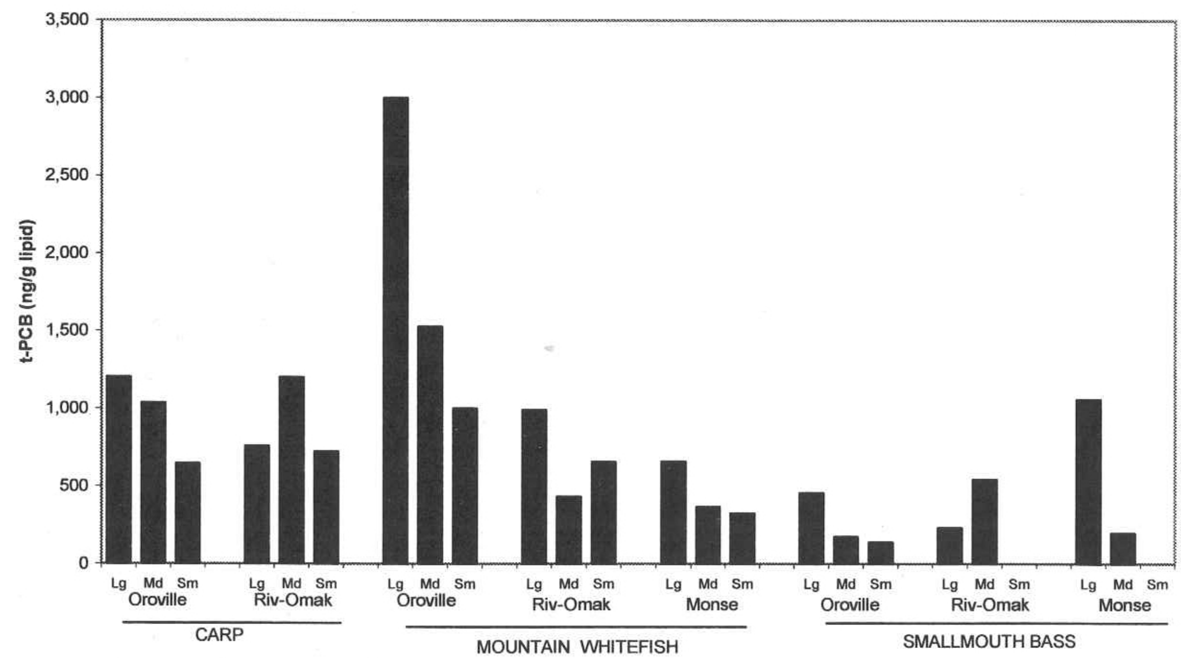


Figure 3. Lipid-Normalized t-PCB in Tissue from the Technical Assessment (Serdar, 2003).

Ordered by mean length of fish in each composite (Lg=large, Md=medium, Sm=small) and location for each species.

The report notes that in nearly all cases, the fish composites with the largest specimens (by length) had the highest t-DDT and t-PCB concentrations for each species at each site. This was generally the case in lipid-normalized concentrations as well.

The report also notes a pattern for carp and mountain whitefish of higher lipid-normalized DDT concentrations at the upper location (Oroville) decreasing in a downstream direction (Omak-Riverside to Monse). This pattern was not observed for smallmouth bass, which had slightly higher concentrations from the downstream location. The same general pattern was also noted for t-PCBs.

A complete data set for previous Ecology studies for DDT and PCBs in the Okanogan basin can be found in Appendix F in the TMDL Technical Assessment of DDT and PCBs in the Okanogan Basin (Serdar, 2003). The report is available on the Department of Ecology website at: www.ecy.wa.gov/pubs/0303013.pdf

Washington State Toxics Monitoring Program

Shared samples from the 2001-02 Technical Assessment study (Serdar, 2003)

Twenty-seven individual mountain whitefish samples were collected on 9/17/01 at the Omak-Riverside location and analyzed as part of the Washington State Toxics Monitoring Program (WSTMP). They were analyzed as individual skin-on fillets for DDT and PCBs. The intent of data collection was to set up possible trend monitoring, although later funding was not available to follow through with this plan. Therefore, no written report is associated with these data. The associated EIM study ID is WSTMP03T. Results are shown in Appendix B (Table B-3).

Shared samples from the 2008 Effectiveness Monitoring study (current study)

At the end of sample processing, selected samples in the current study were split with the WSTMP. These samples were analyzed for lipids, PCB congeners, mercury, polybrominated diphenyl ethers (PBDEs), and dioxins and furans (PCDD/Fs; polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans.)

This split took place at the end of the processing routine: aliquots of the fully homogenized sample were put into different jars for different analyses. Some jars were loaded for the effectiveness monitoring project and assigned a unique sample number. Other jars were loaded for the WSTMP project and assigned a different sample number.

Results from these splits are included as part of the WSTMP 2008 report (Seiders and Deligeannis, 2009). The associated EIM user study ID is WSTMP08. Corresponding sample IDs between this study and the WSTMP 2008 report are listed below:

- 0812022-13 (WSTMP ID: 0812011-38) PBDE, Mercury
- 0812022-09 (WSTMP ID: 0812011-37) PBDE, Mercury
- 0812022-02 (WSTMP ID: 0812011-35) PBDE, Mercury
- 0812022-04 (WSTMP ID: 0812011-36) PBDE, Mercury, PCBs, PCDD/Fs, lipid
- 0812022-03 (WSTMP ID: 0812011-34) PBDE, Mercury, PCBs, PCDD/Fs, lipid
- 0812022-17 (WSTMP ID: 0812011-42) PBDE, Mercury, PCBs, PCDD/Fs, lipid

PCB Background Levels

As mentioned above, a recent study documented background t-PCB levels in composite fish tissue samples collected at sites statewide (Johnson et al., 2010). A statewide detection rate of 98% was reported for t-PCB, with a median, 90th percentile, and maximum of 1.4, 6.5, and 88 µg/kg-ww, respectively. Results from samples collected from three sites near the Okanogan watershed are shown in Appendix B (Table B-4).

Watershed Implementation or Restoration Activities

The *Lower Okanogan DDT/PCB TMDL Water Quality Implementation Plan* (Peterschmidt, 2006) lists many actions and activities already undertaken to reduce the entry of DDT and PCB contamination to the environment. Banning the production and use of these materials was the beginning of environmental recovery. Collection and disposal programs that remove unused pesticides from storage and the waste stream have reduced and continue to reduce the threat of these dangerous and persistent chemicals on the environment. Improving efficiency in the delivery and use of irrigation water along with reduced soil erosion and improved management of riparian lands have all contributed to the reduction of DDT in the Okanogan River. Regulatory restrictions and management of PCB-containing wastes has reduced the quantity of PCBs entering the environment. It is the goal of the Implementation Plan to assure the continuation of these actions and support them as opportunities arise.

Activities in the Implementation Plan have the goal of minimizing the addition of contaminants to the river from the uplands. As previously discussed, the persistent natures of DDT and PCBs in the environment make them a legacy of past practices. While these toxic compounds continue to persist in the environment, their effective levels are reduced over time through degradation and by natural attenuation through dilution and burial. The natural processes resulting in the lower exposure of aquatic life to the contaminants will play a major role in the success of this TMDL, particularly for addressing the contaminants already in the river.

Actions taken pursuant to the TMDL implementation fall into three categories: voluntary stewardship actions, actions that are taken in accordance with a law or legal agreement, and monitoring activities. Agencies assisting with DDT/PCB reduction are summarized in Table 3.

Voluntary Activities

These are implementation actions that are undertaken by individual land owners or larger organizations, such as irrigation districts, and result in the reduced rate of contaminant movement from the uplands into the rivers, streams, or lakes.

Examples of these actions include the following:

- Participate in the Washington State Department of Agricultures' waste pesticide program.
- Protect soils from erosion due to water or wind.
- Efficiently deliver and use irrigation water.

Table 3. Agencies Assisting with DDT/PCB Reduction.

Entity	Responsibilities to be met	Schedule
Washington State Department of Agriculture	Continue to bring Waste Pesticide Collection Program events to the Okanogan Watershed.	ongoing
OCD, NRCS, and Ecology	Continue to fund agricultural BMP implementation to reduce soil losses from agricultural lands.	ongoing
Cities of Oroville, Tonasket, Omak, and Okanogan	Monitor DDT and PCB in wastewater treatment plant discharges in accordance with NPDES permit requirements.	ongoing
OCD, Irrigation Districts, and Ecology	Promote continuing improvements to the efficient and effective use of irrigation water to reduce the potential for agricultural runoff to carry sediment to the river system.	ongoing
Ecology	Periodic monitoring of Okanogan River fish tissues, repeated every 5th year.	every five years
Land Developers	Prevent sediments from reaching the river and streams by implementing BMPs described in the Eastern Washington Storm Water Manual.	ongoing

OCD: Okanogan Conservation District.
NRCS: Natural Resources Conservation Service.
BMP: Best management practice.
NPDES: National Pollutant Discharge Elimination System.

Actions That Are Taken in Accordance with a Law or Legal Agreement

The TMDL addresses water quality impairment from inputs of legacy pollutants. The primary actions for reducing DDT and PCB in the environment was the 1972 regulatory ban on DDT use and the 1979 ban on PCB production with the subsequent phase-out and control of PCB products.

- Comply with the restrictions on DDT and PCBs.
- Prevent entry of sediment into the river through implementation of storm water regulations.
- Implement and comply with NPDES permits.

TMDL Implementation Plan – Monitoring Activities

The Implementation Plan (Peterschmidt, 2006) calls on Ecology to track progress in the improvement of water quality by monitoring the concentrations of DDT and PCBs in fish from the Okanogan River. As the amounts of DDT and PCBs continuing to reach the river diminish, the contaminants existing in the river will diminish, albeit slowly due to their persistence. The fish tissue data from the TMDL Technical Assessment (Serdar, 2003) was designated in the Implementation Plan to serve as the baseline data to judge progress of environmental improvement.

Goals and Objectives

Goals

The goal of this 2008 project is to track changes in water quality by monitoring concentrations of DDT and PCBs in fish from the Lower Okanogan River to verify management activities are effective. It is expected that if the amounts of DDT and PCBs continuing to reach the river diminish, the contaminants existing in the river will diminish. The persistence of these contaminants predicts that such reduction may be slow. To verify changes occurring in the river system, the Implementation Plan (Peterschmidt, 2006) recommends monitoring fish tissue every fifth year, on an ongoing basis.

Objectives

The objectives of this study, described in the Quality Assurance Project Plan (Coffin, 2009), were implemented as follows:

- Collect a set of fish as similar as possible to those analyzed for the 2003 Technical Assessment (Serdar, 2003). Similarities include species, size, and sampling location.
- Sort the fish into groups by species, size, and location.
- Process tissue from these groups into composite samples using standard protocols.
- Analyze these composite tissue samples for DDT, PCB, and lipid content.
- Examine the relationship between DDT/PCB and lipid content.
- Compare DDT/PCB concentrations to those reported in the Technical Assessment to determine if any change is observable.
- Make recommendations for TMDL implementation and future monitoring based on these observations.

Concern has been expressed that since DDT and PCB concentrations are expected to change gradually, current study objectives may be insufficient to meet the study goal. In part this concern arises because the fish tissue data in the Technical Assessment were not originally intended to provide a baseline data set for trend monitoring (Serdar, 2010). There may be too few fish tissue samples within each reach to detect expected concentration changes. This concern was addressed by evaluating the likelihood of detecting various changes in concentration for different sample sizes when using the Mann-Whitney test (see Power Analysis section below).

Methods

Study Design

Fish Species

Species sampled were common carp (*Cyprinus carpio*), mountain whitefish (*Prosopium williamsoni*), and smallmouth bass (*Micropterus dolomieui*). These are the three most common resident game species in the Okanogan River and represent different feeding behaviors and habitat uses. Migration patterns for these fish are also of interest, for understanding how fish might have moved into and out of the river system.

Carp feed throughout the water column and are generally found in slow-moving shallow waters, although they are adaptable to a variety of habitat types. They are known to accumulate high concentrations of DDT, PCBs, and other chlorinated organic chemicals (e.g., Davis and Serdar, 1996; Serdar et al., 1998).

Mountain whitefish are more pelagic, preferring riffle areas and feeding primarily on zooplankton and insects. Mountain whitefish also can accumulate high concentrations of chlorinated organic chemicals due largely to their high lipid content (e.g., Johnson et al., 1988).

Smallmouth bass prefer gravelly substrates along gradually sloped littoral areas. Initially planktivorous or insectivorous as juveniles, they become predators (piscivorous) and are a prized game fish. Due to their lean muscle, their tendency to accumulate DDT and PCBs is less than either carp or mountain whitefish. Smallmouth bass exhibit a definite home range, although they are known to migrate in association with spawning (Wydoski and Whitney, 2003).

Sampling Location

As closely as possible, the same reaches sampled during the 2003 Technical Assessment were resampled in 2008 for the current study (Figure 4). Three reaches were chosen to represent the upper, middle, and lower sections of the Okanogan River. These reaches also encompassed the population centers and public boat launches along the river. The upper reach (Oroville) extends from river mile 76.2-77.3, the middle reach (Riverside-Omak) from 39.4-42 and the lower reach (Monse) from 4.8-10.5.

The goal in 2008 was to collect the same number of samples as in the Technical Assessment (Serdar, 2003), but differences occurred due to species availability. For the Technical Assessment, three composite samples (made up from 5 to 8 fish) were collected at each river reach for three target species (common carp, mountain whitefish, and smallmouth bass). However, no carp were found in the lower reach. In 2008, the number of composite samples per reach varied between one and five. For mountain whitefish, no specimens were found in any of the reaches, but specimens were later collected at the mouth of the Similkameen River and provided to Ecology courtesy of the CCT Department of Fish and Wildlife. These mountain whitefish were processed into three composite samples.

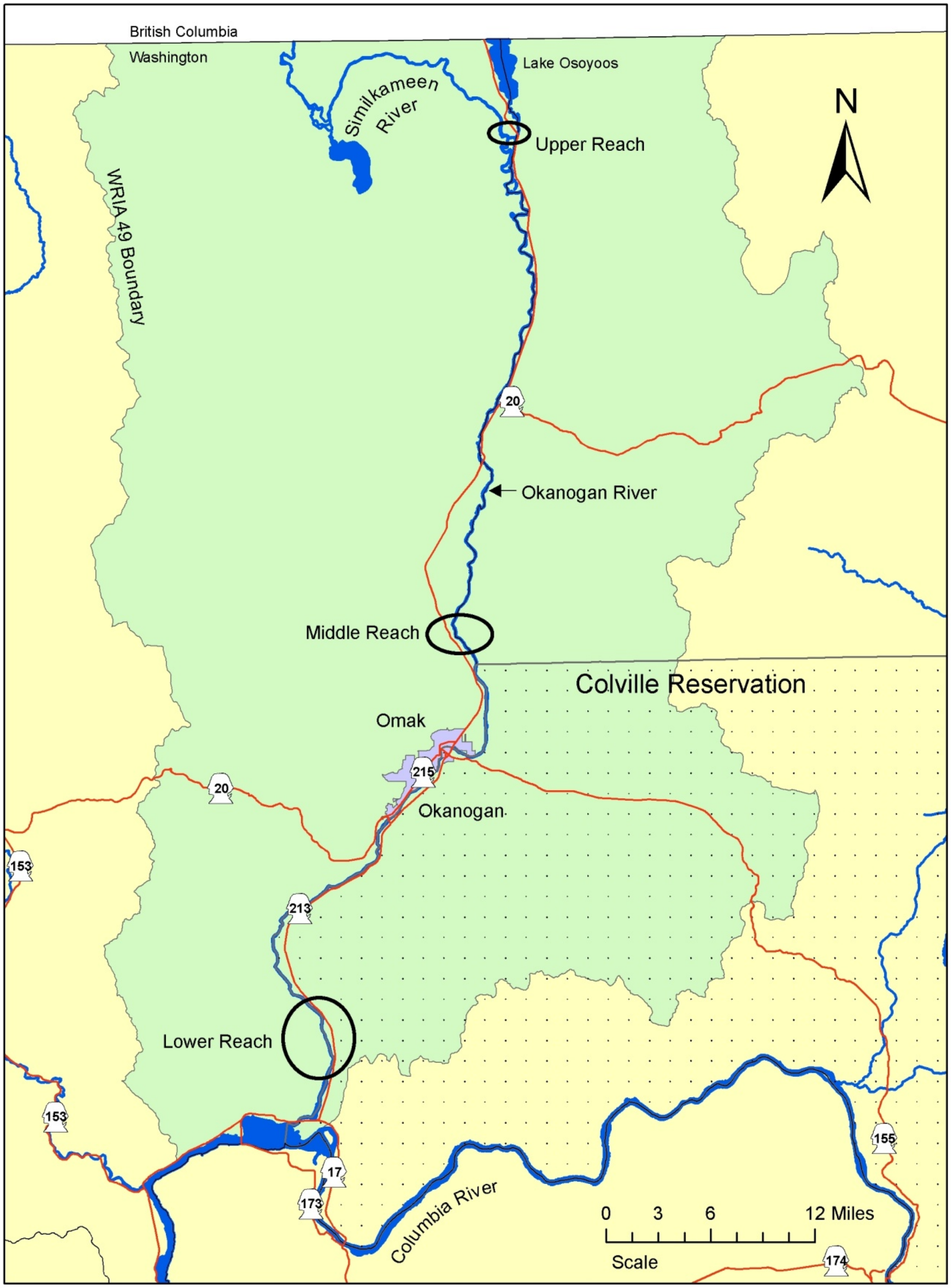


Figure 4. Areas of the Okanogan River Where Fish Samples Were Collected.

Sample Collection and Handling

As described in the Quality Assurance Plan (Coffin 2009), fish specimens were collected using an electrofishing boat in accordance with standard operating procedure (Sandvik, 2006a). Length and weight were measured in the field, and individual fish were assigned a sample number with corresponding identification in the field log. Fish were then double wrapped in aluminum foil (dull side in) and sealed in a ziplock bag. Whole fish samples were kept on ice until return from the field where they were frozen at -20°C.

Following a standard operating procedure (SOP) (Sandvik, 2006b), composite fillet homogenates of mountain whitefish and smallmouth bass were prepared by removing the scales then removing the entire fillet from the left side of each fish. The resulting sample contained the skin and some of the belly flap and dorsal fat. Common carp were processed similarly, except the skin was removed and not included in the homogenate.

Composite samples were prepared by selecting similar sized fish within a species and homogenizing the fillets from these samples using a food processor. Ground tissue was thoroughly mixed following each pass through the processor. Equal portions of individual fish for a composite were then mixed together and passed through the food processor to a uniform color and consistency.

All equipment used for tissue preparation was thoroughly washed with Liquinox® detergent, then rinsed in hot water, de-ionized water, pesticide-grade acetone, and finally, pesticide-grade hexane. This decontamination procedure was repeated between processing of each composite sample.

Fully homogenized samples were stored frozen (-20°C) in two 8-oz. glass jars with Teflon lid liners certified for trace organics analysis: one container submitted for analysis and the other archived at -20°C.

Laboratory Analysis

Fish tissue samples were analyzed by Manchester Environmental Laboratories for DDT and PCBs using method SW80818082 (organochlorine pesticides and polychlorinated biphenyls by gas chromatography, combined method). For lipid analysis, Manchester Laboratory followed SOP 730009 (MEL, 2008).

Data Quality

Laboratory Quality Assurance

Manchester Laboratory reviewed the chemical data for this project. Quality assurance and quality control are described in the laboratory's *Lab Users Manual* (MEL, 2008). Measurement quality objectives (MQOs) for this study were specified in the Quality Assurance Project Plan (Coffin, 2009).

Data quality was affected by several issues during laboratory analysis, which resulted in reported concentrations either being qualified as estimates ("J" or "NJ") or in raising reporting limits for non-detects ("UJ"). Laboratory qualifiers included in this report:

- J: The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.
- N: The analysis indicates the presence of an analyte for which there is presumptive evidence to make a tentative identification.
- NJ: The analysis indicates the presence of an analyte that has been *tentatively identified*, and the associated numerical value represents its approximate concentration.
- U: The analyte was not detected at or above the reported sample quantitation limit.
- UJ: The analyte was not detected at or above the reported sample quantitation limit. However, the reported quantitation limit is approximate and may or may not represent the actual limit of quantitation necessary to accurately measure the analyte in the sample.

Laboratory qualifiers were maintained when calculating total-DDT and total-PCB. The rule followed was to qualify total concentrations in cases where qualified addends made up more than 10% of the total.

Matrix interference resulted in some results being qualified by Manchester Laboratory. The high lipid content in some samples required necessary dilutions during preparation and analysis. High lipid interference also resulted in some continuing calibration verification standards recovering outside established quality control limits. High surrogate recoveries were noted for one sample. Some compounds for another sample were qualified due to DDT degradation check standards.

A few matrix spikes recovered outside established quality control limits due to excessively high concentrations of 4,4'-DDE and 4,4'-DDD in the original sample, greater than 4 times the matrix spikes. Recoveries for these instances were not calculated. Other recoveries are within the established quality control limits.

Manchester Laboratory notes that patterns in many of the Aroclor samples were distorted by matrix interference and/or weathering. The severity of weathering indicates that the source of the Aroclor has spent sufficient time in the environment for the original pattern to become distorted.

Method blanks and laboratory duplicates met quality control limits. All analyses were performed within established holding times.

Laboratory data are acceptable for use as qualified.

Field Quality Assurance

An estimate of precision was obtained by separately analyzing processing splits. These are obtained from the same batch of fish, processed as a single batch, and then split into different jars for individual analyses using unique sample IDs. Variability observed between these splits represents the level of homogeneity within processed samples and variability due to laboratory sources. The splits provide an estimate of precision similar to the laboratory duplicates prepared by Manchester Laboratory.

Processing split sample-ID pairs are as follows (0812022-xx):

- -05 and -25 (carp from the middle Okanogan River).
- -16 and -23 (carp from the lower Okanogan River).
- -18 and -24 (mountain whitefish from the mouth of the Similkameen River).
- -10 and -26 (smallmouth bass from the middle Okanogan River).

Variability between the splits is presented in Table 4 as relative percent difference (RPD). Note that all reported PCB concentrations in the processing splits are J-qualified as estimates. MQOs for split samples are ≤40% RPD[1] for DDT and PCBs and ≤50% RPD for lipids. When reported results are close to detection limits, the effectiveness of RPD to measure precision is limited (Mathieu, 2006).

Table 4. Relative Percent Differences for Processing Splits.

Reach	Sample ID 0812022-	Species/ RPD	Lipids (%)	4,4'-DDD	4,4'-DDE	4,4'-DDT	PCB 1248	PCB 1254	PCB 1260
Middle	5	Carp	2.6	26	410	3.7	6.4 J	7 J	6.7 J
	25		3.02	24	310	3.2 J	5.1 J	6.0 J	5.2 J
		RPD	15%	8%	28%	14%	23%	15%	25%
Lower	16	Carp	7.55	250	2000	2.4 J	7.4 U	28 J	11 J
	23		8.04	210	1900	2.9 J	9.7 UJ	30 J	9.7 UJ
		RPD	6%	17%	5%	19%	NA	7%	NA
Upper	18	MWF	4.21	25	340	6.6	9.8 U	15 J	15 J
	24		4.6	27	380	7	10 U	14 J	16
		RPD	9%	8%	11%	6%	NA	7%	6%
Middle	10	SMB	1	4.7	100	2.5	2.4 U	4.0 J	2.4 U
	26		1.15	6.7	97	3.5	5.0 U	5.0 U	5.0 U
		RPD	14%	35%	3%	33%	NA	NA	NA

All sample pairs met MQOs. However, note the difference for 4,4'-DDE in the 5/25 pair: 410 vs. 310 µg/kg-ww. This difference is on a scale similar to what this study is attempting to detect. This illustrates the need to document an overall pattern among a number of samples, rather than relying on too few data.

[1] The QAPP incorrectly lists the MQO for lab duplicates as 20% instead of 40% RPD.

Data Analysis

To evaluate whether DDT and PCB concentrations have changed, 2008 Effectiveness Monitoring data were compared against those reported in the Technical Assessment (Serdar, 2003). Split sample results were averaged prior to comparison. When a compound was detected in only one of the two splits, the reported detection was used for the analysis. Concentrations were only compared within each fish species.

Several factors potentially affect direct comparison between our data and that of the Technical Assessment: seasonality, species availability, and lipid content.

Seasonality has an uncertain potential to impact the data due to biological changes in the fish which affect lipid content (Nowell et al., 1999). Samples in 2008 were collected in August and September, while samples in the Technical Assessment were collected in May, September, and November. It is not known whether seasonality has any effect on these data.

Species were not always available within each reach, possibly due to seasonal movements or other factors. For the Technical Assessment, no carp were found in the lower reach. In 2008, no mountain whitefish were found in the middle and lower reach. Table 5 compares the number of samples available within each reach. The species with the most samples for comparison is smallmouth bass, carp, and mountain whitefish, in that order.

Table 5. Number of Fish Samples Available for Comparison.

	Carp	MWF	SMB
Upper	3:1	3:3	3:2
Middle	3:2	3:0	3:5
Lower	0:4	3:0	3:3

Left number: number of 2001-02 Technical Assessment samples.
Right number: number of 2008 Effectiveness Monitoring samples.
Shaded cells: one of the numbers is zero, so no direct comparison for that species within that reach is possible.

Lipid content may affect contaminant concentrations, but this relationship is not always clear cut (Nowell et al., 1999). Lipids are believed to play a role in accumulation of hydrophobic contaminants such as DDT and PCBs, but lipid content is also a factor of reproductive cycles. Therefore, it may be difficult to distinguish between these factor's effects on concentration. To account for different lipid content, concentrations are often expressed on a lipid-weight basis as opposed to a wet-weight basis. There is some debate about the usefulness of this normalization in all cases (Herbert and Keenleyside, 1995).

Lipid normalization was applied in cases where concentrations for both years show a linear trend when plotted vs. lipids, and a reasonably good fit is obtained from linear regression. Lipid-normalized concentrations were calculated by dividing wet-weight concentration by lipid content expressed as a decimal (e.g., 3% = 0.03).

Boxplots are used to graphically illustrate data distribution. The style of boxplot chosen for this report is the schematic boxplot (Tukey, 1977). The box is drawn from the 25th to the 75th percentiles, with a dark line showing the median (50th percentile). The height of the box is termed the interquartile range. Depending on the data, lines (called whiskers) extend from the box up to 1.5 times the interquartile range. Data beyond the whiskers are plotted individually as circles. Means are shown on the boxplots as filled triangles. These are found in the "Boxplots" section of Results.

Differences in medians were tested using the non-parametric Mann-Whitney (also called the Wilcoxon-Mann-Whitney) rank sum test. This test assumes the data are independent and come from a common continuous distribution, but the data do not require a specific form of distribution. This test is resistant to outliers (unusually high concentrations). Test results are found in the "Descriptive Statistics and the Mann-Whitney Test for Changes in Median" section of Results and also in Appendix E.

The Kruskal-Wallis test was used to examine differences between the three reaches. It is a non-parametric test similar to the Mann-Whitney test, but it can be applied to more than two independent data sets. Test results are found in the "Differences Between Reaches" section of Results.

Graphs and statistical tests were prepared with the R software package (v. 2.12.0). Kaplan-Meier estimates for descriptive statistics were prepared using the Non-Detects and Data Analysis Package for R (v. 1.5-2).

Results and Discussion

Appendix B presents analytical results for the 2008 samples, along with those from the Technical Assessment (Serdar, 2003). Total DDT (t-DDT) is calculated as the sum of 4,4'-isomers, as in the Technical Assessment. Total PCB (t-PCB) is calculated as the sum of Aroclors. Split samples were averaged prior to summing t-DDT and t-PCB.

Comparison with National Toxics Rule (NTR) Criteria

High t-DDT concentrations were found in 2008 carp samples from the lower reach of the Okanogan River (sample IDs 0812022-16, -23, and -22). No corresponding samples from this reach were obtained in 2001 for the Technical Assessment, due to specimen unavailability. Lipid content is also high in these 2008 samples. As mentioned previously, WDOH is likely to order a fish consumption advisory based in part on these samples.

The overall number of 2008 samples not meeting (exceeding) NTR criteria is similar to the number in the Technical Assessment; both are summarized below. Note that the two studies differed in the number of samples of each species collected in many reaches.

Concentrations in the following 2008 samples exceeded NTR criteria (shown in parenthesis):

- 4,4'-DDE (32 µg/kg): All seven carp, all three mountain whitefish, and all ten smallmouth bass).
- 4,4'-DDD (45 µg/kg): Three of seven carp (from lower reach).
- 4,4'-DDT (32 µg/kg): None.
- t-PCB (5.3 µg/kg): Five of seven carp, all three mountain whitefish, one of ten smallmouth bass. For PCBs, in 2008 almost all analytical results are qualified as estimates.

Concentrations in the following 2001 samples exceeded NTR criteria:

- 4,4'-DDE: Eight of nine smallmouth bass, all nine mountain whitefish, and all six carp.
- 4,4'-DDD: One of nine mountain whitefish[2].
- 4,4'-DDT: None.
- t-PCB: All six carp, all nine mountain whitefish, one of nine smallmouth bass.

Split samples compared consistently to the NTR criteria in all cases (i.e., both results from the split were either above or below the relevant criterion) and were counted as single samples above.

[2] Incorrectly noted as carp in the text of the Technical Assessment (Serdar, 2003.)

Comparison with Recommendations for Prioritizing 303(d) Fish Tissue Listings for PCBs

As discussed above, Johnson et al. (2010) made recommendations for prioritizing 303(d) listings based on t-PCB (Table 2). Comparing 2008 t-PCB results to their recommendations:

- All ten smallmouth bass t-PCB results meet the "<10 No further action" recommendation.
- One mountain whitefish result meets the "20-100 Medium priority" recommendation; the other two meet the "10-20 Low priority" recommendation.
- Three carp results meet the "20-100 Medium priority", one meets the "10-20 Low priority," and three meet the "<10 No further action" recommendations.

Comparison of t-DDT and t-PCB by Species and Reach

Concentrations of t-DDT and t-PCB vs. average fish length are graphed by species and reach in Figures 5 and 6. Axes for concentration are consistent within each figure to allow comparison. Axes for fish lengths are constant within each species.

Non-detect samples are included in Figure 6 to illustrate that they occur in smaller fish. In general, displaying non-detects on a graph can be misleading since the actual contaminant concentration is unknown. This issue was addressed by using unique symbols for non-detects which cannot be confused with measured concentrations. The presence of non-detects are noted along the horizontal axis, but reporting limits are not shown in this figure.

Most t-PCB data in Figure 6 were qualified as laboratory estimates. This includes all 2008 data except for one carp in the upper reach, and over half of the 2001 data. Care should be exercised when comparing these estimates: a relatively consistent pattern across a number of samples is needed to identify overall changes between 2001 and 2008.

Fish length appears related to t-DDT or t-PCB concentration in some cases but not others.

High contaminant concentrations are seen in both figures for large carp from the lower reach. However, the smallest sample from this same reach has a low concentration of t-DDT and is non-detect for PCBs. No carp were found in the lower reach in 2001, possibly due to migration. One possibility is that they move into the Columbia River during cold weather (Coots, 2010).

Middle and upper reach carp contaminant concentrations are roughly similar between 2001 and 2008. Slight increases and decreases are noted but are difficult to interpret.

For mountain whitefish, only three samples are available from the upper reach in 2008. Two of these have lower concentrations of t-DDT and t-PCB than similarly sized fish. The remaining sample has roughly similar t-DDT and slightly higher t-PCB. These samples were collected from the mouth of the Similkameen River.

For smallmouth bass, overall concentrations of both t-DDT and t-PCB are lower than the other two species. A weak relationship is apparent between concentrations and length. Many of the smaller fish are non-detect for PCBs. No clear change is evident for this species.

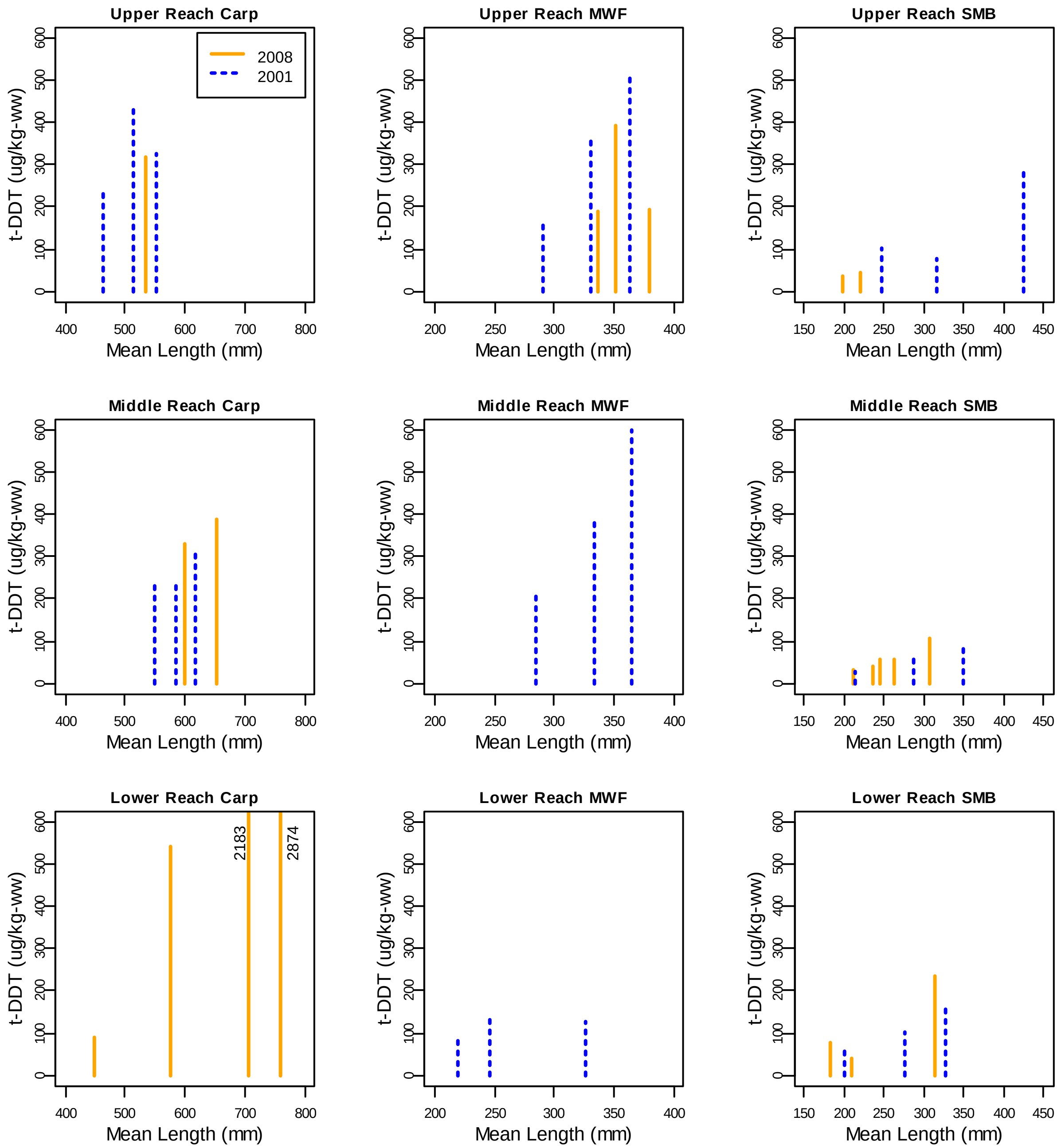


Figure 5. t-DDT vs. Mean Fish Length, by Species and Reach[3].

[3] High concentrations in lower reach carp are plotted near maximum and labeled with t-DDT concentration (ug/kg-ww.)

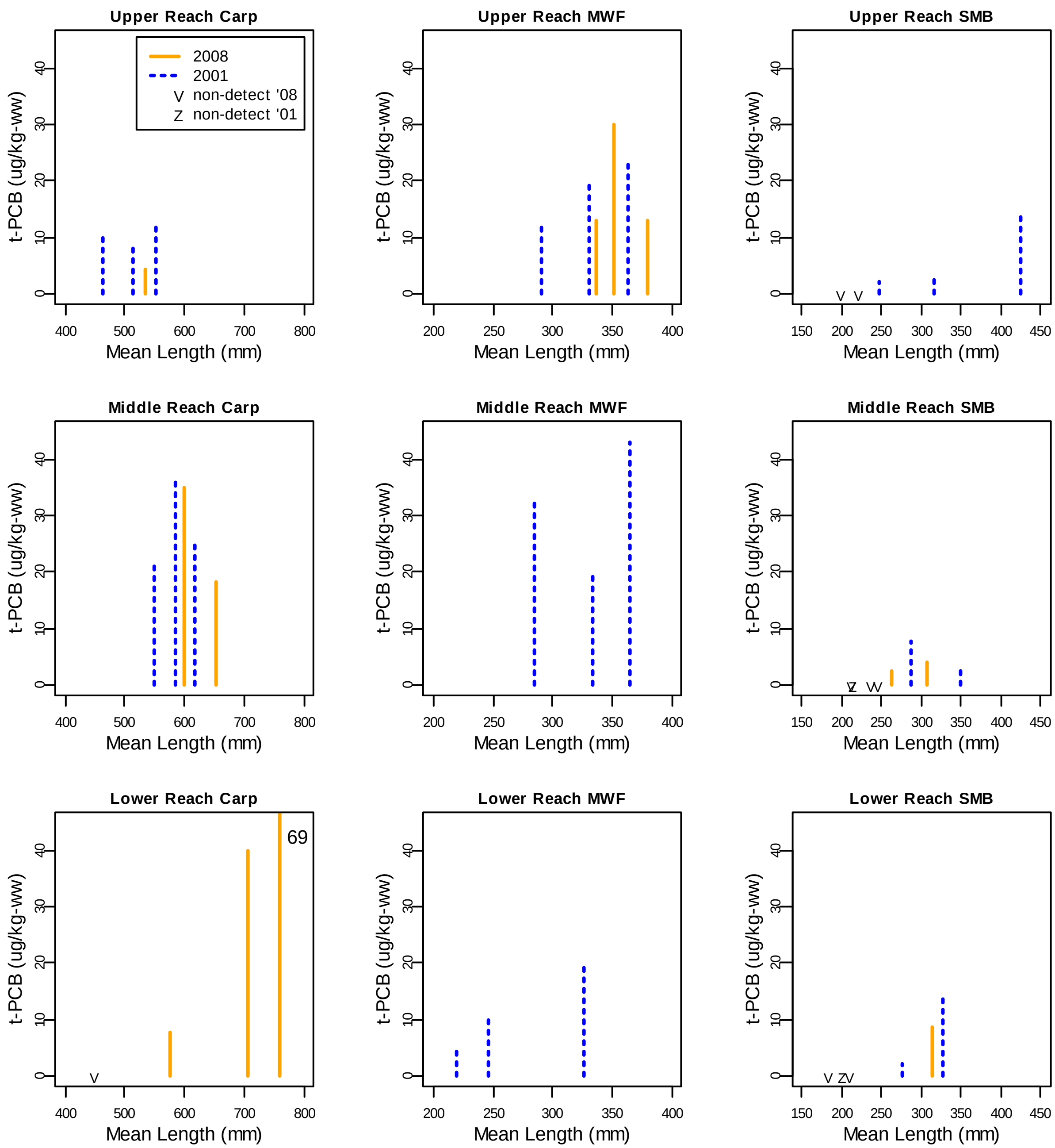


Figure 6. t-PCB vs. Mean Fish Length, by Species and Reach[4].

[4] Highest concentration in the lower reach carp are plotted near maximum and labeled with t-PCB concentration (ug/kg-ww.)

Differences Between Reaches

Is contamination in fish tissue similar among the three reaches? This question was evaluated by testing the combined 2001-2008 data using the Kruskal-Wallis test (Table 6). The p-value from this test indicates the probability that the median is similar among all three reaches. A p-value near one indicates similar reaches, while a value near zero indicates a difference in at least one reach.

Table 6. Kruskal-Wallis Test for Differences by Reach, Combined 2001-08 Data.

Species	Reach	n (2001-08)	Kruskal-Wallis Test p-value	
			t-DDT	t-PCB
Carp	Upper	5	0.35	0.19
	Middle	8		
	Lower	6		
MWF	Upper	6	0.03	0.04
	Middle	3		
	Lower	3		
SMB	Upper	5	0.26	NC*
	Middle	8		
	Lower	6		

*NC: not calculated.

Data from the two studies were combined because so few data were available for testing. While not ideal, this provides a reasonable check on whether a particular reach was consistently higher or lower than the others during both study years.

This test is based on rank-ordering the data, not absolute concentration, making it resistant to excessively high concentrations, such as those found in the large carp from the lower reach.

Smallmouth bass t-PCB data were not tested due to the large number of non-detects.

Results indicate a likely difference between reaches (>95% probability) for mountain whitefish. Less contamination is observed in the lower reach for this species in 2001 but should be confirmed in future studies since no 2008 data are available from this reach.

Other species showed no significant differences between reaches. It is somewhat surprising that carp in the lower reach did not yield a significant difference. However, this reach includes not only the highest contaminant concentrations but also the lowest. With so few data points, it is likely that the low concentration balanced the high ones for this test.

WSTMP Individual Mountain Whitefish Samples, 2001

As mentioned above, 27 individual mountain whitefish samples were collected from the middle reach in 2001 and analyzed for DDT and PCBs. Since these data have not been previously included in any report, they are graphed below (Figures 7 and 8). Although they are individual samples, the 2001 and 2008 composite sample data from the current report for reference are also shown.

Non-detects are displayed as intervals between zero and the detection limit, as recommended by Helsel (2005).

Increased variability is seen in the individual mountain whitefish data since they are not averaged as part of a composite sample. Several high concentrations are seen in t-DDT. Averaging these samples by compositing would result in less extreme concentrations, although no comparison is made between these datasets.

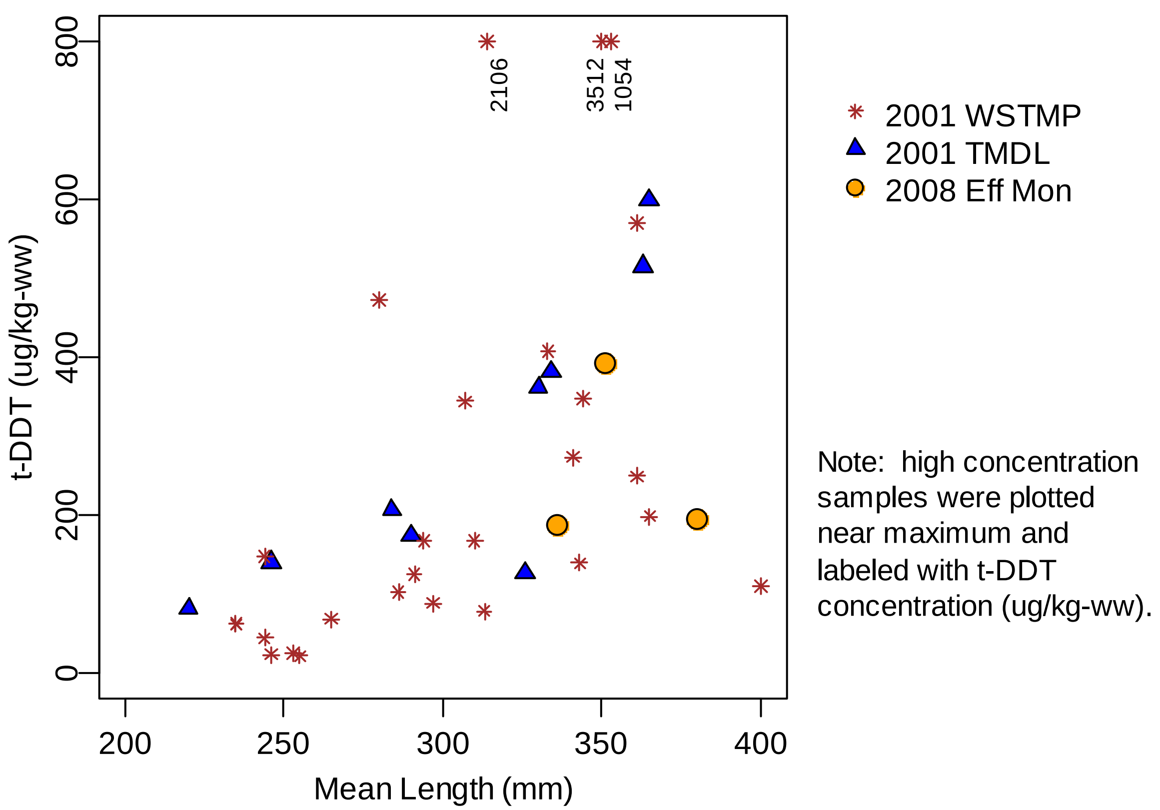


Figure 7. t-DDT in Individual and Composite Mountain Whitefish Samples, 2001-2008.

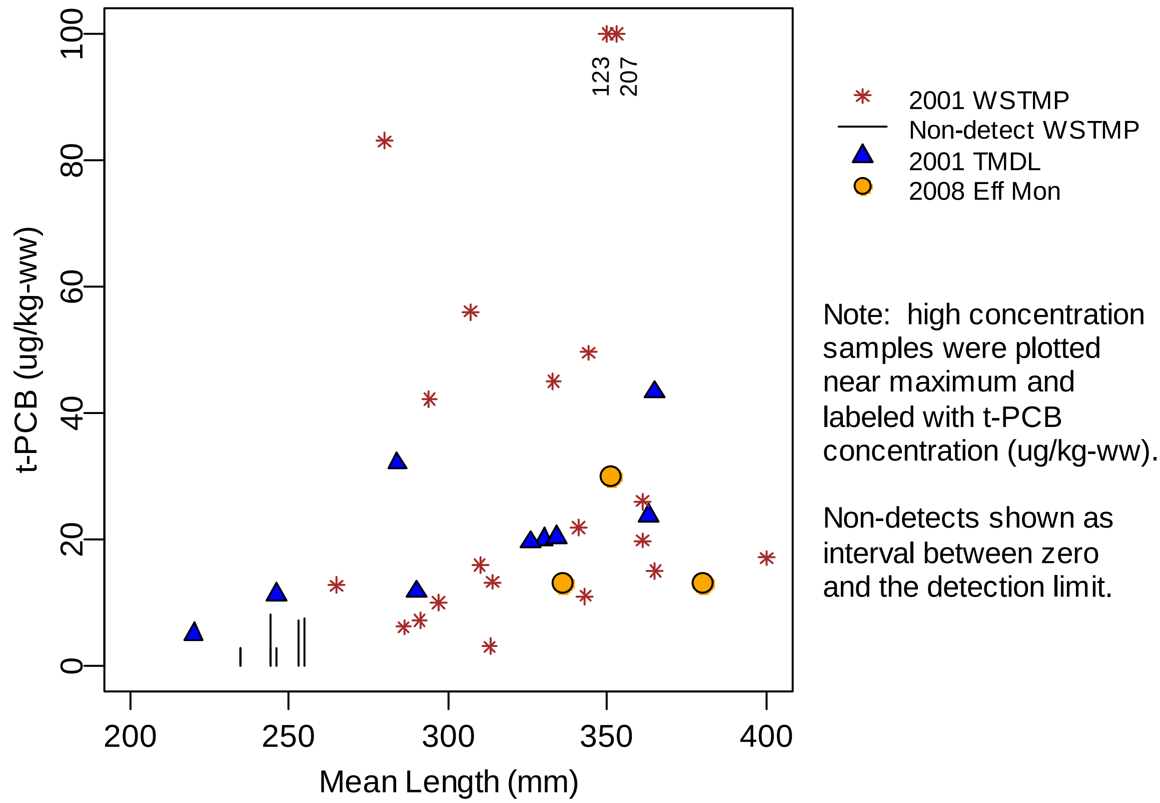


Figure 8. t-PCB Concentrations in Individual and Composite Mountain Whitefish Samples, 2001-2008.

Linear Regression and Decisions About Normalization

Concentrations of t-DDT and t-PCB in fish can be affected by factors such as lipid content, fish length, and fish weight. When a strong relationship exists between concentration and these factors, data may be normalized to account for this. Linear regression was used to identify when data should be normalized.

According to Helsel and Hirsch (2002), there are five assumptions associated with linear regression. The necessity of satisfying them is determined by the purpose to be made of the regression equation. The purpose needed for this report is to predict concentration (y) given lipid content, fish length, or fish weight (x). For this purpose, the two assumptions below are relevant:

- Model form is correct: y is linearly related to x.
- Data used to fit the model are representative of data of interest.

To evaluate these assumptions, the following steps were followed (Helsel and Hirsch, 2002).

- Plot concentrations against the factor of interest, and check for non-linear relationships and marked changes in variability over the range.
- Compute regression statistics. Check that slope and intercepts are reasonable, then evaluate whether much variance is explained by the coefficient of determination (R^2).

Concentrations and regression lines are plotted in Figures 9 and 10 for the two datasets which were later selected for lipid-normalization. Plots for all other concentrations are presented in Appendix D. Table 7 presents R^2 values for all the data.

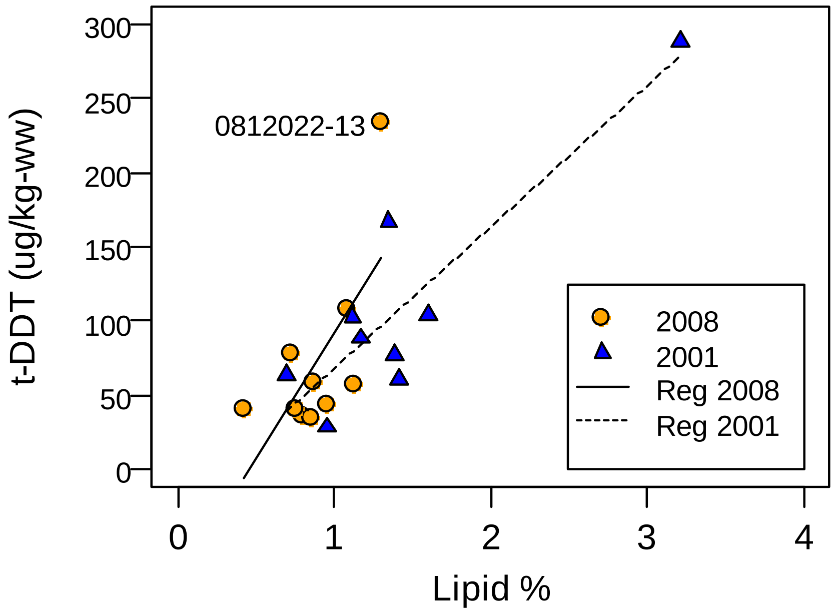


Figure 9. Linear Regression t-DDT vs. Lipid for Smallmouth Bass, 2001 vs. 2008 (all reaches combined).

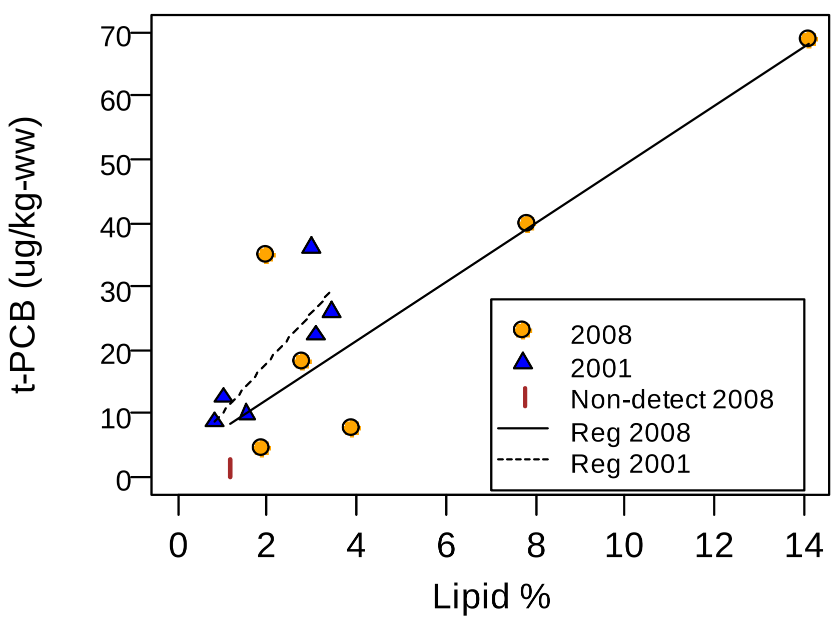


Figure 10. t-PCB vs. Lipid for Common Carp, 2001 vs. 2008 (all reaches combined).

Table 7. Coefficients of Determination (R^2) from Linear Regression.

Species	Year	n	R^2 for t-DDT versus:			R^2 for t-PCB versus:		
			Lipid	Length	Weight	Lipid	Length	Weight
Carp	2001	6	0.38	0.004	0.03	0.73	0.57	0.63
	2008	7	0.95	0.72	0.85	0.78	0.77	0.87
MWF	2001	9	0.01	0.71	0.69	0.31	0.49	0.68
	2008	3	0.27	0.02	0.02	0.25	0.03	0.03
SMB	2001	9	0.79	0.64	0.70	0.48	0.49	0.46
	2008	10	0.46	0.54	0.57	NC*	NC	NC

* NC: Not calculated due to large number of non-detects.

Based on linear regression, it is reasonable to include lipid-normalized t-PCB concentrations for carp in this study. A linear pattern is observed for t-PCB vs. lipid, although there are few data available to assess it. The regression lines have reasonable slopes and intercepts for both years. The R^2 values for both years are reasonable (0.78 and 0.73). It is again difficult to assess variability across the full range of lipids, since high lipid samples were only found in 2008 in the lower reach. (Note: one half the detection limit was substituted for the non-detect in the regression.)

However, it is unclear whether lipid-normalized t-DDT concentrations for smallmouth bass should be included in the study. An overall linear pattern is apparent. Two issues bring the regression into question. First, it is difficult to assess changes in variability due to the limited range of lipids, especially in 2008. Second, the 2008 regression line is unreasonable, since it predicts negative concentrations for samples with less than 0.5% lipid. A possible explanation for this is the high t-DDT concentration in sample 0812022-13 (marked on Figure 9). This sample increases the slope of the regression line. Given so few data points, this concentration cannot be excluded from the analysis. Regression statistics for 2008 are also lower than 2001 (R^2 = 0.46 vs. 0.79, respectively). Further discussion is provided below.

Despite the weakness of linear regression for t-DDT in smallmouth bass, it is possible that the 2008 concentrations may be biased low because these fish tend to be smaller than those from 2001 (Figure 11). The Mann-Whitney rank-sum tests shown in this figure compare median values of t-DDT, lipid content, and fish length for 2001 vs. 2008. The p-values, shown on the right side of this figure, indicate the likelihood that the medians of the datasets are similar. A low p-value indicates that the medians are likely different. This figure shows that the fish sampled in 2008 tend to be significantly smaller with lower lipid content than those from 2001, at the 95% confidence level. Because these size differences could potentially bias estimates of t-DDT change, a comparison of lipid-normalized t-DDT concentrations in smallmouth bass was included.

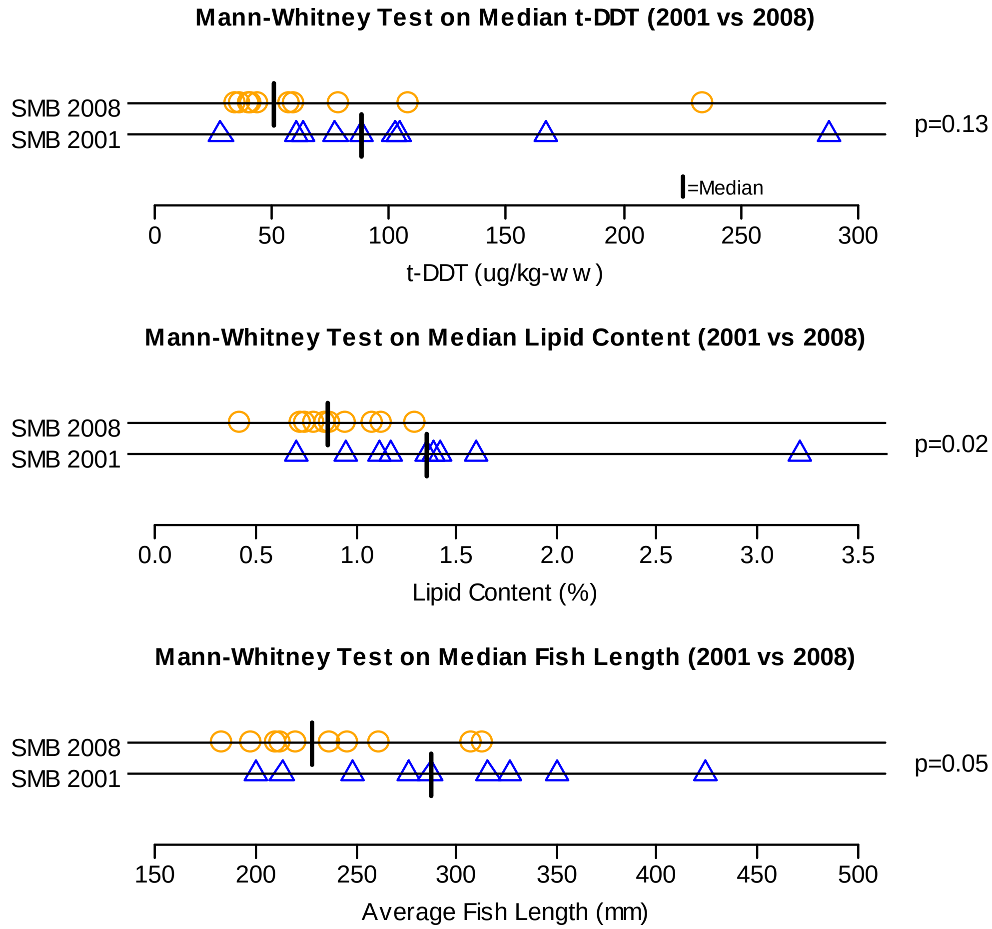


Figure 11. Selected Mann-Whitney Tests on Smallmouth Bass, 2001 vs. 2008 (all reaches combined).

Descriptive Statistics and the Mann-Whitney Test for Changes in Median Concentrations

Table 8 presents descriptive statistics for all species, including lipid-normalized t-DDT in smallmouth bass and lipid-normalized t-PCB in carp. Additionally, as discussed below, separate statistics for t-DDT are calculated for carp after excluding the two highest concentrations found in the lower reach.

Separate statistics after excluding the two highest concentrations of t-DDT in carp were calculated for the following reasons: (1) There is a strong lipid-dependence observed for t-DDT in 2008 carp (R^2=0.95) and, (2) the two excluded samples have much higher lipid content than any other samples for either year.

Given the lipid-dependence, these two high-lipid samples of t-DDT in carp should not be compared to lower lipid samples without normalization. However, normalization is problematic since the 2001 data do not appear lipid dependent. All data (2001 and 2008) should be lipid-normalized, or these two high concentrations should be discarded prior to comparison.

To evaluate whether a comparison is reasonable after excluding these high concentrations, Figure 12 plots t-DDT concentrations in carp vs. lipid, average fish weight, and average fish length. Fish lengths and weights are similar between the two studies, and no clear differences exist between the two studies based on these factors. Despite a possible difference in lipid-dependence, comparing t-DDT in carp seems reasonable after excluding the two highest t-DDT concentrations from 2008.

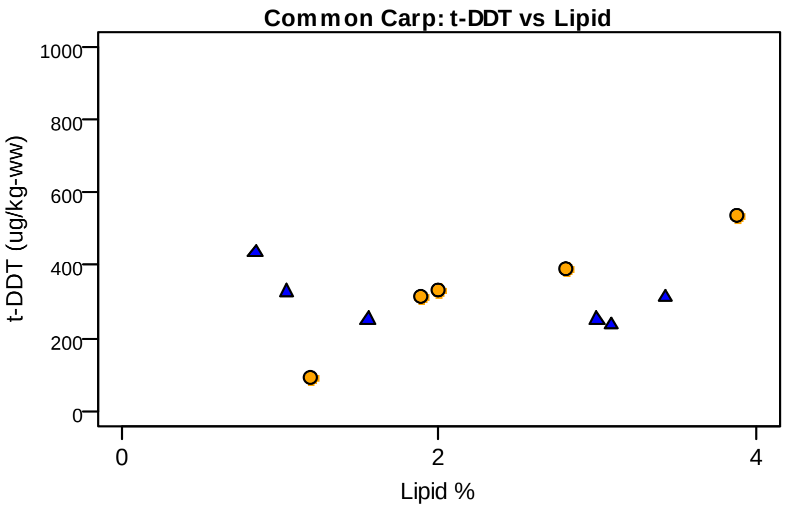
Descriptive statistics for t-PCB data that include non-detects were estimated using the non-parametric Kaplan-Meier (K-M) method. This is a standard non-parametric method for estimating descriptive statistics for datasets with non-detects (Helsel, 2005). This method should not be used when more than 50% of the data are non-detects. It assumes a common distribution but does not require a specific form for this distribution. Estimates for mean, median, and standard deviation are made from a constructed cumulative distribution function. This method offers a way to adjust descriptive statistics for non-detects without having to know the actual non-detect concentration values. This method is more difficult to use than simple substitution but avoids the biases inherent in that method (EPA, 2009).

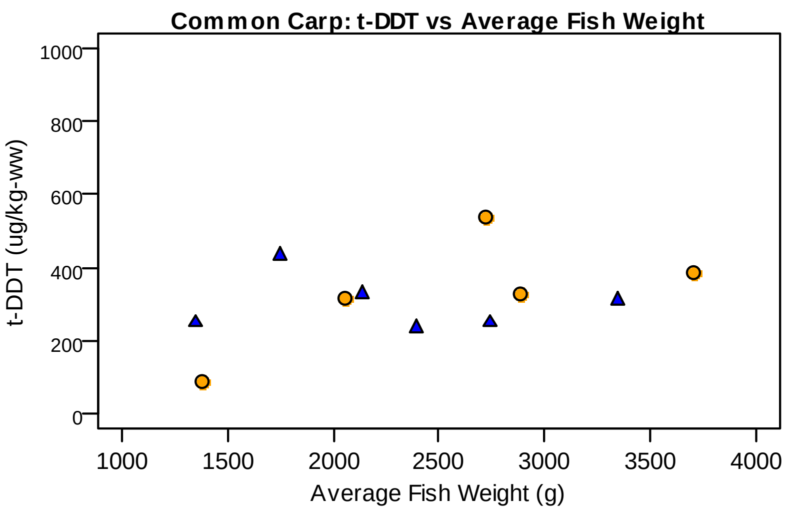
Changes in descriptive statistics between 2001 and 2008 are listed in Table 8. No statistical confidence is attached to these changes except for the median. For changes in median, the Mann-Whitney test was used to calculate a probability that the two medians are significantly different. A p-value near 1 indicates that the medians are likely similar, and a value near zero indicates that the medians are likely different. Mann-Whitney test results are presented graphically in Appendix E.

Table 8. Descriptive Statistics by Species and Year, Including Mann-Whitney Tests for Change in Median Concentrations.

Species	Year	Lipid (%)	Length (mm)	t-DDT (ug/kg-ww except for Lipid-Norm SMB which is ug/kg-lipid)					t-PCB (ug/kg-ww except for Lipid-Norm Carp which is ug/kg-lipid)				
		Median	Median	n	Mean	Median	Max	Std. Dev.	n (*)	Mean	Median	Max	Std. Dev.
Carp	2001	2.3	551	6	301	280	434	75	6	19.3	17.4	36.1	10.8
	2008	2.8	600	7	960	389	2,874	1,098	7 (1*)	25.6	18.3	69	24.3
	Change	0.5	49	---	659	109	2,440	1,023	---	6.3	0.9	32.9	13.5
Mann-Whitney p		0.28	0.28	---	---	0.13	---	---	---	---	0.95	---	---
Carp - Exclude Two Highest t-DDT Conc.	2001	2.3	---	6	301	280	434	75	---	---	---	---	---
	2008	2	---	5	333	330	539	162	---	---	---	---	---
	Change	-0.3	---	---	32	50	105	87	---	---	---	---	---
Mann-Whitney p		---	---	---	---	0.41	---	---	---	---	---	---	---
Lipid-Norm Carp	2001	---	---	---	---	---	---	---	6	928	897	1,203	251
	2008	---	---	---	---	---	---	---	7 (1*)	580	489	1,750	553
	Change	---	---	---	---	---	---	---	---	-348	-408	547	302
Mann-Whitney p		---	---	---	---	---	---	---	---	---	0.05	---	---
MWF	2001	3	326	9	287	206	599	185	9	20.7	20	43.2	11.5
	2008	4.4	351	3	258	194	393	117	3	18.7	13	30	9.8
	Change	1.4	25	---	-29	-12	-206	-68	---	-2	-7	-13.2	-1.7
Mann-Whitney p		0.10	0.10	---	---	0.86	---	---	---	---	1.0	---	---
SMB	2001	1.4	287	9	109	88	288	77	9 (2*)	5.7	2.4	14.6	5.4
	2008	0.9	229	10	73	51	234	61	10 (7*)	NC	NC	8.7	NC
	Change	-0.5	-58	---	-36	-37	-54	-16	---	NC	NC	NC	NC
Mann-Whitney p		0.02	0.05	---	---	0.13	---	---	---	---	NC	---	---
Lipid-Norm SMB	2001	---	---	9	7,354	7,520	12,370	2,889	---	---	---	---	---
	2008	---	---	10	7,868	6,125	18,000	4,335	---	---	---	---	---
	Change	---	---	---	514	-1,395	5,630	1,446	---	---	---	---	---
Mann-Whitney p		---	---	---	---	0.97	---	---	---	---	---	---	---

* Number of non-detect results. In these cases, mean, median, and standard deviation were estimated by Kaplan-Meier method.
NC: not calculated.





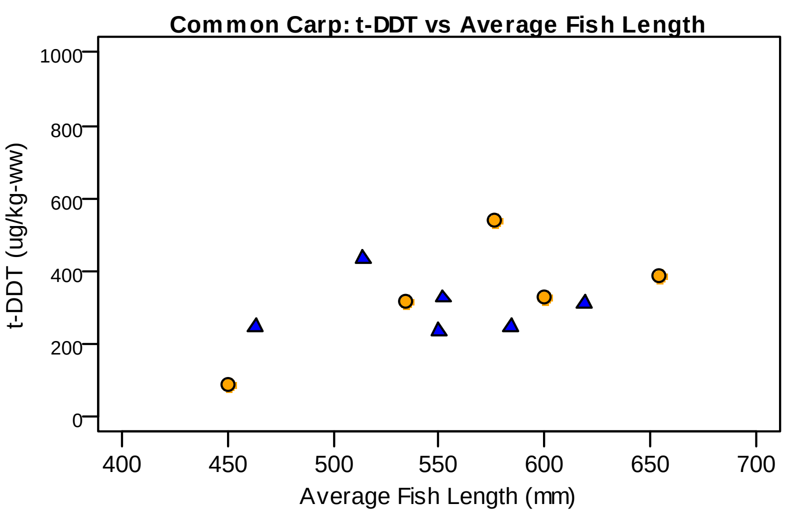


Figure 12. t-DDT in Common Carp, Excluding Two Highest Concentrations in 2008.

Changes in Median t-DDT Based on the Mann-Whitney Tests and Descriptive Statistics

- **Carp**: Median concentrations were not found significantly different at the 90% confidence level (p=0.13 and 0.41), whether or not the two highest concentrations from the lower reach were excluded. An increase is seen in mean, median, maximum, and standard deviation whether or not the two highest concentrations are excluded.
- **Mountain Whitefish**: Median concentrations were not found significantly different at the 90% level (p=0.86). A decrease is seen in mean, median, maximum, and standard deviation.
- **Smallmouth Bass**: Median concentrations were not found significantly different at the 90% level (p=0.13.) As discussed above, 2008 fish tended to be smaller with lower lipid content. Mean, median, maximum, and standard deviation decreased.
- **Lipid-normalized Smallmouth Bass**: Median concentrations were not found significantly different at the 90% level (p=0.97). The median decreased, while the mean, maximum, and standard deviation increased.

Changes in Median t-PCB Based on the Mann-Whitney Tests and Descriptive Statistics

- **Carp**: Median concentrations were not found significantly different at the 90% level (p=0.95). Due to a non-detect, statistics for 2008 were estimated using the Kaplan-Meier method. Mean, median, maximum, and standard deviation increased.
- **Lipid-normalized Carp**: A decrease in median concentration was found significant at the 90% level (p=0.05). The mean decreased; median, maximum, and standard deviations increased.
- **Mountain Whitefish**: Median concentrations were not found significantly different (p=1.0). A decrease is seen in mean, median, maximum, and standard deviation.
- **Smallmouth Bass**: Statistics were not calculated for 2008 because over 50% of the samples are non-detect. It is possible that the increase in non-detects in 2008 is related to smaller fish size.

Boxplots

Boxplots for t-DDT concentrations are presented in Figures 13 and 14. Boxplots provide a graphical summary of the distribution of a data set. This includes the center of the data (median and mean), the variation or spread (interquartile range or height of the box), the skewness (relative size of box halves), and the presence of unusual values (outliers far outside the box). Boxes are drawn from the 25^{th} to 75^{th} percentiles, with the median shown as a dark bar. Means are plotted as triangles. Whiskers extend up to 1.5 times the width of the box (also called the interquartile range). Data beyond the whiskers are plotted as individual points.

- **Carp**: As mentioned above, comparison of 2008 and 2001 t-DDT data for this species is tenuous because the 2008 data appear lipid-dependent while the 2001 data do not. Because of this, the two high-lipid samples from 2008 were excluded from Figure 13. Increases are seen in median and mean.

- **MWF**: No boxplot is shown for 2008 because only three data points were available.
- **SMB**: A decrease is seen in median and mean. This is possibly related to smaller fish size in 2008.
- **Lipid-normalized SMB**: A slight decrease is seen in median, and a slight increase is seen in mean.

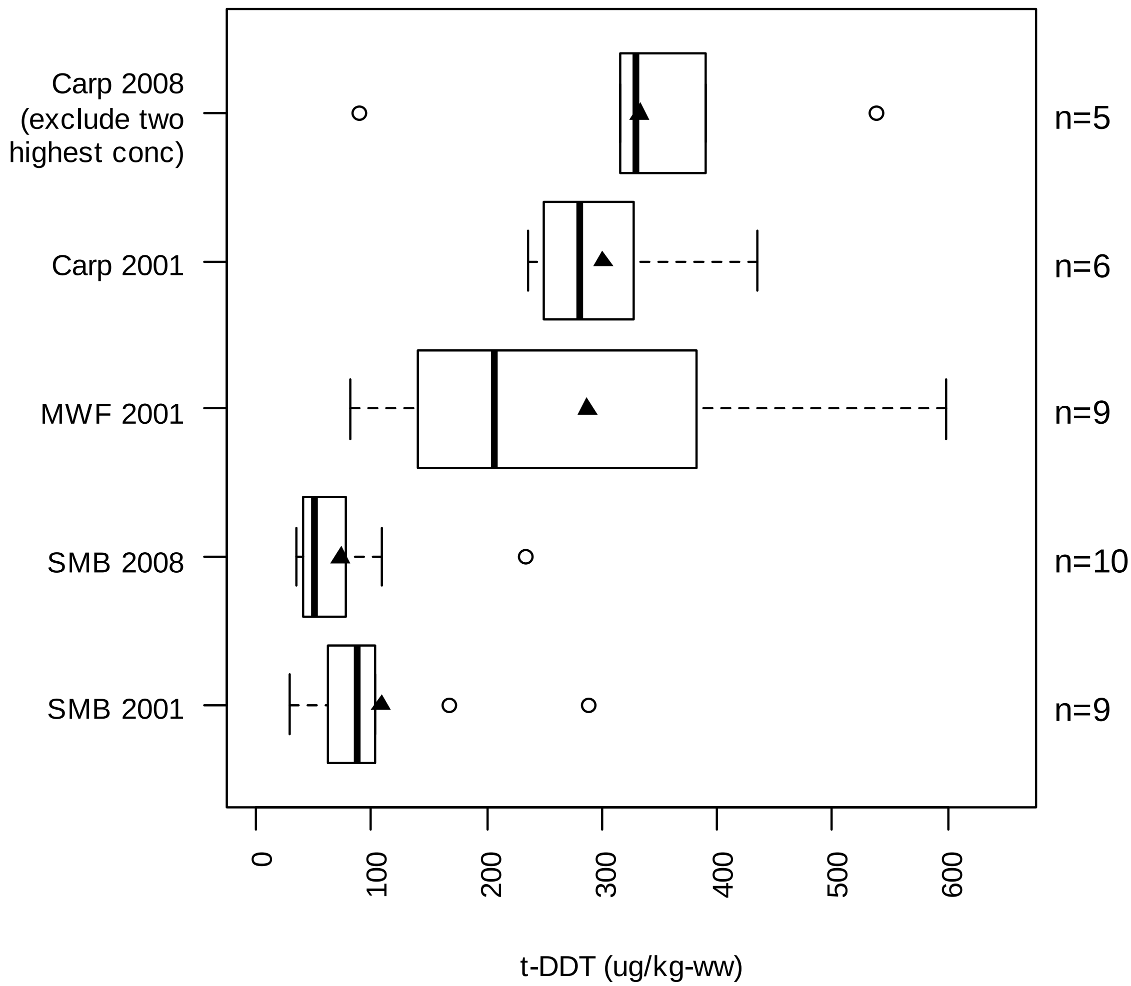


Figure 13. Boxplots of t-DDT by Species and Year (all reaches combined).

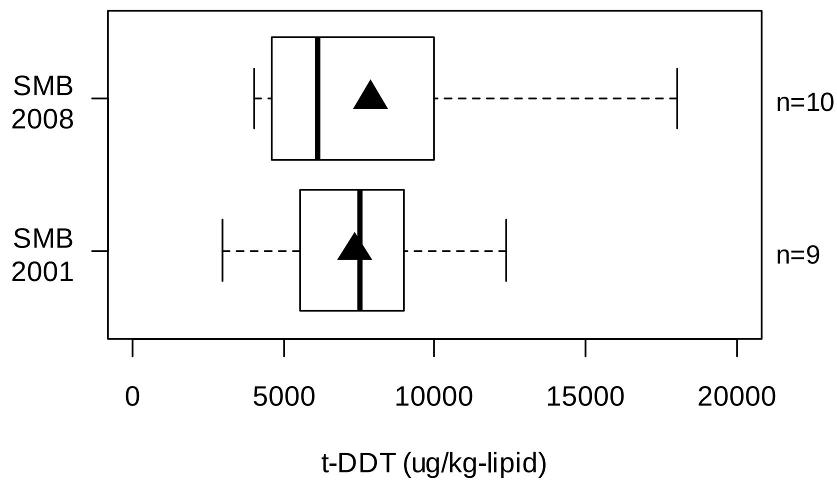


Figure 14. Boxplots of Lipid-Normalized t-DDT for Smallmouth Bass by Year (all reaches combined).

Boxplots for t-PCB concentrations are presented in Figures 15 and 16. As recommended by Helsel (2005), non-detects were included in these boxplots and the maximum detection limit is shown. No interpretation should be made of the boxplot below the detection limit.

- **Carp**: Medians are similar between 2001 and 2008 results, while the mean increases. The 2008 data are skewed to the right due to the high concentrations found in high-lipid samples. Highest concentration samples were included in this boxplot because lipid-normalization is applied.
- **Lipid-normalized Carp**: Decrease in median (significant at the 90% level) and also in the mean.
- **MWF**: No boxplot is shown for 2008 because only three data points were available.
- **SMB**: No boxplot is shown for 2008 because over 50% of the data are non-detect.

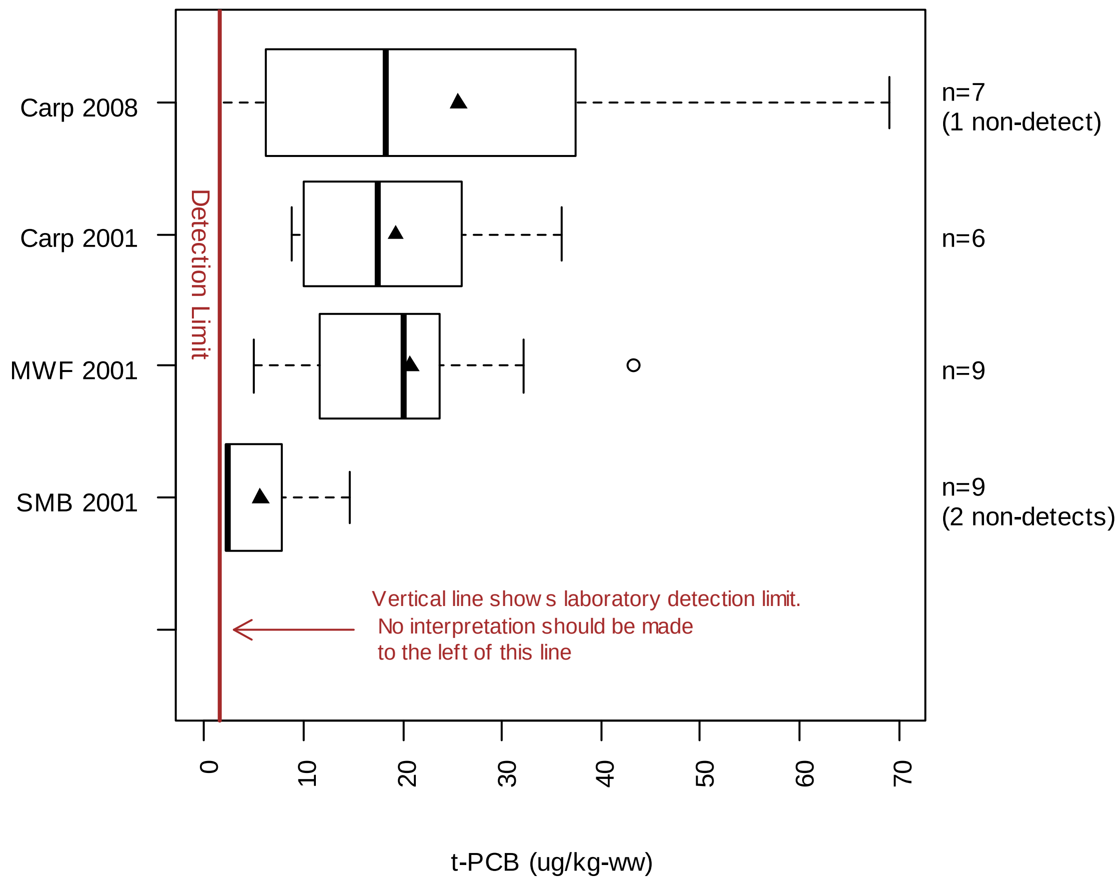


Figure 15. Boxplots of t-PCB by Species and Year (all reaches combined).

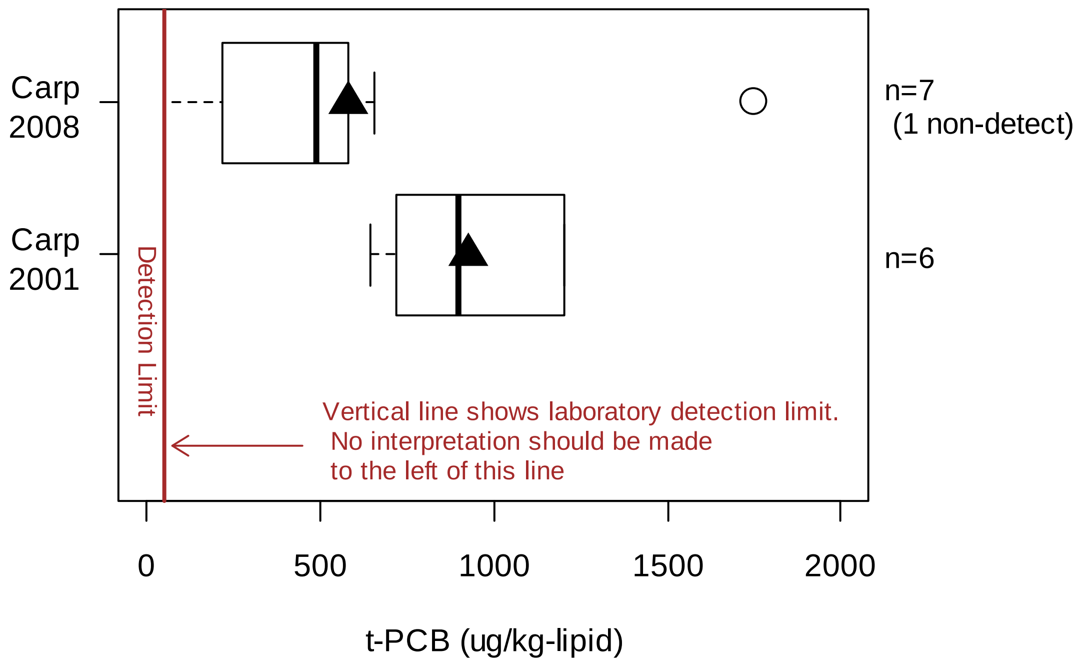


Figure 16. Boxplots of Lipid-Normalized t-PCB for Carp by Year (all reaches combined).

Non-Parametric Confidence Band Around Theil-Sen Line

The Theil-Sen trend line was used to allow comparison without lipid-normalizing data. It is a non-parametric alternative to linear regression (EPA, 2009) which combines the median-pairwise slope with the median concentration value and median lipid content to construct the trend. Because of this construction, it estimates median concentration vs. lipid content.

There are no simple formulas to construct a confidence band around the Theil-Sen line. However a more computationally intensive technique – bootstrapping – can be employed instead. A computer algorithm for this technique is provided by EPA (2009) for the statistical computing package R, used to construct these figures.

This technique does not assume that trend residuals are normal or have equal variance across the data range. However, the residuals are assumed to be statistically independent. It is also important to have 8-10 observations from which to construct the bootstrap. Non-detects can be accommodated as long as the detection frequency is at least 50% by assigning each non-detect a common value less than any other detected measurement (EPA, 2009).

The only dataset which met these requirements for both study years was the t-DDT data in smallmouth bass (Figure 17). This figure shows nearly identical Theil-Sen lines for both studies. The confidence bands significantly overlap. Although the number of observations for each year meets the requirement of 8-10 observations for the bootstrap, the available data are concentrated below 1.5% lipid. Therefore, greater uncertainty exists for higher lipid content.

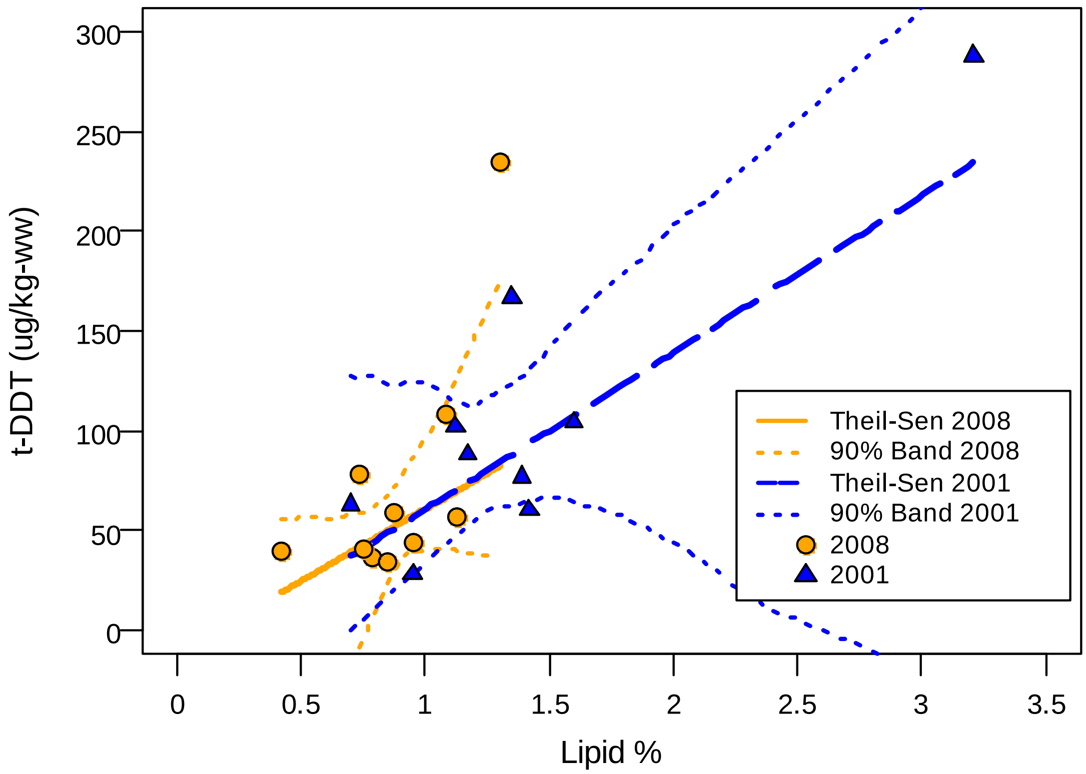


Figure 17. Theil-Sen 90% Confidence Bands for t-DDT in Smallmouth Bass, 2001 vs. 2008.

Power Analysis and Study Design

As mentioned above, there is concern that since DDT and PCB concentrations are expected to change gradually, current study objectives may be insufficient to meet the study goal due to an insufficient number of samples. There may be too few fish tissue samples within each reach to detect expected concentration changes. To address this concern, study power is evaluated.

The likelihood that a study will yield a statistically significant effect is called the study's power. The process of designing a study to ensure an appropriate level of power is referred to as a power analysis.

This study used the Mann-Whitney test to test for differences in the median. This test is a non-parametric equivalent to a t-test. To evaluate the power of the Mann-Whitney test, power curves (Figure 18) were calculated for the t-test. The sample size (n) for these curves was increased by 5% to account for the diminished power of the Mann-Whitney test compared to the t-test (Singer et al., 1986). The increased sample size is reflected in this figure; no further adjustment is necessary.

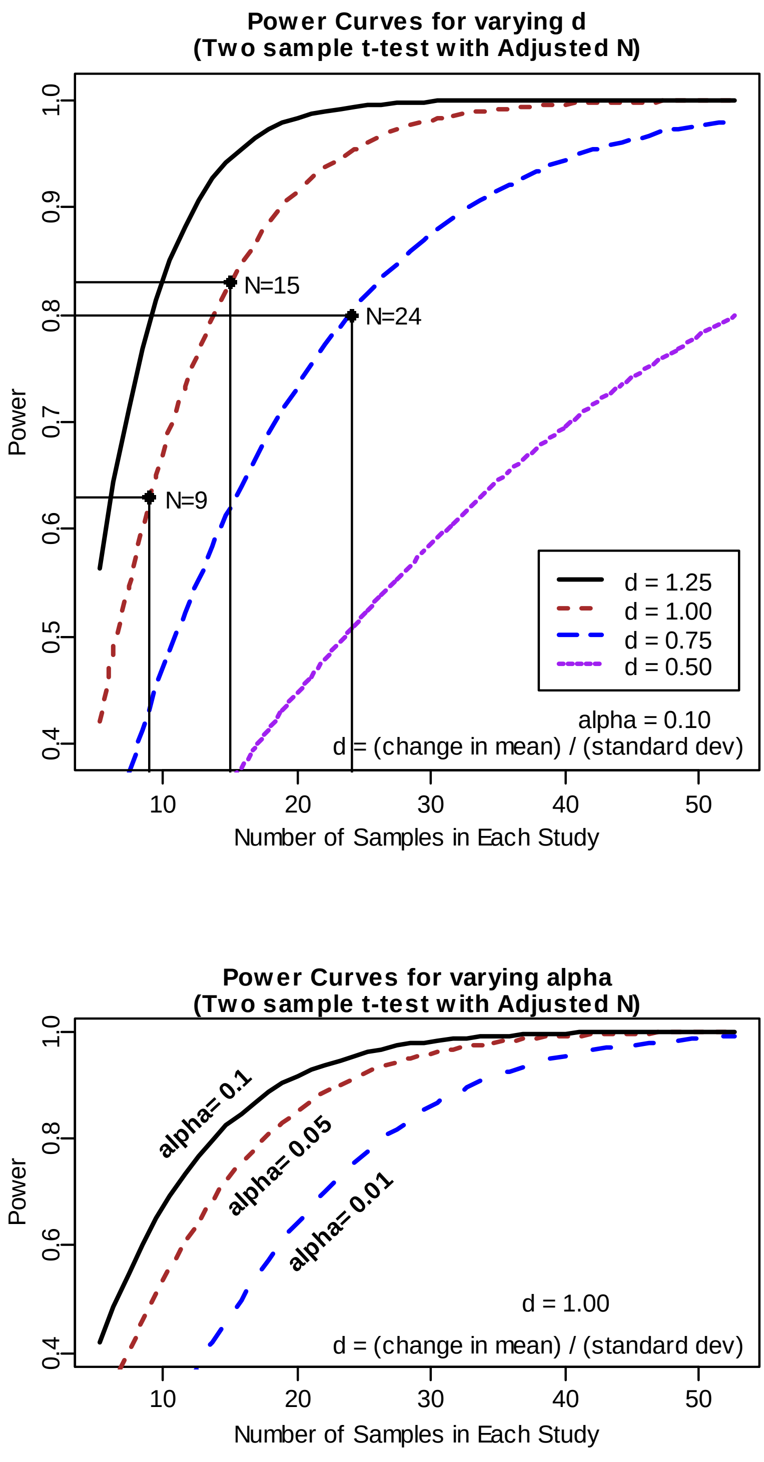


Figure 18. Estimated Power Curves for the Mann-Whitney Test (based on t-test Power Curves with Adjusted N).

The power curves estimate study power based on sample size, confidence level (alpha), and the expected change in median[5] relative to standard deviation (d). The expected change in median is expressed as a fraction of standard deviation (d). For example, when d=1, the medians differ by one standard deviation.

The upper portion of Figure 18 shows power as a function of d (the change in mean divided by the standard deviation). Each curve is calculated for a confidence level of 90% (alpha=0.1).

The lower portion of Figure 18 shows power curves when d=1 for several confidence levels (90%, 95%, and 99% or alpha=0.1, 0.05, and 0.01). Increasing confidence requires greater sample numbers. The discussion below assumes that a confidence level of 90% is adequate.

Three examples are shown for N=9, N=15, and N=24. The current study is designed with N=9 (each dataset has nine samples).

Given the current sample size (N=9 samples per study), this study has 63% power to detect a change in median equal to the standard deviation (d=1.0). For smaller changes in the median, the power is diminished. For example, if the medians changed by 75% of the standard deviation (d=0.75), this study has only 43% power.

Increasing sample size from 9 to 15 samples per species would increase power to 83% for detecting a change in medians equal to the standard deviation. This translates to five samples per species from each reach, instead of three samples. If medians changed by 75% of the standard deviation, the study would have about 62% power.

Increasing sample size from nine to 24 samples per species would increase the chances of detecting smaller changes in the median (80% power for d=0.75). This translates to eight samples per species from each reach, instead of three samples.

Analysis cost and fish availability both limit the number of samples which can be collected. One option to reduce cost is to limit the next effectiveness monitoring event to a single species, using a larger sample size to increase study power. Of the three species in this study, smallmouth bass have the lowest concentrations of both DDT and PCB and could be discontinued in favor of increased numbers of either common carp or mountain whitefish. Should a significant change be observed in the target species, this could then be verified in other species.

Composite samples improve study power by decreasing the standard deviation, and should be continued. If fish numbers are problematic, then fewer fish could be used for each composite. Instead of 5 to 8 fish per composite, future effectiveness monitoring might use only three fish per composite, depending on fish availability.

To provide an estimate of detectable changes in median concentrations, pooled standard deviations by species from combined 2001 and 2008 data are tabulated in Table 9 (excluding the two highest t-DDT samples of carp from the lower reach). One goal of normalization is to

[5] The Mann-Whitney test identifies changes in median, while the t-test identifies changes in mean.

reduce the standard deviation, so it is possible that smaller changes than listed in Table 9 could be achieved if future data can be normalized.

Table 9. Pooled Standard Deviations (ug/kg-ww), 2001 and 2008 Results.

Species	t-DDT	t-PCB
SMB	69	---
Carp	171*	19
MWF	129	11

*The two highest concentrations in 2008 were omitted from this calculation, since they greatly increase the standard deviation and are not comparable to the other samples without normalization.

Conclusions and Recommendations

Conclusions

To monitor the effectiveness of the Lower Okanogan River DDT/PCB TMDL, this study compared 2001 and 2008 concentrations of total DDT and total PCB for three fish species: smallmouth bass, common carp, and mountain whitefish. Comparisons between the two studies were difficult due to small sample size.

No statistically significant changes were found in median total DDT concentrations for the three studied species. A statistically significant decrease was noted for median lipid-normalized total PCB in common carp. No statistically significant changes were found in median total PCB concentrations for smallmouth bass and mountain whitefish. Based on power analysis, it is unlikely that this study would detect changes in median concentrations smaller than one standard deviation.

Major findings include:

- The number of fish samples not meeting (exceeding) National Toxics Rule criteria in 2008 was similar to 2001 results.
- High concentrations of total DDT were found in large specimens of common carp in the lower reach of the Okanogan River in 2008; no common carp were found in this reach in 2001.
- Total PCB concentrations in mountain whitefish and common carp are classed as "medium priority" under recent recommendations for prioritizing 303(d) listings for PCBs, based on maximum concentrations. Total PCB concentrations in smallmouth bass are classed as "no further action," based on maximum concentrations.
- No significant changes were found in median total DDT concentrations between the 2001 and 2008 studies.
- A decrease in median concentration was observed for lipid-normalized total PCB in common carp, significant at the 90% level. No significant difference was found for median concentrations of total PCB in smallmouth bass or mountain whitefish.
- Overall DDT and PCB contamination was similar among smallmouth bass and common carp from all three reaches. Mountain whitefish in the lower reach exhibit lower levels of total DDT and total PCB than the other two reaches. Only 2001 data are available for mountain whitefish in the lower reach.

Recommendations

- Continue the current schedule of recurring effectiveness monitoring studies every five years.
- Increase sample size from nine to at least 15 composite samples per fish species for the next monitoring event.
- Discontinue analysis for PCBs in smallmouth bass samples due to low concentrations.

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Appendices

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Appendix A. Glossary and Acronyms

Glossary

303(d) List: Section 303(d) of the federal Clean Water Act requires Washington State periodically to prepare a list of all surface waters in the state for which beneficial uses of the water – such as for drinking, recreation, aquatic habitat, and industrial use – are impaired by pollutants. These are water quality-limited waterbodies (ocean waters, estuaries, lakes, and streams) that fall short of state surface water quality standards, and are not expected to improve within the next two years.

Analyte: Water quality constituent being measured (parameter).

Aroclor: The registered trademark for a group of polychlorinated biphenyls (PCBs) that were manufactured by the Monsanto Company prior to 1976. Aroclors are assigned specific 4-digit reference numbers dependent upon molecular type and degree of substitution of the biphenyl ring hydrogen atoms by chlorine atoms. The first two digits of a numbered aroclor represent the molecular type, and the last two digits represent the percentage weight of the hydrogen-substituted chlorine.

Bioaccumulative: The increase in the concentration of a substance, especially a contaminant, in an organism or in the food chain over time.

Boxplot: Convenient way of graphically depicting numerical data by summarizing percentiles.

Clean Water Act: Federal Act passed in 1972 that contains provisions to restore and maintain the quality of the nation's waters. Section 303(d) of the Clean Water Act establishes the TMDL program.

Composite: A representative sample created by the homogenization of multiple fish.

Exceed Criteria: Did not meet or violated the criteria.

Effectiveness monitoring: Monitoring to determine whether the recommended *Detailed Implementation Plan*, after a significant portion of the recommendations or prescriptions have been implemented, is adequate in meeting (1) the goals and objectives for the TMDL project or (2) other desired outcomes over long temporal scales.

Legacy: Banned pesticides no longer used but that persist in the environment.

Lipids: A broad group of naturally occurring molecules which includes fats, waxes, sterols, fat-soluble vitamins (such as vitamins A, D, E and K), monoglycerides, diglycerides, phospholipids, and others.

Lipid-normalized concentration: The wet-weight concentration of a contaminant divided by the lipid percentage of the sample.

Lipophilic: Having an affinity for, tending to combine with, or capable of dissolving in lipids.

Load allocation: The portion of a receiving waters' loading capacity attributed to one or more of its existing or future sources of nonpoint pollution or to natural background sources.

Median: One type of average, found by arranging the values in order and then selecting the one in the middle. If the total number of values in the sample is even, then the median is the mean of the two middle numbers.

National Pollutant Discharge Elimination System (NPDES): National program for issuing, modifying, revoking and reissuing, terminating, monitoring, and enforcing permits, and imposing and enforcing pretreatment requirements under the Clean Water Act. The NPDES program regulates discharges from wastewater treatment plants, large factories, and other facilities that use, process, and discharge water back into lakes, streams, rivers, bays, and oceans.

Nonpoint source: Pollution that enters any waters of the state from any dispersed land-based or water-based activities. This includes, but is not limited to, atmospheric deposition, surface water runoff from agricultural lands, urban areas, or forest lands, subsurface or underground sources, or discharges from boats or marine vessels not otherwise regulated under the National Pollutant Discharge Elimination System Program. Generally, any unconfined and diffuse source of contamination. Legally, any source of water pollution that does not meet the legal definition of "point source" in section 502(14) of the Clean Water Act.

Point source: Sources of pollution that discharge at a specific location from pipes, outfalls, and conveyance channels to a surface water. Examples of point source discharges include municipal wastewater treatment plants, municipal stormwater systems, industrial waste treatment facilities, and construction sites that clear more than 5 acres of land.

Pollution: Such contamination, or other alteration of the physical, chemical, or biological properties, of any waters of the state. This includes change in temperature, taste, color, turbidity, or odor of the waters. It also includes discharge of any liquid, gaseous, solid, radioactive, or other substance into any waters of the state. This definition assumes that these changes will, or are likely to, create a nuisance or render such waters harmful, detrimental, or injurious to (1) public health, safety, or welfare, or (2) domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses, or (3) livestock, wild animals, birds, fish, or other aquatic life.

Reach: A specific portion or segment of a stream.

Sediment: Soil and organic matter that is covered with water (ex. river or lake bottom).

Total Maximum Daily Load (TMDL): Water cleanup plan. A distribution of a substance in a waterbody designed to protect it from exceeding water quality standards. A TMDL is equal to the sum of all of the following: (1) individual wasteload allocations for point sources, (2) the load allocations for nonpoint sources, (3) the contribution of natural sources, and (4) a Margin of Safety to allow for uncertainty in the wasteload determination. A reserve for future growth is also generally provided.

Wasteload allocation: The portion of a receiving water's loading capacity allocated to existing or future point sources of pollution. Wasteload allocation constitutes one type of water quality-based effluent limitation.

Watershed: A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

Wet-weight concentration: the concentration directly measured by the laboratory in the fish tissue sample.

90th percentile: A statistical number obtained from a distribution of a data set, above which 10% of the data exists and below which 90% of the data exists.

Acronyms and Abbreviations

CCT	Colville Confederated Tribes
DDT	Legacy pesticide ((1,1,1-trichloro-2,2-*bis*[*p*-chlorophenyl]ethane)
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
MQO	Measurement quality objective
MWF	Mountain whitefish
n	Number
NTR	National Toxics Rule
PCB	Polychlorinated biphenyl
RPD	Relative percent difference
SMB	Smallmouth Bass
SOP	Standard operating procedure
t-DDT	Total DDT (sum of 4,4' DDT, DDD and DDE)
t-PCB	Total PCB (sum of Aroclors)
TMDL	(See Glossary above)
vs.	Versus
WDOH	Washington State Department of Health
WSTMP	Washington State Toxics Monitoring Program

Units of Measurement

°C	degrees centigrade
kg	kilograms, a unit of mass equal to 1,000 grams.
km	kilometer, a unit of length equal to 1,000 meters.
mm	millimeter
ug/Kg	micrograms per kilogram (parts per billion)
ug/kg lipid	micrograms per kilogram of lipid (lipid-normalized concentration)
ww	wet weight

Appendix B. Historical DDT and PCB Concentrations

Table B-1. t-DDT in Okanogan River and Lake Osoyoos Fish, 1983-1995.

Location and Species	Collect Date	Tissue	Mean Length (mm)	Lipids (%)	Total-DDT (ug/kg-ww)	Lipid Normalized[2] DDT (ug/kg-lipid)
Okanogan River at Okanogan (Hopkins et al., 1985)						
Bridgelip sucker	8/29/83	Whole	----	2.1	1,780	85,000
Mountain Whitefish	8/29/83	Whole	----	8.3	810	9,800
Okanogan River below Malott (Hopkins et al., 1985)						
Bridgelip Sucker	9/11/84	Fillet	----	2.7	3,200	119,000
Bridgelip Sucker	9/11/84	Liver	----	23.1	15,000	65,000
Largemouth Bass	9/11/84	Fillet	----	4.2	1,800	43,000
Largemouth Bass	9/11/84	Liver	----	----	3,100	----
Okanogan River above Brewster (Davis and Serdar, 1996)						
Carp	9/13/94	Fillet, skin off	602	9.1	2,853	31,000
Largescale Sucker	9/13/94	Whole	478	8.4	915	11,000
Largescale Sucker	9/13/94	Whole	486	6.1	1,340	22,000
Lake Osoyoos (Johnson and Norton, 1990)						
Largemouth Bass	7/25/89	Fillet, skin on	290-410	1.1	210	19,000
Lake Osoyoos (Serdar et al., 1998)						
Yellow Perch	8/28/95	Fillet, skin on	185	0.85	53	6,200
Yellow Perch	8/28/95	Fillet, skin on	199	1.1	51	4,600
Yellow Perch	8/28/95	Fillet, skin on	206	0.97	61	6,300
Yellow Perch	8/28/95	Fillet, skin on	212	1.12	68	6,100
Yellow Perch	8/28/95	Fillet, skin on	220	0.6	42	7,000
Yellow Perch	8/28/95	Fillet, skin on	223	0.96	76	7,900
Yellow Perch	8/28/95	Fillet, skin on	228	0.99	70	7,100
Yellow Perch	8/28/95	Fillet, skin on	245	0.87	64	7,400
Smallmouth Bass	8/28/95	Fillet, skin on	222	1.04	43	4,100
Smallmouth Bass	8/28/95	Fillet, skin on	252	1.11	83	7,500
Smallmouth Bass	8/28/95	Fillet, skin on	358	0.97	93	9,600
Mountain Whitefish	8/28/95	Fillet, skin on	313	4.06	105 J[1]	2600 J
Carp	8/28/95	Fillet, skin off	438	1.41	223	16,000
Carp	8/28/95	Fillet, skin off	478	2.78	653	23,000
Carp	8/28/95	Fillet, skin off	495	2.8	552	20,000
Carp	8/28/95	Fillet, skin off	539	1.58	321	20,000
Lake Whitefish	8/28/95	Fillet, skin on	510	7.51	987	13,000
Lake Whitefish	8/28/95	Fillet, skin on	555	5.53	1,240	22,000
Largescale Sucker	8/28/95	Fillet, skin on	478	5.82	580	10,000
Largescale Sucker	8/28/95	Fillet, skin on	493	5.08	1,040	20,400
Smallmouth Bass	8/28/95	Fillet, skin on	358	0.61	55	9,000

[1]J: Laboratory estimate of concentration.
[2][lipid-normalized concentration] = [wet-weight concentration] / [lipid content as decimal].

Table B-2. t-PCB Concentrations in Okanogan River Fish, 1984-1995.

Location and Species	Collect Date	Tissue	Mean Length (mm)	Lipids (%)	Total-PCB (µg/kg-ww)	Lipid-normalized[2] PCB (µg/kg-lipid)
Okanogan River below Malott (Hopkins et al., 1985)						
Bridgelip Sucker	9/11/84	Fillet	----	2.7	U[1] (10)	---
Bridgelip Sucker	9/11/84	Liver	----	23.1	210	910
Largemouth Bass	9/11/84	Fillet	----	4.2	22	520
Largemouth Bass	9/11/84	Liver	----	----	U (10)	----
Okanogan River above Brewster (Davis and Serdar, 1996)						
Carp	9/13/94	Fillet	----	9.1	45 NJ[1]	500 NJ
Largescale Sucker	9/13/94	Whole	----	8.4	56 J[1]	670 J
Largescale Sucker	9/13/94	Whole	----	6.1	72 NJ	1200 NJ
Lake Osoyoos (Serdar et al., 1998)						
Largescale Sucker	8/28/95	Fillet, skin on	----	5.82	24	410
Largescale Sucker	8/28/95	Fillet, skin on	----	5.08	66	1,300
Smallmouth Bass	8/28/95	Fillet, skin on	----	0.61	U (40)	---

[1]U: not detected.
[2][lipid-normalized concentration] = [wet-weight concentration] / [lipid content as decimal].
NJ: tentatively identified-concentration estimated.
J: laboratory estimate.

Table B-3. Mountain Whitefish Results from the Omak-Riverside Location (µg/kg-ww), 2001.

Sample_ID	Lipids (%)	Length (mm)	4,4'-DDD	4,4'-DDE	4,4'-DDT	PCB 1248	PCB 1254	PCB 1260
03187230	1.37	400	13	93	3.5 J	2.7 U	5.5 U	17 NJ
03187231	3.04	365	18	180	2.5 UJ	2.7 U	5.3 U	15 NJ
03187232	2.42	361	30	500	40 J	2.8 U	5.5 U	26 NJ
03187233	1.95	361	22	220	7.2	5.3 U	15	4.8
03187234	7.78	353	74	980 J	6.7 UJ	11 NJ	140	56 J
03187235	3.53	350	260	3200	52 J	2.7 U	69 J	54 J
03187236	5.64	344	26	300	21 J	4.5 NJ	31	14 J
03187237	1.96	343	12	120	7.2 J	2.6 U	5.2 U	11 NJ
03187238	5.20	341	19	240	14 J	3.5 NJ	13	5.4
03187239	5.32	333	25	360	22	11 UJ	28 NJ	17
03187240	2.99	314	95	2000	11	3.2 NJ	3.7 NJ	6.3
03187241	2.60	313	7.6	68	2.4	2.6 U	3.0 J	2.6 U
03187242	2.74	310	19	140	7.5	5.2 U	13 NJ	2.9 J
03187243	5.81	307	33	300	11	5.4 U	39	17
03187244	4.03	297	21	64	2.7	5.4 U	10 NJ	5.4 U
03187245	3.12	294	22	140	5.0	4.7 NJ	28	9.4
03187246	2.26	291	11	110	4.0	2.8 U	3.9 J	3.2 NJ
03187247	3.24	286	12	85	5.2	2.7 U	3.0 J	3.1 J
03187248	2.93	280	82	380	9.5	5.0 NJ	60	18
03187249	3.15	265	10	57	1.4	2.7 U	8.6 NJ	4.1 J
03187250	3.35	255	3.0	17	1.1 J	7.4 U	7.4 U	7.4 U
03187251	3.99	253	3.9	20	1.4	7.3 U	7.3 U	7.3 U
03187252	5.59	246	7.7	13	2.1	2.8 U	2.8 U	2.8 U
03187253	2.93	244	6.6	37	2.0 U	8.2 U	8.2 U	8.2 U
03187254	2.69	244	24 J	120 J	2.8 J	2.7 U	2.7 U	2.7 U
03187255	4.43	235	6.8	53	2.4	2.7 U	2.7 U	2.7 U
03187256	3.03	235	6.8	52	2.6	2.8 U	2.8 U	2.8 U

Table B-4. Total PCB Concentrations in Fish Fillets from Background Waterbodies Near the Okanogan Watershed.

Waterbody	Waterbody Number	Species	Total PCBs (µg/kg-ww)	
Omak Lake	WA-49-9250	Cutthroat Trout	3.8	
		Peamouth	3.0	
South Twin Lake	WA-58-9040	Brook Trout (large)	1.2	
		Brook Trout (small)	0.83	
		Largemouth Bass	0.25	NJ
Patterson Lake	WA-13-9120	Rainbow Trout	3.4	
		Yellow Perch	0.23	

Appendix C. Field and Laboratory Analysis Results, 2001 and 2008.

Table C-1. DDT Results and Field Measurements for 2008 Effectiveness Monitoring.

Reach	Sample Date	Sample ID 0812022-	Species	#Fish	Mean Length (mm)	Mean Weight (g)	Lipids (%)	4,4'-DDD (ug/kg-ww)	4,4'-DDE (ug/kg-ww)	4,4'-DDT (ug/kg-ww)	Total DDT (t-DDT) (sum of 4,4'-isomers) (ug/kg-ww)	Lipid Normalized t-DDT (µg/kg-lipid)
Upper	8/6/08	3	Carp	5	534	2,054	1.89	25	**290**	1	316	---
Middle	8/6/08	4	Carp	5	600	2,888	2	18	**310**	1.5	330	---
Middle	8/6/08	05/25*	Carp	6	654	3,708	2.8	25	**360**	3.5 J	389	---
Lower	8/7/08	14	Carp	5	450	1,381	1.19	15	**75**	0.98 U	90	---
Lower	8/7/08	15	Carp	5	576	2,719	3.88	**77**	**460**	1.7 J	539	---
Lower	8/7/08	16/23*	Carp	3	707	4,548	7.8	**230**	**1,950**	2.7 J	2,183	---
Lower	8/7/08	22	Carp	2	760	7,326	14.1	**370 J**	**2,500 J**	4.0 J	2,874 J	---
Upper	9/22/08	17	MWF	8	336	406	6.05	12	**170**	5.8	188	---
Upper	9/24/08	18/24*	MWF	8	351	477	4.41	26	**360**	6.8	393	---
Upper	9/24/08	19	MWF	8	380	612	4.41	16	**170**	7.9	194	---
Upper	8/6/08	1	SMB	4	198	98	0.79	1.9	**34**	0.45	36	4,560
Upper	8/6/08	2	SMB	4	220	153	0.95	2.5	**40**	1	44	4,630
Middle	8/6/08	6	SMB	5	212	127	0.85	1.6	**32**	0.86	34	4,000
Middle	8/6/08	7	SMB	7	237	171	0.75	2	**38**	1.2	41	5,470
Middle	8/6/08	8	SMB	7	246	195	1.13	2.6	**53**	1.6	57	5,040
Middle	8/6/08	9	SMB	6	262	232	0.87	2.8	**55**	1.4	59	6,780
Middle	8/6/08	10/26*	SMB	4	308	387	1.08	5.7	**99**	3	108	10,000
Lower	8/7/08	11	SMB	6	183	75	0.73	3.3	**73**	1.5	78	10,680
Lower	8/7/08	12	SMB	6	210	126	0.42	2.9	**37**	0.56	40	9,520
Lower	8/7/08	13	SMB	5	313	376	1.3	16	**210**	7.9	234	18,000

*Average of field replicates.
Concentrations exceeding NTR criteria shown in bold font. Non-detects are shaded in gray.
J: concentration estimated; NJ: compound tentatively identified and concentration estimated;
U: not detected at reported concentration; UJ: not detected and reporting limit estimated.

Table C-2. PCB Results for 2008 Effectiveness Monitoring.

Reach	Sample ID 0812022-	Species	PCB 1016 (ug/kg-ww)	PCB 1221 (ug/kg-ww)	PCB 1232 (ug/kg-ww)	PCB 1242 (ug/kg-ww)	PCB 1248 (ug/kg-ww)	PCB 1254 (ug/kg-ww)	PCB 1260 (ug/kg-ww)	PCB 1262 (ug/kg-ww)	PCB 1268 (ug/kg-ww)	PCB, Sum of Aroclors (ug/kg-ww)	Lipid Normalized PCB (µg/kg -lipid)
Upper	3	Carp	2.5 U	2.5 U	2.5 U	2.5 U	4.4	4.9 UJ	2.5 U	2.5 U	2.5 U	4.4	233
Middle	4	Carp	2.5 UJ	2.5 UJ	5.0 UJ	5.0 U	**9**	**14 J**	**12**	7.7 UJ	2.5 UJ	**35 J**	1,750 J
Middle	05/25*	Carp	4.9 UJ	4.9 UJ	4.9 UJ	4.9 UJ	**5.8 J**	**6.5 J**	**6.0 J**	6.1 UJ	4.9 UJ	**18.3 J**	654 J
Lower	14	Carp	4.9 U	4.9 U	4.9 U	4.9 U	4.9 U	4.9 U	4.9 U	4.9 U	4.9 U	4.9 U	244 U[1]
Lower	15	Carp	5.0 UJ	5.0 UJ	5.0 UJ	5.0 UJ	5.0 UJ	**7.8 J**	5.0 UJ	5.0 UJ	5.0 UJ	**7.8 J**	201 J
Lower	16/23*	Carp	9.7 UJ	30 UJ	30 UJ	9.7 UJ	9.7 UJ	**29 J**	**11 J**	9.7 UJ	9.7 UJ	**40 J**	513 J
Lower	22	Carp	20 UJ	20 UJ	20 UJ	20 UJ	20 UJ	**41 J**	**28 J**	23 UJ	20 UJ	**69 J**	489 J
Upper	17	MWF	9.7 UJ	9.7 UJ	9.7 UJ	9.7 UJ	9.7 UJ	**13 J**	9.7 UJ	9.7 UJ	9.7 UJ	**13 J**	----
Upper	18/24*	MWF	10 U	12 UJ	12 UJ	10 U	10 U	**14 J**	**16 J**	11 UJ	10 U	**30 J**	----
Upper	19	MWF	9.7 U	9.7 U	12 UJ	9.7 U	9.7 U	**13 J**	9.7 U	9.7 U	9.7 U	**13 J**	----
Upper	1	SMB	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	----
Upper	2	SMB	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	----
Middle	6	SMB	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	----
Middle	7	SMB	2.4 U	2.4 U	2.4 U	2.4 U	2.4 U	2.4 U	2.4 U	2.4 U	2.4 U	2.4 U	----
Middle	8	SMB	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	----
Middle	9	SMB	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.6 J	2.5 U	2.5 U	2.5 U	2.6 J	----
Middle	10/26*	SMB	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	4.0 J	5.0 U	5.0 U	5.0 U	4.0 J	----
Lower	11	SMB	2.5 U	2.5 U	2.5 U	5.0 UJ	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	5.0 UJ	----
Lower	12	SMB	2.4 U	2.4 U	2.4 U	4.9 UJ	2.4 U	2.4 U	2.4 U	2.4 U	2.4 U	4.9 UJ	----
Lower	13	SMB	4.7 U	4.7 U	4.7 U	4.7 U	4.7 U	**8.7 J**	4.7 U	4.7 U	4.7 U	**8.7 J**	----

*Average of field replicates.
Concentrations exceeding NTR criteria shown in bold font. Non-detects are shaded in gray.
J: concentration estimated; NJ: compound tentatively identified and concentration estimated;
U: not detected at reported concentration; UJ: not detected and reporting limit estimated.
[1]Lipid-normalized non-detect value calculated by dividing laboratory detection limit by lipid content.

Table C-3. DDT Results and Field Measurements from 2001 TMDL Technical Assessment (Serdar, 2003).

Reach	Sample Date	Sample ID 021282-	Species	No. of Fish	Mean Length (mm)	Mean Weight (g)	Lipids (%)	4,4'-DDD (ug/kg-ww)	4,4'-DDE (ug/kg-ww)	4,4'-DDT (ug/kg-ww)	Total DDT (t-DDT) (sum of 4,4'-isomers) (ug/kg-ww)	Lipid Normalized t-DDT (µg/kg-lipid)
Upper	11/5/01	30	Carp	8	552	2135	1.04	37	290	1.6 UJ	327	---
Upper	11/5/01	31	Carp	8	514	1749	0.84	24	410	1.5 U	434	---
Upper	11/5/01	32	Carp	7	463	1348	1.55	38	210	0.57 J	249	---
Middle	9/17/01	33	Carp	8	619	3345	3.43	41	270	1.5 UJ	311	---
Middle	9/17/01	34/35*	Carp	8	584	2740	3	29	220	1.6 U	249	---
Middle	9/17/01	36	Carp	8	550	2393	3.09	26	210	1.6 U	236	---
Upper	5/9/01	37	MWF	8	363	315	0.79	38	460	17	515	---
Upper	5/9/01	38	MWF	8	330	229	1.31	21	330	9.8	361	---
Upper	11/5/01	45	MWF	8	290	167	1.17	19	150	5.1	174	---
Middle	9/17/01	39/40*	MWF	10	365	453	4.27	62	520	17	599	---
Middle	9/17/01	41	MWF	10	334	331	4.7	39	330	13	382	---
Middle	9/17/01	49	MWF	10	284	209	4.85	20	180	6.3	206	---
Lower	11/6/01	42	MWF	9	326	301	2.96	14	110	3.2 NJ	127	---
Lower	9/18/01	43	MWF	9	246	127	3.07	16	120	3.7	140	---
Lower	11/6/01	44	MWF	8	220	81	1.55	4.9	73	2.8	81	---
Upper	5/9/01	46	SMB	1	424	1111	3.21	44	230	14	288	8,970
Upper	5/9/01	47	SMB	4	316	472	1.39	11	64	2.3	77	5,540
Upper	11/5/01	48	SMB	1	248	206	1.6	3.5 J	100	0.83 J	104	6,500
Middle	9/17/01	50	SMB	7	350	685	1.17	6.5	78	3.1	88	7,520
Middle	9/17/01	51	SMB	7	287	320	1.42	2.9	55	1.6	60	4,230
Middle	9/17/01	52	SMB	7	213	133	0.95	1.7	25	0.84 J	28	2,950
Lower	9/18/01	53	SMB	5	327	496	1.35	14	150	3	167	12,370
Lower	9/18/01	54	SMB	5	276	276	1.12	11	89	1.6	102	9,110
Lower	9/18/01	55	SMB	5	200	98	0.7	3.4	59	0.83 J	63	9,000

*Average of field replicates. J: concentration estimated; NJ: compound tentatively identified and concentration estimated; U: not detected at reported concentration; UJ: not detected and reporting limit estimated.

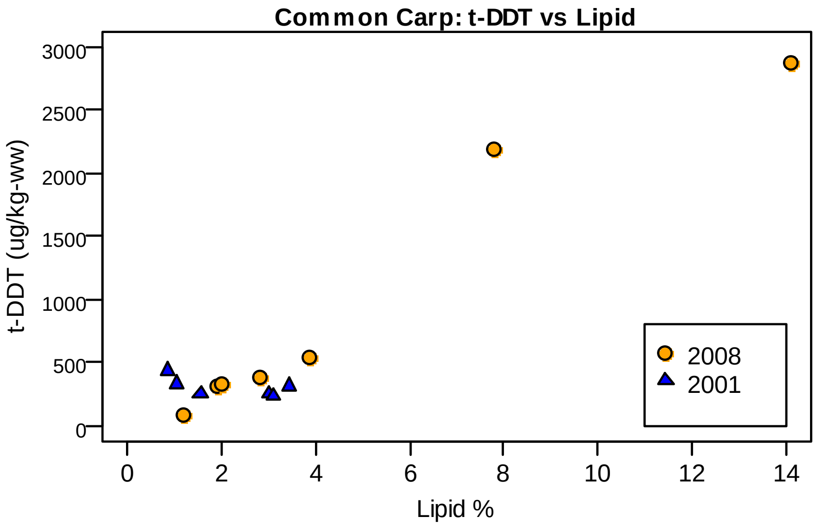
Table C-4. PCB Results from 2001 TMDL Technical Assessment (Serdar, 2003).

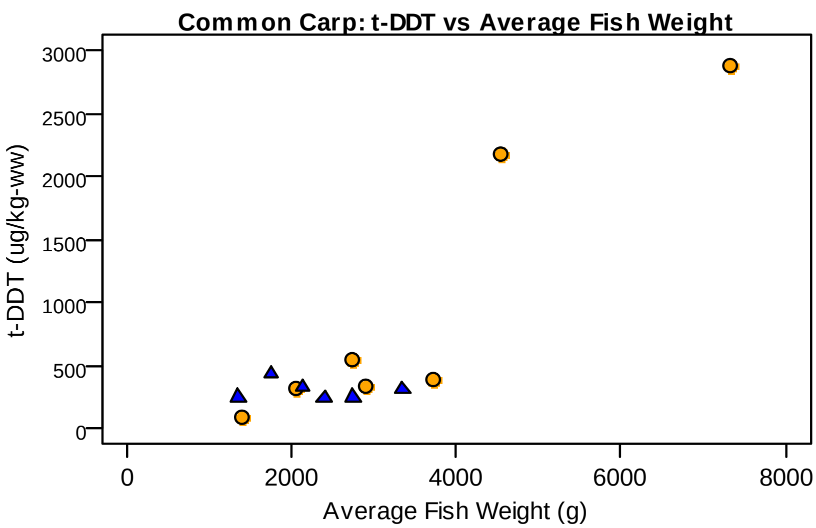
Location	Sample_ ID 021282-	Species	PCB 1016 (ug/kg-ww)	PCB 1221 (ug/kg-ww)	PCB 1232 (ug/kg-ww)	PCB 1242 (ug/kg-ww)	PCB 1248 (ug/kg-ww)	PCB 1254 (ug/kg-ww)	PCB 1260 (ug/kg-ww)	PCB 1262 (ug/kg-ww)	PCB 1268 (ug/kg-ww)	PCB, Sum of Aroclors (ug/kg-ww)	Lipid Normalized PCB (ug/kg-lipid)
Upper	30	Carp	2.8 U	2.8 U	2.8 U	2.8 U	2.7 J	5.1	4.7	2.8 U	2.8 U	12.5 J	1,202 J
Upper	31	Carp	2.7 U	2.7 U	2.7 U	2.7 U	1.7 J	3.9	3.1	2.7 U	2.7 U	8.7 J	1,036 J
Upper	32	Carp	2.7 U	2.7 U	2.7 U	2.7 U	3.6	4.2	2.2 NJ	2.7 U	2.7 U	10 NJ	645 NJ
Middle	33	Carp	2.7 U	2.7 U	2.7 U	2.7 U	6.8	9.2	10	2.7 U	2.7 U	26	758
Middle	34/35	Carp	2.7 U	2.7 U	2.7 U	2.7 U	13	10.1	13	2.7 U	2.7 U	36.1	1,203
Middle	36	Carp	5.4 U	2.7 U	2.7 U	4.0 NJ	18 UJ	9.9	8.4	2.7 U	2.7 U	22.3 NJ	722 NJ
Upper	37	MWF	2.8 U	2.8 U	2.8 U	2.8 U	3	12	8.7	2.8 U	2.8 U	23.7	3000
Upper	38	MWF	2.7 U	2.7 U	2.7 U	2.7 U	2.9	9.8	7.3	2.7 U	2.7 U	20	1,527
Upper	45	MWF	2.7 U	2.7 U	2.7 U	2.7 U	2.4 J	6.1	3.2	2.7 U	2.7 U	11.7 J	1,000 J
Middle	39/40	MWF	2.8 U	2.8 U	2.8 U	2.8 U	5.2	19	19	2.8 U	2.8 U	43.2	1,012
Middle	41	MWF	2.7 U	2.7 U	2.7 U	2.7 U	3.0 NJ	10	7.3	2.7 U	2.7 U	20.3 NJ	432 NJ
Middle	49	MWF	2.7 U	2.7 U	2.7 U	2.7 U	5.2	19	7.9	2.7 U	2.7 U	32.1	662
Lower	42	MWF	2.7 U	2.7 U	2.7 U	2.7 U	3.5 NJ	9.8	6.2 NJ	2.7 U	2.7 U	19.5 NJ	659 NJ
Lower	43	MWF	2.6 U	2.6 U	2.6 U	2.6 U	2.5 J	6.4	2.3 J	2.6 U	2.6 U	11.2 J	365 J
Lower	44	MWF	2.8 U	2.8 U	2.8 U	2.8 U	2.8 U	2.9	2.1 J	2.8 U	2.8 U	5 J	323 J
Upper	46	SMB	2.7 U	2.7 U	2.7 U	2.7 U	3.9	8.1	2.6	2.7 U	2.7 U	14.6	455
Upper	47	SMB	2.7 U	2.7 U	2.7 U	2.7 U	2.7 U	2.4 J	2.7 U	2.7 U	2.7 U	2.4 J	173 J
Upper	48	SMB	2.8 U	2.8 U	2.8 U	2.8 U	2.8 U	2.2 J	2.8 U	2.8 U	2.8 U	2.2 J	138 J
Middle	50	SMB	2.7 U	2.7 U	2.7 U	2.7 U	2.7 U	2.7	2.7 U	2.7 U	2.7 U	2.7	231
Middle	51	SMB	2.7 U	2.7 U	2.7 U	2.7 U	5.6	2.1 J	2.7 U	2.7 U	2.7 U	7.7 J	542 J
Middle	52	SMB	2.8 U	2.8 U	2.8 U	2.8 U	2.8 U	2.8 U	2.8 U	2.8 U	2.8 U	2.8 U	----
Lower	53	SMB	2.8 U	2.8 U	2.8 U	2.8 U	2.9 NJ	9.5	1.9 J	2.8 U	2.8 U	14.3 NJ	1,059 NJ
Lower	54	SMB	2.7 U	2.7 U	2.7 U	2.7 U	2.7 U	2.2 J	2.7 U	2.7 U	2.7 U	2.2 J	196 J
Lower	55	SMB	2.8 U	2.8 U	2.8 U	2.8 U	2.8 U	2.8 U	2.8 U	2.8 U	2.8 U	2.8 U	----

*Average of field replicates.

J: concentration estimated; NJ: compound tentatively identified and concentration estimated; U: not detected at reported concentration;
UJ: not detected and reporting limit estimated.

Appendix D. Plots of t-DDT and t-PCB Concentration versus Lipid Content, Average Length, and Average Weight





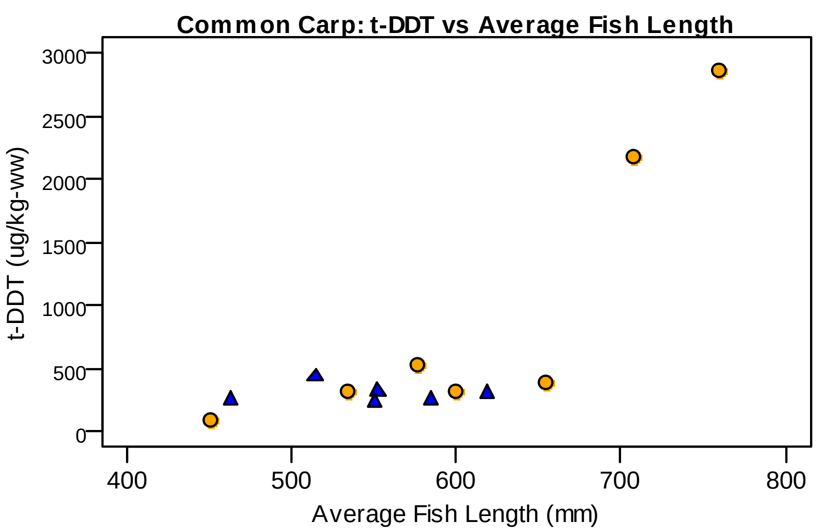


Figure D-1. t-DDT in Common Carp vs. Lipid, Average Fish Weight, and Average Fish Length.

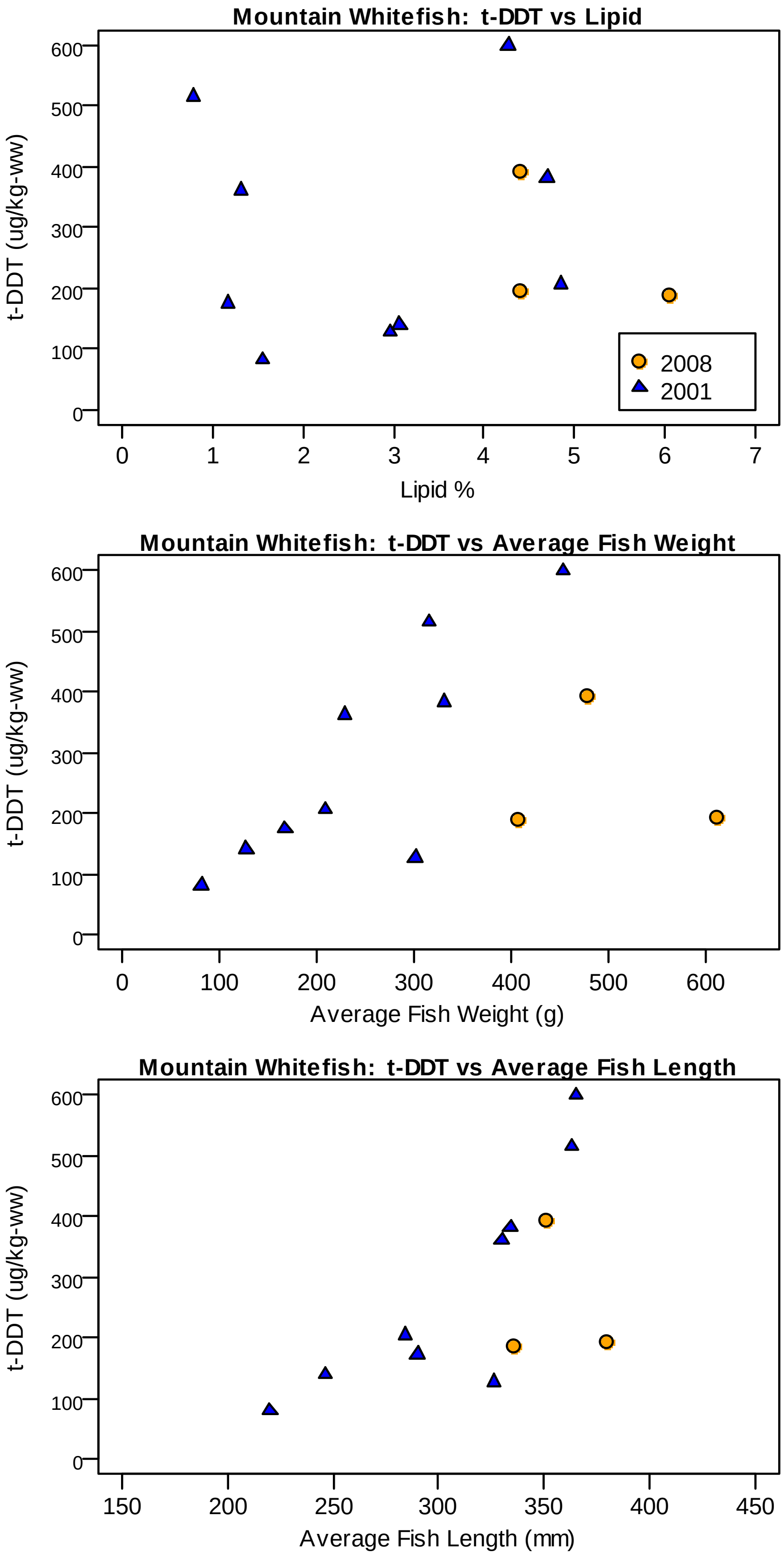


Figure D-2. t-DDT in Mountain Whitefish vs. Lipid, Average Fish Weight ,and Average Fish Length.

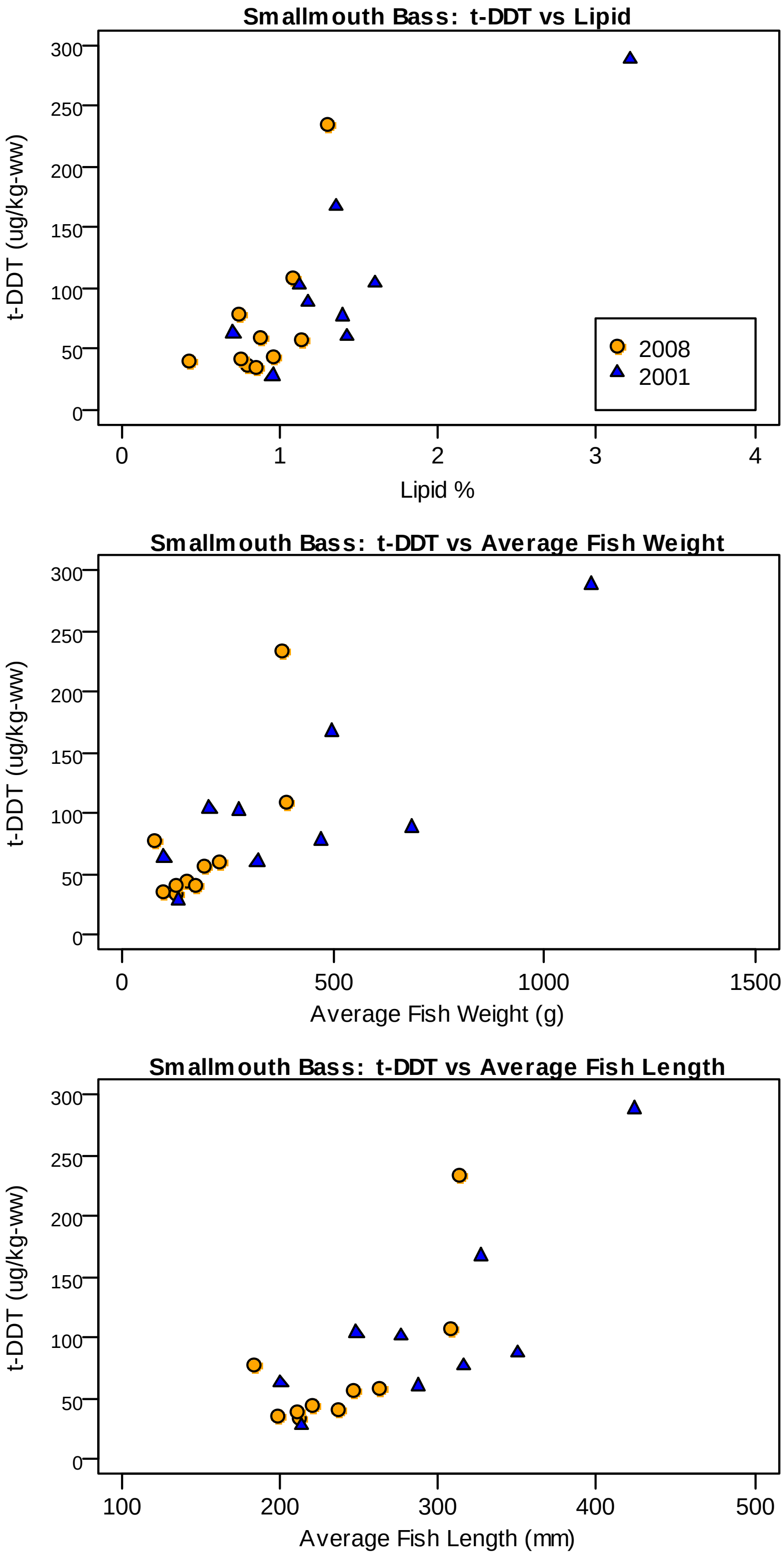


Figure D-3. t-DDT in Smallmouth Bass vs. Lipid, Average Fish Weight, and Average Fish Length.

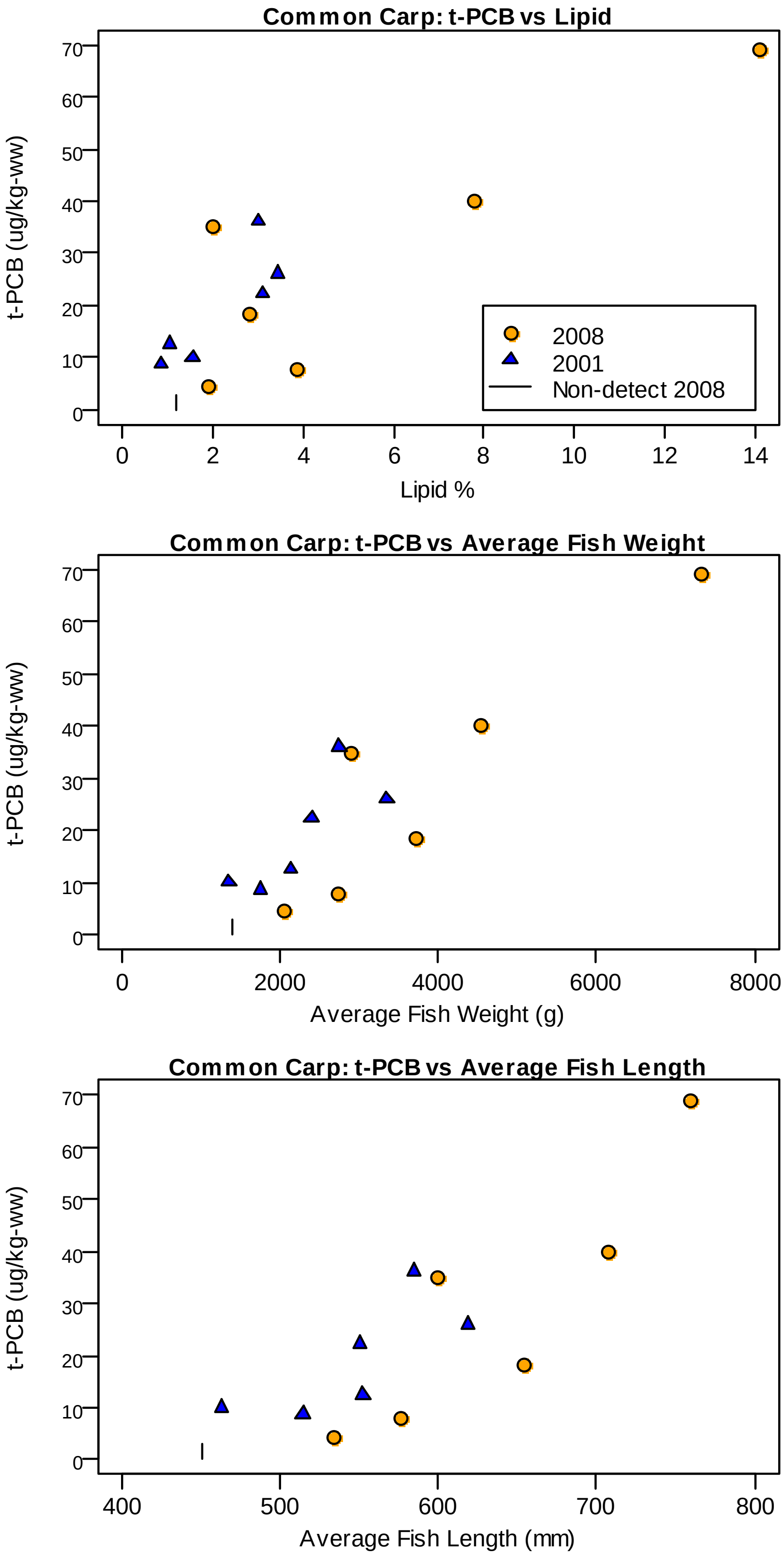


Figure D-4. t-PCB in Common Carp vs. Lipid, Average Fish Weight, and Average Fish Length.

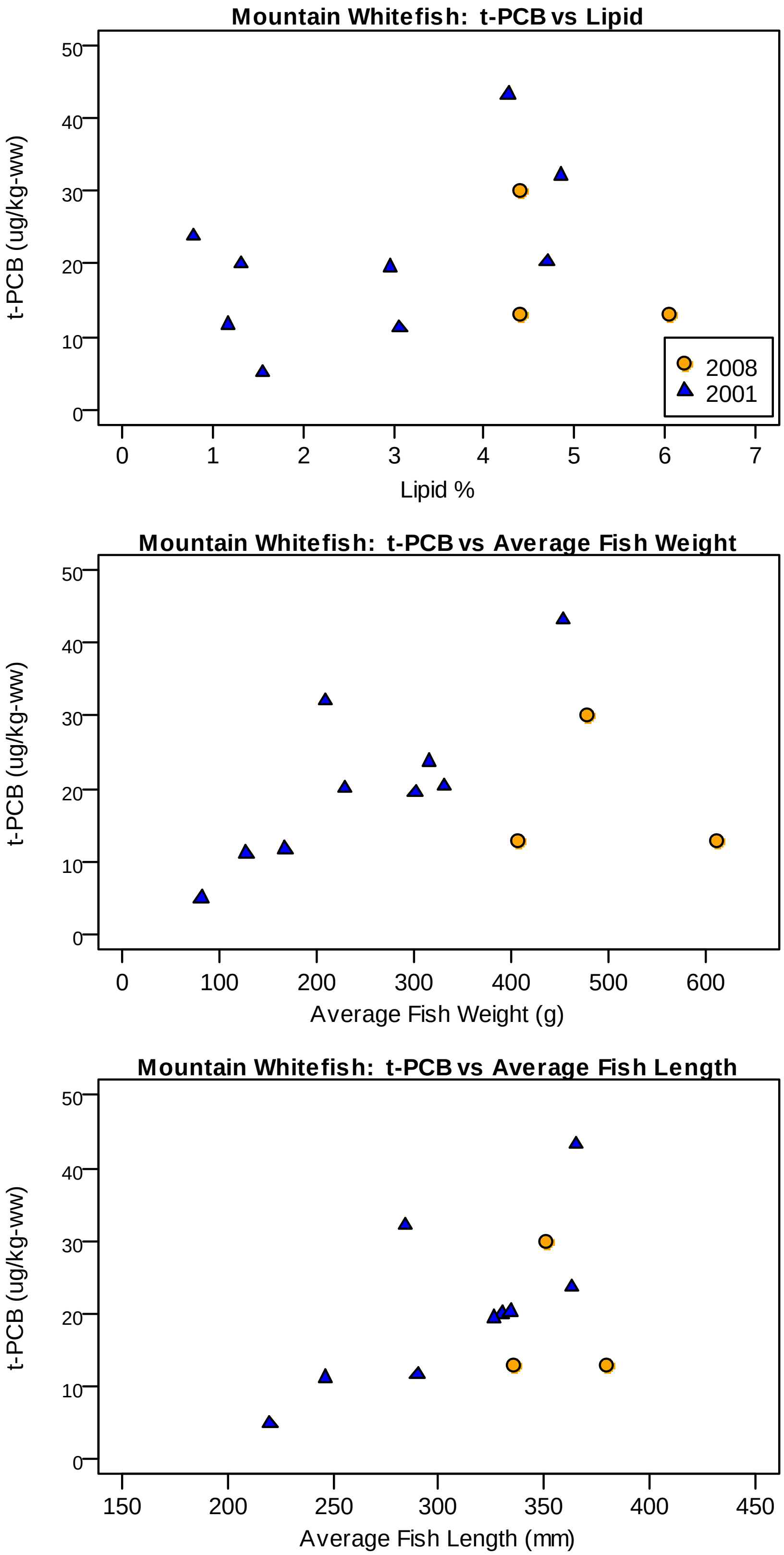


Figure D-5. t-PCB in Mountain Whitefish vs. Lipid, Average Fish Weight, and Average Fish Length.

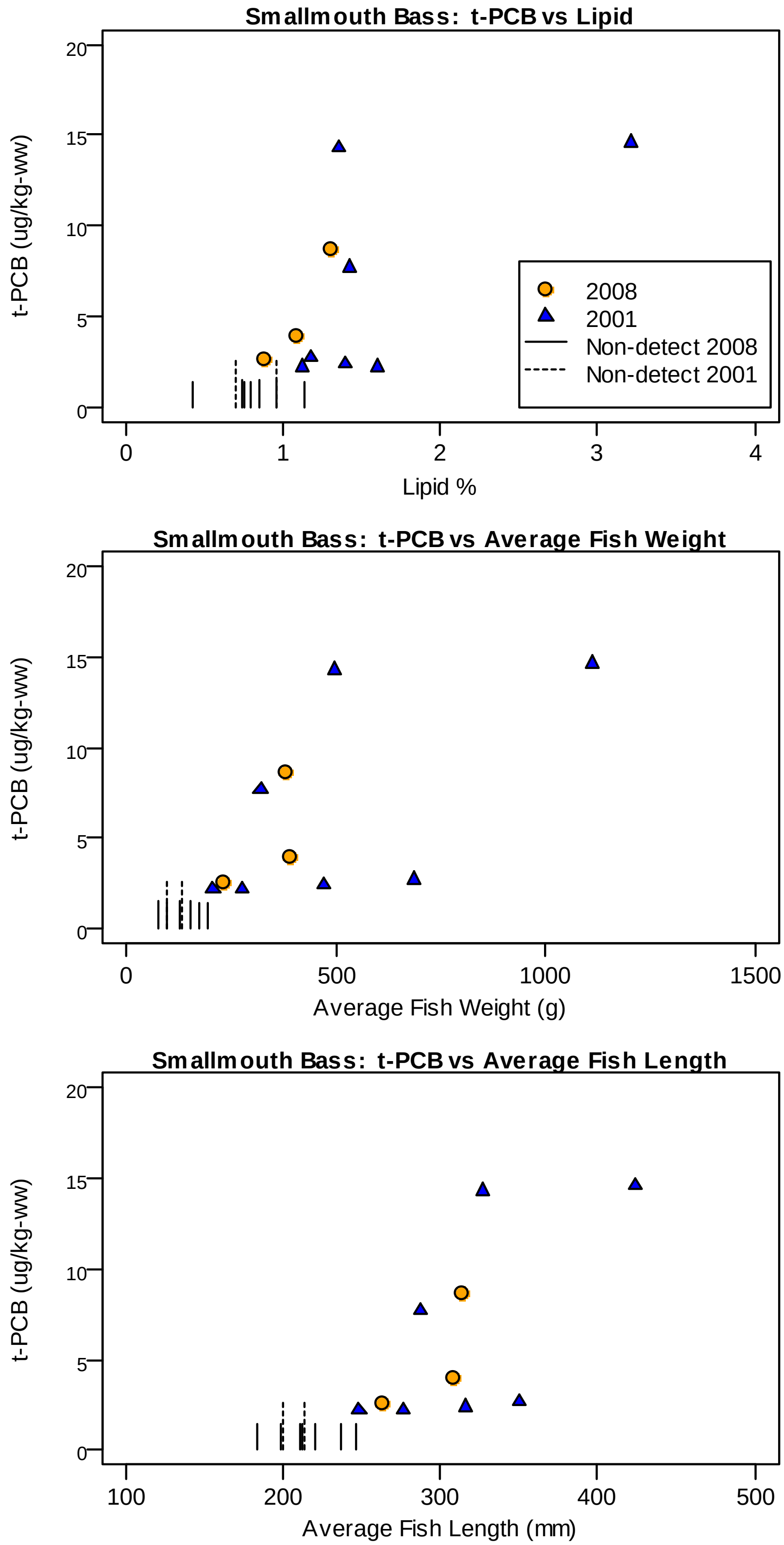


Figure D-6. t-PCB in Smallmouth Bass vs. Lipid, Average Fish Weight, and Average Fish Length.

Appendix E. Mann-Whitney Tests

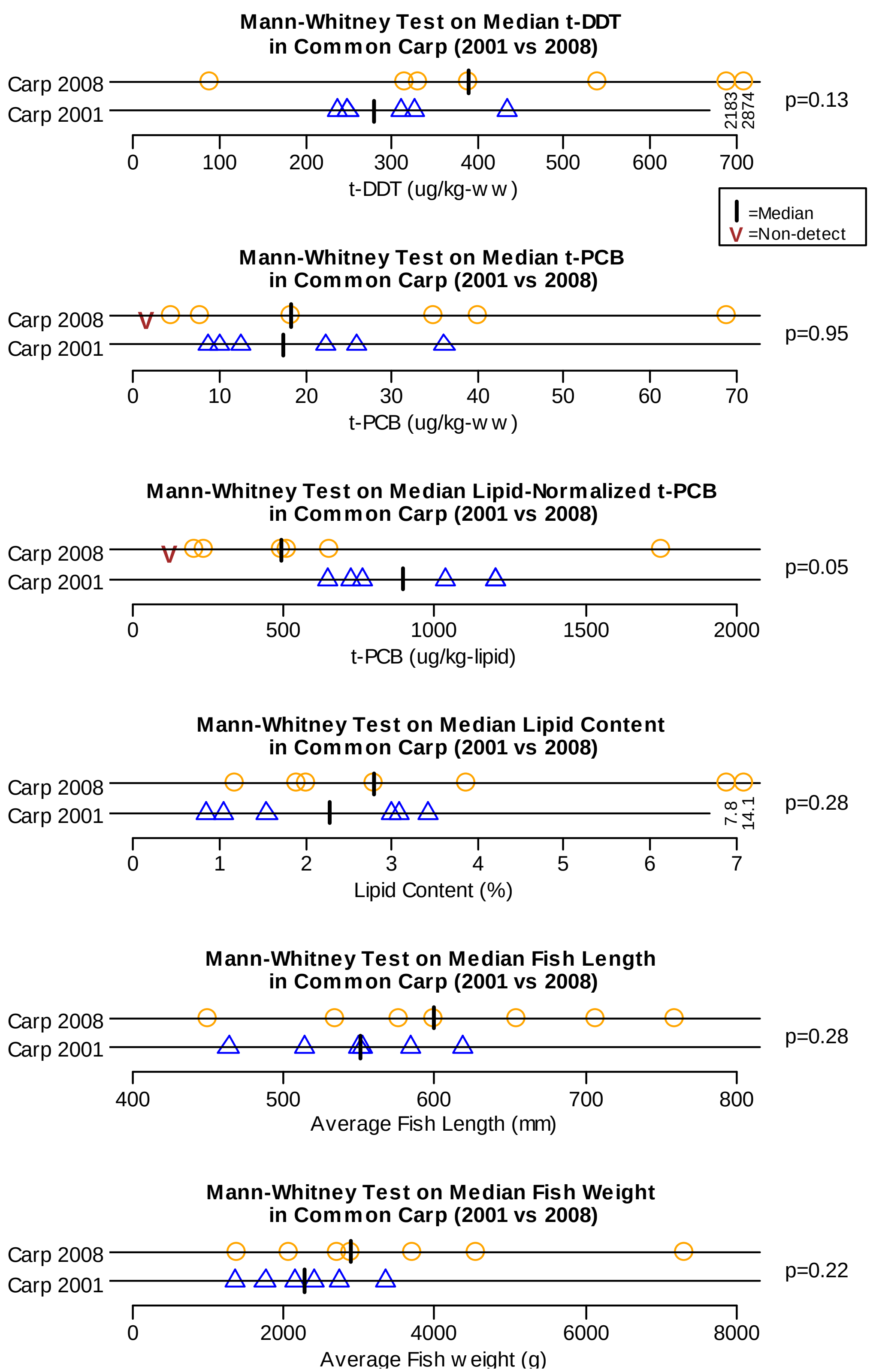


Figure E-1. Mann-Whitney Tests for Common Carp.

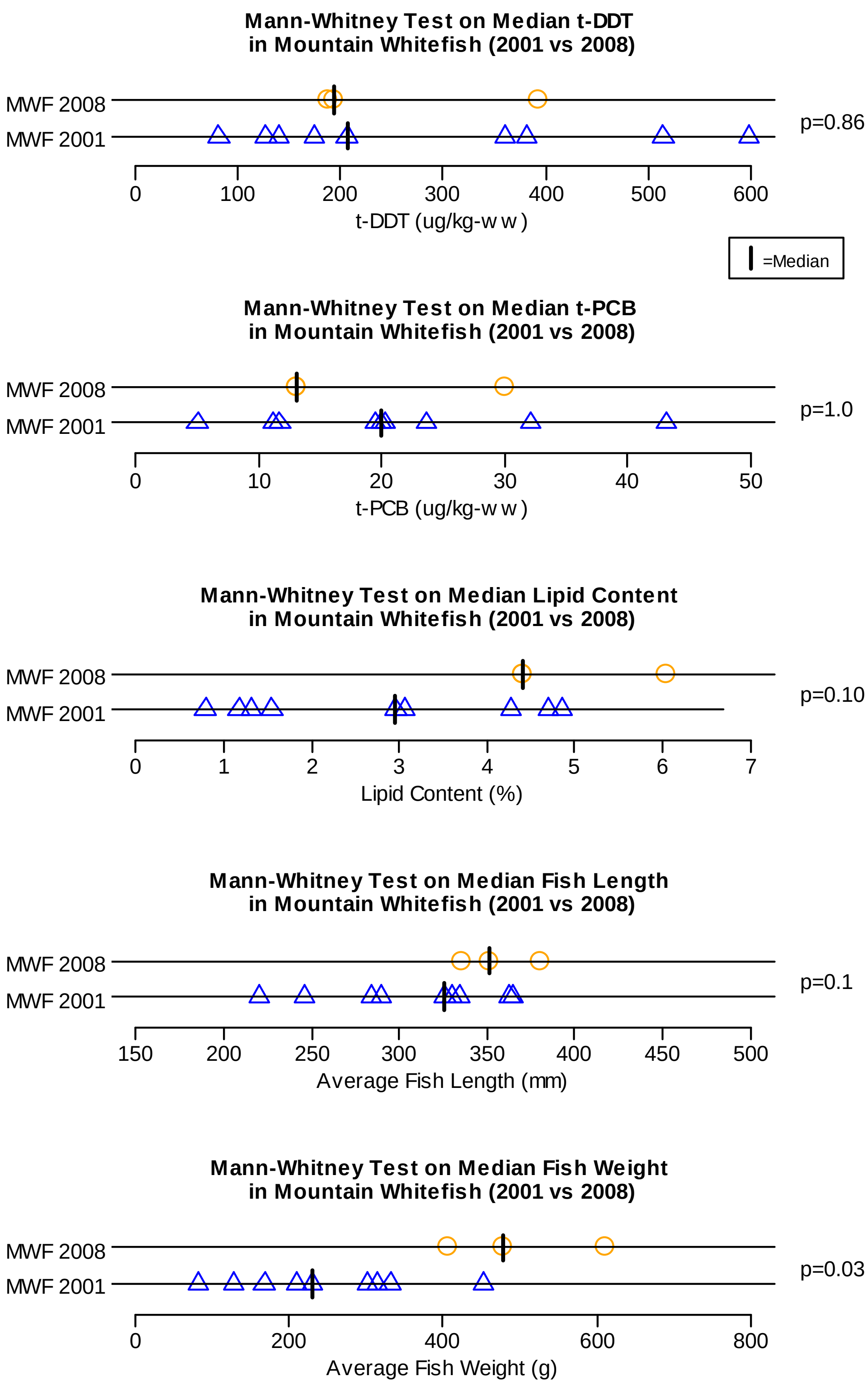


Figure E-2. Mann-Whitney Tests for Mountain Whitefish.

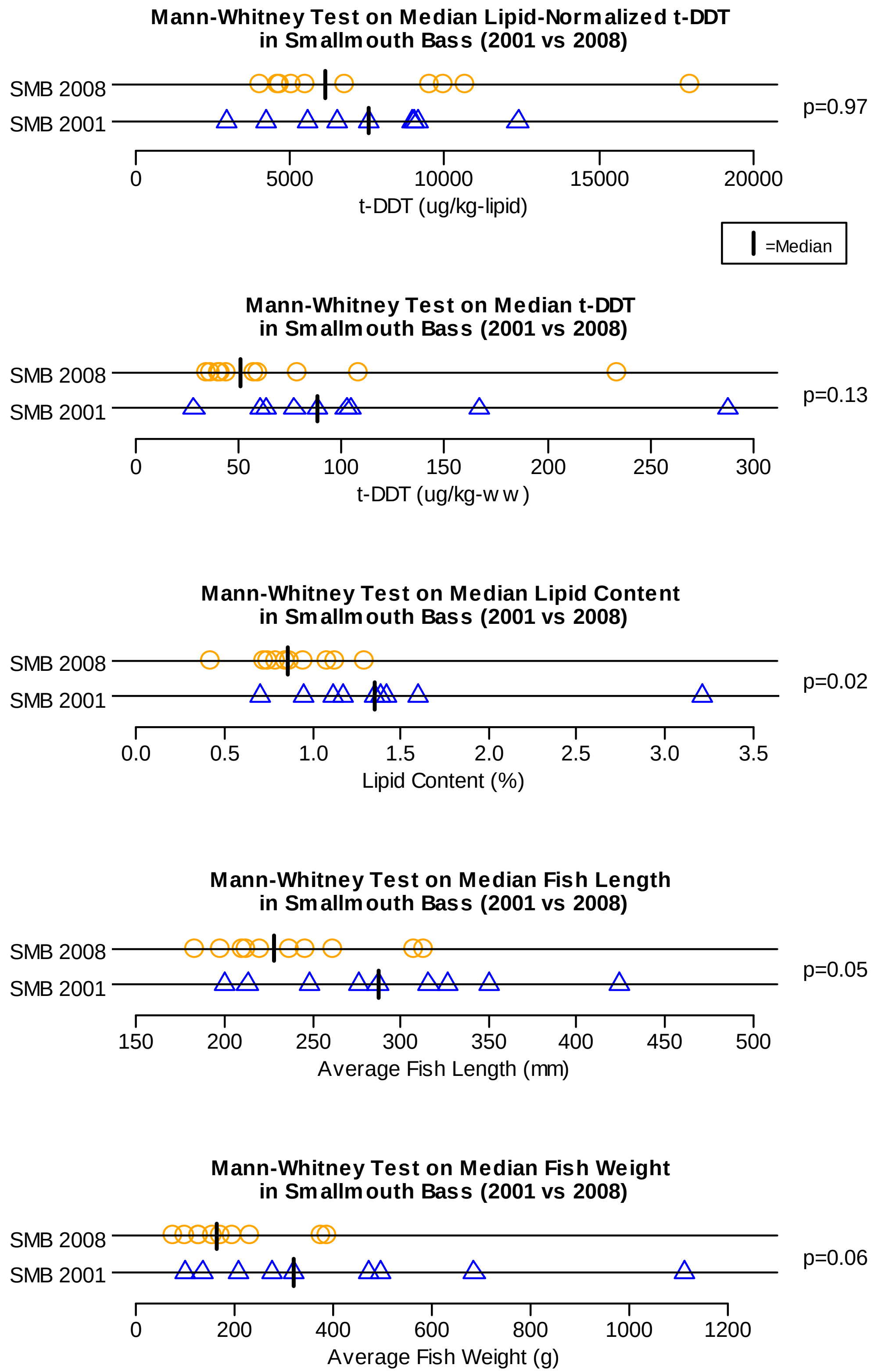


Figure E-3. Mann-Whitney Tests for Smallmouth Bass.