[1]Chlorinated organic contaminants in benthic organisms of the lower Fraser River near Agassiz, British Columbia

DOE FRAP 1998-30

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[1]**Portions of this report were published as a peer-reviewed article: Richardson, J.S. and C.D. Levings. 1996. Chlorinated organic contaminants in benthic organisms of the lower Fraser River near Agassiz, British Columbia. Water Quality Research Journal of Canada 31:153-162.**

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May 1998

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This report was funded by Environment Canada under the Fraser River Action Plan through the Environmental Quality Technical Working Group. The views expressed herein are those of the authors and do not necessarily state or reflect the policies of Environment Canada

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Acknowledgements

We wish to thank the Department of Environment, Canada for funding the chemical analyses of the invertebrate samples. The Department of Fisheries and Oceans, Canada supported JSR under a NSERC Visiting Scientist Fellowship. DFO also administered contracts for field sampling assistance. A number of people helped sort invertebrates under less than ideal conditions and we are grateful to them. Dr. Ken Hall offered helpful comments on the manuscript. Bob Gordon (DFO, Cultus Lake Laboratory) kindly shared unpublished data with us. Colin Gray, Environment Canada, assisted with administrative arrangements.

Abstract

Benthic insects were collected from the Fraser River, British Columbia in winter 1993 to assess concentrations of chlorinated organic contaminants. Concentrations of chlorinated furans were 2.5 to 6.5 pg/g wet mass in four different taxonomic groupings of aquatic insects. Chlorinated dioxins were not detectable, except for some hepta- and octachlorinated dioxins in sediments and detritivorous benthic insects. Some chlorinated phenolics, e.g., 3,4,5-trichloroguaiacol, were found in most taxa. Highest concentrations of phenolics were measured in prickly sculpins, *Cottus asper,* about an order of magnitude higher than in benthos. Concentrations of chlorinated organics measured were in the same range as those published for juvenile chinook salmon collected from nearby sites. Most chlorinated organics were undetectable in sediment samples.

Résumé

Des insectes benthiques ont été recueillis dans le fleuve Fraser (Colombie-Britannique) pendant l'hiver de 1993 afin d'évaluer les concentrations de contaminants organochlorés. Les concentrations de chlorofuranes variaient à 2,5 à 6,5 pg/g de masse humide dans le cas de quatre groupes taxinomiques différents d'insectes aquatiques. La présence de chlorodioxines n'était pas détectable, sauf dans le cas de certaines hepta et octachlorodioxines dans les sédiments et les insectes benthiques détritiphages. Certains chlorophénols, p. ex. 3,4,5-trichloroguaïacol, se retrouvaient dans la plupart des taxons. Les concentrations les plus élevées de composés phénolés étaient mesurées dans les chabots piquants, *Cottus asper*, où elles atteignaient un ordre de grandeur de plus que dans le benthos. Les concentrations de composés organochlorés mesurées étaient du même ordre que celles publiées pour les jeunes saumons quinnats recueillis dans des sites voisins. Les plupart des composés organochlorés n'étaient pas détectables dans des échantillons de sédiments.

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INTRODUCTION

Chlorinated organic contaminants released to the environment are of wide concern for their toxicity, persistence in the environment, bioaccumulation through food chains, and the public health aspects, such as consumption of fish and use of contaminated waters. Knowledge of the fate and effects of chlorinated organic compounds in freshwaters has come from studies of sediments, fish, and birds (Mah et al. 1989, Rogers et al. 1989, Whitehead et al. 1992), but the potential for transmission and bioaccumulation through benthic food webs has not been widely evaluated. Benthic stream invertebrates are in close contact to potentially contaminated sediments, many species feed extensively on those sediments, and these species form the trophic basis for most fish production in stream ecosystems. As a result of the above there is a need to consider the concentrations of these contaminants within benthic food webs and variations in their concentration across different benthic species. In the Fraser River of British Columbia, one of the world's most important catchments for production of salmonids (Northcote and Larkin 1989), the primary source of organochlorines are pulp and paper mills distributed throughout the basin (Servizi 1989).

There is growing interest in the use of benthos for monitoring and assessment of freshwater ecosystem status (Karr 1993, Rosenberg and Resh 1993). Benthos present many advantages for monitoring of freshwaters, including a speciose assemblage, a variety of trophic levels, variation in their tolerance to different kinds of perturbations, and their intimate association with sediments where many persistent contaminants are deposited in rivers. Most ecosystem monitoring in the Fraser River has been directed at measurements of contaminants in sediments and fish. There are now plans to use monitoring of benthic assemblages in the Fraser River as a means of assessing ecosystem condition and responses to management actions (Trefor Reynoldson, Environment Canada, *pers. comm.*). Studies in other catchments have shown that there is great potential for using benthic organisms to assess contaminant loads and ecosystem status (Gobas et al. 1989, Kovats and Ciborowski 1993).

A preliminary sampling program was undertaken to assess the concentrations and food web distribution of selected organochlorine contaminants in benthic organisms in the lower Fraser River in February and March 1993 (Richardson and Levings 1996). Our specific aims were to determine concentrations of selected chlorinated organics within benthic organisms, and to assess variations in the food web distribution of these contaminants. The sampling program also allowed us to evaluate the potential for such a sampling program in light of time and effort involved. Following reconnaissance surveys we sampled two sites with predominantly cobble and gravel substratum on the lower Fraser River between 26 February and 12 March, 1993. The first site sampled was at the northeast shore of Herrling Island, upstream of Chilliwack on the south side of the main channel of the river (121°41'W by 49°15'N) on 26 February. The second site was about 500 m downstream of the Rosedale-Agassiz bridge (121°46'W by 49°12'N), also on the south side of the river on 1 March. These two sites have been sampled previously for fish, invertebrates, and algae (e.g., Northcote et al. 1975, 1976, Brown et al. 1989). Both sites have easy access during low-flow periods, but Herrling Island is inaccessible by vehicle during freshet. The benthic community composition was very similar at both sites (Table 1).

Monitoring and assessment programs for the Fraser River include sampling of benthic assemblages as an index of environmental status. Thus, there is interest in evaluation of potential sites for regular sampling activities. Here we also review other potential collection sites in the lower Fraser River for monitoring of freshwater invertebrate assemblages, and contaminant concentrations.

METHODS AND MATERIALS

Collections of large numbers, usually many thousands, of benthic invertebrates from a number of different taxonomic groups and feeding categories were made at each site. Samples were obtained by wading at depths <0.6 m, using either a pole seine (6.25 mm) for larger animals or smaller mesh dip nets (≈1.0 mm) for smaller invertebrates. In terms of biomass the most abundant organisms were heptageniid mayflies, primarily the genus *Rhithrogena*, with smaller numbers of

Cinygmula and *Heptagenia*. An annotated list of invertebrate taxa found at the sites is presented in Table 1. Some of the samples analyzed were composites of several insect taxa with similar feeding habits in order to obtain samples with as large a mass as possible. Perlodid and perlid stoneflies were collected in part by use of the pole seine. A person kicked up rocks upstream of the net, after which stonefly larvae were picked off the net by hand. Prickly sculpins, *Cottus asper*, were also collected by means of the pole seine. On each date six people spent at least eight hours each collecting and sorting invertebrates. Animals were separated from sediments in plastic basins using stainless steel forceps, placed in hexane-rinsed jars kept on dry ice. Sediment samples were obtained using a small battery-operated electric pump to suck sediment and algal debris from the shallow water. This detrital material was then sieved into a 63um mesh sieve and collected in a jar and kept on ice. The samples were kept in ice during the day until return to the West Vancouver Laboratory in the evening, and then stored at -20ºC until submitted to the laboratories for analysis.

A specific trip to the Rosedale-Agassiz bridge site was made on March 12 to collect samples for dioxin and furan analyses. Benthic organisms were separated into heptageniid mayflies, perlodid stoneflies, hydropsychid caddisflies, and mixed capniid and taeniopterygid stoneflies. Other groups of benthos were too small or insufficiently abundant to collect for analysis. A sample of sediments was also collected as described above. There were therefore four samples of benthos, and one sediment sample submitted for dioxin and furan analysis.

The 20 samples collected on 26 February and 1 March were sent to AXYS Analytical Laboratories in Sidney, British Columbia, frozen in dry ice. The samples were analyzed for concentrations of chlorinated phenolics including chlorophenol, chloroguaiacol, and chlorocatechol using C^{13}-labelled surrogate standards on the GC/MS. Since 20 g wet mass per sample was required for analysis with standard detection limits, some of the samples had to be combined, but where possible samples of different taxa or feeding types were kept separate. Digestions for analysis were of the whole organisms, including gut contents. Detection limits for the analyses varied according to the mass of tissue present in the sample, and thus varied across samples. Quantification criteria were that the estimate had to exceed the detection limit by 3-fold,

thus some analyses appear to have detectable levels but there is uncertainty associated with the measures. QA and QC were based on procedural blanks in each batch and duplicate analyses of a sample from each batch (AXYS Analytical Laboratories).

Table 1. List of benthic invertebrate species found in the Fraser River at Agassiz and Herrling Island, February and March 1993. Estimates of abundance are relative, in the order abundant > common > scarce > rare. Composition of the benthic communities were similar at the two field sites.

Order	Family	Genus	Relative Abundance
Plecoptera			
	Capniidae	*Capnia*	abundant
		Isocapnia	rare
	Taeniopterygidae	*Taenionema*	abundant
	Perlodidae	*Isoperla*	common
	Perlidae	*Claasenia*	common
Ephemeroptera			
	Heptageniidae	*Rhithrogena*	abundant
		Cinygmula	common
		Heptagenia	common
	Ameletidae	*Ameletus*	common
	Baetidae	*Baetis*	common
	Ephemerellidae	*Ephemerella*	abundant
		Drunella	scarce
Trichoptera			
	Hydropsychidae	*Hydropsyche*	abundant
	Brachycentridae	*Brachycentrus*	scarce
	Rhyacophilidae	*Rhyacophila*	rare
Diptera			
	Chironomidae		abundant
	Athericidae	*Atherix*	scarce
	Blephariceridae	*Bibiocephala*	rare
	Tipulidae		rare

The samples collected at the Rosedale-Agassiz bridge site on 12 March were sent to the Enviro•Test Laboratory in Edmonton, Alberta for high resolution mass spectrometry analysis of dioxins and furans. Samples were sent in coolers with dry ice. As for chlorinated phenolics analysis, whole animals were used including gut contents. Analytical methods for dioxin and furan analysis followed standard methods (Environment Canada 1992a, b, US-EPA 1990).

RESULTS

Analysis of invertebrate and sediment samples for chlorinated dioxins and furans (full data set in Appendix 1) found no detectable concentrations of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD). Tetrachlorodibenzofuran (2,3,7,8-TCDF) was found in invertebrates, but not sediments (Table 2). Detection limits varied according to the amount of tissue provided for each analysis and so the limits derived by the analytical laboratory are also shown in the table. Concentrations of 2,3,7,8 TCDF ranged from 2.5 to 6.5 pg/g wet mass. Octachlorinated dioxin was detectable in sediments, hydropsychid larvae, and larvae of taeniopterygid and capniid stonefly larvae at concentrations between 30-33 pg/g. Low levels of heptachlorinated dioxins were detected in sediments (12 pg/g) and hydropsychid larvae (3.2 pg/g).

Table 2. Concentrations of chlorinated dioxins and furan (pg/g wet wt) in sediment and organisms from the lower Fraser River at the Agassiz-Rosedale bridge, collected March 12, 1993. Detection limits for each analysis are shown in brackets. "n.d." indicates not detected. Full data set for all chlorinated dioxins and furans is shown in Appendix 2.

Source	2378 TCDD	2378 TCDF
Sediments	n.d. (0.2)	n.d. (0.2)
Hydropsychidae (filter-feeding caddisflies)	n.d. (0.3)	**2.5** (0.4)
Perlodidae (predaceous stoneflies with a one-year generation time)	n.d. (0.5)	**4.0** (0.6)
Heptageniidae (grazing mayflies)	n.d. (0.4)	**6.5** (0.5)
Taeniopterygidae and Capniidae (detritivorous stoneflies)	n.d. (0.3)	**3.5** (0.3)

Most of the six chlorinated phenols that are routinely tested in fish in the Fraser River were below detection limits in most benthic organisms considered (Table 3). As with chlorinated dioxins and furans the detection limit of each analysis was proportional to the amount of tissue provided and thus the detection limits varied among organisms. The chlorinated phenolic at the highest concentrations was 3,4,5-trichloroguaiacol (3,4,5-TCG) which was above detection limits in most organisms and sediments (Table 3). It is interesting to note that 3,4,5-TCG was not detected in the samples of Ephemerellidae, however if one examines the detection limits it is clear that the sample of ephemerellids had the least mass and therefore the highest detection limits. Hydropsychid caddisflies had the highest concentrations of chlorinated phenolics of all the invertebrate taxa measured. A complete list of all substances measured is in Appendix 2.

The prickly sculpin, *Cottus asper*, a benthivorous fish, had much higher levels of all chlorinated phenols measured than any of the benthic organisms or sediments. The biomagnification factor between prey organisms and the sculpins was about 2 to 10-fold for 3,4,5-TCG. There was considerable variation among the taxa, with organisms feeding primarily on detrital particles (stonefly and Hydropsychidae larvae) having higher concentrations than grazing or predaceous taxa.

There was very limited replication of samples of the same taxon, so to provide an estimate of the variability in actual values in samples we used data for 3,4,5-TCG and standardized the data to a mean of one within each taxon for which there were more than one sample analyzed. The coefficent of variation (CV) was 0.402 and the variance was 0.162 for the 17 values included.

DISCUSSION

Our study showed that chlorinated organic contaminants are detectable in benthic organisms in the lower Fraser River, and suggests that it is feasible to determine food web distribution as an indication of potential for transmission of these compounds to fish and birds through food webs. The levels detected in benthos were in the same range as values based on sampling of juvenile chinook salmon in reaches of the Fraser

Table 3. Concentrations of chlorinated phenolics (ng/g wet weight) in sediment and organisms collected February 26 and March 1, 1993 at Herrling Island and the Agassiz-Rosedale bridge, lower Fraser River. Detection limits and their range of the analyses are presented in brackets. Bold, italicized type followed by a ? denotes peak in GC detected but did not meet quantification criteria. n.d. indicates not detected. Full data set for all chlorinated phenolics measured shown in Appendix 2.

Source	[a]2,4,6 TCP	TeCP	PCP	3,4,5 TCG	4,5,6 TCG	TeCG
Sediments	n.d. (0.02-0.05)	n.d (0.2-0.4)	n.d. (0.2-0.3)	0.5-1.0 (0.1-0.2)	n.d. (0.07-1.0)	n.d. (0.1-0.3)
Heptageniidae	n.d. (0.1)	n.d. (0.1)	n.d. (0.1-0.2)	0.3 - 1.1 (0.04-0.1)	n.d. (0.1-0.3)	n.d. (0.1-0.2)
large Perlodidae	n.d. (0.1)	n.d. (0.1)	n.d. (0.1)	0.5 - 0.6 (0.1)	n.d. (0.1)	n.d. (0.1)
small Perlodidae	n.d. (0.1)	n.d. (0.1)	n.d. (0.2)	0.2 - 0.5 (0.1)	n.d. (0.1)	n.d. (0.1)
Cottus asper	***1.8-2.8?*** 0.4 (0.01-0.1)	n.d. (0.2-0.4)	0.4 - 0.8 (0.2-0.3)	2.3 - 5.8 (0.2-0.3)	0.4 - 1.1 (0.2)	n.d., ***0.5?*** (0.2-0.3)
Taeniopterygidae and Capniidae	***0.3?-1.0?*** (0.1-0.2)	n.d. (0.3-0.4)	n.d. (0.3-0.4)	0.7 - 1.8 (0.3)	n.d. - 0.3 (0.2)	n.d. (0.3)
Hydropsychidae	1.4 (0.1)	n.d. (0.5)	n.d. (0.4)	1.9 (0.3)	0.6 (0.2)	n.d. (0.3)
Ephemerellidae	n.d. (0.5)	n.d. (1.0)	n.d. (0.6)	n.d. (0.6)	n.d. (0.4)	n.d. (0.8)

[a] 2,4,6 TCP - 2,4,6 trichlorophenol; TeCP - Tetrachlorophenol: PCP - Pentachlorophenol; 3,4,5 TCG - 3,4,5 trichloroguaiacol; 4,5,6 TCG - 4,5,6 trichloroguaiacol; TeCG - Tetrachloroguaiacol

River near Agassiz (Rogers et al. 1988, Robert Gordon, Fisheries and Oceans Canada - *pers. comm.*). In general the concentrations of organochlorines in benthic organisms were low.

The higher levels of chlorinated phenolics in prickly sculpins indicates bioaccumulation which would be expected in a primarily benthivorous fish. We have not considered inter-individual variation in contaminant load in this study. Phenolic concentrations were approximately 10-fold above those in invertebrates. In our study, pentachlorophenol was only found in prickly sculpins. In general the concentrations of chlorinated phenolics measured in chinook near the pulp mills in Prince George and Quesnel were more than an order of magnitude greater than that found at the downstream sites (Rogers et al. 1988). The latter values were much higher than our data for sculpins and benthos from near Agassiz.

Concentrations of tetra-chlorinated furans (TCDF) in benthic insects in 1993 were generally higher than observed in juvenile chinook salmon in 1991 and 1992 at a site nearby Herrling Island (R. Gordon - *pers. comm.*). The observed concentrations of TCDF in our samples were 2.5 to 6.5 pg/g. We found no detectable concentration of tetra-chlorinated dioxin, the most toxic of this class of chemicals, in benthos at these lower Fraser River sites. One interpretation of these results is that bioaccumulation of furans by benthos is as high or higher than that of fish, but that there is no further biomagnification in fish feeding on the benthic organisms. However, the location where the chinook actually forage is uncertain, although it is likely that the fish feed on the invertebrate taxa we examined (Levings and Lauzier 1991). The available evidence for chlorinated organics in the Fraser River suggests that concentrations have been declining since actions to reduce chlorinated organics were implemented in 1991 (Servizi 1993). The concentrations of hepta- and octa-chlorinated dioxin in sediments and some of the benthic organisms could be a consequence of not purging the guts of these invertebrates which feed on suspended (Hydropsychidae) or deposited detrital particles (taeniopterygid and capniid stoneflies). Providing an opportunity for these small, numerous organisms to clear their guts would be difficult. Understanding fate and effects of chlorinated dioxins and furans will require sampling of all the components of the ecosystem at one time and development of a basic model of trophic

structure in the river's food web, a preliminary version of which was developed by Northcote et al. (1976).

Hydropsychid caddisfly larvae had the highest concentration of phenolics measured among the invertebrates. The higher concentrations in hydropsychids may be a result of their feeding ecology, which consists of the consumption of small, waterborne organic particles intercepted by their filtering net. Organochlorines may be adsorbed or bound to organic particles. However, other taxa considered were detritivorous and the same argument could be made. Another potential hypothesis is that concentrations of contaminants are age-dependent in aquatic insects.

Our data for Fraser River benthos are unique in representing the first data for stream insects collected from the wild. There are few reports of tissue concentrations of chlorinated phenolics or dioxins and furans in freshwater invertebrates. Most data are based on large invertebrates such as crayfish or crabs, or from experimental exposure of invertebrates to water for a defined period of time. One study which has examined the dynamics of dioxin accumulation in lake benthic invertebrates used radiolabelled dioxin and was able to measure extremely small invertebrates by the radiolabel (Fairchild et al. 1992).

This study shows that it is feasible to measure chlorinated organic contaminants within benthic organisms and that there is variation within the food web which could be important to modelling the fate and effects of organic contaminants. Variation among individuals, across seasons and years, across age-classes (especially given the age dependence of fat storage), and among sites are all issues which await further study, but may be important to understanding the fate and effects of contaminants in Fraser River food webs. Closely related taxa may differ in their sensitivity to chemical alteration and there can be large differences in the bioaccumulation of contaminants from species to species, even within a genus (Cain et al. 1992). Our results suggest some differences in contaminant loads may be due to trophic category, but this assertion needs further study. These data will be vital to parameterizing food-web models (e.g., Northcote et al. 1976) of contaminant fate and effects being developed for Fraser River food webs.

An assessment of potential, long-term sampling sites for invertebrate, fish, and sediment sampling in the lower Fraser River downstream of Hope.

We observed a number of sites on the Fraser River downstream of Hope for sampling benthic organisms. The river can be conveniently considered as two primary habitat types, 1) depositional, soft-bottom substratum, and 2) cobble-bottom substratum. Depositional habitats and off-channel sites are uncommon or transient in most of the Fraser River above Hope and are primarily found in reaches below Hope where the gradient is lower, the channel has a complex geometry and therefore backwaters, or where the influence of the tidal cycle may affect the rate of flow in the river. In terms of sampling sites which could be comparable with upstream stations, it is probably most appropriate to investigate sites with cobble bottom.

Below we discuss the suitability of a number of sites for ongoing studies of contaminant concentrations and fluxes, and other properties of lower Fraser River ecosystems. We have not addressed sites within the estuarine portion of the river where past studies have been conducted (e.g., Northcote et al. 1975, 1976, 1978, Brown et al. 1989) and other ongoing studies have continuing programs (Levings - pers. comm.; Richardson - unpublished data) A number of the sites have extensive background data available for fish distribution and abundance, as well as contaminant studies at some sites. Data are also available for benthos and sediment at several sites. Obviously, having long-term data for some attributes of the Fraser River food web will be valuable in the choice of sites. We will deal first with cobble-bottom reaches, then with depositional zones.

Cobble Bottom Reaches

Herrling Island to Rosedale-Agassiz Bridge: This reach of river has been studied for a number of years as part of a series of investigations. Studies of contaminant loads in fish, primarily halogenated organics, have been carried out by personnel of the Department of Fisheries and Oceans since 1986 (Rogers et al. 1988, Servizi et al. 1988). Scientists based at the Cultus Lake Laboratory are involved in ongoing studies of fish, especially juvenile chinook salmon, with regards to contaminants (Bob Gordon - personal communication). Sampling for sediment

contaminants by an early Westwater Research Centre study included Herrling Island (site 13 in Johnston et al. 1975, Northcote et al. 1975). Limited benthic and sediment sampling for contaminant loads was done in early 1993 (Richardson and Levings - this study).

There are data for fish distribution and abundance among habitats in the reach from the Agassiz Bridge to Herrling Island (Brown et al. 1989; Rosberg et al. 1987; Levings and Lauzier 1991). Another detailed set of data for fish assemblages was collected in 1973-1974 and 1994-1995 and included a site by Herrling Island (site 13 in Northcote et al. 1978, Richardson et al. - in prep.). An ongoing sampling program for monitoring of fish assemblages (Richardson and Lissimore - unpublished data) samples at this reach of river twice a year (late April and late August).

Data on currents, temperatures, and fish feeding are also available from this site (Brown et al. 1989, Levings and Lauzier 1991). Other studies in this river reach include a couple of theses in progress in the Department of Zoology at the University of British Columbia. The first of these is a detailed study of the use of floodplain habitats and deep-water habitats by benthos (Laura Rempel - in prep.). The second is a study related to the ongoing benthos biomonitoring program of Environment Canada (Pamela Dymond - in prep.). There have also been a number of geomorphological studies conducted in this reach of the Fraser River.

Upstream of Herrling Island: Much of the rest of the Fraser River mainstem between Herrling Island and Hope has a cobble bottom, but much less work has been done there. There have been fish surveys done in association with twin-tracking of the railways along the river. Northcote et al.'s (1975, 1976, 1978) site 14 is in this reach of the river, and based on their data this site is very similar to site 13. The site where Northcote et al. (1975, 1976) sampled appears to be just downstream of the mouth of Waleach (Jones) Creek.

Chilliwack River: The benthic fauna of the Chilliwack River is relatively similar to that of the cobble-bottom reaches of the Fraser River, and some of the fish species are similar. The Chilliwack River may be useful as a control site for contaminant loads associated with upstream pulp mills in the Fraser River.

Other sites: Other cobble-bottom reaches to be considered would be some of the other sites sampled by Northcote et al. (1975, 1976, 1978). Gregory et al. (1993) have published data on fish assemblages for the south shore of Nicomen Island. Cobble-bottom conditions do not extend much downstream of Chilliwack.

Depositional Reaches

Nicomen Slough: At the mouth of the Nicomen Slough there is a major depositional zone which has been sampled as part of several studies. There are data available from some fish survey work done at the mouth (Gregory et al. 1993). The crustacean, *Neomysis mercedis*, is found at the site, the furthest upstream in the Fraser River that this species is found. Dr. N.T. Johnston has done detailed studies of the life history of *N. mercedis* at this location (Johnston and Lasenby 1982), and Robert Gordon (DFO) has some contaminant data for this species from the slough. There is good access to this site and it is one of the first major depositional sites downstream of Hope.

Mouth of Vedder River: The mouth of the Vedder River where it empties into the Fraser River is also a major depositional zone. It is almost directly across the Fraser from the mouth of Nicomen Slough. This river drains a large amount of the Sumas Prairie and may have high levels of pesticides. This site is probably not suitable as a control for chlorinated organics which might be found at Nicomen Slough because of confounding by suspected high levels of pesticides.

Other Depositional Sites: Other potential sites have few known data associated with them, but might be useful in certain contexts. Maria Slough is similar in some ways to Nicomen slough. The mouths of two other rivers, Hunter Creek and Ruby Creek, have depositional zones associated with their deltas, but most of the water passing them from these creeks is not expected to be contaminated. These might provide some control or reference areas for depositional areas affected by Fraser River water, although there may be some differences in the fauna associated with these smaller tributaries.

Some of the other sites sampled by Northcote et al. (1975, 1976, 1978) might be appropriate to resample, but many of these sites face multiple inputs of contaminants. The upstream sites above

Chilliwack have the benefit of having less direct modification to the river channel and may be best for monitoring and research objectives. Another reason the cobble-bottom reaches between Chilliwack and Hope are probably the best places to continue much of the ongoing monitoring for fish and invertebrates because they are the habitat most representative of the Fraser River mainstem and therefore likely to be similar in their biological communities.

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Appendix 1

Table A 1. List of chlorinated dioxins and furans measured in benthos collected at Agassiz for this study. Concentrations given in pg/g. Results corrected for surrogate recovery. Data as submitted by Enviro•Test Laboratories, Edmonton, Alberta (Reference # E3-03-213). Toxic equivalencies based on International Toxic Equivalency Factor.

Sample Group	Sediment	*Hydropsyche*	Perlodidae
Sample Mass (g)	4.1 g dry mass	3.0 g dry mass	2.1 g dry mass
2378 - TCDD	ND (0.2)	ND (0.3)	ND (0.5)
12378 - PeCDD	ND (0.2)	ND (0.3)	ND (0.7)
123478 - HxCDD	ND (1.3)	ND (0.9)	ND (2.0)
123678 - HxCDD	ND (1.4)	ND (0.7)	ND (1.9)
123789 - HxCDD	ND (1.3)	ND (0.8)	ND (2.0)
1234678 - HpCDD	**12** (3.1)	**3.2** (0.7)	ND (2.5)
OCDD	**31** (4.6)	**30** (3.4)	ND (26)
2378 - TCDF	ND (0.2)	**2.5** (0.4)	**4.0** (0.6)
12378 - PeCDF	ND (0.2)	ND (0.2)	ND (0.6)
23478 - PeCDF	ND (0.3)	ND (0.2)	ND (0.6)
123478 - HxCDF	ND (0.5)	ND (0.3)	ND (1.0)
123678 - HxCDF	ND (0.6)	ND (0.3)	ND (0.9)
234678 - HxCDF	ND (0.7)	ND (0.3)	ND (1.1)
123789 - HxCDF	ND (0.9)	ND (0.4)	ND (1.7)
1234678 - HpCDF	ND (1.5)	ND (1.7)	ND (2.2)
1234789 - HpCDF	ND (2.6)	ND (3.0)	ND (4.0)
OCDF	ND (6.5)	ND (1.9)	ND (15.0)

Table A 1: Continued.

Sample Group	Heptageniidae	Miscellaneous Stoneflies	Method Blank
Sample Mass (g)	4.7 g dry mass	4.3 g dry mass	10.0 g dry mass
2378 - TCDD	ND (0.4)	ND (0.3)	ND (0.2)
12378 - PeCDD	ND (0.4)	ND (0.4)	ND (0.1)
123478 - HxCDD	ND (0.7)	ND (0.7)	ND (0.2)
123678 - HxCDD	ND (1.0)	ND (0.8)	ND (0.2)
123789 - HxCDD	ND (0.9)	ND (0.8)	ND (0.2)
1234678 - HpCDD	ND (3.5)	ND (2.2)	ND (0.3)
OCDD	ND (5.9)	**33** (12.0)	ND (2.3)
2378 - TCDF	**6.5** (0.5)	**3.5** (0.3)	ND (0.1)
12378 - PeCDF	ND (0.2)	ND (0.3)	ND (0.1)
23478 - PeCDF	ND (0.2)	ND (0.3)	ND (0.1)
123478 - HxCDF	ND (0.8)	ND (0.4)	ND (0.2)
123678 - HxCDF	ND (0.7)	ND (0.3)	ND (0.2)
234678 - HxCDF	ND (0.9)	ND (0.4)	ND (0.2)
123789 - HxCDF	ND (1.3)	ND (0.6)	ND (0.3)
1234678 - HpCDF	ND (1.7)	ND (1.2)	ND (0.4)
1234789 - HpCDF	ND (3.4)	ND (2.4)	ND (0.6)
OCDF	ND (5.6)	ND (8.9)	ND (1.3)

Table A 1: Continued.

Sample Group	Toxic Equivalents relative to 2378 TCDD
2378 - TCDD	1
12378 - PeCDD	0.5
123478 - HxCDD	0.1
123678 - HxCDD	0.1
123789 - HxCDD	0.1
1234678 - HpCDD	0.01
OCDD	0.001
2378 - TCDF	0.1
12378 - PeCDF	0.05
23478 - PeCDF	0.5
123478 - HxCDF	0.1
123678 - HxCDF	0.1
234678 - HxCDF	0.1
123789 - HxCDF	0.1
1234678 - HpCDF	0.01
1234789 - HpCDF	0.01
OCDF	0.001

Appendix 2

Table A 2. List of all chlorinated phenolic compounds measured by AXYS (file #2834). Concentrations given in ng/g with detection limits in parentheses. ND - not detected. All samples from the Fraser River mainstem at Herrling Island or Agassiz-Rosedale bridge. NDR - peak detected, but does not meet quantification criteria. NQ - not quantifiable due to low surrogate recovery. Data as reported by Axys Analytical Services, Sidney, BC.

Sample Group	Sediment - Herrling #1	Sediment- duplicate, Herrling #1	Sediment - Herrling #2
Sample Mass (g)	2.7 g dry mass	2.9 g dry mass	4.4 g dry mass
Chlorinated Phenolics			
4-chlorophenol	ND (0.2)	ND (0.3)	ND (0.4)
2,6-dichlorophenol	ND (0.3)	ND (0.3)	ND (0.2)
2,4/2,5-DCP	ND (0.3)	ND (0.3)	ND (0.2)
3,5-dichlorophenol	ND (0.3)	ND (0.3)	ND (0.2)
2,3-dichlorophenol	ND (0.3)	ND (0.3)	ND (0.2)
3,4-dichlorophenol	ND (0.2)	ND (0.2)	ND (0.1)
6-chloroguaiacol	ND (0.2)	ND (0.2)	ND (0.1)
4-chloroguaiacol	ND (0.2)	ND (0.2)	ND (0.1)
5-chloroguaiacol	ND (0.2)	ND (0.2)	ND (0.1)
2,4,6-trichlorophenol	ND (0.03)	ND (0.03)	ND (0.02)
2,3,6-trichlorophenol	ND (0.1)	ND (0.1)	ND (0.1)
2,3,5-trichlorophenol	ND (0.1)	ND (0.1)	ND (0.1)
2,4,5-trichlorophenol	ND (0.1)	ND (0.1)	ND (0.08)
2,3,4-trichlorophenol	ND (0.1)	ND (0.1)	ND (0.09)
3,4,5-trichlorophenol	ND (0.1)	ND (0.3)	ND (0.1)
3-chlorocatechol	ND (0.2)	ND (0.2)	ND (0.2)
4-chlorocatechol	ND (0.3)	ND (0.3)	ND (0.4)
3,4-dichloroguaiacol	ND (0.2)	ND (0.2)	ND (0.2)
4,6-dichloroguaiacol	ND (0.3)	ND (0.2)	ND (0.2)
4,5-dichloroguaiacol	NDR [1.2] (0.2)	NDR [0.7] (0.2)	**0.8** (0.1)
3,4-dichlorocatechol	ND (0.4)	ND (0.5)	ND (0.2)
3,6-dichlorocatechol	ND (0.4)	ND (0.6)	ND (0.3)
3,5-dichlorocatechol	ND (0.3)	ND (0.5)	NDR [0.3] (0.2)
4,5-dichlorocatechol	**1.5** (0.5)	**1.3** (0.6)	**1.6** (0.3)
2,3,5,6-tetrachlorophenol	ND (0.3)	ND (0.4)	ND (0.2)
2,3,4,6-tetrachlorophenol	ND (0.3)	ND (0.4)	ND (0.3)
2,3,4,5-tetrachlorophenol	ND (0.2)	ND (0.2)	ND (0.2)
3,4,6-trichloroguaiacol	ND (0.1)	ND (0.2)	ND (0.1)
3,4,5-trichloroguaiacol	**0.6** (0.2)	**0.6** (0.2)	**0.6** (0.1)
4,5,6-trichloroguaiacol	ND (0.1)	ND (0.1)	ND (0.1)
3,4,6-trichlorocatechol	ND (0.3)	ND (0.4)	ND (0.3)
3,4,5-trichlorocatechol	**1.5** (0.3)	**1.2** (0.3)	NDR [1.5] (0.3)
pentachlorophenol	ND (0.3)	ND (0.3)	ND (0.3)
3,4,5,6-tetrachloroguaiacol	ND (0.3)	ND (0.2)	ND (0.1)
3,4,5,6-tetrachlorocatechol	ND (8.5)	ND (8.4)	ND (9.7)

Table A 2: Continued

Sample Group	Sediment - Agassiz #1	Sediment - Agassiz #2	Sediment Procedural Blank
Sample Mass (g)	2.5 g dry mass	4.4 g dry mass	3.6 g dry mass
Chlorinated Phenolics			
4-chlorophenol	ND (0.7)	ND (0.2)	ND (0.2)
2,6-dichlorophenol	ND (0.3)	ND (0.2)	ND (0.3)
2,4/2,5-DCP	ND (0.3)	ND (0.2)	ND (0.2)
3,5-dichlorophenol	ND (0.3)	ND (0.2)	ND (0.3)
2,3-dichlorophenol	ND (0.3)	ND (0.2)	ND (0.2)
3,4-dichlorophenol	ND (0.2)	ND (0.1)	ND (0.2)
6-chloroguaiacol	ND (0.2)	ND (0.07)	ND (0.2)
4-chloroguaiacol	ND (0.2)	ND (0.09)	ND (0.2)
5-chloroguaiacol	ND (0.2)	ND (0.08)	ND (0.2)
2,4,6-trichlorophenol	ND (0.05)	ND (0.02)	ND (0.03)
2,3,6-trichlorophenol	ND (0.1)	ND (0.1)	ND (0.1)
2,3,5-trichlorophenol	ND (0.1)	ND (0.1)	ND (0.1)
2,4,5-trichlorophenol	ND (0.1)	ND (0.07)	ND (0.1)
2,3,4-trichlorophenol	ND (0.1)	ND (0.08)	ND (0.1)
3,4,5-trichlorophenol	ND (0.1)	ND (0.08)	ND (0.1)
3-chlorocatechol	ND (0.4)	ND (0.2)	ND (0.2)
4-chlorocatechol	ND (0.6)	ND (0.4)	ND (0.3)
3,4-dichloroguaiacol	ND (0.2)	ND (0.1)	ND (0.2)
4,6-dichloroguaiacol	ND (0.3)	ND (0.1)	ND (0.2)
4,5-dichloroguaiacol	NDR [0.7] (0.2)	NDR [0.7] (0.1)	ND (0.2)
3,4-dichlorocatechol	ND (0.4)	ND (0.2)	ND (0.2)
3,6-dichlorocatechol	ND (0.5)	ND (0.3)	ND (0.2)
3,5-dichlorocatechol	ND (0.4)	ND (0.2)	ND (0.2)
4,5-dichlorocatechol	NDR [0.9] (0.6)	NDR [0.8] (0.3)	ND (0.2)
2,3,5,6-tetrachlorophenol	ND (0.3)	ND (0.2)	ND (0.2)
2,3,4,6-tetrachlorophenol	ND (0.3)	ND (0.2)	ND (0.2)
2,3,4,5-tetrachlorophenol	ND (0.2)	ND (0.1)	ND (0.1)
3,4,6-trichloroguaiacol	ND (0.2)	ND (0.09)	ND (0.1)
3,4,5-trichloroguaiacol	**1.0** (0.2)	**0.5** (0.1)	ND (0.1)
4,5,6-trichloroguaiacol	ND (0.1)	ND (0.07)	ND (0.08)
3,4,6-trichlorocatechol	ND (0.4)	ND (0.3)	ND (0.2)
3,4,5-trichlorocatechol	NDR [1.1] (0.3)	**0.8** (0.2)	ND (0.1)
pentachlorophenol	ND (0.3)	ND (0.2)	ND (0.2)
3,4,5,6-tetrachloroguaiacol	ND (0.3)	ND (0.1)	ND (0.1)
3,4,5,6-tetrachlorocatechol	ND (10.0)	ND (5.5)	ND (0.2)

Table A 2: Continued

Sample Group	Heptageniidae - Herrling #1	Heptageniidae - Herrling #2	Heptageniidae - Agassiz #1
Sample Mass (g)	6.3 g wet mass	9.7 g wet mass	8.4 g wet mass
Chlorinated Phenolics			
4-chlorophenol	ND (0.6)	ND (0.2)	ND (0.1)
2,6-dichlorophenol	ND (0.4)	ND (0.3)	ND (0.1)
2,4/2,5-DCP	ND (0.3)	ND (0.6)	ND (0.9)
3,5-dichlorophenol	ND (0.2)	ND (0.1)	ND (0.1)
2,3-dichlorophenol	ND (0.2)	ND (0.1)	ND (0.1)
3,4-dichlorophenol	**0.1** (0.1)	ND (0.1)	ND (0.2)
6-chloroguaiacol	ND (0.1)	ND (0.1)	ND (0.1)
4-chloroguaiacol	ND (0.1)	ND (0.1)	ND (0.1)
5-chloroguaiacol	ND (0.1)	NDR [1.0] (0.02)	ND (0.7)
2,4,6-trichlorophenol	ND (0.1)	ND (0.1)	ND (0.1)
2,3,6-trichlorophenol	ND (0.1)	ND (0.1)	ND (0.1)
2,3,5-trichlorophenol	ND (0.1)	ND (0.1)	ND (0.1)
2,4,5-trichlorophenol	ND (0.1)	ND (0.1)	ND (0.1)
2,3,4-trichlorophenol	ND (0.1)	ND (0.1)	ND (0.1)
3,4,5-trichlorophenol	ND (0.1)	ND (0.1)	ND (0.1)
3-chlorocatechol	ND (0.2)	ND (0.1)	ND (0.2)
4-chlorocatechol	ND (0.2)	ND (0.1)	ND (0.2)
3,4-dichloroguaiacol	ND (0.1)	ND (0.1)	ND (0.1)
4,6-dichloroguaiacol	NDR [0.2] (0.1)	ND (0.1)	ND (0.3)
4,5-dichloroguaiacol	**1.9** (0.1)	**0.8** (0.1)	**1.8** (0.1)
3,4-dichlorocatechol	ND (0.1)	ND (0.1)	ND (0.1)
3,6-dichlorocatechol	ND (0.1)	ND (0.1)	ND (0.1)
3,5-dichlorocatechol	ND (0.1)	ND (0.1)	ND (0.1)
4,5-dichlorocatechol	**0.6** (0.1)	NDR [0.8] (0.1)	NDR [0.6] (0.1)
2,3,5,6-tetrachlorophenol	ND (0.1)	ND (0.1)	ND (0.1)
2,3,4,6-tetrachlorophenol	ND (0.1)	ND (0.1)	ND (0.1)
2,3,4,5-tetrachlorophenol	ND (0.1)	ND (0.1)	ND (0.1)
3,4,6-trichloroguaiacol	ND (0.1)	ND (0.1)	ND (0.1)
3,4,5-trichloroguaiacol	**0.3** (0.1)	**1.1** (0.1)	**0.4** (0.1)
4,5,6-trichloroguaiacol	ND (0.1)	ND (0.1)	ND (0.3)
3,4,6-trichlorocatechol	ND (0.1)	ND (0.1)	ND (0.1)
3,4,5-trichlorocatechol	NDR [0.7] (0.1)	ND (0.1)	ND (0.1)
pentachlorophenol	ND (0.1)	ND (0.1)	ND (0.6)
3,4,5,6-tetrachloroguaiacol	ND (0.1)	ND (0.1)	ND (0.1)
3,4,5,6-tetrachlorocatechol	ND (0.3)	ND (0.1)	**0.2** (0.04)

Table A 2: Continued

Sample Group	Heptageniidae - duplicate Agassiz #1	Heptageniidae - Agassiz #2	Perlodidae / Perlidae - Herrling #1
Sample Mass (g)	8.7 g wet mass	10.0 g wet mass	5.6 g wet mass
Chlorinated Phenolics			
4-chlorophenol	ND (0.4)	ND (0.2)	ND (0.1)
2,6-dichlorophenol	ND (0.2)	ND (0.1)	ND (0.7)
2,4/2,5-DCP	ND (0.7)	ND (0.7)	ND (1.1)
3,5-dichlorophenol	ND (0.3)	ND (0.1)	ND (0.3)
2,3-dichlorophenol	ND (0.1)	ND (0.1)	ND (0.1)
3,4-dichlorophenol	ND (0.3)	ND (0.2)	ND (0.3)
6-chloroguaiacol	ND (0.1)	ND (0.1)	ND (0.1)
4-chloroguaiacol	ND (0.1)	ND (0.1)	ND (0.1)
5-chloroguaiacol	ND (0.1)	NDR [2.3] (0.1)	ND (0.1)
2,4,6-trichlorophenol	ND (0.1)	**0.02** (0.01)	ND (0.1)
2,3,6-trichlorophenol	ND (0.1)	ND (0.1)	ND (0.1)
2,3,5-trichlorophenol	ND (0.1)	ND (0.1)	ND (0.1)
2,4,5-trichlorophenol	ND (0.1)	ND (0.1)	ND (0.1)
2,3,4-trichlorophenol	ND (0.1)	ND (0.1)	ND (0.4)
3,4,5-trichlorophenol	ND (0.3)	ND (0.3)	ND (0.3)
3-chlorocatechol	ND (0.3)	ND (0.1)	ND (0.1)
4-chlorocatechol	ND (0.1)	ND (0.1)	ND (0.3)
3,4-dichloroguaiacol	ND (0.1)	ND (0.1)	ND (0.1)
4,6-dichloroguaiacol	ND (0.3)	ND (0.3)	ND (0.2)
4,5-dichloroguaiacol	**2.5** (0.1)	**1.9** (0.1)	ND (0.4)
3,4-dichlorocatechol	ND (0.1)	ND (0.1)	NQ
3,6-dichlorocatechol	ND (0.2)	ND (0.4)	NQ
3,5-dichlorocatechol	ND (0.1)	NDR [0.7] (0.1)	NQ
4,5-dichlorocatechol	NDR [0.9] (0.1)	NDR [1.2] (0.1)	NQ
2,3,5,6-tetrachlorophenol	ND (0.1)	ND (0.1)	ND (0.1)
2,3,4,6-tetrachlorophenol	ND (0.1)	ND (0.1)	ND (0.1)
2,3,4,5-tetrachlorophenol	ND (0.1)	ND (0.1)	ND (0.1)
3,4,6-trichloroguaiacol	ND (0.1)	ND (0.04)	ND (0.09)
3,4,5-trichloroguaiacol	**0.6** (0.04)	**0.5** (0.04)	**0.6** (0.1)
4,5,6-trichloroguaiacol	ND (0.1)	NDR [0.1] (0.03)	ND (0.1)
3,4,6-trichlorocatechol	ND (0.1)	ND (0.3)	ND (0.1)
3,4,5-trichlorocatechol	NDR [1.6] (0.05)	**1.1** (0.04)	NDR [0.5] (0.1)
pentachlorophenol	ND (0.2)	ND (0.1)	ND (0.1)
3,4,5,6-tetrachloroguaiacol	ND (0.1)	ND (0.2)	ND (0.1)
3,4,5,6-tetrachlorocatechol	ND (0.2)	**0.6** (0.04)	ND (0.2)

Table A 2: Continued

Sample Group	Perlodidae / Perlidae - Herrling #2	Perlodidae / Perlidae - Agassiz #1	Perlodidae / Perlidae - Agassiz #2
Sample Mass (g)	5.0 g wet mass	5.1 g wet mass	5.2 g wet mass
Chlorinated Phenolics			
4-chlorophenol	ND (0.1)	ND (0.1)	ND (0.6)
2,6-dichlorophenol	ND (0.1)	ND (0.1)	ND (0.6)
2,4/2,5-DCP	ND (1.2)	NDR [1.0] (0.1)	ND (1.2)
3,5-dichlorophenol	ND (0.1)	ND (0.1)	ND (0.1)
2,3-dichlorophenol	ND (0.1)	ND (0.1)	ND (0.1)
3,4-dichlorophenol	ND (0.2)	ND (0.3)	ND (0.3)
6-chloroguaiacol	ND (0.1)	ND (0.1)	ND (0.1)
4-chloroguaiacol	ND (0.1)	ND (0.1)	ND (0.1)
5-chloroguaiacol	ND (0.1)	ND (0.1)	ND (0.1)
2,4,6-trichlorophenol	ND (0.1)	ND (0.1)	ND (0.1)
2,3,6-trichlorophenol	ND (0.1)	ND (0.1)	ND (0.1)
2,3,5-trichlorophenol	ND (0.1)	ND (0.1)	ND (0.1)
2,4,5-trichlorophenol	ND (0.1)	ND (0.1)	ND (0.1)
2,3,4-trichlorophenol	ND (0.1)	ND (0.1)	ND (0.1)
3,4,5-trichlorophenol	ND (0.1)	ND (0.1)	ND (0.1)
3-chlorocatechol	ND (0.1)	ND (0.1)	ND (0.1)
4-chlorocatechol	ND (0.1)	ND (0.2)	ND (0.1)
3,4-dichloroguaiacol	ND (0.3)	ND (0.1)	ND (0.1)
4,6-dichloroguaiacol	ND (0.3)	ND (0.3)	ND (0.3)
4,5-dichloroguaiacol	ND (0.3)	ND (0.4)	ND (0.2)
3,4-dichlorocatechol	ND (0.1)	ND (0.1)	NQ
3,6-dichlorocatechol	ND (0.1)	ND (0.3)	NQ
3,5-dichlorocatechol	ND (0.1)	ND (0.1)	NQ
4,5-dichlorocatechol	ND (0.6)	NDR [1.5] (0.1)	NQ
2,3,5,6-tetrachlorophenol	ND (0.1)	ND (0.1)	ND (0.1)
2,3,4,6-tetrachlorophenol	ND (0.1)	ND (0.2)	ND (0.1)
2,3,4,5-tetrachlorophenol	ND (0.07)	ND (0.1)	ND (0.1)
3,4,6-trichloroguaiacol	ND (0.1)	ND (0.1)	ND (0.1)
3,4,5-trichloroguaiacol	**0.2** (0.1)	**0.5** (0.1)	**0.5** (0.1)
4,5,6-trichloroguaiacol	ND (0.1)	ND (0.1)	ND (0.1)
3,4,6-trichlorocatechol	ND (0.1)	ND (0.3)	ND (0.1)
3,4,5-trichlorocatechol	ND (0.3)	ND (0.4)	ND (0.1)
pentachlorophenol	ND (0.2)	ND (0.1)	ND (0.2)
3,4,5,6-tetrachloroguaiacol	ND (0.1)	ND (0.1)	ND (0.1)
3,4,5,6-tetrachlorocatechol	ND (0.1)	ND (0.1)	ND (0.1)

Table A 2: Continued

Sample Group	miscellaneous stoneflies - Herrling	miscellaneous stoneflies - Agassiz	*Hydropsyche* - Herrling and Agassiz
Sample Mass (g)	5.4 g wet mass	8.06 g wet mass	6.5 g wet mass
Chlorinated Phenolics			
4-chlorophenol	NDR [2.1] (0.3)	NDR [0.4] (0.3)	NDR [1.9] (0.2)
2,6-dichlorophenol	ND (0.2)	ND (0.2)	ND (0.3)
2,4/2,5-DCP	NDR [0.4] (0.1)	NDR [1.2] (0.1)	NDR [2.1] (1.1)
3,5-dichlorophenol	NDR [0.3] (0.2)	NDR [0.4] (0.2)	NDR [0.7] (0.2)
2,3-dichlorophenol	ND (0.2)	ND (0.2)	ND (0.1)
3,4-dichlorophenol	ND (0.1)	ND (0.1)	NDR [0.2] (0.1)
6-chloroguaiacol	NDR [0.2] (0.1)	NDR [0.2] (0.2)	NDR [0.3] (0.1)
4-chloroguaiacol	ND (0.1)	ND (0.2)	ND (0.2)
5-chloroguaiacol	NDR [0.4] (0.2)	NDR [0.8] (0.2)	NDR [2.4] (0.2)
2,4,6-trichlorophenol	NDR [0.3] (0.1)	NDR [1.0] (0.2)	**1.4** (0.1)
2,3,6-trichlorophenol	ND (0.1)	ND (0.2)	ND (0.1)
2,3,5-trichlorophenol	ND (0.1)	ND (0.2)	ND (0.1)
2,4,5-trichlorophenol	ND (0.1)	ND (0.1)	ND (0.1)
2,3,4-trichlorophenol	ND (0.1)	ND (0.2)	**0.2** (0.1)
3,4,5-trichlorophenol	ND (0.1)	ND (0.1)	ND (0.1)
3-chlorocatechol	NDR [0.3] (0.3)	NDR [0.3] (0.3)	NDR [2.3] (0.4)
4-chlorocatechol	ND (0.4)	ND (0.4)	ND (0.4)
3,4-dichloroguaiacol	**0.2** (0.1)	**0.3** (0.1)	**0.2** (0.1)
4,6-dichloroguaiacol			
4,5-dichloroguaiacol	**1.8** (0.2)	**3.0** (0.2)	**2.0** (0.2)
3,4-dichlorocatechol	ND (0.7)	ND (0.4)	ND (0.6)
3,6-dichlorocatechol	ND (0.8)	ND (0.4)	ND (0.6)
3,5-dichlorocatechol	ND (0.6)	NDR [1.0] (0.3)	NDR [1.4] (0.5)
4,5-dichlorocatechol	ND (0.8)	NDR [0.6] (1.0)	NDR [1.8] (0.6)
2,3,5,6-tetrachlorophenol	ND (0.4)	ND (0.3)	ND (0.5)
2,3,4,6-tetrachlorophenol	ND (0.5)	ND (0.4)	ND (0.6)
2,3,4,5-tetrachlorophenol	ND (0.3)	ND (0.2)	ND (0.3)
3,4,6-trichloroguaiacol	ND (0.3)	ND (0.3)	ND (0.4)
3,4,5-trichloroguaiacol	**0.7** (0.3)	**1.8** (0.3)	**1.9** (0.3)
4,5,6-trichloroguaiacol	ND (0.2)	**0.3** (0.2)	**0.6** (0.2)
3,4,6-trichlorocatechol	ND (0.3)	ND (0.3)	ND (0.6)
3,4,5-trichlorocatechol	NDR [0.4] (0.3)	NDR [0.8] (0.2)	**2.4** (0.5)
pentachlorophenol	ND (0.4)	ND (0.3)	ND (0.4)
3,4,5,6-tetrachloroguaiacol	ND (0.3)	ND (0.3)	ND (0.3)
3,4,5,6-tetrachlorocatechol	ND (0.2)	ND (0.5)	ND (0.7)

Table A 2: Continued

Sample Group	*Ephemerella* - Herrling and Agassiz	Tissue Blank #1	Tissue Blank #2
Sample Mass (g)	5.0 g wet mass	7.4 g wet mass	6.9 g wet mass
Chlorinated Phenolics			
4-chlorophenol	NDR [4.0] (0.6)	ND (0.2)	NDR [1.4] (0.2)
2,6-dichlorophenol	ND (0.6)	ND (0.2)	ND (0.2)
2,4/2,5-DCP	NDR [1.7] (0.4)	ND (0.2)	NDR [1.0] (0.1)
3,5-dichlorophenol	NDR [1.2] (0.5)	ND (0.2)	NDR [0.4] (0.2)
2,3-dichlorophenol	ND (0.5)	ND (0.2)	ND (0.1)
3,4-dichlorophenol	ND (0.3)	ND (0.1)	ND (0.1)
6-chloroguaiacol	ND (0.5)	ND (0.07)	NDR [0.2] (0.1)
4-chloroguaiacol	ND (0.6)	ND (0.08)	ND (0.1)
5-chloroguaiacol	NDR [1.0] (0.6)	ND (0.08)	NDR [0.3] (0.1)
2,4,6-trichlorophenol	ND (0.5)	ND (0.02)	ND (0.1)
2,3,6-trichlorophenol	ND (0.4)	ND (0.08)	ND (0.1)
2,3,5-trichlorophenol	ND (0.4)	ND (0.08)	ND (0.1)
2,4,5-trichlorophenol	ND (0.3)	ND (0.06)	ND (0.1)
2,3,4-trichlorophenol	ND (0.3)	ND (0.07)	ND (0.1)
3,4,5-trichlorophenol	**1.3** (0.3)	ND (0.06)	ND (0.1)
3-chlorocatechol	NDR [5.6] (1.0)	ND (0.2)	NDR [0.5] (0.2)
4-chlorocatechol	ND (1.0)	ND (0.2)	ND (0.4)
3,4-dichloroguaiacol	ND (0.2)	ND (0.1)	ND (0.1)
4,6-dichloroguaiacol		ND (0.2)	
4,5-dichloroguaiacol	NDR [0.6] (0.4)	ND (0.1)	ND (0.1)
3,4-dichlorocatechol	ND (1.0)	NQ	ND (0.9)
3,6-dichlorocatechol	ND (1.0)	NQ	ND (1.0)
3,5-dichlorocatechol	NDR [1.3] (0.7)	NQ	ND (0.9)
4,5-dichlorocatechol	ND (1.0)	NQ	ND (1.0)
2,3,5,6-tetrachlorophenol	ND (1.0)	ND (0.1)	ND (0.4)
2,3,4,6-tetrachlorophenol	ND (1.1)	ND (0.1)	ND (0.4)
2,3,4,5-tetrachlorophenol	ND (0.6)	ND (0.08)	ND (0.2)
3,4,6-trichloroguaiacol	ND (0.6)	ND (0.1)	ND (0.2)
3,4,5-trichloroguaiacol	ND (0.6)	ND (0.1)	ND (0.2)
4,5,6-trichloroguaiacol	ND (0.4)	ND (0.08)	ND (0.1)
3,4,6-trichlorocatechol	ND (0.7)	ND (0.1)	ND (0.2)
3,4,5-trichlorocatechol	ND (0.5)	ND (0.1)	ND (0.2)
pentachlorophenol	ND (0.6)	ND (0.06)	ND (0.2)
3,4,5,6-tetrachloroguaiacol	ND (0.8)	ND (0.05)	ND (0.3)
3,4,5,6-tetrachlorocatechol	ND (1.4)	ND (0.3)	ND (2.3)

Table A 2: Continued

Sample Group	*Cottus asper* - Herrling	*Cottus asper* - Agassiz, duplicate #1	*Cottus asper* - Agassiz, duplicate #2
Sample Mass (g)	5.3 g wet mass	9.4 g wet mass	9.7 g wet mass
Chlorinated Phenolics			
4-chlorophenol	NDR [1.7] (0.2)	NDR [1.1] (0.1)	NDR [1.0] (0.1)
2,6-dichlorophenol	NDR [0.2] (0.2)	ND (0.2)	ND (0.2)
2,4/2,5-DCP	ND (0.7)	NDR [1.0] (0.1)	NDR [1.1] (0.1)
3,5-dichlorophenol	NDR [0.8] (0.2)	NDR [0.8] (0.1)	NDR [0.6] (0.1)
2,3-dichlorophenol	ND (0.1)	ND (0.1)	ND (0.08)
3,4-dichlorophenol	ND (0.1)	ND (0.09)	ND (0.06)
6-chloroguaiacol	NDR [0.3] (0.1)	NDR [0.3] (0.2)	NDR [0.4] (0.1)
4-chloroguaiacol	ND (0.1)	ND (0.2)	ND (0.1)
5-chloroguaiacol	NDR [1.0] (0.1)	NDR [2.4] (0.2)	NDR [1.6] (0.1)
2,4,6-trichlorophenol	NDR [1.8] (0.1)	NDR [2.8] (0.2)	**0.4** (0.01)
2,3,6-trichlorophenol	ND (0.1)	ND (0.1)	ND (0.08)
2,3,5-trichlorophenol	ND (0.1)	ND (0.1)	ND (0.08)
2,4,5-trichlorophenol	ND (0.1)	ND (0.1)	ND (0.06)
2,3,4-trichlorophenol	NDR [0.2] (0.1)	ND (0.3)	ND (0.3)
3,4,5-trichlorophenol	ND (0.1)	ND (0.1)	ND (0.06)
3-chlorocatechol	ND (0.3)	NDR [2.9] (0.3)	NDR [1.0] (0.2)
4-chlorocatechol	ND (0.3)	ND (0.3)	ND (0.2)
3,4-dichloroguaiacol	NDR [0.3] (0.1)	**0.7** (0.1)	**0.5** (0.03)
4,6-dichloroguaiacol			
4,5-dichloroguaiacol	**2.2** (0.1)	**3.0** (0.1)	**2.9** (0.1)
3,4-dichlorocatechol	ND (0.4)	ND (0.3)	ND (0.4)
3,6-dichlorocatechol	ND (0.5)	ND (0.3)	ND (0.5)
3,5-dichlorocatechol	ND (0.4)	ND (0.4)	ND (0.4)
4,5-dichlorocatechol	NDR [1.0] (0.4)	ND (0.3)	ND (0.4)
2,3,5,6-tetrachlorophenol	ND (0.3)	ND (0.4)	ND (0.2)
2,3,4,6-tetrachlorophenol	ND (0.3)	ND (0.4)	NDR [0.4] (0.3)
2,3,4,5-tetrachlorophenol	ND (0.2)	ND (0.2)	ND (0.1)
3,4,6-trichloroguaiacol	ND (0.2)	ND (0.3)	ND (0.2)
3,4,5-trichloroguaiacol	**2.3** (0.2)	**5.8** (0.3)	**5.7** (0.2)
4,5,6-trichloroguaiacol	**0.4** (0.2)	**1.1** (0.2)	**1.1** (0.1)
3,4,6-trichlorocatechol	ND (0.2)	ND (0.4)	ND (0.1)
3,4,5-trichlorocatechol	ND (0.1)	ND (0.3)	NDR [0.1] (0.1)
pentachlorophenol	**0.4** (0.2)	**0.7** (0.3)	**0.8** (0.3)
3,4,5,6-tetrachloroguaiacol	ND (0.3)	NDR [0.5] (0.3)	NDR [0.5] (0.2)
3,4,5,6-tetrachlorocatechol	ND (0.6)	ND (0.6)	ND (0.5)