Benthic Conditions in Lyons Creek East
(Niagara River Area of Concern) 2002 - 2010

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SUMMARY

Lyons Creek East (LCE), located within the Niagara River Area of Concern, contains levels of polychlorinated biphenyls (PCBs) in sediment elevated above sediment quality guidelines. Detrimental effects on biota have been reported in studies dating back to 1990. As part of the Great Lakes Action Plan, Environment Canada assessed conditions in LCE in 2002/2003, focusing on the area between the Welland Canal Bypass and Highway 140. In 2008, monitored natural recovery was selected as the best option for the management of the sediments. As part of the monitoring program, Environment Canada sampled LCE in 2010. This report presents those results and a comparison to conditions in 2002/2003.

In September 2010, Environment Canada collected overlying water for physicochemical analyses, surficial sediment for physicochemical analyses and laboratory toxicity tests, and benthic invertebrates for community structure and tissue contaminant analysis. Seven of the eleven LCE sites and 3 of the 6 neighbouring reference creek sites sampled in 2002/2003 were resampled. Resident benthic invertebrate tissue samples were collected at a subset of locations. Sediment and tissue samples were analyzed for PCBs and other organic contaminants, and a series of physicochemical variables were measured in the sediment and overlying water. Using multivariate techniques, the benthic community composition and sediment toxicity at 2010 LCE sites were compared to those in neighbouring reference creeks, Great Lakes reference sites (toxicity component only), and to co-located sites sampled in 2002/2003. Contaminant levels were compared to sediment guidelines and trends were examined from 2002-2010.

Sediment total PCB congeners (≤ 36 µg/g in 2010 cf. to ≤ 19 µg/g in 2002/03), total PAHs (≤ 38 µg/g cf. to ≤ 63 µg/g in 2002/03) and zinc (≤ 3,997 µg/g cf. to ≤ 7,969 µg/g in 2002/03) in LCE at sites from just below a former industrial outfall to at least 400 m downstream of Highway 140 continue to be elevated above sediment quality guidelines and neighboring reference creek concentrations (≤ 0.02 µg/g , < detection limit, and ≤ 115 µg/g, for PCBs, PAHs and Zn, respectively). Higher sediment PCB concentrations in 2010 at some sites may reflect movement of sediments and contaminants from upstream to downstream locations in the creek and/or within-site spatial heterogeneity. Invertebrate total PCB concentrations were similar or lower in 2010 relative to 2002/2003 but remain elevated compared to those in neighbouring reference sites, and were above tissue residue guidelines from downstream of the former outfall to at least Highway 140. Toxicity continues to be limited to the upper creek (≤ 1 km downstream of the Welland Canal Bypass). Overall, there was similar or reduced toxicity in 2010 at co-located sites. Resident benthic communities in LCE appear to be different than those in neighbouring reference creeks, with declines in richness, abundance and diversity evident at most sites in 2010; however, declines were

also observed in the reference creeks. Changes observed in the benthic community composition may reflect anthropogenic impacts and/or natural temporal variation but more sampling events would be required to adequately reflect variability intrinsic in stream benthic communities. It is recommended that LCE continue to be monitored periodically to demonstrate whether the trends observed continue with time. The area of LCE from Ridge Road to ~400 m downstream of Highway 140 remains the most critical area of the creek with the poorest sediment quality, some toxicity, and possibly altered benthic communities.

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ABBREVIATIONS, ACRONYMS AND SYMBOLS

adj	adjusted
AOC	area of concern
BEC	Beaver Creek
BLC	Black Creek
BMF	biomagnification factor
BSAF	biota-sediment accumulation factor
BTEX	benzene, toluene, ethylbenzene and xylene
CI	confidence interval
CL	confidence limit
DL	dioxin-like
dw	dry weight
d/s	downstream
EC	Environment Canada
FCM	food chain multiplier
GL	Great Lakes
GLWQA	Great Lakes Water Quality Agreement
IJC	International Joint Commission
inv	invertebrate
LC	Lyons Creek
LCE	Lyons Creek East
LEL	lowest effect level
max	maximum
min	minimum
MOE	Ministry of the Environment (Ontario)
NPCA	Niagara Peninsula Conservations Authority
OCP	Organochlorine pesticides
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PEL	probable effect level
PHC	Petroleum hydrocarbons
QA/QC	quality assurance/quality control
QEW	Queen Elizabeth Way Highway
RAP	remedial action plan
RC	reference concentration
SEL	severe effect level
SQI	Sediment Quality Index
TC	Tee Creek
TEF	toxic equivalency factor
TEQ	toxic equivalency unit
TKN	total Kjeldahl nitrogen
TOC	total organic carbon
TP	total phosphorus
TRG	tissue residue guideline
wt	weight
ww	wet weight
$[x]_i$	concentration of substance *x* in matrix *i*
UC	Usshers Creek

1 INTRODUCTION

1.1 Background

Benthic conditions in Lyons Creek East (LCE), located within the Niagara River Area of Concern, are evaluated periodically as part of Environment Canada's Great Lakes program. In 2002 and 2003, a benthic study was conducted by Environment Canada to assess general conditions along the creek (Milani and Grapentine 2006; Milani et al. 2013). The studies indicated the primary contaminants of concern to be polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), zinc (Zn) and p,p'-DDE due to frequent exceedences of sediment guidelines. Sediment PCBs (up to 19 µg/g), PAHs (up to 63 µg/g) and Zn (up to 7,969 µg/g) were elevated above the sediment quality guidelines along most of the creek; however, the upper 1.5 km portion of the creek, from the pumping station at the Welland Canal to Highway 140, was the most highly contaminated and therefore the main focus for biological work. Four lines of evidence were used to evaluate the environmental conditions:

1. **Sediment Physico-Chemistry** – to quantify the degree to which sediments are contaminated and provide information on physicochemical attributes of the sediment to assist in the interpretation any observed biological effects.

2. **Benthic Macroinvertebrate Community Structure** – to determine whether natural faunal assemblages in Lyons Creek differ from those in uncontaminated local reference locations.

3. **Sediment Toxicity** – to provide supporting evidence that responses observed in the community are associated with sediment contaminants rather than other potential stressors.

4. **Bioaccumulation/Biomagnification of PCBs** – to provide evidence of bioavailability, and assess the risk to higher trophic levels due to biomagnification.

Although severe toxicity was evident at several locations in the upper creek in 2002/2003, resident benthic communities were minimally affected by sediment contamination. The cause of toxicity was likely related to a combination of stressors, including PCBs, PAHs and metals. The bioaccumulation assessment focused on PCBs due to their biomagnifiable nature. Concentrations in resident macroinvertebrates were up to two orders of magnitude higher than those found in reference creeks and were above tissue residue guidelines, indicating a potential risk for consumers of benthos. This risk was not limited to the upper 1.5 km where other effects were seen.

In 2008, monitored natural recovery was selected as the best option for management of the LCE sediment (NPCA 2014). As part of a monitoring program to ensure continued natural recovery, Environment Canada returned to LCE in 2010 to evaluate benthic conditions and provide a comparison to those from 2002/2003.

1.2 Study Objective

The objective of the 2010 study was to evaluate benthic conditions in the creek and determine whether they are improving over time. The assessment of Milani and Grapentine (2006) offered the most recent and extensive data against which changes in benthic conditions through time could be compared. Benthic conditions at previously sampled stations were assessed for:

(a) Spatial differences between contaminated and reference sediments, and

(b) Temporal differences between conditions before and after 2002/2003 at co-located sites.

2 METHODS

2.0 Sampling Design

Sampling stations were arrayed in a gradient design supplemented with reference sites. The mixed (gradient + control/potential impact) sampling design allowed several types of comparisons for assessing the distribution of PCBs in sediment and biota, including a spatial analysis of PCB conditions, in which locations of elevated PCB in sediment and invertebrates were identified. The location of stations were selected on the basis of (a) results from the 2002/2003 study, (b) representing a wide range of PCBs levels in sediment (c) representing least contaminated/reference conditions in the area, and (d) overlapping locations of previous studies (co-located sites). Sediment was obtained from the top 0 - 10 cm layer of creek bed as this layer includes the vertical home range of most benthic invertebrates.

2.1 Sample Collection and Handling

The survey was conducted September 7 – 13, 2010. Overlying water, surficial (top 10 cm) sediment for chemical and physical analyses and toxicity tests, and benthic invertebrates for community structures analysis were collected at 10 sites: 7 in LCE and 3 in neighbouring reference creeks. Station positions were determined using WAAS enabled hand-held Garmin GPS. All sites sampled in 2002/2003 were revisited as closely as possible in 2010 but in some cases, sites needed to be moved. Site LC03 was moved ~ 17 m downstream because sediment was scoured away at the original station and site LC16 was located 60 m downstream closer to Highway 140 in 2010 and therefore could be considered a new site. Remaining sites were < 10 m apart from original locations (Table 1). Benthic invertebrate tissue samples were collected at 4 of the 7 LCE sites and all 3 reference sites. The 2002-2010 site positions and distance between co-located sites between sampling years is provided in Table 1. Site descriptions are provided in Table 2. The location of LCE sites and reference creeks is shown in Figs. 1 and 2, respectively.

Overlying water was collected from just above the sediment surface using a 1 L Niskin bottle for on-site measurements of temperature, conductivity, pH, and dissolved oxygen with YSI water quality instruments. Water samples were saved for laboratory analysis of alkalinity, total phosphorus (P), nitrates/nitrites-N, ammonia-N and total Kjeldahl nitrogen (TKN).

Benthic invertebrate community samples were collected using five 10-cm length × 6.5-cm diameter acrylic core tubes which were subsampled from a 40 cm × 40 cm steel mini box core frame inserted into the sediment at 7 of the 10 sites. The content of the tubes were sieved through a 250-µm mesh screen and the residue on the screen preserved with 10% buffered formalin for later identification. The remaining top 10-cm layer of sediment inside the frame was removed by grab, homogenized in a Pyrex dish, and allocated to containers for analysis of sediment organic and inorganic contaminants, nutrients and grain size listed in Table 3. At remaining three sites, which were too deep to insert the box core frame into the sediment, the benthic community and sediment samples were collected using a petite Ponar; three grabs were collected for benthic community samples and one grab for sediment physcicochemical properties. The benthic community grabs were sieved in their entirety and residue preserved with formalin as indicated above; samples were transferred to 70% ethanol after a minimum of 72 hours in formalin. Sorting, enumeration, identification (family level) and verification of benthic invertebrate samples were performed by EcoAnalysts, Inc. (Moscow, Idaho, USA). Nonbenthic and colonial taxa and microinvertebrates (e.g., poriferans, nematodes, copepods, and cladocerans) were excluded.

Sediment for toxicity tests was collected using a petite Ponar grab. Five field replicates were collected from each site, placed in plastic bags in a bucket, and stored at 4°C until tests were initiated at Environment Canada’s Ecotoxicology laboratory (Burlington, Ontario).

Resident macroinvertebrates were collected using a petite Ponar sampler from 4 of the 7 Lyons Creek sites and the 3 reference sites for measurement of PCBs and PAHs in tissue. At each site, sediment was collected to fill 2 68-L plastic tubs (approximately 20-30 petite Ponar grabs per site) with ample site water. A small scoop of surficial sediment was taken from each grab and set aside in a glass tray until the tubs were filled after which the sediment was homogenized and distributed to a sample container for PCB congener analysis. (This was a separate sample to the PCB sample indicated above.) Oligochaetes, chironomids, amphipods, and isopods were removed from the sediment by wet sieving (using water pumped from the Welland Canal) the sediment through 12” stainless steel sieves (500-µm mesh).

Macroinvertebrates were sorted into separate taxa in glass trays using stainless steel instruments. Due to sample size requirements for PCB analysis and time constraints, only one sample of each taxon was collected per site. Amphipods were collected from all 10 sites, oligochaetes from 8 sites (6 LCE and 2 reference), and isopods from two sites (1 LCE and 1 reference). Biota were rinsed with reverse osmosis water, placed in pre-weighed and pre-cleaned (20% HCl, hexane rinsed) 5-mL scintillation vials, weighed and frozen (-20°C) without allowing time to clear sediment from their guts. Macroinvertebrate samples were later freeze-dried and reweighed.

2.2 Sample Analysis

Analyses of overlying water alkalinity, total phosphorus, nitrates/nitrites-N, ammonia-N and total Kjeldahl nitrogen were performed using procedures outlined in Cancilla (1994) and Environment Canada (2010).

Sediments were analyzed by Caduceon Environmental Laboratories (Ottawa, Ontario) for total mercury by cold-vapor atomic absorption (EPA method 7471A); trace metals (hot aqua regia extracted) by Inductively Coupled Plasma (ICP)- Atomic Emission Spectroscopy; EPA method 6010 or ICP-Mass Spectrometry (MS) EPA method 6020 (USEPA 2010a); major oxides (whole rock) by in house procedure); loss on ignition by in house procedure; total organic carbon by combustion method using a Leco carbon analyzer; total phosphorus by automated colorimetry (EPA method 365.4) (USEPA 1983); and total Kjeldahl nitrogen by semiautomated colorimetry (EPA method 351.2) (USEPA 1993).

Organic contaminant analyses were performed by ALS Laboratory Group in Burlington, Ontario for PCB congener analysis and in Waterloo, Ontario for remaining organic contaminants. Volatile organics (BTEX and F1) were analyzed by Gas Chromatography with flame ionization detection (GC/FIC)-headspace, F2-F4 by GC/FIC-extraction, and F4G gravimetrically as per the CCME Canada-Wide petroleum method for hydrocarbon analysis (CCME 2008). Semivolatile organic compounds (PAHs and OCPs) were determined by EPA 8270D-GC/MS (USEPA 2010a), oil and grease samples by extraction and gravimetrically modified from SM 5520 (APHA et al. 2006), and PCB congeners by High Resolution MS (HRMS) using USEPA method 1668C (USEPA 2010b).

Particle size distribution (percents gravel, sand, silt and clay) was determined by EC's Sedimentology Laboratory (Burlington, Ontario) using sieving apparatus and a Horiba Partica Laser Diffraction Particle Size Analyzer (LA-950). A sodium metaphosphate solution was added to 5-10 g of freeze dried sediment sample, mixed for 15 minutes, and poured through a 4.0 Phi sieve (62.5 µm). The material retained on the sieve (sand and gravel) was dried and weighed. If the weight was more than 10% of the sample, the material was sieved using sieve stack procedures described in Duncan and LaHaie (1979). The solution that passed through the sieve (silt and clay) was analyzed using the laser analyzer and the computer software programs Merge (Frazer 1990) and Sedi Web Page (Gorrie 2008) used to convert the light scattering to particle size. The particle size analysis methodology for the 2010 samples differed from that from the 2002/2003 samples, which were analyzed using a Sedigraph analyzer. The Sedigraph analyser measures the sedimentation rates of different size particles (gravity induced) suspended in a liquid with known properties and therefore would not be directly comparable to the laser analyzer. Therefore, particle size fractions < 62.5 um cannot be directly compared between studies.

2.3 Whole Sediment Toxicity Tests

Sediments were initially sieved through a 250-µm mesh sieve prior to testing to eliminate native organisms which have been shown to interfere with toxicity responses (Reynoldson et al. 1994). For each replicate treatment, 600 mL of sediment was wet sieved with 2 L of carbon-filtered, aerated and dechlorinated City of Burlington (Ontario) tap water (water characteristics (means): conductivity 312 µS/cm; pH 8.2; hardness 127 mg/L; alkalinity 84 mg/L; chloride ion 26 mg/L). Sediment was allowed to settle for a minimum of 24 hours and water decanted; decanted water was used as the overlying water in the toxicity tests.

Four invertebrate species were used in toxicity tests: the amphipod *Hyalella azteca*, the chironomid *Chironomus riparius*, the oligochaete worm *Tubifex tubifex*, and the mayfly *Hexagenia* spp. Tests were conducted in 250-mL beakers containing 50-100 mL of sediment and 125-150 mL of overlying water, with the exception of the mayfly test, which were conducted in 1-L jars with 125 mL of sediment and 650 mL of overlying water. Tests were aerated for 7 to 10 days prior to the introduction of test organisms. All tests were run under static conditions in environmental chambers at 23°C ±1 °C, under a photoperiod of 16: 8-hour light:dark photoperiod and an illumination of approximately 500 lux, with the exception of the *T. tubifex* test which was run in the dark. Temperature, conductivity, pH, dissolved oxygen and ammonia were measured in the overlying water at the beginning and end of tests. Tests were initiated with the random addition of 15 organisms per beaker for *H. azteca* (juveniles 3-10 days old) and C. riparius (1st instar), 10 organisms per jar for *Hexagenia* spp. (5-10 mg wet weight, weighed prior to addition to jar), and 4 organisms (sexually mature adults) per beaker for *T. tubifex*. *H. azteca* and *C. riparius* beakers received 8 mg crushed Nutrafin® fish food flakes twice per week over the course of the exposure period. *Hexagenia* jars received 50 mg mixture of crushed Nutrafin® fish flakes, cereal grass and brewers yeast once per week. *T. tubifex* beakers received 80 mg crushed Nutrafin® fish flakes mixed directly into the sediment (prior to the introduction of worms) and no other feeding was carried out during the exposure period. Tests were terminated after 10 and 21 days for *C. riparius* and *Hexagenia* spp., respectively, and 28 days for both *H. azteca* and *T. tubifex*. At test termination, sediment was passed through a 250-µm screen for *C. riparius* and *H. azteca*, 500-µm screen for *Hexagenia* and through a 500-

µm and 250-µm sieve sequentially for *T. tubifex* to collect large worms and cocoons (500 µm) and small worms (250 µm). Amphipods, chironomids and mayflies were dried at 60°C to a constant weight. Test endpoints included percent survival and growth (increase in mg dry weight per individual) for *H. azteca*, C. *riparius* and *Hexagenia*. Initial weights of *H. azteca* and *C. riparius* were considered negligible. Initial mayfly wet weight was predicted to dry weight using a statistical model derived specifically for mayflies and growth was estimated as the difference between the initial and final dry weight. Test endpoints for *T. tubifex* included adult survival and reproduction which was assessed with three endpoints: total number of cocoons produced per adult, percent of cocoons that hatched, and total number of young produced per adult.

2.4 Data Analysis

2.4.1 Sediment Chemistry

To assess patterns of similarity among LCE sites, principal components analysis (PCA) was conducted on the sediment chemistry data (including contaminants of concern). The eigenanalysis was performed on the correlation matrix. Concentrations of the various chemical variables measured in the sediments were also compared to the 99th percentile of the neighbouring reference creek concentrations and where applicable, to the Provincial Sediment Quality Guidelines (PSQG) Lowest Effect Level (LEL) and Severe Effect Level (SEL) (Fletcher et al. 2008) and the Canadian SQG Probable Effect Level (PEL) (CCME 2001a). The LEL defines the level below which no effect on the majority of the sediment-dwelling organisms is expected. The SEL and PEL are concentrations frequently associated with adverse effects on the health of benthic organisms. To account for the contaminant mixtures present within each sediment sample, the metal and organic contaminant data (total PCBs and PAHs) were summarized using a site specific Sediment Quality Index (SQI). The SQI was modified from the Canadian Water Quality Index and was calculated using a two-component, scope and amplitude, SQI equation (Grapentine et al. 2002; Marvin et al. 2004a). The Canadian PELs were selected as guideline values; where the PEL was not available, SELs were used. Based on the SQI value, sediments were categorized as: excellent (95-100), good (80-94), fair (60-79), marginal (45-59), or poor (0-44) (Marvin et al. 2004a). Comparisons for individual contaminants were also made, showing conditions from 2002 to 2010. The key feature of the representations is the change through time in how the LCE sites compared to the reference sites.

2.4.2 Benthic Invertebrate Community

Benthic invertebrate community composition at Lyons Creek sites was compared to those from neighbouring reference creeks. These reference creeks were deemed appropriate for comparison to Lyons Creek based on five parameters: watershed area, stream order, wetland percentage, flow type and sediment type (Milani et al. 2013). The overall comparisons of LCE benthos data (65 macroinvertebrate family counts) to reference sites were conducted by semi strong hybrid multidimensional scaling (HMDS) (Belbin 1991) applied to a Bray-Curtis distance matrix. Three separate HMDS were conducted: 1) with the matching (3 co-located) unimpacted reference sites between sampling years, 2) with the 2010 LCE and reference data, and 3) using the entire set of unimpacted sites and LCE site data (2002-2010). A description of HMDS is provided in Milani et al. (2013). The extent to which HMDS adequately represents the relationships is reflected in the stress value (Kruskal and Wish 1978) which defines the amount of scatter around the line of best fit through the HMDS distances and the actual distances (Clarke 1993). The lower the stress value the better the representation; generally stress values > 0.2 yield plots which can potentially be misleading or difficult to interpret (Clarke 1993). Principal axis correlation, which finds the location of the best fitted vector presenting a variable in ordination space (Belbin 1993), was performed to examine the relationships between habitat (n = 33 variables) and benthos data. The observed pattern was tested using a Monte Carlo permutation procedure (Belbin 1993). HMDS was performed with PATN (Blatant Fabrications Pty Ltd 2008). The locations of Lyons Creek sites in ordination space were compared to prediction intervals (PIs) computed using the neighbouring reference creek benthic community data. PIs allowed the prediction of individual future observations with a given level of confidence (e.g., 95%). PIs were computed for each axis using the equation in Steele and Torrie (1980). Comparisons for commonly used community descriptors — total benthos, taxon richness, evenness, and Shannon-Weiner index as well as key macroinvertebrate taxa — were also made from 2002 to 2010. The key feature of the representations is the change through time in how the LCE sites compared to the reference sites.

2.4.3 Sediment Toxicity

Lyons Creek and neighbouring reference creek toxicity data were analysed with 136 Great Lakes (GL) reference sites toxicity data (Environment Canada unpublished data) using HMDS with Euclidean distance site × site association matrices calculated from range-standardized data. Five separate ordinations were conducted, each with 1-3 test or reference creek sites plus the GL reference sites. Principal axis correlation and Monte Carlo permutation tests (as described above) were conducted to examine relationships between habitat and toxicity data. This did not include organic contaminants however, as these data were not available for the GL reference sites. LCE and neighbouring reference creek ordination site scores were assessed by graphical comparison to confidence bands of GL reference site scores (Reynoldson et al. 2000, 2002). Three probability ellipses (90%, 99%, 99.9%) were constructed around the GL reference site scores, establishing four toxicity bands: Band 1 (within the 90% probability ellipse) = non-toxic; Band 2 (between the 90 and 99% ellipses) = potentially toxic; Band 3 (between the 99 and 99.9% ellipses) = toxic; and Band 4 (outside the 99.9% ellipse) = severely toxic. Test (and local reference creek) sites were categorized according to which band they fell in. To assess the contribution of organic contaminant data, patterns in sediment toxicity and sediment contamination were assessed graphically without the inclusion of GL reference data. Lyons Creek and neighbouring reference creek sites were ordinated again by HMDS, as a single group. Principal axis correlation and Monte Carlo permutation tests were conducted and this time included the sediment organic contaminant data (PCBs (total and TEQ), total PAHs, total PHCs, oil and grease), as well as sediment metal, nutrient, particle size data and the SQI. HMDS was performed with PATN (Blatant Fabrications Pty Ltd 2008) and probability ellipses constructed using SYSTAT (Systat Software Inc. 2007). Comparisons for the ten toxicity endpoints were also made, showing the change in conditions from 2002/2003 to 2010. The key feature of the representations is the change through time in how the LCE sites compared to the reference sites.

2.4.4 Contaminant Bioaccumulation in Benthos

Levels of PCBs and PAHs in LCE biota were compared to those in reference creeks and to those from co-located sites from 2002/2003; sites in which concentrations of total PCBs and PAHs in invertebrates were significantly elevated above background levels for the study area were also identified by comparing test site concentrations to the upper 99th percentile for the neighbouring reference sites.

Dioxin-like PCB concentrations in the tissues of benthic invertebrates, expressed in toxic equivalency (TEQ) units, were compared to Tissue Residue Guidelines (TRGs) for the protection of wildlife consuming aquatic biota developed by the Canadian Council of Ministers of the Environment (CCME 2001b). The World Health Organization toxic equivalency factors for birds (Van den Berg et al. 1998) were used in calculations of the TEQs for comparability with the avian-based TRG.

Relationships between concentrations of total PCBs in sediment ($[PCB]_{sed}$) and invertebrates ($[PCB]_{inv}$), normalized to TOC and lipids, respectively, were determined using linear regression analysis separately for each invertebrate taxon (amphipods and oligochaetes). Simple linear regression (ordinary least squares) was used for a single predictor ($[PCB]_{sed}$) model. Data points were limited to n=7 and n=5 for amphipod and oligochaete models, respectively.

2.5 Quality Assurance/Quality Control

One site (LC18) was randomly selected as a QA/QC stations where triplicate water, sediment and benthic community samples were collected for determination of within-site and among-sample variability. The variation among the field-replicated analytical data was examined using the coefficient of variation (CV) which is the ratio between standard deviation and the mean multiplied by 100.

Quality control procedures employed by analytical laboratories included the analysis of reagent blanks, matrix and surrogate spikes, certified reference materials, laboratory control samples and sample duplicates, which are used in each analytical run. Calibration standards were run before and after each run. Precision of sample duplicates was evaluated using the relative percent difference (RPD), defined as RPD $= (\times_1 - \times_2)/ ((\times_1 + \times_2)/2) \times 100$.

For the benthic invertebrate identification and enumeration performed by EcoAnalysts, Inc., 20-25% of every sample was resorted. If a 95% level sorting efficiency was not achieved the sample was resorted until a minimum of 95% was achieved. At least one specimen of each taxon encountered was kept in a separate vial to comprise a project reference collection. Internal quality assurance of the identifications involved examination of the reference collection by a second taxonomist to verify accuracy of all taxa identified. Additionally, 10% of samples were randomly selected and re-identified by a QA taxonomist. Data entry involved visual confirmations of the taxonomic identification and number of specimens in each taxon. Benthic data were entered directly on the Canadian Aquatic Biomonitoring Network (CABIN) database.

For toxicity tests, bias was assessed through the use of control sediment, which contains only background quantities of the analytes of interest. This “clean" sediment was collected from Long Point Marsh (Lake Erie) (42°35.213′ N, 80°27.130′ W) and was included in each test set. The assessment of organism response from the use of the control sediment established the test validity and data within the bias window (e.g., mean plus or minus two standard deviations and percent survival greater than a set limit) established for Long Point sediment was used in data analysis.

3 RESULTS AND DISCUSSION

3.1 QA/QC

Variability among replicate samples from a site in a measured analyte can be broken down into three sources: natural within-site heterogeneity in the distribution of the analyte in sediment or water, differences in handling among samples, and laboratory measurement error. Among-replicate sample variability estimates the overall “error” associated a sample from a site.

Three unique field replicate samples were collected during the sampling phase of the program at site LC18 and treated as separate samples throughout the rest of the sample preparation and analysis phases. The individual sets of samples are used to assess the overall (laboratory plus field) precision. The variability in field-replicate sample measurements, expressed as the coefficient of variation (CV), is provided in Appendix A, Tables A1-A3. Differences in variability were seen among the various parameters. For metals and nutrients, variability was quite low, with CVs ranging from 1.9 to 46.6% (median: 11.3%) (Table A1). Variability was also low for oil and grease with a CV of 21.3%, but much higher for the F2 – F4 petroleum hydrocarbons and PAH analytes, ranging from 67.2 to 88.8% (median: 71.1%), and from 33.2 to 54.7% (median: 45%), respectively (Table A2). Where analytes were not detected in the sediments, the CVs were not calculable (BTEX, F1 hydrocarbons, some PAHs and OCPs). Variability in PCB congeners was highest of all analytes measured, with CVs ranging from 13.8 to 99.1 (median: 65.0%) (Table A3). Typically higher CVs are seen where analytes present are in low concentrations and significant variability may exist in the field which may make interpretation of the results of the field replicates difficult (USEPA 1994). Generally, a failure to meet the measurement quality objectives for the field replicates would result in only a minor concern, indicating the existence of minor uncertainty in the data (assuming that the laboratory replicates show no major problem with analytical variability) (USEPA 1994). Such concerns should not be used in isolation to disqualify data from the sample or sample batch (Papp et al. 1989).

Laboratory duplicate

Analytical precision was measured by analyzing subsamples in duplicate (intralaboratory split samples). The relative percent difference (RPD), calculated for the laboratory determined values, are provided in Appendix A, Tables A1 and A4-A6. For metals and nutrients, values < 20% indicates that the measurements were within precision standards. The RPD for metals and nutrients ranged from 0 to 23.5% (median: 0.4%), with arsenic (As) and CaO just slightly above 20% (Table A1). The RPDs for PAHs, PHCs, and oil and grease were ≤ 9.9%; for OCPs, they were higher overall (range 1.2-48%; median: 24%) but were within precision limits for these compounds of 45-50% (Appendix A, Table A4). For PCB congeners, the RPDs ranged from 0 to 111% (median: 14%); while one value was quite high (PCB 4/10), 91% of RPDs were ≤25% (Table A5). The RPDs for congener group totals was ≤ 26.1 and for total PCBs was 0.6 (Table A6). These results indicated that generally there was good agreement between sample duplicates and that a high level of precision was achieved for sample measurements.

Laboratory control sample

Laboratory control samples (LCS) have known analytes and concentrations and are used to quantify the variance and bias of the chemical preparation and instrumental testing stages without matrix interference. The percent recovery of the target analytes in the LCS were compared to established control limits and assists in determining whether the laboratory is capable of making accurate and precise measurements at the required reporting limit. LCS, expressed in percent recovery, is provided in Appendix A, Tables A5, A7-A11. For sediment PCB congener analysis, LCS recoveries were very good, ranging from 90 to

120% (median: 100%) (Table A5). For F2-F4 PHCs and oil and grease, LCS recoveries ranged from 80-101% and were within QC limits (Table A7). For sediment PAH analysis, recovery of LCSs ranged from 76 to 104% (median: 94%) (Table A8), and for OCPs ranged from 42-100% (median: 79%) (Table A9). One OCP (pp-DDE) was outside the QC limits; however, due to the number of analytes, 10% may exceed QC limits and the analyte was not present in related samples. In the tissue PCB and PAH analytical runs, LCS recoveries were good and all within control limits, ranging from 101-114% (median: 106%) and from 78-129% (median: 114.5%), respectively (Tables A10-A11).

Reference material

Reference material is analyzed to assess the bias of measurements being made at the analytical laboratory. Reference materials commonly used include CRMs (certified reference materials) and SRMs (standard reference materials). Bias is determined by comparing the analytical results to the known value of the reference material, plus or minus an established acceptance range either provided with the reference material or agreed upon as part of the data quality objective process. For example for the USEPA ARCS Program, the accuracy requirement for bias in either SRMs or CRMs is that the measured value must be within +/-20 percent of the known concentration (USEPA 1994). For the trace metals, total mercury, metal oxides, TOC and TKN and total P, six CRMs were processed and analyzed with each batch of samples. Overall, recoveries ranged from 47-114% (median: 95%); while some compounds had lower recoveries (e.g., molybdenum - 47%) all values were within the QC limits for each CRM (Appendix A, Table A12).

Method blank

The method blank (MB) is an analyte-free matrix that was subjected to the same preparation and analytical procedure as other samples and is used to document contamination resulting from the analytical process. MB results should be below the reporting limit for most analytes being tested. MBs were included with the analysis of every organic contaminant sample preparation batch and are reported in Appendix A, Table A5, A7-A11. MBs were below all reporting limits with the exception of very few PCB congeners (Tables A5 and A10); however, MBs specifically with PCB congeners detected is almost unavoidable. Typically, for total PCB via 1668C, a good blank is below about 150 pg total weight per sample (or 15 pg/g for a 10 g sample) and excellent blanks are below 100 pg total weight per sample (Ron McLeod pers. Comm.).

Matrix spike

A matrix spike sample is used to assess the efficiency of the extraction technique and as a form of accuracy testing (USEPA 1994). An aliquot of sample is spiked with a known concentration of target analyte(s) prior to sample preparation and analysis. Matrix spiked samples are used to quantify the variance and bias of the chemical preparation and testing stages with matrix interference. Matrix spike recoveries for the sediment OCPs throughout the sample analyses ranged from 54 to 116% (median: 74%) and were within the QC limits with the exception of one sample that that did not meet the data quality objective (Endrin aldehyde) (Appendix A, Table A13). However, due to the number of analytes, 10% may exceed QC limits and endrin aldehyde was not present in related samples (Table 9).

Surrogate spike

A surrogate spike is used to assess the efficiency of the extraction technique and as a form of accuracy testing, but without the confounding influence of the analyte of interest already present in the sample (USEPA 1986). A surrogate spike may be defined as an added organic compound that is similar to the analytes of interest in chemical composition, extraction, and chromatography, but that is not normally found in the environmental sample (USEPA 1986). Surrogate spikes, applicable to the organic analyses, such as for PCBs, chlorinated pesticides, PCDDs and PCDFs, and PAHs, are compounds that are spiked into blanks, standards, reference materials, routine samples, and matrix spike samples prior to extraction. Percent recoveries are calculated for each surrogate compound. Acceptable surrogate spike recoveries were set at 100 +/- 30 percent (USEPA 1994). Two or three surrogates were used for each of volatile organic compounds, hydrocarbons, PAHs, and organochlorine pesticides. Recoveries ranged from 34 to 104% (median: 86%) (Appendix A, Table 14). Surrogate recoveries were within acceptable limits with the exception of OCPs (LC12, LC1802) and PAHs (LC1802) due to sample interference, which may result in a source of variability and inaccuracy; however, OCPs were not present in related samples.

Benthic invertebrate community composition

LCE samples (n= 50) were processed by four sorters by EcoAnalysts Inc. Sorting efficiencies ranged from 96.1 to 100%; 41 of the 50 samples had 100% sorting efficiency (Appendix A, Table A15). These efficiencies exceeded the acceptable level (95%), indicating that a good representation of the benthic community was achieved. For taxonomic identification and enumeration, 10% of samples were recounted and verified by a QC taxonomist. The taxonomy re-identification percent similarities per whole sample are provided in Appendix A, Table A16. The overall sample % similarity ranged from 96.38 – 100%, with each of the five samples meeting the CABIN methods quality objectives (Environment Canada 2012) and therefore no corrective actions were needed. The data reported herein contain all taxa and abundances for every sample and is the final data set after all re-identifications were done.

Toxicity tests

Toxicity tests had to pass data quality objectives (DQOs) for each organism before they were used in data analysis. DQOs included a minimum percent survival in the laboratory control sediment, collected from Long Point, Lake Erie. Warning charts were constructed for chronic responses which had to be within two standard deviations from the mean response for Long Point sediment (minimum of seven points used in the warning chart). All tests passed DQOs with the exception of one *T. tubifex* test, which failed the DQO for reproduction (no. young/adult) and was therefore repeated (Appendix A, Table A17). The subsequent test passed the DQO and was included in data analysis.

3.2 Sediment and Water Physico-Chemical Properties

3.2.1 Overlying Water

In 2010, conditions of overlying water 0.5 m above the sediment were fairly similar from LC01 to LC18 (Table 4). Site LC38, located furthest downstream (Fig. 1) had higher alkalinity, conductivity and TKN, while nitrates + nitrites (NO_3/NO_2) and temperature were highest in the upper reach of the river (LC01 to LC08) (Table 4). Site LC18 had low dissolved oxygen (4.6 mg/L) compared to other sites. The variable ranges across 2010 Lyons Creek sites were: alkalinity 22 mg/L, conductivity 122 µS/cm, dissolved oxygen 6.4 mg/L, NH_3 0.02 mg/L, NO_3/NO_2 0.12 mg/L, pH 0.7, TKN 0.19 mg/L, total P 0.11 mg/L, and temperature 5.2 °C. Two of the three reference creeks were fairly similar in overlying water characteristics to Lyons Creek. The Beaver Creek reference site (BEC02) had higher alkalinity, conductivity, TKN and TP than Lyons Creek sites, and had low in dissolved oxygen (3.7 mg/L) (Table 4).

Trends in overlying water conditions from 2002 to 2010 are shown in Figures 3-9. Generally warmer temperatures and lower dissolved oxygen were evident (with some exceptions) in 2010 (Figs. 3 and 4), likely a reflection on sampling time (early to late October in 2002/2003 vs. early September in 2010). Dissolved oxygen was slightly below the provincial water quality objective (PWQO) bottom range of 5 mg/L for warm water biota at LC18 (4.6 mg/L) as well as reference site BEC02 (3.7 mg/L). Alkalinity was ≥ 92 mg/L and was fairly stable across sampling periods with the exception of reference creek site BEC02 which increased a fair amount (Fig. 5) and pH both increased or decreased depending on the site but remained slightly basic (≥7.6) (Fig. 6). TKN and nitrate + nitrite concentrations were similar or decreased by 2010 in Lyons Creek but were within the range of that observed for reference creeks, which also showed decreases (Figs. 7 and 8). Total P showed similar concentrations or increases between years depending on the site, ranging from to 0.03-0.12 mg/L in LCE and from 0.02-0.14 mg/L for reference creeks (Fig. 9). Total P at most LCE sites was within the range of concentrations observed at reference sites but five sites (2 LCE and 2 reference sites) were above the PWQO of 0.03 mg/L to prevent the growth of nuisance algae (Fig. 9).

3.2.2 Surficial Sediment

The general pattern of 22 variables for 2010 LCE samples was assessed by PCA and included the sediment data of ecological concern: 12 metals (As, Cd, Co, Cr, Cu, Fe, Hg, Mn, Ni, Pb, V, Zn), total PAHs, total PCBs, total PHCs, oil and grease, as well as particle size (percents sand, silt and clay) and nutrients (total P, TKN, and TOC). The first two components accounted for 77% of the variation in the data and score and loading plots are shown in Fig. 10. The first principal component increased with increasing clay, metals (except Mn, Co, Cu, V), total phosphorus, oil and grease and TPHCs, while the second principal component increased with increasing Mn, sand, silt, PAHs and PCBs and decreasing TOC and TKN; the nutrients and Mn have the strongest loadings for PCA Axis 2 (Fig. 10). There was a separation of sites LC01 and LC03 (upstream and furthest downstream sites) from remaining sites along the first axis influenced by particle size, and metal and organic contaminants, some of which had similar loadings for PCA Axis 1 (Fig. 10). Sites LC01 and LC38 had higher proportions of sand and clay particles while remaining sites were characterized by greater metals, PAHs and PCBs (e.g., LC12 and LC18) and higher silt and nutrients (e.g., LC16) (Fig. 10). In an initial chemical survey of LCE conducted by the MOE in 2002, there was a distinct separation of sites along LCE also influenced by sediment particle size, nutrients and contaminant levels from upstream to downstream of Highway 140, although this assessment included 38 sites , which were more evenly distributed from upstream to downstream locations (Milani et al. 2013). Sediment elements are discussed in more depth below.

3.2.2.1 Particle size

Particle size distribution data for 2010 samples are shown in Figure 11a. Lyons Creek sediments consisted mainly of silty fines; silt ranged from 61.8 to 89.3% (median 85.4%), and clay ranged from 4.6 to 16.8% (median 7.5%). Sand content was ≤ 22.6% and gravel was ≤ 0.1%. Sediments from two of the three reference sites (BECO2 and TC) were generally similar to that for Lyons Creek consisting mainly of fines (silt and clay) but Usshers Creek (UC) sediment was much coarser, consisting mainly of gravel (66.1%) and sand (33.4%) (Fig. 11a). In 2002/2003, grain size distribution was more similar between LCE and reference sites (Fig. 11b) and for UC could indicate that fines were scoured away in 2010 or the heterogeneous nature of the creek, as sites were 15 m apart between sampling years (Table 1). Sediment particles < 63 µm were not comparable between sampling years because methodology changed; percent fines were determined using a sedigraph analyzer in 2002/2003 and a laser analyzer in 2010. The distribution of sand and gravel however, would be comparable (the same stacking sieve method was used). Sand content at LCE sites was fairly similar between years, ranging from 4.6 to 22.6% (median 6.5%) in 2010 compared to 0.8 to 17.9% (median 4.4%) in 2002/2003. While the reference creeks were determined to be appropriate reference locations for Lyons Creek based on proximity, geomorphology, and physical and chemical characteristics in the 2002/2003 study (Milani et al. 2013), UC in 2010 may not be a suitable reference site based on physical characteristics.

3.2.2.2 Nutrients

In 2010, TOC ranged from 2.1 to 9.8% (median 6.3%), TKN from 2,370 to 8,940 µg/g (median 4,670 µg/g), and total P from 815 to 6,503 µg/g (median 1,940 µg/g) at LCE sites (Table 5). Sediment nutrients were overall lower at reference sites, with TOC ranging from 1.6 to 7.0% (median 4.7%) TP ranging from 637 to 898 µg/g (median: 775 µg/g), and TKN from 1,430 to 5,460 µg/g (median 3,420 µg/g) (Table 5).

Trends in the three sediment nutrients from 2002 to 2010 are shown in Figures 12-14. TOC concentrations were consistently above the LEL across all sites and sampling years, with both increases and decreases observed in 2010 depending on the site (Fig. 12). TOC decreased at all reference sites in 2010. Two LCE sites (LC06 and LC16) were outside the upper range for the reference sites but below the SEL. Sediment TKN concentrations mostly decreased by 2010, although LC06 showed a considerable increase (Fig. 13). TKN levels were above the SEL at reference site BEC02 and sites LC06 and LC16 were outside the upper range for the reference sites as well as above the SEL. Total P showed large increases at two LCE sites in 2010 (LC12 and LC18) (Fig. 14). Five LCE sites had total P concentrations that were outside the upper range of the reference sites, and 3 of the 5 sites were also above the SEL (Fig. 14).

3.2.2.3 Trace metals

Trace metals were mostly higher at LCE sites than reference sites and was most pronounced for zinc, which ranged from 116 to 3,997 µg/g (4.9 times the SEL) (median 840 µg/g) at LCE sites compared to 64 to 115 µg/g (median 91 µg/g) at reference creeks (Table 5). Zinc concentrations peaked at LC18 in 2010, downstream of Highway 140, whereas in 2002/2003 the peak was further upstream at LC03 (7,969 µg/g, 9.7 times the SEL), which is just below the former outfall.

Trends in sediment metal concentrations from 2002 to 2010 for co-located sites are shown in Figures 15-24. Site LC18 had increased concentrations across all metals and had consistently the highest metal concentrations, whereas in 2002/2003, site LC03 was highest in most metals (Milani and Grapentine 2006). In 2010, LC03 showed decreases in all metals except manganese (Fig. 21) with decreases most pronounced for arsenic (Fig. 15), copper (Fig. 18), nickel (Fig. 22), and zinc (Fig. 24).

Remaining sites showed little difference between sampling years, with slight increases or decreases evident depending on the site. Metals that were above SEL in 2010 included Fe for two sites (LC12 and LC18) (Fig. 19), Ni for one site (LC18) (Fig. 22), and Zn for three sites (LC12, LC16 and LC18) (Fig. 24). In 2002/2003, the SEL was exceeded for As, Cu, Ni, and Zn at LC03 and for Zn at LC08, LC10, LC12 and LC14. Zinc was the only metal was elevated above the SEL and above the reference site range (Fig. 24).

3.2.2.4 PCB congeners

In 2010, total PCB congeners were elevated in Lyons Creek compared to reference creek sediments, ranging from 14.5 to 36,100 ng/g (c.f. 2002/2003: 20–12,600 ng/g) at LCE sites compared to 8.8 to19.8 ng/g at reference sites (c.f. 2002/03: 3–16 ng/g) (Table 6) and were also elevated compared to the average concentration reported for the Eastern basin of Lake Erie of 36 ng/g (Marvin et al. 2004b). With the exception of site LC38, all LCE sites exceeded the 99th percentile (= maximum) reference site PCB concentration by 1 to 3 orders of magnitude (Fig. 25). The CCME (2001a) freshwater sediment quality guideline Probable Effect Level (PEL) for total PCBs (0.277 µg/g) was also exceeded from LC03 to LC18 in 2010, consistent with that found in 2002/2003 (Fig. 25). Results were consistent with those of the 2002/2003 survey for some sites; however, in 2010, PCB concentrations peaked further downstream at LC12 (36,100 ng/g) and high contamination extended further down the creek to LC18 (20,433 ng/g), whereas in 2002/2003 PCB concentration peaked just downstream of the former outfall at LC03 (12,548 ng/g) and was 40-fold lower at LC18 (506 ng/g) than at LC18 in 2010. Overall, [PCB] was higher along the creek in 2010, including the upstream site (LC01), while similar at the site furthest downstream (LC38). This could reflect heterogeneity in the creek sediment and/or the movement of sediments downstream from the upper more contaminated portions which act as a source to lower parts of the creek. LCE sites positions were < 10 m apart (a co-located site is generally considered to be within 10 m) between sampling years at 5 of the 7 sites but 2 sites (LC03 and LC16) were sufficiently far apart to be considered new sites altogether (Table 1). Reference site PCB concentrations were consistent between years (Fig. 25); sites were between 4-15 m apart between sampling years (Table 1).

Concentrations of dioxin-like PCBs, expressed in toxic equivalents (TEQs), ranged from 0.6 to 153 ng TEQ kg^{-1} for LCE sites and from 0.04 to 0.114 for reference sites (Table 6). Under both the lower bound condition (non-detects are assigned a zero) and upper bound (non-detects are assigned the DL), the PEL (21.5 ng TEQ kg^{-1}) was exceeded from LC03 to LC18 in 2010 from 1.4 to 7 times, whereas in 2002/2003, one site (LC19) was slightly above the PEL (Fig. 26).

3.2.2.5 PAHs

In 2010, total PAHs ranged from 1.7 to 37.6 mg/kg at LCE sites and were below detection at reference sites (Table 7). The highest [PAH] occurred at LC12 followed by LC18 (19.4 mg/g), the same pattern that was observed with PCBs. In 2002/2003, total PAHs ranged from 0.5 to 62.9 µg/g at LCE sites and from 0.4 to 1.1 µg/g at reference sites (Milani and Grapentine 2006). From 1 to 13 PAHs exceeded PEL or LEL criteria from LC03 to LC18 (Table 7), with most exceedences for sites LC12 and LC18 (Table 7). Fluoranthene, pyrene, and chrysene had the highest concentrations (Table 7) and accounted for 44-71% of the total PAHs (Table 7). Total PAHs followed a similar pattern as seen with metals, with a significant decrease in concentration at LC03, and increased concentrations at LC18 and LC12; the LEL (4 mg/kg) was exceeded at 4 of the 6 sites (Fig. 27).

3.2.2.6 Oil and grease

Total oil and grease ranged from 1,660 mg/kg to 76,900 mg/kg at LCE sites and was quite high from LC03 to LC18 (Table 8); concentrations at reference sites ranged from 1,200 to 5,980 mg/kg and concentrations at LC01 and LC38 were within the reference site range (Table 8). LC03 and LC18 had similar very high concentrations, up to ~13 times higher than reference sites. Oil and grease was not measured in 2002/2003 but were overall elevated compared to the St. Marys River AOC, where concentrations were ≤ 15,100 mg/kg (Milani 2012).

3.2.2.7 BTEX and petroleum hydrocarbons

BTEX (benzene, toluene, ethylbenzene and xylene) and petroleum hydrocarbon (PHC) concentrations in Lyons Creek and reference sediments are provided in Table 8. The BTEX and F1 (C6-C10 hydrocarbons) compounds were below method detection limits (MDLs, values preceded by "<") at all sites. The F2 (C10-C16 hydrocarbons) PHCs were detected at all LCE sites except LC38 (furthest downstream, ranging from 22 to 810 mg/kg; concentrations at reference sites were below detection at two sites and 1,670 mg/g at BEC02 (Table 8). The F3 (C16-C34 hydrocarbons) PHCs were detected at 6 of the 7 LCE sites, ranging from 140 to 25,400 mg/kg (Table 8). Reference site F3 PHC concentrations were increased at BEC02 relative to the other two reference sites. The F4 fraction (C34-C50 hydrocarbons) was detected at 5 LCE sites with concentrations ranged from 1,490 to 7,990 mg/kg, while the F4G fraction ranged from 3,500 to 18,000 at LCE sites. The gravimetric heavy hydrocarbons (F4G: ~C24-C50+), typically include the very heavy hydrocarbons (e.g., heavy lubrication oils), were detected at sites from LC03 to LC18. The F2-F4 fractions were most elevated at LC16 (Hwy 140) but were quite high from LC12 to LC18 compared to other parts of the creek and reference sites (Table 8). Total PHCs (sum of C6 to C50) ranged from 160 to 34,200 mg/kg. The chromatogram did not reach baseline at C50 (i.e., there were PHC with carbon chain lengths >50) at LC03 to LC18, indicating the presence of very heavy hydrocarbons in this part of the creek. Reference sites F4G concentrations were below detection but the chromatogram did not reach baseline at C50 at BEC02 as well (Table 8). It is not clear why BEC02 would be elevated in PHCs and what possible sources there could be. PHCs were not measured in the 2002/2003 study; therefore, comparisons could not be made. However, in comparisons to other AOCs, PHCs in LCE are elevated overall. Total PHCs in Moberly Bay, the western arm of Jackfish Bay, were ≤ 4,253 mg/kg (Milani and Grapentine 2009) and in the St. Marys River were ≤ 16,800 mg/kg (Milani 2012).

3.2.2.8 Organochlorine pesticides

OCPs were not detected in any of the samples in 2010 (Table 9). In 2002/2003, p,p'-DDE was present (p,p'-DDT and p,p'-DDD were below the analytical detection limits of 0.005 µg/g) and the PEL (6.75 µg/kg) was exceeded at 13 of the 15 Lyons Creek sites with a maximum concentration of 0.34 µg/g at LC03; concentrations decreased overall with distance downstream (Milani and Grapentine 2006).

3.2.2.9 Sediment Quality Index

To summarize the organic and inorganic sediment quality measures and provide a general description of Lyons Creek sediment, a SQI was applied (calculated using trace metal, total PAH and total PCB concentrations). The robustness of the SQI was evaluated against hazard quotients (HQs) and PCA incorporating reference sites in assessing AOCs in Lakes Superior and Huron, where metals were the primary contaminants of concern (Grapentine et al. 2002). Similar sediment trends and rankings for sediment quality were found for the SQI and PCA and the SQI and also allowed a straightforward integration of multiple components compared to the calculation of HQs. The SQI was expanded to include organic contaminants to assess sediment quality in the lower Great Lakes, and was useful in detecting spatial trends in contamination across Lakes Erie and Ontario using individual stations as well as spatial trends over broader geographic regions using an area frequency component (Marvin et al. 2004a).

The SQIs for Lyons Creek and reference sites are provided in Table 10. All reference sites had a SQI of 100, indicating excellent quality. The SQIs for upstream site LC01 and furthest downstream site LC38 were also 100 (excellent) and consistent between sampling years. These two areas of Lyons Creek would represent background or baseline levels in LCE as all measurements fell within the guidelines values. The SQI dropped to 33-39 at LC03 indicating poor quality just below the former outfall. Further downstream from LC08 to LC18, quality was similarly poor (LC12, LC18) or marginally improved (LC08, LC16). With the exception of sites LC16 and LC18, results were similar to 2002/2003 (Table 10).

The marginal quality at LC16 and poor quality at LC18 in 2010 compared to good quality in 2002/2003 was due to both the greater number of variables that did not meet guidelines (scope) in 2010 and the magnitude by which total PCBs (as well as zinc) exceeded the guidelines (amplitude).

3.3 Contaminant Bioaccumulation in Benthos

3.3.1 PCBs

In 2010, total PCB congeners at 2 of the 4 LCE sites were higher than those at the reference sites for 2-3 benthic invertebrate taxa; concentrations at upstream and downstream sites (LC01 and LC38) were similar to reference (Fig. 28). Total PCB concentrations ranged from 254 - 9,740 ng/g and from 120 - 1,570 ng/g dw for Lyons Creek and reference sites, respectively. Differences in PCB bioaccumulation between taxa within a site were ≤ 1 order of magnitude (Table 11). In comparison, total PCB concentrations for benthos collected from co-located sites in 2002/2003 were overall higher at LCE sites, ranging from 82 - 52,577 ng/g and overall lower at reference sites, ranging from 48 - 301 ng/g; differences in bioaccumulation between taxa within a site were again ≤ 1 order of magnitude (Milani and Grapentine 2006). Total PCBs were elevated above the 99th percentile for reference creek concentrations for 1 of the 2 taxa at LC12, and all taxa at LC16 in 2010 (Fig. 28).

Mean PCB bioaccumulation was similar at the upstream and downstream sites (LC01 and LC38) between sampling years, while lower at LC12 and higher at LC16 in 2010 (Fig. 29). PCB bioaccumulation was also higher at reference sites in 2010 (Fig. 29). PCB bioaccumulation peaked at site LC12 (500 m upstream of Hwy 140), and decreased downstream to LC38 in 2002/2003 while peaked further downstream at LC16 (at Hwy 140) in 2010 (Fig. 29); the difference between PCB accumulation at LC16 in 2002/03 vs. 2010 was not significant, however (t=-1.999, p=0.116).

PCBs in amphipods were significantly influenced by sediment PCB concentrations in 2010, which was also found in 2002/2003. The log-log relationship for concentrations of PCBs in sediment (normalized to % TOC) versus amphipods (normalized to % lipid) across sites was fairly strong for amphipods but had limited data points ($r^2 = 0.74$, p=0.017, n=7) (Fig. 30). In 2002/2003, the sediment - crustacean relationship was stronger but had ~twice the number of data points and included both amphipods and isopods ($r^2 = 0.88$, $p \leq 0.001$, n=15) (Milani and Grapentine 2006). The sediment-oligochaete relationship was not significant in 2010 ($r^2=0.467$, p=0.20, n=5) or in 2002/2003 ($r^2=0.250$, p=0.08, n=13), although in 2002/2003, the addition of pH, total P, and sand into the model resulted in a significant slope for oligochaetes (R^2 [adjusted for degrees of freedom] = 0.78, p = 0.002) (Milani and Grapentine 2006). Because concentrations of PCBs in the benthic invertebrates were measured without clearing their guts, a fraction of the observed invertebrate PCBs would be sediment bound in the gut. Although this is relevant for assessing uptake of PCBs by predators of invertebrates, which consume whole organisms, it likely contributed to the strength of the $[PCB]_{sed}$–$[PCB]_{inv}$ relationship for the amphipods.

Comparison of resident invertebrate tissue concentrations to TRGs provided a screening level evaluation of Lyons Creek. Invertebrate PCB concentrations, expressed in TEQ units, were compared to an avian Reference Concentration (RC) of 7.4 ng TEQ·kg^{-1} diet ww. This RC was calculated using information on the lowest tolerable daily intake for PCBs (CCME 2001b), and body weight (bw) and daily food ingestion (FI) for an anseriforme (common goldeneye) provided in CCME (1999). The avian TRG for PCBs of 2.4 ng TEQkg^{-1} ww (CCME 2001b) was not used because it was based on the FI and body weight of Wilson's storm-petrel (seabird). An avian RC was used because there would be a direct feeding relationship between the benthos and an avian receptor (e.g., diving duck). In 2010, Lyons Creek sites LC12 and LC16 had taxa with TEQ units well above the RC (Fig. 31b). TEQ units for LC16 were quite similar between years but showed an increase at LC12 in 2010 (Fig. 31a, b); this increase was largely driven by PCBs 77 and 81, which were below detection limits in 2002/2003 samples, but were detected in 2010 (Table 11). In contrast, reference sites as well as the upstream (LC01) and downstream (LC38) LCE sites had similar TEQ units either below or just slightly above the RC.

The level of PCB bioaccumulation in the resident benthos of LCE indicated that consumers of benthos (and their predators) could still be at risk from the sediment. In other streams with levels of sediment PCB concentrations similar to those of LCE, risks to greater trophic levels in both aquatic and terrestrially connected food web have been determined (Kay et al. 2005; Maul et al. 2006; Walters et al. 2008).

3.3.2 PAHs

In 2010, total PAHs in the benthos were greater at 1 of the 4 LCE sites (LC16) than those at the reference sites (99th percentile); concentrations at remaining LCE sites were similar to reference (Fig. 32). Total PAH concentrations in the benthos ranged from 349 - 3,112 ng/g and from 338 - 1,677 ng/g dw for LCE and reference sites, respectively in 2010 (Table 12a, b). Total PAH concentrations in benthos collected from LCE sites in 2002 (there are no PAH data for 2003) were overall higher than in 2010, ranging from 220 - 12,060 ng/g and were overall lower at reference sites, ranging from 120 – 440 ng/g (Milani and Grapentine 2006). However, only sites LC01 and LC12 had comparative data between sampling years. In 2010, mean PAH concentrations were lower at LC12, falling below the reference 99th percentile (Fig. 32). Although PAHs were slightly higher at LC01 in 2010 than in 2002, they were nonetheless a fair bit lower than the 99th percentile for reference sites (Fig. 32).

3.4 Benthic Invertebrate Community Composition

In 2010, benthic communities in LCE consisted predominantly of Chironomidae (range 542 to 15,069m^{-2}) and Tubificidae (range 144 to 9,705 m^{-2}) (Table 13). Chironomids were generally lower on average in LCE than in the reference creeks (reference mean: 2,993 m^{-2}), except at Hwy 140 (LC16) where they were highest and ~400 m downstream of Hwy 140 (LC18 – 4,882 m^{-2}). Tubificids were more dense just below the former outfall (LC03) compared to reference sites (reference mean: 2,777 m^{-2}) but remaining LCE sites had similar or lower densities than reference sites (Table 13). Other taxon groups present at the majority (4-6 of the 7 sites) of LCE sites included naidid worms (60 to 2,230 m^{-2}), caenid mayflies (39 to 1,989 m^{-2}), pisidiid clams (26 to 1,989 m^{-2}), ceratopogonid dipterans (52 to 784 m^{-2}), leptocerid caddisflies (13 to 783 m^{-2}), coenagrionid odonates (66 to 663 m^{-2}), hyalellid amphipods (13 to 542 m^{-2}) and hydrobiid snails (44 to 422 m^{-2}) (Table 13). Taxon richness (number of families) ranged from 8 to 26 at LCE sites, compared to 10 to 15 at reference sites; one LCE site (LC38) was below the reference range while three sites were above the range (LC01, LC16, LC18) (Table 13). Total abundances ranged from 1,084 to 34,840m^{-2} at LCE sites compared to 8,137 to 14,346 m^{-2} for reference sites; LCE sites had similar or lower total abundances compared to reference sites with the exception of LC16 (Hwy 140), which had up to 2.4 fold increased abundance due primarily to increased midges as well as asellids (isopods) and naidids (Table 13).

Trends for four commonly used community descriptors - total benthos, taxon richness, evenness, and Shannon-Weiner index are shown in Figs. 33-36 for co-located LCE and reference sites. In 2002/2003, total benthos for LCE sites was within, or higher than, the reference sites range. By 2010, decreases in total benthos were apparent for all LCE sites as well as for the reference sites; however, 4 LCE sites were below the reference range while 1 was site above (Fig. 33). Taxon richness (number of families) for three LCE sites was below the range for reference sites in 2002/2003. In 2010, decreased richness was evident at all reference sites and 5 of the 7 LCE sites – but only 1 LCE site (LC38 – farthest downstream) was below the reference range (Fig. 34). Evenness is a measure of how individuals in a sample are distributed among taxa — 1 indicates all taxa have the same number and the closer to 0 the more uneven the numbers among taxa. Evenness was lower for 3 LCE sites compared to reference sites in 2002/2003. In 2010, increases were observed for 3 LCE sites (most notably LC12) and in all reference sites; however, 5 of the 7 LCE sites were below the range for the reference sites (Fig. 35). The Shannon-Weiner (S-W) index is a measure of diversity in the community and is different from richness in that it takes into consideration the relative abundance of taxa that are present and the evenness. Communities with a large number of taxa that are evenly distributed are the most diverse and communities with few taxa that are dominated by one taxon are the least diverse. In 2002/2003, the S-W index range was very narrow for reference sites; 4 LCE sites had lower diversity while 3 sites had higher diversity (Fig. 36). In

2010, the S-W index increased for 3 of the 7 LCE sites to within the reference range or higher, 1 LCE site decreased but was within the reference range, and the remaining 3 LCE sites decreased to well below the reference range (Fig. 36).

Analyses of dominant LCE taxa (those present at most LCE sites) were by the same procedure as for the community descriptors. The numerically most important taxon was the Chironomidae (midges). Midge densities in the LCE samples as well as the reference samples declined in 2010, most notably for site LC03; 5 of the 7 LCE sites were below the range for reference sites in 2010 compared to none in 2002/2003 (Fig. 37). Tubificids, naidids, and amphipods (sum of Hyalellidae + Gammaridae) followed similar trends with generally similar or lower densities in 2010 for both test and reference sites (Figs. 38-41). Tubificids were less abundant overall than the chironomids but were present in reference sites at densities similar to those in LCE in 2010 with the exception of LC03 (Fig. 38). Like the tubificids, the naidids worm densities in LCE were generally similar to the reference sites with the exception of LC16 (Fig. 39) and the amphipod densities at LCE sites were similar or higher than those at reference sites (Fig. 40). Coenagrionids (damselfly) densities showed a large decline at LC03 while a fair increase at LC16 in 2010; densities in 2010 were within the reference range for all LCE sites except for LC16 (Fig. 41). Trends for the mayfly and fingernail clams (pisidids) varied more among sites in LCE than for other taxa (Figs. 42-43). For mayfly, densities declined substantially at 1 reference site and 1 LCE site, increased greatly at 1 site while showed minor changes at remaining sites; 5 LCE sites were below the reference range in 2010 (Fig. 42). For the fingernail clams, 1 reference site showed a sharp decline while 1 LCE site showed a sharp increase from 2002/2003; two LCE sites were outside the reference range in 2010, showing increased densities (Fig. 43).

The three-dimensional (3D) HMDS (stress = 0.07) showed the degree of similarity/dissimilarity among the three matching (co-located) reference sites between years, as indicated by the spatial proximity of the sites in ordination space (close proximity indicates similar benthic invertebrate community composition) (Figs. 44a, b). Taxa that were significantly correlated ($p \leq 0.05$) to axes scores included Tubificidae ($r^2 = 0.98$), Ceratopogonidae (biting midge) ($r^2 = 0.96$), Sialidae (alderfly) ($r^2 = 0.79$), Empididae (dance fly) and Ephemeridae (mayfly) ($r^2 = 0.65$) (shown as vectors in Fig. 44a, b). Dissimilarities between sampling years was evident for all sites, with densities of tubificids, and to a lesser degree ceratopogonids and sialids, largely accounting for the differences seen for sites that were separated along the first axis (Fig. 44a). There was also variability along the second axes for Usshers Creek, due to increased empidids and ephemerids in 2010 (Fig. 44b). The relationship between the benthic community response and habitat variables was examined by correlation of the ordination of community data and habitat information. Two variables were significantly ($p \leq 0.01$) correlated to the three ordination axes scores, overlying water TKN, and sediment total P (shown as vectors in Fig. 44a, b). UC was generally associated with lower nutrients compared to TC and BEC.

LCE benthic community data were not compared to those from GL reference sites (BEAST model) because this method can only be applied with confidence to test sites within the range of habitats and geographic areas contained within the reference data set (Reynoldson and Day 1998). The GL reference database consists of sites mostly restricted to harbours, embayments and nearshore waters of the GL. Ideally, reference conditions should include both spatial and temporal variation, which could include disturbance events (Stoddard et al. 2006). The 3D HMDS indicating the degree of (dis)similarity among 2010 reference and LCE sites (stress = 0.12) is shown in Fig 45a, b. Five taxa were significantly correlated ($p \leq 0.01$) to axes scores; the most highly correlated ($r^2 \geq 0.50$) are shown as vectors and included Tubificidae ($r^2 = 0.78$), Elmidae (riffle beetle) ($r^2 = 0.73$), Limnesiidae (mite) ($r^2 = 0.72$) and Ceratopogonidae ($r^2 = 0.66$) (Fig. 45a). There was a separation of LC03 and the LCE sites at, and further downstream of, highway 140 (LC16, LC18, LC38) along Axis 1, with densities of the mite and tubificid worms largely accounting for these differences (Fig. 45a). There was also a separation between reference and LCE sites along the third axis primarily due to Elmidae and Ceratoponidae densities (Fig. 45b) which were increased at 2 of the 3 reference sites. No habitat variables were significantly ($p \leq 0.05$) correlated to ordination axes scores. The PIs computed using 2010 reference data alone (n=3 reference sites) are shown in Fig. 45b. The use of the limited 2010 reference data resulted in fairly large PIs and as a result all 2010 LCE sites fell well within the PIs (Fig. 45b). The PIs, originally computed for 2002/2003 reference data (n = 6 reference sites), resulted in fairly large PIs and subsequently all 2002/2003 LCE sites, with the exception of LC14, fell within the PIs (Milani et al. 2013). The 3D HMDS indicating the degree of (dis)similarity among 2002-2010 reference and LCE sites (stress = 0.13) is shown in Fig. 46a,b. Several taxa (n=15) were significantly correlated ($p \leq 0.01$) to axes scores; the most highly correlated ($r^2 \geq 0.35$) are shown as vectors and included Tubificidae ($r^2 = 0.64$), Chironomidae ($r^2 = 0.60$), Hyalellidae ($r^2 = 0.50$), Plagiostomidae (flatworm) ($r^2 = 0.41$), Coenagrionidae ($r^2 = 0.39$), Dreissenidae ($r^2 = 0.38$), Ceratopogonidae ($r^2 = 0.37$), and Naididae ($r^2 = 0.35$) (Fig. 46a, b). There was a separation between reference sites and LCE sites along axes 1 and 3 with densities of ceratopogonids, naidids, dreissenids and chironomids most correlated to the separation (Fig. 46b). Three habitat variables, temperature, dissolved oxygen (DO), and alkalinity, were significantly ($p \leq 0.05$) correlated to ordination axes scores, albeit not very strongly ($r^2 = 0.24 - 0.31$). (No sediment metal or organic contaminants were significantly correlated.) Increased temperature and decreased DO were associated with most reference sites as well as LC sites collected in 2010 (Fig. 46a, b). Increased alkalinity was associated with some LCE and reference sites sampled in 2010 (Fig. 46b), although generally alkalinity was fairly stable across years with the exception of reference site BEC02 (Fig. 5). The PIs computed using 2002-2010 reference creek

HMDS axes scores (n = 9 reference sites) were narrower than those for the 2010 reference samples (Fig. 46a, b). Resultantly, 8 of the 15 LCE sites from 2002/2003 fell outside the PI on axis 1 (LC03, LC06, LC08, LC14, LC16, LC17, LC19, LC22), and 5 of the 7 sites were outside the PIs in 2010 (LC01, LC08, LC12, LC18 and LC38) (Fig. 46a, b). Most 2002/2003 LCE sites fell outside the PIs along the first axis, due to combined increases of chironomids, dreissenids, coenagrionids, plagiostomids, and hyalellids compared with the reference creeks or on the third axis due to increased naidids (Fig. 46a, b). This differed for 2010, where sites fell outside the PIs due to decreased abundances of above mentioned taxa as well as decreases in naidid worms and ceratopogonids (Fig. 46b). Based on comparison with all reference sites sampled from 2002-2010, some LCE sites sampled in 2010 had depauperate communities compared to the co-located sites sampled in 2002/2003 and reference communities, most notably site LC12 (high contamination) but downstream site LC38 as well, where contaminant concentrations were low (comparable to reference concentrations). Ideally, reference conditions should represent both spatial and temporal variability. The difference when not including the temporal variability were evident when PIs calculated using the 2010 reference data alone were compared to those where 2002-2010 reference data were used. Although sampling year changes were observed in the co-located reference creeks sites, some LCE sites, mainly those located in the upper creek above Highway 140 (from LC03 to LC16) appear to be altered, based on total abundance, abundance of some key taxa and diversity. Benthic invertebrate communities in LCE as well as those in the reference locations should continue to be monitored to determine whether this trend continues.

3.5 Sediment Toxicity

Mean species survival, growth, and reproduction for 2010 Lyons Creek and reference creek sites are listed in Table 14. Decreased survival was evident at 2 sites, LC03 and LC12, with 1 to 3 test species affected per site. Similarly, in 2002/2003, these same 2 sites as well as LC08 exhibited toxicity (Milani et al. 2013). Each ordination of the 10 sediment- toxicity end points by HMDS produced three descriptors of sediment toxicity. Stress values for the ordinations were good, ranging from 0.08 to 0.09. Overall (integrated endpoint assessment), severe toxicity occurred at LC12 and LC03, as indicated in the ordination plot by the position of these sites farthest away from the reference centroid in Band 4 (Appendix C, Fig. C1-C2). Remaining LCE sites were non-toxic (located in Band 1 - Appendix C, Fig. C1-C4). Results are summarized in Table 14 and include results from 2002/2003 for comparison. In 2002/2003, the most toxic site was just below the former industrial outfall at site LC03 followed by LC08, which is located ~500 m downstream from the Welland Canal by-pass (Milani et al. 2013). Acute responses of *Hexagenia* were evident at both LC12 and LC03 in 2010, with survival ranging from 14 to 18%, and of *Chironomus* at LC12, with 25% survival (Table 14). In addition *Tubifex* reproduction was affected at LC12, with low cocoon production (5 cocoons/adult) compared to reference creeks (mean: 9.5 cocoons/adult) and GL reference sites (mean: 10.3 cocoons/adult) (Table 14). Sediments at LC12 and LC03 were of poor quality (based on metal, PCB and PAH concentrations) as indicated by a low SQI (34-39) (Table 10); site LC03 had high guideline exceedences for Zn, PCBs, and one PAH (benzo(a)pyrene) while LC12 had similar exceedences for Zn and PCBs but had 10 PAHs elevated above the PELs (Tables 5-7). Reference site BEC02 exhibited chronic toxicity with a low percentage of hatched cocoons (12.2%) compared to remaining reference and LCE sites (range: 51.6-75.4%) and GL reference (mean: 56.8%); subsequent low young production (0.3 young/adult) was also observed at BEC02 compared to other two reference creeks (13.4-15.2/adult) and GL reference sites (mean: 22.8/adult) (Table 14). Overall, site BEC02 was categorized as toxic (fell in Band 3) (Appendix C, Figure C4). Notable though, was that the *Tubifex* endpoint affected differed for BEC02 vs. LC12. For LC12, the affect was primarily on gametogenesis (cocoon production) whereas for BEC02 it was embryogenesis (development of worm inside the cocoon), suggesting different causative agents for these two sites. Sediment quality was excellent at BEC02 (SQI = 100; Table 10), although total PHCs were elevated at this site (8,240 mg/kg) compared to the other two reference sites (<100-310 mg/kg) (Table 8). Although sediment quality was poor or marginal at other LCE sites (e.g., LC08, LC16 and LC18), toxicity was not evident. Elevated Zn (r^2 = 0.51) as well as elevated sediment total P (r^2 = 0.57) were correlated to LC12's position and are shown as vectors in the ordination plot (Appendix C, Fig. C2). Elevated Zn was also correlated to LC03's position, but fairly weakly (r^2 = 0.17); overlying water total P was also weakly correlated (r^2 = 0.20) (Appendix C, Fig. C1). Organic contaminants were not included in this analysis because these data were not available for GL reference sites. Toxicity observed in upper Lyons Creek was consistent with 2002/2003 results as well as study conducted by the MOE in 1992 (MOE 1998). An oily sheen and/or a strong oily odour were also noted in the 1992 MOE study, which concluded that joint chemical toxicity (other organic contaminants and perhaps metals) was probable (MOE 1998). In 2002/2003, metals and nutrients were weakly correlated to positions of sites in ordination space, with Zn (r^2 = 0.28) or Hg (r^2 = 0.14) being the most significant variable (Milani et al. 2013).

The ordination of the multiple measurements of sediment toxicity by HMDS for the 2010 Lyons and neighbouring reference creek sites, without the GL reference data, produced two descriptors of sediment toxicity (Fig. 47). Organic contaminants (total PAHs, PCBs (total and TEQ), PHCs, oil and grease), as well as the SQI were included in this analysis. The resultant axes represented the original 10-dimensional among-site resemblances well (stress = 0.04), and 5 of the 10 endpoints were significant (r^2=0.62-0.99, $p \leq 0.05$). *Hexagenia* survival was the most highly correlated endpoint to axis scores (r^2 = 0.99) followed by *Tubifex* young production (r^2 = 0.94). Significant ($p \leq 0.05$) environmental variables included alkalinity (r^2 = 0.92), LOI (r^2 = 0.71), SQI (r^2 = 0.69), Cr (r^2 = 0.67), Cu (r^2 = 0.59), TOC (r^2 =

0.55), and pH (r^2 = 0.53). The PCB TEQ, significant at p = 0.06 (r^2 = 0.58), is included in Figure 47 as well. Sites LC03 and LC12, correlated with decreased *Hexagenia* survival and growth, were oriented along a gradient of increasing PCBs, metals, sediment organic matter and pH (shown overall as 2 vectors because of their close proximity) (Fig. 47). Increasing SQI (shown as a vector) was associated with reference sites and the upstream site LC01, while reference site BEC02, correlated with decreased *Tubifex* young production, was associated with increased alkalinity levels (~2 fold higher than other sites - Table 4). In 2002/2003, *Hexagenia* survival was again the most highly correlated endpoint (r^2 = 0.95) to axis scores and the most significant habitat variables included total PCBs (r^2 = 0.84), total PAHs (r^2 = 0.81), and Zn (r^2 = 0.73) (Milani et al. 2013). Contaminant mixtures can exhibit various interactive and confounded effects that are complex and difficult to recognize using a correlation/regression approach and a very small sample size. Additionally, sediments in the current study were sieved before testing to remove indigenous species, which is especially important to obtain adequate counts in the *Tubifex* reproduction test but which may also alter organism exposure through changes in porewater contaminant concentrations. Burgess and McKinney (1997) provided evidence to changes in porewater chemistry when they examined the distribution of PCB congeners after sediment homogenization (and storage). An increase in concentrations of PCBs in both the colloidal and dissolved phases was observed when sediments were homogenized compared with undisturbed sediments; increases were significant for all PCB congeners in the colloidal phases. Equilibrium partitioning theory supported PCBs and perhaps PAHs as causative agents of toxicity but did not fully explain toxicity evident in 2002/2003 and the additive effects of multiple metals present at increased concentrations could also not be discounted (Milani et al. 2013).

For the 2010 study, comparisons to the 2002/2003 results is important in determining whether conditions in the creek are improving over time. Overall, toxicity was similar or reduced in 2010 compared to 2002/2003; LC03 and LC12 were severely toxic in both sampling years, while LC08 went from severely toxic (Band 4) in 2002/2003 to non-toxic in 2010 (Band 1) (Table 14). Figures 48-51 show the changes from 2002-2010 by site for each individual endpoint. Each bar represents the mean 2010 value minus the 2002/2003 value. *Hyalella* results showed improvement in survival and growth for 6 of the 7 LCE sites with ~3 - 55% increases in survival and from 0.05 - 0.44 mg/individual increases in growth; LC18 showed a slight negative change in amphipod survival (-3%) but less than that observed for the Tee Creek reference site (-16%) (Fig. 48). For the remaining endpoints, where negative changes were observed, they were less than those for reference creek with the exception of LC12 (Figs. 49-51). Results indicated that while in some cases there were decreases in survival, growth or reproduction observed in LCE in 2010, similar decreases were also observed in the neighbouring reference creeks and other than site LC12, the changes in LCE were not as great as those observed for reference sites. Overall, sites that were toxic in 2010 were toxic in 2002/2003, and one site (LC08) showed improvement.

4 CONCLUSIONS

The purpose of this 2010 assessment of benthic conditions in Lyons Creek East (LCE) was to determine if, and by how much, benthic conditions were recovering from impairment since 2002/2003. The 2010 study repeated 7 of the 11 LCE sites and 3 of the 6 neighbouring reference creek sites that were sampled in 2002/2003. Contaminant levels in the sediment and resident benthos, benthic community composition, and sediment toxicity at LCE sites were compared to those at neighbouring reference creeks as well to those at GL reference sites (toxicity component only).

Consistent with the past studies, contamination in the creek was most severe in the upper 1.5-2 km reach, where the main contaminants of concern (PCBs, PAHs, and Zn) were above sediment quality guidelines and above maximum concentrations observed in local reference creeks. Sediment and invertebrate tissue PCB concentrations in Lyons Creek remained elevated compared to those in neighbouring reference sites and above sediment quality guidelines from downstream of the former industrial outfall to, at minimum, 400 m downstream of Highway 140. Invertebrate total PCB concentrations were similar or lower in 2010 compared to 2002/2003. Other organic contaminants such as PAHs, petroleum hydrocarbons, and oil and grease were also elevated in LCE sediment compared to reference creeks, and generally followed the same pattern as PCBs. Total PAH levels decreased just below the former outfall then increased at sites further downstream. Relative to 2002/2003 PAH bioaccumulation in the resident benthos was similar or lower in 2010. Exceedences by metals of high sediment quality guidelines were mostly restricted to zinc. Concentrations for LCE in 2010 were mostly elevated compared to those in neighbouring reference site sediment, but overall zinc levels were lower in 2010 than in 2002/2003. Zinc followed the same pattern as PAHs with decrease just below the former industrial outfall and increase at sites further downstream. The higher sediment PCB, PAH and zinc concentrations at some sites in 2010 may reflect movement of sediments and thus contaminants from upstream to downstream locations in the creek and/or site heterogeneity, as sampling locations were not exact between years.

Benthic communities in LCE appear to be different than those in neighbouring reference creeks. Relative to 2002/2003 richness, abundance and diversity were lower at most sites in 2010, including in the reference creeks. One sampling event would not adequately reflect variability intrinsic in stream benthic communities; therefore, LCE sites were assessed against all reference sites sampled in 2002, 2003 and 2010. The extent of natural variability in macroinvertebrate community structure was evidenced for the reference sites, where changes in community composition were also observed from 2002 to 2010 at the co-located sites. Although decreases were observed in certain taxa at some LCE sites in 2010, continued monitoring are required to demonstrate whether change is associated with anthropogenic impacts versus natural temporal variation. Toxicity continued to be limited to the upper creek (≤ 1 km downstream of the Welland Canal Bypass) and overall, there was similar or reduced toxicity in 2010 at the resampled sites.

Overall, the area of LCE from Ridge Road to ~ 400 m downstream of Highway 140 is the critical area of the creek, where the highest sediment and invertebrate PCB concentrations occurred and where some toxicity was evident. It is recommended that Lyons Creek continue to be monitored for recovery of benthic conditions as part of the monitoring program in place.

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Tables

Table 1. Lyons Creek (LC) and reference creek sites positions and depth (m), 2002-2010. BEC = Beaver creek, BLC = Black Creek, UC = Usshers Creek, TC = Tee Creek. Distance apart is between locations in 2002/2003 and 2010.

2002 / 2003 (n = 21)						**2010 (n = 10)**						Distance Apart (m)
Site	Year	Sampling Device	Site Depth (m)	Northing	Easting	Site	Sampling Device	Site Depth (m)	Northing	Easting		
BEC01	2002	Petite Ponar	0.47	4757776	662817							
BEC02	2002	Petite Ponar	0.39	4757808	661752	BEC 02	Cores	0.50	4757812	661752		4
BLC01	2002	Cores	0.60	4757786	660280							
BLC02	2002	Petite Ponar	0.66	4757674	660139							
UC	2003	Cores	0.25	4768269	661074	UC	Cores	0.50	4768256	661082		15
TC	2003	Cores	0.33	4765367	654026	TC	Cores	0.70	4765379	654027		12
LC01	2002	Petite Ponar	2.00	4759467	645094	LC01	Petite Ponar	1.10	4759467	645088		6
LC03	2002	Cores	0.91	4759516	645129	LC03	Cores	0.50	4759532	645134		17
LC06	2003	Cores	0.41	4759641	645233							
LC08	2003	Cores	0.36	4759768	645404	LC08	Cores	0.40	4759765	645401		4
LC10	2003	Cores	0.25	4759964	645617							
LC12	2002	Cores	0.90	4759890	645934	LC12	Cores	0.50	4759887	645941		8
LC14	2003	Cores	0.41	4759917	646252							
LC16	2002	Cores	0.46	4760195	646313	LC16	Cores	0.40	4760253	646329		60
LC17	2002	Cores	0.40	4760309	646441							
LC18	2003	Cores	0.35	4760589	646681	LC18	Petite Ponar	1.0	4760582	646681		7
LC19	2003	Cores	0.30	4760662	646759							
LC22	2003	Cores	0.46	4761488	647894							
LC23	2003	Cores	0.46	4761691	648039							
LC29	2002	Cores	0.56	4762067	649666							
LC38	2002	Cores	0.47	4766330	655076	LC38	Petite Ponar	1.0	4766330	655071		5

Table 2. Descriptions for 2010 Lyons Creek and reference sites.

Site/Date Sampled	Creek	Year	Description
BEC02 (Sep 10, 2010)	Beaver Creek	2010	4-8cm fine silt with lots of organic debris (fine and coarse). Organic smell.
LC01 (Sep 7, 2010)	Lyons Creek	2010	Weedy, some patches of shells.Fine brown mud, mostly dark with some lighter patches.
LC03 (Sep 7, 2010)	Lyons Creek	2010	10cm coarse mud and organics. Weeds. Oily sheen and tar balls. Grey with some brown patches.
LC08 (Sep 9, 2010)	Lyon's Creek	2010	10cm dark brown soft silt, organic, oily sheen
LC12 (Sep 9, 2010)	Lyons Creek	2010	10cm black organic mud, soft, fluffy. Oily sheen. Petro smell.
LC16 (Sep 9, 2010)	Lyons Creek	2010	10cm silty, organic mud. Thin brown layer over black. Gas odour.
LC18* (Sep 9, 2010)	Lyon's Creek	2010	10cm black mud, fine organics. Sheen of fuel. PAH odour.
LC38 (Sep 8, 2010)	Lyons Creek	2010	8cm fine grey sandy organic twigs, leaves over grey mud. Organic smell.
TC40 (Sep 8, 2010)	Tee Creek	2010	10cm soft grey mud. Lots of twigs, branches,leaves and logs. Organic with sandy sections. Organic smell.
UC01 (Sep 8, 2010)	Usshers Creek	2010	2-3cm sand,gravel silt. Some clay patches. Best sediment in Lilypad patch.

* QA/QC site

Table 3. List of environmental variables measured at each site in 2010.

Field	Water	Sediment	Benthic Invertebrates
Northing	Alkalinity	29 Trace Metals	PCB congeners
Easting	Conductivity	PCB congeners	PAHs
Site Depth	Dissolved Oxygen	PAHs	
	pH	Organochlorine pesticides	
	Temperature	Petroleum Hydrocarbons	
	Total Kjeldahl Nitrogen	Oil and Grease	
	Total Phosphorus	Total Phosphorus	
	NH_3-N,	Total Kjeldahl Nitrogen	
	NO_3/NO_2-N	Total Organic Carbon	
		Loss on Ignition	
		Clay, Silt, Sand, & Gravel	

Table 4. Overlying water characteristics for 2010 Lyons Creek and reference sites.

Site	**Alkalinity**	**Conductivity**	**Dissolved Oxygen**	**pH**	**Temp.**	**NH_3**	**NO_3/NO_2**	**Total Kjeldahl Nitrogen**	**Total Phosphorus**
Units	mg/L	µS/cm)	mg/L	-	°C	mg/L	mg/L	mg/L	mg/L
LC01	94	319	8.9	8.2	21.1	0.03	0.13	0.31	0.02
LC03	92	315	9.8	8.4	22.5	0.02	0.12	0.34	0.05
LC08	92	310	11.0	8.4	20.0	0.01	0.10	0.23	0.02
LC12	101	330	6.5	7.9	17.5	0.01	0.02	0.22	0.03
LC16	92	312	6.3	7.8	18.1	0.03	0.02	0.28	0.13
LC18[a]	97	326	4.6	7.7	17.3	0.02	0.01	0.28	0.02
LC38	114	432	8.0	7.8	19.4	0.02	0.01	0.41	0.08
BEC02	201	1255	3.7	7.6	17.3	0.02	0.01	0.62	0.14
UC	94	304	8.3	8.1	20.1	0.01	0.08	0.21	0.03
TC	117	429	6.8	7.7	19.6	0.02	0.01	0.40	0.08

[a] QA/QC site (value represents the mean of three field replicates).

Table 5. Sediment trace metal and nutrient concentrations (µg/g dry wt) for 2010 Lyons Creek and reference sites. Values > the Interim Sediment Quality Guideline or Lowest Effect Level (LEL) are indicated in blue; values > Probable Effect Level (PEL) or Severe Effect Level (SEL) are indicated in red.

Parameter	Units	M.D.L.	Reference Method	ISQG/ LEL	PEL/ SEL	LC01	LC03	LC08	LC12	LC16	LC18[a]	LC38	TC[b]	UC	BEC02
Aluminum	µg/g	10	EPA 6010			14600	13200	18600	17500	24000	21400	24000	20600	9880	17700
Antimony	µg/g	0.5	EPA 6020			< 0.5	< 0.5	0.6	1.0	1.1	1.6	< 0.5	< 0.5	< 0.5	< 0.5
Arsenic	µg/g	0.5	EPA 6020	5.9	17/33	4.1	**8.5**	**8.0**	**16.0**	**13.5**	**21.1**	3.6	3.4	2.2	3.6
Barium	µg/g	1	EPA 6010			75	88	108	119	135	126	104	93	47	77
Beryllium	µg/g	0.2	EPA 6010			0.5	0.5	0.7	0.6	0.9	1	0.9	0.8	0.4	0.8
Bismuth	µg/g	5	EPA 6010			< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Cadmium	µg/g	0.5	EPA 6010	0.6	3.5/10	< 0.5	< 0.5	**0.7**	**0.8**	**0.9**	**1.1**	< 0.5	< 0.5	< 0.5	**0.8**
Calcium	µg/g	10	EPA 6010			91800	88900	19000	78900	11700	25833	10800	8110	34700	9690
Chromium	µg/g	1	EPA 6010	37.3	90/110	19	**44**	**38**	**42**	**44**	**50**	27	23	12	19
Cobalt	µg/g	1	EPA 6010			10	11	12	14	15	16	17	16	8	11
Copper	µg/g	1	EPA 6010	35.7	197/110	**47**	**56**	**59**	**64**	**62**	**65**	26	21	14	23
Iron	µg/g	10	EPA 6010	20000	40000	20000	**25500**	**30400**	**48800**	**35300**	**65433**	**28200**	**24100**	14900	**21300**
Lead	µg/g	5	EPA 6010	35	91.3/250	17	**37**	**51**	**59**	**55**	**80**	18	15.5	10	17
Magnesium	µg/g	10	EPA 6010			16400	12800	7790	8840	9660	8293	7950	7900	14600	4590
Manganese	µg/g	1	EPA 6010	460	1100	**503**	381	268	**479**	371	**505**	444	393	307	220
Mercury	µg/g	0.005	EPA 7471A	0.17	0.486/2	0.042	0.099	0.110	0.125	0.104	0.153	0.068	0.091	0.028	0.077
Molybdenum	µg/g	1	EPA 6010			< 1	2	1	2	2	4	< 1	< 1	< 1	< 1
Nickel	µg/g	1	EPA 6010	16	75	**30**	**56**	**45**	**64**	**53**	**81**	**37**	**35**	15	**30**
Phosphorus	µg/g	5	EPA 6010			789	1030	2150	6270	2010	6323	911	794.5	627	724
Potassium	µg/g	30	EPA 6010			1840	1420	1590	1700	2240	1890	1790	1725	1080	1420
Silicon	µg/g	1	EPA 6010			231	316	292	233	225	228	275	241	229	315
Silver	µg/g	0.2	EPA 6010			5.5	17.6	11.7	16.1	15.7	25.6	< 0.2	< 0.2	< 0.2	< 0.2
Sodium	µg/g	20	EPA 6010			220	160	170	210	240	243	190	200	140	260
Strontium	µg/g	1	EPA 6010			132	164	63	201	63	111	56	41	37	204
Tin	µg/g	10	EPA 6010			< 10	< 10	< 10	10	< 10	10	< 10	< 10	< 10	< 10
Titanium	µg/g	1	EPA 6010			227	174	171	149	176	152	158	155	185	105
Vanadium	µg/g	1	EPA 6010			23	22	27	27	35	35	35	30	18	25
Yttrium	µg/g	0.5	EPA 6010			11.7	10.6	10.7	8.4	10.8	9.0	12.4	11.65	9.2	11.2
Zinc	µg/g	1	EPA 6010	120	820	116	**840**	**759**	**2450**	**1210**	**3997**	**143**	115	64	91
Zirconium	µg/g	0.1	EPA 6010			< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Aluminum (Al2O3)	%	0.2	IN-HOUSE			10.1	8.6	12.1	9.8	12.9	12	13.5	13.4	9.6	13.6
Barium (BaO)	%	0.01	IN-HOUSE			0.04	0.04	0.16	0.04	0.05	0.05	0.05	0.05	0.05	0.05
Calcium (CaO)	%	0.3	IN-HOUSE			9.7	9.1	1.6	7.8	0.9	2.7	2.6	2.25	5.1	1.6
Chromium (Cr2O3)	%	0.03	IN-HOUSE			< 0.03	0.03	< 0.03	0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03
Iron (Fe2O3)	%	0.1	IN-HOUSE			4.0	4.8	5.9	9.5	6.3	12.3	5.3	4.9	3.8	4.3
Magnesium (MgO)	%	0.2	IN-HOUSE			2.6	2.1	1.8	1.8	1.4	1.6	2.7	2.7	2.2	1.6
Manganese (MnO)	%	0.01	IN-HOUSE			0.15	0.07	0.05	0.07	0.05	0.07	0.06	0.06	0.07	0.04
Phosphorus (P2O5)	%	3	IN-HOUSE			< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3
Potasium (K20)	%	2	IN-HOUSE			2	2	3	2	3	2	3	3	2	2
Silica (SiO2)	%	0.5	IN-HOUSE			44.9	40.8	41.7	34.6	41.9	38.2	44.0	49	45.0	42.8
Sodium (Na2O)	%	3	IN-HOUSE			< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3
Titanium (TiO2)	%	0.1	IN-HOUSE			0.5	0.4	0.6	0.5	0.6	0.6	0.7	0.8	0.6	0.5
Loss on Ignition	%	0.05	IN-HOUSE			17.8	21.9	24.2	23.4	26.1	20.4	18.0	14.9	11.0	19.0
Whole Rock Total	%		IN-HOUSE			92.2	90.0	90.8	92.0	92.9	92.5	89.5	90.5	79.4	86.0
Total Organic Carbon	wt	0.1	LECO	1	10	**2.1**	**6.0**	**9.8**	**6.3**	**9.8**	**6.3**	**5.6**	**4.7**	**1.6**	**7.0**
Total Kjeldahl Nitrogen	µg/g	0.05	EPA 351.2	550	4800	**2370**	**3220**	**8940**	**4670**	**8000**	**4813**	**4460**	**3420**	**1430**	**5460**
Phosphorus-Total	µg/g	0.01	EPA 365.4	600	2000	**815**	**1050**	**2280**	**5770**	**1940**	**6503**	**855**	**898**	**637**	**775**

[a] values represent mean of field-replicated samples; [b] value represents mean of lab duplicate sample

Table 6. Sediment PCB congener group totals (ng/g dw) and toxic equivalents (ng TEQ/kg dw) for 2010 Lyons Creek and reference sites. Values in red are above the Probable Effect Level based on total PCBs (277 ng/g) and toxic equivalents (TEQs) (21.5 ng TEQ kg^{-1} dw).

	LC01[a]	**LC03**	**LC08**	**LC12**	**LC16**	**LC18[b]**	**LC38**	**TC**	**UC**	**BEC02**
Congener Group Totals (ng/g)										
Monochlorobiphenyls	66.35	1.41	0.509	12.6	1.91	4.3	0.0427	0.024	0.0102	0.0538
Dichlorobiphenyls	9.41	141	32.8	1290	169	565	0.477	0.179	0.0931	0.364
Trichlorobiphenyls	20.15	2800	473	11400	1840	6503	2.4	0.968	1.06	2.06
Tetrachlorobiphenyls	60.9	9690	2300	17100	4430	9760	4.73	2.33	3.52	5.08
Pentachlorobiphenyls	34.85	3720	1480	5070	1700	2840	3.4	2.26	2.3	4.05
Hexachlorobiphenyls	10.13	721	381	871	327	494	2.14	1.86	3.54	2.62
Heptachlorobiphenyls	4.215	166	148	268	108	184	0.794	0.824	5.46	1.27
Octachlorobiphenyls	1.51	67.3	38.1	66	28.1	43.5	0.308	0.258	3.23	0.589
Nonachlorobiphenyls	0.05225	9.72	5.23	9.15	3.77	5.85	0.0672	0.0936	0.57	0.128
Decachlorobiphenyl	0.05025	0.834	0.48	0.835	0.285	0.566	0.106	0.048	0.0675	0.0949
Total PCBs (ng/g)	207.5	**17300**	**4850**	**36100**	**8610**	**20433**	14.5	8.84	19.8	16.3
TEQ - lower bound	0.634	**95.95**	**29.84**	**152.97**	**51.27**	**97.45**	0.103	0.073	0.044	0.112
TEQ - upper bound	0.717	**95.95**	**29.84**	**152.97**	**51.27**	**97.45**	0.105	0.075	0.056	0.114

[a] value represents mean of lab duplicate sample

[b] values represent mean of field-replicated samples

Table 7. Sediment PAH concentrations (mg/kg dw) for 2010 Lyons Creek and reference sites. Values in blue exceed the LEL; values red exceed the PEL.

Polycyclic Aromatic Hydrocarbons	LEL	PEL	LC01	LC03	LC08	LC12	LC16	LC18[a]	LC38	TC	UC	BEC02
Acenaphthene		0.0889	<0.10	<1.5	<0.25	**0.66**	<0.25	<0.40	<0.20	<0.25	<0.10	<0.25
Acenaphthylene		0.128	<0.10	<1.5	<0.25	<0.25	<0.25	<0.40	<0.20	<0.25	<0.10	<0.25
Acridine			<1.6	<24	<4.0	<4.0	<4.0	<40	<3.2	<4.0	<1.6	<4.0
Anthracene		0.245	<0.10	<1.5	<0.25	**0.61**	<0.25	**0.4**	<0.20	<0.25	<0.10	<0.25
Benzo(a)anthracene		0.385	0.13	<1.5	0.26	**1.95**	0.28	**1.7**	<0.20	<0.25	<0.10	<0.25
Benzo(a)pyrene		0.782	0.124	**1.30**	0.42	**1.38**	0.27	**1.5**	<0.080	<0.10	<0.040	<0.10
Benzo(b&j)fluoranthene			0.11	<1.5	0.46	1.52	0.30	1.0	<0.20	<0.25	<0.10	<0.25
Benzo(g,h,i)perylene	0.17		0.15	**1.6**	0.85	**1.37**	**0.39**	**1.3**	<0.20	<0.25	<0.10	<0.25
Benzo(k)fluoranthene	0.24		0.112	**0.70**	0.22	**0.78**	0.16	**0.4**	<0.080	<0.10	<0.040	<0.10
Chrysene		0.862	0.18	**3.0**	0.72	**4.12**	0.74	**4.0**	<0.20	<0.25	<0.10	<0.25
Dibenzo(ah)anthracene		0.135	<0.10	<1.5	<0.25	**0.35**	<0.25	**0.5**	<0.20	<0.25	<0.10	<0.25
Fluoranthene		2.355	0.29	1.8	0.57	**10.5**	0.54	**2.8**	<0.20	<0.25	<0.10	<0.25
Fluorene		0.144	<0.10	<1.5	<0.25	**1.09**	<0.25	**0.4**	<0.20	<0.25	<0.10	<0.25
Indeno(1,2,3-cd)pyrene	0.20		0.11	<1.5	**0.45**	**0.76**	<0.25	**0.7**	<0.20	<0.25	<0.10	<0.25
1-Methylnaphthalene			<0.10	<1.5	<0.25	<0.25	<0.25	<0.40	<0.20	<0.25	<0.10	<0.25
2-Methylnaphthalene		0.201	<0.10	<1.5	<0.25	<0.25	<0.25	<0.40	<0.20	<0.25	<0.10	<0.25
Naphthalene		0.391	<0.020	<0.30	<0.050	<0.050	<0.050	<0.50	<0.040	<0.050	<0.020	<0.050
Phenanthrene		0.515	0.177	<0.90	0.18	**3.76**	<0.15	**0.8**	<0.12	<0.15	<0.060	<0.15
Pyrene		0.875	0.28	4.0	**0.96**	**8.75**	0.76	**3.9**	<0.20	<0.25	<0.10	<0.25
Quinoline			<0.10	<1.5	<0.25	<0.25	<0.25	<0.40	<0.20	<0.25	<0.10	<0.25
Total PAHs	4		1.7	**12.4**	**5.1**	**37.6**	3.4	**19.4**	<	<	<	<

[a] values represent mean of field-replicated samples

Table 8. Sediment total petroleum hydrocarbon concentrations (mg/kg dw) for 2010 Lyons Creek and reference sites.

	LC01	**LC03**	**LC08**	**LC12**	**LC16**	**LC18**[a]	**LC38**	**TC**	**UC**	**BEC02**
Physical Tests										
% Moisture	64.2	74.0	80.3	86.2	88.1	87.2	76.6	71.1	58.5	81.7
Oil and Grease, Total	**1660**	**76900**	**20300**	**48200**	**34400**	**75300**	**4340**	**3540**	**1200**	**5980**
Volatile Organic Compounds										
Benzene	<0.10	<0.15	<0.25	<0.25	<0.25	<0.25	<0.25	<0.15	<0.10	<0.25
Ethyl Benzene	<0.10	<0.15	<0.25	<0.25	<0.25	<0.25	<0.25	<0.15	<0.10	<0.25
Toluene	<0.10	<0.15	<0.25	<0.25	<0.25	<0.25	<0.25	<0.15	<0.10	<0.25
o-Xylene	<0.10	<0.15	<0.25	<0.25	<0.25	<0.25	<0.25	<0.15	<0.10	<0.25
m+p-Xylenes	<0.20	<0.30	<0.50	<0.50	<0.50	<0.50	<0.50	<0.30	<0.20	<0.50
Xylenes (Total)	<0.22	<0.34	<0.56	<0.56	<0.56	<0.56	<0.56	<0.34	<0.22	<0.56
Hydrocarbons										
F1 (C6-C10)	<10	<15	<25	<25	<25	<25	<25	<15	<10	<25
F1-BTEX	<10	<15	<25	<25	<25	<25	<25	<15	<10	<25
F2 (C10-C16)	22	296	67	698	810	615	<40	<30	<20	1670
F2-Naphth	22	296	67	698	810	615	<40	<30	<20	1670
F3 (C16-C34)	140	16700	3910	23200	25400	19027	<200	310	<100	4210
F3-PAH	140	16700	3910	23200	25400	19023	<200	310	<100	4210
F4 (C34-C50)	<100	6330	1490	7160	7990	7080	<200	<150	<100	2360
F4G-SG (GHH-Silica)	<1000	14100	3500	16800	14900	18000	<2000	<1500	<1000	<2500
Total Hydrocarbons (C6-C50)	**160**	**23300**	**5470**	**31100**	**34200**	**26733**	**<200**	**310**	**<100**	**8240**
Chromatogram to baseline at nC50	YES	NO	NO	NO	NO	NO	YES	YES	YES	NO

Table 9. Sediment organochlorine pesticide concentrations (mg/kg dw) for 2010 Lyons Creek and reference sites.

Organochlorine Pesticides	LC01	LC03	LC08	LC12	LC16	LC18[a]	LC38	TC01	UC01	BEC02
Aldrin	<0.040	<0.60	<1.0	<0.10	<0.10	<0.10	<0.080	<0.060	<0.040	<0.10
alpha-BHC	<0.040	<0.60	<1.0	<0.10	<0.10	<0.10	<0.080	<0.060	<0.040	<0.10
beta-BHC	<0.040	<0.60	<1.0	<0.15	0.14	<0.80	<0.080	<0.060	<0.040	<0.10
Lindane	<0.040	<0.60	<1.0	<0.20	<0.10	<0.25	<0.080	<0.060	<0.040	<0.10
delta-BHC	<0.040	<0.60	<1.0	<0.15	<0.10	<0.15	<0.080	<0.060	<0.040	<0.10
a-chlordane	<0.040	<0.60	<1.0	<0.10	<0.10	<0.10	<0.080	<0.060	<0.040	<0.10
g-chlordane	<0.040	<0.60	<1.0	<0.10	<0.10	<0.10	<0.080	<0.060	<0.040	<0.10
op-DDD	<0.040	<0.60	<1.0	<0.10	<0.10	<0.10	<0.080	<0.060	<0.040	<0.10
pp-DDD	<0.040	<0.60	<1.0	<0.10	<0.10	<0.10	<0.080	<0.060	<0.040	<0.10
o,p-DDE	<0.040	<0.60	<1.0	<0.10	<0.10	<0.10	<0.080	<0.060	<0.040	<0.10
pp-DDE	<0.040	<0.60	<1.0	<0.10	<0.10	<0.10	<0.080	<0.060	<0.040	<0.10
op-DDT	<0.040	<0.60	<1.0	<0.10	<0.10	<0.10	<0.080	<0.060	<0.040	<0.10
pp-DDT	<0.040	<0.60	<1.0	<0.10	<0.10	<0.10	<0.080	<0.060	<0.040	<0.10
Dieldrin	<0.040	<0.60	<1.0	<0.10	<0.10	<0.15	<0.080	<0.060	<0.040	<0.10
alpha-Endosulfan	<0.040	<0.60	<1.0	<0.10	<0.10	<0.30	<0.080	<0.060	<0.040	<0.10
beta-Endosulfan	<0.040	<0.60	<1.0	<0.12	0.12	<0.35	<0.080	<0.060	<0.040	<0.10
Endosulfan Sulfate	<0.040	<0.60	<1.0	<0.10	<0.10	<0.10	<0.080	<0.060	<0.040	<0.10
Endrin	<0.040	<0.60	<1.0	<0.10	<0.10	<0.20	<0.080	<0.060	<0.040	<0.10
Endrin Aldehyde	<0.040	<0.60	<1.0	<0.10	<0.10	<0.12	<0.080	<0.060	<0.040	<0.10
Heptachlor	<0.040	<0.60	<1.0	<0.10	<0.10	<0.12	<0.080	<0.060	<0.040	<0.10
Heptachlor Epoxide	<0.040	<0.60	<1.0	<0.10	<0.10	<0.10	<0.080	<0.060	<0.040	<0.10
Methoxychlor	<0.040	<0.60	<1.0	<0.10	<0.10	<0.10	<0.080	<0.060	<0.040	<0.10
Mirex	<0.040	<0.60	<1.0	<0.10	<0.10	<0.10	<0.080	<0.060	<0.040	<0.10
Oxychlordane	<0.040	<0.60	<1.0	<0.10	<0.10	<0.10	<0.080	<0.060	<0.040	<0.10

Table 10. Sediment Quality Index (SQI) for 2002/03 and 2010 Lyons Creek and reference sites.

Site	SQI - 2002/03	Quality	SQI - 2010	Quality
Black Cr 01	100	Excellent	n/a	-
Black Cr 02	100	Excellent	n/a	-
Beaver Cr 01	100	Excellent	n/a	-
Beaver Cr 01	100	Excellent	100	Excellent
Usshers Cr	100	Excellent	100	Excellent
Tee Cr	100	Excellent	100	Excellent
LC01	100	Excellent	100	Excellent
LC03	33	Poor	39	Poor
LC06	91	Good	n/a	-
LC08	54	Marginal	57	Marginal
LC10	68	Fair	n/a	-
LC12	49	Marginal	34	Poor
LC14	65	Fair	n/a	-
LC16	85	Good	46	Marginal
LC17	81	Good	n/a	-
LC18	92	Good	35	Poor
LC19	85	Good	n/a	-
LC22	94	Good	n/a	-
LC23	87	Good	n/a	-
LC29	93	Good	n/a	-
LC38	100	Excellent	100	Excellent

n/a = not applicable

Table 11. Concentrations of PCB congeners (pg/g dw) in benthic invertebrates collected from 2010 Lyons Creek and reference sites.

Site	**LC01**		**LC12**		**LC16**			**LC38**		**TC**		**UC**		**BEC02**	
Invertebrate	AMP	OLIG	AMP	OLIG	AMP	OLIG	ISO	AMP	OLIG	AMP	ISO	AMP	OLIG	AMP	ISO
Dioxin-like PCBs (ng/g)															
PCB 77	1640	413	30700	8590	16100	62100	33100	672	474	414	368	1050	107	<470	334
PCB 81	55.1	<64	1260	<270	657	2460	1440	<82	<46	<48	<56	<140	<19	<82	<59
PCB 126	<94	<170	649	<340	<290	<710	511	<150	<340	<130	<110	<370	<57	<360	<180
PCB 169	<7.0	<15	<18	<81	<18	<48	<22	<4.6	<14	<2.9	<1.8	<1.2	<8.2	<8.2	<5.4
PCB 105	5420	2730	70600	26300	42500	141000	89800	3250	2130	1990	1980	5100	535	2610	2030
PCB 114	487	<130	5120	1600	4430	10600	6490	<430	<210	<200	249	<360	<40	375	<160
PCB 118	13500	6830	132000	42800	88400	256000	116000	11400	6320	7560	7010	18400	1750	8940	7280
PCB 123	<57	<100	4460	1250	2770	<360	4920	<89	<190	<72	<69	<230	<33	<240	<250
PCB 156	464	<240	4340	1800	2800	9210	3880	269	<330	106	<85	<110	101	131	<92
PCB 157	<110	79.6	1040	614	672	2200	1310	<36	<98	<22	<27	<1.3	<24	57.9	27.8
PCB167	232	161	1660	867	1160	<2800	972	<62	<160	<8.9	<44	<38	<5.5	<54	<41
PCB 189	<38	<27	203	252	<140	663	103	<18	102	<6.4	<1.4	<3.3	<15	<16	<6.8
Congener Group Totals (ng/g)															
Monochlorobiphenyls	0.437	1.61	0.463	<	0.147	0.397	0.977	<	<	0.372	0.315	<	<	0.159	<
Dichlorobiphenyls	27.5	0.496	55.6	29.2	35.1	91.4	139	18.3	9.02	32.8	40.2	14.5	1.44	8.56	34.9
Trichlorobiphenyls	216	15.7	735	170	407	1360	1160	180	31.6	348	309	173	15.1	226	332
Tetrachlorobiphenyls	594	112	2720	585	1750	5610	3140	581	134	883	740	682	60.1	695	706
Pentachlorobiphenyls	246	100	1060	298	702	2090	1110	299	91.6	293	239	418	35.1	296	260
Hexachlorobiphenyls	39	21.7	183	60.3	97.8	425	133	31.5	18.9	15.9	6.15	39.1	3.25	32	16
Heptachlorobiphenyls	7.03	1.16	40.7	22.7	24.3	138	17.6	2.51	0.642	0.714	0.539	<	4.66	0.311	0.204
Octachlorobiphenyls	0.326	0.478	4.18	7.09	3.87	18.3	3.02	0.321	2.02	0.205	<	0.404	<	<	0.0291
Nonachlorobiphenyls	<	<	0.494	0.868	0.136	1.87	<	<	<	<	<	<	0.199	<	0.0379
Decachlorobiphenyl	<	<	<	0.506	<	0.238	<	<	<	<	0.914	<	<	<	<
Total PCBs (ng/g)	1130	254	4790	1170	3020	9740	5700	1110	288	1570	1340	1330	120	1260	1350

AMP = amphipod, OLIG = oligochaete, ISO=isopod

Table 12a. Concentrations of PAHs in benthic invertebrates (ng/g dw) collected from 2010 Lyons Creek sites.

Site	LC01				LC12			LC16						LC38			
Invertebrate	Amphipod		Oligochaete		Amphipod	Oligochaete		Amphipod		Oligochaete		Isopod		Amphipod		Oligochaete	
Target Analytes (Blank Corrected)	ng/g		ng/g		ng/g	ng/g		ng/g		ng/g		ng/g		ng/g		ng/g	
Naphthalene	<50		<50		<50	<250		<50		<50		<50		<50		216.0	
2-Methylnaphthalene	<30		<30		<30	<100		<30		<30		<30		<30		82.0	
1-Methylnaphthalene	<10		<10		<10	<50		<10		<10		<10		<10		44.4	
Acenaphthylene	<10		<10		<10	<50		<10		<10		<10		<10		11.2	
Acenaphthene	<10		<10		<10	<50		<10		<10		<30		<10		30.0	
Fluorene	<20		<10		<20	<100		<10		<20		37		<10		91.2	
Phenanthrene	255		<40		200	<200		228		<50		486		230		285	
Anthracene	<10		<10		<10	<50		<10		<10		<20		<10		<10	
Fluoranthene	108		<10		131	192		70		160		347		138		102	
Pyrene	436		196		385	390		349		341		1290		692		282	
Benzo(a)anthracene	1.26		<4.5	U	24.6	108		13.3		316		119		<3.3	U	<7.2	U
Chrysene/Triphenylene	15.8		56.5		83.4	392		45.7		872		364		<41.8	R	<111	R
Benzo(b)flouranthene	2.29		29.5		12.8	124		<8	R	185		83.6		<3.3	U	<98.4	R
Benzo(k)fluoranthene	<1	U	<4.5	U	3.0	34		<1.49	R	<39.4	R	17.2		<3.3	U	<7.2	U
Benzo(e)pyrene	<1	U	33.5		24.8	382		13.5		561		184		<3.3	U	<552	R
Benzo(a)pyrene	1.14		18		12.2	<18	U	8.37		<88.3	R	86.4		<3.3	U	<7.2	U
Perylene	<1	U	16		6.17	<18	U	6.79		<51.1	R	40.4		<3.3	U	322	R
Indeno(1,2,3-cd)pyrene	<1	U	<4.5	U	3.5	22		<1.86	R	15.4		<14	R	<3.3	U	<7.2	U
Dibenzo(a,h/a,c)anthracene	<1	U	<4.5	U	3.58	<18	U	<1.95	R	<34	R	<15.2	R	<3.3	U	<7.2	U
Benzo(g,h,i)perylene	<1	U	<28	R	11.8	72		11.1		130		57.2		<3.3	U	<7.2	U
Total PAHs	819.83		349		902.39	1716		745.41		2580.1		3111.6		1060.2		1466.2	

U = Indicates that this compound was not detected above the limit of detection

R = Indicates ratio failure on confirming ion

Table 12b. Concentrations of PAHs in benthic invertebrates (ng/g dw) collected from 2010 reference creek sites.

Site	**Beaver Creek 02**				**Tee Creek**				**Usshers Creek**			
Invertebrate	Amphipod		Isopod		Amphipod		Isopod		Amphipod		Oligochaete	
Target Analytes (Blank Corrected)	ng/g		ng/g		ng/g		ng/g		ng/g		ng/g	
Naphthalene	<100		<50		<50		<50		<50		<50	
2-Methylnaphthalene	<30		<30		<30		<30		<30		<30	
1-Methylnaphthalene	<30		<10		<10		<10		<10		<10	
Acenaphthylene	<10		<10		<10		<10		<10		<10	
Acenaphthene	<10		<10		<10		<30		<10		<10	
Fluorene	<30		<20		<10		<30		<10		<10	
Phenanthrene	288		468		310		484		178		<50	
Anthracene	<10		<10		<10		<10		<10		<10	
Fluoranthene	161		167		165		196		161		37	
Pyrene	737		768		721		904		969		108	
Benzo(a)anthracene	6.0		<2.8	R	<2.8	U	<2.1	U	<9	U	9.43	
Chrysene/Triphenylene	39.3		46.2		29.2		<45.4	R	63		27.6	
Benzo(b)flouranthene	6.67		10.8		<2.8	U	9.41		<17	R	23.3	
Benzo(k)fluoranthene	<3	U	6.6		<2.8	U	<2.1	U	<9	U	6.43	
Benzo(e)pyrene	10.3		13.6		<2.8	U	<9.65	R	<9	U	<70.3	R
Benzo(a)pyrene	6.67		<4.4	R	<2.8	U	<3.06	R	<9	U	<1.3	U
Perylene	4.67		75.8		<2.8	U	80.7		22		118	
Indeno(1,2,3-cd)pyrene	8.00		3.6		<2.8	U	2.35		<9	U	7.29	
Dibenzo(a,h/a,c)anthracene	6.00		<1.8	U	<2.8	U	<2.1	U	<9	U	<1.3	U
Benzo(g,h,i)perylene	8.33		<8	R	<2.8	U	<2.1	U	<9	U	<9.29	R
Total PAHs	1282.1		1558.7		1225.8		1676.9		1392.5		337.61	

U = Indicates that this compound was not detected above the limit of detection

R = Indicates ratio failure on confirming ion

Table 13. Abundance (No. m^{-2}) of predominant macroinvertebrate families and taxon richness for 2010 Lyons Creek and reference sites.

Family	Reference Creek Mean (SD[a])	Reference Creeks			Lyons Creek Upstream Hwy 140				Hwy 140	Downstream Hwy 140	
		BEC02	UC	TC	LC01	LC03	LC08	LC12	LC16	LC18[a]	LC38
Chironomidae	2,993 (749)	3,797	2,532	3,471	1,267	1,507	1,627	542	15,069	4,882	693
Tubificidae	2,773 (2,506)	844	1,869	5,606	1,521	9,705	1,266	301	2,773	501	144
Elmidae	1,828 (1,482)	2592	121	2773	875	121	0	0	0	0	39
Ceratopogonidae	1326 (1425)	2833	0	1145	52	0	0	60	784	100	131
Caenidae	683 (729)	422	121	1507	39	60	362	121	1989	105	0
Asellidae	583 (527)	1025	723	0	13	0	0	121	7294	0	0
Pisidiidae	241 (104)	362	181	181	0	60	603	121	1989	26	39
Naididae	221 (194)	0	362	301	91	60	0	60	2230	353	0
Planorbidae	181 (313)	0	543	0	183	0	0	60	0	83	0
Coenagrionidae	161 (228)	60	422	0	66	121	181	121	663	135	0
Valvatidae	161 (278)	0	482	0	0	0	60	0	60	0	0
Physidae	121 (121)	0	241	121	0	0	0	60	60	22	0
Hydrobiidae	101 (174)	0	301	0	0	422	301	60	121	44	0
Leptoceridae	60 (60)	0	121	60	13	0	0	181	723	83	0
Limnesiidae	40 (35)	0	60	60	65	181	0	0	0	4	0
Gammaridae	20 (35)	60	0	0	0	0	422	0	60	0	13
Hyalellidae	0 (0)	0	0	0	118	0	60	60	542	22	13
Total No. taxa[b]	12 (3)	10	15	12	26	11	11	14	19	19	8
Total Abundance[b]	11,513 (3,140)	12,055	8,137	14,346	11,169	12,413	5,003	1,929	34,840	6,454	1,084

[a] standard deviation; [b] Includes minor taxa not listed – complete counts are listed in Appendix B

Table 14. Mean percent survival and growth (mg dry wt. per individual) and reproduction in 2010 whole-sediment toxicity tests. The numerical criteria based on Great Lakes reference sites (non-toxic, potentially toxic and toxic categories) are included: values falling within the potentially toxic and toxic categories are highlighted blue and red, respectively. The BEAST difference-from-reference bands, based on the assessment of integrated endpoints, are provided for 2010 and 2002/2003 sites.

		C. riparius		*H. azteca*		*Hexagenia spp.*		*T. tubifex*					
Site	Year	growth	% survival	growth	% survival	growth	% survival	No. cocoons/ adult	% cocoons hatched	% survival	No. young/ adult	Beast Band 2010[b]	Beast Band 2002/03[c]
Great Lakes reference[a] mean (range)	2000-2010	0.37(0.23-0.60)	90.4 (69.3-100)	0.51 (0.12-0.94)	87.8 (60.0-98.7)	4.12 (1.55-7.77)	99.0 (90.0-100)	10.3 (4.8-12.7)	56.8 (20.5-85.2)	99.9 (95.0-100)	22.8 (1.4-36.9)		
BEC02	2010	0.45	97.3	0.47	90.7	5.75	100	10.5	**12.2**	100	**0.3**	3	1
TC	2010	0.35	90.7	0.42	77.3	5.00	100	10.2	54.4	100	13.4	1	1
UC	2010	0.47	92.0	0.65	97.3	7.92	100	7.9	58.2	95	15.2	1	1
LC01	2010	0.43	86.7	0.69	93.3	7.91	100	10.3	55.8	100	17.7	1	1
LC03	2010	0.32	84.0	0.47	74.7	**-0.18**	**14**	9.7	60.0	100	16.5	4	4
LC08	2010	0.48	78.7	0.60	89.3	2.43	96	11.1	70.7	100	19.1	1	4
LC12	2010	**0.19**	**25.3**	0.46	97.3	**0.26**	**18**	**5.0**	75.4	100	7.7	4	4
LC16	2010	0.40	89.3	0.64	84.0	2.72	96	10.8	57.9	100	25.6	1	1
LC18	2010	0.27	85.3	0.81	91.7	5.13	100	10.5	54.7	100	18.9	1	1
LC38	2010	0.31	78.7	0.72	94.7	5.25	100	11.3	51.6	100	20.6	1	1
Non-toxic[d]		0.53 - 0.22	≥77.7	0.83 - 0.20	≥68.2	7.30 - 0.93	≥95.5	12.8 - 7.8	78.7 - 34.9	≥98.3	38.7 - 6.9	-	-
Potentially Toxic		0.21 - 0.14	77.6 - 71.4	0.19 - 0.04	68.1 - 58.3	0.92 - 0.00	95.4 - 93.8	7.7 - 6.5	34.8 - 23.9	98.2 - 97.5	6.8 - 0.1	-	-
Toxic		<0.14	<71.4	<0.04	<58.3	-	<93.8	<6.5	<23.9	<97.5	<0.1	-	-

[a] Environment Canada, unpublished data; reference sites (n=78).

[b] HMDS of a subset of 1-3 sites with Great Lakes (n=78)

[c] HMDS of a subset of 3-6 sites with Great Lakes reference sites (n=136).

[d] The upper limit for non-toxic category is set using 2 standard deviations of the mean and indicates excessive growth or reproduction

Figures

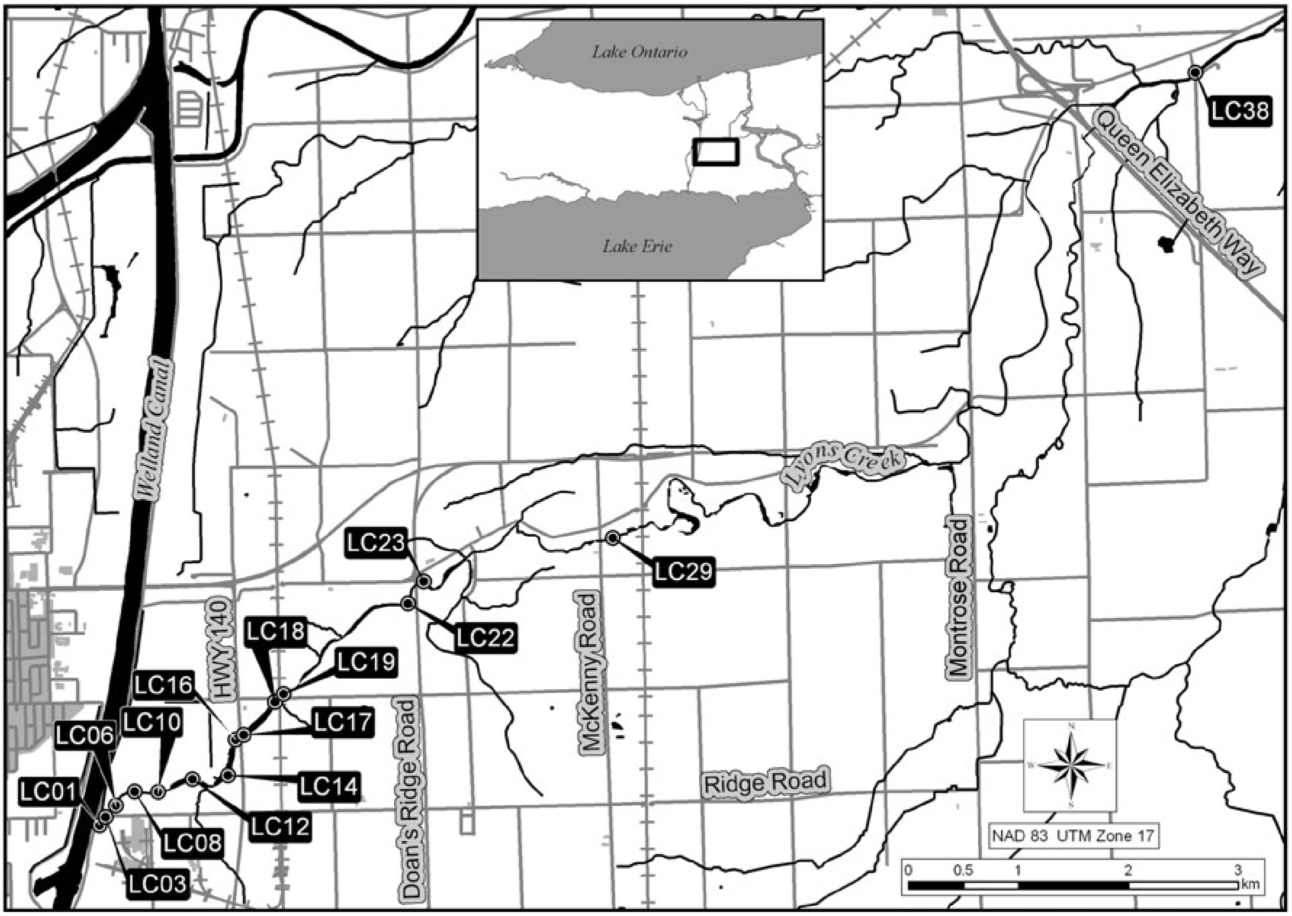

Figure 1. Lyons Creek sampling locations from 2002- 2010. Sites sampled in 2010 are LC01, LC06, LC08, LC12, LC16, LC18, and LC38.

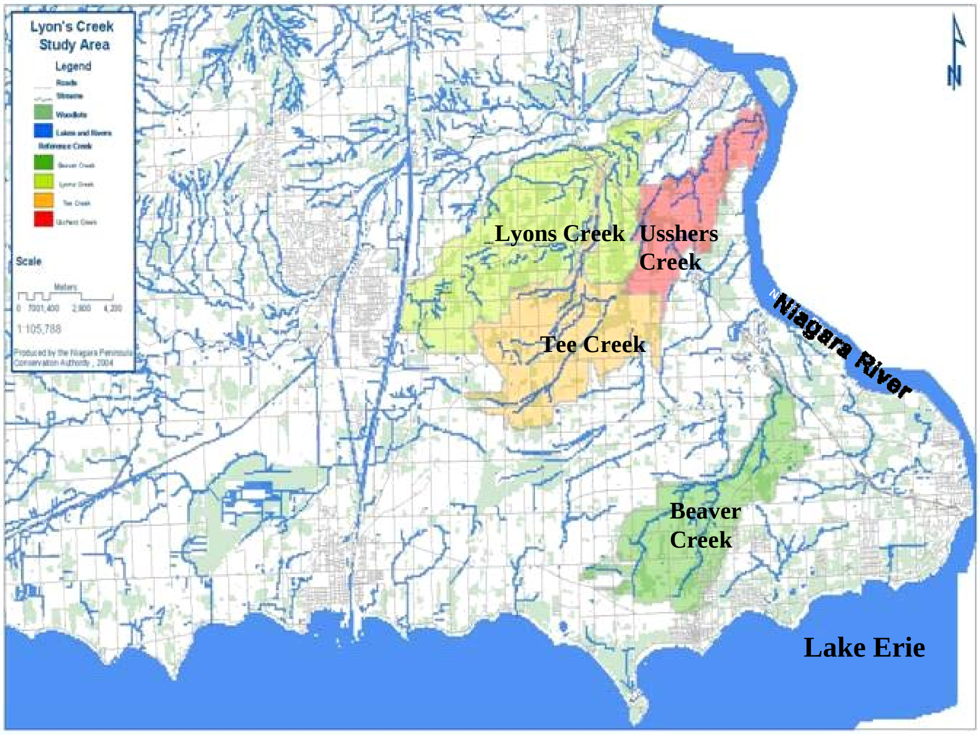

Figure 2. Location of Lyons Creek and three neighbouring reference creeks: Tee Creek, Usshers Creek, and Beaver Creek.

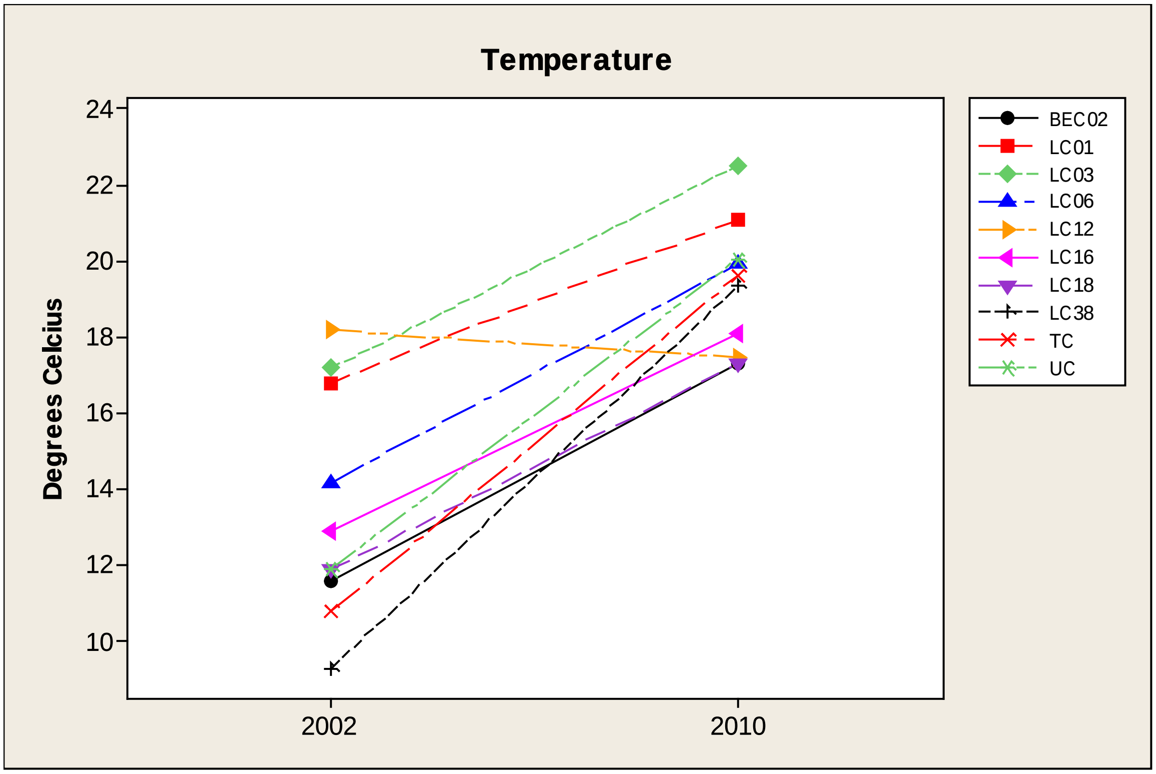

Figure 3. Trends in temperature of overlying water from co-located Lyons Creek (LC) and reference sites.TC= Tee Creek, UC=Usshers Creek, BEC02=Beaver Creek, site 2.

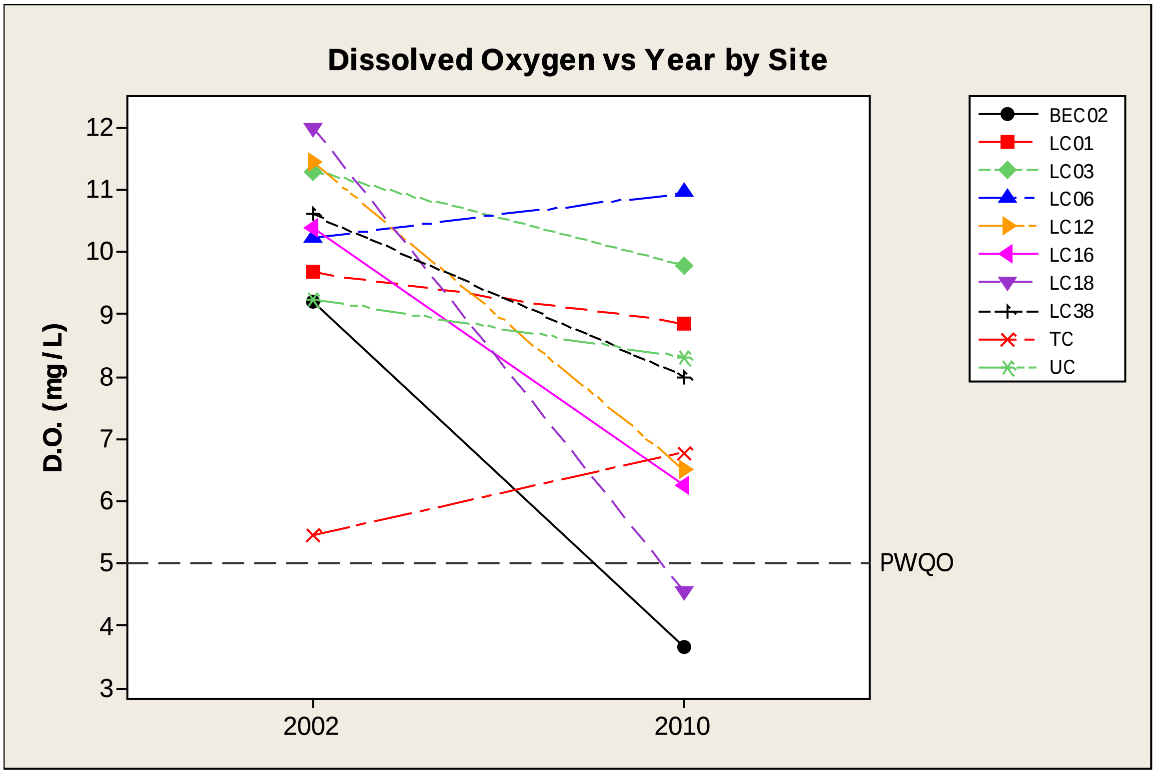

Figure 4. Trends in concentration of dissolved oxygen in overlying water from co-located Lyons Creek (LC) and reference sites. PWQO = provincial water quality objective (MOE 1994). TC= Tee Creek, UC=Usshers Creek, BEC02=Beaver Creek, site 2.

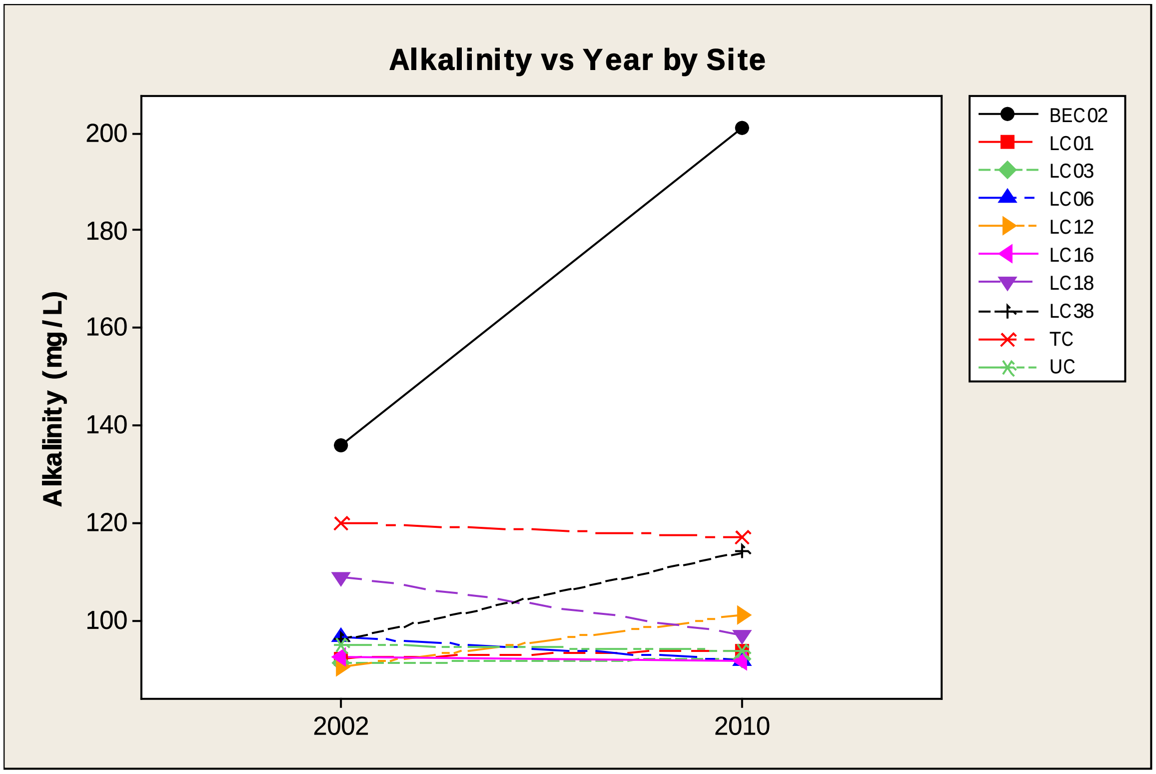

Figure 5. Trends in concentration of alkalinity in overlying water from co-located Lyons Creek (LC) and reference sites. TC= Tee Creek, UC=Usshers Creek, BEC02=Beaver Creek, site 2.

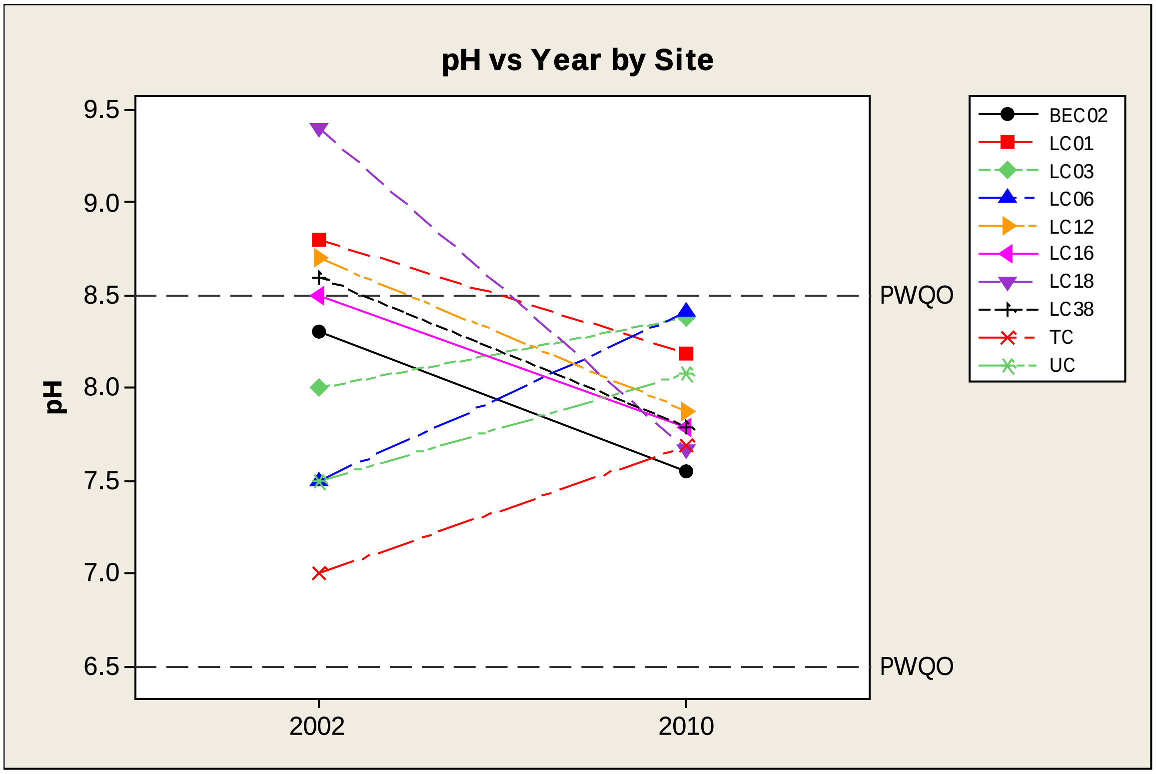

Figure 6. Trends in pH in overlying water from co-located Lyons Creek (LC) and reference sites. PWQO = provincial water quality objective (MOE 1994). TC= Tee Creek, UC=Usshers Creek, BEC02=Beaver Creek, site 2.

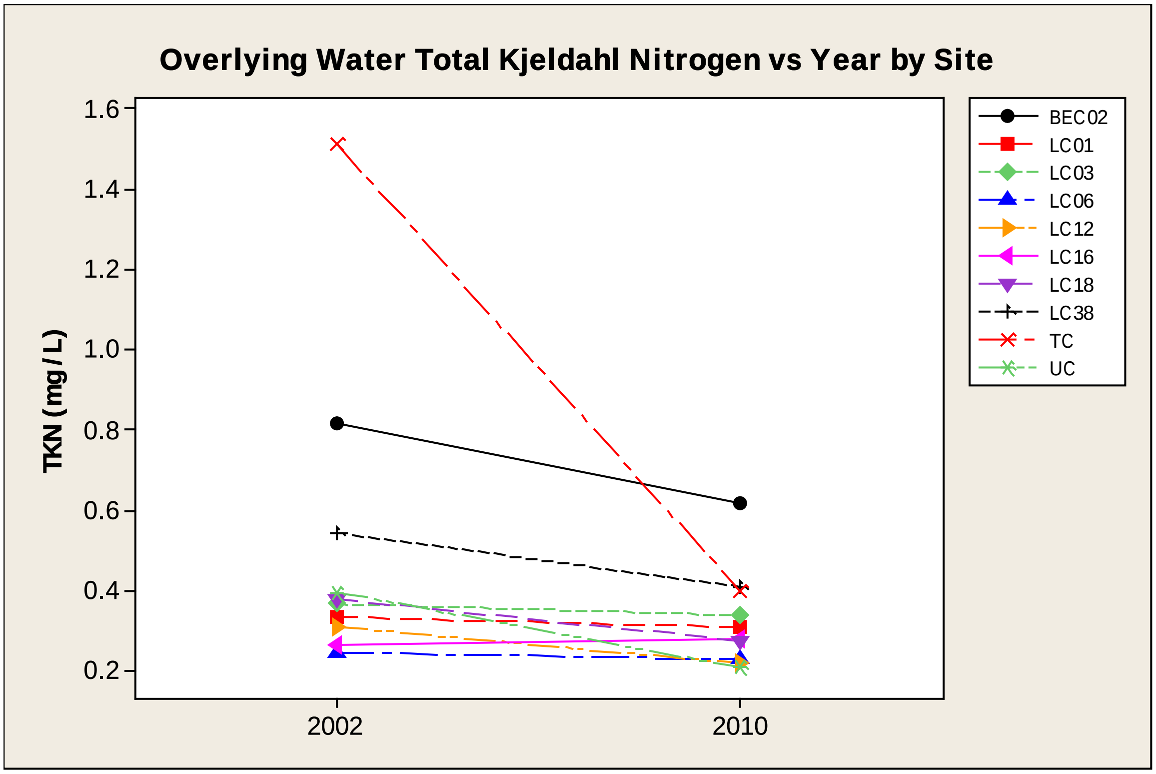

Figure 7. Trends in concentration of total Kjeldahl nitrogen in overlying water from co-located Lyons Creek (LC) and reference sites. TC= Tee Creek, UC=Usshers Creek, BEC02=Beaver Creek, site 2.

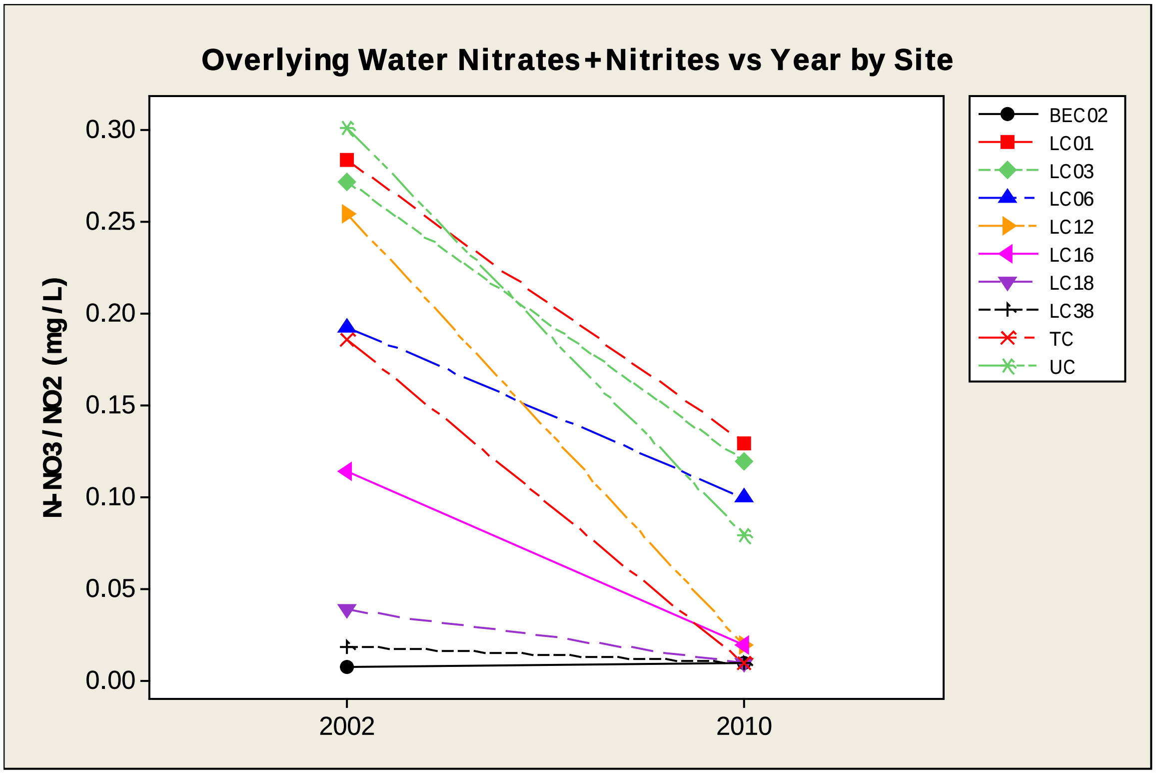

Figure 8. Trends in concentration of nitrates+nitrites in overlying water from co-located Lyons Creek (LC) and reference sites. TC= Tee Creek, UC=Usshers Creek, BEC02=Beaver Creek, site 2.

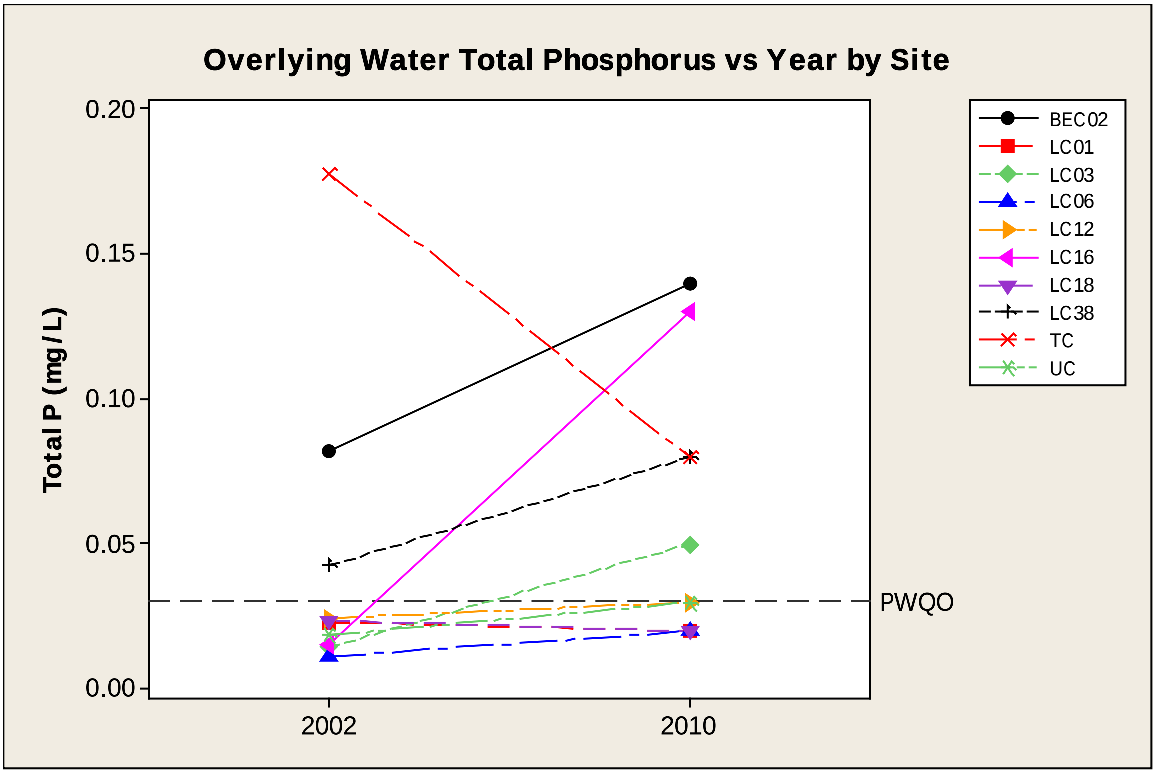

Figure 9. Trends in concentration of total phosphorus in overlying water from co-located Lyons Creek (LC) and reference sites. PWQO = provincial water quality objective (MOE 1994). TC= Tee Creek, UC=Usshers Creek, BEC02=Beaver Creek, site 2.

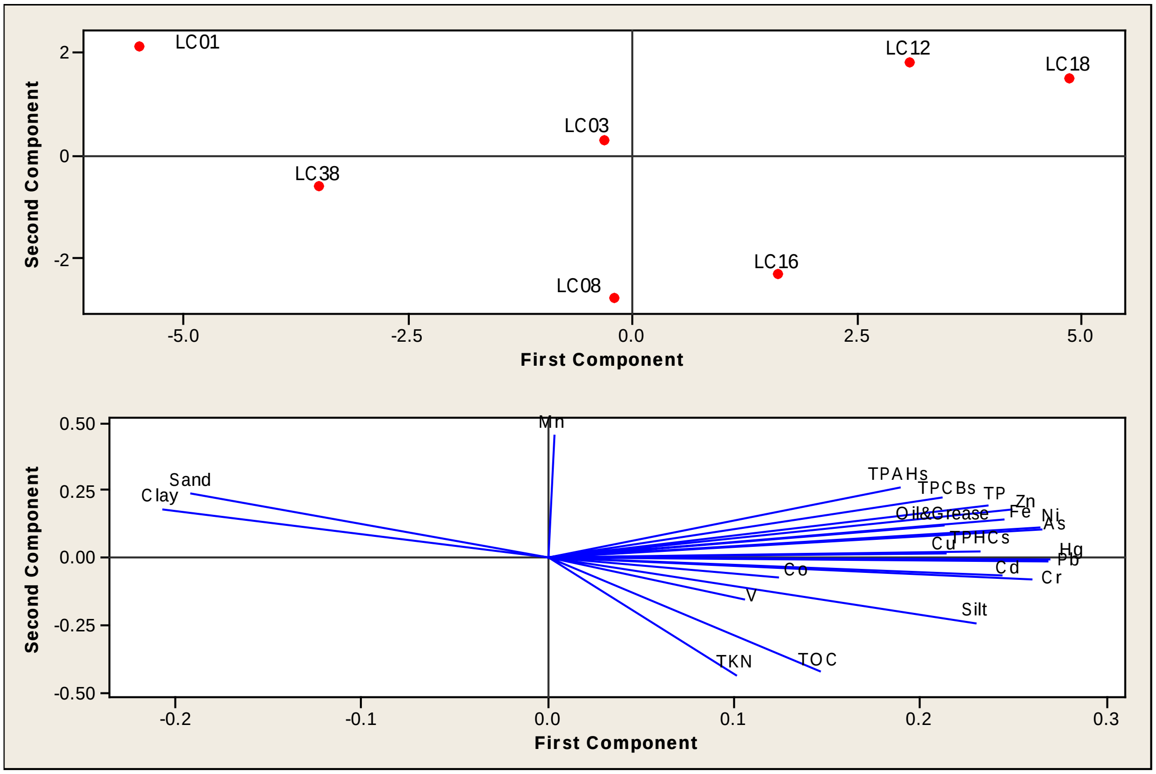

Figure 10. Principal components analysis of 2010 Lyons Creek site habitat data (22 sediment variables) showing site scores in the upper panel and variable loadings in the lower panel.

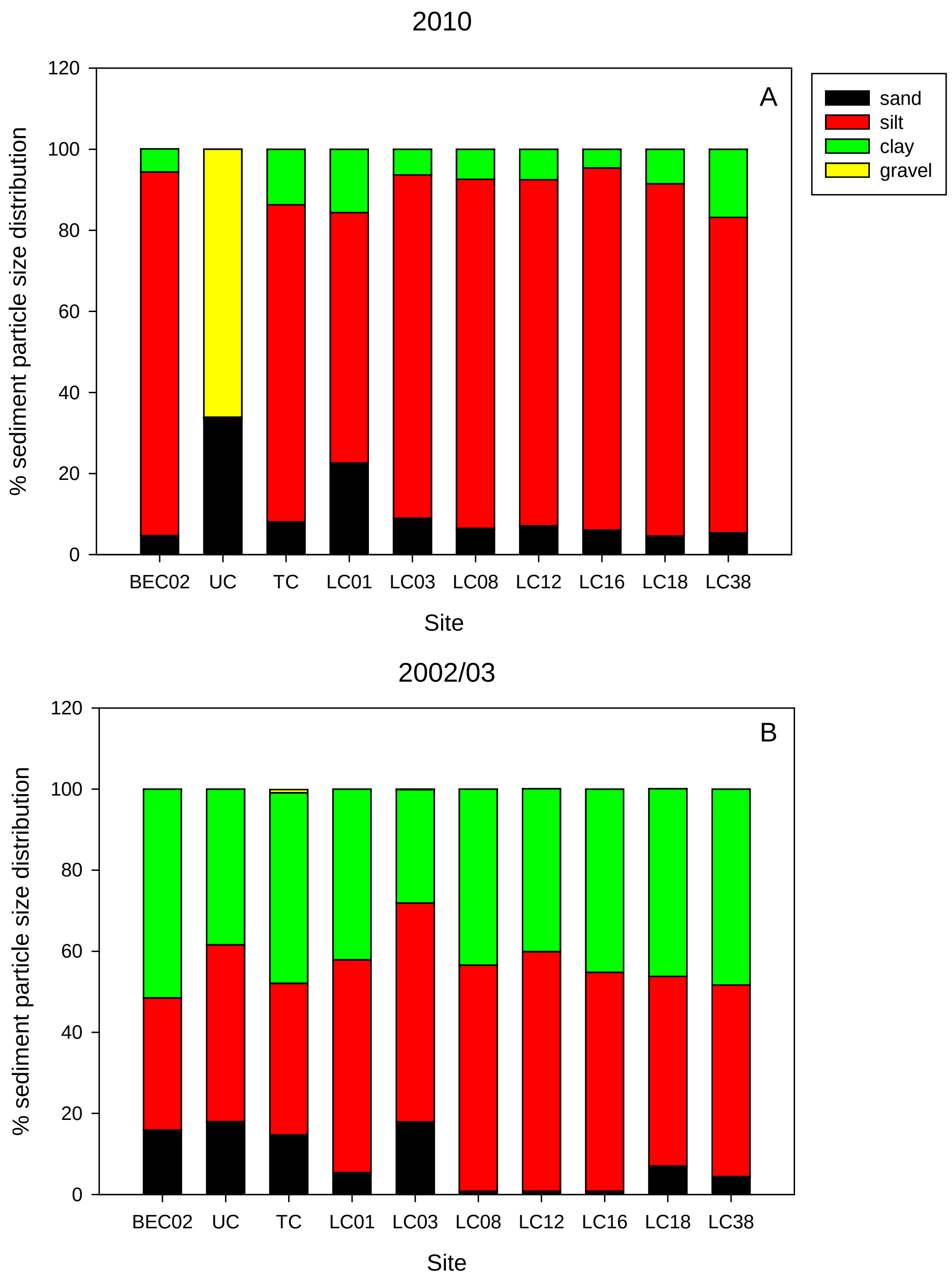

Figure 11. Particle size distributions in 2010 and 2002/2003 Lyons Creek and reference sediment, co-located sites.

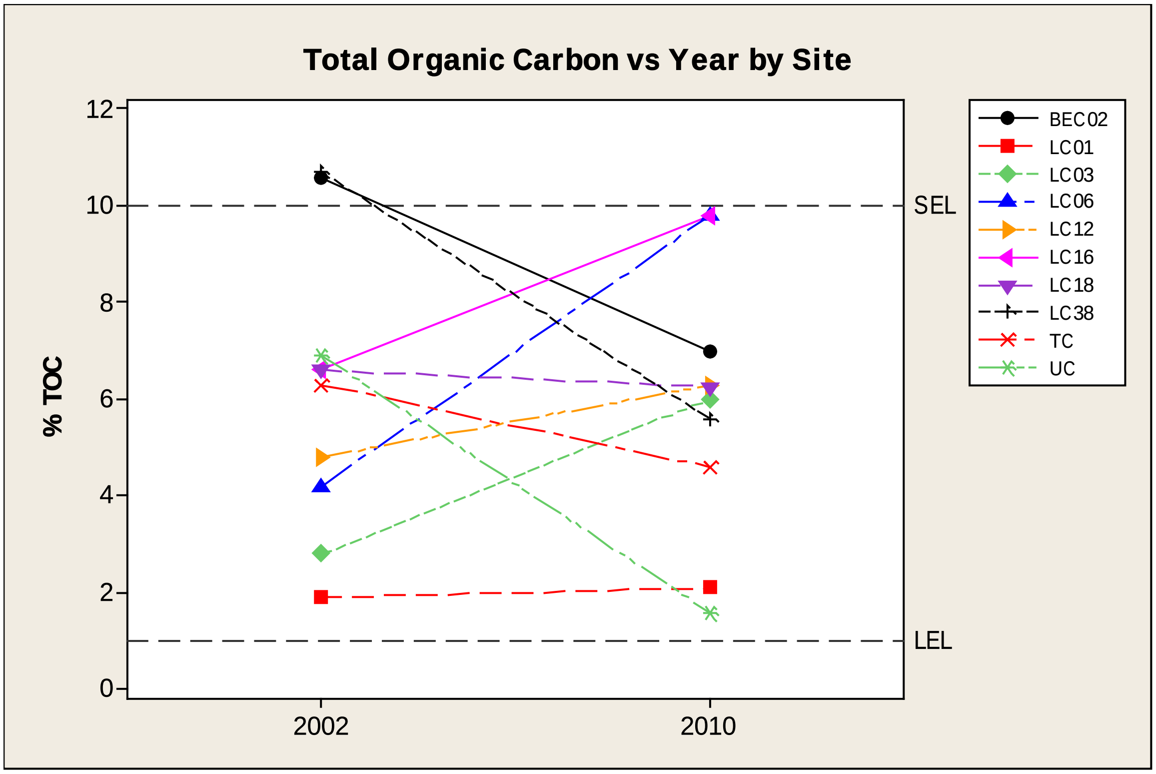

Figure 12. Trends in percent total organic carbon in sediment from co-located Lyons Creek (LC) and reference sites. LEL = lowest effect level; SEL = severe effect level (Fletcher et al. 2008). TC= Tee Creek, UC=Usshers Creek, BEC02=Beaver Creek, site 2.

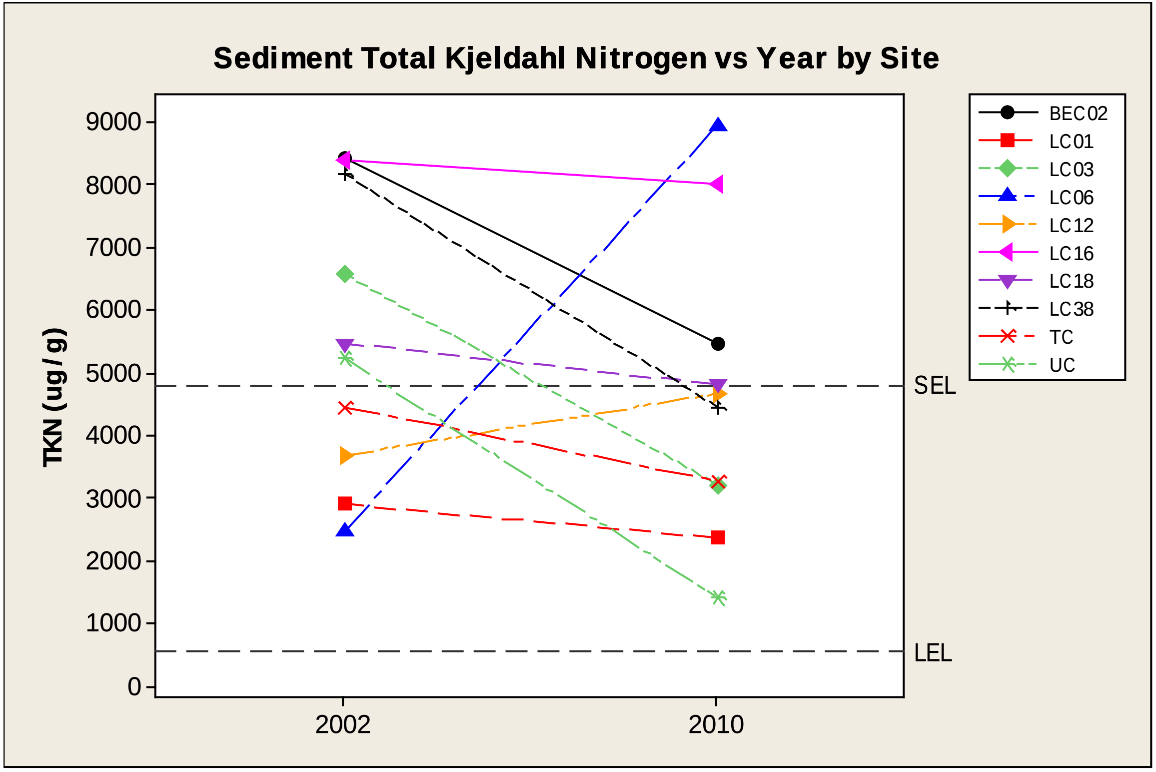

Figure 13. Trends in concentration of total Kjeldahl nitrogen in sediment from co-located Lyons Creek (LC) and reference sites. LEL = lowest effect level; SEL = severe effect level (Fletcher et al. 2008). TC= Tee Creek, UC=Usshers Creek, BEC02=Beaver Creek, site 2.

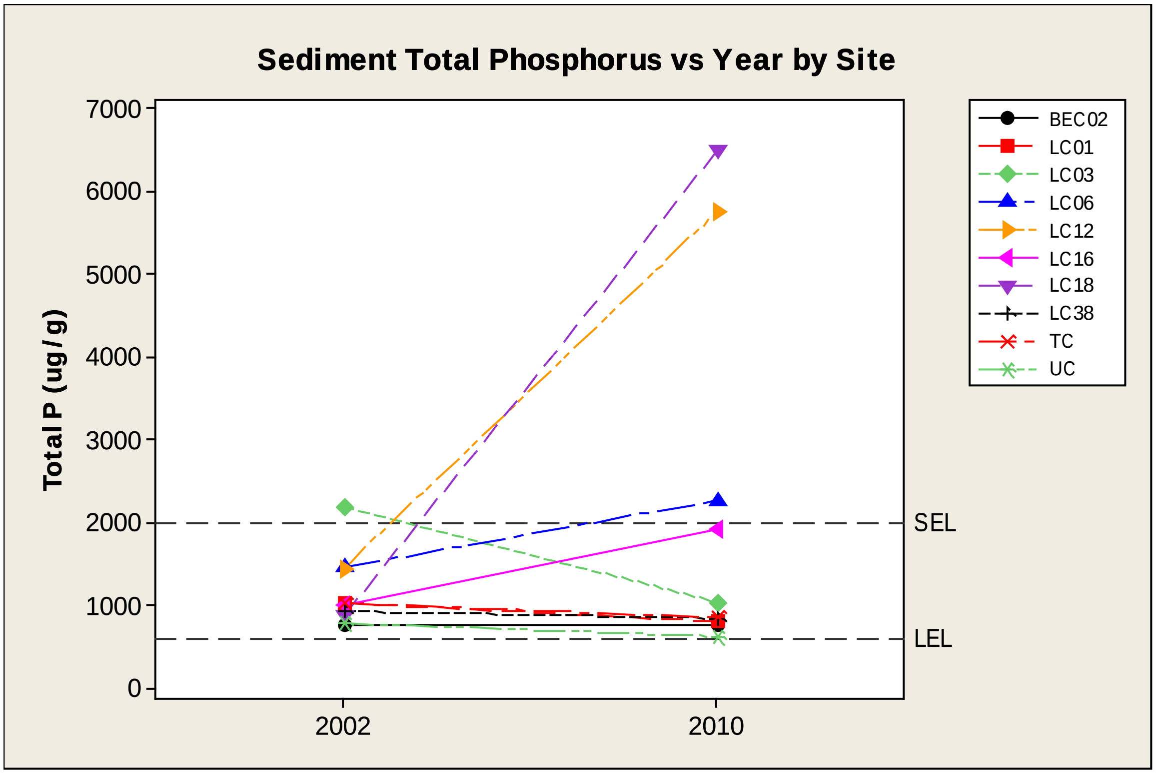

Figure 14. Trends in concentration of total phosphorus in sediment from co-located Lyons Creek (LC) and reference sites. LEL = lowest effect level; SEL = severe effect level (Fletcher et al. 2008). TC= Tee Creek, UC=Usshers Creek, BEC02=Beaver Creek, site 2.

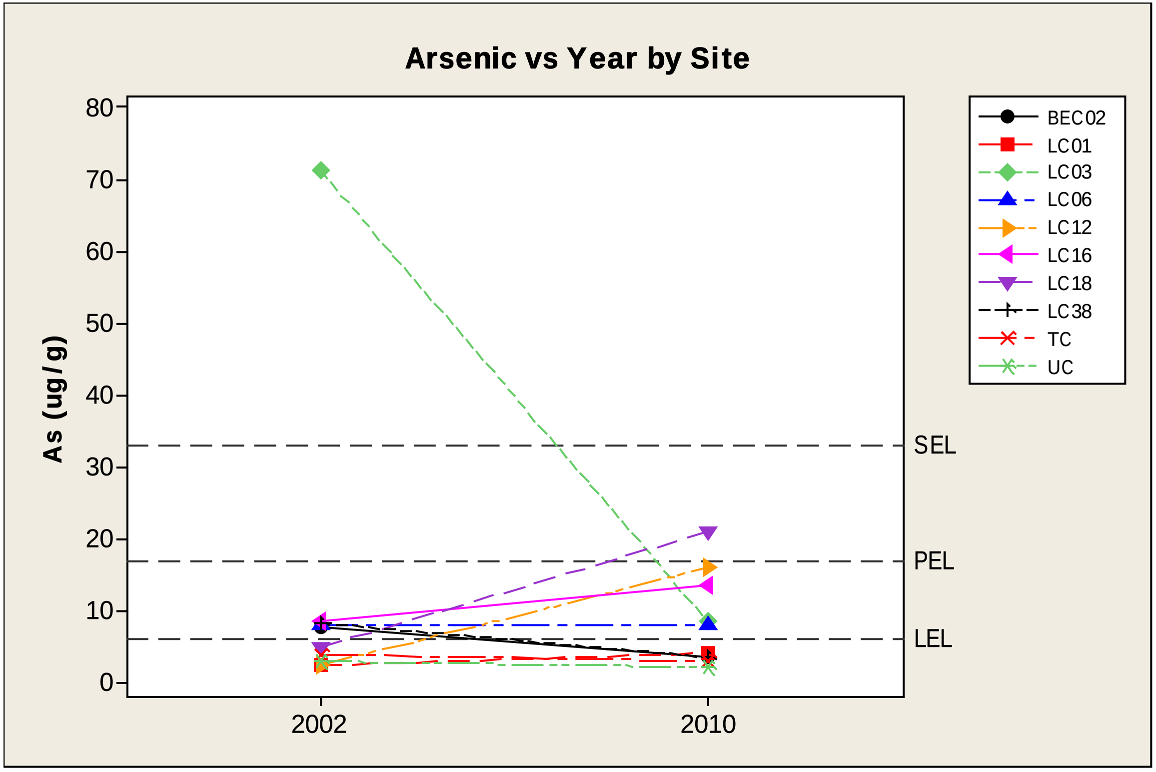

Figure 15. Trends in concentration of extractable arsenic in sediment from co-located Lyons Creek (LC) and reference sites. LEL = lowest effect level; SEL = severe effect level (Fletcher et al. 2008); PEL = probable effect level (CCME 2001a). TC= Tee Creek, UC=Usshers Creek, BEC02=Beaver Creek, site 2.

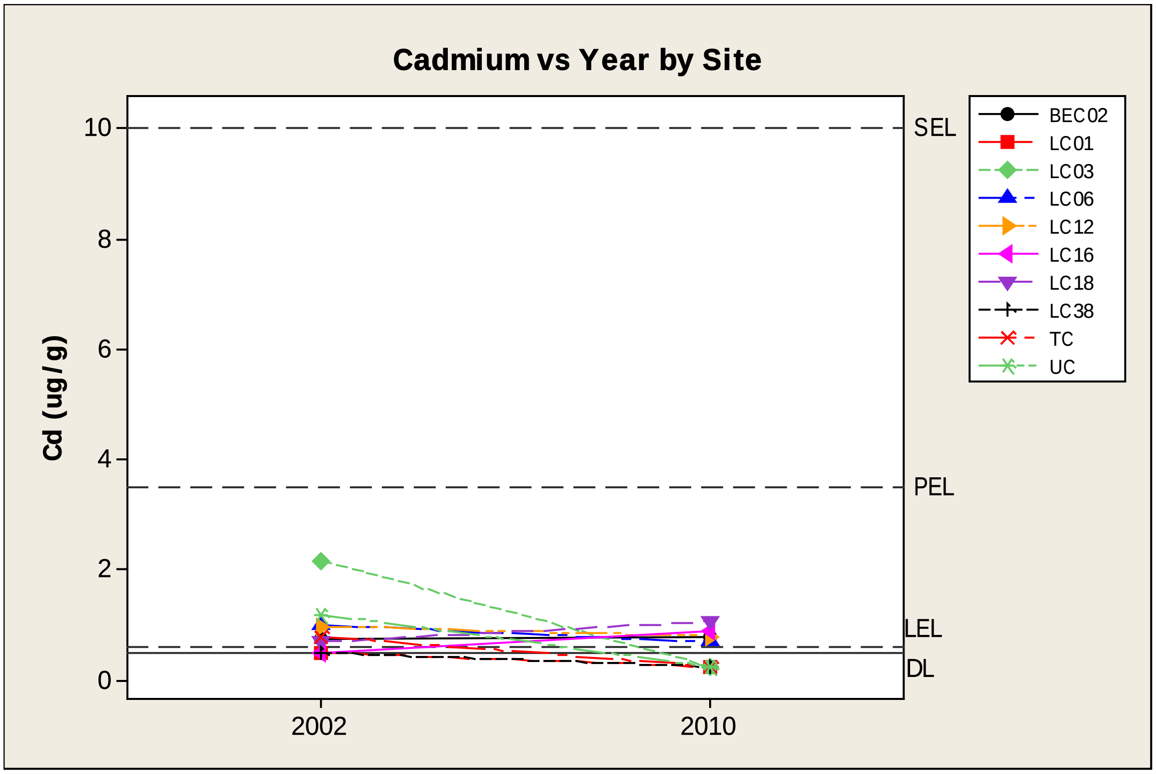

Figure 16. Trends in concentration of extractable cadmium in sediment from co-located Lyons Creek (LC) and reference sites. DL = lower detection limit. LEL = lowest effect level; SEL = severe effect level (Fletcher et al. 2008); PEL = probable effect level (CCME 2001a). TC= Tee Creek, UC=Usshers Creek, BEC02=Beaver Creek, site 2.

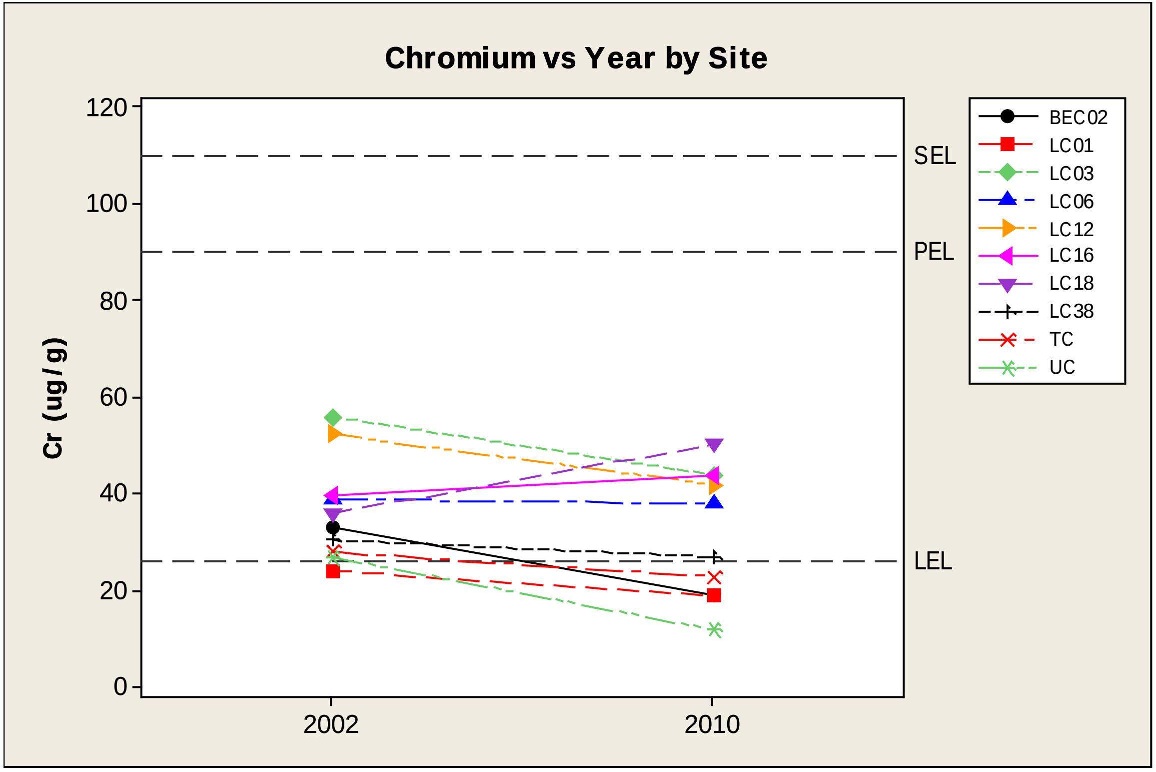

Figure 17. Trends in concentration of extractable chromium in sediment from co-located Lyons Creek (LC) and reference sites. LEL = lowest effect level; SEL = severe effect level (Fletcher et al. 2008); PEL = probable effect level (CCME 2001a). TC= Tee Creek, UC=Usshers Creek, BEC02=Beaver Creek, site 2.

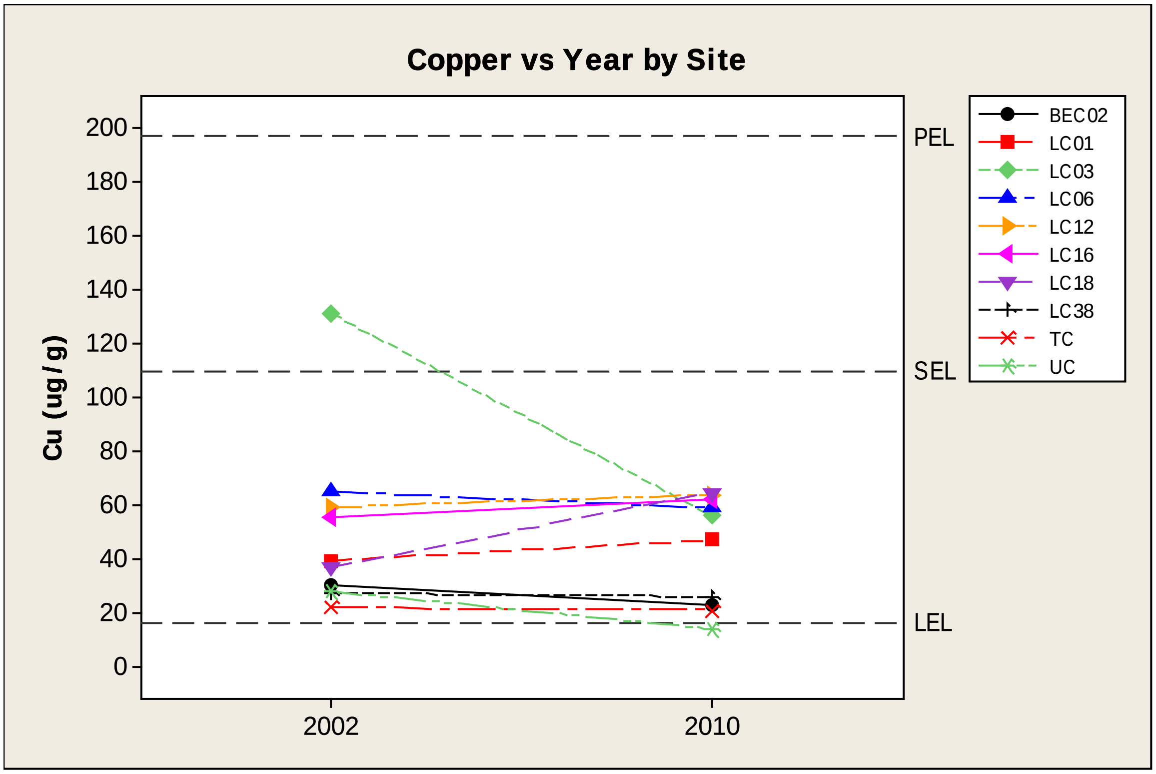

Figure 18. Trends in concentration of extractable copper in sediment from co-located Lyons Creek (LC) and reference sites. LEL = lowest effect level; SEL = severe effect level (Fletcher et al. 2008). TC= Tee Creek, UC=Usshers Creek, BEC02=Beaver Creek, site 2.

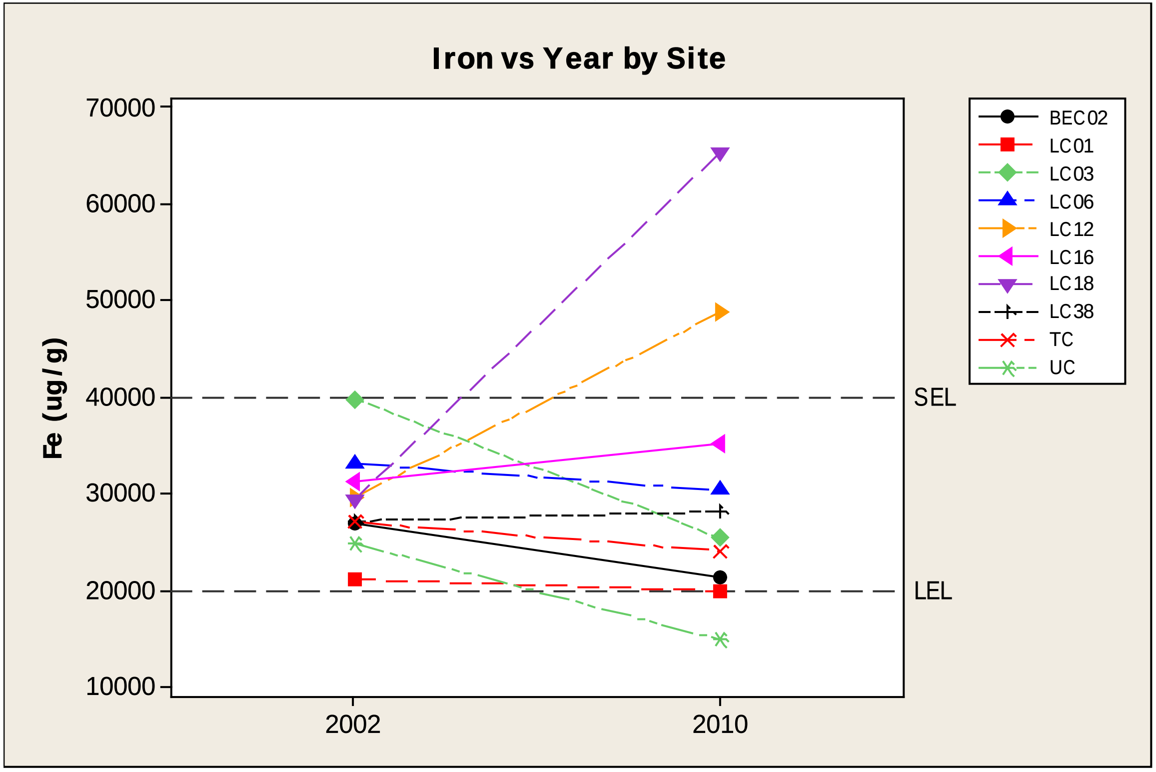

Figure 19. Trends in concentration of extractable iron in sediment from co-located Lyons Creek (LC) and reference sites. LEL = lowest effect level; SEL = severe effect level (Fletcher et al. 2008). TC= Tee Creek, UC=Usshers Creek, BEC02=Beaver Creek, site 2.

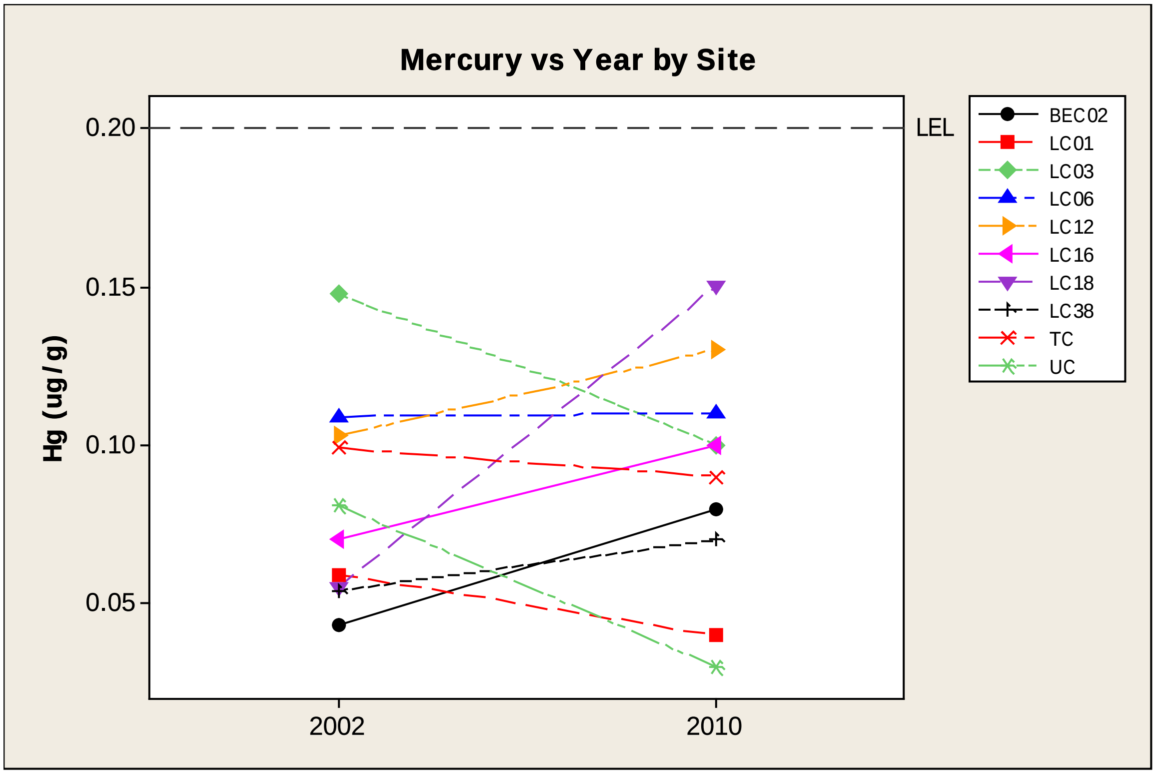

Figure 20. Trends in concentration of extractable mercury in sediment from co-located Lyons Creek (LC) and reference sites. LEL = lowest effect level (Fletcher et al. 2008). TC= Tee Creek, UC=Usshers Creek, BEC02=Beaver Creek, site 2.

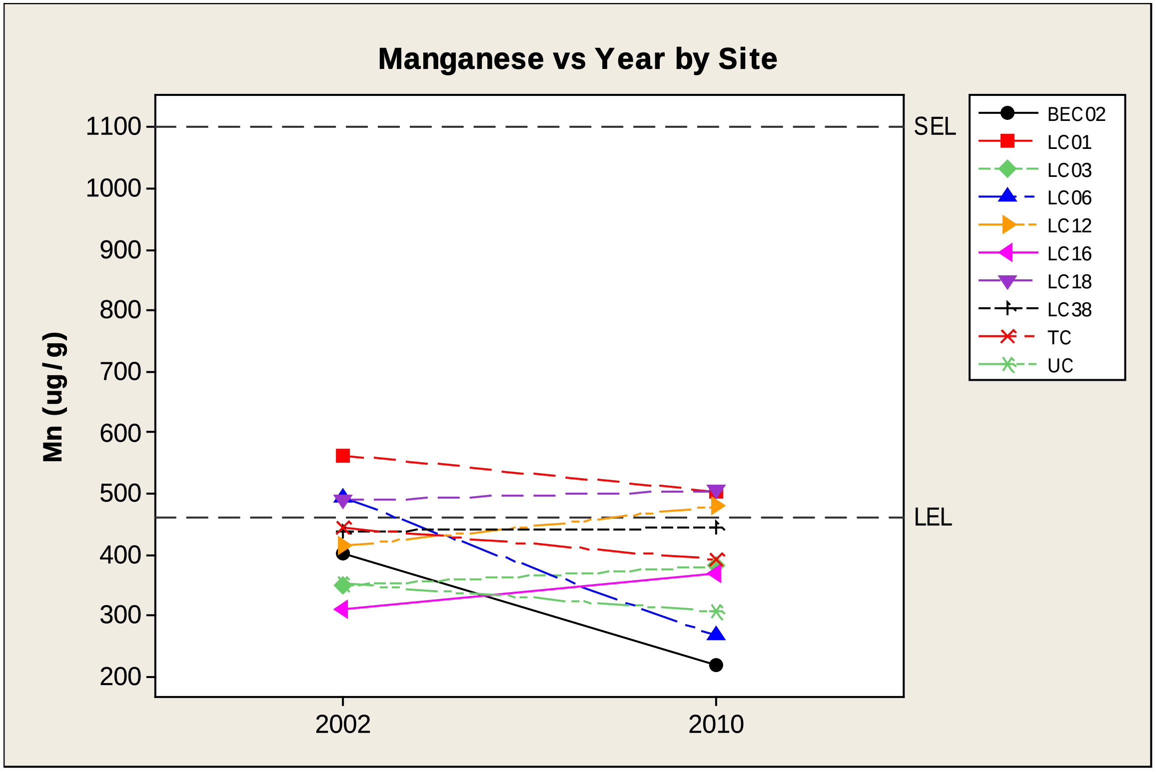

Figure 21. Trends in concentration of extractable manganese in sediment from co-located Lyons Creek (LC) and reference sites. LEL = lowest effect level; SEL = severe effect level (Fletcher et al. 2008). TC= Tee Creek, UC=Usshers Creek, BEC02=Beaver Creek, site 2.

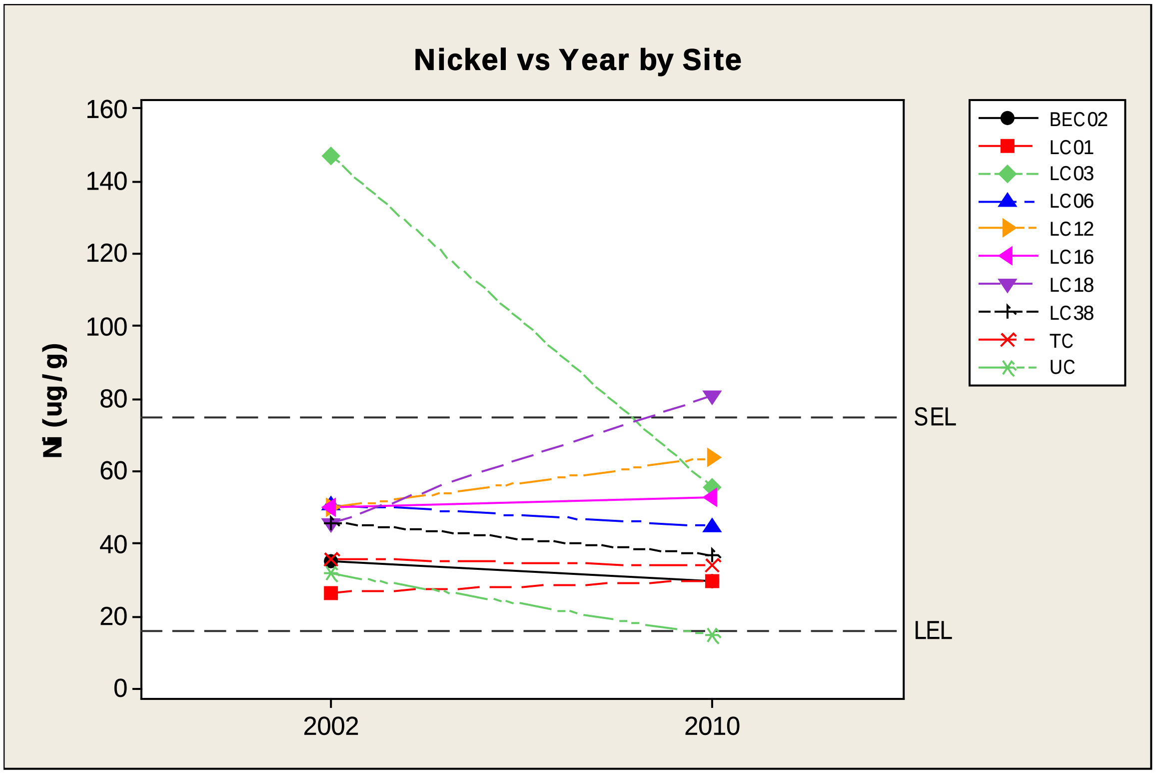

Figure 22. Trends in concentration of extractable nickel in sediment from co-located Lyons Creek (LC) and reference sites. LEL = lowest effect level; SEL = severe effect level (Fletcher et al. 2008). TC= Tee Creek, UC=Usshers Creek, BEC02=Beaver Creek, site 2.

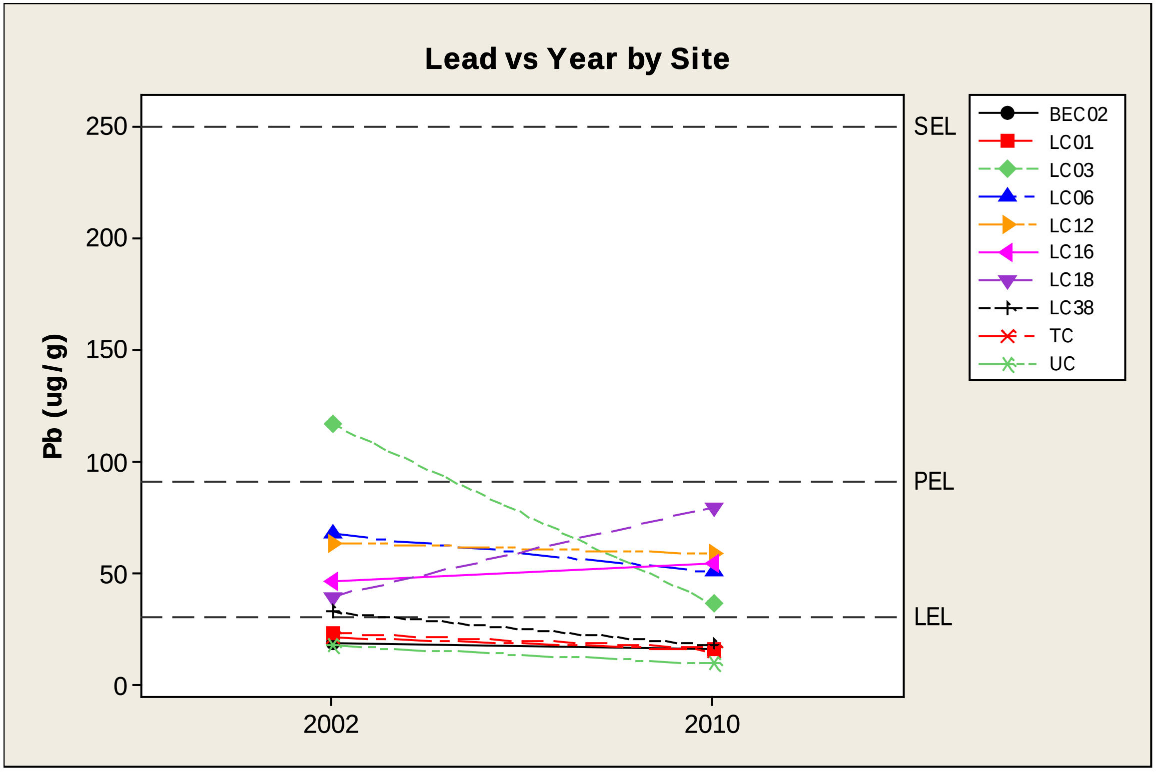

Figure 23. Trends in concentration of extractable lead in sediment from co-located Lyons Creek (LC) and reference sites. LEL = lowest effect level; SEL = severe effect level (Fletcher et al. 2008). TC= Tee Creek, UC=Usshers Creek, BEC02=Beaver Creek, site 2.

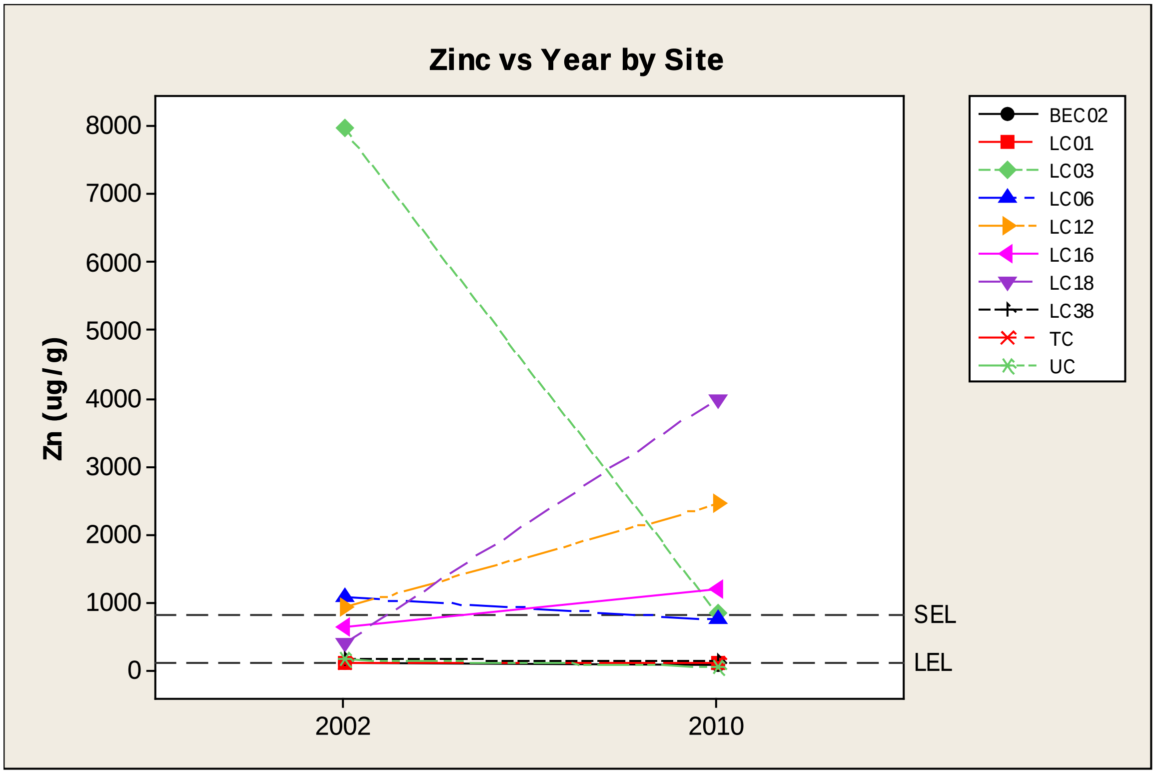

Figure 24. Trends in concentration of extractable zinc in sediment from co-located Lyons Creek (LC) and reference sites. LEL = lowest effect level; SEL = severe effect level (Fletcher et al. 2008). TC= Tee Creek, UC=Usshers Creek, BEC02=Beaver Creek, site 2.

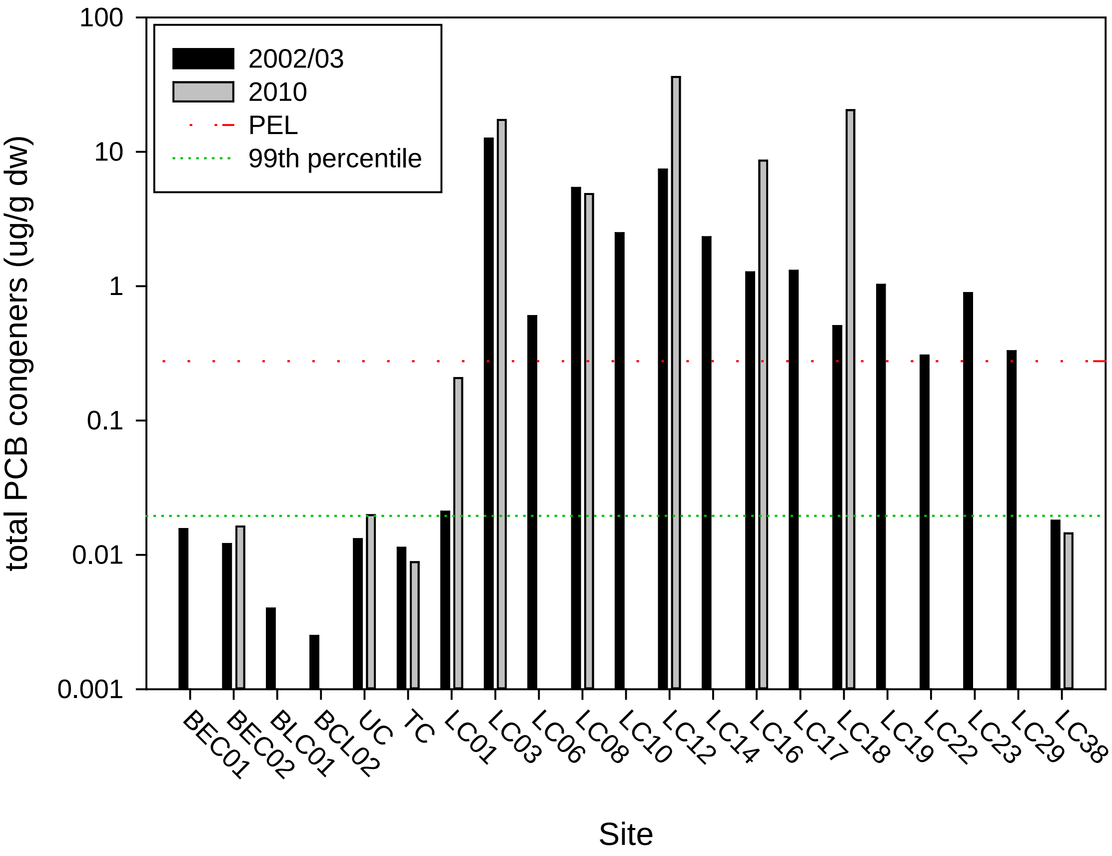

Figure 25. Sediment concentrations of total PCB congeners (µg/g dw) for Lyons Creek and reference sites, 2002 - 2010. The dotted green line indicates the 99th percentile for reference creek sites and the dashed red line represents the Probable Effect Level (PEL) of 0.277 µg/g for total PCBs.

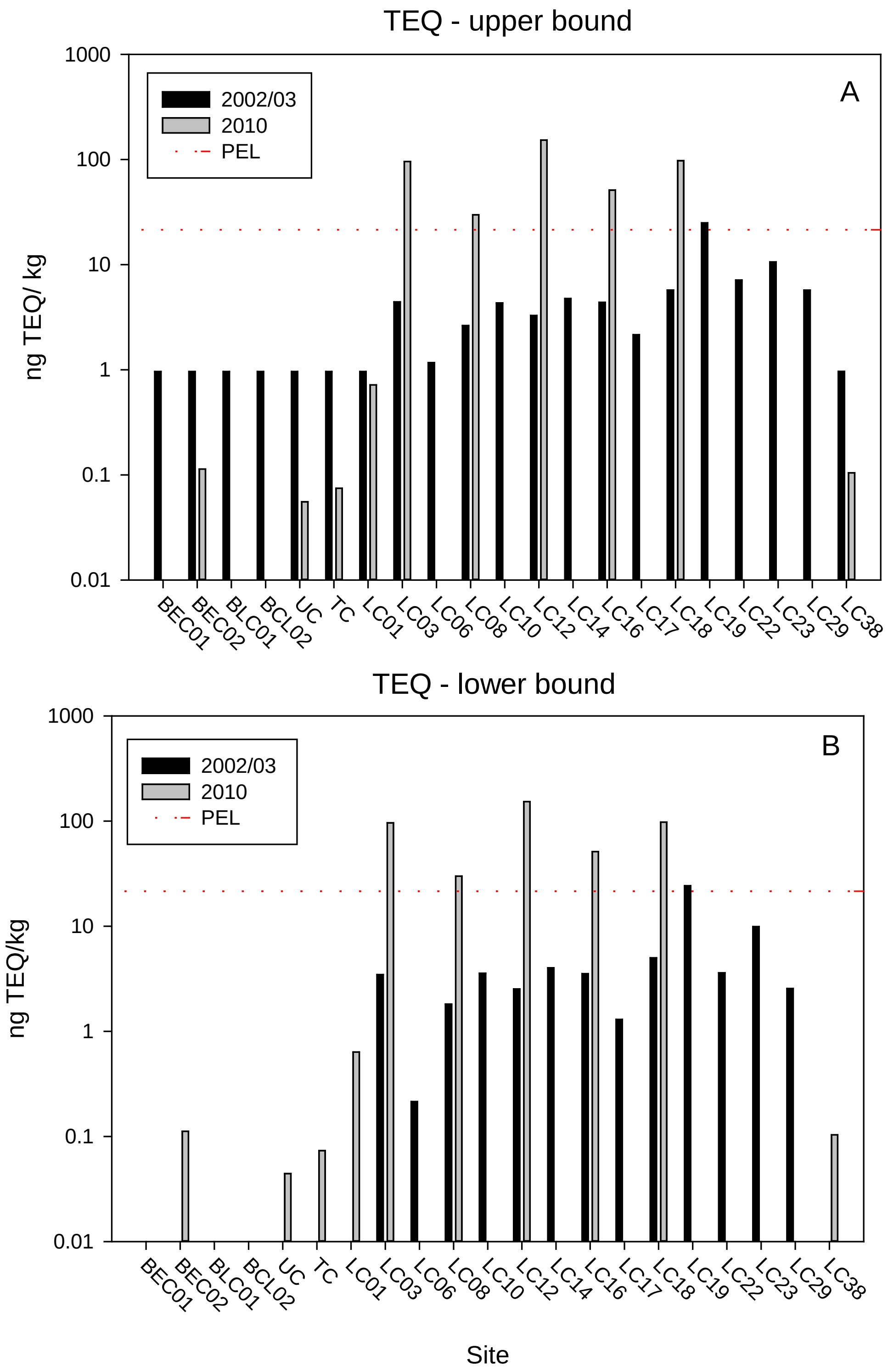

Figure 26. Sediment concentrations of dioxin-like PCBs expressed in toxic equivalents (ng TEQ kg^{-1}) for Lyons Creek and reference sites, 2002-2010 - upper bound (A) and lower bound (B). The dashed red line indicates the Probable Effect Level (PEL) of 21.5 ng TEQ kg^{-1}. Non-detects are assigned the detection limit and a zero for the upper bound and lower bound calculations, respectively.

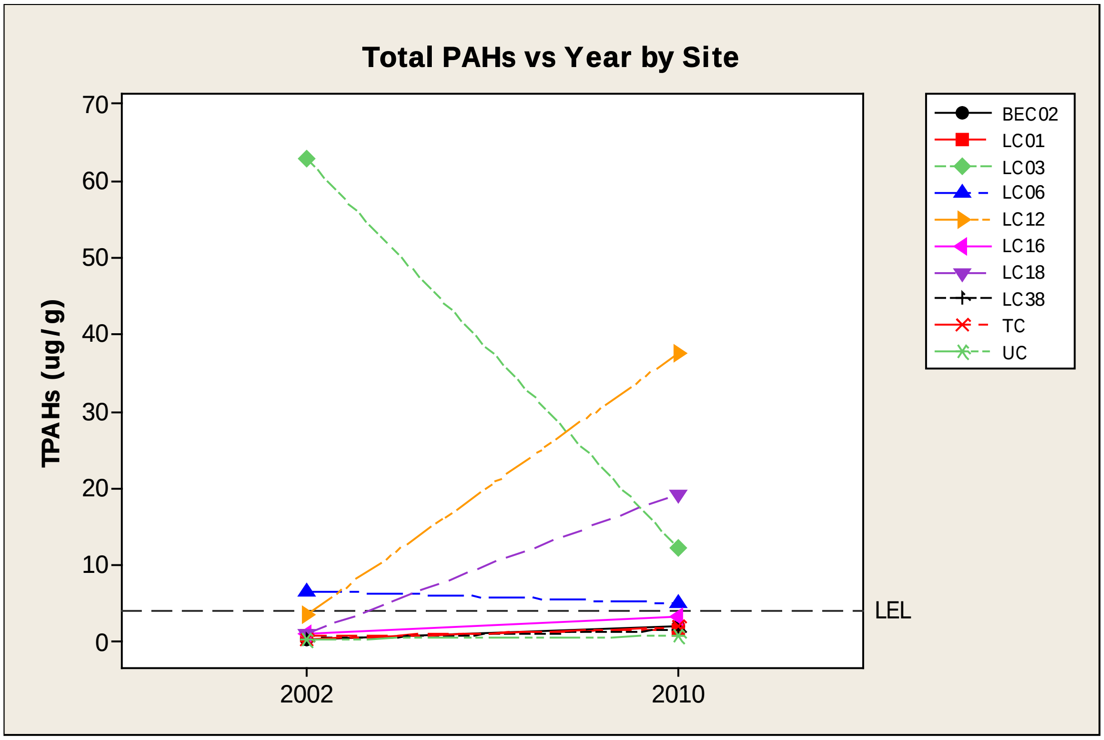

Figure 27. Trends in concentration of total PAHs in sediment from co-located Lyons Creek and reference sites. TC= Tee Creek, UC=Usshers Creek, BEC02=Beaver Creek, site 2.

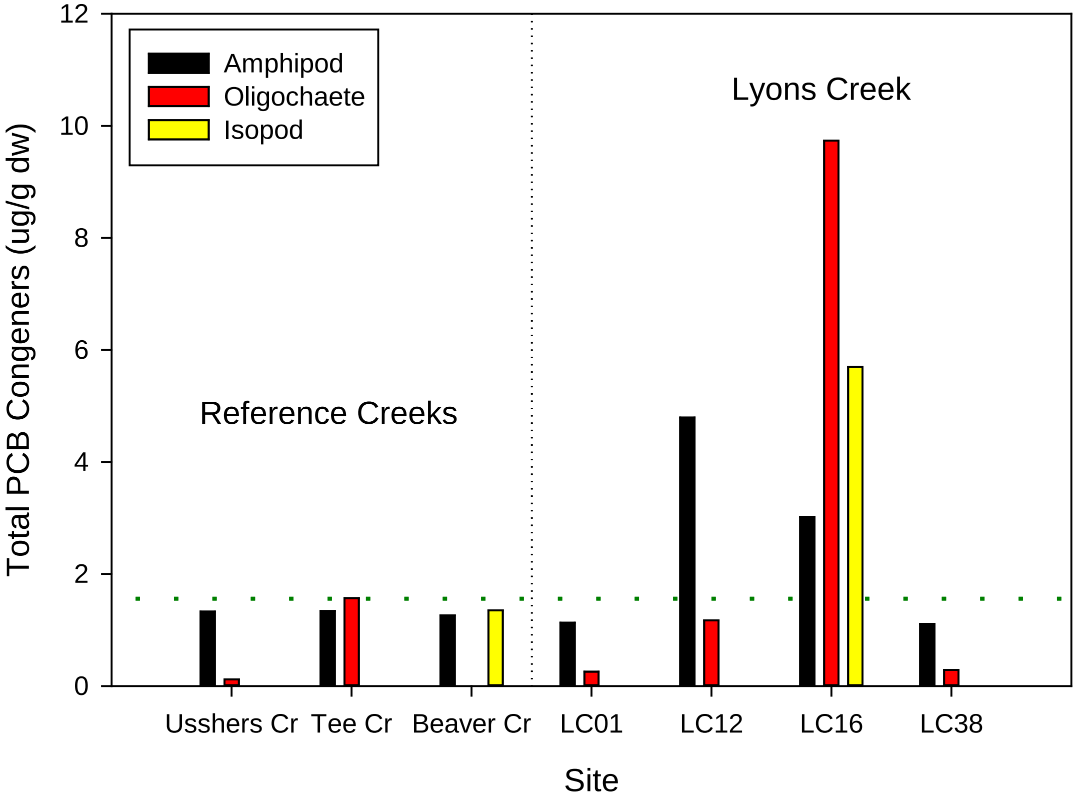

Figure 28. Total PCB congeners in benthic invertebrates (µg/g dry weight) collected from 2010 Lyons Creek (LC) and reference (Usshers, Tee and Beaver) creeks.

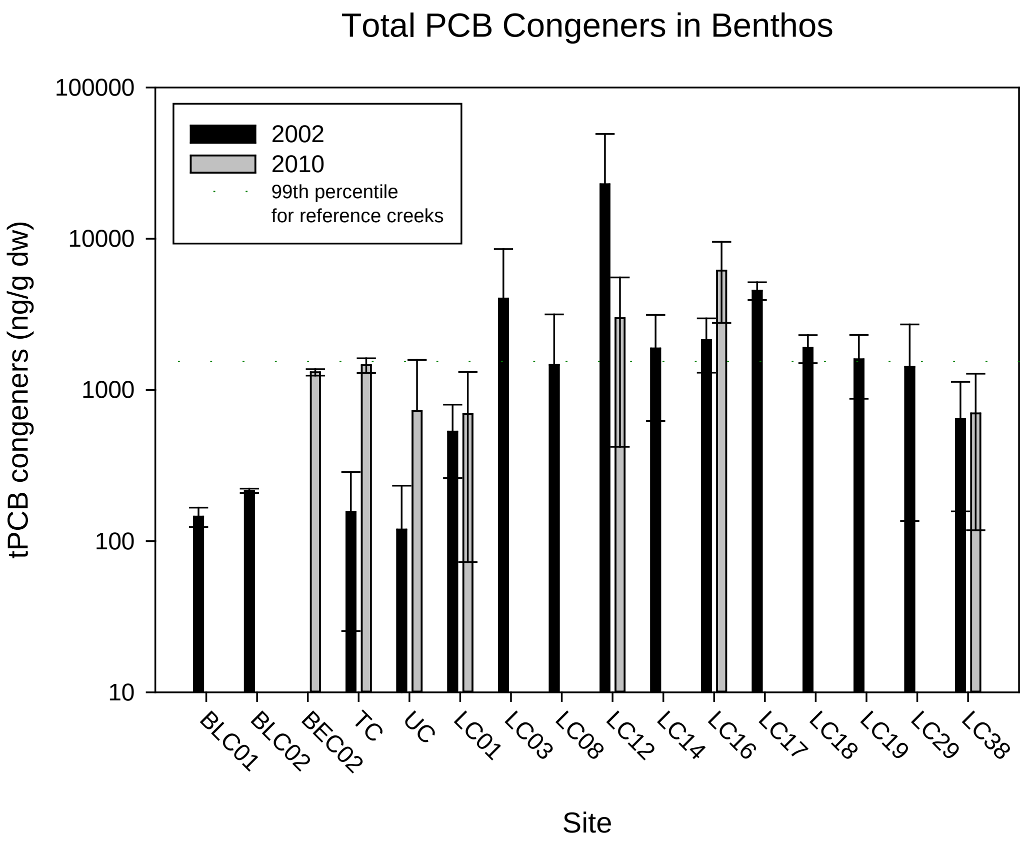

Figure 29. Comparison of total PCB congeners (ng/g dw) for benthos 2002-2010. Error bars represent the standard deviation. The dashed line represents the 99th percentile for 2002-2010 biota collected from reference creeks.

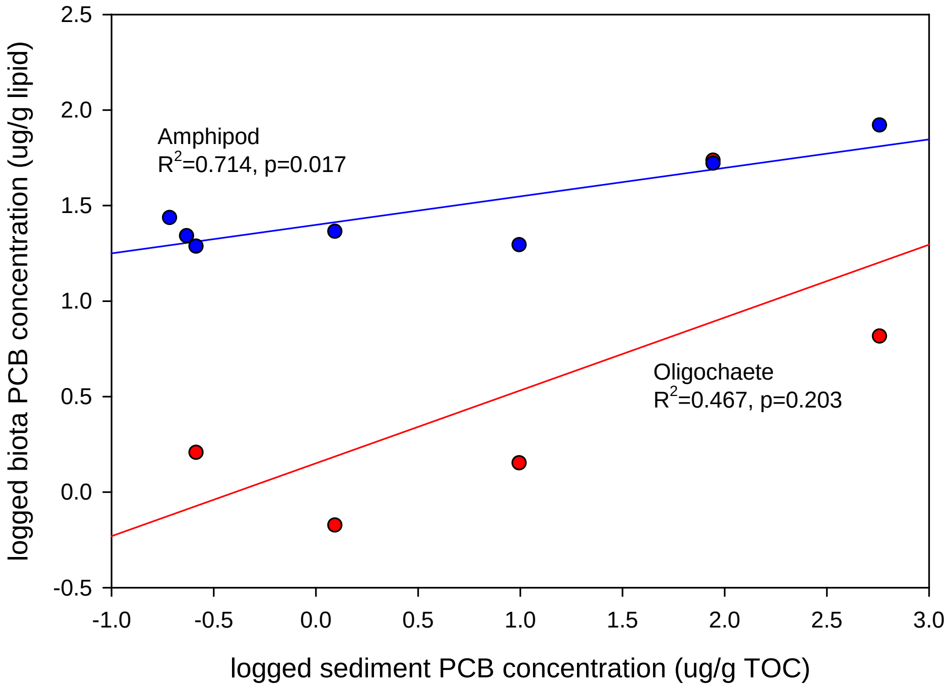

Figure 30. Relationships between 2010 total PCBs in biota (normalized to % lipid) and total PCBs in sediment (normalized to % total organic carbon). Separate regression lines are shown for each taxon.

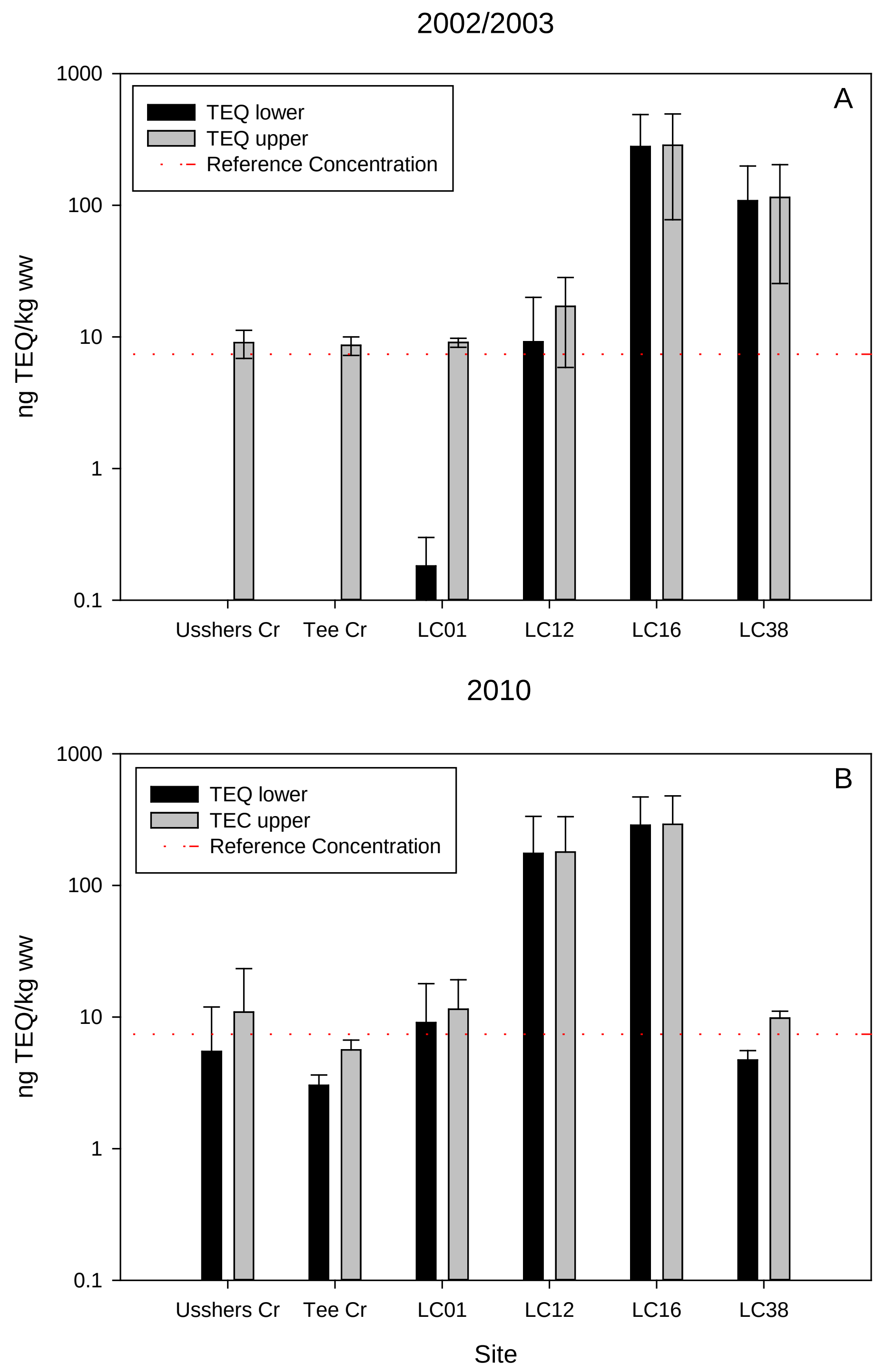

Figure 31. Invertebrate PCB concentrations expressed in toxic equivalent quantities for dioxin-like PCBs in A) 2002/2003 and B) 2010, co-located sites. The error bars represent the standard deviation. The red dotted line indicates the reference concentration (7.4 ng TEQ/kg) for the protection of avian consumers of aquatic biota calculated using the food ingestion: body weight ratio for the common goldeneye (CCME 1998).

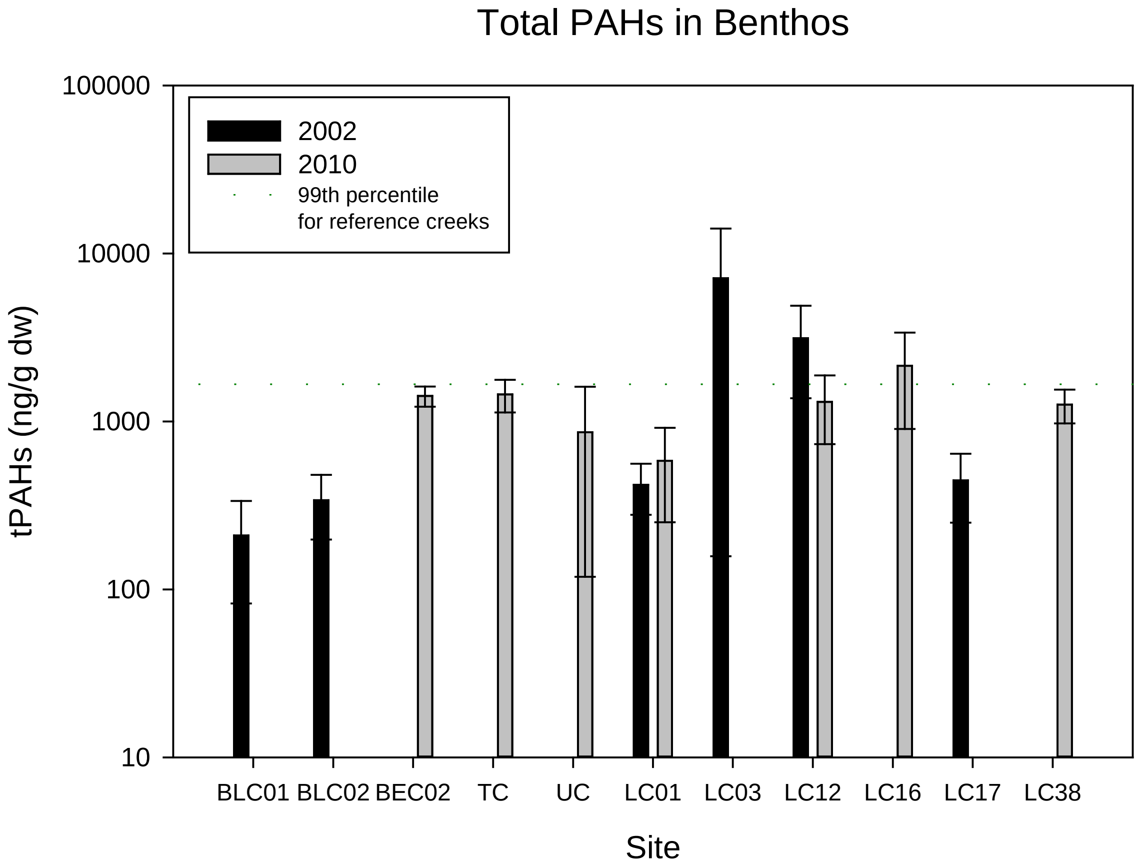

Figure 32. Comparison of total PAHs (ng/g dry weight) in biota for 2010 and 2002/03. Error bars represent the standard deviation. The dashed line represents the 99th percentile for 2002-2010 biota collected from reference creeks.

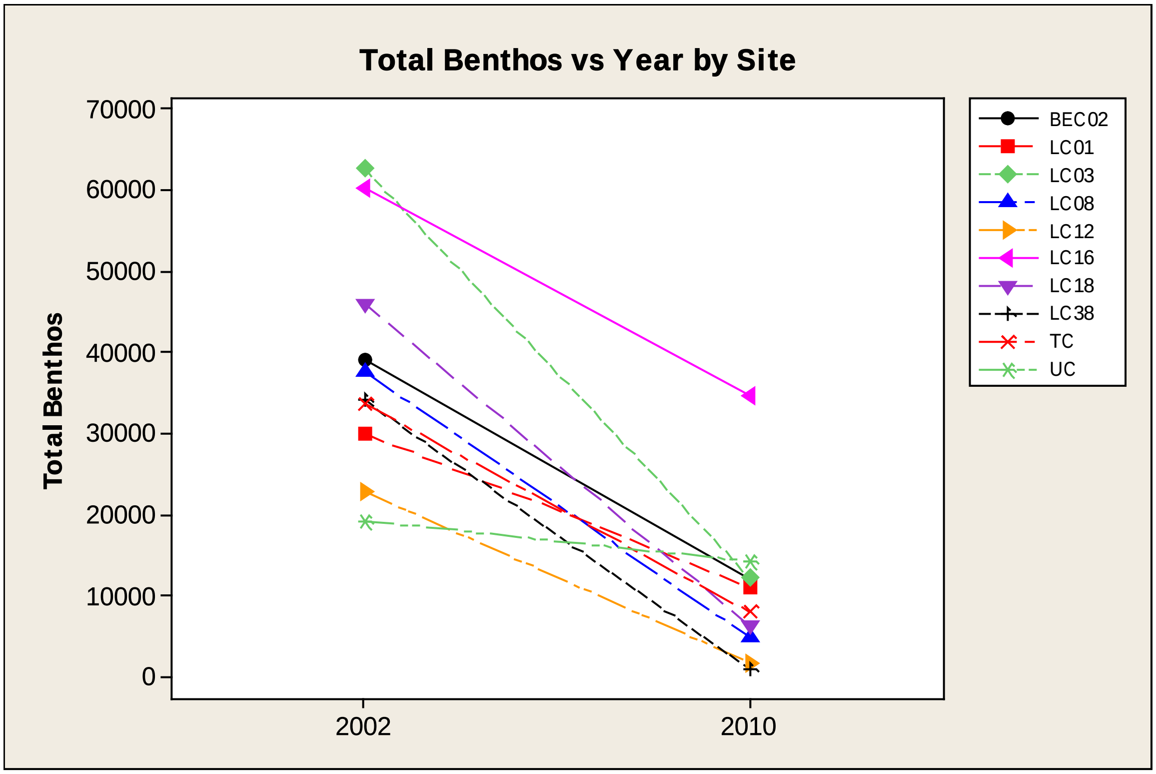

Figure 33. Trends in total benthos (total number of individuals per m^2) in samples from Lyons Creek and reference sites.

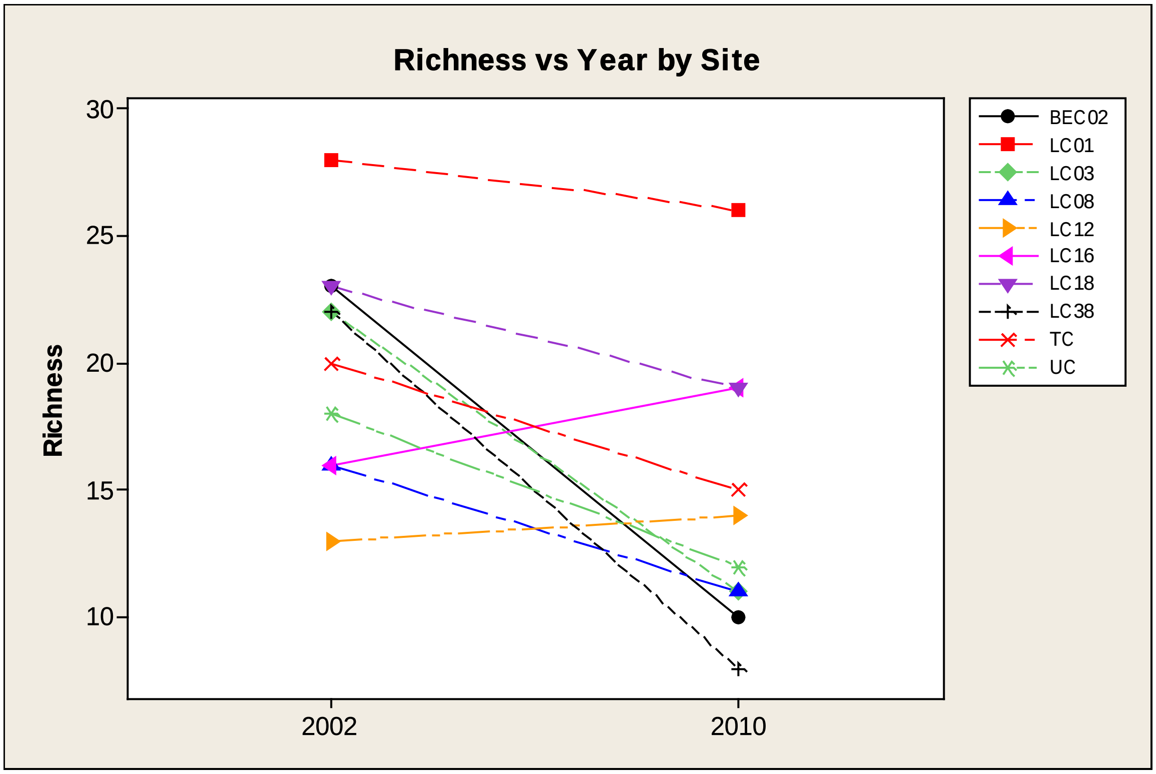

Figure 34. Trends in taxon richness (number of families) in samples from Lyons Creek and reference sites.

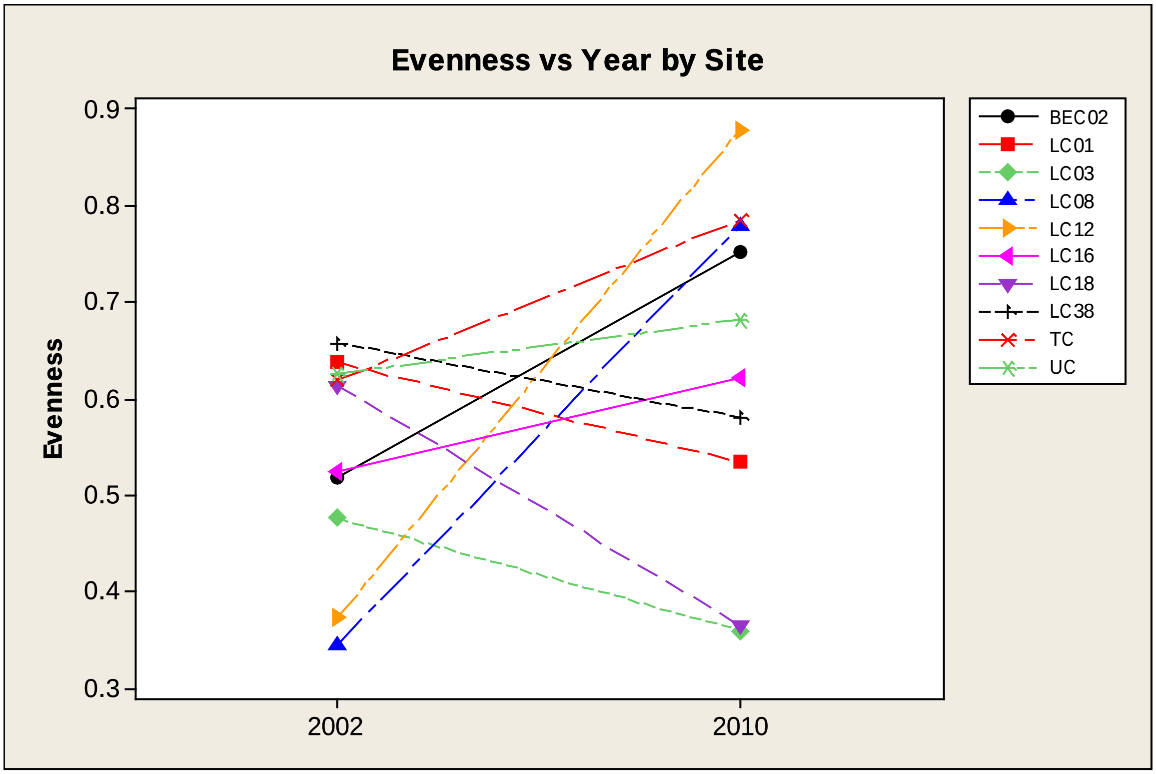

Figure 35. Trends in Pielou's evenness (= Shannon diversity / ln (richness)) in samples from Lyons Creek and reference sites.

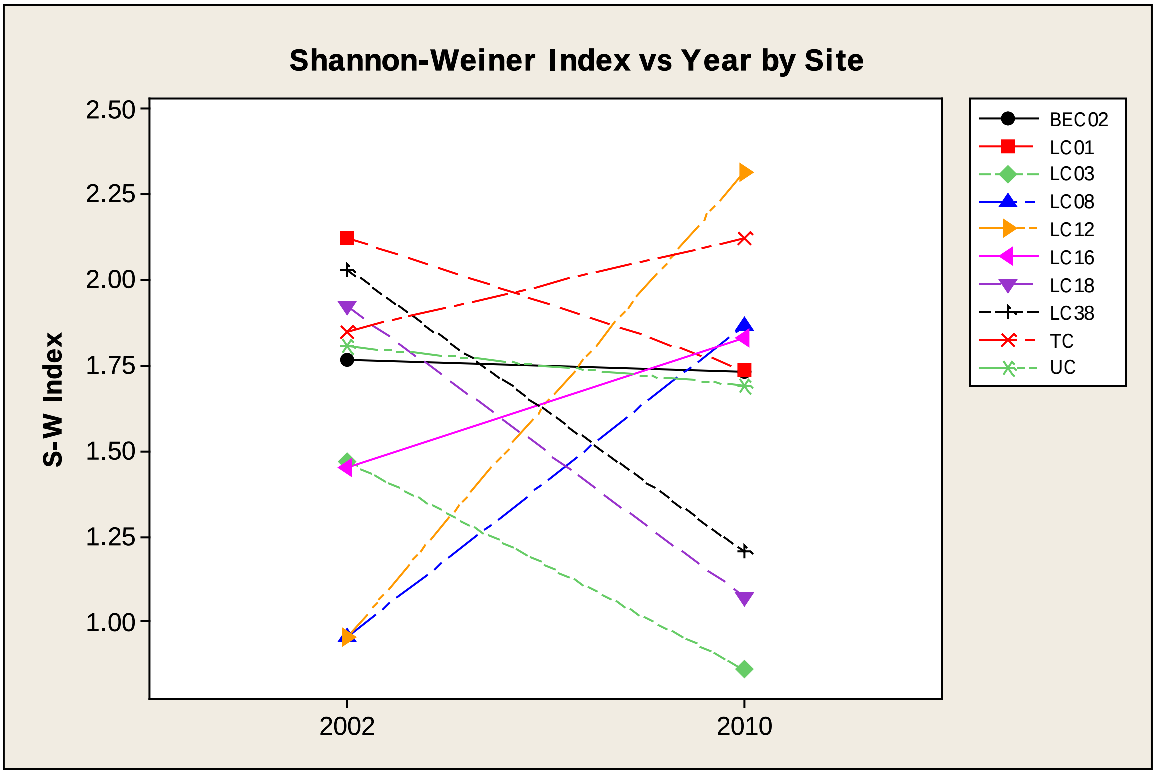

Figure 36. Trends in Shannon-Weiner diversity index in samples from Lyons Creek and reference sites.

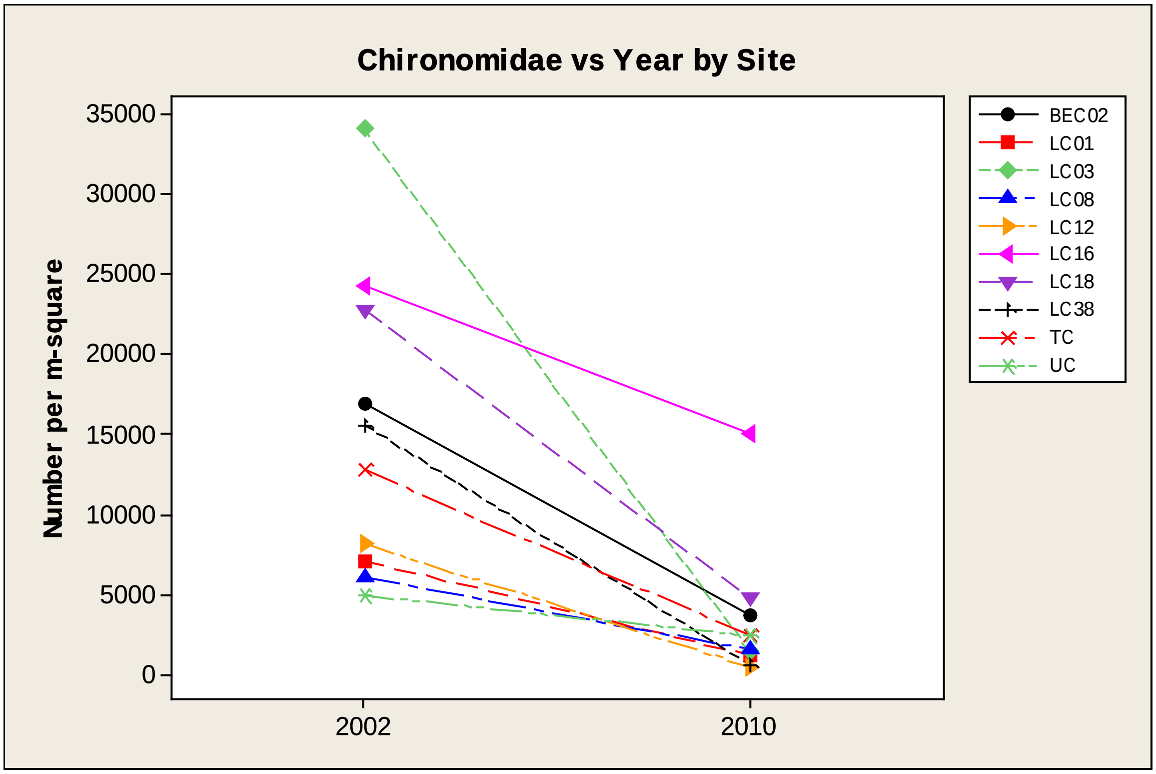

Figure 37. Trends in densities of chironomids (larval midges) in samples Lyons Creek and reference sites.

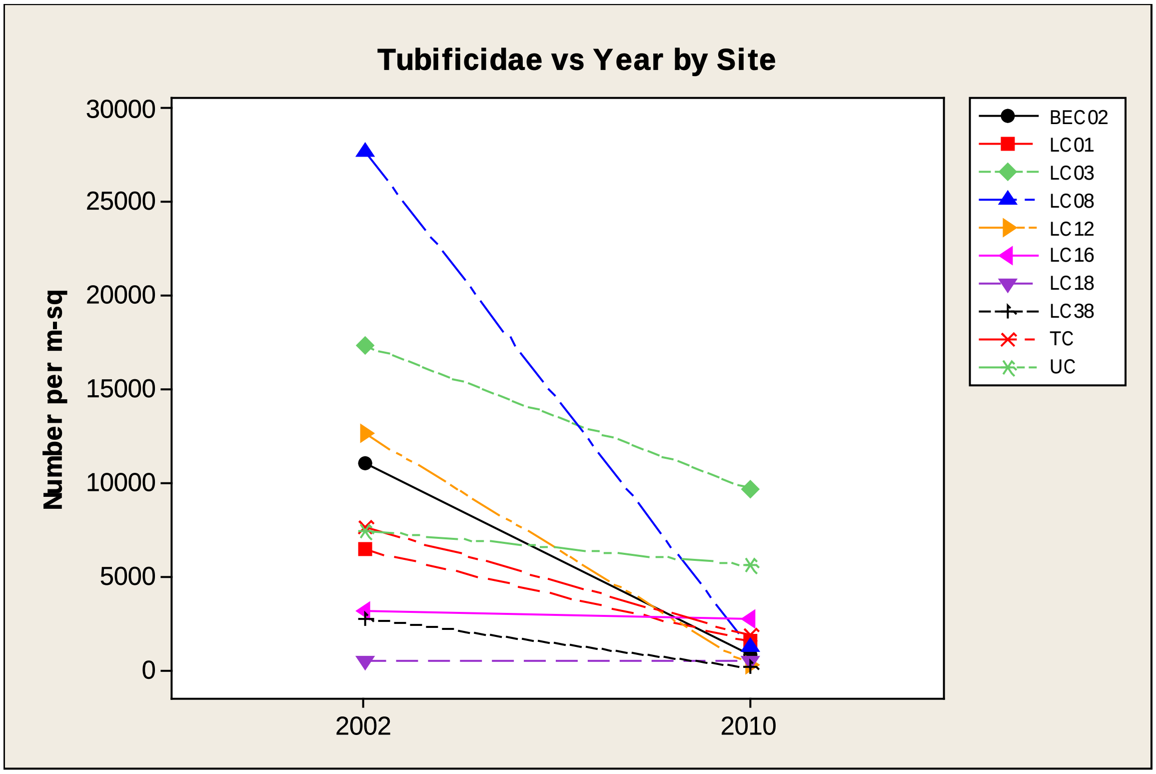

Figure 38. Trends in densities of tubificid worms in samples from Lyons Creek and reference sites.

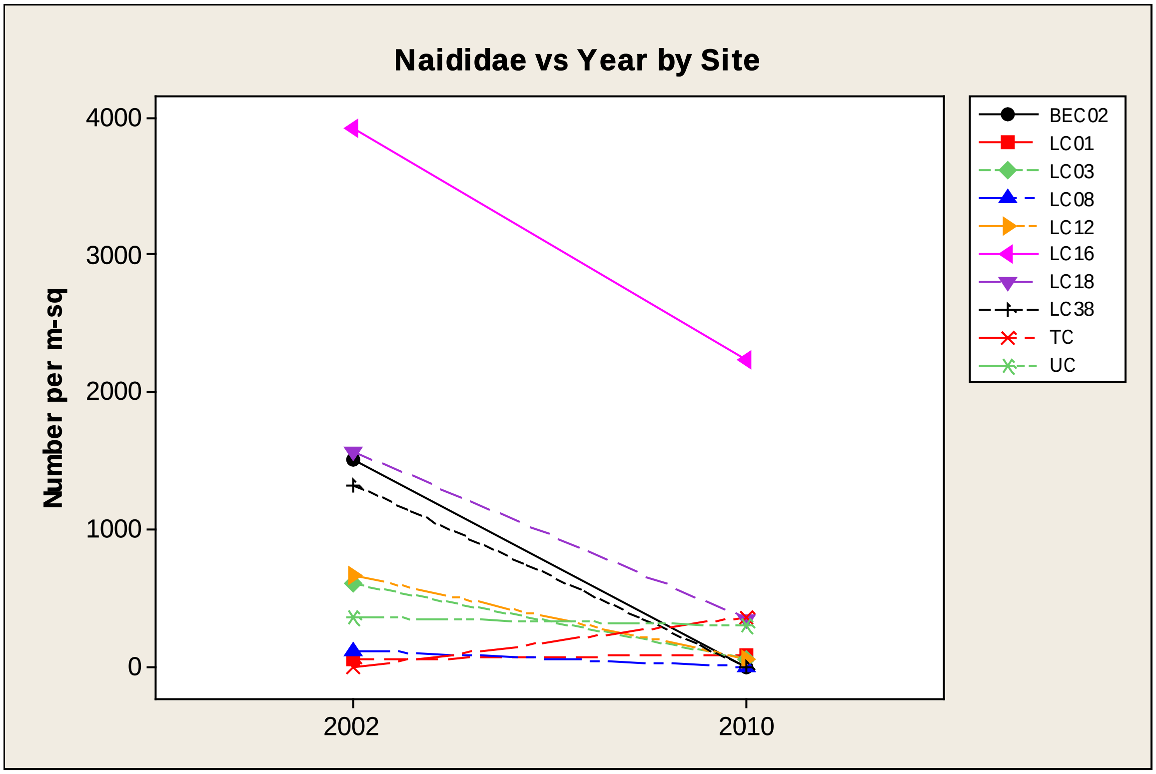

Figure 39. Trends in densities of naidid worms in samples from Lyons Creek and reference sites.

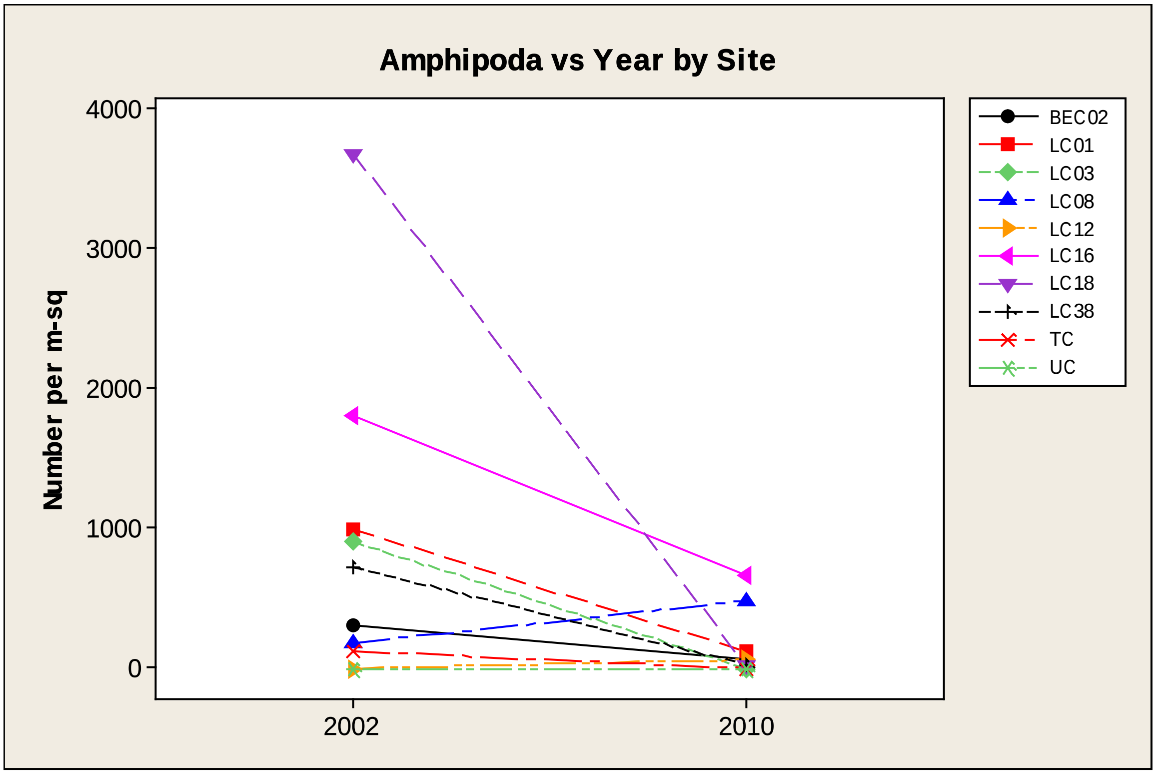

Figure 40. Trends in densities of amphipods in samples from Lyons Creek and reference sites.

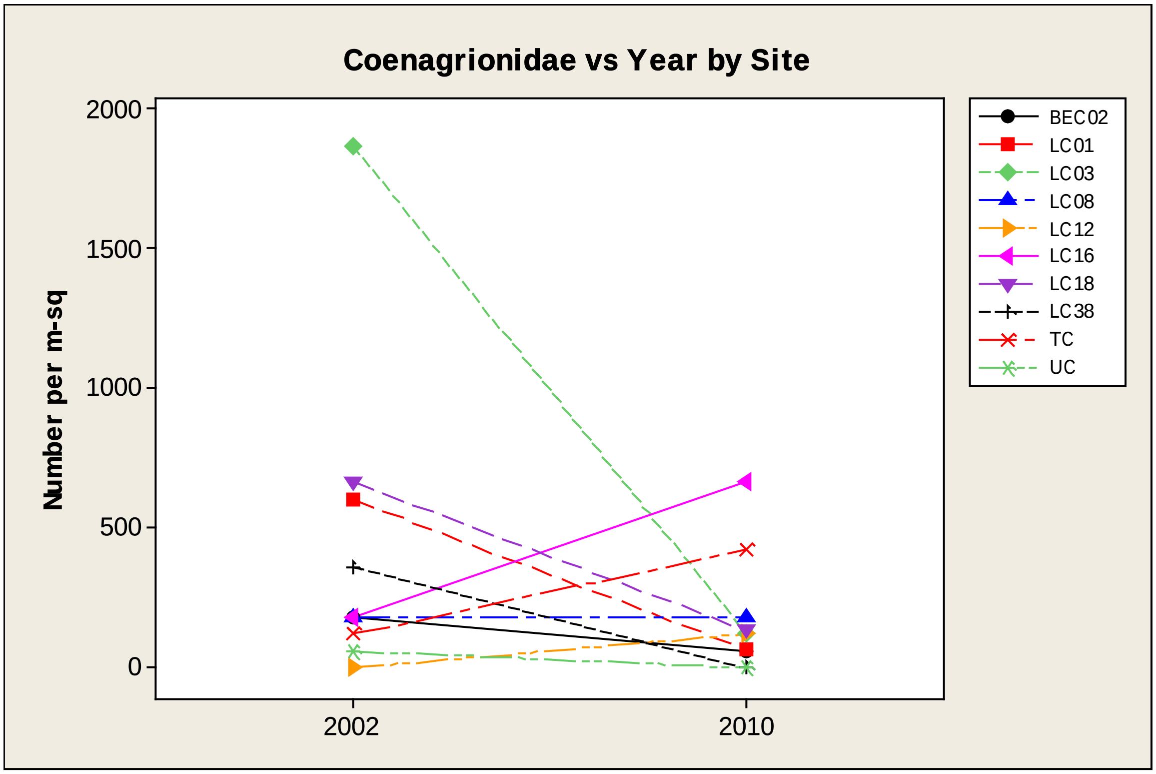

Figure 41. Trends in densities of coenagrionids (larval damselfly) in samples from Lyons Creek and reference sites.

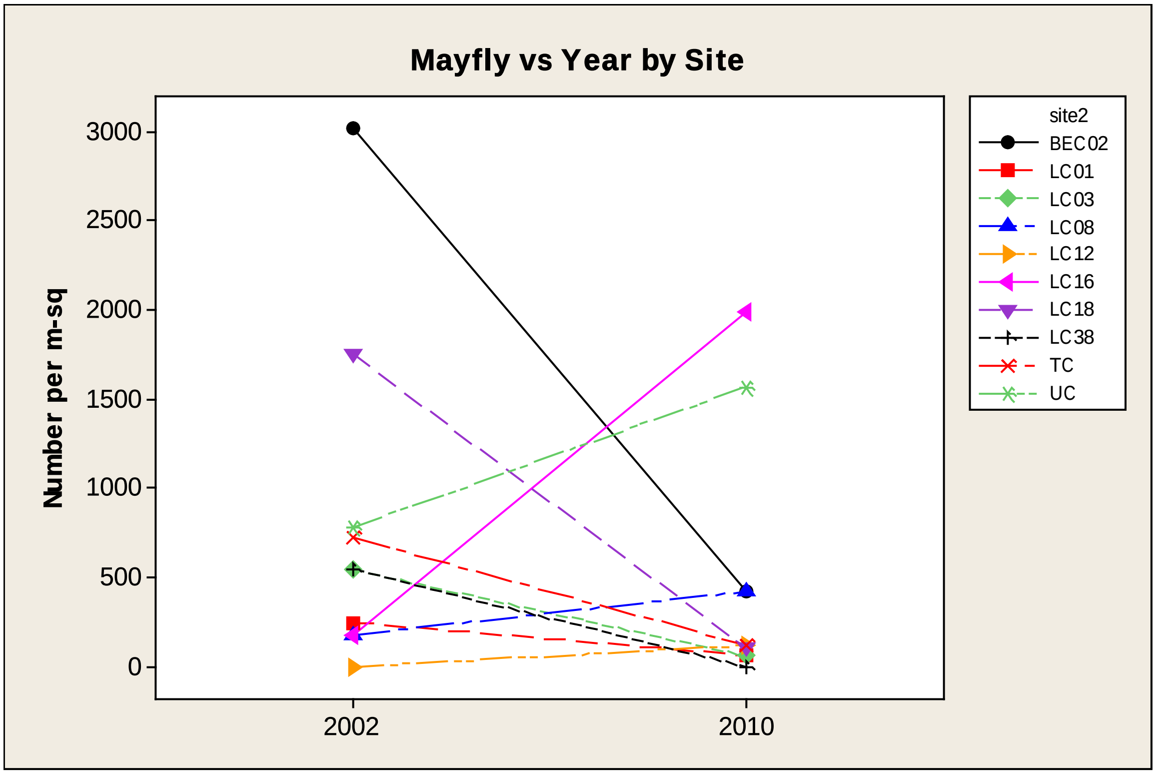

Figure 42. Trends in densities of mayflies in samples from Lyons Creek and reference sites.

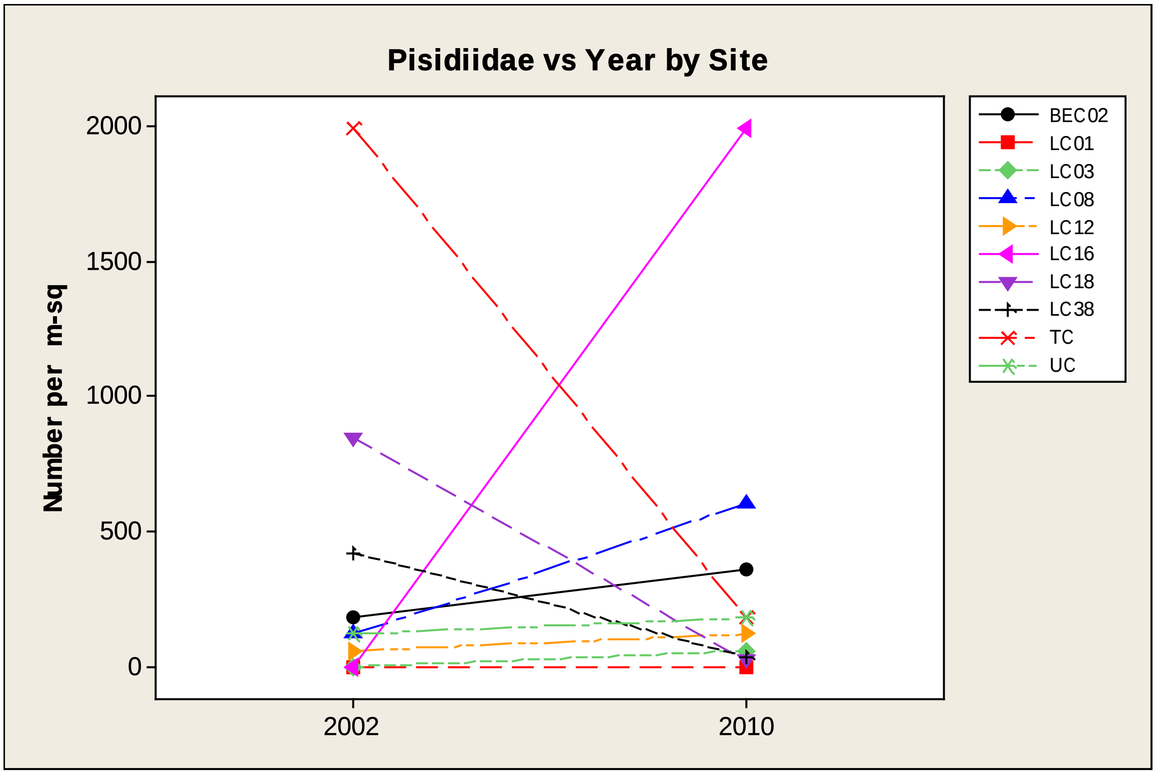

Figure 43. Trends in densities of pisidids (fingernail clam) in samples from Lyons Creek and reference sites.

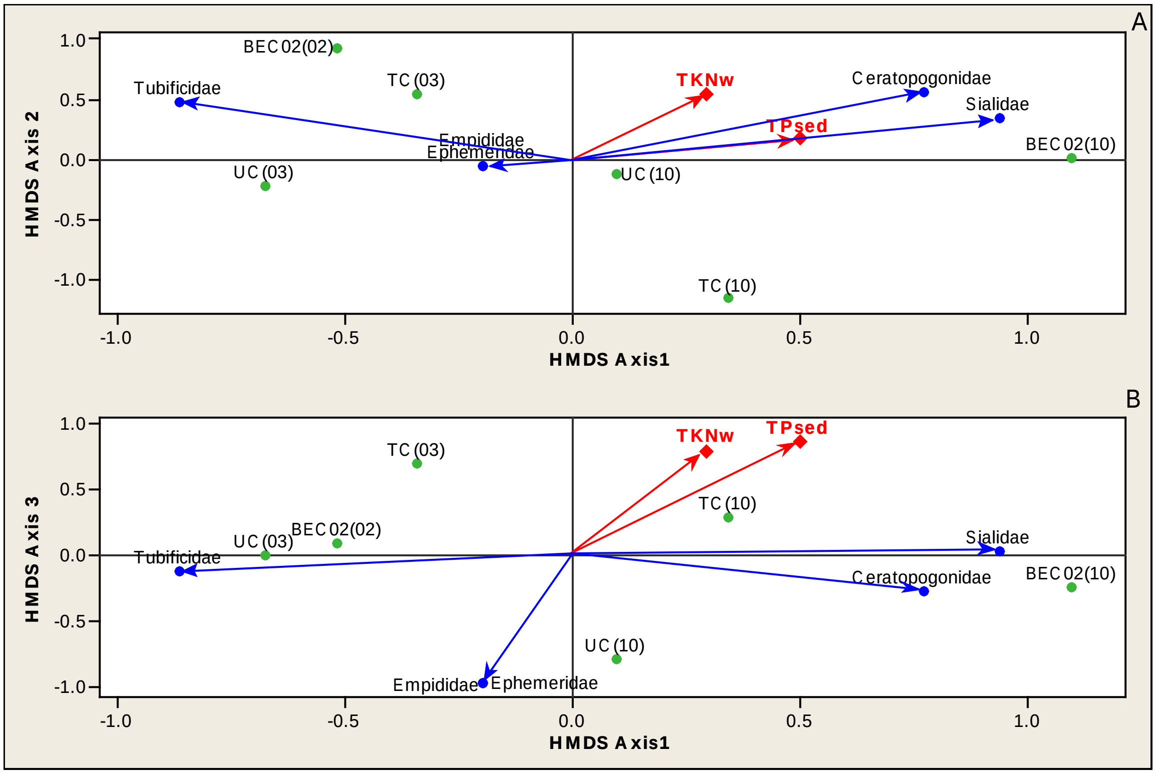

Figure 44. Ordination of 2002-2010 reference creek invertebrate community composition data for co-located sites, represented by 3-dimensional hybrid multidimensional scaling (HMDS) (stress = 0.07). BC= Beaver Creek; UC = Usshers Creek, TC = Tee Creek. The directions of maximum correlations of family and habitat variables are shown as vectors.

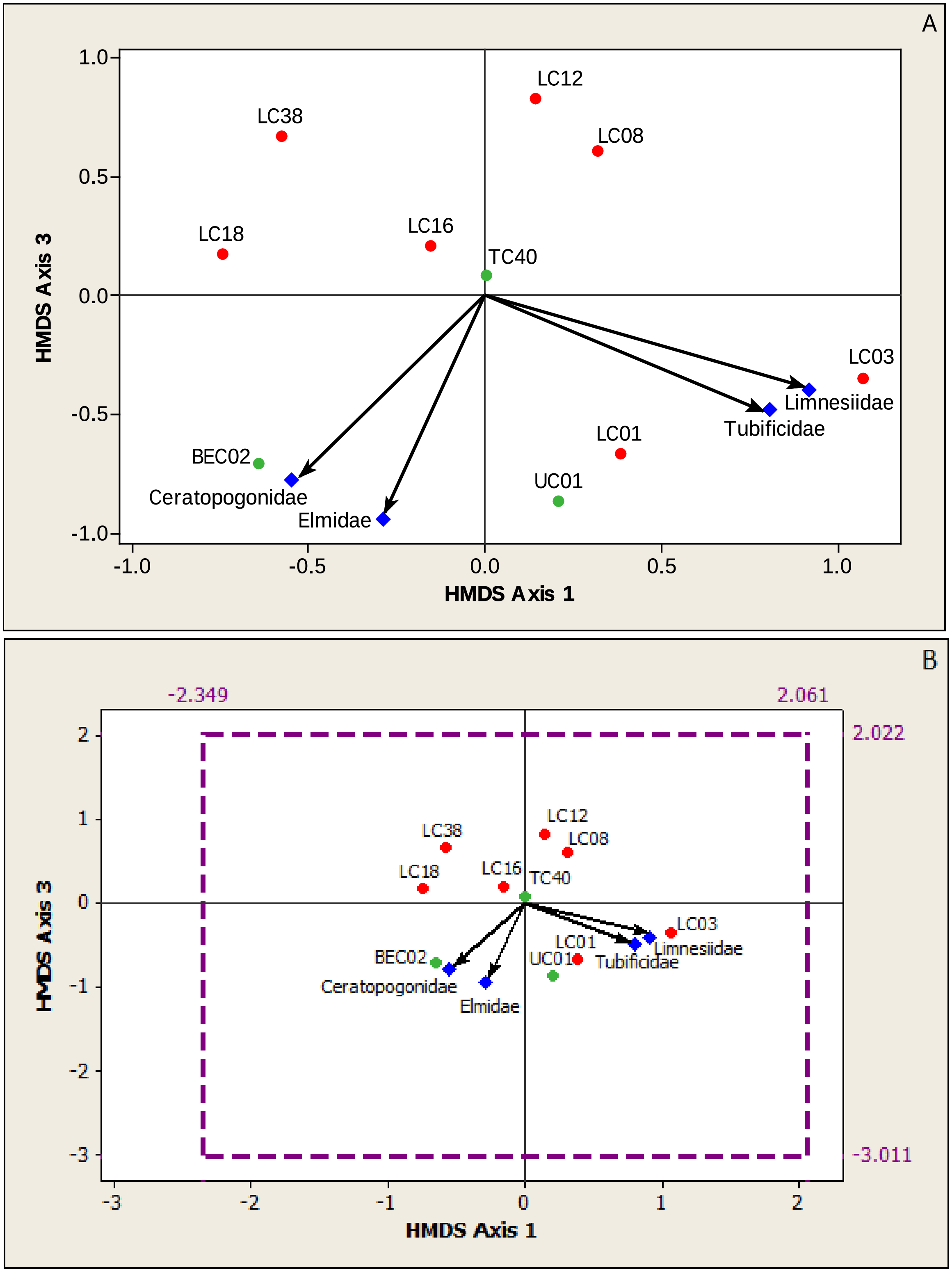

Figure 45. Ordination of 2010 Lyons Creek (red dots) and reference creek (green dots) benthic invertebrate community composition data represented by 3-dimensional hybrid multidimensional scaling (stress = 0.12). (A) Scores for axes 1 & 3. (B) Prediction intervals computed using 2010 reference creek data, indicated by the dashed lines. The directions of maximum correlations of community endpoints ($r^2 \geq 0.66$) with sites are shown as vectors. No habitat variables were significant.

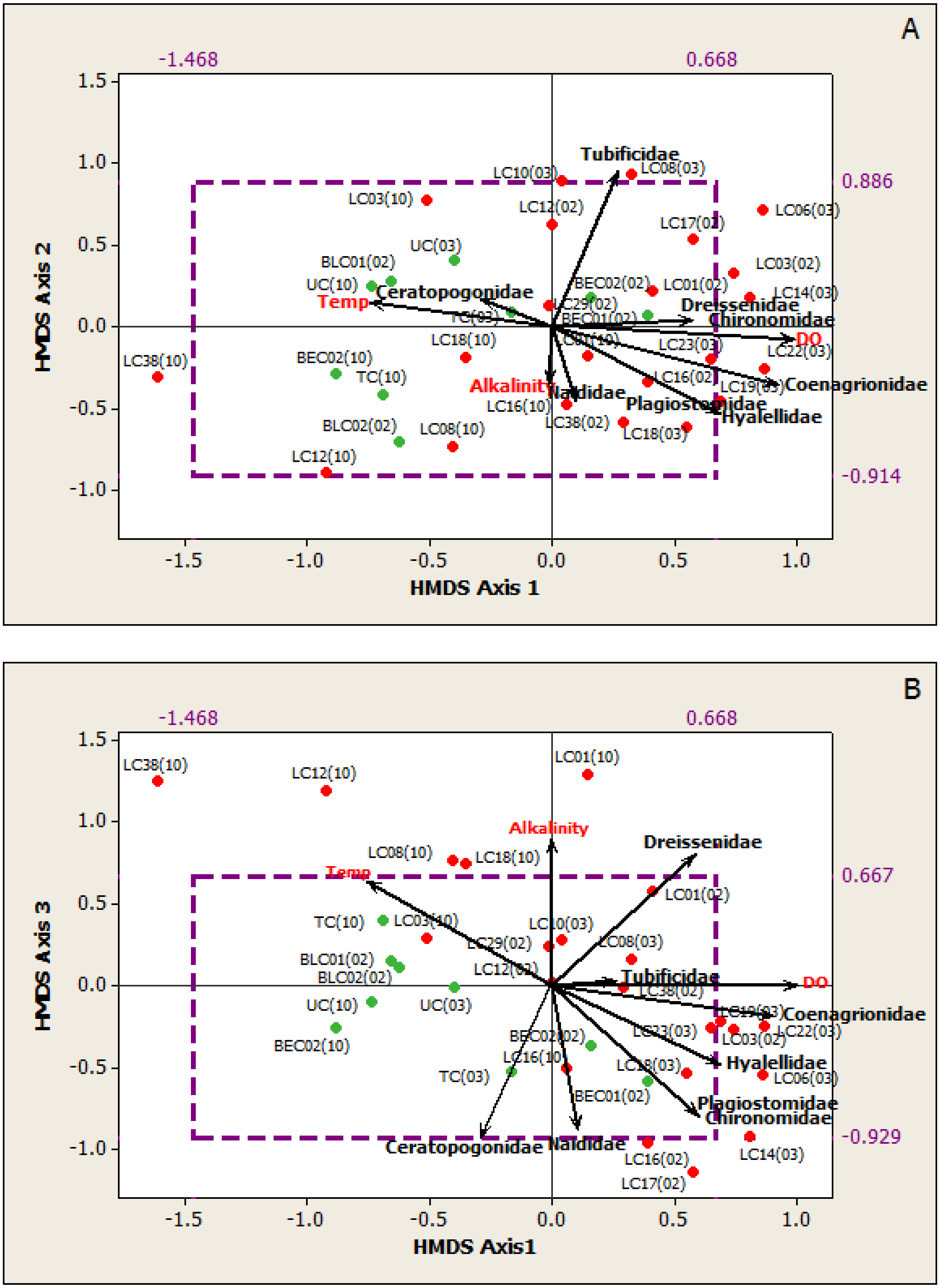

Figure 46. Ordination of 2002-2010 Lyons Creek (red dots) and reference creek (green dots) benthic invertebrate community composition data represented by 3-dimensional hybrid multidimensional scaling (stress = 0.13). (A) Scores for axes 1 & 2. (B) Scores for axes 1 & 3. Prediction intervals computed using 2002-2010 reference creek data are indicated by the dashed lines. The directions of maximum correlations of community endpoints ($r^2 \geq 0.35$) and habitat variables ($r^2 \geq 0.28$) with sites are shown as vectors.

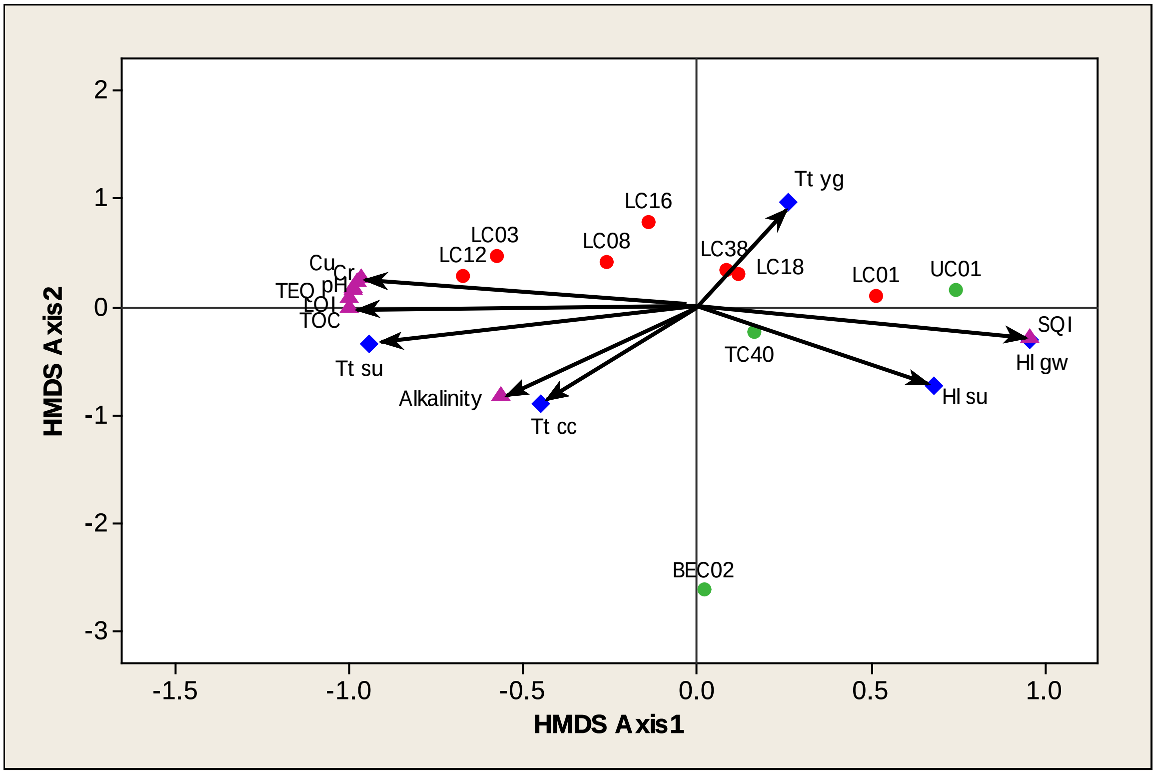

Figure 47. Ordination of 2010 Lyons Creek (red dots) and reference creek (green dots) toxicological data represented by 2-dimensional hybrid multidimensional scaling (stress = 0.04). The Great Lakes reference site data are not included. The directions of maximum correlations of community endpoints and habitat variables with sites are shown as vectors. [*Hexagenia* survival and growth (Hl su and Hl gw), *Tubifex* survival, cocoon production, and young production (Tt su, Tt cc, and Tt yg)].

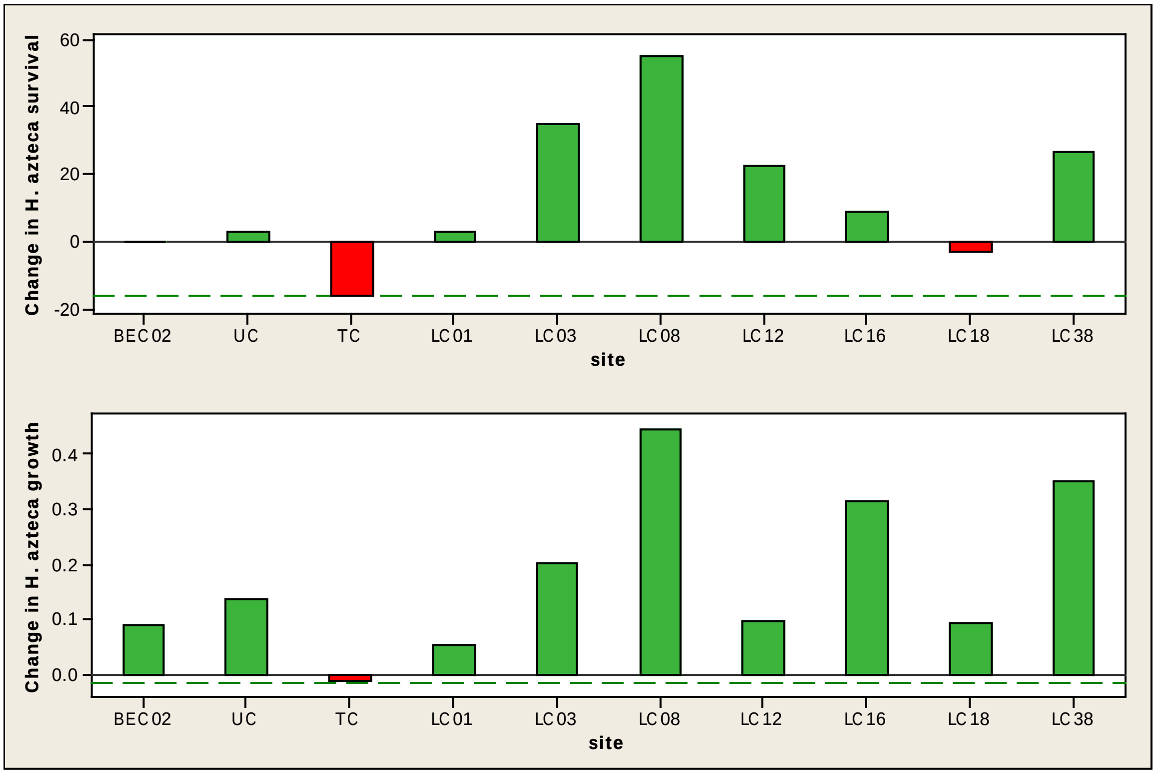

Figure 48. Change in *H. azteca* survival (A) and growth (B), for sites sampled in both 2002/2003 and 2010. Bars represent % survival or growth (mg dw per individual) for 2010 minus that for 2002/2003. Dashed lines show maximum increases (+) and decreases (–) for reference sites since 2002.

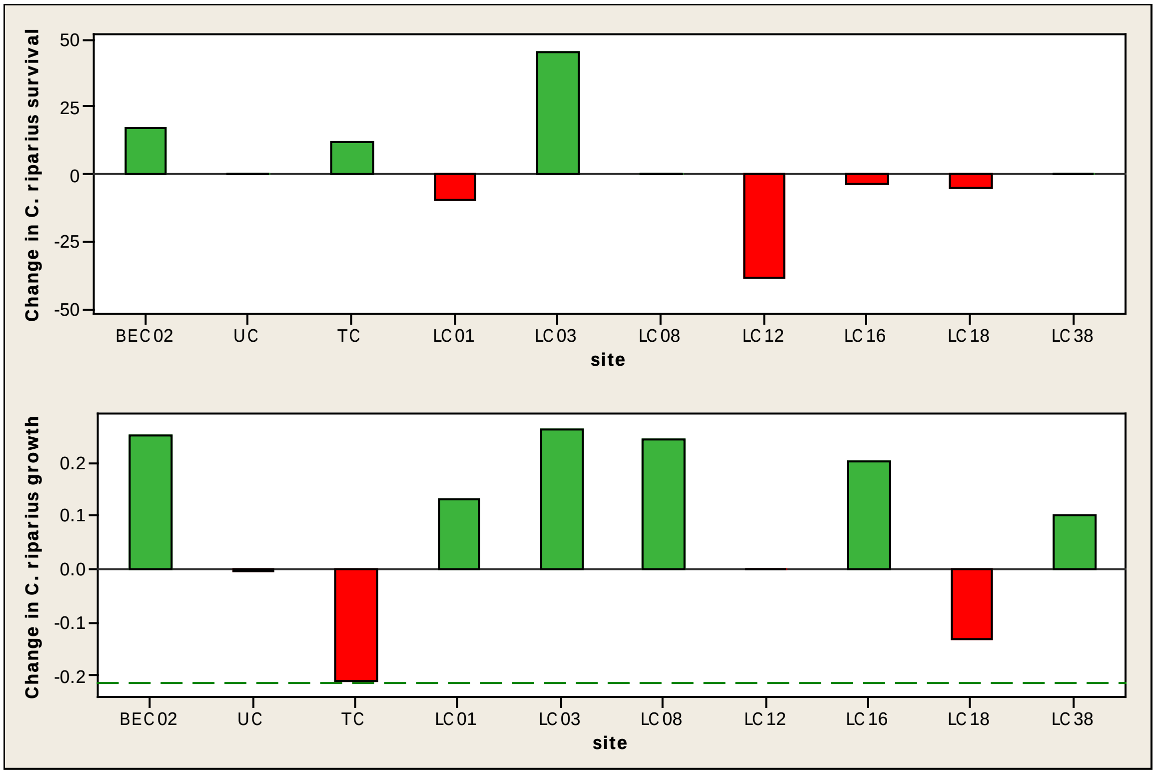

Figure 49. Change in *C. riparius* survival (A) and growth (B), for sites sampled in both 2002/2003 and 2010. Bars represent % survival or growth (mg dw per individual) for 2010 minus that for 2002/03. Dashed lines show maximum increases (+) and decreases (–) for reference sites since 2002.

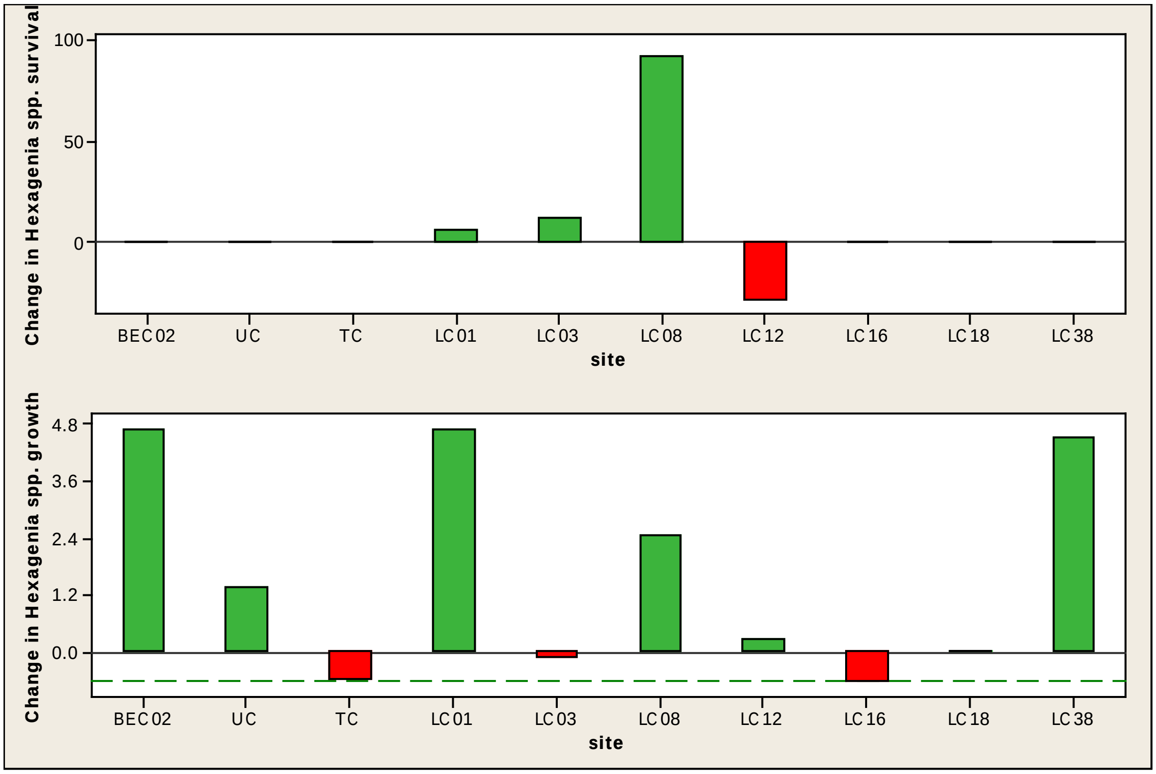

Figure 50. Change in *Hexagenia* spp. survival (A) and growth (B), for sites sampled in both 2002/2003 and 2010. Bars represent % survival or growth (mg dw per individual) for 2010 minus that for 2002/2003. Dashed lines show maximum increases (+) and decreases (–) for reference sites since 2002.

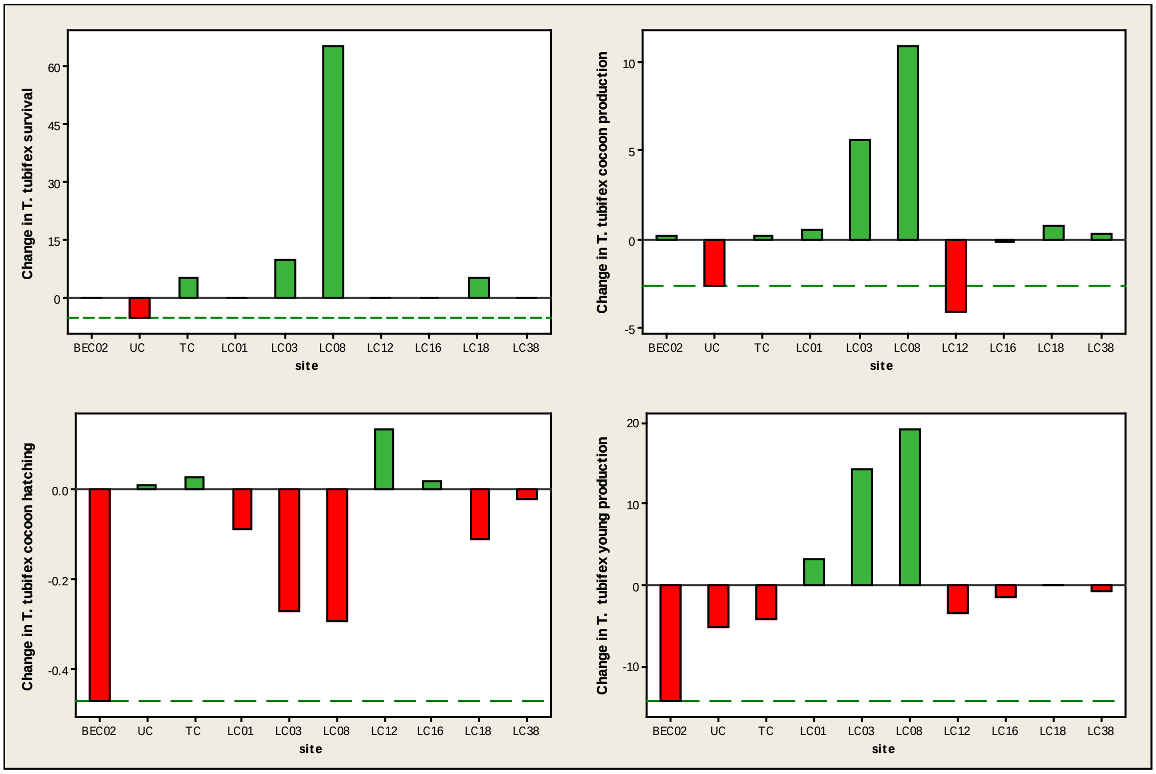

Figure 51. Change in *T. tubifex* (A) survival, (B) cocoon production, (C) cocoon hatching, and (D) young production, for sites sampled in both 2002/2003 and 2010. Bars represent % survival and reproduction (no. cocoons/adult, % cocoons hatched, no. young/adult) for 2010 minus that for 2002/2003. Dashed lines show maximum increases (+) and decreases (–) for reference sites since 2002.

APPENDIX A QA/QC

Table A1. Coefficients of variation (CV) for field-replicated site (LC18) and relative percent difference (RPD) for sample duplicate –sediment metals and nutrients (Caduceon Environmental Laboratories).

Parameter	**Units**	LC1800	LC1801	LC1802	**CV**	TC	TC - Duplicate	**R.P.D.**
Aluminum	µg/g	21100	22300	20800	**3.7**	20700	20500	**1.0**
Antimony	µg/g	2.1	1.1	1.7	**30.8**	< 0.5	< 0.5	**0.0**
Arsenic	µg/g	27.6	14.7	20.9	**30.6**	3.0	3.8	**23.5**
Barium	µg/g	125	138	115	**9.2**	93	93	**0.0**
Beryllium	µg/g	0.7	0.8	0.8	**7.5**	0.8	0.8	**0.0**
Bismuth	µg/g	< 5	< 5	< 5	**-**	< 5	< 5	-
Cadmium	µg/g	1.2	0.9	1.1	**14.3**	< 0.5	< 0.5	**0.0**
Calcium	µg/g	25500	24000	28000	**7.8**	8050	8170	**1.5**
Chromium	µg/g	52	47	52	**5.7**	23	23	**0.0**
Cobalt	µg/g	16	16	17	**3.5**	16	16	**0.0**
Copper	µg/g	64	57	73	**12.4**	21	21	**0.0**
Iron	µg/g	67500	55400	73400	**14.0**	24100	24100	**0.0**
Lead	µg/g	79	66	95	**18.2**	16	15	**6.5**
Magnesium	µg/g	7860	8800	8220	**5.7**	7890	7910	**0.3**
Manganese	µg/g	499	470	546	**7.6**	392	394	**0.5**
Mercury	µg/g	0.162	0.133	0.164	**11.3**	0.091	0.091	**0.0**
Molybdenum	µg/g	5	3	4	**25.0**	< 1	< 1	-
Nickel	µg/g	91	71	81	**12.3**	34	35	**2.9**
Phosphorus	µg/g	6910	4220	7840	**29.7**	794	795	**0.1**
Potassium	µg/g	1870	2000	1800	**5.4**	1740	1710	**1.7**
Silicon	µg/g	226	200	259	**12.9**	261	221	**16.6**
Silver	µg/g	19.0	23.3	34.5	**31.3**	< 0.2	< 0.2	**0.0**
Sodium	µg/g	220	230	280	**13.2**	200	200	**0.0**
Strontium	µg/g	98	100	134	**18.3**	41	41	**0.0**
Tin	µg/g	< 10	< 10	10	**-**	< 10	< 10	-
Titanium	µg/g	145	163	148	**6.3**	156	153	**1.9**
Vanadium	µg/g	34	36	35	**2.9**	30	30	**0.0**
Yttrium	µg/g	8.4	9.7	8.8	**7.4**	11.7	11.6	**0.9**
Zinc	µg/g	3810	2870	5310	**30.8**	115	115	**0.0**
Zirconium	µg/g	< 0.1	< 0.1	< 0.1	**-**	< 0.1	< 0.1	-
Aluminum (Al2O3)	%	11.7	12.1	11.5	**2.6**	13.9	12.9	**7.5**
Barium (BaO)	%	0.05	0.05	0.04	**12.4**	0.05	0.05	**0.0**
Calcium (CaO)	%	2.0	1.9	4.1	**46.6**	2.0	2.50	**22.2**
Chromium (Cr2O3)	%	< 0.03	< 0.03	< 0.03	**-**	< 0.03	< 0.03	-
Iron (Fe2O3)	%	12.7	10.2	13.9	**15.4**	4.8	4.9	**2.1**
Magnesium (MgO)	%	1.2	1.3	2.4	**40.8**	2.7	2.7	**0.0**
Manganese (MnO)	%	0.07	0.06	0.07	**8.7**	0.06	0.06	**0.0**
Phosphorus (P2O5)	%	< 3	< 3	< 3	**-**	< 3	< 3	-
Potasium (K20)	%	2	2	3	**24.7**	3	3.00	**0.0**
Silica (SiO2)	%	38.6	40.5	35.4	**6.8**	49.2	48.8	**0.8**
Sodium (Na2O)	%	< 3	< 3	< 3	**-**	< 3	< 3	-
Titanium (TiO2)	%	0.6	0.6	0.5	**10.2**	0.8	0.7	**13.3**
Loss on Ignition	%	21.4	21.4	18.4	**8.5**	14.8	15.0	**1.3**
Whole Rock Total	%	92.9	90.6	94.0	**1.9**	90.9	90.1	**0.9**
Total Organic Carbon	% by wt	6.8	5.9	6.1	**7.5**	4.6	4.7	**2.2**
Nitrogen	µg/g	4940	4600	4900	**3.9**	3280	3560	**8.2**
Phosphorus-Total	µg/g	6800	4540	8170	**28.2**	862	933	**7.9**
				min	1.9			0.0
				max	46.6			23.5
				median	11.3			0.4

Table A2. Coefficients of variation (CV) for field-replicated site (LC18) – sediment organic contaminants (ALS Laboratory Group). (OCP - none calculable – all below LOD).

Sample ID	**LC1800**	**LC1801**	**LC1802**	**CV**
% Moisture	89.0	87.7	85.0	2.3
Aggregate Organics				
Oil and Grease, Total	63500	93600	68800	21.3
Volatile Organic Compounds				
Benzene	<0.25	<0.25	<0.25	NC
Ethyl Benzene	<0.25	<0.25	<0.25	NC
Toluene	<0.25	<0.25	<0.25	NC
o-Xylene	<0.25	<0.25	<0.25	NC
m+p-Xylenes	<0.50	<0.50	<0.50	NC
Xylenes (Total)	<0.56	<0.56	<0.56	NC
Hydrocarbons				
F1 (C6-C10)	<25	<25	<25	NC
F1-BTEX	<25	<25	<25	NC
F2 (C10-C16)	422	1090	334	67.2
F2-Naphth	422	1090	334	67.2
F3 (C16-C34)	14300	34300	8480	71.2
F3-PAH	14300	34300	8470	71.2
F4 (C34-C50)	5690	13100	2450	77.1
F4G-SG (GHH-Silica)	12100	36100	5800	88.8
Total Hydrocarbons (C6-C50)	20400	48500	11300	72.5
Polycyclic Aromatic Hydrocarbons				
Acenaphthene	<0.25	<2.5	<0.40	NC
Acenaphthylene	<0.25	<2.5	<0.40	NC
Acridine	<4.0	<40	<6.4	NC
Anthracene	0.44	<2.5	<0.40	NC
Benzo(a)anthracene	1.38	2.7	0.94	54.7
Benzo(a)pyrene	1.75	1.8	0.84	36.9
Benzo(b&j)fluoranthene	1.34	<2.5	0.69	45.3
Benzo(g,h,i)perylene	1.78	<2.5	0.83	51.5
Benzo(k)fluoranthene	0.54	<1.0	0.24	54.4
Chrysene	4.01	5.7	2.25	43.3
Dibenzo(ah)anthracene	0.52	<2.5	<0.40	NC
Fluoranthene	2.73	4.1	1.63	43.9
Fluorene	0.40	<2.5	<0.40	NC
Indeno(1,2,3-cd)pyrene	0.72	<2.5	<0.40	NC
1-Methylnaphthalene	<0.25	<2.5	<0.40	NC
2-Methylnaphthalene	<0.25	<2.5	<0.40	NC
Naphthalene	<0.050	<0.50	<0.080	NC
Phenanthrene	1.00	<1.5	0.62	33.2
Pyrene	3.63	5.7	2.25	45.0
Quinoline	<0.25	<2.5	<0.40	NC

NC = not calculable due to value(s) below limit of detection

Table A3. Coefficients of variation (CV) for field-replicated site (LC18) – sediment PCB congeners (ALS Laboratory Group).

Sample Name	LC1800	LC1801	LC1802	CV	Sample Name	LC1800	LC1801	LC1802	CV
PCB	**pg/g**	**pg/g**	**pg/g**		**PCB**	**pg/g**	**pg/g**	**pg/g**	
*1	1050	1290	3800	74.4	65	<370	<270	<2200	NC
2	128	178	435	66.7	62	<640	<450	<2700	NC
*3	1480	1370	3160	50.1	44	655000	784000	1910000	61.8
*4/+10	50500	77000	187000	69.0	59	42100	51200	<21000	13.8
9/7	5820	7790	22600	76.0	42	227000	280000	912000	80.6
6	17400	18400	60400	76.5	41	<2.1	2770	<9.1	NC
+8/5	138000	162000	420000	65.1	71	175000	250000	611000	67.5
14	<12	<11	<27	NC	72/64/68	481000	555000	1210000	53.6
11	275	446	1390	85.3	+40/57	87500	111000	308000	71.7
12/13	23600	30500	68500	59.2	67	17000	21600	60800	72.6
*15	61700	102000	242000	70.0	58	1230	1380	2990	52.3
*19	45200	54900	162000	74.2	63	23000	28400	74500	67.4
30	143	205	<2.9	NC	+74/61	368000	438000	1000000	57.5
18	621000	689000	2240000	77.4	76/70	728000	873000	2180000	63.5
17	164000	234000	566000	66.8	+66/80	597000	701000	1580000	56.3
27/24	28500	33900	106000	77.1	55	9570	11900	30700	66.6
16/32	297000	371000	1670000	99.1	56	308000	362000	867000	60.2
34/23	3510	4550	11700	67.7	60	123000	229000	472000	65.1
29	2580	3260	9840	76.7	79	302	424	975	63.2
26	83100	118000	341000	77.4	78	<2.2	<1.6	<11	NC
25	24100	26300	<2.9	NC	*81	2050	2770	6960	67.5
31/+28	1170000	1440000	4630000	79.7	*77	47600	62500	147000	62.6
20/+33/21	359000	411000	1270000	75.2	*104	42.1	58.6	134	62.6
22	237000	277000	792000	71.1	96/103	7420	10200	22700	60.6
36	3560	4140	480	72.1	100	1020	1370	3180	62.4
39	13300	13900	38000	64.8	94	2880	4050	9380	63.7
38	57.2	5790	<170	NC	98/102	17400	24000	50600	57.3
35	18300	20900	55800	66.1	+95/93/121	154000	248000	484000	57.6
*37	156000	170000	509000	71.8	88	1790	2400	5210	58.2
*54	1750	2210	5150	60.7	91	51700	68600	161000	62.7
50	1520	1960	5080	68.0	92	34600	45500	100000	58.4
53	99200	126000	361000	73.7	84/90	62000	82300	257000	80.1
51	29700	36800	101000	70.3	101/113/89	230000	326000	618000	51.6
45	106000	156000	375000	67.4	99	119000	202000	366000	54.9
46/69/73	35000	45300	121000	70.0	119	5290	7200	15300	57.4
52	711000	829000	2030000	61.3	112	1060	1230	3190	64.8
43	18400	24000	<71000	18.7	108/83	16200	21700	47200	58.3
49	442000	526000	1420000	68.1	86/97/125	95500	126000	280000	59.2
48/47/75	327000	404000	883000	56.0	117/111	7920	10600	21300	53.3
					115/116/+87	98100	161000	302000	55.8

Table A3. Continued.

Sample Name	LC1800	LC1801	LC1802	CV	Sample Name	LC1800	LC1801	LC1802	CV
85/120	58500	75800	169000	58.8	*167	2460	3460	7440	59.2
110	258000	376000	625000	44.6	*156	6820	9510	23300	66.9
82	52100	68900	177000	68.2	*157	1570	2200	4710	58.8
124	6980	9530	24000	68.0	*169	20.4	30.6	94.6	82.9
109/107	15500	21300	54900	69.6	*188	<6.7	<5.2	<32	NC
123	6170	8180	18500	60.4	184	<6.4	<5.3	<38	NC
*118/106	179000	257000	427000	44.1	179	4230	7340	18100	73.6
*114	8640	11700	28700	66.1	176	1300	2310	5410	71.2
122	3430	4630	10700	62.3	186	<6.8	<5.7	<42	NC
*105/127	106000	138000	327000	62.7	178	2100	3590	8380	70.0
*126	801	1130	2360	57.5	175	431	741	1670	68.1
*155	<5.7	<4.0	<25	NC	182/+187	12600	21700	54200	74.1
150	62.6	92.9	214	65.0	183	5920	10100	24300	71.7
152	110	152	323	57.9	185	1350	2280	5770	74.4
145/148	94.3	136	306	62.7	174	11300	18500	46400	73.0
136/154	7950	11600	27600	66.5	181	<2.2	<1.8	<13	NC
151	9960	15000	33800	64.1	177	6390	10300	<45	33.1
135	7140	10400	23300	62.8	171	3060	4940	11700	69.2
144	2140	3520	7680	64.9	173	271	440	1120	73.6
147	1220	1750	4010	63.7	192/172	1870	2960	6910	67.8
139/+149	38800	57000	137000	67.3	+193/+180	23600	35900	92400	72.5
140	268	406	903	63.5	191	458	716	1710	68.8
143	321	499	963	55.8	+170/190	12400	19000	43600	65.8
134	3480	5260	12100	65.5	*189	470	701	1770	70.7
142	705	1030	2110	57.4	*202	1110	1480	3200	57.8
133/165/131	976	1480	3320	64.1	201	616	864	2090	66.3
161/146	6210	9270	20100	61.5	204	<2.6	<2.0	<14	NC
+168/+153	39800	58800	133000	63.8	197	178	281	716	72.9
132	22300	33600	80000	67.5	200	622	926	2320	70.2
141	11000	16800	39300	66.8	198	297	414	996	65.8
137	3820	5590	12600	63.3	199	5920	8370	20200	66.4
130	4190	6160	13200	60.3	196/+203	6300	8810	21200	65.9
164/163	14000	21400	49000	65.6	195	1970	2540	6930	71.2
+138/160	46400	67700	137000	56.6	194	5330	6960	18000	68.3
158	5290	8110	21100	73.3	*205	301	409	1050	69.0
129	3850	5710	12200	60.4	*208	589	782	1750	59.8
166	205	385	757	62.7	207	260	349	836	64.4
159	<4.4	<3.4	<23	NC	*206	2320	3160	7490	64.2
162	244	346	774	61.9	*209	384	378	937	56.7
128	13400	19100	43100	62.5					

Table A4. Relative percent different (RPD) for sample duplicates - sediment organic contaminants (ALS Laboratory Group).

Sample ID	Analyte	RPD	RPD Limit		Sample ID	Analyte	RPD	RPD Limit
Aggregate Organics					**Organochlorine Pesticides**			
WG1168580-2	F4G-SG (GHH-Silica)	0	50		WG1170356-2	Aldrin	5.1	50
WG1168634-2	Oil and Grease, Total	7.3	45		WG1171966-2	Aldrin	8.5	50
					WG1170356-2	alpha-BHC	7.4	50
Hydrocarbons					WG1171966-2	alpha-BHC	6.7	50
WG1168576-2	F2 (C10-C16)	2.6	50		WG1170356-2	beta-BHC	3.2	50
WG1168576-2	F3 (C16-C34)	3	50		WG1171966-2	beta-BHC	1.8	50
WG1168576-2	F4 (C34-C50)	1.4	50		WG1170356-2	Lindane	4.1	50
					WG1171966-2	Lindane	3.5	50
Polycyclic Aromatic Hydrocarbons					WG1170356-2	delta-BHC	6.6	50
WG1170347-2	Acenaphthene	7.9	50		WG1171966-2	delta-BHC	4.2	50
WG1170347-2	Acenaphthylene	8.2	50		WG1170356-2	a-chlordane	28	50
WG1170347-2	Acridine	8.5	50		WG1171966-2	a-chlordane	26	50
WG1170347-2	Anthracene	7.1	50		WG1170356-2	g-chlordane	30	50
WG1170347-2	Benzo(a)anthracene	7.2	50		WG1171966-2	g-chlordane	27	50
WG1170347-2	Benzo(a)pyrene	6.6	50		WG1170356-2	op-DDD	29	50
WG1170347-2	Benzo(b&j)fluoranthene	9.9	45		WG1171966-2	op-DDD	29	50
WG1170347-2	Benzo(g,h,i)perylene	2.6	50		WG1170356-2	pp-DDD	27	50
WG1170347-2	Benzo(k)fluoranthene	8.7	50		WG1171966-2	pp-DDD	24	50
WG1170347-2	Chrysene	4.4	50		WG1170356-2	o,p-DDE	29	50
WG1170347-2	Dibenzo(ah)anthracene	2.9	50		WG1171966-2	o,p-DDE	29	50
WG1170347-2	Fluoranthene	6.2	50		WG1170356-2	pp-DDE	29	50
WG1170347-2	Fluorene	8.5	50		WG1171966-2	pp-DDE	27	50
WG1170347-2	Indeno(1,2,3-cd)pyrene	2.3	50		WG1170356-2	op-DDT	15	50
WG1170347-2	1-Methylnaphthalene	9.2	50		WG1171966-2	op-DDT	19	50
WG1170347-2	2-Methylnaphthalene	9.8	50		WG1170356-2	pp-DDT	11	50
WG1170347-2	Naphthalene	8.7	50		WG1171966-2	pp-DDT	11	50
WG1170347-2	Phenanthrene	8.9	50		WG1170356-2	Dieldrin	27	50
WG1170347-2	Pyrene	5.6	50		WG1171966-2	Dieldrin	30	50
WG1170347-2	Quinoline	6.8	50		WG1170356-2	alpha-Endosulfan	48	50
					WG1171966-2	alpha-Endosulfan	28	50
					WG1170356-2	beta-Endosulfan	24	50
					WG1171966-2	beta-Endosulfan	31	50
					WG1170356-2	Endosulfan Sulfate	23	50
					WG1171966-2	Endosulfan Sulfate	16	50
					WG1170356-2	Endrin	18	45
					WG1171966-2	Endrin	14	45
					WG1170356-2	Endrin Aldehyde	29	50
					WG1171966-2	Endrin Aldehyde	29	50
					WG1170356-2	Heptachlor	1.2	50
					WG1171966-2	Heptachlor	6.2	50
					WG1170356-2	Heptachlor Epoxide	34	50
					WG1171966-2	Heptachlor Epoxide	31	50
					WG1170356-2	Methoxychlor	4.5	50
					WG1171966-2	Methoxychlor	6.5	50
					WG1170356-2	Mirex	25	50
					WG1171966-2	Mirex	24	50
					WG1170356-2	Oxychlordane	31	50
					WG1171966-2	Oxychlordane	29	50
	min	0				min	1.2	
	max	9.9				max	48	
	median	7.1				median	24.0	

Table A5. Relative percent difference (RPD) of sample duplicate and recovery of laboratory control sample (LCS) - sediment PCB congener samples (ALS Laboratory Group). Values highlighted red are above reporting limits.

Sample Name	LC01 (pg/g)	LC01 - Duplicate (pg/g)	RPD	% Recovery LCS	Method Blank (pg/g)
*1	56900	53100	6.9	101	<1.3
2	4510	3440	26.9		<1.2
*3	7650	7100	7.5	98	<1.1
*4/+10	11900	3390	111.3	109	<5.7
9/7	84.9	46.7	58.1		<3.0
6	188	121	43.4		<3.0
+8/5	921	662	32.7		<3.0
14	<1.6	<1.8	-		<2.9
11	71.6	81.5	12.9		13.6
12/13	160	150	6.5		<3.1
*15	582	467	21.9	101	**6.80**
*19	345	287	18.4	100	<2.6
30	1.85	<0.98	-		<1.4
18	3600	3240	10.5		**6.12**
17	1100	928	17.0		**3.01**
27/24	229	189	19.1		<1.5
16/32	1680	1540	8.7		**3.55**
34/23	30.1	27.5	9.0		<0.95
29	20.8	15.3	30.5		<0.91
26	683	570	18.0		<0.93
25	147	160	8.5		<0.92
31/+28	7890	7790	1.3		**15.0**
20/+33/21	2310	2080	10.5		**5.23**
22	1330	1290	3.1		**2.96**
36	37.7	42.5	12.0		<0.86
39	174	187	7.2		<0.91
38	<0.48	<0.65	-		<0.93
35	200	224	11.3		<0.95
*37	969	1010	4.1	98	<4.1
*54	16.9	20.9	21.2	101	<3.0
50	20.5	<20	-		<3.7
53	1310	1480	12.2		<3.9
51	413	464	11.6		<3.9
45	1310	1480	12.2		<4.2
46/69/73	440	480	8.7		<3.4
52	7000	8470	19.0		<3.6
43	<300	<310	-		<4.9
49	5160	6190	18.1		<3.9
48/47/75	3050	3600	16.5		<3.2
65	<15	21.0	-		<2.9
62	<3.5	<5.0	-		<3.7
44	7730	10200	27.6		<5.5
59	<90	<120	-		<2.4
42	3060	3780	21.1		<5.5
41	<2.4	<3.5	-		<2.6
71	1990	2560	25.1		<3.5
72/64/68	3660	4270	15.4		<3.2
+40/57	900	1140	23.5		<3.8
67	113	124	9.3		<2.6
58	14.0	17.5	22.2		<3.4
63	204	221	8.0		<2.8
+74/61	2900	3380	15.3		<3.2
76/70	6130	7780	23.7		<3.1
+66/80	5230	6270	18.1		<2.8
55	54.3	65.3	18.4		<3.4
56	2270	2750	19.1		<2.8
60	1420	1560	9.4		<3.7
79	<2.9	<4.1	-		<3.0
78	<2.9	<4.2	-		<3.1
*81	18.1	<14	-	95	<3.3

Table A5. Continued.

Sample Name	LC01 (pg/g)	LC01 - Duplicate (pg/g)	RPD	% Recovery LCS	Method Blank (pg/g)
*77	520	597	13.8	100	<3.4
*104	<4.3	<28	-	105	<3.6
96/103	136	146	7.1		<4.7
100	24.1	<47	-		<5.6
94	56.0	<55	-		<6.3
98/102	330	363	9.5		<5.9
+95/93/121	3570	3750	4.9		<5.6
88	<24	<53	-		<6.2
91	1160	1230	5.9		<6.1
92	869	859	1.2		<6.1
84/90	1620	1660	2.4		<6.0
101/113/89	5140	5050	1.8		<5.7
99	2980	2890	3.1		<5.5
119	111	110	0.9		<4.1
112	18.1	<41	-		<4.8
108/83	327	321	1.9		<5.7
86/97/125	1900	2050	7.6		<5.7
117/111	167	172	2.9		<4.6
115/116/+87	2070	2210	6.5		<5.1
85/120	1330	1430	7.2		<4.9
110	5420	5590	3.1		<4.6
82	1060	1130	6.4		<3.9
124	156	171	9.2		<2.5
109/107	314	321	2.2		<2.6
123	151	156	3.3	101	<2.8
*118/106	3470	3510	1.1	100	<2.6
*114	131	134	2.3	99	<2.8
122	70.9	75.8	6.7		<2.8
*105/127	1890	1890	0.0	103	<3.1
*126	16.2	<32	-	103	<3.8
*155	<1.9	<3.1	-	98	<2.4
150	<2.5	<3.7	-		<2.8
152	3.45	<3.5	-		<2.7
145/148	<3.0	<4.4	-		<3.4
136/154	296	260	12.9		<2.9
151	437	380	14.0		<2.4
135	282	251	11.6		<2.5
144	104	87.9	16.8		<2.4
147	54.1	43.4	21.9		<2.4
139/+149	1710	1490	13.8		<2.4
140	11.5	<8.6	-		<2.4
143	11.8	<7.9	-		<2.6
134	140	118	17.1		<2.8
142	35.3	28.1	22.7		<2.6
133/165/131	36.3	28.6	23.7		<2.4
161/146	296	256	14.5		<2.1
+168/+153	1910	1650	14.6		<2.0
132	868	762	13.0		<2.8
141	460	398	14.5		<2.5
137	141	127	10.4		<2.5
130	174	147	16.8		<2.7
164/163	663	587	12.2		<1.9
+138/160	1970	1620	19.5		<2.3
158	240	199	18.7		<1.8
129	130	109	17.6		<2.7
166	<1.6	<2.4	-		<1.8
159	<1.7	<2.5	-		<1.9
162	10.7	6.43	49.9		<2.0
128	518	455	12.9		<2.8
*167	120	99.8	18.4	95	<1.6
*156	236	201	16.0	101	<0.50
*157	59.0	57.2	3.1	96	<0.44
*169	<1.1	<1.6	-	101	<0.35
*188	<2.6	<4.3	-	120	<2.6
184	<2.3	<3.3	-		<2.4
179	209	171	20.0		<2.4
176	75.4	51.4	37.9		<2.5
186	<2.5	<3.6	-		<2.6

Table A5. Continued.

Sample Name	LC01 (pg/g)	LC01 - Duplicate (pg/g)	RPD	% Recovery LCS	Method Blank (pg/g)
178	113	<83	-		<3.4
175	<22	<17	-		<3.2
182/+187	694	570	19.6		<3.2
183	347	243	35.3		<3.1
185	71.9	58.3	20.9		<3.4
174	555	458	19.2		<0.81
181	<2.7	<1.2	-		<0.84
177	309	267	14.6		<0.86
171	162	126	25.0		<0.80
173	14.3	<1.2	-		<0.87
192/172	101	79.1	24.3		<0.74
+193/+180	1310	1100	17.4		<0.66
191	30.2	22.2	30.5		<0.60
+170/190	695	539	25.3		<0.67
*189	29.4	24.0	20.2	100	<0.30
*202	74.0	90.6	20.2	95	<2.6
201	48.4	40.9	16.8		<1.8
204	<1.2	<1.8	-		<1.8
197	<12	<10	-		<1.8
200	44.2	<28	-		<1.8
198	<17	<19	-		<2.4
199	401	417	3.9		<2.5
196/+203	465	435	6.7		<2.3
195	135	116	15.1		<1.6
194	392	344	13.0		<1.5
*205	24.6	<10	-	99	<1.0
*208	58.0	<32	-	107	<3.9
207	21.5	25.0	15.1		<3.5
*206	<97	<110	-	90	<5.1
*209	48.3	52.2	7.8	102	**5.55**

		min	0.0	90	
		max	111.3	120	
		median	14.0	100	

Table A6. Relative percent difference (RPD) of sample duplicate - sediment PCB congener samples (ALS Laboratory Group).

Sample Name	**LC01 (pg/g)**	**LC01 - Duplicate (pg/g)**	**RPD**
Congener Group Totals	**pg/g**	**pg/g**	**RPD**
Monochlorobiphenyls	69100	63600	2.1
Dichlorobiphenyls	13900	4920	23.9
Trichlorobiphenyls	20700	19600	1.4
Tetrachlorobiphenyls	54900	66900	4.9
Pentachlorobiphenyls	34500	35200	0.5
Hexachlorobiphenyls	10900	9360	3.8
Heptachlorobiphenyls	4720	3710	6.0
Octachlorobiphenyls	1580	1440	2.3
Nonachlorobiphenyls	79.5	25.0	26.1
Decachlorobiphenyl	48.3	52.2	1.9
Total PCB	210000	205000	0.6

Table A7. Laboratory control sample (LCS) and method blank (MB) recovery for 2010 sediment organic compound samples (ALS Laboratory Group).

Matrix	QC Type	Analyte	Result	Target	Units	%	Limits	Qualifier
Physical Tests								
Soil	LCS	% Moisture	10.0900090009001	10.0	%	101	70-130	
Soil	MB	% Moisture	<0.10	<0.1	%	-	0.1	
Aggregate Organics								
Soil	LCS	Oil and Grease, Total	9660.00000000005	10000	mg/kg	97	60-120	
Soil	MB	Oil and Grease, Total	<500	<500	mg/kg	-	500	
Volatile Organic Compounds								
Soil	MB	Benzene	<0.050	<0.05	mg/kg	-	0.05	
Soil	MB	Ethyl Benzene	<0.050	<0.05	mg/kg	-	0.05	
Soil	MB	Toluene	<0.050	<0.05	mg/kg	-	0.05	
Soil	MB	o-Xylene	<0.050	<0.05	mg/kg	-	0.05	
Soil	MB	m+p-Xylenes	<0.10	<0.1	mg/kg	-	0.1	
Hydrocarbons								
Soil	LCS	F2 (C10-C16)	276.85	344	mg/kg	80	70-130	
Soil	LCS	F3 (C16-C34)	577.63	666	mg/kg	87	70-130	
Soil	LCS	F4 (C34-C50)	73.96	87	mg/kg	85	70-130	
Soil	MB	F1 (C6-C10)	<5.0	<5	mg/kg	-	5	
Soil	MB	F2 (C10-C16)	<10	<10	mg/kg	-	10	
Soil	MB	F3 (C16-C34)	<50	<50	mg/kg	-	50	
Soil	MB	F4 (C34-C50)	<50	<50	mg/kg	-	50	

Table A8. Laboratory control sample (LCS) and method blank (MB) recovery for 2010 sediment PAH samples (ALS Laboratory Group).

Analyte	LCS Result	LCS Target	Units	LCS %	LCS Limits	Qualifier	MB Result	MB Target	Units	MB %	MB Limits	Qualifier
Polycyclic Aromatic Hydrocarbons												
Acenaphthene	.73904	0.800	mg/kg	92	50-140		<0.050	<0.05	mg/kg	-	0.05	
Acenaphthylene	.73164	0.800	mg/kg	91	40-140		<0.050	<0.05	mg/kg	-	0.05	
Acridine	1.44576	1.63	mg/kg	89	50-140		<0.80	<0.8	mg/kg	-	0.8	
Anthracene	.74852	0.800	mg/kg	94	50-140		<0.050	<0.05	mg/kg	-	0.05	
Benzo(a)anthracene	.7501	0.800	mg/kg	94	50-140		<0.050	<0.05	mg/kg	-	0.05	
Benzo(a)pyrene	.821	0.800	mg/kg	103	40-130		<0.020	<0.02	mg/kg	-	0.02	
Benzo(b&j)fluoranthene	.6053	0.800	mg/kg	76	50-140		<0.050	<0.05	mg/kg	-	0.05	
Benzo(g,h,i)perylene	.80452	0.800	mg/kg	101	50-140		<0.050	<0.05	mg/kg	-	0.05	
Benzo(k)fluoranthene	.80644	0.800	mg/kg	101	50-150		<0.020	<0.02	mg/kg	-	0.02	
Chrysene	.74984	0.800	mg/kg	94	50-140		<0.050	<0.05	mg/kg	-	0.05	
Dibenzo(ah)anthracene	.82328	0.800	mg/kg	103	40-140		<0.050	<0.05	mg/kg	-	0.05	
Fluoranthene	.74806	0.800	mg/kg	94	50-140		<0.050	<0.05	mg/kg	-	0.05	
Fluorene	.72514	0.800	mg/kg	91	50-140		<0.050	<0.05	mg/kg	-	0.05	
Indeno(1,2,3-cd)pyrene	.82932	0.800	mg/kg	104	30-130		<0.050	<0.05	mg/kg	-	0.05	
1-Methylnaphthalene	.7381	0.800	mg/kg	92	50-130		<0.050	<0.05	mg/kg	-	0.05	
2-Methylnaphthalene	.69802	0.800	mg/kg	87	50-140		<0.050	<0.05	mg/kg	-	0.05	
Naphthalene	.73876	0.800	mg/kg	92	50-130		<0.010	<0.01	mg/kg	-	0.01	
Phenanthrene	.74594	0.800	mg/kg	93	50-140		<0.030	<0.03	mg/kg	-	0.03	
Pyrene	.77012	0.800	mg/kg	96	40-140		<0.050	<0.05	mg/kg	-	0.05	
Quinoline	.63798	0.812	mg/kg	79	50-140		<0.050	<0.05	mg/kg	-	0.05	

min	76
max	104
median	94

Table A9. Laboratory control sample (LCS) and method blank (MB) recovery for 2010 sediment organochlorine pesticide samples (ALS Laboratory Group).

Analyte	LCS Result	LCS Target	Units	LCS %	LCS Limits	Qualifier	MB Result	MB Target	Units	MB %	MB Limits	Qualifier
Organochlorine Pesticides												
Aldrin	.20074	0.200	mg/kg	100	50-150		<0.020	<0.02	mg/kg	-	0.02	
alpha-BHC	.17968	0.200	mg/kg	90	50-150		<0.020	<0.02	mg/kg	-	0.02	
beta-BHC	.1685	0.200	mg/kg	84	50-150		<0.020	<0.02	mg/kg	-	0.02	
Lindane	.1884	0.200	mg/kg	94	50-150		<0.020	<0.02	mg/kg	-	0.02	
delta-BHC	.18878	0.200	mg/kg	94	50-150		<0.020	<0.02	mg/kg	-	0.02	
a-chlordane	.14856	0.200	mg/kg	74	50-150		<0.020	<0.02	mg/kg	-	0.02	
g-chlordane	.1551	0.200	mg/kg	78	50-150		<0.020	<0.02	mg/kg	-	0.02	
op-DDD	.16318	0.200	mg/kg	82	50-150		<0.020	<0.02	mg/kg	-	0.02	
pp-DDD	.17318	0.400	mg/kg	43	40-140		<0.020	<0.02	mg/kg	-	0.02	
o,p-DDE	.16446	0.200	mg/kg	82	50-150		<0.020	<0.02	mg/kg	-	0.02	
pp-DDE	.1688	0.400	mg/kg	42	50-150	G	<0.020	<0.02	mg/kg	-	0.02	
op-DDT	.15744	0.200	mg/kg	79	40-160		<0.020	<0.02	mg/kg	-	0.02	
pp-DDT	.17586	0.400	mg/kg	44	30-140		<0.020	<0.02	mg/kg	-	0.02	
Dieldrin	.16946	0.200	mg/kg	85	50-150		<0.020	<0.02	mg/kg	-	0.02	
alpha-Endosulfan	.17652	0.200	mg/kg	88	40-130		<0.020	<0.02	mg/kg	-	0.02	
beta-Endosulfan	.15374	0.200	mg/kg	77	40-140		<0.020	<0.02	mg/kg	-	0.02	
Endosulfan Sulfate	.17078	0.200	mg/kg	85	40-160		<0.020	<0.02	mg/kg	-	0.02	
Endrin	.1652	0.200	mg/kg	83	40-170		<0.020	<0.02	mg/kg	-	0.02	
Endrin Aldehyde	.14536	0.200	mg/kg	73	50-150		<0.020	<0.02	mg/kg	-	0.02	
Heptachlor	.19352	0.200	mg/kg	97	50-150		<0.020	<0.02	mg/kg	-	0.02	
Heptachlor Epoxide	.16574	0.200	mg/kg	83	50-150		<0.020	<0.02	mg/kg	-	0.02	
Methoxychlor	.17572	0.200	mg/kg	88	20-150		<0.020	<0.02	mg/kg	-	0.02	
Mirex	.16824	0.200	mg/kg	84	50-150		<0.020	<0.02	mg/kg	-	0.02	
Oxychlordane	.1629	0.200	mg/kg	81	50-150		<0.020	<0.02	mg/kg	-	0.02	
Aldrin	.16666	0.200	mg/kg	83	50-150		<0.020	<0.02	mg/kg	-	0.02	
alpha-BHC	.1708	0.200	mg/kg	85	50-150		<0.020	<0.02	mg/kg	-	0.02	
beta-BHC	.16588	0.200	mg/kg	83	50-150		<0.020	<0.02	mg/kg	-	0.02	
Lindane	.18876	0.200	mg/kg	94	50-150		<0.020	<0.02	mg/kg	-	0.02	
delta-BHC	.18412	0.200	mg/kg	92	50-150		<0.020	<0.02	mg/kg	-	0.02	
a-chlordane	.1131	0.200	mg/kg	57	50-150		<0.020	<0.02	mg/kg	-	0.02	
g-chlordane	.12144	0.200	mg/kg	61	50-150		<0.020	<0.02	mg/kg	-	0.02	
op-DDD	.12204	0.200	mg/kg	61	50-150		<0.020	<0.02	mg/kg	-	0.02	
pp-DDD	.1251	0.200	mg/kg	63	40-140		<0.020	<0.02	mg/kg	-	0.02	
o,p-DDE	.12332	0.200	mg/kg	62	50-150		<0.020	<0.02	mg/kg	-	0.02	
pp-DDE	.13084	0.200	mg/kg	65	50-150		<0.020	<0.02	mg/kg	-	0.02	
op-DDT	.14686	0.200	mg/kg	73	40-160		<0.020	<0.02	mg/kg	-	0.02	
pp-DDT	.13934	0.200	mg/kg	70	30-140		<0.020	<0.02	mg/kg	-	0.02	
Dieldrin	.1296	0.200	mg/kg	65	50-150		<0.020	<0.02	mg/kg	-	0.02	
alpha-Endosulfan	.1154	0.200	mg/kg	58	40-130		<0.020	<0.02	mg/kg	-	0.02	
beta-Endosulfan	.1137	0.200	mg/kg	57	40-140		<0.020	<0.02	mg/kg	-	0.02	
Endosulfan Sulfate	.11704	0.200	mg/kg	59	40-160		<0.020	<0.02	mg/kg	-	0.02	
Endrin	.1587	0.200	mg/kg	79	40-170		<0.020	<0.02	mg/kg	-	0.02	
Endrin Aldehyde	.10086	0.200	mg/kg	50	50-150		<0.020	<0.02	mg/kg	-	0.02	
Heptachlor	.20096	0.200	mg/kg	100	50-150		<0.020	<0.02	mg/kg	-	0.02	
Heptachlor Epoxide	.1242	0.200	mg/kg	62	50-150		<0.020	<0.02	mg/kg	-	0.02	
Methoxychlor	.13768	0.200	mg/kg	69	20-150		<0.020	<0.02	mg/kg	-	0.02	
Mirex	.12528	0.200	mg/kg	63	50-150		<0.020	<0.02	mg/kg	-	0.02	
Oxychlordane	.1246	0.200	mg/kg	62	50-150		<0.020	<0.02	mg/kg	-	0.02	
			min	42								
			max	100								
			median	78.9								

G Due to the number of analytes, 10% may exceed QC limits. Analyte not present in related samples.

Table A10. Recovery (%) of PCB congeners in laboratory control sample (LCS) and method blanks - benthic invertebrate tissue samples (ALS Laboratory Group).

Target Analytes	Method Blank (pg/g)	Target Analytes	Method Blank (pg/g)
*1	<88	85/120	<27
2	<97	110	53.3
*3	<110	82	<54
*4/+10	<4600	124	<33
9/7	747	109/107	<34
6	<330	123	<42
+8/5	<340	*118/106	<43
14	<340	*114	<46
11	<510	122	<35
12/13	<350	*105/127	<44
*15	<230	*126	<62
*19	<150	*155	<26
30	<32	150	<11
18	<100	152	<11
17	<44	145/148	<13
27/24	<33	136/154	<12
16/32	86.8	151	<11
34/23	<72	135	<12
29	<36	144	<11
26	<35	147	<11
25	<36	139/+149	<11
31/+28	<270	140	<11
20/+33/21	96.4	143	<12
22	<56	134	<14
36	<34	142	<12
39	<35	133/165/131	<11
38	<33	161/146	<9.7
35	<36	+168/+153	<9.4
*37	52.1	132	<13
*54	<16	141	<12
50	<13	137	<12
53	<13	130	<13
51	<13	164/163	<9.3
45	<14	+138/160	<10
46/69/73	<12	158	<9.7
52	<190	129	<13
43	<16	166	<8.3
49	<98	159	<9.9
48/47/75	<230	162	<10
65	<9.5	128	<15
62	<12	*167	<11
44	<89	*156	<13
59	<9.8	*157	<13
42	<32	*169	<9.5
41	<9.5	*188	<38
71	<10	184	<19
72/64/68	<150	179	<19
+40/57	<13	176	<19
67	<9.8	186	<21
58	<11	178	<27
63	<9.8	175	<26
+74/61	<53	182/+187	<26
76/70	<110	183	<25
+66/80	<94	185	<31
55	<12	174	<5.0
56	<33	181	<5.9
60	23.2	177	<5.5
79	<7.4	171	<4.8
78	<7.6	173	<5.1
*81	<10	192/172	<4.6
*77	<7.7	+193/+180	<13
*104	<0.70	191	<3.8
96/103	<1.2	+170/190	<4.5
100	<1.4	*189	<3.7
94	<1.7	*202	<43
98/102	<1.5	201	<32
+95/93/121	159	204	<32
88	<1.6	197	<33
91	<1.6	200	<34
92	<65	198	<51
84/90	<37	199	<50
101/113/89	109	196/+203	<43
99	76.5	195	<38
119	<22	194	<38
112	<24	*205	<28
108/83	<30	*208	<110
86/97/125	<30	207	<71
117/111	<24	*206	<86
115/116/+87	<26	*209	<280

Target Analytes	LCS % Recovery
*1	106
*3	103
*4/+10	109
*15	104
*19	101
*37	107
*54	107
*81	104
*77	108
*104	111
123	106
*118/106	107
*114	108
*105/127	105
*126	105
*155	104
*167	114
*156	106
*157	109
*169	103
*188	109
*189	110
*202	101
*205	101
*208	101
*206	107
*209	108
min	101
max	114
median	106

Table A11. Recovery (%) of PAHs in laboratory control sample (LCS) and method blanks - benthic invertebrate tissue samples (ALS Laboratory Group).

Target Analytes (Blank Corrected)	**Method Blank (ng/g)**		**LCS % Recovery**
Naphthalene	<		127
2-Methylnaphthalene	<		n/s
1-Methylnaphthalene	<		n/s
Acenaphthylene	<		113
Acenaphthene	<		129
Fluorene	<		110
Phenanthrene	<		123
Anthracene	<		120
Fluoranthene	<		115
Pyrene	<		103
Benzo(a)anthracene	<3.6	U	114
Chrysene/Triphenylene	<3.6	U	127
Benzo(b)flouranthene	<3.6	U	106
Benzo(k)fluoranthene	<3.6	U	109
Benzo(e)pyrene	<3.6	U	n/s
Benzo(a)pyrene	<3.6	U	105
Perylene	<3.6	U	n/s
Indeno(1,2,3-cd)pyrene	<3.6	U	78
Dibenzo(a,h/a,c)anthracene	<3.6	U	117
Benzo(g,h,i)perylene	<3.6	U	116

U=Indicates that this compound was not detected above the Limits of Detetion

min	78
max	129
median	114.5

Table A12. Sample recoveries for certified reference materials (Caduceon Environmental laboratories).

PARAMETERS	**QC Sample Recovery Calculation**				
	Raw Data (µg/g)			**QC Sample Recovery**	
LKSD-3 (11-Nov-10)	**QC Result**	**Reference Value**	**Lab Mean**	**%Recovery**	**Control Limits**
Silver	2.4	2.4		**102**	50 - 117
Antimony	0.8	1.0	0.95	**84**	63 - 137
Arsenic	24.2	23	23.9	**101**	68 - 132
Barium	156	N/A	169	**93**	81 - 118
Beryllium	0.6	N/A	0.5	**111**	47 - 153
Cobalt	28.1	30		**94**	51 - 114
Chromium	45.8	51		**90**	54 - 125
Copper	31.1	34		**91**	79 - 116
Iron	27900	35000		**80**	74 - 102
Manganese	1270	1220		**104**	76 - 124
Molybdenum	0.93	2		**47**	0 - 260
Nickel	41.6	44.0		**95**	75 - 125
Lead	23.1	26		**89**	72 - 107
Strontium	22.6	N/A	25.4	**89**	76 - 124
Titanium	971	N/A	980	**99**	49 - 151
Vanadium	46.1	55		**84**	63 - 113
Zinc	126	139		**91**	76 - 124
SS-1 (11-Nov-10)					
Silver	2.0	1.9		**104**	50 - 117
Aluminum	9947	9518		**105**	34 - 166
Arsenic	16.4	18	16.9	**97**	66 - 134
Barium	91.6	102		**90**	68 - 132
Cadmium	33.6	34		**99**	71 - 129
Cobalt	29.3	28		**105**	68 - 132
Chromium	45.5	64		**71**	20 - 180
Copper	784	690		**114**	73 - 127
Iron	19634	20406		**96**	62 - 138
Lithium	9.54	11		**87**	27 - 173
Magnesium	5871	6088		**96**	65 - 135
Manganese	412	425		**97**	76 - 124
Molybdenum	4.3	5		**85**	40 - 160
Nickel	226	231		**98**	68 - 132
Phosphorus	1093	1070		**102**	78 - 122
Lead	224	233		**96**	65 - 135
Strontium	178	202		**88**	84 - 116
Titanium	243	248		**98**	75 - 125
Vanadium	17.2	19		**91**	42 - 158
Yttrium	9.0	8		**112**	70 - 130
Zinc	6725	6775		**99**	75 - 125
LKSD-2 (09-Nov-10)					
Mercury	0.145	0.160	0.144	**91**	77 - 122

WH89-1 (29-Nov-10)					
Aluminum (Al2O3)	12.8	12.1	11.6	**106**	75 - 125
Barium (BaO)	0.29	0.29	0.28	**100**	75 - 125
Calcium (CaO)	4.76	5.9	5.7	**81**	75 - 125
Chromium (Cr2O3)	0.03	0.03	0.03	**100**	50 - 150
Iron (Fe2O3)	6.46	6.9	6.62	**94**	75 - 125
Magnesium (MgO)	2.81	3.5	3.4	**80**	75 - 125
Manganese (MnO)	0.09	0.14	0.13	**64**	60 - 140
Phosphorus (P2O5)	< 3	0.4	0.4	-	75 - 125
Potasium (K20)	2.09	2.5	2.2	**84**	75 - 125
Silica (SiO2)	47.9	60.5	59	**79**	75 - 125
Sodium (Na2O)	< 3	2.0		-	75 - 125
Titanium (TiO2)	0.82	1.0		**82**	75 - 125
D053-542 (21-Oct-10)					
Total Kjeldahl Nitrogen	1385	1300	1372	**101**	57 - 143
Phosphorus-Total	983	811	939	**105**	53 - 147
TOC QC (27-Oct-10)					
TOC	4.51	4.84		**93**	91 - 109

min	47
max	114
median	94

Table A13. Matrix spike recoveries for 2010 organochlorine pesticide samples (ALS Laboratory Group).

Analyte	MS Result	MS Target	Units	MS %	MS Limits	Qualifier
Aldrin	0.22120158	0.234	mg/kg	95	55-145	
alpha-BHC	0.23133599	0.234	mg/kg	99	55-145	
beta-BHC	0.24315556	0.234	mg/kg	104	55-145	
Lindane	0.24406836	0.234	mg/kg	104	55-145	
delta-BHC	0.24317897	0.234	mg/kg	104	55-145	
a-chlordane	0.15035435	0.234	mg/kg	64	55-145	
g-chlordane	0.1584057	0.234	mg/kg	68	55-145	
op-DDD	0.16329737	0.234	mg/kg	70	55-145	
pp-DDD	0.17932986	0.234	mg/kg	77	55-145	
o,p-DDE	0.16191647	0.234	mg/kg	69	55-145	
pp-DDE	0.1776915	0.234	mg/kg	76	55-145	
op-DDT	0.20137746	0.234	mg/kg	86	55-145	
pp-DDT	0.2295338	0.234	mg/kg	98	55-145	
Dieldrin	0.17303389	0.234	mg/kg	74	55-145	
alpha-Endosulfan	0.14670315	0.234	mg/kg	63	55-145	
beta-Endosulfan	0.15683756	0.234	mg/kg	67	55-145	
Endosulfan Sulfate	0.16236116	0.234	mg/kg	69	55-145	
Endrin	0.1997157	0.234	mg/kg	85	55-145	
Endrin Aldehyde	0.12725352	0.234	mg/kg	54	55-145	G
Heptachlor	0.27091401	0.234	mg/kg	116	55-145	
Heptachlor Epoxide	0.16364845	0.234	mg/kg	70	55-145	
Methoxychlor	0.21879086	0.234	mg/kg	93	55-145	
Mirex	0.16961675	0.234	mg/kg	72	55-145	
Oxychlordane	0.16168242	0.234	mg/kg	69	55-145	

min	54
max	116
median	75

G - Due to the number of analytes, 10% may exceed QC limits. Analyte not present in related samples.

Table A14. Recovery of surrogates for sediment organic contaminant samples (ALS Laboratory Group).

	LC01	LC03	LC08	LC12	LC16	LC1800	LC1801	LC1802	LC38	TC01	UC01	BEC02
Volatile Organic Compounds												
Surrogate: 4-Bromofluorobenzene	87	87	85	86	83	86	87	86	89	92	94	80
Surrogate: 3,4-Dichlorotoluene	84	71	79	75	67	73	75	72	74	77	71	72
Surrogate: 1,4-Difluorobenzene	93	85	89	89	86	88	88	89	86	91	97	85
Hydrocarbons												
Surrogate: 2-Bromobenzotrifluoride	80	76	77	77	76	76	82	70	79	79	86	86
Surrogate: Octacosane	95	85	83	77	85	88	77	88	101	102	99	92
Polycyclic Aromatic Hydrocarbons												
Surrogate: 2-Fluorobiphenyl	100	104	103	100	97	101	100	**34**	104	51	100	98
Surrogate: p-Terphenyl d14	97	102	104	96	90	90	101	**37**	103	50	98	98
Organochlorine Pesticides												
Surrogate: 2-Fluorobiphenyl	98	85	96	61	51	88	74	**44**	97	92	76	94
Surrogate: d14-Terphenyl	90	88	95	**45**	51	81	77	**47**	89	84	62	84
min	34											
nax	104											
median	86											

Red flag - indicates a recovery outside of acceptable limits due to matrix interference

Table A15. Sorting efficiency for 2010 Lyons Creek benthic invertebrate community samples.

Site	Rep	Date	Sort Date	QC Date	%Efficacy 1	%Efficacy 2	%Efficacy 3
LC01 P1	1	09/07/10	01/19/11	01/19/11	98.56	N/A	N/A
LC01 P2	2	09/07/10	01/11/11	01/21/11	97.72	N/A	N/A
LC01 P3	3	09/07/10	01/21/11	01/31/11	98.83	N/A	N/A
LC03 i	1	09/07/10	01/24/11	01/21/11	100.00	N/A	N/A
LC03 ii	2	09/07/10	01/24/11	01/31/11	100.00	N/A	N/A
LC03 iii	3	09/07/10	01/24/11	02/01/11	100.00	N/A	N/A
LC03 iv	4	09/07/10	01/24/11	01/31/11	97.30	N/A	N/A
LC03 v	5	09/07/10	01/24/11	01/27/11	100.00	N/A	N/A
LC08 i	1	09/09/10	01/25/11	01/26/11	100.00	N/A	N/A
LC08 ii	2	09/09/10	01/25/11	02/01/11	100.00	N/A	N/A
LC08 iii	3	09/09/10	01/25/11	01/26/11	100.00	N/A	N/A
LC08 iv	4	09/09/10	01/25/11	01/26/11	100.00	N/A	N/A
LC08 v	5	09/09/10	01/25/11	02/01/11	100.00	N/A	N/A
LC12 i	1	09/09/10	01/25/11	01/27/11	100.00	N/A	N/A
LC12 ii	2	09/09/10	01/25/11	01/27/11	100.00	N/A	N/A
LC12 iii	3	09/09/10	01/25/11	01/26/11	100.00	N/A	N/A
LC12 iv	4	09/09/10	01/25/11	01/26/11	100.00	N/A	N/A
LC12 v	5	09/09/10	01/25/11	02/01/11	100.00	N/A	N/A
LC16 i	1	09/09/10	01/26/11	01/27/11	100.00	N/A	N/A
LC16 ii	2	09/09/10	01/26/11	01/31/11	100.00	N/A	N/A
LC16 iii	3	09/09/10	01/26/11	01/26/11	96.47	N/A	N/A
LC16 iv	4	09/09/10	01/26/11	02/01/11	100.00	N/A	N/A
LC16 v	5	09/09/10	01/26/11	01/27/11	100.00	N/A	N/A
LC1800 P1	1	09/09/10	02/07/11	02/09/11	100.00	N/A	N/A
LC1800 P2	2	09/09/10	02/01/11	02/01/11	100.00	N/A	N/A
LC1800 P3	3	09/09/10	01/27/11	01/31/11	100.00	N/A	N/A
LC1801 P1	1	09/09/10	02/02/11	02/02/11	100.00	N/A	N/A
LC1801 P2	2	09/09/10	02/08/11	02/08/11	96.10	N/A	N/A
LC1801 P3	3	09/09/10	02/08/11	02/09/11	100.00	N/A	N/A
LC1802 P1	1	09/09/10	02/08/11	02/09/11	96.29	N/A	N/A
LC1802 P2	2	09/09/10	02/08/11	02/09/11	97.67	N/A	N/A
LC1802 P3	3	09/09/10	02/09/11	02/09/11	99.22	N/A	N/A
LC38 P1	1	09/08/10	02/08/11	02/09/11	100.00	N/A	N/A
LC38 P2	2	09/08/10	02/10/11	02/10/11	100.00	N/A	N/A
LC38 P3	3	09/08/10	02/09/11	02/09/11	100.00	N/A	N/A
BEC02 i	1	09/10/10	02/10/11	02/10/11	100.00	N/A	N/A
BEC02 ii	2	09/10/10	02/10/11	02/09/11	100.00	N/A	N/A
BEC02 iii	3	09/10/10	02/11/11	02/11/11	100.00	N/A	N/A
BEC02 iv	4	09/10/10	02/11/11	02/11/11	100.00	N/A	N/A
BEC02 v	5	09/10/10	02/10/11	02/11/11	100.00	N/A	N/A
TC01 i	1	09/08/10	02/10/11	02/10/11	100.00	N/A	N/A
TC01 ii	2	09/08/10	02/11/11	02/11/11	100.00	N/A	N/A
TC01 iii	3	09/08/10	02/09/11	02/10/11	100.00	N/A	N/A
TC01 iv	4	09/08/10	01/19/11	01/19/11	100.00	N/A	N/A
TC01 v	5	09/08/10	02/11/11	02/11/11	100.00	N/A	N/A
UC01 i	1	09/08/10	01/11/11	01/21/11	100.00	N/A	N/A
UC01 ii	2	09/08/10	01/11/11	01/21/11	100.00	N/A	N/A
UC01 iii	3	09/08/10	01/12/11	01/21/11	100.00	N/A	N/A
UC01 iv	4	09/08/10	01/12/11	01/21/11	100.00	N/A	N/A
UC01 v	5	09/08/10	01/12/11	01/21/11	100.00	N/A	N/A

Table A16. Taxonomy identification quality control percent similarity for Lyons Creek 2010 samples.

EcoA#	Site#, Rep	General AB	Olig. AB	Total AB	Gen. Wtd AB	Gen. % Sim	Olig. Wtd AB	Oig. % Sim	Overall Sample %Similarity	Meets MQO?
5587.1-5	LC03 ii	8	28	36	22.22	90.00	77.78	99.87	**97.68**	Yes
5587.1-20	LC16 ii	97	31	128	75.78	96.67	24.22	99.89	**97.45**	Yes
5587.1-23	LC16 v	99	5	104	95.19	96.97	4.81	100	**97.12**	Yes
5587.1-32	LC1802 P3	308	41	349	88.25	96.45	11.75	95.82	**96.38**	Yes
5587.1-41	TC01 i	2	5	7	28.57	100.00	71.43	100	**100.00**	Yes

WTD= weighted
MQO= method quality objectives

Table A17. Toxicological response in laboratory control sediment (Long Point, Lake Erie) run concurrently with 2010 Lyons Creek test sites.

Test set No.	Sites	*H. azteca*		*C. riparius*		*Hexagenia* spp.		*T. tubifex*				Meets DQO?
		survival	growth	survival	growth	survival	growth	survival	No. cocoons/ adult	% hatched cocoons	No. Young/ adult	
1	BEC02, UC, TC, LC01	93.33	0.358	92.0	0.336	100	5.10	100	11.1	55.4	27.7	Yes
2	LC03, LC08, LC12, LC16	94.6	0.623	92.0	0.390	100	4.67	100	9.0	45.0	14.4	No – *T. tubifex test repeated*
3	LC03, LC08, LC12, LC16	-	-	-	-	-	-	100	10.6	56.9	27.8	Yes
4	LC18, LC38	96.0	0.597	80.0	0.331	100	4.79	100	11.0	54.7	30.6	Yes
5	LC18	-	-	93.3	0.324	-	-	-	-	-	-	Yes

DQO= data quality objectives

APPENDIX B Macroinvertebrate Counts

Table B1. Complete macroinvertebrate counts (per core tube = 33.18 cm^2), taxon richness, and total abundance (No. per core tube and m^{-2}) for 2010 Lyons and reference creek sites (LC = Lyons BEC = Beaver Creek, C=Usshers Creek, TC=Tee Creek).

	Site	**LC01**	**LC03**	**LC08**	**LC12**	**LC16**	**LC18**	**LC38**	**BEC02**	**TC**	**UC**
Ephemeroptera	Baetidae	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Caenidae	0.00	0.20	1.20	0.40	6.60	0.35	0.00	1.40	0.40	5.00
	Ephemeridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20
	Heptageniidae	0.01	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Leptohyphidae	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Odonata	Coenagrionidae	0.00	0.40	0.60	0.40	2.20	0.45	0.00	0.20	1.40	0.00
	Libellulidae/Corduliidae	0.38	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
Coleoptera	Elmidae	0.00	0.40	0.00	0.00	0.00	0.00	0.13	8.60	0.40	9.20
	Haliplidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00
	Hydrophilidae	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
Megaloptera	Sialidae	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00
Diptera	Chironomidae	0.02	5.00	5.40	1.80	50.00	16.20	2.30	12.60	8.40	8.20
Diptera	Ceratopogonidae	0.00	0.00	0.00	0.20	2.60	0.33	0.43	9.40	0.00	3.80
	Diptera	0.00	0.00	0.00	0.00	0.20	0.03	0.00	0.00	0.00	0.00
	Empididae	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.20
	Ephydridae	0.01	0.40	0.00	0.00	0.40	0.00	0.00	0.00	0.00	0.00
	Tabanidae	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Trichoptera	Hydroptilidae	0.01	0.00	0.00	0.00	0.60	0.06	0.04	0.00	0.00	0.00
	Leptoceridae	0.00	0.00	0.00	0.60	2.40	0.27	0.00	0.00	0.40	0.20
Lepidoptera	Crambidae	0.26	0.00	0.00	0.00	0.60	0.00	0.00	0.00	0.00	0.00
Gastropoda	Ancylidae	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Gastropoda	0.00	0.00	0.00	0.00	0.40	0.03	0.00	0.00	0.00	0.20
	Hydrobiidae	0.00	1.40	1.00	0.20	0.40	0.14	0.00	0.00	1.00	0.00
	Physidae	0.08	0.00	0.00	0.20	0.20	0.07	0.00	0.00	0.80	0.40
	Planorbidae	0.00	0.00	0.00	0.20	0.00	0.27	0.00	0.00	1.80	0.00
	Valvatidae	2.44	0.00	0.20	0.00	0.20	0.00	0.00	0.00	1.60	0.00
Bivalvia	Dreissenidae	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Pisidiidae	0.01	0.20	2.00	0.40	6.60	0.09	0.13	1.20	0.60	0.60
Annelida	Erpobdellidae	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Glossiphoniidae	0.01	0.00	0.00	0.00	0.20	0.13	0.00	0.00	0.00	0.00
	Hirudinea	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Lumbricina	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Naididae	0.68	0.20	0.00	0.20	7.40	1.17	0.00	0.00	1.20	1.00
	Tubificidae	0.01	32.20	4.20	1.00	9.20	1.66	0.48	2.80	6.20	18.60
Acari	Acari	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Arrenuridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Hydrodromidae	0.01	0.00	0.20	0.00	0.00	0.09	0.00	0.00	0.00	0.00
	Hygrobatidae	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Lebertiidae	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Limnesiidae	0.00	0.60	0.00	0.00	0.00	0.01	0.00	0.00	0.20	0.20
	Oribatei	0.01	0.00	0.00	0.00	0.20	0.01	0.00	0.00	0.00	0.00
	Oxidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Pionidae	0.02	0.00	0.00	0.00	0.20	0.01	0.00	0.00	0.00	0.00
Crustacea	Amphipoda	0.01	0.00	2.40	1.60	1.00	0.01	0.00	0.40	0.00	0.00
	Asellidae	0.00	0.00	0.00	0.40	24.20	0.00	0.00	3.40	2.40	0.00
	Crangonyctidae	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00
	Gammaridae	0.05	0.00	1.40	0.00	0.20	0.00	0.04	0.20	0.00	0.00
	Hyalellidae	0.01	0.00	0.20	0.20	1.80	0.07	0.04	0.00	0.00	0.00
Other Organisms	Hydridae	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Tetrastemmatidae	4.89	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00
Total abundance: No. per core tube		9.8	41.2	19.0	8.0	118.0	21.5	3.6	40.4	27.0	47.8
	Total abundance: No. m^{-2}	2,944	12,417	5,726	2,411	35,564	6,489	1,084	12,176	8,137	14,406
	No. families	26	11	11	14	20	13	8	10	15	12

APPENDIX C Toxicity Ordinations

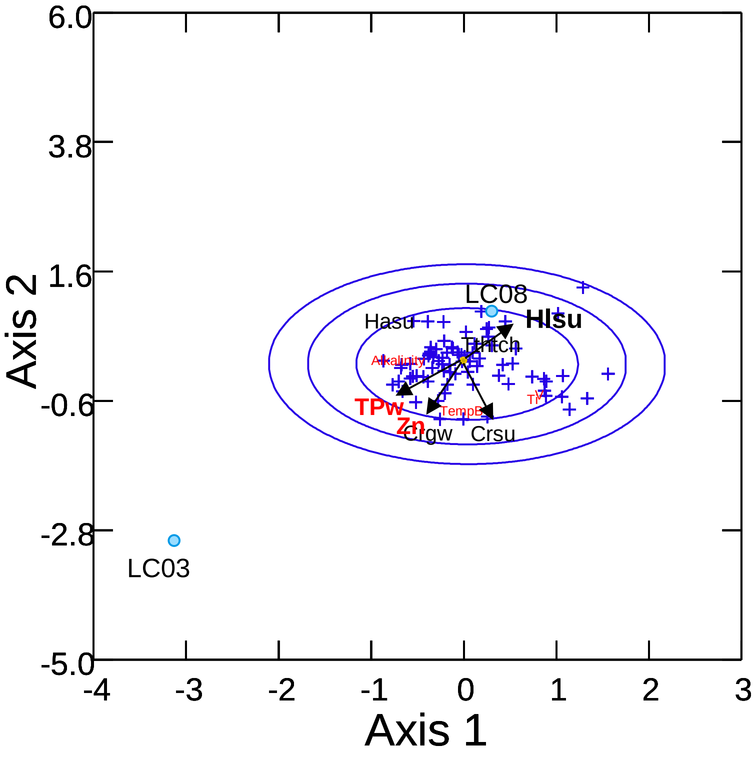

Figure C1. Ordination of subset of Lyons Creek sites (LC03, LC08) using 10 toxicity test endpoints summarized on Axes 1 and 2, with 90%, 99%, and 99.9% probability ellipses around Great Lakes reference sites (shown as cross hairs). Most significant toxicity endpoints and environmental variables are shown. Endpoints and habitat variables associated with site positions are shown as vectors. [*Hyalella* survival (Hasu), *Tubifex* young production (Ttyg), *Chironomus* survival and growth (Crsu, Crgw), *Hexagenia* survival (Hlsu)]. Stress level = 0.09.

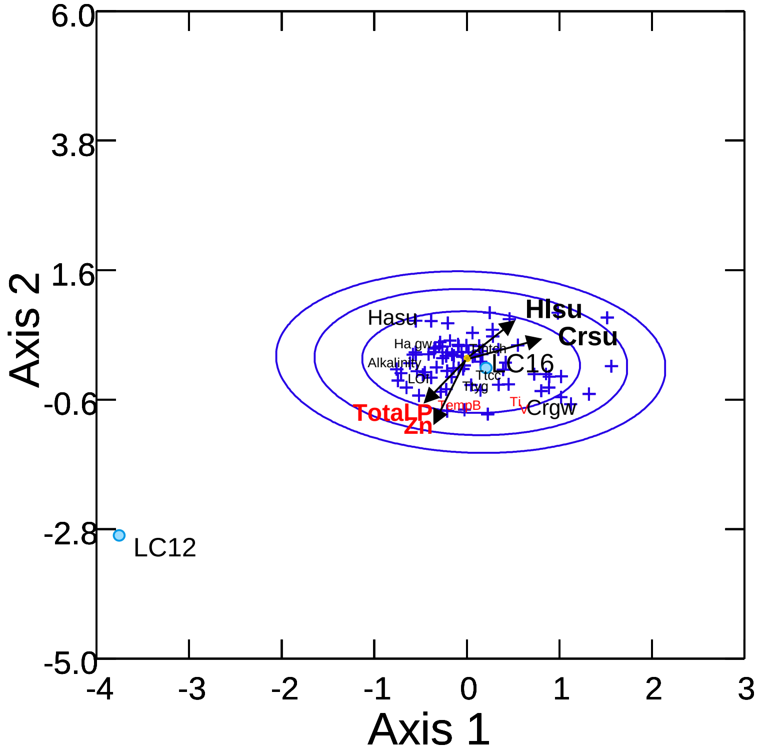

Figure C2. Ordination of subset of Lyons Creek sites (LC12, LC16) using 10 toxicity test endpoints summarized on Axes 1 and 2, with 90%, 99%, and 99.9% probability ellipses around Great Lakes reference sites (shown as cross hairs). Most significant toxicity endpoints and environmental variables are shown. Endpoints and habitat variables associated with site positions are shown as vectors. [*Hyalella* survival (Hasu), *Tubifex* young production (Ttyg), *Chironomus* survival and growth (Crsu, Crgw), *Hexagenia* survival (Hlsu)]. Stress level = 0.08.

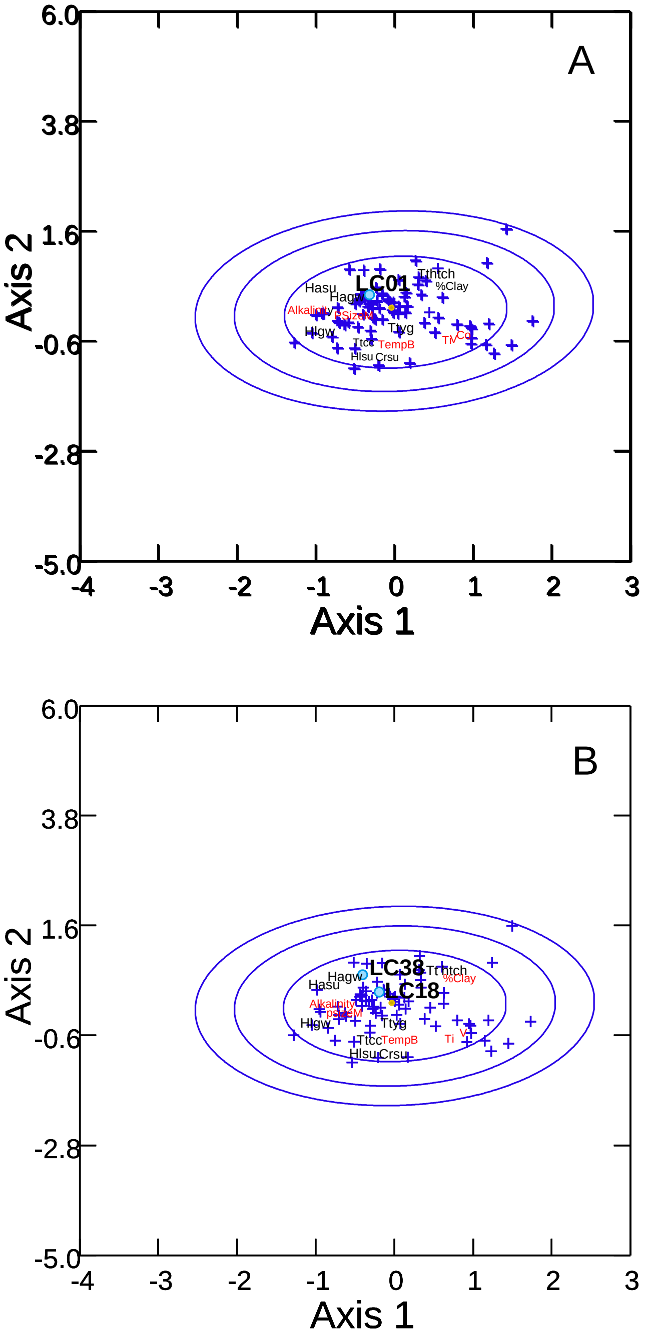

Figure C3. Ordination of (A) upstream site LC01 and (B) LC18 and LC38, using 10 toxicity test endpoints summarized on Axes 1 and 2, with 90%, 99%, and 99.9% probability ellipses around Great Lakes reference sites (shown as cross hairs). Most significant toxicity endpoints and environmental variables are shown for each ordination. [*Hyalella* survival (Hasu), *Tubifex* young production (Ttyg), *Chironomus* survival and growth (Crsu, Crgw), *Hexagenia* survival (Hlsu)]. Stress level = 0.09.

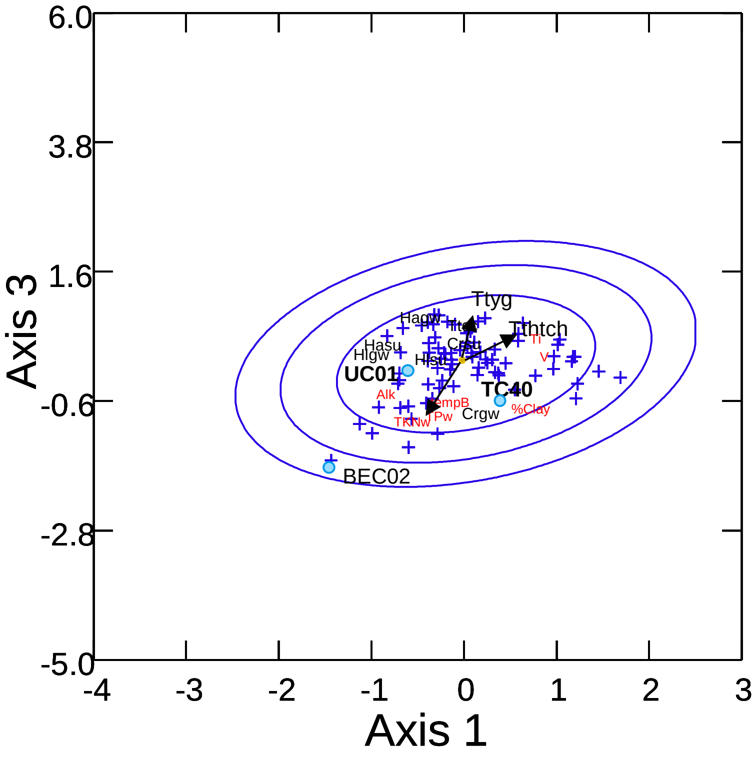

Figure C4. Ordination of subset of reference creek sites (BEC02, TC40, UC01) using 10 toxicity test endpoints summarized on Axes 1 and 3, with 90%, 99%, and 99.9% probability ellipses around Great Lakes reference sites (shown as cross hairs). Most significant toxicity endpoints and environmental variables are shown. Endpoints and habitat variables associated with site positions are shown as vectors. [*Hyalella* survival (Hasu), *Tubifex* young production (Ttyg), *Chironomus* survival and growth (Crsu, Crgw), *Hexagenia* survival (Hlsu)]. Stress level = 0.08.